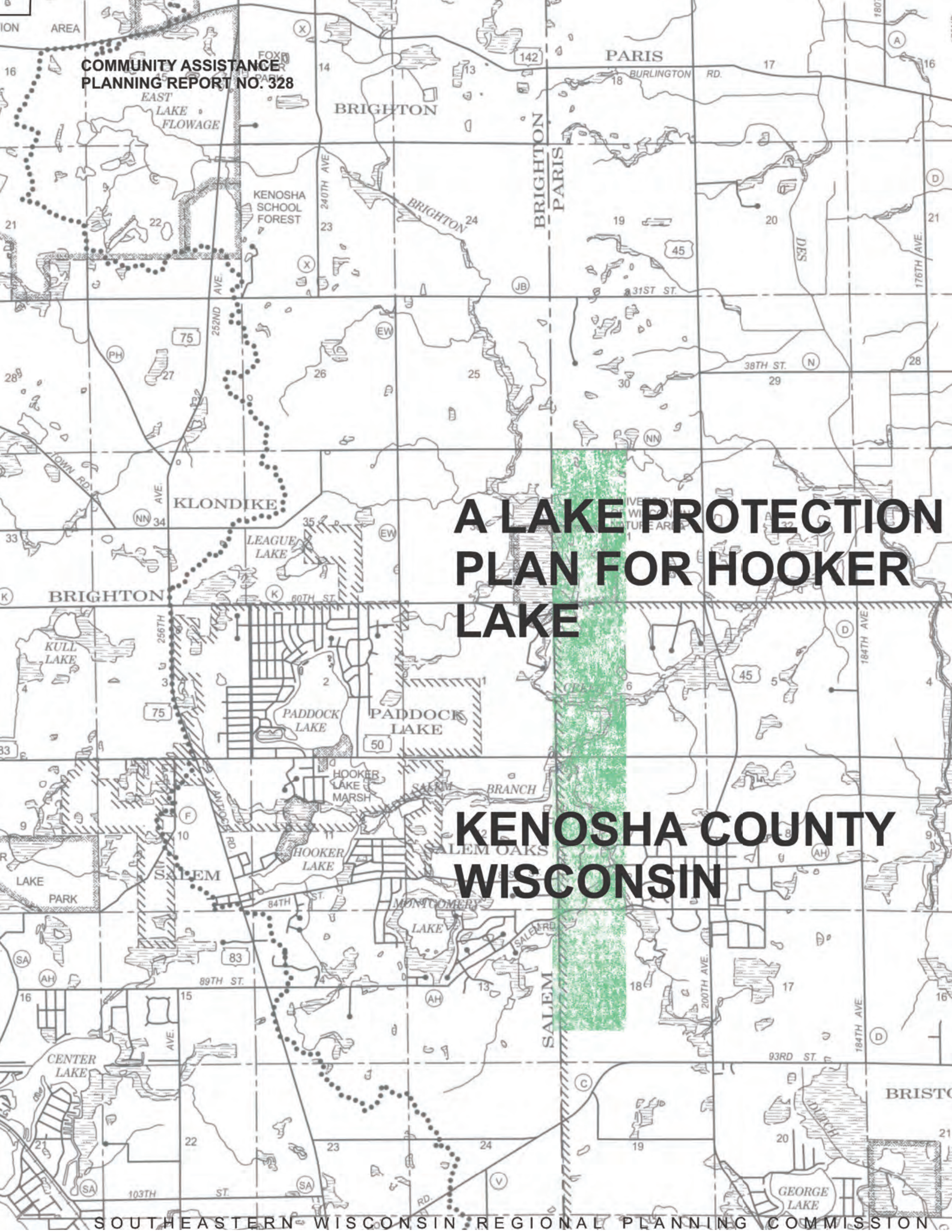
COMMUNITY ASSISTANCE PLANNING REPORT NO. 328

A LAKE PROTECTION PLAN FOR HOOKER LAKE

KENOSHA COUNTY WISCONSIN



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Special acknowledgment is due Jim Grumbeck who gathered and reported lake and stream water quality information.

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A LAKE PROTECTION PLAN FOR HOOKER LAKE
KENOSHA COUNTY, WISCONSIN

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Chapter I

INTRODUCTION

PURPOSE OF PLAN

The health of a lake or stream is usually a direct reflection of use and management of land within the lake's or stream's watershed. Hooker Lake, together with its watershed and associated wetlands, is a highly valued natural resource located within U.S. Public Land Survey Sections 10 and 11, Township 1 North, Range 20 East, in the Town of Salem, Kenosha County (see Map 1 and "Hooker Lake Characteristics and Assets" section below). The purpose of this plan is to provide a framework that helps maintain and enhance the land and water resources of Hooker Lake and its watershed with a focus on *protecting* this existing high-quality resource from human impacts and *preventing* future degradation. This report's recommendations are appropriate and feasible lake management measures. Actively following appropriate lake management measures can enhance and preserve Hooker Lake's native plant community and water quality while retaining and even enhancing opportunities for safe and enjoyable public recreation and beneficial use of lands within the Lake's watershed.

This plan complements other existing plans,[1] programs, and ongoing management actions in the Hooker Lake watershed. It is important to note that it relies upon the continuing commitment of government agencies, municipalities, and citizens to diligent lake planning and natural resource protection. Additionally, this plan assists State agencies, local units of government, nongovernmental organizations, businesses, and citizens in developing strategies benefitting the natural assets of Hooker Lake. By using the strategies outlined in this plan, the natural environment will be enriched and preserved.

This planning program was funded, in part, by the Hooker Lake Management District (HLMD), and in part, through a Chapter NR 190 Lake Management Planning Grant awarded to the HLMD and administered by the Wisconsin

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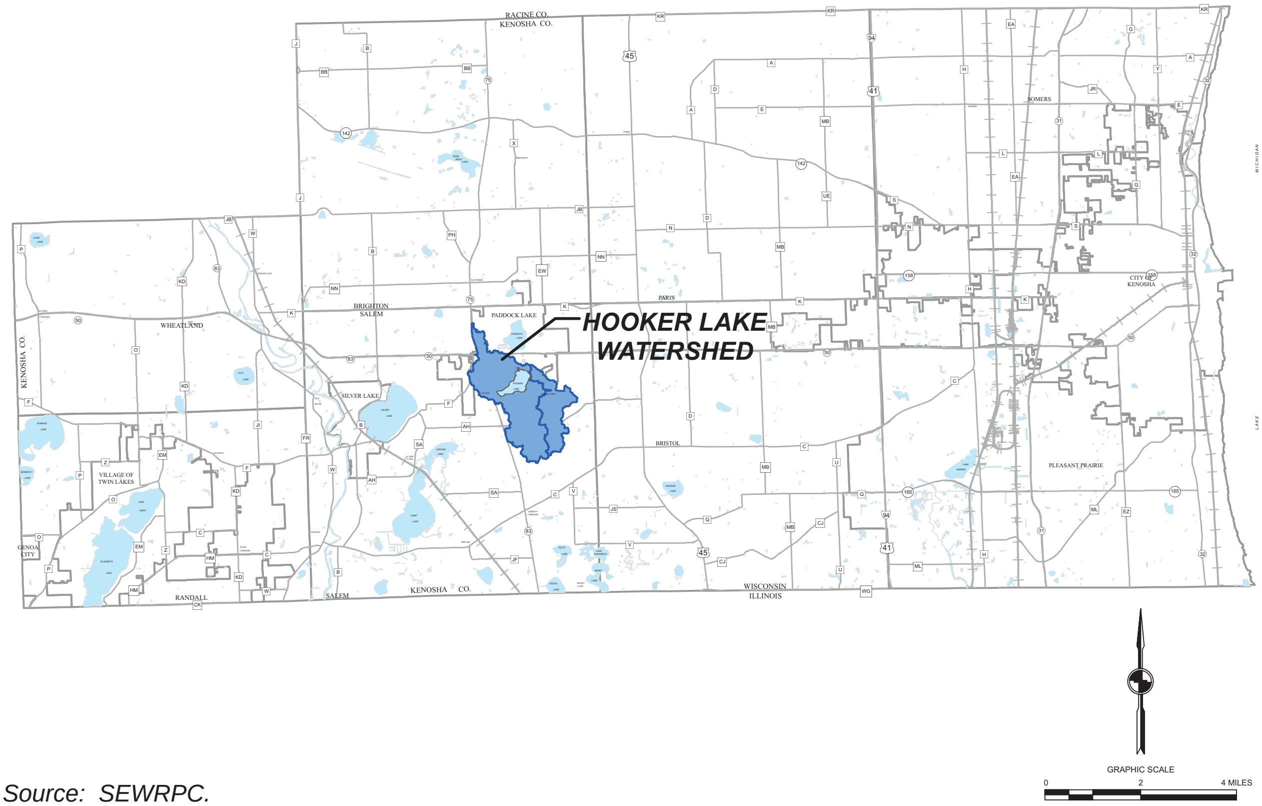
[1]*SEWRPC Planning Report No. 44,* A Comprehensive Plan for the Des Plaines River Watershed, Part One, Chapters 1-10, *June 2003; SEWRPC Planning Report No. 44,* A Comprehensive Plan for the Des Plaines River Watershed, Part Two, Chapters 11-17, *June 2003; Town of Salem, Storm Water Management Plan, September 2009; SEWRPC Community Assistance Planning Report No. 275,* A Park and Open Space Plan for the Town of Salem: 2020, Kenosha County Wisconsin, *2005; and SEWRPC Community Assistance Planning Report No. 306,* A Comprehensive Plan for the Town of Salem: 2035, Kenosha County Wisconsin, *2010.*

Map 1

LOCATION OF THE HOOKER LAKE WATERSHED



Source: SEWRPC.

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 relevant *Wisconsin Administrative Codes*.[2]

HOOKER LAKE CHARACTERISTICS AND ASSETS

Based upon interpretation of the Hooker Lake shoreline on the 2010 aerial photography, the Lake has a surface area of 111 acres.[3] Assuming the current dam has increased water depth by one foot, Hooker Lake has a maximum water depth of 28 feet (see Map 2 for the Lake's bathymetry). The Lake's water elevation is controlled by a small

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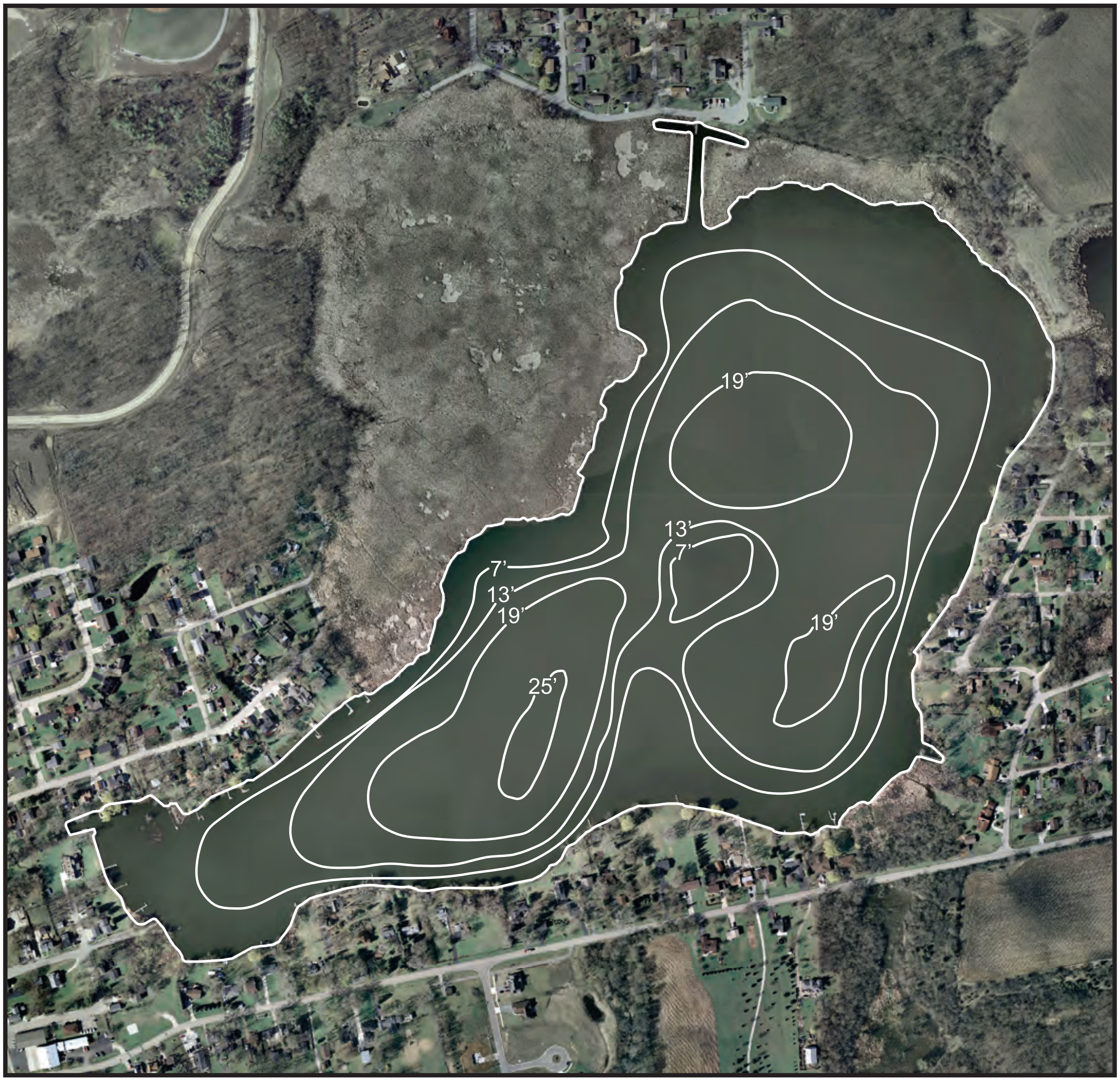
[2] *This plan has been prepared pursuant to the standards and requirements set forth in the following chapters of the* Wisconsin Administrative Code: *Chapter NR 1, "Public Access Policy for Waterways;" Chapter NR 40, "Invasive Species Identification, Classification and Control;" Chapter NR 103, "Water Quality Standards for Wetlands;" Chapter NR 107, "Aquatic Plant Management;" and Chapter NR 109, "Aquatic Plants Introduction, Manual Removal and Mechanical Control Regulations."*

[3] *The surface area of Hooker Lake has been variously reported as 87 acres in WDNR publication PUB-FH-800 2005, 102 acres on the 1952 bathymetric map produced by the Wisconsin Conservation Department, and 103 acres on the WDNR web site.*

Map 2

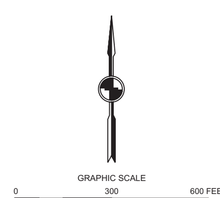
HOOKER LAKE BATHYMETRY



DATE OF PHOTOGRAPHY: APRIL 2010

—20'— WATER DEPTH CONTOUR IN FEET

Note: Bathymetric contour lines were defined by the Wisconsin Department of Natural Resources in 1952. One foot was added to lake depth to account for the lake elevation increase following the 2002 Bryzek Dam reconstruction.



Source: Wisconsin Department of Naural Resources and SEWRPC.

privately-owned dam located at the northeast corner of the Lake that raises water elevations approximately one to two feet.[4] The dam is located downstream of a small shallow lake just northeast of Hooker Lake. The dam controls the water elevation of both Hooker Lake and the small, shallow downstream lake. Hooker Lake forms the headwater of the Salem Branch of Brighton Creek, a second order stream. From its confluence with the Salem Branch, Brighton Creek, a fourth order stream, flows to the east approximately four miles to its confluence with the Des Plaines River.

The WDNR classifies Hooker Lake as a deep headwater lake. Deep headwater lakes are larger than 10 acres, are likely to thermally stratify during warm weather and have hydrologic characteristics consistent with the definition of a drainage lake. Hooker Lake's primary source of water is precipitation and direct drainage from the surrounding land, but it likely does receive some flow from groundwater. Table 1 further details the hydrologic and morphologic characteristics of the Lake. Chapter II provides more insight on the importance of these characteristics.

Table 1

HYDROLOGY AND MORPHOMETRY OF HOOKER LAKE

Parameter	Measurement
Size	
Surface Area of Lake	111 acres
Total Tributary Area[a]	1,269 acres
Lake Volume	1,365 acre-feet
Residence Time[b]	1.0 -1.3 years
Shape	
Length of Lake	0.8 mile
Width of Lake	0.3 mile
Length of Shoreline	2.5 miles
Shoreline Development Factor[c]	1.3
General Lake Orientation	SW-NE
Depth	
Maximum Depth	28 feet
Mean Depth	12.3 feet

[a]Total tributary area represents land contributing runoff to the lake, and specifically excludes the lake surface but may include localized internally drained basins.

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

[c]Shoreline development factor is the ratio of the shoreline length to the circumference of a circular lake of the same area.

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

Hooker Lake and its watershed have a wide range of assets. For example, Hooker Lake is able to support a variety of recreational opportunities as evidenced by the recreational survey completed by Southeastern Wisconsin Regional Planning Commission (SEWRPC) staff during the summer and winter of 2012 and 2013 (see Chapter II). This survey shows that lake users engage in full-body contact uses (such as swimming and paddle boarding) as well as high- and low-speed boating and fishing. The Lake enjoys a reputation for good fishing, especially for northern pike, largemouth bass and panfish. The Lake's watershed contains a variety of wetlands, uplands, and woodlands that help support a wide variety of wildlife. Moreover, as is further described in Chapter II, the Lake contains two WDNR-designated Sensitive Areas: Hooker Lake Marsh and a small wetland area in the southwest corner of the Lake. The Lake and its watershed likely support a variety of reptile and amphibian species that live in and around the Lake, as well as a number of bird species that inhabit the area year round or during migration.[5]

[4] *Information regarding the outlet dam is found on the WDNR's dam information database found at http://dnr.wi.gov/topic/dams/damSearch.html.*

[5] *Based on bird, amphibian, and reptile databases for the Region.*

LAKE PROTECTION PROGRAMS AND GOALS

General lake protection goals and objectives for Hooker 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 HLMD and the general public. These objectives also directly address goals established in the Kenosha County multi-jurisdictional comprehensive plan[6] and the Town of Salem Comprehensive Plan,[7] and include:

1. Describe existing conditions in the Hooker Lake tributary area including identifying and quantifying potential point and nonpoint sources of pollution, nutrient and contaminant inputs, and nutrient and contaminant balances;

2. Document changes in lake surface area over time, as an indicator of changes in lake surface elevation;

3. Identify the extent of existing and potential future water quality problems likely to be experienced in the Lake, including an assessment of the Lake's water quality using water quality monitoring data being collected as part of ongoing programs and estimates of changes in these conditions in the future; and,

4. Formulate appropriate lake protection programs, including public information and education strategies and other possible actions necessary to address the identified problems and issues of concern.

This plan uses the information described above to develop a comprehensive set of specific lake protection recommendations to protect and enhance Hooker Lake, and provides recommendations related to the issues and concerns of Hooker Lake residents, including an aquatic plant management plan. Implementing the recommended actions set forth herein should serve as an important step in achieving Lake use/protection objectives over time.

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[6] *SEWRPC Community Assistance Planning Report No. 299,* A Multi-Jurisdictional Comprehensive Plan for Kenosha County: 2035, *April 2010.*

[7] *SEWRPC Community Assistance Planning Report No. 306*, A Comprehensive Plan for the Town of Salem: 2035, *March 2010.*

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Chapter II

ISSUES AND CONCERNS

INTRODUCTION

Despite being a valuable resource, as discussed in Chapter I of this report, Hooker Lake is subject to a number of existing and potential future problems and issues of concern. To better define and understand these issues, and to foster continued recreational use of the Lake, the Hooker Lake Management District (HLMD) executed an agreement with the Southeastern Wisconsin Regional Planning Commission (SEWRPC) to investigate causes of community concern and to develop a comprehensive lake protection plan to address those causes. Table 2 lists issues of concern identified through consultation with the HLMD.[1] This chapter summarizes each issue of concern and presents information relevant to understanding the recommendations provided in Chapter III of this report.

ISSUE 1: WATER QUALITY

Actual and perceived water quality conditions are important issues for many Hooker Lake residents who have expressed concerns about pollutants that could enter the Lake from various sources. These sources include: the Lake's several tributary streams; the nearby and recent resurfacing and reconstruction of STH 83 adjacent to the west end of the Lake; fertilizer and pesticide runoff from shoreline properties; fertilizer runoff from agricultural properties within the watershed; and, bacteria sources throughout the watershed (e.g., feces from birds and other animals that live in the watershed). Additionally, concerns about excessive aquatic plant growth further reinforce water quality as an issue of concern given the fact that water quality conditions (such as levels of phosphorus) greatly influence the ability of a lake to support excessive aquatic plant growth.

As part of the discussion of water quality in Hooker Lake, it is important to succinctly define what *water quality* means since individuals have varying interpretations and levels of understanding. Water quality is often discussed in terms of visual cues. Algal blooms or cloudy water, for example, can lead an observer to come to the conclusion that the water in a lake is "unclean." However, to quantify actual lake water quality, lake managers and residents need to look at specific chemical, physical, and biological parameters that influence, or are indicators of, water quality.

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[1]*The issues of concern are organized so those most commonly referenced by stakeholders over the entire project duration are listed first. Attention directed at denser aquatic plant growth during recent years, and especially during 2015, suggests that aquatic plants concerns may now garner increasing relative importance.*

The most commonly used parameters for assessing water quality include water clarity and the concentrations of phosphorus, chlorophyll-*a*, and dissolved oxygen (see Table 3 for descriptive details). These parameters interact with one another in a variety of ways. For example, nutrient pollution derived from phosphorus containing fertilizers can cause a lake's phosphorus levels to increase, its clarity to decrease (due to algal growth in the water column), and chlorophyll-*a* (a measure of algae content) to increase. To develop a meaningful water quality maintenance and improvement program, <u>key water-quality indices must be regularly measured over extended periods of time. This allows lake managers to establish baseline levels and identify trends.</u> [2]

Table 2

ISSUES OF CONCERN

	Issues and Concerns
1	Water Quality
2	Water Quantity
3	Lake Outlet Dam
4	Aquatic Plant Growth
5	Cyanobacteria and Floating Algae
6	Recreational Use and Facilities
7	Shoreline Maintenance
8	Fish and Wildlife
9	Plan implementation

Source: SEWRPC.

Historic water quality measurement data for Hooker Lake includes several isolated samples taken by WDNR staff in the 1970s (see Appendix A); data collected during 1991 and 1992 by WDNR Self-Help Program volunteers and U.S. Geological Survey (USGS) staff (see Appendix A); data collected in 1998, 2001, and 2004 by WDNR staff; and, most recently, data collected in 2009, 2010, and 2012-2015 by volunteers enrolled in the University of Wisconsin-Extension (UWEX) Citizen Lake Monitoring Network (CLMN), formerly known as the WDNR Self-Help Monitoring Program. The primary water quality sampling station is located at the deepest portion of Hooker Lake's western basin, as shown on Map 3. In addition to the water quality samples collected at the deep hole in the western basin, additional tributaries were sampled at six different locations (Map 3). As part of the preparation for this lake protection plan, Commission staff reviewed available water quality data listed above as well as that which appeared in various existing reports on Hooker Lake.

In addition to water clarity, phosphorus, chlorophyll-*a*, and dissolved oxygen measurements, a number of other parameters can also be measured to determine the "general health" of a lake (see Appendix A). For example, measurements of the bacteria *E-coli* are frequently taken on some lakes to determine swimming safety and chloride concentrations can indicate pollution entering a lake.[3]

The basic factors that need to be considered when assessing water quality conditions in a lake include:

1. **General characteristics of a lake, including past and current water quality conditions**—It is important to establish and benchmark lake water quality. To do this, concentrations of the aforementioned parameters (phosphorus, water clarity, chlorophyll-*a*, dissolved oxygen) should be measured and compared to past levels to determine if water quality has changed over time. Parameters that have been getting progressively worse can help determine which pollutants should be targeted for reduction. This information can then be reviewed within the context of the general lake characteristics to determine the extent of water quality problems as well as the most practical methods for effectively dealing with them.

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[2]*Throughout this report, the use of underlining denotes items having management implications.*

[3]*Chlorides are used as an indicator of human-sourced pollution because they are naturally present in low quantities in Southeastern Wisconsin. Often, abnormally high chloride levels can indicate malfunctioning residential septic systems in areas not served by public sanitary sewer systems or may be the result of road salt or excessive fertilizer applications.*

Table 3

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

<table>
<tr><th rowspan="2">Parameter</th><th rowspan="2">Description</th><th colspan="2">Southeastern Wisconsin Values[a]</th><th rowspan="2">Regulatory Limit or Guideline</th><th colspan="2">Hooker Lake Values</th></tr>
<tr><th>Median</th><th>Range</th><th>Median</th><th>Range</th></tr>
<tr><td>Chloride (mg/L)</td><td>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.</td><td>16</td><td>1-57</td><td>Acute toxicity [b,c]
757
Chronic toxicity [b,c]
395</td><td>105[d]</td><td>38-121</td></tr>
<tr><td>Chlorophyll-a (µg/L)</td><td>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-colored water that may be severe enough to impair recreational activities such as swimming or waterskiing and are commonly associated with eutrophic lake conditions</td><td>9.9</td><td>1.8-706.1</td><td>2.6[e]</td><td>9.8[f]</td><td>2.5-31.3[f]</td></tr>
<tr><td>Dissolved Oxygen (mg/L)</td><td>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. Many species of fish are unlikely to survive when dissolved oxygen concentrations drop below 2.0 mg/L.</td><td>- -</td><td>- -</td><td>≥5.0[g]</td><td>- -[h]</td><td>0.1-13.2</td></tr>
<tr><td>Growing Season Epilimnetic Total Phosphorus (µg/L)</td><td>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 30 µg/L is the concentration considered necessary in a drainage lake such as Hooker Lake to limit algal and aquatic plant growth to levels consistent with recreational water use objectives. Phosphorus concentration exceeding 30 µg/L are considered to be indicative of eutrophic lake conditions</td><td>30</td><td>8-720</td><td>30[g]</td><td>29[f]</td><td>18-63[f]</td></tr>
<tr><td>Water Clarity (feet)</td><td>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</td><td>4.6</td><td>3-12</td><td>10.9[e]</td><td>8.8[f]</td><td>2.0-15.3[f]</td></tr>
<tr><td>Water Temperature (°F)</td><td>Temperature increases above seasonal ranges are dangerous to fish and other aquatic life. Higher temperatures depress dissolved oxygen concentrations and often correlate with increases of other pollutants.</td><td>- -</td><td>- -</td><td>Ambient[g]
35-77
sub-lethal[g]
49-80
Acute[g]
77-87</td><td>- -[h]</td><td>33-86</td></tr>
</table>

[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]*Pollutants that will kill or adversely affect aquatic organisms after a short-term exposure are termed acutely toxic. Chronic toxicity relates to concentrations of pollutants that will kill or adversely affect aquatic organisms our long time periods (time periods that are a substantial portion of the natural life expectancy of an organism).*

[d]*A series of lake water chloride concentration data points was collected in between May and November 2014. The average value from 2014 data is presented as the “mediam” value. Chloride concentrations have been consistently increasing across the region, and current chloride concentrations are likely higher.*

[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]*Values collected, during growing season (June 1 through August 31).*

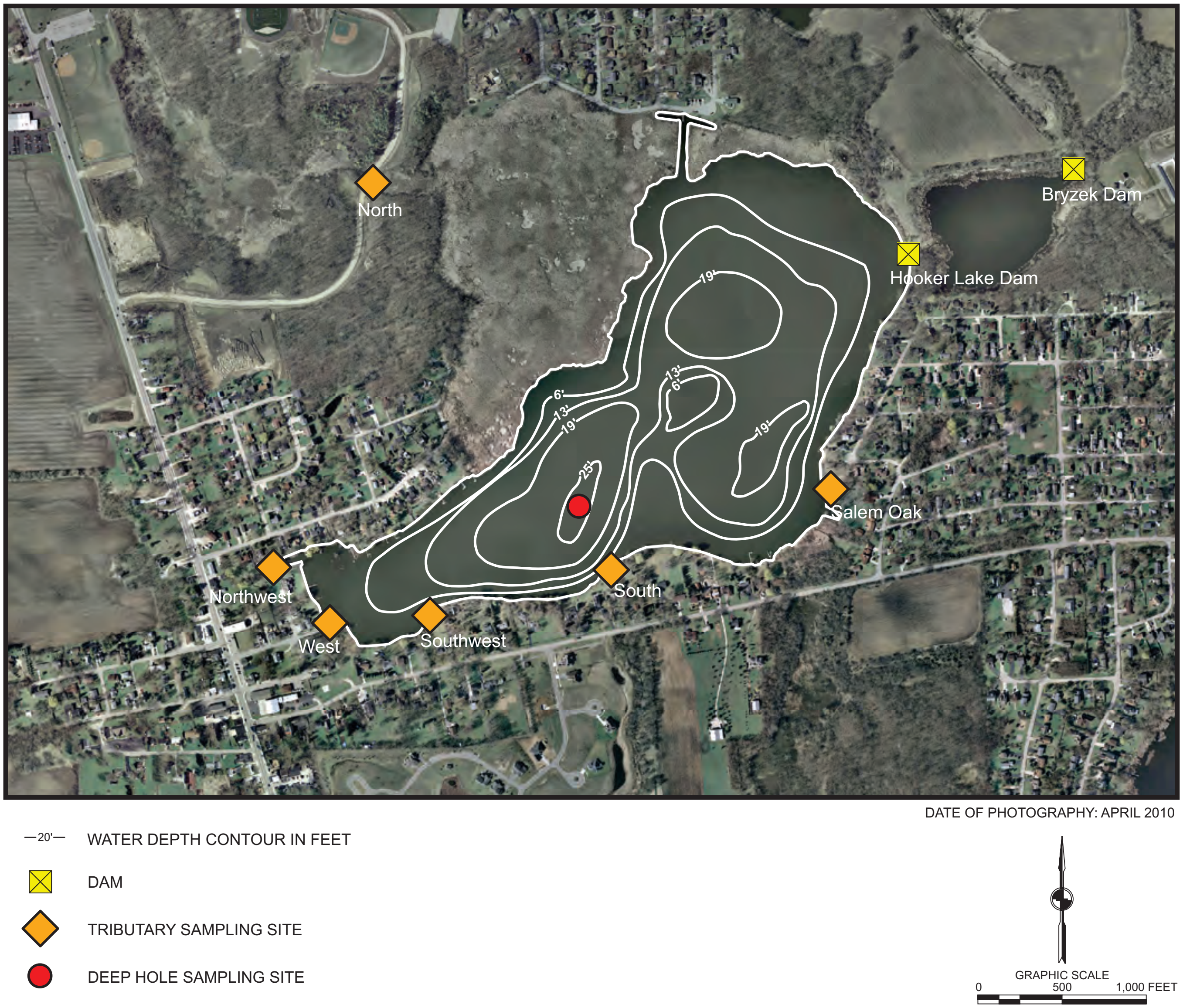
[g]*Wisconsin Administrative Code Chapter NR 102, Water Quality Standards for Wisconsin Surface Waters, November 2010.*

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

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

Map 3

HOOKER LAKE AND TRIBUTARY SAMPLING SITES: 2014



Source: Wisconsin Department of Natural Resources and SEWRPC.

2. **A lake's watershed characteristics, including land use and pollutant loadings**—Pollutants that enter a lake are highly dependent on the ways that the lands surrounding and draining to the lake (i.e., its *watershed*) are used. Different kinds of land use produce different kinds of pollutants (see Figure 1). For example, agricultural land can be a significant contributor of sediment (from soil erosion in fields) and nutrients (from fertilizers), depending on the type of agricultural practices that are used (e.g., tillage farming can loosen soils and make it easier for pollutants to enter the waterways). In contrast, urban land uses (e.g., residential, industrial, and commercial developments) can contribute a significant amount of heavy metals, oils, and nutrients. The amount and type of pollutants depend on actual use characteristics. For example, pollution related to human activities—oil leaked from cars onto pavement and fertilizers on lawns—may drain to a lake during rain events. Given this connection, it is important to understand the past, current, and planned land uses within the watershed. Based on these land use conditions, models can be applied to estimate the amount of pollution that is likely to be entering a lake. Knowing this can help identify areas that are more likely contributing to water quality deterioration, and can help determine where in the watershed to focus pollution reduction efforts.

Figure 1

ILLUSTRATIONS OF LAND USE AFFECTING WATERBODIES

NATURAL STREAM ECOSYSTEM

AGRICULTURAL STREAM ECOSYSTEM

URBAN STREAM ECOSYSTEM

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

3. **The filtering ability of a lake's watershed and shorelines**—Various natural features can help filter pollutants which would otherwise enter a lake. These features, such as wetlands and vegetative buffers[4] can significantly decrease the amount of pollution that enters a lake either by absorbing and utilizing them (in the case of nutrients) and/or trapping pollutants (such as sediments) prior to their entering the lake. Certain wetland plants, such as cattails, are particularly effective in this capacity. Pollutants may be detained or retained within the watershed, with varying effects on the lake's water quality.

Each of these three factors is discussed below.

Lake Characteristics and Water Quality

As previously mentioned, the evaluation of water quality depends on monitoring (ideally over a protracted time period) the levels of various chemical and physical parameters of a lake's waters. In general, this monitoring data is used to determine the level and nature of pollution within a lake, the risks associated with that pollution, as well as the overall health of the lake. When evaluating water quality, it is important to know certain lake characteristics that provide context for evaluation. These lake characteristics include:

1. **Whether the lake stratifies, and, if it does, when the lake mixes**—*Stratification* refers to a condition in a lake in which the temperature difference (and associated density difference) between the surface waters (i.e., the epilimnion) and the deep waters (i.e. the hypolimnion) is great enough to form thermal layering that can prevent circulation and mixing between the two layers (see Figure 2).[5] 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

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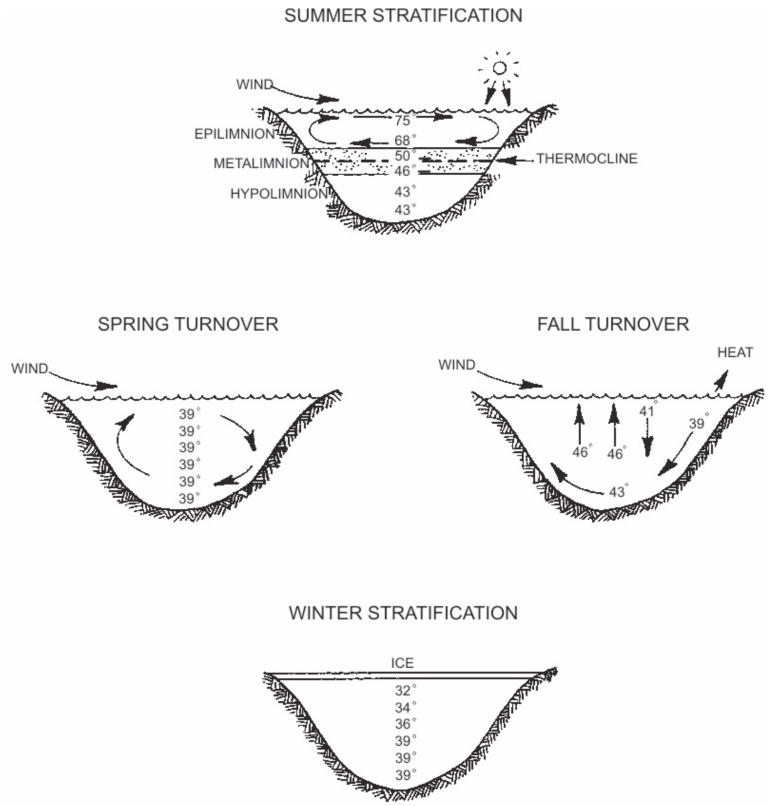
[4]*Vegetative buffers (e.g., forests, grassed waterways, and engineered vegetative strips) and wetlands each have the natural ability to slow down water. This encourages pollutants to settle out prior to their entering the lake.*

[5]*The thermocline (sometimes referred to as the metalimnion) is the thin layer of rapid temperature change that divides the epilimnion from the hypolimnion.*

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), water in deep portions of lakes can become extremely low in, or even completely void 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 in response to changing seasons and ambient weather conditions.

Figure 2

LAKE THERMAL STRATIFICATION



Source: University of Wisconsin-Extension and SEWRPC.

A lake must be sufficiently deep to create sufficient temperature differences between surface and bottom waters for the lake 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. **The maximum depth of Hooker Lake is 28 feet, which is adequate depth for stratification to occur.**

For most stratifying lakes in the Region, the pattern is to become stratified sometime during mid- to late-spring, with a short-lived period (usually less than a week) of whole-lake mixing of water (called a "turnover") that takes place once during the spring and once again in the fall (see Figure 2). 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, denser water is found in the deeper portions of the lake. It is important to determine if stratification and subsequent turnovers occur because nutrients, low-oxygen water, and in some cases pollutants and sediment that have accumulated in the isolated bottom waters can suddenly mix into the entire water column during the turnover period, causing management problems. For example, excess nutrients can fuel nuisance-level algae and plant growth in a lake.

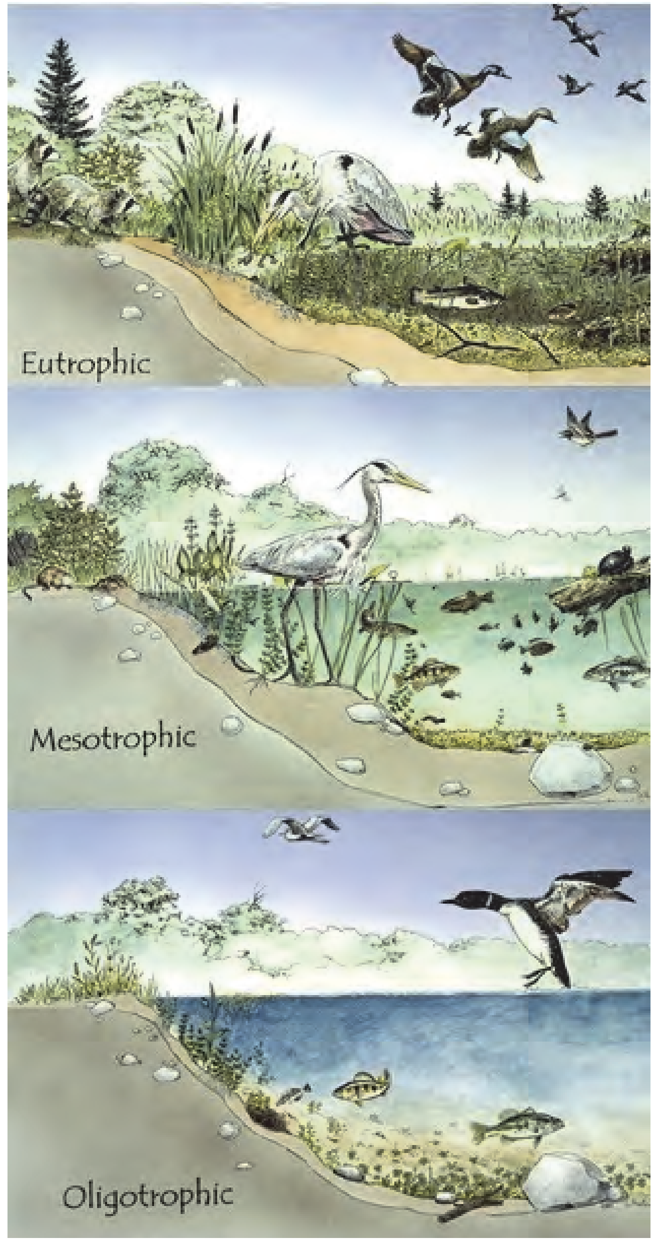
2. **Whether internal loading is occurring**—Internal loading refers to the release of accumulated phosphorus from a lake's bottom sediments that can occur under certain conditions associated with stratification. Phosphorus is typically not particularly soluble, and often adheres to particles that settle to the lake-bottom. When bottom waters become void of oxygen, the activities of decomposer bacteria in the bottom sediments, together with certain geochemical reactions that occur only in the complete absence of oxygen, can allow phosphorus in 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. Released phosphorus can mix into the water column during the next turnover period fueling plant and al-

gae 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 needs to focus on in-lake phosphorus management efforts in addition to pollution prevention. The shape of a lake's basin can influence the relative importance of this factor. Lakes with a large percentage of the surface area occupied by water just deep enough to stratify generally have more potential for significant internal phosphorus loading. **Three deeper regions of the Lake have adequate depth to stratify, making internal loading of phosphorus a potential concern.**

3. **A lake's current and past trophic states**—Lakes are commonly classified according to their degree of nutrient enrichment or t*rophic state*. The ability of lakes to support a variety of recreational activities and healthy fish and other aquatic life communities is often correlated with the degree of nutrient enrichment that has occurred. Three terms are generally used to describe the trophic state of a lake: *oligotrophic* (nutrient poor), mesotrophic (moderately fertile), and *eutrophic* (nutrient rich) (see Figure 3). Each of these states can happen naturally. Lakes tend to gradually shift from nutrient poor to nutrient rich as part of the natural lake aging process (see Figure 4); however, if a lake rapidly shifts to a more eutrophic state at a fast rate, pollution issues may be the cause. Another indication of pollution issues is when a lake enters the "hyper-eutrophic" level, which indicates highly enriched lakes (see Figure 5). Hyper-eutrophic lakes do not occur naturally (i.e., without contribution of human pollution).

Figure 3

ILLUSTRATIONS OF TROPHIC STATES

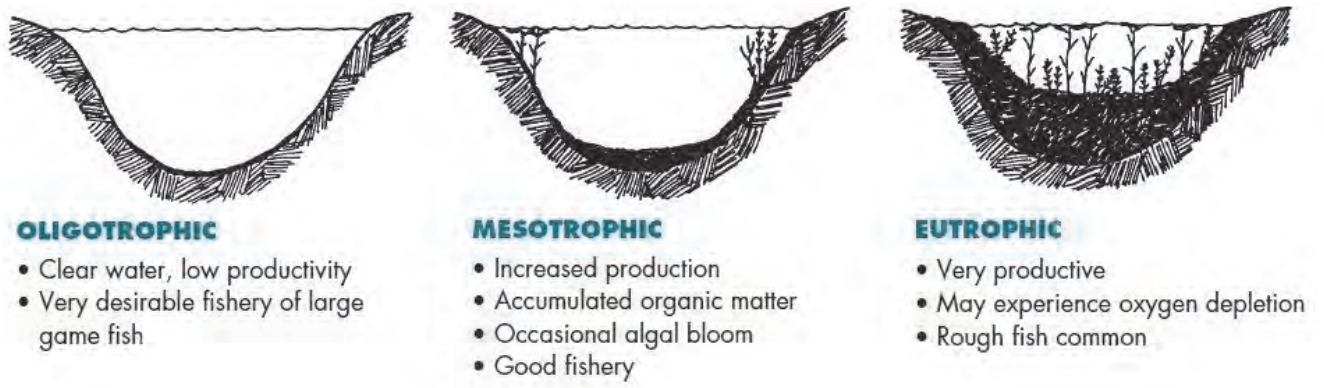


Source: DH Environmental Consulting, 1995.

4. **A lake's residence time**—*Residence time*, also known as retention time or flushing rate, refers to the average length of time a water molecule remains in a lake. The length of time water remains in a lake is significant because it can control how quickly pollution problems can be solved. For example, in lakes with short retention times, nutrients and pollutants are flushed out fairly quickly, meaning that management efforts could likely focus only on preventing pollution from the watershed. In contrast, lakes with long retention times tend to accumulate nutrients that can eventually become concentrated in bottom sediments, meaning that in addition to preventing pollution, it is also necessary to engage in in-lake water quality management efforts. The residence time of a lake is determined by comparing the volume of water in a lake to the amount of time it would take an equal volume of water to enter the lake; factors which influence the amount of water entering a lake include: the size of the lake's watershed, the average amount of precipitation and evaporation over the watershed, the average watershed runoff yield, and the surface area of the lake itself.

Figure 4

LAKE AGING AND TROPHIC STATES



Source: University of Wisconsin-Extension.

Figure 5

A HYPER-EUTROPHIC POND

Source: SEWRPC.

5. **Current and past water quality conditions of a lake and any tributaries**—The quality of water in a lake at any given time is determined by measuring an array of chemical and physical parameters, as described above. (See Appendix A for a comprehensive list of these parameters). Also, the water quality of a lake's tributary streams can greatly affect lake water quality, especially when the amount of in-flowing water from the tributary represents a significant percentage of total inflow to the lake. Other sources of water to a lake can include surface runoff, precipitation, and groundwater (seeps and springs).

General Surface-Water Hydrology

Water enters and leaves Hooker Lake. The relationship between inflow, storage, and outflow is examined in this section.

Lake Type, Water Sources, and Outflow

The WDNR classifies Hooker Lake as a deep headwater lake, a lake type that is deep enough to stratify and is largely fed by surface water. Deep headwater lakes are considered drainage lakes and have both an inlet and an outlet. The nutrient levels of drainage lakes tend to be higher than seepage or spring lakes due to their connection to streams and rivers and therefore greater surface runoff volumes enter such lakes. Hooker Lake is connected to the Salem Branch of Brighten Creek, which is a tributary to the Des Plaines River. Six tributary streams are mapped, entering the Lake from the north, northwest, west, southwest, south, and east. According to available records, the Lake's present outlet is Bryzek Dam located at the east end of the embayment.

Even though the lake is classified as a drainage lake, the inflow to the lake is modest, and **during dry weather, little to no water may enter or leave the Lake via streams.** At such times, the Lake's hydrology more closely resembles a seepage lake.

Residence Time

Based upon typical watershed yields within the Des Plaines River basin, **residence times for Hooker Lake range from 0.99 to 1.27 years, averaging 1.11 years.** During periods of heavy precipitation, the instantaneous residence time may be much shorter, while during drought, the instantaneous hydraulic detention time may be much longer. Long-term average pollutant loadings become more important considerations in assessing water quality in lakes with longer residence times. Therefore, the degree of nutrient inflow is very important in managing water quality conditions within a lake (since pollutants accumulate in a lake).

Water Quality

Hooker Lake has been studied for many years, with records extending back to the 1970s. Therefore, information is available to help quantify lake conditions and contrast changes over time. The available data is compiled in Appendix A and interpretations are presented in the following sections.

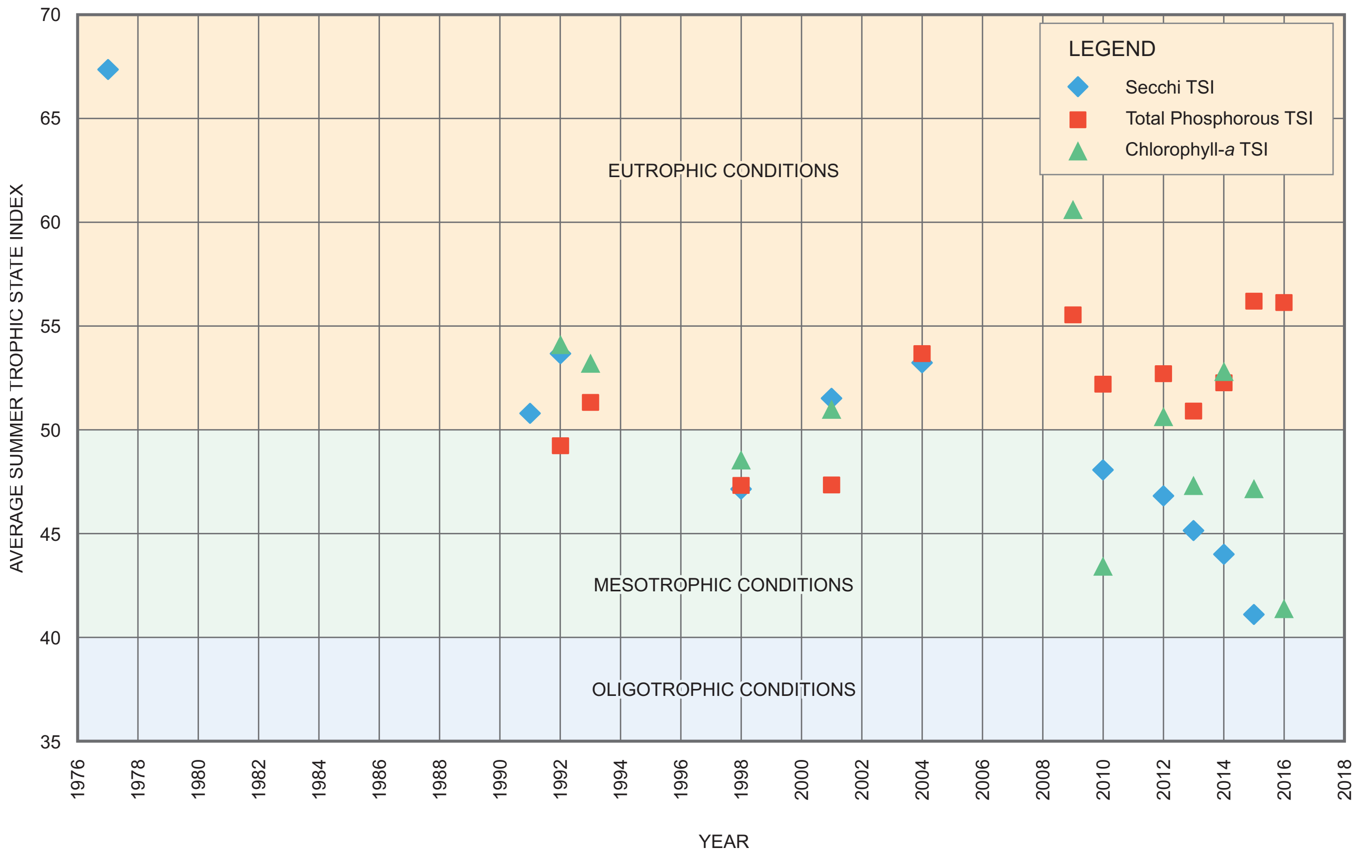
Trophic State and Nutrients

Like many lakes in southeastern Wisconsin, Hooker Lake is a fertile water body with abundant aquatic plants and green-colored water. Abundant aquatic plants impede some lake users from enjoying certain recreational pursuits and navigating portions of the Lake. Free-floating algae also has become overly abundant at times, reducing water clarity and causing recreational use problems. For this reason, the HLMD attempts to manage or reduce nuisance plant and algae growth (see Issues 4 and 5 of this chapter for additional detail). Several factors help describe and quantify the dynamic relationship between water clarity, nutrient levels, and plant and algae abundance. Tracking and analyzing nutrient concentrations, water clarity, and chlorophyll-*a* concentration can help the HLMD develop and employ Lake management practices that more effectively and efficiently meet natural resource protection and lake user needs.

Hooker Lake was historically eutrophic (see Figure 6). More recent water clarity and chlorophyll-*a* trophic state indices suggest that the Lake is becoming less eutrophic, and now easily meets values classifying it as a mesotrophic lake. However, the total phosphorus trophic state index has slowly risen, suggesting more eutrophic conditions. This apparently contradictory relationship is examined in the following paragraphs.

Figure 6

TROPHIC STATE OF HOOKER LAKE: 1991-2014



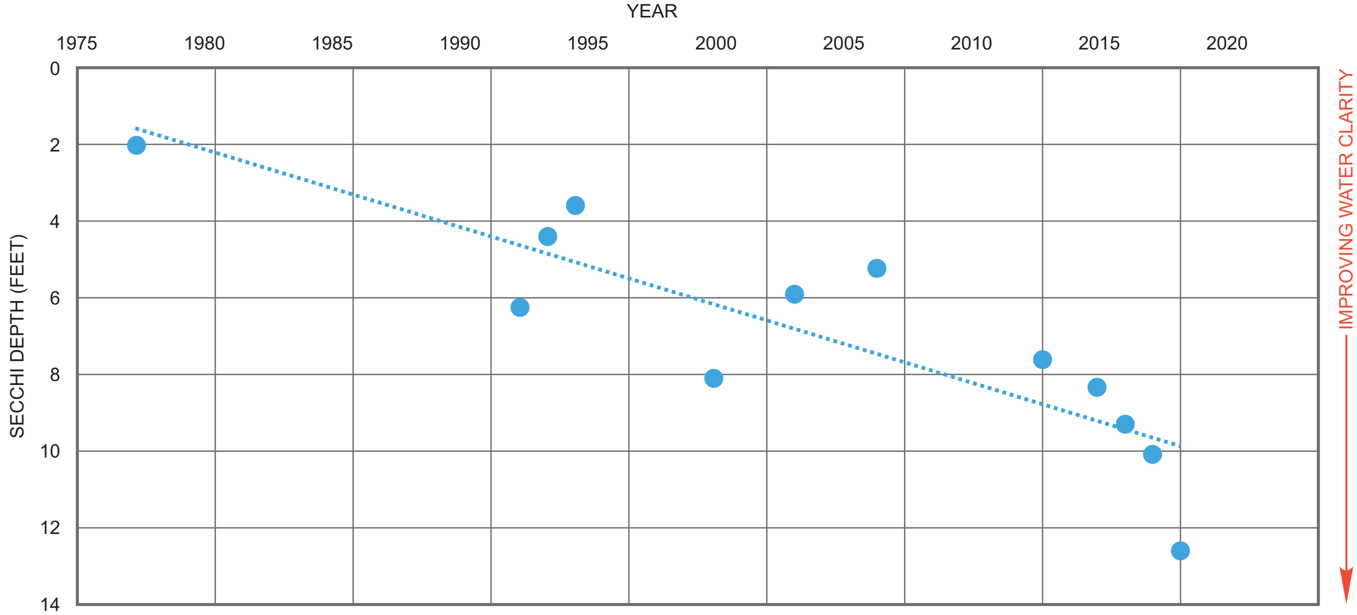
Source: U.S. Geological Survey, University of Wisconsin-Extension Citizen Monitoring Network, Wisconsin Department of Natural Resources Surface Water Information Management System, and SEWRPC.

In most lakes, changes in water clarity are controlled by free-floating algae abundance. Therefore, as free-floating algae populations decline, lake water becomes increasingly clear. Since algae and rooted plants compete for nutrients, increasingly abundant rooted aquatic plants require large amounts of the total phosphorus available in a lake. This decreases phosphorus available to algae, in turn reducing the abundance of free-floating algae which in turn causes lake water to clear. Similarly, when rooted aquatic plants senesce (or are digested or artificially killed), nutrients can return to the water column allowing algae populations to increase and water to become less clear. The increasingly clear water noted in Hooker Lake may be related to an increasingly abundant population of rooted aquatic plants in the Lake. Aquatic plant abundance has noticeably increased during recent years. Similarly, algae blooms may be related to time periods when large masses of aquatic plants are dying.

Hooker Lake's water clarity and free-floating algal abundance are plotted in Figures 7 and 8. Average summer water clarity has improved over the decades. In a similar fashion, chlorophyll-a concentrations have declined for at least 25 years. Most data conform to this long term declining trend. However, on four isolated recent occasions, chlorophyll-a concentrations were much higher than typical. During these periods, chlorophyll-*a* concentrations reached levels higher than any measured in the past. Interestingly, the high concentrations of chlorophyll-*a* noted on June 29, 2014 occurred around the same time as when the lake sampler entered the following notes: "lake sprayed for weeds" (June 7), "weeds dying" (June 18th), and "weeds dead" (June 29th). Similarly, the high concentrations of chlorophyll-*a* high noted on August 31, 2015 occurred several weeks after an herbicide application and during a time period when plants naturally senesce. **These data suggest that free-floating algal abundance increase when significant masses of aquatic plants die.**

Figure 7

MEAN SUMMER (JUNE THROUGH AUGUST)
SECCHI DISK MEASUREMENTS FOR HOOKER LAKE: 1977-2015



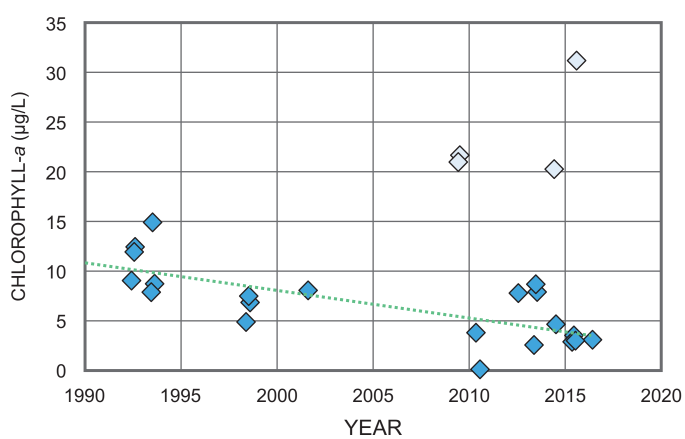
Source: U.S. Geological Survey, University of Wisconsin-Extension Citizen Monitoring Network, Wisconsin Department of Natural Resources Surface Water Information Management System, and SEWRPC.

The amount of phosphorus in the water column limits algal growth in most Wisconsin lakes. However, in some lakes, the amount of nitrogen limits algal growth. Awareness of the nutrient constraining algal growth is important when making management decisions that aim to control the growth of algae in a lake. In general, when the ratio of nitrogen (N) concentration to phosphorus (P) concentration is greater than 15:1, phosphorus limits algal growth. Conversely, when this proportion is less than 10:1, nitrogen availability limits plan growth. Ratios between 15:1 and 10:1 are transitional. Water quality data reveal that algal growth in Hooker Lake is limited by available phosphorus during all sampling periods (Table 4). This means that small additions of phosphorus can lead to large increases in algal growth. Therefore, **the Lake is prone to algae blooms when pulses of phosphorus enter the Lake.** Phosphorus pulses that affect Hooker Lake include:

- heavy runoff events (especially in spring and fall when tree pollen and leaf phosphorus increase phosphorus loads),
- turnover of the Lake's water column, enabling phosphorus from bottom sediment to reach the lake surface,
- time periods when large masses of rooted aquatic plants are in the process of dying or senescing.

Figure 8

GROWING SEASON CHLOROPHYLL-a
CONCENTRATIONS FOR HOOKER LAKE: 1990-2016



NOTE: The trendline does not consider four isolated high chlorophyll-*a* concentration values collected on June 30 and July 28, 2009, June 29, 2014, and August 31, 2015.

Source: U.S. Geological Survey, University of Wisconsin-Extension Citizen Monitoring Network, Wisconsin Department of Natural Resources Surface Water Information Management System, and SEWRPC.

Other factors can reduce free-floating algae abundance and increase lake water clarity without significantly changing phosphorus concentrations. For example, zooplankton feed upon free-floating algae. When zooplankton populations are high, heavy feeding pressure reduces the abundance of free-floating algae. Fish populations control zooplankton populations. Therefore, if few fish are present that feed on zooplankton, water can be clearer than in a situation where fish feed heavily on zooplankton, which in turn feed on free-floating algae. Similarly, filter feeders such as zebra mussels can also reduce the abundance of free-floating algae.

Table 4

HOOKER LAKE NITROGEN: PHOSPHORUS RATIOS 1977-2014

DATE	TOTAL NITROGEN (as N, mg/l)	TOTAL PHOSPHORUS (as P, mg/l)	N:P RATIO
11/23/2014	1.300	0.038	34.21053
10/27/2014	0.900	0.017	52.94118
9/4/2014	0.680	0.021	32.38095
6/11/2014	0.730	0.006	121.6667
5/13/2014	0.680	0.019	35.78947
8/17/2004	1.194	0.031	38.51613
8/28/2001	0.919	0.020	45.95000
4/2/1998	1.732	0.030	57.73333
4/22/1993	2.100	0.066	31.81818
4/2/1992	2.000	0.037	54.05405
4/13/1978	2.460	0.040	61.50000
2/2/1978	1.747	0.050	34.94000
11/3/1977	0.900	0.070	12.85714
7/14/1977	2.106	0.040	52.65000

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

Tributary Streams

In response to concerns about pollutants entering Hooker Lake from its watershed, water samples were collected in six tributary streams on six different dates between April and November 2014. The locations and general appearance of these sampling sites are shown on Map 3 and Figure 9. All water samples were collected by HLMD members using the University of Wisconsin – Stevens Point Water and Environmental Analysis Lab (WEAL) stream sampling protocol and analytical package. Resultant water quality data is tabulated in Appendix A (Tables A-7 through A-10).

Water collected from all six streams exceeded phosphorus standards at some point during the year and contained nitrogen concentrations in excess of guideline limits most of the time. However, the nitrogen concentration of water from several streams was less than that found in water samples drawn directly from Hooker Lake on the same date. Water from the Southwest Tributary (site number 4) and the West Tributary (site number 3) generally contained less or the same nitrogen concentration as Lake water, while the largely agricultural South Tributary (site number 5) contained nitrogen concentrations less than lake concentrations except during late spring. **The tributary streams do not generally have total suspended sediment concentrations in excess of typical guideline limits.** Even though no samples were collected during the winter deicing season, **water from certain streams regularly contained concentrations of chloride above chronic toxicity levels.** Water from Salem Oaks Tributary (site number 6) had chloride concentrations essentially at acute toxicity levels during one sampling period. The abundance and diversity of aquatic life likely suffers in the Salem Oaks tributary, due to excessively high chloride concentrations. Chloride concentrations in all streams are likely even higher during winter and early spring because of road deicing.

The concentrations of phosphorus, nitrogen, suspended solids, and chlorides varied significantly with time and place (see Figures 10 through 13). This can be related to many factors including precipitation and temperature patterns, the condition of the streams' channels and floodplains, vegetation, agricultural cropping and drainage practices, stormwater infrastructure, and street maintenance. For example, high intensity storms have the ability to generate intense runoff, increasing suspended solids and phosphorus concentrations in the receiving streams (see Figure 14 for nearby precipitation data collected during the sampling period). Similarly, freshly-plowed fields can release more sediment, nutrients, and water than a densely vegetated field. Such factors must be considered when evaluating changes in water quality over time. Examples of factors that may contribute to observed water quality conditions on the dates of sampling are summarized below.

- April 27, 2014: the Des Plaines River hydrograph suggests generally fair weather conditions after periods of rainfall, suggesting that little effective (runoff producing) precipitation fell during the previous week.[6]

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[6]*United States Geological Survey Gaging Station 05527800, Des Plaines River at Russell, Illinois*

Figure 9

HOOKER LAKE TRIBUTARY STREAM SAMPLING SITES: 2014

Number 1 “North” (Looking Upstream)

Number 4 “Southwest” (Looking Downstream)

Number 2 “Northwest” (Looking Downstream)

Number 5 “South” (Looking Downstream)

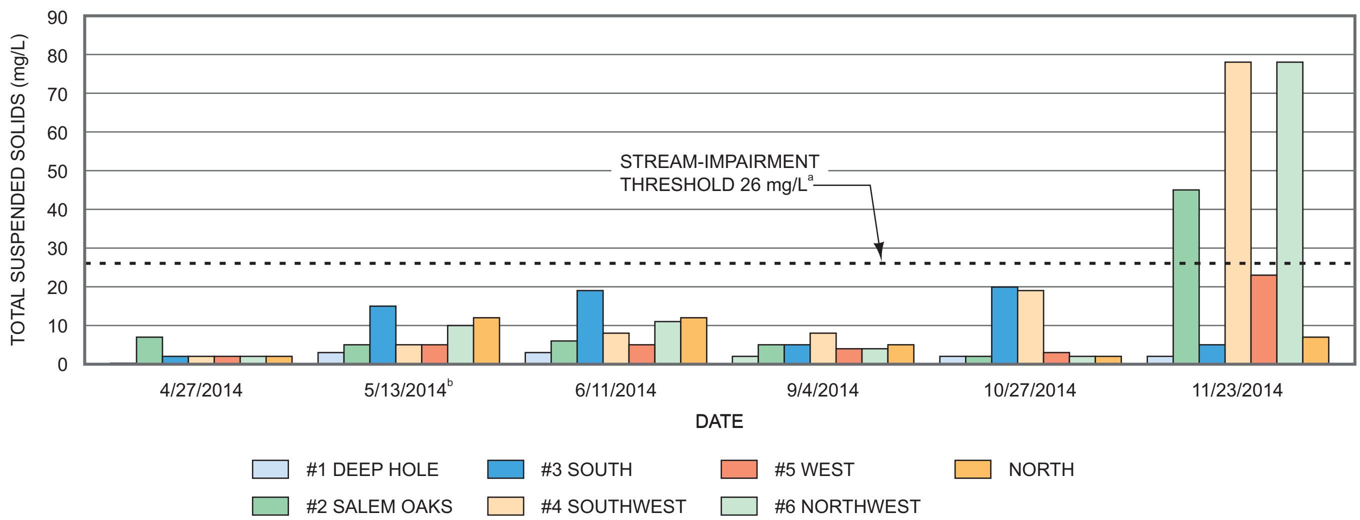
Number 3 “West” (Looking Upstream)

Number 6 Salem Oaks, (Looking Downstream)

Source: SEWRPC.

Figure 10

TOTAL SUSPENDED SOLIDS, HOOKER LAKE TRIBUTARIES 2014



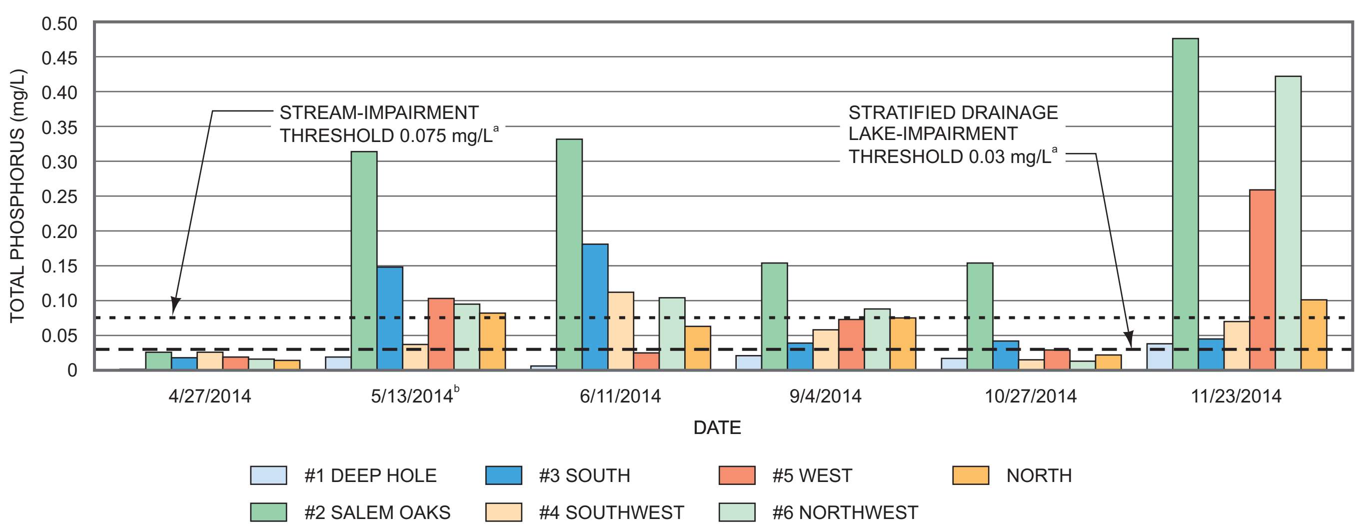
[a] *Value from Rock River Total Maximum Daily Load; U.S. Environmental Protection Agency and Wisconsin Department of Natural Resources, Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin: Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin, July 2011.*

[b] *Data Collected following a 3 inch rainfall.*

Source: University of Wisconsin-Extension Citizen Monitoring Network and SEWRPC.

Figure 11

TOTAL PHOSPHORUS, HOOKER LAKE TRIBUTARIES 2014



[a] *As set forth in Chapter 102.06(4) of the* Wisconsin Administrative Code, *November 2010.*

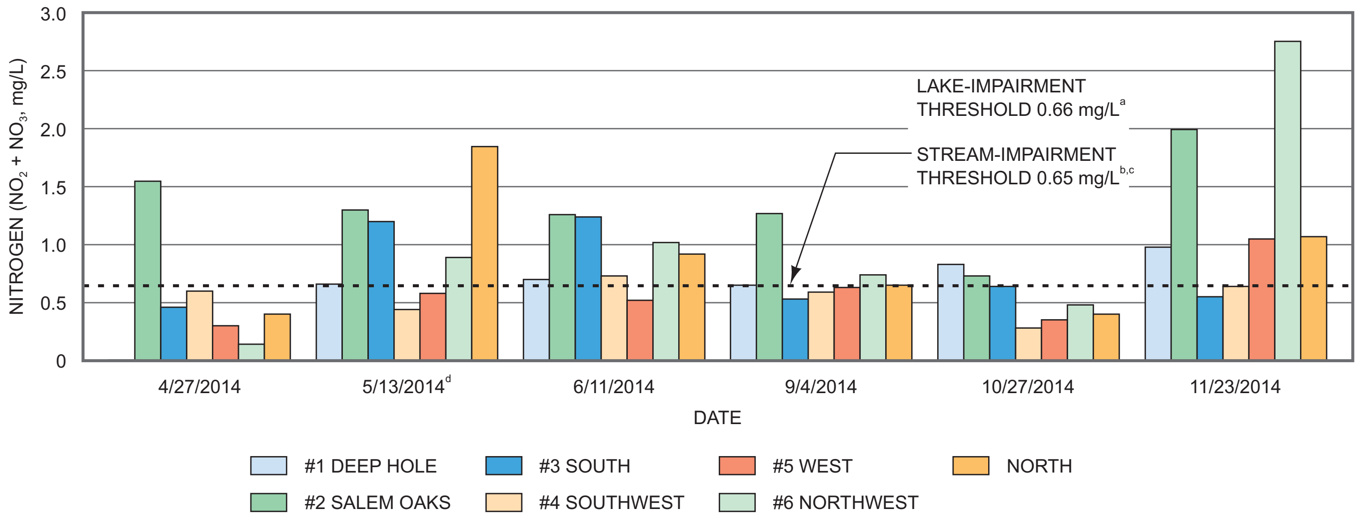
[b] *Data Collected following a 3 inch rainfall.*

Source: University of Wisconsin-Extension Citizen Monitoring Network and SEWRPC.

Kenosha precipitation records indicate light rain fell on four days the week before sampling (on the 21st 24th, 25th, and the 27th). Vegetation in the area was not likely well developed, decreasing the ability of run-off to be detained on the landscape. Fields may have been tilled, and some may have been freshly planted, potentially increasing nutrient availability.

Figure 12

TOTAL NITROGEN, HOOKER LAKE TRIBUTARIES 2014



[a]*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.*

[b]*D.M. Robertson, D.J. Graczyk, L. Wang, G. LaLiberte, and R. Bannerman,* Nutrient Concentrations and their Relations to Biotic Integrity of Wadeable Streams in Wisconsin, *U.S. Geological Survey Professional Paper No. 1722, 2006.*

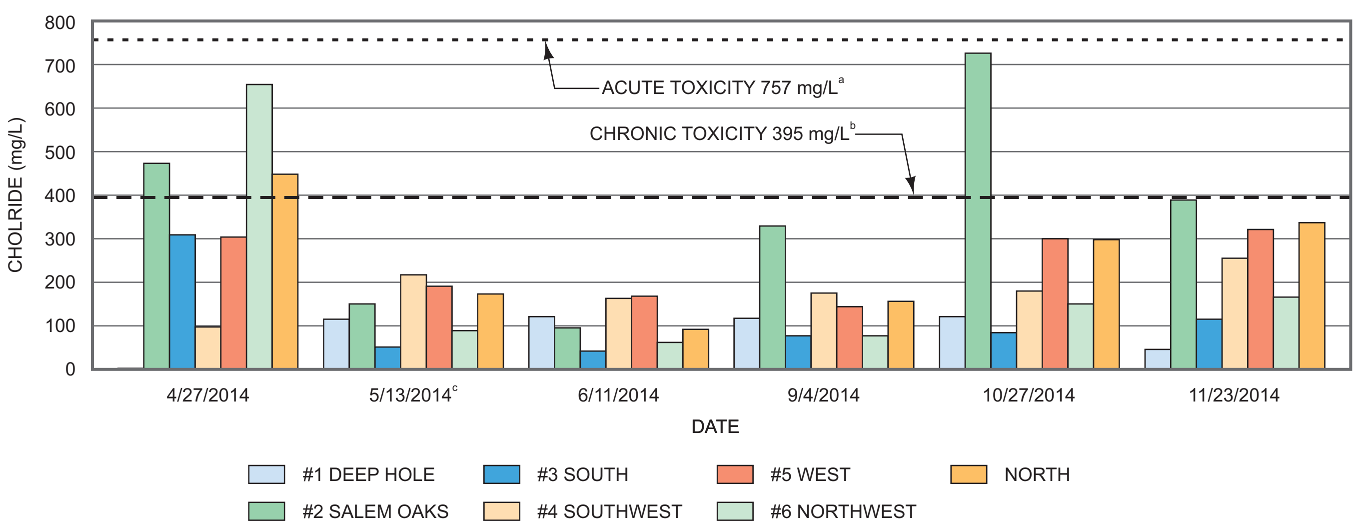
[c]*The reference value was developed by the U.S. Geological Survey and the Wisconsin Department of Natural Resources for southeastern Wisconsin. The U.S. Environmental Protection Agency has developed a similar reference value for southeastern Wisconsin till plains area of 1.30mg/L and a recommended criterion for Nutrient Ecoregion VII (mostly glaciated dairy region) of 0.54 mg/L.*

[d]*Data Collected following a 3 inch rainfall.*

Source: University of Wisconsin-Extension Citizen Monitoring Network and SEWRPC.

Figure 13

TOTAL CHLORIDE, HOOKER LAKE TRIBUTARIES 2014



[a]*As set forth in Chapter NR 105.05(2) of the* Wisconsin Administrative Code*, November 2010. Acute toxicity is the maximum daily concentration of substance which ensures protection of sensitive species.*

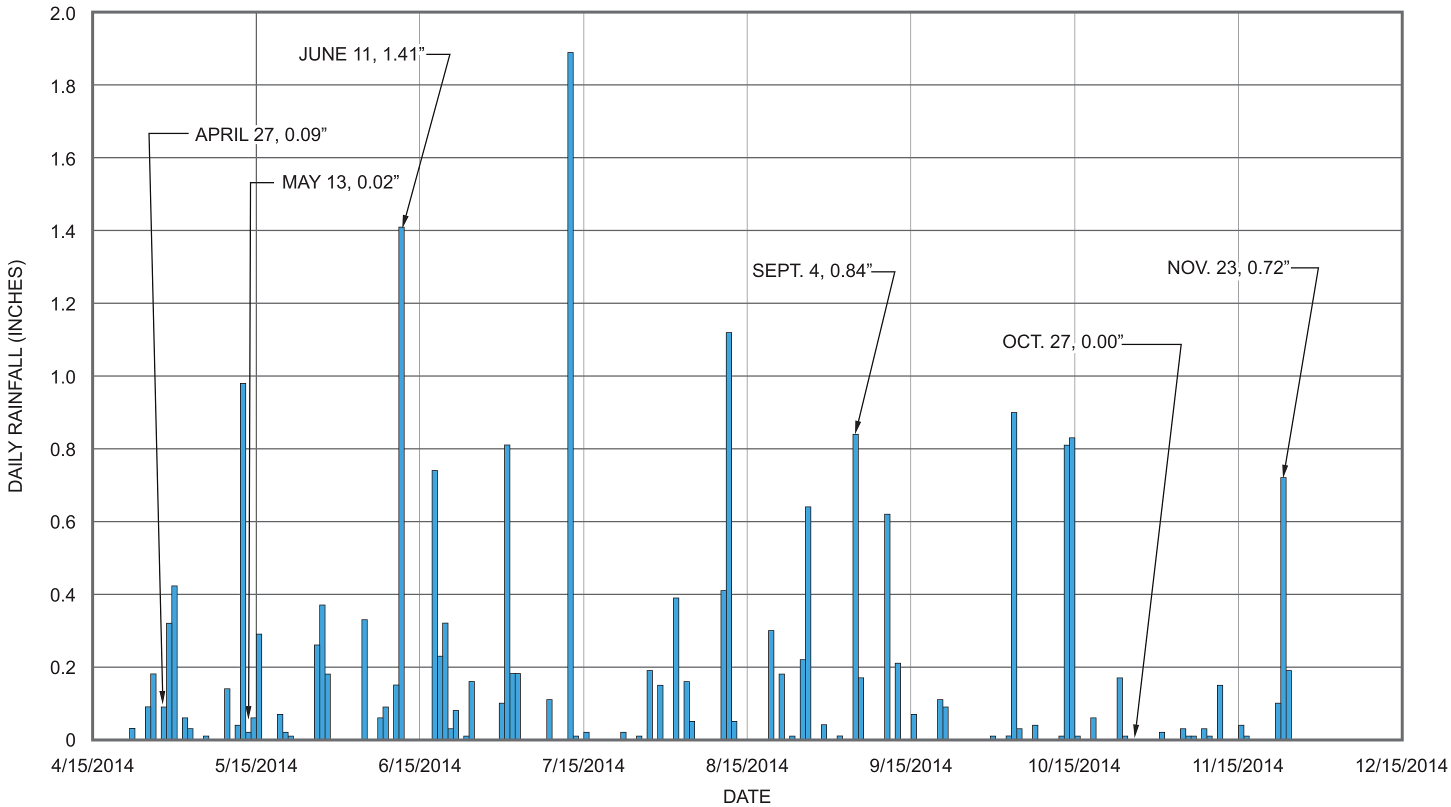
[b]*As set forth in Chapter NR 105.05(2) of the* Wisconsin Administrative Code*, November 2010. Chronic toxicity is the maximum four-day concentration of substance which ensures protection of sensitive species.*

[c]*Data Collected following a 3 inch rainfall.*

Source: University of Wisconsin-Extension Citizen Monitoring Network and SEWRPC.

Figure 14

DAILY RAINFALL AT THE KENOSHA REGIONAL AIRPORT COMPARED TO TRIBUTARY SAMPLING DATES: 2014



Source: The Weather Company and SEWRPC.

- May 13, 2014: The Des Plaines River hydrograph suggests that the previous week had been fair, with a large intense storm moving through the area shortly before sampling. Heavy rain did fall a day or two before sampling as confirmed by precipitation records (approximately one inch of rain fell on May 12 at the Kenosha Regional Airport). According to sampler notations, three inches of rain fell at Hooker Lake a short time before samples were collected. Heavy runoff would tend to increase sediment and nutrient loads. Vegetation in the area was likely still not well developed, decreasing the ability of the landscapes to detain runoff. Fields may have been tilled, and some may have been freshly planted and fertilized, potentially increasing sediment and nutrient availability.

- June 11, 2014: The Des Plaines River hydrograph suggests extended period of modest rainfall and runoff, interspersed with periods of heavy runoff. Heavy runoff would tend to increase sediment and nutrient loads. Rainfall records document heavy rain fell the day samples were collected. Pastures and natural areas were likely fully leafed out, increasing the ability of the landscape to detain stormwater. Crops were not likely yet well developed, decreasing the ability tilled agricultural parcels to detain runoff. Tilled fields may have been freshly dressed with nitrogen potentially increasing nutrient availability.

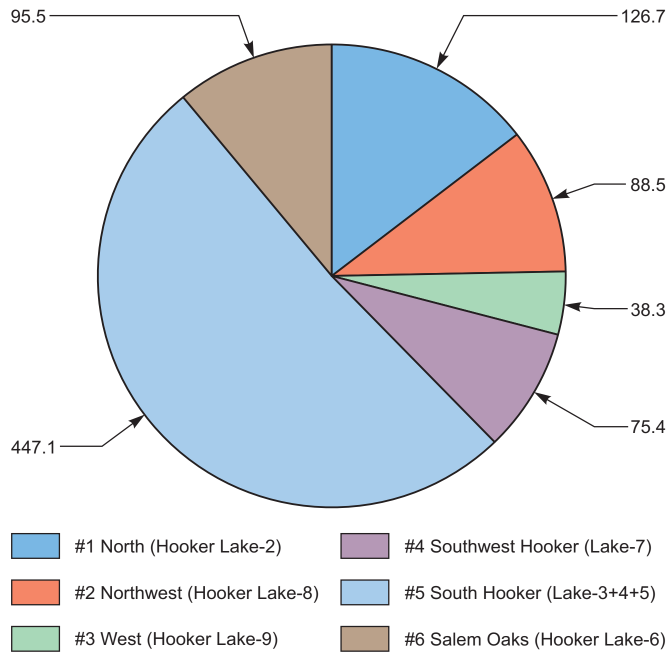
- September 4, 2014: The Des Plaines River hydrograph suggests an extended period of above average rainfall and runoff with occasional storms and periods of heavy runoff. Heavy runoff would tend to increase sediment and nutrient loads. Rainfall records document heavy rain fell the day the samples were collected. Pastures and natural areas were likely fully vegetated, increasing the ability of the landscape to detain stormwater. Crops were mature, increasing runoff detention on agricultural parcels. Some fields may have been harvested.

- October 27, 2014: The Des Plaines River hydrograph suggests wetter than normal conditions persisted through mid-October, but they were then followed by an extended period of fair weather. According to precipitation records, the October samples were collected during a period of little to no rainfall. Most vegetation was likely becoming dormant, decreasing the ability of the landscape to detain stormwater. Most crops had been harvested, decreasing runoff detention on agricultural parcels. Tree and shrub leaves, which can contribute significant nutrient pulses to surface water bodies, were falling, allowing them to be washed into streams when runoff producing storms occurred.

- November 23, 2014: The Des Plaines River hydrograph suggests a long period of fair weather ended on November 23 with a storm. Runoff rates increased, enhancing the potential for sediment and nutrient loading to streams. Precipitation records show that little effective rainfall fell for most of late October and early November and that the samples were collected during the first large rainfall after this extended dry period. Essentially all vegetation was likely dormant, decreasing the ability of the landscape to detain stormwater. Crops were harvested and many fields were likely tilled, decreasing the ability of runoff to be detained on agricultural parcels and increasing the potential yield of sediment and nutrients to streams. Trees had lost their leaves – the fair weather may have allowed fallen leaves to accumulate on streets and other uplands areas. However, when the November storm broke this drier weather period, the accumulated leaves may have been carried *en masse* to the Lake by the tributary stream.

Figure 15

HOOKER LAKE TRIBUTARY AREAS



Note: Values in acres.

Source: Town of Salem and SEWRPC.

Comparing these factors with the tributary water quality data, it becomes apparent that:

- The greatest pollutant concentrations are not correlated with the heaviest rainfall, a finding suggesting factors other than general soil erosion deliver sediment to the Lake.

- The highest pollutant concentrations were commonly found in streams draining developed watersheds.

- The highest pollutant concentrations were detected after periods of dry weather and/or after leaf fall.

The concentrations of pollutants helps reveal which streams, events, and time periods yield the poorest quality water. While this is important to the stream itself, the impact of the stream on the Lake's water quality depends upon the mass of pollutant delivered to the Lake by that stream. The mass of pollutants entering the Lake is controlled by the concentration of a pollutant in water, and the overall volume of water delivered to the Lake by the stream in question. No flow information was collected as part of the tributary water sampling program. However, the relative sizes of the sampled watersheds and the simulated flows for various storm events have been estimated.[7] These estimates reveal significant differences in watershed characteristics. The South Tributary drains by far the largest area, with a watershed essentially the same size as the other five streams' watersheds combined (see Figure 15). In addition to varying in size, the watersheds vary in the volume of runoff produced by identical amounts of rainfall. This is related to many factors including topography, soils, the amount of impervious cover, the presence of engineered

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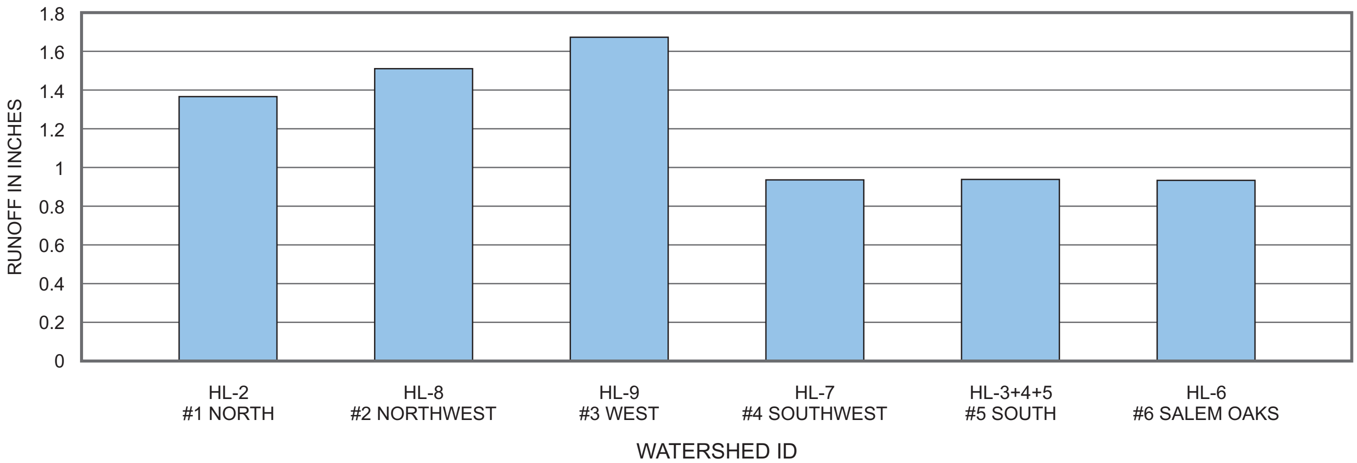
[7]R. A. Smith National, Inc., Town of Salem – Storm Water Management Plan, December 2009. A copy of this document is available online at http://www.townofsalem.net/index.asp?SEC=ECC25DEF-D98F-4529-913D-713DF-6BAC4D0&Type=B_BASIC.

Figure 16

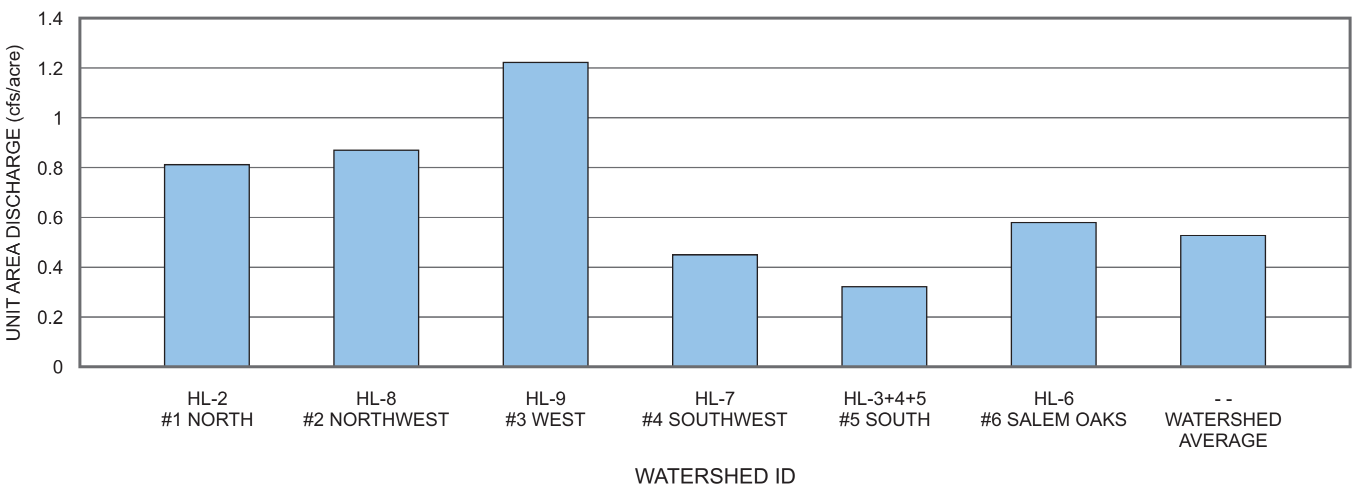
RUNOFF RESULTING FROM 50-PERCENT ANNUAL PROBABILITY (TWO-YEAR RECURRENCE INTERVAL) STORM



Source: Town of Salem and SEWRPC.

Figure 17

PEAK UNIT AREA DISCHARGE RESULTING FROM 50-PERCENT ANNUAL PROBABILITY (TWO-YEAR RECURRENCE INTERVAL) STORM



Source: Town of Salem and SEWRPC.

features that enhance runoff (e.g., ditches and storm sewers), and other factors. Using information from the Town of Salem's stormwater management plan, the volume of runoff and peak discharge rate generated by each acre of watershed from the 50-percent-annual probability (two-year recurrence interval) storm is compared (Figures 16 and 17).[8] The streams draining the comparatively more urbanized west and northwest areas yield greater runoff volumes and discharge rates per acre of watershed. Therefore, while the streams draining the more urbanized lands may not have the largest watersheds, they do provide the most runoff volume per acre of watershed area and do have higher potentials to erode banks and channels. The North, Northwest, and West Watersheds likely provide opportunity to manage stormwater quantity and quality (see Chapter III for additional detail).

[8]*Runoff volume per acre is expressed as an equivalent depth (e.g., inches) of runoff.*

As stated previously, the mass of pollutants reaching the Lake is more important than the concentrations detected in discrete water samples. A thorough sampling regimen would need to quantify the mass of pollutants reaching the Lake from each tributary stream watershed. However, a basic estimate of pollutant mass for a particular storm can be made using modelled flow volumes and the tributary water quality information already collected by the HLMD. Such information can be useful to compare the pollutant masses contributed by each tributary. For this exercise, the flow volume delivered by each tributary during the 50 percent annual recurrence interval storm was multiplied by the minimum, average, and maximum total phosphorus, total nitrogen, and total suspended solids concentrations detected in each tributary during 2014. This yields the mass of pollutants delivered by such a storm to the Lake by each stream (see Figure 18), allowing the relative contribution of each to be contrasted. This exercise reveals that, **even though the South Tributary is by far the largest tributary by watershed area, pollutant mass contributions from several of the much smaller but more highly developed watersheds rival the South Tributary's loads.**

The smaller watersheds high pollutant loads suggest much higher pollutant yields per acre of watershed. Figure 19 contrasts calculated pollutant mass contributed by each acre of each tributary's watershed. A watershed-average load helps illustrate those watersheds that are heavy contributors. As can be seen from that figure, **the Northwest tributary produces the most pollutant mass per acre,** and may therefore be a watershed to focus additional attention on strategies to improve water quality.

In summary, the available data clearly reveals that the **Salem Oaks Tributary has the poorest water quality.** However, the total mass of pollutants entering the Lake is highly dependent on the amount of water entering carried by each tributary. Flow rates were not quantified when the samples were taken and therefore the mass load contributed to the Lake from each tributary cannot currently be contrasted with available data. Flow estimates from stormwater management studies were used to estimate storm pollutant loading. Streams draining more highly developed areas yielded higher total pollutant mass and higher unit-area-pollutant mass loading. Since phosphorus is the pollutant most closely related to Lake management goals, active management focused on the tributary streams exhibiting the highest unit area phosphorus loadings may provide the most benefit. These tributary streams include the North, Northwest, West, and Salem Oaks Tributaries. Future tributary sampling should include measurement of discharge and description of the physical characteristics of water quality and stream flow. Methods for measuring and estimating water flow are outlined in Chapter III.

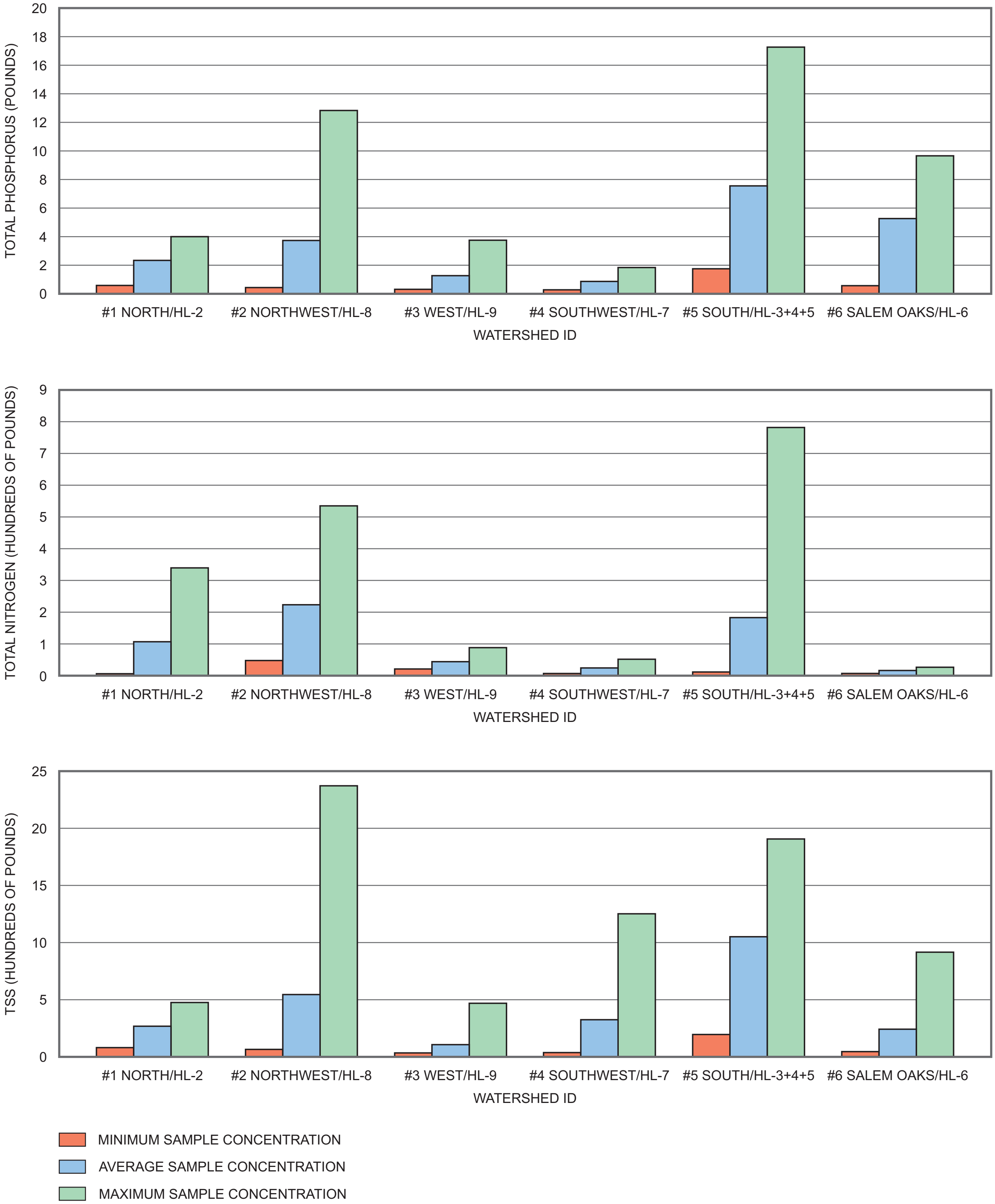
Temperature, Oxygen, and Stratification

When the Lake is stratified, shallow depths are considerably warmer, support abundant algae, and contain abundant oxygen. The thermocline is generally found somewhere between 12 and 24 feet below the surface, with the depth varying month-to-month and year-to-year. Water within the thermocline rapidly becomes colder with depth and contains less oxygen than the epilimnion. Water below the thermocline (the hypolimnion) is much 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.

Water temperature profiles (Figure 20) suggest that Hooker Lake stratifies at about the 15 to 20 foot depth range. The development of a thermocline has far-reaching implications for the plant and animal life in the Lake, the general water quality of the Lake, and management decisions. Dissolved oxygen profiles (Figure 21) reveal extremely low oxygen levels in the deeper basins during late summer. Three separate deeper basins are found in Hooker Lake (Figure 22). The Lake's hypolimnion is confined to these deeper areas. The volume of the lake deep enough to be considered part of the hypolimnion and that commonly contains little to no oxygen during summer accounts for almost a quarter of the Lake's total water volume. The anoxic water found in the Lake's hypolimnion not only is uninhabitable for fish, but also reveals the likelihood of conditions that foster internal phosphorus loading in the Lake. Oxygen levels have not been measured at depths deeper than 10 feet since 2004. Measuring oxygen in the deep areas during the growing season will determine if the hypolimnion regularly becomes anoxic, allowing internal phosphorus loading to occur.

Figure 18

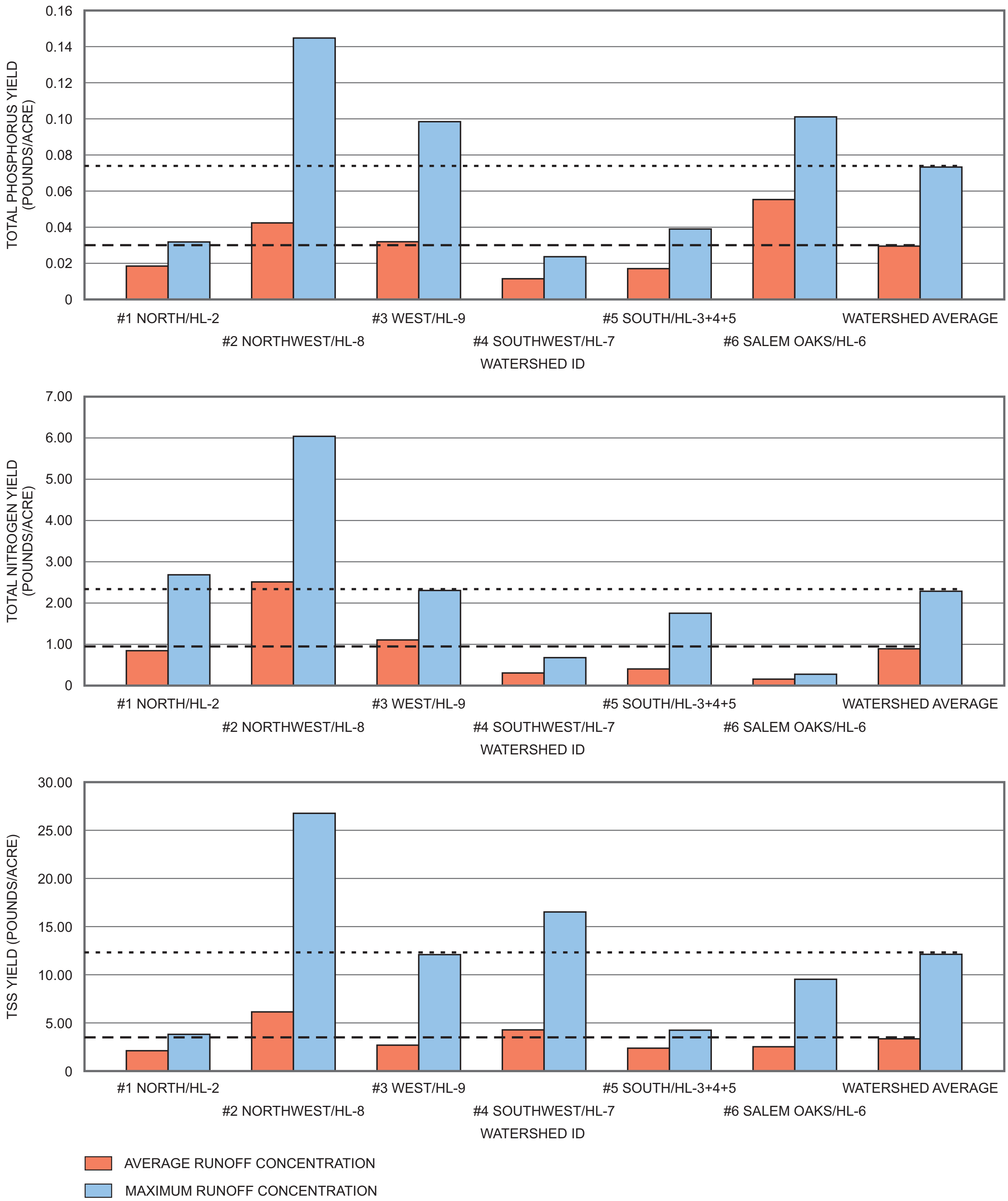
POLLUTANT MASS DELIVERED BY TRIBUTARY STREAMS BY 50-PERCENT ANNUAL PROBABILITY (TWO-YEAR RECURRENCE INTERVAL) STORMFLOW BASED UPON 2014 TRIBUTARY SAMPLING DATA



Source: The Wisconsin Department of Natural Resources, Town of Salem, and SEWRPC.

Figure 19

POLLUTANT UNIT AREA LOAD DELIVERED BY TRIBUTARY STREAMS BY 50-PERCENT ANNUAL PROBABILITY (TWO-YEAR RECURRENCE INTERVAL) STORMFLOW BASED UPON 2014 TRIBUTARY SAMPLING DATA

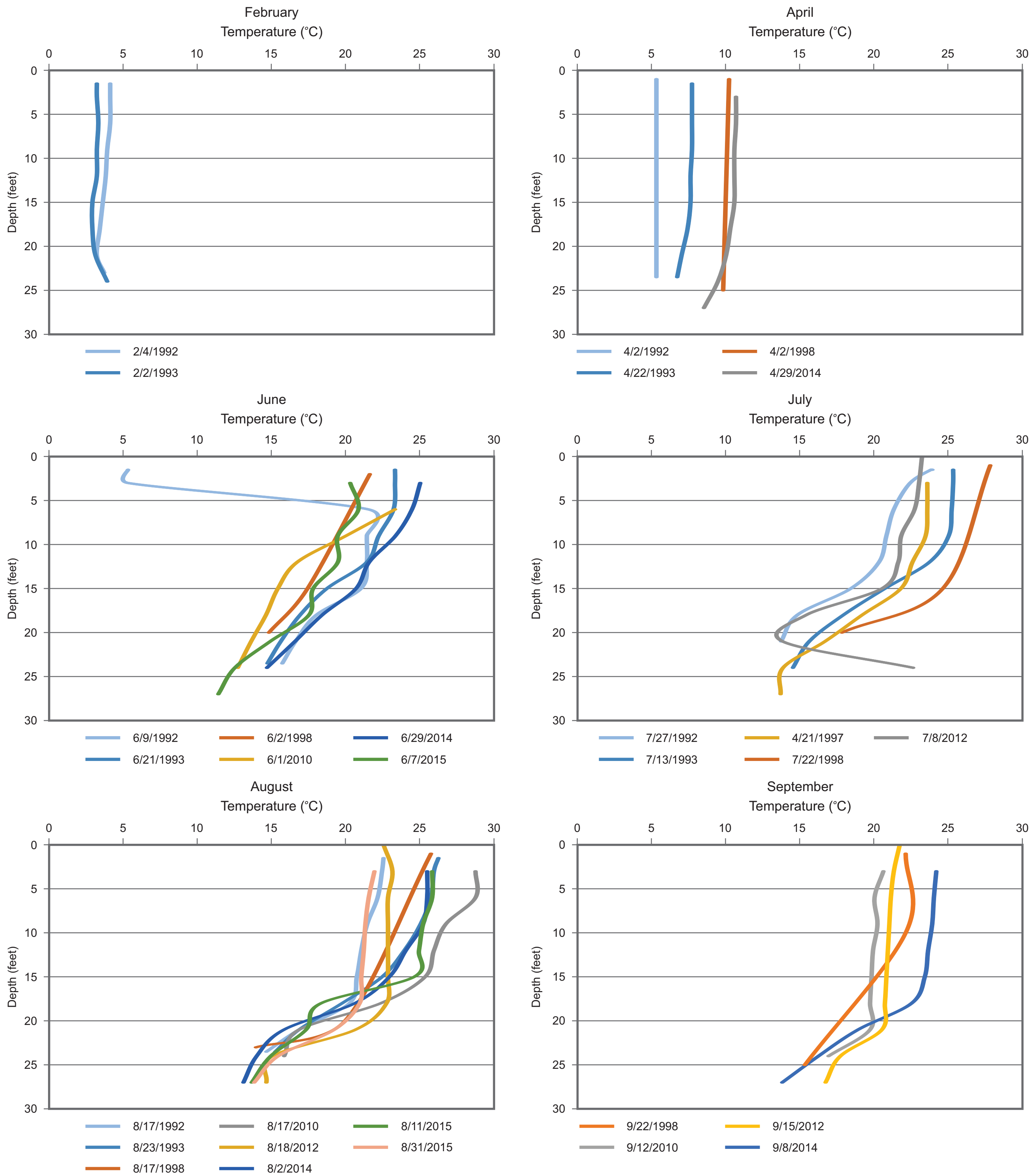


NOTE: THE HORIZONTAL LINES RESPRESENT WATERSHED-WIDE AVERAGES FOR AVERAGE AND MAXIMUM CONCENTRATIONS. BARS EXTENDING ABOVE THE LINE REPRESENT WATERSHEDS WITH HIGHER THAN AVERAGE UNIT AREA POLLUTANT LOADING.

Source: The Wisconsin Department of Natural Resources, Town of Salem, and SEWRPC.

Figure 20

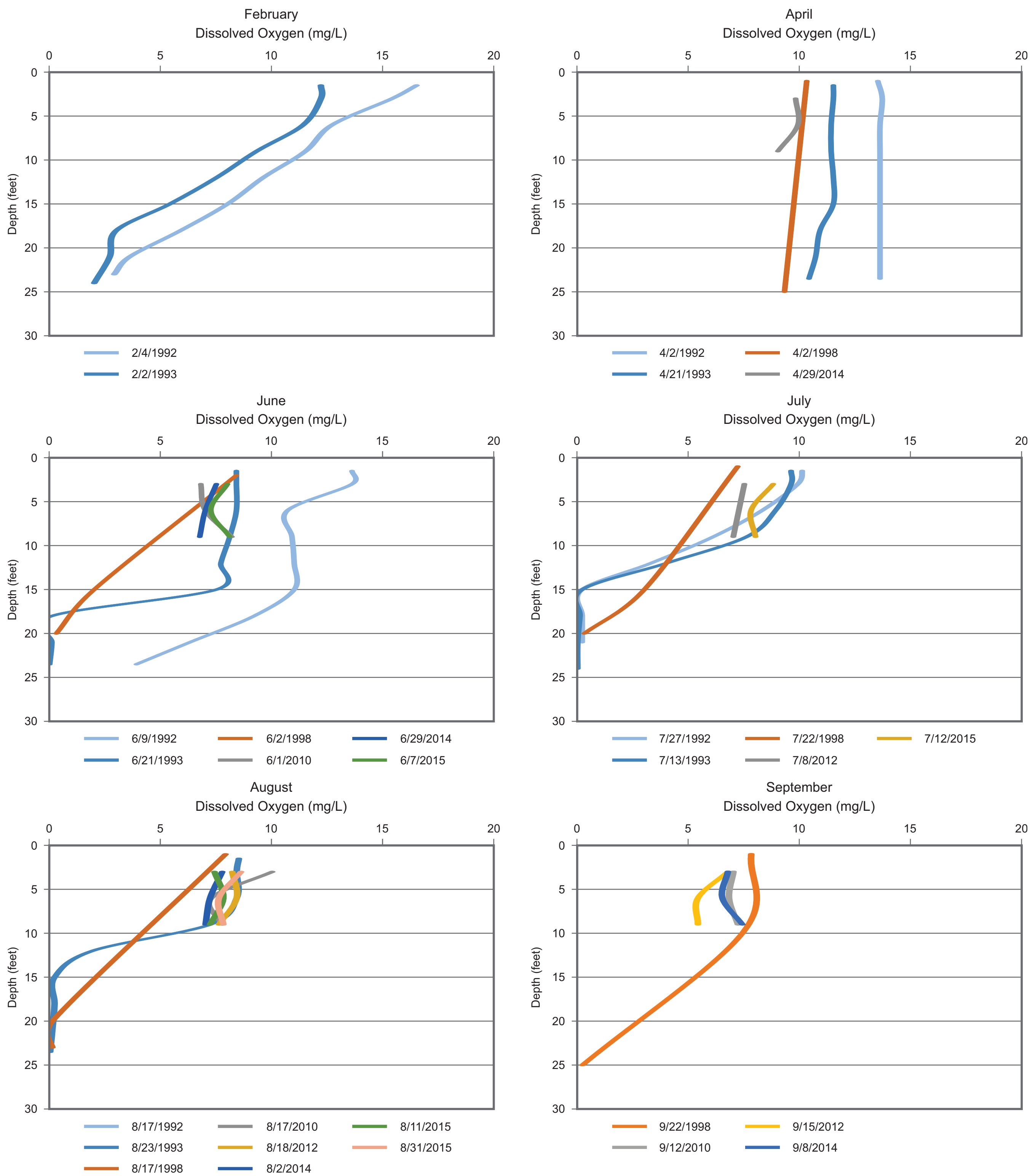
MONTH-BY-MONTH TEMPERATURE PROFILES, HOOKER LAKE



Source: The Wisconsin Department of Natural Resources, University of Wisconsin-Extension Citizen Monitoring Network, and SEWRPC.

Figure 21

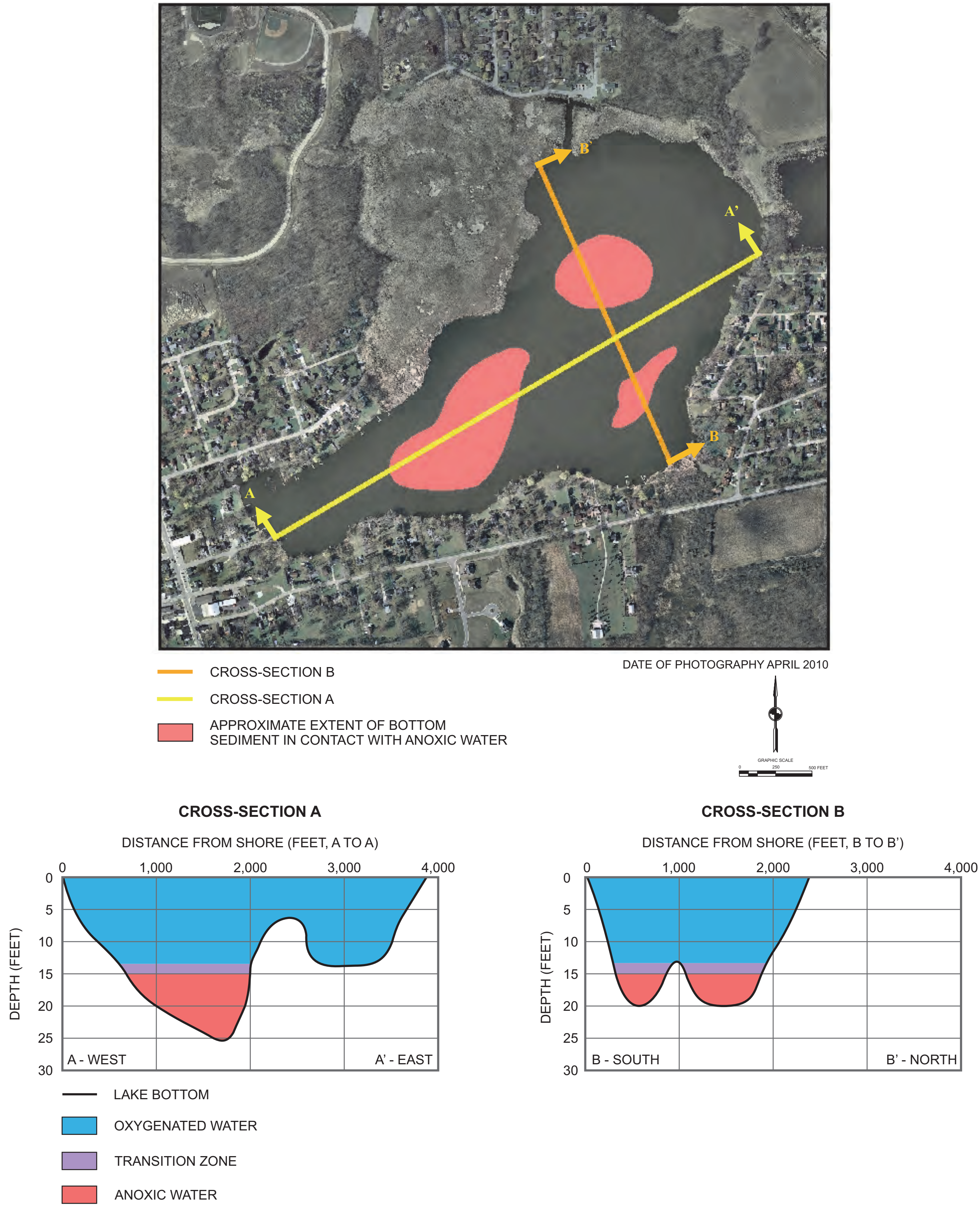
MONTH-BY-MONTH DISSOLVED OXYGEN CONCENTRATION PROFILES, HOOKER LAKE



Source: The Wisconsin Department of Natural Resources, University of Wisconsin-Extension Citizen Monitoring Network, and SEWRPC.

Figure 22

TYPICAL EXTENT OF BOTTOM SEDIMENT IN CONTACT WITH ANOXIC WATER DURING LATE SUMMER, HOOKER LAKE



Source: SEWRPC.

Phosphorus

When the Lake is fully mixed in the spring, phosphorus concentrations are similar throughout the Lake, with phosphorus concentrations averaging 30 µg/L over the period of record. Phosphorus concentrations vary widely within Hooker Lake when the Lake is stratified. Samples collected near the surface during the growing season range from 18 to 38 µg/L with an average of 28 µg/L. The average growing season phosphorus concentrations have remained well below the aquatic life impairment threshold of 60 µg/L for deep drainage lakes. However, the upper end of this range is close to the substantially lower recreational impairment threshold of 30 µg/L for such lakes,[9] and mandated by the *Wisconsin Administrative Code*.[10] The threshold standard is meant to represent an average of three monthly values collected from near-surface water between June 1 and September 15.

PHOSPHORUS SEQUESTRATION

In areas of mineral rich calcareous groundwater ("hardwater"), marl deposits often exist on the beds of lakes fed by 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 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.[11] 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.[12] It is likely that marl formation actively occurs in the Lake, and that the Lake's phosphorus concentrations may be attenuated by phosphorus co-precipitation.

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.

Research in Europe has found that although marl lakes are resistant to phosphorus enrichment and eutrophication, the bottom-dwelling species of algae that promote 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, in turn decreasing 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

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[9]*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

[10]*Wisconsin Administrative Code Chapter NR 102, op. cit.*

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

[12]*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.*

are now eutrophic lakes with low water clarity.[13] This graphically illustrates how the algae-based 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 discharge dependent algae is reduced, 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.

INTERNAL LOADING

As mentioned earlier in this report, Hooker Lake's productivity is controlled by available phosphorus. Phosphorus, under oxygenated conditions, is tightly bound to solids and large amounts of phosphorus are commonly found in lake-bottom sediment. However, when oxygen is absent, geochemical reactions can take place 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. Even though two lakes may have equivalent maximum depths, a lake that has broad shallow areas and a small deep hole has less deep water bottom sediment area than an equal depth lake that is uniformly deep. 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. Moderate depth/size stratified lakes are among the most prone to internal phosphorus loading. Such lakes lack large water volumes, and, hence, have comparatively little stored oxygen in the hypolimnion, making them prone to anoxia.

It should be noted that phosphorus released to the hypolimnion is not directly available to most algae growing in the lake since little sunlight penetrates to these depths. Even though the thermocline is a barrier to circulation, it is imperfect and some phosphorus can migrate to shallower areas. For this reason, the highest levels of algal productivity are often found just above the thermocline in lakes with phosphorus internal loading. Mixing caused by wind and/or seasonal turnover can cause large concentrations of phosphorus from the hypolimnion to suddenly mix with surface water. This can lead to algal blooms.

Hooker Lake stratifies slowly in late summer and the stratification tends to be weak, potentially allowing some mixing to occur. In 1992, the Lake had not stratified by June and there was sufficient amount of oxygen present to support aquatic life all the way to the bottom of the Lake. However, anoxic conditions commonly develop in waters great than 15 feet below the surface by July. With the limited data, the bottom of the Lake appears to commonly experience oxygen deficiency and occasionally anoxia.

A phosphorus internal loading scenario was examined using dates with the highest phosphorus concentrations at the Lake bottom (Table 5). These concentrations occurred during August with anoxia occurring at a depth of approximately 15 feet. In this scenario, approximately 38 acres of the Lake's bottom sediment is in contact with anoxic

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[13] *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.*

Table 5

SURFACE AND BOTTOM WATER TOTAL PHOSPHORUS CONCENTRATIONS IN HOOKER LAKE: 1992-1998

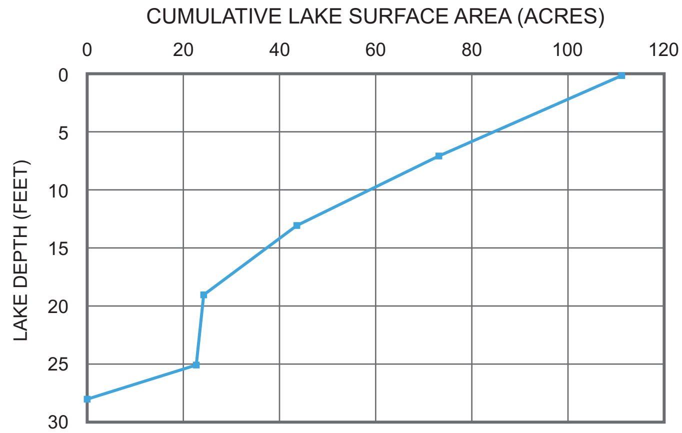
Date	Surface (µg/L)	Bottom (µg/L)
9/22/98	18	60
8/17/98	22	214
7/22/98	19	54
6/2/98	19	121
8/23/93	18	262
7/13/93	26	60
6/21/93	39	88
4/22/93	66	61
8/17/92	22	184
7/27/92	26	60
6/9/96	20	23
4/2/92	37	27

Source: SEWRPC.

water, and approximately 315 acre-feet of Hooker Lake's total water volume is anoxic (Figure 22, 23, and 24). This worst-case scenario suggests that up to 172 pounds of phosphorus could be released from lake-bottom sediment over the warm season. In such a case, the mass of phosphorus released from lake-bottom sediment would only be one-quarter the mass of phosphorus estimated by models to be contributed to the lake from its watershed (Table 6). Since anoxic water covers about 38 acres of the lake-bottom at its greatest extent, each acre of lake-bottom exposed to anoxic water contributes approximately 4.5 pounds of phosphorus to the water column over the summer season under this worst-case condition. Since Hooker Lake weakly stratifies, conditions necessary to support internal loading can break down fairly easily. Therefore, the actual average contribution of internal loading to the Lake's overall phosphorus budget is likely to be lower than this worst-case estimate. Therefore, **internal loading is not believed to be a dominant contributor to Hooker Lake's phosphorus budget, and effort to control phosphorus should remain primarily focused on the watershed. External loading must be minimized before any effort to reduce internal loading would be successful. Methods for reducing both internal and external loading are discussed in further detail in chapter III.**

Figure 23

LAKE DEPTH VERSUS SURFACE AREA, HOOKER LAKE

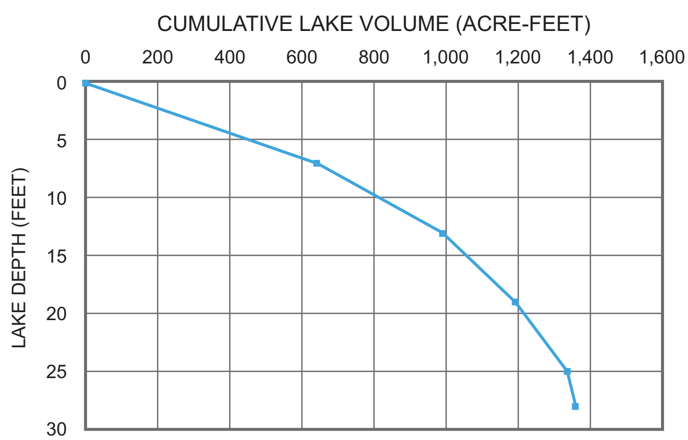


NOTE: THIS IS A CUMULATIVE PLOT OF THE TOTAL SURFACE AREA OF THE LAKE WITH WATER DEPTHS GREATER THAN OR EQUAL TO DEPICTED VALUES. FOR EXAMPLE, ROUGHLY 60 ACRES OF THE LAKE IS DEEPER THAN 10 FEET.

Source: The Wisconsin Department of Natural Resources and SEWRPC.

Figure 24

LAKE DEPTH VERSUS VOLUME, HOOKER LAKE



NOTE: THIS IS A CUMULATIVE PLOT OF THE TOTAL VOLUME OF THE LAKE CONTAINED IN DEPTHS LESS THAN OR EQUAL TO DEPICTED VALUES. FOR EXAMPLE, ROUGHLY 1,200 ACRE-FEET OF THE LAKE'S TOTAL VOLUME IS CONTAINED IN THE UPPER 20 FEET OF THE LAKE'S WATER COLUMN.

Source: The Wisconsin Department of Natural Resources and SEWRPC.

A corollary to the subject of tributary and lake nutrient levels is a study conducted in the Lake Wingra watershed in Dane County.[14] Over several years, researchers investigated sources of phosphorus in urban environments. Their

[14]*Roger Bannerman, of the USGS, has described the findings of the Lake Wingra study in his presentation entitled* "Urban Phosphorus Loads: Identifying Sources and Evaluating Controls.

Table 6

ESTIMATED ANNUAL POLLUTANT LOADINGS BY LAND USE CATEGORY WITHIN THE HOOKER LAKE TRIBUTARY

Land Use Category	Pollutant Loads: Circa 1835			
	Sediment (tons)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)
Urban				
Residential	- -	- -	- -	- -
Commercial	- -	- -	- -	- -
Industrial	- -	- -	- -	- -
Governmental	- -	- -	- -	- -
Transportation	- -	- -	- -	- -
Recreational	- -	- -	- -	- -
Subtotal	- -	- -	- -	- -
Rural				
Agricultural	- -	- -	- -	- -
Wetlands	0.9	20.3	- -	- -
Woodlands	1.4	30.4	- -	- -
Water	2.4	3.3	- -	- -
Subtotal	4.7	54.0	- -	- -
Total	4.7	54.0	0	0

Land Use Category	Pollutant Loads: 2010			
	Sediment (tons)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)
Urban				
Residential	10.0	61.5	4.1	29.2
Commercial	8.6	26.4	4.8	32.8
Industrial	1.5	4.7	0.9	6.0
Governmental	15.6	82.4	4.3	48.8
Transportation	4.6	9.2	20.2	72.2
Recreational	0.1	1.4	- -	- -
Subtotal	40.4	185.6	34.3	189.0
Rural				
Agricultural	110.0	497.9	- -	- -
Wetlands	0.3	5.8	- -	- -
Woodlands	0.3	5.5	- -	- -
Water	2.4	3.3	- -	- -
Subtotal	113	512.5	- -	- -
Total	153.2	698.1	34.3	189.0

Land Use Category	Pollutant Loads: 2035			
	Sediment (tons)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)
Urban				
Residential	19.3	152.9	8.5	61.9
Commercial	46.3	141.6	26.0	175.8
Industrial	1.5	4.7	0.9	6.0
Governmental	20.7	109.4	5.7	64.8
Transportation	4.7	9.5	20.6	74.0
Recreational	0.7	16.2	- -	- -
Subtotal	93.2	434.3	61.7	382.5
Rural				
Agricultural	11.7	44.7	- -	- -
Wetlands	0.3	6.0	- -	- -
Woodlands	0.2	5.3	- -	- -
Water	2.4	3.4	- -	- -
Subtotal	14.6	59.4	- -	- -
Total	107.8	493.7	61.7	382.5

Note: Circa 1835 land cover values estimated from public land survey notes.

Source: SEWRPC.

findings reveal that, after lawn fertilizers, leaves left on streets in residential areas are the principle source of phosphorus in urban settings. Although the State of Wisconsin has passed legislation prohibiting use of lawn fertilizers containing phosphorus, little has been done in residential communities to address the issue of leaf litter and its role as a major contributor to phosphorus in lakes.

The Lake Wingra study has shown that of the various urban land uses, residential use contributes the greatest percentage of total phosphorus – nearly 60 percent. Furthermore, of the residential land uses, streets and lawns accounted for 65 percent of the total phosphorus loading. Residential streets yielded the largest total phosphorus loading, especially during autumn. On average, about 55 percent of the total annual residential loading of phosphorus in runoff occurs during autumn, and that percentage can be 70 percent or more. Phosphorus loading from streets was shown to be the result of curbside and street-area leaf litter. As traffic rolls over leaves, the crushed leaf structure accentuates phosphorus leaching during wet weather. Runoff then washes the leaf litter, and especially the released phosphorus from the crushed leaves, into the drainage system and eventually into lakes.

The Lake Wingra study underscores the importance of effectively managing leaves on residential streets during the fall, an action that can significantly reduce this large external phosphorus load. This would be especially important for Hooker Lake in residential areas on the north side of the Lake that are higher in elevation than the shoreland of the Lake and would, thus, drain toward it. A small portion of this area is serviced by the Village of Paddock Lake's leaf collection program. Residents of the Town of Salem currently decide how to dispose of their leaves individually, usually burning or composting. <u>Keeping leaves from collecting on residential streets through prompt leaf collection, and especially the timing of that collection from the streets, is a critical part of reducing phosphorus external loading from residential areas. Leaf burning is also a suitable method, as long as the leaves are not burned near the lakeshore, the shores and beds of tributary streams, or within intermittent ditches.</u>

Chloride

Under natural conditions, surface water in Southeastern Wisconsin contains very low chloride concentrations. Studies completed in Waukesha County lakes during the early 1900s report three to four mg/L of chloride. Most Wisconsin lakes saw little increase in chloride concentrations until the 1960s, but a rapid increase thereafter. Chloride in Hooker Lake was measured in the Lake once in 1998, with concentrations of 87 mg/L reported. This value is typical of present-day chloride levels in the lakes of Southeastern Wisconsin. Chloride concentrations in most lakes have been consistently increasing for decades.

Samples collected from tributaries feeding Hooker Lake contain much higher concentrations of chloride, and are an example of why chloride concentrations are increasing. Chloride concentrations were measured in the Hooker Lake tributaries during 2014 (Figure 13). Chloride concentrations in the summer months ranged between 41.8 and 726 mg/L, with an average of 209 mg/L. Concentrations above chronic toxicity occurred in the Salem Oaks, north, and northwest tributaries. Chloride concentrations were lower than typical during the estimated higher flows occurring on June 11 and November 23. Chloride concentrations are generally higher during cold weather months when road deicing chemicals are actively used. These measurements indicate that chloride concentrations in Hooker Lake have likely significantly increased since 1998. Chloride concentration should be regularly measured to evaluate if they are continuing to increase and if they are reaching harmful levels to aquatic life.

Chloride is considered a conservative pollutant, meaning that natural processes other than evaporation typically do not detain or remove it from water. Humans use chloride bearing materials for a multitude of purposes (e.g., road salt, water softening, industrial processes), and 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 Hooker Lake do not exceed current guidelines, rapidly increasing chloride concentrations attest to the fact that Hooker 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. Management efforts to reduce chloride loading to Hooker Lake and other waterbodies throughout the Region are an important issue of concern. Winter road deicing practices are one related issue.

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

Available chloride concentration data reflect actual concentrations at set positions during discrete points in time, and are not necessarily representative of the range of values actually present over longer periods or over larger areas. For example, the chloride concentrations found in a tributary stream that drains a large roadway segment will likely have higher concentrations during periods of active de-icing or snow melt than during late summer. Similarly, such a tributary will likely have higher chloride concentrations than a similar tributary draining an undeveloped, unpopulated watershed. Therefore, chloride concentrations can vary over time and over short distances. Some streams in Southeastern Wisconsin have been found to contain chloride concentrations far above guideline standards for discrete periods of time but have acceptable concentrations during other periods of time. Episodic high chloride concentrations can dramatically alter the types and numbers of plants and animals living in a stream, even though "average" concentrations appear acceptable.

Chloride concentrations provide an excellent low-cost mechanism to monitor overall human influence on the Lake and can induce change to plant and animal communities. Therefore, chloride concentrations should be determined as part of regular water quality monitoring. Chloride reduction best management practices should be implemented. More details are provided in Chapter III.

Watershed Characteristics and Water Quality

Research shows that the health of a lake or stream is usually a direct reflection of the use and management of the land within its watershed. Research also shows that interventions are often necessary to maintain or improve the conditions of these resources. As mentioned earlier, different land uses can contribute different types of pollution to a lake. Though it is normal for some sediments 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 introduce pollutants (such as heavy metals, fertilizers, and oils) which would not have otherwise entered the system and/or accelerate natural erosion and sediment/nutrient delivery processes. Issues commonly arise when land use changes and when land is disturbed through tilling and construction. Such activity causes soils to loosen, erode, and eventually enter streams and lakes.

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 the 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 characterizing a watershed, it is first necessary to delineate that watershed. The process of watershed delineation essentially involves analyzing elevation data of the surrounding locale to determine the area draining towards the lake. Completing this analysis provides the basis for determining whether potential pollutant sources are threats to the lake. For example, if a nonpoint source is near a lake but outside of its watershed, surface runoff from that source would not reach the lake, and, therefore, is not an issue of concern in terms of that lake's water quality.

2. **Ratio of watershed size to lake surface size**—Lakes with a high watershed area to lake surface area ratio 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 wash into a lake as a result of precipitation events. The greater the amount of land surface draining to the lake, the greater is the likelihood that pollutants will be washed into the lake. Lakes with a watershed to lake surface ratio in excess of 10:1 often experience some type of water quality problems.[15]

3. **The type and location of existing land uses within the watershed**—The extent and location of current land uses within the watershed can help determine the potential causes of pollution to a lake. Land use conditions can be represented in models to estimate total pollutant loads that could enter a lake. 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 pollution reduction efforts).

4. **The type and location of past land use changes within the watershed**—Being aware of past land use changes can provide a context for understanding what caused past issues within a lake, particularly when considered with water quality monitoring data or well-known historical issues. If a long-term lake property owner, for example, remembers or has record of the years of high aquatic plant growth, large algal blooms, or low or high lake levels, those conditions can be assessed in terms of the historical land use changes to determine whether something happened within the watershed to cause that issue (such as an increase in cropping practices or development). This information can be helpful to future planning, because it offers insight into how the lake might react to similar situations.

5. **The nature and location of planned land use within the watershed**—In addition to current land use in the watershed, it is also possible to estimate land use changes that will occur in the future. Applying this information is important, as it helps determine the areas that may need to be targeted for management efforts in the future, as well as the potential extent of future pollution issues.

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

The Hooker Lake watershed boundary was delineated using two-foot interval elevation contours developed from a 2003 digital terrain model. Actual land use within the watershed in 2010 and planned year 2035 land use were quantified by urban and rural categories, and that land use information was used with two models that calculate pollutant loadings.[16] Pollutant loading characteristics are discussed below.

Summary of Hooker Lake Watershed Characteristics and Water Quality

Hooker Lake's watershed, shown on Map 4, is situated within the Town of Salem and the Village of Paddock Lake, both in Kenosha County.[17] The **total land area that drains into Hooker Lake is approximately 1,269 acres,** or about two square miles. Hooker Lake has a **watershed to lake surface ratio of 11:1;** such a large ratio increases the likelihood of the Lake experiencing **some water quality issues.** According to 2010 land use statistics, **approximately two-thirds of Hooker Lakes watershed is used for rural land use purposes** (see Map 5 and Table 7). Currently, the Hooker Lake watershed has a distinctly agricultural tone: **agricultural and other open land uses represent the single largest land use in any category**—rural or urban—comprising about 45 percent of the total

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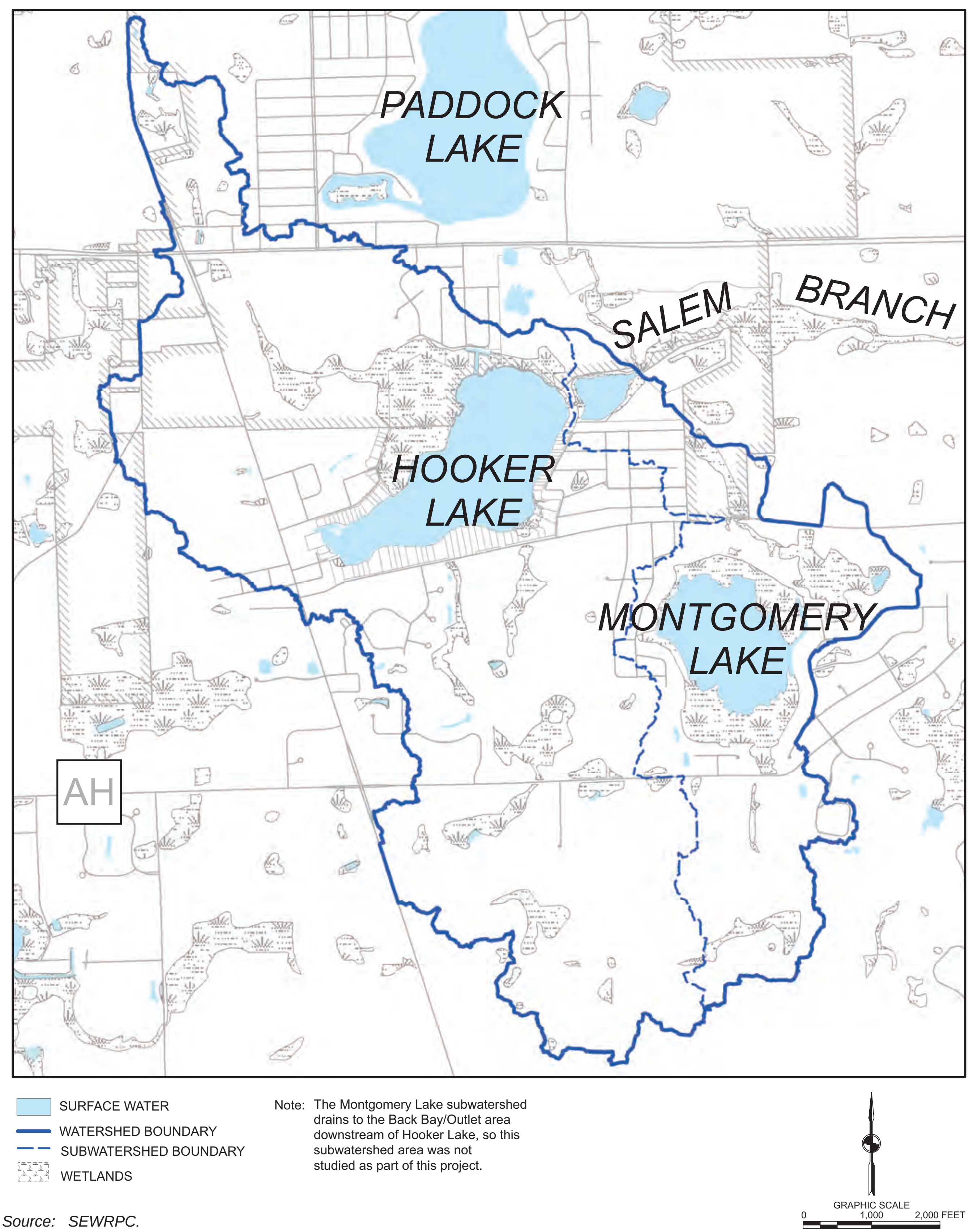
[15]*Aron and Associates,* Hooker Lake, Aquatic Plant Management Plan, *May 2009.*

[16]*Wisconsin Lake Model Spreadsheet (WiLMS version 3.0) and the unit area load-based (UAL) models.*

[17]*As shown on the watershed map for Hooker Lake, the Montgomery Lake subwatershed area drains to the back outlet bay of Hooker Lake downstream of the main Hooker Lake body. Since any inflow from the Montgomery subwatershed would, therefore, have negligible effect on the water quality of the main Hooker Lake body, this subwatershed area was not included as part of this report.*

Map 4

HOOKER LAKE WATERSHED



Note: The Montgomery Lake subwatershed drains to the Back Bay/Outlet area downstream of Hooker Lake, so this subwatershed area was not studied as part of this project.

Source: SEWRPC.

watershed. About 11 percent of the total watershed area is wetland (namely Hooker Lake Marsh as well as a number of smaller areas located along with the tributary streams located northwest and south of the Lake). Woodland covers about 10 percent of the watershed.

Based on current, predicted, and pre-settlement land use data estimated from public land survey notes, a model was used to estimate pollutant loadings that could potentially enter Hooker Lake,[18] as summarized in Table 6. These estimates could not, however, be contrasted to current in-lake data due to the absence of recent comprehensive water chemistry measurements. Consequently, they should only be used as guidance for where to target watershed management efforts when data is obtained. These calculations suggest that post-settlement land uses significantly increased sediment and phosphorus loads to the Lake. The Lake is estimated to now receive 30 times as much sediment and nearly 13 times as much phosphorus as it did before 1835 (i.e., before European settlement). As of 2010, over 70 percent of the sediment and phosphorus was contributed by rural land use. In 2035, with the forecast urbanization of rural lands, a decrease in sediment and phosphorus contribution is predicted. However, contributions will remain many times higher than pre-settlement conditions. Methods to decrease sediment and phosphorus loading should be implemented in both rural and urban areas. Urban land use is the only significant source of heavy metals. Urban areas should be targeted if heavy metals are found to be an issue within the Lake after further monitoring.

Past land use in a watershed can, to some degree, be reflected by the amount of historical urban growth in the area, and by historical changes in populations and number of households. Historical urban growth patterns for the Hooker Lake watershed are shown on Map 6 and represented in Table 8. Historical changes in population and households are shown in Table 9. An example of these changes can be seen by comparing aerial photographs representing conditions in 1970 and 2010 (Figure 25). As indicated in Tables 8 and 9, urban development was particularly intense between 1950 and 1980. Unfortunately, historical water quality data for Hooker Lake during this same time is not comprehensive enough to determine correlations with changes in the Lake's water quality, although it is probably a safe assumption that the urban development occurring in the watershed during and since that time likely has had some effect on the Lake.

Year 2035 planned land use for the Hooker Lake watershed is shown on Map 7.[19] It is evident that a significant amount of open and agricultural land is planned to be developed, mostly for residential and commercial uses. This pattern is more clearly shown in Map 8, which identifies those parts of the watershed that are in agricultural and open land use in 2010, but are forecast to be changed to urban uses by 2035. As can be seen from Map 8, the majority of the forecasted development is going to occur in the southern part of the watershed as single-family residential uses, and west of STH 83 where the development will be mostly single-family residential and commercial. The northern tip of the watershed (north of STH 50) will experience development mainly in the form of single-family and multi-family residential uses, although some amount of commercial development is also expected to occur. As summarized in Table 7, **agricultural land uses are expected to decrease significantly from about 42 percent of the land area in 2010, to about only 4 percent of the land area in 2035.** In addition to changing the nature of the pollutants in stormwater runoff, as can be seen from a comparison of the 2010 and 2035 pollution loading estimates in Table 6, this change also poses an **issue in terms of risk for pollution from areas where construction will take place.** Construction and grading associated with development pose a transient, although serious, pollution risk. **If not properly managed, construction sites can release large pulses of sediment and entrained nutrients**

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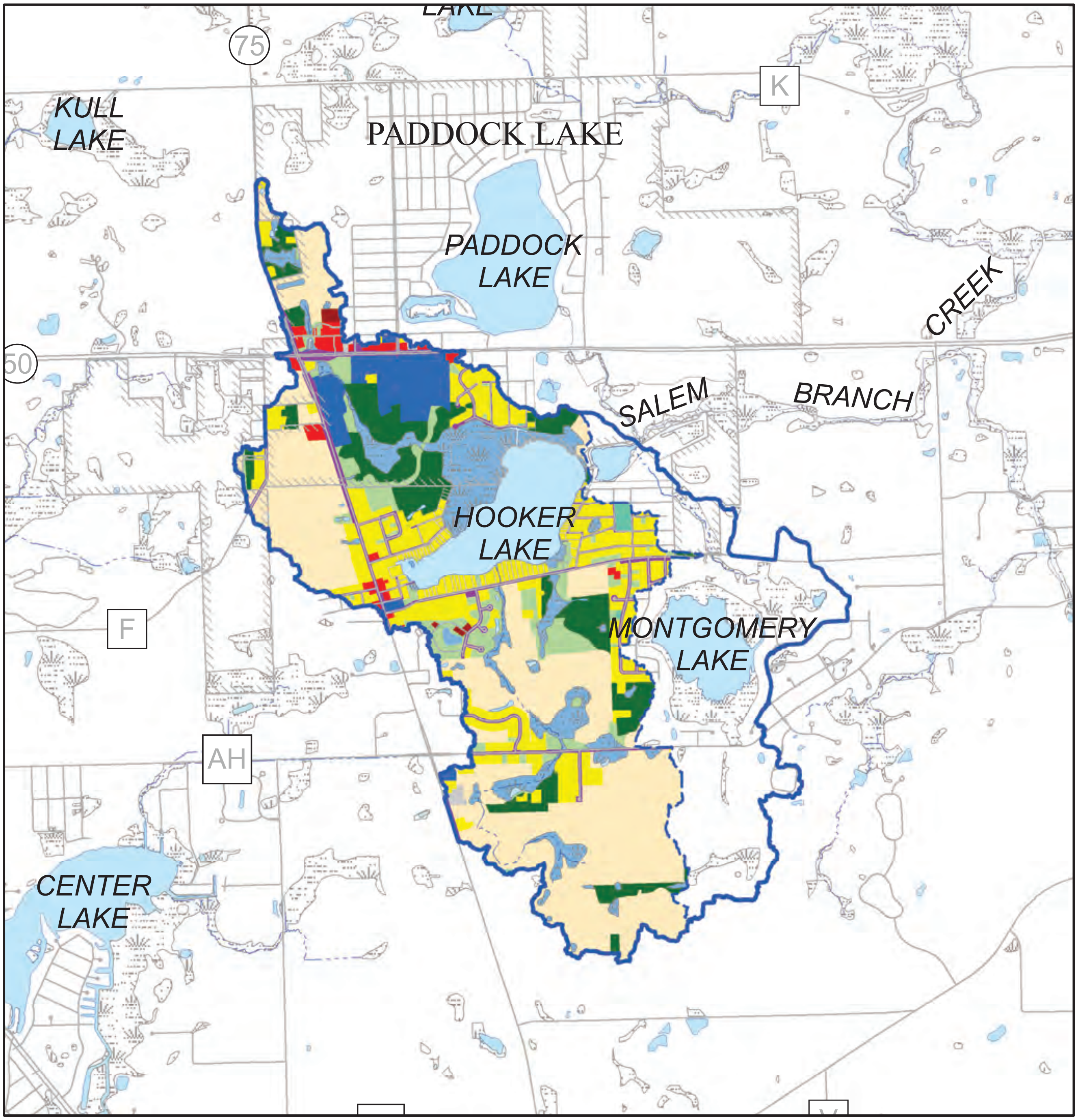
[18]*The calculations for nonpoint source phosphorus, suspended solids, and urban-derived metal inputs to Hooker Lake were estimated using either the Wisconsin Lake Model Spreadsheet (WiLMS version 3.0), or the unit area load-based (UAL) model developed for use within the Southeastern Wisconsin Region. These two models operate on the general principal that a given land use will produce a typical mass of pollutants on an annual basis.*

[19]*See SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006.*

Map 5

LAND USES IN THE HOOKER LAKE WATERSHED: 2010



SINGLE-FAMILY RESIDENTIAL
MULTI-FAMILY RESIDENTIAL
COMMERCIAL
INDUSTRIAL
TRANSPORTATION, COMMUNICATIONS, AND UTILITIES
GOVERNMENT AND INSTITUTIONAL
AGRICULTURAL
OTHER OPEN LANDS
RECREATION
WETLANDS
WOODLANDS
EXTRACTIVE AND LANDFILL
SURFACE WATER
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY
WETLANDS

Note: The Montgomery Lake subwatershed drains to the Back Bay/Outlet area downstream of Hooker Lake, so this subwatershed area was not studied as part of this project.

GRAPHIC SCALE
0 1,500 3,000 FEET

Source: SEWRPC.

Table 7

EXISTING AND PLANNED LAND USE WITHIN THE TOTAL DRAINAGE AREA TRIBUTARAY TO HOOKER LAKE: 2010 AND 2035

Land Use Categories[a]	2010 Acres	2010 Percent of Total Tributary Drainage Area	2035 Acres	2035 Percent of Total Tributary Drainage Area
Urban				
Residential				
Single-Family, Suburban Density	- -	- -	- -	- -
Single-Family, Low Density	45	3.5	292	22.6
Single-Family, Medium Density	182	14.1	265	20.5
Single-Family, High Density	- -	- -	- -	- -
Multi-Family	4	0.3	27	2.1
Commercial	22	1.7	118	9.1
Industrial	4	0.3	4	0.3
Governmental and Institutional	61	4.7	81	6.3
Transportation, Communication, and Utilities	84	6.5	86	6.7
Recreational	5	0.4	60	4.6
Subtotal	407	31.5	933	72.2
Rural				
Agricultural and Other Open Lands	579	44.8	52	4.0
Wetlands	145	11.2	149	11.5
Woodlands	137	10.6	133	10.3
Water[b]	25	1.9	26	2.0
Extractive	- -	- -	- -	- -
Landfill	- -	- -	- -	- -
Subtotal	886	68	360	27.8
Total	1293	100.0	1293	100.0

[a]*Parking included in associated use.*

[b]*25 acres of open water exist within the upland area draining to Hooker Lake. Hooker Lake occupies an additional 111 acres.*

Source: SEWRPC.

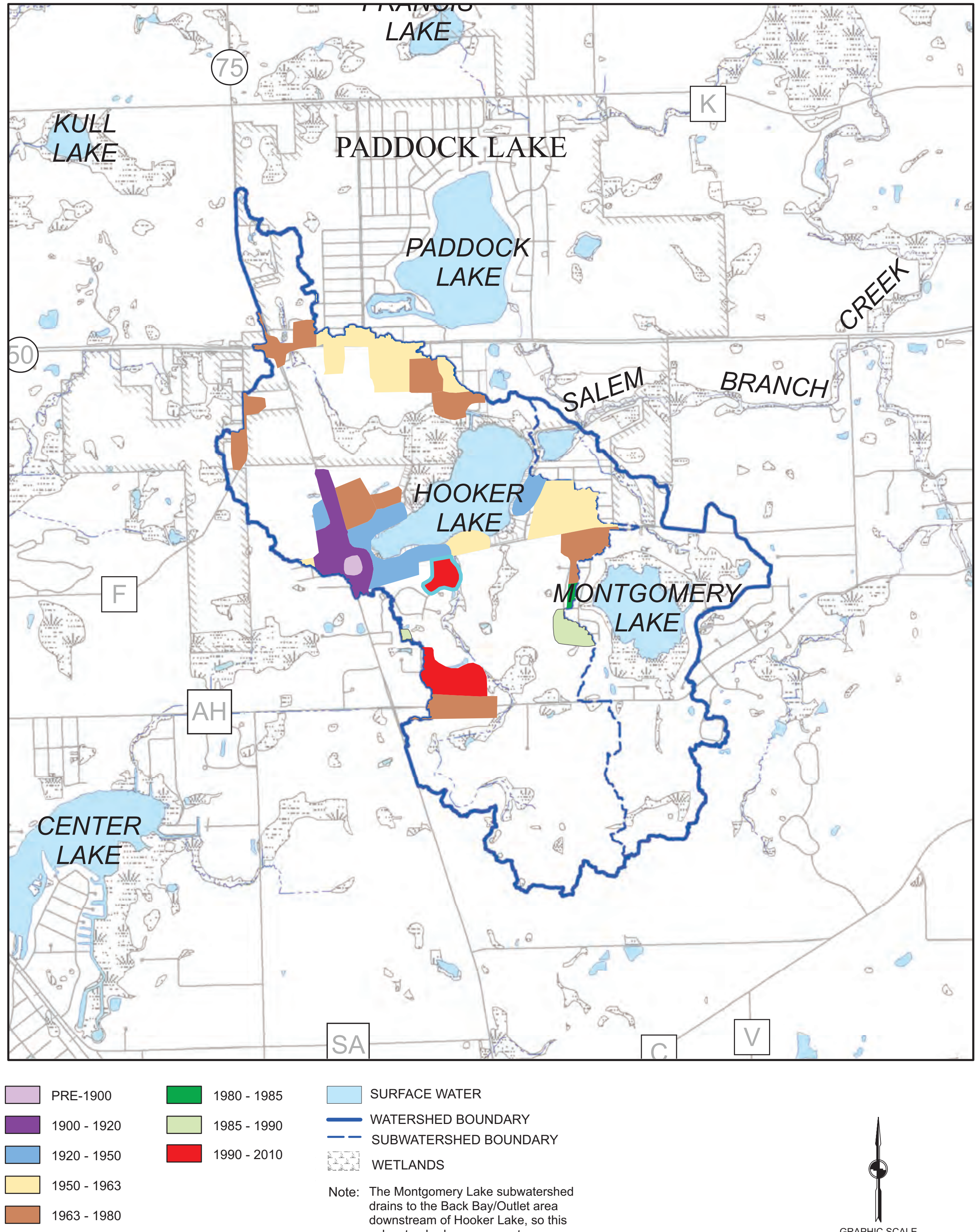
into water courses. Dissolved and floating pollutants and fine-grained sediment may be delivered to the Lake very quickly, while larger-grained sediment transported near and along the bed of streams may require considerable time to reach the Lake. Consequently, recommendations to mitigate this risk and ensure the continued health of the Lake are included in Chapter III of this report.

Finally, **nearly the entire Hooker Lake watershed is served or is planned to be served by either the Village of Paddock Lake or the Town of Salem sanitary sewer systems** (Map 9).[20] Some areas in the extreme southern portion of the watershed continue to be served by privately owned septic systems. Management of private onsite waste treatment systems is not a critical issue of concern in the Hooker Lake watershed.

[20]*It is important to note that the Town of Salem and Village of Silver Lake merger was approved by the Wisconsin Department of Administration in November 2016. It is anticipated that these two municipalities will officially become the new "Village of Salem Lakes" in February 2017.*

Map 6

HISTORIC URBAN GROWTH IN THE HOOKER LAKE WATERSHED



Source: SEWRPC.

Since there has not been a recent comprehensive analysis of water quality in Hooker Lake, the conditions responsible for some of the perceived management problems are somewhat challenging to determine. However, the models suggest that agricultural land uses contribute about two-thirds of the sediment and phosphorus entering the Lake. Since many of the concerns center on water quality, and since phosphorus is the nutrient limiting aquatic plant growth in the Lake, actions to reduce phosphorus delivery from agricultural lands are important components of the effort to reduce concentrations of this limiting aquatic plant nutrient. Therefore, agriculture is currently land use targeted for management efforts. Attention should also be given to the channels draining rural lands. All size stream channels commonly exhibit unstable beds and banks fostered by artificially enhanced drainage. Bed and bank erosion can be major contributors to a stream's load of sediment and nutrients. Finally, the impending conversion of agricultural lands to urban use should be considered, especially in light of the potential to reduce runoff intensity and pollutant loadings through modern stormwater management practices, and the potential for heavy loads to be generated during construction. Chapter III includes a protocol that should be followed and amended as more data is obtained. Consideration should be given to enhance the existing or latent pollution mitigation ability of the watershed (e.g., through maintenance and expansion of riparian buffers), since this will prevent many types of pollution from many different sources rather than just from one land use.

Table 8

HISTORIC URBAN GROWTH IN THE HOOKER LAKE WATERSHED

Time Period	Land Developed During Time Period (acres)	Annual Increase in Land in Urban Use (Percent of watershed land area per year)
Pre-1900	3	- -
1900-1920	33	0.1
1920-1950	46	0.1
1950-1963	89	0.5
1963-1970	33	0.4
1970-1975	26	0.4
1975-1980	41	0.6
1980-1985	2	0.3
1985-1990	11	0.2
1990-2010	31	0.2

Source: SEWRPC.

How Watershed and Shoreland Filtering and Storage Affect Water Quality

Sediment deposition within a lake can result from erosion of the shoreline, watershed or aquatic plant death and biomass accumulation, and transport of sediment from the lake's watershed. Sediments can bury natural sand and gravel bottom substrate, degrading fish habitat and causing a loss of aquatic organisms. Species such as sunfish (e.g., largemouth bass, bluegill, and green sunfish), and darters and minnows (e.g., common shiner, sand shiner, and

Table 9

POPULATION AND HOUSEHOLDS IN THE HOOKER LAKE WATERSHED: 1960-2035

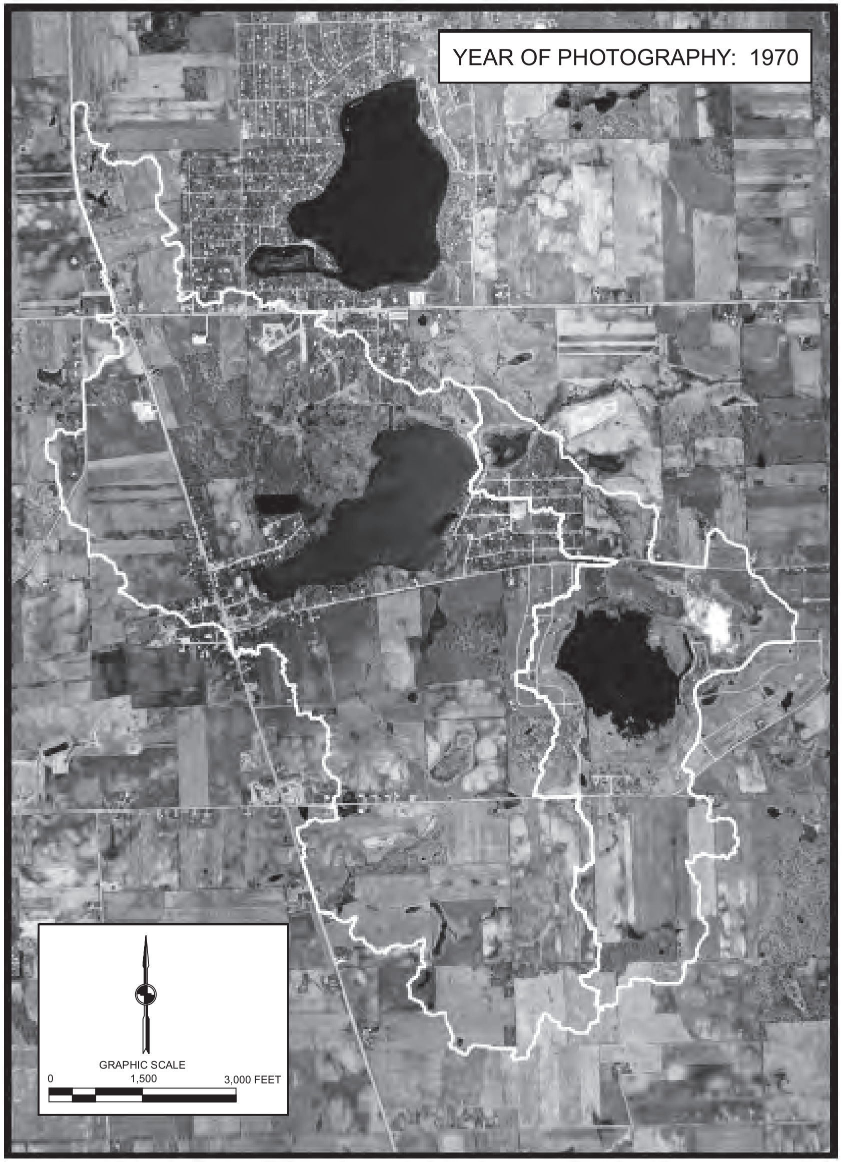
Year	Population	Change from Previous Decade		Households	Change from Previous Decade	
		Number	Percent		Number	Percent
1960	495	- -	- -	170	- -	- -
1970	861	366	74	257	87	51
1980	1,306	445	52	408	151	59
1990	1,293	-13	-1	452	44	11
2000	1,590	297	23	551	99	22
2010	1,731	141	9	643	92	17
2035	2,899	1,168	67	1,091	448	70

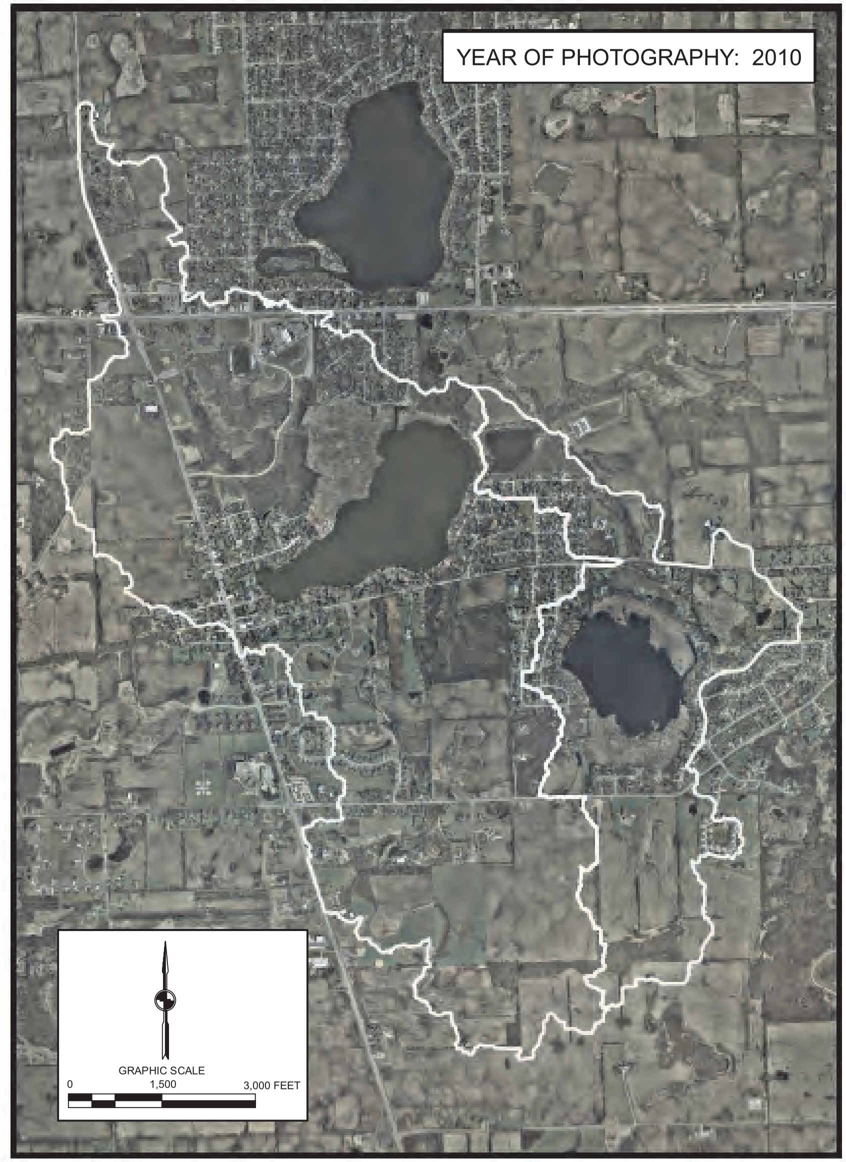
NOTE: Planned 2035 data based on 2000 census data and does not reflect change which may have occurred between 2000 and 2010.

Source: SEWRPC.

Figure 25

HISTORIC AERIAL PHOTOGRAPHS OF HOOKER LAKE: 1970 AND 2010

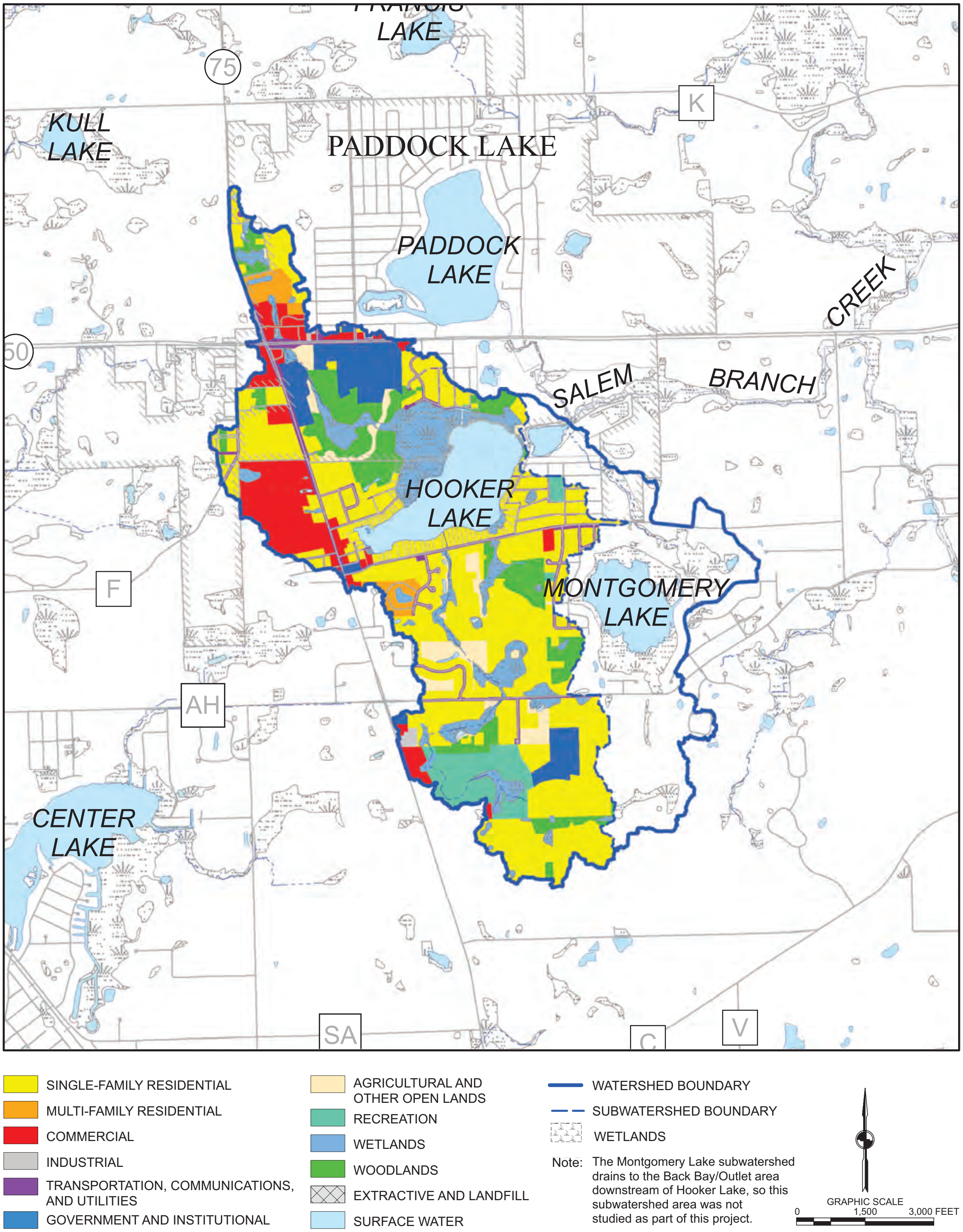




Source: SEWRPC.

Map 7

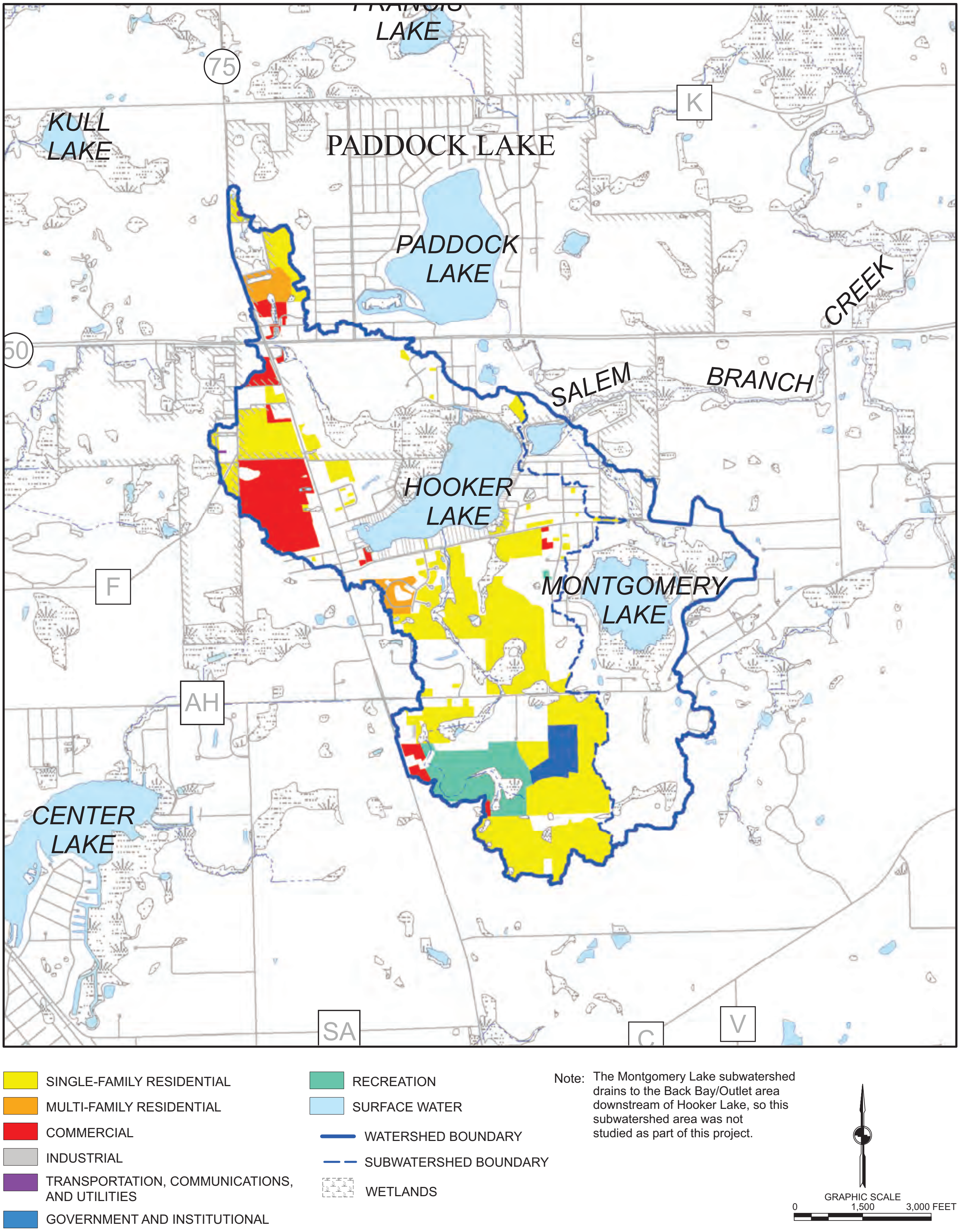
PLANNED LAND USES IN THE HOOKER LAKE WATERSHED: 2035



Source: SEWRPC.

Map 8

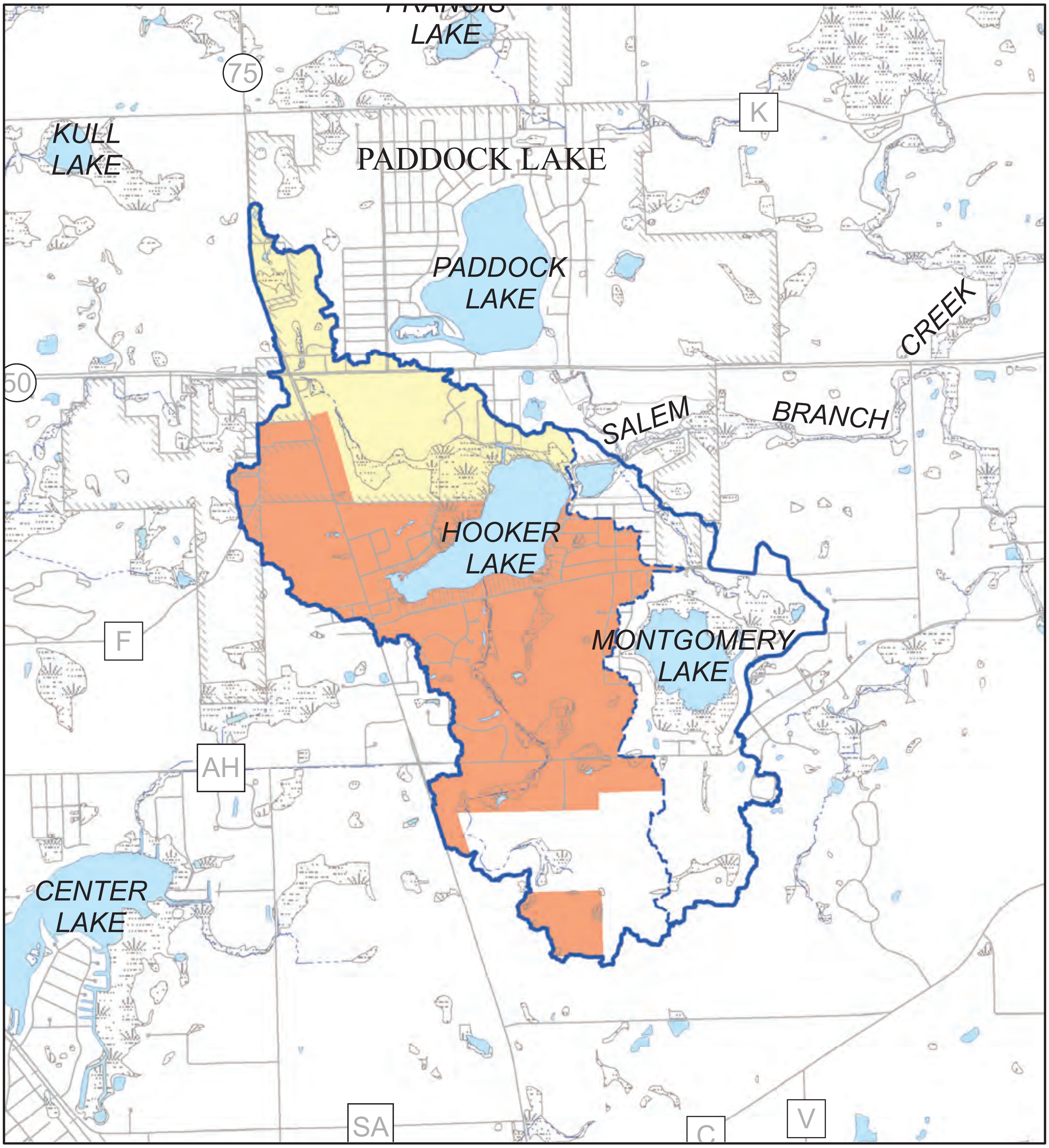
2010 AGRICULTURAL AND OPEN LANDS CONVERTED TO URBAN DEVELOPMENT UNDER PLANNED 2035 LAND USE CONDITIONS WITHIN THE HOOKER LAKE WATERSHED



Source: SEWRPC.

Map 9

PLANNED SANITARY SEWER SERVICE AREAS IN THE HOOKER LAKE WATERSHED: 2035



VILLAGE OF PADDOCK LAKE
TOWN OF SALEM
WETLANDS
SURFACE WATER
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY

Note: The Montgomery Lake subwatershed drains to the Back Bay/Outlet area downstream of Hooker Lake, so this subwatershed area was not studied as part of this project.

The Town of Salem merged with the Village of Silver Lake and will officially become the "Village of Salem Lakes" in February 2017.

GRAPHIC SCALE
0 1,500 3,000 FEET

Source: SEWRPC.

spotfin shiner) are dependent upon sand and gravel substrates for feeding, nesting, and rearing of juveniles.[21] The loss of water volume associated with sedimentation can limit recreational opportunities, the total population of fish able to reside in a lake, and the quality of deep-water habitat in a lake. Finally, sediment may act as a reservoir for nutrients, and have the potential to re-enter the water column given the right conditions (e.g., agitation, dissolution under anoxic conditions).

It is important to note, however, that some sedimentation happens naturally when lakes "age," (Figure 4). Though this process normally occurs naturally over centuries, **sedimentation can be accelerated to unnaturally high levels when land use practices in the watershed limit natural attenuation (e.g., filtering provided by streamside vegetation) and instead favor erosion, heavy runoff, and artificial pollutant loading.**

Since certain types of land use features can serve to filter or remove pollutants prior to the pollutants entering a lake system, it is important to evaluate where such features exist within the Hooker Lake watershed. It should be noted that these features can overlap and may provide multiple benefits. Examples of these features include:

1. **Stormwater detention or retention ponds**—Stormwater management ponds, when properly maintained, can capture and store runoff water during rainfall events, slowing the flow of water and allowing many pollutants (such as sediment and heavy metals) to settle out before reaching downstream waterbodies. Since phosphorus is tightly bound to sediment, trapping sediment also reduces phosphorus loads passed downstream. These ponds need to be periodically dredged and may require other maintenance to ensure they function properly. Stormwater detention or retention ponds in a lake's watershed are a useful means of protecting, or improving, lake water quality by significantly reducing pollution loads to the lake. Stormwater ponds are normally 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. 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 warm water, can sometimes attract nuisance species, and can be barriers to aquatic organism migration.

2. **Wetlands**—Wetlands, which are generally characterized by wet soils and wetland-based plants, are beneficial to the health of a lake, particularly when located at or near a lake's inlet and along the course of tributary streams. These areas slow the flow of water moving toward the lake, causing sediment, bound phosphorus, and heavy metals to settle in a similar fashion to stormwater management ponds. Additionally, **the plant life located in wetlands is able to absorb pollutants such as phosphorus and incorporate them into biomass,** thereby preventing the pollutant from entering the lake. These natural features are invaluable ecosystems, are well known as "nature's pollution filtration system", and are integral to the life histories of a large number of familiar fish, amphibians, birds, and other animals. Knowing where wetlands are located can help determine if a pollution source is a high risk to waters downstream from the wetlands or can provide significant ecological value to lake residents such as northern pike, a fish that spawns in wetlands.

3. **Natural terrestrial buffers (e.g., forests or prairies with extensive natural vegetation)**—Natural buffers primarily refer to natural terrestrial vegetative features such as forests or prairies. These areas, like wetlands, are densely vegetated and can slow the flow of water and incorporate pollutants into biomass. Consequently, **these areas, if located in an area that intercepts water flowing toward the lake, can help lower pollution risks to the lake.** Additionally, enhancing these features, particularly in areas adjacent to a waterbody, can help assure that the watershed can naturally reduce the amount of pollution entering that waterbody. Like wetlands, buffers are critical to the life cycle of many herptiles (amphibians and turtles) and birds.

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[21] *Despite the potential for the sedimentation process to adversely affect fish populations, a number of projects can be put into place to encourage healthy fish populations, even if sandy and rocky sediments are buried. These projects are further described in the "Shoreline Maintenance" and "Wildlife" sections of this chapter.*

4. **Floodlands**—are areas inundated during periods of heavy runoff. Such areas may be directly adjacent to streams and convey floodwater (floodways) spreading the energy of the flowing water over a broader area or can store water in a relatively quiescent fashion (floodplains) helping reduce downstream flood elevations. Floodlands can reduce stream power and thereby reduce erosion and pollutant mobilization. Additionally, floodplains can act as sediment, nutrient, and pollutant traps, and provide refuge to aquatic life, providing similar ecological services as wetlands. Floodlands provide the broadest value in their natural state, but can still provide valuable service when developed in compatible open spaces uses. Floodland can be restored along manipulated drainageways as part of projects that help stabilize eroding beds and banks.

5. **Constructed terrestrial buffers (e.g., grassed waterways, vegetative strips)—Constructed** buffers can take a number of forms including grassed waterways, vegetative strips, and rain gardens located along the shoreline. Such buffers are generally constructed to intercept the flow of water toward a river or lake. They function in a similar way to natural buffers (i.e., slowing the flow of water); however, they do need to be carefully designed and should use native plants to ensure that they function well. **Constructing buffers can enhance the water quality of a lake without negatively affecting residential or agricultural land use.** Further details on buffers and their efficacy are included in Appendix B.

6. **Nearshore aquatic (In-Lake) habitat**—Lake vegetation in the shoreline areas, such as bulrushes and cattails, can filter and assimilate nutrients and sediment to some degree. Such areas also help protect vulnerable shorelines from erosion and provide valuable aquatic habitat. Consequently, encouraging their survival and enhancement can help improve lake water quality.

To locate examples of the features described above, SEWRPC staff completed an inventory of detention basins, wetlands, woodlands within the Hooker Lake watershed using existing databases, mapping software, field inspections, and aerial imagery. Additionally, to identify the extent of shoreline terrestrial buffers and in-lake vegetative buffers, SEWRPC staff completed a field assessment of the Hooker Lake shoreline in the summer of 2014. These inventories are discussed below.

Summary of How Watershed and Shoreland Filtering Affect the Water Quality of Hooker Lake

Several stormwater basins are located within the Hooker Lake watershed. If they are being properly maintained, these basins help limit the amount of pollution entering Hooker Lake from the residential areas draining to these basins. Consequently, maintaining these ponds should be a <u>high priority</u>. Recommendations related to this topic are provided in Chapter III of this report.

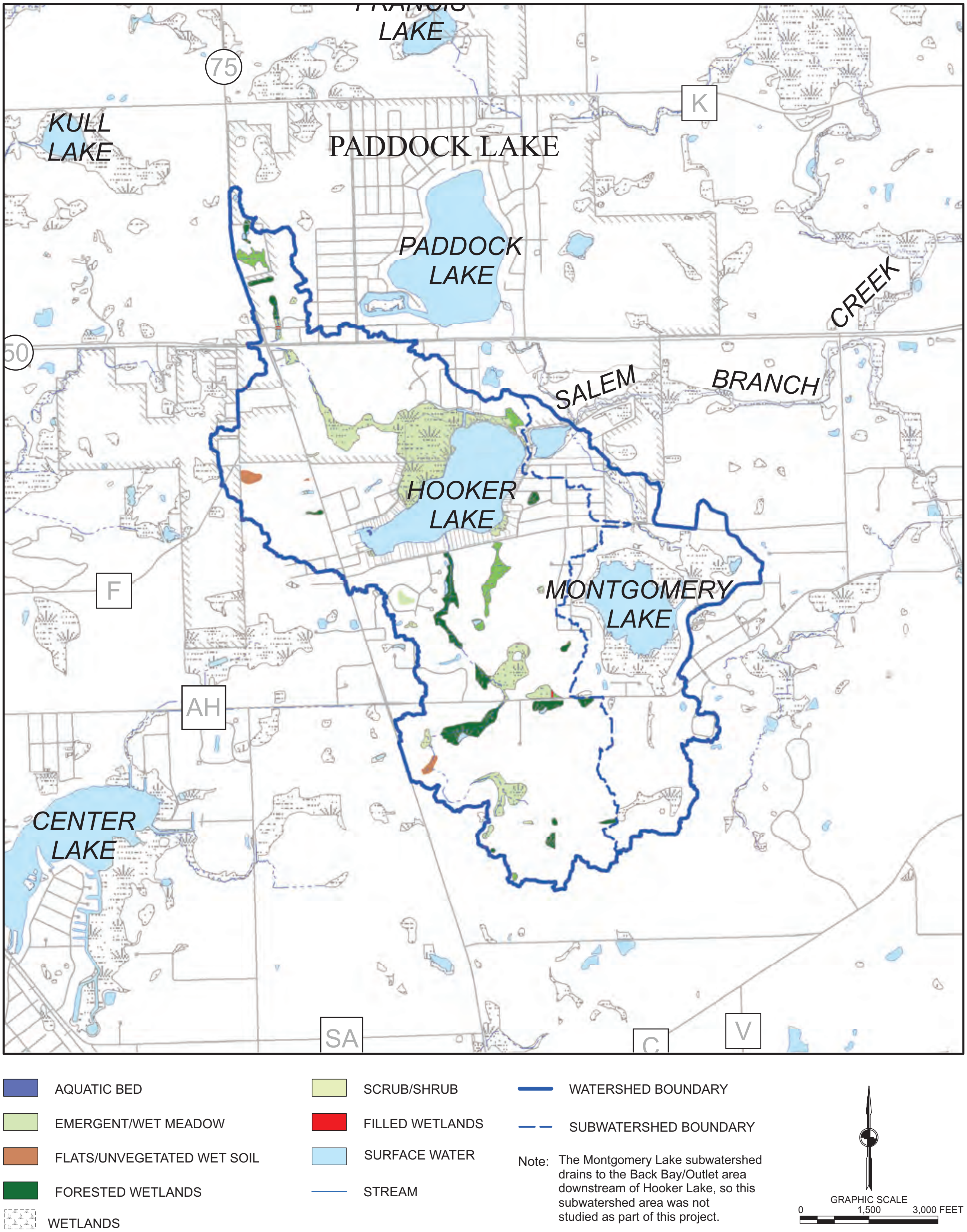
As of 2010, eleven percent of the Hooker Lake watershed in 2010 was comprised of wetlands. Wetlands are located primarily at the northwest end of the Lake and along the stream that enters the Lake from the south (see Map 10). These wetland areas help protect the Lake from pollution and sediment from those areas of the watershed and provide valuable and diverse habitat function for aquatic, terrestrial and avian life. The potential to naturally remove pollutants, in combination with the many other benefits provided by wetlands, illustrates how <u>crucial maintenance of wetlands is for Hooker Lake</u>. Consequently, recommendations related to maintaining and enhancing wetland functions are also included in Chapter III of this report.

About 10 percent of the Hooker Lake watershed is composed of woodlands. Woodlands and other natural areas are particularly valuable when located in areas adjacent to the Lake or its tributaries (see Map 11). Consequently, <u>these areas should be protected to the greatest extent practical to protect water quality and the overall environmental integrity of the Lake</u> (see Chapter III for recommendations).

The locations of constructed terrestrial buffers along the shoreline of Hooker Lake, and other shoreline protection measures (e.g., seawalls), are shown on Map 12. **There are very few existing terrestrial buffers,** primarily small gardens along the shoreline. Such buffers can provide the Lake with protection from the pollution that could otherwise enter the Lake (e.g., lawn clippings, fertilizers, and oil from cars). Consequently, <u>installation and enhancement</u>

Map 10

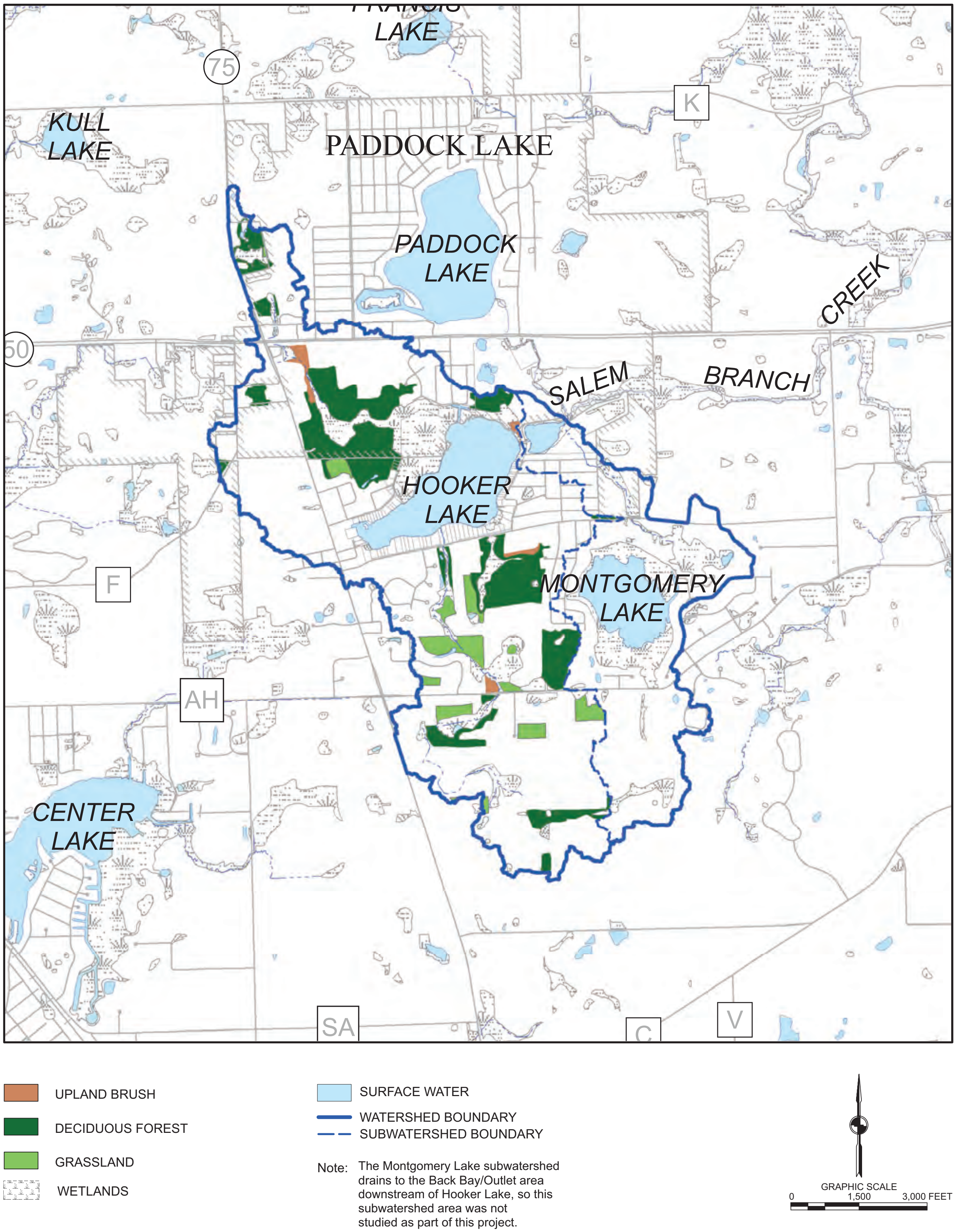
WETLAND COVER TYPES IN THE HOOKER LAKE WATERSHED: 2010



Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 11

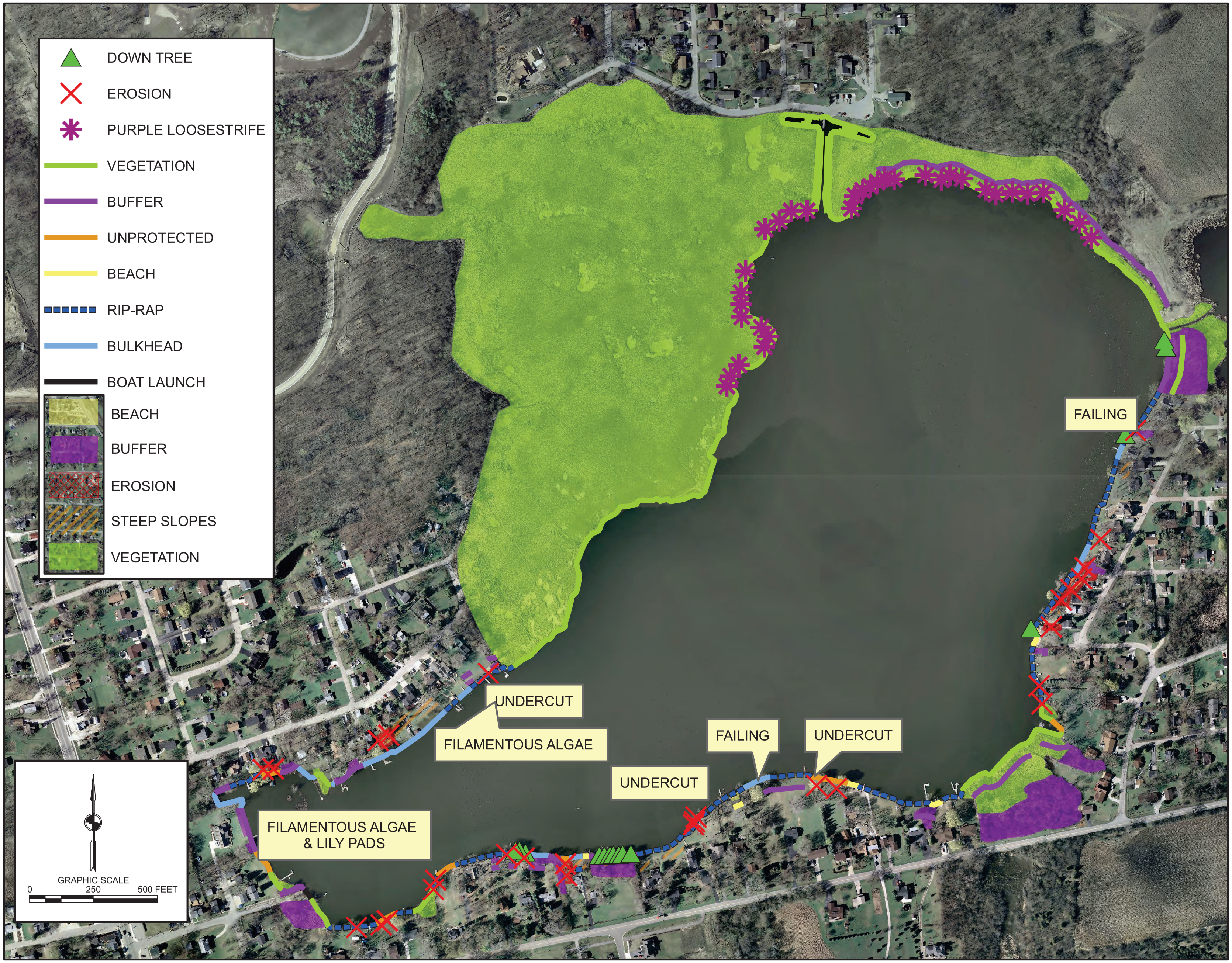
UPLAND COVER TYPES IN THE HOOKER LAKE WATERSHED: 2010



Source: SEWRPC.

Map 12

SHORELINE PROTECTION AND BUFFERS ON HOOKER LAKE: 2014



Source: SEWRPC.

of terrestrial buffers along the shoreline of Hooker Lake should be considered a high priority. Recommendations related to terrestrial buffers, as well as in-lake vegetative buffers, are further discussed in Chapter III of this report.

Buffer creation and enhancement of existing buffers/wetlands should be crucial aspects of protecting the water quality of Hooker Lake. Buffer and wetland maintenance and development should likely target strategic areas in the watershed, that produce runoff which does not filter through existing buffers or wetland systems prior to entering the Lake or a tributary stream. Some of these areas were identified by comparing the flow pathways within the watershed to the locations of the natural and constructed features discussed above.[22] Map 13 shows identified flow pathways. Referring to this map, surface water in the southern part of the watershed drains mostly from single-family residential areas and is collected by the tributary stream that enters the lake along its southern shore (tributary site 5-south- in Map 3). This tributary is currently buffered by small natural wetlands that should help filter and reduce the pollutant load coming from future residential areas. Therefore, it is important that these small wetlands, and the stream itself, be protected, left intact, and/or be naturalized and enhanced during construction of these residential areas.

The flow pathways in the northern part of the Lake's watershed cross an area of woodlands and wetlands (see Map 13). The wetlands and woodlands, if protected from development and adverse manipulation, should act as a buffer to protect the Lake from pollutant load coming from the planned residential and commercial lands in that part of the watershed. However, it has been reported that certain portions of the tributaries draining this area are actively eroding. The lands to the west of STH 83 present a challenge. Runoff from much of these lands does not currently drain through any natural buffer areas and portions of the channels are actively eroding. Indeed, most of the southern part of this area, which would be commercial under planned land use conditions drains directly into the Lake at the west end (site 3, Map 3). Thus, it is important to target this area for pollution reduction efforts (strict enforcement of stormwater management and construction site erosion control ordinances), buffer enhancement projects, streambed and bank erosion control and enhancement, and initiation of programs to deal with phosphorus loading from residential and urban areas (proper street leaf litter disposal, no-phosphorus lawn fertilizers). Recommendations related to water quality enhancement within Chapter III will focus on these areas.

ISSUE 2: WATER QUANTITY

This section examines factors that influence the supply of water to Hooker Lake. The initial portion of this section examines three separate, yet related, variables that are of particular concern to Lake residents. These factors include the extent of open water and contiguous marshland, the amount of water reaching the Lake from the western portions of the Lake's watershed, and the water surface elevation of the Lake over time.

Surface Area of Hooker Lake and Contiguous Marshlands

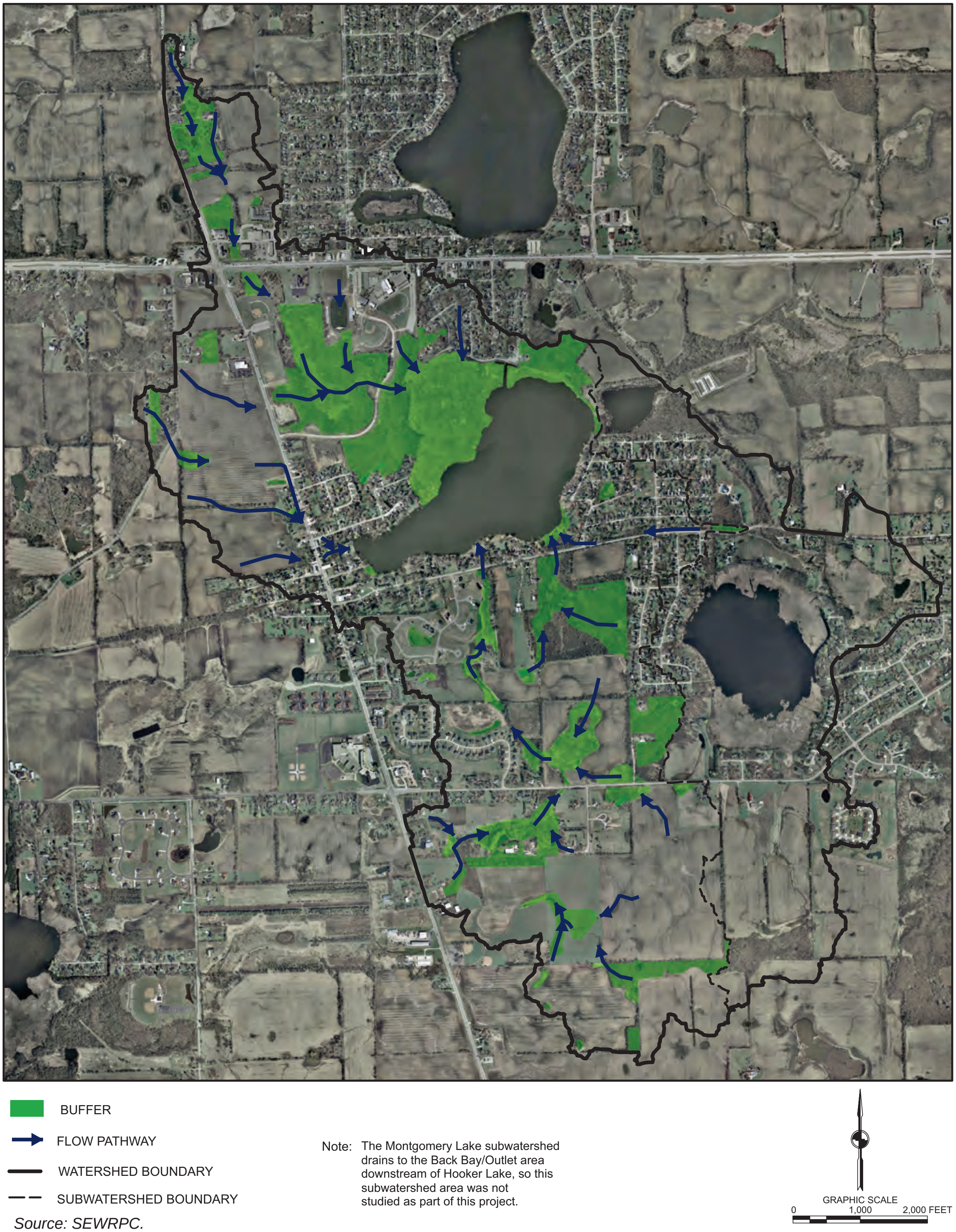
Hooker Lake's water levels have been noted to fluctuate since at least the 1970s.[23] Fluctuating water levels can change the acreage of the Lake and the extent of and elevation of floodplain areas. Information was gathered from a variety of sources to help quantify changes over time. Aerial photographs of Hooker Lake were collected and the apparent area of open water, adjacent marshland, and the small lake/wetland just downstream of Hooker Lake were contrasted. The earliest aerial photograph located as part of this analysis was 1937 while 2015 was the most recent. Copies of these aerial photographs are included in Appendix C. The apparent areas of the Lake and adjacent wetlands for each aerial photograph are summarized in Table 10. As can be seen from these values, the Lake

[22]*Flow pathways within the Hooker Lake watershed were determined using elevation data and field investigations.*

[23]*Plening, Ronald R., Surface Water Resources of Kenosha County, Wisconsin Department of Natural Resources, 1982.*

Map 13

EXISTING BUFFERS AND WATER FLOW PATHWAYS IN THE HOOKER LAKE WATERSHED



Note: The Montgomery Lake subwatershed drains to the Back Bay/Outlet area downstream of Hooker Lake, so this subwatershed area was not studied as part of this project.

Source: SEWRPC.

Table 10

SURFACE AREA FLUCTUATIONS OF HOOKER LAKE AND ADJOINING WATER BODY: 1937-2015

Year	Hooker Lake	Waterbody immediately downstream of former Hooker Lake Dam
	Surface Area (Acres)	
Open Water		
1937	97	0
1963	107	4
1970	109	5
1980	109	4
1990	110	6
2000	110	8
2010	112	9
2015	112	9
Mean	108	6
Contiguous Marsh		
1937	51	7
1963	54	6
1970	52	6
1980	55	8
1990	55	6
2000	53	4
2010	53	4
2015	54	4
Mean	53	6
Open Water + Contiguous Marsh		
1937	148	7
1963	161	10
1970	161	11
1980	164	12
1990	165	12
2000	163	12
2010	165	13
2015	166	13
Mean	162	11

Note: Each surface area value is based upon average of three independent measurements.

Source: Kenosha County Interactive Mapping and SEWRPC.

surface area appears to have slowly but consistently increased since 1937. Since the open water acreage is determined through interpretation of aerial photographs, the increased open water area may be related to changes in vegetation around the periphery of the Lake. For example, manicured residential landscaping allows the water/land interface to be seen much more plainly than natural shorelines. The apparent open water acreage of Hooker Lake has increased about five acres (approximately five percent) during the past 53 years, two acres (about two percent) of the total being noted since 2002.

Western Watershed Runoff Volume and Flow Rates

Portions of Hooker Lake's watershed lie to the west of, and must drain under, State Trunk Highway (STH) 83. The Wisconsin Department of Transportation (WisDOT) reconstructed STH 83 during 2006, a project which included changing and adding stormwater management infrastructure. During the same approximate time period, Lake residents began noticing that heavy precipitation correlated with abnormally high Lake water-surface elevations and abnormally long periods of high water in the Lake. Based upon their intimate knowledge of the local watershed, the HLMD suggested two potential reasons for changed water levels: reconstruction of the Lake's outlet dam and reconstruction of STH 83. Dam reconstruction was found to have increased the crest elevation of the outlet and reduced the width of the spillway, conditions that cause higher water levels and prolonged flooding during periods of heavy runoff (see the "Issue 3: Lake Outlet Dam" section of this chapter for more information). HLMD was further concerned that changes in the stormwater drainage system associated with STH 83 reconstruction increased runoff volume and intensity. This section evaluates potential changes to runoff volume and intensity from portions of the watershed draining under STH 83.

Members of the HLMD believe that local runoff patterns have changed over the past 10 to 15 years. Evidence of this included less widespread incidental ponding in the area directly west of the Lake and intense runoff in the newly created open drainageway immediately adjacent to and paralleling 83rd Street.[24] Lake residents reported these observations to the WDNR and the WisDOT, noting that they believed STH 83 reconstruction was at least partially respon-

[24]*This new drainageway merged runoff from several smaller drainage systems which were not as readily apparent to casual observation. Increased flow in this new channel is largely attributable to the increased number of acres served by this single discharge point, and not large increases in the total volume of runoff reaching the Lake.*

sible for these changes. In response to these concerns, the WisDOT reviewed the HLMD's concerns and commissioned a hydrology and drainage study.[25] Copies of several maps, tables, and correspondence related to this study are included in Appendix D.[26]

As part of their study, the WisDOT examined five subwatersheds situated west of STH 83 near the extreme western end of Hooker Lake. The study labelled these subwatersheds from north to south:

- North Non-Contributing Subwatershed (35.2 acres). This area is a closed depression meaning that surface water accumulates in low spots with no surface outlet. Water leaves closed depressions by evaporation, by seeping into the soil and becoming part of groundwater flow, and/or by agricultural drainage tiles.
- North Subwatershed (20.7 acres)
- Central Subwatershed (22.1 acres)
- 83rd Street Subwatershed (22.7 acres)
- 85th Street Subwatershed (8.38 acres).

Water from the North and Central Subwatersheds drains under STH 83 a short distance northwest of the intersection of STH 83 and 82nd Street (see Map 14). Although the North Non-Contributing Subwatershed does not provide direct surface-water runoff to Hooker Lake, it could contribute surface-water flow through agricultural drainage tile outlets.[27] The actual presence of tile outlets will need to be investigated in the field. After passing under STH 83, water from the combined area drains toward the Lake in an open channel, enters a pipe about 150 feet north of 83rd Street near 249th Avenue, and then discharges underwater in Hooker Lake. The inlet of this pipe reportedly clogs and the resultant flooding detains stormwater.[28] The drainage network east of STH 83 serving the North Non-Contributing, North, and Central Subwatersheds was not modified as part of the highway reconstruction project. Therefore, assuming all other factors remained the same, the stormwater conveyance system downstream of STH 83 that serves the North Non-Contributing, North, and Central Subwatersheds delivers water to the Lake in the same fashion as before construction, and is not a significant source of higher water levels or increased pollutant loads

Highway reconstruction did substantially change the drainage system serving the North and Central Subwatersheds upstream (west) of STH 83. Portions of open ditch were replaced with buried storm sewers, a change that could slightly speed runoff. Wider roads and sidewalks contributed to slightly more impervious area in the watershed, slightly increasing runoff speed and volume Pre-existing buried storm sewers pipes paralleling STH 83 were replaced, but the pipe size (36-inch diameter) remained the same as that present before road reconstruction.[29] A

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[25]Kapur and Associates, Inc., STH 83 (1322-00-70) Hydrology Evaluation, Memorandum dated May 2, 2009.

[26]*Additional information regarding the Town of Salem's stormwater management plans may be found at the following website: http://www.townofsalem.net/index.asp?SEC=ECC25DEF-D98F-4529-913D-713DF6BAC4D0&Type=B_BASIC*

[27]*Based upon soil coloration patterns evident in historical aerial photographs, the North Non- Contributing Subwatershed is likely tiled. Agricultural drainage tiles may divert water from this closed drainage basin to discharge points adding to the overall overland flow volume reaching Hooker Lake.*

[28]*Flierl, Kurt (Project Manager, Wisconsin Department of Transportation Southeast Region). Hooker Lake Drainage Meeting Minutes, December 12, 2008, December 18, 2008.*

[29]*Flierl, Kurt (Project Manager, Wisconsin Department of Transportation Southeast Region), op. cit.*

Map 14

GENERALIZED PRE AND POST 2006 RECONSTRUCTION OF STH 83

Source: Kapur and Associates and SEWRPC.

stormwater detention pond was constructed immediately northwest of the intersection of STH 83 and 81st Street as part of the highway reconstruction project (see Map 14). The stormwater detention swale reduces peak runoff flow rates by storing and gradually releasing water draining from the North Subwatershed, and probably water stored in the depression in the North Non-Contributing Subwatershed and then conveyed in an agricultural drain tile. The stormwater detention swale enhances the potential for groundwater infiltration and reduces sediment and pollutant loads reaching the Lake. The WisDOT information reports that the time needed for runoff to reach the Lake from the North Non-Contributing, North, and Central Subwatersheds is essentially unchanged, while peak runoff flowrates were substantially reduced.[30]

The changes made to the stormwater conveyance network servicing the North and Central Watersheds as part of the STH 83 reconstruction project do not appear to significantly affect the overall intensity, quality, or quantity of stormwater reaching Hooker Lake. Therefore, changes made to the stormwater conveyance system in the North and Central Subwatersheds as part of STH 83 reconstruction are not significant contributors to recent flooding and water quality concerns in Hooker Lake. Furthermore, the WisDOT information suggests that water quality from this area may be marginally improved and the erosive potential of the stream in the unmodified channel reach downstream of STH 83 is should be reduced.

Before highway reconstruction, the 83rd Street Subwatershed drained under STH 83 at more than one location. Ditches and a partial storm sewer system discharged to a two-foot by two-foot box culvert that passed under STH 83 and directed runoff to a steep ravine-like drainage ditch roughly midway between 83rd and 82nd Streets (see Map 14). Water from this area then joined runoff from the North and Central Subwatersheds before entering the pipe which carried the combined flow to an underwater discharge in Hooker Lake. Other partially buried culverts reportedly drained under STH 83 near 83rd place.[31]

According to the HLMD, incidental ponding occurred in some areas in response to flows greater than the capacity of the existing pipes, inlet elevations, and clogging. Some buildings occasionally experienced flooding problems,[32] a condition likely attributable to incidental ponding. Based upon pre-construction photographs (see Figure 26), there was very little treatment or storage of runoff draining from the developed areas immediately adjacent to STH 83. The water from the 83rd Street Subwatershed entered a very steep and reportedly eroding ravine-like drainageway,[33] a fea

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[30]*The WisDOT's consultant used the U.S. Army Corps of Engineers Hydrologic Engineering Center's Hydrologic Modelling System (HEC-HMS) software to simulate pre-construction and post-construction conditions. This model was applied in a design storm mode that evaluates the runoff from a single event of a given frequency. The modeling approach considers antecedent soil moisture conditions, interception storage by vegetation, and infiltration into the soil. The model has a limited pollutant load estimation capability which was not available at the time of the WisDOT study. However, an alternative approach to load estimation, based in part on application of pollutant concentrations measured by the HLMD, was applied for the study documented herein. The HLMD has stated that a dynamic runoff model such as the U.S. Environmental Protection Agency's Storm Water Management Model (SWMM) would be appropriate to apply for estimating runoff from the watershed. If SWMM were run in continuous simulation mode under which a longer time series of meteorological data were used as input, rather than in a design storm mode, it would yield different runoff information than would HEC-HMS applied in a design storm mode. However, the information generated using SWMM would not necessarily lead to different conclusions than were reached based on the analysis with HEC-HMS. HLMD could hire a consultant to perform a SWMM evaluation of the watershed runoff characteristics if desired.*

[31]*Ibid.*

[32]*Telephone conversation, Kurt Flierl (WisDOT) with Dale Buser (SEWRPC), February 17, 2017.*

[33]*Ibid.*

ture that would not contribute to water detention or water quality improvement. The new ditch and culvert serving the 83rd Street Subwatershed were needed to address property flooding and assure a reliable route to convey water to the Lake, and were not installed to eliminate areas of known natural ponding.[34] In summary, **while STH 83 reconstruction could theoretically slightly speed runoff to the Lake and could slightly increase runoff volume contributed by the 83rd Street Subwatershed, the small changes in runoff volume or speed would not tangibly change Lake elevations.** If the HLMD desires, stormwater detention ponds could be located, designed, and permitted to intercept runoff from the area upstream of STH 83 with the intent of improving water quality and reducing runoff intensity from the 83rd Street Subwatershed before it enters Hooker Lake. The most practical location for a detention pond would be just west of the developed area paralleling STH 83.

Runoff from the 85th Street Subwatershed formerly followed a diffuse overland conveyance route directly east of STH 83 (see Map 14). Also, topographic maps reveal at least one closed depression in the area east of STH 83. Both the diffuse overland conveyance route and the closed depression intercepted and detained stormwater, slowing runoff. It is not possible to predict the actual amount of water detained in the depression without detailed study. However, changes to runoff patterns made as part of highway reconstruction would tend to increase the volume of runoff reaching the Lake. These changes bypassed storage in closed depressions and the formally diffuse conveyance route; and, in turn, reduced groundwater recharge and evapotranspiration. Based upon personal observations before and after road reconstruction, HLMD members believe that water and sediment reach the Lake more quickly after highway reconstruction. The 85th Street Subwatershed area was also enlarged by about 10 percent, much of which is impervious surface. The somewhat diffuse conveyance and ponded areas that existed before reconstruction were replaced with a single discharge point that quickly conveys water directly to the Lake in a straight, steep open channel paralleling 83rd Street (see Map 14).

Given the information available at the time of this study, the changes made to the 83rd and 85th Street Subwatersheds as part of STH 83 reconstruction would slightly increase the volume of water delivered to the Lake, would slightly increase peak flow rates, and would slightly decrease the amount of time needed for stormwater to reach the Lake. Nevertheless, the runoff volume from the 83rd and 85th Street Subwatersheds are only a small fraction of the Lake's total

Figure 26

EXAMPLES OF STATE HIGHWAY 83 CORRIDOR STORMWATER INFRASTRUCTURE BEFORE THE 2006 HIGHWAY RECONSTRUCTION PROJECT

Source: Wisconsin Department of Transportation.

[34]*Ibid.*

watershed area (about 3.4 percent), and, assuming all other factors remaining unchanged, **increased runoff from this small area would not measurably increase Lake elevations on its own, and, therefore, is not the primary reason for noticeably higher water elevations in Hooker Lake.** Given the information now available, **the most probable reason for increased Lake water elevation is reconstruction of the Lake outlet dam,** as discussed in the "Issue 3: Lake Outlet Dam" section of this chapter. However, the changes to the 85th Street Subwatershed enhance the ability of stormwater to carry sediment and other pollutants to Hooker Lake.

Although STH 83 reconstruction is not the most probable cause of higher Lake elevations, steps can be taken that can tangibly enhance the timing and quality of water reaching Hooker Lake. The stormwater detention swale immediately northwest of the intersection of STH 83 and 81st Street was designed to modulate runoff volumes to better match downstream infrastructure. While the design should incidentally benefit the Lake, runoff volume reduction and water quality enhancement were not primary factors guiding design.[35] Steps could be taken to increase stormwater retention (through groundwater infiltration and evapotranspiration), increase the ability of the detention pond to remove sediment and other pollutants from runoff, and provide extended baseflow to downstream stream reaches. Examples include enlarging the detention swale or providing supplemental upstream water storage,[36] examining and potentially modifying vegetation in and around the swale, providing quiescent floodplain areas along conveyance routes, and potentially reconfiguring the detention swale's inlet and outlet configuration. Similar techniques should be employed in the 83rd and 85th Street Subwatersheds to replace and increase stormwater storage and treatment features lost as part of STH 83 reconstruction.

Highway reconstruction was not the only recent change in the 109 acres of the Hooker Lake watershed to the west of STH 83. For example, a network of newly excavated ditches is visible in the western portion of the watershed on recent aerial photography (see Map 14). The new ditches are found in actively cropped areas and were likely constructed to enhance or maintain efficient drainage of wet areas in cropped areas. The ditches may have been dug to supplant failing agricultural tile lines or breach topographic highs that cause water to accumulate in portions of the fields. A particularly relevant example of recent ditch expansion is detailed in Figure 27. This ditch extends toward an extensive area of wet soil,[37] and may intercept failing agricultural tile lines originating in the closed depression in the North Non-Contributing Subwatershed and/or promotes more efficient drainage in the immediate area. **This ditch may increase the effective watershed area contributing to Hooker Lake, increasing flow volumes and pollutant loads.** Therefore, this new ditch could increase water, sediment, and other pollutant loads delivered to the Lake. The pollutant load increase would be most pronounced if there is surface water directly entering the tile line. Furthermore, diverted water may decrease the effectiveness of the WisDOT stormwater detention swale. As suggested in Chapter III, the presence and purpose of this ditch should be examined, and the potential effect on runoff further investigated.

Lake Surface Elevation

Water elevations have been measured on Hooker Lake since at least the early 1990s. Unfortunately, the reference elevations of the measuring points differ and/or have apparently changed in response to damage, replacement, and other factors. Detailed review of lake levels, downstream gaging station data, and the records themselves allowed us to estimate mean sea level (NDVD 29 datum) lake surface elevations for a 24-year period of record. Some years included one point of measurement, while many measurements were collected during most years. High, average, and low water elevations for the available period of record are graphed in Figure 28. In addition to water levels, the

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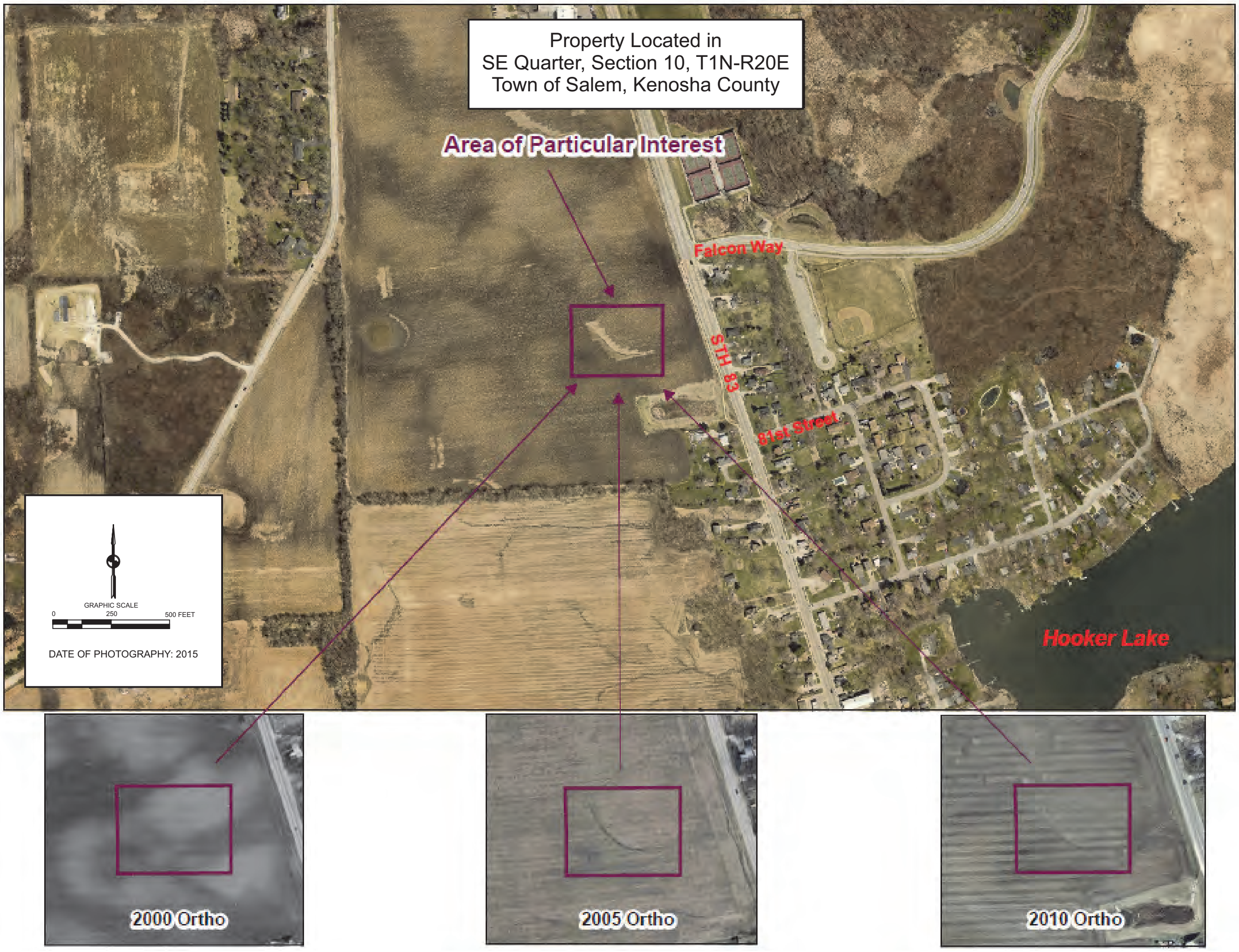
[35]*Flierl, Kurt (Project Manager, Wisconsin Department of Transportation Southeast Region), op. cit.*

[36]*Excellent opportunities to enhance stormwater storage appear to be present in the areas draining to the existing detention pond. An example is discussed at the end of this section.*

[37]*Wet soils often appear darker in color on spring aerial photography.*

Figure 27

INDICATIONS OF RECENT DITCHING IN THE HOOKER LAKE WATERSHED



Source: SEWRPC.

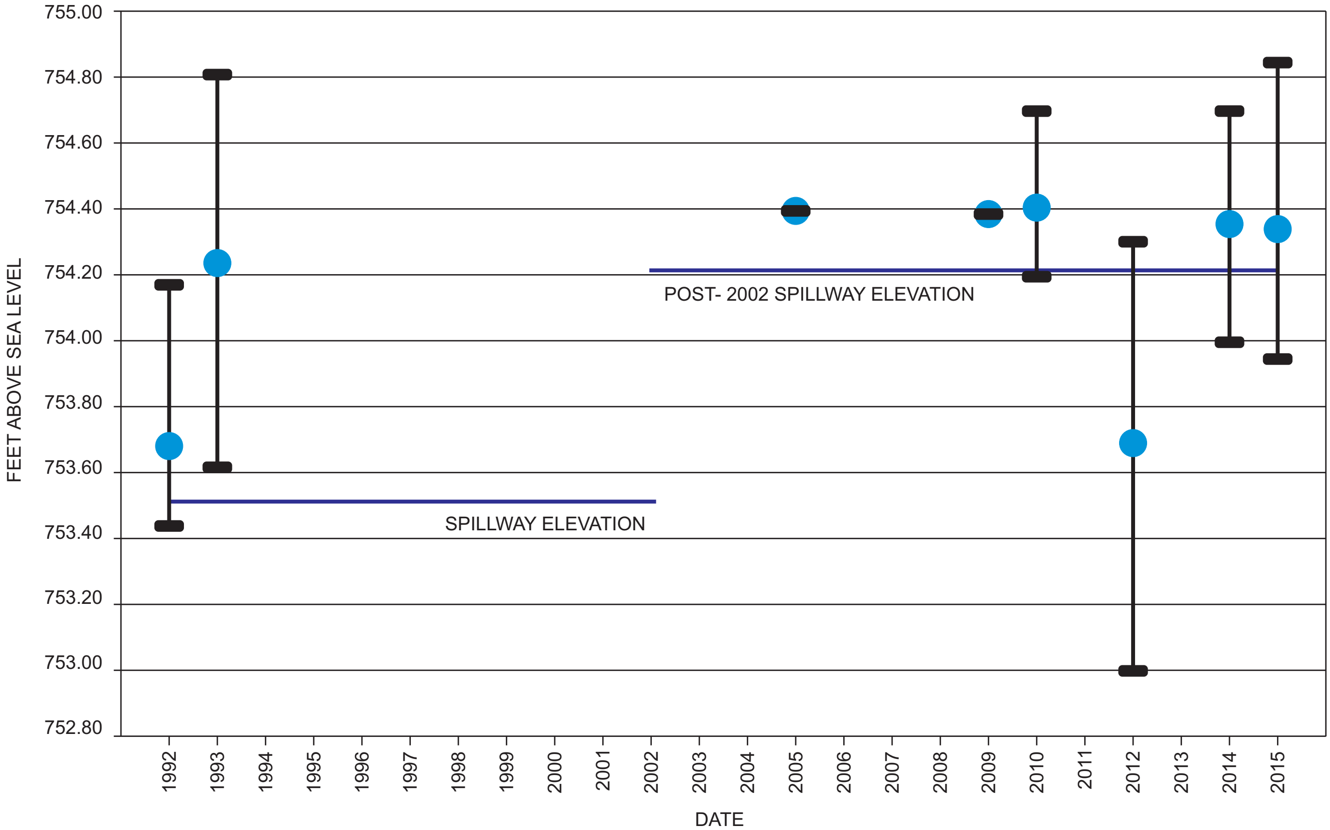
elevation of the outlet dam spillway is illustrated. Since the outlet dam was rebuilt in 2002 at a different elevation, both the original and post-2002 dam reconstruction spillway elevations are illustrated.

Water elevation data reveal that the absolute range of water-surface elevation has remained essentially unchanged over the period of available record. The lowest water level was recorded during a drought when the new and higher outlet dam spillway was dry. Conversely, the highest water levels occurred both before and after dam reconstruction. However, the high water level measured before dam reconstruction is associated with a period of extreme precipitation, whereas the post-dam reconstruction high water level is associated with less remarkable precipitation events. These facts underscore the profound effect of precipitation on lake elevation and the possible influence of the higher dam spillway. Aside from the year-to-year precipitation changes, the extremely limited data set generally suggests that Hooker Lake water levels have marginally increased since dam reconstruction

Although very limited data is available, the fair and wet-weather water elevations of Hooker Lake appear to have been increased after the Bryzek Dam was reconstructed in 2002. Since the dam's spillway capacity was likely reduced, extreme runoff events could generate higher than typical water elevations and may take a longer than typical length of time to return to normal. <u>The potential for this situation can be quantified by carefully measuring the dam's spillway configuration and contrasting it to current floodplain model values, and, if necessary, modifying the model</u>

Figure 28

APPROXIMATE LAKE LEVEL ELEVATION OF HOOKER LAKE: 1992-2015



NOTE: The blue circles represent annual average lake levels and the black bars represent the maximum and minimum elevations. Only a single measurement was available for 2005 and 2009.

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

to account for the actual spillway capacity. Moreover, given that climate patterns are changing within Wisconsin,[38] **lake levels could potentially be susceptible to variability in the future.** 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, some climate models predict that certain future climate changes could alter hydrologic budgets, leading to changes in water levels or flows, and cause water levels to change due to changes in the precipitation regime and in evapotranspiration.

Lake elevations are vulnerable to change if surface water and/or groundwater inflow are manipulated, inconsistent or lost over a season. For the long-term health of the Lake, it is important to focus on projects that can be undertaken to protect sources of water for 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 periods of drought. These factors are:

A) The ability of the watershed to store and gradually release surface water runoff (i.e., surface water detention) and

B) The recharge rates of aquifers (i.e., groundwater systems) that supply the baseflow of water to the Lake and withdrawals from the contributing groundwater flow system.

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

Both of these factors are discussed below.

Surface Water Runoff Management

The speed at which incident precipitation or snowmelt leaves the land surface is dependent on many variables. These variables include the nature of soils, the slope of the land surface, vegetation, and the amount of storage available in a watershed. Storage in a watershed can detain runoff and slow the speed at which stormwater leaves the landscape. Storage can be provided by stormwater detention basins, buffers, or wetlands which slow the water velocity, temporarily storing and gradually releasing it, and, in some instances, allowing the water to soak deep into the ground. Some of the water that infiltrates into the ground becomes part of the local surface water system. This water moves slowly toward a lake or stream, maintaining baseflow over a period well beyond the day of the rain event. If buffers and wetlands do not exist to store and gradually release the runoff, the runoff could more rapidly enter a lake and, depending on the lake size and outlet characteristics, quickly flow out of the lake. In this case, a smaller volume of water is kept within the watershed to gradually supply the lake over time. This rapid flow often results in higher erosion and greater concentrations of sediment and nutrients reaching lakes and streams.

Impervious surfaces greatly increase the volume and velocity of runoff after a rainfall (see Figure 29).[39] 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 dramatically decline 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.[40] Consequently, reducing or preventing impervious cover, or installing measures that reduce the direct runoff from impervious cover (such as rain gardens or buffers), are crucial components in ensuring consistent high quality water supply to a lake. The effect of impervious surfaces can be reduced in many ways, including the following examples:

- Limit the size of hard surfaces
  - Limit driveway width or share between neighbors
  - Minimize building footprints (i.e., build tall instead of wide, consistent with local zoning ordinances)
  - Remove unneeded sidewalks and parking spots

- Opt for pervious materials
  - Green roads (e.g., incorporate bioswales, grassed ditches)
  - Mulch walkways
  - Permeable pavers for walkways and driveways

- Capture or infiltrate runoff
  - Use rain barrels
  - Plant rain gardens
  - Channel gutters and downspouts to rain barrels, rain gardens, or places where they can infiltrate
  - Assure that the soil in lawn areas is not compacted

- Maintain and restore shoreline buffers (discussed further under Issue 5)

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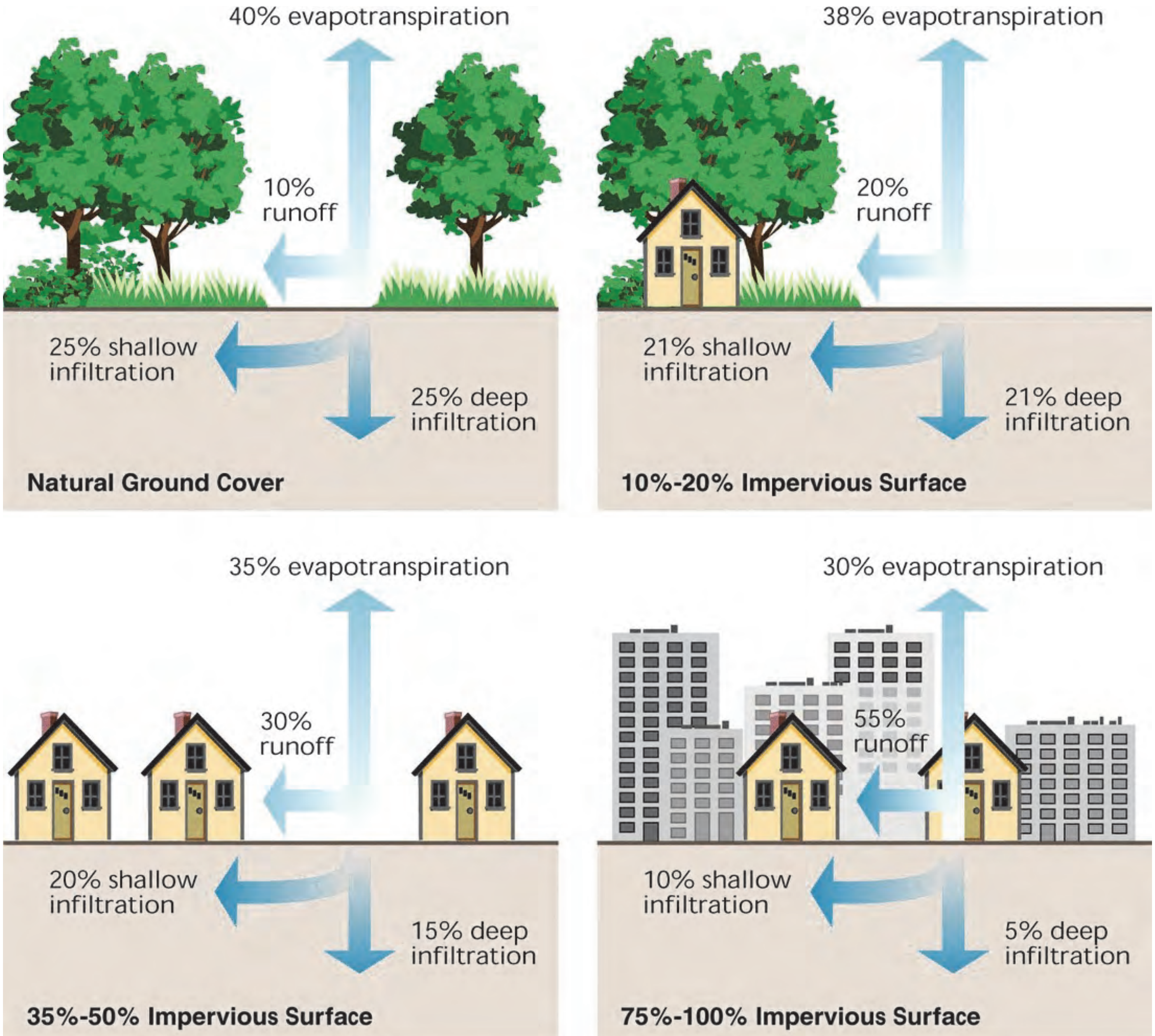
[39] *Impervious surfaces are those that resist or prevent absorption or transmission of water (e.g., asphalt or concrete driveways or sidewalks and roads, buildings).*

[40] *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.*

Figure 29

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



Source: Federal Interagency Stream Restoration Working Group and SEWRPC.

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

1. **The location and extent of 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 the speed and/or reduce the volume of runoff leaving these areas) it is necessary to identify where urban land use exists.

2. **The location and extent of planned land use changes within the watershed**—Since urban land use has 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 reduce runoff velocity and/or volume when the development occurs. During development, efforts can be made to enhance infiltration and runoff characteristics beyond those of the undeveloped land cover. Such measures can help mitigate the effects of impervious surfaces in other historical developments that did not consider stormwater management.

3. **The location and extent of natural areas and stormwater management structures**—Stormwater retention and detention basins and natural areas (e.g., buffers, grassed waterways, floodlands, wetlands, and woodlands) can slow flowing surface water, in some cases can store and gradually release water, and can promote infiltration of water into the groundwater flow system. Consequently, if runoff passes through these kinds of areas, it can moderate runoff peaks and lengthen the time during which water is supplied to a lake.

To help target water volume management efforts, the SEWRPC staff inventoried the three preceding factors for the Hooker 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 use data are shown on Maps 5 and 7. **Urban land use currently occupies about 30 percent of the watershed.** Additionally, by comparing the 2010 and 2035 land use data, it can be seen that **an extensive portion of the watershed which is currently used for agriculture is anticipated to be converted to residential uses under planned year 2035 conditions** (see Map 8). Though much of the land in the southern and northern parts of the watershed that is planned for conversion from agricultural to residential uses is currently well buffered (see Map 12), the proximity of these development areas to the Lake and tributary streams may be a cause for concern if infiltration practices, stormwater management, and buffer enhancement are not considered high priorities in these new developments, especially in those areas of residential and commercial development to the west of STH 83. Consequently, <u>recommendations for stormwater management 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.</u>

Map 13 also indicates, as was discussed in the "Water Quality" section, that, **with the exception of the majority of the shoreline properties, most runoff within the watershed enters a natural feature that could aid with infiltration and/or filtering.** Consequently, <u>recommendations to increase water infiltration and filtering on shoreline properties are also included in Chapter III of this report.</u>

Baseflow Recharge Rate Management

Baseflow refers to water that reaches the Lake from groundwater. This groundwater is replenished through recharge (precipitation that soaks deeply into the ground and enters local aquifers). **Baseflow is crucial to Hooker Lake because it supplies water to the Lake during times when surface runoff is scarce** (e.g., during droughts). Groundwater typically contains little to no sediment and 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 or plants and animals and provide unique ecological functions. Consequently, <u>it is important to maintain recharge to local aquifers that supply Hooker Lake and streams and wetlands within the watershed.</u>

Generally, groundwater supplies can be depleted by two reasons: 1) pumping from the aquifer that supplies the baseflow, thereby reducing, or in extreme cases, eliminating, flow from springs and seeps and 2) reducing aquifer recharge through land use changes that increase impervious cover and speed runoff. The first of these most commonly occurs when a high-capacity well, or multiple wells, are installed in the groundwatershed of a waterbody without proper consideration for the effect pumping may have on the aquifer's naturally occurring groundwater discharge areas. Since water levels in Hooker Lake have not decreased, sufficient quantities of groundwater reach the Lake to maintain its normal elevation. This does not mean that flow volumes have not been affected, but it is beyond the scope of this study to quantify change in groundwater flux to the Lake over time. Since sufficient groundwater discharges to the Lake during dry periods to maintain its elevation, groundwater depletion is not considered a priority issue of concern at the present time. However, if high capacity or numerous additional wells are 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.[41] Whatever the case, actions that lessen consumptive use of groundwater in the Lake's groundwatershed should help maintain or enhance groundwater flux to the Lake.

The second common cause of groundwater depletion is reduced recharge. Recharge to an aquifer can be reduced in many ways. Hastening stormwater runoff, eliminating native vegetative cover, ditching and disconnecting floodplains from streams, and increasing the amount of impervious land surface can all reduce stormwater infiltration, increase runoff, and reduce groundwater recharge. Development and land management activities need to consider groundwater recharge,[42] and actions to protect and enhance recharge should be a priority. Consequently, to maintain groundwater-sourced baseflow to Hooker Lake, it is necessary to identify 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 groundwater contributions to a lake's water budget, it is important to know where groundwater recharge occurs and in what direction groundwater flows. Groundwater elevation is normally a subdued reflection of surface topography, and groundwater normally flows in directions perpendicular to groundwater elevation contours. Topographically higher areas are commonly recharge areas; while lakes, wetlands, and streams are commonly groundwater discharge areas. Groundwater recharge/discharge systems occur on many 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 flow systems typically occur within the Lake's surface-water watershed, regional flow paths may move in 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 groundwater flow paths is illustrated in Figure 30.

   Local groundwater flow paths are relatively easy to estimate from topographic maps. However, to approximate the flow direction of deeper, more regionally extensive systems, groundwater elevation measurements collected in water supply or monitoring wells need to be consulted. Since groundwater normally moves perpendicular to potentiometric contours, deep groundwater flow directions can be predicted. The locations of streams, ponds, and lakes 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, maps can be prepared identifying land areas that likely contribute recharge and are therefore sources of groundwater-sourced baseflow to a lake, and areas that convey groundwater to a lake.

2. **The groundwater recharge potential in the area that is likely contributing to the groundwater supply**—Groundwater recharge potential is based on the amount of impervious cover, topographic relief, and soil characteristics. A flat area with no impervious cover and highly permeable soils, for example, would be classified as having high or very high groundwater recharge potential, whereas sleeply sloping area with lower permeability (e.g., clay soils) would be classified as low potential. Identifying groundwater recharge potential enables the areas with the highest infiltration potential to be identified and protected (e.g., the areas where impervious surfaces should be avoided or where appropriate infiltration facilities should be constructed).

To determine where management efforts should be employed to protect groundwater recharge to Hooker Lake, SEWRPC staff analyzed groundwater elevation contours and the groundwater recharge potential in the areas surround

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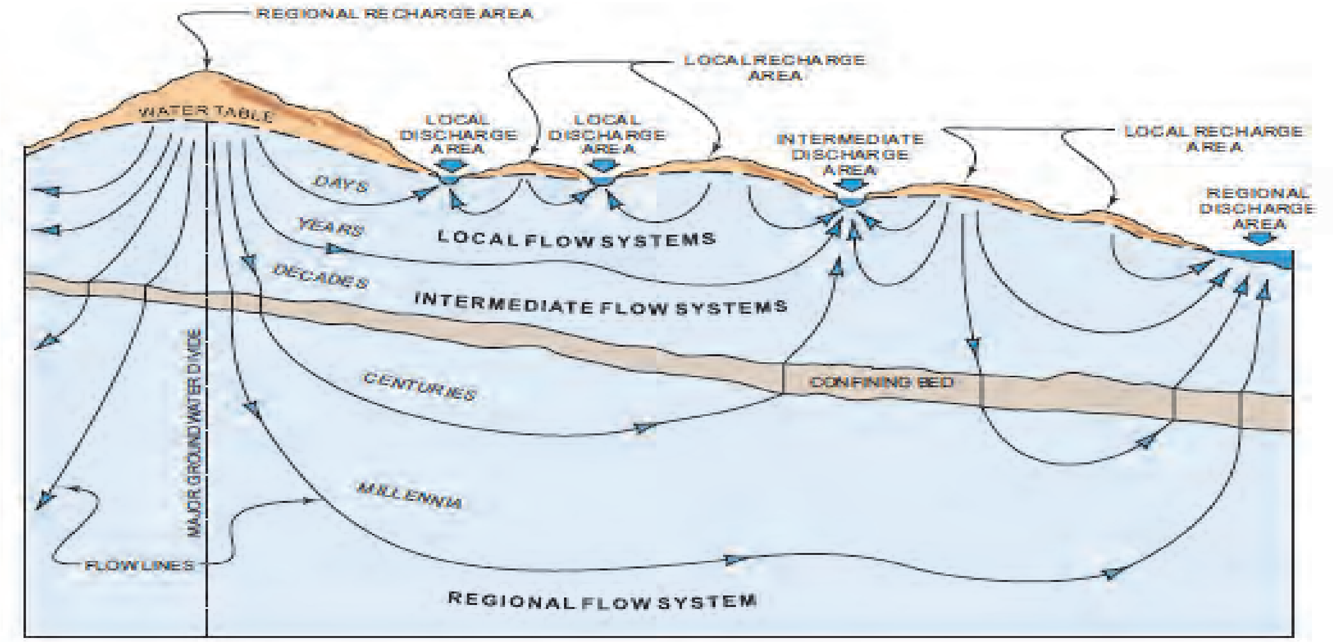
[41]*SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin, *December 2010.*

[42]*Ibid.*

Figure 30

CROSS SECTION DEPICTING LOCAL VERSUS REGIONAL GROUNDWATER FLOW PATHS



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

ing the Lake.[43] 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 may be coming from outside of the watershed. The results of these inventories are described below.

Map 15 shows the general water table elevation contours, in feet above NGVD 29, in the immediate Hooker Lake area. In general, the shallow regional groundwatershed divide is located approximately three miles to the west-northwest. **Large portions of the recharge area for shallow regional groundwater may lie to the west outside the Lake's surface-water watershed.** Shallow groundwater in the regional system to the west of the groundwatershed divide flows to discharge points in the Fox River watershed. Near Hooker Lake, shallow regional groundwater flow is predominately to the southeast and flow is likely to the southeast in the southern portion of the Lake's watershed and to the northeast in northern portions of the Lake's watershed. Given the typical water elevation of Hooker Lake, the Lake may lose water to the groundwater flow system along its southern and eastern shorelines while the wetlands abutting the northwest shoreline may be fed by the regional shallow groundwater flow system. Localized flow systems likely contribute groundwater to the Lake in steeply sloping areas that essentially surround the Lake, while areas near the dam may lose water to localized flow systems connecting the Lake to the stream downstream of the dam. Water in the deeper aquifers is separated from the shallow aquifer by hundreds of feet of impermeable shale and exhibit a current potentiometric surface essentially equivalent to the Lake's elevation.[44] Little to no water exchange is anticipated between the Lake and deep aquifers under natural conditions and current pressure head distributions. Overall, it appears that the Lake is neither a strong groundwater discharge area nor a significant groundwater recharge area.

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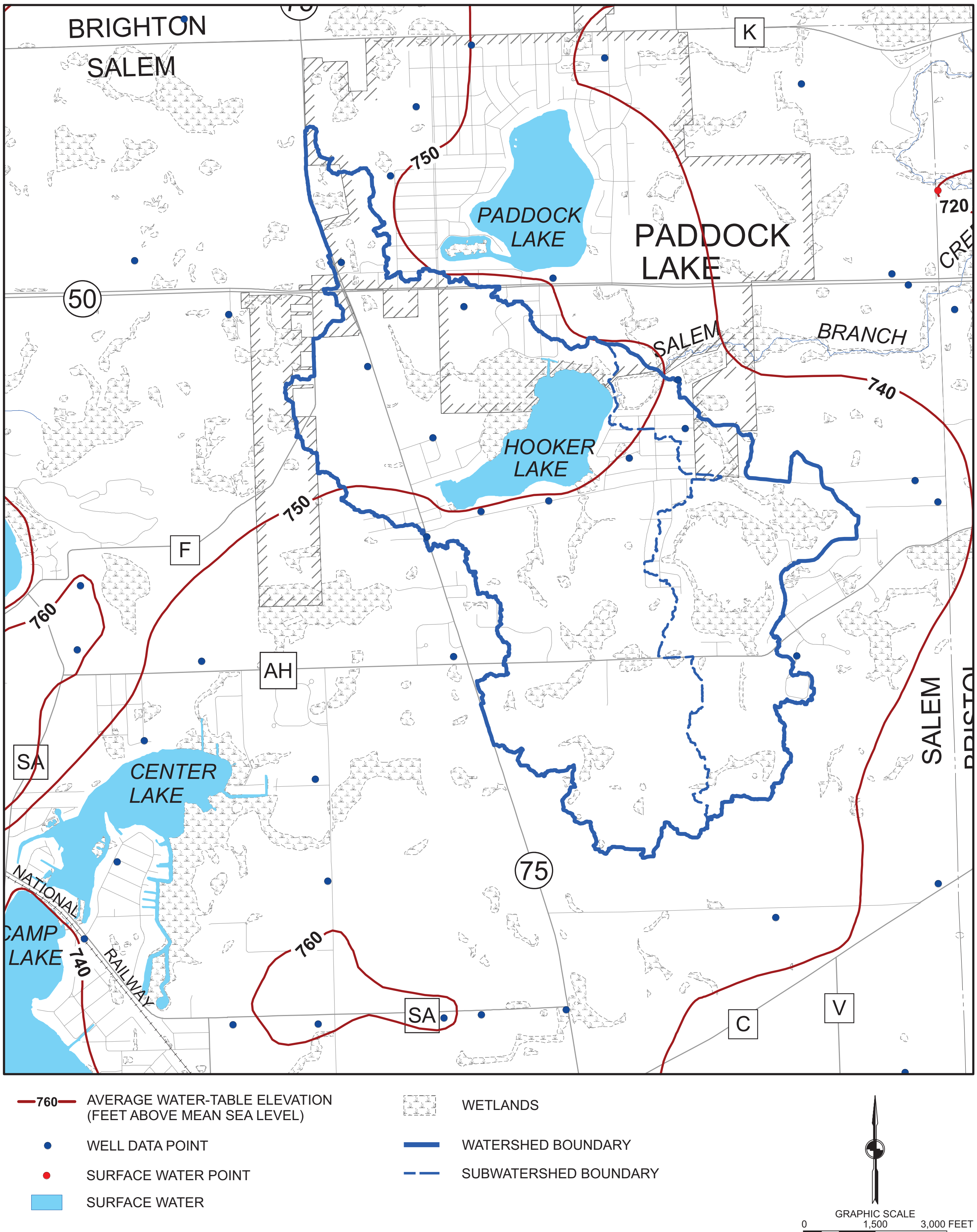
[43]*SEWRPC Planning Report No. 52, op. cit.*

[44]*Potentiometric surface is the elevation to which water will rise in a well penetrating an aquifer confined by impermeable rock layers.*

Map 15

GROUNDWATER TABLE ELEVATIONS BASED ON WELL ELEVATIONS WITHIN THE HOOKER LAKE WATERSHED



Source: Wisconsin Geological and Natural History Survey and SEWRPC.

Groundwater recharge potential of the lands near Hooker Lake is illustrated in Map 16. The areas with the highest groundwater recharge potential abut the south shore of the Lake and the large inlet wetland on the northwest side of the Lake. Both these areas are within the Lake's surface water watershed and very likely contribute water to the Lake's local groundwater flow system. Infiltration of precipitation into these areas enhances the amount of groundwater entering the Lake and reduces runoff volume. Reduced runoff volume usually correlates with lower erosion potential and decreased sediment and pollutant loading to downstream water bodies. The high recharge potential area located to the west of the inlet wetland is in an area where both local and regional flow paths contribute water to the Lake. This area may provide an excellent opportunity to protect and even enhance groundwater recharge. The high recharge potential area located to the south of the Lake probably does not contribute recharge to the regional shallow groundwater flow system. However, infiltrated water has a high likelihood of entering localized flow systems discharging to Hooker Lake and its tributary streams. Some of this area is used for residential purposes, and likely has a significant amount of impervious surface, a fact potentially decreasing the current groundwater recharge value of this area. Such an area is a prime target for stormwater management measures that enhance infiltration, helping offset the effect of impermeable surfaces. The groundwater recharge potential of most of the remaining groundwatershed is classified as moderate. Opportunities to enhance the proportion of precipitation infiltrated in such areas should be actively pursued in all areas to the northwest of the Lake, but their ability to directly impact groundwater flow to the Lake decreases with increasing distance from the Lake. Recommendations related to investigating these recharge areas are also included in Chapter III.

Some projects can be undertaken to improve the volume, timing, and quality of water delivered to the Lake without further study. In the interest of encouraging these kinds of actions, Chapter III of this report describes recommendations focused on increasing infiltration, particularly in the moderate and high groundwater recharge potential areas in the Hooker Lake watershed and in areas to the west of the surfacewater watershed that may contribute to groundwater recharge and Hooker Lake's baseflow. These recommendations should be implemented whenever and wherever practical. Consideration should be given to active promotion of stormwater infiltration practices. Examples of promotion includes providing incentives that encourage stormwater infiltration and/or promulgating ordinances that incorporate performance metrics that can be efficiently met using stormwater infiltration techniques.

ISSUE 3: LAKE OUTLET DAM

The water surface of Hooker Lake has been controlled by a dam since at least 1929.[45] At least 3 dams have controlled the Lake's water level over this period. The locations of these dams are illustrated on Map 3. The most upstream dam is located at the shoreline of the eastern-most area of Hooker Lake proper, and is generally referred to as "Hooker Lake Dam". At present, this dam is not known to be used and is largely submerged. Water levels within the Lake are now controlled by the "Bryzek Dam" located approximately 1,100 feet east-northeast of the Hooker Lake Dam (Figure 31). A culvert located a short distance downstream of the Bryzek Dam appears to backwater during intense runoff events (Figure 32).[46] Backwatering can diminish the ability of the Bryzek Dam to pass high flow events. The Bryzek Dam was reconstructed in 2002, and an after-the-fact permit was issued by the WDNR in 2005. Both dams are situated on private property and are privately owned. The dam owner has granted HMLD permission to operate the dam and clear debris.

In 2007 and 2008, residents of Hooker Lake contacted the WDNR with concerns regarding high water levels and flooding at Hooker Lake. In 2007, the WDNR reviewed survey data from SEWRPC Planning Report No. 44, *A*

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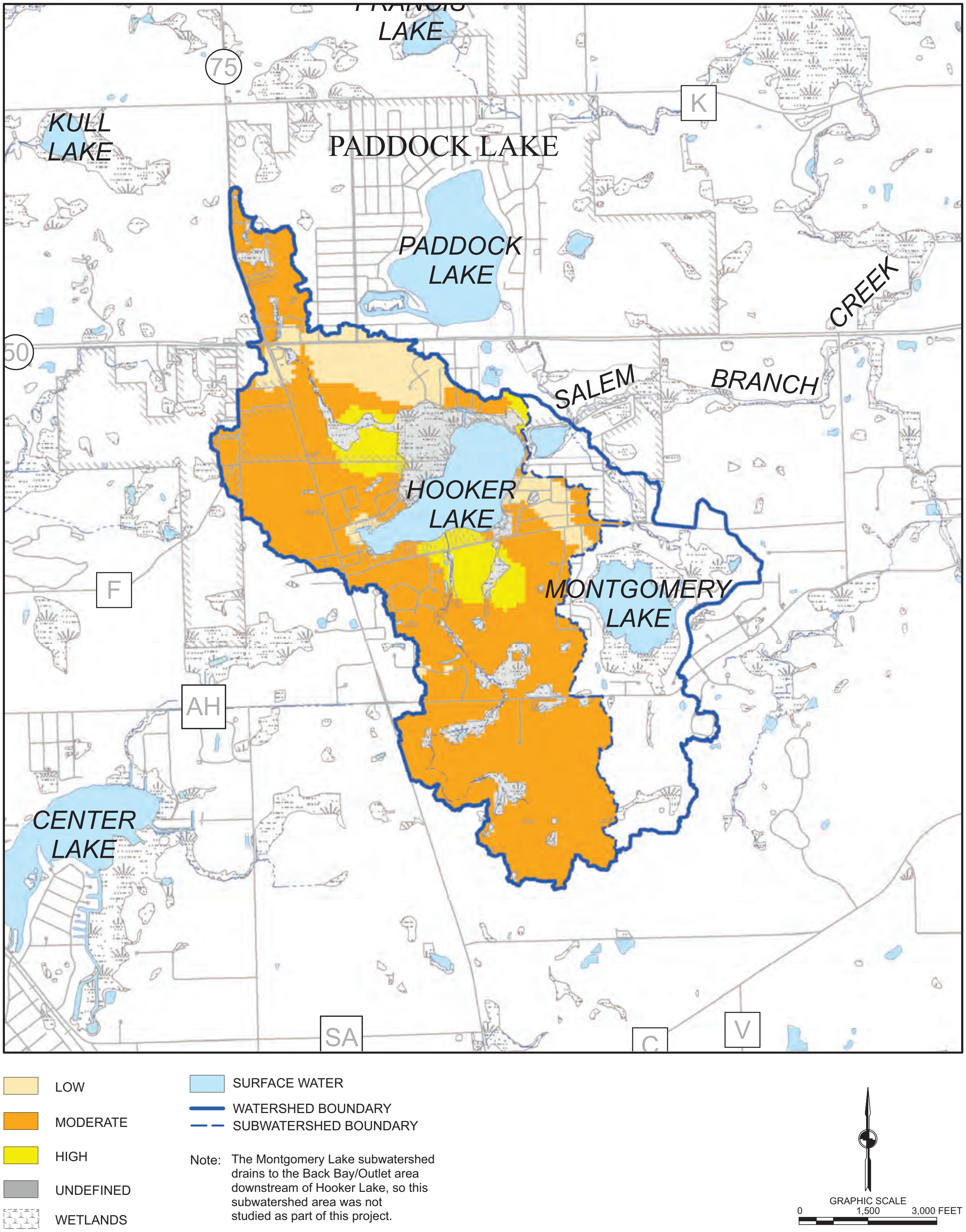
[45]*Wisconsin Department of Natural Resources,* Detailed Information for Dam HOOKER LAKE*, On-Line Dam Database, April 4, 2016.*

[46]*Southeastern Regional Planning Commission, Planning Report No. 44,* A Comprehensive Plan for the Des Plaines River Watershed*, June 2003.*

Map 16

ESTIMATES OF GROUNDWATER RECHARGE POTENTIAL
WITHIN THE HOOKER LAKE WATERSHED



Source: Wisconsin Geological and Natural History Survey and SEWRPC.

Figure 31

BRYZEK DAM: 2014

Source: SEWRPC.

Figure 32

CULVERT DOWNSTREAM OF BRYZEK DAM: 2014

Source: SEWRPC.

Comprehensive Plan for the Des Plaines River Watershed, June 2003. This report provides drawings and elevations of the earlier Bryzek Dam as it existed before the 2002 reconstruction (Appendix E contains records and photos of the dam). Combining this data with field observations made by WDNR staff in 2009, it was ascertained that the reconstructed dam had a spillway elevation approximately 10 inches higher than the earlier dam. Additionally, the reconstructed dam had a spillway that was about 11 inches narrower than the original Bryzek Dam. **A higher spillway elevation and reduced spillway width could exacerbate the magnitude and duration of high lake water elevation periods** following large precipitation and snowmelt events. In exceptional high flow conditions, the amount of discharge may possibly overtop the dam's engineered spillway and embankment. Overtopping can destabilize a dam and is a condition prohibited by Chapter NR 333 of the *Wisconsin Administrative Code*. The WDNR dam database includes a notation that an order was issued by the WDNR on November 8, 2010 requiring that the dam be modified and easements procured, or the dam should be removed. **A time extension was issued by the WDNR on May 18, 2016 requiring the spillway elevation to be restored to the pre-2002 spillway elevation, 0.7 feet lower than the current elevation, between July 1, 2016 and August 1, 2016. In lieu of restoration, a petition to raise and enlarge the dam or a request for a permit to abandon the dam may be submitted to the WDNR by August**

Figure 33

ACCUMULATED DEBRIS AT CULVERT DOWNSTREAM OF BRYZEK DAM: 2016

Source: Village of Paddock Lake and SEWRPC.

1, 2016, with written notification submitted by July 1, 2016.[47] The HLMD should actively monitor progress and results of this negotiation and should actively assert itself in this matter. <u>Consequently, recommendations related to dam design, inspection, operation, and ownership are made in Chapter III of this report.</u>

The Bryzek Dam and the downstream culvert commonly become clogged with floating debris such as cattails and tree branches. The Village of Paddock Lake or the HLMD has cleared such flow obstructions in the past, which is important to maintaining proper water level, flow capacity, and safe operation. Some of these debris jams can be quite severe, appreciably restricting flow (see Figure 33). **Restricted outlet capacity could raise water levels to higher than expected water levels which in turn can lead to property damage.** For this reason, Chapter III includes recommendations that integrate the HLMD into dam operation and potentially ownership.

ISSUE 4: AQUATIC PLANT GROWTH

Aquatic plant management is a significant issue of concern to Hooker Lake stakeholders. Consequently, this section first discusses the general need for aquatic plant management by evaluating the current state of aquatic plants in Hooker Lake, compares the current state with past surveys, and then discusses management alternatives.

It is important to note that <u>all lakes have plants</u>. In fact, in a nutrient-rich lake such as Hooker Lake (nutrient-rich lakes are common in the Southeastern Wisconsin Region due to nutrient-rich soils), it is actually normal to have luxuriant aquatic plant growth in the shallow areas. Additionally, it is important to note that **native aquatic plants**

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[47]*As of the writing of this report, we are not aware of any progress to resolve this issue.*

Table 11

AQUATIC PLANT SPECIES OBSERVED IN HOOKER LAKE: 1992, 2008, AND 2014

Aquatic Plant Species	Native (N) or Nonnative (I)	1992	2008	2014
Ceratophyllum demersum (coontail)	N	X	X	X
Chara spp. (muskgrass)	N	X	X	X
Elodea canadensis (waterweed)	N	X	X	X
Lemna minor (Duckweed)	N	X	X	- -
Myriophyllum spicatum (Eurasian water milfoil)	I	X	X	X
Myriophyllum verticillatum (native milfoil)	N	- -	X	- -
Najas flexilis (bushy, or slender, pondweed)	N	X	X	X
Najas marina (spiny, or brittle, naiad)	N	X	X	- -
Nitella spp. (stonewort)	N	X	- -	- -
Nuphar variegata (spatterdock)	N	X	X	X
Nymphaea odorata (white water lily)	N	X	X	X
Potamogeton crispus (curly-leaf pondweed)	I	X	X	- -
Potamogeton foliosis (leafy pondweed)	N	- -	X	- -
Potamogeton illinoensis (Illinois pondweed)	N	X	X	- -
Potamogeton praelongus (white-stem pondweed)	N	- -	X	- -
Potamogeton richardsonii (clasping-leaf pondweed)	N	X	X	- -
Potamogeton zosteriformis (flat-stem pondweed)	N	X	X	- -
Stuckenia pectinata (Sago pondweed)	N	X	X	X
Utricularia vulgaris (bladderwort)	N	X	X	- -
Vallisneria americana (eel-grass/wild celery)	N	X	X	X
Zosterella dubia (water stargrass)	N	- -	X	X
Total Number of Species	- -	17	20	10

Source: Aron and Associates and SEWRPC.

form an integral part of lake ecosystems. These plants serve a number of valuable functions including: improving water quality by using excess nutrients, providing habitat for invertebrates and fish, stabilizing lake bottom sediments, and supplying food and oxygen to the Lake through photosynthesis. It is also important to note that even though aquatic plants may hinder use of and/or access to a lake, aquatic plants should not necessarily be eliminated or even significantly reduced because they may serve other beneficial functions. For example, the white water lily (found only sparsely in Hooker Lake) plays a major role in providing shade, habitat, and food for fish and other important aquatic organisms. It also plays a significant role in preventing shoreline erosion, as it can dampen waves that would otherwise damage the shoreline. Additionally, the shade that this plant provides helps reduce the growth of other plants, such as Eurasian water milfoil (EWM) and coontail, because it limits the amount of sunlight reaching young plants on the lake bottom. Furthermore, aquatic plants compete with free floating algae for plant nutrients. Without aquatic plants, free floating algae may become extremely abundant, reducing water clarily. Given these benefits, removing native "nuisance" plants (especially white water lilies) beyond the need for gaining access to the lake should be avoided.

Aquatic Plants in Hooker Lake

To document the types, distribution, and relative abundance of aquatic macrophytes in Hooker Lake and, thus, to determine the need for aquatic plant management, aquatic plant surveys were conducted in 1992 and 2008 by Aron and Associates and by SEWRPC staff in 2014. Table 11 a lists the aquatic plant species observed in the 1992, 2008, and 2014 surveys.

Table 12

ABUNDANCE DATA FOR AQUATIC PLANT SPECIES IN HOOKER LAKE: 2014

Aquatic Plant Species	Native or Invasive	Number of Sites Found	Dominance Value[a]
Floating Plants			
Nuphar variegata (spatterdock)	Native	3	5.5
Nymphaea odorata (white water lily)	Native	4	5.5
Submerged Plants			
Ceratophyllum demersum (coontail)	Native	78	112.6
Chara spp. (muskgrass)	Native	40	68.5
Myriophyllum spicatum (Eurasian water milfoil)	Invasive	25	23.6
Elodea canadensis (waterweed)	Native	15	22.1
Zosterella dubia (water stargrass)	Native	14	15.8
Vallisneria americana (eel-grass/wild celery)	Native	4	3.2
Najas flexilis (bushy pondweed)	Native	3	2.4
Potamogeton pectinatus (Sago pondweed)	Native	3	1.6

NOTE: There are a total of 253 grid-point sampling sites on Hooker Lake; all 253 sites were visited during the survey. 138 of those sites were at, or shallower than, the 15-foot maximum depth at which plants grew; 127 of those sites actually had vegetation.

[a]*The* ***dominance value*** *of a species is derived from a combination of how often it was observed at sampling sites that had some kind of vegetation present and its relative density at those sites; it provides an indication of the relative importance and abundance of a species within a community.*

Source: SEWRPC.

The 2014 survey revealed that the five most dominant native plant species in Hooker Lake, in descending order of abundance were:

- coontail (*Ceratophylum demersum*),
- muskgrass (*Chara spp.*),
- elodea (*Elodea canadensis*),
- water stargrass (*Zosterella dubia*), and
- eel-grass/water celery (*Valesneria americana*).

See Table 12 for the list of aquatic plant species that were found and for detailed characterization of their abundance and dominance. Individual distribution maps for each species are included in Appendix F along with text explaining the ecological significance of each plant and guidance on their identification. It should be noted that muskgrass is the aquatic macrophyte largely responsible for marl formation. Marl formation reduces lake water phosphorus concentrations which helps improve water, demonstrating the valuable ecological service muskgrass provides the lake.

Data from the 2014 survey reveals that of the 138 sites having a water depth at or less than the 15-foot maximum depth of plant growth in Hooker Lake, 127 had moderate[48] amounts of vegetation and most of them **contained vegetation known to interfere with recreational use when found growing in abundance** (such as coontail). <u>These results indicate that the Lake has types of plants at levels of abundance that deters recreational use. Therefore, aquatic plant management is warranted.</u>

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[48]*Moderate vegetation in this context refers to a rake fullness measurement of 2 on a scale of zero to three (see Appendix F for schematic of rake fullness ratings).*

Table 13

SUMMARY STATISTICS FOR ALL AQUATIC PLANT SPECIES IN HOOKER LAKE: 2008 AND 2014

Summary Statistics	2008	2014
Total number of survey sites visited/sampled	225.00	253.00
Total number of survey sites with vegetation	65.00	127.00
Total number of sites shallower than the maximum depth of plants	110.00	138.00
Frequency of occurrence at sites shallower that the maximum depth of plants	59.09	93.03
Simson Diversity Index	0.87	0.79
Maximum depth of plants (ft)	13.50	15.00
Number of sites sampled using rake on rope (R)	102.00	0
Number of sites sampled using rake on pole (P)	122.00	253.00
Average number of all species per site (shallower than max depth)	0.94	1.95
Average number of all species per site (veg. sites only)	1.72	2.17
Average number of native species per site (shallower than max depth)	0.83	1.77
Average number of native species per site (veg. sites only)	1.59	1.98
Species Richness	16.00	10.00
Species Richness (including visuals)	20.00	10.00

NOTE: The WDNR-generated map of grid points provides 238 sampling points. During the 2008 survey, 225 of those sites were visited; during the 2014 survey, SEWRPC field staff sampled an additional 15 sites to fill in apparent "blank spots" on the site map.

Source: Aron and Associates, Wisconsin Department of Natural Resourdes, and SEWRPC.

Since the 2008 and 2014 surveys were both conducted using the same point-intercept methodology,[49] comparing data from these two surveys should accurately reflect changes in the aquatic plant communities in Hooker Lake over the intervening six year period. It is worth noting that six years is more than enough time for a lake to undergo significant changes in its aquatic plant composition. *To accurately monitor plant populations and identify developing trends in plant communities, relatively frequent (three- to five-year intervals) point-intercept plant surveys should be conducted; more frequently if negative developments are observed, such as loss of native species or rapid increase of plants, especially nonnatives.*

Table 13 contrasts the results of the 2008 and 2014 aquatic plant surveys. Two things become immediately apparent. First, the number of species markedly decreased between from 2008 to 2014 (see Table 11 for species lists). In six years, the number of aquatic species decreased by 50 percent, with species richness falling from 20 to 10. This loss in species diversity has significantly affected the pondweed species – and has affected pondweeds that are both sensitive to water quality disturbances and those that are tolerant of eutrophic conditions and disturbance. This suggests that an external condition is affecting the health of the plant community. Aquatic herbicides such as chemical treatment 2,4-D and Endothall are likely the cause for the loss of bladderwort (*Utricularia vulgaris*) and white water crowfoot (*Ranunculus longirostrisis*). It is also notable that white water crowfoot was listed as a dominant

[49]*The point intercept method uses predetermined points arranged in a grid pattern across the entire lake surface as sampling sites. Each site is located using global positioning system (GPS) technology and a single rake haul is taken at that 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 at Wisconsin Department of Natural Resources, Publication No. PUB-SS-1068 2010.*

species in the 2007 Hooker Lake Integrated Sensitive Area Report (Appendix J) yet was not found in the 2008 or 2014 survey. White water crowfoot is uncommon to this area and considered an ecologically important species as it supports ducks, upland game birds, invertebrates, and fish.[50]

Reviewing Table 14, it can be seen that the frequency of occurrence of nearly all native plants decreased between 2008 and 2014. Thirteen of the 15 submerged plants found in the Lake in 2008 were found at fewer locations or not at all in 2014. Again, aquatic plant management strategies have been noted to dramatically effect aquatic plants. For example, shoreline algal treatments can decimate muskgrass populations.[51] Muskgrass is a critical component of the Lake's phosphorus sequestration system, and reducing muskgrass populations can have a serious impact on a lake's trophic state, clarity, and free floating and toxic algae abundance.

In addition to the marked decrease in native species richness and frequency of occurrence, there was a concurrent significant increase in the occurrence of coontail (see Map 17). It should be noted that the significant increase in coontail does not correlate to an increase in other plant species. While there is no definitive hypothesis explaining the increase in coontail, it is known that coontail recovers more quickly following application of some aquatic herbicides, allowing coontail to grow more quickly than other native species. This allows coontial to suppress other native plants by shading.

Table 14

FREQUENCY OF OCCURRENCE OF SUBMERGED AQUATIC PLANT SPECIES IN HOOKER LAKE: 2008 AND 2014

Aquatic Plant Species	2008	2014
Ceratophyllum demersum (coontail)	23.1	61.4
Chara spp. (muskgrass)	46.2	31.5
Elodea canadensis (waterweed)	6.2	11.8
Myriophyllum spicatum (Eurasian water milfoil)	21.5	19.7
Myriophyllum verticillatum (native milfoil)	13.9	- -
Najas flexilis (bushy pondweed)	- -	2.4
Najas marina (spiny, or brittle, naiad)	7.7	- -
Potamogeton crispus (curly-leaf pondweed)	1.5	- -
Potamogeton illinoensis (Illinois pondweed)	1.5	- -
Potamogeton praelongus (white-stem pondweed)	1.5	- -
Potamogeton richardsonii (clasping-leaf pondweed	4.6	- -
Potamogeton zosteriformis (flat-stem pondweed)	15.4	- -
Stuckenia pectinata (Sago pondweed)	4.6	2.4
Utricularia vulgaris (bladderwort)	1.5	- -
Vallisneria americana (eel-grass/wild celery)	6.2	3.1
Zosterella dubia (water stargrass)	15.4	11.0

NOTE: The Frequency of Occurrence, expressed as a percent, is the number of occurrences of a species divided by the number of sampling sites with vegetation.

Source: Aron and Associates and SEWRPC.

A key aspect of the ability of an ecosystem, such as a lake, to maintain its ecological integrity is through biological diversity, or *species richness*. Conserving the biodiversity of an ecosystem helps not only to sustain the ecological integrity of the system, but preserves a spectrum of options for future decisions regarding the management of that system. With seven different native submerged species of aquatic plants, the 2014 survey indicated 1) that Hooker Lake contains only a **fair diversity of aquatic species, with only ten species,** for a lake of its size and 2) as indicated in Table 14 and Map 18, a decline in the number of native species. Native plant presence and diversity are crucial parts of the Lake's health. Therefore, <u>the native plants should be protected to the greatest extent practical</u>. By comparison, nearby Lake Mary has been reported to have 15 species;[52] Elizabeth Lake, 18 species;[53] Geneva Lake,

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[50]*Heidi Bunk, Wisconsin Department of Natural Resources email to SEWRPC, Hooker Lake Lake Management Plan Comments, November 4, 2016 and follow up telephone conversations.*

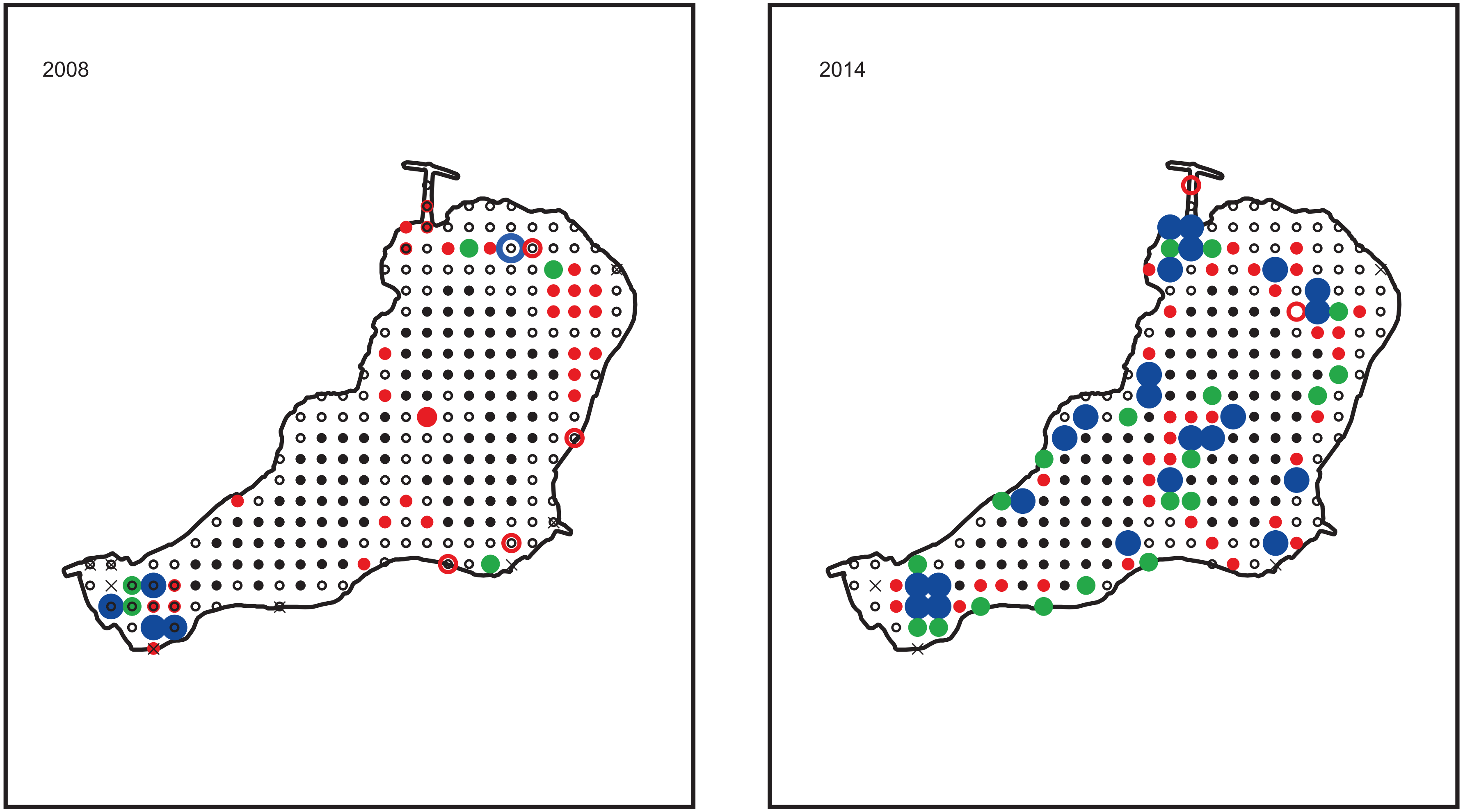
[51]*Ibid.*

[52]*SEWRPC Community Assistance Planning Report No. 302*, A Lake Management Plan For Elizabeth Lake And Lake Mary, Kenosha County, Wisconsin, *Volume One*, Inventory Findings, *July 2009*.

[53]*Ibid.*

Map 17

COONTAIL OCCURENCE IN HOOKER LAKE: 2008 VS 2014



RAKE FULLNESS RATING

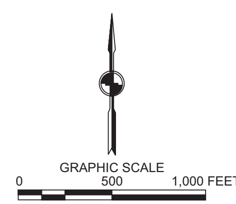
A LITTLE VISIBLE NEARBY

NO COONTAIL FOUND

NOT SAMPLED

A LOT VISIBLE NEARBY

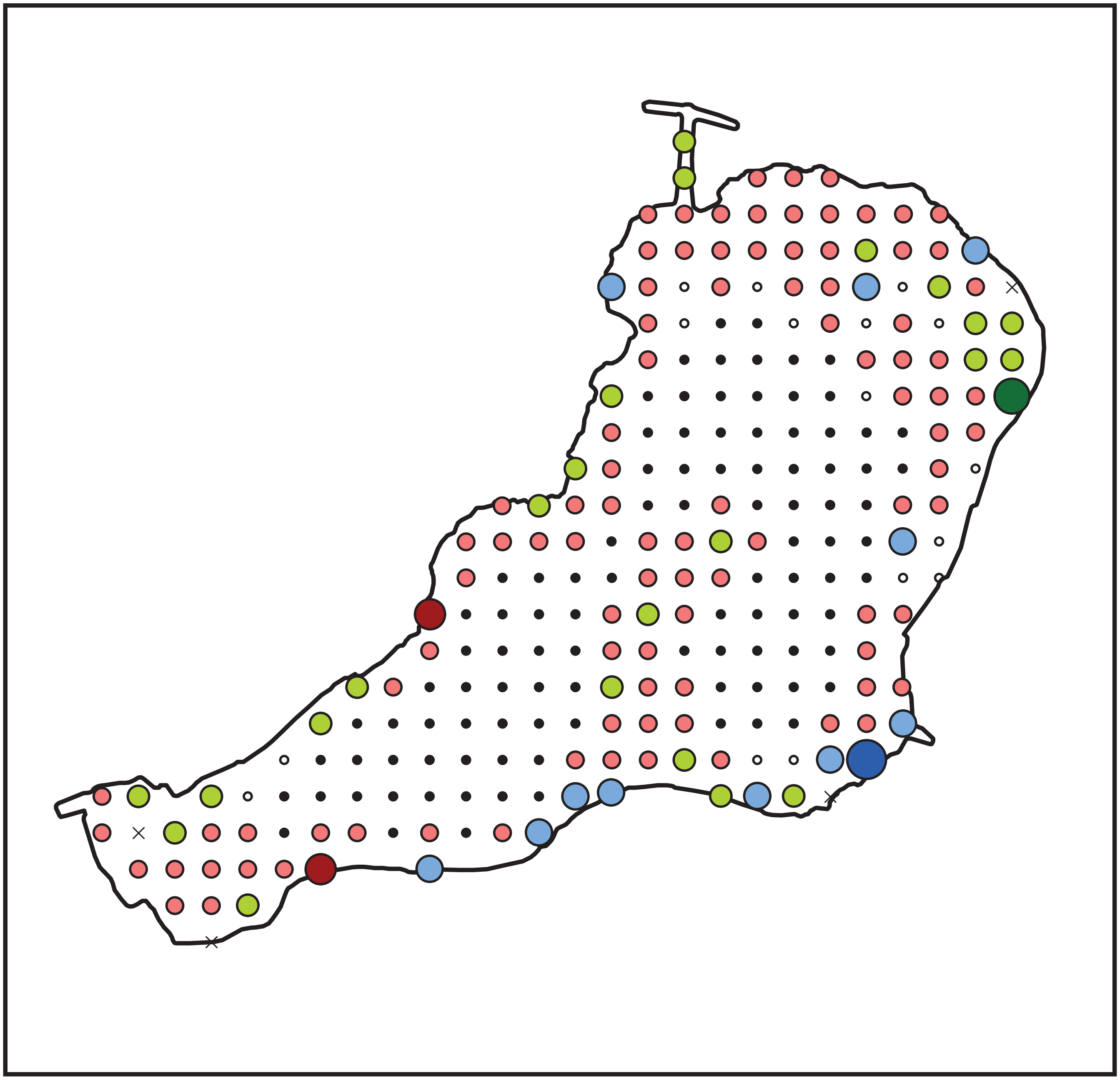
TOO DEEP TO SAMPLE



Source: SEWRPC.

Map 18

SPECIES RICHNESS AT SURVEY SITES IN HOOKER LAKE: 2014



NOTE: The above diagram presents the data for number of species observed in Hooker Lake at each sampling site during the 2014 aquatic plant survey; sampling occurred at 253 sampling sites, 127 had vegetation.

Source: Wisconsin Department of Natural Resources and SEWRPC.

20 species;[54] George Lake, 11 species;[55] and, Voltz Lake, ten species.[56] Future aquatic plant surveys will be needed to determine if there is an overall sustained downward trend in the number of native plant species.

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 damage the ecological health of their new environments and/or are considered a nuisance to human use values. In summary, **invasive species are non-native but not all non-native species are invasive.**

Introducing 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 outcompete native species for space and other necessary resources. This can have devastating effects on native species that have well developed dependencies on the availability of native plants and animals.**

A list of common invasive wetland and aquatic plants of current concern in the Southeastern Wisconsin Region is found below. This list is based upon conversations with WDNR staff that took place during early 2016. A full list with photos may be found in Appendix G:

- Eurasian water milfoil (*Myriophyllum spicatum*),
- Curly-leaf pondweed (P*otamogeton crispus*),
- Non-native phragmities (*Phragmities australis subspecies australis*),
- Reed canary grass (*Phalaris arundinaceae*),
- Hybrid cattail (*Typha x glauca*), and
- Common buckthorn (*Rhamnus cathartica*).

The WDNR officially lists six invasive species in or near Hooker Lake (Figure 34):

- Eurasian water milfoil (*Myriophyllum spicatum*),
- Curly-leaf pondweed (*Potamogeton crispus*),
- Hybrid water milfoil (cross between EWM and the native Northern water milfoil),
- Reed canary grass (*Phalaris arundinaceae*),
- Purple Loosestrife (*Lythrum salicaria*), and
- Zebra mussel (*Dreissena polymorpha*).

EWM was found in about 20 percent of the vegetated sampling sites in Hooker Lake during the 2014 survey and was overall the third most dominant species. Table 15 and Map 19 show the distribution of EWM has increased between 2008 and 2014, but the density at the sites where it was found has decreased. As EWM has been

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[54]SEWRPC Community Assistance Planning Report No. 60, 2nd Edition, A Lake Management Plan for Geneva Lake Walworth County, Wisconsin, May 2008.

[55]S*EWRPC Community Assistance Planning Report No. 300*, A Lake Management Plan for George Lake, Kenosha County, Wisconsin, *August 2007*.

[56]*SEWRPC Memorandum Report No. 159*, An Aquatic Plant Management Plan for Voltz Lake, Kenosha County, Wisconsin, *January 2005*.

known to cause severe recreational use problems in lakes within the Southeastern Wisconsin Region, and since EWM populations can displace native plant species and interfere with recreational use, the abundance of this species indicates the need to control its population. This further emphasizes the need to continue to actively employ a well thought out aquatic plant management effort.

The zebra mussel (*Dreissena polymorpha*) has been shown to affect lake water clarity. This nonnative species of shellfish rapidly colonizes nearly any clean, stable, flat underwater surface, artificial or natural, and this behavior has caused the zebra mussel to become a costly nuisance to humans as massive populations of the mollusk have clogged municipal water intake pipes and fouled underwater equipment. The animal also has been known to negatively impact native benthic organism populations, disrupting aquatic food chains by removing significant amounts of bacteria and smaller phytoplankton, which serve as food for a variety of other aquatic organisms, including larval and juvenile fishes and many forms of zooplankton. By removing desirable algal species from the water column, the competition for nutrients is reduced, which often can foster growth of undesirable filamentous algae and cyanobacteria which are not consumed by zebra mussels. Therefore, zebra mussels can cause desirable algae populations to decline and the abundance of undesirable algal species to concomitantly increase.

Figure 34

INVASIVE SPECIES IN HOOKER LAKE AND ITS WATERSHED

Source: Wisconsin Department of Natural Resources, The Nature Conservancy and SEWRPC.

Table 15

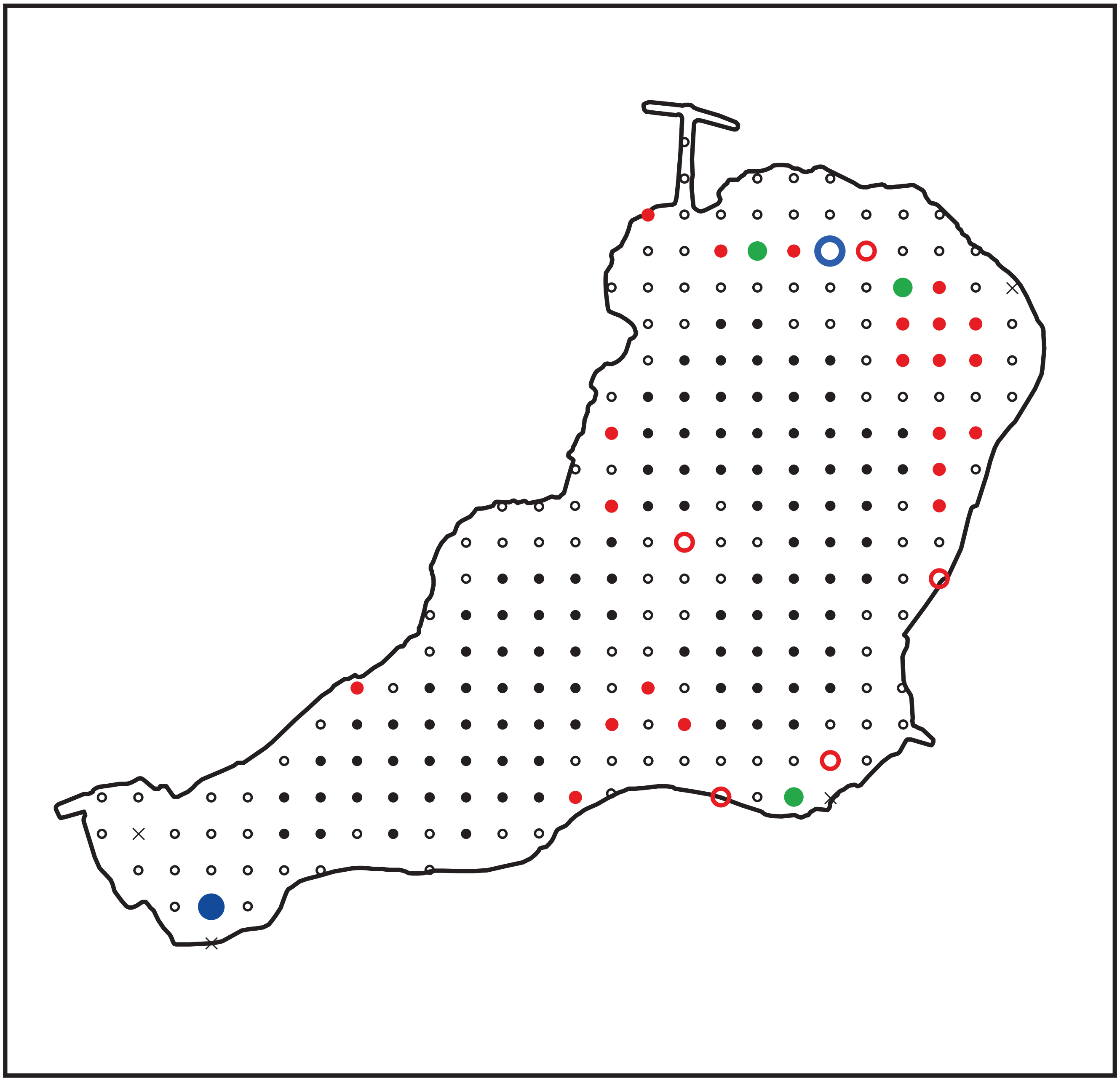
INDIVIDUAL SPECIES STATISTICS FOR KEY AQUATIC PLANT SPECIES IN HOOKER LAKE: 2008 AND 2014

Summary Statistics	EWM 2008	EWM 2014	Coontail 2008	Coontail 2014	Chara 2008	Chara 2014
Frequency of occurrence within vegetated area (percent)	21.50	19.70	23.10	61.40	46.20	31.50
Frequency of occurrence at sites shallower than maximum depth of plants	12.70	18.10	13.60	56.50	27.30	28.90
Relative Frequency (percent)	12.50	9.10	13.40	28.40	26.80	14.50
Relative Frequency (squared)	0.02	0.01	0.02	0.08	0.07	0.02
Number of sites where species found	14.00	25.00	15.00	78.00	30.00	40.00
Average rake fullness	1.00	1.20	2.00	1.80	1.00	2.20
Number of visual sightings	6.00	6.00	- -	2.00	2.00	1.00
Present (visual or collected)	present	present	present	present	present	present

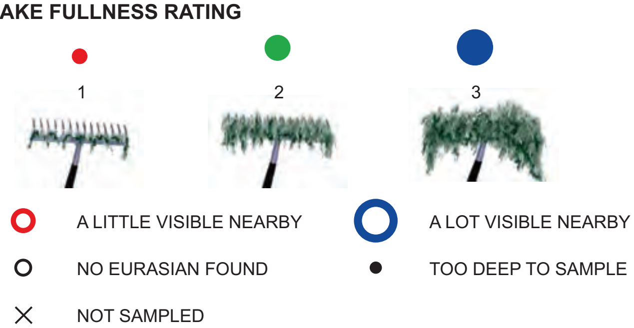
Source: Aron and Associates and SEWRPC.

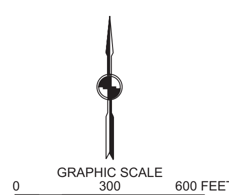
Map 19

EURASIAN WATER MILFOIL DISTRIBUTION IN HOOKER LAKE: 2014



RAKE FULLNESS RATING



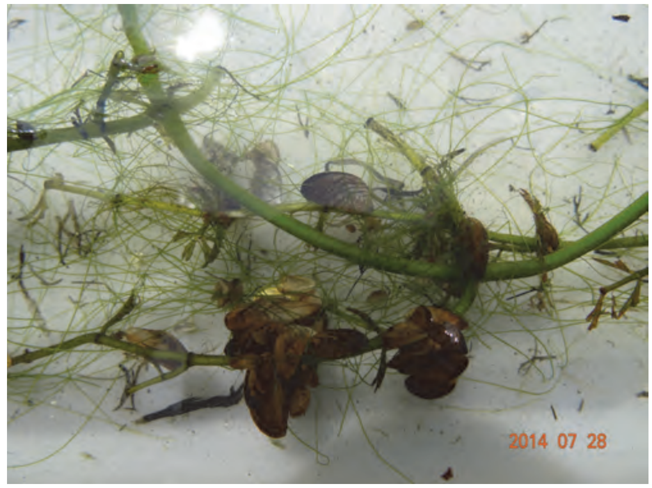


Source: SEWRPC.

As a result of the filter feeding proclivities of these animals, many lakes have experienced improved water clarity. Ironically, in some lakes, **improved water clarity has resulted in increased growth of rooted aquatic plants, including EWM. This may be what is being observed in Hooker Lake at the present time.** As described in the water quality discussion earlier in this report, water clarity in Hooker Lake has steadily improved since 2010. Hooker Lake residents reported the presence of zebra mussels since at least 2010, thereby lending support to the notion that increased clarity may be a reflection of the zebra mussel activity. Interestingly, aquatic plant survey data from 2014 indicates a substantial increase (nearly 100 percent) in the number of survey sites containing aquatic plants since the previous survey in 2008 as well as a substantial increase in the number of sites with EWM (see Table 15).

Figure 35

ZEBRA MUSSELS ATTACHED TO AQUATIC PLANTS DURING 2014 AQUATIC PLANTS SURVEY OF HOOKER LAKE



Source: SEWRPC.

A curious caveat to the interplay between zebra mussels, water clarity, EWM and native aquatic plants has been observed within the Southeastern Wisconsin Region. Zebra mussels have been noted to attach themselves to the stalks of the EWM plants (Figure 35). The weight of the attached mussels then acts as ballast, dragging the EWM stems deeper into the water column and below the zone of light penetration. This interferes with the competitive strategy of the EWM plants and in some cases has contributed to improved growth of beneficial native aquatic plants, while in other cases has led to nuisance growths of filamentous algae (which are too large to be ingested by the zebra mussels). Regardless of the seemingly beneficial impacts of these animals, the overall effect on a lake's aesthetics, ecology, and cost to lake uses are negative.

Zebra mussel abundance has been observed to fluctuate in Southeastern Wisconsin lakes over time. Populations have been noted to quickly build after introduction, peak, and then decline. It is not uncommon to note substantially reduced zebra mussel populations over periods of time of a year or more, a situation that correlates with the zebra mussels' life cycle (it lives for three to five years) and exhaustion of desirable food sources. However, once established in a lake, remaining zebra mussel populations can quickly re-establish a large year class of offspring when conditions improve, repopulating the lake to abundance levels similar to previous peak population densities.

Aquatic Plant Management Alternatives

Conflicting interests commonly occur when it comes to aquatic plant management, because pursuing one goal may interfere with the accomplishment of another. EWM eradication, for example, could be accomplished with heavy chemical treatment. However, given that EWM often coexists with native plants (including a very similar looking native milfoil plant), this technique would fail to accomplish the goal of conserving native plant populations. Consequently, the aquatic plant management alternatives described in this section take into consideration the sometimes conflicting goals of maintenance of access, control of EWM and other nonnative species, and protection of native species.

Aquatic plant management measures can be classified into five groups: 1) *physical measures*, which include lake-bottom coverings; 2) *biological measures*, which include the use of organisms, including herbivorous insects; 3) *manual measures*, which involve the manual removal of plants by individuals; 4) *mechanical measures*, which include simple cutting machines combined with hand-removal of cut plant material, harvesting with a machine that both cuts plants and collects the cuttings, or suction harvesting (described below); and 5) *chemical measures*, which include the use of aquatic herbicides to kill nuisance and nonnative aquatic plants. All of these control measures are stringently regulated. Additionally, most of the alternatives require a State of Wisconsin permit. Chemical controls, for example, require a permit and are regulated under Chapter NR 107 of the *Wisconsin Administrative Code*, while placement of bottom covers, a physical measure, requires a Wisconsin Department of Natural Resources (WDNR) permit under Chapter 30 of the *Wisconsin Statutes*. All other aquatic plant management practices are regulated under Chapter NR 109 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, NR 107, and NR 109 of the *Wisconsin Administrative Code*. Further, the alternative aquatic plant management measures are consistent with the requirements of Chapter NR 7 of the *Wisconsin Administrative Code* and with the public recreational boating access requirements relating to eligibility under the State cost-share grant programs set forth in Chapter NR 1 of the *Wisconsin Administrative Code*.

Physical Measures

Lake-bottom covers and light screens provide limited control of rooted plants by creating a physical barrier that reduces or eliminates sunlight available to plants. 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 success rates. For example, pea gravel, which is usually widely available and relatively inexpensive, is often used as a cover material despite the fact that plants readily recolonize areas where pea gravel is used. Other options include synthetic materials, such as polyethylene, polypropylene, fiberglass, and nylon, all of which can provide relief from rooted plants for several years. These synthetic materials, known as bottom screens or barriers, generally have to be placed and removed annually, as they are susceptible to disturbance by watercraft propellers and to the build-up of gasses from decaying plant biomass trapped under the barriers. In the case of Hooker Lake, the need to encourage native aquatic plant growth while simultaneously controlling the growth of exotic species, often in the same location, suggests that the placement of lake-bottom covers as a method to control for aquatic plant growth is not viable, as it is not consistent with the objective of encouraging native aquatic plant growth.

Biological Measures

Biological controls offer an alternative approach to controlling nuisance plants. Traditional biological control techniques use herbivorous insects to control nuisance plants and have been shown to be successful in some southeastern Wisconsin lakes.[57] However, given that heavy boat traffic is allowed on the Lake (a factor which often limits the efficacy of these programs), Hooker Lake would likely not be a valid candidate for this kind of project, specifically if *Eurhychiopsis lecontei*, an aquatic weevil species, is released for the purpose of controlling EWM. Thus, <u>the use of *Eurhychiopsis lecontei* as a means of aquatic plant management control is not considered a viable option for use on Hooker Lake.</u>

Manual Measures

Manual removal of specific types of vegetation provides a highly selective means of controlling the growth of nuisance aquatic plant species, including EWM. There are two common manual removal methods: raking and hand-pulling.

Raking is conducted in nearshore areas with specially designed rakes. This method provides an opportunity to remove nonnative plants in shallow nearshore areas and also provides a **safe and convenient method for controlling aquatic plants in deeper nearshore waters around piers and docks.** Advantages of using these rakes includes:

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[57]*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.*

1) they are relatively inexpensive (costing between $100 and $150 each); 2) they are easy to use; 3) they produce immediate results; and 4) they immediately remove the plant material from a lake, thereby preventing nutrient release and sedimentation from decomposing plant material. Should Hooker Lake residents decide to implement this method of control, an interested party could acquire a number of these specially designed rakes for use by the riparian owners on a trial basis. Therefore, to manage dense plant growth in areas where other control alternatives are not feasible, raking is considered a viable option.

The second type of manual control—hand-pulling of stems where they occur in isolated stands—provides an alternative means of controlling plants such as EWM. **This method is particularly helpful when attempting to target nonnative plants in the high growth season, when native and nonnative species often coexist.** This method allows for higher selectivity than rakes, mechanical removal, and chemical treatments, and, therefore, results in less loss of native plants. Additionally, the physical removal of the plants also prevents sedimentation and nutrient release, which could help maintain water depths in the Lake and could incrementally help mitigate water quality concerns. Given these advantages, manual removal of EWM through hand-pulling and removal from the Lake is considered a viable option in Hooker Lake where practical. It could be employed by volunteers or homeowners, as long as they are trained to properly identify EWM. If hand removal of plants is contemplated within defined sensitive areas, a permit must be procured from the WDNR before any plants are removed.[58] The WDNR provides abundant guidance materials, including an instructional video, on the manual removal of plants.

Pursuant to Chapter NR 109 of the *Wisconsin Administrative Code*, **both raking and hand-pulling of aquatic plants in a 30 by 100 foot area (30 linear feet along the shoreline, including the "use" area, extending 100 feet out into a lake) is allowed without a WDNR permit, provided that the hand-pulled plant material is removed from the lake. Any other manual removal would require a State permit, unless employed to control designated nonnative invasive species,** such as EWM. In general, State permitting requirements for manual aquatic plant removal call for all hand-pulled material to be removed from the lake.

Mechanical Measures

Traditional Harvesting

Aquatic plants can be harvested mechanically with specialized equipment known as harvesters. This equipment consists of an apparatus that cuts up to a depth of five feet below the water surface and a collection system (e.g., a conveyor and a basket) that picks up the majority of the cut plants. Mechanical harvesting can be a practical and efficient means of controlling sedimentation, as well as plant growth, as it removes the plant biomass, which would otherwise decompose and release nutrients into a lake. Mechanical harvesting is particularly effective for large-scale plant growth problems.

An advantage of mechanical harvesting is that the harvester, when properly operated, typically **leaves enough plant material in a lake to provide shelter for aquatic wildlife and stabilize lake-bottom sediment, something that none of the other aquatic plant management methods accomplish.** Aquatic plant harvesting also has been shown to facilitate the growth of native aquatic plants by allowing light to penetrate to the lakebed. 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 operations may **fragment plants and, thus, unintentionally facilitate the spread of EWM,** which utilizes fragmentation as a means of propagation, particularly in areas where plant roots have been removed. This further emphasizes the need to prevent harvesting that removes the roots of native plants. Harvesting may also disturb bottom sediments in shallow areas, thereby increasing tur

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[58]*Hand pulling of plants in sensitive areas is regulated under Wisconsin Administrative Code Chapter NR 109* Aquatic Plants: Introduction, Manual Removal and Mechanical Control Regulations, *March 2011.*

bidity and resulting in deleterious effects, including smothering fish breeding habitat and nesting sites. Disrupting lake-bottom sediments also could increase the risk of nonnative species recolonization, as these species tend to thrive under disturbed bottom conditions. To this end, **most WDNR-issued permits do not allow deep-cut harvesting in areas having a water depth of less than three feet,**[59] which would limit the utility of this alternative in some areas of Hooker Lake. Nevertheless, if done correctly and carefully and accomplished under suitable conditions, harvesting has been shown to be of benefit in maintaining navigation lanes and ultimately reducing the regrowth of nuisance plants while still maintaining native plant communities.

Another disadvantage of harvesting is that some cut **plant fragments can escape the collection system on the harvester.** This side effect occurs fairly frequently on lakes where harvesting is used. Generally, to compensate for this, most harvesting programs include a plant pickup program which includes using the harvester to pick up large amounts of floating plant material, as well as a program to pick up plants from lakefront property owners who have raked plant debris onto their docks. This kind of program, when completed systematically, can help alleviate the aesthetic consequences of plant debris which can accumulate on the lake shore.

Aquatic plant harvesters are commonly fairly large and are difficult to operate in shallow near shore areas containing numerous obstacles such as piers and rafts. However, smaller harvesters are now available, which make near-shore harvesting a practical option. These harvesters are designed to enable operation in shallow water, are shorter and narrower, and have stern mounted propulsion.[60] Small harvesters allow near-shore vegetation to be controlled, and are a practical alternative for Hooker Lake.

Given the costs of a harvesting program, residents of the HLMD would need to demonstrate a strong commitment to this approach of aquatic plant management. If the Lake community were willing to undergo the expense, harvesting could be considered a viable option for Hooker Lake. However, if this program is selected, plant collection programs to prevent nuisance amounts of aquatic plant fragment accumulation and a training program for all operators must be employed.[61]

Cutting

Smaller versions of weed harvesting machines (weed cutters) typically do not have means to retrieve plant cuttings from the water like larger harvesters. As a result, cut plants are generally left to be removed by hand raking – a labor intensive job. Although some cutters have been equipped with a basket arrangement to facilitate cut plant retrieval, the use of weed cutters is better suited to small areas in shallower water, such as around piers. Therefore, weed cutters are not considered a viable option for Hooker Lake.

Suction Harvesting

An emerging harvesting method called Diver Assisted Suction Harvesting (DASH) is now available in Wisconsin. First permitted in Wisconsin in 2014, DASH, also known as suction harvesting, is a mechanical process where divers identify and pull out aquatic plants by their roots at the bottom of the lake and then insert the entire plant into

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[59]*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.*

[60]*An example of a small harvester is the Aquarius Systems FB-120 series skimmer/harvester. Reference to this product is not an endorsement, but rather gives the reader the ability to locate information to better envision such equipment.*

[61]*WDNR staff can host training sessions to ensure that all harvester operators are aware of the terms of a harvesting permit.*

a suction device which transports the plant to the surface for disposal. The process is essentially a more efficient method for hand-pulling plants. However, such a labor–intensive operation by skilled professional divers is, at present, a costly undertaking and long-term evaluations will need to take place to determine the efficacy of the technique. However, many technical advantages appear to be related to the method when performed in small, isolated spots, including: 1) **lower possibility of plant fragmentation** compared to harvesting and traditional hand-pulling, thereby reducing regrowth of invasive plants like EWM; 2) **increased selectivity of plant removal** compared to harvesting with a harvester, thereby reducing the loss of native plants, and 3) **lower frequency of fish habitat disturbances.** Despite these advantages, considering of the size of area needing treatment and the cost associated with this type of management, DASH is not presently considered a viable option for the HLMD to employ for large-scale application at Hooker Lake.

Even though DASH may not be a practical option for the HLMD to employ to control nuisance aquatic plants over large areas, it may be a convenient and practical method for individual landowners or groups of landowners to privately contract to control nuisance plants in critical areas. For example, this technique may be attractive to employ in portions of the Lake adjacent to their own piers and swimming areas. Although such work would be conducted at the landowners' expense, it may allow certain landowners to be more satisfied with the appearance and usability of their own Lake frontage.

Both mechanical harvesting and suction harvesting are regulated by WDNR and require a permit. Non-compliance with the permit requirements is legally enforceable with a fine or permit revocation. The information and recommendations provided in this report will help meet the requirements for these permits, which can be granted for up to a five-year period.[62] At the end of that period, a new plant management plan will need to be developed to determine the success of the management technique. This updated plan should be based on a new aquatic plant survey and should evaluate the harvesting activities that occurred in the Lake during the harvesting period.[63] Operation is overseen by the WDNR aquatic invasive species coordinator for the region.[64]

Chemical Measures

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

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 negative (acute) effects on humans and wildlife. Additionally, some studies also determine the long-term negative (chronic) effects of the chemical on animals (e.g., the effects of being exposed to these herbicides for long periods of time). However, it is often impossible to conclu

[62]*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.*

[63]*Aquatic plant harvesters must report harvesting activities as a part of the permit requirements.*

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

sively state that there will be no a long-term effects due to the constraints of animal testing, time, and other issues. Additionally, long-term studies have not been completed on all of the potentially affected species[65] and there are conflicting studies/opinions regarding the role of the chemical 2,4-D as a carcinogen in humans.[66] Please see Appendix H for further facts on 2,4-D. For some lake property owners, the risk of using this chemical may, therefore, be considered too great, despite the legality of use. Consequently, the concerns of lakefront owners should be taken into consideration whenever chemicals are used. Additionally, if chemicals are used, they should be used as early in the season as possible to allow sufficient time for them to decompose before swimmers and other lake users actively utilize the lake in the summer.[67]

Figure 36

NUISANCE ALGAE IN HOOKER LAKE: 2015

Source: Hooker Lake Resident and SEWRPC.

2. **A risk of increased algal blooms due to the eradication of macrophyte competitors**—Nutrients in lake water promotes plant and algae growth. Generally, if rooted plants are not the primary user of nutrients, algae has a tendency to increase in abundance, decreasing water clarity. Therefore native plants must be preserved whenever and wherever pracitcal, and excessive use of chemicals must therefore be avoided; particularly if fish populations are to be maintained at a healthy level (fish require aquatic plants for food, shelter, and oxygen). Further details on this topic are discussed in the "Cyanoboctena and Floating Algae" section of this chapter. Residents reported that 2015 was a particularly bad year for algae in Hooker Lake with algal blooms and filamentous algae (see Figure 36) presenting many problems for boaters and others recreating on the Lake. In view of the decline in the number of aquatic plant species from 20 species observed in 2008 to only ten species observed in 2014, the abundance of algae in 2015 is not a particular surprise. A balance between the rooted plants and algae must be promoted. When one of the two declines, the other increases in abundance. This may be the case in Hooker Lake in 2015 when fewer rooted aquatic plants resulting in increased algal abundance. Subsequent surveys, observations, and analyses will be needed to evaluate this potential linkage.

3. **A potential increase in organic sediments, as well as associated anoxic conditions that can cause fish kills**—When chemicals are used on 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 sediment. Additionally, this process can also lead to a loss of oxygen in the deep areas of a lake as bacteria use oxygen to decompose plant remains (particularly in stratified lakes like Hooker Lake). Extensive loss of oxygen can create conditions that inhibit a lake's ability to support fish, causing fish kills. This process emphasizes the need to limit chemical control to early spring, when EWM has yet to form dense mats.

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

[66]*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.*

[67]*Though the labels allow swimming in 2,4-D-treated lakes 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.*

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 inappropriate chemical application, fish and wildlife populations often suffer. Additionally, native plants may be replaced by more aggressive non-native nuisance plants. It should be noted that navigational treatments for Eurasian water milfoil can greatly diminish white water crowfoot and bladderwort populations, and shoreline treatments for algae can eliminate muskgrass. Consequently, great care and prudence must be exercised when electing to apply aquatic herbicides. In general, other aquatic plant control measures have less long-term potential to harm native plant communities, and should therefore be favored over chemical measures. Nevertheless, if chemical application is truly needed to combat aggressive nuisance populations of EWM, only chemicals that specifically target EWM should be used, and these should be applied in the early spring when native plants have not yet emerged.

5. **A need for repeated treatments due to existing seed banks and/or plant fragments**—Chemical treatment is not a one-time solution. The fact that the plants are not specifically removed from the lake increases the possibility for seeds/fragments to remain in a lake after treatment, thereby allowing for a resurgence of the species. Additionally, leaving large areas void of plants (both native and invasive) creates an area of disturbance (i.e., an area without an established plant community) which tends to be where EMW thrives. In short, chemically treating large areas can sometimes leave opportunities for reinfestation. Consequently, repeated chemical treatment would likely be needed.

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. Subsequently, further research on the efficacy and impacts of herbicides on hybrid water milfoil is needed to better understand appropriate dosing.

Certain factors complicate application of chemicals to lakes, namely the coincidence of EWM with native species, the physical similarities between Northern (native) and EWM, and the presence of hybrid Eurasian water milfoil (HWM). However, **due to EWM's tendency to grow very early in the season, early spring chemical treatment is an effective way to target the non-native plant while minimizing impact on native plants.** Early spring treatments have the advantage of being more effective due to the colder water temperatures, which enhance the herbicidal effects and reduce the concentrations needed. As discussed above, early spring treatment also reduces human exposure (swimming is not particularly popular in very early spring) and limit the potential for collateral damage to native species.

Another factor to consider is the way a lake has reacted to chemicals that were applied previously (see Table 16). Chemical controls have been documented since 1979 and have been fairly consistent for macrophyte treatment since 1990. Although there are no obvious correlations between aquatic plant surveys and chemical treatment applications, chemical treatment is likely a significant factor in the changes seen between 2008 and 2014 aquatic plant surveys.

According to WDNR staff, if chemicals are used to control EWM, low volumes of chemicals should be used over the entire Lake in the *early spring* (i.e., a whole lake treatment). Spot treatments are known to be less effective and more detrimental to native plant communities. However, the WDNR generally will not approve whole-lake chemical herbicide treatments without evidence of a significant infestation of EWM. To document the degree of infestation, a recent comprehensive, complete point-intercept survey is required and EWM amounts, as measured at each sampling site by rake fullness, need to average between two and three on the rake fullness scale (see Appendix F for schematic of rake fullness) in 35 to 75 percent of vegetated sampling sites.[68] The WDNR will also likely require

[68]*As per personal communication with Craig Helker and Heidi Bunk, WDNR.*

Table 16

HISTORICAL CHEMICAL TREATMENT ON HOOKER LAKE

Year	Algae Control			Macrophyte Control					
	Cutrine Plus (gallons)	Copper Sulfate (pounds)	Copper Ethanolamine (gallons)	2,4-D (gallons)	AM40-Amine Salt (gallons)	Diquat (gallons)	Habitat (Pints)	Triclopyr (quarts)	Endothall/ Aquathol (gallons)
1979	- -	- -	- -	35.0	- -	- -	- -	- -	- -
1990	6.0	- -	- -	37.0	- -	- -	- -	- -	- -
1992	12.5	- -	- -	40.0	- -	8.0	- -	- -	5.0
1993	- -	- -	- -	10.0	- -	- -	- -	- -	- -
1994	- -	- -	- -	82.5	- -	- -	- -	- -	- -
1995	- -	- -	- -	71.5	- -	- -	- -	- -	- -
1996	- -	- -	- -	45.0	- -	- -	- -	- -	- -
1997	- -	- -	- -	500 lbs.	- -	- -	- -	- -	- -
1998	- -	- -	- -	12.0 + 1,200 lbs.	- -	- -	- -	- -	- -
1999	- -	- -	- -	1,200 lbs.	- -	- -	- -	- -	- -
2000	- -	- -	- -	156.0	- -	- -	- -	- -	- -
2002	- -	- -	- -	781 lbs.	- -	- -	- -	- -	- -
2003	- -	- -	- -	515 lbs.	- -	- -	- -	- -	- -
2004	- -	- -	- -	1,600 lbs.	- -	- -	- -	- -	- -
2005	- -	- -	- -	650 lbs.	- -	- -	- -	- -	- -
2006	- -	- -	- -	910 lbs.	- -	- -	- -	- -	- -
2007	- -	- -	- -	1,115 lbs.	- -	- -	- -	- -	- -
2008	- -	5	- -	500 + 215 lbs.	- -	- -	- -	- -	- -
2011	- -	- -	- -	- -	49.5 +3	- -	1	- -	38 lbs.
2013	- -	- -	- -	259.5	- -	- -	- -	- -	1.5
2014	- -	- -	- -	180.5	- -	0.14	- -	0.28	120
2015	- -	- -	1	- -	- -	0.89	- -	3.56	- -
Total	18.5	5	1	917, 9,198 lbs.	52.5	9.03	1	3.84	126.5, 38 lbs.

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

Source: Wisconsin Department of Natural Resources and SEWRPC.

a treatment efficacy test to evaluate dosage and the sensitivity of the target plants to the proposed chemical mix. The 2014 point-intercept survey of Hooker Lake (the most recent available) found EWM at about 20 percent of the vegetated sampling sites and had a rake fullness average of 1.2 (see Table 15). Considering that the EWM population in Hooker Lake does not appear to satisfy the WDNR abundance requirements for whole-lake treatments, the apparent fragile nature of the native plant population in Hooker Lake, the lack of success of EWM spot treatments, and the probable need of a chemical efficacy test, a whole-lake chemical treatment for EWM does not appear to be a viable option in the immediate future.

Other Aquatic Plant Management Issues of Concern

The recommendations in this section call for monitoring and controlling aquatic plants that already grow in the Lake. However, many other activities contribute to *inhibiting or preventing* nuisance aquatic plant growth in the Lake (which helps avoid the adverse effects that result from many in-lake control alternatives). A number of factors create a lake environment conducive to “excessive” plant growth, both in terms of EWM and native plants. For example, poor water quality with high phosphorous content (which can be caused by polluted surface water runoff entering the Lake) provides the building blocks that all plants need to thrive and eventually reach what is perceived as a nuisance level. Consequently, implementing recommendations to improve water quality should to be an integral part of any comprehensive aquatic plant management plan. This is why many of the issues of concern discussed in the Water Quality section of this chapter are also considered priorities and why recommendations related to these factors are included in Chapter III of this report.

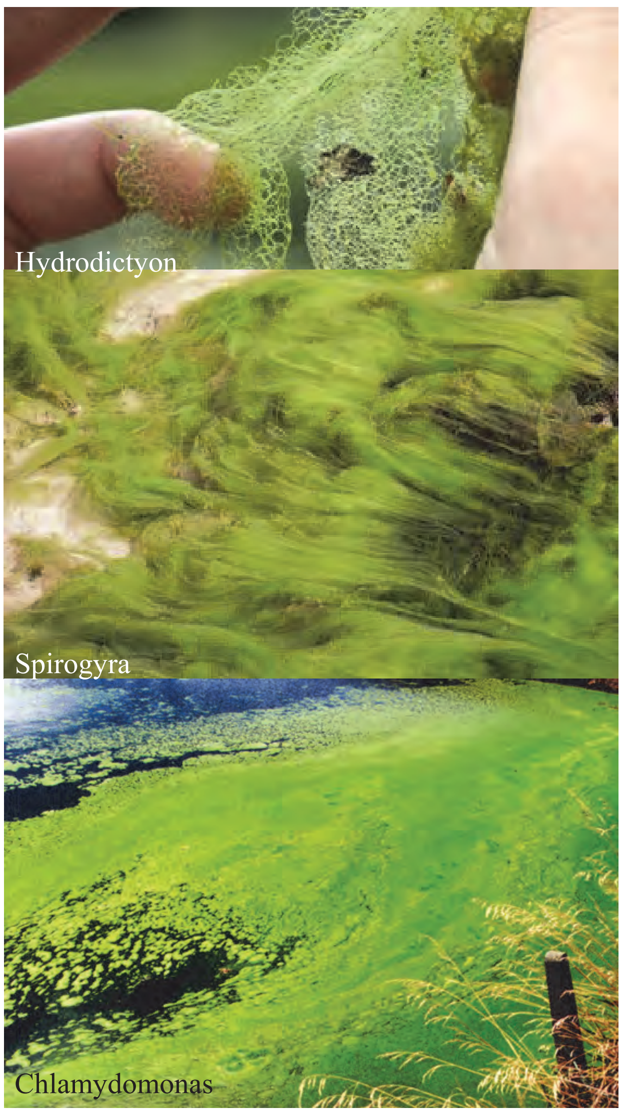
ISSUE 5: CYANOBACTERIA AND FLOATING ALGAE

Cyanobacteria and floating algae are ongoing issues of concern for Hooker Lake residents and users because periodic, relatively minor algal blooms have occurred in the spring and summer. As was discussed in earlier sections, Lake residents report that 2015 was a particularly bad year for algae in Hooker Lake with algae blooms and filamentous algae presenting many problems for boaters and others engaged in recreation on the Lake (Figure 36).

Before discussing excessive algae growth and management, it is important to note that the presence of **algae is generally a healthy component of any aquatic ecosystem.** Algae are primary building blocks of a lake food chain, and it can produce oxygen in the same way as rooted plants. Many forms of algae exist, from filamentous algae to cyanobacteria (formerly blue-green algae; see Figure 37). The majority of algae strains are beneficial to lakes in moderation. However, the presence of toxic strains (see Figure 38) as well as excessive growth patterns should be considered an issue of concern. As with aquatic plants, algae generally grow at faster rates in the presence of abundant dissolved phosphorus (particular-

Figure 37

DIFFERENT TYPES OF NON-TOXIC ALGAE



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

Figure 38

EXAMPLES OF TOXIC ALGAE

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

ly in stagnant areas). Consequently, when toxic or high volumes of algae begin to grow in a lake, it often indicates a problem with phosphorus enrichment/pollution.

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

1. **Manage water quality with a focus on phosphorus reduction**—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, diverse and active native aquatic plant community**—As mentioned in the "Aquatic Plant Growth" section of this chapter, maintaining a diverse, healthy, robust native plant community is tied to prevention of excessive algal blooms because aquatic plants and algae directly compete for phosphorus which inhibits either from dominating the lake. Consequently, careful implementation of the Aquatic Plant Management recommendations provided in Chapter III and communicating this nutrient-algae/plant growth relationship to residents (to encourage conservative hand-pulling of rooted vegetation) should be considered a priority.

In addition to these approaches, in-lake measures and manual removal methods could also be implemented including:

1. **Alum treatments** involve spreading a chemical (alum: hydrated potassium aluminum sulfate) over the surface of the lake. This chemical precipitates as a solid and carries algae and other solids to the bottom of the lake. Alum treatments can reduce phosphorus concentrations in the water column inhibiting regrowth of excess plants or algae. Nevertheless, this is a temporary solution and is often cost prohibitive. However, if algae become excessive, this method could be considered.

2. **Aeration** involves pumping air to a diffuser on the bottom of a lake that creates a rising column of small air bubbles. The rising bubbles create an upwelling current of lake water which circulates the water, preventing stratification and the accompanying anoxic conditions in deep water areas. This prevents internal loading (i.e., the release of phosphorus from deep sediments under anoxic conditions) and reduces the occurrence of algae blooms during the mixing (turnover) periods. This method is only necessary if internal loading is excessive. If poorly executed, aeration can exacerbate algal blooms.

3. **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.

All of the above measures are generally only implemented when algal blooms become so serious and long lasting that recreational use is impaired. This is often because each method is only temporarily effective, and repeated implementation of these measures can be cost prohibitive. Since Hooker Lake has had only relatively minor issues with algal blooms in the past, these methods are not recommended at this time. <u>The more permanent methods of algal control discussed above (i.e., pollution control and plant community maintenance) are considered most viable for Hooker Lake.</u>

As a final note about algae, though management for algae prevention is crucial, 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* measurements, which quantify the concentration of suspended algae levels in the water column (i.e., the green color in water). The second is to collect algae samples to determine whether the algae species actually present are non-toxic. Neither of these monitoring efforts has occurred on Hooker Lake; however, if blooms become excessive and/or very common, monitoring should be considered.

ISSUE 6: RECREATIONAL USE AND FACILITIES

Essentially all Lake residents and users want to ensure that Hooker Lake continues to support conditions favoring recreation and, relatedly, property value. Therefore, maintaining or enhancing the Lake's ability to sustain recreational use is a primary driving force behind essentially all issues of concern. Many of the topics discussed in this report (e.g., aquatic plants, water quality, algal blooms, water quantity, and wildlife) are related because each one can affect various recreational uses.

Table 17

RECREATIONAL WATER CRAFT DOCKED ON HOOKER LAKE: Wednesday, July 30, 2014

Category	Observation	Docked Boats
Type of Watercraft	Power/ski boat	23
	Pontoon boat	27
	Fishing boat	10
	Personal watercraft	9
	Kayak	10
	Canoe	12
	Rowboat	14
	Sailboat	0
	Wind board/paddle board	2
	Paddleboat (pedalboat)	12
	Rafts	4
Total		123

Source: SEWRPC.

Boating

SEWRPC staff counted the number and type of watercraft docked on Hooker Lake during July 2014 (Table 17) and counted boats on the water during 2012 (Tables 18 and 19). These numbers provide insight into the intensity of watercraft use as well as the type of activities in which watercraft engage. From the 2012 data, it appears that weekday boat traffic is quite limited. The maximum number of boats on the water occurred during late morning and evenings, when four boats were counted. In contrast, many more boats were found to be actively in use on the Lake during weekends, when up to seven boats were on the water. Fishing was far and away the most popular boat use during weekdays, particularly throughout the morning and early afternoon. During weekends, fishing remains the most popular boating activity through mid-morning, but cruising/water skiing are more popular than fishing later in the day. Very little other boating activity was noted on Hooker Lake.

The type and intensity of boating taking place varies by the day of the week, time of day, season, and prevailing weather conditions. According to a statewide survey that subdivided results by region,[69] 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 (Table 20). These three months account for approximately two-thirds of the total number of boater-days logged in the Region for the entire year. About three to four times as many boaters use their boats on weekends than weekdays (Table 21). The weekday/weekend statistics compares favorably with SEWRPC 2012 Hooker 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 Hooker 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 22 and 23). Sailboats comprise approximately 24 percent of boat traffic (15 percent non-powered and 9 percent non-powered), while other nonpowered boats comprise only two percent of boats found on waterbodies in the region.

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[69]*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.*

Table 18

ACTIVE RECREATIONAL WATERCRAFT AND RELATED ACTIVITIES ON HOOKER LAKE—WEEKDAYS: SUMMER 2012

Category	Observation	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.	
		Wednesday June 20	Thursday June 28	Thursday June 21	Tuesday June 19	Tuesday June 26	Wednesday July 27	Friday July 27	Thursday August 30	Tuesday June 26	Wednesday June 27	Friday July 31	Wednesday August 15
Type of Watercraft (number in use)	Power/ski boat	0	0	0	0	0	1	0	0	1	1	1	1
	Pontoon boat	0	0	0	0	0	0	0	0	0	0	0	0
	Fishing boat	1	1	2	2	4	2	1	0	2	0	0	2
	Personal watercraft	0	0	0	0	0	0	0	0	0	0	0	0
	Kayak/canoe	0	0	0	0	0	0	0	0	0	0	0	1
	Rowboat	0	0	0	0	0	0	0	0	0	0	0	0
	Sailboat	0	0	0	0	0	0	0	0	0	0	0	0
	Wind board/paddle board	0	0	0	0	0	0	0	0	0	0	0	0
	Paddleboat (pedalboat)	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0
Activity of Watercraft (number engaged)	Motorized cruise/pleasure												
	Low speed	0	0	0	0	0	0	0	0	0	0	0	0
	High speed	0	0	0	0	0	0	0	0	0	0	0	0
	Fishing	1	1	2	2	4	2	1	0	2	0	0	2
	Skiing/tubing	0	0	0	0	0	1	0	0	1	1	1	1
	Sailing/windsurfing	0	0	0	0	0	0	0	0	0	0	0	0
	Rowing/paddling/pedaling	0	0	0	0	0	0	0	0	0	0	0	1
	Other	0	0	0	0	0	0	0	0	0	0	0	0
Total	On water	1	1	2	2	4	3	1	0	3	1	1	4
	In high-speed use	0	0	0	0	0	1	0	0	1	1	1	1

NOTE: Shaded columns denotes local no-wake ordinance in effect from 6:00 p.m. to 10:00 a.m. on Hooker Lake.

Source: SEWRPC.

Table 19

ACTIVE RECREATIONAL WATERCRAFT AND RELATED ACTIVITIES ON HOOKER LAKE—WEEKENDS: SUMMER 2012

		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	Saturday July 21	Saturday August 11	Saturday August 25	Sunday August 19	Saturday August 25	Labor Day September 3	Saturday July 21	Saturday August 11
Type of Watercraft (number in use)	Power/ski boat	0	0	2	1	3	1	3	2
	Pontoon boat	0	0	1	1	3	1	2	2
	Fishing boat	4	6	2	0	0	1	2	1
	Personal watercraft	0	0	0	0	0	0	0	0
	Kayak/canoe	0	0	0	0	0	0	0	0
	Rowboat	0	0	0	0	0	0	0	0
	Sailboat	0	0	0	0	0	0	0	0
	Wind board/paddle board	0	0	1	0	0	0	0	0
	Paddleboat (pedalboat)	0	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0
Activity of Watercraft (number engaged)	Motorized cruise/pleasure								
	Low speed	0	0	1	1	3	0	2	1
	High speed	0	0	0	0	0	1	0	1
	Fishing	4	6	1	0	0	1	2	2
	Skiing/tubing	0	0	2	0	3	0	3	1
	Sailing/windsurfing	0	0	0	0	0	0	0	0
	Rowing/paddling/pedaling	0	0	1	0	0	0	0	0
	Other	0	0	1	1	0	1	0	0
Total	On water	4	6	6	2	6	3	7	5
	In high-speed use	0	0	2	0	3	1	3	2

NOTE: Shaded columns denotes local no-wake ordinance in effect from 6:00 p.m. to 10:00 a.m. on Hooker Lake.

Source: SEWRPC.

Table 20

BOATING ACTIVITY IN SOUTHEASTERN WISCONSIN 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]Repondents may have participated in more than one activity.

Source: Wisconsin Department of Natural Resources.

Table 21

DAILY DISTRIBUTION OF BOATING IN SOUTHEASTERN WISCONSIN BY MONTH: 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.

Table 22

HULL TYPES IN SOUTHEASTERN WISCONSIN BY MONTH: 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.

Only a few respondents to the WDNR boating survey felt that excessive boat traffic was present on Southeastern Wisconsin lakes.[70] 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[71] provides a reasonable and conservative average maximum desirable boating density,** and covers a wide variety of boat types, recreational uses, and lake characteristics.[72] **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:

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

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[70]*Ibid.*

[71]*"Useable lake area" is the size of the open water area that is at least 100 feet from the shoreline. However, local ordinances require slow/no-wake operation within 200 feet of the shoreline, further reducing useable lake area.*

[72]*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 23

PROPULSION TYPES IN SOUTHEASTERN WISCONSIN BY MONTH: 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.

The 2012 SEWRPC boat count demonstrates that highest boat use occurs during weekends. Most boats in use during peak periods were capable of high-speed operation; however, less than half were actually being operated at high speed. If one assumes that half of the boats could potentially be operating at high speed during the day, the formula presented above suggests that 12.5 or more acres of useable open water should be available per boat. Given that roughly 60 useable acres are available for boating on Hooker Lake (using a 200 foot slow no wake shore zone), no more than four boats should be present on the lake at any one time to avoid use problems. If the more liberal 100 foot standard is used, the useable lake area increases to 80 acres, suggesting that no more than six boats should be on the lake at any one time to avoid use problems. During weekdays, the density of boats actually observed on Hooker Lake does not exceed suggested maximum boat densities. However, boat density appears to slightly exceed maximum densities during heavy use periods (weekends and holidays). This means that **the potential for use conflicts, safety concerns, and environmental degradation is slightly higher than desirable on Hooker Lake during peak use periods.** 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.

One-hundred twenty-three watercraft were observed moored or on the shore around the Lake on July 30, 2014 (Table 17). Over half of all docked or moored boats were motorized, with fishing boats and pontoon boats comprising just over half the motorized boat total. Paddleboats and canoes are the most popular types of non-motorized watercraft. The total number of boats present around the Lake suggests that between two and six boats will be in active use on the Lake during peak use periods.[73]

Three boat launches provide public boating access to Hooker Lake. A paved single single-lane boat ramp operated by the Village of Paddock Lake is located at the extreme north end of the Lake. The boat launch is accessed by 78th Street. Dedicated parking for 6 to 10 vehicle/trailer combinations is available, handicap-accessible features and a boarding pier are available at this site, and portable restroom facilities are present. The Town of Salem operates the other two boat launches. A single-lane gravel boat launch is found on the east side of Hooker Lake at the terminus of 80th Street. This launch does not include dedicated parking or other supporting facilities. The other Town of Salem boat launch is found on the extreme west end of the Lake at the terminus of 83rd Street. Little additional information is presently available regarding this boat launch; however, aerial photographs suggest that it is a single lane gravel ramp with no supporting facilities.

The Village of Paddock Lake charges a fee to park at the Village boat launch between May 1 and October 31. A seasonal pass can be purchased for $35.00 (Wisconsin resident)/$40.00 (non-resident), or a daily parking pass may be purchased for $7.00. A seasonal pass allowing parking at both the Paddock Lake and Hooker Lake boat launches is available for $45.00 (Wisconsin resident)/$55.00 (non-resident). The Town of Salem does not charge a fee for use of its boat launches.

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[73]*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.*

Given what is known about the Village of Paddock Lake launch site, **boat launch facilities and daily fees appear to conform to the minimum requirements set forth in Chapter NR 1 of the *Wisconsin Administrative Code*.** Compliance with this section is important, since certain grant and assistance funding is predicated by compliance with Chapter NR 1. It appears that daily launch fees could be increased by at least $1.00.[74] 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.

Other Recreational Pursuits

Hooker Lake supports, or has the potential to support, a wide range of recreation beyond boating. The Lake is generally supportive of all common lake-based recreational activities. However, as pointed out in previous sections, some activities could be more fully realized through focused management. Some of the recreational activities supported by Hooker Lake are wholly reliant upon the presence of the Lake and shoreline areas. These activities include (but are not limited to) swimming, ice and open-water fishing (see "Issue 7: Fish and Wildlife" below for more detail regarding fish populations), ice skating, winter motorsports upon the ice, waterfowl hunting, and trapping. Local aesthetic appeal, property value, and many other recreational activities (e.g., nature study, bird and wildlife viewing, hunting, general outdoor relaxation) benefit from the presence of the Lake. While many recreational activities are relatively passive, intense active use (e.g., excessively heavy fishing pressure, motorsport racing on the ice, high speed boating) and/or out-of-place use (e.g., swimming in high-speed boating areas, high-speed boating near shorelines or shallow areas) can create use conflicts and compromise the overall recreational value of the Lake. The Village of Paddock Lake and the Town of Salem developed ordinances and regulations to regulate such issues (see Appendix I for copies of the lake use ordinances). <u>Relevant ordinances should be reviewed on a regular basis, amended to address current concerns, and conscientiously enforced.</u>

Hooker Lake's non-boating recreational benefits extend beyond the riparian community. The three boat launches provide access to the Lake. No swimming and very little practical access to shoreline fishing is available given the Lake's configuration and the locations of the boat launches. The State of Wisconsin owns approximately 42 acres of the marshland area located along the Lake's northwestern shoreline. This parcel is named the Hooker Lake Marsh Fishery Area. Its presence helps assure that the sensitive, large, and vital habitat area is protected into perpetuity. Hooker Lake Marsh Fishery Area abuts nearly 150 acres of publically-owned school property. Much of the school property remains undeveloped wetland and woodland. This property could be stewarded to protect natural resource functions that benefit the Lake, the adjacent state land, and which can serve as a vital component to conservation efforts. <u>The combined publically owned natural areas constitute the largest expanse and most diverse habitat area in the entire Hooker Lake watershed and form an ideal long-term conservation opportunity.</u>

ISSUE 7: SHORELINE MAINTENANCE

Many Hooker Lake shoreline property owners are concerned about maintaining the Lake's shorelines and the recreational and aesthetic use/appeal of the Lake without jeopardizing its health. This issue of concern is further emphasized by the fact that water quality, sedimentation, and aquatic plant growth can all be affected by shoreline maintenance practices.

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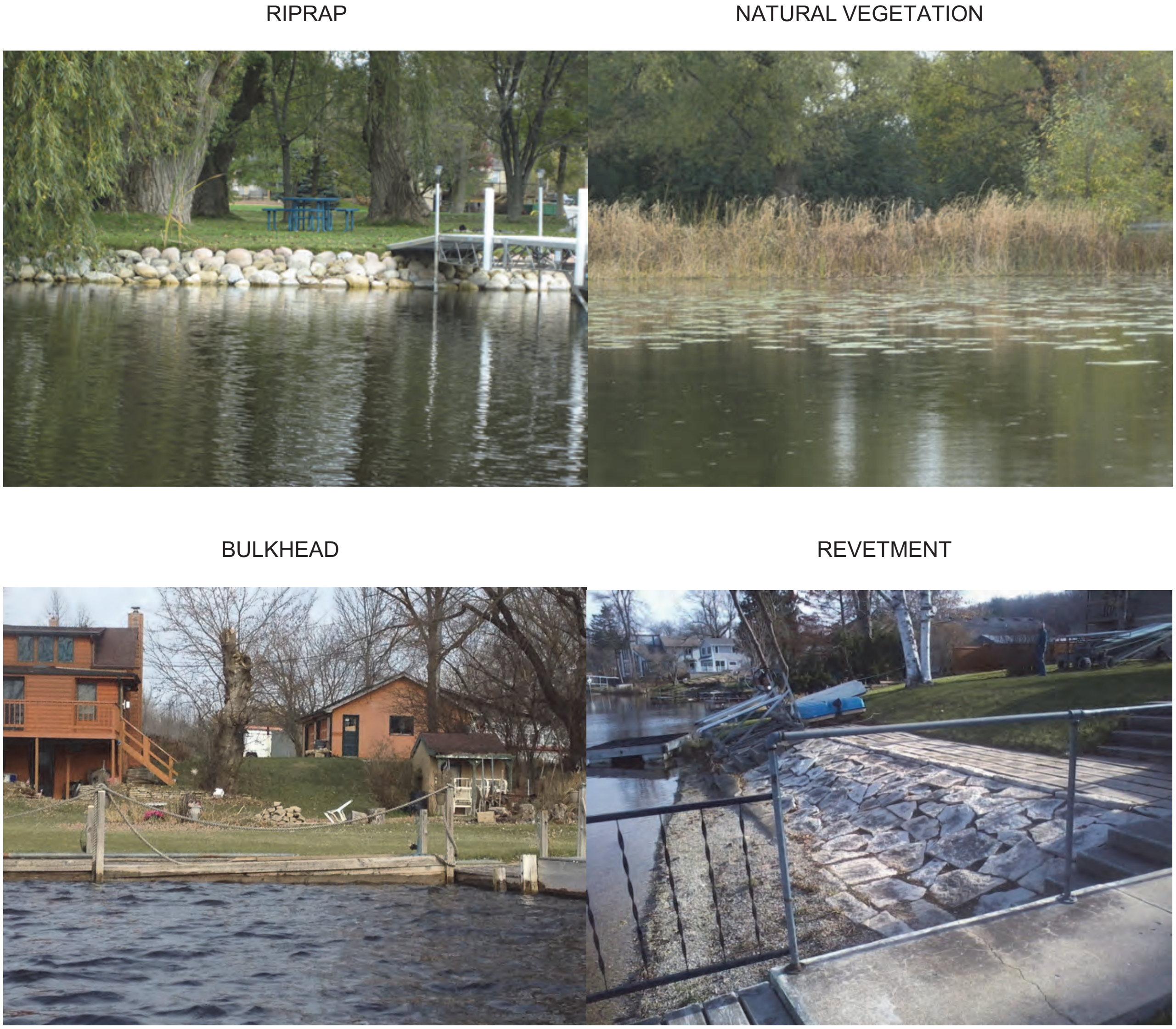
[74]*NR 1.91(11)a encourages free boat launching but allows a maximum one-day base fee equivalent to the one-day fee for residents to enter state parks ($8.00 at the time of this report). NR1.91(11)b allows additional surcharges based upon the presence of an attendant (20 percent base fee surcharge), the size of boats served (30 percent base fee surcharge for boats between 20 and 26 feet in length and 60 percent base fee surcharge for boats greater than 26 feet in length), and the presence of on-site toilet facilities (20 percent base fee surcharge).*

Figure 39

TYPICAL SHORELINE PROTECTION TECHNIQUES



Source: SEWRPC.

Before discussing shoreline maintenance in Hooker Lake, it is important to understand the difference between two terms: *shoreline protection and buffers. Shoreline protection* encompasses those various measures—artificial or natural—that shield the immediate shoreline (water-land interface) against the erosive forces of wave action; buffers are those areas of plant growth—human-induced 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 options exist for home owners. These options (see Figure 39), include: "bulkheads," where a solid, *vertical* wall of some material, such as poured concrete, steel, or timber, is erected; "revetments," where a solid, *sloping* wall, usually asphalt, as in the case of a roadway, or poured concrete, is used; and "riprap," where loose stone material is placed along the shoreline. All of the structures listed above require permits from WDNR.

It must be emphasized that **shoreline protection does not always need to rely on construction of engineered structures.** Many different kinds of natural shorelines offer substantial protection against erosive forces. The rock boulders and cliffs found along Lake Superior, for example, are natural barriers that serve to protect against shoreline erosion. Additionally, marshlands, such as those found in Hooker Lake Marsh and in the WDNR Sensitive Area at the southeast end of Hooker Lake, and areas of exposed cattail stalks and lily pads, such as those found around the Lake's shoreline, are effective mitigators of shoreline erosive forces, as the exposed plant stalks act to disperse and dampen waves by dissipating energy. (See the "Aquatic vegetative buffers" section earlier in this report.)

"Hard" artificially armored shoreline constructed of stone, riprap, concrete, timbers, and steel, once considered "state-of-the-art" in shoreline protection, are now recognized as only part of the solution in protecting and restoring 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 can increase wave energy in other portions of a lake since the wave energy is refracted back into the lake. More recently, "soft" shoreline protection techniques, referred to as "vegetative shoreline protection" (see Figure 40), involving a combination of materials, including native plantings, are increasingly required pursuant to Chapter NR 328 of the *Wisconsin Administrative Code*. Vegetative shoreline protection is becoming more popular as people living along lakes and streams have become aware of the value of protecting their shorelines, improving the viewshed, and providing natural habitat for wildlife. Additionally, **shorelines protected with vegetation help shield the Lake from both land-based and shoreline pollution and sediment deposition.**

Given the benefits of "soft" shoreline protection measures, the WDNR no longer permits construction of "hard" structures in lakes that do not have extensive wave action threatening the shorelines (although repair of existing structures is permitted). Consequently, this plan recommends that shoreline restoration focus on "soft" measures, including native planting, the maintenance of aquatic plants along the shorelines, and the use of "bio-logs" (see Figure 41). Artificial beach areas, which legally need to be made from pea gravel,[75] are considered as a separate category. The placement of pea gravel may be permitted; however, this would have to be evaluated by WDNR on a case-by-case basis.

Shorelines of Hooker Lake

To determine the shoreline restoration and maintenance needs of Hooker Lake, and to develop recommendations related to shoreline maintenance and pollution reduction, SEWRPC staff visited the Lake to assess Lake shoreline conditions during the summers of 2012 and 2014. The results of these surveys are shown on Map 12. As the map indicates, **there were few shoreline buffers along the developed residential properties** (a common condition for lakes in the Region). <u>Educating shoreline property owners regarding the importance of buffers, especially using native plants, to prevent pollution and shoreline erosion should be considered a priority</u>. Additionally, **several areas around the Lake have failing or inadequate shoreline protection and a number of sites exhibited eroded and/or undercut banks.** Given the desire of Lake users to promote long-term Lake health and the need to preserve recreational use and aesthetics of the Lake, <u>it should be considered a priority to repair existing shoreline structures where feasible, and to install "soft" shoreline protection, such as vegetative shoreline protection (i.e., the maintenance of near-shore native plants) whenever and wherever possible.</u>

Further project recommendations for Hooker Lake's shoreline are included in Chapter III of this report.

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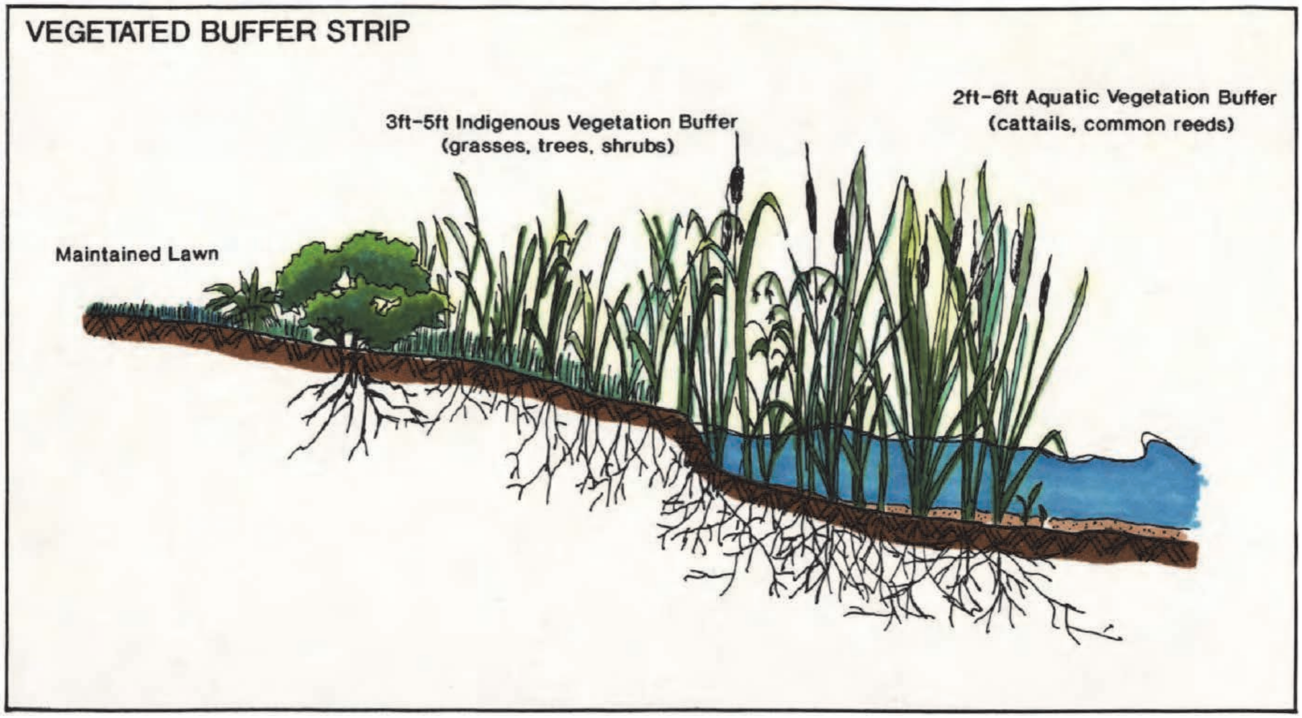
[75]*WDNR does not permit the use of sand because these materials quickly flow into a waterbody and contribute to lake sedimentation.*

Figure 40

NATURAL SHORELINE BUFFER SCHEMATIC AND EXAMPLE



Source: Washington County Planning and Parks Department and SEWRPC.

Figure 41

"SOFT" SHORELINE PROTECTION TECHNIQUES

Natural Shoreline

Bio-logs

Buffers (Vegetative Strips)

Cattails

Source: SEWRPC.

ISSUE 8: FISH AND WILDLIFE

Protecting and enhancing lake-dependent aquatic and terrestrial wildlife populations is an important consideration of any lake protection plan. Based on field work and study of the Lake and its watershed, SEWRPC staff identified the following considerations related to aquatic and terrestrial wildlife:

1. Fishing was identified as an important recreational use of the Lake, as was verified by direct observations by Commission staff in 2012 and 2014 (see Tables 17 through 19);
2. Hooker Lake is reported to contain one critical fish species, the lake chubsucker (*Erimyzon sucetta*), a State Special concern species. Additionally, Salem Branch (the stream extending from Hooker Lake to the Des Plaines River) has been reported to contain State Special concern fish species, the pirate perch (*Aphredoderus sayanus*);

3. The WDNR manages Hooker Lake as a warmwater sport fishery;[76]

4. Two Natural Areas[77] are located within the Lake's watershed;

5. Hooker Lake contains two WDNR-designated Sensitive Areas;

6. About 12 species of amphibians and 13 species of reptiles are expected to be present in the Lake's watershed (amphibians and reptiles, including frogs, toads, salamanders, turtles, and snakes, are vital components of a lake ecosystem);

7. The Lake's watershed likely supports a significant population of waterfowl, including mallards, wood ducks, and blue-winged teal, particularly during the migration seasons; and

8. The Lake's watershed likely supports both small and large mammals, such as foxes and whitetail deer.

WDNR Sensitive Areas
Within or immediately adjacent to bodies of water, the WDNR, pursuant to authorities granted under Chapter 30 of the *Wisconsin Statutes* and Chapter NR 107 of the *Wisconsin Administrative Code*, can designate environmentally sensitive areas that have special biological, historical, geological, ecological, or archaeological significance, offer critical or unique fish and wildlife habitat including seasonal or life-stage requirements, or which offer water quality or erosion control benefits to the body of water.

Hooker Lake was surveyed by WDNR personnel utilizing sensitive area survey protocol in 2001 and again in 2007. As a result of these surveys, it was determined that two areas on Hooker Lake met the criteria for designation as sensitive areas (Map 20). The WDNR Sensitive Area report for Hooker Lake is presented in Appendix J.

WDNR-Designated Sensitive Area 1
Sensitive Area 1, locally known as Hooker Lake Marsh, abuts the northwest shoreline of Hooker Lake, and includes approximately 4,000 feet of lakeshore (see Map 20). About two-thirds of this shoreline is owned by the WDNR. The marshland has an average water depth of about two feet. This area was selected for its good quality wetland plants, its relatively large size, its location adjacent to the large undeveloped upland environmental corridor immediately to the west, and its important habitat for many wildlife species such as hawks, songbirds, waterfowl, and some kinds of reptiles and amphibians. This area also likely provides life-cycle critical spawning, nursery, refuge and feeding areas for several species of fish including northern pike.

Of the 16 native aquatic plant species observed in this area in 2007, the dominant emergent species was cattail and the dominant submerged species was muskgrass. Cattails provide a valuable mechanical barrier to natural wind-wave erosive forces acting against a lake's shoreline. The roots of such plants help stabilize lake-bottom sediment while the dense plant beds reduce the ability of nonnative invasive plant species to invade the Lake.

As part of the management of Sensitive Area 1, the WDNR recommends a variety of measures including maintaining the nearshore "Slow, No Wake" ordinance; minimizing disturbance of the stands of native aquatic vegetation; prohibiting mechanical aquatic plants harvesting; protecting seasonal fish spawning habitat; avoiding chemical

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[76]*SEWRPC Memorandum Report No. 93*, A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995*.

[77]*Natural areas are those tracts of land so little modified by human activity, or which have recovered sufficiently from the effects of such activity, that they contain intact native plant and animal communities believed to be representative of the pre-European-settlement landscape.*

Map 20

WDNR-DESIGNATED SENSITIVE AREAS IN HOOKER LAKE

Source: Wisconsin Department of Natural Resources and SEWRPC.

treatment of EWM in areas adjacent to stands of susceptible aquatic plant species such as bladderwort or northern water milfoil; considering the use of mechanical or chemical treatments for reed canary grass and biological controls for purple loosestrife and milfoil where appropriate; and minimizing disturbance of herbs, trees, and shrubs along the shoreline to maintain wildlife habitat.

WDNR-Designated Sensitive Area 2

The shoreline and littoral zone along the southwest corner of the Lake compose up the bulk of Sensitive Area 2 (see Map 20). This site is approximately 1000 feet in length with an average water depth of about four and a half feet. Although the natural function and aesthetics of this area are disrupted (the shoreland area being comprised of about one-third wetland and two-thirds residential lawn), the site was chosen for the value of its aquatic plants to waterfowl, fish, and some amphibians and reptiles. The dominant submergent plants are coontail, white water crowfoot (*Ranunculus longirostris*), and nonnative EWM. Like Sensitive Area 1, the combination of emergent vegetation such as cattails with the silt/muck bottom substrate provide a high quality spawning habitat for northern pike and other species of fish that utilize aquatic vegetation for nursery, feeding, refuge, and resting sites.

Management recommendations for Sensitive Area 2 are similar to those for Area 1. An additional recommendation includes replacing existing shoreline stabilization practices with bioengineered practices such as vegetative shoreline protection or bio logs, and that buffer strips be installed along highly developed shoreline stretches. As was the case for Sensitive Area 1, protecting the native submergent and floating leaf aquatic plants in Sensitive Area 2 is considered critical to maintaining the fishery in Hooker Lake.

SEWRPC-Designated Natural Areas and Critical Species Habitat

As part of its regional planning program, and as a logical extension of its environmental corridor concept expounded through the regional, county-, and local-level land use plans for southeastern Wisconsin,[78] SEWRPC identified natural areas and critical species habitat areas within the Southeastern Wisconsin Region.[79] These areas reflect the attributes of the landscape that help: 1) protect and preserve the ambience, natural beauty, and biological diversity of southeastern Wisconsin and 2) maintain public health and welfare, support and sustain economic development, and provide continuing choices and opportunities for future generations. Areas identified as critical species habitat and/or natural areas were designated as being of local significance, regional significance, or state/national significance. Two such areas were identified in the Hooker Lake watershed. These areas are:

<u>Hooker Lake Marsh</u>: As described above as Sensitive Area 1, this WDNR-owned, forty-plus-acre, deep and shallow cattail marsh wetland complex is classified as NA-3, identifying it as a natural area of local significance.

<u>Hooker Lake</u>: A drainage lake with good water quality, wildlife habitat and other physical characteristics, classified as AQ-3, identifying it as a lake of local significance.

Aquatic and Terrestrial Habitat

Healthy fish, bird, amphibian, reptile, and mammal populations require: 1) good water quality, 2) sufficient water levels, 3) healthy aquatic plant populations, and 4) access to life-cycle critical habitat, and 5) well preserved or maintained aquatic and terrestrial habitat. Additionally, wildlife populations can also be enhanced by implementing "best management practices." Since aquatic plant management, water quality, and water quantity have been dis

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[78]*See SEWRPC Planning Report No. 7,* The Regional Land Use-Transportation Study, *1965, and subsequent editions; see also Bruce P. Rubin and Gerald H. Emmerich, Jr., "Refining the Delineation of Environmental Corridors in Southeastern Wisconsin," SEWRPC Technical Record, Volume 4, Number 2, March 1981.*

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

cussed previously in this chapter, this section will focus on maintaining and improving habitat conditions, and use of best management practices to enhance wildlife populations. The practices actually employed vary and are influenced by the type of wildlife. Therefore, this section first discusses aquatic wildlife enhancement and then addresses terrestrial wildlife enhancement.

Aquatic Wildlife Enhancement

Aquatic Best Management Practices

Aquatic best management practices can be implemented by landowners, recreationalists, and resource managers. Such activities include catch and release fishing and fish stocking, both of which help enhance a lake's overall 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 size structure of fish in a lake help managers understand issues that might face fish populations. For example, if low numbers of juvenile fish are found, this may indicate that the fish are not successfully reproducing, and, therefore, spawning and nursery, habitat may need to be improved. Similarly, if many juvenile fish are found with few large fish, over-fishing may be a factor limiting the growth of fish, thereby indicating that catch-and-release should be promoted in the lake. This type of information can therefore help lake managers efficiently and effectively refine fish population enhancement efforts.

2. **The history of fish stocking in a lake**—To evaluate fish population studies, it is important to understand how many fish of different sizes have been introduced through stocking. For example, if only large fish exist in a lake, it is possible that little to no natural spawning is taking place, which in turn could mean the lake's fishery is heavily dependent on fish stocking. This may suggest that enhanced or artificial spawning and rearing areas could add value to the lake's fishery.

Hooker Lake has been intermittently stocked by public agencies for over 100 years. For example, casual review of historical documents reveals that 374,000 walleyes and 275 white bass were planted into Hooker Lake during 1898.[80] More recently, the Lake has been stocked with northern pike, largemouth bass, and walleye since 1972 (see Table 24). The WDNR reports that largemouth bass are considered "abundant" in Hooker Lake, while panfish and northern pike are "common."[81] Additionally, a fish survey conducted in 2008 (see Table 25), by electrofishing[82] noted the presence of other fish in the Lake, including black crappie, warmouth, lake chubsucker, common carp, smallmouth bass, yellow bullhead, and bowfin. The WDNR plans to complete fish surveys in the fall of 2017 and spring 2018.

Overall, WDNR concludes that **Hooker Lake has a largemouth bass and panfish population with below average size.** In regards to the panfish population, this may be the result of high angler harvest concentrated on the biggest fish. As regards the bass population, the WDNR feels that having a top predator such as northern pike that can cull some of the smaller bass may result in improving both the size structure of the bass population as well as

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

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

[82]*Electrofishing is a process where an electrical pulse is placed in the water, causing fish to be temporarily stunned and 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.*

Table 24

FISH STOCKED INTO HOOKER LAKE

Year	Species Stocked	Age Class	Number Stocked	Average Length (inches)
1972	Walleye	Fry	1,000,000	1.00
1972	Northern Pike	Fry	400,000	1.00
1972	Largemouth Bass	Fry	40,000	1.00
1973	Walleye	Fry	1,300,000	1.00
1973	Northern Pike	Fry	577,500	1.00
1973	Walleye	Fingerling	19,190	3.00
1974	Walleye	Fingerling	18,250	3.00
1975	Walleye	Fingerling	7,500	5.00
1982	Northern Pike	Fingerling	180	7.00
1985	Northern Pike	Fingerling	180	8.00
1991	Northern Pike	Fingerling	550	8.00
1992	Northern Pike	Fingerling	170	8.00
1995	Northern Pike	Fingerling	174	8.50
2000	Northern Pike	Large fingerling	174	8.00
2006	Northern Pike	Large fingerling	175	9.20
2008	Northern Pike	Large fingerling	259	9.10
2010	Walleye	Small fingerling	3,614	1.70
2011	Walleye	Small fingerling	3,045	1.9
2012	Northern Pike	Large fingerling	207	7.5
2013	Walleye	Small fingerling	3,045	1.5
2014	Northern Pike	Large fingerling	174	9.1
2015	Walleye	Small fingerling	3,614	1.2

Source: Wisconsin Department of Natural Resources and SEWRPC.

improving the pike fishery. To this end, the WDNR has been putting small numbers of northern pike into the Lake over the years (Table 24). If approved by the WDNR fishery manager, additional northern pike could be stocked into the Lake by an association or similar entity to assist this management practice. Actions could be taken to promote northern pike access to preferred spawning areas (e.g., periodically flooded areas with firm-stemmed plants). Additionally, maintaining current practices and aquatic habitats (see "Aquatic Habitat" subsection below) within the Lake is crucial. Since stocking of walleye into Hooker Lake has not resulted in establishment of a reproducing population, the walleye population should probably be managed as a "put-grow-take" fishery with little expectation of natural reproduction.[83] Thus, periodic fish stocking should continue if the fishery is to remain viable. Recommendations related to these conclusions are included in Chapter III of this report.

Table 25

HOOKER LAKE FISH SURVEY SUMMARY: 2008

Species Collected	Average Length (inches)
Bluegill	5.5
Common Carp	- -[a]
Northern Pike	19.4
Warmouth	- -[a]
Lake Chubsucker	- -[a]
Largemouth Bass	10.8
Bowfin	- -[a]
Black crappie	7.5
Smallmouth bass	14.8

[a]*Species was found during WDNR fish survey but not sampled for size.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

[83]*E-mail communication from Luke S. Roffler, WDNR, May 18, 2015.*

Aquatic Habitat
Aquatic habitat enhancement generally refers to encouraging native aquatic plant (particularly pondweed) growth within a lake, as these plants provide food, shelter, and spawning areas for fish. Aquatic habitat enhancement also involves protecting wetlands (see "Terrestrial Habitat" section below), maintaining good ecological connectivity between the lake and its watershed, and encouraging the presence of woody debris along the shorelines. Woody debris is found in abundance in natural environments, provides shelter for fish populations, act as basking and rest areas for herptiles (e.g. frogs and turtles), may provide perch areas for important birds and insects, and can help protect shorelines from erosion in some instances.

To determine the status of aquatic habitat within the Lake beyond that identified as part of the summer 2014 aquatic plan survey (see "Issue 4: Aquatic Plant Growth" section), SEWRPC staff completed a shoreline assessment in the summer of 2014 (see "Issue 6: Shoreline Maintenance" section). The aquatic plant survey revealed that **Hooker Lake has only fair plant diversity, with only two different pondweed species,**[84] **while the shoreline assessment concluded that few areas along the Lake's shoreline have significant woody debris** (see Map 12). These conclusions suggest that the current aquatic native plant community should be maintained and enhanced, to the greatest extent practical, and that projects should be implemented to provide more woody debris along the shorelines. Consequently, recommendations related to both are presented in Chapter III of this report.

Hooker Lake's bottom is composed primarily of muck (i.e., silt and organic debris). Healthy aquatic ecosystems generally require a variety of habitat and substrate found in differing places within the Lake itself and tributary streams. For example, fish spawning, rearing, refuge, and feeding commonly take place in 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 debris all promote healthy fish populations.

Terrestrial Wildlife
Two general practices can enhance terrestrial wildlife populations: application of best management practices and habitat enhancement. Each is described below.

Terrestrial Best Management Practices
The way people manage their individual plots of land and treat wild animals and plants has a significant impact on terrestrial wildlife populations. Turtles, for example, need to travel overland long distances from their home lake to lay their eggs. If pathways to acceptable habitats are not available, or are dangerous due to pets, fences, or traffic, turtle populations will decline. Many conservation organizations have developed "best management practices" (BMPs) or behaviors that homeowners and land managers can employ sustain or even increase wildlife populations.

Although some BMPs are species- or animal-type specific (e.g., spaying or neutering cats to limit reproduction and reduce their desire to kill birds), many are general practices that benefit all wildlife. In general, best management practices for wildlife enhancement primarily target agricultural and residential land uses. Agricultural measures tend to focus on encouraging land management that enhances habitat value, such as allowing fallen trees to naturally decompose where practical, or allowing for uneven topography which can create microhabitats needed by certain plants and animals. In contrast, residential measures tend to focus on practices that owners of smaller parcels can initiate on their own to provide or enhance habitat. Examples include installing a rain garden, avoiding heavy applications of fertilizers and herbicides, landscaping to provide food and cover, and preventing introduction of nonnative plants and insects. Other recommendations are generally applicable to all landowners. For example, careless, wanton, and/or indiscriminant killing of native wildlife, particularly amphibians, reptiles, and birds, is strongly discouraged and should be publicly censured.

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

Actively communicating best management practices to the public often provides an excellent means of encouraging healthy wildlife populations without major investment of public funds. <u>Consequently, implementing and increasing the acceptance of best management practices is recommended in Chapter III of this report.</u>

Terrestrial Habitat

Terrestrial wildlife needs large, well-connected areas of open natural or nature-like habitat. Consequently, protecting, connecting, and expanding natural habitat is crucial if wildlife populations are to be maintained or enhanced. Open space natural areas can generally be classified as either wetlands or uplands, as described below:

1. **Wetlands**—Wetlands are defined based on hydrology, hydric soils, and the presence of wetland plants. There are many types of wetlands (see Figure 42), from the familiar cattail and bulrush marsh to forested wetlands. Most aquatic and terrestrial wildlife relies upon, or is associated with, wetlands for at least a part of their lives. This includes crustaceans, mollusks, aquatic insects, fish, amphibians, reptiles, mammals (e.g., deer, muskrats, and beavers), and resident bird species, (e.g., turkey, songbirds and migrant species, such as sandhill and whooping cranes).

2. **Uplands**—Uplands are often characterized by the presence of drier, more stable soils. Like wetlands, natural uplands can also exist in many forms (e.g., prairies and woodlands) and also provide many critical functions for many upland game and nongame wildlife species through provision of critical breeding, nesting, resting, and feeding areas, as well as providing refuge from predators. However, unlike wetlands, the dry and stable soils make uplands more desirable for urban development and, therefore, such areas are more challenging to protect.

Figure 42

EXAMPLE WETLAND TYPES

MARSH WETLAND

Source: SEWRPC.

SCRUB/SHRUB WETLAND

Source: University of New Hampshire Cooperative Extension.

FORESTED WETLAND

Source: Prince William Conservation Alliance.

As mentioned above, **both wetlands and uplands are critical to wildlife populations. However, the dynamic interaction and movement between uplands and wetlands are also crucial** because many terrestrial organisms spend part of their time in the wetlands and the rest of their time in upland areas. For example, some amphibians live most of their lives in upland areas but depend on wetlands for breeding. Consequently, if the connections between uplands and wetlands are compromised (e.g., if a large road is placed between the two land types) it becomes dangerous, if not impossible, for amphibians to gain access to their breeding grounds, thereby reducing their ability to seasonally migrate or reproduce. In fact, habitat fragmentation (i.e., splitting up of large connected habitat areas) has been cited as the primary global cause of wildlife population decreases.[85] Therefore, protecting and expanding uplands and wetlands, as well as maintaining or enhancing their connectivity, will help maintain or enhance wildlife populations and diversity.

To determine the extent of the uplands and wetlands in the Hooker Lake watershed, and to gauge the state of the connections between these two areas, SEWRPC staff completed an inventory of the wetland and upland habitat within the Hooker Lake watershed. Wetland and woodland habitat areas are shown on Map 21. Most wetland acreage is located northwest of Hooker Lake in the form of emergent and wet meadow along the stream that enters the Lake in that area, as well as forested wetlands along the tributary stream south of the Lake. Upland habitat in the watershed includes deciduous woodlands and some grassland located northeast and south of the Lake. **These wetland and upland habitat complexes are likely ecologically connected.** Consequently, protecting and expanding these complexes as well as enhancing their connectivity should be made a priority to maintain and enhance wildlife populations. It is important to note, however, that wetland and upland protection and enhancement require a number of actions, including:

1. Preventing and/or limiting development within wetland and certain upland areas;

2. Taking steps to ensure new, rebuilt, or repaired infrastructure maintains or enhances environmental corridors and ecological connectivity between habitat areas;

3. Expanding uplands and/or wetlands where practical (e.g., reestablishing wetlands that are currently farmed, creating grasslands, or reforesting cleared areas); and

4. Ensuring that wetlands and uplands continue to function in a natural manner by controlling and/or removing invasive plant species introduced to those areas and avoiding activities that can disrupt habitat value (e.g., excessive use of motorsport vehicles).

A comprehensive plan must consider each of these elements individually and as a part of a larger habitat system. Consequently, recommendations related to each of these actions are included in Chapter III of this report. Additionally, implementation guidance is included in the "Issue 9: Implementation" section below and in Chapter III.

Other Wildlife Issues

The presence of aquatic birds (primarily geese) on the shorelines was also mentioned as an issue of concern. Though some management measures help control geese populations (e.g., oiling goose eggs to prevent hatching), the number of geese observed on Hooker Lake does not currently appear to warrant such action. Nevertheless, the presence of naturally vegetated buffers can discourage congregation of geese along shorelines. Geese prefer mowed shorelines. Consequently, a recommendation related to the installation of buffers is further emphasized in Chapter III of this plan as a part of the wildlife recommendations.

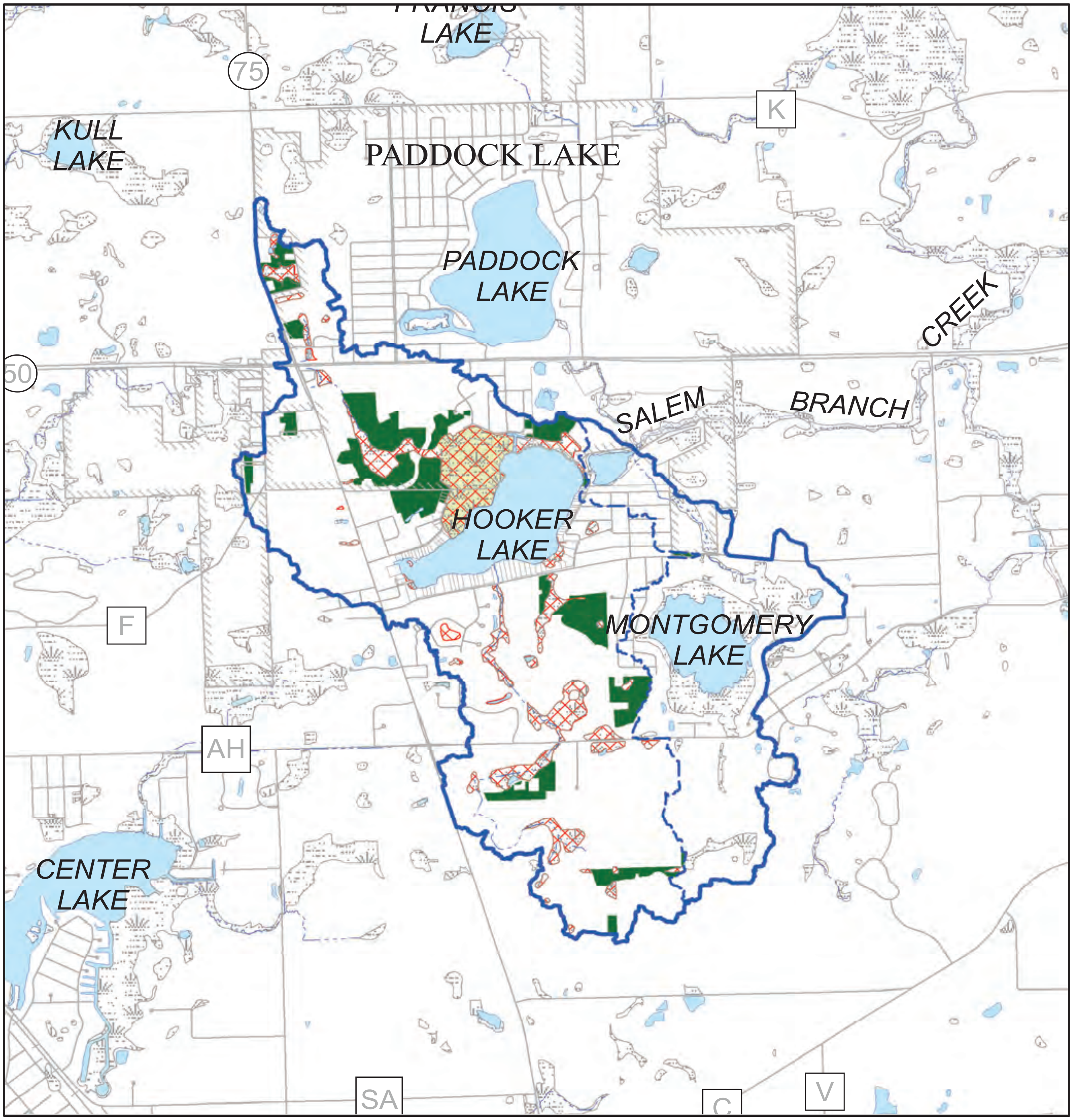
ISSUE 9: PLAN IMPLEMENTATION

A core issue for any lake protection plan is the need for guidance to implement plan recommendations. A significant step toward implementation of a plan is development of an action plan with timelines, goals, and identified responsible parties. These kinds of target metrics can help implementing agencies 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,

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

Map 21

CRITICAL SPECIES SITES, WOODLANDS, AND WETLANDS WITHIN THE HOOKER LAKE WATERSHED



NATURAL AREAS

CRITICAL SPECIES HABITAT SITE (NONE)

WETLANDS: 2010

WOODLANDS: 2010

WETLANDS

SURFACE WATER

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

Note: The Montgomery Lake subwatershed drains to the Back Bay/Outlet area downstream of Hooker Lake, so this subwatershed area was not studied as part of this project.

GRAPHIC SCALE
0 1,500 3,000 FEET

Source: SEWRPC.

it is important to know what on-the-ground implementation will involve. Consequently, some recommendations can be achieved using regulation while others involve proactively implementing new management efforts. Both are discussed below.

Regulatory Implementation

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 and laws. A number of regulations relating to activities within the Hooker Lake watershed, such as zoning ordinances, boating and in-lake ordinances, and State regulations related to water quality, already help protect the Lake. These regulations help mitigate pollution, prevent or limit development, avoid activities that damage the resources base or intrinsic value, and encourage the 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 proceed. Consequently, **zoning can be a particularly effective tool for protecting buffers, wetlands, uplands, and shorelands when environmental considerations are taken into account during formulation of zoning districts.** A way for these environmental considerations to be taken in account is for the local zoning authorities and other regulatory agencies to use SEWRPC-designated environmental corridors (see Figure 43) in applying conservancy zoning district regulations to help determine where development is permitted and not permitted, and to determine the extent and intensity of development that is allowed.

In the Hooker Lake watershed, **three different units of government have different regulatory authorities** that apply to lake protection: Kenosha County, the Village of Paddock Lake, and the Town of Salem (see Table 26 and Map 22). **Kenosha County has zoning authority in most of the watershed.** This is advantageous because the general zoning ordinance for Kenosha County specifically states what development is constrained in environmental corridors. **Environmental corridor designations are used to set "no development" zones as well as "limited development" zones** depending on whether the area within the corridor is a lowland or upland, respectively. The fact that these corridors are used in zoning decisions means that the areas within the Hooker Lake watershed that are within environmental corridors (see Map 23) are well protected.

In addition to general zoning, shoreland zoning and **construction site erosion control and stormwater management ordinances also play a key part in protecting the resources within the watershed.** For example, shoreland zoning, which is administered by Kenosha County (except in the Village of Paddock Lake), follows statewide standards to create building setbacks around navigable waters.[86] Additionally, stormwater management and construction erosion control ordinances help minimize water pollution, flooding, and other negative impacts of urbanization on water resources (lakes, streams, wetlands, and groundwater) and property owners, both during and after construction activities.

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[86]*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 that it is regulated by a Sate 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 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.

Table 26

LAND USE REGULATIONS WITHIN THE AREA TRIBUTARY TO HOOKER LAKE IN KENOSHA COUNTY BY CIVIL DIVISION: 2016

Community	Type of Ordinance				
	General Zoning	Floodplain Zoning	Shoreland Zoning	Subdivision Control	Construction Site Erosion Control and Stormwater Management
Kenosha County.....	Adopted	Adopted	Adopted	Adopted[a]	Adopted[a]
Town of Salem	Regulated under County ordinance	Regulated under County ordinance	Regulated under County ordinance	Adopted[a]	Adopted[a]
Village of Paddock Lake......................	Adopted	Adopted	Adopted[b]	Adopted	Adopted

[a]*Both the Kenosha County and Town of Salem subdivision ordinances and erosion control and stormwater management ordinances apply within the Town of Salem. In the event of conflicting regulations, the more restrictive regulation applies.*

[b]*The Village of Paddock Lake has adopted a Shoreland-Wetland Overlay Zoning District to comply with the requirements of Chapter NR 117 of the* Wisconsin Administrative Code*. The Village has also adopted a Shoreland Overlay Zoning District that applies within 100 feet of the ordinary high water mark of navigable waters, which regulates building setbacks and removal of vegetative cover. These latter regulations are more restrictive than the State-mandated shoreland zoning regulations for cities and villages in NR 117.*

Source: SEWRPC.

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 inadvertent damage to the Lake such as overfishing or severe shoreline erosion from excessive wave action reaching the shoreline.** The boating ordinance for the Town of Salem (including Hooker Lake) is provided in Appendix I. This ordinance is generally enforced by a warden or by the local law enforcement agency.

State Regulations

The State Legislature required the WDNR to develop performance standards for controlling nonpoint source pollution from agricultural and nonagricultural land and from transportation facilities.[87] 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.

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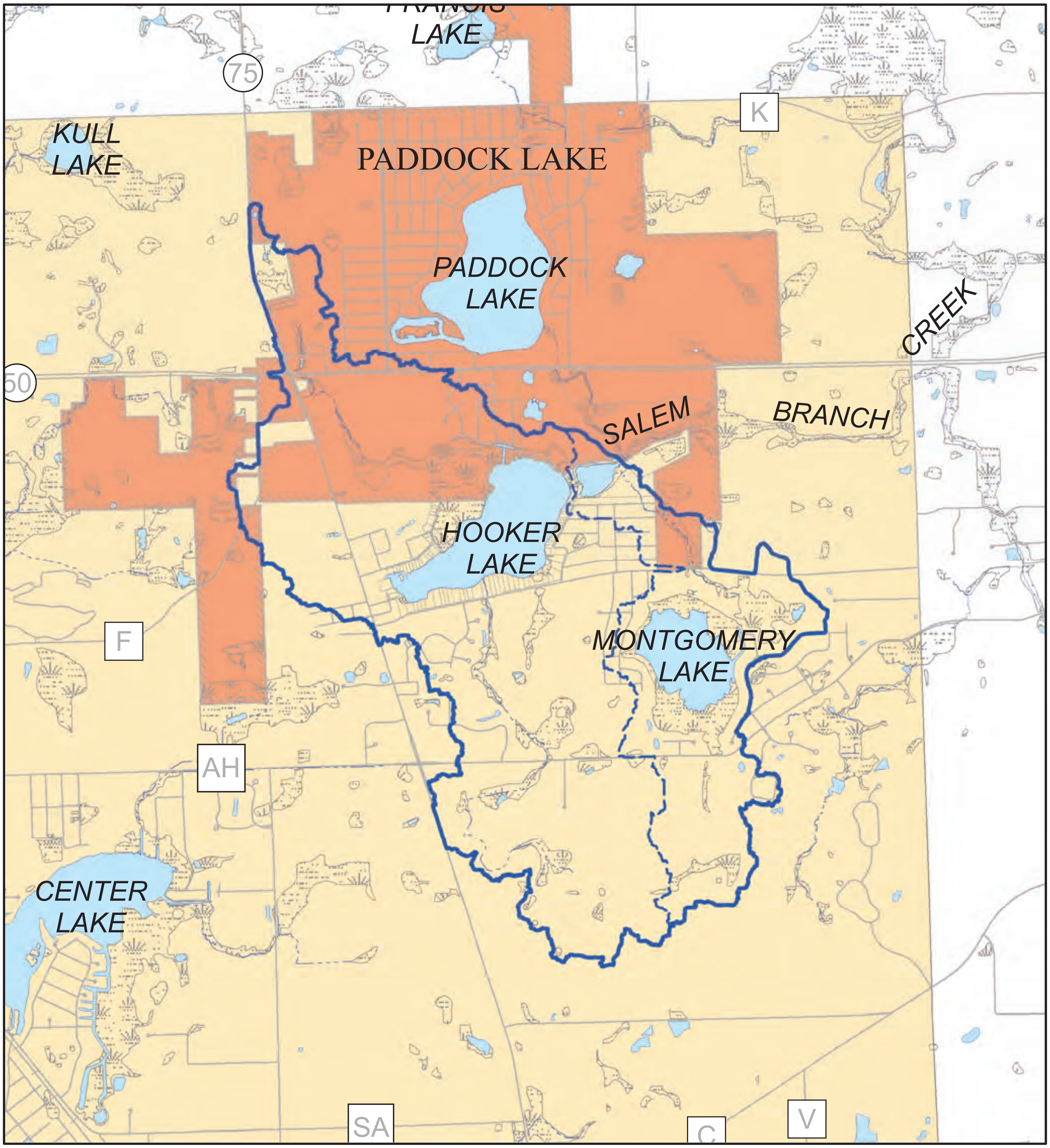
[87]*The State performance standards are set forth in the Chapter NR 151, "Runoff Management," of the* Wisconsin Administrative Code. *Additional code chapters that are related to the State nonpoint source pollution control program include: Chapter NR 152 (This Chapter will be revised in response to the 2013 Wisconsin Act 20 as noted in WDNR Guidance #3800-2014-3, "Implementation of 2013 Wisconsin Act 20 for Construction Site Erosion Control and Stormwater Management," October 2014.), "Model Ordinances for Construction Site Erosion Control and Storm Water Management;" Chapter NR 153, "Runoff Management Grant Program;" Chapter NR 154, "Best Management Practices, Technical Standards and Cost-Share Conditions;" 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 22

CIVIL DIVISIONS WITHIN THE HOOKER LAKE WATERSHED



VILLAGE OF PADDOCK LAKE

TOWN OF SALEM

WETLANDS

SURFACE WATER

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

Note: The Montgomery Lake subwatershed drains to the Back Bay/Outlet area downstream of Hooker Lake, so this subwatershed area was not studied as part of this project.

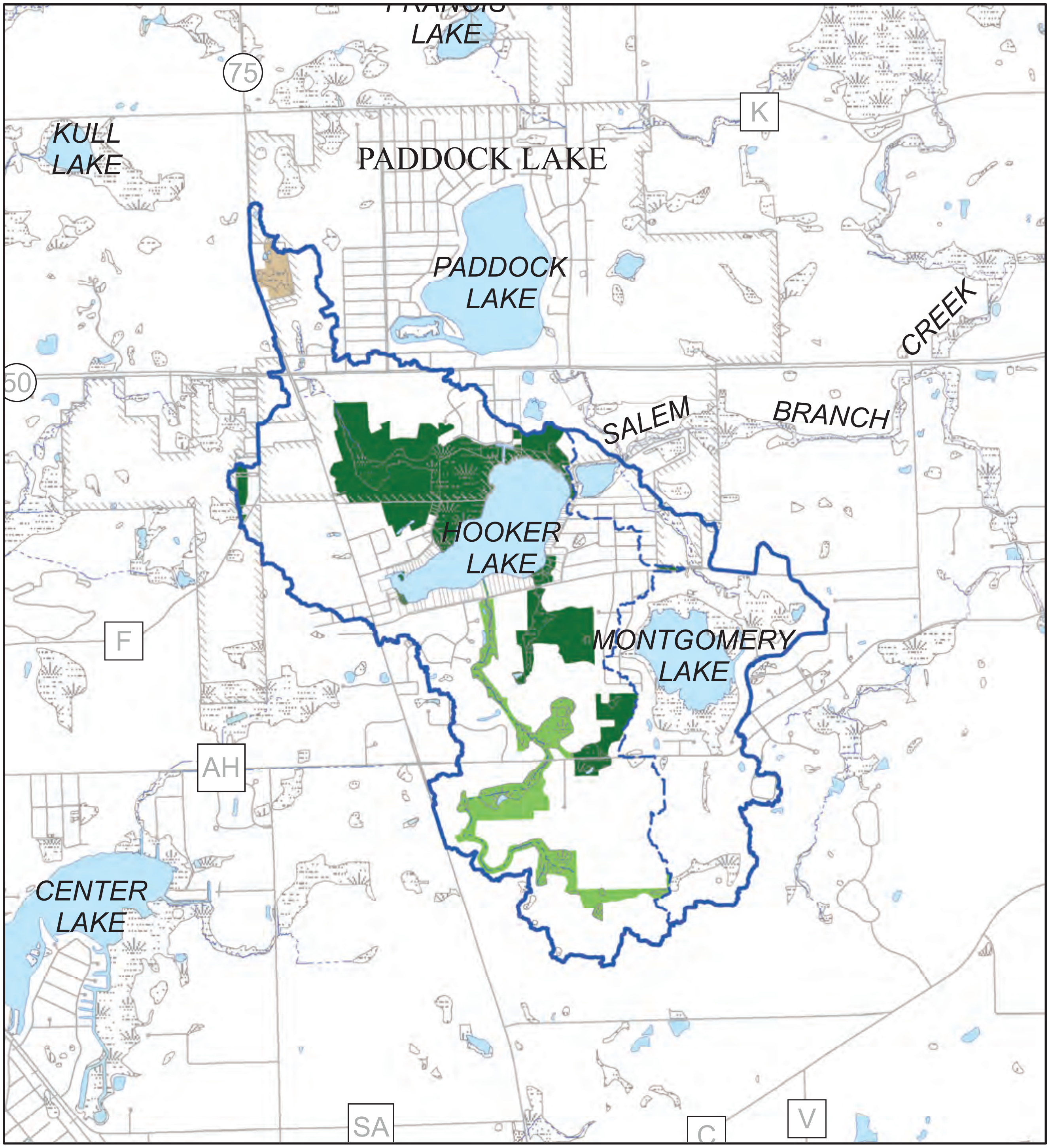
The Town of Salem merged with the Village of Silver Lake and will become the "Village of Salem Lakes" in February 2017.

GRAPHIC SCALE
0 1,500 3,000 FEET

Source: SEWRPC.

Map 23

ENVIRONMENTAL CORRIDORS WITHIN THE HOOKER LAKE WATERSHED



PRIMARY ENVIRONMENTAL CORRIDOR
SECONDARY ENVIRONMENTAL CORRIDOR
ISOLATED NATURAL RESOURCE ARA
WETLANDS

SURFACE WATER
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY

Note: The Montgomery Lake subwatershed drains to the Back Bay/Outlet area downstream of Hooker Lake, so this subwatershed area was not studied as part of this project.

GRAPHIC SCALE
0 1,500 3,000 FEET

Source: SEWRPC.

The regulations discussed above play a crucial role in maintaining the health of the Lake and of all the resources within the Hooker Lake watershed. However, even though developers, residents, and lake users are legally obligated to adhere to the ordinances, limited resources within the enforcement bodies at the State, County, and municipal levels can sometimes make the task of ensuring compliance difficult. Consequently, Chapter III provides recommendations on the best ways for the HLMD to work with regulatory agencies to help them enforce the existing ordinances and regulations to the greatest extent practical.

Proactive Management Efforts
In addition to continued and enhanced ordinance enforcement, a number of recommendations made under this plan also seek to proactively improve conditions within the Lake through voluntary efforts. Chapter III provides details on these recommendations and guidance on their implementation. However, several challenges can limit the ability of lake residents and the Management District to engage in certain management efforts recommended under this plan. Some of these challenges include:

1. **Lack of adequate funding**—The HLMD, as a taxing body, has authority to levy taxes within the District to secure funding necessary to manage the Lake. In addition, grant funds may be available to for larger, more extensive projects that would otherwise be beyond the financial capacity of the District.

2. **Institutional capacity**—Institutional capacity refers to the capacity that agencies within the watershed have to implement projects in terms of knowledge, staff, and other resources. Map 22 depicts the civil divisions within the watershed and Table 26 lists the land use regulations enforced by those civil divisions. Many resources are available to help residents and lake users implement management measures. Nevertheless, some guidance will likely be necessary to ensure that those attempting management projects are completing the projects in an effective and efficient fashion consistent with plan recommendations.

3. **Volunteer and Interest Base**—To increase the advocacy and volunteer base for labor intensive or broad-based projects like hand-pulling or wetland invasive species monitoring, it is desirable to reach a broader stakeholder group beyond lakeshore and near-lakeshore residents.

Consequently, Chapter III provides recommendations and suggested actions that seek to ensure that the above capacity issues are addressed.

In addition to capacity building, communicating the details of this plan will also be crucial to encouraging voluntary management efforts. For example, communicating the difference between native and nonnative plants and the fact that removing plants can spur algae growth, are important to ensure that homeowners understand why a “clean” shoreline is not always the best option for a lake, and to ensure that homeowners maintain a healthy plant community on the shoreline. Consequently, another major recommendation in Chapter III is communicating the necessary and important components of this plan.

SUMMARY

All issues of concern expressed by Hooker Lake residents during the development of this plan have merit. Additionally, as discussed in the “Aquatic Plant Growth” section of this report, addressing these issues will contribute to effectively managing the aquatic plant population within Hooker Lake and improving the general health of the Lake. Therefore, each issue has associated recommendations set forth in Chapter III. It is important to note that many opportunities exist to help ensure the sustainable use of Hooker Lake and its watershed. The implementation of the recommendations provided in Chapter III of this report will help capitalize on these opportunities.