Chapter I

INTRODUCTION

PURPOSE OF PLAN

The health of a lake or stream is usually a direct reflection of the use and management of the land within its watershed. Research shows that intervention is often necessary to maintain or improve the conditions of these resources. Located within U.S. Public Land Survey Sections 22, 23, 26, and 27, Township 10 North, Range 18 East, in the Town of Hartford, Washington County (see Map 1), Pike Lake, together with its watershed and associated wetlands, is a high-quality natural resource (see "Pike Lake Characteristics and Assets" section below). The purpose of this plan is to provide a framework to maintain or improve the land and water resources of Pike Lake and its watershed with a focus on *protecting* existing high-quality resources from human impacts, *preventing* future degradation from occurring, and *enhancing* ecological and recreational values.

The recommendations provided in this report are appropriate and feasible lake management measures for enhancing and preserving the native plant community and water quality of Pike Lake, while still providing the public with opportunities for safe and enjoyable recreation within the Lake's watershed. It is important to note that this plan complements other existing plans,[1] programs and ongoing management actions in the Pike Lake watershed and represents the continuing commitments of government agencies, municipalities, and citizens to diligent lake planning and natural resource protection. Additionally, it was designed to assist State agencies, local units of government, nongovernmental organizations, businesses, and citizens in developing strategies that will benefit the natural assets of Pike Lake. By using the strategies outlined in this plan, results will be achieved that enrich and preserve the natural environment.

This planning program was funded, in part, by the Pike Lake Protection and Rehabilitation District (PLPRD) and, in part, through a Chapter NR 190 Lake Management Planning Grant awarded to the PLPRD and administered by the

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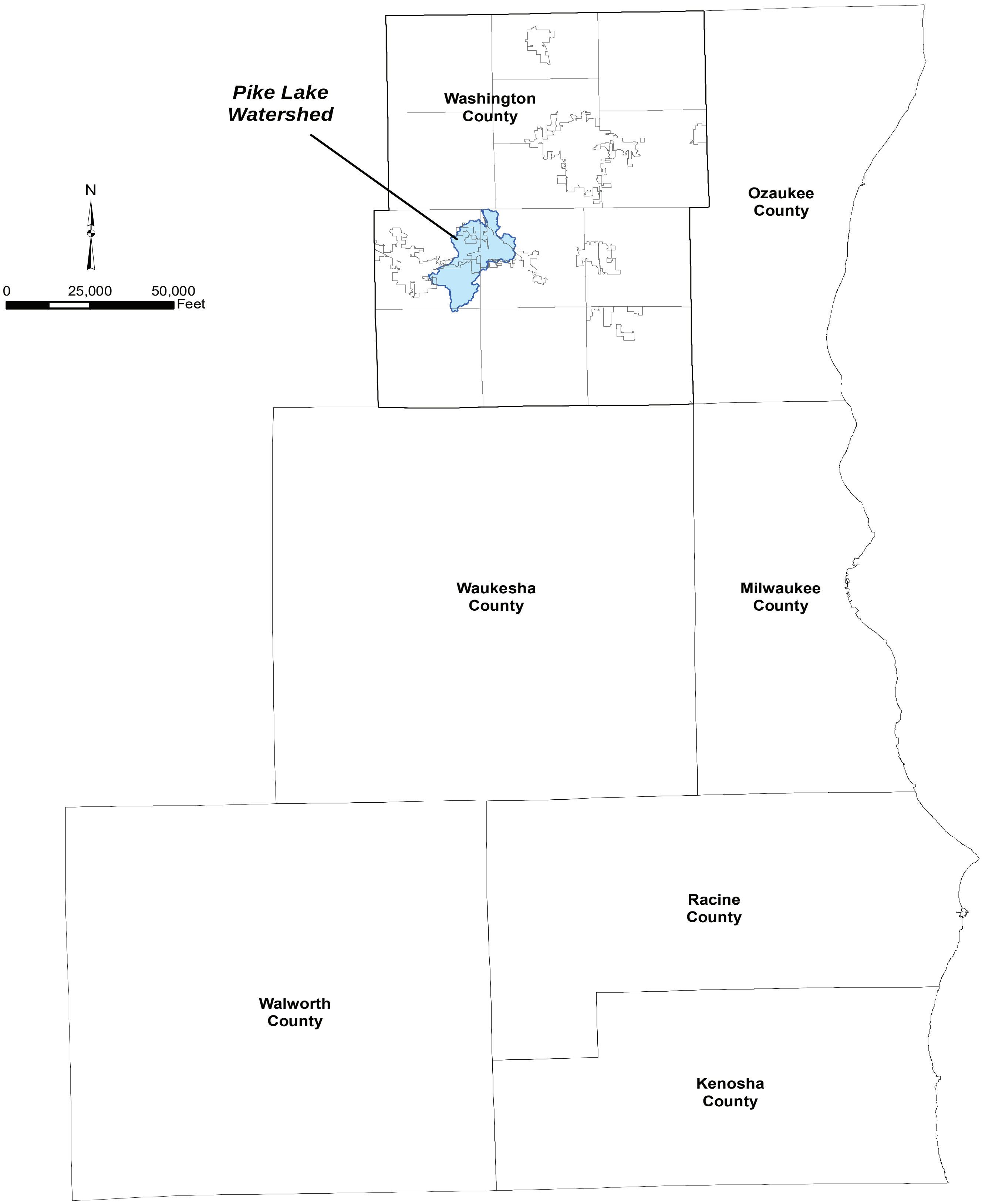
[1] SEWRPC Community Assistance Planning Report No. 273, *A Lake Management Plan for Pike Lake, Washington County, Wisconsin*, December 2005.

Map 1

LOCATION OF THE PIKE LAKE WATERSHED



Source: SEWRPC.

Wisconsin Department of Natural Resources (WDNR). The inventory and aquatic plant management plan elements presented in this report conform to the requirements and standards set forth in the relevant *Wisconsin Administrative Codes*.[2]

PIKE LAKE CHARACTERISTICS AND ASSETS

Pike Lake is a 461-acre lake with a maximum water depth of 45 feet (see Map 2 for the Lake's bathymetry). The Lake's water-surface elevation is controlled by a dam. The Rubicon River (a tributary to the Rock River) flows through Pike Lake. The WDNR classifies the Lake as a drainage lake, which means that the Lake has both a defined inflow and outflow. In addition to the Rubicon River drainage system, two small, intermittent streams enter the Lake from the south: one, locally known as Glasgow Creek, enters the Lake from the southeast, and the other, unnamed stream enters the Lake from the southwest. Additionally, a number of small streams and springs drain to the Lake from the eastern shore. Table 1 summarizes the hydrologic and morphologic characteristics of the Lake. Chapter II provides more details on the importance of these characteristics.

Pike Lake and its watershed have a wide range of assets. For example, Pike Lake is a recreational lake which is able to support a variety of recreational opportunities as is evidenced by the recreational survey completed by Southeastern Wisconsin Regional Planning Commission (SEWRPC) staff in the summer of 2012 (see Chapter II for more details). The survey showed that Lake users engage in full-body contact uses (such as swimming from the beach) as well as high-speed boating and fishing. The Lake also supports a wide variety of wildlife and fish including gamefish such as large and smallmouth bass, panfish, northern pike, and walleye. In fact, it is one of the few lakes in Southeastern Wisconsin that has a naturally reproducing walleye population. Additionally, as is also further described in Chapter II, the Lake's watershed contains a critical species habitat and SEWRPC designated natural areas, as well as a variety of wetlands, uplands, and woodlands. It is also expected that the Lake and its watershed support several species of reptiles and amphibians, small and large mammals, insects, invertebrates, as well as a number of bird species that inhabit the area year around or visit during migration.[3]

LAKE PROTECTION PROGRAMS AND GOALS

General lake protection goals and objectives for Pike Lake, aimed at maintaining and enhancing the Lake's many assets, were developed as a part of this planning process. These goals and objectives were developed in consultation with the PLPRD the general public. In addition, these goals and objectives directly address goals established in the Washington County multi-jurisdictional comprehensive plan[4] and the Town of Hartford Comprehensive Plan,[5] including:

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[2] *This plan has been prepared pursuant to the standards and requirements set forth in the following chapters of the* Wisconsin Administrative Code: *Chapter NR 1, "Public Access Policy for Waterways;" Chapter NR 40, "Invasive Species Identification, Classification and Control;" 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."*

[3] *These estimates are based on bird, amphibian, and reptile databases for the Region.*

[4] *SEWRPC Community Assistance Planning Report No. 287,* A Multi-Jurisdictional Comprehensive Plan for Washington County: 2035, *April 2008.*

[5] *SEWRPC Community Assistance Planning Report No. 293,* A Comprehensive Plan for the Town of Hartford: 2035, *April 2009.*

Map 2

PIKE LAKE'S BATHYMETRY

DATE OF PHOTOGRAPHY: APRIL 2015

—5'— WATER DEPTH CONTOUR IN FEET

N

0 500 1,000 Feet

Source: SEWRPC.

- Documenting the aquatic plant community and fishery of Pike Lake, with emphasis on the occurrence and distribution of nonnative species. This report details the findings of the 2012 SEWRPC aquatic plant to help quantify the status of the aquatic plant community, and summarizes fish surveys completed by WDNR staff;

- Describing existing and historical conditions in the Pike Lake watershed including potential point and nonpoint pollutant sources, nutrient and contaminant inputs, hydrology, and nutrient and contaminant balances. This report identifies pollution sources, and provides nutrient load estimates which can inform pollution control management efforts;

- Identifying the extent of existing and potential future water quality problems likely to be experienced in the Lake. This effort includes examining Lake water quality using monitoring data collected as part of ongoing programs along with estimating the magnitude of potential future changes. This report includes an inventory of available water quality data for Pike Lake, draws conclusions from those data, and provides recommendations based on the evaluation of those data; and

- Formulating appropriate Lake protection programs, including engineering concepts, public information and education strategies, and other actions necessary to address the identified problems and issues of concern.

This report uses the information described above to develop a comprehensive set of specific recommendations to protect and enhance Pike Lake, related to the issues and concerns of Pike Lake residents, including an aquatic plant management plan. Implementing the recommended actions should be an important step in achieving long-term, sustainable Lake use/protection objectives.

Table 1

HYDROLOGY AND MORPHOMETRY OF PIKE LAKE

Parameter	Measurement
Size	
Surface Area of Lake	461 acres
Total Tributary Area	8,323 acres
Lake Volume	6,915 acre-feet
Residence Time[a]	1.1 years
Shape	
Length of Lake	1.2 mile
Width of Lake	1.1 mile
Length of Shoreline	3.8 mile
Shoreline Development Factor[b]	1.5
General Lake Orientation	Indistinctly NE-SW
Depth	
Maximum Depth	45 feet
Mean Depth	15 feet
Depth Area Less Than Five Feet	39 percent
Depth Area Five to 30 Feet	34 percent
Depth Area More Than 30 Feet	27 percent

NOTE: The original SEWRPC report on Pike Lake (CAPR No. 273, *A Lake Management Report for Pike Lake*, 2005) reported the area of Pike Lake as 470 acres and the total tributary area as 7,966 acres. The data presented above is based on refinements to the watershed boundary made using the most current available ground elevation information from 2013.

[a]Residence time is the number of years required for natural water sources under typical weather conditions to fill the lake one time. Natural water sources include runoff from surrounding areas, precipitation falling directly upon a lake, water entering from tributary streams, and water contributed to a lake by groundwater.

[b]Shoreline development factor is the ratio of the shoreline length to the circumference of a circular lake of the same area. It can be used as an indicator of biological activity (i.e., the higher the value, the more likely the lake will be to have a productive biological community) and the length of shoreline per acre of open water.

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

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Chapter II

ISSUES AND CONCERNS

INTRODUCTION

Despite being a valuable resource as described in Chapter I, Pike Lake is subjected to conditions that help create a number of existing and potential future problems and issues of concern. To better define and understand these issues and help maintain recreational use and the ecological value of the Lake, the Pike Lake Protection and Rehabilitation District (PLPRD) executed an agreement with the Southeastern Wisconsin Regional Planning Commission (SEWRPC) to investigate the causes of community concerns and develop a plan to address these concerns. The primary goals of this plan are to quantify current water quality conditions, provide an overview of aquatic plant issues and concerns, and suggest strategies and actions that address aquatic plant concerns.

As a part of this planning program, five general issues of concern were identified through consultations with Pike Lake community members, including board members of the PLPRD. Four additional concerns were identified by SEWRPC. Table 2 lists all nine issues. This chapter examines each issue of concern and seeks to answer the questions posed by Lake residents at workshops and during subsequent consultations. Information is presented to help define the basis of the recommendations provided in Chapter III of this report.

ISSUE 1: AQUATIC PLANT GROWTH

Aquatic plant management is the initial and primary purpose of this planning effort. To develop aquatic plant management alternatives it is important to examine: 1) the need for in-lake aquatic plant management (active aquatic plant management is not always necessary) and 2) the alternatives that could potentially be employed and their possible impact on the overall health of the Lake and its users. This section first discusses the general need for aquatic plant management by evaluating the current state of aquatic plants in Pike Lake as compared to historical plant conditions and effectiveness of past plant management efforts. This data is then used to consider potential future aquatic plant management alternatives.

Aquatic Plants in Pike Lake

All lakes have plants. In fact, in a nutrient-rich lake such as Pike Lake,[1] it is actually normal to have abundant aquatic plant growth in shallow areas. Additionally, it is important to note that **native aquatic plants are an integral part of lake** ecosystems. Aquatic plants serve a number of valuable functions including: improving water quality by

[1] *Nutrient-rich lakes are very common in Southeastern Wisconsin due to nutrient-rich soils. Southeastern Wisconsin soils are rich in phosphorus, a key and oftentimes growth-limiting plant nutrient.*

using excess nutrients; providing habitat for invertebrates and fish; stabilizing lake bottom sediment; and supplying food and oxygen to a lake through photosynthesis. Given the importance of native aquatic plants to overall Lake health, it is desirable to periodically re-examine the abundance, distribution, and diversity of aquatic plants. Such data is contrasted to historical conditions in the Lake itself and other similar lakes, both comparisons help quantify the overall health of the aquatic plant community. A judgement can subsequently be made regarding the need for aquatic plant management, and the locations and methods that provide the most overall apparent benefit to the Lake's health and user needs. Data and interpretations related to Pike Lake are presented below.

Table 2

ISSUES OF CONCERN

	Issues and Concerns
1	Aquatic Plant Growth
2	Water Quality
3	Cyanobacteria and Floating Algae
4	Shoreline Maintenance
5	Water Quantity
6	Rubicon River Bypass Channel
7	Recreation
8	Fish and Wildlife
9	Plan Implementation

Source: SEWRPC.

2012 Aquatic Plant Survey

SEWRPC staff completed an aquatic plant survey during July 2012 using the point-intercept method.[2] This was the first point-intercept survey for the lake. Previous studies were transect surveys. This survey revealed that the five most dominant plant species in Pike Lake were (descending order of abundance): muskgrass (*Chara* spp.), sago pondweed (*Stuckenia pectinata*), nitella spp. (*Nitella*), Eurasian water milfoil (*Myriophyllum spicatum*), and eel-grass (*Vallisneria americana*). Table 3 lists all aquatic plant species detected by SEWPRC during 2012 as well as each plant's relative abundance and dominance. Appendix A includes distribution maps for each aquatic plant species along with a brief description of the ecological significance of each plant and identification tips.

Of the 289 sites shallow enough to be sampled in Pike Lake in the summer of 2012, 283 locations had heavy vegetation.[3] Very little vegetation commonly known to interfere with recreational use (e.g., coontail, lilies, and Eurasian water milfoil) was noted in the survey. With 25 different native submerged and floating species of aquatic plants being found during the 2012 survey, Pike Lake appears to have a diverse and healthy plant community, particularly when compared to other Southeastern Wisconsin lakes. For example, Little Muskego Lake in Waukesha County, which is comparable to Pike Lake in size, morphology, and lake type,[4] has 15 native species.[5] The health of Pike Lake is further supported by the fact that 10 native pondweeds, including a widely dispersed population of white-

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[2] *The point-intercept method uses predetermined sampling locations arranged in a grid pattern across the entire lake surface as fixed sampling sites. Each site is located using global positioning system (GPS) technology and a single rake haul is taken at each site. A quantitative assessment of the rake fullness (on a scale of zero to three) is then made for each species identified. Further details on the methodology can be found in Wisconsin Department of Natural Resources, Publication No. PUB-SS-1068 2010.*

[3] *Heavy vegetation in this context refers to a rake fullness measurement of three (Appendix A for schematic).*
[4] *Pike and Little Muskego lakes are both drainage lakes, meaning these lakes have both an inlet and an outlet.*

[5] *SEWRPC completed an aquatic plant survey on Little Muskego Lake in the summer of 2015. A report is anticipated to be published later this year.*

Table 3

AQUATIC PLANT ABUNDANCE DATA PIKE LAKE: JULY 2012

Aquatic Plant Species	Native or Invasive	Number of Sites Found	Frequency of Occurrence Within Vegetated Area (%)	Relative Frequency[a] (%)	Average Rake Fullness	Visual Sightings
Floating Plants						
Nymphaea odorata (white water lily)	Native	7	2.47	1.0	2.00	0
Nuphar variegata (spadderdock)	Native	4	3.2	0.6	2.25	0
Emergent Plants						
Scirpus subterminalis (water bulrush)	Native	5	1.77	0.7	1.60	0
Sagittaria jatfolia (common arrowhead)	Native	1	0.35	0.1	2.00	0
Submerged Plants						
Chara spp. (muskgrass)	Native	230	81.27	34.3	2.87	0
Stuckenia pectinata (Sago pondweed)	Native	106	37.46	15.8	1.73	0
Nitella (Nitella spp.)	Native	67	23.67	10.0	2.52	0
Myriophyllum spicatum (Eurasian water milfoil)	Invasive	56	19.79	8.3	1.59	0
Vallisneria americana (eel-grass/wild celery)	Native	46	16.25	6.9	1.39	0
Potamogeton praelongus (white-stem pondweed)	Native	37	13.07	5.5	1.38	0
Ceratophyllum demersum (coontail)	Native	22	7.77	3.3	1.50	0
Najas marina (spiny, or brittle, naiad)	Naturalized	24	8.48	3.6	1.25	0
Najas flexilis (slender naiad)	Native	5	1.77	0.7	1.20	0
Potamogeton gramineus (variable pondweed)	Native	18	6.36	2.7	1.72	
Myriophyllum sibiricum (native milfoil)	Native	10	3.53	1.5	1.20	0
Heteranthera dubia (water stargrass)	Native	4	1.41	0.6	2.50	0
Ranunculus longirostris (white water crowfoot)	Native	4	1.41	0.6	1.00	0
Potamogeton richardsonii (clasping-leaf pondweed)	Native	5	1.77	0.7	1.80	0
Potamogeton pusillus (small pondweed)	Native	5	1.77	0.7	1.40	0
Potamogeton illinoensis (Illinois pondweed)	Native	4	1.41	0.6	1.75	0
Najas flexilis (bushy pondweed)	Native	5	1.77	0.7	1.20	0
Potamogeton crispus (curly-leaf pondweed)	Invasive	3	1.06	0.4	1.67	0
Potamogeton nodosus (long-leaf pondweed)	Native	2	0.71	0.3	1.50	0
Potamogeton robinsii (Fern pondweed)	Native	1	0.35	0.1	3.00	0
Elodea canadensis (waterweed)	Native	2	0.71	0.3	1.00	0
Potamogeton foliosus (leafy pondweed)	Native	1	0.35	0.1	1.00	0
Potamogeton zosteriformis (flat-stem pondweed)	Native	1	0.35	0.1	1.00	0
Potamogeton natans (floating-leaf pondweed)	Native	1	0.435	0.1	1.00	0

NOTE: Sampling occurred at 289 sampling sites; 283 sites had vegetation. Note, also, in surveys prior to 2012, *Nuphar variegata* (spatterdock) is labelled as *Nuphar advena* (yellow water lily), considered by SEWRPC botanists to likely be a misidentification; likewise, *Nuphar odorata* has been re-identified as *Nymphaea odorata*. *Red text indicates nonnative/exotic species, see Appendix A for more details.*

[a]*The relative frequency is an individual plant's frequency of occurrence divided by the sum of the frequency of occurrence of all plants*

Source: SEWRPC.

stem pondweed,[6] and the **very high diversity of aquatic species** (see Figure 1) found during the 2012 survey. The presence of a diverse plant community (especially pondweeds) is generally associated with a healthy lake with good habitat for fish and/or other aquatic life. Therefore, native plants should be protected to the greatest extent practical.

The terms "nonnative" and "invasive" are often confused and incorrectly assumed to be synonymous. Nonnative is an overarching term describing living organisms introduced to new areas beyond their native range with intentional or unintentional human help. Nonnative species may not necessarily harm ecological function or human use values in their new environments. Invasive species are the subset of nonnative species that have damaging impacts on the ecological health of their new environments and/or are commonly considered a nuisance to human use values. In summary, **invasive species are non-native but not all non-native species are invasive.**

Invasive species, either plants or animals, can severely disrupt both terrestrial and aquatic natural systems. **Invasive species reproduce prolifically and often have no natural predators to control their growth, factors that combine to allow them to out-compete native species for space and other necessary resources. This can devastate native species population that have well developed co-dependencies with native plants and animals.**

The 2012 survey revealed two invasive species within the Lake, namely Eurasian water milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (Potamogeton crispus). Figures 2 and 3 show the distribution and density of Eurasian water milfoil and curly-leaf pondweed infestations in Pike Lake. Brittle water nymph (*Najas minor*) was also identified in the Lake in March 2012 but was not found by SEWRPC during the subsequent summer 2012 survey.

Eurasian water milfoil and curly-leaf pondweed are known to grow prolifically in lakes, often to levels that hinder navigation. Consequently, control strategies targeting these species are commonly considered. The fact that **Eurasian watermilfoil is the fourth most dominant species during 2012** (Eurasian water milfoil was found at 56 sites, or in about 20 percent of the sampled sites) reveals that a control campaign for this plant should be a priority. Interestingly, the 2016 Washington County aquatic plant survey did not identify Eurasian water milfoil (see Appendix B for Washington County's aquatic plant survey information).

A New Invasive Plant Species—Starry Stonewort (*Nitellopsis obtusa*)

During fall 2014, the Wisconsin DNR confirmed that a new invasive aquatic plant species (starry stonewort (*Nitellopsis obtuse*)) was present in the State, specifically in southeastern Wisconsin.[7] This is a concern since starry stonewort can form extremely dense vegetative mats that may affect aquatic plant community species richness and can impede recreational use. Dense growth of starry stonewort can also interfere with life-cycle critical functions of

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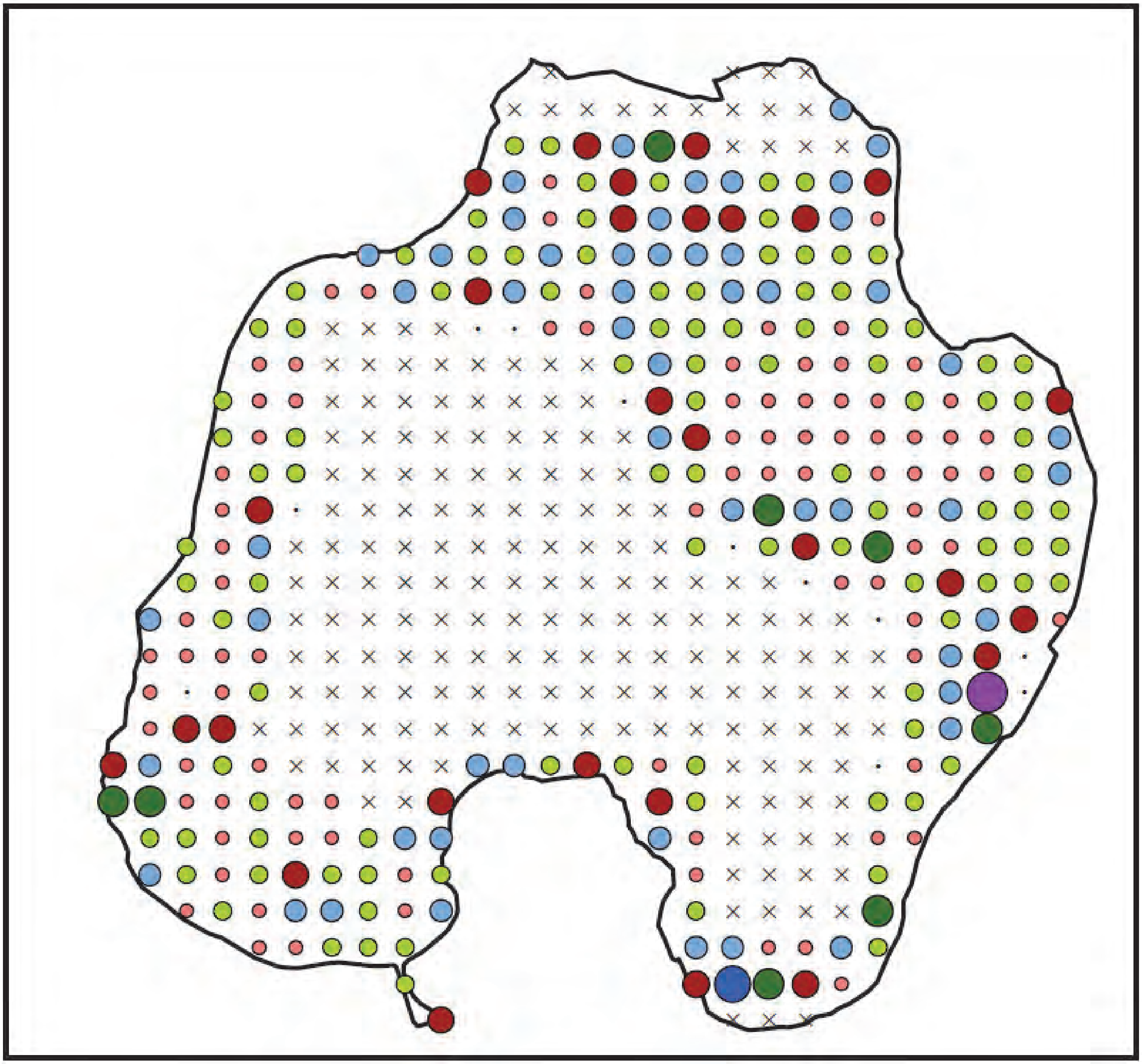
[6] *Of the pondweeds that occur in the Region, white-stem pondweed is of special importance because of its sensitivity to changes in water quality and intolerance of turbidity. It is considered a valuable water quality indicator species, since its disappearance from a lake is usually an indication of deteriorating water quality. Of the 289 sampled sites, 37 sites contained white-stem pondweed (the sixth most dominant plant in the Lake).*

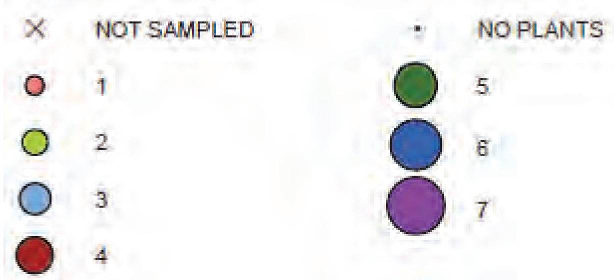
[7] *According to John Jung, President of the Pike Lake Advancement Association and Board Member of the Pike Lake Protection and Rehabilitation District, aquatic plants resembling starry stonewort were present in Pike Lake for many years before positive identification was made during 2014.*

Figure 1

PIKE LAKE AQUATIC PLANT SURVEY SITES AND SPECIES RICHNESS: JULY 2012



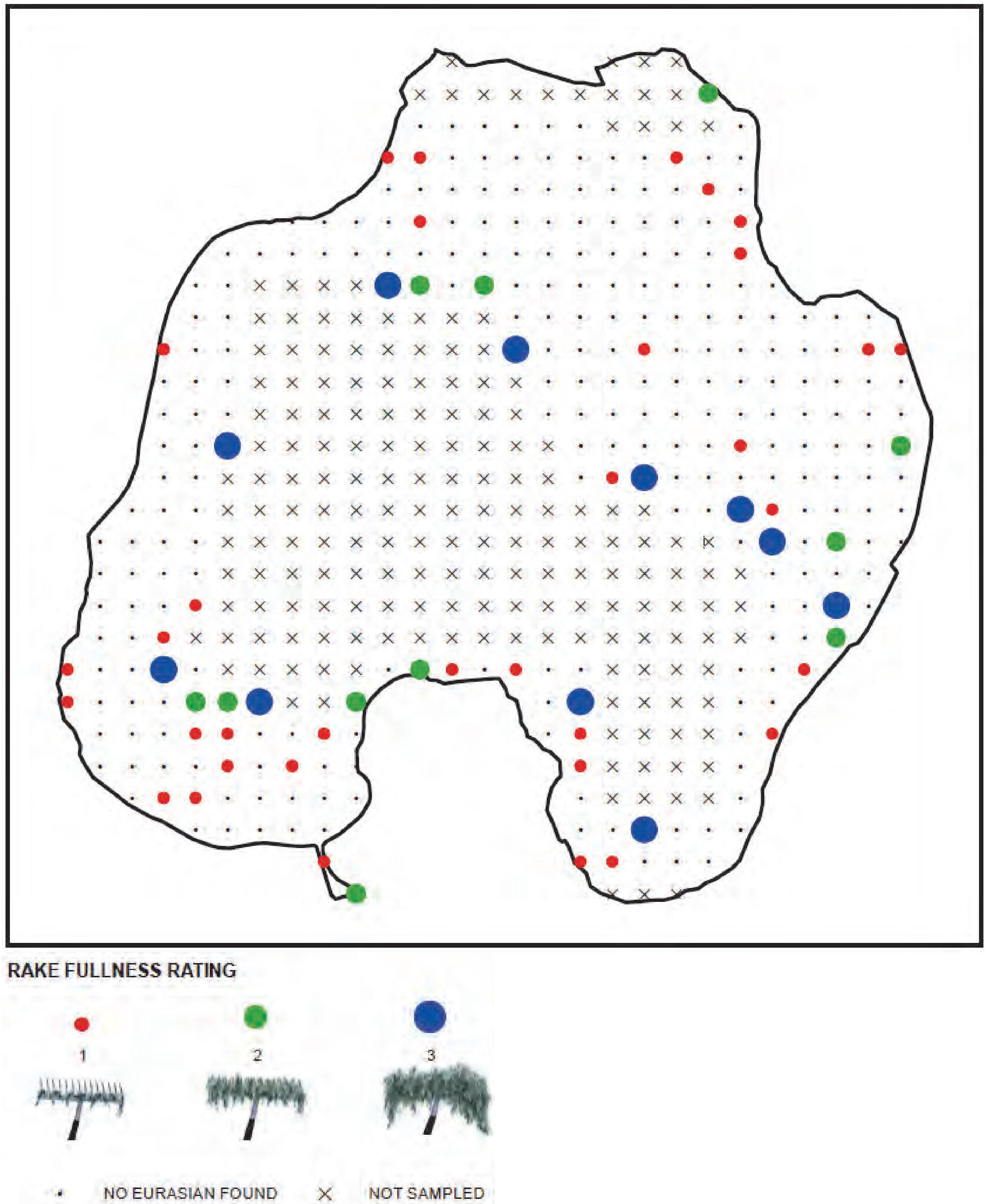
NOTE: The above diagram presents the data for number of species observed in Pike Lake at each sampling site during the July 2012 aquatic plant survey; sampling occurred at 288 sampling sites, 283 had vegetation.



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 2

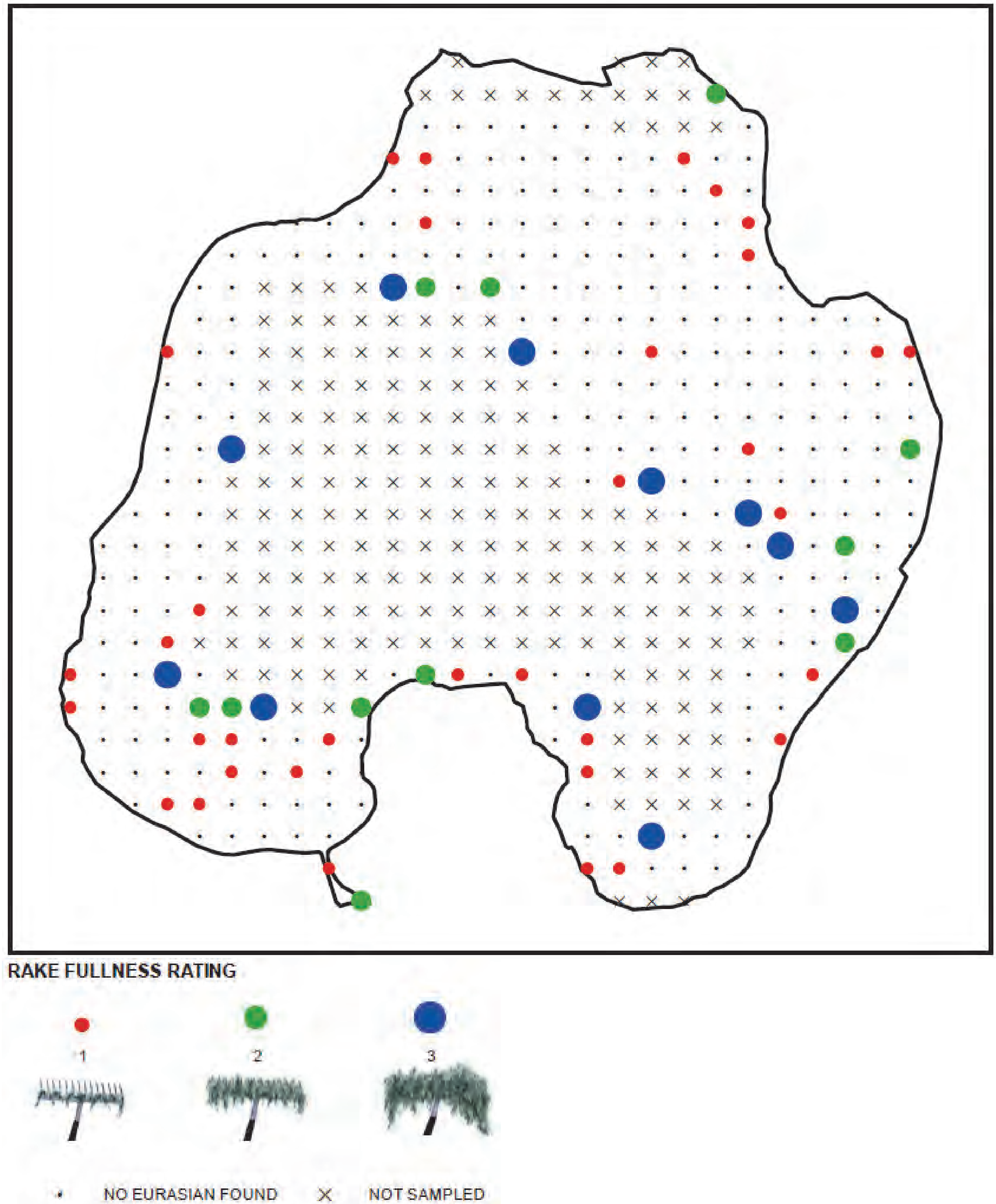
EURASIAN WATER MILFOIL OCCURRENCE IN PIKE LAKE: JULY 2012



Source: SEWRPC.

Figure 3

CURLY-LEAF PONDWEED OCCURRENCE IN PIKE LAKE: JULY 2012



Source: SEWRPC.

fish and other animals, including fish spawning.[8] Finding this invasive aquatic plant in the region led to a randomized sampling of lakes. A team of WDNR staff members searched for and identified starry stonewort in Pike Lake during August 2015. Map 3 outlines the areas in the Lake where starry stonewort was found to be most prevalent; however, it was noted that the population was not present at nuisance levels during August 2015. The PLPRD has since met with the WDNR and Washington County Aquatic Invasive Species Coordinator to discuss steps to manage this infestation. Details of management decisions are discussed in Chapter III of this report.

Washington County completed another point-intercept plant survey during July 2016. Washington County's July 2016 point intercept data was used to map the most recent known occurrence of starry stonewort in Pike Lake (see Figure 4). Comparing the August 2015 (Map 3) starry stonewort distribution with the July 2016 (Figure 4) data reveals that starry stonewort may have colonized additional areas. However, it must be remembered that the 2015 data was collected during late August using a meander survey. Meander surveys are used to rapidly assess if an invasive species is present in a lake, and are not designed to provide a quantitative estimate of the population dynamics of a plant in a lake. Furthermore, the 2015 data was collected much later in the growing season, which could affect the abundance and visibility of starry stonewort. Both these factors complicate comparison of the 2015 and 2016 data sets. The starry stonewort population is currently not known to disrupt Pike Lake's ecology.

Historical Aquatic Plant Comparison

Pike Lake's aquatic plant community was surveyed two times prior to 2012: in 1976 and June 2001. The WDNR's 1976 survey lists 13 species present while SEWRPC's 2001 survey lists 17 species. Both surveys reveal muskgrass as the most dominant species; however, the 2001 report listed Eurasian water milfoil as the next dominant species in Pike Lake.[9] These surveys suggest that the health of Pike Lake's aquatic plant community is improving as evidenced by increasing species richness and reduced frequency of occurrence for Eurasian water milfoil. Table 4 compares species that were found in the previous aquatic plant surveys with those found in 2012 and 2016 and notes the most dominant species for each survey.

Aquatic Plant Management Alternatives

Local meetings and workshops revealed that most lake users and managers believe that managing Eurasian water milfoil is the most important aquatic plant community concern. Based upon this finding, this section examines management alternatives as they relate to Eurasian water milfoil control. Additionally, the risks posed by these management alternatives to Lake users and native aquatic plant species (preservation of which is another important management concern) is also examined. The management alternatives potential utility as control strategies for starry stonewort is also examined. The section concludes with initial recommendations for each of the management alternatives.

Competing and sometimes conflicting interests and goals commonly must coexist when it comes to aquatic plant management because pursuing one goal may interfere with the accomplishing another goal. For example, Eurasian

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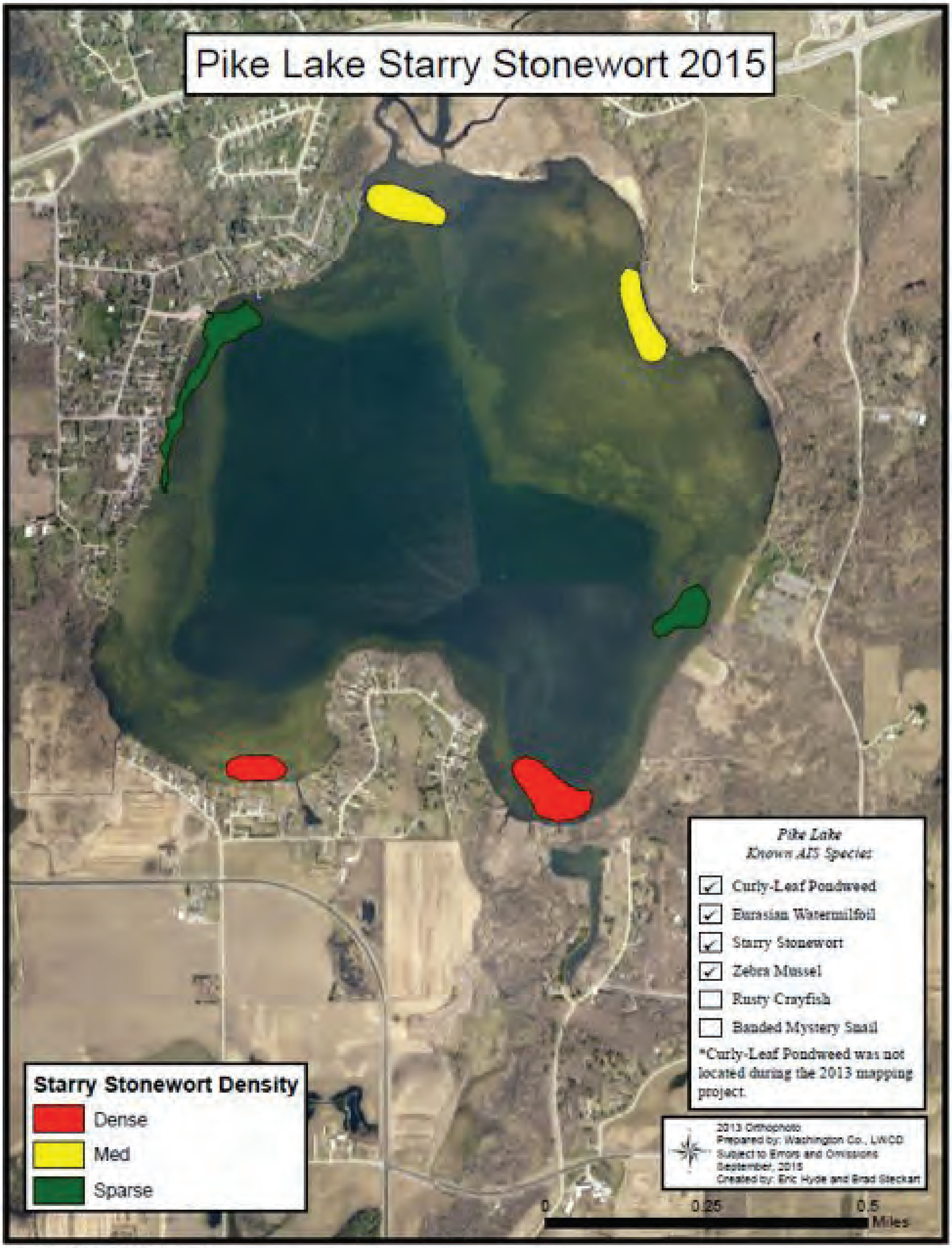
[8] "Aquatic Invasive Species Quick Guide: Starry Stonewort *(Nitellopsis obtusa L.)". Golden Sands Resource Conservation and Development Council, Inc.*
This Quick Guide is part of a series on aquatic invasive species, and may be reproduced for educational purposes. Visit www.uwsp.edu/cnr/uwexlakes/clmn or www.goldensandsrcd.org/our-work/water to download this series of handouts. Developed by Golden Sands Resource Conservation & Development Council, Inc. as part of an aquatic invasive species education program, supported by a grant from the Wisconsin Department of Natural Resources. Maintained and updated by the Wisconsin Citizen Lake Monitoring Network.

[9] *A direct comparison between the historic 1976 and 2001 aquatic plant surveys and the 2012 survey was not made because of the different methodologies that were undertaken for each of the surveys (grid point versus transect surveys).*

Map 3

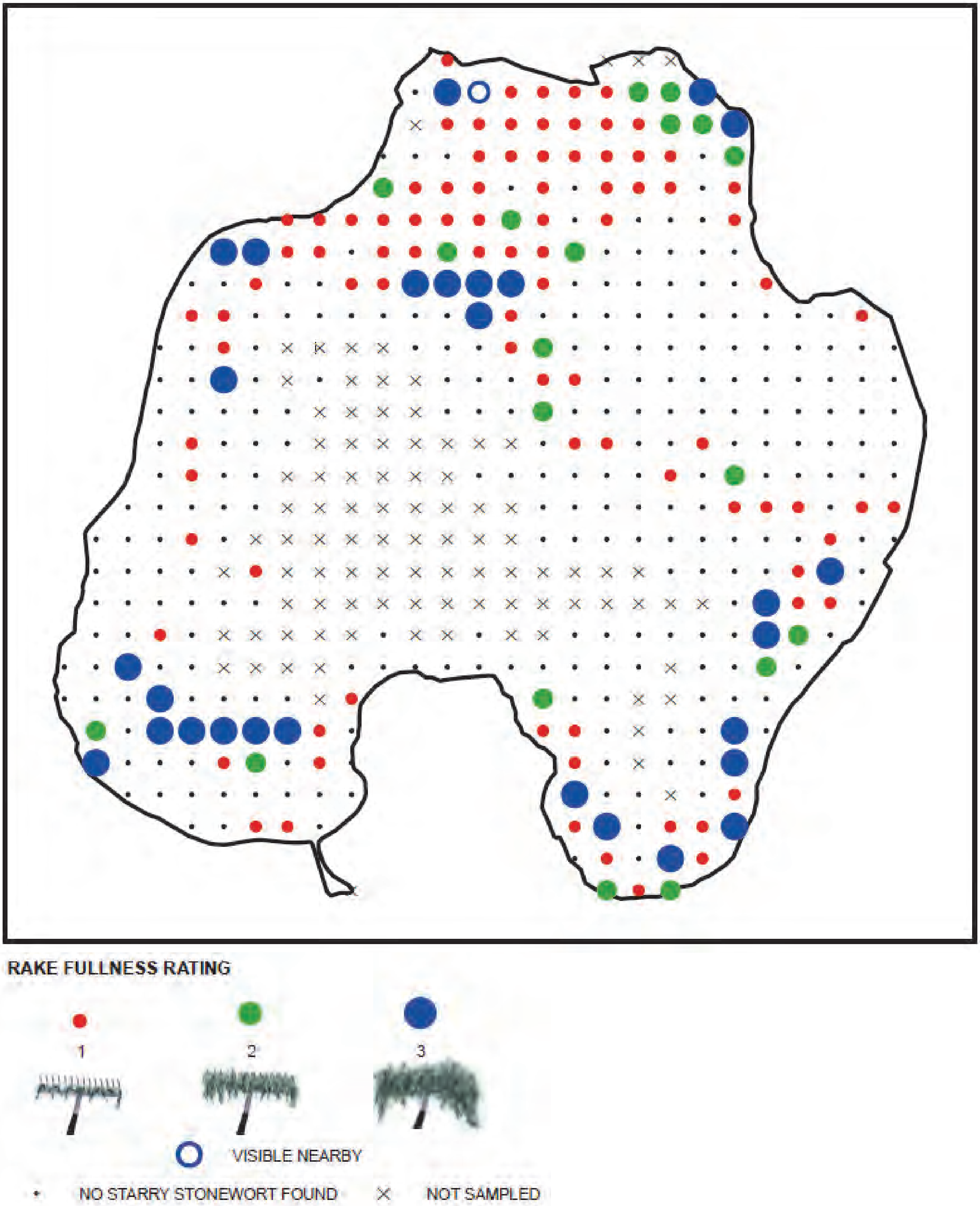
PIKE LAKE STARRY STONEWORT DISTRIBUTION: AUGUST 2015



Source: Washington County.

Figure 4

STARRY STONEWORT OCCURRENCE IN PIKE LAKE: JULY 2016



Source: Washington County LWCD, WDNR, and SEWRPC.

Table 4

AQUATIC PLANT SPECIES OBSERVED IN PIKE LAKE: 1976, 2001, 2012, and 2016

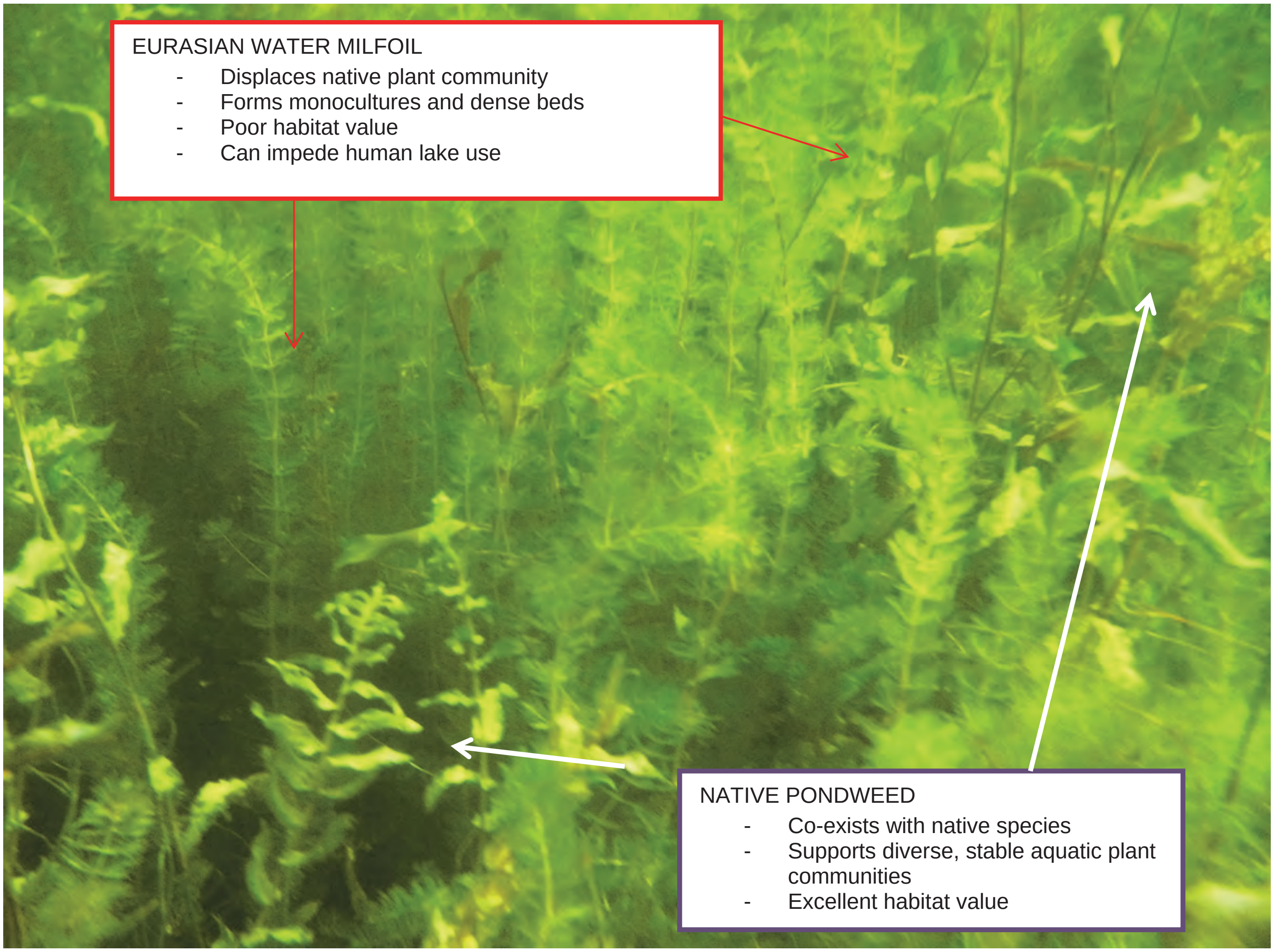
Aquatic Plant Species	July 2016	July 2012	June 2001	1976
Floating Plants				
Nymphaea odorata (white water lily)	X	X	- -	X
Nuphar variegata (yellow water lily or spadderdock)	- -	X	- -	X
Emergent Plants	- -	- -		
Scirpus subterminalis (water bulrush)	- -	X	- -	X
Sagittaria spp. (arrowhead)	- -	X	- -	- -
Submerged Plants				
Chara spp. (muskgrass)	X	X	X	X
Stuckenia pectinata (Sago pondweed)	X	X	X	X
Nitella (Nitella spp.)	- -	X	- -	
Myriophyllum spicatum (Eurasian water milfoil)	- -	X	X	X
Vallisneria americana (eel-grass/wild celery)	X	X	X	X
Potamogeton praelongus (white-stem pondweed)		X	- -	- -
Ceratophyllum demersum (coontail)	X	X	X	- -
Najas marina (spiny, or brittle, naiad)	X	X	X	- -
Potamogeton gramineus (variable pondweed)	X	X	X	- -
Myriophyllum sibiricum (native milfoil)	X	X	X	- -
Zosterella dubia (water stargrass)	X	X	X	- -
Ranunculus longirostris (white water crowfoot)	X	X	X	- -
Potamogeton richardsonii (clasping-leaf pondweed)	X	X	X	- -
Potamogeton pusillus (small pondweed)	- -	X	- -	- -
Potamogeton illinoensis (Illinois pondweed)	X	X	X	- -
Najas flexilis (slender naiad)	X	X	X	X
Potamogeton crispus (curly-leaf pondweed)	X	X	X	- -
Potamogeton nodosus (long-leaf pondweed)	- -	X	- -	- -
Potamogeton robinsii (Robbins pondweed)	- -	X	- -	- -
Elodea canadensis (waterweed)	- -	X	X	- -
Potamogeton foliosus (leafy pondweed)	- -	X	- -	X
Potamogeton zosteriformis (flat-stem pondweed)	X	X	X	- -
Potamogeton natans (floating-leaf pondweed)	- -	X	X	X
Lemna minor (duckweed)	X	- -	- -	X
Zizania aquatica (wild rice)	- -	- -	- -	X
Potomogeton amplifolius (Large-leaf pondweed)	- -	- -	- -	X
Najas guadalupensis (Southern naiad)	X	- -	- -	- -
*Potamogeton friesii (*Fries pondweed*)*	X	- -	- -	- -
*Ulricularia vulgaris (*Common bladderwort*)*	X	- -	- -	- -
*Nitellopsis obtusa (*Starry stonewort*)*	X	- -	- -	- -
Total Number of Species	20	27	17	13

NOTE: surveys prior to 2012 label *Nuphar variegata* (spatterdock) as *Nuphar advena* (yellow water lily), considered by SEWRPC botanists to likely be a misidentification; likewise, *Nuphar odorata* has been re-identified as *Nymphaea odorata. Red text indicates nonnative/exotic species, see Appendix A for more details.*

Source: SEWRPC.

Figure 5

COMINGLED STAND OF EURASIAN WATER MILFOIL AND NATIVE PONDWEED



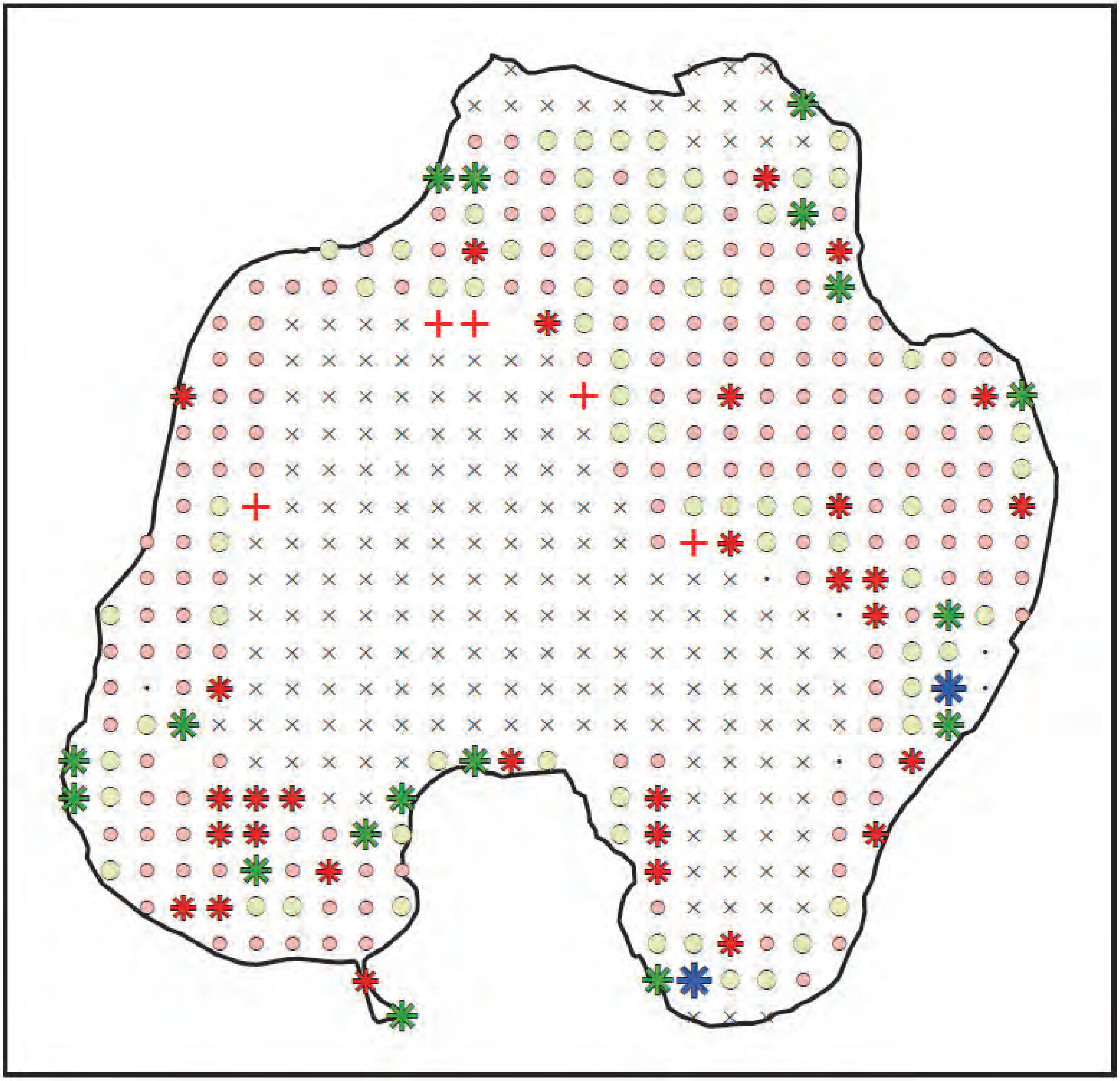
Source: SEWRPC.

water milfoil could be eradicated with heavy chemical treatment. However, since Eurasian water milfoil often forms mixed stands with native plants (see Figures 5 and 6), including a very similar looking native milfoil plant (see Figure 7 and Appendix A), this technique would fail to accomplish the goal of preserving native plant populations. Therefore, all aquatic plant management alternatives described in this section balance three oftentimes conflicting goals: maintaining human access to open waters, controlling the extent and spread of Eurasian water milfoil and other nonnative species, and protecting native aquatic plants.

Aquatic plant management measures can be classified into five groups: 1) *physical measures* which include lake bottom coverings; 2) *biological measures* which include use living organisms, including herbivorous insects; 3) *manual measures* which involve manual removing plants by people using hand-held rakes or by hand; 4) *mechanical measures* which include harvesting and removing aquatic plants with a machine known as a harvester or by suction harvesting; and 5) *chemical measures* which include using aquatic herbicides to kill nuisance and nonnative aquatic plants. More information regarding these alternatives are provided below. All of these control measures are stringently regulated and most require a State of Wisconsin permit. Chemical controls, for example, require a permit and are regulated under Chapter NR 107 “Aquatic Plant Management” of the *Wisconsin Administrative Code*, while

Figure 6

COMINGLED STANDS OF EURASIAN WATER MILFOIL AND NATIVE AQUATIC PLANTS IN PIKE LAKE: JULY 2012

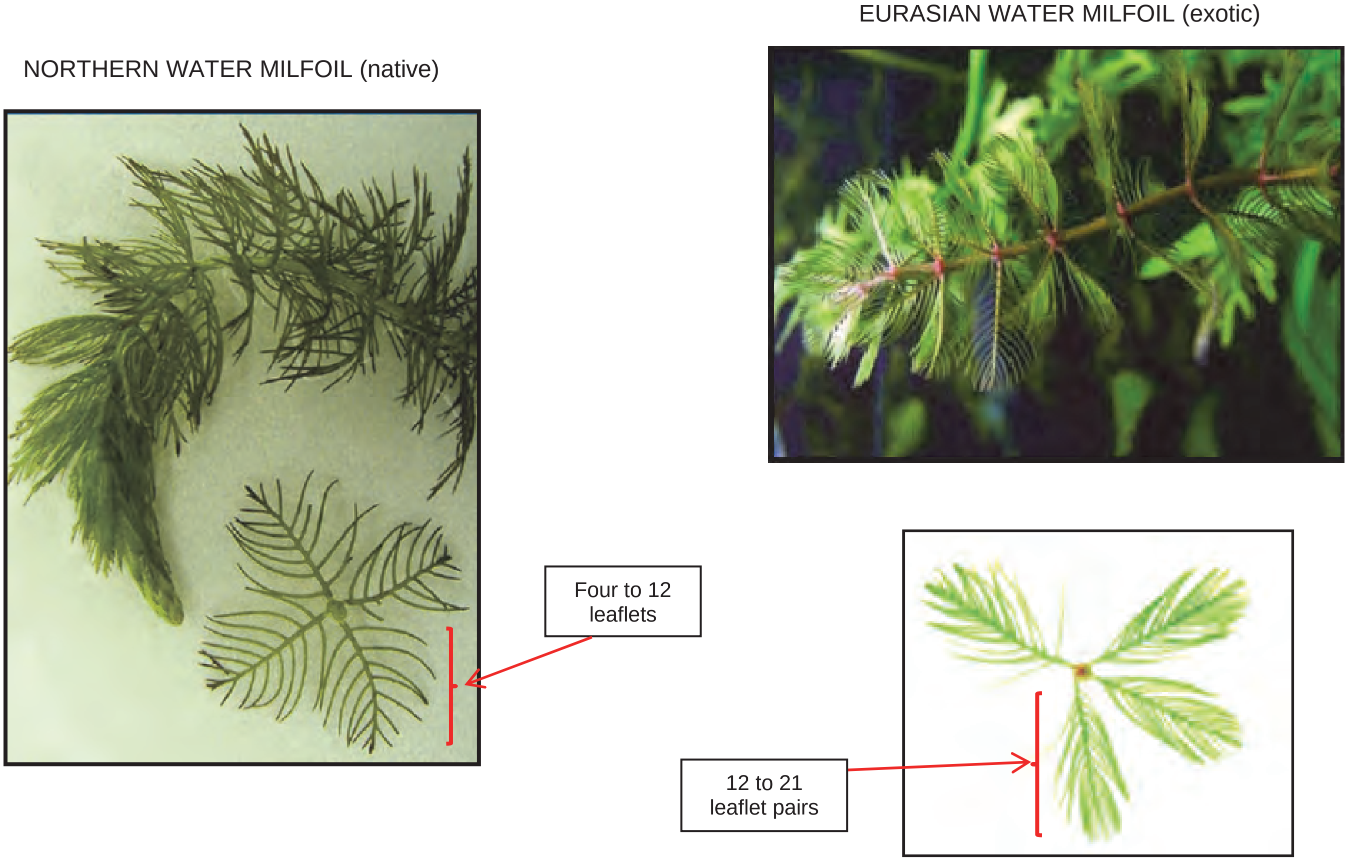


[a]Native species richness refers to the number of native plants present at sampling site: Low=1 or 2; Medium=3, 4 or 5; and High=6 or 7.

Source: SEWRPC.

Figure 7

COMPARISON OF NATIVE AND EURASIAN WATER MILFOIL



Source: SEWRPC.

placing bottom covers (a physical measure) requires a WDNR permit under Chapter 30 of the *Wisconsin Statutes*. All other aquatic plant management practices are regulated under Chapter NR 109 "Aquatic Plants: Introduction, Manual Removal and Mechanical Control Regulations" of the *Wisconsin Administrative Code*.

The aquatic plant management elements presented in this section consider alternative management measures consistent with the provisions of Chapters NR 103 "Water Quality Standards for Wetlands" NR 107, and NR 109 of the *Wisconsin Administrative Code*. Further, the alternative aquatic plant management measures are consistent with Chapter NR 7 "Recreational Boating Facilities Program" requirements of the *Wisconsin Administrative Code*, and with public recreational boating access requirements relating to eligibility under the State cost-share grant programs set forth in Chapter NR 1 "Natural Resources Board of Policies" of the *Wisconsin Administrative Code*.

Physical Measures

Lake-bottom covers and light screens control rooted plants by creating a physical barrier that reduces or eliminates plant-available sunlight. They are often used to create swimming beaches on muddy shores, to improve the appearance of lakefront property, and to open channels for motorboats. Various materials can be used with varied levels of success. For example, pea gravel, which is usually widely available and relatively inexpensive, is often used as a bottom cover material despite the fact that plants readily recolonize pea gravel deposited upon lake bottoms. Other options include synthetic materials (e.g., polyethylene, polypropylene, fiberglass, and nylon) known as bottom screens or barriers, can provide relief from rooted plants for several years. Synthetic bottom screens are susceptible to disturbance by watercraft propellers and to gas build-up from decaying plant biomass trapped under the barrier and therefore may have to be placed and removed each year. In the case of Pike Lake, the need to encourage native aquatic plant growth while simultaneously controlling the growth of exotic species, often in the same location, suggests that **placing lake bottom covers is not believe to be a viable method to control aquatic plants,** as it is not consistent with the objective of encouraging native aquatic plant growth. Also, no physical measure is known to be effectively used to control starry stonewort; therefore, physical measures are not considered viable for the management of this new invasive plant.

Biological Measures

Biological controls offer an alternative approach to controlling nuisance plants. Biological control techniques commonly employ herbivorous insects that feed upon nuisance plants. Such approaches have been successful in some southeastern Wisconsin lakes.[10] In fact, given that **Pike Lake has had a historically documented population of Euhrychiopsis lecontei (an aquatic weevil species known to feed on Eurasian water milfoil),** biological control may be a desirable way to help control Eurasian water milfoil. These weevils overwinter in dead plant debris along shorelines. The weevil population may increase if more shoreline property is allowed to revert to a more natural condition, thereby increasing overwintering habitat for the weevils. These insects are no longer commercially available; therefore, purchasing weevils to augment existing populations is not presently viable. Consequently, increasing the amount of natural shorelines may be the only method currently available to bolster populations of this Eurasian water milfoil control agent. Shoreline property owners would be the primary focus of such an approach, since much of the publically owned shoreline is already naturalized. Since naturalized shorelines generally help improve water quality and habitat value, such an initiative should be given a high priority. Alternatively, if these insects were to become commercially available in Wisconsin, stocking weevils may be a viable option to consider in the future, subject to further investigation. Stocking could temporarily bolster populations, but would have the more lasting value if overwintering habitat is increased allowing stocked weevils to reproduce.

No biological control measures are presently known to combat starry stonewort.

Manual Measures

Manually removing specific types of aquatic vegetation is a highly selective means of controlling nuisance aquatic plant growth, including Eurasian water milfoil. Two common manual removal methods are used: raking and hand-pulling. Each is described in the following paragraphs.

Raking is conducted in nearshore areas with specially designed hand tools. Raking allows nonnative plants to be removed in shallow nearshore areas and also provides a **safe and convenient method to control aquatic plants in deeper nearshore waters around piers and docks.** The advantages associated with using rakes include: 1) the tools are relatively inexpensive ($100 to $150 each), 2) they are easy to use, 3) they generate immediate results, and 4) they immediately remove plant material from a lake (including seeds and plant fragment) thereby reducing nutrient release and sedimentation from decomposing plant material and reducing the reproductive potential of target plants. Should Pike Lake residents decide to implement this method of control, an interested party could acquire a number of these specially designed rakes for riparian owners to use on a trial basis. Therefore, **raking is considered viable option** to manage overly abundant or undesirable plant growth in areas where other management efforts are not feasible, However, when managing starry stonewort, the main reproductive source to remove is the bulbils (see Appendix A) found under the sediment or near the bottom of the algae making rake removal ill-advised as the reproductive structure may not be removed with this method.

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[10] *B. Moorman, "A Battle with Purple Loosestrife: A Beginner's Experience with Biological Control,"* Lake Line, *Vol. 17, No. 3, September 1997, pp. 20-21, 34-3; see also, C.B. Huffacker, D.L. Dahlsen, D.H. Janzen, and G.G. Kennedy,* Insect Influences in the Regulation of Plant Population and Communities, *1984, pp. 659-696; and C.B. Huffacker and R.L. Rabb, editors,* Ecological Entomology, *John Wiley, New York, New York, USA.*

The second manual control—hand-pulling of stems where they occur in isolated stands—provides an alternative means of controlling plants such as Eurasian water milfoil and starry stonewort. **This method is particularly helpful when attempting to target nonnative plants in the high growth season, when native and nonnative species often coexist and intermix.** This method is more highly selectivity than rakes, mechanical removal, and chemical treatments, and if carefully applied, is less damaging to native plants. Additionally, physically removing plant materials prevents sedimentation and nutrient release from targeted plants, which incrementally helps maintain water depth and better water quality. Physical removal also reduces the amount of target plant seed and plant fragments, which helps reduce the reproductive ability of the target plants. Given these advantages, **<u>manual removal of Eurasian water milfoil and starry stonewort through hand-pulling is considered a viable option</u>** <u>in Pike Lake, where practical</u>. To control starry stonewort, hand pulling may need to be consistently employed for at least five consecutive years. It could be employed by volunteers or homeowners, as long as they are properly trained to identify Eurasian water milfoil, starry stonewort, or any other invasive plant species of interest. WDNR provides a wealth of guidance materials, including an instructional video describing manual plant removal, to help educate volunteers and homeowners.

Pursuant to Chapter NR 109 of the *Wisconsin Administrative Code,* **both raking and hand-pulling of aquatic plants are allowed without a WDNR permit** under the following conditions:

- Eurasian water milfoil, curly-leaf pondweed, and purple loosestrife may be removed if the native plant community is not harmed in the process.
- Thirty feet or less of shoreline may be cleared, however, this total must include docks, piers, boatlifts, rafts, and areas undergoing other plant control treatment. Vegetation may generally be removed up to 100 feet out from the shoreline.
- Plant material that drifts onto the shoreline must be removed.
- The shoreline in question is not a designated sensitive area.
- Raked and hand-pulled plant material is removed from the lake.

Any other **manual removal requires a State permit, unless employed to specifically control designated nonnative invasive species** such as Eurasian water milfoil. In general, State manual aquatic plant removal permits call for all hand-pulled material to be removed from the lake. **No mechanical equipment (e.g., towing equipment such as a rake behind a motorized boat or using weed rollers) may be legally used without a WDNR-issued permit. <u>Recommendations regarding hand-pulling and raking are included in Chapter III.</u>**

Mechanical Measures

Two mechanical harvesting methods are currently permitted and employed in Wisconsin. These methods include aquatic plant harvesters (mechanical harvesting) and suction harvesting. More details about each are presented in following paragraphs.

Plant Harvesting

Aquatic plants can be mechanically gathered using specialized equipment known as harvesters (see Figure 8). This equipment consists of an adjustable cutting apparatus that cut plants at selected depths from the surface to up to about five feet below the water surface and a collection system (e.g., a conveyor and a basket) that gathers most cut plant material. Mechanical harvesting can be a practical and efficient means of controlling sedimentation and plant growth, as it removes plant biomass which would otherwise decompose and release nutrients and sediment into a lake. Mechanical harvesting is particularly effective for large-scale projects.

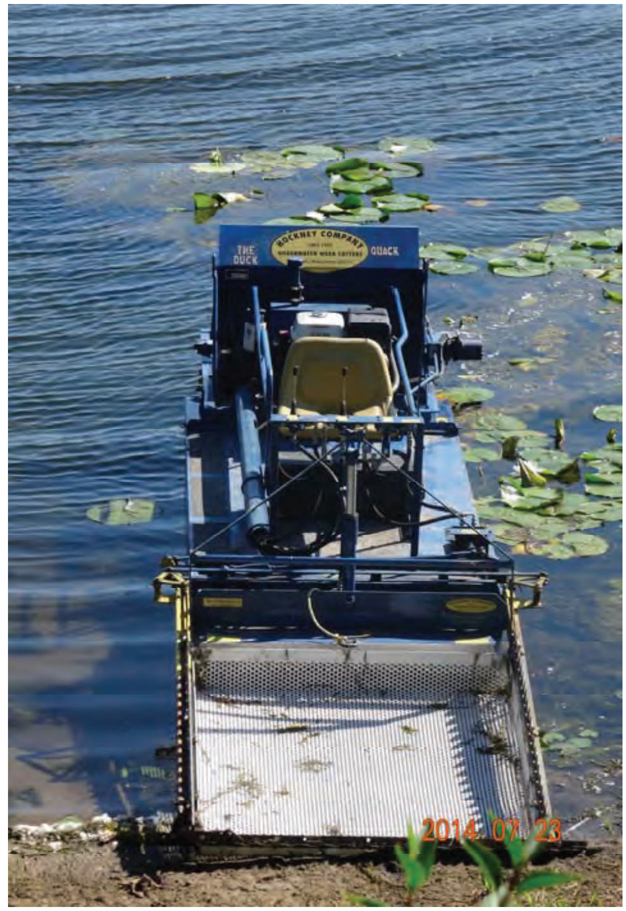
An advantage of mechanical harvesting is that the harvester, when properly operated, "mows" the tops off of aquatic plants. There, **this method typically leaves enough living plant material in the lake to provide shelter for aquatic wildlife and to stabilize lake-bottom sediment. None of the other aquatic plant management meth-**

ods leave living plant material in place after treatment. Aquatic plant harvesting also has been shown to facilitate growth of suppressed native aquatic plants by allowing light to penetrate to the lakebed. This is particularly effective when controlling invasive plant species that commonly grow very early in the season when native plants have not yet emerged or appreciably grown. Finally, harvesting does not kill native plants in the way that other control methods do. Instead, this method simply trims them back.

A disadvantage of mechanical harvesting is that **the harvesting process may fragment plants and thereby unintentionally facilitate the spread of Eurasian water milfoil and starry stonewort,** both of which utilize fragmentation as a means of propagation, particularly in areas where plant roots have been removed. This <u>further emphasizes the need to prevent harvesting that removes the roots of native plants</u>. Harvesting may also agitate bottom sediments in shallow areas, thereby increasing turbidity and resulting in deleterious effects such as smothering of fish breeding habitat and nesting sites. Agitating bottom sediment also increases the risk of nonnative species recolonization, as invasive species tend to thrive on disrupted and/or bare lake bottom. To this end, **most WDNR-issued permits do not allow deep-cut harvesting in water less than three feet deep,**[11] which limits the utility of this alternative in many littoral areas. Nevertheless, if employed correctly and carefully under suitable conditions, harvesting can benefit navigation lane maintenance and can ultimately reduce regrowth of nuisance plants while maintaining native plant communities.

Figure 8

TYPICAL SMALL-SCALE HARVESTER



NOTE: This photo shows a harvester used on another southeastern Wisconsin lake. This picture solely illustrates the appearance of such equipment, and is not meant to advocate any particular brand or design.

Source: SEWRPC.

It should again be noted that some **cut plant fragments can escape the harvester's collection system.** This negative side effect is fairly common. To compensate for this, most harvesting programs include a plant pickup program. The plant pickup program often uses the harvester to gather and collect large accumulations of floating plant debris as well as arranging regular pickup from lakefront property owners who actively rake plant debris onto their docks. This kind of program, when applied systematically, can reduce plant propagation from plant fragments and can help alleviate the negative aesthetic consequences of plant debris accumulating on the lake shore.

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[11] *Deep-cut harvesting is harvesting to a distance of only one foot from the lake bottom. This is not allowed in shallow areas because it is challenging to properly ensure that the harvester does not hit the lake bottom in these areas.*

A mechanical harvester has never been used to control Eurasian water milfoil or maintain navigation lanes in Pike Lake. Mechanical harvesting contractors estimate they would charge roughly $10,000 per year for a turn-key program to harvest aquatic plants in likely areas of Pike Lake.[12] Due to the high cost of mechanical harvesting, as well as the sparse community of Eurasian water milfoil and little to no navigational issues of concern on Pike Lake, harvesting is not considered further in this report. Cost is not the only factor for not utilizing this method – harvesting could also encourage the spread of starry stonewort.

Suction Harvesting

An alternative aquatic plant harvesting method has emerged - Diver Assisted Suction Harvesting (DASH). First permitted in 2014, DASH (also known as suction harvesting) is a mechanical process where divers identify and pull select aquatic plants by their roots from the lakebed and then insert the entire plant into a suction hose that transports the plant to the lake surface for collection and disposal. The process is essentially a more efficient and wide-ranging method for hand-pulling aquatic plants. Such labor-intensive work by skilled professional divers is, at present, a costly undertaking and long-term evaluations will need to evaluate the efficacy of the technique. Nevertheless, many apparent advantages associated with this method, including: 1) **lower potential to fragment plants** when compared to traditional harvesting and hand-pulling, thereby reducing spread and regrowth of invasive plants like Eurasian water milfoil and starry stonewort; 2) **increased selectivity in terms of plant removed** when compared to traditional harvesting, thereby reducing the loss of native plants; and 3) **lower frequency of fish habitat disturbance.** Given these advantages, DASH is considered a viable option for shallower areas (less than three feet) and in areas where Eurasian water milfoil is intermixed with native plants, subject to a review of costs and permit requirements and provisions. DASH is not currently recommended to remove starry stonewort since the current population appears to be too large and widespread for this method to be feasible. However, DASH could be an appropriate future technique if management is warranted in a specific location or if the population decreases.

Both mechanical harvesting and suction harvesting are regulated by WDNR and require a permit. Non-compliance with permit requirements is legally enforceable and may lead to fines and/or complete permit revocation. The information and recommendations provided in this report will help frame permit requirements. Permits can be granted to cover up to a five-year period.[13] At the end of that period, a new plant management plan must be developed. The updated plan must consider the results of a new aquatic plant survey and must evaluate the success or failure and effects of completed plant management activities.[14] These plans and plan execution are overseen by the WDNR aquatic invasive species coordinator for the region.[15] Recommendations are included in Chapter III.

Chemical Measures

Use of chemical herbicides in aquatic environments is **stringently regulated and requires a WDNR permit and WDNR staff oversight during application.** Chemical herbicide treatment is a short-term method to control heavy growths of nuisance aquatic plants. Chemicals are applied to growing plants in either liquid or granular form. The advantages of using chemical herbicides to control aquatic plant growth include relatively low cost as well as the ease, speed, and convenience of application. Disadvantages associated with chemical control include:

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[12] *This probable annual cost is based upon an average of 2015 and 2016 contractor rates of one harvester and associated labor, supplies, and support services needed to control aquatic plants over an estimated 43 acres subjected to shallow cut mechanical harvesting.*

[13] *Five-year permits are granted so that a consistent aquatic plant management plan can be implemented over that time. This process allows the aquatic plant management measures that are undertaken to be evaluated at the end of the permit cycle.*

[14] *Aquatic plant harvesters must submit reports documenting harvesting activities as an integral part of permit requirements.*

[15] *Information on the current aquatic invasive species coordinator can be found on the WDNR website.*

1. **Unknown and/or conflicting evidence about long-term effects of chemicals on fish, fish food sources, and humans**—Chemicals approved by the U.S. Environmental Protection Agency to treat aquatic plants have been studied to rule out short-term (acute) effects on human and wildlife health. Some studies also examine long-term (chronic) effects of the chemical on animals (e.g., the effects of being exposed to these herbicides for many years). However, it is often impossible to conclusively state that *no* long-term effects exist due to the animal testing protocol, time constraints, and other issues. Additionally, long-term studies have not addressed all potentially affected species.[16] For example, conflicting studies/opinions exist regarding the role of the chemical 2,4-D as a human carcinogen.[17] Appendix C contains additional facts on the herbicide 2,4-D. Some lake property owners judge the risk of using chemicals as being too great, despite legality of use. Consequently, the concerns of lakefront owners should be considered whenever chemicals treatments are considered. Additionally, <u>if chemicals are used, they should be applied as early in the season as practical and possible. This helps assure that the applied decompose before swimmers and other lake users begin to actively use the lake</u>.[18] Furthermore, many of the commonly targeted nuisance species begin growing very early in the spring, before many desirable native plants emerge.

2. **A risk of increased algal blooms due to suppressed macrophyte competition**—Water borne nutrients promote aquatic plants and algae growth. If rooted aquatic plants are not the primary user of water-borne nutrients, algae tends to be more abundant. <u>Action must be taken to avoid loss of native plants and excessive chemical use</u>, particularly if healthy fish populations are to be maintained since fish require aquatic plants for food, shelter, and oxygen. Further details on this topic are discussed in the "Issue 3: Cyanobacteria and Floating Algae" section of this chapter. **Balance must be maintained between rooted aquatic plants and algae - when the population of one declines, the other may increase in abundance to nuisance levels.**

3. **A potential increase in dissolved plant nutrients and organic sediments, and associated anoxic conditions, which can stress aquatic life, cause algal blooms, and promote fish kills**—When chemicals are used to control large mats of aquatic plants, the dead plant material generally settles to the bottom of a lake and subsequently decomposes. This process leads to an accumulation of organic-rich sediment and can deplete oxygen from the water column as bacteria decompose plant remains. Stratified lakes, such as Pike Lake, are particularly vulnerable to oxygen depletion in deep areas. Excessive oxygen loss can inhibit a lake's ability to support fish and can trigger processes that release phosphorus from bottom sediment, further increasing lake nutrient levels. These concerns emphasize the need <u>to limit chemical control to early spring, when Eurasian water milfoil has not yet formed dense mats</u>.

4. **Adverse effects on desirable aquatic organisms due to loss of native species**—Native plants, such as pondweeds, provide food and spawning habitat for fish and other wildlife. Consequently, if native plants are unintentionally lost due to chemical application, fish and wildlife populations often suffer. Consequently, <u>if chemicals are applied, the only chemicals used should be those that preferentially target Eurasian water milfoil. Such chemicals should be applied in early spring when native plants have not yet emerged</u>.

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[16] *U.S. Environmental Protection Agency, EPA-738-F-05-002, 2,4-D* RED Facts, *June 2005.*

[17] *M.A. Ibrahim, et al., "Weight of the Evidence on the Human Carcinogenicity of 2,4-D"*, Environmental Health Perspectives, *Vol. 96, December 1991, p. 213-222.*

[18] *Though the manufacturers indicate that swimming in 2,4-D-treated lakes is allowable after 24 hours, it is possible that some swimmers may want more of a wait time to ensure that they receive less exposure to the chemical. Consequently, allowing for extra time is recommended so that residents and Lake users can feel comfortable that they are not being unduly exposed.*

5. **A need for repeated treatments due to existing seed banks and/or plant fragments**—As mentioned previously, chemical treatment is not a one-time solution. The fact that the plants are not actively removed from the lake increases the possibility for seeds/fragments to remain in the lake after treatment, thereby allowing for a resurgence of the species the next year. Additionally, leaving large areas void of plants (both native and invasive) creates a disturbed area (i.e., an area without an established plant community). Eurasian water milfoil thrives in such areas. In summary, applying chemical herbicides to large areas can provide opportunities for nuisance plant reinfestation, which in turn necessitates repeated herbicide applications.

6. **Hybrid water milfoils resistance to chemical treatments**—Hybrid water milfoil complicates management since research suggests that certain strains may have higher tolerance to commonly utilized aquatic herbicides such as 2,4-D and Endothall. Consequently, further research on the efficacy and impacts of herbicides on hybrid water milfoil is needed to better understand appropriate dosing rates.

As discussed earlier, other factors complicate chemical application to lakes, namely coincident, intermixed growth of Eurasian water milfoil and native species, the physical similarities between Northern (native) water milfoil and Eurasian water milfoil, and the presence of hybrid Eurasian water milfoil. Hybrid water milfoil has been report in Pike Lake. **Since Eurasian water milfoil tends to grow early in the season, early spring chemical application is an effective way to target the Eurasian water milfoil while minimizing impact to desirable native plants.** Early spring applications has the advantage of being more effective due to treatment chemical's enhanced effect in colder water, a condition enhancing the herbicidal effects and reducing the dosing needed for effective treatment. Early spring treatment also reduces human exposure (swimming is not particularly popular in very early spring) and limits the potential for collateral damage to native species.

Another factor to consider is the **history of chemical treatment on Pike Lake** (see Table 5) and the ways target plants have reacted to these treatments. The first recorded chemical treatments were completed during the early 1950s. Treatment resumed in 1962 and occurred every year until 1975. Two small-scale applications of herbicides were made in 1982 and 2002, but no chemical treatment has occurred on Pike Lake since 2002 as the need to control invasive species eased. Table 4 compares the relative abundance of aquatic plants over a 40-year period. From this data, it is evident that species richness increased while the dominance of invasive milfoil decreased.[19] From this data, it appears that the treatment methodology selectively eliminated invasive milfoil. Three native plants are now far more dominant than Eurasian water milfoil. Since plants do not impede navigation in the Lake, and since comparatively modest populations of Eurasian water milfoil are present, chemical treatment is not currently considered a necessary or viable option for Pike Lake. However, should treatment become necessary in the future, monitoring should be resumed to ensure that invasive milfoil is selectively eliminated.

At this time, chemical treatments are not advised to control starry stonewort. Since starry stonewort is a new occurrence in Wisconsin, the WDNR is still researching effective means of treatment, and the Department is partnering with industry to evaluate control strategies. To date, no particularly effective or attractive chemicals or chemical mixtures have been identified. Nevertheless, chemical applications may be an approved method to control starry stonewort in the future.[20]

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[19] *As stated earlier, historical plant surveys followed different sampling and analysis protocol, and therefore cannot be compared directly to one another. Nevertheless, comparing plants individually reveals that that Eurasian water milfoil is listed with the fourth highest value in the 2012 survey while listed as a close second in the 2001 survey.*

[20] *Bunk, Heidi (Wisconsin Department of Natural Resources), conversation with SEWRPC staff, August 2016.*

Table 5

CHEMICAL HERBICIDES APPLIED TO AQUATIC PLANTS IN PIKE LAKE: 1950-2002

	Algae Control		Macrophyte Control					
Year	Cutrine Plus (gallons)	Copper Sulfate (pounds)	Sodium Arsenite (pounds)	2,4-D (gallons)	Hydrothol (gallons)	Diquat (gallons)	Glyphosate (gallons)	Endothall/ Aquathol (gallons)
1950	- -	1,000.0	600.0	- -	- -	- -	- -	- -
1951	- -	850.0	- -	- -	- -	- -	- -	- -
1952	- -	1,000.0	- -	- -	- -	- -	- -	- -
1962	- -	85.0	- -	- -	- -	- -	- -	- -
1963	- -	850.0	1,260.0	- -	- -	- -	- -	- -
1964	- -	1,712.0	1,440.0	- -	- -	- -	- -	- -
1965	- -	800.0	- -	- -	- -	- -	- -	- -
1966	- -	800.0	- -	- -	- -	- -	- -	- -
1967	- -	1,900.0	- -	8.8	- -	- -	- -	- -
1968	- -	250.0	- -	- -	- -	- -	- -	48.6
1969	- -	1,125.0	- -	- -	- -	- -	- -	51.0
1970	- -	- -	- -	- -	- -	- -	- -	750.0 lbs
1971	- -	- -	- -	- -	- -	- -	- -	150.0 lbs
1973	- -	- -	- -	- -	- -	- -	- -	1,010.0 lbs
1974	- -	- -	- -	- -	- -	- -	- -	1,060.0 lbs
1975	- -	- -	- -	- -	- -	- -	- -	400.0 lbs
1982	0.3	- -	- -	- -	- -	- -	- -	
2002	- -	0.3	- -	- -	- -	0.3	- -	0.3
Totals	0.3	10,372.3	3,300.0	8.8	- -	0.3	- -	99.9 + 3,370.0 lbs

NOTE: Gallons represent liquid forms of chemical; pounds represent granular forms.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Other Aquatic Plant Management Issues of Concern

The recommendations presented in this section address monitoring and controlling aquatic plants already found in the Lake. Many allied activities can inhibit or prevent future nuisance aquatic plant growth, which, in turn, helps avoid adverse effects related to many in-lake control alternatives. A number of factors create a lake environment conducive to "excessive" plant growth, both in terms of Eurasian water milfoil and native plants (see Table 6). For example, poor water quality with high phosphorous content (which can result from polluted surface water runoff or from internal loading) provides the building blocks that all plants need to thrive and eventually reach what is perceived as nuisance levels. Consequently, implementing recommendations to improve water quality must be integral to any comprehensive aquatic plant management plan. This is the reason why many of the issues of concern discussed below under "Issue 2: Water Quality" are also priorities for aquatic plant management. Recommendations related to these factors are included in Chapter III of this report.

Lake users should be vigilant regarding new invasive species and should proactively manage the very real threat of new species colonizing the Lake. Many additional aquatic invasive species threaten lakes but are not known to be present in southeastern Wisconsin (e.g., hydrilla (*Hydrilla verticillata*) or, if found in southeastern Wisconsin, are not found in Pike Lake (e.g., yellow floating heart (*Nymphoides peltata*). Such species can cause harm to the ecology of a lake; therefore, ways to protect Pike Lake against new nonnative species are discussed in Chapter III of this report.

Table 6

WATERSHED MANAGEMENT EFFORTS AND ASSOCIATED BENEFITS TO AQUATIC PLANT COMMUNITIES

Measure	Goal	Benefit
Nutrient Management	Reduce mass of phosphorous and nitrogen entering the Lake.	Reduced nutrient abundance decreases aquatic plant and algal growth.
Sediment Reduction	Lessen accumulation of fine-grained sediment on lake bottom, reduce mass of phosphorus entering the Lake with entrained sediment.	Soft fine grained substrates are often a preferred rooting media. Deeper water with firmer bottoms helps prevent growth of plants farther into the Lake. Also prevents burial of granular sediment that is often important to aquatic animals.
Buffer Development and Wetland Enhancement	Lessens the mass of pollutants and sediment entering the Lake.	See benefits associated with nutrient management and sediment reduction listed above.

Source: SEWRPC.

ISSUE 2: WATER QUALITY

Actual and perceived water quality conditions continue to be important issues for the Pike Lake community. Lake residents have expressed concern that specific pollutants could be entering the Lake from various sources and could be decreasing water quality over time. These sources include phosphorus loading from the upstream Village of Slinger wastewater treatment plant, fertilizer and pesticide runoff from shoreline properties, and fertilizer runoff from agricultural properties within the watershed. Additionally, the concerns about algal blooms (discussed more fully in a subsequent section), reinforces the importance of water quality as an issue of concern given that water quality (more specifically phosphorus levels) greatly influence the tendency of algal blooms to occur throughout the growing season.

As part of the discussion regarding the Lake's water quality, it is important to define what "water quality" means since individuals have varying perceptions, experiences, and levels of understanding. Water quality is commonly described in terms of visual cues. Algal blooms or cloudy water, for example, can lead an observer to conclude that water in a lake is "unclean." However, to *quantify* water quality, lake managers and residents need to collect data and study specific chemical, physical, and biological parameters that influence, or that are indicators of, water quality.

The most commonly used metrics for assessing water quality include: water clarity, water temperature, and the concentrations of chloride, phosphorus, chlorophyll-*a*, and dissolved oxygen (see Table 7 for more information regarding these parameters). These parameters interact with one another in a variety of ways. For example, nutrients from eroded topsoil and common fertilizers can cause a lake's phosphorus concentrations to increase, its clarity to decrease (due to increased algal growth in the water column), and chlorophyll-*a* (a measure of algae content) to increase. In addition to water clarity, phosphorus, chlorophyll-*a*, and dissolved oxygen values, a number of other parameters can also help determine the "general health" of a lake. For example, the abundance of the bacteria *Escherichia coli*, commonly known as *E-coli*, is often measured as an indicator if water is safe for swimming while chloride concentrations are an indicator of overall human-induced pollution entering a lake.[21] To develop water quality maintenance and improvement program, key water-quality indices must be regularly measured over long periods of time. This allows lake managers to establish baselines and identify trends.

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[21] *Chloride is used as an indicator of human-induced pollution because natural chloride concentrations are low in southeastern Wisconsin. Chloride is a "conservative pollutant" meaning that it remains in the environment once released and is not attenuated by natural processes other than dilution. High chloride concentrations may result from road salt transported in runoff, fertilizer application, private onsite wastewater treatment systems that discharge to groundwater which provides baseflow for streams and lakes, and a multitude of other sources.*

Table 7

WATER QUALITY PARAMETER DESCRIPTIONS, TYPICAL VALUES, AND REGULATORY LIMITS/GUIDELINES

Parameter	Description	Southeastern Wisconsin Values[a]		Regulatory Limit or Guideline	Pike Lake Values	
		Median	Range		Median	Range
Chloride (mg/L)	Low concentrations (e.g. < 5 mg/L) naturally occur in lakes due to natural weathering of bedrock and soils. Human activities increase concentrations (e.g., road salts, wastewater, water softener regeneration) and can effect certain plants and animals. Chloride remains in solution once in the environment and **can serve as an excellent indicator of other pollutants.**	41	18-126	Acute toxicity [b,c] 757 Chronic toxicity [b,d] 395	37.5[d]	20.0-80.1[d]
Chlorophyll-*a* (μg/L)	The major photosynthetic "green" pigment in algae. The amount of chlorophyll-*a* present in the water is an indicator of the biomass, or amount of algae, in the water. **Chlorophyll-*a* levels above 10 μg/L generally result in a green coloration of the water** that may be severe enough to impair recreational activities such as swimming or waterskiing and are commonly associated with eutrophic lake conditions	9.9	1.8-706.1	2.6[e]	6.5	0.6-30.8
Dissolved Oxygen (mg/L)	Dissolved oxygen levels are one of the most critical factors affecting the living organisms of 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 usually lowest near the bottom of a lake where decomposer organisms and chemical oxidation processes deplete oxygen during the decay process. **A concentration of 5.0 mg/L is considered the minimum level below which many oxygen-consuming organisms, such as fish, become stressed**, while many species of fish are unlikely to survive when dissolved oxygen concentrations drop below 2.0 mg/L.	- -	- -	≥5.0[f]	- -[g]	0.00-17.00[h]
Growing Season Epilimnetic Total Phosphorus (mg/L)	Phosphorus enters a lake from natural and human-derived sources and is a fundamental building block for plant growth. Excessive phosphorus can lead to nuisance levels of plant growth, unsightly algal blooms, decreased water clarity, and oxygen depletion, all of which can stress or kill fish and other aquatic life**. A concentration of less than 0.030 mg/L is considered necessary in a stratified drainage lake such as Pike Lake** to limit algal and aquatic plant growth to levels consistent with recreational water use objectives. Phosphorus concentration exceeding 0.030 mg/L are considered to be indicative of eutrophic lake conditions	0.030	0.008-0.720	0.030[f]	0.026	0.01-0.83
Water Clarity (feet)	Measured with a Secchi disk (a ballasted black-and-white, eight-inch-diameter plate) which is lowered into the water until a depth is reached at which the disk is no longer visible. It can be affected by physical factors, such as suspended particles or water color, and by various biologic factors, including seasonal variations in planktonic algal populations living in a lake. **Measurements less than 5 feet are considered indicative of poor water clarity and eutrophic lake conditions**	4.6	3-12	10.9[e]	7.1	3.0 -16.5
Water Temperature (°F)	Temperature increases above seasonal ranges are dangerous to fish and other aquatic life. Higher temperatures depress dissolved oxygen concentrations. They also serve as an indicator of increases in other pollutants.	- -	- -	Ambient[f] 35-77 Sub-Lethal[f] 49-80 Acute[f] 77-87	- -[g]	32.0-85.3

[a]*Wisconsin Department of Natural Resources Technical Bulletin No. 138,* Limnological Characteristics of Wisconsin Lakes, *Richard A. Lillie and John W. Mason,* 1983.

[b]*Wisconsin Administration Code Chapter NR 105, Surface Water Quality Criteria and Secondary Values for Toxic Substances. July, 2010.*

[c]*The acute toxicity criterion is the maximum daily concentration of a substance which, if not exceeded more than once every three year, ensures adequate protection of sensitive species of aquatic life and will adequately protect the designated fish and aquatic life use of the surface water can be maintained..*

[d]*The median chloride concentrations likely does not reflect current conditions in the Lakes because chloride concentrations have consistently increased over time. The most upper range likely better represents current Lake concentrations.*

[e]*U.S. Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Lakes and Reservoirs in Nutrient Ecoregion VII, *EPA 822-B-00-009, December 2000.*

[f] *Wisconsin Administrative Code Chapter NR 102, Water Quality Standards for Wisconsin Surface Waters, November 2010.*

[g]*Oxygen concentrations and temperatures vary with depth and season. Median values provide little insight to understand lake conditions.*

[h]*Concentration above the upper saturation limit of oxygen in water. Supersaturation is also injurious to fish and other aquatic life.*

Source: Wisconsin Department of Natural Resources, Wisconsin State Legislature, U.S. Environmental Protection Agency, and SEWRPC.

Pike Lake has been studied for many years, with consistent water quality data records going back to 1973.[22] The Lake has active Citizen Lake Monitoring Network volunteers whom have collected data since 1985. The U.S. Geological Survey (USGS) completed a detailed study of Pike Lake's hydrology and nutrient dynamics. As part of this study, water quality and quantity data was collected on numerous occasions during 1999 and 2000.[23] Available data were compiled to establish existing conditions, identify trends, and evaluate the need for management efforts. To develop a water quality maintenance and improvement program, several factors need to be investigated and considered. The basic factors include:

1. **The past and current water quality of the Lake as well as the general characteristics of the Lake itself**—To determine what water quality management efforts are needed to achieve goal, it is important to quantify current conditions, contrast past values, and estimate historical and future water quality. To do this, concentrations of the critical chemical parameters (i.e., phosphorus, water clarity, chlorophyll-*a*, dissolved oxygen), temperature, and potentially other factors, are measured and compared to determine if the water quality has been changing over time, and how the lake changes seasonally. Water quality values from various depths are also contrasted to evaluate in-lake distribution, circulation, and processes. Values that suggest deteriorating conditions can help identify pollutants and issues that should be targeted for management. This information, in combination with general characteristics of the lake (e.g., depth, shape, circulation patterns) can help provide context for understanding water quality data, will help determine the extent of water quality problems, as well as the viable method for water quality management.

2. **A lake's watershed characteristics, including land use and associated pollutant loadings**—The type and amount of pollutants entering a lake greatly depend on the ways surrounding land (i.e., its watershed) are used. Different land uses produce different pollutants (see Figure 9). For example, agricultural land can be a significant contributor of sediment (from soil eroded from cultivated areas and subsequently delivered to lakes by streams) and nutrients (from fertilizers and topsoil washed off fields). The types of agricultural practices employed influence the amount and timing of erosion and sediment and nutrients delivered to a lake. For example, tillage can loosen soils promoting erosion while tiles and ditches may hasten runoff and reduce the ability of sediment and nutrients to be captured before they enter waterways. Conversely, conservation tillage, cover crops, and pastured lands can reduce erosion and nutrient delivery. Similarly, urban land uses (e.g., residential, industrial, commercial development) can contribute significant amounts of heavy metals, petroleum products, toxic organic compounds, nutrients, and other substances. For example, oil leaked onto pavement, aromatic compounds in paving materials and sealers, and fertilizers applied to lawns may be transported to a lake by stormwater runoff. The potential for runoff and pollutant transport is influenced by the permeability, degree of cover, and slope of soils. The amount of pollutant actually reaching water bodies may be higher if slopes are steep and ground is bare, paved, or relatively impermeable. Given this connection, it is important to understand past, present and planned future land use within the watershed. Based on these land use conditions, models can estimate the amount of pollution likely entering a lake. This can help identify portions of the watershed that are more likely contributing to water quality deterioration and can therefore help focus pollution reduction strategies and efforts.

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[22] *Water quality data is available at the following website: http://dnr.wi.gov/lakes/CLMN/Station.aspx?id=673123*

[23] *Rose, William J, Dale M. Robertson, and Elizabeth A. Mergener,* Water Quality, Hydrology, and Effects of Changes in Phosphorus Loading to Pike Lake, Washington County, Wisconsin with Special Emphasis on Inlet-to-Outlet Short-Circuiting, *United Stated Geological Survey Scientific Investigations Report 2004-5141, 2004.*

Figure 9

EXAMPLES ILLUSTRATING HOW LAND USE AFFECTS WATERBODIES

Source: Illustrations by Frank Ippolito/www.productionpost. com. Modified from D.M. Carlisle and others, The quality of our Nation's waters—Ecological health in the Nation's streams, 1993-2005: U.S. Geological Survey Circular 1391, 120 p., http://pubs.usgs.gov/circ/1391/, 2013, and SEWRPC.

3. **The filtration ability of a lake's watershed and shorelines**—A variety of natural or nature-like features can help filter polluted runoff. Features such as wetlands and vegetative buffers,[24] can significantly decrease the amount of pollution entering a lake. Pollutants can either by absorbed and utilized (in the case of nutrients) and/or trapped (such as sediment).

Each of these three factors is discussed in more detail in the following paragraphs.

General Lake Characteristics

Water quality fluctuates over short- and long-term time periods. Therefore, thorough evaluation of lake water quality must rely on periodically monitoring various chemical and physical properties (ideally at the same depths and locations) over protracted time periods. Monitoring data is used to evaluate the level and nature of pollution within a lake, the risks associated with that pollution, the lake's ability to support various fish and recreational uses, and the overall lake health. When examining water quality, it is important to understand certain lake characteristics that provide context and meaning to the data. These lake characteristics include:

1. **A lake's residence time**—Hydraulic residence time refers to the average length of time needed for the lake's natural water sources to completely replace the lake's entire water volume.[25] Residence time helps determine how quickly pollution problems can be resolved. For example, if retention times are short, pollutants are flushed out of the lake fairly quickly. In such cases, management

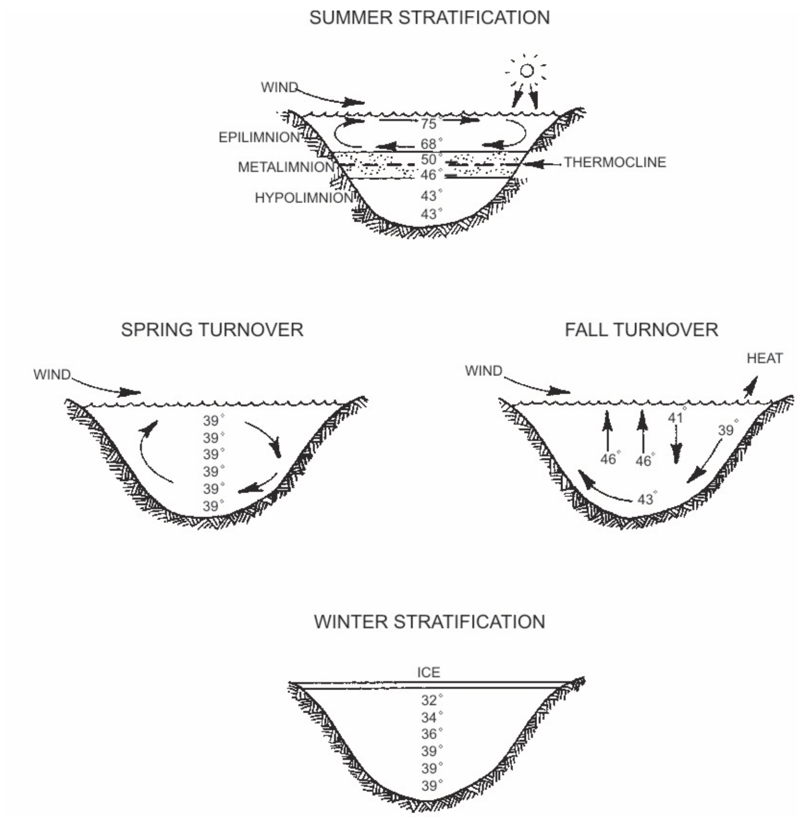
[24] *Vegetative buffers (e.g., forests, grassed waterways, and manmade vegetative strips) and wetlands have the natural ability to slow runoff. This encourages pollutants to be trapped, stored, and/or consumed before they enter the adjacent lake.*

[25] *The term "flushing rate" is also commonly used to describe the amount of time runoff takes to replace one lake volume. Flushing rate is the mathematic reciprocal of hydraulic residence time. Therefore, while retention time is expressed in years and has units of time, flushing rate is typically expressed as the number of times lake water is completely replaced by runoff in one year, and is therefore a rate (units/time).*

efforts can likely focus on pollutant and nutrient loads contributed to the lake from the watershed. In contrast, lakes with long retention times tend to accumulate nutrients and pollutants which can eventually become concentrated in bottom sediment. In this case, in addition to preventing external pollution, it is also may be necessary to employ in-lake water quality management efforts.

Figure 10

THERMAL STRATIFICATION OF LAKES



Source: University of Wisconsin-Extension and SEWRPC.

2. **Whether the lake stratifies and, if it does, when the lake mixes**—Stratification refers to a condition when the temperature difference (and associated density difference) between a lake's surface waters (the *epilimnion*) and the deep waters (the *hypolimnion*) is great enough to form thermal layers that can impede mixing of gases and pollutants between the two layers (see Figure 10). If a lake stratifies, oxygen-rich surface waters in contact with the atmosphere do not freely mix with water in deeper portions of the lake. Therefore, the deeper hypolimnetic water cannot exchange gases with the atmosphere. Metabolic processes continue to consume oxygen in the hypolimnion. If oxygen demands are high (such as in an enriched lake), or if the volume of deep isolated hypolimnetic water is small (limiting oxygen storage potential), deep portions of a lake can become extremely low or even completely devoid of oxygen (anoxic) for a period of time. While some lakes remain permanently stratified, stratification in most Wisconsin lakes breaks down at least twice per year (once in spring and once in fall) in response to changing seasons and ambient weather conditions.

   A lake must be relatively deep to stratify. In general, lakes in southeastern Wisconsin less than 15 feet deep are unlikely to stratify, whereas lakes with depths greater than 20 feet are likely to stratify. A lake's propensity to stratify is heavily influenced by the lake's shape, size, and orientation, landscape position, surrounding vegetation, through flow, water sources, and a host of other factors. Depth to the *thermocline* (the transition layer between the epilimnion and hypolimnion, sometimes also called the *metalimnion*) can range from less than 10 feet to well over 20 feet in typical southeastern Wisconsin lakes.

   Most stratifying lakes in the Region become stratified sometime during mid- to late-spring, with a short (usually less than a week) period of whole-lake water circulation and mixing (turnover) that takes place once during spring and once again in the fall (Figure 10). At turnover, the lake's temperature is uniform from the surface to the bottom. Lakes that stratify and turn over in the spring and fall are termed "dimictic." Mixing can also occur in response to windy conditions in some lakes. Lakes can also stratify in winter when warmer, warmer, denser water is found in the deeper portions of the lake. <u>It is important to determine if stratification and turnovers occur because nutrients, low-oxygen water, and in some cases pollutants and</u>

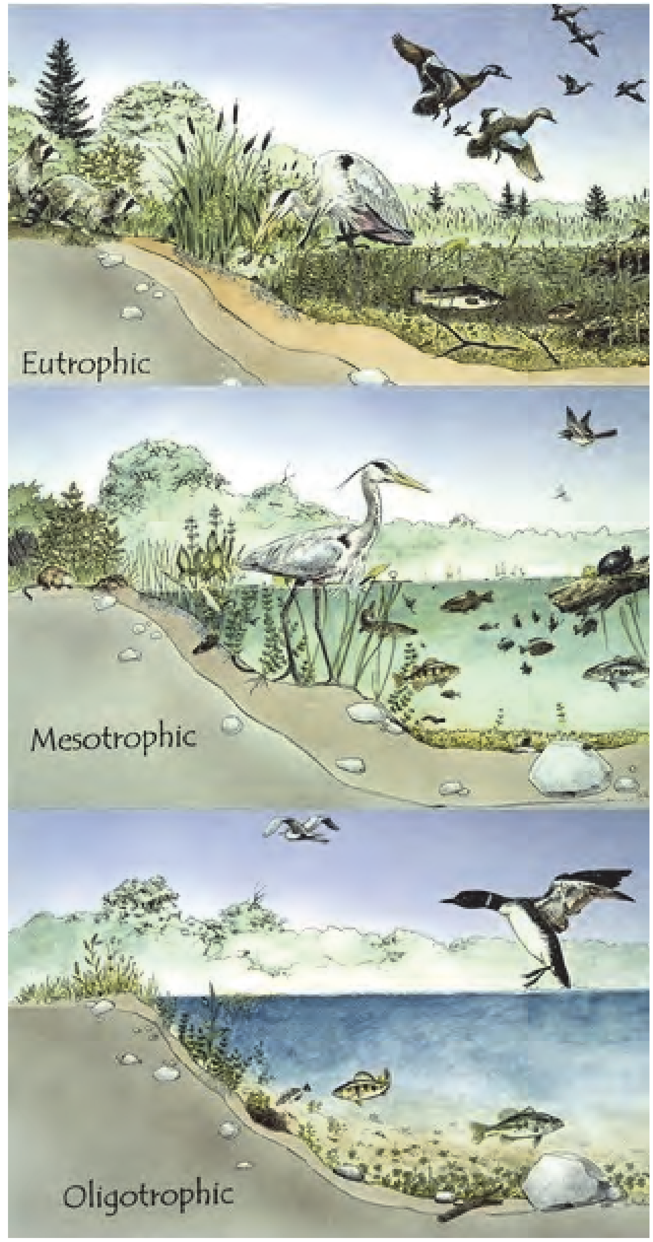
sediment that have accumulated in the isolated bottom waters can suddenly mix into the entire water column during the turnover period, causing water quality and plant management problems. For example, abundant nutrients from deep portions of a lake can mix into near-surface water which in turn can fuel nuisance-level algae and plant growth.

3. **Whether internal loading is occurring**—*Internal loading* refers to release of phosphorus stored in a lake's bottom sediment under certain water quality conditions associated with stratification. Phosphorus is typically not particularly soluble and often adheres to particles that settle to the lake bottom. When organic detritus and sediment settle to the lake bottom, decomposer bacteria break down organic substances, a process that consumes oxygen. If lake-bottom waters become devoid of oxygen, the activity of certain decomposer bacteria, together with certain geochemical reactions that occur only in the absence of oxygen, can allow phosphorus from plant remains and lake-bottom sediment to dissolve into the water column. This allows phosphorus that is otherwise trapped in deep lake-bottom sediment to be released into lake water. This liberated phosphorus can mix into the water column during the next turnover period fueling plant and algae growth. In most lakes, phosphorus is the nutrient controlling overall plant and algal growth, so additional phosphorus loading can lead to increased plant and algal growth. If this is occurring, a water quality management plan may focus on in-lake phosphorus management efforts in addition to preventing polluted runoff from entering the lake.

4. **The lake's current and past trophic statuses**—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 with the lake's degree of nutrient enrichment. Three terms are generally used to describe the trophic status of a lake: oligotrophic (nutrient poor), mesotrophic (moderately fertile), and eutrophic (nutrient rich) (see Figure 11). Each of these states can happen naturally. Lakes tend to naturally shift to a more nutrient-rich state, a progression sometimes referred to as "aging" (see Figure 12). However, if a lake rapidly shifts to a more eutrophic state, human-induced pollution may be responsible for this change. An indicator of severe human pollution is when a lake displays "hyper-eutrophic" nutrient levels, a condition indicating highly enriched water (see Figure 13). Hyper-eutrophic conditions do not commonly occur under natural conditions, and are nearly always related to human pollutant sources.

Figure 11

EXAMPLE LAKE TROPHIC STATE CONDITIONS



Source: DH Environmental Consulting, 1995.

Figure 12

THE EFFECT OF AGING ON LAKE TROPHIC STATUS

Source: Wisconsin Department of Natural Resources.

Figure 13

EXAMPLE OF A HYPER-EUTROPHIC LAKE

Source: University of Minnesota, College of Natural Resources, 2003.

5. **Lake tributary area/type**—Lakes with large tributary streams commonly receive larger sediment and nutrient loads than lakes that are fed primarily by precipitation or groundwater. The type of land use in the watershed greatly effects the pollutant loads carried by tributary streams. Lakes that are fed primarily by tributary streams are labeled drainage lakes.

To determine the preceding characteristics for Pike Lake, SEWRPC staff completed a comprehensive data inventory and examined the resultant values. By analyzing oxygen/temperature profiles, phosphorus concentrations, chlorophyll-*a* concentrations, and Secchi-depth measurements, it was determined that **Pike Lake thermally stratifies during the summer, is prone to internal loading of phosphorus, is now a drainage lake, and is meso-eutrophic.**[26] These characteristics are examined and discussed in more detail in the following sections.

Lake Type, Water Sources Outflow, and Manipulation

The WDNR classifies Pike Lake as a deep lowland lake. Deep lowland lakes stratify and are considered drainage lakes. Lowland lakes have more than four square miles of watershed draining to the lake. Drainage lakes have inlets and outlets and most of the water entering the lake is delivered by streams.

The United States Geological Survey completed a two-year study of Pike Lake's hydrology.[27] This study revealed that the Rubicon River contributes 55 percent of the water entering Pike Lake. The Village of Slinger's wastewater treatment plant contributes about 15 percent of the annual flow of the Rubicon River. A large amount of land drains directly to Pike Lake through smaller streams and ephemeral water courses, contributing about 21 percent of the total water reaching Pike Lake. Precipitation falling directly upon the lake contributes about 17 percent of the water entering Pike Lake, while groundwater contributes about seven percent. According to the USGS, no water is believed to leave the Lake via the groundwater flow system, so groundwater likely enters the lakes along all shorelines.[28] Just over one-eighth of the water leaving Pike Lake exits via evaporation. The Rubicon River outlet drains almost 87 percent of the water that enters the Lake from all sources.

Historical maps and survey records were reviewed to evaluate pre-development locations of shorelines, streams, and rivers near Pike Lake (see Map 4). Early maps show that the Rubicon River did not flow through Pike Lake. Instead, the Rubicon River completely bypassed Pike Lake, passing through a wetland about a quarter mile north of the present-day shoreline of the Lake. An outlet stream drained excess water from Pike Lake to the Rubicon River and likely allowed floodwaters from the Rubicon River to enter and be detained in Pike Lake. Nonetheless, the Rubicon River's primary flow did not pass through the Pike Lake before the River's artificial diversion. Early maps also show a stream entering the Lake from the east, and suggest that the marsh at the north end of the Lake was formerly an open water area.

Since the artificial diversion of the River's channel, water elevation in the Rubicon River upstream of Pike Lake has been controlled by the Pike Lake outlet dam. Nevertheless, much of the River's flow at times passes directly to the outlet, allowing much of the River's flow to bypass the Lake. In recent years, the inlet channel began to enter the main body of the Lake, eliminating the inlet/outlet bypass flow. The PLPRD installed a fence-like structure across the inlet channel during 2011 to help restore bypass flow (see Figure 14). To increase the efficiency of this flow diversion structure, slats were interwoven with the chain-link material during 2013. This structure slows the flow of water to the Lake, and has allowed the channel that directly connects the inlet to the Lake to pass less water to

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[26] *The trophic status of Pike Lake was determined using the Wisconsin Trophic State Index value formula with Secchi-disk measurements, total phosphorus levels, and chlorophyll-*a *levels.*

[27] *Rose, W.J., Robertson, D.M., and Mergener, E.A., op. cit.*

[28] *Some lake water likely leaves the lake as groundwater around and below the dam at the lake outlet.*

Map 4

CURRENT AND HISTORICAL COURSE OF THE RUBICON RIVER

DATE OF PHOTOGRAPHY: APRIL 2015

1837 HYDROLINE

2010 HYDROLINE

NOTE: This figure contrasts the flow of Rubicon River in connection with Pike Lake shoreline from 1837 and 2010. The blue lines represent the current location of the Lake's shoreline and course of the Rubicon River. The yellow lines depict the presettlement locations of the Lake's shoreline, the Rubicon River, and the short outlet stream that formerly connected the Lake and the River. The River was artificially diverted to enter the Lake to benefit a downstream water-powered milling operation

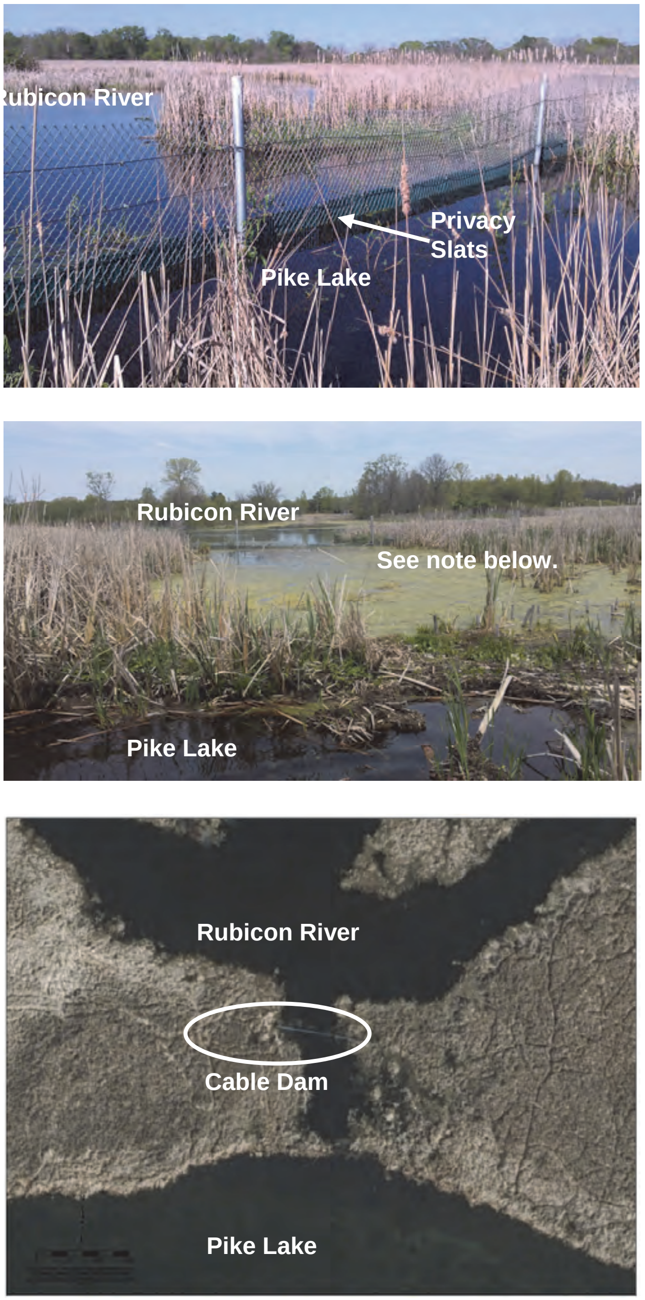
N

0 500 1,000 Feet

Source: Board of Commissioners of Public Lands, UW-Madison Libraries, and SEWRPC.

Figure 14

PIKE LAKE INLET DIVERSION STRUCTURE: 2016



NOTE: Note accreted sediment, stagnant water, and apparent separation of the Rubicon River from Pike Lake at low flow.

Source: Pike Lake Protection and Rehabilitation District, Washington County, and SEWPRC.

the Lake.[29] Additional information on the damming, diversion, and bypass of the Rubicon River into Pike Lake is found in the "Issue 5: Water Quantity" and "Issue 6: Rubicon River Bypass Channel" sections of this chapter.

A dam currently regulates Pike Lake's water elevation. According to WDNR records (Appendix D) **dam operators are directed to maintain the elevation of Pike Lake between 993.40 and 993.80 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29).** The PLPRD dam operator reports difficulty maintaining minimum water levels in the Lake during periods of dry weather and also reports that the lake levels are to remain between 994.13 and 994.60 feet fee above NGVD.[30] Furthermore, the PLPRD has stated that water cannot be released from the Lake during drought conditions since water levels will fall, or already have declined below, the established minimum Lake elevation. More information regarding the dam can be found in the "Issue 5: Water Quantity" section of this chapter.

Given that the Rubicon River originally did not flow through Pike Lake, that no other large streams enter the Lake, and that an outlet stream carried excess water from Pike Lake to the Rubicon River, **Pike Lake was either a spring or deep seepage lake under natural conditions.** In either case, groundwater and/or local precipitation were the largest sources of water to the Lake under natural conditions. However, under natural conditions some water, sediment, and nutrients were likely delivered to Pike Lake with stored floodwater during high-flow events.

Hydraulic Residence Time

Hydraulic residence time (commonly shortened to "residence time) is the number of years required for natural water sources under typical weather conditions to fill the lake one time. Natural water sources include runoff from surrounding areas, precipitation falling directly upon a lake, water entering from tributary streams, and water contributed to a lake by groundwater. It gives a theoretical estimate of the amount of time needed for a lake to refill. Lower hydraulic residence times relate to faster flushing rates. Turnover is the reciprocal of residence time and expresses the number of times a lake's total volume is exchanged per year. Lakes that have high res-

[29] *Jung, John (PLPRD), email to Dale Buser (SEWRPC), September 15, 2016*

[30] *Jung, John (PLPRD), email to Dale Buser (SEWRPC), October 27, 2016*

idence times have low turnover rates. For example, a lake with a residence time of 0.5 years has a turnover rate of 2.0, while a lake with a residence time of five years has a turnover rate of 0.2.

Based upon WiLMS model output, Pike Lake's residence time is rather low, with an estimated to be 0.8 years.[31] This means that on average, the Lake's entire water volume is replaced by new inflow in about 10 months. The water budget completed as part of the USGS lake study states that 8,631 acre-feet of water enter Pike Lake each year, also suggesting a hydraulic residence time of 0.8 years. The average retention time for other stratified drainage lakes in Wisconsin is 1.92 years, which means that Pike Lake has a hydraulic residence time much shorter than the average Wisconsin stratified drainage lake. It should be noted that this residence time includes inflow from the Rubicon River, which at times partially bypasses the Lake. Therefore, **when the Rubicon River's flow wholly or partially bypasses the Lake, actual residence times may be longer.**

Residence time is related to the watershed to lake surface area ratio and to lake volume. Larger watershed to lake area ratios typically correspond with shorter retention times. The average watershed to lake surface area ratio for other Wisconsin stratified drainage lakes is 39 acres of watershed for each acre of lake surface area.[32] Pike Lake only has about 18 acres of watershed (including the artificially-diverted Rubicon River portion) for each acre of open-water lake surface. Therefore, Pike Lake would be expected to have a longer than average residence time. Lake volume relates to the average depth of the lake. Lakes with greater volumes typically have greater retention times. Pike Lake's mean depth of 15 feet is the same as the mean depth of Wisconsin stratified lakes, however, it has over twice the surface area of a typical Wisconsin stratified lake. Therefore, Pike Lake would be expected to have a longer than average retention time.

Even though comparative metrics suggest that Pike Lake should have a longer than typical hydraulic residence time, two independent calculations suggest it has a much shorter than the average hydraulic residence time. While it is beyond the scope of this study to closely examine the reasons for this dichotomy, two factors likely contribute to shorter than expected retention times, both relating to higher than typical water volumes delivered to the Lake. Each are described below.

Pike Lake lies on the western edge of both the Kettle Moraine and the Niagara Escarpment. High relief and permeable soils produce a situation of unusually abundant groundwater discharge. Water table maps suggest strong groundwater discharge to the Lake's eastern shore and throughout much of the Rubicon River watershed upstream of Pike Lake. **Higher than typical groundwater discharge volumes increase the amount of water delivered to the Lake,** which decreases hydraulic retention time. Groundwater flow patterns are discussed in greater detail in the section of this chapter entitled "Issue 5: Water Quantity."

Urbanization in the Pike Lake watershed could be responsible for shorter than expected retention times. For example, **the wastewater treatment plant discharges to the Rubicon River upstream of Pike Lake, and is believed to augment the stream's flow by about 18 percent.** The water discharged to the River is drawn from deeper portions of the shallow dolomite aquifer that may not naturally discharge to Pike Lake; therefore, that source of water supplements the natural flow of the River and decreases hydraulic retention time. Additionally, urbanized areas are typically occupied by significant areas of impervious surface, a condition that can increase total runoff volume.

As mentioned in the previous section, the Rubicon River did not enter Pike Lake prior to the mid-1800s. The effect of River artificial diversion on hydraulic retention time can be estimated using the available data. The USGS study

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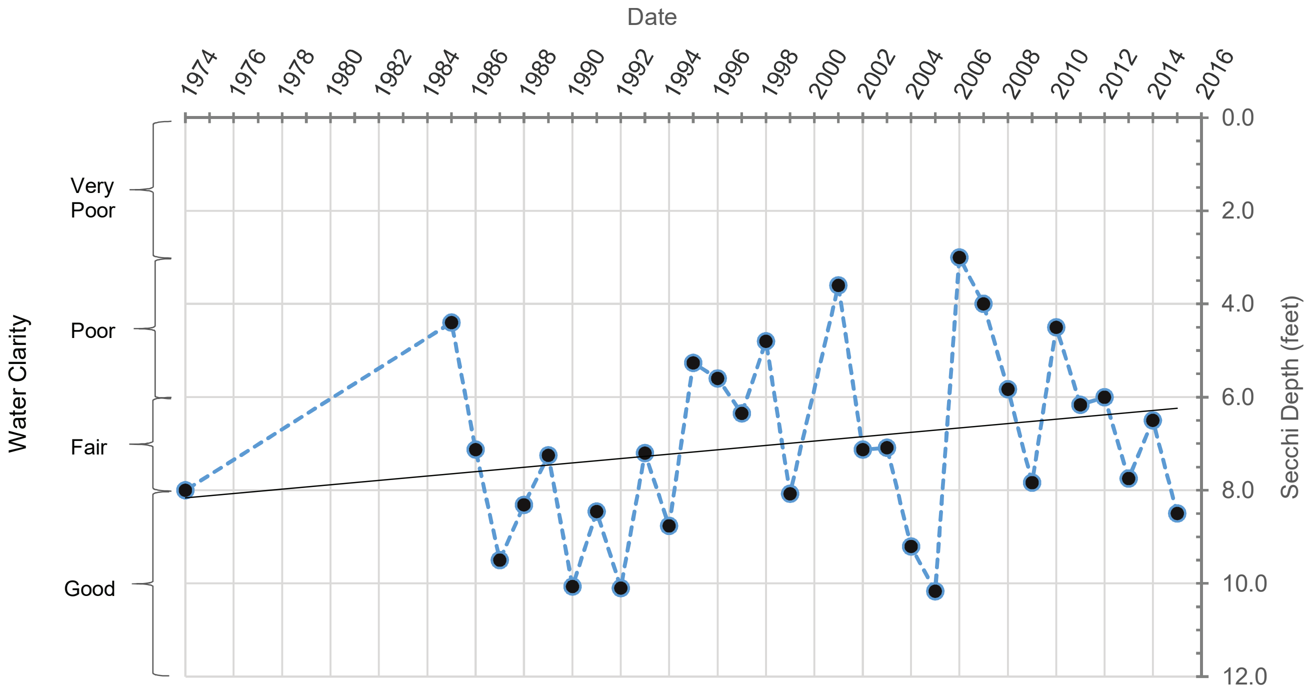
[31] *A slow residence time would be greater than 2 years.*

[32] *Wisconsin Department of Natural Resources Technical Bulletin Number 138, Limnological Characteristics of Wisconsin Lakes, 1983.*

Figure 15

PIKE LAKE AVERAGE ANNUAL SUMMER SECCHI-DISK MEASUREMENTS: 1974-2015



Source: Wisconsin Department of Natural Resources and SEWRPC.

estimates that **the Rubicon River currently contributes about 55 percent of the water entering Pike Lake. If this contribution is removed, the hydraulic retention time increases to 1.8 years. Without the input from the Rubicon River, Pike Lake would be considered a deep seepage or spring lake.** The average retention time for stratified seepage lakes in Wisconsin is 2.63 years. The shorter than average hydraulic retention time in this scenario provides further evidence of the strong groundwater contribution to Pike Lake's water budget.

Secchi Depth, Trophic Status, and Nutrients

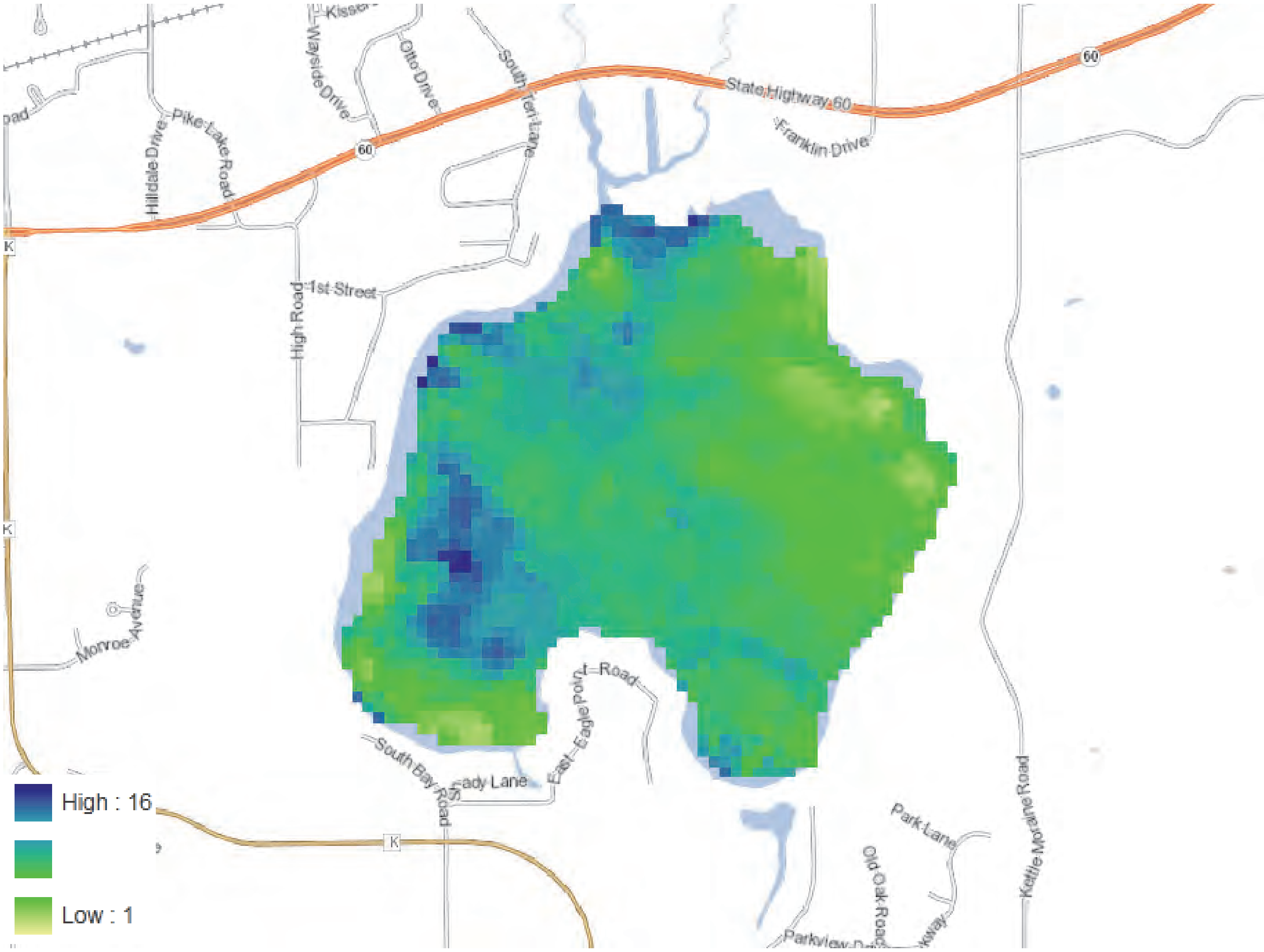
Secchi depth, a measure of water transparency, is often used as an easy to measure and understand water quality indicator. Water transparency can be affected by physical factors such as water color and suspended particles and by various biological factors, including seasonal variations in planktonic algal populations living in the water column. Secchi depth is often greatest during winter months, indicating high water clarity, and lowest during summer months, when biological activity is highest and water clarity is lowest. Secchi depths have been collected at the "deep hole," or deepest area of the Lake. Measurements have been taken at the deep hole since 1974.

Summer average water clarity has varied between poor and good; however, water clarity has overall has slightly deteriorated when compared to the clearest water period recorded during the early 1990s. Secchi depths have averaged about seven feet during the past five years. However, other time periods appear to have had similar average water quality (e.g., late 1990s/early 2000s) (Figure 15) Therefore, **recently decreased water clarity may be consistent with observed short-term fluctuations.**

The WDNR has recently began publishing satellite-based water clarity information, a surrogate for Secchi depth measurements. The WDNR website suggests that the most recent satellite-based water clarity values are between 4 and 8 feet, a range of values consistent with Secchi-depth water clarity measured of the past 10 years. Three years of satellite-based water clarity information are now available: 2013 (Figure 16), 2014 (Figure 17), and 2015 (Figure 18).

Figure 16

PIKE LAKE SATELLITE-DERIVED WATER CLARITY, JUNE 16, 2013



Source: Wisconsin Department of Natural Resources.

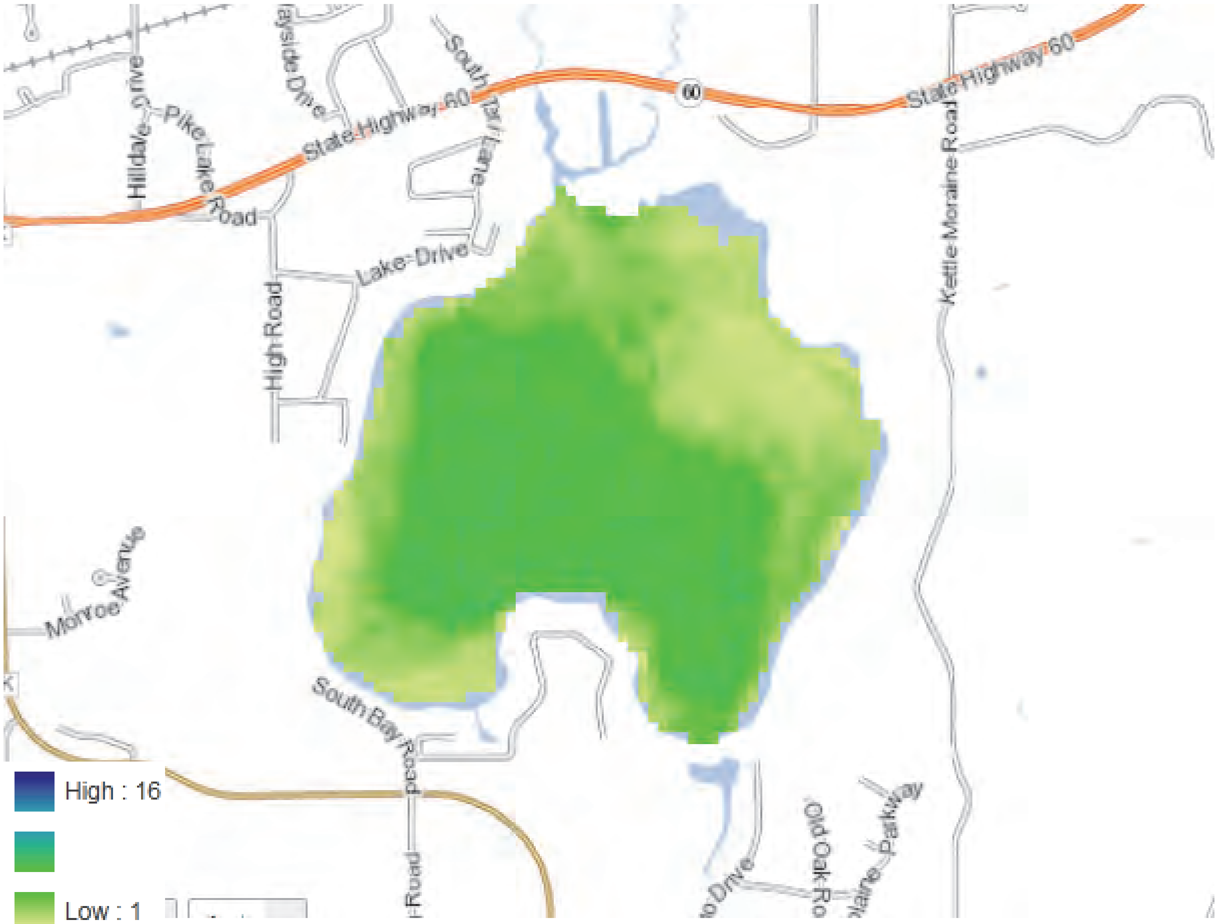
Secchi depth measurements contrast water clarity at a single location in the Lake whereas satellite-derived clarity maps provide clarity information throughout the Lake, allowing differences in water clarity within the Lake on the same day to be studied. The June 2013 image suggests that water in Pike Lake was much clearer in the western portion of the Lake. The September 2014 and July/August 2015 satellite image shows that the clearest water was found in the deep water areas. The reason for water clarity differences would require careful consideration of weather, runoff, and other factors, but do provide evidence of considerable variability. Based upon available satellite imagery, Secchi depth readings collected by the Citizens Lake Monitoring Network generally appear to be measured in a clearer portion of the Lake. Therefore, **nearshore water clarity may be noticeably lower than the values recorded at the deep hole site.**

Based water chemistry and other data collected during the past five years, **Pike Lake appears to be a meso-eutrophic lake** with Wisconsin Trophic State Index (WTSI) ranging from the high forties to low fifties (Figure 19).[33] For a

[33] *Lillie, R. A., S. Graham, and P. Rasmussen,* Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes, *Research Management Findings, Number 35, May 1993, Bureau of Research – Wisconsin Department of Natural Resources.*

Figure 17

PIKE LAKE SATELLITE-DERIVED WATER CLARITY, SEPTEMBER 23, 2014



Source: Wisconsin Department of Natural Resources.

deep lowland lake that average WTSI is considered to represent a "good" lake condition.[34] Over the long term, both phosphorus and chlorophyll-*a* levels have been slowly decreasing. On the other hand, Secchi disk WTSI values have been increasing over the long term, suggesting that water is becoming progressively less clear. Since chlorophyll-*a* WTSI values are decreasing over the same period, the lower water clarity is probably related to changing water color or suspended sediment.

The amount of phosphorus limits algal growth in most Wisconsin lakes. However, in some lakes, the amount of nitrogen limits algal growth. Awareness of which nutrient constraining algal growth can be important when making management decisions. In general, when the concentration ratio of total nitrogen (N) to total phosphorus (P) is 15:1 or greater, available phosphorus limits algal growth. Conversely when this proportion is less than 10:1, nitrogen concentrations limit plant growth. Ratios between 15:1 and 10:1 are considered transitional.[35] Available data reveal

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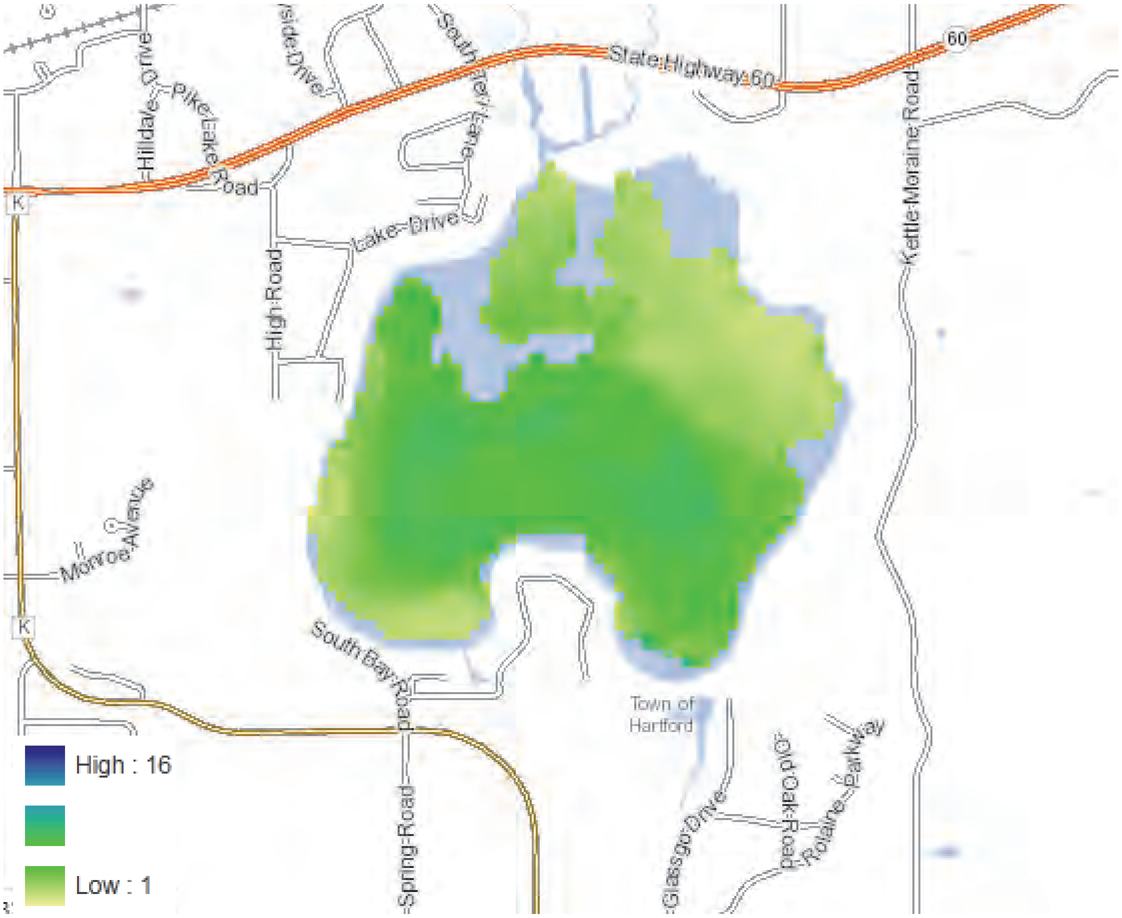
[34] *Wisconsin Department of Natural Resources,* Wisconsin 2014 Consolidated Assessment and Listing Methodology (WisCALM) Clean Water Act Section 305(b), 314, and 303(d) Integrated Reporting, *September 2013.*

[35] *Wisconsin Department of Natural Resources Technical Bulletin Number 138, op. cit.*

Figure 18

PIKE LAKE SATELLITE-DERIVED WATER CLARITY, JULY 15/AUGUST 1, 2015



Source: Wisconsin Department of Natural Resources.

that **Pike Lake is phosphorus limited** (Table 8). During spring turnover, N/P ratios typically average in the high twenties to low thirties, and range from as low as 26:1 to as high as 48:1. N/P ratios differ seasonally and by the depth from which samples are drawn while the Lake is stratified.

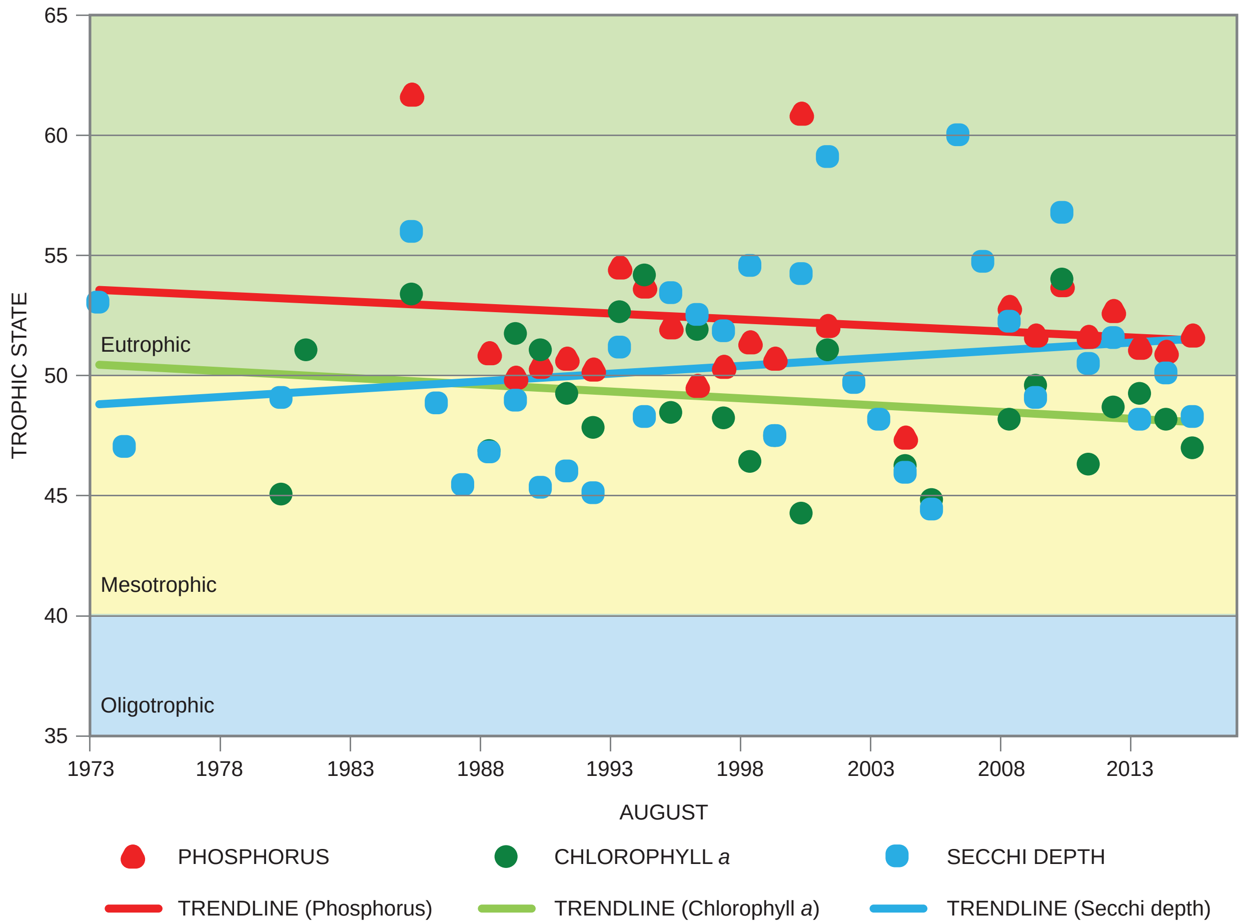
Because Pike Lake is phosphorus limited, small increases in lake water phosphorus concentrations can significantly increase algal growth. Increased algal abundance decreases water clarity and increases chlorophyll-*a* concentrations. Therefore, all other factors remaining unchanged, **increased phosphorus concentrations in Pike Lake likely translates to more eutrophic conditions.** Phosphorus and nitrogen concentrations appear to have peaked during the mid-1990s. Since that time, the concentrations of phosphorus at spring turnover have consistently decreased, while nitrogen concentrations appear to have remained relatively static since the late 1990s (Figure 20). Although the data is rather limited, this information suggests that the Lake may progressively be more phosphorus limited over time.

Temperature, Oxygen, and Stratification

When a lake is stratified, near-surface water is considerably warmer, supports abundant algae, and contains abundant oxygen. The thermocline is generally found somewhere between 10 and 20 feet below the surface, with the depth varying lake-to-lake, month-to-month, and year-to-year. Water within the thermocline rapidly cools with depth and contains less oxygen than the epilimnion. Below the thermocline, water in the hypolimnion is much

Figure 19

PIKE LAKE AVERAGE SUMMER TROPHIC STATE INDICES: 1973 TO 2015



Source: Wisconsin Department of Natural Resources and SEWRPC.

colder than water at the lake's surface and may not mix with the epilimnion until fall. Little sunlight penetrates past the thermocline, therefore, the deeper portions of the lake do not host significant photosynthetic activity and hence do not receive oxygen from plants. However, oxygen continues to be consumed by decomposition and other processes in the deeper portions of the lake. As a result, oxygen concentrations in the hypolimnion decline after the lake stratifies and cannot be replenished until the lake fully mixes during its fall turnover.

Temperature and oxygen concentration profiles suggest that **Pike Lake stratifies every year and remains stratified throughout the summer** (Figures 21 and 22). The depth to the thermocline varies month-to-month and year-by-year, however, it commonly is found somewhere between 12 and 21 feet below the Lake's surface. Little profile data has been collected outside of summer, but the few data points suggest that **the Lake has stratified as early as April.**

Table 8

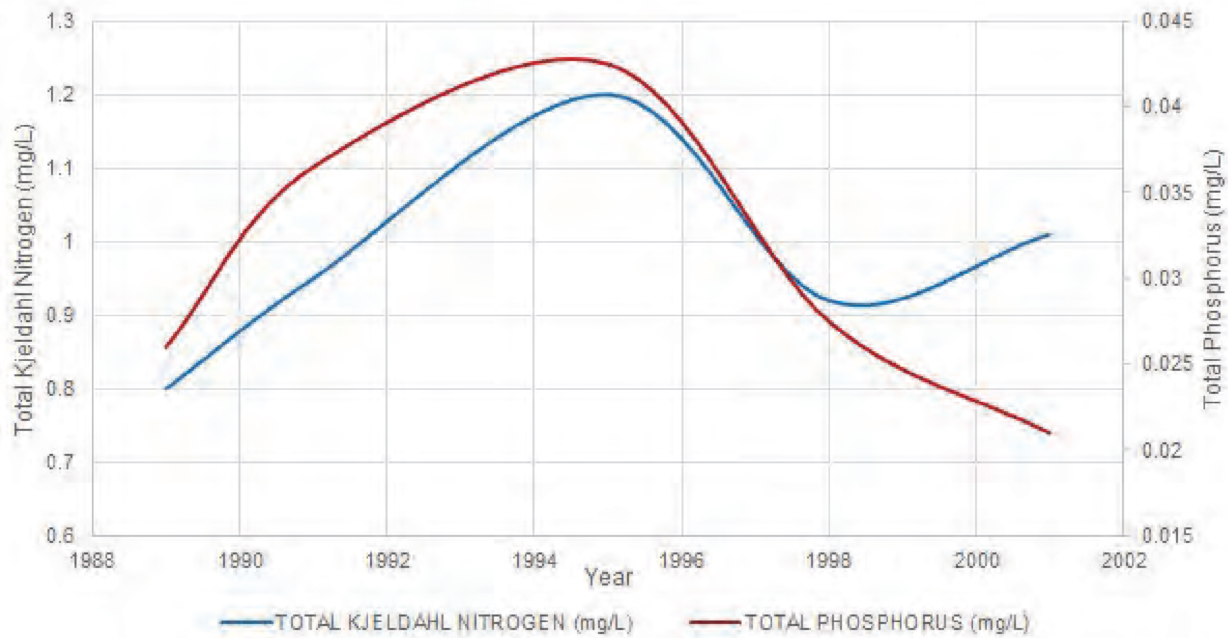
PIKE LAKE SPRING NITROGEN/PHOSPHORUS RATIOS: 1989-2001

Year	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	N:P Ratio
2001	1.01	0.021	48.10
1998	0.92	0.028	33.45
1995	1.20	0.043	28.24
1991	0.95	0.037	26.03
1989	0.80	0.026	30.77

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 20

PIKE LAKE SPRING FULLY MIXED NITROGEN AND PHOSPHORUS TRENDS: 1989-2001



Source: Wisconsin Department of Natural Resources and SEWRPC.

During summer, water in Pike Lake's hypolimnion contains little to no oxygen. Approximately half of Wisconsin lakes containing similar phosphorus concentrations develop anoxia in their hypolimnia during the summer.[36] By early to mid-June, not long after the Lake stratifies, the waters below 20 feet contain less than 5 mg/L of oxygen during most years. The extent of the area with low oxygen is depicted in Figure 23. **This means that approximately one-quarter of the Lake's total water volume cannot fully support fish and most other desirable aquatic life during a typical summer** (Figure 24). During a typical summer, anoxic waters cover about 130 acres or over one-quarter of the Lake's bottom sediment (Figure 25). The available data demonstrates that Pike Lake has developed anoxia since at least the 1970s.

Winter oxygen profiles suggest that the Lake also stratifies in winter. Anoxic water is found near the bottom of the Lake during some cold weather periods.

Oxygen saturation relates the concentration of oxygen actually measured in water to a concentration in equilibrium with the atmosphere at a given temperature. Values between 90 and 110 percent saturation are generally considered desirable for aquatic life. Summer oxygen saturation profiles (Figure 26) reveal that the near-surface water of Pike Lake is supersaturated with oxygen during portions of the day,[37] a result of abundant photosynthetic activity, a factor likely related to human-induced nutrient enrichment. Although no information is available for nighttime

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[36] *Wisconsin Department of Natural Resources Technical Bulletin Number 138, op. cit.*

[37] *Supersaturation refers to a condition when the amount of dissolved substance exceeds the substance's maximum solubility in the solvent under normal circumstances. Such conditions are typically unstable. Dissolved gas comes out of water as bubbles. Fish exposed to oxygen saturations greater than 115 percent can develop bubbles in their tissues (a condition similar to "the bends" experienced by deepwater divers).*

Figure 21

PIKE LAKE SUMMER TEMPERATURE PROFILES

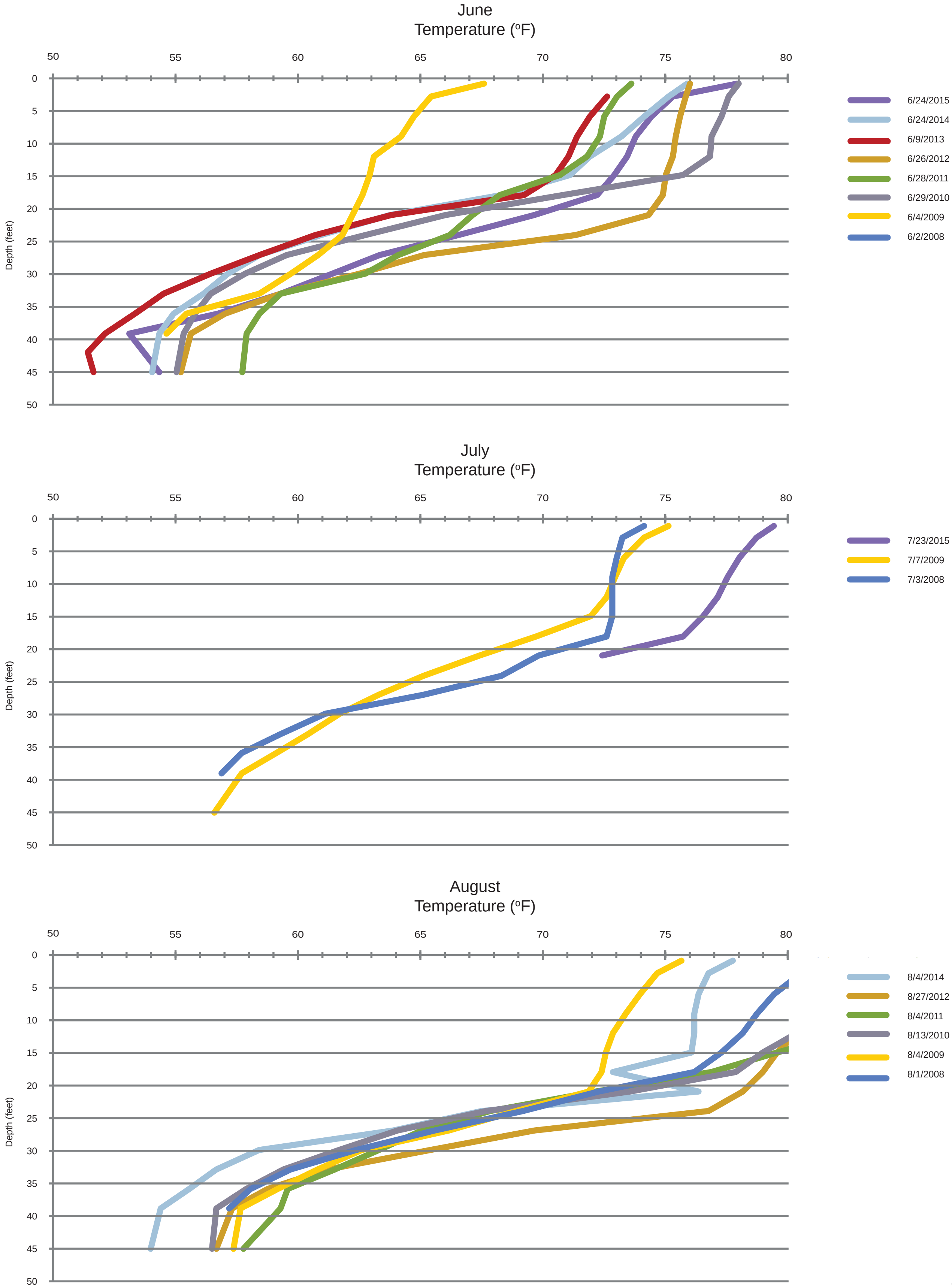
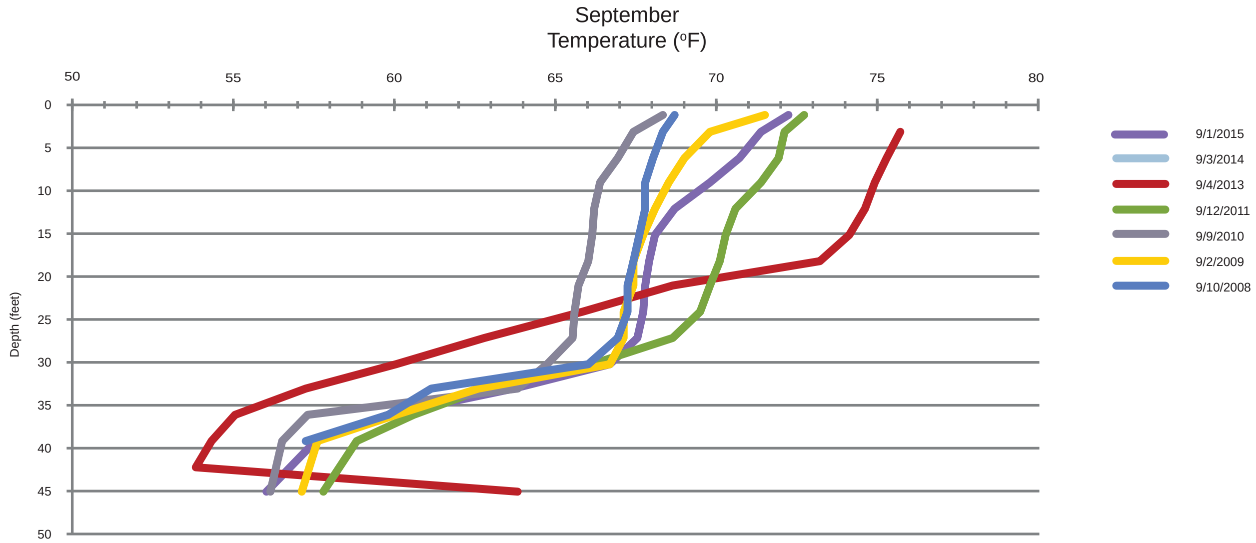


Figure 21 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

conditions, many water bodies exhibiting oxygen supersaturation during the day experience low oxygen saturation levels at night, a condition related to respiration and decomposition continuing to occur while photosynthesis is lacking. Such conditions are stressful to aquatic organisms. Oxygen supersaturation far exceeding 110 per cent has been recorded on several occasions during the summer, a condition that may represent time periods unfavorable to the Lake's fish community and potentially other aquatic organisms. Oxygen concentrations have great influence on the Lake's biota and chemistry. For this reason, detailed oxygen concentration profiles should be regularly measured, including profiles collected at night during the summer. More details of this recommendation may be found in Chapter III.

The phosphorus concentrations in deep portions of the Lake have not been determined for the past 15 years. The available data sets show that phosphorus concentrations in the hypolimnion vary considerably from year to year. **Phosphorus concentrations in the deep portions of the Lake generally appear to reach their maxima during August,** with values typically in the .3 to .4 mg/L range being the most common (Figure 27). Values as high as 0.6 mg/L and as low as 0.022 mg/L have been recorded. The highest concentrations generally appear to loosely correlate with years of greater than average runoff, while years with lower readings correlate with droughts. When the Lake turns over in fall, phosphorus-rich water mixes with surface water enhancing conditions for abundant algal growth.

Chlorophyll-a

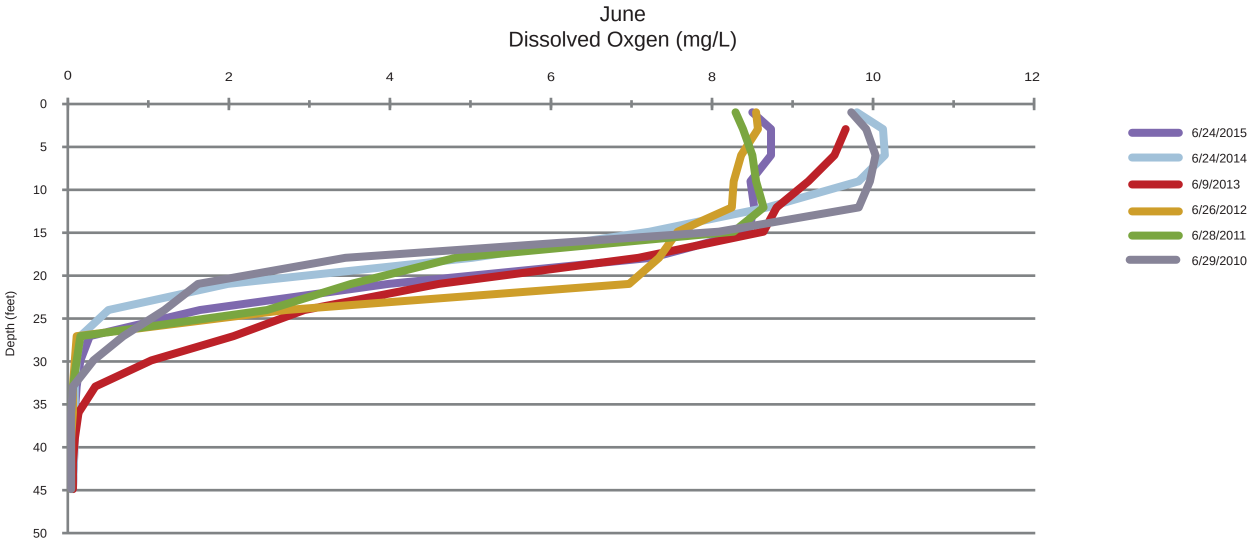
As indicated in Table 7, chlorophyll-*a* concentrations above 10 µg/L tend to impair recreational activities on account of excessive algae. Chlorophyll-*a* samples have been collected in Pike Lake since 1980. Chlorophyll-*a* concentrations have sporadically exceeded 10 µg/L, with concentrations over 25 µg/L detected several years between the late 1980s and mid1990s. Chlorophyll-*a* concentrations have rarely exceeded the 10 µg/L standard since the late 1990s (Table 9). It is interesting to note that the highest chlorophyll-*a* concentrations coincide with the time period with the highest spring overturn phosphorus concentrations (Figure 20). Since the Lake is phosphorus limited, decreased phosphorus concentrations likely inhibit algal growth, reducing recent chlorophyll-a concentrations.

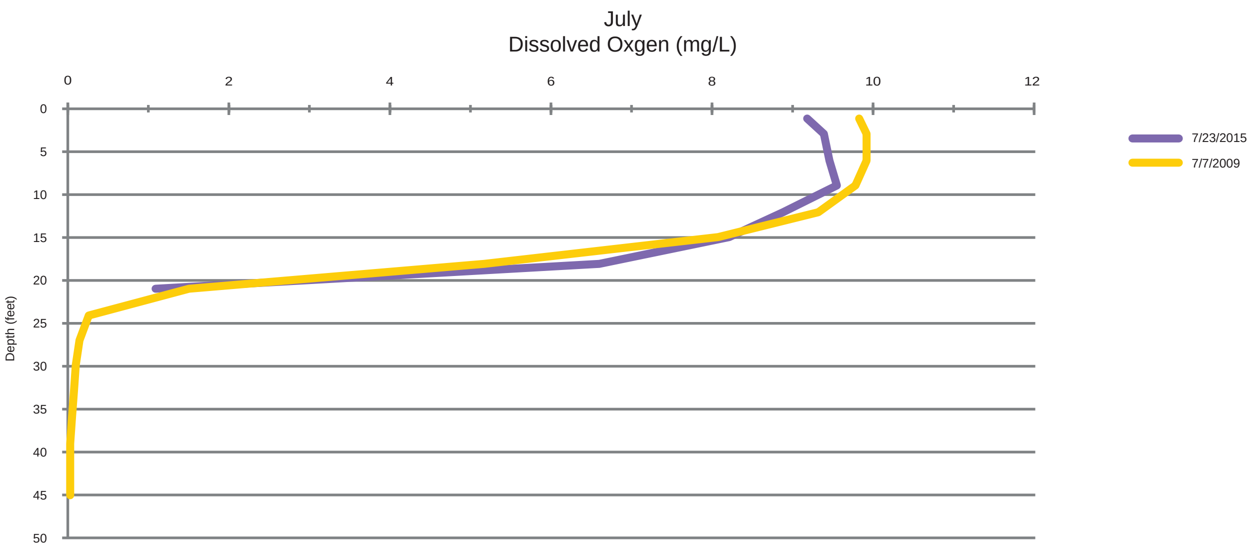
Phosphorus

When the Lake is fully mixed in the spring, phosphorus concentrations are similar throughout the various depths of the Lake, with phosphorus concentrations averaging 0.028 mg/L over the period of record. Phosphorus concentrations vary widely within the Lake when it is stratified, Figure 27 plots summer phosphorus concentrations recorded since 1973. Samples collected near the surface during the growing season commonly have the lowest phosphorus concentrations, averaging 0.020 mg/L, a value well below the aquatic life impairment threshold of 0.060 mg/L for

Figure 22

PIKE LAKE SUMMER DISSOLVED OXYGEN PROFILES





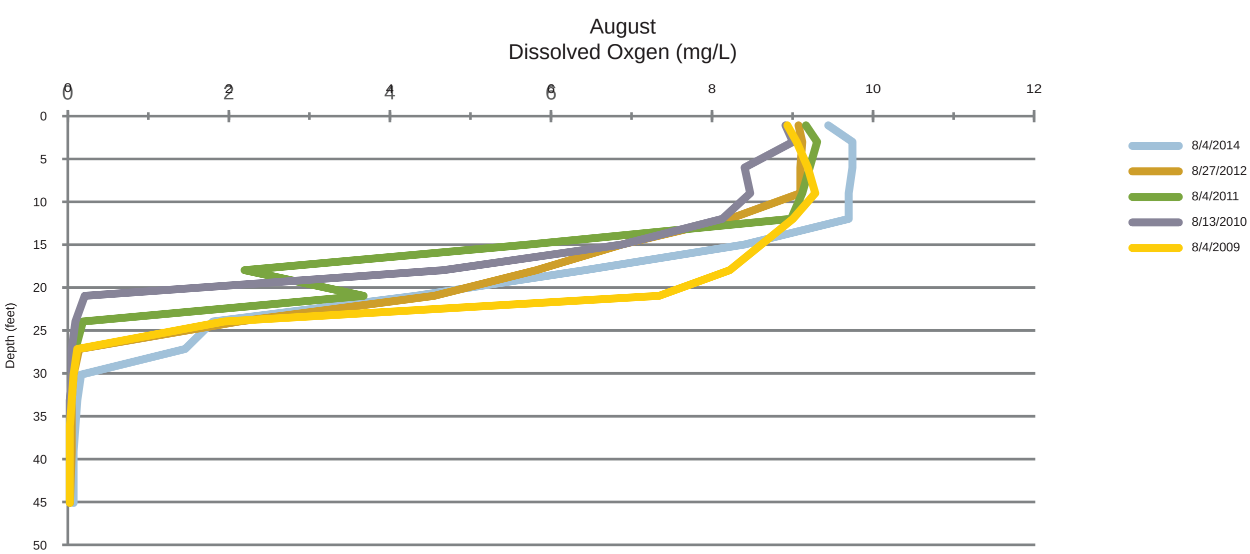
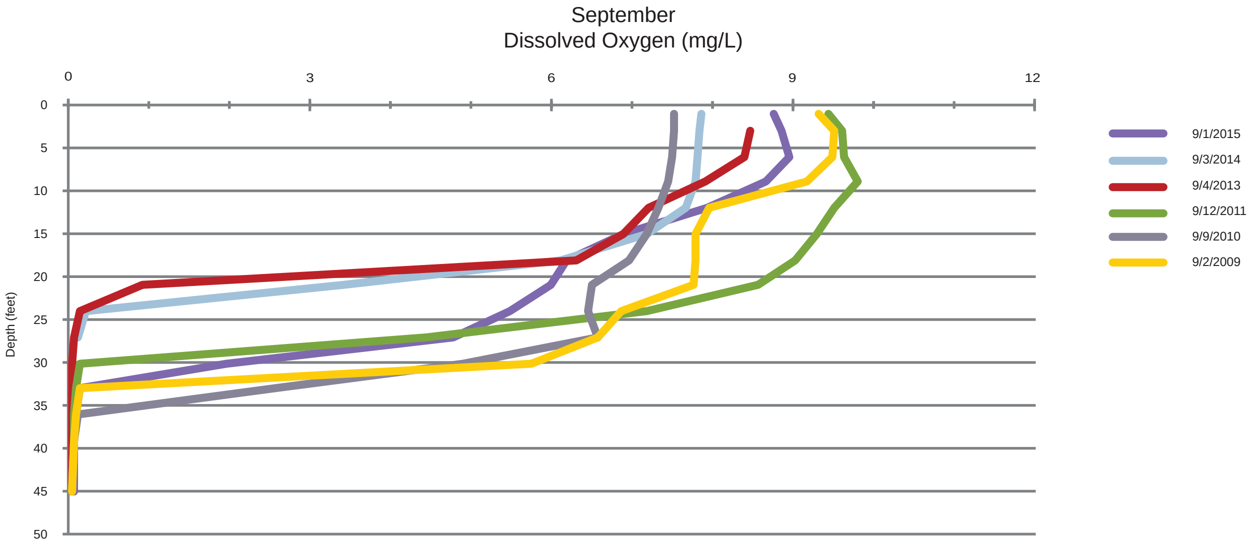


Figure 22 (continued)



Source: *Wisconsin Department of Natural Resources and SEWRPC.*

deep drainage lakes. This value is also less than the substantially lower recreational impairment threshold of 0.030 mg/L for such lakes,[38] which is mandated by the *Wisconsin Administrative Code*.[39]

A limited number of samples were collected from Pike Lake during the winter. Several of these available date sets demonstrate that the Lake stratifies by late winter. Phosphorus concentrations are significantly elevated in deep areas of the Lake when such conditions exist, with concentrations about ten times higher than water in shallower portions of the Lake. This phosphorus-rich water from the depths of the Lake mixes with shallower water in spring, and increases the mass of phosphorus in the early part of the growing season. Such conditions can contribute to early season algal blooms.

Phosphorus Sequestration

In areas of mineral-rich calcareous groundwater ("hardwater"), marl is often deposited on the beds of lakes fed by significant groundwater seeps and springs. Marl is composed chiefly of calcium carbonate, clays and silts, and some organic detritus. The formation of marl can co-precipitate dissolved phosphorus, a condition which helps reduce phosphorus concentrations in the water of some lakes. In such instances, co-precipitated phosphorus is deposited as a stable mineral upon the lake bed. Over fifty percent of a lake's external phosphorus loading is typically retained in lake-bottom sediment. The actual amount retained in a lake varies widely with watershed and lake characteristics, but up to ninety percent can be retained in some instances.[40] Studies of Lake Nagawicka in Waukesha County have shown that 87 percent of the phosphorus contributed to the Lake is retained in lake-bottom sediment.[41]

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[38] *Wisconsin Department of Natural Resources*, Wisconsin 2014 Consolidated Assessment and Listing Methodology (WisCALM) Clean Water Act Section 305(b), 314, and 303(d) Integrated Reporting

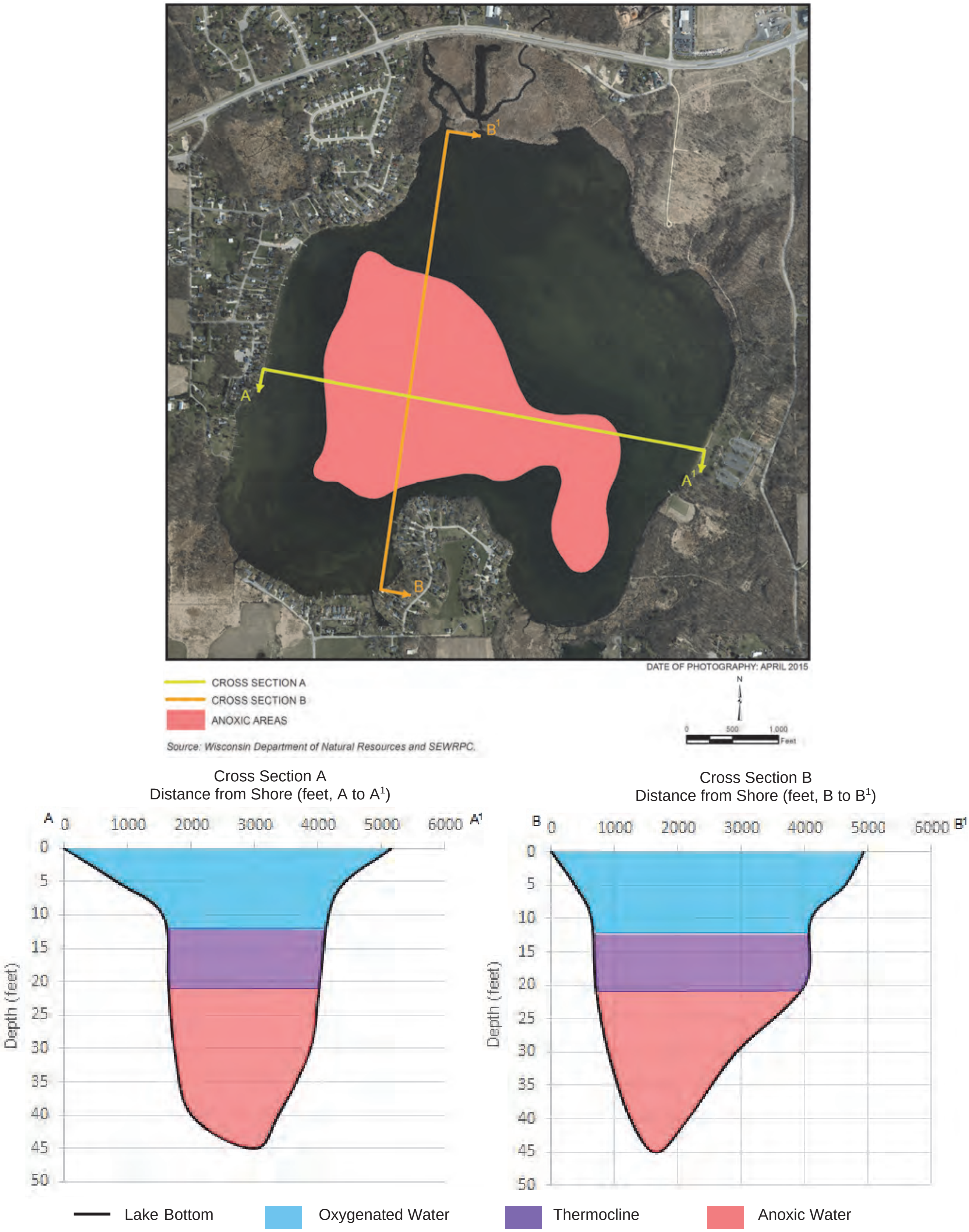
[39] *Wisconsin Administrative Code Chapter NR 102, Water Quality Standards for Wisconsin Surface Waters, November 2010.*

[40] *Lijklema L., "Phosphorus accumulation in sediments and internal loading," Hydrological Bulletin 20:213, 1986.*

[41] *U.S. Department of the Interior, Geological Survey Scientific Investigations Report 2006-5273*, Water Quality, Hydrology, and Response to Changes in Phosphorus Loading of Nagawicka Lake, a Calcareous Lake in Waukesha County, Wisconsin, *2006*.

Figure 23

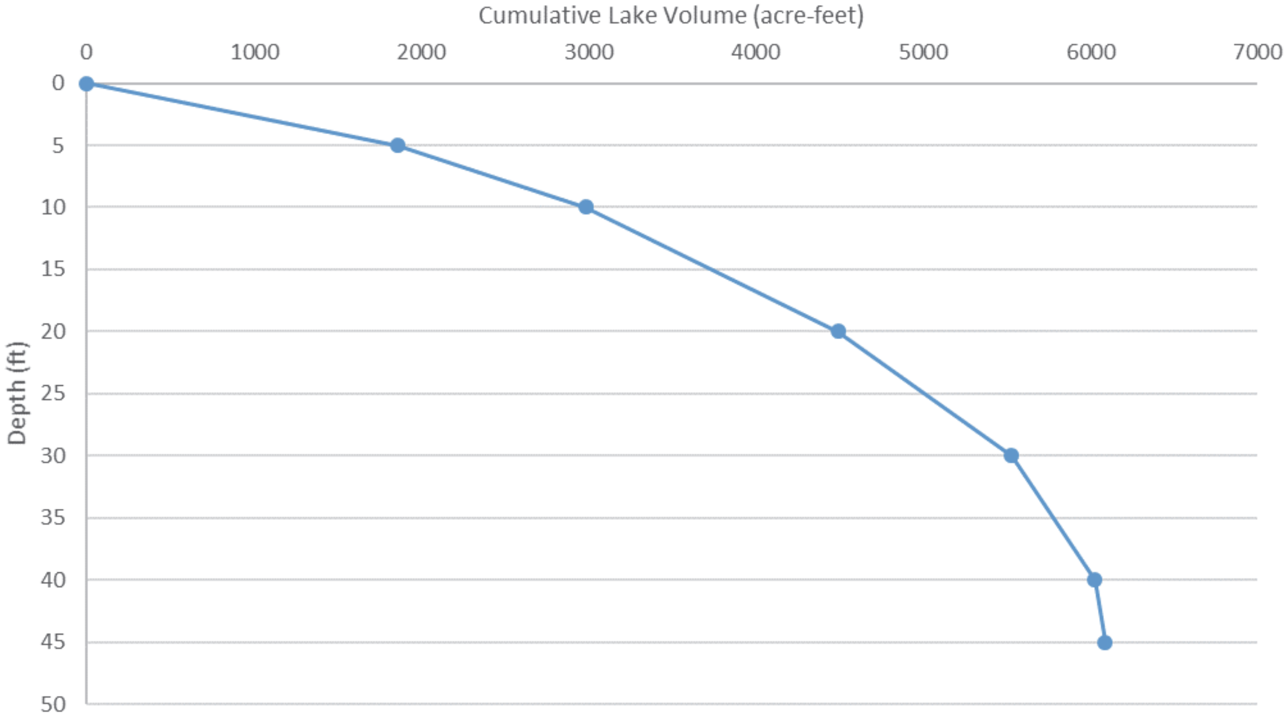
TYPICAL MIDSUMMER EXTENT OF ANOXIC WATER IN PIKE LAKE



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 24

PIKE LAKE DEPTH VERSUS VOLUME



Note: This is a cumulative plot of the Lake's total volume contained in depths less than or equal to the depicted values. For example, roughly 3,000 acre-feet of the Lake's total volume is contained in the upper 10 feet of the Lake's water column.

Source: Wisconsin Department of Natural Resources and SEWRPC.

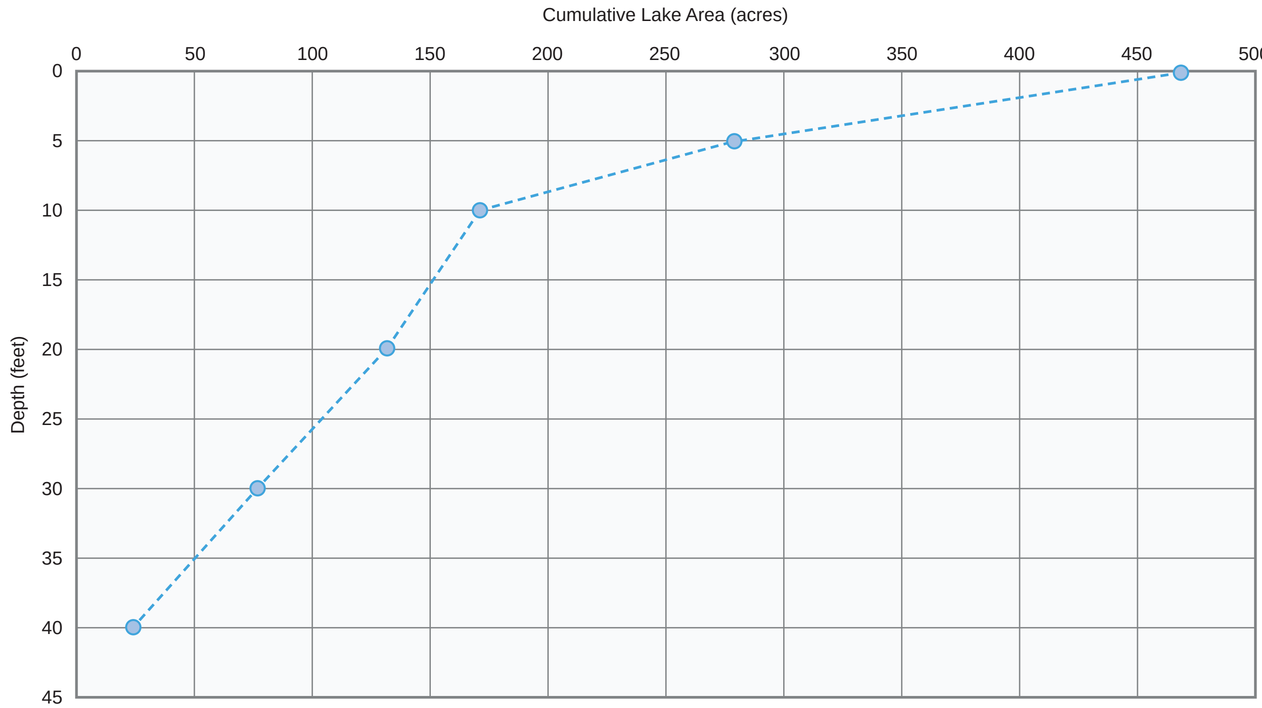
Marl is commonly formed as a byproduct of growth of certain algae species (e.g., muskgrass), accumulates on plant stems and leaves, and ultimately falls to the lake bottom as the algae grows and dies. Photosynthesis increases water pH in the immediate vicinity of the plant, enhancing precipitation of calcite. Since enriched lakes generally support more algae, enriched lakes can have a self-reinforcing feedback loop to sequester more phosphorus. However, calcite/phosphorus minerals may become less stable at high pH ranges, potentially reducing the effect of this feedback loop. While not specifically called out on available maps, marl is likely deposited in portions of Pike Lake, especially in areas of active groundwater discharge. Marl formation in Pike Lake likely co-precipitates phosphorus, attenuating phosphorus concentrations in the Lake's open water areas.

Research in Europe has found that although marl lakes are resistant to phosphorus enrichment and eutrophication, the bottom-dwelling species of algae promoting marl production can be sensitive to long-term phosphorus enrichment. Decreased water clarity associated with higher phosphorus concentrations can decrease the depth to which bottom-dwelling algae can grow, which in turn decreases the extent of marl-precipitating algae near the lake bottom. Less marl precipitation increases overall dissolved phosphorus in the lake which fosters higher abundance of free-floating algal species. This further decreases water clarity, forming a self-reinforcing loop that eventually breaks down the marl formation process. Some formerly clear European marl lakes that had successfully buffered heavy, long-term external phosphorus loads went through rapid change after the lake's buffering capacity was exceeded and are now eutrophic lakes with low water clarity.[42] This graphically illustrates how the algae-based

[42] *Wiik, Emma, Helen Bennion, Carl D. Sayer, Thomas A. Davidson, Suzanne McGowan, Ian R. Patmore, and Stewart J. Clarke,* "Ecological sensitivity of marl lakes to nutrient enrichment: evidence from Hawes Water, UK", Freshwater Biology, *Volume 60, Issue 11, November 2015, p. 2226-2247.*

Figure 25

LAKE DEPTH VERSUS SURFACE AREA FOR PIKE LAKE



Note: This is a cumulative plot of the total surface area of the lake with depths greater than or equal to depicted values. For example, roughly 170 acres of the Lake has water depths greater than 10 feet.

Source: Wisconsin Department of Natural Resources and SEWRPC.

phosphorus sequestration process is vulnerable to excessive long-term high phosphorus loads, demonstrating the importance of reducing external phosphorus loads to lakes.

Marl formation/phosphorus co-precipitation depends upon continued discharge of mineral-rich groundwater to springs and seeps on the lake bottom. If the supply of groundwater is reduced, the vigor of hardwater algae is lessened, compromising the phosphorus sequestration cycle. Therefore, the lake's groundwater supply must be protected to ensure that phosphorus sequestration remains active.

In Wisconsin, phosphorus is sequestered in lake-bottom sediment with calcite (as described above) or with iron. Unlike calcium minerals, iron-bound phosphorus is sensitive to the concentration of oxygen in adjacent water. Under low oxygen conditions, iron-bound phosphorus minerals dissolve and release plant-available phosphorus to the water column. This source of phosphorus, an important component of what is commonly referred to as internal loading, can be a significant contributor to the total phosphorus available to algae in lakes, especially in lakes that have fewer sources of external phosphorus during the growing season. For this reason, the presence of anoxic water can profoundly influence the nutrient dynamics of certain lakes.

External Loading

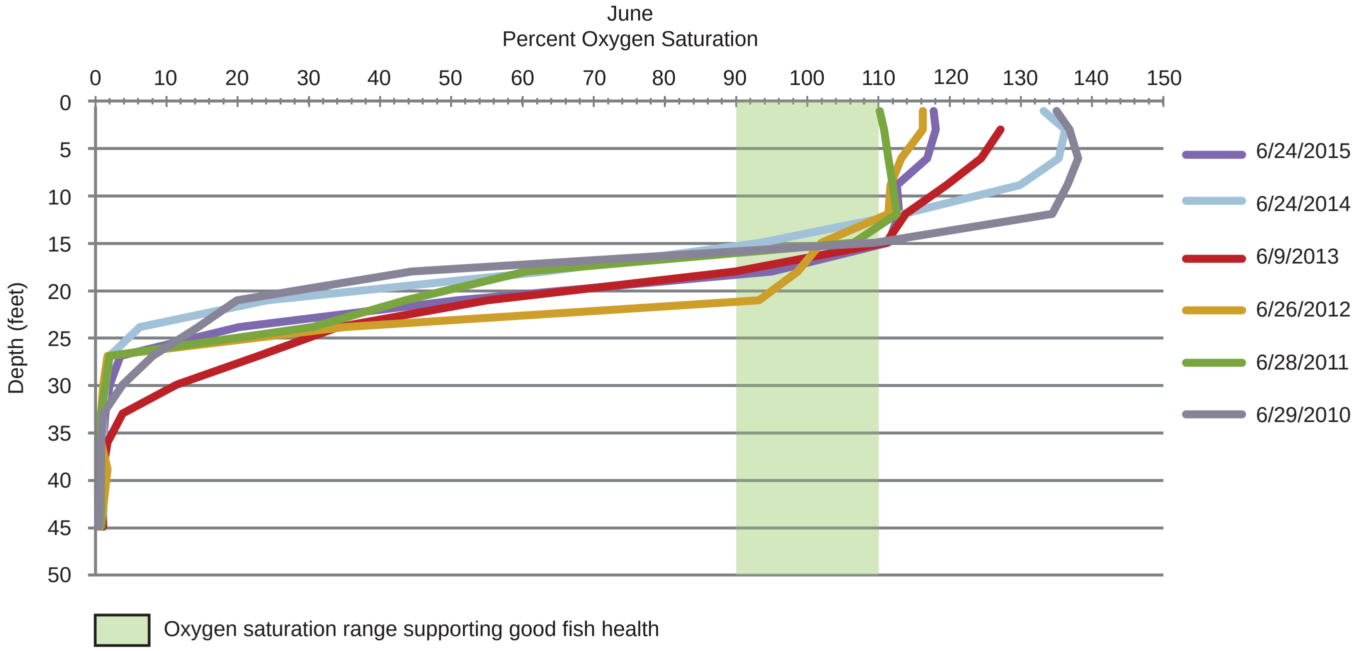
Phosphorus external loading is factor dependent upon activities occurring beyond the Lake's shoreline. As such, phosphorus external loading is examined in detail under the "Watershed Characteristics and Pollutant Loadings" section of this chapter.

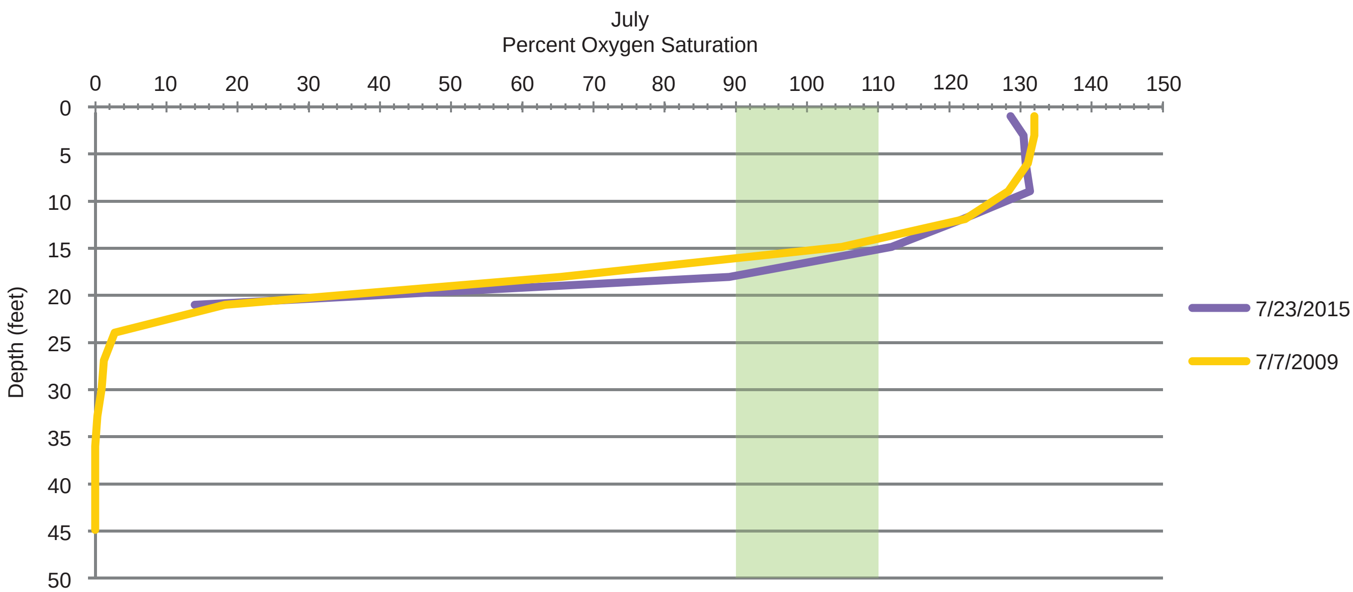
Internal Loading

As mentioned earlier in this report, aquatic plant and algal growth and overall lake productivity are highly influenced phosphorus dissolved in lake water. Under oxygenated conditions, phosphorus is tightly bound to solids;

Figure 26

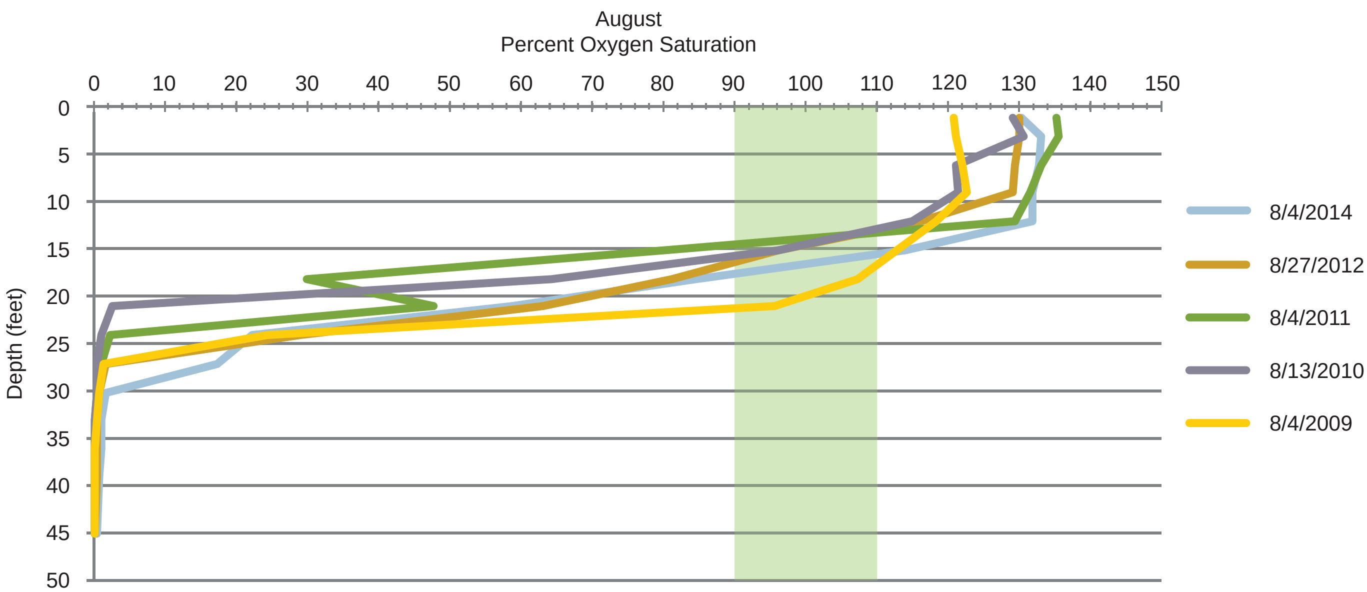
SUMMER OXYGEN SATURATION PROFILES FOR PIKE LAKE BY MONTH

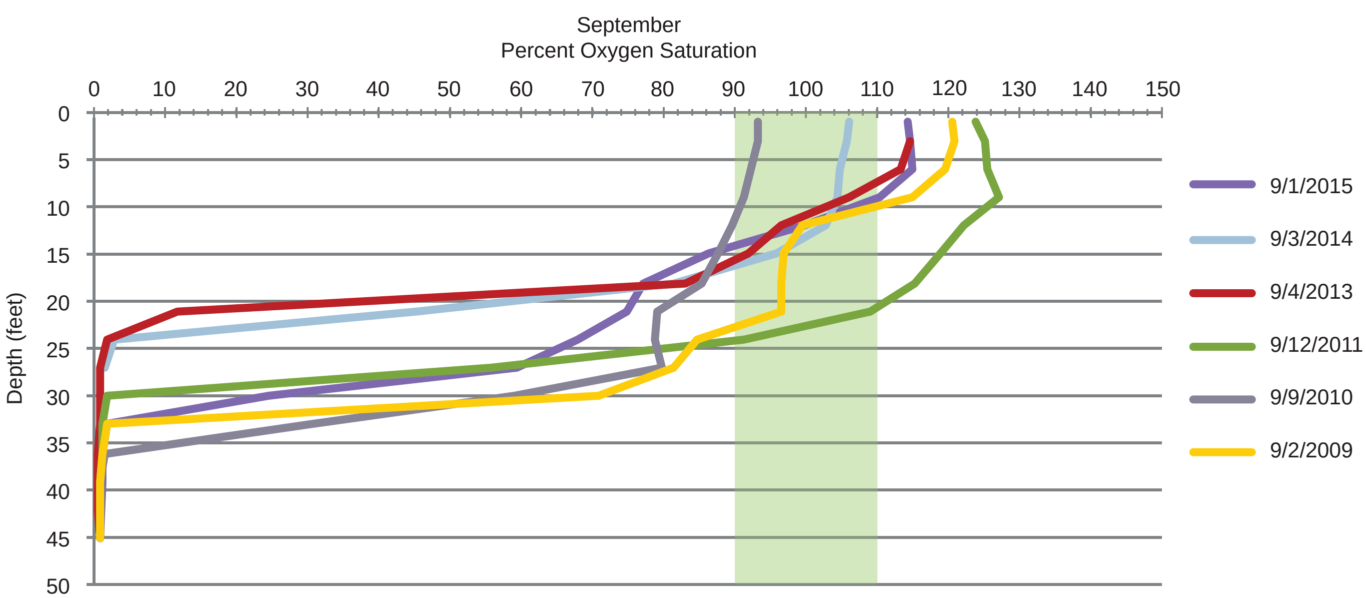




however, when oxygen is absent, geochemical reactions are enabled that release phosphorus from the bottom sediment into the water column. The amount of sediment exposed to anoxic water is controlled by the shape of the lake basin. Since sediment exposed to anoxic water can release phosphorus into the water column, lakes with more deep water sediment area are more susceptible to significant phosphorus internal loading. **About a third of Pike Lake's bottom is covered by water deep enough to stratify, making internal loading of phosphorus a potential concern.** Waters below about 20 feet contain little to no oxygen during much of the summer, meaning that a large proportion of the lake-bottom is prone to phosphorus dissolution from bottom sediment (Figure 23). Over a quarter of lake-bottom sediment is covered with anoxic water during a typical summer (Figure 25), **making internal loading of phosphorus in Pike Lake a concern.**

Figure 26 (continued)





Source: Wisconsin Department of Natural Resources and SEWRPC.

Given what is known about the concentrations of total phosphorus during the fully mixed conditions occurring during or shortly after spring turnover and during the stratified conditions occurring in summer, and assuming that little mixing occurs between the epilimnion and hypolimnion after the Lake stratifies, internal phosphorus load rates can be estimated. Although values vary significantly between years, internal loading likely contributes on average about 1,400 pounds of phosphorus to the water column between late spring and late summer. Since anoxic water covers about 130 acres of the Lake bottom during a typical year, each acre of Lake bottom exposed to anoxic water contributes approximately eleven pounds of phosphorus to the water column during a typical summer.

The USGS completed a detailed study of phosphorus loading to Pike Lake between 1999 and 2000.[43] This study reported that the net phosphorus load contributed to Pike Lake by precipitation, the Rubicon River, direct drainage to the Lake, and groundwater was 864 pounds, while the gross loading was about 3,000 pounds. Thus, the estimated 1400 pounds of **phosphorus contributed to the Lake by internal loading is likely a significant contributor to the overall phosphorus budget.**

Assuming that phosphorus is contributed to the water column between May 1 and August 31, a unit area phosphorus flux rate[44] can be computed. Pike Lake's computed unit area phosphorus flux rate is 10 milligrams per square meter per day (roughly one-tenth of a pound per acre per day). This value is near the middle of the range of values determined as part of a State of Michigan lake sediment column study. The Michigan study reports unit-area phosphorus flux rates ranging from 1.6 to 29.5 milligrams per square meter per day.[45] The Pike Lake value also agrees well with studies completed in Minnesota. Minnesota lakes that were eventually treated to reduce internal phosphorus loading exhibited unit area phosphorus flux rates ranging from 9.3 to 14.1 milligrams per square meter per day.[46] These comparisons add creditability to the phosphorus flux rates calculated for Pike Lake and point to the importance of internal loading in the overall nutrient balance of the Lake.

It should be noted that phosphorus released to the hypolimnion is not directly available to most algae growing in a lake since little sunlight penetrates to these depths. Even though the thermocline is a barrier to circulation, the barrier is imperfect, and some phosphorus can still migrate to shallower areas. For

Table 9

PIKE LAKE CHLOROPHYLL-*a* MEASUREMENTS

Year	Annual Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
2015	5.65	2.73	9.48
2014	6.03	4.08	7.72
2013	7.06	4.63	10.20
2012	6.65	3.75	8.99
2011	4.70	3.51	6.44
2010	13.36	8.57	20.00
2009	7.20	4.87	8.87
2008	7.20	2.32	14.40
2006	5.72	5.72	5.72
2005	3.87	2.51	5.10
2004	4.68	3.37	6.79
2001	5.88	1.50	8.00
2000	6.33	1.00	9.00
1999	5.22	5.00	5.67
1998	7.43	3.48	15.40
1997	8.52	4.29	14.50
1996	7.36	3.41	12.10
1995	11.02	3.06	30.80
1994	9.83	0.61	13.90
1993	10.87	1.02	20.80
1992	6.30	4.00	10.90
1991	11.40	5.00	28.00
1990	9.80	4.00	16.00
1989	12.60	6.00	25.00
1988	5.00	4.00	6.00
1985	11.50	10.00	13.00
1981	8.90	8.90	8.90
1980	4.00	4.00	4.00
Overall	7.65	0.61	30.80

Source: Wisconsin Department of Natural Resources, and SEWRPC.

[43] *Rose, W.J., Robertson, D.M., and Mergener, E.A., op. cit*

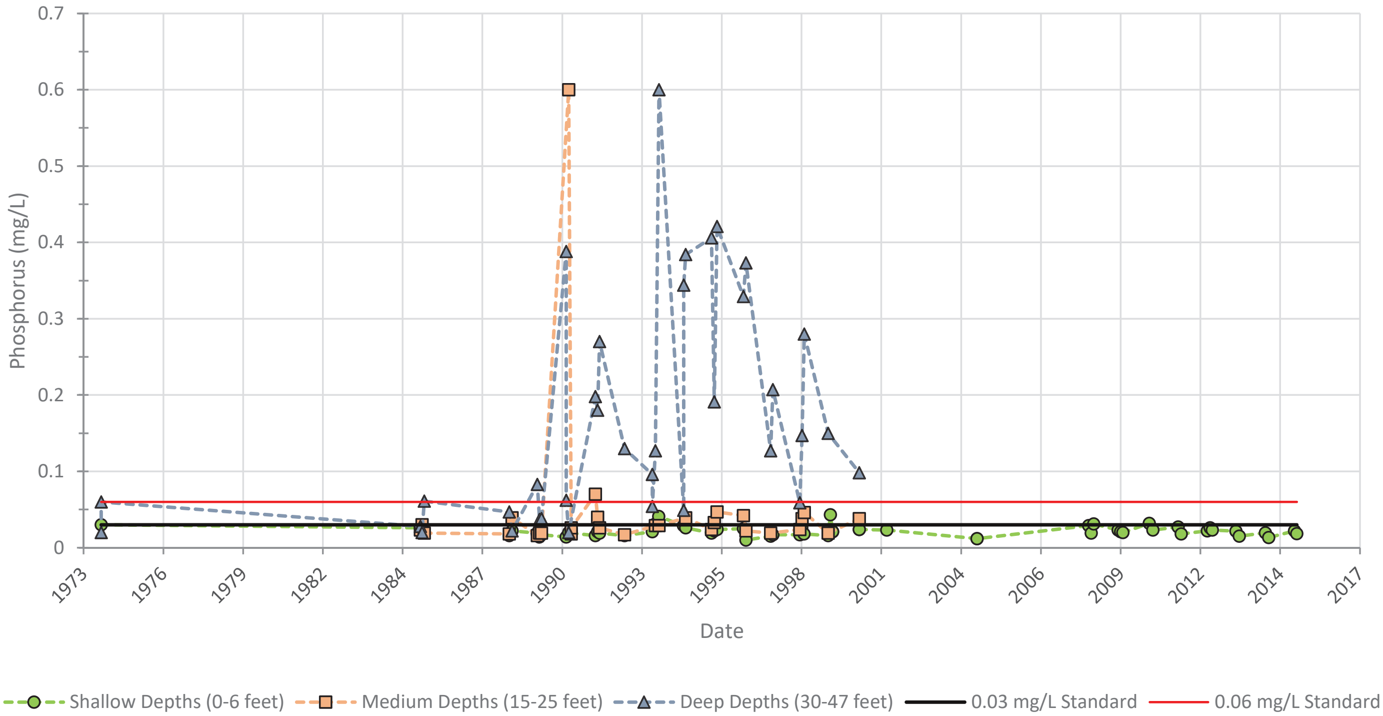
[44] *Unit area flux rate refers to the mass of a substance moving past a threshold over a set area during a unit of time.*

[45] *Steinman, Alan, Rick Rediske and K. Ramesh Reddy, "The Reduction of Internal Phosphorus Loading Using Alum in Spring Lake, Michigan,"* Journal of Environmental Quality, *33:2040-2048, 2004.*

[46] *Bassett Creek Watershed Management Commission,* "Twin Lake Phosphorus Internal Loading Investigation," *March, 2011*.

Figure 27

PIKE LAKE SUMMER PHOSPHORUS MEASUREMENTS: 1973-2015



Source: Wisconsin Department of Natural Resources and SEWRPC.

this reason, the highest levels of algal productivity are often found just above the thermocline in lakes with phosphorus internal loading. The highest oxygen supersaturation values are commonly found in Pike Lake at this depth, suggesting that internal phosphorus loading contributes to abundant algae near the thermocline. Mixing caused by wind and/or seasonal turnover can cause large concentrations of phosphorus from the hypolimnion to suddenly mix with surface water. This could cause algal blooms.

Spring nutrient concentration trends representing a fully mixed Lake are graphed in Figure 20. This graph suggests that surface water quality appears to be slowly improving over time. Since phosphorus is the nutrient in short supply for algal growth, an increase in the phosphorus concentration could translate to higher populations of algae, less water clarity, and an increase in plant detritus delivered to the hypolimnion, all of which could reinforce internal phosphorus loading.

Lake Management Implications and Recommendations

Phosphorus internal loading is a problem in many lakes. Several approaches have been developed to help mitigate its water quality effects. However, to be truly effective, **efforts to reduce phosphorus internal loading must be preceded by, or accompanied with, efforts that permanently reduce and control external phosphorus loading.** Pike Lake receives heavy phosphorus inputs from its watershed; therefore, any improvement in Lake health from internal load reduction efforts will likely be short lived. Consequently, any activity that helps incrementally reduce external loading will increase the relative success and longevity of internal load control efforts. **Efforts to reduce internal loading of phosphorus must not take the place of an aggressive program to identify and minimize external phosphorus loading.** Phosphorus external loading is discussed in the "Watershed Characteristics and Pollutant Loadings" section.

A wide variety of methods have been used in other lakes to attempt to reduce phosphorus internal loading. The applicability of each method is highly dependent on lake-basin morphology, hydrology, water chemistry, cost, and other factors. Some of these methods are listed below along with a judgement of practicality for employment at Pike Lake.

DREDGING

Internal loading depends upon the presence of phosphorus-rich bottom sediment. **Dredging physically removes phosphorus rich sediment from the water body.** Dredging is generally very costly and can negatively affect lake ecology. Furthermore, it is most effective on small, shallow lakes with limited sediment depth. Since sediment contributing to internal loading are found in deep areas of the Lake, and since Pike Lake has large areas of deep water, dredging is impractical form of phosphorus internal loading control from logistical and cost standpoints. Dredging is not recommended for further evaluation.

CHEMICAL INACTIVATION

Internal phosphorus loading results when low-oxygen water destabilizes and dissolves minerals trapped in bottom sediment, allowing phosphorus to dissolve into overlying water. Substances can be added to a lake to suppress this process. **In the Midwest, chemical inactivation generally uses alum (aluminum sulfate), a compound used to clarify drinking water.** Alum works in two ways. First, a solid is immediately formed upon contact with lake water. The solid captures particles, clears the water, and settles on the lake bottom. The alum forms a layer that is not affected by low oxygen levels, and it therefore isolates the reactive lake bottom sediment from anoxic lake water, hindering phosphorus release from bottom sediment during all seasons. Alum treatments are reasonably priced, can be applied to lakes of essentially all depths and sizes, and have provided long-term improvement in the right application. However, alum treatments are not suitable for drainage lakes and other lakes with heavy external phosphorus loading, since the nonreactive cap is soon buried by more phosphorus bearing sediment. For this reason, alum treatment is not considered a feasible alternative for Pike Lake at the present time.

HYPOLIMNETIC DISCHARGE

The goal of hypolimnetic discharge is to reduce the volume and, relatedly, the extent of a lake's anoxic hypolimnion and the amount of phosphorus released from bottom sediment. When functioning properly, hypolimnetic discharge does *not* increase phosphorus loads passing through a lake's outlet. This is done by modifying the lake's outlet to pull water from deeper areas, reducing the volume of cool water in the hypolimnion, while preserving the volume of warm oxygenated water in the epilimnion. Although the lake may still develop anoxia in its deepest areas, the overall volume of the hypolimnion will be reduced. As a result of this, the proportion of the lake's bottom in contact with anoxic water will be reduced, and the flux of phosphorus from bottom sediment will also be reduced. If well designed, the cool water discharge may also benefit downstream aquatic communities. Hypolimnetic discharge is potentially a practical way to reduce the mass of phosphorus released from bottom sediment, and is discussed in more detail in Chapter III.

HYPOLIMNETIC WITHDRAWAL AND ON-SHORE TREATMENT

This process draws phosphorus-rich water from deep in a lake, actively removes dissolved phosphorus, and discharges the purified water to the lake or other discharge points. This process can remove legacy phosphorus from deep lakes. This technique has employed standard wastewater treatment plant processes, and has been used in modest sized lakes, but the long-term success of the technique is not well documented. Natural or nature-like treatment processes can be used to supplant all or some of the wastewater treatment processes. On-shore treatment is considered a potentially practical method to reduce phosphorus internal loading, and is described in more detail in Chapter III.

AERATION/CIRCULATION

Aeration/circulation supplements oxygen levels in the hypolimnion and circulates lake water. The goal is to hinder formation of anoxic deep-water areas. To accomplish this goal, air is pumped to the lake bottom and is discharged through diffusers, creating columns of air bubbles that rise to the surface. On their way to the surface, the air bubbles contribute oxygen to the water and form upwelling currents that mix the lake. Aeration/circulation is feasible, but requires careful design, maintenance, and operation to be effective. Furthermore, if poorly designed and/or operated, **aeration/circulation may not provide sufficient oxygen or mixing to prevent internal loading and phosphorus that would otherwise remain in the hypolimnion may be transported to the surface during the growing season, a situation increasing plant and algal abundance,** worsening lake conditions. In addition to this concern, **a lake as large as Pike Lake will require an extensive (and therefore expensive) system to be assure success, and such a system would need to be operated indefinitely.** <u>For these reasons, aeration/circulation for Pike Lake is not recommended and is not further considered</u>.

Chloride

Under natural conditions, surface water in Southeastern Wisconsin contains very low chloride concentrations. Most Wisconsin lakes saw little increase in chloride concentrations until the 1960s, but a rapid increase thereafter.[47] **Pike Lake was recorded to have 5.1 mg/L Chloride in 1960.[48] Chloride concentrations increased to 80.1 mg/L by 2000, about 16 times the concentrations measured during 1960.**

Chloride is considered a conservative pollutant, meaning that natural processes other than evaporation typically do *not* detain it or remove it from water. Humans use chloride bearing materials for a multitude of purposes (e.g., road salt for anti-icing and deicing, water softening, industrial processes). Therefore, chloride concentrations are normally positively correlated with human-derived pollutant concentrations. Chloride is indicative of a suite of human-sourced and human-enriched chemicals. These chemicals include agricultural nutrients and pesticides, pharmaceuticals, petroleum products, and a host of other substances in common use by modern society. For this reason, chloride concentrations are a good indicator of the overall level of human activity/potential impact and possibly the overall health of a water body. While the concentrations of chloride in Pike Lake do not exceed the current chronic toxicity of 395 mg/L,[49] rapidly increasing chloride concentrations attest to the fact that **Pike Lake is subject to a great deal of cultural pressure and the Lake has a propensity to accumulate human-introduced substances,** a condition that could reduce water quality and overall ecosystem function over time.

Although Lake water chloride concentrations are within current toxicity limits, different species of plants and animals have varying abilities to survive or thrive in saltier environments. For example, reed canary grass, a common invasive species in wetland and riparian settings, is much better adapted to salty water environments.[50] Similarly, Eurasian water milfoil (EWM) can survive levels of industrial and salt pollution that eliminates native aquatic plants.[51] At least a few invasive animal species also are more tolerant of saltier water than native fish species. For example, invasive round goby, a fish introduced from brackish water areas of Eurasia, grows better in higher salt environments and tolerates concentrations lethal to native fish species.[52] Therefore, **<u>high and increasing chloride concentrations may progressively favor unfavorable changes to the flora and fauna of a lake and its watershed</u>.**

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[47] *Wisconsin Department of Natural Resources Technical Bulletin Number 138, op. cit.*

[48] *Rose, W.J., Robertson, D.M., and Mergener, E.A., op. cit.*

[49] W*isconsin Administration Code Chapter NR 105,* Surface Water Quality Criteria and Secondary Values for Toxic Substances, *July, 2010*.

[50] *Prasser, Nick and Joy Zedler,* Salt Tolerance of Invasive Phalaris arundinacea Exceeds That of Natice Carex stricta (Wisconsin), *Ecological Restoration 28(3):238-240, August 2010.*

[51] S*chuyler, A.E., S.B. Andersen, and V.J. Kolaga,* Plant zonation changes in the tidal portion of the Delaware River, *Proceedings of The Academy of Natural Sciences of Philadelphia, 144:263-266, 1993.*

[52] *Karsiotis, Susanne, Lindsay Pierce, Joshua Brown, and Carol Stepien,* Salinity tolerance of the invasive round goby: Experimental implications for seawater ballast exchange and spread to North America estuaries, *Journal of Great Lakes Research, Volum 38, Issue 1, pp 121-128, March 2012.*

Chloride concentrations provide an excellent low-cost mechanism to monitor overall human influence on the Lake. Therefore, it is recommended that chloride concentrations be quantified as part of regular water quality monitoring work. More details are provided in Chapter III.

Watershed Characteristics and Pollutant Loadings

Different land uses contribute different pollutants to a lake. While it is normal for some sediment and nutrients to enter a lake from the surrounding lands (contributing to the natural lake aging process), it becomes an issue of concern when people greatly accelerate soil erosion and introduce anthropogenic pollutants such as heavy metals, fertilizers, and oils.

Given these connections between the practices around a lake and lake water quality, it is important to characterize the area that drains to a lake—its *watershed*—to determine potential pollution sources and risks to a lake's water quality. Several items need to be examined to complete this characterization, including:

1. **The location and extent of a lake's watershed**—Before a watershed can be characterized, the boundaries of the watershed must be carefully identified and located. Watershed delineation involves analyzing land surface elevations surrounding a lake to identify areas where runoff drains toward the lake. This analysis determines whether identified potential pollution sources have a route to enter the Lake. For example, if a nonpoint pollution source is near a lake but outside of the watershed, surface runoff from that source would not reach the lake, and this pollution source would therefore not be a direct threat to the lake's water quality.

2. **Ratio of watershed size to lake surface area -Lakes with a high watershed area to lake surface area ratios can be more prone to water quality problems.** As will be discussed below, the ways that the lands in a lake's watershed are used (e.g., agriculture, residential development, industrial) can greatly influence the types and amounts of pollutants that are carried into a lake by precipitation and runoff events. The greater the amount of land surface draining to the lake, the greater likelihood that pollutants will be washed into the lake. As a rule of thumb, lakes with a watershed to lake surface ratio in excess of 10:1 often experience some type of water quality problems. The Pike Lake watershed size to lake surface area to watershed ratio of 18:1 is relatively high, suggesting that external sources of pollution would be very likely to contribute to lake water quality problems.[53]

3. **The type and location of existing land uses within the watershed**—The extent and location of various land use categories within the watershed can help determine the sources of pollutants reaching a lake. Past, current, and planned land use conditions can be represented within models that use this information to estimate total pollutant loads entering a lake, evaluate the relative contribution of certain land uses or areas, and predict consequences of land use change. Once these loads are determined, it is then possible to determine where to focus management efforts (e.g., if agriculture is the primary source of phosphorus, this may be an effective place to begin nutrient reduction efforts).

4. **The type and location of past land use changes within the watershed**— Knowledge of past land uses and use changes can provide a context for understanding what factors contributed to past issues. This is particularly valuable when contrasted to historical water quality monitoring records or well-documented observations. For example, if long-term lake users or residents have detailed records of years recording algal blooms, heavy aquatic plant growth, or low or high lake levels, these conditions can be assessed in terms

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[53] *The present watershed to lake surface area ratio results from an artificial diversion of the Rubicon River that occurred during the mid-1800s. The watershed to lake area ratio without the artificially diverted Rubicon River watershed is roughly five. This value suggests that under natural conditions, Pike Lake was less prone to external pollutant sources.*

of historical land use changes to help ascertain whether something in the watershed changed and caused or contributed to the problem. For example, was turbid water noted after construction of a new subdivision or roadway? Such information can help future planning efforts because it offers insight into how a lake might react to similar situations.

5. **The nature and location of planned land use within the watershed**—In addition to past and current land use in the watershed, it is also possible to estimate future land use changes. Forecasts help determine the areas that may need to be particularly targeted for management efforts in the future, as well as the potential magnitude of future pollution issues.

6. **The location of septic systems in the watershed (if applicable)**—Private onsite wastewater treatment systems (POWTS), or septic systems, can be a significant source of phosphorus pollution when not properly maintained, and are a source of chloride. Consequently, it is important to investigate where POWTS exist within the watershed.

The extent of Pike Lake's watershed was determined using two-foot interval ground elevation contours developed from a 2013 digital terrain model obtained by Washington County under a program administered by SEWRPC. Pike Lake's watershed, shown on Map 5, is situated almost entirely within the Town of Hartford, Washington County. The **total land area that currently drains to Pike Lake is 7,862 acres,** or about 12.3 square miles. It must be remembered that **the land area draining to Pike Lake was essentially tripled when the Rubicon River was artificially rerouted into the lake during the mid-1800s.** Without the Rubicon River diversion, only about 2,300 acres (3.6 square miles) would drain to the Lake. This issue is discussed in more detail in the "Issue 6: Rubicon River Bypass Channel" section of this report.

Pre-settlement land cover was estimated from early government survey reports. The Pike Lake area was heavily forested before settlement. Except for wetlands and open water areas, essentially the entire landscape was mantled with dense deciduous forest dominated by sugar maple.

Current (2010) land use and planned (2035) land use within the watershed were quantified by urban and rural categories. Urban land uses continue to increase in the watershed (see Tables 10 and 11, Maps 6, 7, 8, and 9). As of 2010, urban land uses occupied approximately 30 percent of Pike Lake's watershed, while rural land uses occupied 70 percent (see Map 6 and Table 12). Fourteen percent of the total watershed area was wetland (most of which is located to the east and north of the Lake, and some to the south), 1 percent of the watershed was part of water bodies other than Pike Lake, 13 percent was woodlands, and 41 percent was devoted to agricultural. Rapid development is anticipated to occur in the Pike Lake watershed between 2010 and 2035 (see Map 9). From 2010 to 2035, about 1200 acres of rural land is anticipated to be urbanized (see Table 12).

Land use data and documented changes to hydrology were used to estimate past, present, and near-term future pollutant and sediment loadings to Pike Lake.[54] Additionally, information gathered by the USGS was closely examined to provide additional perspective and refine estimates. The data resulting from these analyses are presented in Tables 13 and Figure 28 and are discussed in the following paragraphs.

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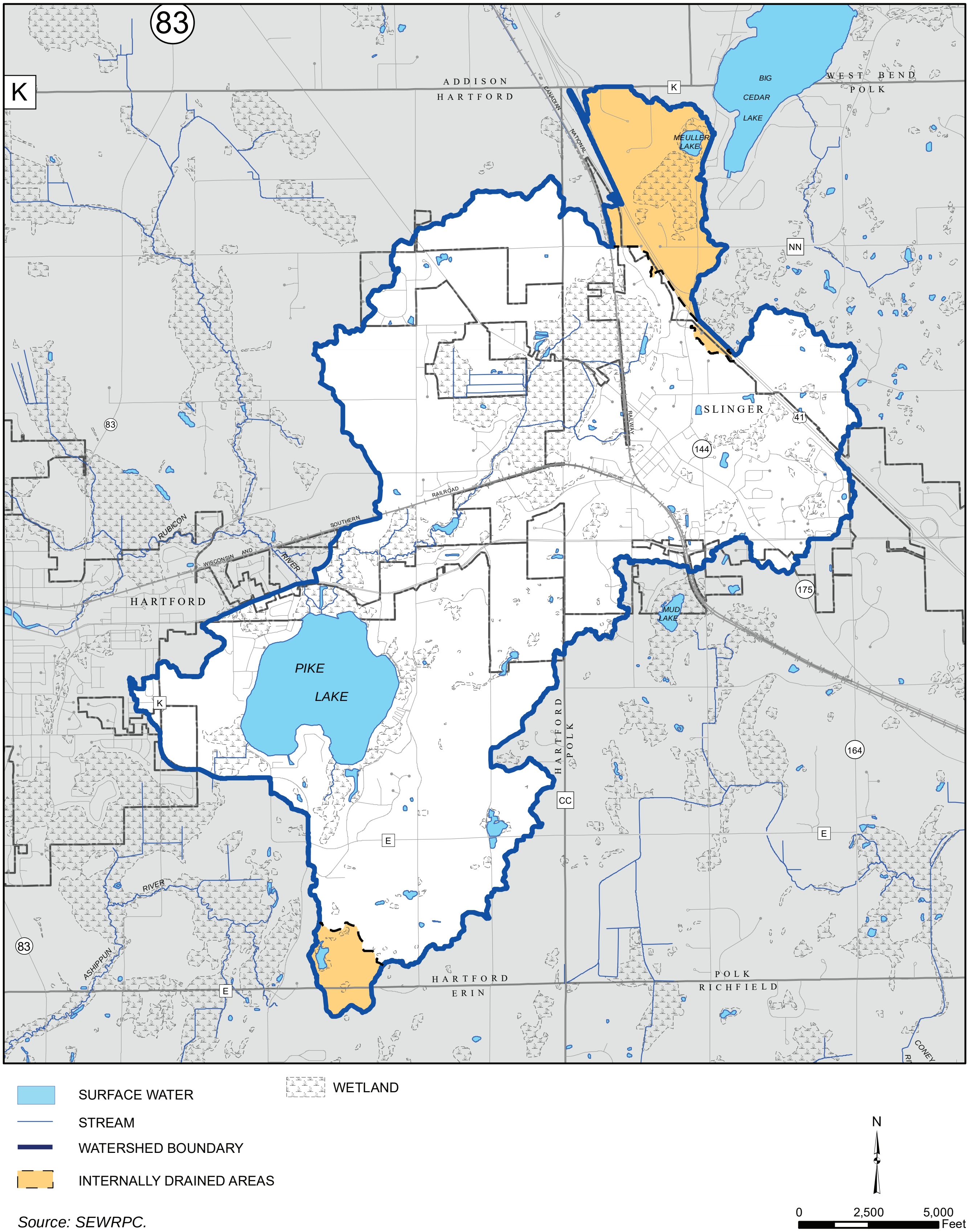
[54] *The calculations for nonpoint source phosphorus, suspended solids, and urban-derived metal inputs to Pike Lake were estimated using the Wisconsin Lake Model Spreadsheet (WiLMS version 3) and the unit area load-based (UAL) model developed for use within the Southeastern Wisconsin Region. These two models operate on the general principal that a given land use will deliver a typical mass of pollutants to a lake.*

Map 5

PIKE LAKE WATERSHED



Source: SEWRPC.

Table 10

INCREMENTAL HISTORICAL URBAN GROWTH IN THE PIKE LAKE WATERSHED

Year	Land Converted to Urban Use During Time Period (acres)
Before 1850	5
1850-1880	9
1880-1920	76
1920-1950	131
1950-1963	120
1963-1970	133
1970-1975	72
1975-1980	220
1980-1985	292
1985-1990	74
1990-1995	185
1995-2000	151
2000-2010	336
TOTAL	1,804

Year	Total Urban Land Use	
	Acres	Percent Total Watershed Area
1850	5	0.1
1880	13	0.2
1920	89	1.2
1950	220	3.0
1963	340	4.7
1970	473	6.6
1975	546	7.7
1980	766	11.2
1985	1,058	16.1
1990	1,132	17.4
1995	1,317	20.9
2000	1,468	23.8
2010	1,804	30.1

Source: SEWRPC.

Compared to pre-settlement conditions, up to 37 times more sediment, nutrients, and other pollutants now reach Pike Lake. Two factors combine to create this situation: conversion of forests to agricultural and urban land use, and artificial diversion of flow from the upstream portion of the Rubicon River into Pike Lake. Collectively, these changes are estimated to have increased total phosphorus loads reaching the lake by about 37 times. Similarly sediment loads increased over 190 times.

The sources of various pollutants reaching the Lake were estimated using the UAL model (see Table 14). As of 2010, the UAL model estimates that over 900 tons of sediment and over 3700 pounds of phosphorus reach the lake from nonpoint sources. Some of this load bypasses the Lake and flows directly to the Lake's outlet. **Agricultural land use contributes approximately three-quarters of the total nonpoint source sediment and phosphorus reaching the Lake.** Urban sources are the only known nonpoint sources of copper and zinc to the Lake. Continuing urbanization lessens the importance of agriculture's contribution to sediment and phosphorus delivered to the Lake. Nevertheless, agriculture is likely to remain the dominant contributor of phosphorus and sediment to the Lake for decades to come.

The WiLMS model allows both point and nonpoint pollution sources to be considered when estimating phosphorus loads to lakes. Loads are derived from watershed land use and point source load data. Wastewater quality information provided by the Village of Slinger spanning the 2008 to 2015 time period suggests that treatment plant effluent contributes about 1,200 pounds of phosphorus per year to the Rubicon River upstream of Pike

Table 11

POPULATION AND HOUSEHOLDS IN THE PIKE LAKE TRIBUTARY AREA: 1960-2035

Year	Population	Change from Previous Decade		Households	Change from Previous Decade	
		Number	Percent		Number	Percent
1960	1,874	- -	- -	538	- -	- -
1970	2,465	591	32	678	140	26
1980	3,383	918	37	1,088	410	60
1990	3,943	560	17	1,448	360	33
2000	6,390	2,447	62	2,498	1,050	73
2010	7,284	894	14	2,941	443	18
Planned 2035	8,895	1,611	22	3,653	712	24

NOTE: Planned 2035 data based on 2000 census data and does not reflect change which may have occurred between 2000 and 2010.

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

Table 12

EXISTING AND PLANNED LAND USE WITHIN THE TOTAL AREA TRIBUTARY TO PIKE LAKE: 2010 AND 2035

Land Use Categories[a]	2010 Acres	2010 Percent of Total	2035 Acres	2035 Percent of Total
Urban				
Residential				
Single-Family, Suburban-Density	83	1.1	99	1.3
Single-Family, Low-Density	716	9.1	835	10.6
Single-Family, Medium-Density	323	4.1	667	12.3
Single-Family, High-Density	- -	- -	- -	- -
Multi-Family	115	1.5	197	2.5
Commercial	85	1.1	198	2.5
Industrial	75	1.0	341	4.3
Governmental and Institutional	109	1.4	144	1.8
Transportation, Communication, and Utilities	722	9.2	933	11.9
Recreational	135	1.7	153	1.9
Subtotal	2363	30.1	3567	45.4
Rural				
Agricultural and Other Open Lands	3247	41.3	2023	25.7
Wetlands	1124	14.3	1124	14.3
Woodlands	1014	12.9	1014	12.9
Water	88[b]	1.1	88[b]	1.1
Extractive	26	0.3	46	0.6
Landfill	- -	- -	- -	- -
Subtotal	5499	69.9	4295	54.6
Total	7862	100.0	7862	100.0

[a]*Parking included in associated use.*

[b]*Eighty-eight acres of open water exist within the upland area draining to Pike Lake. Pike Lake occupies an additional 461 acres.*

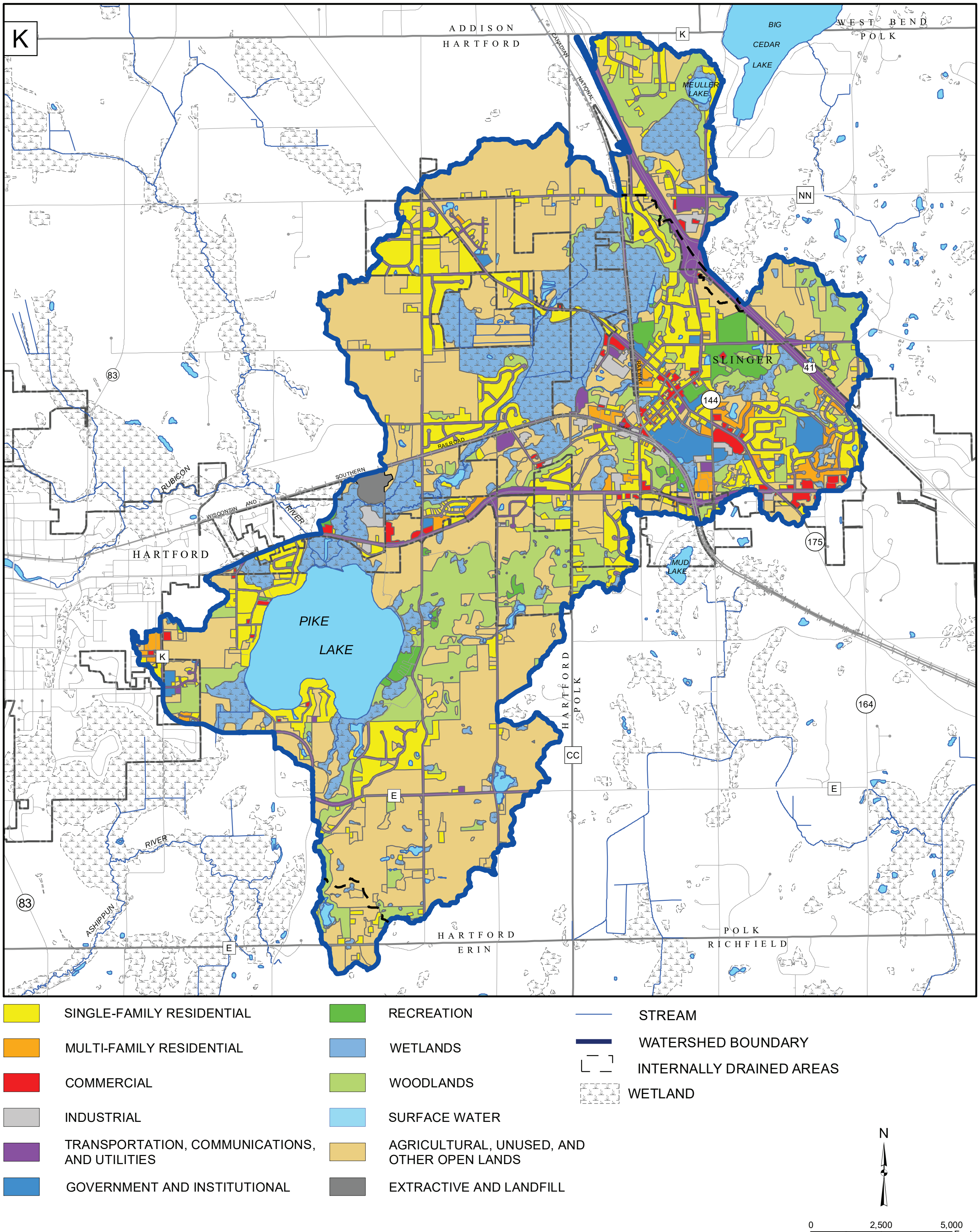
Source: SEWRPC.

Lake. These loads can then be used to estimate resultant open-water phosphorus concentrations in receiving lakes. Several scenarios were developed to estimate the volume of water and phosphorus loads reaching Pike Lake under predevelopment, 2010, and 2035 land use conditions and with various amounts of the Rubicon River's flow by-passing Pike Lake. The WiLMS model yielded 2010 non-point phosphorus load "most likely" estimates essentially equivalent to the UAL model output. However, these loads produced lake-water phosphorus estimates much higher than actually observed in Pike Lake. Lower-bound phosphorus load values produced mass loads that better matched in-Lake conditions, better matched USGS River water quality data, and were used for simulation. Lower-bound phosphorus yield estimates may reflect that much of the River's flow bypasses the Lake. Other factors that may contribute to situation where the lower bound estimate best matches predicted in-lake phosphorus concentrations include that much of the watershed is underlain by permeable soils, that the irregular topography of the Kettle Moraine encourage less runoff and more infiltration, and that agricultural practices are limited by soils and topography to less intense use. The lower bound Canfield-Bachman Artificial Lake Scenario appeared to best predict in-Lake phosphorus concentrations, and was therefore used to predict values under various scenarios. Mass load and hydraulic retention estimates for various scenarios are presented in Table 15.

A two-year USGS study examined the source and fate of water and pollutants in Pike Lake. The mass of phosphorus entering and leaving through the Lake's inlet and outlet channels was directly measured (as opposed to estimated

Map 6

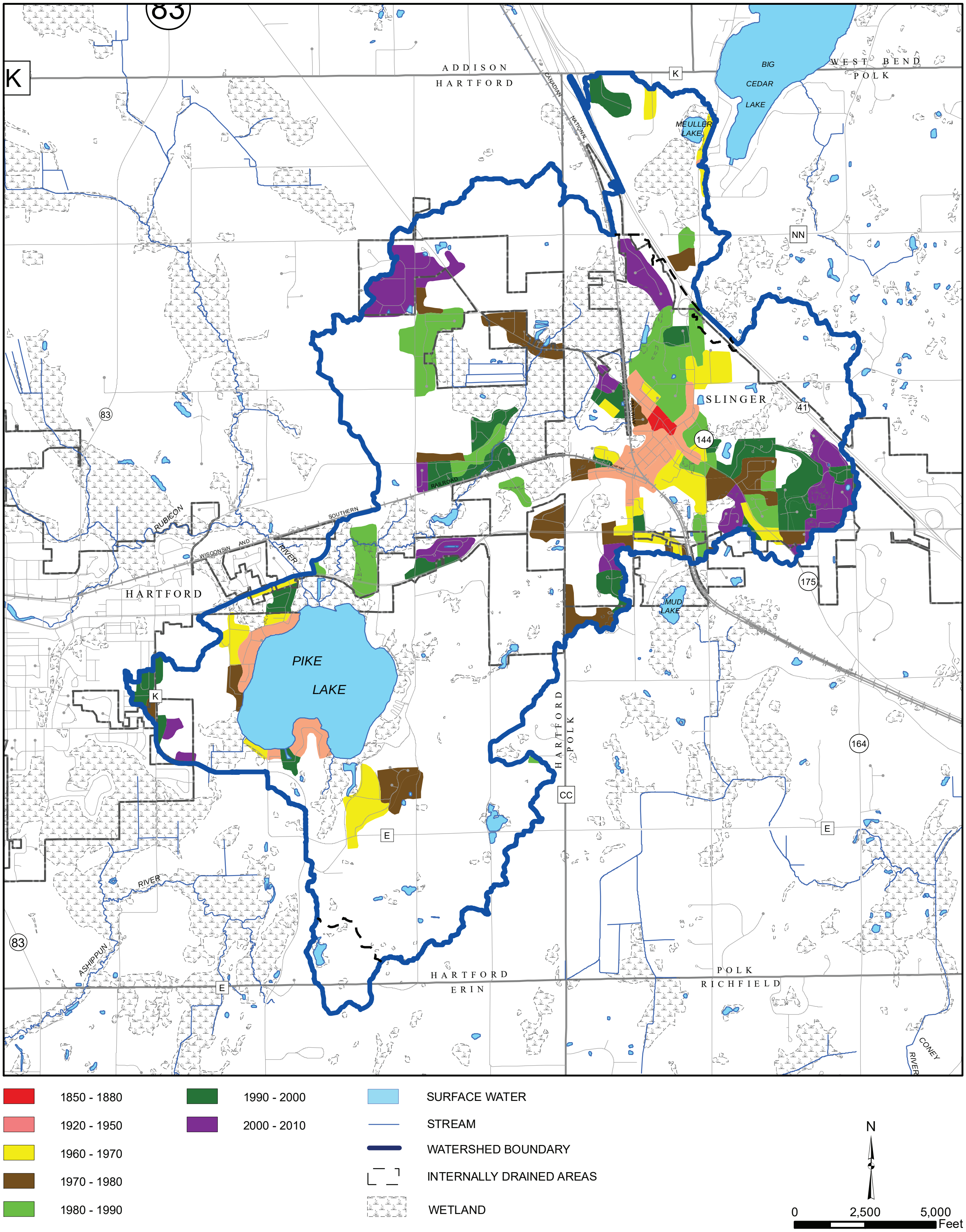
2010 EXISTING LAND USE FOR THE PIKE LAKE WATERSHED



Source: SEWRPC

Map 7

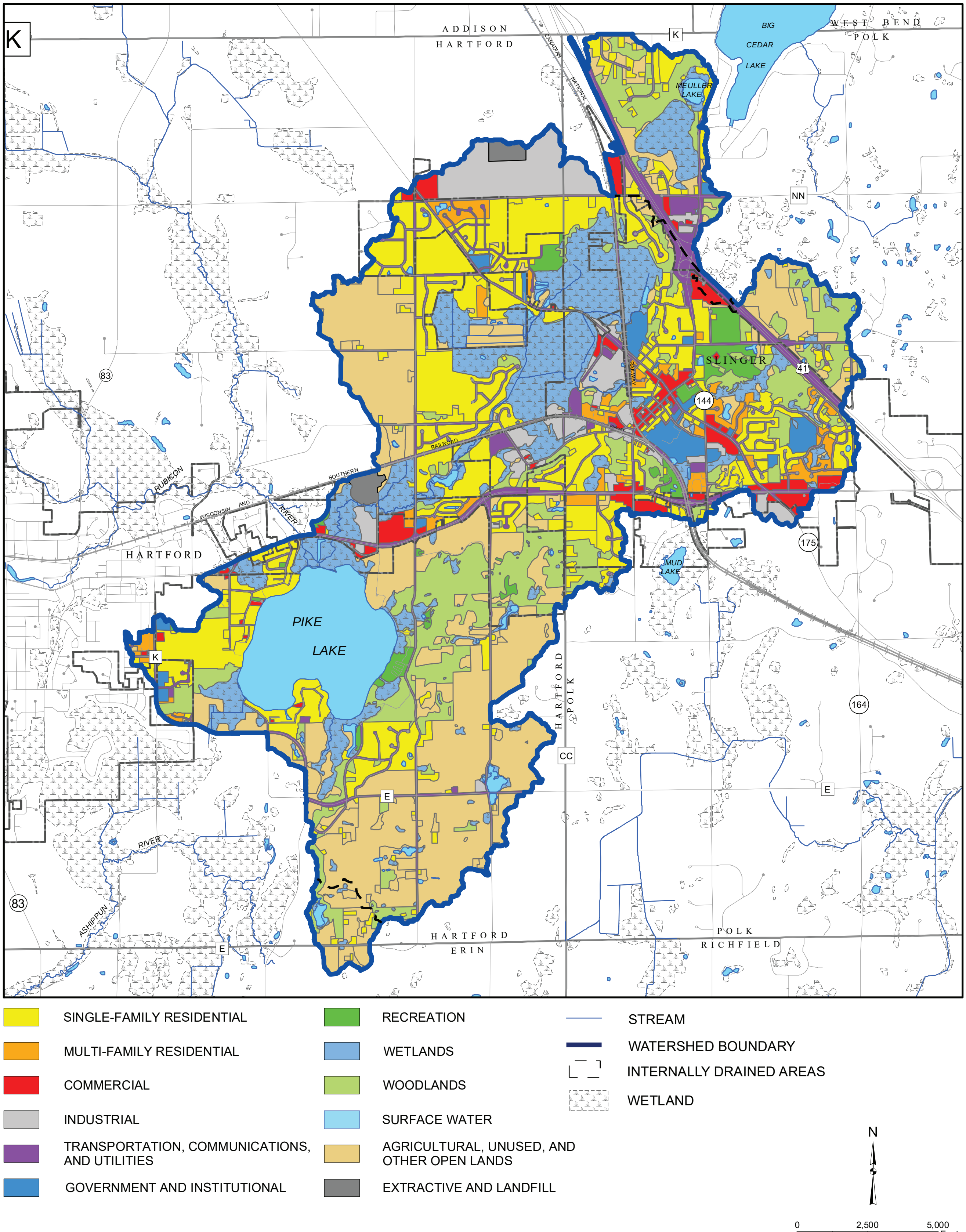
HISTORICAL URBAN GROWTH WITHIN THE PIKE LAKE WATERSHED: 1850 - 2010



Source: SEWRPC

Map 8

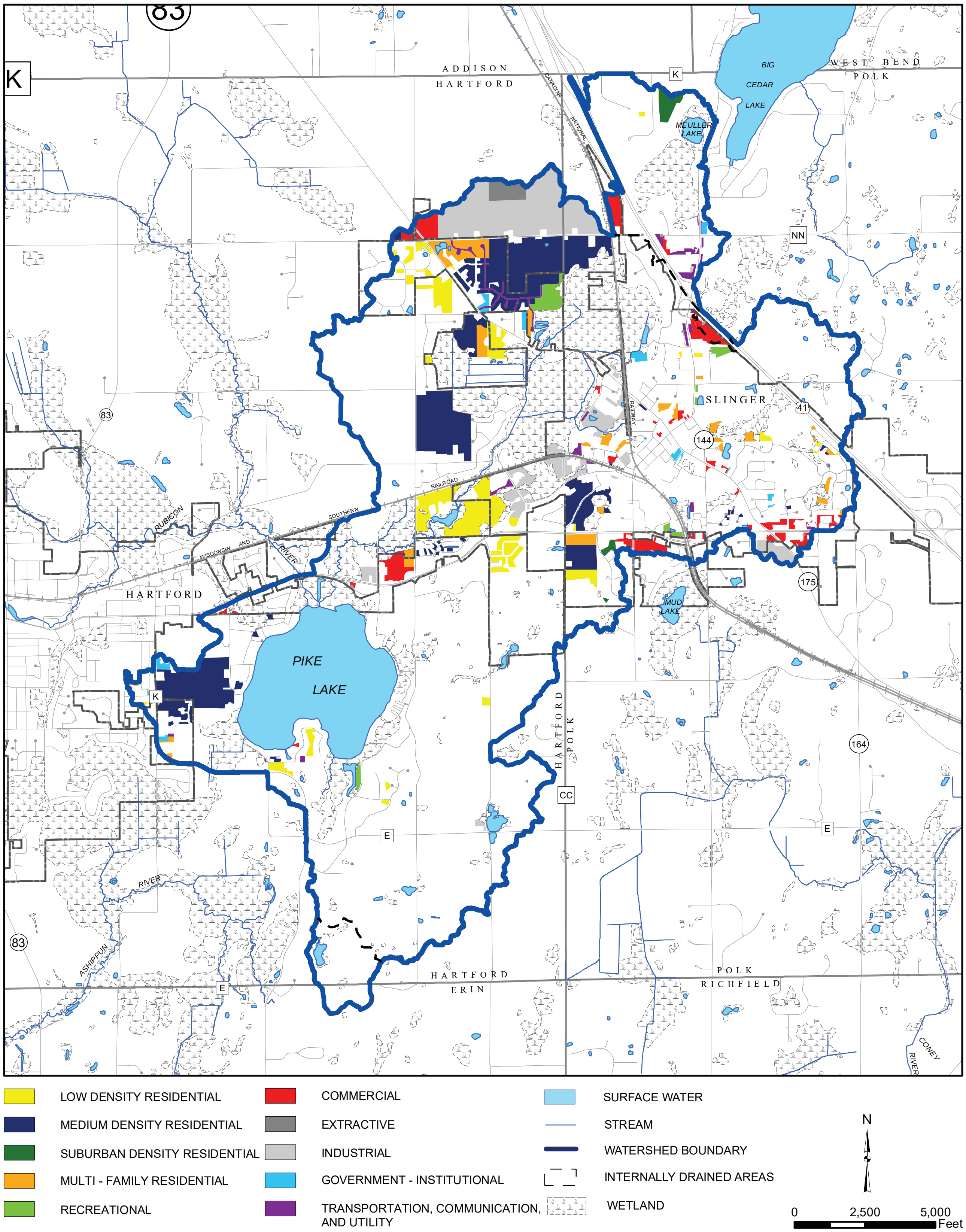
2035 PLANNED LAND USE WITHIN THE PIKE LAKE WATERSHED



Source: SEWRPC

Map 9

AGRICULTURAL LANDS, OPEN LANDS, AND WOODLANDS THAT WOULD BE CONVERTED TO URBAN LAND USE UNDER YEAR 2035 PLANNED CONDITIONS WITHIN THE PIKE LAKE WATERSHED



Source: SEWRPC

Table 13

UNIT AREA LOAD MODEL ESTIMATED ANNUAL POLLUTANT LOADING: PIKE LAKE

Land Use Category	Pollutant Loads: 2010			
	Sediment (tons/year)	Phosphorus (pounds/year)	Copper (pounds/year)	Zinc (pounds/year)
Urban				
Residential[a]	50.1	398.7	30.2	212.8
Commercial	33.3	102	18.7	126.7
Industrial	28.2	87.8	16.5	111.8
Governmental	27.8	147.1	7.6	87.2
Transportation	20.5	40.9	0.0	0.0
Recreational	1.6	36.5	0.0	0.0
Subtotal	161.5	813.0	73.0	568.5
Rural				
Agricultural	730.6	2792.4	0.0	0.0
Wetlands	2.1	45.0	0.0	0.0
Woodlands	1.9	41.0	0.0	0.0
Subtotal	742.2	2888.9	0.0	0.0
Water				
Pike Lake Atmospheric Deposition	43.3	59.9	0.0	0.0
Other Water Bodies Atmospheric Deposition	7.6	10.5	0.0	0.0
Subtotal	50.9	70.4	0.0	0.0
Total	954.6	3772.3	73.0	568.5

Land Use Category	Pollutant Loads: 2035			
	Sediment (tons/year)	Phosphorus (pounds/year)	Copper (pounds/year)	Zinc (pounds/year)
Urban				
Residential[a]	77.0	598.7	48.9	341.5
Commercial	77.6	237.6	43.6	295.0
Industrial	128.2	399.0	75.0	508.1
Governmental	36.8	194.4	10.1	115.2
Transportation	0.0	0	0.0	0.0
Recreational	1.8	41.3	0.0	0.0
Subtotal	321.4	1471.0	177.6	1259.8
Rural				
Agricultural	455.2	1739.8	0.0	0.0
Wetlands	2.1	40.6	0.0	0.0
Woodlands	1.9	45.0	0.0	0.0
Subtotal	466.8	1835.9	0.0	0.0
Water				
Pike Lake Atmospheric Deposition	43.3	59.9	0.0	0.0
Other Water Bodies	7.6	10.5	0.0	0.0
Subtotal	50.9	70.4	0.0	0.0
Total	839.1	3377.3	177.6	1259.8

NOTE: Pre-settlement (100% woodland) pollutant loads were calculated for the current watershed that includes the Rubicon River. These estimates suggest that the pre-settlement land use would contribute 14.5 tons of sediment and 313 pounds of phosphorus to the Lake each year. These values include portions of the watershed that originally did not naturally drain to the Lake. The Lake's smaller natural watershed likely contributed about 5 tons of sediment and 100 pounds of phosphorus to the Lake each year.

[a] *Includes low density, medium density, high density, and multi-family residential land use.*

Source: SEWRPC.

Figure 28

PHOSPHORUS BUDGETS, PIKE LAKE WATERSHED: 1999 AND 2000

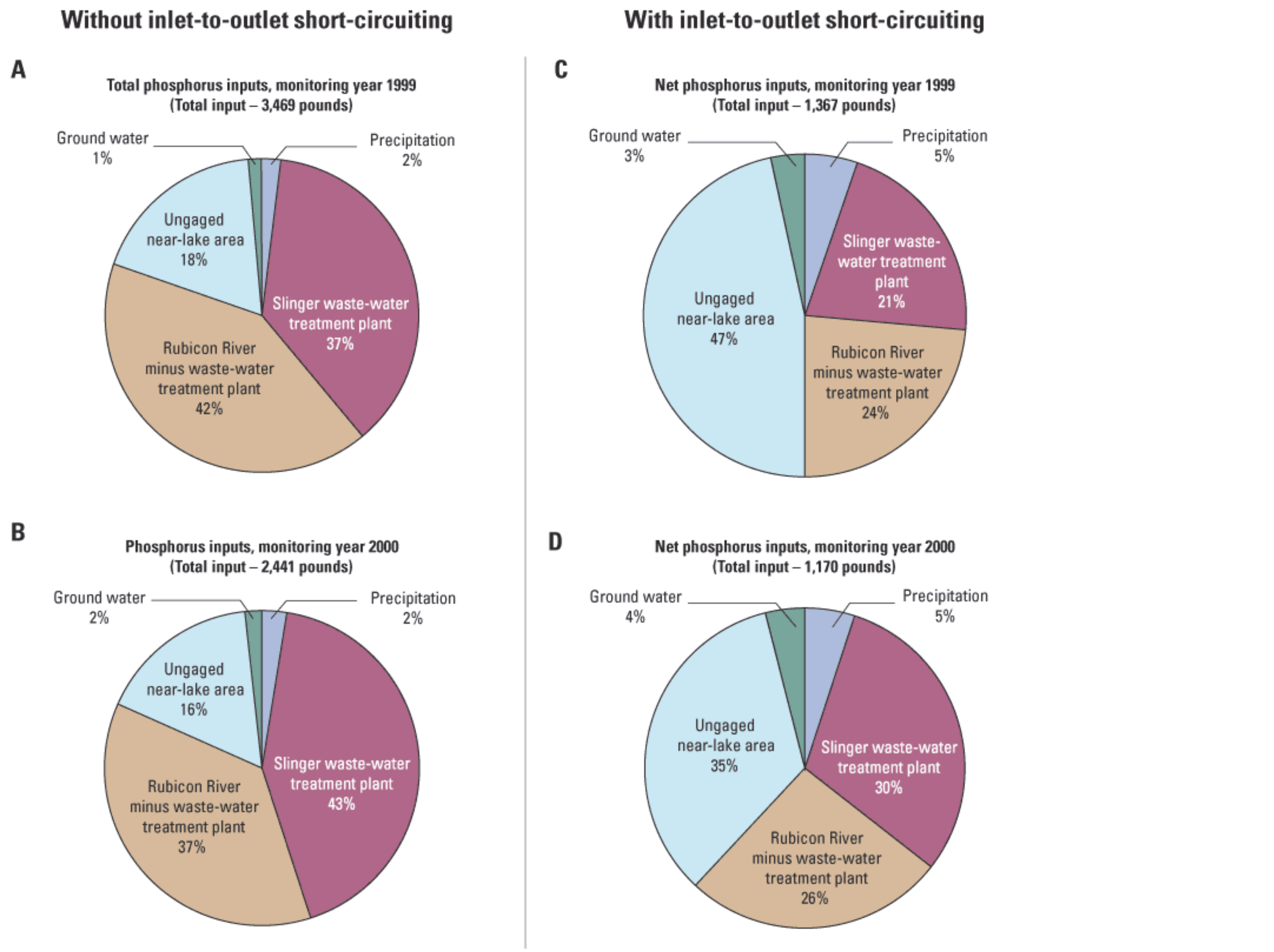


Figure 12. Phosphorus budgets for Pike Lake, near Hartford, Wis., for monitoring years 1999 and 2000. [Monitoring year, December to November; %, percent]

Source: United States Geological Survey.

with models) for this two-year period (see Figure 28). Slightly less than 3,000 pounds of phosphorus were found to enter Pike Lake each year. Of this total, the Slinger wastewater treatment plant contributed well over one-third of the total mass of phosphorus delivered to the Lake during the period of study while the upper Rubicon River watershed contributed a similar mass of phosphorus as the wastewater treatment plant. The Rubicon River was found to deliver about 80 percent of the annual phosphorus loading to Pike Lake (including runoff from the land surface and treated effluent from the Slinger wastewater treatment plant). However, since the Lake's inlet and outlet are very close to one another, the USGS believes that much of the combined Rubicon River/wastewater loading bypasses the Lake and is carried directly to the lake outlet. Under bypassing conditions, the USGS estimates that **the Rubicon River watershed and the Slinger wastewater treatment plant together contribute about half of Pike Lake's total annual phosphorus load.** Table 15 uses USGS data to estimate phosphorus mass loadings under various conditions.

The WiLMS model uses phosphorus loading to estimate the concentration of phosphorus predicted to be found in a lake of similar size and morphology. Short circuiting of Pike Lake's inlet and outlet channels and in-lake attenuation reduce the actual concentration of phosphorus found in the Lake well below that predicted by models. This underscores the importance of both processes in maintaining the Lake's water quality. For example, The USGS estimated that **in-lake phosphorus concentrations would double if the upper Rubicon River would directly enter Pike**

Table 14

WiLMS SIMULATED PHOSPHORUS LOADING AND HYDRAULIC RETENTION TIMES UNDER VARIOUS CONDITIONS

	Input Variables		WiLMS Model Estimates	
Scenario Description	Land Use in Watershed	Percent of Rubicon River's Annual Flow Entering Pike Lake[A]	Total Annual Phosphorus Load to Pike Lake (Pounds/Year)[A,B]	Water Retention Time (Years)
Pre-Settlement (mid 1830s)	100% Forested	0%	144	3.5
2010 Land Use, River's Entire Flow Enters Lake	Mixed urban, rural, natural land use and full load from Slinger WWTP	100%	3144	1.0
2010 Land Use, Partial River Diversion	Mixed urban, rural, natural land use and some load from Slinger WWTP	25%	1376	2.1
2010 Land Use, River Completely Bypasses Lake	Mixed urban, rural, natural land use. No load from River or Slinger WWTP.	0%	652	3.5
2035 Land Use, River's Entire Flow Enters Lake	Mixed urban, rural, natural land use and full load from Slinger WWTP	100%	3479	1.0
2035 Land Use, Partial River Diversion	Mixed urban, rural, natural land use and some load from Slinger WWTP	25%	1540	2.1
2035 Land Use, River Completely Bypasses Lake	Mixed urban, rural, natural land use. No load from River or Slinger WWTP	0%	759	3.5

Note A: The United States Geological quantified the daily flow and phosphorus load of the Rubicon River just upstream of Pike Lake during 1999 and 2000. The flow over this two-year period averaged 4009 acre-feet per year, and the phosphorus load averaged 1164 pounds per year.

Note B: WiLMS output was compared to water quality records collected by the United States Geological Survey. This comparison reveals that the Rubicon River watershed yields phosphorus at the low range of simulated values.

Source: SEWRPC.

Table 15

ANNUAL PIKE LAKE PHOSPHORUS LOADING ESTIMATES UNDER VARIOUS WATERSHED CONDITIONS

Simulation Variables			Phosphorus Loading to Pike Lake Based Upon USGS 1999/2000 Phosphorus Budget	
Land Use Condition	Rubicon River Diverted to Lake?	Slinger WWTP Load Included?[a]	Gross	Gross Load Minus Phosphorus Exported to Rubicon River[b]
Pre-settlement (circa 1836)	No	No	102[c]	n/a
1999/2000	No	No	630[d]	n/a
	Yes	No	1794	-297[e]
	Yes	Yes	2955	864

[a]Wastewater treatment plant loadings are based upon 1999/2000 data and are not adjusted to account for population or treatment technology changes.

[b]The USGS estimated that 2091 pounds of phosphorus per year left that Lake via the outlet channel during 1999 and 2000.

[c]Estimate derived from WiLMS model for pre-settlement condition of the area draining directly to Pike Lake. Excludes the Rubicon River watershed.

[d]Includes phosphorus contributed by rainfall, groundwater, and areas draining directly to Pike Lake but excludes the Rubicon River.

[e]The negative value results from ignoring a major source of phosphorus loading to the lower Rubicon River (e.g., the Slinger WWTP).

Source: United States Geological Survey and SEWRPC.

Lake, eliminating inlet/outlet bypass flows. Such an increase in concentration is predicted to move Pike Lake solidly into the eutrophic category, with water clarity reduced by about 20 percent. Similarly, if more Rubicon River watershed/wastewater were diverted away from the Lake, water quality in Pike Lake would improve, with water clarity improved by about 11 percent.

The largest source of phosphorus to the Lake may be one of the most straight-forward to actively manage. **<u>Returning all or portions of the flow of the Rubicon River to its original natural channel substantially reduces phosphorus loads reaching Pike Lake</u>.** Diverting the River's flow could influence Lake elevation. The River's flow now helps support higher Lake levels during drought. Special measures would need to be engineered to allow the River to continue to maintain dry-weather lake elevation yet allow the River to bypass the Lake during fair and wet weather periods. In addition to the Rubicon River source, direct runoff presently delivers significant amounts of phosphorus to the Lake as compared to natural conditions. <u>Measures that reduce sediment, phosphorus, and other pollutants from the Lake's direct watershed should also be taken. Recommendations for such actions are presented in Chapter III</u>.

A WiLMS simulation was constructed that allows the water quality impact of naturalizing the course of the Rubicon River to be simulated. This scenario's basic precept is that the Rubicon River bypasses Pike Lake, yet remains connected by an outlet channel to the River. In times of drought, much of the Rubicon River's flow would continue to enter Pike Lake to support water levels. In times of high water, flood water would be allowed to backwater into the Lake, preserving the Lake's flood control benefits to downstream areas. However, **flow <u>through</u> the Lake would be eliminated, and most of the nutrients and sediment carried by the river would continue downstream.[55] This single change is estimated to decrease phosphorus loads to Pike Lake by 56 percent and would cause summer phosphorus concentrations in Lake water to fall to 16 µg/L, a value that would likely cause Pike Lake to become a solidly mesotrophic lake** (Pike Lake is now at the borderline of becoming a eutrophic lake). Actions to reduce non-point sources of phosphorus throughout the watershed, but particularly in the areas that drain to the Lake, would be particularly beneficial.

All shoreline properties along the Lake are served by sanitary sewer. However, some developed areas farther away from the Lake that are served by private onsite wastewater treatment (septic) systems. Without proper maintenance, septic systems can malfunction possibly causing bacterial contamination and increased phosphorus loadings to the stream tributary to the Lake and the groundwater. <u>Therefore, management of current systems and any new systems is an important consideration and is discussed in Chapter III of this report</u>.

The water quality of Pike Lake appears to be slowly improving over time. Chlorophyll-*a* and total phosphorus concentrations are slightly less indicative of eutrophic conditions, especially when compared to the early- to mid-1990s. However, water clarity appears to be slowly deteriorating. Chloride concentrations, an indicator of overall human influence on the Lake, have been consistently increasing over the years. Although phosphorus and chlorophyll-*a* concentrations are decreasing, they should be further reduced to lessen the potential for excessive aquatic plant growth and algal blooms. Therefore, <u>Chapter III addresses phosphorus reduction measures. Monitoring should continue to track trends of important Lake health indicators and provide insight regarding changes to Lake health and the relative success of various Lake and watershed management programs</u>. The monitoring program would be enhanced by periodically collecting additional data (e.g., chloride samples and supplemental total phosphorus samples collected from deep water areas). <u>Targeted efforts (e.g., maintenance and expansion of riparian buffers) can enhance the pollution mitigation ability of the watershed</u>, since this has the potential to reduce pollution from multiple land uses.

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[55] *This scenario is not unlike the conditions that currently exist by diverting flow with the fence-like structure. However, the amount of water diverted and overall reliability and durability of the diversion would increase, benefitting the Lake.*

How Water Quality is Affected by Watershed/Shoreland Filtering and Storage
Sediment, plant nutrients, and other pollutants can be deposited in a lake from shoreline erosion, aquatic plant death and biomass accumulation, and transport of sediment from the lake's watershed. Sediments can bury natural sand and gravel substrate, degrading fish habitat and causing loss of desirable aquatic organisms. Species such as largemouth bass, bluegill, green sunfish, darters and minnows (e.g., common shiner, sand shiner, and spotfin shiner) depend upon sand and gravel substrates for feeding, nesting, and rearing of juveniles.[56] Loss of water volume and depth associated with sedimentation can limit recreational opportunities, can reduce the number of types of fish and the overall fish population, and can reduce the quality of deep water habitat. Finally, sediment may act as a nutrient reservoir that has the potential to re-enter the water column given the right conditions (e.g., agitation, dissolution under anoxic conditions).

It is important to note that some sedimentation naturally happens as lakes age (Figure 12). Although this process naturally occurs over centuries, **sedimentation can be accelerated to abnormally high rates when land use practices in the watershed limit natural attenuation (e.g., filtering provided by streamside vegetation) and instead favor erosion, heavy direct runoff, and artificial pollutant loading.**

Since certain land use features and management activities filter or remove pollutants from runoff prior to entering a lake system, it is important to evaluate where such features exist within the Pike Lake watershed. It should be noted that features can overlap and may provide multiple benefits. Identifying the type and location of such features can help determine if pollutant sources have the potential to directly enter the Lake (without any filtration) or pass through treatment features. Examples of features that help protect a lake's water quality include:

1. **Stormwater detention or retention ponds**— Stormwater management ponds, when properly maintained, can detain water during and after rainfall events, slowing runoff velocity, and allowing many pollutants (e.g., sediments, nutrients, heavy metals) to settle out before reaching downstream water bodies. Since phosphorus is tightly bound to sediment, trapping sediment reduces phosphorus loads passed downstream. Stormwater ponds need to be periodically dredged and may require other maintenance to ensure proper function. **Stormwater detention or retention ponds in a lake's watershed help protect or improve lake water quality by significantly reducing sediment and nutrient loads delivered to the lake.** Stormwater ponds normally are designed to decrease peak flows by storing water during the heaviest runoff period and releasing stored water at a controlled rate over an extended period of time. Some ponds are designed to infiltrate a portion of the stormwater, recharging groundwater supplies. On account of this, stormwater management ponds may also help mitigate downstream bed and bank erosion problems, extend the period when intermittent streams actively flow, and contribute to the value of riparian and in-stream habitat. However, they may also increase water temperature, can sometimes attract nuisance species, and can be barriers to aquatic organism migration.

2. **Wetlands**— Wetlands are commonly recognized by the presence of organic and/or wet soils and water-loving plants. **Wetlands benefit lake health, particularly when located at or along the lake's shoreline, within floodplain areas, and along the shores of tributary streams.** Wetlands slow runoff moving toward the lake reducing flood peaks and allowing sediment and affiliated pollutants to settle in a fashion similar to stormwater management ponds. Additionally, **plant life located in wetlands can assimilate and process pollutants such as phosphorus, incorporate them into biomass,** thereby detaining or retaining the pollutant from entering the lake. Wetlands have a well-deserved reputation of being "nature's kidneys", filtering pollutants from water. They are provide life-cycle critical habitat for a large number of fish, amphibians,

[56] *Despite the potential for sedimentation to adversely affect fish populations, a variety of projects can still be initiated that encourage healthy fish populations. Examples of such projects are described in the "Shoreline Maintenance" and "Fish and Wildlife" sections of this chapter.*

birds, and other animals. Without wetlands, familiar species such as northern pike may not be able to naturally reproduce. Knowing where wetlands are located can help determine if a pollution source is a high risk to downstream waters, since wetlands can detain or retain certain pollutants.

3. **Floodplains**—Floodplains are situated adjacent to water bodies and are inundated during heavy runoff. The portion of floodplains that conveys floodwater is referred to as floodway. Flood fringe areas are located adjacent to and beyond the floodway on either side of a water body. Flood fringe areas *temporarily store* floodwater, reducing peak flow rates in the floodplain. Water stored in flood fringe lands also helps reduce downstream flood elevations and can reduce stream power reducing erosion and pollutant mobilization/transport. Water stored in flood fringes is relatively still, is commonly spread over large areas, may recharge groundwater supplies, and may be purified by an array of biological, physical, and geochemical processes. Flood fringe areas can act as sediment, nutrient, and pollutant traps, and provide important habitat used by aquatic life for functions such as feeding, refuge, reproduction, and juvenile rearing. Floodplains provide the broadest value in their natural state, but still provide valuable service when developed if compatible open space uses are chosen. Floodplains can be restored along manipulated drainage ways as part of projects that help reduce flooding, improve habitat, and stabilize eroding beds and banks.

4. **Natural terrestrial buffers**—Natural buffers include vegetative features such as woodlands or prairies. When these areas are densely vegetated, they, like wetlands, can slow runoff and incorporate pollutants into biomass. Consequently, **when located in areas intercepting runoff flowing toward a lake, buffers can help lower pollutant loads reaching a lake.** Moreover, enhancing these features, particularly in areas adjacent to a waterbody, can reduce the amount of pollutants entering that waterbody. Like wetlands, such areas are critical to the life cycle of many herptiles (amphibians and reptiles), mammals, and birds.

5. **Artificial buffers (e.g., grassed waterways, vegetative strips)**—Artificial buffers can take a number of forms. A few examples include grassed waterways, vegetative strips, and gardens located along shorelines. Such buffers are generally constructed to intercept runoff shortly before it enters a river or lake. They function in a similar way to natural buffers (i.e., slowing runoff), need to be carefully designed, and should use native plants to promote reliable long-term function. **Artificial buffers can enhance lake water quality without significant adverse effects to residential and agricultural land uses.** More information regarding artificial buffers and their efficacy is included in Appendix E.

6. **Nearshore Aquatic Vegetative Buffers**—In-lake vegetation (e.g., bulrush, cattails) in shallow nearshore areas can filter and assimilate nutrients and sediments to some degree before runoff reaches the main body of a lake. **Nearshore aquatic vegetation also helps protect shorelines from erosion and provides valuable aquatic habitat to a wide range of animals.** Consequently, encouraging survival and enhancement of nearshore vegetation can help improve lake water quality.

As noted above, the location, appearance, and function of these features commonly overlaps, providing multiple benefits. To identify and locate each of the features described above, SEWRPC staff completed an inventory of the detention basins, wetlands, and natural features such as woodlands within the watershed, using existing databases, mapping software, and aerial imagery. Additionally, to identify the extent and condition of shoreline buffers, SEWRPC staff completed a field assessment of the Pike Lake shoreline during summer of 2014. These inventories are discussed below.

Numerous stormwater basins are located within the Pike Lake watershed. The stormwater basins are particularly numerous in developments constructed during the past 20 years, and are generally more common in rapidly urbanizing areas (e.g., new construction within the Village of Slinger and along the STH 60 corridor). If stormwater basins are properly maintained, they can limit the amount of pollution entering Pike Lake from the commercial and residential areas draining to these basins. Consequently, assuring proper inspection and maintenance of these ponds should be considered a high priority. Recommendations related to this topic are provided in Chapter III of this report.

Fourteen percent of the Pike Lake watershed is occupied by wetlands. Most are located along the Lake's eastern, southwest, and northern shorelines and along the Rubicon River just upstream of the Lake (see Map 6). These wetlands reduce the amount of pollutants and sediment reaching the Lake from surface-water runoff from adjacent portions of the watershed. Riparian wetlands found in wetlands along the Rubicon River have the ability to treat water originating from large areas. The potential to naturally remove pollutants, when combined with the many other benefits provided by wetlands, illustrates how critical preserving these wetlands is for the health of Pike Lake. Consequently, <u>recommendations related to maintaining and enhancing wetland functions are also included in Chapter III of this report</u>.

Woodlands, uplands, and other "natural areas," as mentioned above, act as buffers to water-bodies. About 12 percent of the Pike Lake watershed is composed of woodlands, a relatively large percentage when compared with much of Southeastern Wisconsin. The presence of the Pike Lake Unit of the Kettle Moraine State Forest helps protect these resources. Woodlands and other natural areas are particularly valuable when located in areas adjacent to the Lake or its tributaries (see Map 6). Consequently, <u>these areas should be protected to the greatest extent practical to protect the water quality of the Lake</u> (see Chapter III for recommendations).

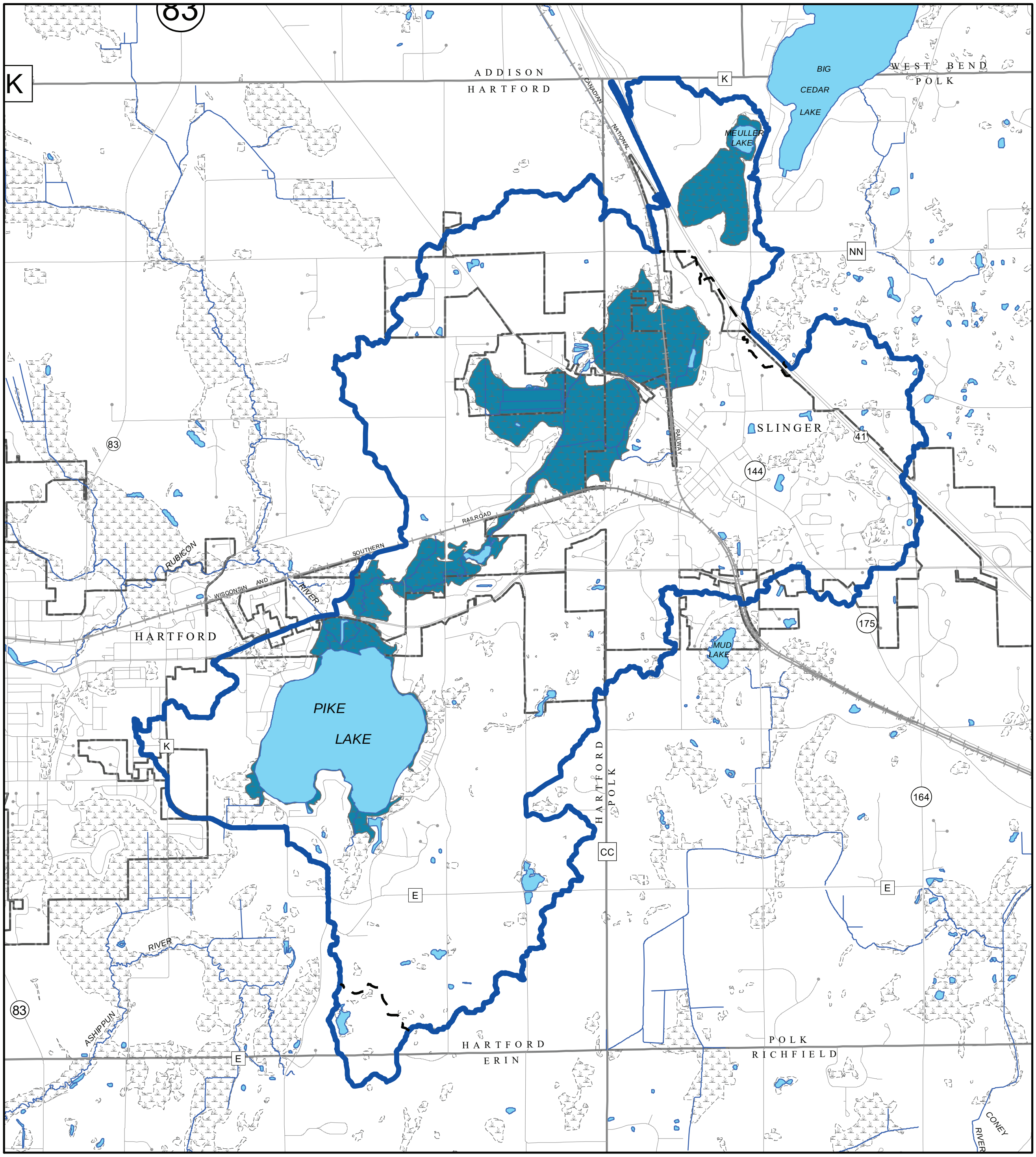
Mapped floodplains occupy about 780 acres of the land tributary to Pike Lake. As shown on Map 10, these areas are located primarily within the wetlands flanking the Rubicon River northeast of the Lake. Relatively small wetland floodplains also fringe the Lake's south shoreline. These **floodplains provide valuable functions such as providing quiescent floodwater detention, reducing downstream flooding, lowering the erosive power of tributary streams, and allowing sediments and entrained pollutants to be deposited in riparian areas instead of the Lake.** Such areas may also encourage stormwater infiltration, helping bolster groundwater-sourced dry-weather flow to the Lake. Finally, floodplains are critical habitat to many aquatic species, including amphibians such as frogs and toads, and also serve as spawning and nursery areas for gamefish such as northern pike. <u>It is important to protect floodplains from filling, isolation from adjacent streams, and development through conscientious application of local zoning ordinances. Furthermore, when opportunities arise, action should be taken to enhance them wherever and whenever possible</u>. Such opportunities need not solely rely on grant funding, but may also be part of permit conditions issued by local municipalities.

Artificial buffers and vegetative buffers along the shoreline of Pike Lake are shown on Map 11. A few artificial buffers, primarily gardens along the shoreline, as well as a few vegetative buffers, provide the Lake some protection from pollutants that could otherwise directly enter the Lake (e.g., lawn clippings, fertilizers, and oil from cars). The Lake substantially benefits from the Pike Lake Unit of the Kettle Moraine State Forest bordering a large portion of the northeastern shoreline, which, along with the wetland to the north, provides long-term protection. However, outside of those areas, **a large portion of the shoreline is mowed to the water line.** These near-lake areas pose risks to the water quality of the Lake, consequently, <u>enhancing shoreline buffers along the shorelines should be considered a high priority</u>. Recommendations related to this topic are further discussed in Chapter III of this report.

***Protecting and enhancing* natural buffers, wetlands, woodlands, natural areas, and floodplains and *creating/maintaining* artificial buffers and stormwater treatment infrastructure are foundational aspects to protect Pike Lake's water quality.** This reflects and agrees with the goals of the *Wisconsin's Healthy Lakes Implementation Plan.* This plan focuses on habitat restoration, runoff, and erosion control projects to improve and protect the health of our lakes through shoreline owner participation (see Appendix F for more information). Buffer and stormwater maintenance/development should target strategic areas in the watershed that produce high pollutant loads which do not currently filter through an existing buffer or wetland system prior to entering a waterbody. Examples of some of the areas were identified by comparing likely stormwater flow paths to the locations of identified natural and artificial water quality features discussed above (see Map 12. Most of these example areas are adjacent to the Lake. <u>Consequently, nearshore areas need to be targeted for pollution reduction efforts and/or buffer enhancement projects</u>. Recommendations related to water quality enhancement within Chapter III focus on such opportunities.

Map 10

MAPPED FLOODPLAINS WITHIN THE PIKE LAKE WATERSHED: 2017



- 1 PERCENT ANNUAL PROBABILITY (100-YEAR RECURRENCE INTERVAL) FLOODPLAIN
- SURFACE WATER
- STREAM
- WATERSHED BOUNDARY
- INTERNALLY DRAINED AREAS
- WETLAND

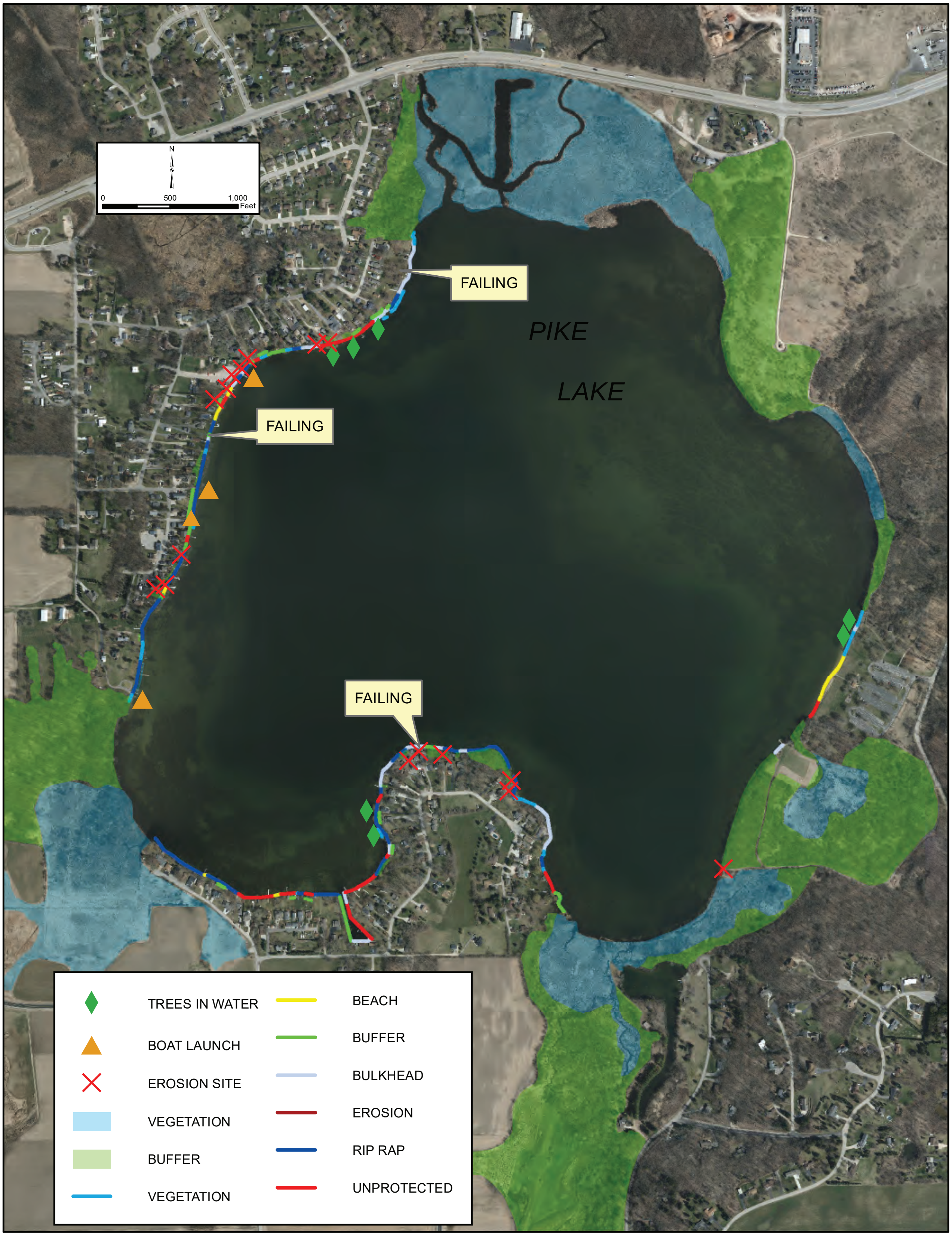
N

0 2,500 5,000 Feet

Source: SEWRPC.

Map 11

PIKE LAKE SHORELINE CONDITION ASSESSMENT: 2014

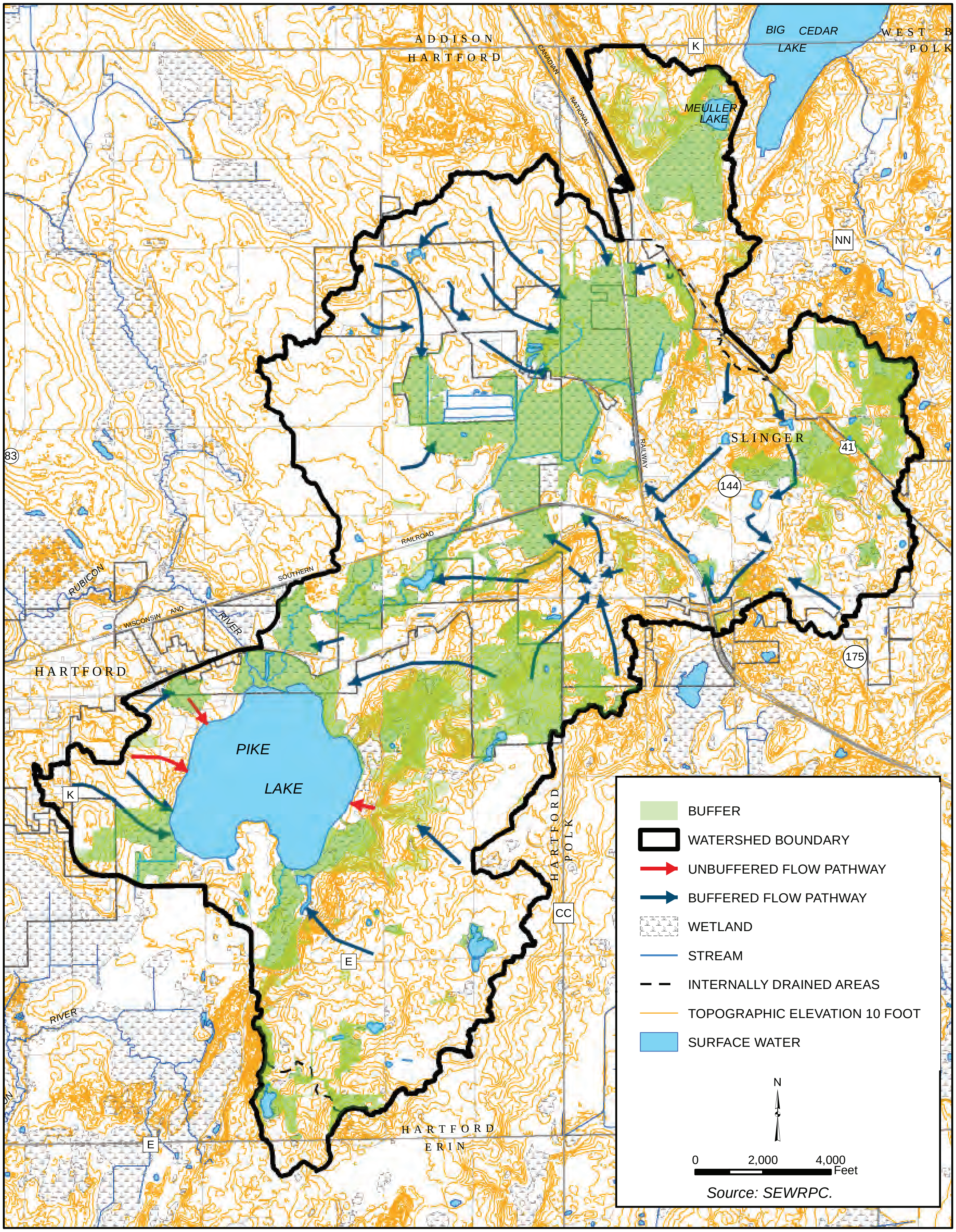


DATE OF PHOTOGRAPHY: APRIL 2015

Source: SEWRPC.

Map 12

EXISTING BUFFERS AND SURFACE-WATER FLOW PATHWAYS WITHIN THE PIKE LAKE WATERSHED



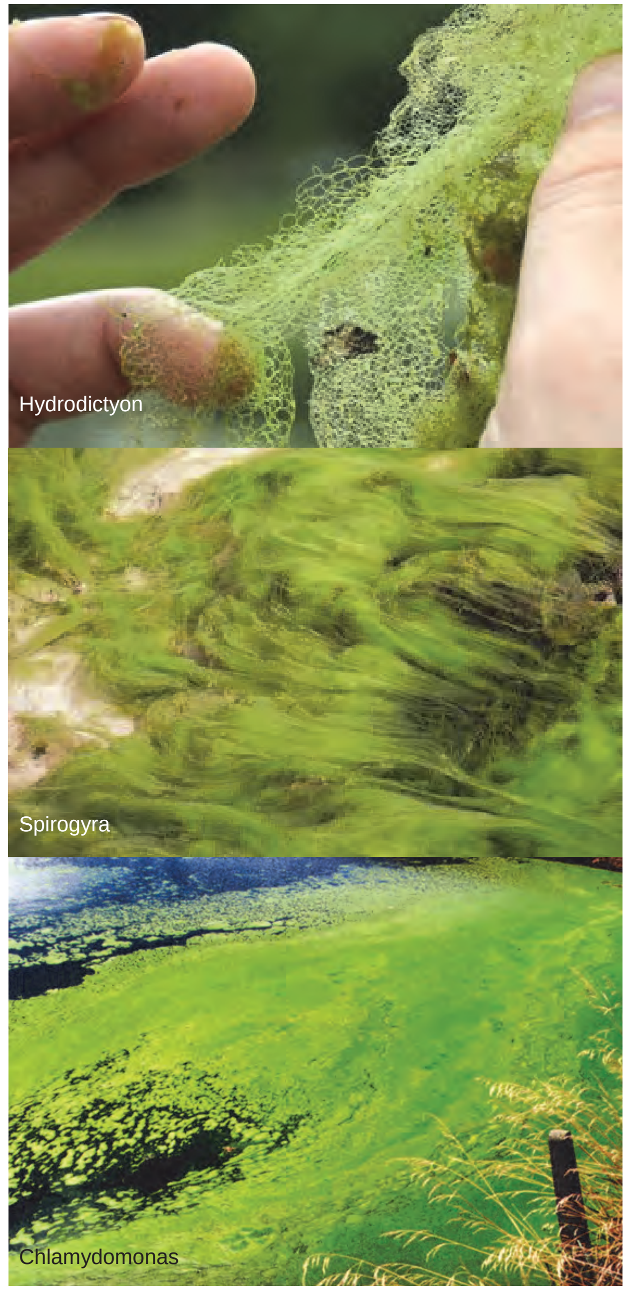
ISSUE 3: CYANOBACTERIA AND FLOATING ALGAE

Before discussing management of excessive algal growth, it is important to appreciate that **algae is an integral part of healthy waterbody ecosystems.** Algae are foundational components of lake food chains and produce oxygen in the same way as rooted plants. Many kinds of single-cell and colonial algae exist, from filamentous algae (see Figure 29) to cyanobacteria (formerly called blue-green algae). Most algal strains benefit lakes when present at moderate levels. However, the presence of toxic strains (see Figure 30), as well as excessive growth patterns should be considered issues of concern. As with aquatic plants, algae generally grow faster in phosphorus-rich water (particularly in stagnant areas). Consequently, when toxic strains or over abundant algae begin to grow in a lake, phosphorus enrichment or pollution may be present.

Algae is an ongoing issue of concern for Pike Lake residents and users. The Lake has periodically experienced relatively minor algal blooms, most recently during summer 2015. Past algal blooms typically lasted for one to three days and reportedly caused the water to have a green coloration. However, the 2015 algal bloom was uncharacteristic as the bloom lasted for several weeks (see Figure 31). Prior to the late 1990s, chlorophyll-*a* values varied widely from 0 to 31 µg/l; however, since the late 1990s the values rarely rise above 10 µg/l, with an average of 6 µg/l (see Figure 32). These values border on concentrations associated with eutrophic conditions, which are represented by values greater than 7-10 µg/l. Chlorophyll-a concentrations greater than 20 to 30 µg/l are typically associated with algal blooms.[57]

Figure 29

EXAMPLES OF NON-TOXIC ALGAE



Source: Lewis Lab, University of New Mexico, Landcare Research.

Based upon the presently available data, phosphorus is the nutrient limiting algal growth in Pike Lake. Phosphorus concentrations, on average, have been declining for many years. However, **certain short-term events can trigger conditions that could cause in-lake phosphorus concentrations to temporarily increase and fuel excessive algal growth.** Examples of such events include phosphorus-rich anoxic water from deep areas of the lake being brought to the surface during seasonal (spring and fall) turnover, summer storms that create wind-induced currents that mix deep Lake water rich in phosphorus with surface water, storms and snowmelt delivering spikes of phosphorus-rich runoff to the Lake, and failure of the diversion structure that diverts most of the Rubicon River's flow directly to the Lake outlet. Episodic increases in wastewater treatment plant effluent phosphorus concentrations could also temporarily increase loads to the River, but much of this higher phosphorus load would bypass the Lake.

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[57] *Rose, W.J., Robertson, D.M., and Mergener, E.A., op. cit.*

The overall influence of episodic increases in phosphorus loads delivered to the Lake would be decreased if day-to-day phosphorus loads were reduced. Therefore, **it is important to manage nonpoint source phosphorus contributions throughout the watershed.** Additionally, as discussed previously, **returning the flow (and hence phosphorus load) of the upper Rubicon River to its original course would reduce phosphorus loads and would also greatly reduce the incidence of stormwater runoff induced algal blooms.**

In general, **the most permanent methods for preventing excessive and toxic algae growth are:**

1. **Manage water quality with a focus on reducing phosphorus concentrations in the Lake**—Phosphorus pollution is often the cause of excessive algal growth. Consequently, the water quality recommendations discussed in Chapter III should be implemented.

2. **Maintain a healthy and beneficial native plant community**—As mentioned in the "Chemical Measures" subsection of this chapter, maintaining a healthy, robust native plant community helps prevent excessive algal blooms since the native aquatic plants directly compete with algae for nutrients. Particular attention should be directed at fostering the abundance and health of the bottom dwelling algae species responsible for the natural phosphorus sequestration process (i.e., muskgrass). Consequently, carefully implementing the aquatic plant management recommendations provided in Chapter III and communicating this nutrient-growth relationship to residents (to encourage land owners to employ conservative hand-pulling of vegetation and phosphorus-reducing landscaping and land use) should be a priority.

3. **Return the Rubicon River to its natural course bypassing Pike Lake**—Even when recent Lake inlet/outlet bypassing schemes are considered, up to half of the annual phosphorus load reaching Pike Lake enters via the Rubicon River. The Rubicon River was diverted into the Lake to support now defunct milling operations in Hartford, and, in its natural state, the Rubicon River completely bypassed the Lake.

Figure 30

EXAMPLES OF TOXIC ALGAE

Source: National Oceanic and Atmospheric Administration, St. John's River Water Management District.

Figure 31

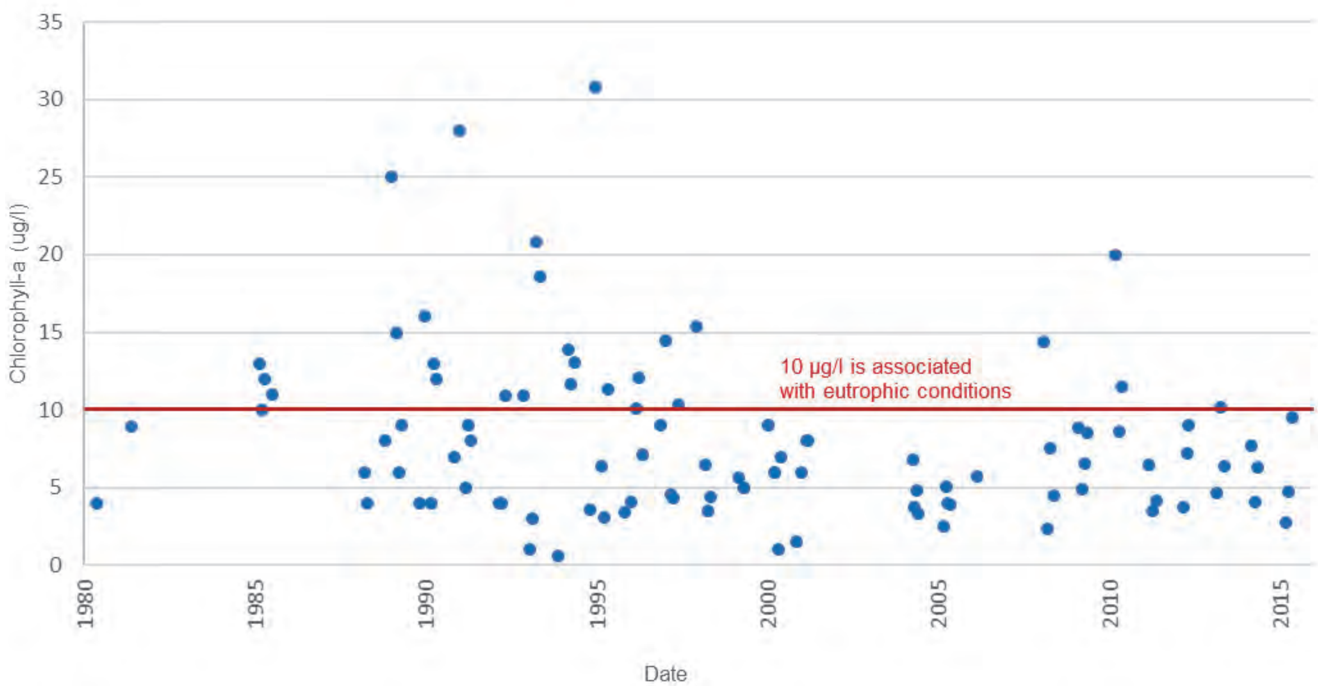
PIKE LAKE ALGAE: 2015

Source: Jerome Kabelowsky, Pike Lake resident.

Although earlier diversion attempts have failed, the new cable dam appears to be successfully diverting Rubicon River water, and undoubtedly benefits the Lake. The exact amount of water diverted has not been

Figure 32

PIKE LAKE CHLOROPHYLL-*a* CONCENTRATION MEASUREMENTS: 1980-2015



Source: Wisconsin Department of Natural Resources and SEWRPC.

quantified and the long-term integrity/reliability of the cable dam is unknown. High flow events may overtop or breach the cable dam, allowing large storm-related nutrient and sediment pulses to enter the Lake. <u>Returning the River's flow to its natural course would reliably and permanently reduce phosphorus loads to the Lake and would provide other benefits</u> (e.g., less infrastructure maintenance, improved aquatic organism passage).

In addition to these approaches, in-lake measures and manual removal methods could also be employed. Some methods focus on the symptom (i.e., the nuisance algae itself) while others attempt to address the cause – high phosphorus concentrations.

1. **In-lake treatments.** Floating algae growth is fueled by nutrients dissolved or suspended in lake water. If lake-water nutrient levels are reduced, the abundance of algae can be controlled. Water quality enhancement recommendations were discussed earlier in this chapter under "Issue 2: Water Quality." Both alternatives presented as feasible under that section could be considered to help control algae. These methods are summarized below. Additional information regarding this alternative can be found in the Water Quality sections of Chapters II and III.

   a. **Alum treatments**—Alum treatment involves spreading a chemical (alum: hydrated potassium aluminum sulfate) over the surface of a lake. This chemical forms a solid that sinks, carrying algae, other solids, and associated phosphorus to the bottom of the lake. This is a temporary solution to immediately improve water quality and can be high cost action to treat individual blooms. However, alum-bound phosphorus precipitated to the lake bottom does not become soluble under anoxic water conditions and can help form a cap to reduce internal phosphorus loading. When lake conditions are right, this method can yield a long-term remedy to lower lake water phosphorus concentrations in lakes where internal phosphorous loading is occurring. Given the size of Pike Lake, this method is likely cost prohibitive.

Alum could also be employed to reduce phosphorus concentrations of water entering the Lake. For example, water leaving the Slinger Wastewater Treatment Plant could be polished to reduce phosphorus concentrations. However, other phosphorus reduction strategies could be likely be employed for less cost to achieve the same goal through adaptive management.

Overall, alum treatments will not likely provide an efficient means to prevent algae blooms.

b. **Hypolimnetic withdrawal and on-shore treatment—The overall goal of this alternative is removing phosphorus from the Lake.** Some of the phosphorus available to fuel warm-season algal growth is released from Lake bottom sediment during summer, is available to fuel algal growth when conditions are right, and is returned to the Lake bottom where it remains available to fuel algal growth in the future. At least some of this stored phosphorus is likely a legacy from periods of time when the Lake was heavily loaded with pollutants. Since the Lake has a only a modest natural capacity to flush pollutants downstream, actions to actively and permanently remove phosphorus from the Lake can help decrease future nutrient levels. Hypolimnetic withdrawal and on-shore treatment would use pumps or gravity to remove nutrient-rich waters from deep within the Lake, treat the water on shore, and then allow the treated water to pass downstream or re-enter the Lake or the lower Rubicon River. This approach can be designed at a variety of scales, with the most intensive approaches yielding the quickest results. Less costly low-intensity approaches can operate essentially indefinitely and lead to incremental water quality improvement over decades.

c. **Hypolimnetic discharge—The overall goal of hypolimnetic discharge is to reduce the mass of phosphorus entering the Lake from bottom sediments.** This is done by reducing the volume of the hypolimnion. At present, the Lake's warm waters spill over a weir. The lake outlet would be modified to draw cold water from deeper portions of the Lake. This action decreases the volume of the hypolimnion, and should create a situation where less sediment is exposed to anoxic water, which in turn decreases the amount of phosphorus entering the lake from internal loading.

2. **Manual removal**—Manual removal of algae using a suction device has recently been tested within the Region. This measure, though legal, is currently in the early stages of application. Additionally, "skimming" of algae has been tried by lake managers, with little success. Consequently, it would be necessary to further investigate these kinds of measures prior to implementation.

Alum treatment is generally used for direct algal control only when algal blooms become so excessive that they greatly inhibit recreational use. Alum treatments target the algae itself are only temporarily effective, and need to be repeated or continually implemented, making them potentially cost-prohibitive. Additionally, such a process is in essence treating the effect, and not the underlying cause. Since Pike Lake's algal bloom is more than likely directly related to the phosphorus loads coming from the Rubicon River the more permanent methods of algal control discussed above (i.e., runoff quality enhancement, naturalizing the course of the Rubicon River to bypass the Lake) are considered viable. As discussed earlier in this section, maintaining existing stormwater infrastructure and natural features should be done whatever management plan is adopted.

As a final note, although managing and preventing excess algae is vital, it may also be advantageous to actively monitor algae. Two primary methods are typically used to monitor algae levels. The first is to collect chlorophyll-a samples which quantify the concentration of suspended algae in lake water (i.e., the green color in water). The second is to collect algae samples to determine whether algae is non-toxic. Figure 32 shows summer chlorophyll-*a* measurements for Pike Lake are often below the 0.010 mg/L (10 µg/L) level above which green colored water and algae blooms are more prevalent. If blooms become excessive and/or common, or if toxic algae are identified, regular monitoring should be considered. Monitoring could be done in cooperation with the state park personnel who are likely interested in water quality at their bathing beach.

ISSUE 4: SHORELINE MAINTENANCE

Shoreline maintenance was identified as an issue of concern by SEWRPC after field inspections of shoreline condition and its correlation to aquatic plant growth and water quality. This issue of concern is further emphasized by the fact that water quality, and aquatic plant growth, are all directly influenced by shoreline maintenance practices, as was described throughout this chapter.

Before discussing shoreline maintenance, it is important to understand the difference between two terms: shoreline protection and buffers. Shoreline protection encompasses various measures – artificial or natural – that shield the immediate shoreline (water-land interface) against erosive forces of wave action. Buffers are areas of plant growth – artificial or natural – in the riparian zone (lands immediately back from the shoreline) that trap sediment and nutrients emanating from upland and nearshore erosion (buffers were described in detail earlier in this report).

When it comes to shoreline protection, several artificial options are available to home owners. Most artificial shoreline protection structures are installed to check erosive forces, check shoreline recession and reduce soil loss to a lake, and oftentimes to provide a “finished” or “manicured” appearance to developed lots. These structures include 1) “bulkheads,” where a solid, *vertical* wall of some material, such as poured concrete, steel, or timber, is erected; 2) “revetments,” where a solid, *sloping* asphalt or concrete wall is used; and 3) “riprap,” where rocks and/or stones are placed along the shoreline. See Figure 33 to view examples of several shoreline protection techniques. All structures listed above require permits from WDNR to construct.

It must be emphasized that, in certain cases, **shoreline protection does not have to rely on artificial, engineered structures.** Many types of natural shorelines offer substantial protection against erosive force. For example, boulders and rock cliffs function as natural rip-rap or bulkheads. Additionally, wetlands (such as those found along the northern, southeastern, and southwestern shorelines of Pike Lake) and areas of exposed cattail stalks and lily pads, such as those found around the Lake’s nearshore area, effectively reduce shoreline erosive forces. Similarly, emergent plant stalks and leaves disperse and dampen waves by dissipating and absorbing energy.

“Hard” engineered seawalls of stone, riprap, concrete, timbers, and steel, once considered “state-of-the-art” shoreline protection, are now recognized as only a partial solution to protect and restore a lake’s water quality, wildlife, recreational opportunities, and scenic beauty. Indeed, evidence suggests that, in some cases, the inability of hard shorelines to absorb wave energy increases wave energy in other portions of a lake since wave energy is reflected back into open water areas. More recently, “soft” shoreline protection techniques, referred to as “vegetative shoreline protection,” (see Figure 34) involving a combination of materials, including native plantings, are increasingly required pursuant to Chapter NR 328, “Shore Erosion Control Structures in Navigable Waterways,” of the *Wisconsin Administrative Code*. Vegetative shoreline protection is becoming more popular as people living along lakes and streams become aware of the value of protecting their shorelines, improving their view and overall aesthetic appeal, and promoting natural and nature-like habitat for wildlife. Additionally, **shorelines protected with vegetation help shield a lake from both land-based and shoreline pollution and sediment deposition.**

Given the benefits of soft shoreline protection measures, WDNR no longer permits construction of hard structures in lakes that do not have extensive wave action threatening the shoreline. However, existing structures may be repaired. As a result, since Pike Lake is a not a large lake, is used for fishing, and has a healthy natural walleye reproduction (as further discussed in the “Recreation” and “Fish and Wildlife” sections below), it is unlikely that new hard shoreline protection structures would be permitted, with the exception of riprap in discrete high energy areas. Consequently, the recommendations in this plan related to shoreline restoration focus on soft measures, including native planting, maintaining aquatic plants along the shorelines, and the use of “bio-logs” (see Figure 35). Beach areas, which legally need to be made from pea gravel,[58] are considered as a separate category. Placing pea gravel may be permitted; however, this would have to be evaluated by WDNR on a case-by-case basis.

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[58] *WDNR no longer permits the use of sand to create new beaches because these materials quickly flow into a waterbody and contribute to the “fill-in” of the Lake.*

Figure 33

TYPICAL SHORELINE PROTECTION TECHNIQUES

RIPRAP

NATURAL VEGETATION

BULKHEAD

REVETMENT

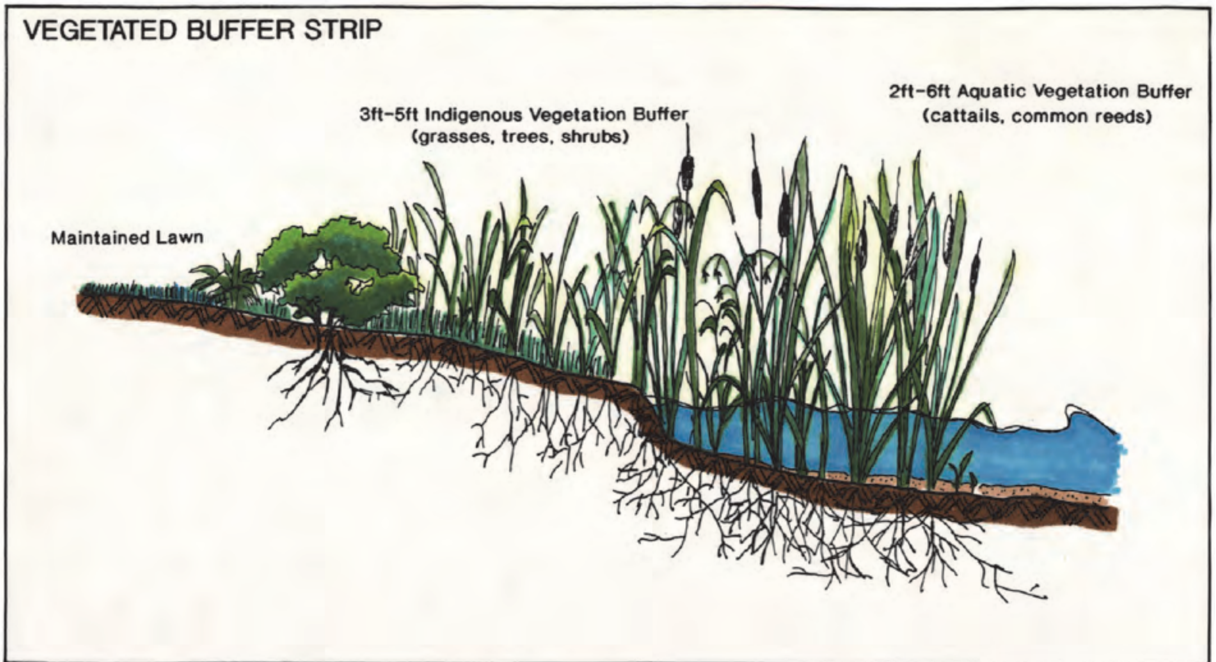
Source: SEWRPC.

Pike Lake's Shoreline

To quantify shoreline condition as well as restoration and maintenance needs around Pike Lake, and to help develop recommendations related to shoreline maintenance and pollution reduction, SEWRPC staff inspected the Lake's shoreline during summer 2014. The results of this survey are shown on Map 11. With the exception of the riparian wetlands scattered around the lake, **few shoreline buffers are present** along developed properties (a condition not unusual for lakes in the Region). Additionally, **actively eroding shoreline was noted at several sites.** <u>Educating shoreline property owners about the importance and role of buffers (especially when using native plants) to prevent pollution and shoreline erosion should be considered a priority</u>. Given the desire of Lake users to ensure Lake health, as well as the need to preserve recreational use and aesthetics, <u>priority should be given to keep existing shoreline structures in good repair (when feasible) and to maintain/install soft shoreline protection such as vegetated shoreline buffers (e.g., maintain the health of near-shore native plants) whenever and wherever possible. Further project recommendations for Pike Lake's shoreline are included in Chapter III of this report</u>.

Figure 34

NATURAL SHORELINE BUFFER SCHEMATIC AND EXAMPLE



Source: Washington County Planning and Parks Department and SEWRPC.

Figure 35

EXAMPLE OF "SOFT" SHORELINE STRUCTURES

Natural Shoreline

Bio-logs

Buffers (Vegetative Strips)

Cattails

Source: Native Lakescapes and SEWRPC.

ISSUE 5: WATER QUANTITY

During recent years, Pike Lake's water surface elevation has again become an issue of concern. Water levels have been a matter of contention for decades. Complaints dating back over 80 years have been documented.[59] While no unusual water level fluctuations have been recently documented in Pike Lake, there has been recent concern regarding nearby high-capacity wells. The concern is that pumping these wells could reduce groundwater discharge to the

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[59] *Public Service Commission of Wisconsin*, In the Matter of the Application of E. A. Goetz, John R. Jones and Elmer Bergman to Establish a Minimum and Maximum Level of Water to be Maintained by the Dam Across the Rubicon River Below the Outlet of Pike Lake in Washington County, *2-WP-178, March 14, 1935.*

Lake, thereby lowering Lake levels during dry weather. This issue and other potential issues related to the Lake's supply of water are discussed in this section.

Water Sources Feeding Pike Lake and Dry-Weather Lake Elevation

The Lake receives water from several sources. Several of these water sources are highly episodic and variable. Precipitation that falls directly upon the Lake surface and surface-water runoff from upland areas provide large shares of the Lake's total water supply on an annual basis. It must be remembered that much of this water is delivered during short periods of heavy runoff. Such periods are often related to high Lake elevations, and do not necessarily contribute to maintaining the Lake's fair- and dry-weather water surface elevation since they provide essentially no water to the Lake during extended periods of dry weather. Therefore, these water sources are of little value to maintaining the elevation of the Lake during periods of drought.

Two sources of water discharge to the Lake that occur on a more-or-less consistent basis over the entire year. These sources are groundwater discharging directly to the Lake and to perennial streams that ultimately feed the Lake, and treated effluent discharged to the Rubicon River by the Slinger wastewater treatment plant. These are the only sources of water consistently available to offset evaporation during long periods of dry weather, and are therefore critical to help maintain the Lake's elevation during dry periods. Each is examined in the following paragraphs.

The Village of Slinger provided the Commission with wastewater discharge records. Effluent flow records for the period beginning July 1, 2014 and ending September 30, 2015 show that relatively more wastewater effluent is discharged to the Rubicon River during wet weather. However, **roughly 600,000 gallons of water per day are consistently contributed to the Lake by the wastewater treatment plant. This volume is roughly equivalent to adding one-third of an inch of water over the entire Lake surface each week. In contrast, one inch of water can easily evaporate from a lake's water surface each week during summer.**[60]

No direct measurement or concise estimate of direct groundwater contribution to the Lake has yet been made. The USGS assigned a value to groundwater contribution to the Lake by assuming the residual in their water balance was groundwater contribution. **This yielded a groundwater contribution of 621 acre-feet per year (roughly 550,000 gallons per day).** It should be noted that the USGS specifically assumed that no water leaves the Lake as groundwater, an assumption that decreases the residual value assigned to groundwater inflow. Groundwater likely does leave the Lake in at least the outlet dam area, and considering such outflow in Lake water balance computations could meaningfully increase the estimated quantity of groundwater entering the Lake. Given the conservative groundwater flow estimate, **groundwater contributes almost a third of an inch of water over the Lake's entire surface each week.**

The Rubicon River is a perennial stream, and its dry-weather flow is supported by groundwater. The amount of groundwater entering this stream has not yet been quantified but can be roughly estimated using the Lake inlet flow data collected by the USGS between December 1, 1998, and November 30, 2000. Hydrographs suggest that the Rubicon River delivers approximately two cubic feet per second (1.3 million gallons per day) during dry weather. Based upon the discharge data available from Slinger, approximately half of this total likely consists of effluent from the Wastewater Treatment Plant. Therefore, **groundwater entering the Rubicon River upstream of Pike Lake likely contributes about 650,000 gallons of water to Pike Lake per day. This volume is equivalent to just over a third of an inch over the Lake's entire surface each week.**

Available data suggests that effluent from the Slinger wastewater treatment plant, groundwater entering the Rubicon River upstream of the Lake, and groundwater discharging directly to the Lake contribute essentially equal shares to the Lake's dry weather water budget. The combined contribution from all three sources essentially matches the

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[60] *Roberts, Wynham J. and John B. Stall,* Lake Evaporation in Illinois, *Report of Investigation 57, Illinois State Water Survey, 1967.*

average summer evaporation rate of approximately one inch per week. Therefore, **during periods of drier than normal weather with elevated rates of evaporation, it can be expected that the Lake water level will fall. Sufficient dry weather flow appears to exist to support the Lake's elevation during cooler weather.** Groundwater is the source of water for all three of these water sources.[61] Exporting water from the Pike Lake watershed (e.g., redirecting wastewater downstream of Pike Lake) or consumptively using water (e.g., increased evaporation from crops in the watershed) will cause Lake levels to decline more and with greater frequency. Therefore, to help maintain current Lake elevations, groundwater contributions to the Lake should be protected or enhanced.

High-capacity wells, paired with the potential that climate patterns are changing within Wisconsin,[62] could result in potential dry-weather water elevation changes for Pike Lake. With potential increases in future air temperatures and/or precipitation, water level fluctuations could be different than those experienced during the past 150 years. Similarly, if groundwater supplies are reduced by climatic changes, pumping, or decreased infiltration caused by development, dry-weather Lake elevations could decrease. Increased precipitation, lower temperatures, and increased groundwater contribution could cause dry-weather Lake levels to increase. However, the extent and nature of these changes are difficult to predict on a local level without a comprehensive local climate analysis (which is beyond the scope of this study). In general, climate models predict that climate change could alter hydrologic budgets, leading to changes in water levels and/or flows, and cause water levels to fluctuate more aggressively due to larger fluctuations in precipitation.[63]

Desired dry-weather water levels can sometimes be more easily maintained if wet-weather water is purposely stored in the Lake. In such a case, the dam operator would adjust dam gates to cause water levels to rise and remain near maximum permitted levels during wet weather. This water would be conserved for release during dry weather. Higher water levels for longer periods of time could be seen as a drawback for some riparian property owners. Raising water levels above current operating range would require close communication with riparian landowners, negotiation with regulatory agencies, and a permit.

It is important to focus on projects that can increase the consistency of water flows to the Lake. These types of projects generally address the two primary factors that influence water supply to a lake during both periods of adequate rainfall and drought. These factors include 1) the ability of the watershed to store and gradually release surface water runoff (i.e., surface water detention); and 2) the recharge rates of aquifers (i.e., groundwater systems) that supply the baseflow to the Lake. Both of these factors are discussed below.

Dams and Artificial Diversions

A small dam was constructed across Pike Lake's outlet around 1870 by the Rubicon Hydraulic Company. Water stored in Pike Lake acted as a reservoir for a milling operation in Hartford.[64] The existing Lake dam is now solely used to manage Pike Lake's water surface elevation. The dam is located just upstream of the culvert which passes under State Trunk Highway (STH) 60, connecting the Lake with the downstream portions of the Rubicon River. The culvert is a seven-foot high concrete box culvert with two five-foot wide barrels. The upstream end of each barrel is fitted with a lift gate and actuator. Each gate is approximately 27 inches tall, allowing water to freely overtop the gate during high flow. During low flow, flow exits below the gate. Photographs of the outlet structure are included in Figure 36.

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[61] *Because the water supply for the Village of Slinger is obtained from groundwater, the dry weather discharge of the wastewater treatment plant is largely groundwater.*

[62] *Wisconsin Initiative on Climate Change Impacts (WICCI),* Wisconsin's Changing Climate—Impacts and Adaptation, *2011*.

[63] *Ibid.*

[64] P*ublic Service Commission of Wisconsin,* Investigation on Commission's Motion for Establishment of a Maximum Level for Pike Lake in Washington County, *2-WP-909, date page missing – approximately 1953.*

Figure 36

PIKE LAKE OUTLET DAM, JULY 2016

Source: SEWRPC.

Although Pike Lake naturally connected with the Rubicon River through a short low-grade outlet stream, **the Rubicon River did not naturally flow through Pike Lake.**[65] Floodwater from the Rubicon River likely backflowed through the outlet channel into to the Lake. However, fair- and dry-weather flows of the Rubicon River, along with **the vast majority of the River's suspended, dissolved, and sediment load, would have completely bypassed Pike Lake under natural conditions.** The channel of the Rubicon River was artificially ditched, filled, and diverted to enter Pike Lake a short distance to the east of the natural lake outlet stream. This was done to greatly increase water volumes entering the Pike Lake reservoir to benefit mill operation located downstream in Hartford. Multiple sources of information attest to this fact including local histories and maps. For example, Public Service Commission of Wisconsin documents record the following:[66]

> *"The land survey of the United States at a time before the dam at Pike Lake was constructed shows a short outlet stream from the lake joining a stream originating in a marsh northeast of Pike Lake which ran generally southwesterly past the north end of Pike Lake, thence westerly through the City of Hartford. Pike Lake also has a small feeder stream entering its east side. Before the dam was constructed, it was a ground-water lake with an outlet. Its levels could then have been expected to vary with ground-water stage, and the lake would have fed the Rubicon River when the water table was high and probably would have had little or no outflow at low stages.*
>
> *The construction of the Pike Lake dam involved channel changes which diverted into the lake the stream, which originally by-passed Pike Lake, thereby furnishing it with more water than it would have had in the natural state."*

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[65] *Flow in the Lake's natural outlet channel was controlled by water elevations in the Rubicon River. During high runoff periods, water flowed south to the Lake, allowing the Lake to store floodwater and raise Lake elevation. During fair and dry weather, stored floodwater and groundwater flowed north out of the Lake, feeding the Rubicon River.*

[66] *Public Service Commission of Wisconsin,* Petition by the City of Hartford, Washington County, for an Order Regulating the Flow of Water From Pike Lake in the Rubicon River, *2-WP-1323, June 5, 1959.*

Figure 37

RUBICON RIVER INLET TO PIKE LAKE, JULY 2016

Source: SEWRPC.

The location of the lakeshore and streams as recorded in 1837 is overlain upon the current lakeshore and stream alignment in Map 4. As can be seen by this graphic, **the 1837 natural course of the Rubicon River passed just north of the present location of STH 60.** Historical aerial photographs reveal traces of historical River, Lake outlet channels, and straight ditches. Furthermore, it appears that marsh located south of STH 60 now occupies about 20 to 30 acres of what was originally identified as lake in 1837. This lost lake area is located near the mouth of the artificial Rubicon River inlet, and may be the result of sediment deposited into the Lake by the Rubicon River after the River was diverted from its natural course. As has been mentioned previously in this report, diverting the headwaters of the Rubicon River into Pike Lake increased its watershed from roughly 3.6 square miles to 12.3 square miles, more than tripling the tributary area and vastly increasing pollutant and sediment loads to the Lake.

The Rubicon River just upstream of Pike Lake is a very low gradient stream, a condition likely related to artificially rerouting and lengthening the stream and raising the level of Pike Lake. STH 60 passes over the present artificial course of the Rubicon River just upstream of Pike Lake with the River's inlet flow conveyed through a concrete box culvert. This box culvert appears to measure six feet tall,[67] and is divided into two eight-foot wide bays. Photographs of the inlet channel culvert under STH 60 are included in this report (Figure 37).

Source Water Protection

Surface Water Management

The speed at which precipitation and snowmelt leaves the land surface is controlled by many variables including the nature of underlying soils, the slope of the land surface, vegetation, and the amount of water detention available on the landscape. Detention can be provided by floodplains, ambient vegetation, localized ponding, stormwater detention basins, transient near-surface infiltration, buffers, or wetlands, all of which detain runoff, temporarily storing and gradually releasing stormwater, and, in some instances, allowing the water to soak deep into the ground where it becomes a component of groundwater recharge. Some of the water that infiltrates into the ground becomes part of the local groundwater flow system, moves slowly towards lakes and streams, and eventually discharges to a water body. Such discharge is critically important to certain species and overall lake health since the water released to the stream has a cool stable temperature, is relatively free of pollutants, and is available during times of drought.

If buffers, wetlands, and other features do not exist to temporarily store and gradually release the runoff, stormwater will enter a lake more rapidly, and (depending on the lake size and outlet characteristics) will quickly flow out of

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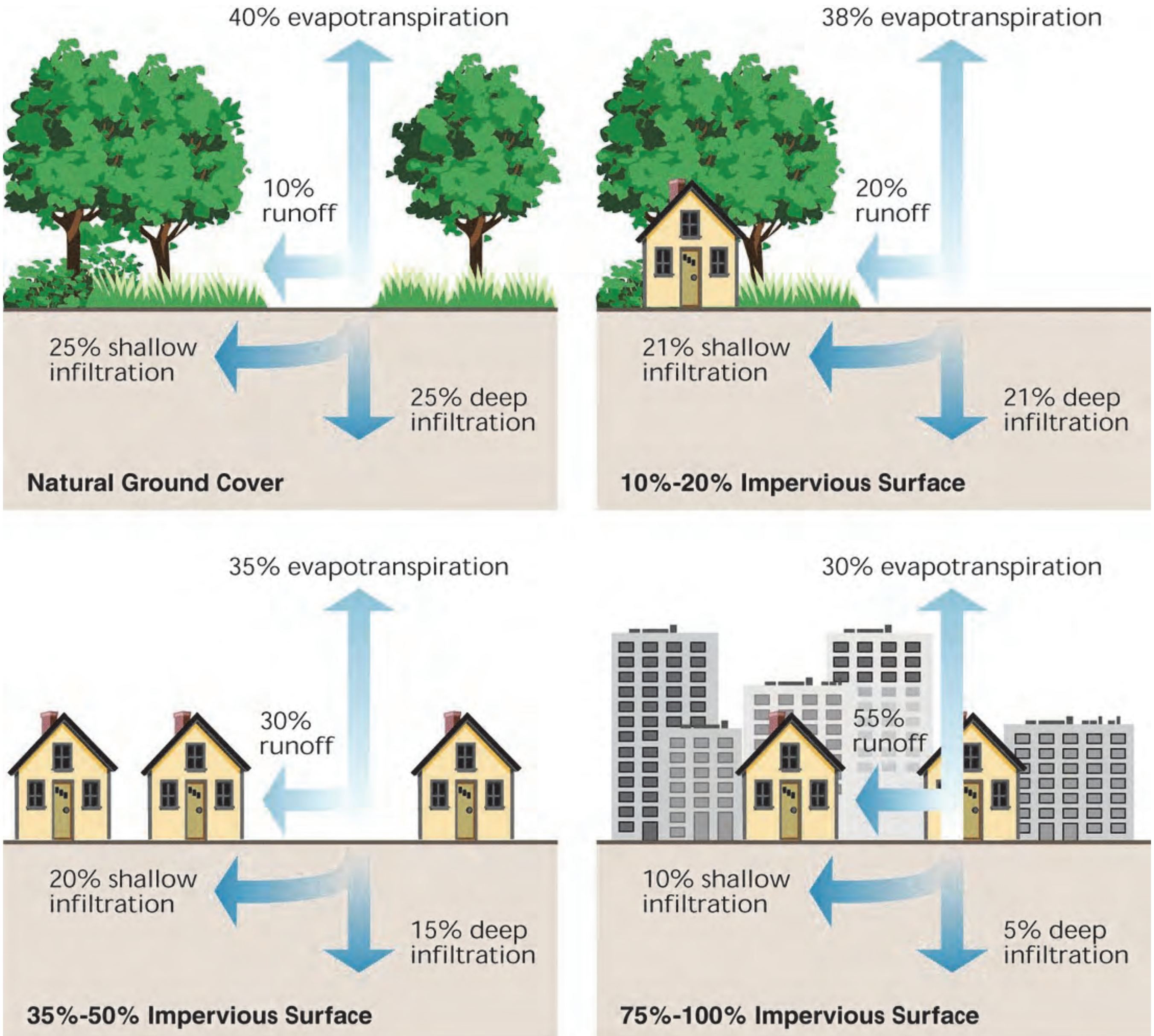
[67] *The bottom was covered with at least one to two feet of sediment, making measurement difficult.*

Figure 38

SCHEMATIC OF THE EFFECTS OF IMPERVIOUS SURFACES ON RUNOFF AND GROUNDWATER RECHARGE



Source: Federal Interagency Stream Restoration Working Group.

the lake. In this case, a smaller volume of relatively clean, cool water is available within the watershed to gradually supply the lake over time and during dry periods. Rapid runoff generally results in higher rates of erosion and greater concentrations of sediment and nutrients reaching lakes, streams, and wetlands.

Impervious surfaces increase the volume and velocity of runoff during/directly after a rainfall (see Figure 38). Many studies directly link increases in impervious land surface to decreases in habitat quality and ecological integrity. For example, a 2003 study of 47 southeastern Wisconsin streams reported that fish and insect populations decline dramatically when impervious surfaces cover more than about 8 to 10 percent of the watershed, and streams with more than 12 percent watershed impervious surface consistently have poor fish communities.[68] Consequently, reducing or preventing impervious cover, or installing measures meant to reduce the runoff from impervious surfaces (e.g., rain gardens and buffers), are critical components to help ensure adequate volumes of water supply to a lake during dry periods, and that stormwater runoff volumes are reduced during wet periods. The effect of impervious surfaces can be reduced in many ways, including the following examples:

1. Limit the size of hard surfaces:
   a. Limit driveway width or share between neighbors.
   b. Minimize building footprints (i.e., build taller instead of wider or deeper, consistent with local zoning ordinances).
   c. Remove unneeded sidewalks and parking areas.
2. Opt for pervious materials:
   a. Green roads (e.g., incorporate bioswales, grassed ditches, and similar design components).
   b. Install mulch walkways as opposed to concrete walkways.
   c. Use permeable pavers for walkways and driveways.
3. Capture or infiltrate runoff:
   a. Use rain barrels.
   b. Establish rain gardens.
   c. Channel gutters and downspouts to rain barrels, rain gardens, or places water can soak into the ground.
   d. Assure that lawn area soils are not compacted
4. Maintain and restore shoreline buffers (as discussed under "Issue 4: Shoreline Maintenance").

Additional information and ideas may be found in Appendix G.

To determine where improvements can be made to maintain and extend the volume of water supplied to Pike Lake, several factors need to be assessed. These include understanding the location and extent of:

1. **Current urban land use within the watershed**—Urban land uses generally have a much higher percentage of impervious cover than rural land uses. Consequently, to assess where management efforts can be made to reduce the amount of impervious cover (or where efforts can be made to slow down or reduce the runoff leaving these areas), it is necessary to identify where urban land use exists.
2. **Planned land use changes within the watershed**—Since urban land use generates a higher percentage of impervious cover, it is important to know where rural land is expected to be converted to urban land in the future. In such cases, extra precautions can be taken to implement management efforts that will reduce post-development runoff velocity and/or volume.
3. **Natural areas and stormwater management structures**—Stormwater retention and detention basins and natural areas (e.g., buffers, grassy waterways, and woodlands) slow runoff velocity, in some cases to store and gradually release water, and to promote infiltration of water into the soils. Consequently, if runoff passes through such features, it can modulate runoff peaks and increase the time during which a volume of runoff is supplied to the Lake.

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[68] Center for Land Use Education. Page 13. www.uwsp.edu/cnr/landcenter/pdffiles/Imp_Surf_Shoreland_Dev_Density.pdf Research studies: Wang, L., J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons 2000. Watershed Urbanization and Changes in Fish Communities in Southeastern Wisconsin Streams. *Journal of the American Water Resources Association.* 36:5(1173-1187); Wang, L., J. Lyons, and P. Kanehl 2001. Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales. *Environmental Management.* 28(2):255-266.

To help target water volume management efforts, the SEWRPC staff inventoried the three preceding factors over the Pike Lake watershed using geographic information system techniques and 2010 color digital orthophotography collected under a Regional orthophotography program administered by the Commission. Current and planned land uses are shown on Maps 6 and 8. **Urban land uses currently occupy about 30 percent of the watershed.** [69]By comparing the 2010 and 2035 land use data, it can be seen that **an extensive portion of the watershed which is currently in agricultural uses would be converted to urban uses under planned year 2035 conditions** (see Map 9). Though the land planned for conversion from agricultural to residential uses is currently well buffered (see Map 12), the proximity of some of this development area to the Lake may be a cause for concern if infiltration practices, stormwater management, and buffer enhancement are not considered priorities in these new developments. Consequently, recommendations related to this new planned development, as well as general recommendations for slowing, storing, and infiltrating runoff, are included in Chapter III of this report. Map 12 also reveals that, **with the exception of the majority of Lake shoreline properties, most runoff within the watershed enters a natural feature that could filter and process stormwater pollutants. Consequently,** recommendations to manage stormwater on shoreline properties are also included in Chapter III of this report.

Groundwater Management

Water that reaches the Lake via groundwater is commonly referred to as baseflow. Groundwater is replenished by precipitation that soaks into the ground and enters the aquifers. This is referred to as "groundwater recharge". Baseflow is important to Pike Lake since it helps maintain dry-weather Lake elevation. Groundwater typically contains little to no sediment or phosphorus, has a more stable temperature regimen, and commonly contains a lower overall pollutant load when compared to surface water runoff – all of which are favorable to aquatic life and the ecology of waterbodies. Groundwater-derived baseflow sustains many wetlands and creeks during drier periods, enabling these features to maintain a diverse assemblage of plants and animals and enable them to provide unique ecological functions. Consequently, it is important to maintain recharge to local aquifers that supply Pike Lake and the streams and wetlands that drain to the Lake.

Generally, humans deplete groundwater in two ways: 1) pumping from an aquifer supplying baseflow, thereby reducing, or in extreme cases eliminating, flow from springs and seeps and 2) reducing groundwater recharge through land use changes that increase impervious cover. The first of these most commonly occurs when a high-capacity well, or multiple smaller wells, are installed in the groundwatershed without considering the effect pumping may have on naturally occurring groundwater discharge areas. At least two municipal water supply wells are reportedly already located within 500 feet of Pike Lake.[70] If high-capacity wells, or numerous smaller wells, were proposed in the Lake's groundwatershed in the future, their effect on Lake levels should be carefully investigated, and, if those effects were found to be significant, they should be mitigated.[71]

The second common cause of groundwater depletion is reduced groundwater recharge. Groundwater recharge can be reduced in many ways. Hastening stormwater runoff, eliminating native vegetative cover, ditching and tiling and otherwise draining wet areas, disconnecting floodplains from streams, and increasing the amount of impervious land surface can all contribute to reduced stormwater infiltration, increased runoff, and reduced groundwater recharge. Similarly, if sanitary sewers are installed in areas now served by private onsite wastewater treatment systems, much of the water that currently re-enters the shallow aquifer may be directed to the Rubicon River, a condition that could reduce the amount of groundwater entering the Lake. Development and land management activities need to consider groundwater recharge,[72] and actions to protect and enhance recharge should be a priority.

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[69] *The Village of Slinger is almost entirely located in the Pike Lake Watershed.*

[70] *Jung, John (PLPRD), email to Dale Buser (SEWRPC), October 27, 2016.*

[71] *SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin, *December 2010.*

[72] *Ibid.*

Since the Lake's water surface elevation is reportedly remaining within a desirable range, groundwater pumping and impervious surfaces apparently are not unduly reducing baseflow to the Lake. Nevertheless, since groundwater flow systems react only slowly to change, decreases in baseflow may only be noticeable with time, and vigilance is warranted. Consequently, to maintain groundwater baseflow to Pike Lake, it is necessary to identify both high priority groundwater recharge areas for protection and watershed-wide practices that enhance recharge in all areas. To help support this activity, two factors need to be analyzed, including:

1. **The direction of groundwater flow**—To understand lake baseflow dynamics, it is important to know where groundwater recharge occurs and in what direction groundwater flows. **In most instances, water table elevation is a subdued reflection of surface topography.** Topographically higher areas are commonly recharge areas, while lakes, wetlands, and streams are commonly groundwater discharge areas. Groundwater recharge/discharge systems occur on many spatial scales: long regional recharge/discharge relationships and short localized flow paths, both of which can be important contributors to a lake's overall water budget. While localized groundwater flow systems are commonly confined within the lake's surface-water watershed, regional groundwater flow paths may trace directions and distances out of phase with surface water feeding a lake. Therefore, some groundwater feeding a lake may originate in areas distant from the lake and/or outside the lake's surface-water watershed boundary. The relationship between short- and long-distance flow paths is illustrated in Figure 39.

   Smaller-scale local groundwater flow paths generally mirror surface-water flow paths. However, to estimate the direction of deeper, more regionally extensive flow systems, groundwater elevation contours derived from measurements collected in water supply or monitoring wells need to be consulted. Since water normally moves perpendicular to elevation contours, groundwater flow directions can be predicted. When performing such analysis, it is necessary to consider the locations and elevations of streams, ponds, and lakes in addition to the waterbody of interest. This relationship can be used to predict if a surface water body is fed by groundwater, recharges groundwater, or has little interaction with groundwater. By combining these data, <u>maps can be prepared identifying land areas that likely contribute recharge and are therefore sources of baseflow to a surface water feature, and areas that convey groundwater to the lake</u>.

2. **The groundwater recharge potential of the area feeding aquifers**—Groundwater recharge potential is related to slope, soil characteristics, the amount of impervious cover, and other factors. For example, a flat area with no impervious cover and highly permeable soils likely has high or very high groundwater recharge potential, whereas a hilly area with low permeability (e.g., clay soils) would be classified as low potential. <u>Evaluating groundwater recharge potential helps identify the areas most important to sustainable groundwater supplies</u>. The Commission evaluated groundwater recharge potential for all of Southeastern Wisconsin.[73] Such data can help planners decide which areas should not be covered with impervious surfaces or where infiltration basins would be most effective.

To help determine where management efforts could be best employed to protect groundwater recharge to aquifers feeding Pike Lake, SEWRPC staff analyzed groundwater elevation contours and the groundwater recharge potential in the areas surrounding the Lake.[74] This inventory was not confined to the surface watershed (as was the case for the other inventories completed in this report) because the groundwater flow paths may extend outside of the surface-water watershed. The results of these inventories are described below.

Groundwater elevation contours for the Pike Lake area are shown in Map 13. The depth to groundwater varies considerably across the landscape. In and near waterbodies and wetlands, groundwater is found near the land surface, whereas it can be lie easily 50 feet or more below the land's surface in upland areas. The depth to groundwater for a particular area can be estimated by contrasting surface topography (see map 12) with groundwater elevation (Map 13).

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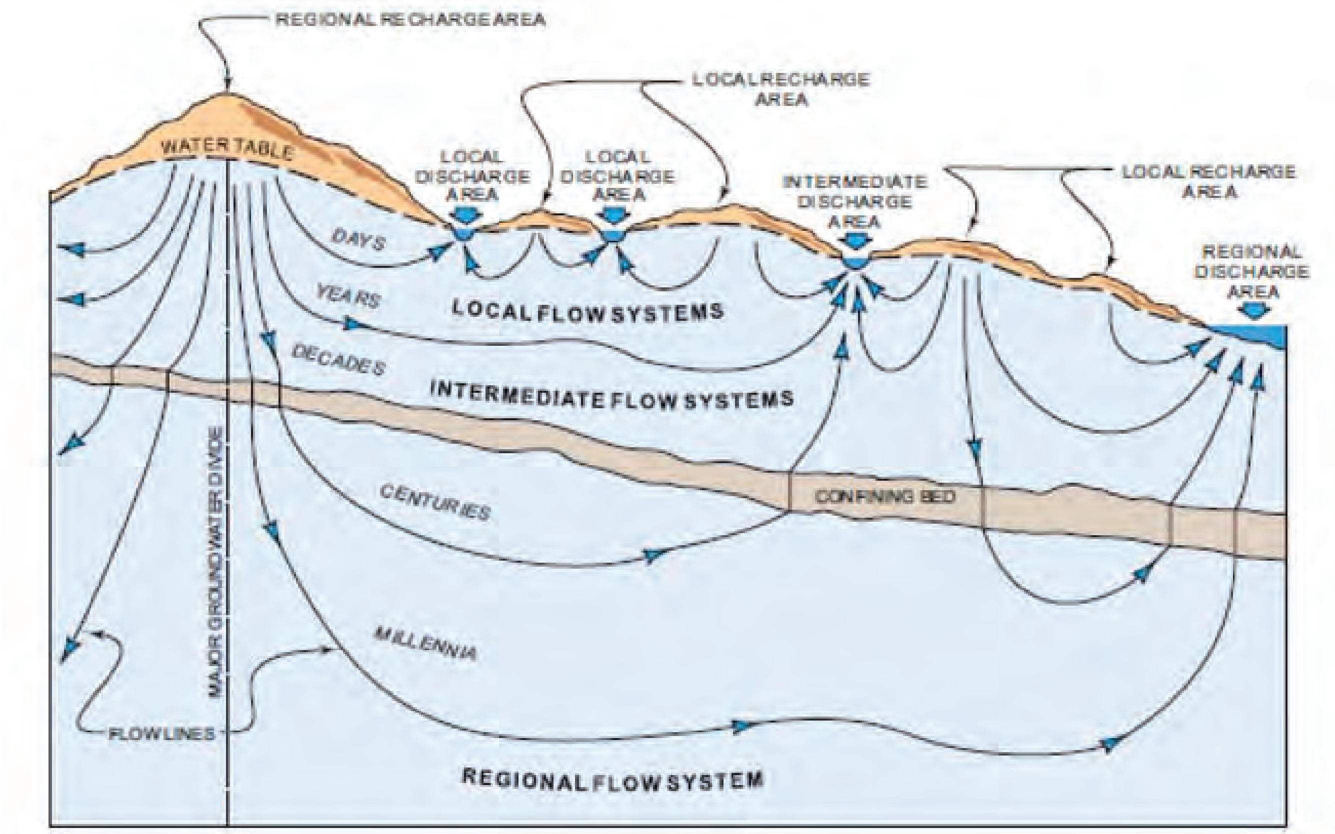
[73] *SEWRPC Technical Report No. 47,* Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water-Balance Method, *July 2008.*

[74] *SEWRPC Planning Report No. 52, op. cit.*

Figure 39

CROSS SECTION DEPICTING LOCAL VERSUS REGIONAL GROUNDWATER FLOW PATHS



Source: A. Zaporozec in SEWRPC Technical Report Number 37, Groundwater Resources of Southeastern Wisconsin, 2002.

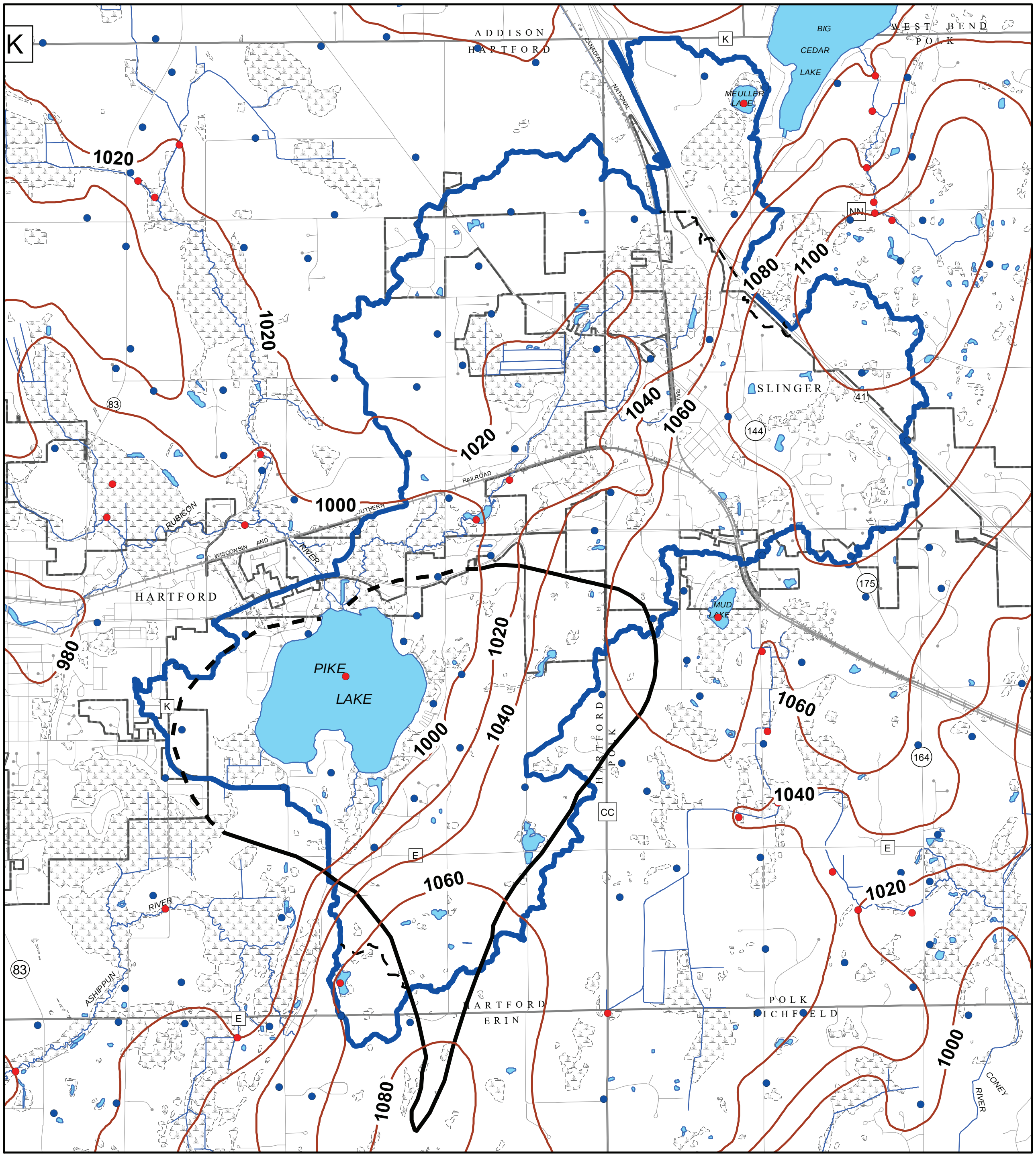
A prominent groundwater divide underlies the highly permeable sediment of the Kettle Moraine. Most groundwater reaching Pike Lake is fed by infiltration entering the groundwater flow system under high and very high recharge potential found to the east of the Lake (see Map 14). The steep gradient of the **water table surface suggests vigorous groundwater discharge to the eastern portion of the Lake,** with noticeable springs likely occurring in this area. Existing 10-foot contour interval maps do not illustrate the shorter, localized, less steep flow paths that likely contribute smaller quantities of water to the Lake's western shores. Lake water likely seeps into the lake bottom and shoreline sediments near the dam, and re-emerges a short distance downstream in the lower Rubicon River.

The artificially diverted upper Rubicon River appears to be a significant groundwater discharge area, and like Pike Lake, likely receives the bulk of its groundwater from permeable deposits in the Kettle Moraine. The groundwatershed contributing to the Rubicon River includes most of the Village of Slinger and small areas extending beyond IH 41.

An area of very high groundwater recharge potential parallels STH 60 (see Map 14). Fortunately, the portion of these high recharge potential areas that contribute groundwater directly to Pike Lake is protected as part of the Kettle Moraine State Forest – Pike Lake Unit. The very high recharge potential area is flanked by areas of high recharge potential, and again, these areas are part of the Kettle Moraine State Forest and should therefore be protected. The balance of the groundwatershed directly tributary to the Lake generally has moderate recharge rates that is less critical to protect. Therefore, **the Kettle Moraine State Forest – Pike Lake Unit protects most of the most important recharge areas that contribute groundwater directly to Pike Lake.** Therefore, little action needs be taken to protect the most valuable groundwater recharge areas contributing groundwater directly to Pike Lake. Nevertheless, actions should always be taken to minimize impervious surfaces and encourage local infiltration of stormwater.

Map 13

WATER TABLE ELEVATION CONTOURS AND PIKE LAKE GROUNDWATERSHED BOUNDARY



1060 WATER TABLE ELEVATION CONTOUR AND ELEVATION (FEET ABOVE MEAN SEA LEVEL)

WETLAND

WELL DATA POINT

SURFACE WATER POINT

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

GROUNDWATERSHED BOUNDARY, DASHED WHERE INFERRED

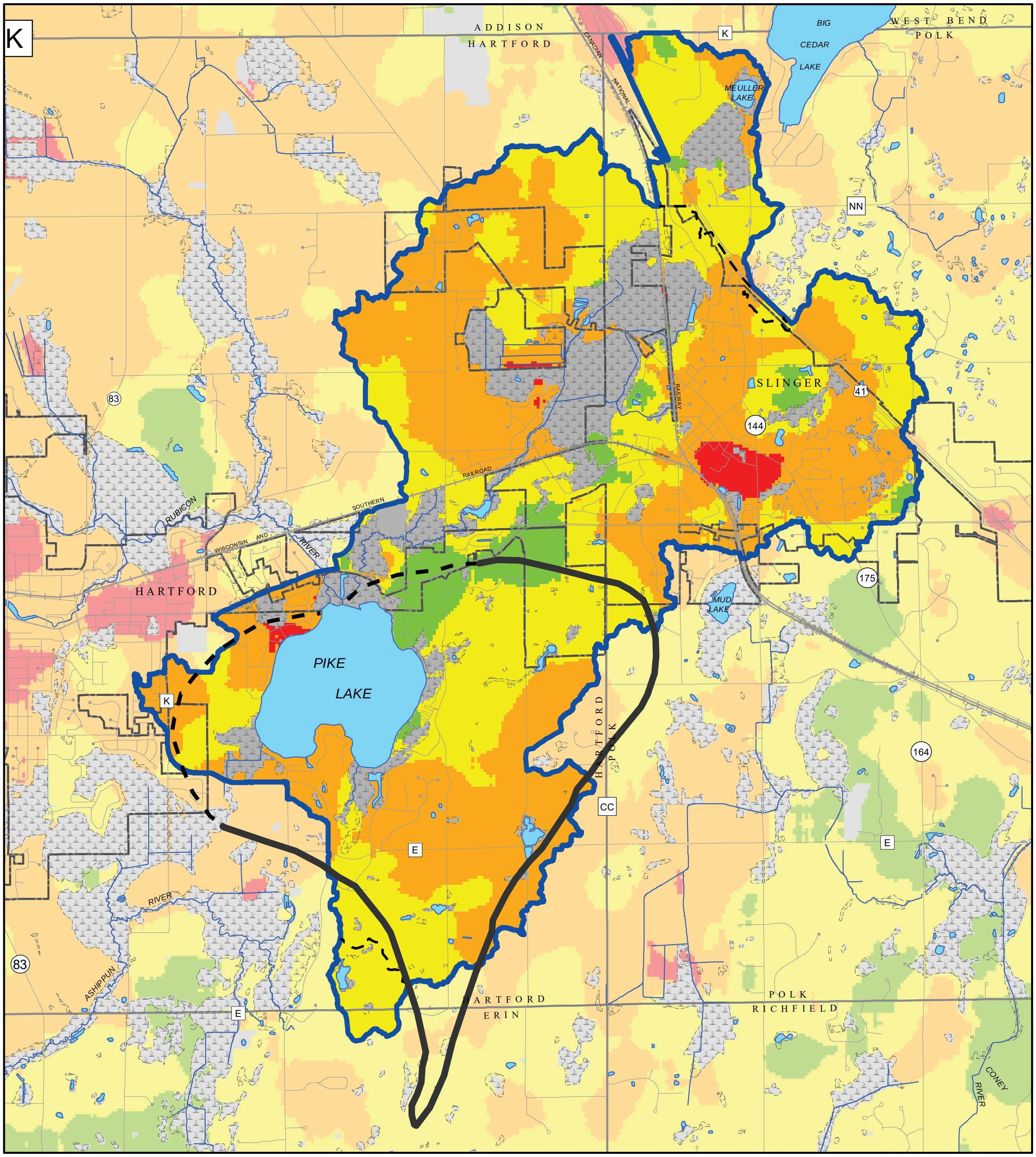
N

0 2,500 5,000 Feet

Source: Wisconsin Geological and Natural History Survey and SEWRPC.

Map 14

GROUNDWATER RECHARGE POTENTIAL OF LAND WITHIN THE PIKE LAKE WATERSHED: 2000



LOW

MODERATE

HIGH

VERY HIGH

UNDEFINED

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLAND

GROUNDWATERSHED BOUNDARY, DASHED WHERE INFERRED

N

0 2,500 5,000 Feet

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

Source: Wisconsin Geological and Natural History Survey and SEWRPC.

The most important groundwater recharge areas contributing flow to the upper Rubicon River are located in areas of existing development or areas that are rapidly being converted to urban land uses. Therefore, **the source of recharge feeding groundwater discharge to the upper Rubicon River is at risk.** Actions can be taken to mitigate these risks, as discussed above and in Chapter III. Appropriate practices should be employed whenever practical. Consideration should especially be given to promoting stormwater infiltration. Examples include providing incentives that encourage stormwater infiltration and/or promulgating ordinances that incorporate performance metrics that can be efficiently met using stormwater infiltration techniques

ISSUE 6: RUBICON RIVER BYPASS CHANNEL

Pike Lake residents and users are also concerned about maintenance of the Rubicon River bypass channel and cable dam in the wetland abutting the north end of Pike Lake. This channel and the cable dam prevent much of the River's flow from entering Pike Lake, a condition better approximating the natural river/lake relationship, and reducing sediment and nutrient loads reaching the Lake. The public's primary concern regarding the bypass channel and cable dam are believed to be related to the impact of effluent from the Slinger wastewater treatment plant on the Lake's water quality should the bypass cease.

To better understand the concern regarding the bypass channel, the history of the existing bypass channel needs to be understood. As noted previously, under natural conditions, the Rubicon River completely bypassed Pike Lake. Higher flow events may have created higher water surface elevations in the River's natural channel, which in turn may have caused floodwaters to back up into the Lake. However, in all natural cases, the River's floodway and primary flow path would have completely bypasses the Lake. Artificial ditching and filling during the mid-1800's diverted the Rubicon River's primary flowpath into Pike Lake. By the first half of the 20th century, low and fair weather flow of the Rubicon River did not directly enter Pike Lake. Instead, the River flowed into the wetland on the north end of Pike Lake (see Figure 39), curved to the west, was joined by the outlet from Pike Lake, and the combined flow exited over the outlet dam and flowed to the northwest under STH 60. During high flow events, the River likely overtopped the banks of the river. Therefore, during high water periods, the Rubicon River's flow likely directly entered Pike Lake.

STH 60 was reconstructed and partially rerouted sometime between 1950 and 1963. A boat landing was established using portions of the former roadway. A broad channel was excavated from the boat landing through the wetlands and River channel towards the Lake (see Figure 40). Over time, the River abandoned its former course, favoring a route paralleling the boat access channel. By 1980's, the River fully entered the Lake, and the bypass channel no longer flowed during low and fair weather flows (Figure 40). The access channel now connected the formerly wetland-bound River directly to the Lake, allowing the River's entire flow to enter the Lake under most conditions. **This created a wholly unnatural situation where all of the River's sediment and nutrient load was now delivered to Pike Lake.**

The additional nutrient and sediment loading was recognized as a major concern, and the PLPRD commissioned a study to examine alternatives to return the flow of the Rubicon River to a channel largely bypassing the Lake.[75] In conformance with recommendations, a project was completed during fall 1995 that included excavating a bypass channel between the inlet and outlet streams and constructing a clay-core earthen berm in the inlet channel to divert the River's flow into the new bypass channel. The inlet channel plug began to erode during the late 1990's allowing the River's inlet to again enter the Lake. By 2007, a study concluded that all of the River's flow was entering the Lake and that the bypass channel constructed in 1995 was plugged by organic debris and beaver activity.[76]

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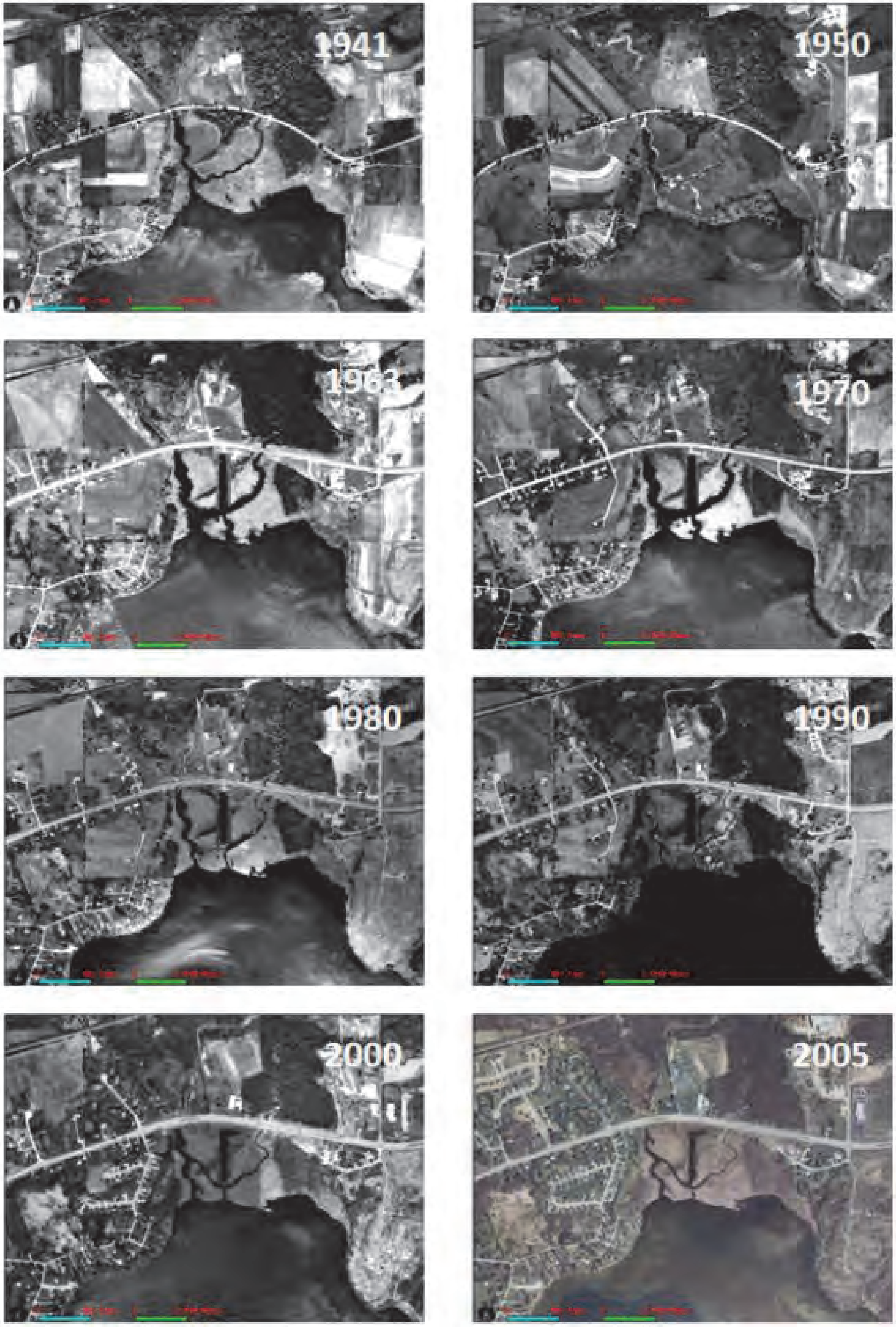
[75] *R. A. Smith and Associates,* Incorporated, NR 103 Practicable Alternatives Analysis, Pike Lake Inlet Re-Diversion Project, Project Number 86563-3-332-332, *February 17, 1993.*

[76] *Hey and Associates, Inc.* Evaluation of Alternatives for Rubicon River Phosphorus Input Diversion, Pike Lake, Washington County, Wisconsin, *February 2010.*

Figure 40

PIKE LAKE INLET AERIAL PHOTOGRAPHS: 1941-2005



Source: Hey and Associates, Inc. and Washington County.

The USGS examined Pike Lake's water and phosphorus budgets during 1999 and 2000, especially focusing on the phosphorus loads and how they were affected by inlet-to-outlet channel bypass flows. During that time, the measures implemented to re-establish Rubicon River inlet-to-outlet bypass flow were only partially intact and functioning poorly because the clay plug had begun to erode. The study sampled surface water phosphorus at the deep hole of the Lake and at the outlet, reporting concentrations of 0.02 mg/L and 0.103 mg/L, respectively. The study concluded that much of the Rubicon River's flow bypassed through the wetland at the north end of the Lake, reducing phosphorus loading to the Lake by 77 percent during 1999 and by 65 percent during 2000.

Preventing Rubicon River water from entering the Pike Lake is vital to the health of Lake. According the USGS information, the River delivers 80 percent of the total phosphorus load to the Lake, with the Slinger WWTP contributing about half of the River's load, while the other half of the River's load is largely attributable to agricultural land uses.[77] Lake residents are specifically concerned about the phosphorus loads from the treatment plant; however, the plant is below its permitted discharge limits. These loads may be reduced with new standards and permit requirements reflecting the Rock River total maximum daily load study, completed by the United States Environmental Protection Agency, the WDNR, and their contractors during 2011.

The PLPRD commissioned another study to examine inlet-to-outlet bypass flows and loads contributed by sources on the upper Rubicon River.[78] The resultant report, a copy of which is included in Appendix H, discusses various management alternatives to reduce total phosphorus input to Pike Lake. These alternatives fall into three categories: controlling pollutant sources, trapping River-borne pollutants found in an area upstream of the Lake, and diverting the River's flow around the Lake. The source control alternatives look at reducing loads from runoff and other non-point sources, diverting the discharge from the WWTP so it does not flow directly downstream to Pike Lake, and advanced phosphorus removal at the treatment plant. Trapping pollutants upstream includes alum treatments and constructing stormwater wetlands. The bypass options include relocating the River to a channel paralleling STH 60, replacing the plug on the man-made channel, or constructing a cable dam. While many of these alternatives are worthy of further consideration, the costs of some are high and care must be taken to consider unintended consequences (e.g., reduced dry weather flow to the Lake and therefore lower Lake levels). These alternatives are examined in more detail in Chapter III of this report.

ISSUE 7: RECREATION

Essentially all Lake residents and users want to ensure that Pike Lake continues to support conditions favoring recreation and, relatedly, property value. This issue of concern relates with many of the topics discussed in this chapter (e.g., aquatic plants, water quality, algal blooms, water quantity, and wildlife) because each can affect different recreational uses.

Boating

To evaluate the needs and habits of Pike Lake users, a watercraft census (i.e., a boat count along the shoreline) and recreational survey (i.e., a count of active boats, users, and recreational use type on randomly selected weekdays and weekends) were completed These studies sought to identify the variability of Lake use, as well as to determine the primary uses of the Lake. The results are discussed in the following paragraphs.

Two hundred and ninety-two watercraft were observed during the census, either moored in the water or stored on land in the shoreland areas around the Lake (see Table 16 for additional details). About 57 percent of all docked or

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[77] *Rose, W.J., Robertson, D.M., and Mergener, E.A., op. cit.*

[78] *Hey and Associates, Inc. Evaluation of Alternatives for Rubicon River Phosphorus Input Diversion, Pike Lake, Washington County, Wisconsin, February 2010.*

moored boats were motorized, with pontoon boats and powerboats being the most common boat types. The remaining 43 percent of all docked or moored boats were nonmotorized (e.g., kayaks, rowboats, canoes, and pedal-boats/paddleboats). The number of moored or docked boats would generally suggest that about six to fifteen watercraft would be found on the Lake during high-use periods.[79]

SEWRPC staff counted the number, type, and use of watercraft on Pike Lake on randomly selected weekdays and weekends during the summer of 2012 (Tables 17 and 18). These data provide insight into the primary recreational boat uses of the Lake. **The recreational survey revealed at least five and as many as 35 boats on the Lake at any given time.** Fishing and low-speed cruising are the most popular weekend boating activities on Pike Lake. However, **the overall most popular boat-related recreational activities on both the weekends and weekdays were using shoreland park facilities, fishing from boats, and swimming at the beach.** This finding emphasizes the need to encourage boating access to the Lake without risking aesthetic beauty and the opportunity to swim.

The type of boating taking place varies by the day of the week, time of day, and prevailing weather conditions. According to a Statewide survey that subdivided results by region,[80] boaters in Southeastern Wisconsin took to the water in the greatest numbers during July, with slightly lower numbers of boaters found on the water during June and August. These months account for approximately two-thirds of the total number of boater-days logged in the Region for the entire year. About two to three times as many boaters use their boats on weekends than weekdays (Table 19). The weekday/weekend statistics compare favorably with SEWRPC 2012 Pike Lake boat counts.

Fishing was by far the most popular activity in Southeastern Wisconsin in both spring and fall, and remains a leading reason for boat use throughout the summer (Table 20). Again, the data produced by the Commission's 2012 boat count corresponds quite well with regional averages, suggesting that Pike Lake's boating activity is fairly represented by regional averages. The typical boat used on inland lakes in Southeastern Wisconsin is an open hulled vessel measuring approximately 18 feet long powered by a motor producing approximately 90 horsepower (Tables 21 and 22). Sailboats comprise approximately 24 percent of boat traffic (15 percent non-powered and 9 percent powered), while other non-powered boats comprise only two percent of boats found on waterbodies in the region.

Only a few respondents to the WDNR boating survey felt that excessive boat traffic was present on Southeastern Wisconsin lakes.[81] Studies completed in Michigan attempt to quantify desirable levels of boat traffic on an array of lakes used for a variety of purposes. This study concluded that 10 to 15 acres of useable lake area[82] per boat provides a reasonable and conservative average maximum desirable boating density, and covers a wide variety of boat types, recreational uses, and lake characteristics.[83] Use rates above this threshold are considered to negatively influence public safety, environmental conditions, and the ability of a lake to host a variety of recreational pursuits. High-speed watercraft require more space, necessitating boat densities less than the low end of the range. The suggested density for a particular lake is:

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[79] *At any given time it is estimated that between about 2 percent and 5 percent of the total number of watercraft docked and moored will be active on the Lake.*

[80] *Penaloza, Linda J.,* "Boating Pressure on Wisconsin's Lakes and Rivers, Results of the 1989-1990 Wisconsin Recreational Boating Study, Phase 1," *Wisconsin Department of Natural Resources Technical Bulletin 174, 1991.*

[81] *Ibid.*

[82] *Useable lake area is the size of the open water area that is at least 100 feet from the shoreline.*

[83] *Progressive AE,* "Four Township Recreational Carrying Capacity Study, Pine Lake, Upper Crooked Lake, Gull Lake, Sherman Lake", *Study prepared for Four Township Water Resources Council, Inc. and the Townships of Prairieville, Barry, Richland, and Ross, May 2001.*

Table 16

WATERCRAFT DOCKED ON OR STORED ADJACENT TO PIKE LAKE: 2012[a]

Type of Watercraft									
Powerboat	Fishing Boat	Pontoon Boat	Personal Watercraft	Canoe	Sailboat	Kayak	Pedalboat	Rowboat	Total
47	25	72	21	23	15	41	34	14	292

[a]*Including trailered watercraft and watercraft on land observable during survey; 1 hydroplane and 1 deck boat were also observed.*

Source: SEWRPC.

Table 17

PIKE LAKE RECREATIONAL BOATING SURVEY—WEEKDAYS: SUMMER 2012

		Active Recreational Watercraft and Related Activities on Pike Lake								
		Time and Date								
		8:00 a.m. to 10:00 a.m.	10:00 a.m. to Noon		Noon to 2:00 p.m.			2:00 p.m. to 4:00 p.m.		4:00 p.m. to 6:00 p.m.
Category	Observation	June 29	August 8	August 17	July 27	July 31	August 8	June 21	August 23	August 23
Type of Watercraft (number in use)	Power/ski boat	1	1	0	1	1	1	0	2	2
	Pontoon boat	1	1	0	1	0	1	0	2	0
	Fishing boat	10	7	10	3	4	9	4	6	8
	Personal watercraft	0	0	0	0	1	1	2	1	1
	Kayak/canoe	0	0	0	0	0	1	2	0	0
	Sailboat	0	0	0	0	1	0	0	1	0
Activity of Watercraft (number engaged)	Motorized cruise/pleasure									
	Low speed	1	1	0	1	1	1	0	1	1
	High speed	1	0	0	0	0	1	2	1	3
	Fishing	10	7	10	3	4	9	4	7	6
	Skiing/tubing	0	1	0	1	1	1	0	2	1
	Sailing/windsurfing	0	0	0	0	1	0	0	1	0
Total	On water	12	9	10	5	7	13	8	12	11
	In high-speed use	1	1	0	1	2	2	4	3	4
		Recreational Activities Observed on Pike Lake								
Activity (average number of people)	Park Goer	28	35	27	25	110	40	35	48	12
	Beach Swimming	25	11	5	25	50	22	20	37	16
	Boat/Raft Swimming	0	0	0	0	0	0	0	2	0
	Canoeing/Kayaking	0	0	0	0	0	1	2	0	0
	Sailboating	0	0	0	0	2	0	0	2	0
	Fishing from Boats	20	0	17	6	8	18	8	14	14
	Fishing from Shore	2	0	0	0	0	0	0	0	0
	Low-Speed Cruising	4	0	0	4	0	4	0	0	2
	High-Speed Cruising	5	0	0	0	0	0	2	0	2
	Skiing/Tubing	0	0	0	3	3	3	0	4	3
	Personal Watercraft Operation	0	0	0	0	1	1	0	2	0

Source: SEWRPC.

Table 18

PIKE LAKE RECREATIONAL BOATING SURVEY—WEEKENDS: SUMMER 2012

		Active Recreational Watercraft and Related Activities on Pike Lake								
		Time and Date								
		6:00 to 8:00 a.m.	8:00 to 10:00 a.m.		10:00 a.m. to Noon	Noon to 2:00 p.m.		2:00 to 4:00 p.m.		4:00 to 6:00 p.m.
Category	Observation	August 19	July 21	August 19	August 19	July 21	August 11	August 11	August 25	August 25
Type of Watercraft (number in use)	Power/ski boat	0	3	1	1	4	4	8	12	2
	Pontoon boat	1	6	1	6	1	1	2	7	3
	Fishing boat	15	24	15	17	8	13	4	6	7
	Personal watercraft	0	0	0	1	2	0	2	1	4
	Kayak/canoe	1	2	0	0	1	1	2	5	4
	Wind board/paddle board	0	0	0	0	0	0	0	2	0
	Other	0	0	0	0	0	0	0	1 inflatable	0
Activity of Watercraft (number engaged)	Motorized cruise/pleasure									
	Low speed	0	0	0	2	1	1	2	12	2
	High speed	0	0	0	0	6	3	5	1	2
	Fishing	17	32	17	21	8	13	6	6	7
	Skiing/tubing	0	1	0	1	0	1	3	6	4
	Sailing/windsurfing	0	0	0	0	0	0	0	1	0
	Rowing/paddling/ pedaling	0	2	0	0	1	1	2	5	4
	Other	0	0	0	0	0	0	0	3 at anchor	1 at anchor
Total	On water	17	35	17	25	16	19	18	34	20
	In high-speed use	0	1	0	2	6	4	8	7	6
		Recreational Activities Observed on Pike Lake								
Activity (average number of people)	Park Goer	0	32	19	73	215	125	200	200+	125
	Beach Swimming	0	4	0	14	50	10	12	67	42
	Canoeing/Kayaking	0	2	0	0	1	2	2	5	5
	Wind Surfing/Paddle Boarding	0	0	0	0	0	0	0	1	0
	Fishing from Boats	27	68	26	45	16	26	12	6	12
	Fishing from Shore	0	2	0	0	0	0	0	0	0
	Low-Speed Cruising	0	0	0	10	4	4	6	41	12
	High-Speed Cruising	0	0	0	0	12	9	15	4	6
	Skiing/Tubing	0	3	0	3	0	3	9	18	14
	Personal Watercraft Operation	0	0	0	0	2	0	2	1	4

Source: SEWRPC.

Minimum desirable acreage per boat = 10 acres + (5 acres x (high-speed boat count/total boat count))

The 2012 SEWRPC recreational survey demonstrates that highest boat use occurs during weekends. Most boats in use during peak periods were capable of high-speed operation; however, no more than half were being operated at high speed. If one assumes that no more than half of the boats could potentially be operating at high speed during high-use periods, the formula described in the preceding paragraph suggests that 12.5 or more acres of useable open water should be available per boat. Given that roughly 414 useable acres are available for boating in Pike Lake, **no more than 33 boats should be present on the lake at any one time to avoid use problems.** The number of boats actually observed on Pike Lake was nearly always less than the optimal maximum density. However, boat density appears to meet or slightly exceed the optimal maximum density during heavy use periods (weekends and holidays). **This means that the potential for use conflicts, safety concerns, and environmental degradation is slightly**

Table 19

SOUTHEASTERN WISCONSIN DAY-OF-THE-WEEK BOAT USE: 1989-1990

Day of the Week	Percent Respondents Participating[a]
Sunday	46
Monday	16
Tuesday	14
Wednesday	16
Thursday	13
Friday	17
Saturday	46

[a]*Repondents may have participated in more than one day.*

Source: Wisconsin Department of Natural Resources.

higher than desirable on Pike Lake during a few weekends and holidays. To help mitigate this concern, boating ordinances and regulations should be reviewed and if necessary modified. Such ordinances and regulations should be conscientiously enforced to help reduce the potential for problems related to boat overcrowding during periods of peak boat traffic. Additional details regarding this recommendation are presented in Chapter III.

The PLPRD sets slow-no-wake buoys to limit high-speed boat traffic in the shallow areas along the north shoreline near the Rubicon River inlet and outlet. These buoys have been set every year since 1985 with the purpose of advising boaters of the broad areas of shallow water depth, and limiting resuspension of phosphorus-rich sediment which is particularly prevalent in this area.[84]

The public has been able to launch boats on Pike Lake since at least the 1930's. Four boat launches are found on the west side of the lake off of Lake Drive. Of these four launch sites, two are private launches (Reef Point Resort at the northwest corner of the Lake and Johnny's Landing at the southwest corner of the Lake). The Reef Point launch site includes a concrete ramp capable of accommodating two active launches at the same time. The Reef point launch site has sufficient space to allow parking for at least 50 vehicle/trailer rigs, and has an agreement with the State of Wisconsin to provide eight parking spots free of charge if the boater inquires. The free parking agreement has been in affect at least 10 years. The Johnny's Landing launch is a single unpaved ramp that has space to allow approximately 15 vehicle/trailer rigs to park.[85]

The Town of Hartford operates two free public boat launch sites. Both sites have concrete ramps but neither launch site includes dedicated parking areas. The Town of Hartford launches are located in close proximity to each other. One is actually the east end of Second Street while the other is located roughly 250 feet to the south and is accessed from Lake Drive. Some ramp users park at a nearby tavern, while others launch their boat and head to their Lake home, the State Park, or other convenient destination to park.[86]

In addition to the official boat launches, a large number of access points provide for carry-in watercraft (e.g., wind surfers, paddle boards, canoes, kayaks, rowboats, etc.). Future State Park plan include a boat launch and carry-in area with at least 11 parking spaces.[87]

Launch fees can influence the intensity of use of the launch facility, and can be considered as part of a program to help avoid excess boat densities on the Lake. This is discussed in more detail in Chapter III.

[84] *Kabelowsky, Jerome (PLPRD), email to Dale Buser (SEWRPC), November 10, 2016.*

[85] *Ibid.*

[86] *Ibid.*

[87] *Ibid.*

Table 20

SOUTHEASTERN WISCONSIN BOAT USER ACTIVITY BY MONTH: 1989-1990

Activity	Percent Respondents Participating[a]						
	April	May	Jun	July	August	September	October
Fishing	68	57	49	41	44	42	49
Cruising	29	39	42	46	46	47	43
Water Skiing	3	9	20	27	19	16	8
Swimming	2	4	18	31	25	19	5
Average boating party size: 3.4 people							

[a]Respondents may have participated in more than one activity.

Source: Wisconsin Department of Natural Resources.

Table 21

BOAT HULL TYPES IN SOUTHEASTERN WISCONSIN: 1989-1990

Day of the Week	Percent Respondents Participating[a]
Open	68
Cabin	17
Pontoon	9
Other	6
Average length: 18.4 ft	
Average beam width: 6.4 ft	

[a]Repondents may have participated in more than one day.

Source: Wisconsin Department of Natural Resources.

Table 22

PROPULSION TYPES IN SOUTHEASTERN WISCONSIN: 1989-1990

Day of the Week	Percent Respondents Participating[a]
Outboard	53
Inboard/outboard	14
Inboard	6
Other (powered)	1
Sail	15
Sail with power	9
Other (nonpowered)	2
Average horse power: 86.5	

[a]Repondents may have participated in more than one day.

Source: Wisconsin Department of Natural Resources.

Given that boaters (including fishermen), swimmers, and individuals who enjoy the aesthetics of the Lake are the primary users of the Lake, maintaining these primary uses should be considered a priority. Consequently, all of the recreation-related recommendations included in Chapter III intend to ensure full use of the Lake. Since accommodating some lake users is not always advantageous or desirable to other lake users, the recommendations contained in Chapter III seek to encourage compromise between conflicting users so that all users may gain access to the Lake for their intended legal purpose.

Pike Lake Unit of the Kettle Moraine State Forest

The Pike Lake Unit of the Kettle Moraine State Forest ("State Forest") provides ample recreational opportunities at Pike Lake. Located on the east side of the Lake with parking for over 250 vehicles, park users can enjoy a 500-foot sand beach, trails for hiking, biking, and skiing, as well as public access for hunting and fishing.

As the State Forest covers a large section of Pike Lake's watershed and attracts many users, lake residents and users are concerned what effect the State Forest has on the health of the Lake and what is being done to improve the Lake and its watershed. With that in mind, many projects are identified in the State Forest, many of are outlined in the 2009 Kettle Moraine State Forest–Pike Lake Unit Master Plan.[88] The projects recently implemented include installing a fishing pier and an osprey nest, as well as, beginning lakeshore restoration focused on removing invasive honey suckle and restoring the area with native plants.

Management of the Brown Property within the State Forest is a specific concern of Lake residents, since it is farmed, creating concern for high-nutrient runoff to the Lake. The master plan calls for phasing out farming on this property. Managers are currently discussing various natural buffers that could be installed on the Brown Property. The general area where the property is located is managed as a Headwaters Recreation Management Area meaning that the Forest will be maintained and trails developed for hiking, biking, and skiing. Planned trail developments include a trail to connect existing snowmobile trails, and an addition to the Ice Age National Scenic Trail. The area already offers public access for hunting, fishing, and wildlife viewing. This management area will maintain and enhance native plant communities including forested areas, grasslands, prairie, wetlands, and shoreline habitats.

As was discussed earlier in this Chapter, the State Forest's holdings cover the areas with the highest groundwater recharge potential for groundwater flow paths that terminate in Pike Lake. Since parklands typically have very little impervious service, the presence of the State Forest benefits conservation of the Lake's groundwater supply.

ISSUE 8: FISH AND WILDLIFE

Pike Lake residents and SEWRPC staff identified protecting and enhancing Lake-dependent aquatic and terrestrial wildlife was identified as an issue of concern. Based upon field work and study of the Lake and its watershed, SEWRPC staff identified the following factors related to aquatic and terrestrial wildlife.

1. Fishing was identified as a primary recreational use of the Lake, as was verified by the 2012 recreational survey (see "Issue 7: Recreation" section).
2. Pike Lake's walleye population is considered to be amongst the best naturally reproducing population in the Southeastern Wisconsin region.[89]
3. Pike Lake is home to species of special concern—the Blanding's turtle (*Emydoidea blandingii*),[90] little yellow lady's slipper orchid (*Cypripedium parviflorum var. makasin*), least darter (*Etheostoma microperca*), and a threatened species of the pugnose shiner (*Notropis anogenus*).[91]
4. A healthy fish population is present in the Lake, according to WDNR fish population surveys (see Table 23) and 2008 walleye study, indicating the need for continued effective management.
5. About 16 species of amphibians and 19 species of reptiles are expected to be present in the Lake's watershed. Amphibians and reptiles, including frogs, salamanders, turtles, and snakes, are vital components of a lake ecosystem.

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[88] *Wisconsin Department of Natural Resources.* Kettle Moraine State Forest – Pike Lake Unit Master Plan. *October 2009.*

[89] *Nelson, John E.*, Comprehensive Fish Community Survey of Pike Lake, Washington County, *Wisconsin Department of Natural Resources, 2000*.

[90] *Wisconsin Department of Natural Resources - Natural Heritage Inventory.*

[91] *SEWRPC Record.*

6. The Lake's watershed likely supports a significant population of waterfowl, including mallards, wood duck, and blue-winged teal, particularly during the migration seasons. The watershed is also inhabited by ospreys and bald eagles.

7. The Lake's watershed support both small and large mammals, such as foxes and whitetail deer.

A healthy fish, bird, amphibian, reptile, and mammal population requires: 1) good water quality, 2) sufficient water levels, 3) healthy aquatic plant populations, and 4) sensitively maintained aquatic and terrestrial habitat. Additionally, wildlife populations can also be enhanced by the implementing "best management practices." Since aquatic plant management, water quality, and water quantity have each been discussed previously in this chapter, this section focuses on maintaining and expanding habitat and using best management practices to enhance wildlife populations. In general, these practices vary depending on the type of wildlife in question. Therefore, this section first examines aquatic wildlife enhancement and then terrestrial wildlife enhancement.

Table 23

RECENT PIKE LAKE FISH SURVEYS

Species Collected	Average Length (inches)[a]	
	2000	2014
Black Bullhead	- -	- -
Black Crappie	- -	2.5
Bluegill	5.9	4.8
Bowfin	- -	- -
Brown Bullhead	- -	- -
Largemouth Bass	12.7	12.0
Longnose Gar	- -	- -
Northern Pike	23.6	20.9
Pumpkinseed	- -	5.75
Rock Bass	- -	6.6
Smallmouth Bass	- -	10.5
Walleye	18.0	16.3
White Sucker	- -	- -
Yellow Bullhead	- -	- -
Yellow Perch	6.5	4.6

[a]*Species collected but not measured.*

Source: Wisconsin Department of Natural Resources.

Aquatic Wildlife Enhancement

Aside from being enhanced through aquatic plant management, water quality improvement, and water quantity management, aquatic wildlife populations can be enhanced by implementing best management practices and enhancing aquatic habitat. Each is discussed below.

Aquatic Best Management Practices

Aquatic best management practices can be implemented by homeowners, recreationalists, and resource managers. Such activities include catch-and-release fishing, fish habitat management and enhancement, minimum length and daily bag limits, and fish stocking, all of which will focus on the Lake's fishery. To determine the most needed and effective practices, it is important to consider the following:

1. **The population and size structure of the fish species present in a lake**—Studies that examine the species, populations, and sizes of the fish help managers understand issues that may face fish populations. For example, if low numbers of juvenile fish are found, this may suggest that fish are not successfully reproducing in the lake and its watershed, and, therefore, spawning and rearing habitat may need attention. Similarly, if abundant juveniles are found with few large fish populations, over-fishing may be is a factor limiting the fish, thereby suggesting that catch and release should be promoted in the lake. This type of information helps lake managers efficiently and effectively target specific fish population enhancement efforts.

2. **The history of fish stocking in a lake**—The only fish stocking that has occurred since the mid-1990s is planting of walleye fry hatched from eggs taken from the Lake.[92] To evaluate the information found in fish

[92] *Motl, Travis, op. cit.*

Table 24

FISH STOCKED INTO PIKE LAKE

Year	Species Stocked	Age Class	Number Stocked	Average Length (inches)
1989	Walleye	Fry	263,972	3.00
1990	Walleye	Fry	350,000	1.00
1991	Walleye	Fry	2,000,000	0.40
1992	Walleye	Fry	200,000	0.40
2011	Walleye	Fry	2,000,000	0.50

Source: Wisconsin Department of Natural Resources.

population studies, it is important to know how many fish of different sizes have been introduced through stocking activities. For example, if only large stocked fish are found in a lake, it is possible that natural reproduction is not taking place, meaning that the lake's fishery wholly depends on continuous fish stocking at the present time. This information could then be used as a cue to identify and pursue projects that enable fish to naturally reproduce.

Fish stocks of Pike Lake have been the subjected to human intervention for over a century. For example, 280,000 walleyes were introduced into the Lake during 1899 and 350,000 walleyes were stocked during 1900.[93] SEWRPC staff completed an inventory of the studies and stocking efforts completed by WDNR since 1989. During the past 27 years, nearly five million walleye fry have been stocked in Pike Lake (see Table 24). Nevertheless, Pike Lake has a relatively healthy and naturally reproducing walleye population. While walleye are noted as "abundant", northern pike and both smallmouth and largemouth bass are reported to be "present." [94]

Fish surveys were completed on the Lake many times over the years. The most recent fish surveys were completed during 2000 and 2014. [95,96] These surveys used electrofishing,[97] fyke nets, and seines to quantify the type and size of fish in the Lake (see Table 23). The more recent survey concludes that largemouth bass and walleye are the dominant gamefish in Pike Lake, northern pike are present, bluegill are the principal panfish species, and pumpkinseed, rock bass and yellow perch are common. Overall, WDNR concludes in its reports that **Pike Lake has a very healthy fish population.** Some interesting facts regarding the fishery noted in the most recent fisheries management plant include the following:

- The forage base in the Lake is sufficient to sustain current gamefish types and populations.

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[93] Biennial Report of the Commissioners of Fisheries of Wisconsin for the Years 1899 and 1900, *Democrat Printing Company, State Printer, 1901*.

[94] *Department of Natural Resources Lake Page:* http://dnr.wi.gov/lakes/LakePages/LakeDetail.aspx?wbic=746000.

[95] *Nelson, John E., op. cit.*

[96] *Motl, Travis, op. cit.*

[97] *Electrofishing is a process where an electrical pulse is placed in the water, causing fish to be stunned and to float to the top of the lake. This process allows for fisheries biologists to record fish types, counts, and sizes without harming the fish populations.*

- Pike Lake walleyes grow faster than statewide averages and continue to successfully reproduce in the wild. However, if fishing pressure increases on the Lake, size and bag limits should be changed to protect the fishery.

- Few large northern pike are present in the Lake.

- Smaller largemouth bass are abundant, but few fish exceed the 14 inch minimum length limit, suggesting heavy angling pressure.

- Anglers report that Pike Lake is a good lake to fish for bluegills and perch. Pike Lake's bluegills and perch are smaller than desirable, a possible result of heavy angling pressure.

Figure 41

COMMON CARP

Source: U.S. Geological Survey.

Overall, **available information suggests that current Lake management practices effectively maintain a viable fishery.** Consequently, maintaining current practices and aquatic habitats (see "Aquatic Habitat" subsection below) within the Lake is very important. Recommendations related to such maintenance practices are included in Chapter III. Additionally, recommendations related to increasing public access to the Lake (which in turn increases the fishery resources the WDNR is able to invest in the Lake) are also included in Chapter III.

As a final note, the 2000 and 2014 fishery survey of the Lake revealed the presence of common carp,[98] a restricted species within Wisconsin (see Figure 41). Several measures can be taken to reduce the carp population; however, management is based on the perceived nuisance level of the carp population in a specific lake. Given that the population of carp is small, they are not likely a major concern.[99] For this reason, no active management is needed at this time, however, the population should be monitored over time.

Aquatic Habitat

Aquatic habitat enhancement generally includes encouraging growth of native aquatic plants (particularly pondweeds) within a lake. These plants provide desirable food, shelter, and spawning areas for fish. Additionally, aquatic habitat enhancement also can involve protecting wetlands (see "Terrestrial Habitat" section below), maintaining good ecological connectivity between the lake and its watershed, and encouraging the presence of woody structure along shorelines.[100] Woody structure is an abundant and important part of natural environments.

To determine the state of the aquatic habitat within the Lake, SEWRPC staff completed an aquatic plant survey (see "Issue 1: Aquatic Plant Growth" section), and a shoreline assessment (see "Issue 4: Shoreline Maintenance" section)

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[98] *Common carp, found throughout Wisconsin, are considered an issue of concern when found in high populations because their feeding method involves re-suspending sediments at the bottom of a lake.*

[99] *Personal communication with the regional WDNR fisheries biologist.*

[100] *Woody structure generally refers to the remains of trees that fall into a water body. Woody structure provides cover for fish, basking areas for amphibians and turtles, perching areas for birds and insects, and places for invertebrates, algae, and aquatic plants to anchor themselves. It also can protect shorelines from erosion by dampening wave and current energy.*

during summer 2012.[101] The aquatic plant survey revealed that **Pike Lake has very good plant diversity, with ten different pondweed species,[102] while the shoreline assessment concluded there are very few areas around the Lake with woody structure.** These conclusions suggest that the current aquatic plant community should be maintained to the greatest extent practical, and that projects should be implemented whenever and wherever possible that help provide more woody structure along shorelines. Recommendations related to both are presented in Chapter III.

The WDNR describes the Lake's bottom as comprised of 20 percent sand, 30 percent gravel, and 50 percent muck (generally a mixture of organic debris and silt). **It is important to note that healthy aquatic ecosystems require a variety of habitat and substrate.** For example, fish spawning, rearing, refuge, and feeding commonly take place is very different environments. Buffer installation, water quality management, removing fish passage impediments on perennial and intermittent streams, reconnecting floodplains to tributary streams, and maintaining nearshore vegetation and woody structure all promote fish populations. The shoreline maintenance recommendations in Chapter III are further refined to promote healthy fish populations.

Terrestrial Wildlife

Two general practices can enhance terrestrial wildlife populations. These practices include active application of best management practices in upland areas and terrestrial habitat enhancement. Each is discussed below.

Terrestrial Best Management Practices

The way individual plots of land are managed and the way people interact with wild animals and plants can significantly affect the ecological value of a parcel and, in turn, terrestrial wildlife populations. Turtles, for example, often travel long distances from their home lake or stream to lay eggs. If pathways to acceptable habitats are not available on account of fences, walls or other barriers; or are hazardous due to pets, fences, or traffic, turtle populations will decline. Many conservation organizations have developed "best management practices" or behaviors that homeowners and managers can employ to sustain or even enhance wildlife diversity and populations within a watershed.

While certain best management practices are species- or animal-type specific (e.g., spaying or neutering cats to limit feral cat populations and reduce their desire to kill birds), many recommendations relate to general practices that benefit all wildlife. In general, best management practices for wildlife enhancement target agricultural and residential lands. Agricultural practices tend to focus on encouraging practices that increase habitat abundance and/or value (e.g., allowing fallen trees to naturally decompose where practical or allowing for uneven topography in certain landscapes creating microhabitats needed by certain plants and animals to persist and procreate). In contrast, residential measures tend to focus on practices that owners of smaller parcels can initiate that provide habitat, enhance water quality, enhance aesthetics, and/or maintain natural communities. Examples include installing a rain garden, avoiding heavy applications of fertilizers or pesticides, landscaping to provide food and cover for native species, and preventing the introduction of nonnative plants and insects. Other recommendations are generally applicable to all landowners. For example, indiscriminant or careless killing of native wildlife, particularly amphibians, reptiles, and birds, is highly discouraged.

Actively communicating best management practices to the public often is an excellent means of protecting and enhancing wildlife populations without major investment of public funds. Consequently, measures that help increase acceptance and implementation of best management are included in the recommendations presented in Chapter III.

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[101] *Washington County is currently completing an aquatic plant survey based on summer 2016 data, the results of which were not available at the time this report was written.*

[102] *Pondweed species are significant in a lake because they serve as excellent habitat, providing food and shelter to many aquatic organisms.*

Figure 42

EXAMPLE WETLAND TYPES

MARSH WETLAND

Source: SEWRPC.

FORESTED WETLAND

Source: Prince William Conservation Alliance.

SCRUB/SHRUB WETLAND

Source: University of New Hampshire Cooperative Extension.

Terrestrial Habitat

Terrestrial wildlife prospers in the presences of large, well-connected tracts of open natural habitat. Consequently, protecting, connecting, and expanding natural habitat areas are important aspects to maintaining and enhancing wildlife populations. Open space natural areas can generally be classified as either wetlands or uplands as described below:

1. **Wetlands**—Wetlands are defined by hydrology, hydric soils, and the presence of wetland plants. Many types of wetlands exist (see Figure 42) from the familiar cattail and bulrush wetlands to forested wetlands. Most aquatic and terrestrial wildlife relies upon, or is associated with, wetland areas for at least a part of their life cycle. Examples of wetland-dependent animals includes crustaceans, mollusks, aquatic insects, fish, amphibians, reptiles, mammals (e.g., deer, muskrats, and beavers), and various bird species, (e.g., resident birds such as turkey, and migrant species such as sandhill and whooping cranes).

2. **Uplands**—Uplands are basically any land areas not classified as wetland or floodplain. They are often characterized by little to no ponding after heavy precipitation and by the presence of drier, more stable soils. Like wetlands, undisturbed, natural uplands can exist in many forms (e.g., prairies and woodlands) and provide many critical functions for many game and nongame wildlife species through provision of critical breeding, nesting, resting, and feeding areas, as well as refuge from predators and unfavorable weather. However, unlike wetlands, their dry and stable soils make them desirable urban development opportunities making protection more challenging.

As mentioned above, **both wetlands and uplands are critical to wildlife populations. The dynamic interaction and wildlife movement between these two types of land are crucial to a robust natural environment.** Many terrestrial organisms spend part of their lives in wetlands and the rest of their time in uplands. For example, some amphibians live most of their lives in upland areas but depend on wetlands for hibernation and breeding. Consequently, if access corridors between uplands and wetlands are compromised (e.g., if a large road is placed between two land types) it makes it dangerous, if not impossible, for amphibians to access breeding grounds, thereby lowering their ability to seasonally migrate and/or reproduce. In fact, **habitat fragmentation (i.e., the splitting up of large connected habitat areas) has been cited as the primary global cause of wildlife population decrease.**[103] Therefore, protecting and expanding uplands and wetlands, providing naturalized transition habitat, and maintaining or enhancing natural area connectivity helps maintain and enhance wildlife populations.

To determine the extent and location of the uplands and wetlands in the Pike Lake watershed, and gauge the state of the connections between these two habitat types, SEWRPC staff inventoried land use. Natural areas, wetlands and upland woodlands within the Pike Lake watershed are located on Map 15. Wetlands in the watershed are located primarily along the Rubicon River, as well as the north end, east side, and southwest corner of Pike Lake, while uplands woodlands are located primarily to the east of the Lake and encircling wetlands. **Wetland and upland forest areas are well connected to the east and south of the Lake, enhancing the ecological potential of both habitat types.** Protecting and expanding wetland/upland woodland complexes, providing naturalized transition habitat, and maintain or enhancing connectivity will help maintain or enhance the abundance and diversity of wildlife in the watershed. It is important to note, however, that the wetland and upland protection and enhancement requires a number of actions, including the following.

1. Prevent and/or limit development within the wetlands, natural uplands meadows, and woodlands.
2. Take steps to ensure new, reconstructed, or repaired infrastructure maintains or enhances environmental corridors and ecological connectivity between habitat and/or potential habitat areas.
3. Expand uplands and/or wetlands wherever practical (e.g., re-establishing wetlands that are currently farmed or reforesting cleared areas). Particular emphasis should be placed on connecting large blocks of diverse habitat through naturalized corridors.
4. Control and/or remove invasive plant species introduced to wetlands and uplands.
5. Avoid activities that can disrupt habitat value (e.g., excessive use of motorsport vehicles, intensive or extensive pedestrian or pet use). This could include prohibiting access to or certain activities within high-value areas during critical seasons.

A comprehensive management plan must consider each of these elements as being important. Recommendations are included in Chapter III. Additionally, implementation guidance is included in the "Issue 9: Plan Implementation" section below and in Chapter III.

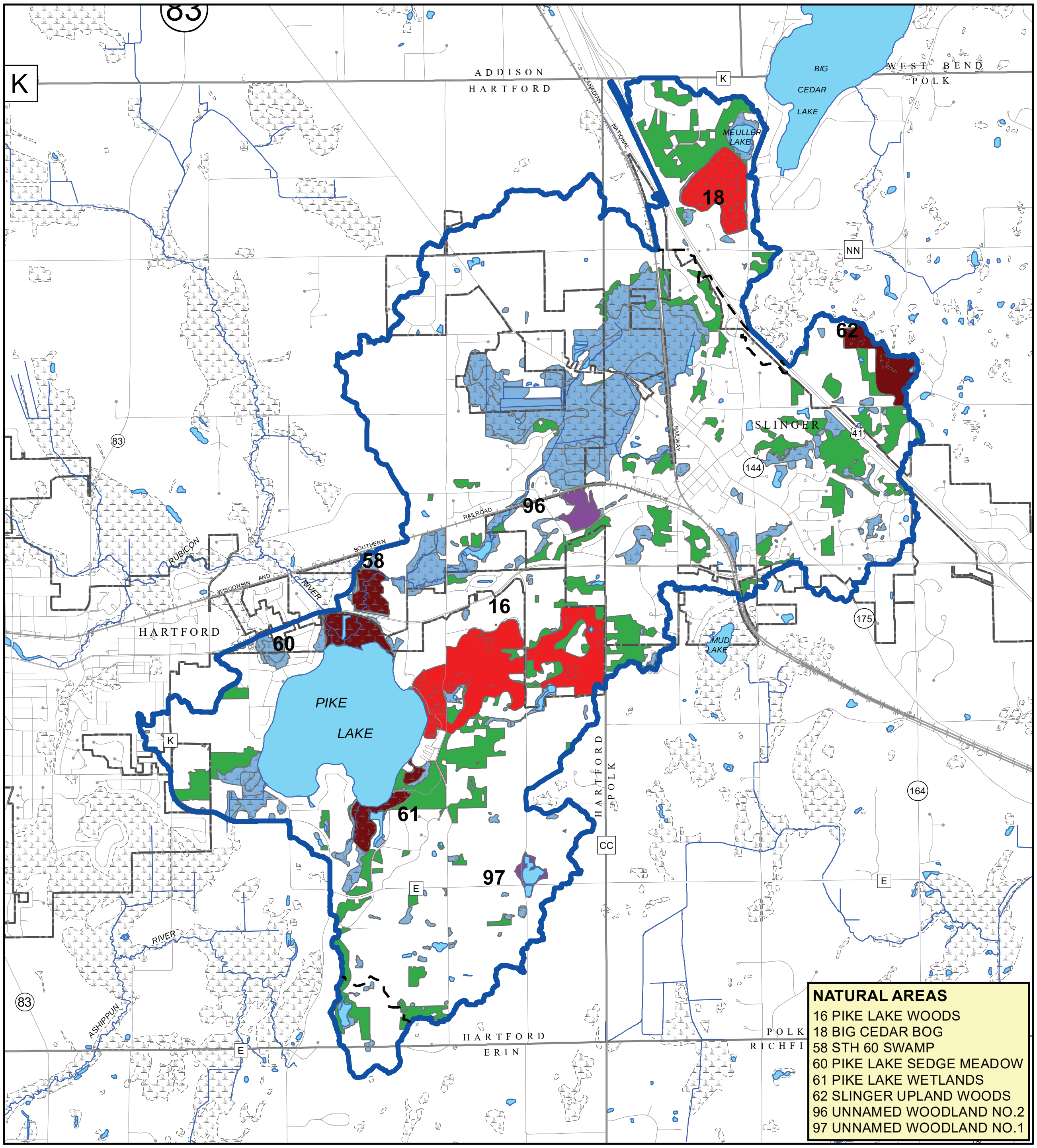
ISSUE 9: PLAN IMPLEMENTATION

A core issue for any lake protection plan is the need for advice and guidance that helps sequence and execute plan recommendations, sets tangible goals, and establishes quantifiable metrics to measure progress and relative success. Developing an action plan with timelines, goals, and identified responsible parties is a significant step toward plan implementation. Target metrics can help implementing agencies and grantors gauge progress over time and can help motivate participants, ensuring that the plan is carried through in the long term. When developing an action plan, it is important to understand what on-the-ground implementation involves.

[103] *Lenore Fahrig, "Effects of Habitat Fragmentation on Biodiversity,"* Annual Review of Ecology, Evolution, and Systematics, *Vol. 34, 2003, pp. 487-515.*

Map 15

NATURAL AREAS, WETLANDS AND WOODLANDS WITHIN THE PIKE LAKE WATERSHED



NATURAL AREA OF COUNTYWIDE OR REGIONAL SIGNIFCANCE (NA - 2): 2005

NATURAL AREA OF LOCAL SIGNIFCANCE (NA - 3): 2005

WETLANDS: 2010

WOODLANDS: 2010

97 SITE IDENTIFICATION NUMBER

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLAND

N

0 2,500 5,000 Feet

Source: SEWRPC

Some recommendations can be best achieved using regulations while others involve new proactive management efforts. Both are described below.

Regulatory Implementation

Relative to this plan, regulatory implementation refers to the maintenance and improvement of water quality, water quantity, and wildlife populations, through the use of local, State, and Federal rules, laws, and guidelines. A number of regulations already govern activities within the Pike Lake watershed, examples of which include zoning ordinances, boating and in-lake ordinances, and State regulations related to water quality. These regulations help protect the Lake by mitigating pollution, preventing or limiting development, and encouraging use of best management practices.

Ordinances

Zoning ordinances dictate where development can take place, the types of development allowed, and the terms that need to be met for development to be permitted. Consequently, **zoning can be a particularly effective tool for protecting buffers, wetlands, uplands, and shorelands if environmental goals are integrated into ordinance development, formulation, and enforcement.** One way to integrate environmental considerations into ordinances is for the local zoning authorities and other regulatory agencies to actively consider and use SEWRPC-designated environmental corridors (see Figure 43). Environmental corridors can be integrated into conservancy zoning district ordinances to help determine where development is permitted and not permitted, and help determine the intensity and types of allowable land uses.

In the Pike Lake watershed, **six different units of government have regulatory authorities that apply to lake protection.** These municipalities are Washington County, the City of Hartford, the Village of Slinger, and the Towns of Erin, Hartford, and Polk (see Map 16 and Table 25). **All local governments (city, village, and towns) in the watershed have adopted a general zoning ordinance.** Of the five local governments, the City of Hartford and the Towns of Erin and Polk limit development within woodlands, and the Town of Erin zoning ordinance specifically addresses the restoration of woodlands and limits development in upland portions of environmental corridors. Zoning ordinances adopted by all five local governments limit development in wetlands, and the Washington County shoreland zoning ordinance limits development in shoreland-wetlands and other shoreland areas, many of which are included in environmental corridors or isolated natural resource areas. As this directly benefits water quality (as discussed in the "Issue 2: Water Quality" section) and wildlife and their habitat (as discussed in the "Issue 8: Fish and Wildlife" section above), and indirectly benefits most other identified lake management issues, it is recommended that all local governments in the watershed adopt zoning regulations that limit development within environmental corridors and help protect and restore other natural features (see Map 17).

In addition to general zoning, **shoreland zoning and construction site erosion control and stormwater management ordinances play a key part in protecting the resources within the watershed.** Shoreland zoning, for example, which is administered by Washington County in this instance, follows State-wide standards to create building setbacks around navigable waters.[104] Additionally, stormwater management and construction erosion con-

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[104] *The 2015-2017 State Budget (Act 55) changed State law relative to shoreland zoning. Under Act 55 a shoreland zoning ordinance may not regulate a matter more restrictively than it is regulated by a State shoreland-zoning standard unless the matter is not regulated by a standard in Chapter NR 115, "Wisconsin's Shoreland Protection Program," of the Wisconsin Administrative Code. (Examples of unregulated matters may involve wetland setbacks, bluff setbacks, development density, and stormwater standards.) In addition, under Act 55, a local shoreland zoning ordinance may not require establishment or expansion of a vegetative buffer on already developed land and may not establish standards for impervious surfaces unless those standards consider a surface to be pervious if its runoff is treated or is discharged to an internally drained pervious area. Additional legislation relative to shoreland zoning enacted after the 2015-2017 State budget legislation includes Act 41 which addresses town shoreland zoning authority relative to county authority (effective date: July 3, 2015) and Act 167 which codifies and revises current Wisconsin Department of Natural Resources shoreland zoning standards.*

Figure 43

SYNOPSIS OF SEWRPC-DESIGNATED ENVIRONMENTAL CORRIDORS

SEWRPC has embraced and applied the environmental corridor concept developed by Philip Lewis (Professor Emeritus of Landscape Architecture at the University of Wisconsin-Madison) since 1966 with the publication of its first regional land use plan. Since then, SEWRPC has refined and detailed the mapping of environmental corridors, enabling the corridors to be incorporated directly into regional, county, and community plans and to be reflected in regulatory measures. The preservation of environmental corridors remains one of the most important recommendations of the regional plan. Corridor preservation has now been embraced by numerous county and local units of government as well as by State and Federal agencies. The environmental corridor concept conceived by Lewis has become an important part of the planning and development culture in southeastern Wisconsin.

Environmental corridors are divided into the following three categories.

- **Primary environmental corridors** contain concentrations of our most significant natural resources. They are at least 400 acres in size, at least two miles long, and at least 200 feet wide.
- **Secondary environmental corridors** contain significant but smaller concentrations of natural resources. They are at least 100 acres in size and one mile long, unless they link primary corridors.
- **Isolated natural resource areas** contain significant remaining resources that are not connected to environmental corridors. They are at least five acres in size and at least 200 feet wide.

Key Features of Environmental Corridors

- Lakes, rivers, and streams
- Undeveloped shorelands and floodlands
- Wetlands
- Woodlands
- Prairie remnants
- Wildlife habitat
- Rugged terrain and steep slopes
- Unique landforms or geological formations
- Unfarmed poorly drained and organic soils
- Existing outdoor recreation sites
- Potential outdoor recreation sites
- Significant open spaces
- Historical sites and structures
- Outstanding scenic areas and vistas

Source: SEWRPC.

trol ordinances help minimize water pollution, flooding, erosion, and other negative impacts of urbanization on water resources (e.g., lakes, streams, wetlands, and groundwater). The ultimate aim of such ordinances is to protect natural resource assets and property owners, both during and after construction of new infrastructure.

Boating and In-Lake Ordinances

Boating and in-lake ordinances regulate the use of the Lake in general, and, when implemented properly, **can help prevent user conflicts and inadvertent damage to the Lake such as excessive noise and wildlife disturbance, severe shoreline erosion from excessive wave action reaching the shoreline, agitation of bottom sediment and vegetation, and overfishing.** The boating ordinance for the Town of Hartford (including Pike Lake) is provided in Appendix I. This ordinance is generally enforced by a warden or by a local law enforcement agency.

State Regulations

The State Legislature requires the WDNR to develop performance standards for controlling nonpoint source pollution from agricultural and nonagricultural land and from transportation facilities.[105] The performance standards, which are set forth in Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*, set forth requirements for best management practices. Regulations also cover construction sites, wetland protective areas, and buffer standards.

Water quality objectives are presented in Chapter NR 102, "Water Quality Standards for Wisconsin Surface Waters," of the *Wisconsin Administrative Code*. These rules set water quality standards that promote healthy aquatic ecosystems and public enjoyment of the water body. Some of the standards set in this rule applicable to Pike Lake include the following:

1. Dissolved oxygen greater than or equal to 5.0 mg/L,
2. pH between 6.0 and 9.0 SU,
3. Fecal coliform geometric mean less than or equal to 200 colonies per 100 milliliters, single sample maximum less than or equal to 400 colonies per 100 milliliters,
4. Total phosphorus (summer epilimnion) less than or equal to 30 μg/L, and
5. Chloride acute toxicity 757 mg/L, chronic toxicity 395 mg/L.

This rule further stipulates maximum temperatures for each month, with the highest standards applying to July and August when the following maxima apply: ambient water temperature of less than or equal to 77^{o}F, sublethal water temperature of less than or equal to 80^{o}F for one week or less, and acute water temperature of less than or equal to 87oF for one day or less.

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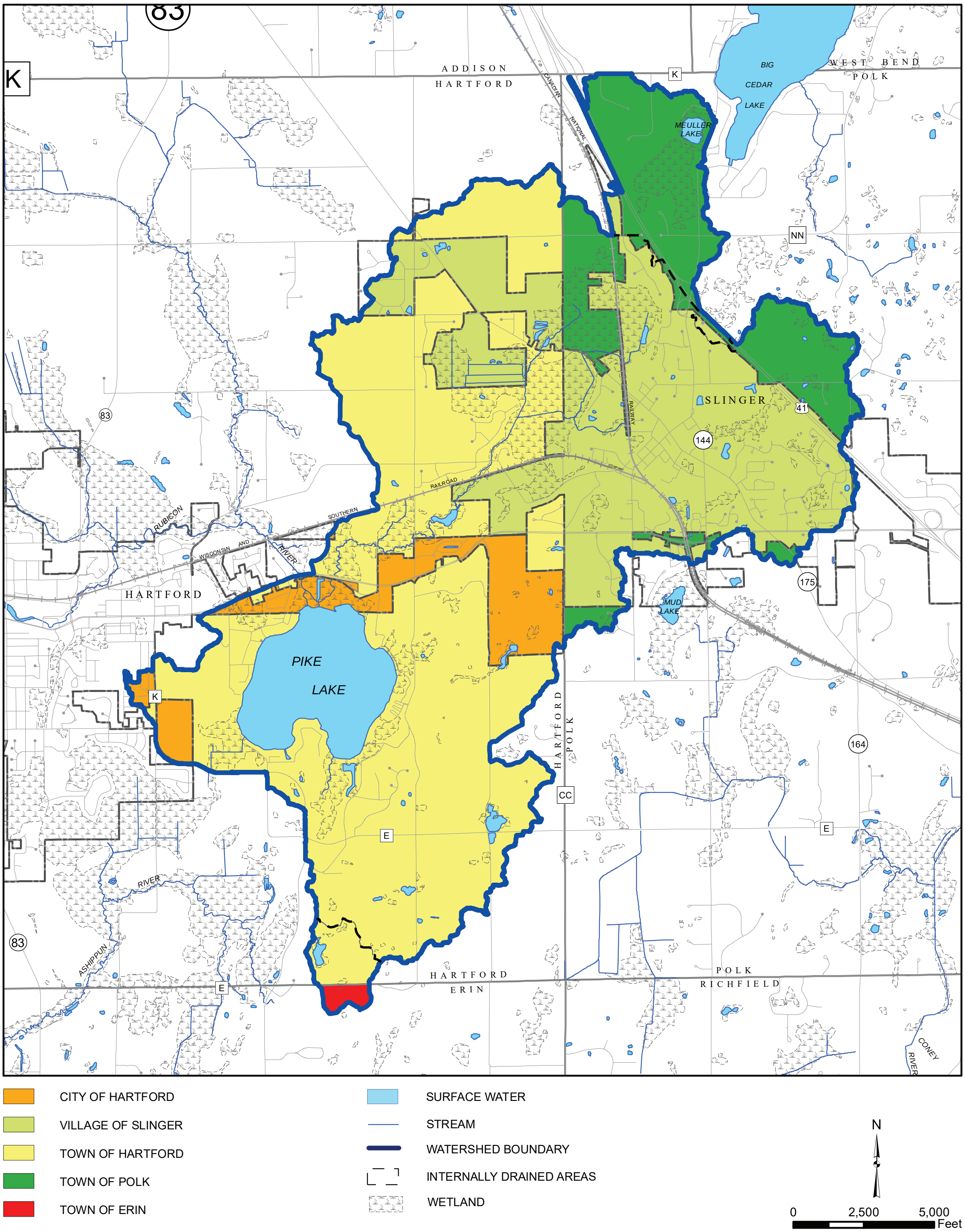
[105] *The State performance standards are set forth in the Chapter NR 151, "Runoff Management," of the* Wisconsin Administrative Code. *Additional code chapters that are related to the State nonpoint source pollution control program include: Chapter NR 152, "Model Ordinances for Construction Site Erosion Control and Storm Water Management" (This Chapter will be revised in response to 2013 Wisconsin Act 20 as quoted in WDNR Guidance #3800-2014-3, "Implementation of 2013 Wisconsin Act 20 for Construction Site Erosion Control and Stormwater Management," October 2014.); Chapter NR 153, "Runoff Management Grant Program;" Chapter NR 154, "Best Management Practices, Technical Standards and Cost-Share Conditions;" Chapter NR 155, "Urban Nonpoint Source Water Pollution Abatement and Storm Water Management Grant Program;" and Chapter ATCP 50, "Soil and Water Resource Management." 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.*

Map 16

CIVIL DIVISIONS WITHIN THE PIKE LAKE WATERSHED: 2017



Source: SEWRPC

Table 25

LAND USE REGULATIONS WITHIN THE AREA TRIBUTARY TO PIKE LAKE IN WASHINGTON COUNTY BY UNIT OF GOVERNMENT: 2015

Community	Type of Ordinance				
	General Zoning	Floodplain Zoning	Shoreland Zoning	Subdivision Control	Erosion Control and Stormwater Management
Washington County	- -[a]	Adopted[a]	Adopted[a]	Adopted	Adopted
City of Hartford	Adopted	Adopted	Adopted[b]	Adopted	Adopted
Village of Slinger	Adopted	Adopted	Adopted[c]	Adopted	Adopted
Town of Erin	Adopted	Regulated under County ordinance	Regulated under County ordinance	Adopted[d]	Regulated under County ordinance[e]
Town of Hartford	Adopted	Regulated under County ordinance	Regulated under County ordinance	Adopted[d]	Regulated under County ordinance[e]
Town of Polk	Adopted	Regulated under County ordinance	Regulated under County ordinance	Adopted[d]	Regulated under County ordinance[e]

[a]Washington County rescinded its general zoning ordinance in 1986. All towns in the County have adopted a town zoning ordinance. County floodplain and shoreland regulations continue to apply in unincorporated (town) areas.

[b]The City of Hartford zoning ordinance includes a shoreland-wetland district, which applies to wetlands five acres or larger within the shoreland area (per Chapter NR 117 of the Wisconsin Administrative Code), and a Shoreland Overlay district that applies to shoreland areas annexed from a town after May 7, 1982 (per Section 62.233 of the Wisconsin Statutes).

[c]The Village of Slinger zoning ordinance includes a C-1 district that applies to lowland conservancy areas, including shoreland-wetlands (per Chapter NR 117 of the Wisconsin Administrative Code). The Village zoning ordinance was amended in September 2015 to add development setbacks and riparian buffers in shoreland areas annexed from a town after May 7, 1982 (per Section 61.353 of the Wisconsin Statutes).

[d]Both the Washington County and Town subdivision ordinances apply within the Towns of Erin, Hartford, and Polk. Land divisions in the Towns may also be regulated by the City or Village subdivision ordinance if the area being divided is in the extraterritorial plat review jurisdiction of the City or Village (within three miles of the City of Hartford or 1.5 miles of the Village of Slinger). In the event of conflicting regulations, the more restrictive regulation applies.

[e]All towns in Washington County were given the option of being regulated under the County Erosion Control and Stormwater Management Ordinance, adopting a Town ordinance based on a model ordinance developed by the County and contracting with the County for enforcing the ordinance, or adopting a Town ordinance based on a model ordinance developed by the County with the Town taking responsibility for enforcing the ordinance. The Towns of Erin, Hartford, and Polk chose to be regulated under the County ordinance.

Source: SEWRPC.

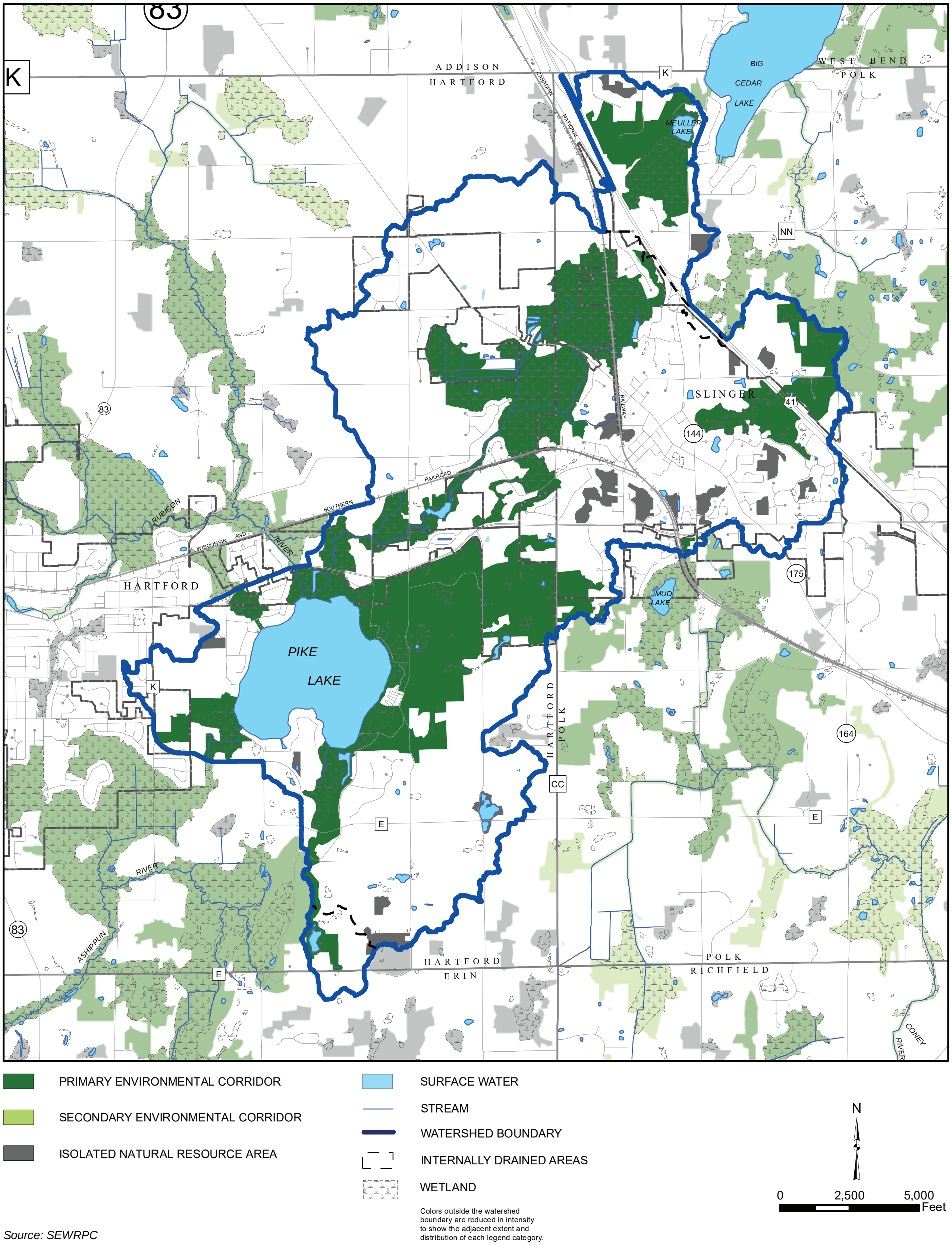
The regulations described above help maintain the health of the Lake and of all the resources within the Pike Lake watershed. However, even though developers, residents, and Lake users are legally obligated to adhere to the ordinances, **limited resources within the enforcement arms of State, County, and local agencies can make the task of ensuring compliance difficult.** Consequently, Chapter III recommends ways that lake organizations can help regulatory agencies enforce existing ordinances and regulations.

Proactive Management Efforts

In addition to continued and enhanced ordinance enforcement, a number of recommendation made in this plan seek to proactively improve conditions within the Lake through voluntary management efforts. Chapter III provides details on these recommendations and implementation guidance. Several challenges can limit the ability of Lake residents and the PLPRD to actively engage in certain management efforts recommended in this plan. Some of these challenges include:

Map 17

ENVIRONMENTAL CORRIDORS AND ISOLATED NATURAL RESOURCE AREAS WITHIN THE PIKE LAKE WATERSHED: 2010



Source: SEWRPC

1. **Lack of adequate funding**—General concern regarding the cost of implementing management plans suggests a need for additional funding sources. Though grant funds may be available to help with some of the projects (as detailed in Chapter III of this report), fundraising, creative partnerships, and wise permitting strategies can be important to help fund Lake management efforts over time.

2. **Institutional Capacity**– Institutional capacity refers to assets available through public agencies, universities and schools, service groups, and non-governmental organizations that can be used to implement projects. These assets can be defined in terms of knowledge, staff, equipment, and other resources. Many resources are available to help residents and lake users implement management measures. Nevertheless, some guidance will likely be necessary to ensure that such efforts help the overall project proceed in an effective and efficient fashion consistent with plan recommendations and goals.

3. **Volunteers**– To increase the advocacy, learning opportunities, and volunteer base for labor intensive or broad-based projects (e.g., hand pulling or monitoring of wetland invasive species), it is desirable to reach a broad stakeholder group. The stakeholder group should extend beyond lakeshore and near-lakeshore residents. Unfortunately, it was noted that the participants in the planning process were composed almost entirely of lakeshore or near-lakeshore residents. To increase the advocacy and volunteer base for projects it will be necessary to reach a wider group and demonstrate why their interest is important to overall project results.

The funding and involvement issues considered in this report subsection are highly relevant to most if not every recommendation under the plan. Consequently, Chapter III provides recommendations and suggested actions that seek to ensure that the above capacity issues are addressed.

In addition to capacity building, openly sharing and communicating plan details is a crucial element to encouraging voluntary management efforts. For example, communicating the difference between native, nonnative, and invasive plants, and the fact that removing aquatic plants can spur algae growth helps assure that homeowners understand why a "clean" shoreline is not always the best option for a lake, and that a healthy plant community includes aquatic plants within a lake and along its shoreline. Consequently, another major recommendation in Chapter III is openly and actively communicate the critical key plan elements.

SUMMARY

All of the issues of concern expressed by Pike Lake residents during the development of this plan have merit and are worth considering. Additionally, as discussed in the "Issue 1: Aquatic Plant Growth" section of this report, addressing these issues will help maintain the aquatic plant population within Pike Lake and improve the general health of the Lake. Therefore, each issue has associated recommendations set forth in Chapter III. It is important to note that, despite the issues of concern in Pike Lake, a number of opportunities exist to help ensure sustainable use of Pike Lake and its watershed. Implementing recommendations provided in Chapter III will help capitalize on those opportunities.

Chapter III

LAKE MANAGEMENT RECOMMENDATIONS AND IMPLEMENTATION

INTRODUCTION

Pike Lake provides many valuable services to lakeshore property owners, people visiting the Lake and the adjacent State Forest, nearby residents, and to the larger Rock River watershed due to its function as a headwater lake (e.g., provision of key ecological, water quality, and floodwater detention services). Because of the Lake's great value to the nearby community and overall watershed, the Pike Lake Protection and Rehabilitation District (PLPRD) requested and was awarded a grant to study issues that are perceived to harm or threaten the Lake, and to suggests solutions to these problems. The resultant recommendations are based upon the interests and priorities of the stakeholder group (e.g., the PLPRD: Washington County; the City of Hartford; the Village of Slinger; the Towns of Hartford, Polk and Erin; the Wisconsin Department of Natural Resources (WDNR); members of the general public; organizations; and other agencies), analysis of available data, practicality, and potential for successful implementation, all of which were discussed in Chapter II. Implementing these recommendations helps maintain and enhance the health of the Lake and improves its ability to provide short- and long-term benefit to the overall community.

The recommendations made in this chapter cover a wide range of programs and seek to address a broad array of factors and conditions that significantly influence the health, aesthetics, and recreational use of Pike Lake. Since the plan addresses a wide scope of issues, it may not be feasible to implement every recommendation in the immediate future. To promote efficient plan implementation, the relative importance and significance of each recommendation is noted to help Lake managers prioritize plan elements. Nevertheless, all recommendations should eventually be addressed, subject to possible revision based on analysis of yet-to-be collected data (e.g., future aquatic plant surveys and water quality monitoring results), project logistics, and/or changing/unforeseen conditions.

Those responsible for Lake planning and management should actively conceptualize, seek, and promote projects and partnerships that enable the recommendations of the plan to be implemented. The measures presented in this chapter focus primarily on those that can be implemented through collaboration between local organizations, watershed property owners, and others who have a vested interest in Pike Lake. Examples include the PLPRD, Pike Lake residents, Washington County, the City of Hartford, the Village of Slinger, and the Pike Lake Unit of the Kettle Moraine State Forest. Additionally, collaborative partnerships formed among other stakeholders (e.g., other agencies within the WDNR, developers, non-governmental organizations (NGOs), and other watershed municipalities) help promote efficient, affordable, and sustainable actions to assure the long-term ecological health of Pike Lake.

As a planning document, this chapter provides concept-level descriptions of activities that can be undertaken to help protect and enhance Pike Lake. The full logistical and design details needed to implement most recommendations must be more fully developed when various components of the plan are executed. Grants are oftentimes available to take concepts and produce actionable design drawings and plans It is important to note that the recommendations provide implementing entities with guidance regarding the type and nature of projects to pursue to meet plan goals.

In summary, **this chapter provides a context for understanding what needs to be done and what elements are believed to be relatively more important.** In doing so, those implementing the plan can better envision what such efforts may look like and can more fully comprehend the overall intent. Such concepts can be invaluable for building coalitions and partnerships, writing competitive and meaningful grant requests, and initiating project design work.

ISSUE 1: AQUATIC PLANT GROWTH

Pike Lake supports a diverse aquatic plant community, habitat capable of supporting a healthy warm water fishery as well as a wide range of recreational uses. However, the 2012 aquatic plant survey (see Appendix A for distribution maps), along with newer findings point to reasons why an aquatic plant management plan should be considered extremely important—the presence of three invasive plant species.[1] All three of those species (Eurasian water milfoil, curly-leaf pondweed, and starry stonewort) have the potential to threaten the native aquatic plant community and the ecosystem that depends upon the plant community. This section describes a comprehensive aquatic plant management plan based on the data and suggestions provided in Chapter II.

The combined recommendations presented below collectively outline the recommended aquatic plant management plan. The plan must balance three major goals:

- Protecting the native aquatic plant community,
- Effectively controlling invasive plans (particularly Eurasian water milfoil and any hybrids, curly-leaf pondweed, and starry stonewort), and
- Maintaining or improving navigational access.

Plan provisions help ensure that current recreational uses of the Lake (e.g., swimming, boating, and fishing) are maintained to the greatest extent practical. The plan recommendations described below rely upon WDNR-approved, aquatic plant management alternatives (see Chapter II), including manual, biological, physical, chemical, and mechanical measures.

Plant Management Recommendations

The most effective plans for managing nuisance and invasive aquatic plant growth rely on a *combination* of methods and techniques. A "silver bullet" single-minded strategy rarely produces the most efficient, most reliable, or best overall result. Therefore, to enhance access to, and the health of, Pike Lake, four aquatic plant management techniques are recommended under this plan, as described below:

- **Manually remove nuisance plant growth in near-shore areas** should be considered in areas too shallow, inaccessible or otherwise unsuitable for other plant control methods. "Manual removal" is defined as control of aquatic plants by hand or using hand-held non-powered tools. Given what is known of plant

[1] *Washington County completed a point-intercept survey of Pike Lake's aquatic plant community during 2016. A complete report documenting the 2016 point-intercept report is available through Washington County, and a summary table and key data is included in Appendix B of this report. As new point-intercept data does become available, the recommendations of this plan should be reviewed and revised as necessary.*

distribution, this element is given a low priority. Riparian landowners need not obtain a permit for manually removing aquatic plants if this activity is confined to a 30-foot width of shoreline (which must include and integrate recreational use areas such as a piers or docks) that does not extend more than 100 feet into the Lake, provided that all resulting plant material is removed from the lake.[2] A permit is required if the PLPRD or other group actively engages in such work.[3] Prior to the "hand-pulling" season, an educational campaign should be actively promoted to help assure that shoreline residents appreciate the value of native plants, understand the relationship between algae and plants (i.e., more algae will grow if fewer plants remain), know the basics of plant identification, and comprehend the specifics about the actions they are allowed to legally take to "clean up" their shorelines.[4]

- **Hand-pull or use Diver-Assisted Suction Harvesting (DASH) to control Eurasian water milfoil populations** should be considered a medium priority. Hand-pulling should occur in the shallow areas along the southern and western shorelines (see Map 18), as well as in any other place feasible. Eurasian water milfoil populations in this area are sparse enough that this effort could be undertaken by volunteers. No permit is needed for hand-pulling as long as the effort specially targets non-native plants (in the case of Pike Lake, Eurasian water milfoil, curly-leaf pondweed, and starry stonewort) and as long as all plant materials are removed from the Lake. Hand-pulling starry stonewort is also recommended as this technique, if done properly, will remove the reproductive bulbils from the Lake. Before actively participating in such work, residents must be educated to help them understand the need to prevent extensive loss of native plants and must be trained to enable them to identify aquatic plants. These actions help ensure that this plant management measure does not adversely affect local wildlife and fisheries, desirable aquatic plant communities, aesthetics, shoreline protection, and/or water quality.

  In addition to hand pulling, a DASH contractor could be considered for Eurasian water milfoil control in offshore areas. This activity requires a NR 109 permit. This measure may help ensure that Eurasian water milfoil does not displace native communities in deeper water areas. Suction harvesting is feasible for certain select communities of starry stonewort or if the population decreases to a manageable size, which should be reevaluated in the future. Suction harvest may occur in intermixed beds of starry stonewort and Eurasian water milfoil; however, suction harvesting equipment should not be used in starry stonewort beds then be moved and used in monotypic Eurasian water milfoil beds without thorough cleaning. If not properly cleaned, harvesting equipment may transport starry stonewort to new areas within the Lake.

- **Support biological measures (i.e., aquatic weevils) to control Eurasian water milfoil (high priority). Pike Lake has a documented population of Euhrychiopsis lecontei, a weevil that damages the tops of water-milfoil plants** causing the plant to fall away from the water surface and prevents milfoil from flowering, allowing native plants to compete.[5] Weevils are no longer commercially available for stocking

[2] *The manual removal area limitation for nearshore aquatic plants applies to shorelines where native plants are present. The removal area limitation does not apply to areas populated solely with nonnative and invasive plants.*

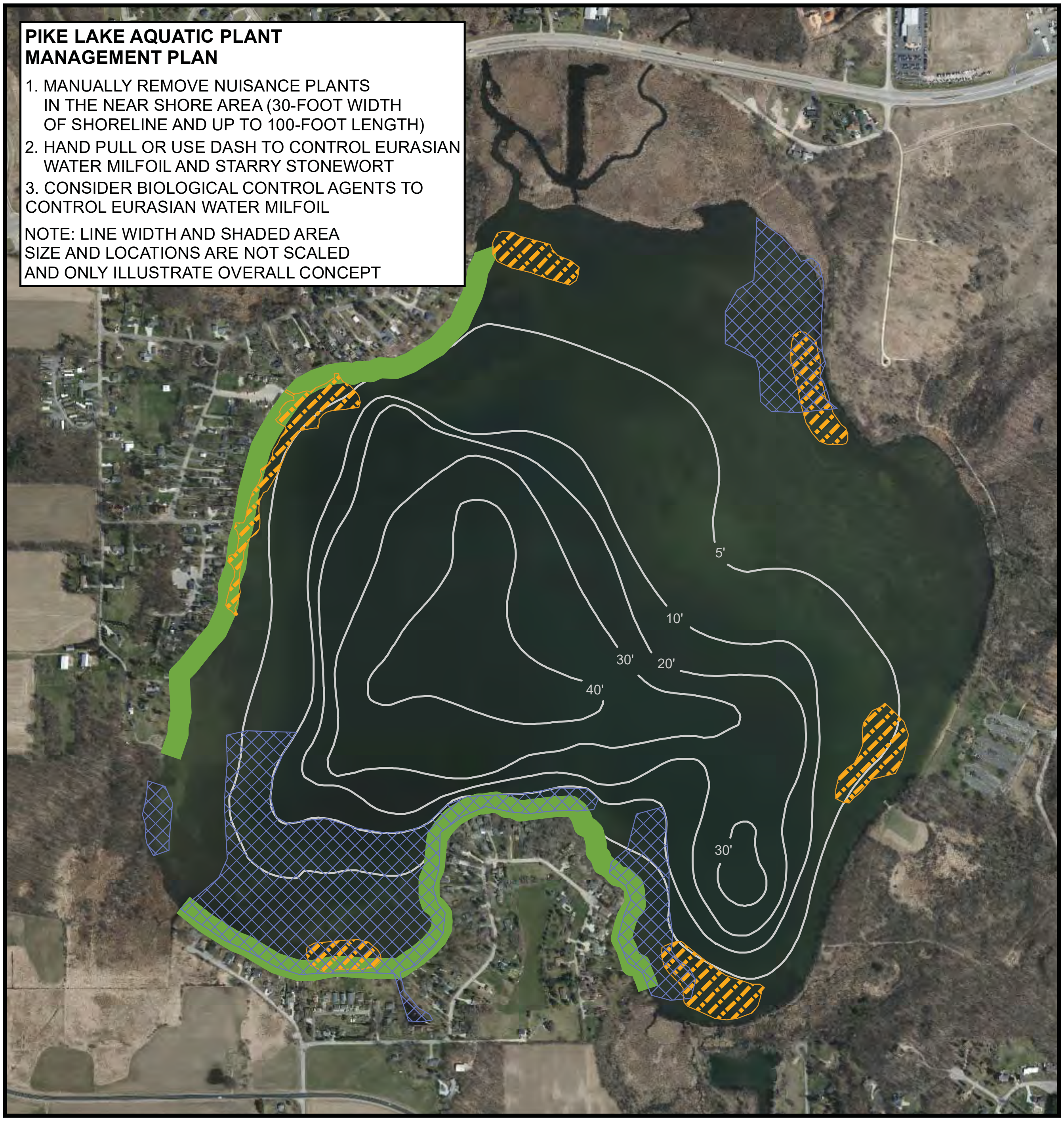
[3] *If a lake district or other group wants to complete a project to remove invasive species along the shoreline, a permit is necessary under Chapter NR 109, "Aquatic Plants: Introduction, Manual Removal And Mechanical Control Regulations," of the* Wisconsin Administrative Code*, as the removal of aquatic plants is not being completed by an individual property owner along his or her property.*

[4] *SEWRPC and WDNR staff could help review this document.*

[5] *Citizen Lake Monitoring Network, Aquatic Invasive Species Monitoring Manual, Chapter 12 Native Water-milfoil Weevil, May 2014. Available online at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Documents/programs/CLMN/publications/Ch12-NativeWeevil.pdf.*

Map 18

AQUATIC PLANT MANAGEMENT RECOMMENDATIONS FOR PIKE LAKE



DATE OF PHOTOGRAPHY: APRIL 2015

AQUATIC PLANT MANAGEMENT AREAS

Source: Washington County and SEWRPC.

lakes. Therefore, stocking is not an option to increase weevil populations. However, Pike Lake's existing weevil population may be bolstered by increasing the amount of shoreline kept in a more natural condition, allowing plant debris to remain, which is the preferred overwintering habitat for the weevil. Private lands provide the greatest collective opportunity for increasing the amount of overwintering habitat. Additionally, shorelines maintained in a more natural state support fish and wildlife populations and can help improve water quality.

- ***Early spring* chemical treatment of Eurasian water milfoil if it begins displacing the native plant community.** If Eurasian water milfoil reaches nuisance levels or becomes the dominant plant in the Lake (based on another aquatic plant survey), measures other than harvesting, hand-pulling, and aquatic weevils may be necessary. If this is documented by a future aquatic plant survey, chemical treatment should be considered for Eurasian water milfoil control (medium priority). If chemical treatment is used, it should only occur in the early spring when human contact and risks to native plants are most limited. Additionally, only herbicides that somewhat selectively control Eurasian water milfoil (e.g., 2,4-D and endothall)[6] should be used to prevent loss of native aquatic plant species. A WDNR permit and WDNR staff supervision are required to implement this alternative. Lakeshore property owners must be notified of planned chemical treatment schedules and permit conditions before chemicals are applied to the Lake. If chemical treatment does occur, **monitoring chemical residue in the Lake is also recommended.** Chemical residue monitoring is typically a standard component of whole-lake treatments. Residue monitoring would be a high priority if chemicals are used to control plants. Additionally, if Lake residents are concerned about chemicals entering their water-supply wells, **water supply wells could be tested for select chemical constituents.** However, given that groundwater discharges to most of the Lake, there is a low risk of the wells being affected. Therefore, well testing is assigned a low priority.

Map 18 is intended to help guide future aquatic plant managers implement aquatic plant management plan recommendations. Nevertheless, **aquatic plant management must address actual on-the-ground conditions present at the time of treatment,** and must not be overly reliant on Map 18. Consequently, this aquatic plant management plan should be re-evaluated in three to five years (at the end of the five-year permitting cycle) or at another time when data becomes available. Washington County completed a point-intercept plant survey during summer 2016, the results of which were considered in this report. Washington County intends to complete another point-intercept study during 2017. The yet-to-be collected 2017 Washington County data and any subsequent plant information should be considered when it becomes available, and, if this new data reveals significant change to the current understanding of the Lake's plant community, changes to the management plant recommendations may be warranted. Periodic collection and review of new plant and Lake condition data should be given a high priority. This helps Lake managers better evaluate the effectiveness of the aquatic plant management plan and make appropriate refinements as needed. **The management plan is unlikely to remain static.** Instead, the plan must evolve as the understanding of the Lake and actual conditions in the Lake change. Therefore, regular plan updates should be given a high priority.

Other Recommendations

New invasive species introductions are a constant threat to all Southeastern Wisconsin waterbodies. Lake residents and users should be educated in ways that help prevent new species from entering the Lake and how to avoid carrying invasive species from Pike Lake to other waters (see Appendix I). To help accomplish this goal, the PLPRD should consider enrolling in the Clean Boats Clean Waters program (a State program targeting invasive

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[6] *Wisconsin Department of Natural Resources PUBL-WR-236 90,* Chemical Fact Sheet: 2,4-D, *May 1990; Wisconsin Department of Natural Resources PUBL-WR-237 90,* Chemical Fact Sheet: Endothall, *May 1990.*

Figure 44

HYDRILLA (*Hydrilla verticillata*)

- Serrated leaves, with whorls of 4-8 short leaves
- Stems have several spines
- Females produce small, white flowers that rise to the surface, and males release free-floating green flowers

Source: Paul Skawinski, (2014). *Aquatic Plants of the Upper Midwest: A Photographic Field Guide to Our Underwater Forests, 2nd* Edition. Wausau, Wisconsin, USA: Self-Published*; and SEWRPC.*

species prevention),[7] to proactively encourage Lake users to clean their boats and equipment before launching and using them in Pike Lake (high priority). This will help reduce the probability of introducing new invasive species into the Lake. Boat launches are likely entry points for alien species. Therefore, boat launch sites should be conscientiously targeted for focused education and boat/equipment cleaning efforts (high priority).

A distinct risk is present that a new invasive species (e.g., hydrilla) could enter the Lake. Hydrilla resembles elodea when casually observed and could be overlooked (see Figure 44). Hydrilla is just one of many potential new invasive species that could create future management problems.[8] If a new aquatic invasive plant infestation were discovered, prompt and deliberate eradication efforts should be immediately employed to quickly reduce the chance that the new invasive species becomes firmly established. If a new species is detected, the WDNR offers funding that can aid in early eradication, particularly as it pertains to aquatic plants. Therefore, **citizen monitoring for new invasive species is recommended** as a high priority. Furthermore, a written action plan with contact information and procedures should be immediately developed (high priority). The Wisconsin Citizen Lake Monitoring Network (CLMN) trains local citizens who wish to engage in these efforts.

Finally, a number of conditions (notably excessive nutrients and sediment loads delivered to the Lake) can cause excessive plant growth, leading to nuisance levels of certain aquatic plants. Accordingly, efforts to mitigate these nuisance conditions—which often go along with improving the overall quality of the Lake and its watershed—can also reduce the amount of overall aquatic plant growth. Consequently, **implementing recommendations highlighted in the "Issue 2: Water Quality" section of this chapter is an integral and important** for aquatic plant management, and should be assigned a high priority.

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[7] *Further information about Clean Boats Clean Waters can be found on the WDNR website at: http://dnr.wi.gov/lakes/cbcw/.*

[8] *The WDNR's website posts information describing invasive species and the threats they bring. For example, pictures of regulated aquatic invasive species can be found at the following website: http://dnr.wi.gov/topic/Invasives/documents/NR40Aquatics.pdf*

Starry Stonewort Action Plan
As discussed in Chapter II of this report, starry stonewort (*Nitellopsis obtusa*) was confirmed to be present in Pike Lake during August 2015. The PLPRD met with the WDNR and the Washington County Aquatic Invasive Species Coordinator to discuss this infestation which in turn resulted in a management strategy focusing on preventing the spread of starry stonewort and educating lake users and others to the presence and problems posed by the presence of starry stonewort in Pike Lake. Primary actionable components of the plan are to install a Clean Boats Clean Waters station at the public launch including a cleaning station and posting updated signs to educate Lake users on aquatic invasive species and their spread.

Washington County completed a point intercept survey during 2016 which is the first quantitative estimate of starry stonewort extent and abundance in the Lake. This information provides a good comparative reference for future point-intercept studies, and will allow the changes in the starry stonewort infestation to be better understood. Such information will be very helpful to choosing an appropriate management approach. A follow-on point-intercept study should be completed as soon as possible, perhaps as early as later this year (high priority).[9]

ISSUE 2: WATER QUALITY

Pike Lake's water contains moderate to high amounts of critical plant nutrients, classifying the Lake as a meso-eutrophic lake. The fact that many Lake residents are concerned about various water-quality-related issues, including sources of pollution in the watershed and algal growth, suggests that attention to water quality management is warranted to safeguard or improve water quality. Evaluation of the existing data set reveals the following:

- Over ten times more sediment and phosphorus enter Pike Lake compared to pre-settlement conditions.
- Phosphorus concentrations reached their peak during the mid-1990s and have since declined.
- Under natural conditions, Pike Lake would be classified as a deep seepage lake. Artificial rerouting of the Rubicon River creates a situation where the Lake is now classified as a deep lowland lake. Phosphorus concentrations meet the deep lowland lake standards but meet or exceed standards for deep seepage lakes.
- Phosphorus is the limiting nutrient in Pike Lake.
- The Rubicon River is the primary external source of phosphorus to Pike Lake. Approximately half of the Rubicon River's phosphorus load is contributed by the Village of Slinger wastewater treatment plant.
- The Lake's external phosphorus loads are substantially reduced by water at the Lake's inlet bypassing most of the Lake and immediately exiting the Lake through the outlet dam.
- Up to half of the Lake's total annual phosphorus loading may come from internal loading.
- While chloride concentrations are below State standards, they continue to increase and offer clear evidence of the impact of human-induced pollution. Even though chloride concentrations are below State standards, saltier environments preferentially favor many undesirable plants and animals.

As explained in Chapter II, management efforts to improve Pike Lake's water quality should focus on the following strategies:

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[9] *Bradley Steckart, Washington and Waukesha Counties Aquatic Invasive Species Coordinator, plans on completing a point-intercept survey in Pike Lake during 2017.*

Continue to Actively Track Key Water Quality Parameters

Water quality monitoring is an important tool helping allow the Lake's current condition to be quantified, longer term changes to be understood, and the factors responsible for change to be identified. Monitoring is a key factor to maintaining and improving Lake health. Therefore, regularly recurring water quality monitoring should be a high priority. To allow comparison with previously collected data and, thereby, allow trends to be identified, sample collection should continue at the site identified as the "deep hole" site (i.e., the point above the deepest part of the Lake). Laboratory samples should be collected in early spring shortly after ice out (e.g., early April) and at least once during mid-summer (e.g., late July). Field measurements (e.g., water clarity, temperature, and dissolved oxygen) should be collected much more frequently. At a minimum, samples should be analyzed for the following parameters:

- Field measurements
  - Water clarity (i.e., Secchi depth in the Lake)
  - Temperature (profiled over the entire water depth range at the deepest portion of the Lake with more frequent readings near the thermocline)
  - Dissolved oxygen (profiled over the entire water depth range at the deepest portion of the Lake with more frequent readings near the thermocline)
  - Specific conductance (near-surface sample, profiles with depth if equipment is available)
- Laboratory samples
  - Total phosphorus (near-surface sample with supplemental samples collected near the deepest portions of the Lake)
  - Total nitrogen (near-surface sample)
  - Chlorophyll-*a* (near-surface sample)
  - Chloride (near-surface sample)

Laboratory tests quantify the amount of a substance within a sample under a specific condition at a particular moment in time, and are particularly valuable benchmark values. Field measurements can often serve as reasonable surrogates for common laboratory tests. For example, water clarity decreases when total suspended solids and/or chlorophyll-*a* concentrations are high, samples with high concentrations of total suspended solids commonly contain more phosphorus, and water with higher specific conductance commonly contains more salt and, therefore, more chloride. Periodically sampling water while concomitantly running a targeted array of laboratory and field tests not only provides data for individual points in time, but can also allow laboratory/field test results to be compared. Once a relationship is established between laboratory and field values, this relationship may be used as an inexpensive means to estimate the concentrations of key water quality indicators normally quantified using laboratory data. Such data would supplement, not supplant, regularly scheduled laboratory sample analyses.

The Clean Lakes Monitoring Network (CLMN) provides training and guidance on monitoring lake health.[10] Volunteers commonly monitor water clarity, temperature, and dissolved oxygen throughout the open water season (preferably every 10 to 14 days) and basic water chemistry (i.e., phosphorus and chlorophyll-a concentrations) four times per year (two weeks after ice off and during the last two weeks of June, July, and August). Supplemental temperature/oxygen profiles collected at other times (e.g., other summer dates, nighttime summer, fall, winter) can provide additional insight. For example, oxygen profiles collected during midsummer nights, just before sunrise, help evaluate diurnal oxygen saturation swings. In addition, chloride should also be monitored once per year when

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[10] *More information regarding the CLMN may be found at the following website: http://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/clmn/default.aspx*

the Lake is fully mixed. Monitoring chloride concentrations allows the rate of concentration increase over time to be quantified. This will help discern the overall impact of cultural influence on the Lake and will help determine if chloride concentrations are approaching levels that could foster negative changes in the Lake's ecosystem.

In addition to the in-Lake monitoring, **water quantity and quality information should be collected from the Lake's inlet and outlet** (i.e., the Rubicon River) (medium priority). Notations should be made by the sampler regarding current and recent weather conditions, and a qualitative description should be recorded of flow and water quality (e.g., "inlet is very high and muddy", "most inlet flow is bypassing the Lake and discharging directly to outlet") and of the exact location, date, and time where the observation was made. Sampling parameters should include the following:

- Field Measurements
  - Flow rate
  - Water clarity (use transparency tubes, see below)
  - Temperature
  - Dissolved oxygen
  - Specific conductance
- Laboratory Measurements
  - Total phosphorus
  - Chlorophyll-*a*
  - Total nitrogen
  - Chloride
  - Total suspended solids

A wealth of information can be collected that help further clarify the Rubicon River's role in the water quality and quantity dynamics of Pike Lake. Field tests can be completed with simple tools and observations. Assuming volunteers are available, and since the techniques and equipment are simple and of modest cost, data can be regularly collected over long periods of time. The periodicity of data collection is related to ambient conditions – extreme or rare events may need more measurements, while long stretches of essentially stable conditions do not need frequent measurement.

Flow rate information allows the mass of a substance entering or leaving the Lake via the Rubicon River to be estimated. The most practical way of measuring flow is to measure the water surface elevation at a control section of the River and relate the stage elevation to flow by using empirical formulae or rating curves. The USGS measured the flow of the Rubicon River at the inlet and outlet of the Lake as part of a 1999/2000 study requested by SEWRPC and PLPRD as part of the Lake Management Plan update. Valid rating curves may still exist relating stream elevation to flow, or a rating curve can be developed that relates water elevation with flow.

Even if rating curves are not available, elevations at control sections should be recorded for later conversion to flow rate. These measurements can be collected manually or with automated equipment. **Collecting water flow rate information is a relatively low cost activity that can provide substantial value to future study of the relationship between the Rubicon River and Pike Lake,** and should, therefore, be given a medium priority. Furthermore, the Village of Slinger quantifies the rate at which the wastewater treatment plant releases water to the Rubicon River and the concentrations of phosphorus and values for other important water quality indicators. **The PLPRD should regularly request copies of discharge reports that the Village of Slinger submits to the WDNR.** Receiving and filing copies of this information is an easy method to expand the data base available to Pike Lake management efforts. Regularly filing this information in PLPRD records should be given a high priority.

The limited depth of water in the Lake's inlet and outlet channels can make direct clarity measurement impossible to measure; however, transparency tubes (sometimes called turbidity tubes) provide a convenient way to quantify water clarity in shallow water. Transparency tubes are available from several vendors and cost well under $100 each. Water Action Volunteer (WAV) stations may be established to quantify turbidity at important locations. **Water turbidity is commonly related to the amount of sediment and phosphorus in water and can provide a method to estimate loads when laboratory data are unavailable.** Other field tests can also be completed along with turbidity measurements (i.e., temperature, dissolved oxygen, conductivity) if field equipment is available. Given the low cost of field measurements, this data should be collected whenever flows are measured at the inlet and outlet, and that this effort be assigned a medium priority.

Regular water quality monitoring helps Lake managers promptly identify variations in Pike Lake's water quality and improves the ability to understand problems and propose solutions. Given the rapidly changing landscape in which Pike Lake is situated, water quality and the conditions influencing water quality can rapidly change. **Regular review and revision of water quality monitoring protocol and recommendations should be considered a high priority.**

Naturalize Pike Lake's Hydrology

Pike Lake was a spring lake before the Rubicon River was artificially diverted into the Lake to benefit a downstream mill dam in Hartford. The mill dam no longer produces power, therefore, it is no longer necessary that Pike Lake function as a reservoir to support milling. Diverting the Rubicon River into the Lake increased the size of the Lake's watershed by over 300 percent, substantially increasing the mass of sediment and pollutants reaching the Lake. Increased nutrient loads normally cause lakes to become more eutrophic. Allowing the Rubicon River to bypass Pike Lake in a fashion similar to what existed before artificial diversion could decrease Lake phosphorus loads by almost 80 percent. Conversely, if the channel that currently allows much of the River's flow to bypass the Lake were obstructed (e.g., by a beaver dam), and all of the Rubicon River's flow directly entered Pike Lake, phosphorus loading to the Lake could increase by nearly 25 percent. Therefore, **actions that mimic or restore the natural hydrology of the Rubicon River and Pike Lake are important to maintaining or improving Lake water quality, and should be given a high priority.**

The PLPRD has long recognized the Rubicon River's significant contribution to Pike Lake's nutrient and sediment loading, completing a project during 1995 that helped bypass more of the Rubicon River's flow past the Lake. The project included construction of a berm to obstruct flow from the Rubicon River into Pike Lake and excavating a channel between the Lake's inlet and outlet channels. Beginning in 1997, the berm partially washed out. By 2007, a beaver dam obstructed the bypass channel, and all Rubicon River flow was entering Pike Lake.[11] The PLPRD commissioned a new study to explore ways to more effectively bypass the phosphorus loads of the Rubicon River around Pike Lake and/or reduce phosphorus delivered to Pike Lake from the Slinger wastewater treatment plant.[12] The resultant report offered concepts to achieve these goals. These concepts included nonpoint source controls in the watershed, trapping River nutrients upstream of the Lake, bypassing the Rubicon River's flow around Pike Lake, increasing phosphorus removal efficiency at the treatment plant, closing the Slinger wastewater treatment plant and piping Slinger's wastewater to Hartford for treatment, and piping the Slinger wastewater treatment plant effluent to a point downstream of Pike Lake. The study concluded that a combination of nonpoint source control, advanced phosphorus removal at the Slinger wastewater treatment plant, replacing the inlet diversion dam with a cable dam, and continuous beaver management provided the best solution to reduce nutrient loading to Pike Lake. As was described in Chapter II, a fence-like structure was erected to encourage the River's inlet to directly enter the Lake's outlet channel. The current diversion structure likely allows some flow through the Lake during high-water periods.

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[11] *Hey and Associates, Inc.* Evaluation of Alternatives for Rubicon River Phosphorus Input Diversion, Pike Lake, Washington County, Wisconsin. *Project Number 08158, February 2010.*

[12] Ibid.

In general, management actions that restore natural ecosystem function and hydrology are commonly easier to permit and maintain than those that apply further artificial constraints to natural system function. The finding that the Rubicon River (and hence Slinger's wastewater treatment plant effluent) naturally bypassed the Lake makes concepts that modify the artificial lake/river connection even more favorable. More specifically, the "new channel along STH 60" option actually returns the Rubicon River to a route similar to that which existed before Pike Lake was converted to a reservoir to store the Rubicon River's flow to benefit the downstream mill. This concept is particularly interesting since it best emulates the natural hydrology of the local area. Therefore, this concept was analyzed in most detail by Commission staff.

Recent studies recommend an essentially straight bypass channel paralleling STH 60, connecting the inlet culvert area with the Lake level control dam area.[13] Coincidentally, this route closely approximates the pre-settlement course of the Rubicon River in the 1830s (see Map 4). This may not be a coincidence, since the abandoned natural channel of the Rubicon River may have provided the easiest crossing point over the wetland area north of the Lake, which would mean that the pre-settlement river channel is buried under the STH 60 embankment. The 2010 study proposes that the bypass channel divert all flow events below 60 cubic feet per second away from the Lake to achieve a 70 percent reduction in the annual phosphorus load to the Lake.

Since it best emulates the natural hydrology of the area, the recently proposed bypass channel design was scrutinized in more detail. Several details need to be considered if this plan were to be implemented, as described below:

- **Diversion channel design and location.** The concept proposed in the 2010 report suggests an essentially straight, ditch-like waterway paralleling STH 60. A straight ditch paralleling the roadway offers little habitat value, would serve as a conduit for polluted runoff leaving the roadway to enter the River with little to no attenuation, may imperil drivers due to its close proximity to the roadway, and would be highly vulnerable to pollution from fuels and other chemicals purposely or accidentally released on or near the roadway. Furthermore, the natural riverbed may be inaccessible because it is buried by fill placed for construction of STH 60. Other channel configurations could offer the same bypass function without the problems and risks of a roadside ditch bypass. For example, the Rubicon River appears to have once occupied a channel a little more than a quarter mile north of STH 60. A nature-like channel through this low wetland/floodplain area could provide excellent in-channel and riparian habitat value, would maintain and enhance floodwater storage and treatment functions, would pose fewer safety hazards, and would occupy land with little to no development potential. The new channel should be designed to emulate natural channels, and should include sinuosity, floodplains, channel bottom, and other features inspired by nearby natural sections of the Rubicon River. A well-designed channel in this area should not appear like or function as a man-made ditch.

- **Phosphorus load reduction benefits.** A channel emulating pre-settlement River conditions could eliminate essentially all Rubicon River through-Lake flow. The Lake's quiescent water allows much of the River's bedload, suspended sediment, and sediment-bound phosphorus to remain in the Lake, greatly increasing the total external pollutant load delivered to the Lake. Two attempts have been made to re-engineer the artificial River channel and redirect most of the River's flow around the Lake. Both of these attempts likely allow wet-weather flow from the River to flow through the Lake. Before human manipulation, floodwaters from the Rubicon River could backwater into Pike Lake, but the River's primary flow did not flow directly through the Lake. Returning the River's flow to a more natural channel condition north of STH 60 would better restore the hydrology of the Lake/River system to a state most like that naturally existed before European settlement and would more effectively reduce sediment and nutrient loads to the Lake.

[13] Ibid.

- **Dry weather Lake level maintenance.** Pike Lake's water levels decline during periods of dry weather. The current water levels are maintained by a dam – the artificially elevated Lake level may decrease the volume of groundwater volume entering the Lake and may increase seepage leaving the Lake near the dam. The dry-weather water contributions of the Rubicon River and the Slinger wastewater treatment plant help maintain desired dry-weather Lake elevations. Therefore, complete diversion of the entire Rubicon River's flow below 60 cubic feet per second could worsen undesirably low Lake Elevations, and these undesirably low elevations could stretch for longer periods of time.[14] Since dry-weather Lake elevation is partially maintained by flow from the River, the existing Lake/River connection should be maintained during low flow, and higher sediment-laden flows should bypass the Lake.

- **Downstream flood elevations.** Pike Lake is able to store considerable volumes of water due to its large size. If the Rubicon River were prevented from entering the Lake under all flow conditions, regulatory flood elevations could increase in downstream areas. Modifications to the Lake/River connection must consider this very important connection. Moreover, floodwater from the Rubicon River likely backwatered into the Lake through the Lake outlet under natural conditions, a situation that should be emulated as part of any channel naturalization program.

To be effective from a broad range of perspectives, any design approach that attempts to naturalize Pike Lake's hydrology should consider all the factors listed above. Example design considerations include, but are not limited to, the following:

- Under natural conditions, the high flows in the River likely backwatered into the Lake through the Lake's natural (possibly intermittent) outlet channel. In such cases, the Lake probably detained floodwater from the River, but very little floodwater flowed through the Lake. The artificial diversion of the River into the Lake completely changed this dynamic, allowing the River to actively flow through the Lake, trapping sediment and nutrients carried by the River, increasing the Lake's fertility. Recent efforts have helped reduce the amount of River water flowing through the Lake, but wet weather flow still has the potential to flow through the Lake. Moving the channel well away from the Lake minimizes the potential for River water to flow through the Lake. A much lower overall volume of water would enter the Lake through backwatering as opposed to artificial situations that allow the River to actively flow through the Lake.

- In addition to greatly reducing the volume of River water entering the Lake, the naturalized course of the River returns the River's primary course and floodway to a location that completely bypasses the Lake. Much of the sediment carried in floodwater is entrained by high velocity flow, allowing sediment to saltate along the River's bottom. If designed properly, floodwater will gently back up into the Lake, but most of the entrained sediment will be transported downstream by the River or settle in floodplain and wetland areas.

- The water contributed by the River is critical to the Lake's ability to maintain desired water level elevations during dry weather. The future channel connecting the Lake with the River (either the existing inlet or outlet channel can be repurposed) can be designed to flow in two directions. As such, the channel would allow excess water to leave the Lake during fair weather, feed water to the Lake during dry periods, provide a modest maintenance flow to downstream portions of the River, allow floodwater to backwater into the

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[14] *The Hey and Associates report entitled Evaluation of Alternatives for Rubicon River Phosphorus Input Diversion dated February 2010 included an alternative that would divert all of the Rubicon River's flow below 60 cubic feet per second around the Lake to reduce phosphorus loads to the Lake by 70 percent. However, this alternative still allows high flows to enter the Lake yet deprives the Lake of baseflow during drought, a situation that would exacerbate the problem of maintaining desired Lake levels during drought. We suggest that the opposite approach should be employed. That is, divert high flows and allow low flows to enter the Lake.*

Lake, and yet allow the River's active higher discharge flow that carries heavy sediment loads to completely bypass the Lake. To achieve this goal, a nature-like grade-control riffle or (less preferably) a weir would be constructed at a strategic location along the newly naturalized course of the Rubicon River or immediately upstream of the location where the Rubicon River currently passes under the railroad right-of-way currently owned by the State of Wisconsin Department of Transportation.[15] The new grade-control riffle or weir would have an elevation essentially equivalent to the desired Lake elevation, allowing much of the River's low flows to pass to the Lake. Given the available data, preliminary analysis suggests that probable historical channel routes appear to provide the conditions needed to accomplish this goal.[16] Some of these locations require modification to the Lake's outlet dam/channel, while others would involve deepening of existing marsh and/or creation of wetland areas. All alternatives require detailed consideration of permitting issues (e.g., wetlands, floodplains, dams), landowner desires and cooperation, and tangential benefits (e.g., water quality and habitat enhancement).[17]

- Naturalizing the course of the River has great potential to enhance aquatic system connectivity, riparian habitat function, and the ability of the River's floodplain to improve water quality. Navigation, aquatic organism and fish passage, floodwater detention, nutrient/sediment trapping and removal, and flotsam and debris management can all be improved.

To help explain how these ideas lay out on the ground and function, SEWRPC staff developed several concepts. A wide spectrum of design approaches can achieve the goals outlined above. Two concepts are described in this report and are illustrated in Figure 45 and Figure 46. These concepts are labelled "Naturalized Channel Concept" and "Downstream Control/Wetland Enhancement Concept Creation" in the balance of this report. Each is described in more detail below.

Naturalized Channel Concept

The naturalized channel concept returns the River's flow to an alignment similar to that suggested by historical documents, yet preserves river frontage for property owners immediately downstream of the dam whose properties adjoin the artificially ditched channel segment of the River. The elevation difference between the upstream diversion point and the river bed just downstream of the dam would be spread over a series of riffles (see Figure 47). The basic elements include construction of a new nature-like channel, construction of a control reach to maintain Lake water levels, retaining the ditched channel downstream of the dam but naturalizing it to the extent possible, and decommissioning or modifying the dam (see Figure 45 for more detail). Under this approach, **the Rubicon River's flow would be transferred from the artificial inlet ditch to a nature-like channel that shunts the River's primary water, sediment, and debris flow capacity through existing floodplain and wetland areas to the north of the shooting range.** The new naturalized channel would then bend to the south, follow the periphery of the shooting range's upland area, connect to the ditched lake outlet channel just downstream of the dam, and then

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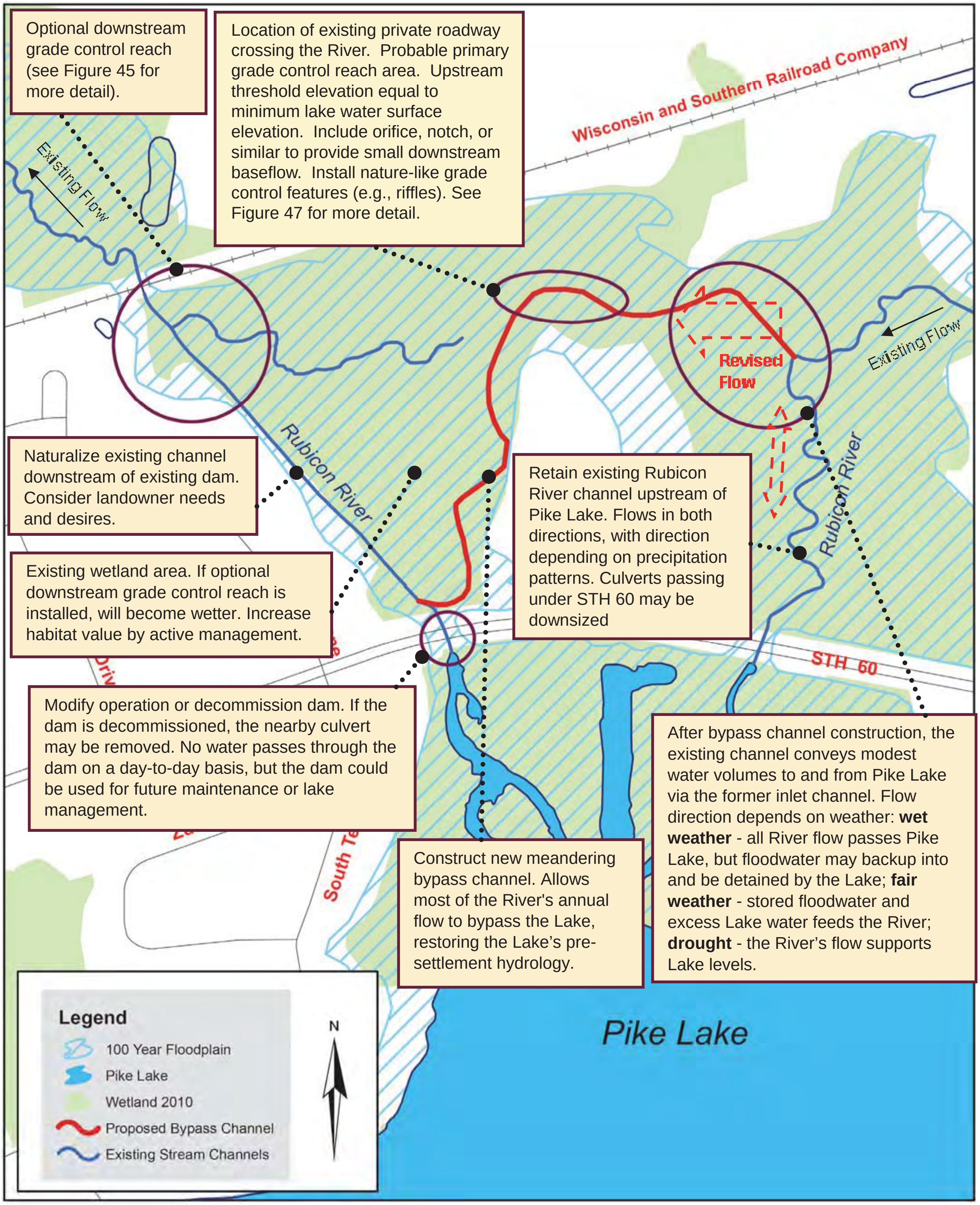
[15] *The railway is operated by the Wisconsin & Southern Railroad Company.*

[16] *Channel traces are plainly visible on historical aerial photography (see Figure 39, particularly the 1950 image). A portion of one such channel remains identified in the 2010 hydroline set (see Map 4, note the tributary entering the River just upstream of the railroad crossing). These legacy channels represent potential options for the route of the naturalized River channel. These areas are already mapped as floodplain and cross lands owned by the Hartford Conservation and Gun Club and the City of Hartford, both of which may be receptive to conservation-themed initiatives that help improve water quality and habitat value*.

[17] *SEWRPC staff considered several alternative design concepts to return the primary flow of the Rubicon River to a more natural route bypassing Pike Lake. Developing details of all scenarios is well beyond the scope of the commissioned aquatic plant management plan.*

Figure 45

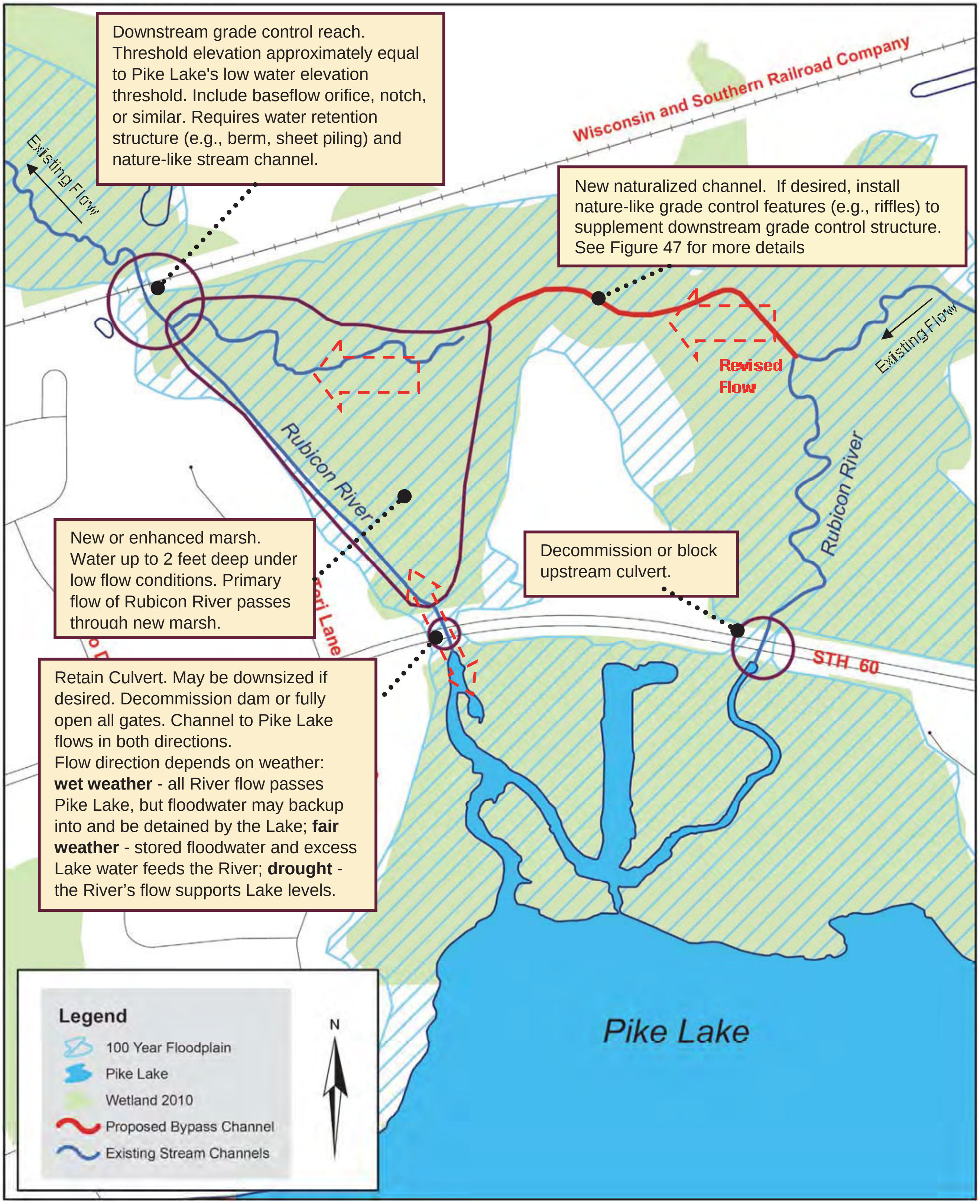
NATURALIZED CHANNEL DESIGN CONCEPT EXAMPLE: 2017



Source: SEWRPC.

Figure 46

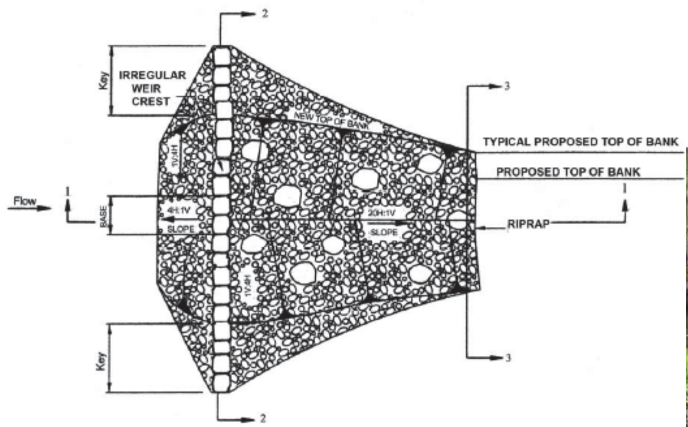
DOWNSTREAM CONTROL REACH/WETLAND ENHANCEMENT CONCEPT EXAMPLE: 2017



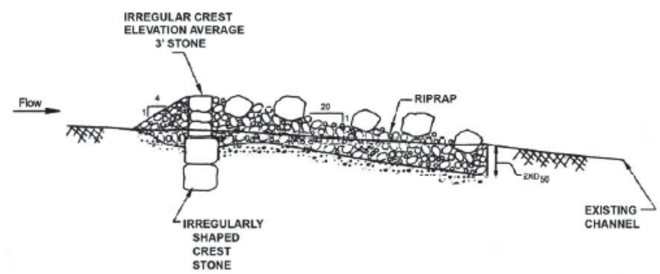
Source: SEWRPC.

Figure 47

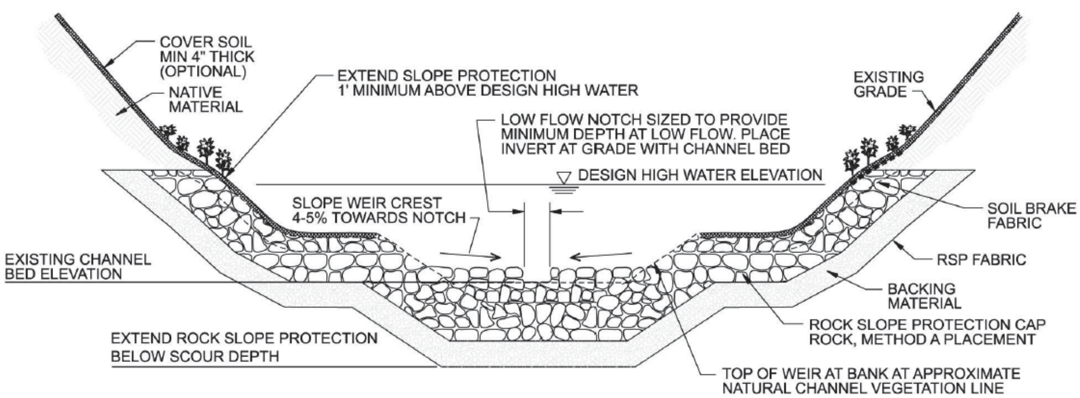
EXAMPLE DESIGN ELEMENTS – NATURALIZED CHANNEL GRADE CONTROL CONCEPTS



TYPICAL RIFFLE STUCTURE PLAN VIEW



PROFILE VIEW



SECTION AT WEIR

Note: Avoid excessive use of stone - avoid pavement-like or armored appearance. All installations must include choker material to bind and seal streambed. Coarse wood structure may be used to supplant stone in some applications. Grade control elements must be able to withstand high flow – key pieces must be sized to remain immobile and structures must extend beyond flood-prone width. Distribute vertical fall over several short (e.g., < 6-inch tall) riffles, and avoid channel sections with > 2 feet of vertical fall over 100 feet of channel length.

Sources: David T. Williams, Ph.D., P.E., David T. Williams and Associates, Engineers, david@dtwassoc.com and William White, John Beardsley, Scott Tomkins, Waukegan River Illinois National Nonpoint Source Monitoring Program Project, Illinois State Water Survey, January 2011; Caltrans, Fish Passage Design for Road Crossings: An Engineering Document Providing Fish Passage Design Guidance for Caltrans Project, May 2007; and SEWRPC.

would proceed downstream following the present channel alignment. While it may be cheaper and more natural to construct a nature-like channel directly connected to downstream areas, a number of homes downstream of the dam would lose River frontage, a situation that is not likely to be acceptable to these property owners. Habitat conditions in the downstream ditched channel would be improved as agreeable to riparian land owners. These improvements could include remeandering the channel, introducing coarse woody structure, and removing fill that reduces floodplain connectivity and increases flood elevations.

A small private roadway crosses the floodplain just north of the shooting range clubhouse, creating a point that is likely filled and that must likely be restored for construction of a naturalized channel (see Figure 45). The roadway fill segment would likely be an ideal location for constructing grade-control riffles and establishing the lake level control threshold. The threshold elevation would be equivalent to the minimum permitted lake level elevation. This allows most average and high flow of the River to pass directly downstream, but also would allow the Rubicon River to contribute water to the Lake during drought periods through the existing inlet channel. To maintain flow in the downstream channel during drought, a small maintenance flow would be conveyed downstream through the grade-control threshold with an orifice, notch, or other means. The existing inlet channel to Pike Lake would allow floodwater to backflow into the Lake during wet weather and be detained, and would allow excess water to drain out of the Lake during fair weather. Since the culvert upstream of the Lake that passes under STH 60 would no longer convey the River's primary flow, it could be downsized in the future, if desired. **With this approach, sediment laden floodwater would entirely bypass the Lake when water is not needed for Lake level maintenance, flood mitigation benefits provided by the Lake to downstream areas could be preserved with carefully designed, and Pike Lake would be reliably relieved of the role of being a prime repository for much of the River's upstream sediment and phosphorus load.**

Since the River would no longer flow through the Lake, the dam and the downstream culverts under STH 60 would not need to convey flood flows associated with the River, and could be decommissioned. If desired, the dam could be retained to allow water levels to be manipulated for specific purposes (e.g., infrastructure repair, weed control) but this benefit may not outweigh the investment in operation, maintenance, and potential liability.

The new nature-like channel could be partially supplanted with an engineered, fish passable, grade control structure just upstream of the point where the Rubicon River passes below the Wisconsin and Southern Railway. This would cause existing floodplain and wetland to become shallow marsh. While it could supplement the naturalized channel concept, it could also wholly replace it. More details about this approach are found in the following section.

Downstream Control Reach/Wetland Enhancement Concept

The naturalized channel concept relies upon the Lake level being maintained by a control threshold elevation just north of the shooting range clubhouse. The downstream control reach/wetland enhancement concept relocates the Lake level control threshold to a downstream location near the Wisconsin and Southern Railroad bridge over the River (see Figure 46 and Figure 48). This means that **the entire wetland/floodplain area west of the shooting range and downstream of STH 60 would now have a water elevation equivalent to Pike Lake, converting the existing wetland area to shallow marsh likely resembling present conditions at the north end of Pike Lake just above the Lake level control dam** (see Figure 49). See Figure 50 for a typical existing appearance of Rubicon River channel just upstream of the railroad bridge. The River would be allowed to thread through this enhanced marsh, and eventually would create a defined channel as sediment is deposited into the new shallow marsh.

The downstream control reach/wetland enhancement concept requires construction of the upstream half of the naturalized channel to divert water from the artificial Pike Lake inlet channel. Under this concept, the artificial inlet channel downstream of the point of diversion would no longer convey the Rubicon River's flow, or water moving from the Lake to the River. Therefore, the culvert passing the Rubicon River inlet flow to Pike Lake would need to be blocked or removed. The culvert downstream of the lake level control dam would remain, but could be downsized in the future if desired since it no longer conveys the bulk of the River's flow.

Figure 48

WISCONSIN AND SOUTHER RAILROAD BRIDGE DOWNSTREAM OF PIKE LAKE: 2017

Source: SEWRPC.

As part of this concept, a nature-like channel would be constructed just upstream of the railroad bridge. **The channel would be designed to pass fish and other aquatic organisms and be navigable to small watercraft (e.g., kayaks and canoes), but still may be classified as a dam for permitting purposes since it does not restore the River's original bed configuration.** The installation would include grade-control riffles, a water-surface control threshold, and a low-flow support mechanism similar to those described above as part of the naturalized channel concept. A berm, sheet piling, or other water detention infrastructure would need to be installed to maintain higher water levels equivalent to Pike Lake, potentially requiring filling a small portion of wetland near the railroad bridge. This installation would fully supplant the current lake-level control dam, which therefore could be decommissioned.

Other In-Lake and Watershed Water Quality Practices

A wide variety of practices can be employed in the Lake and the Lake's watershed to benefit water quality. Examples with particular merit for Pike Lake include the following examples.

- **Maintain healthy and robust native plant populations.** This goal should be considered a high priority. Native aquatic plants compete for nutrients with algae and undesirable plant species, which in turn can slow growth of nuisance vegetation. Some species (particularly muskgrass) foster biogeochemical processes that remove phosphorus from the water column, reducing the fertility of the Lake. Additional information regarding aquatic plant management is found in "Issue 1: Aquatic Plant Management."

Figure 49

EXISTING RUBICON RIVER OUTLET CHANNEL UPSTREAM OF LAKE LEVEL CONTROL DAM: 2017

Source: SEWRPC.

- **Protect and enhance buffers, wetlands, and floodplains.** Protecting these features helps safeguard areas that already benefit the Lake with little to no additional input of money and labor. On a landscape scale, it is important to protect all such features. However, with a narrower focus on Pike Lake, **it is most important to protect and enhance buffers, wetlands, and floodplains in areas directly tributary to the Lake.** Most of these areas are located east and southeast of the Lake, with smaller areas south and west of the Lake. Protecting and enhancing buffers, wetlands, and floodplains in this area should be assigned a high priority. Such features also exist in the much larger Rubicon River watershed upstream of Pike Lake, and also warrant protection. However, since much of the pollution emanating from the upper Rubicon River watershed bypasses the Lake, the relative importance of such features is reduced. Therefore, protecting and enhancing buffers, wetlands, and floodplains in the Rubicon River watershed upstream of the Lake should be currently assigned a medium priority. If action is taken to naturalize the hydrology of the Rubicon River, actions in the Rubicon River watershed will have little impact on Pike Lake. In this case, when referencing Pike Lake's water quality, protecting and enhancing buffers, wetlands, and floodplains in the Rubicon River should be reassigned a low priority. Implementing this recommendation could involve the following examples.
    - Continue to limit development in SEWRPC-delineated environmental corridors (see Map 17 in Chapter II of this report) through various town, village, city, and County ordinances.

Figure 50

TYPICAL RUBICON RIVER BED AND BANK CONDITIONS UPSTREAM OF WISCONSIN AND SOUTHERN RAILROAD BRIDGE: 2017

Source: SEWRPC.

- Continue to actively enforce shoreland setback requirements and construction site erosion control, drainage, and stormwater management ordinances.[18]
- Control the spread of invasive species and, when possible, eradicate invasive species in shoreland and wetland areas. A common wetland aquatic invasive species is reed canary grass (*Phalaris arundinacea*). The distribution of reed canary grass in the Pike Lake watershed is illustrated in Figure 51.[19] A guide to managing reed canary grass is found in Appendix J. Many other invasive plant species are already found in, or threaten, Wisconsin wetlands.[20]
- Provide information to shoreland property owners along mapped tributaries that describes how near-shore and terrestrial buffers benefit the Lake. Encourage landowners to protect buffers where they remain. Enhance, restore, or create buffers in favorable areas where they are highly degraded or absent. Information such as installation instructions, typical costs, and potentially a list of service and material suppliers can help engage landowners. This program would be most successful if accompanied by financial incentives that helps defray landowner design, permitting, and installation costs.
- U.S. Department of Agriculture Farm Service Agency programs such as the Conservation Reserve Program (CRP) and affiliated Conservation Reserve Enhancement Program (CREP) can be applied in agricultural areas. Both of these programs routinely employ practices that use vegetation to slow and filter stormwater runoff. If thoughtfully designed and located, groundwater recharge may also be enhanced. Grants may also be available for novel initiatives such as cropped buffers, a practice that compensates farmers to grow lower value crops that help reduce erosion and filter runoff. Additionally, rain gardens can be beneficially installed in residential areas.
- Implement a formalized shoreline best management practice and shoreline buffer enhancement program. This program encourages installing rain gardens, disconnecting roof and driveway drains, substituting bioswales for piped stormwater conveyance, buffers along shorelines, and similar practices. WDNR recently introduced a "Healthy Lakes" grant program that could help fund some of these efforts, particularly in areas of urban lakeshore development.[21]
- Actively seek conservation or use easements or purchase wetlands, floodplains, and uplands in key areas. Buffers can be preserved indefinitely and their ecological value can be enhanced which in turn improves habitat, pollutant filtering, and hydrologic functions.
- Monitor and protect natural vegetation and take steps to control invasive species that threaten ecological value. An example would be to monitor and control reed canary grass in wetlands and shorelands. This species, a two- to nine-foot tall grass, spreads and quickly displaces native wetland plants that help treat polluted water and provide desirable habitat. Consequently, visually evaluate appropriate locations along shorelines and other watershed areas to determine whether reed canary grass is a widespread problem. If reed canary grass is found to be a significant issue, the infestation should be controlled and incrementally eradicated.

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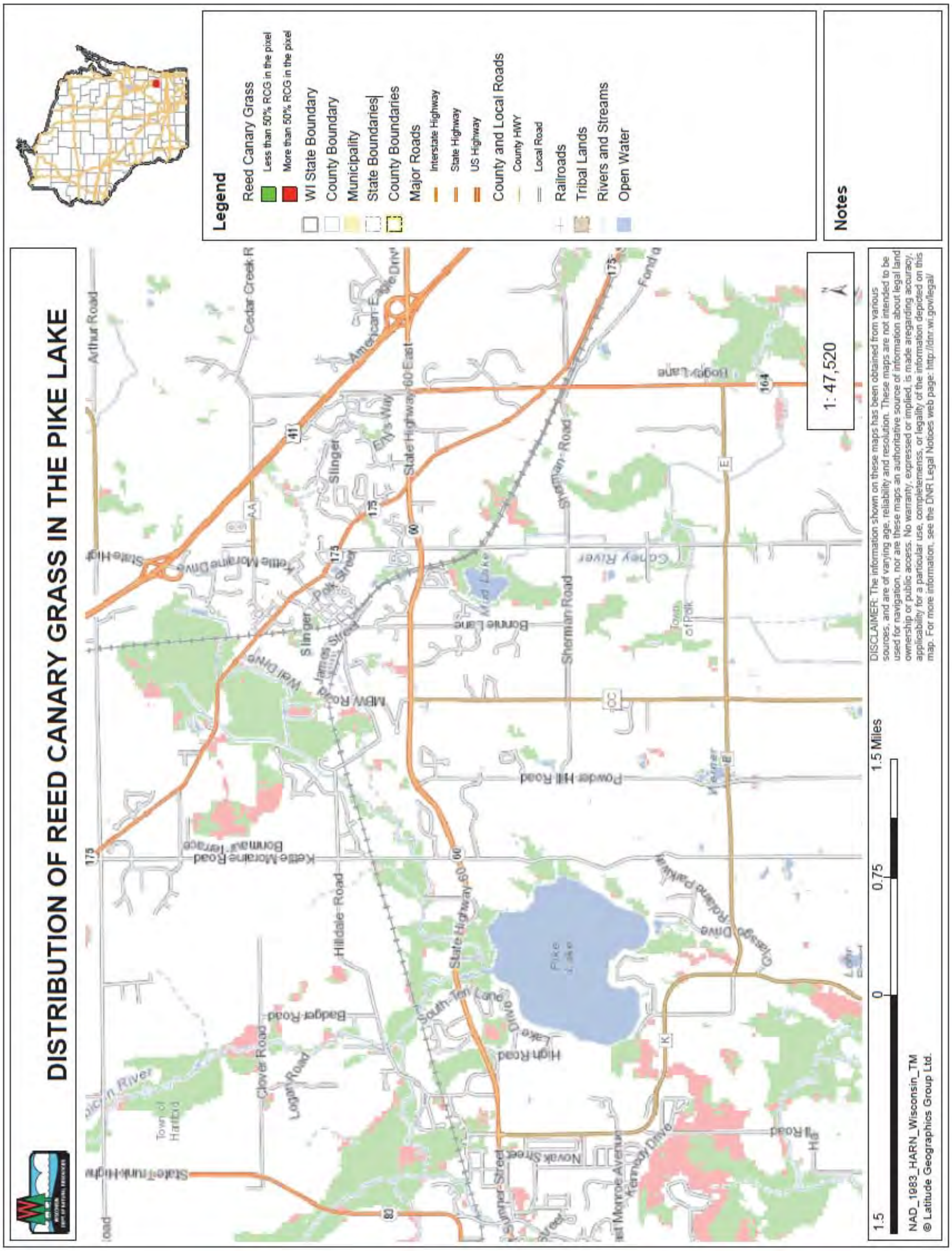
[18] *Ordinances are commonly overlooked and/or poorly understood. Stakeholders can increase the impact of existing ordinances by educating the regulated community and reporting infractions when education fails to provide results.*

[19] *More information about reed canary grass and a host of other invasive species, including control strategies, can be found at the Southeastern Wisconsin Invasive Species Control Consortium (SEWISC) website http://sewisc.org/invasives/invasive-plants/86-reed-canary-grass?gclid=Cj0KEQjw_qW9BRCcv-Xc5Jn-26gBEiQAM-iJhf3jlHu-J74MRfRxHcVNeHek9R5fos_d3T796-QyxkAIaAlPe8P8HAQ*

[20] *Common and early detection wetland invasive plant species are described on the WDNR's website at the following address: http://dnr.wi.gov/topic/Invasives/documents/wetland_species.pdf*

[21] *More information regarding the WDNR Healthy Lakes program may be found at the following website: http://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/healthylakes/default.aspx*

Figure 51



Source: Wisconsin Department of Natural Resources.

- ○ Maintain or restore natural stream channel form and function. The floodplains of natural stream channels temporarily store water, improving water quality and reducing downstream flood peaks. Ditched and/or straightened channels should be naturalized to restore such function whenever possible. This commonly involves restoring a meandering channel form, eliminating fill that constrains floodwaters, and allowing streams to access floodplains.

- **Monitor and actively manage woodlands.** Monitoring and actively managing woodlands should be considered a medium priority. Perhaps the largest threat to many Southeastern Wisconsin woodlands is the combined problem of a) disease and insects that destroy the native tree canopy and b) invasive plants such as buckthorn (common buckthorn, *Rhamnus cathartica*, and glossy buckthorn, *Frangula alnus*) that inhibit or prevent native tree regeneration. Introduced pests have attacked ash, elm, butternut, and oak species. New pests are on the horizon that target black walnut, beech, and other trees. Existing woodlands should be kept free of invasive plant species and actions should be taken to prepare the woodland for the arrival of pests. For example, increasing the diversity of tree species through careful stand management and or planting can help assure that complete canopy loss does not occur in the future. State programs are available to assist woodland owners with stand management, tax implications, and professional forestry advice.

- **Encourage pollution reduction efforts along shorelines.** Applying relevant best management practices is considered a high priority. Example pollution reduction measures include minimizing or eliminating fertilizer use wherever practical, ensuring cars are not leaking fluids, maintaining rain gardens to mitigate impermeable surface runoff volume and quality, preventing soil erosion, properly disposing leaf litter and grass clippings, and properly storing salts and other chemicals. Communicating best management practices, and engaging in a campaign to encourage their use (e.g., offering to collect grass clipping or leaves) will incrementally reduce shoreline contribution to water quality problems.

- **Conscientiously maintain stormwater detention basins.** This suggestion should be considered important, and is currently given a medium priority. As stormwater basins age, performance can deteriorate. A few examples reasons for decreased performance include basins filling with sediment, plugged or malfunctioning inlet and outlet pipes, and flow short-circuiting due to excessive aquatic plants or improper design. Design specifications should mandate regular inspection and maintenance to ensure that basins function properly.[22] Regularly inspecting and monitoring detention basin conditions is essential for effectively evaluating the need for both routine and major maintenance such as dredging and disposal of accumulated sediment. Educating local citizens and pond owners to understand the importance of maintenance can help promote sustained water quality benefits.

- **Stringently enforce construction site erosion control and stormwater management ordinances.** This should be considered a medium priority. However, this should increase to high priority if major construction or other land-use changes are planned within the watershed. Ordinances must be enforced by the responsible regulatory entities; however, local citizens can help by reporting potential violations to the appropriate authorities (see “Issue 9: Plan Implementation” section). [23]

- **Manage in-Lake phosphorus sources.** Phosphorus has been deposited in Pike Lake since the Lake’s creation, with dramatically increased loading occurring during the past 170 years. This phosphorus is stored in bottom sediment. Some of this phosphorus re-enters the water column, especially during the summer. Data suggests that internal loading is likely a significant component of Pike Lake’s overall phosphorus budget. While strategies do exist that help reduce the internal phosphorus loading, most approaches work best when ongoing external loads are low and controlled. **Pike Lake receives significant phosphorus loads from the Rubicon River. Hence, Pike Lake is not likely to be a good candidate for in-Lake phosphorus control strategies in its current condition.** Therefore, in-Lake phosphorus control options should be assigned a low priority. If external phosphorus loading is greatly reduced, internal phosphorus loading may become

[22] *Technical standards for design and maintenance of wet detention basins and other stormwater management practices can be found at* *http://dnr.wi.gov/topic/stormwater/standards/postconst_standards.html.*

[23] *Enforcing construction site erosion control and stormwater management ordinances was also mentioned in Washington County’s* Erosion Control & Stormwater Management Ordinance adopted in January 1998, the City of Hartford’s Chapter 20 of the Harford Municipal Code, and *the Village of Slinger’s* Village Code of Ordinances.

the primary source of this nutrient to the Lake. If the Lake continues to be excessively eutrophic, in-Lake phosphorus control strategies will likely become a high priority. Common in-Lake phosphorus strategies include aeration, chemical inactivation using alum, hypolimnetic discharge, and hypolimnetic withdrawal and on-shore treatment

- **Maintain septic systems.** Septic system maintenance is considered a high priority. Although sanitary sewers serve lakefront properties, septic systems are still used in other areas of the watershed. Septic system maintenance is regulated by Washington County. Outreach to educate septic system owners on system maintenance could positively impact water quality with minimal investment. For example, this effort could include a program where septic system owners register to be automatically reminded of when their septic tanks require service. Washington County provides information regarding operation and maintenance of private onsite wastewater treatment systems on its website and provides an educational poster. Amongst other things, this guidance recommends that mound-type septic systems be pumped at two-year intervals, and other system types by pumped every three years. Septic maintenance is most important to the Lake water quality where septic systems are located close to the Lake itself or streams directly tributary to the Lake. Septic maintenance initiatives should therefore selectively target these areas.

Implementing these recommendations will help maintain or improve Pike Lake's water quality and maintain or enhance the value of most human and wildlife uses. Washington County distributes a document addressing many of the recommendations covered in the water quality and subsequent sections of this report.[24]

ISSUE 3: CYANOBACTERIA AND FLOATING ALGAE

As was described in Chapter II, algae is an ongoing issue of concern to Lake residents. However, no strong evidence supports the need for immediate, specially targeted algal control efforts. Consequently, the recommendations provided in this section focus on monitoring algae, preparing Lake residents how to respond to excessive algal growth (should any occur in the future), and promoting conditions that help discourage or suppress future algal growth. The four recommendations are:

- Monitor water-borne algae populations. This effort should focus on tracking chlorophyll-a concentrations as was described in the water quality monitoring recommendations. This effort should be considered a high priority. If large amounts of suspended algae begin to be noticed in the future (as was the case in 2015), monitoring should be expanded to include toxic algae identification (medium priority). Samples can be sent to the Wisconsin State Laboratory of Hygiene.
- Warn residents to stay out of the water during algal blooms. This should be considered a high priority unless testing positively confirms the absence of toxic algae. Therefore, methods should be developed to rapidly communicate water conditions not conducive to body contact. The following rule of thumb precautions may prove useful in Lake management:[25]
    - Choose recreational areas that do not have noticeably green water, as wind can concentrate cyanobacteria (formerly known as blue-green algae) blooms into near-shore areas. Do not boat, swim, water ski, or engage in other water-based recreation in or through water that looks like "pea soup," green or blue

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[24] *Washington County's shoreland property owner guidebook can be found at the following website: http://www.co.washington.wi.us/uploads/docs/LU_ShlndPropOwnerBook_Copy.pdf*

[25] *Personal communication with Gina LaLiberte, Statewide Blue-Green Algae Coordinator. For questions regarding lake health and algae, and algae testing residents may contact WDNR's Washington County Lake Coordinator Heidi Bunk, or Gina LaLiberte of the WDNR staff.*

paint, or that has a scum layer or puffy blobs floating on the surface. People can be exposed through inhalation and need not touch contaminated water.

  - Do not let children play with scum layers, even from shore.
  - Always offer fresh, clean drinking water to pets. Do not let pets swim in or drink lake water experiencing algal blooms or noticeably green water.
  - Always take a shower after significant contact with any surface water (whether or not a cyanobacteria bloom appears to be present; surface waters may contain other potentially harmful bacteria and viruses).
  - After swimming, pets should be immediately washed before they self-groom.
  - Avoid swallowing untreated surface water – it may contain pathogens other than cyanobacteria that could make you ill.

- **Maintain and improve ambient lake water quality** by implementing recommendations set forth in the "Issue 2: Water Quality" section of this chapter. This should be considered a high priority.

- **Maintain a healthy aquatic plant community** to compete with algal growth. This can be promoted by implementing recommendations provided in the "Issue 1: Aquatic Plant Growth" section of this chapter. This should be assigned a high priority.

Implementing these recommendations will help manage the impact of excess algae growth in Pike Lake. Nevertheless, conditions noted during summer 2015 raise concern about excessive algal growth. **If future monitoring reveals excessive or highly increased levels of algal growth, or if toxic strains are identified, these recommendations should be reevaluated (high priority).** Reevaluation should consider the continued utility and suitability of all relevant Lake management plans and ongoing efforts.

ISSUE 4: SHORELINE MAINTENANCE

The 2014 shoreline assessment found lengths of unbuffered, eroded and/or unprotected shoreline and failing shoreline protection infrastructure. Based upon these findings, shoreline maintenance is considered an important issue. Based upon the field assessment and Lake-user goals, three major shoreline maintenance recommendations are made:

- **Encourage repair or removal of failing "hard" shoreline structures.** This should be considered a high priority. Since this is a voluntary program focused primarily at private landowners, communication and education and grant-based cost-share or donation–based programs are key elements to effective implementation. Since hard shoreline infrastructure typically provides little habitat value, the length of hard shoreline protection should be minimized. Hard infrastructure should only be maintained where it is truly needed to protect shorelines from active erosion. Hard shoreline protection structures used to "tidy up" the water's edge should be targeted for removal or naturalization (see below). Removing and repairing shoreline protection structures may require engineering and technical expertise, consequently, the WDNR and shoreline restoration experts should be consulted and integrated into the process.

- **Encourage installation of "soft" or "natural" shoreline protection** (e.g., bio-logs, buffers, native plantings, and native aquatic plantings) wherever appropriate (medium priority). **Focus on areas where little to no shoreline protection exists, excessive erosion is taking place, and where it is possible to replace hard shoreline protection.** Natural shoreline protection often has the additional benefit of deterring geese from congregating in shoreland areas and becoming a nuisance to some individuals. Should shoreline protection measures take the form of shoreline buffers (as recommended in the "Issue 2: Water Quality" section of this chapter), funding may be available through the WDNR "Healthy Lakes Initiative."[26]

- **Enforce shoreline setbacks/shoreland zoning rules** as discussed in the "Issue 2: Water Quality" section (high priority).

Implementing programs that encourage stable and ecologically friendly shorelines will significantly contribute to the health of the Lake in terms of wildlife populations, sedimentation, and water quality. To track success, **shoreline restoration goals should be established and a new shoreline assessment should be completed after a restoration program has been implemented** (medium priority). This will help document the degree of participation and progress.

ISSUE 5: WATER QUANTITY

Pike Lake's water elevations vary in accordance with prevailing weather conditions. According to the PLPRD and the dam operator, it can be difficult to maintain requisite Lake water elevations during protracted dry periods. This in turn raises concern regarding the ability to maintain desired Lake elevations in the future, especially as it relates to the long-term reliability of the Lake's water supply. A significant component of the Lake's water budget is groundwater, raising additional concern regarding local groundwater supplies. Several recommendations can help assure the reliability of Pike Lake's water supply in the long term.

- **Monitor Lake water-surface elevation and the flow of the Rubicon River.** Monitoring and data collection should be assigned a high priority. The elevation of the Lake is influenced by several factors including precipitation, evaporation, other weather conditions, the position of the gate at the outlet dam, and point-source discharges to the Rubicon River upstream of Pike Lake (e.g., the Slinger wastewater treatment plant). Variations in these factors are the primary reasons why water levels fluctuate in the Lake. Having on-the-ground local information relating these factors helps advance water resource engineering concept development and design. To better understand the inter-relationship of these and other factors, the following data should be collected by the PLPRD. Several of the data sets are components related to the recommendations for "Issue 2: Water Quality."
    - **Lake water-surface elevation.** Water elevations can be measured anywhere on the Lake using a staff gage or automated equipment. Staff gages can be as simple as precisely measuring the distance to the water surface from a point of known elevation with a measuring tape. Permanently installed, graduated, direct-read scales are also commonly used for this purpose. Automated data recorders using pressure transducers, compressed air, sonar and other techniques are commercially available and can allow near-continuous measurement and posting of live conditions to a Lake-information page. The reference point elevation for any system should referenced to National Geodetic Vertical Datum, 1929 adjustment, or to North American Vertical Datum of 1983 to allow comparison with other data sets. Water levels should be collected at least once per week, more frequently during periods of heavy runoff
    - **Lake inflow and outflow.** The flow of the Rubicon River as it enters and leaves the Lake should be quantified. The outlet flow can be estimated using Lake water elevation, weir position, and an appropriate formula. A formula can also be developed that relates the channel characteristics and water depth in the Rubicon River to flow. Rating curves may already be available that directly relate River water elevations and flow.[27] Flow information should be collected or estimated at the same time and frequency as Lake level elevation.

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[26] *The WDNR sponsors a number of web-based to assist shoreland property owners. The following website helps shoreland property owners locate resources: http://dnr.wi.gov/topic/shorelandzoning/*

[27] *Consult the U. S. Geological Survey in Madison, Wisconsin for more information regarding rating curves they may have developed.*

- ○ **Other information.** The PLPRD should make it a matter of practice to compile other relevant information collected by others. These data help managers and designers to better understand the relationship between Lake water-surface elevation, water inflow, and water outflow. For example, the PLPRD should consider obtaining copies of the Village of Slinger wastewater treatment plant discharge monitoring reports that the Village already prepares for WDNR, and should keep a record of weather conditions using data from nearby weather data collection points (e.g., National Weather Service stations, personal observations by Lake community and watershed residents).

Figure 52

EXAMPLE RAIN GARDEN

NOTE: Further details are provided on Natural Resource Conservation Service and Wisconsin Department of Natural Resources websites at: http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/ndpmctn7278.pdf; and http://dnr.wi.gov/topic/Stormwater/raingarden/

Source: U.S. Department of Agriculture, Natural Resource Conservation Service.

- **Implement measures that promote stormwater storage and infiltration in existing urban areas.** Implementing this recommendation could involve:
  - ○ **Enhancing the ability of rainfall and snowmelt to be detained, filtered, and/or infiltrated into soils.** This could be most easily achieved by installing modern BMPs associated with low-impact development, including rain gardens (see Figure 52) and other stormwater infrastructure specifically designed and carefully located to slow runoff, improve water quality, and promote infiltration.[28] Examples of simple infiltration measures are voluntarily directing stormwater to areas of permeable soil and favorable topography or encouraging reduced extent of impermeable surfaces. These can be promoted by active educational outreach, providing instructions and supplies to property owners, and/or through subsidies. Some practices and projects, especially on public property, may qualify for partial funding through the WDNR "Healthy Lakes" initiative. Given the relatively low cost and relative ease of implementation, this recommendation should be given a high priority.
  - ○ **Integrating advanced stormwater management practices into local permitting processes.** A step toward a more comprehensive approach would be an ordinance requiring onsite stormwater management practices such as detention, permeable conveyance, limits to impervious surface, porous pavement, or other measures as a condition of issuance of a building permit affecting the overall impermeable surface area of a parcel. Such ordinances should be actively enforced when they exist, or should be incorporated into existing ordinances. This should be considered a high priority.
  - ○ **Retrofitting current stormwater management systems with modern stormwater management infrastructure elements** Public works projects can be completed within existing urban development. Elements such as stormwater retention/infiltration basins, bioswales, permeable conveyance, and other infrastructure elements can help reduce the impact of existing development on water quality and quantity. In certain instances, stormwater infrastructure built for new development can be located and sized to manage stormwater runoff from existing development. Such projects are commonly difficult to execute

[28] *Rain gardens are depressions that retain water, are vegetated with native plants, and help water infiltrate into the ground rather than enter the Lake through surface runoff. Rain gardens can help reduce erosion and the volume of unfiltered pollution entering the Lake and can also help augment baseflow to the Lake.*

and costly. Therefore, this recommendation should be generally assigned a low priority. Nevertheless, some retrofits can be easily integrated into system updates and should be considered whenever practical.

- **Reduce the impact of future urban development on groundwater.** This recommendation can be implemented by:

  - Controlling new development on the watershed's best groundwater recharge potential areas. This helps assure local and sometimes regional groundwater flow systems are protected. Control can include excluding certain types of development, maintaining recharge potential through thoughtful design, and minimizing impervious surface area. Consider purchasing or obtaining protective or conservation easements on open lands with high and very high groundwater recharge potential. Promote policies that protect or enhance infiltration on public lands such as the nearby State Forest. The recommended priorities for preserving recharge areas are:[29]

    - High priority should be given to areas identified as having high and very high groundwater recharge potential within the direct groundwatershed of Pike Lake.
    - Medium priority should be given to portions of the Lake's direct groundwatershed with a medium groundwater recharge potential and areas identified as having high and very high groundwater recharge potential in areas in the Rubicon River groundwatershed upstream of Pike Lake.
    - Low priority should be assigned to low groundwater recharge potential areas of Pike Lake's direct groundwatershed and medium and low groundwater recharge potential areas within the Rubicon River's groundwatershed upstream of Pike Lake.

  - Requiring conformance with the infiltration recommendations in the current City of Hartford Municipal Code,[30] and Washington County's Erosion Control and Stormwater Management Ordinance (high priority).[31]

  - Purchasing land or conservation easements on agricultural and other open lands with high groundwater recharge potential (medium priority).

  - Encouraging developers to incorporate infiltration in stormwater management designs and encouraging local government to consider groundwater recharge as an integral part of new development and infrastructure replacement proposals. Some Southeastern Wisconsin communities have integrated analysis of groundwater and surface water impact into the process through which developers obtain permission to build new buildings and subdivisions (high priority).[32]

  - Closely examine proposals that would export groundwater from the Lake's groundwatershed (medium priority).

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[29] *The recharge potential of areas with the watershed are contrasted in Map 14.*

[30] *City of Hartford's* Chapter 20 of the Hartford Municipal Code, *p. 16. This recommendation can be found at: https://ci.hartford.wi.us/DocumentCenter/View/255.*

[31] Washington County Code – Chapter 17 – Erosion Control and Stormwater Management, *p. 20-22. This recommendation can be found at: http://www.co.washington.wi.us/uploads/docs/2_CCO_ordchap17.pdf.*

[32] *The Village of Richfield in Washington County is such an example. More information may be found at the Village's website: http://www.richfieldwi.gov/index.aspx?NID=300*

- **Continue to protect sensitive areas and areas providing water quality and habitat benefits by enforcing town, village, and city zoning ordinances** as discussed in the "Issue 2: Water Quality" section of this chapter. This recommendation should be given a high priority.

- **Consider the Lake's water budget when operating the dam or proposing modification to inlet and outlet flow regimens.** Pike Lake's dry-weather elevation is substantially supported by groundwater and the Slinger wastewater treatment plant discharge. **Schemes that bypass flow should focus on high-water discharge to avoid lower dry-weather water surface elevation in Pike Lake.** This recommendation is assigned a medium priority under prevailing conditions. However, should serious consideration be given to modifying the inlet, outlet, or bypass channels, this should be considered a high priority.

As with the other recommendations made in this chapter, any unanticipated or large future changes in Lake surface elevation spurs the need for a re-evaluation of the recommendations above. Consequently, **periodic re-evaluation of the suitability of water elevations is recommended** and is given a high priority.

ISSUE 6: RUBICON RIVER BYPASS CHANNEL

The recommendations related to this issue are integral to water quality and quantity management and are, therefore, addressed under "Issue 2: Water Quality" and "Issue 5: Water Quantity."

ISSUE 7: RECREATION

As was discussed in Chapter II, the primary recreational uses for Pike Lake (in no particular order) are boating, fishing, swimming, and support of State Forest activities. Since maintaining high quality recreation is a priority under this plan, it is necessary to emphasize the recommendations that help maintain or encourage these recreational uses.

Boat counts suggest that Pike Lake is occasionally subject to boat densities at the upper end or slightly exceeding desirable levels during some weekends and holidays. Excessive boat density decreases the ability of the Lake to safely, sustainably, and satisfactorily support a wide range of activities. This means that the potential for use conflicts, safety concerns, and environmental degradation is slightly higher than desirable during extreme use periods. To help avoid such problems, **existing boating regulations should be reviewed for compatibility with current conditions and expectations** (high priority), and **ordinances should be conscientiously enforced during peak use periods.** Given the variability of boat density, enforcement should be considered a low priority for most week days, but high priority for summer-season weekends and holidays.

The Pike Lake Unit of the Kettle Moraine State Forest is the largest single owner of Pike Lake shoreline and also occupies critical groundwater recharge areas, large public swimming beach/shoreland recreational areas, and unique upland recreational areas. As such, the PLPRD should endeavor to strengthen cooperation and ties with the State Forest management team. When possible, The PLPRD should actively participate with review and revision of the Park's master plan. Conversely, the PLPRD should share this plan's results and recommendations with the WDNR staff that manage the Forest. **The PLPRD should solicit input regarding this plan from WDNR Forest management and should actively request cooperation in achieving the plans goals.** Cooperation with the Pike Lake Unit of the Kettle Moraine State Forest should be considered a high priority.

The water quality, aquatic plant management, water quantity, fish and wildlife, and other issues are integral to various forms of recreational use. Therefore, the recommendations called for in other parts of this chapter promote actions answering to the recreational needs.

ISSUE 8: FISH AND WILDLIFE

Fish and wildlife depend upon the Lake's health. The presence of fish and wildlife increases the Lake's recreational use, aesthetic appeal, overall enjoyment by humans, and the functionality of the Lake as an ecosystem. To enhance fish and wildlife within the Pike Lake watershed, the following recommendations are made:

- Understand fishery information, actively participate in WDNR planning processes, and support management recommendations. The WDNR presently suggests the following actions be taken:

  - Reduce walleye daily bag limit to three fish, minimum length 18 inches.
  - Further assess the northern pike and panfish populations.

  The PLPRD may be able to provide the WDNR with information useful to fish management strategies. For example, reports of spawning areas, creel surveys, angler pressure, baitfish and prey abundance, and other conditions. This task should be given a medium priority.

- **Protect valuable fish habitat and avoid disturbing vulnerable fish.** Fish require a variety of habitats to successively engage in all life-cycle critical functions. For example, the locations where fish breed may be very different than where they feed. Fish can enter shallow water and may be quite vulnerable to harm at certain points during the year. While the types of habitat vary by season and with fish, a few types of habitat are clearly related to preserving populations of popular fish. For example, protecting rocky shorelines helps maintain suitable walleye spawning areas, while seasonally flooded stands of stiff vegetation are important to spawning northern pike. **The health of the walleye and northern pike fisheries can be protected by limiting high-speed boating and other disruptive activities in such areas during spawning periods.** WDNR fisheries staff can help PLPRD identify the locations of these areas and the timing of protective measures. This should be considered a medium priority.

- **Identify and remove barriers to passage of fish and aquatic organisms.** Even ephemeral streams, which only flow seasonally, can provide fish passage and two-way access to spawning and nursery grounds. Streams and ditches connected to the Lake flow through wetlands which may be critical feeding, breeding, and spawning habitat for many fish species, including northern pike. Barriers to fish and aquatic organisms are often categorized by permanence. Barriers that occasionally block passage and which may be temporary in nature include examples such as debris jams, sediment and railroad ballast accumulations, and channel overgrowth by invasive plants. Examples of permanent barriers include culverts that are perched, too narrow, or too long and dams. These barriers vary greatly in their ease of removal. Best practices include prioritization of barrier removal along a single reach, with highest habitat benefits and highest ease of removal given the highest rank for remediation. Ozaukee County's Fish Passage Program is well developed and a good resource when establishing a fish passage program.[33] Identifying, prioritizing, and ultimately removing fish passage barriers should be considered a high priority.

- **Improve in-Lake aquatic habitat by maintaining or installing large woody structure and/or vegetative buffers along shorelines.** The vegetative communities along the Lake's shoreline have been simplified through traditional landscaping practices, a situation that reduces habitat for aquatic organisms. Improving in-Lake habitat should be considered a medium priority. Implementing this recommendation could take the form of educational or incentive-based programs to encourage riparian landowners to install "fish sticks"[34] (Figure 53), to allow fallen trees to remain in the water, and to develop buffer systems along the shoreline. WDNR grant money is available through the "Healthy Lakes" program on a competitive basis for the implementation of "fish sticks" projects. Installing buffers will have the added benefit of deterring geese populations from congregating on shoreline properties and promoting better water quality.

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[33] *See website at http://www.co.ozaukee.wi.us/619/Fish-Passage*

[34] *Natural shorelines generally have hundreds of fallen trees per mile along the shoreline. "Fish sticks" is a term coined for engineered installation of woody debris (logs) along lake shorelines to mimic these natural conditions. Generally these projects involve anchoring logs into the shore so that the log is oriented perpendicular to the shoreline. See Appendix E, "Healthy Lakes Initiative."*

- **Adopt best management practices to improve wildlife habitat.** This should be considered a medium priority, although this should increase to high priority if wildlife populations decline. The acceptance and employment of best management practices can be fostered through voluntary, educational, or incentive-based programs for properties adjacent to shoreline and riparian areas, and by directly implementing these practices on public and protected lands. Some special interest non-governmental organizations ("NGOs", e.g., Walleyes for Tomorrow, Pheasants Forever, Ducks Unlimited, Trout Unlimited) foster habitat improvement projects and collaborate with land owners to install beneficial projects. As part of implementing this element, a list of best management practices and relevant NGOs should be compiled and provided to landowners.

- **Promote proper implementation of the aquatic plant management plan** described earlier in this chapter (see "Issue 1: Aquatic Plant Growth" section) specifically as it relates to avoiding inadvertent damage to native species. This should be assigned a high priority.

Figure 53

EXAMPLE
"FISH STICKS" PROJECTS

Source: Wisconsin Department of Natural Resources.

- **Preserve and expand wetland and terrestrial wildlife habitat, while making efforts to ensure connectivity between these natural areas.** This could be achieved by implementing the buffer and wetland protection recommendations provided in the "Issue 2: Water Quality" section of this chapter. Benefit could also be accrued by reconnecting floodplains to ditched and straightened tributary streams. These reconnected floodplains detain floodwater, improve floodwater quality, may enable groundwater recharge, and provide seasonally wet areas that are of great value for a wide range of birds, fish, amphibians, insects, and terrestrial animals. This should be assigned a high priority.

- **Mitigate water quality stress on aquatic life and maximize areas habitable to desirable fish.** The primary issue in this category is current low oxygen and supersaturated oxygen concentrations during some seasons at certain depths. The water quality recommendations discussed earlier in this chapter call for measures to address those oxygen conditions, and implementation of those recommendations should be considered a high priority. Other stressors may develop in the future (e.g., new invasive species and other water quality concerns) and conditions should be carefully monitored for their impact on aquatic life.

- In general, tracking the diversity and abundance of fish and wildlife would help future Lake managers detect change. Consequently, **continued monitoring of fish populations and periodic recording of the types of animals found on and in the Lake and within its watershed** is also a high priority. Monitoring **data can be collected from government agencies, non-governmental organizations (e.g., Audubon Society), and from volunteers** around the Lake and throughout the watershed.

ISSUE 9: IMPLEMENTATION

The methods to implement the plan vary with the type of recommendation made. For example, several important recommendations relate to municipal or county ordinance enforcement (e.g., shoreline setbacks, zoning, construction site erosion control, drainage, and boating). Such agencies often have limited inspection and enforcement staff to assure rules are respected and properly applied. Consequently, the following recommendations target local citizens and management groups, and are made to enhance the ability of the responsible entities to monitor and enforce existing regulations. **These tasks should be considered central to the PLPRD's mission.**

- **Maintain and enhance relationships with the County, the WDNR managers of the Pike Lake Unit of the Kettle Moraine State Forest, the Village of Slinger, municipal zoning administrators, and law enforcement officers.** This helps build open relationships with responsible entities and facilitates efficient communication and collaborations wherever needed. <u>High priority</u>.
- **Vigilantly track planned and ongoing activities within the watershed** that have the potential to affect the Lake (e.g., construction, filling, erosion), **maintain good records (e.g., notes, photographs),** and judiciously notify relevant regulatory entities of problems whenever appropriate. <u>High priority</u>.
- **Educate watershed residents about relevant ordinances and update ordinances as necessary to face evolving use problems and threats.** This will help ensure that residents know why these rules are important, that permits are required for almost all significant grading or construction, and that such permits offer opportunities to regulate activities that could harm the Lake. <u>High priority</u>.

In addition to regulatory enforcement, a number of voluntary and/or incentive-based programs can be considered, all of which focus proactive effort to protect and manage the Lake.

- **Encourage key PLPRD members to attend meetings, conferences, and/or training programs to build available lake management knowledge** and to enhance institutional knowledge and capacity. In recognition of limits on financial resources and time available for such activities, this element is assigned a <u>medium priority</u>. Some examples of capacity-building events are the Wisconsin Lakes Conference (which targets local lake managers) and the "Lake Leaders" training program (which teaches the basics of lake management and provides ongoing resources to lake managers). Both of these are hosted by the University of Wisconsin-Extension. Additionally, in-person and on-line courses, workshops, training seminars, regional summits, and general meetings are valuable. Attending such events should include follow-up documents/meetings so that the lessons learned can be communicated to the larger Lake group.
- **Continue to reinforce stakeholder inclusivity and transparency with respect to all Lake management activities.** If stakeholders do not fully understand the aims and goals of a project, or if they do not trust the process, excess energy can be devoted to conflict, a result benefiting no one. For this reason, this element is assigned <u>high priority</u>. These efforts should be implemented through public meetings and postings, social media, newsletters, emails, and any other mechanisms that help gather a full suite of information and build consensus. In this way, all data and viewpoints can be identified and considered, and conflicts can be discussed, addressed, and mitigated prior to finalizing plans and implementing projects.
- **Foster and monitor efforts to communicate and record concerns, goals, actions, and achievements to benefit future Lake managers.** Institutional knowledge is a powerful tool that should be preserved whenever possible. Actions associated with this are sometimes embedded in organization bylaws (e.g., recording minutes). A <u>high priority</u> should be assigned to developing and communicating institutional knowledge to current and future PLPRD members. Open communication helps further increase the capacity of Lake management entities. This may take the form of annual meetings, internet websites, social media, newsletters, emails, reports, and other means; all of which help compile and report actions, plans, successes, and lessons learned. These records should be kept indefinitely to benefit future generations.

- **Apply for grants when available** to support implementation of programs recommended under this plan (see Appendix K for examples). This should be considered a high priority. This process requires coordination, creativity, and investment of stakeholder time to be effective. Table 26 provides examples of state grant application opportunities that can potentially be used to implement plan recommendations. Many other sources or grant funding are commonly available. Examples include charitable institutions, businesses, a large number of federal agencies, and in-kind donations. It is often desirable to collaborate with project partners to increase the scope and thereby appeal of projects to grantors.

  Individual lakeshore property owners may also be eligible for funding through the WDNR Healthy Lakes Grant program (see Appendix E for more details), but the PLPRD must apply on the property owners behalf. The PLPRD is a qualified sponsor and the State of Wisconsin's Healthy Lakes Implementation Plan has been fully integrated into the comprehensive planning goals and recommendations of this plan. In addition, also note that the PLPRD is eligible for a Board of Commissioners of Public Lands loan program to implement projects for this Lake (see Appendix L).

- **Encourage Lake users and residents to actively participate in future management efforts.** Not only does this effort help assure community support, but also supplements the donor and volunteer pool working toward improving the Lake. This should be considered a medium priority.

Additionally, as discussed in Chapter II, **a plan should be created that highlights action items, timelines, goals, and responsible parties** (high priority). This document will help ensure that the plan recommendations are implemented in a timely, comprehensive, transparent, and effective manner. An action plan can help ensure that all responsible parties are held accountable for their portions of the plan's implementation.

As a final note, to promote plan implementation, **actively reach out and educate Lake residents, users, and governing bodies regarding the content and goals of this plan.** A campaign to communicate the most important information should therefore be given a high priority. This outreach/education effort must include a message that recognizes and stresses that this plan is a dynamic document that uses the best available information, goals, and situation at a set point in time. As such, **the plan should continually evolve to incorporate new ideas and new data.**

SUMMARY AND CONCLUSIONS

The future will undoubtedly bring change to the Pike Lake watershed. For example, projections suggest that some of the agricultural land use in the watershed of today will give way to urban residential land use. It is critical that proactive measures be actively pursued that lay the groundwork for effectively dealing with, and benefiting from, future change. Working relationships with appropriate local, County, and State entities need to be nurtured now and in the future to help protect critical environmentally valuable areas in the watershed during development, to implement recommended actions, and to instill attitudes among current and future leaders and residents that will foster cooperation and coordination of effort on many levels.

To help implement plan recommendations, Table 27 summarizes all recommendations and their suggested priority level. Additionally, Maps 18 through 20 summarize and illustrate where key recommendations should be implemented. These maps will provide current and future Pike Lake managers with a visual representation of where to target management efforts.

As stated in the introduction, this chapter is intended to stimulate ideas and action. The recommendations should, therefore, provide a *starting* point for addressing the issues that have been identified in Pike Lake and its watershed. Successful implementation of the plan will require vigilance, creativity, cooperation, and enthusiasm from local management groups, State and regional agencies, Washington County, municipalities, professional service providers, and Lake residents. The recommended measures foster water quality and habitat protection necessary to maintain or enhance lake and watershed conditions. This in turn promotes the natural beauty and ambience of Pike Lake and its ecosystems and the enjoyment by its human population today and in the future.

Table 26

EXAMPLE WDNR GRANT PROGRAMS SUPPORTING LAKE MANAGEMENT ACTIVITIES

Category	Program	Grant Program	Maximum Grant Award	Minimum Financial Match	Application Due Date	Examples of Potentially Eligible Issues as designated in Chapters II and III
Water	Surface Water Grants	Aquatic Invasive Species (AIS) Prevention and Control	Education, Prevention, and Planning Projects: **$150,000**	25%	December 10	Issues 3 and 9
			Established Population Control Projects: **$200,000**	25%	February 1	
			Early Detection and Response Projects: **$20,000**	25%	Year-Round	
			Research and Development: annual funding limit of **$500,000**	25%	Year-Round	
			Maintenance and Containment: **permit fee reimbursement**	25%	Year-Round	
		Lake Classification and Ordinance Development	**$50,000**	25%	December 10	Issues 1, 2, 4, 5, and 7
		Lake Protection	**$200,000**	25%	February 1	All
		Lake Management Planning: Large and Small Scale	Small-Scale: **$3,000**	33%	December 10	
			Large Scale: **$25,000**	33%	December 10	
	Citizen-Based Monitoring Partnership Program		**$4,999**		Spring	Issues 1 and 2
	Targeted Runoff Management	- -	Small-Scale: **$150,000**	30%	April 15	Issues 1, 2, and 3
			Large-Scale: **$1,000,000**	30%	April 15	
	Urban Nonpoint Source & Stormwater Management	- -	Design/construction: **$150,000**	50%	April 15	
			Property Acquisition: **$50,000**	50%	April 15	
Conservation & Wildlife	Knowles-Nelson Stewardship Program	Acquisition of Development Rights		- -	May 1	Issues 1, 2, 3, 5, and 8
		Natural Areas		- -	February 1, August 1	
		Sport Fish Restoration	- -	50%	February 1	Issue 8
		Streambank Protection		- -	February 1, August 1	Issues 1, 2, 3, 6, 8
Boating	Boat Enforcement Patrol	- -	Up to **75% reimbursement**	None	Various	Issue 7
	Recreational Boating Facilities	- -	Up to **50%of total eligible cost**	50%	- -	Issue 7
Recreation	Knowles-Nelson Stewardship Program	Acquisition and Development of Local Parks	- -	- -	May 1	Issues 7, 8
		Habitat Area	- -	- -	February 1, August 1	
		Urban Green Space	- -	- -	May 1	

Note: More information regarding these example grant programs may be found online at the following address: http://dnr.wi.gov/aid/grants.html. Additional Federal, state, and local grant opportunities are available.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 27

SUMMARY OF RECOMMENDATIONS

Recommendation Number	Strategies and Tactics	Suggested Priority Level
ISSUE 1: AQUATIC PLANT GROWTH		
1	Manually remove of nuisance plants by riparian landowners in nearshore areas	LOW
2	Hand pull or retain a DASH contractor to control Eurasian water milfoil. These methods may also be used to control other non-native plants (curly-leaf pondweed and starry stonewort).	MEDIUM
3	Support biological control measures targeting Eurasian water milfoil.	HIGH
4	Chemically treat Eurasian water milfoil in early spring.	
a	Current abundance and nuisance levels.	NOT RECOMMENDED
b	Only If future populations reach nuisance levels or displace native plants.	MEDIUM
c	If treatment occurs, sample lakeshore water supply wells as part of treatment monitoring.	LOW
d	If treatment occurs, monitor herbicide chemical residues.	HIGH
5	Periodically collect and evaluate aquatic plant and water quality information.	HIGH
6	Re-evaluate Lake management plan to address change. Periodically reevaluate aquatic plant community (i.e., every three to five years or whenever data is available). Consider completing a point-intercept evaluation as early as 2017 to help identify starry stonewort population changes. Adjust aquatic plant management plan recommendations as necessary.	HIGH
7	Implement an invasive species education, prevention, and monitoring program (i.e. Clean Boats Clean Waters). Focus on boat launch sites.	HIGH
8	Implement of “Issue 2: Water Quality” recommendations to reduce conditions encouraging nuisance aquatic plant growth.	HIGH
ISSUE 2: WATER QUALITY		
1	Monitor and track key water-quality and quantity parameters.	
a	Lake water quality and lake-surface elevation.	HIGH
c	Monitor flow and water quality within the Lake’s inlet and outlet.	MEDIUM
d	Obtain and file copies of discharge reports from the Village of Slinger wastewater treatment plant.	HIGH
e	Regularly review and revise water quality monitoring protocol.	HIGH
2	Naturalize Pike Lake’s Hydrology.	HIGH
3	Maintain robust native aquatic plant community.	HIGH
4	Protect and enhance buffers, wetlands, and floodplains.	
a	Pike Lake direct watershed – current and future conditions.	HIGH
b	Rubicon River watershed upstream of Pike Lake under current conditions.	MEDIUM
c	Rubicon River watershed upstream of Pike Lake with naturalized hydrology.	LOW
5	Monitor and actively manage woodlands.	MEDIUM
6	Encourage pollution reduction measures along shorelines.	HIGH
7	Conscientiously maintain stormwater detention basins.	MEDIUM
8	Stringently enforce construction site erosion control and stormwater management ordinances.	MEDIUM, HIGH during periods of significant construction.
9	Manage in-lake phosphorus sources.	LOW
10	Maintain septic systems.	HIGH
ISSUE 3: CYANOBACTERIA AND FLOATING ALGAE		
1	Monitor water-borne algae populations.	HIGH
2	When algae levels are excessively high, expand monitoring to include toxic strain identification.	MEDIUM
3	Warn residents to stay out of the water during algal blooms.	HIGH unless testing confirms toxic algae are absent.
4	Maintain and improve water quality (integral to Issue 2 above).	HIGH
5	Maintain a healthy aquatic plan community (integral to Issue 1 above).	HIGH
6	Periodically re-evaluate algae management strategy.	HIGH

Table 27 (continued)

Recommendation Number		Strategies and Tactics	Suggested Priority Level
ISSUE 4: SHORELINE MAINTENANCE			
1		Encourage repair or removal of failing hard shoreline structures. Retain protection only where genuinely needed for erosion control.	HIGH
2		Encourage installation of soft or natural shoreline protection when a need for shoreline genuinely exists.	MEDIUM
3		Enforce shoreline setback and shoreland zoning ordinances.	HIGH
4		Develop shoreline restoration goals. Resurvey shoreline condition to monitor progress.	MEDIUM
ISSUE 5: WATER QUANTITY			
1		Monitor Lake water-surface elevation and flow of the Rubicon River. Measure flow at both the lake inlet and lake outlet. Compile information already recorded by other entities for other uses.	HIGH
2		Promote stormwater storage and treatment in existing development.	
a		Enhance performance of existing landscape and infrastructure.	HIGH
b		Integrate advanced stormwater management processes into local permitting processes.	HIGH
b		Retrofit current urban development with modern stormwater management practices.	LOW
3		Reduce the impact of future urban development.	
a		Prevent or limit development in important groundwater recharge areas.	
i		High and very high groundwater recharge potential with the Lake's direct groundwatershed (does not include the Rubicon River).	HIGH
ii		Medium groundwater recharge potential with the Lake's direct groundwatershed and high/very high recharge potential in the Rubicon River watershed.	MEDIUM
iii		All other areas not listed in i and ii above.	LOW
b		Require conformance with the infiltration requirements of the City of Hartford and Washington County.	HIGH
c		Purchase land or conservation easements.	MEDIUM
d		Incorporate infiltration into new stormwater management systems and consider groundwater protection ordinances.	HIGH
e		Closely examine development schemes that export groundwater from the watershed.	MEDIM
4		Continue to protect sensitive areas by enforcing local ordinances.	HIGH
5		Consider the Lake's annual water budget when operating the dam or modifying inlet/outlet flow regimens).	MEDIUM under current conditions HIGH if consideration is given to inlet/outlet configuration changes
6		Reevaluation of the above recommendations if water levels fluctuate more than anticipated or desired.	HIGH

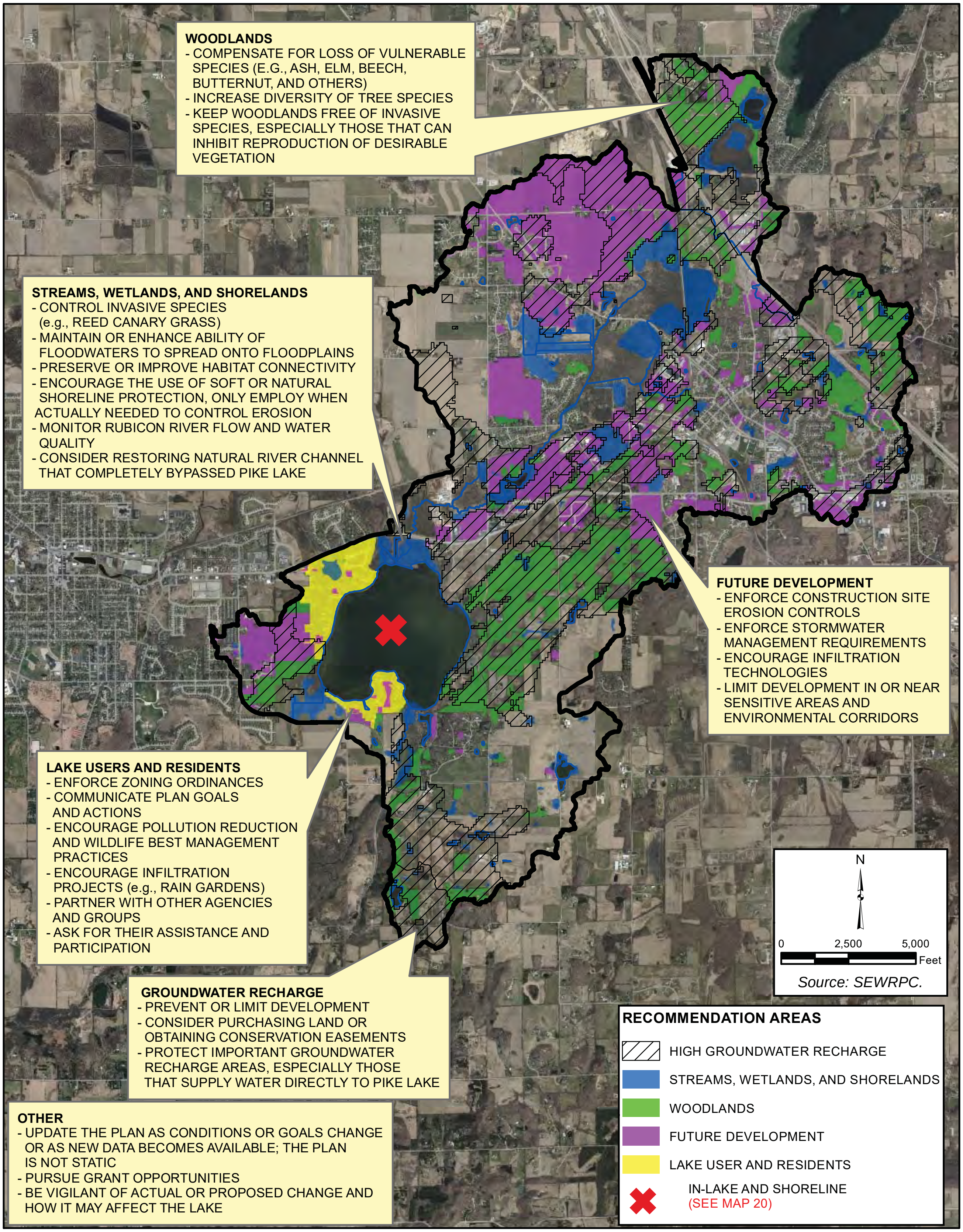
Table 27 (continued)

Recommendation Number		Strategies and Tactics	Suggested Priority Level
ISSUE 6: RUBICON RIVER BYPASS CHANNEL			
		All recommendations are addressed under "Issue 2 Water Quality" and "Issue 5 Water Quantity."	- -
ISSUE 7: RECREATION			
1		Review boating ordinances for compatibility with current conditions and expectations.	HIGH
2		Conscientiously enforce boating ordinances.	HIGH – peak use periods (summer weekends and holidays LOW – all other times
3		Actively partner with management of the Pike Lake Unit of the Kettle Moraine State Forest.	HIGH
4		Implement water quality, aquatic plant management, water quantity, fish and wildlife and other recommendation of this plan, all of which support recreational use.	- -
ISSUE 8: FISH AND WILDLIFE			
1		Understand, participate in, and support WDNR fishery management recommendations.	MEDIUM
2		Protect fish and fish habitat from molestation.	MEDIUM
3		Identify and remove fish/aquatic organism passage barriers.	HIGH
4		Improve in-lake habitat.	MEDIUM
5		Promote wildlife habitat best management practices.	MEDIUM
6		Ensure proper implementation of the aquatic plant management plant.	HIGH
7		Preserve and expand wetland and terrestrial habitat and connectivity.	HIGH
8		Mitigate water quality stress on aquatic life and maximize habitat areas that can be used by desirable fish and wildlife.	HIGH
9		Periodically monitor fish and wildlife populations.	HIGH
ISSUE 9: IMPLEMENTATION			
1		Maintain and enhance relationships with local units of government.	HIGH
2		Vigilantly track planned and ongoing activities in the watershed.	HIGH
3		Educate watershed residents about relevant ordinances and ordinance updates.	HIGH
4		Build community lake management knowledge.	MEDIUM
5		Reinforce inclusivity and transparency with respect to lake management activities.	HIGH
6		Foster and monitor communication with future lake managers.	HIGH
7		Apply for grants.	HIGH
8		Encourage Lake users to actively participate in future management efforts.	MEDIUM
9		Create a plan highlighting action items, timelines, goals, and responsible parties.	HIGH
10		Actively publicize this plan.	HIGH

Source: SEWRPC.

Map 19

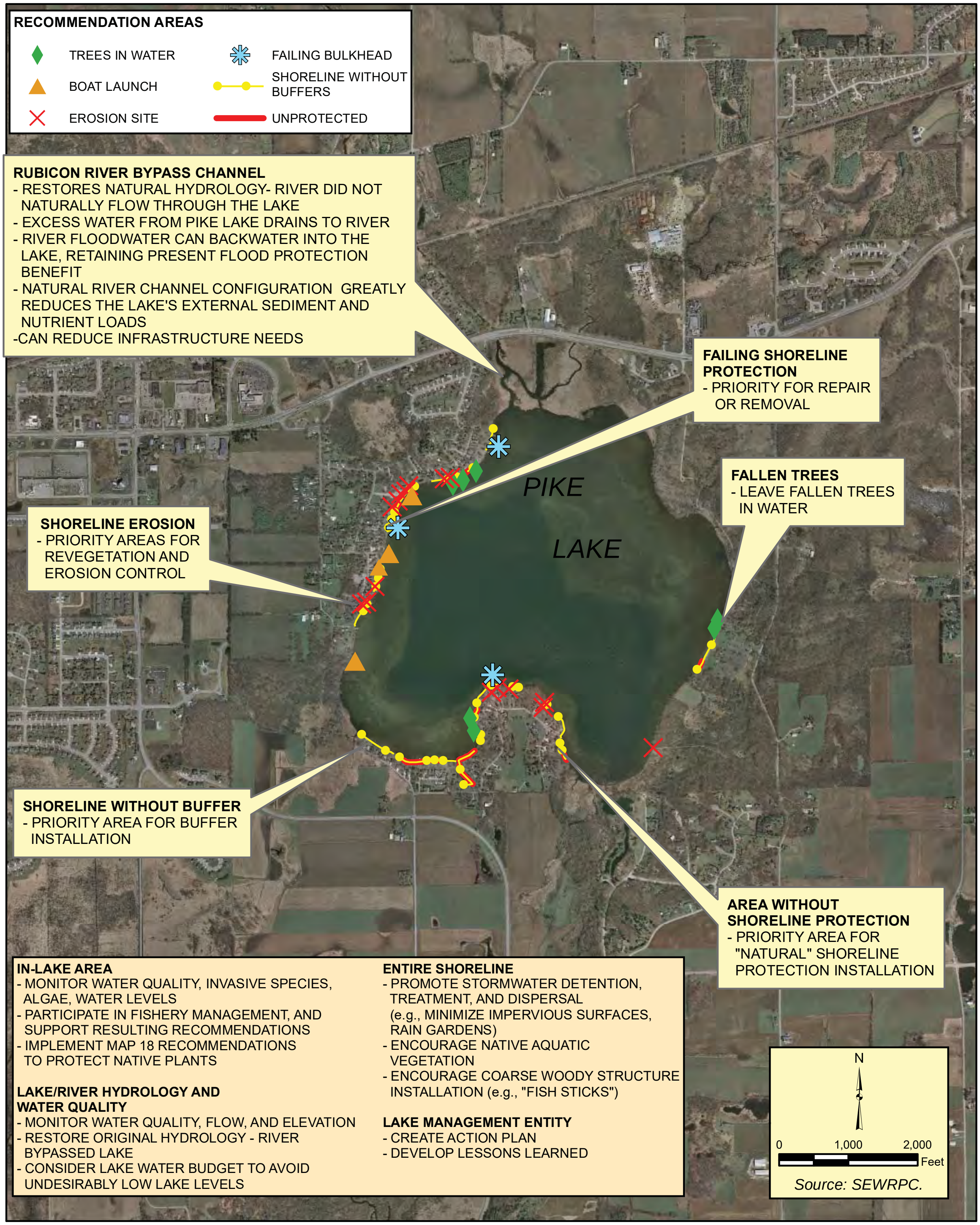
SELECTED RECOMMENDATIONS FOR THE PIKE LAKE WATERSHED



DATE OF PHOTOGRAPHY: APRIL 2015

Map 20

SELECTED IN-LAKE, SHORELINE, AND INSTITUTIONAL RECOMMENDATIONS, PIKE LAKE



DATE OF PHOTOGRAPHY: APRIL 2015

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APPENDICES

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Appendix A

PIKE LAKE
AQUATIC PLANT SPECIES DETAILS