COMMUNITY ASSISTANCE
PLANNING REPORT NO. 313

PEWAUKEE RIVER WATERSHED PROTECTION PLAN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgement is due to Dr. Thomas M. Slawski, SEWRPC Principal Specialist Biologist; Ms. Beverly A. Saunders, SEWRPC Senior Specialist Biologist; Mr. Aaron W. Owens, SEWRPC Planner; Mr. Edward J. Schmidt, Former SEWRPC GIS Planning Specialist; and Ms. Megan A. Beauchaine, SEWRPC Research Analyst, for their contributions to the conduct of this study and the preparation of this report.

The photographs on the front cover were taken by Ray Schwabe and Charlie Shong. They are active members of the Pewaukee River Partnership.

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Chapter I

INTRODUCTION

PURPOSE OF THE PLAN

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 and that interventions are often necessary to maintain or improve the conditions of these resources (see Figure 1). Located entirely within Waukesha County (Map 1), the Pewaukee River, together with its tributaries and associated wetlands, provides a unique cold and warmwater system that struggles to maintain good health as a result of significant urbanization in the watershed. The purpose of this plan is to provide a framework to enable communities in the area to work together with a common goal: *to protect and improve the land and water resources of the Pewaukee River watershed*.

This watershed protection plan focuses on what can be done to continue to *protect* the existing high-quality resources from human impacts and *prevent* future water pollution or resource degradation from occurring. This plan complements other existing programs and ongoing management actions in the Pewaukee River watershed and represents the continuing commitments of government agencies, municipalities, and citizens to diligent land use planning and natural resource protection. This plan presents recommendations for appropriate and feasible watershed management measures for enhancing and preserving the water quality of the Pewaukee River and for providing the public with opportunities for safe and enjoyable recreation within the Pewaukee River watershed.

Figure 1

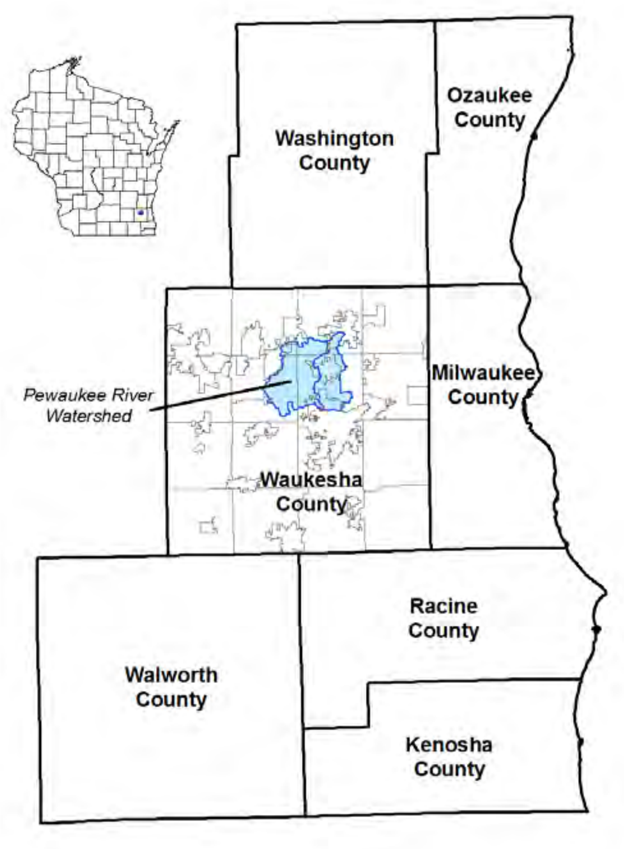
WORKING TO RESTORE FISHERIES HABITAT WITHIN THE PEWAUKEE RIVER: 2012

This photo shows members of the Pewaukee River Partnership (PRP), Lake Pewaukee Sanitary District, and a group of Pewaukee School District students actively working to restore a section of the Pewaukee River to a more appropriate stream width and depth, and "natural" conditions. This is just one of several projects conducted by the PRP to protect the River and its landscape. See Chapter V for more details on past and existing projects.

Source: Thomas Koepp, Lake Pewaukee Sanitary District, and SEWRPC.

Map 1

LOCATION OF THE PEWAUKEE RIVER WATERSHED STUDY AREA



Source: SEWRPC.

The Pewaukee River watershed Protection Plan is designed to assist State and local units of government, nongovernmental organizations, businesses, and citizens in developing strategies that will benefit the natural assets of the River system and protect sensitive habitats within the watershed. By using the strategies outlined in this plan, results will be achieved that enrich and preserve the natural environment. In addition, carefully planned urban development can create and maintain open space, groundwater recharge areas, and wildlife corridors for the benefit of the Pewaukee River, the residents of the watershed, and its visitors. This protection plan serves as a practical guide for the management of water quality within the Pewaukee River watershed and for the management of the land surfaces that drain directly and indirectly to the streams and lake in the watershed.

BACKGROUND

In 1966, *The Milwaukee Journal* featured the Pewaukee River in its Pulitzer Prize winning series "The Spreading Menace".[1] The first installment of this three-part series featured the River, as shown in Figure 2. Much like other watersheds throughout the State, communities within the Pewaukee River watershed had inadequate sanitary sewerage facilities to deal with expanding populations and increasing urbanization. The resultant environmental consequences were highlighted in the Milwaukee Journal series, which chronicled the inadequate treatment of human waste or "a cascade of sewage,"[2] discharges of untreated industrial effluents, major fish kills, massive algal blooms, foaming rivers full of leftover detergents, significant trash and debris accumulations, and public health impacts, all of which can be seen in the photographs included in the Milwaukee River series. It is important to note that this series pre-dates the clean water act amendments to the Federal Water Pollution Control Act and the numerous subsequent, significant efforts to improve water quality in the Pewaukee River watershed, including the abandonment of the Village of Pewaukee wastewater treatment plant and connection of the Pewaukee sanitary sewer service areas to the Fox River Water Pollution Control Facility or the City of Waukesha wastewater treatment plant, consistent with the recommendations of the 1979 Southeastern Wisconsin Regional Planning Commission (SEWRPC) regional water quality management plan;[3] connection of certain areas in the western part of the watershed to the Delafield-

[1]The Milwaukee Journal, *Sunday Picture Journal, "The Spreading Menace," Sunday, April 17, 1966.*

[2]Ibid.*, page 6.*

[3]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume Three*, Recommended Plan, *June 1979.*

Figure 2

THE MILWAUKEE JOURNAL ARTICLE

The state of Wisconsin and the Nation as a whole were at an historic tipping point in 1966 where water resources degradation provided clear evidence that "our effluent society" has outstripped the ability of aquatic systems to assimilate our wastes, resulting in a "septic tank suburbia" where "dilution obviously is no longer a really adequate solution to pollution….Little wonder then that conservationists call some rivers 'open sewers'."

Source: The Milwaukee Journal*, Sunday, April 17, 1966, and SEWRPC.*

Hartland Water Pollution Control Commission wastewater treatment plant; the issuance of discharge permits to municipalities for control of stormwater runoff in the watershed pursuant to the 1987 amendment to the Federal Clean Water Act, the banning of leaded gasoline, the promotion of phosphorus-free detergents, and restrictions on the use of fertilizers containing phosphorus. However, it was the original 1966 Milwaukee Journal series that helped place water quality concerns on the legislative agenda and contributed to the passage of more stringent point source pollution controls in the State and for the Pewaukee River watershed, as summarized in this plan. Even at this stage in our state's history, there was a clear understanding of the potential loss of recreational value both in terms of resources and cash value to "a billion-dollar [in 1966 money] business in the Badger state," if no action was taken.[4]

The Pewaukee River was featured on the cover of the Milwaukee Journal series, as shown in Figure 2. The article illustrated significant water quality impairments due to excessive loading of human effluent, trash, and debris. The Village of Pewaukee wastewater treatment plant did not provide adequate treatment relative to the assimilative capacity of the Pewaukee River. Significant amounts of trash and debris were commonplace in this River system and foaming detergents were common downstream of the treatment plant discharge point. All of these impairments, which degraded water quality in both the River and Pewaukee Lake, significantly affected human use and enjoyment of the water resources. These major impairments have largely been addressed through a number of planning efforts, legislative initiatives, and remedial programs at the State, regional, county, and local planning levels.[5]

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[4]Ibid., *page 12.*

[5]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume Two,* Alternative Plans, *February 1979; SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report*, March 1995; Wisconsin Department of Natural Resources Publication PUBL-WR-366-94,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project, *June 1994; Lake Pewaukee Sanitary District,* An Aquatic Plant Management Plan for Pewaukee Lake, Wisconsin, *January 1992; SEWRPC Community Assistance Planning Report No. 58,* A Lake Management Plan for Pewaukee Lake, Waukesha County, Wisconsin*, March 1984 (1st Edition), May 2003 (2nd Edition); SEWRPC Memorandum Report No. 56,* A Lakefront Recreational Use and Waterway Protection Plan for the Village of Pewaukee, Waukesha County, Wisconsin*, March 1996; Wisconsin Department of Natural Resources,* Pewaukee Lake, Waukesha County: Long-Term Trend Lake, 1986, *1986; Wisconsin Department of Natural Resources,* Pewaukee Lake, Waukesha County: Long-Term Trend Lake,1987, *1987; E.R. Schumacher, Wisconsin Department of Natural Resources Fish Management Report No. 131,*Creel Survey on Pewaukee and Nagawicka Lakes, Waukesha County*, Summer 1982, February 1987; and, Wisconsin Department of Natural Resources,* Pewaukee Lake Sensitive Area Study*, June 1994.*

Local concern over the state of the Lake and River resulted in the provision of public sanitary sewer service to the urban lands within the watershed, beginning in 1930 within what is now the Village of Pewaukee, and continuing from 1976 through 1979 when all lakeshore properties were provided with public sanitary sewerage service. Provision of sewerage services was aided by the formation, in 1944, of the Lake Pewaukee Sanitary District, under Section 60.70 of the *Wisconsin Statutes*.[6] Since its formation, the Lake Pewaukee Sanitary District had assumed powers to protect and manage Pewaukee Lake. More recently, the Pewaukee River Partnership had been created in the year 2004 as a vehicle for improvement projects and public awareness throughout the watershed (see website for more details at *www.pewaukeeriver.blogspot.com*). In 2005 the Pewaukee River Partnership registered as a not for profit charitable organization under 501(c)(3) of the Federal Internal Revenue Code. This status has helped the Partnership to be involved in numerous projects to preserve, protect, and improve water quality and recreation in the Pewaukee River watershed.

Watershed Location and Current Status

The Pewaukee River and its tributaries are a unique water resource located in portions of the Cities of Delafield, Pewaukee, and Waukesha, the Village of Pewaukee, portions of the Villages of Hartland and Sussex, and portions of the Towns of Delafield, Lisbon, and Merton (see Map 2). The River system includes the 2,493-acre Pewaukee Lake and several other tributaries, including Coco Creek, Meadowbrook Creek, Zion Creek, Audley Creek, as well as numerous smaller unnamed tributaries. The system supports a variety of terrestrial and aquatic wildlife, including seven State-listed threatened and endangered species and 13 species of special concern of mussels, fishes, reptiles, amphibians, birds, and plants. The system is sustained by groundwater recharge, seepage from wetlands and moraines, and precipitation runoff from a 38-square-mile watershed. The Pewaukee River is a headwater tributary to the Fox River; the confluence of these rivers is located in the City of Waukesha. The Fox River is a 199-mile-long tributary to the Illinois River within the Mississippi River basin in the States of Wisconsin and Illinois.

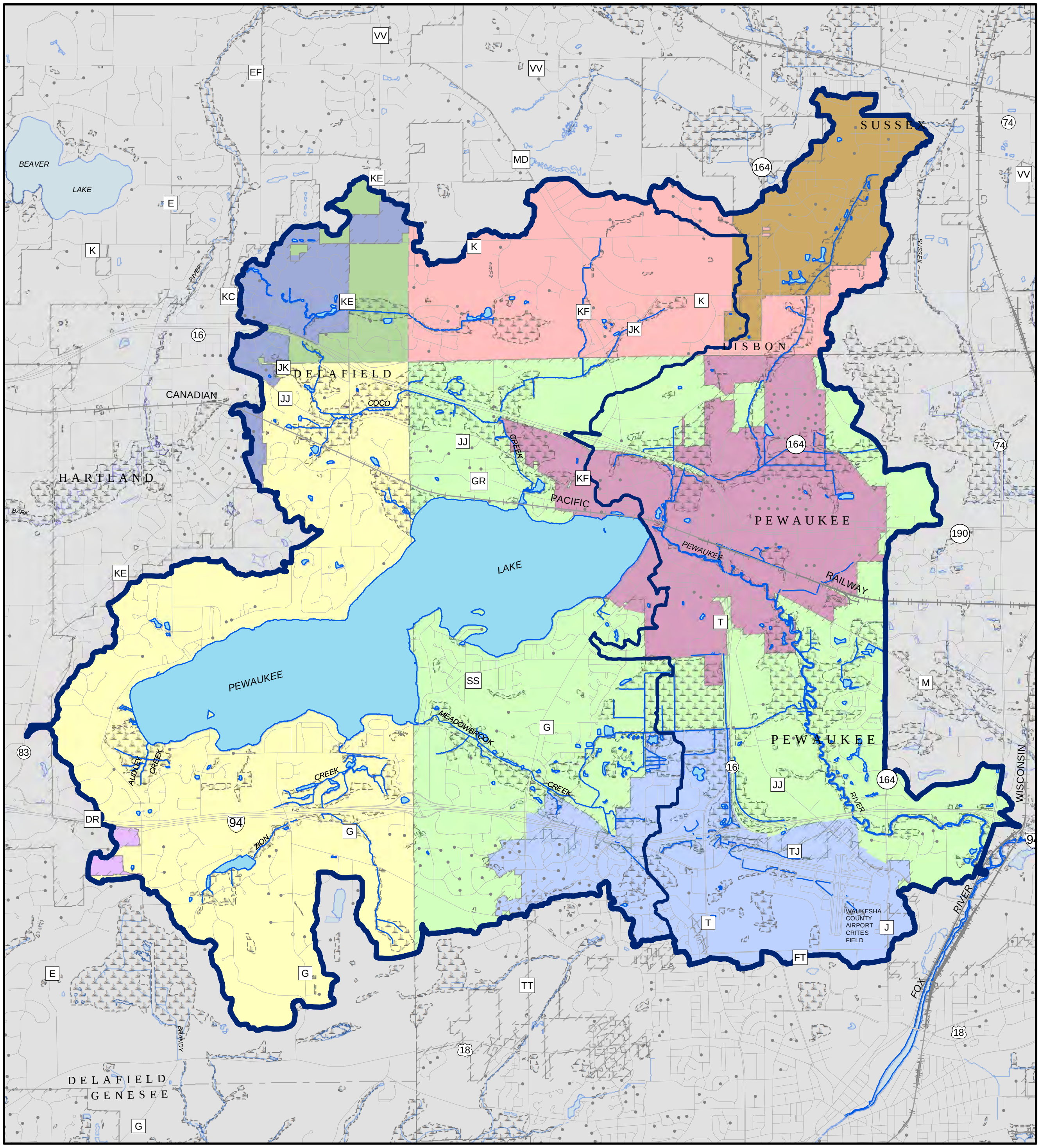
The Pewaukee River watershed has been divided into two *subwatersheds* for this plan to assist in evaluating land use, water quality, biological community, and instream habitat conditions: the *Lake* subwatershed and the *River* subwatershed. The Lake subwatershed is comprised of Pewaukee Lake and all the lands that drain to it, as well as all the lands that drain to that portion of the Pewaukee River that are located upstream of the Pewaukee Lake dam; the River subwatershed is comprised of that portion of the Pewaukee River located downstream of the dam as well as all the lands that drain to that portion. The Lake subwatershed is directly tributary to the main stem of the Pewaukee River and is a significant component of the entire Pewaukee River watershed system. Map 2 also shows the extent of the approximately 14 miles of stream that were surveyed under this study.

Based upon the results of a recent recreational use survey developed as part of this planning process, this combination of Lake and River establishes both the human connection and the unique mix of recreational values this river system has to offer (see Figure 3). Despite a fairly high amount of urban development within the watershed, the majority of the stream and adjacent riparian corridors continue to exhibit a rural character that provides recreational opportunities within and adjacent to the River system. Utilized for fishing, hunting, boating, water skiing, wading, canoeing, kayaking, wildlife watching, and scenic viewing, the River provides ecological and recreational benefits for adjacent landowners and other users. Public recreational access opportunities are provided through boating access sites on Pewaukee Lake and public parks and other facilities adjacent to the lake and river system.

[6]*Note: Wastewater from the Lake Pewaukee Sanitary District service area is treated at the Fox River Water Pollution Control Center sewage-treatment facility in City of Brookfield and discharged to the Fox (Illinois) River.*

Map 2

CIVIL DIVISIONS WITHIN THE PEWAUKEE RIVER WATERSHED: 2012



CITY OF DELAFIELD	TOWN OF MERTON	SURFACE WATER
CITY OF PEWAUKEE	VILLAGE OF HARTLAND	STREAM
CITY OF WAUKESHA	VILLAGE OF PEWAUKEE	WATERSHED BOUNDARY
TOWN OF DELAFIELD	VILLAGE OF SUSSEX	SUBWATERSHED BOUNDARY
TOWN OF LISBON		

N

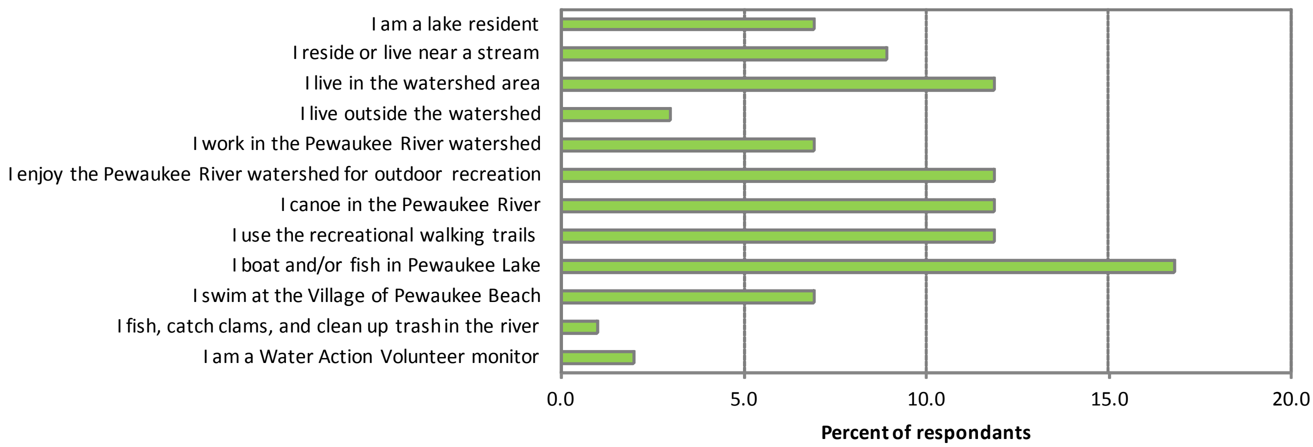
0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

Figure 3

WHAT IS YOUR CONNECTION TO THE PEWAUKEE RIVER WATERSHED?



NOTE: The answers to this question were obtained from attendees of the public informational meeting as part of the formulation of the Pewaukee River Watershed Protection Plan dated April 1, 2011.

Source: SEWRPC.

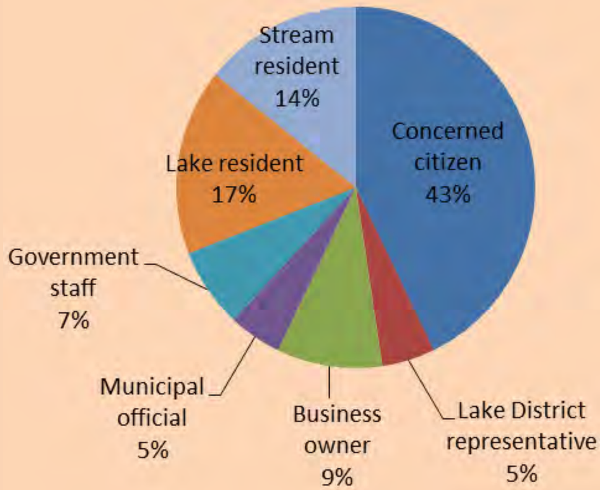
The Pewaukee River system also has significant aesthetic and ecological values and has the potential to be a more diverse aquatic ecosystem within the urbanizing portion of the Southeastern Wisconsin Region within which the River is located. The majority of the Pewaukee River system is generally classified as a warmwater fish community, but Coco Creek has been designated as a potential Class II brown trout fishery for its entire length to its confluence with Pewaukee Lake. Pewaukee Lake has a highly managed muskellunge fishery which is well known and attracts anglers from both Wisconsin and Illinois.

The attributes that make the Pewaukee River and its watershed unique within the Southeastern Wisconsin Region are the same attributes that attract new residents, businesses, and supporting infrastructure to the watershed. This increasing urban development in recent years has led to conversion of agricultural and open lands to residential lands with increased impervious area and volumes of stormwater runoff, increased demands for groundwater, and increased demands on the recreational opportunities throughout the river system. Such demands have raised concerns about the effects on the hydrologic and ecological integrity of this water system. These concerns, combined with the need to protect and preserve the ecology and water quality of Pewaukee Lake, led to the development of a second edition comprehensive lake management plan that set forth priority actions to protect and preserve the ecology and water quality of Pewaukee Lake.[7] While these plans have led to the implementation of actions by the Pewaukee Lake Sanitary District and municipalities that have addressed the immediate concerns relating to the Lake itself, ongoing concern over the state of the River linking the Lake has remained. These concerns led to the formation of the Pewaukee River Partnership as a means of focusing attention on the entire hydrologic system.

[7] *SEWRPC Community Assistance Planning Report No. 58*, op. cit.; *SEWRPC Community Assistance Planning Report No. 58, 2nd Edition*, A Lake Management Plan for Pewaukee Lake, Waukesha County, Wisconsin, *May 2003.*

Figure 4

BREAKDOWN OF WORK GROUP MEMBERS CONTRIBUTING TO THE FORMULATION OF THE PEWAUKEE RIVER WATERSHED PROTECTION PLAN: 2011 THROUGH 2012



The composition of the work group demonstrates that the **greatest assets** to protect and improve the Pewaukee River **have been and continue to be the dedicated people** (individuals, organizations, and agency staff) **that live and/or work within the watershed**.

Source: SEWRPC.

PLANNING PROCESS

The Pewaukee River Partnership received Wisconsin Department of Natural Resources (WDNR) funding through the Chapter NR 195 River Planning and Management Grant Program, with additional financial support from Waukesha County, to complete a Protection Plan for the Pewaukee River watershed. This planning effort was conducted cooperatively and involved the WDNR, Waukesha County, Pewaukee Lake Sanitary District, City and Village of Pewaukee, City of Waukesha, Town of Brookfield, Town of Delafield, Town of Lisbon, Town of Waukesha, Village of Sussex, and SEWRPC.

SEWRPC has prepared this plan on behalf of the Pewaukee River Partnership in cooperation with representatives from the *ad hoc* Pewaukee River Watershed Protection Plan Advisory Group. The Advisory Group was comprised of self-nominated individuals representing a range of stakeholders with interests in the Pewaukee River watershed who volunteered their time to meet and review portions of the plan. The Advisory Group represents the diversity of interests and perspectives that affect the watershed, including businesses, stream and lake residents, and County and local government staff as shown in Figure 4. During 2011 and 2012, participants in the Advisory Group either attended one or more of the several meetings or provided electronic mail correspondence to define issues, develop goals, and establish recommendations that would help manage local community growth while protecting the natural resources in the Pewaukee River watershed. It is important to note that the plan goals, which were based upon the feedback provided by the Advisory Group, form the foundation for generating and evaluating the alternative and recommended plans, and for establishing a sound framework within which to implement the recommendations.

The Watershed Advisory Group developed the following general goals for the plan:

- Protect and improve wildlife, land, surface water, and groundwater resources;
- Minimize impacts of land development by controlling both nonpoint agricultural and urban runoff pollution and flooding; and
- Build partnerships and inform the public to promote protection and safe recreational use of natural resources.

This plan elaborates on each of these planning goals by outlining more specific objectives and action items recommended to accomplish the goals. These objectives and management measures also benefited from discussions with Advisory Group members throughout the planning process. Four major/key findings, seven emerging threats/issues of concern, and five key opportunities were identified through this planning process and listed below (no order of importance implied by position in the list).

Major Findings

- Water quality in the River is dependent upon water quality in the Lake.

- Water quantity in the River and Lake is dependent upon both surface runoff and groundwater recharge.

- Recreational uses of the Lake and River are linked and interrelated.

- Volunteer water quality monitoring programs in the Lake and Stream were invaluable to our understanding this system.

Emerging Threats

- The River and Lake are highly vulnerable to drought, as experienced during the summer 2012 drought conditions, and illustrate the need to protect groundwater recharge areas throughout the watershed for existing and planned land uses.

- Riparian buffer lands adjacent to the waterways are necessary to protect water quality and wildlife, but these buffer areas are most vulnerable within and among small headwater tributaries throughout the watershed as well as along Pewaukee Lake.

- Existing and planned urban growth can limit groundwater recharge in the absence of mitigation measures, and could negatively impact both water quality and water quantity.

- Agricultural land use practices could be improved to reduce nutrient and sediment loads to the River.

- The amount of trash and debris within this river system degrades water quality, aesthetics, and recreational value.

- Stream channelization and road crossings have limited the quality and quantity of instream fisheries habitat.

- Nonnative invasive species such as Eurasian Water Milfoil, zebra mussels, purple loosestrife, and Phragmites threaten the biological integrity of this system.

Opportunities

- To better integrate land-based and water-based recreation to improve access to and quality of recreational experiences;

- To protect existing riparian buffer width and longitudinal connectivity—and expand them where feasible—to improve water quality, minimize streambank erosion, and protect and enhance fish and wildlife habitat;

- To enhance groundwater recharge by protecting critical sites with high and very high groundwater recharge potential[8] through appropriate zoning, purchase, and land management measures;

- To implement mitigation measures to protect water quality and groundwater recharge through application of green infrastructure, stormwater treatment practices, and community coordination mechanisms; and

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[8]*Such sites are identified on Map 127 on page 716 of SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin, *December 2010.*

- To improve the fishery by enhancement of fish passage, protection of potential spawning areas in the River, tributaries, and Lake, and protection of the land-water interface through preservation of surface and groundwater linkages.

This plan forms a logical complement to the management actions that have been implemented on the land and water resources throughout the Pewaukee River watershed, and represents an ongoing commitment by the Pewaukee River Partnership, municipalities, and citizens to sound environmental planning. This plan is also consistent with the implementation of the Waukesha County Land and Water Resource Management Plan goals of protecting and improving the natural resources within the County by applying a watershed-based protection planning approach.[9] This plan recognizes the important role that land use plays in affecting water quality and fishery habitat, establishes priority areas, and projects to protect these resources. Continued coordination among stakeholders is recommended to influence land use decisions, as well as information and educational programming.[10]

PLAN FORMAT AND ORGANIZATION

This document incorporates land, groundwater, and stream management data and analyses compiled from the following sources: the WDNR Priority Watershed Project and State of the Basin Reports;[11] the SEWRPC regional land use and water supply plans, various technical reports completed by engineering and scientific consulting firms; and, County and local government Comprehensive Management Plans. This plan incorporates water quality, physical habitat, biological data, and land use information obtained from various agencies and organizations that include: WDNR, U.S. Geological Survey (USGS), Wisconsin Geological and Natural History Survey (WGNHS), Waukesha County Department of Parks and Land Use, and volunteer Lake and stream (Water Actions Volunteer) monitors. In addition, SEWRPC staff conducted a comprehensive instream inventory of the physical conditions, fish passage impediments, and navigation hazards within the Pewaukee River in the spring of 2012 as well as a riparian buffer analysis of lands directly adjacent to the River and its tributaries.

This report is divided into six chapters. Following this introductory chapter, the second chapter presents information on the natural and human-made features of the watershed, including a description of the natural resource base and environmentally sensitive areas, land use data, and population demographics. Chapter III briefly describes State and local plans, regulations, and programs related to this watershed protection plan. Chapter IV summarizes the physical conditions of the stream system, existing surface water quality, and habitat and biological conditions in the Pewaukee River watershed. Chapters V and VI include the goals, objectives, alternative and recommended plan elements, and implementation steps to address the identified issues and concerns of the watershed. These chapters contain recommendations regarding outreach and education, methods of program performance review, and plan implementation.

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[9] *Waukesha County Department of Parks and Land Use-Land Resources Division,* Waukesha County Land and Water Resources Management Plan: 2006-2010*, March 2006; Waukesha County, A* Comprehensive Development Plan for Waukesha County*, February 2009.*

[10] *State of Minnesota, Department of Natural Resources, Section of Fisheries, Fish Habitat Plan:* A Strategic Guidance Document*, 2013.* http://files.dnr.state.mn.us/fish_wildlife/fisheries/habitat/2013_fishhabitatplan.pdf

[11] *Wisconsin Department of Natural Resources, Publication No. PUBL-WT-701-2002,* The State of the Southeast Fox River Basin*, February 2002.*

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Chapter II

NATURAL AND CONSTRUCTED FEATURES OF THE WATERSHED

INTRODUCTION

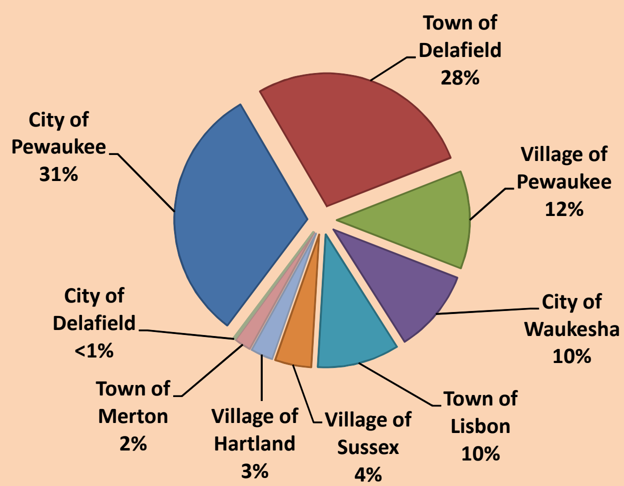
Information on the natural and constructed features of a study area is essential to sound planning for water quality, stormwater, and floodland management. Natural features, such as watershed topography and local hydrology, influence rates and volumes of runoff, affecting instream water quality, the composition of plant and fish communities, and flooding conditions. Constructed (human-made) features also have significant impacts on a river's watershed. For example, streams and lakes can be highly susceptible to water quality degradation due to human activities. This can interfere with desired water uses, and is often difficult and costly to correct.

LAND USE

Land uses and population levels in the watershed are important considerations in stream and lake water quality management. Soil erosion problems, water pollution problems, and the risk of damage to the environment, as well as the ultimate means for abatement of these problems, are primarily a function of human activities within a River's watershed, and of the ability of the underlying natural resource base to sustain those activities. This becomes especially significant in areas that are in close proximity to lakes, wetlands, and streams where user conflicts can occur.

Figure 5

PROPORTION OF CITIES, VILLAGES, AND TOWNS WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



Source: SEWRPC.

Civil Divisions

Civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed. Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 1 in Chapter I of this report, nine civil divisions lie wholly or partially within the Pewaukee River watershed, as shown on Map 2 in Chapter I of this report and listed in Figure 5. The governmental units within the Pewaukee River watershed include the entire Village of Pewaukee, portions of the Villages of Hartland and Sussex; portions of the Towns of Delafield, Lisbon, and Merton; and portions of the Cities of Delafield, Pewaukee, and Waukesha. The City of Pewaukee and

Town of Delafield, combined, comprise nearly 60 percent of the areal extent of Pewaukee River watershed, as shown in Figure 5. The City of Waukesha, Town of Lisbon, and Village of Pewaukee each generally account for about 10 percent of the watershed, or an additional combined 32 percent of the watershed. The remaining four municipalities (City of Delafield, Town of Merton, and Villages of Hartland and Sussex) together comprise a little less than 10 percent of the watershed.

Historical Urban Growth

The types, intensity, and spatial distribution of land uses within the Pewaukee River watershed are important elements in natural resource management. In this regard, the current and planned future land use patterns, placed in the context of the historical development of the area, are important considerations in developing and implementing this plan. Historical urban growth within the Pewaukee River watershed is summarized on Map 3. Much of the early growth (pre-1900) in the watershed centered on the downtown area of the Village of Pewaukee.[1] Between 1900 and 1950, most of the growth was focused around the Pewaukee Lake shoreline. Starting after 1950 and extending until 1980, a post-war housing boom occurred throughout the entire watershed, probably spurred by the construction of IH 94 and STH 16. A lull in urban development occurred from 1980 to 1990, when urban growth dropped from about 2,200 acres in the preceding decade to less than half of that, or about 1,050 acres. After that slow period, urban growth increased from 1990 to 2000 to the highest recorded, or nearly 2,550 acres, which is consistent with the population and housing trends discussed below. Growth once again decreased to about 1,340 acres in the most current period from 2000 to 2010. Despite these changes over time, urban growth also showed two distinct patterns. First, the earliest growth that began around the perimeter of Pewaukee Lake continues to emanate from the Lake and expand outward. Second, growth is expanding around the perimeter of the watershed boundary from the outlying cities, towns, and villages.

More than 50 percent of the urban growth within the Pewaukee River watershed has occurred within the Lake subwatershed (hereinafter PL subwatershed) compared to the Pewaukee River subwatershed (hereinafter PR subwatershed). This is to be expected given the desirability of lake property and that the Lake subwatershed is twice the size of the River subwatershed. Despite this urban growth, the Pewaukee River watershed still contains a significant amount of rural land uses (see “Existing and Planned Land Use” subsection below for more details).

Population and Households

Growth in population and numbers of households from 1960 to 2010 in the Pewaukee River watershed is shown in Figure 6. The resident population grew from about 11,400 to 33,725 individuals; the number of households grew from about 2,900 to 13,760 from 1960 through 2010. During this period the PR subwatershed comprised about 41 percent of both the population and number of households within the entire watershed. The greatest increase in population occurred between 1990 and 2000, and was followed by the smallest increase between 2000 and 2010. The greatest household increases occurred between 1970 to 1980 and 1990 to 2000. It is also interesting to note that rates of growth in the number of households within the PR subwatershed were greater than in the PL subwatershed for every time period except for 2000 to 2010, which also was associated with a slight decrease in population size for this area.

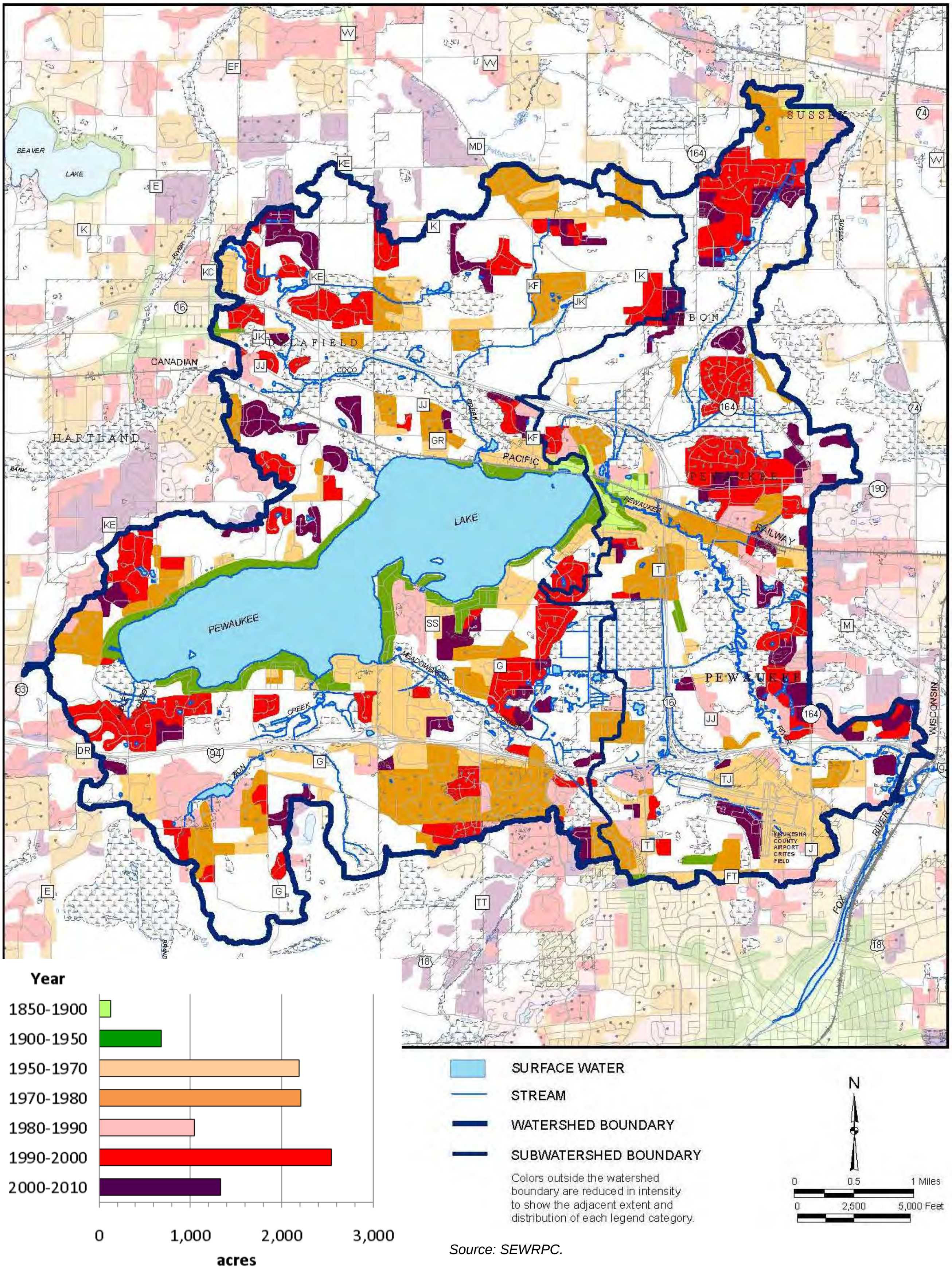
Based upon the adopted regional land use plan, the population in the Pewaukee River watershed is projected to increase through the year 2035 by about 24 percent, while the number of resident households in the watershed is projected to increase by about 21 percent.[2]

[1]*Information and resources on the history of Pewaukee is provided on the Pewaukee Areas Historical Society website at* http://www.pewaukeehistory.org/

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

Map 3

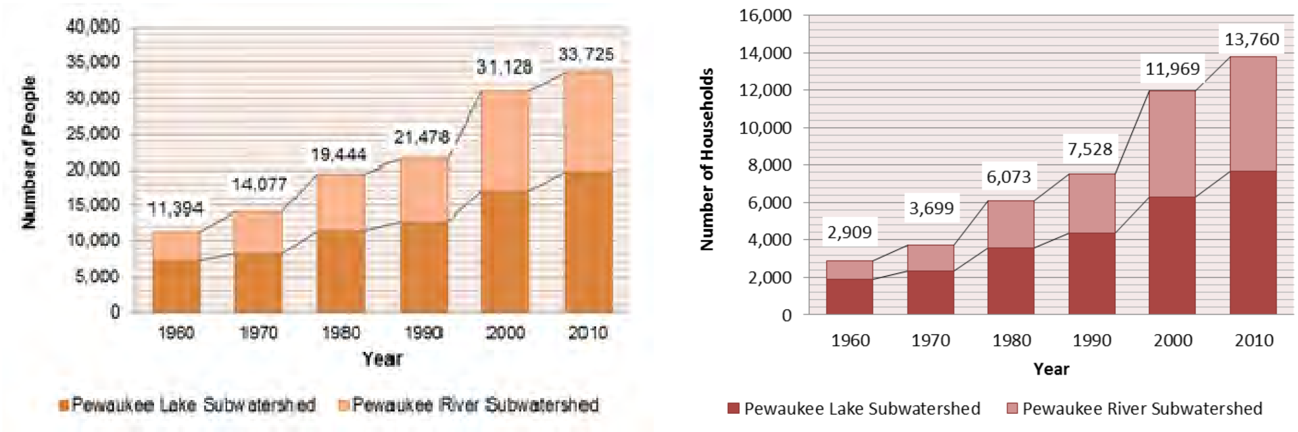
HISTORICAL URBAN GROWTH WITHIN THE PEWAUKEE RIVER WATERSHED: 1850-2010



Source: SEWRPC.

Figure 6

POPULATION AND HOUSEHOLDS AMONG SUBWATERSHEDS
WITHIN THE PEWAUKEE RIVER WATERSHED: 1960-2010



NOTE: Watershed areas approximated by whole U.S. Public Land Survey quarter sections.

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

Existing and Planned Land Use

This section characterizes existing land use conditions for the entire Pewaukee River watershed, as well as the PL and PR subwatersheds, for the year 2010, and examines changes anticipated to occur through planned year 2035 conditions. More detailed breakdowns of the existing and planned land use for each subwatershed can be found in Appendix A.

Urban Land Use

In 2010, as indicated in Table 1 and on Map 4, urban land uses—which include residential; commercial; industrial; governmental and institutional; transportation, communication, utilities; and recreational lands—encompassed nearly 49 percent of the total watershed area. Residential land uses comprised the largest urban land use, covering about 6,207 acres, or about 25 percent, of the total watershed. As shown in Map 5 and Figure 7, over three-fourths of the residential development is located within the PL subwatershed. In contrast, nearly all of the industrial, commercial, and governmental and institutional lands are located within the PR subwatershed. Transportation, communication, and utilities are nearly evenly split among each of the two subwatersheds at about 7 percent each, which comprises the second largest urban land use category in the entire watershed. In terms of recreational lands, nearly 830 acres or about 4 percent of the total watershed area is comprised of golf courses, parks with picnic areas and baseball diamonds, and trail systems (see Recreational Use section in Chapter IV of this report for more details).

Under planned 2035 land use conditions, about 15,482 acres, or 64 percent, of the watershed, are anticipated to be in urban land uses. Residential development is anticipated to comprise about 45 percent of the increase in urban land use between 2010 and 2035 as shown in Table 1 and on Map 5. Twenty-seven percent of the increase in urban land use is planned to occur in the PL subwatershed and 18 percent is anticipated to occur in the PR subwatershed (see Appendix A). The remaining 55 percent of the increase in urban land between 2010 and 2035 is planned to be in commercial, industrial, governmental, transportation, or recreational uses. Map 5 shows the future growth of these types of development is planned to occur primarily along IH 94 and STH 16. As indicated in Table 1, a corresponding decrease of more than 3,500 acres of agricultural and open lands and 124 acres of woodlands is planned to occur.

Table 1

LAND USE IN THE PEWAUKEE RIVER WATERSHED: 2010-2035[a,b]

Category[c]	2010 Acres	2010 Percent of Total	2035 Acres	2035 Percent of Total	Change: 2010-2035 Acres	Change: 2010-2035 Percent
Urban						
Residential	6,207	25.4	7,819	32.1	1,612	26.0
Commercial	623	2.6	973	4.0	350	56.2
Industrial	387	1.6	675	2.8	288	74.4
Governmental and Institutional	476	1.9	770	3.2	294	61.8
Transportation, Communication and Utilities	3,330	13.7	4,168	17.1	838	25.2
Extractive	- -	- -	9	<0.1	9	>100
Recreational	828	3.4	1,068	4.4	240	29.0
Subtotal	11,851	48.6	15,482	63.6	3,631	30.6
Rural						
Agricultural and Open Lands[d]	5,798	23.8	2,291	9.4	-3,507	-60.5
Wetlands[e]	2,798	11.5	2,798	11.5	0	0.0
Woodlands	1,294	5.3	1,170	4.8	-124	-9.6
Water	2,639	10.8	2,639	10.7	0	0
Subtotal	12,529	51.4	8,898	36.4	-3,631	-29.0
Total	24,380	100.0	24,380	100.0	0	- -

[a]*As approximated by whole U.S. Public Land Survey one-quarter sections.*

[b]*As part of the regional land use inventory for the year 2000, the delineation of existing land use was referenced to real property boundary information not available for prior inventories. This change, which is also reflected in the 2010 inventory, increases the precision of the land use inventory and makes it more usable to public agencies and private interests throughout the Region. As a result of the change, however, year 2000 and later land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the county and regional level, the most significant effect of the change is to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

[c]*Off-street parking of more than 10 spaces is included with the associated land use.*

[d]*It is important to note that farmed wetlands are included with the Agricultural and Open Lands category for the year 2010. However, if farmed wetland is adjacent to Primary Environmental Corridor (PEC) lands, it is included with the PEC lands category for the year 2035 planned land use, which would represent part of the reduction in the Agricultural and Open Lands category.*

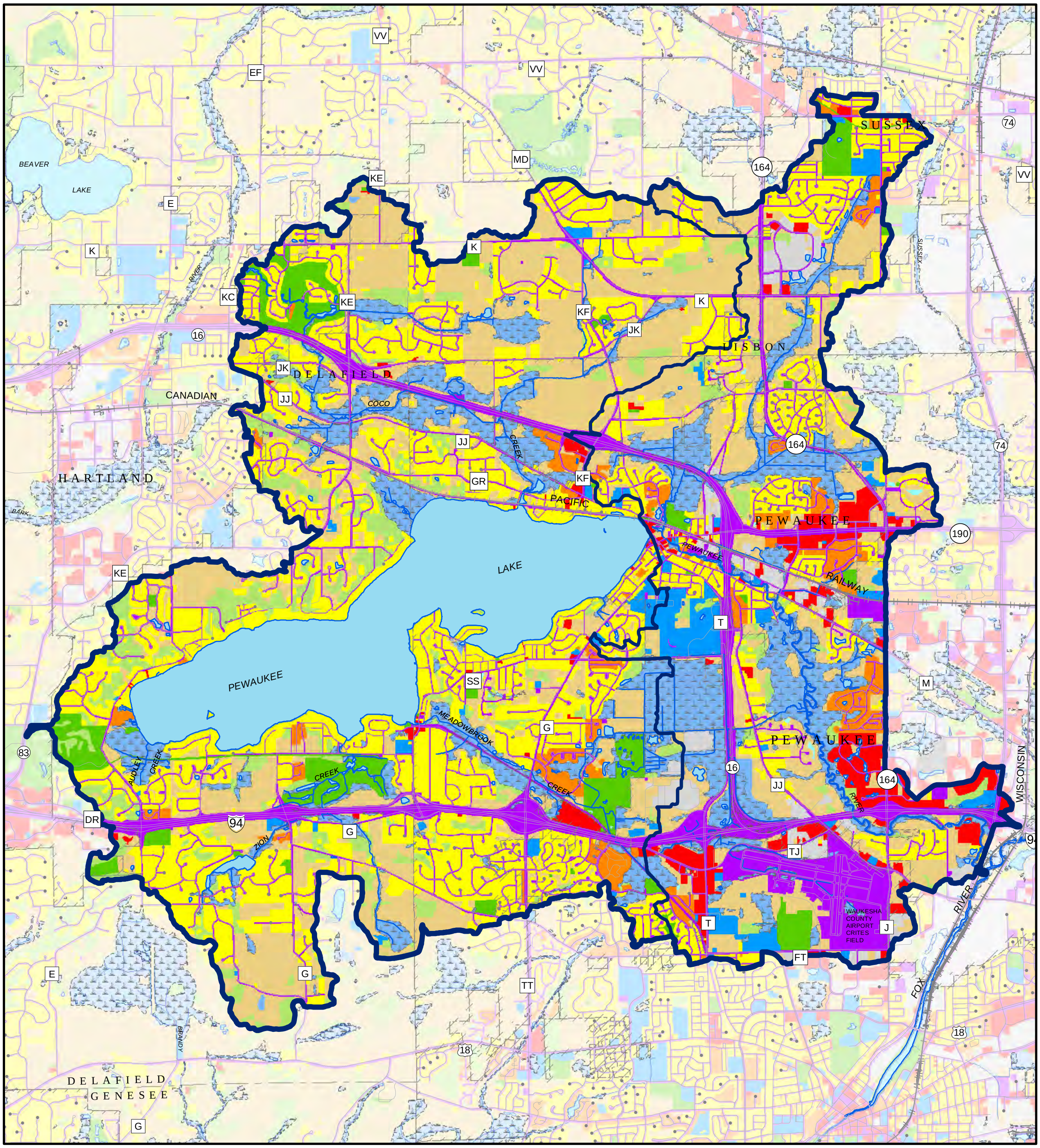
[e]*As part of the Wisconsin Department of Natural Resources Wisconsin Wetland Inventory (WWI) beginning in the year 2005, the wetlands were mapped to a much finer scale and greater level of detail (more wetland categories) than prior inventories. This change increased the accuracy and precision of wetland mapping throughout the Region. As a result of the change, however, year 2010 wetland inventory data are not comparable with data from the year 2000 and prior inventories. At the county and Regional level, the most significant effect of the change is that more, smaller wetlands were able to be delineated, which led to an overall increase in the number and total acreage of wetlands. At the local scale of this study, the most significant wetland area increases were due to an increase in the number of wetlands, farmed wetlands reverting back to wetlands due to inactivity/abandonment of agricultural cultivation activities, and expansion of boundaries within pre-existing wetland areas. However, there was also significant loss of wetland due to urban development, primarily related to residential housing and roadway construction.*

Source: SEWRPC.

Adopted sanitary sewer service areas are shown on Map 6. These sewer service areas have been delineated through a local sewer service area planning process. As part of this process, the community concerned, assisted by SEWRPC, determines a precise sewer service area boundary consistent with local land use plans and development objectives. Sewer service area plans include detailed maps of environmentally significant areas within the sewer service area. Following adoption of the plan by the designated management agency for the wastewater treatment plant, local sewer service area plans are considered for adoption by SEWRPC as a formal amendment to the regional water quality management plan. The Commission then forwards the plans to the WDNR for approval.

Map 4

EXISTING LAND USE WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



SINGLE-FAMILY RESIDENTIAL

MULTI-FAMILY RESIDENTIAL

COMMERCIAL

INDUSTRIAL

TRANSPORTATION, COMMUNICATIONS, AND UTILITIES

GOVERNMENT AND INSTITUTIONAL

RECREATION

WETLANDS

WOODLANDS

SURFACE WATER

AGRICULTURAL, UNUSED, AND OTHER OPEN LANDS

EXTRACTIVE AND LANDFILL

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

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

N

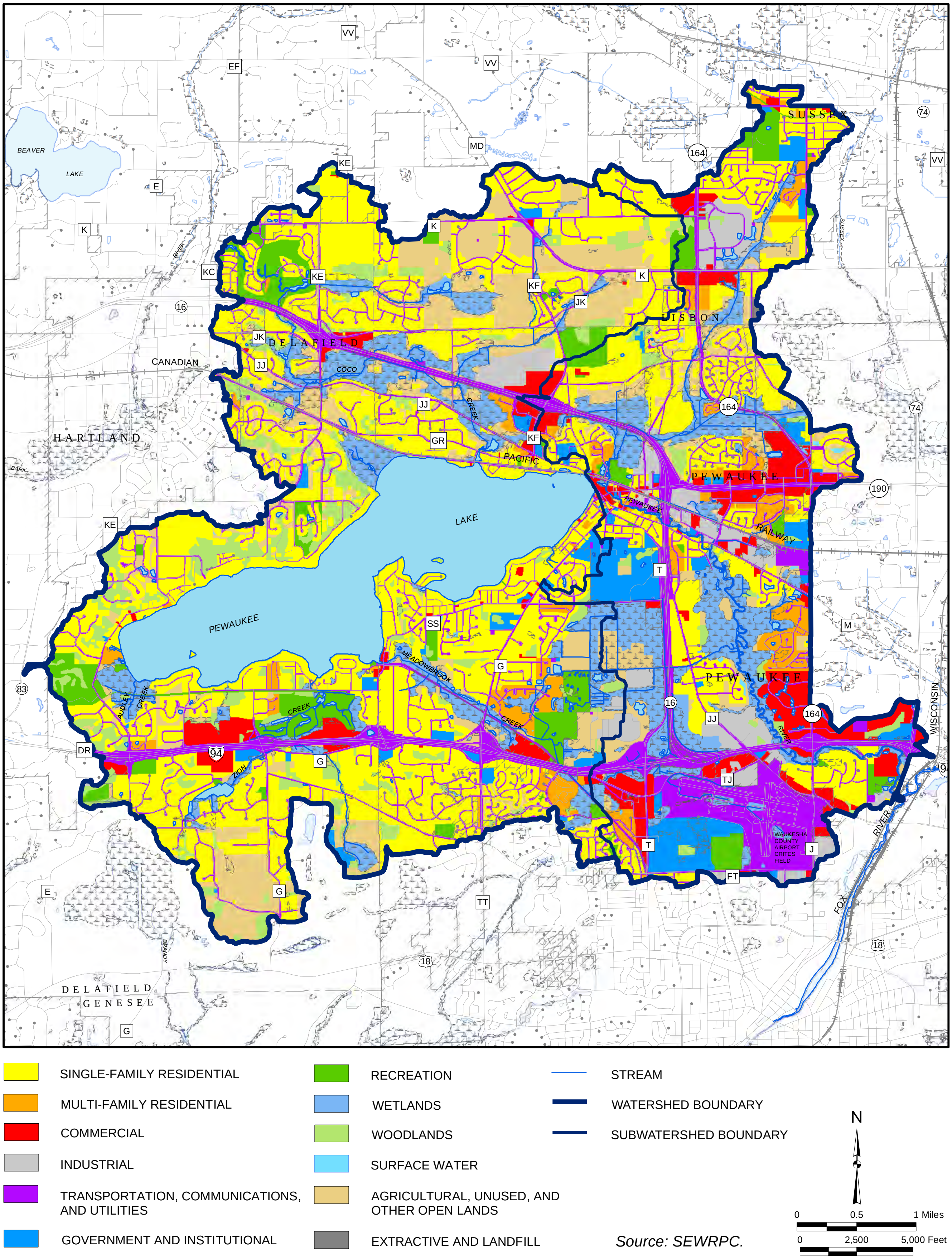
0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

Map 5

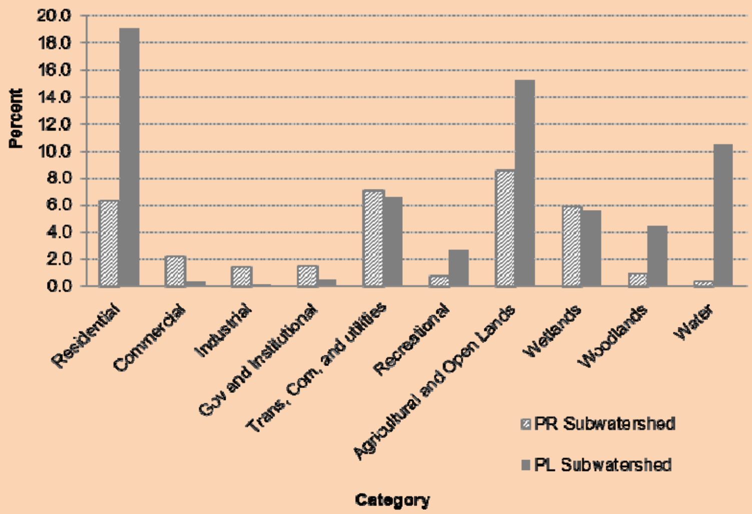
PLANNED LAND USE WITHIN THE PEWAUKEE RIVER WATERSHED: 2035



Source: SEWRPC.

Figure 7

PROPORTION OF LAND USE AMONG THE PEWAUKEE RIVER (PR) AND PEWAUKEE LAKE (PL) SUBWATERSHEDS WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



Source: SEWRPC.

There are no wastewater treatment plants within the Pewaukee River watershed. The closest sewage treatment plant is located outside of the watershed in the Village of Sussex. Sewer service areas have been adopted for most of the watershed area except for parts of the Towns of Delafield, Lisbon and Merton and a portion of the City of Pewaukee.

Rural Land Use

As shown in Table 1, in 2010, rural lands—consisting of woodlands, wetlands, surface water, agricultural croplands and other open lands—comprised about 51 percent of the total land area of the Pewaukee River watershed. Agricultural, unused and other open land uses were the largest rural land use in the watershed, encompassing nearly 24 percent of the total land area. Agricultural land use is comprised of active cropland and other open lands, which includes farm buildings, pastures, grasslands that have not succeeded to wetland or woodland communities, and lands adjacent to cropland, such as treelines and hedgerows. For the agricultural and open lands present within the watershed during 2010, approximately 5,190 acres or 90 percent of the soils are considered most suitable for agricultural uses (i.e., "prime" agricultural lands or "soils of statewide importance" as shown on Map 7). The category of agricultural land that meets the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) definition of "prime" agricultural soils includes those lands that would meet the prime classification if artificially drained or protected from flooding. These lands include approximately 3,800 acres, or 66 percent of the watershed. A second category includes agricultural land that does not meet the Federal definition of prime agricultural soils, but is classified by the State as being "soils of statewide importance." These lands include 1,391 acres, or 24 percent of the watershed land area.[3] The third category, shown on Map 7, includes other lands that do not meet either the State or Federal definitions, and primarily includes fields with slopes greater than 12 percent. This category contains 607 acres, or 10 percent of the remaining agricultural and other lands. In summary, the PL subwatershed contains nearly twice the amount of agricultural and open lands and the majority of the highest soils for agriculture purposes compared to the PR subwatershed.

Historically, before European settlement in the mid 1800s, the landscape within the Pewaukee River watershed consisted largely of oak savanna (oak opening), a transitional habitat between forest and grassland containing prairie grasses and forbs beneath widely spaced trees, primarily Bur oaks. Other natural habitats in the watershed included oak forest, open wetlands, maple-basswood forest, lowland hardwoods, and conifer swamp. The extent of these natural habitat types in the Pewaukee River watershed, derived from the original land survey records, is shown on Map 8.

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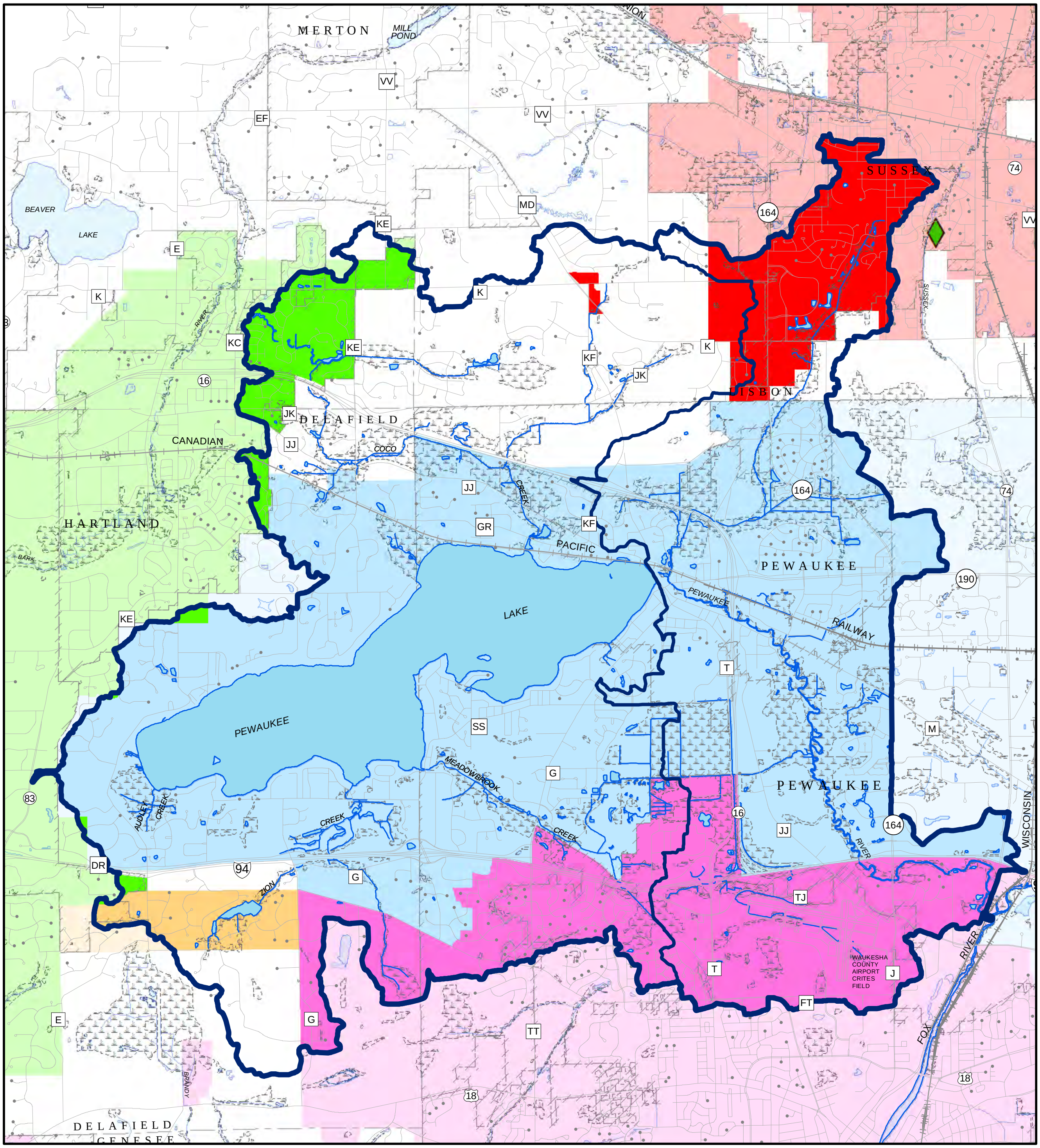
[3]*In the Pewaukee River watershed, the agricultural lands placed in the second category do not meet the Federal definition primarily because of steep slopes (6 to 12 percent) and poor drainage (water table at zero to three foot depth). However, with the application of soil conservation or drainage practices, these soils have proven to be very productive in Wisconsin.*

Map 6

ADOPTED SANITARY SEWER SERVICE AREAS WITHIN THE PEWAUKEE RIVER WATERSHED: 2009



	CITY OF WAUKESHA
	CITY OF WAUKESHA OR FOX RIVER WATER POLLUTION CONTROL COMMISSION
	DELAFIELD-HARTLAND WATER POLLUTION CONTROL COMMISSION
	FOX RIVER WATER POLLUTION CONTROL COMMISSION
	VILLAGE OF SUSSEX
	EXISTING TREATMENT PLANTS: DECEMBER 2010
	SURFACE WATER
	STREAM
	WATERSHED BOUNDARY
	SUBWATERSHED BOUNDARY

Source: SEWRPC.

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

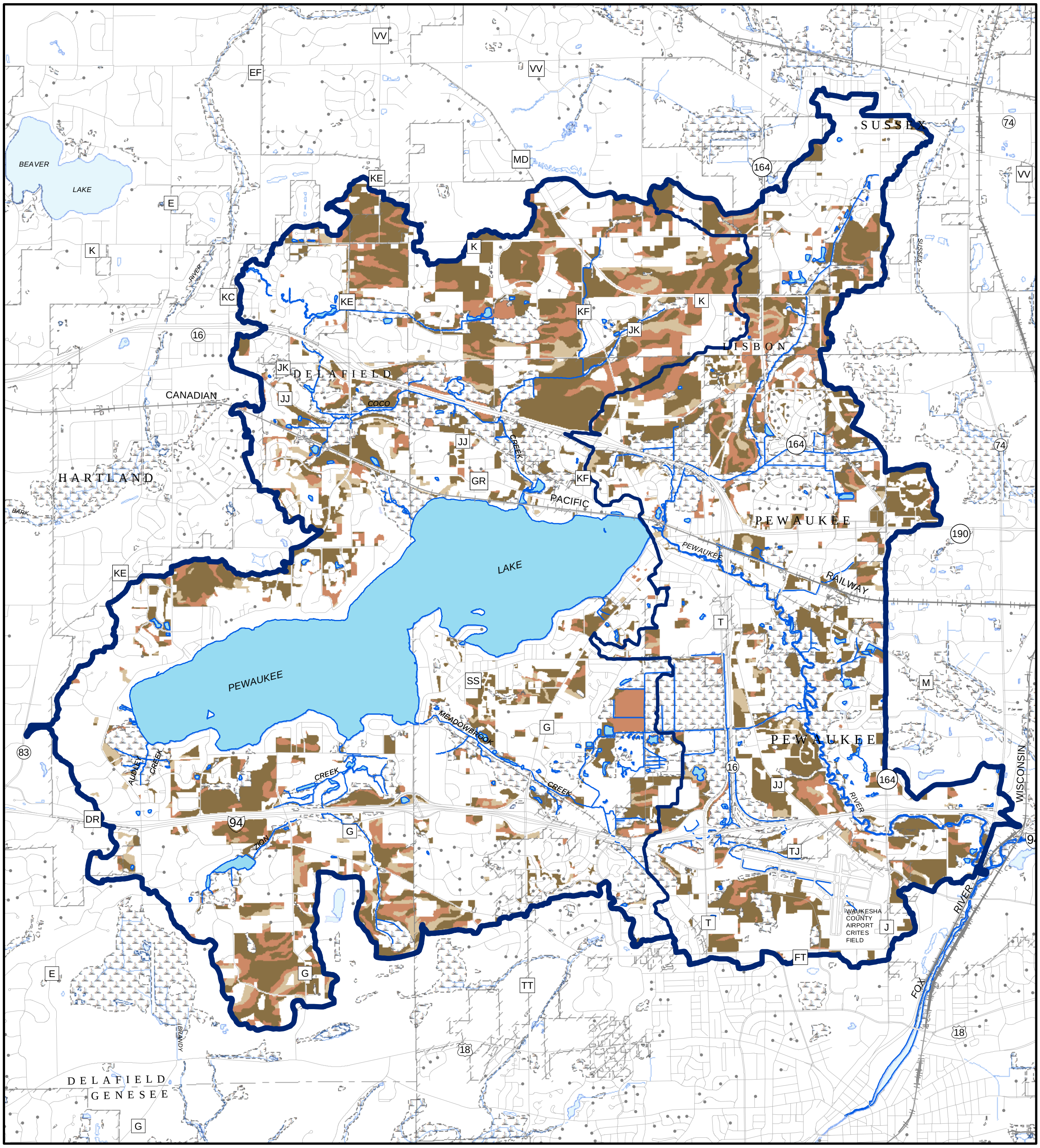
N

0 0.5 1 Miles

0 2,500 5,000 Feet

Map 7

FEDERAL AND STATE SOIL CLASSIFICATIONS FOR AGRICULTURAL AND OPEN LAND USES WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



NRCS PRIME AGRICULTURAL SOILS GROUP (INCLUDES PRIME IF DRAINED OR PROTECTED FROM FLOODING)

SOILS OF STATEWIDE IMPORTANCE (NOT IN NRCS PRIME GROUP)

OTHER AGRICULTURAL LANDS (NOT MEETING STATE OR FEDERAL CATEGORIES)

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

N

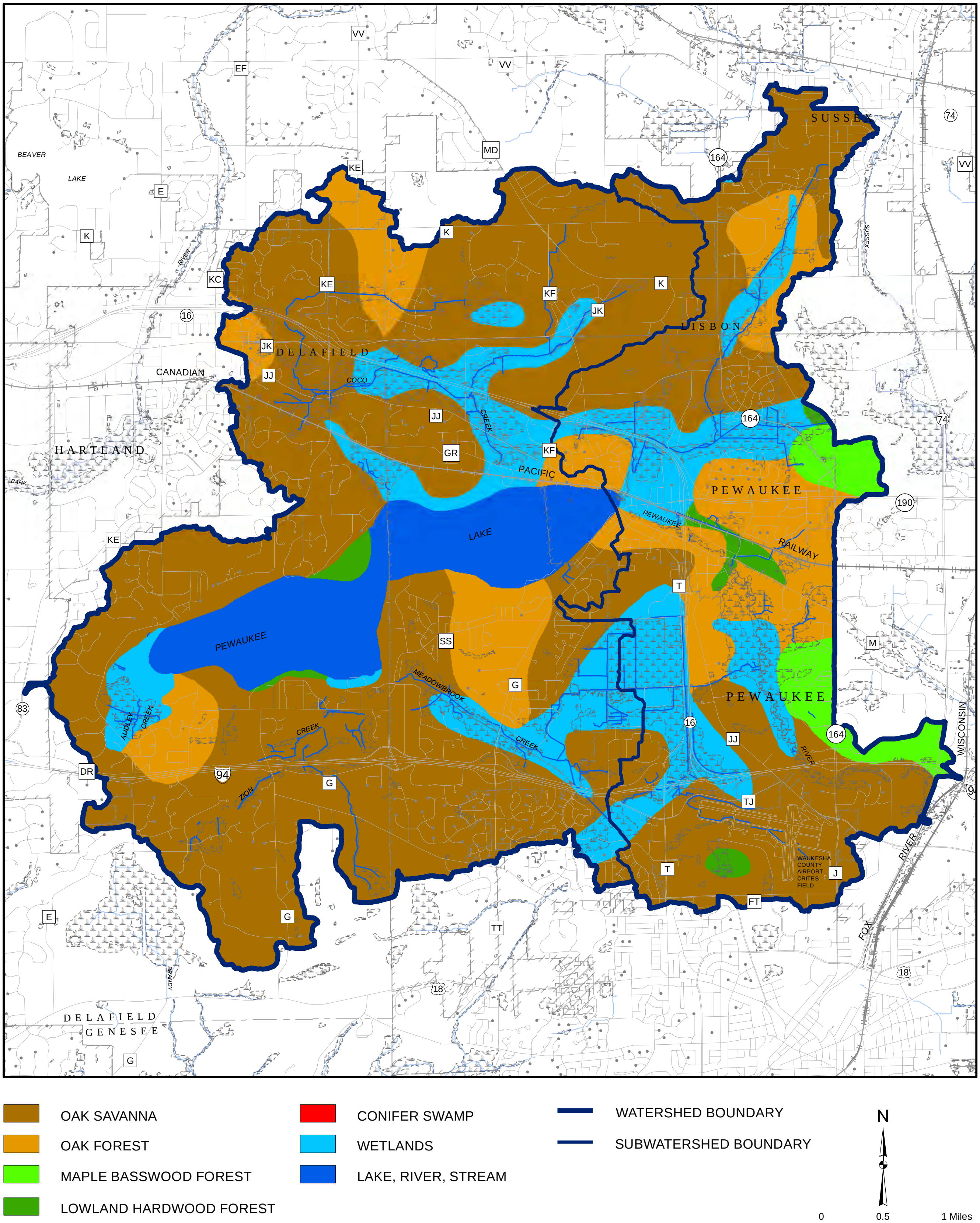
0 0.5 1 Miles

0 2,500 5,000 Feet

Source: Natural Resources Conservation Service and SEWRPC.

Map 8

PRE-SETTLEMENT VEGETATION WITHIN THE PEWAUKEE RIVER WATERSHED: 1836



Source: SEWRPC.

Following European settlement, large portions of the landscape were converted to agricultural use. Natural vegetation was cleared to make way for crops. Efforts were made to open up wetlands to cultivation through ditching and draining of wet soils. Steeply sloped lands that were spared the plow were often opened up to grazing by livestock. This land conversion had significant consequences on water quality, water quantity, and wildlife habitat. For example, water quality has been compromised through increases in erosion leading to siltation of surface waters. Natural waterways have been dredged and straightened to facilitate rapid runoff bypassing natural functions of adjacent wetlands including absorbing flood waters.

By 1940, agricultural land was the most dominant land use and comprised more than 70 percent of the total watershed area, based on the historical urban growth data and historical aerial photographs. Comparing this to the area of agricultural land in the year 2010, there has been a loss of nearly 11,300 acres. This agricultural land has been largely converted into urban land uses, primarily residential, but also transportation. The construction of IH 94 and of STH 16 subsequent to 1950 contributed to the development of residential land uses in the watershed. This second major phase of land conversion has led to other water quality and quantity issues For instance, the substantial increase in impervious surfaces has altered the infiltration rates throughout the watershed. However, comparison of 1941 aerial photographs to the year 2010 aerial photographs shows that a significant portion of the agricultural land has reverted back to woodland and wetland throughout large areas of the watershed. This reversion is especially evident along the riverine corridors, as shown in Figures 8, 9, and 10 (see also Riparian Management Practices subsection below). This has served to de-fragment and expand the environmental corridors that are currently present, and substantiating the ability of the landscape to shift from a "disturbed" condition to a more "natural" condition.

Between 2010 and 2035, rural land uses in the watershed are anticipated to continue to decrease by more than 60 percent, or 3,500 acres, as indicated in Table 1. The majority of this loss is anticipated to be from the conversion of agricultural croplands and other open lands to urban lands for residential, commercial, and industrial uses. Woodlands also are anticipated to experience a loss of about 124 acres during this period due to planned urban development as suggested by the current zoning ordinances within the watershed (see Table 1). Wetlands and woodlands are primarily located adjacent to the Pewaukee River, Coco Creek, Meadowbrook Creek, Zion Creek, Audley Creek, and the tributaries associated with these streams. These lands are considered to be largely Class I and II wildlife habitat areas. In addition, the majority of this wildlife habitat is located within the primary and secondary environmental corridors adjacent to the river system. Other significant portions of wildlife habitat are located within isolated natural resource areas located throughout the basin. For more details on habitat, see the Natural Resource Base-Related Elements section below.

CLIMATE

"*Wisconsin's climate is changing,*[4] *and our water resources are changing, too. Many aspects of our water resources respond to climate and can serve as indicators of climate change at various temporal and spatial scales. Analysis of historical data shows that water resources are intimately linked to local and regional climate conditions. Long-term records of lake water levels, lake ice duration, groundwater levels, and stream baseflow are correlated with long-term trends in atmospheric temperature and precipitation.*"[5]

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[4] *C.J. Kucharik, S.P. Serbin, S. Vavrus, E.J. Hopkins, and M.M. Motew, "Patterns of climate change across Wisconsin from 1950 to 2006,"* Physical Geography, *Vol. 31, No. 1, 2010.*

[5] *Wisconsin Initiative on Climate Change Impacts (WICCI),* Wisconsin's Changing Climate: Impacts and Adaptation, *Nelson Institute for Environmental Studies, University of Wisconsin-Madison, and Wisconsin Department of Natural Resources, February 2011.*

Figure 8

COMPARISON OF LAND USE NEAR PEWAUKEE RIVER IN 1941 VERSUS 2010

Figure 8 (continued)

Source: SEWRPC.

Figure 9

COMPARISON OF LAND USE NEAR THE PEWAUKEE RIVER UPSTREAM OF PEWAUKEE LAKE WITHIN COCO CREEK 1941 VERSUS 2010

Source: SEWRPC.

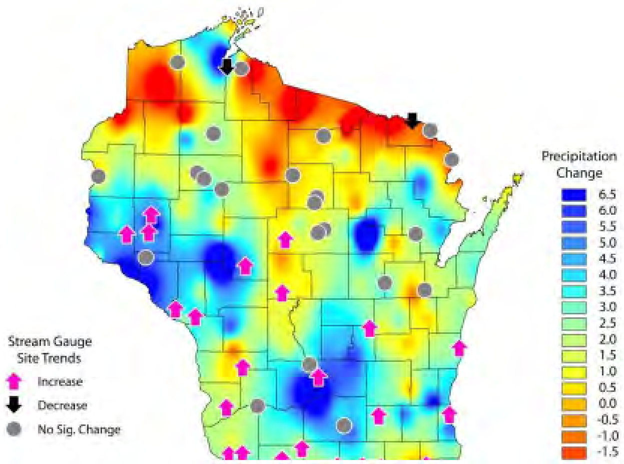
Figure 10

COMPARISON OF LAND USE NEAR THE PEWAUKEE RIVER UPSTREAM OF PEWAUKEE LAKE WITHIN MEADOWBROOK CREEK 1941 VERSUS 2010

Source: SEWRPC.

Figure 11

RIVER BASEFLOW TRENDS AND PRECIPITATION CHANGE IN WISCONSIN: 1950-2006

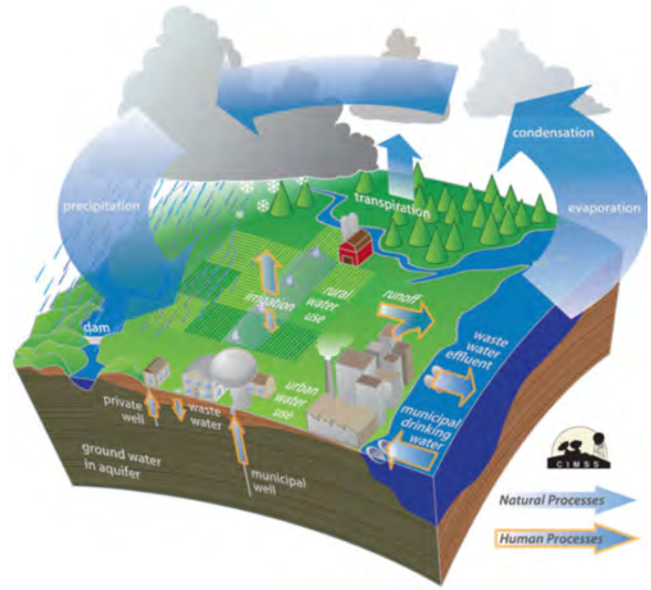


From 1950-2006, Wisconsin as a whole has become wetter, with an increase in annual precipitation of 3.1 inches. This observed increase in annual precipitation has primarily occurred in southern and western Wisconsin, while northern Wisconsin has experienced some drying. The southern and western regions of the State show increases in baseflow, corresponding to the areas with greatest precipitation increases.

Source: Wisconsin Initiative on Climate Change Impacts Water Resources Working Group and SEWRPC.

Figure 12

HYDROLOGIC CYCLE OF WATER MOVEMENT



These schematic shows how human processes associated with land use development affect the natural processes of how water moves through its different states of the hydrologic cycle. Water returns to the atmosphere through evaporation (process by which water is changed from liquid to vapor), sublimation (direct evaporation by snow and ice), and transpiration (process by which plants give off water vapor through their leaves).

Source: Wisconsin Initiative on Climate Change Impacts Water Resources Working Group and SEWRPC.

The Wisconsin Initiative on Climate Change Impacts (WICCI) has concluded that future climate projections will affect the State of Wisconsin's water resources in both quantity and quality.[6] However, WICCI also found clear evidence from analysis of past trends and probable future climate projections that there will be different hydrologic responses to climate change in different geographic regions of the State (see Figure 11). The differences reflect local variations in land use, soil type and surface deposits, groundwater characteristics, and runoff and seepage responses to precipitation, which illustrates the importance of including the existing and future conditions of these characteristics as part of the watershed protection plan strategy. Climate change seems to be altering the availability of water (volume), the distribution of rainfall over time, and whether precipitation falls as rain or snow, each of which affects water's movement through a water cycle. As shown in Figure 12, most of the water entering the landscape arrives as precipitation (rain and snowfall) that falls directly on waterbodies, runs off the land surface and enters streams, rivers, wetlands, and lakes, or percolates through the soil, recharging groundwater that flows underground and re-emerges as springs into lakes, wetlands, and streams. Even in the absence of climate change, when one part of the system is affected, all other parts are affected. For example, overdrafting the shallow groundwater for agricultural crops can lead to a reduction or complete loss in discharge of a local stream (see the Groundwater Resources subsection below). More important, climate change exposes the vulnerabilities of water available within a given community, and this vulnerability is proportional to how much humans have altered how water moves through the water cycle. This vulnerability becomes particularly evident during periods of prolonged drought conditions.

The WICCI Water Resources Working Group (WRWG) incorporated WICCI's 1980-2055 projections for temperature, precipitation (including occurrence of events), and changes in snowfall to guide their evaluation of

[6] *Wisconsin Initiative on Climate Change Impacts (WICCI), 2011.*

potential impacts to hydrologic processes and resources.[7] This team of experts prioritized the highest potential climate change impacts on water resources and proposed adaptation strategies to address impacts across the State of Wisconsin (see below). It is important to note that the WRWG developed several goals that guided the development of the adaptation strategies for local communities as well:[8]

> ***Minimize threats to public health and safety by anticipating and managing for extreme events—floods and droughts.***
> *We cannot know when and where the next flooding event will occur or be able to forecast drought conditions beyond a few months, but we do know that these extreme events may become more frequent in Wisconsin in the face of climate change. More effective planning and preparing for extreme events is an adaptation priority.*
>
> ***Increase resiliency of aquatic ecosystems to buffer the impacts of future climate changes by restoring or simulating natural processes, ensuring adequate habitat availability, and limiting human impacts on resources.***
> *A more extreme and variable climate (both in temperature and precipitation) may mean a shift in how we manage aquatic ecosystems. We need to try to adapt to the changes rather than try to resist them. Examples include managing water levels to mimic pre-development conditions at dams and other water level structures, limiting groundwater and surface water withdrawals, restoring or reconnecting floodplains and wetlands, and maintaining or providing migration corridors for fish and other aquatic organisms.*
>
> ***Stabilize future variations in water quantity and availability by managing water as an integrated resource, keeping water "local" and supporting sustainable and efficient water use.***
> *Many of our water management decisions are made under separate rules, statutory authorities, administrative frameworks, and even different government entities. This can lead to conflicting and inconsistent outcomes. In the face of climate change, the more we can do to integrate these decisions at the appropriate geographic scale, the better adapted and ready for change we will be. In addition, treating our water as a finite resource and knowing that supply will not always match demand will allow for more sustainable water use in the future.*
>
> ***Maintain, improve, or restore water quality under a changing climate regime by promoting actions to reduce nutrient and sediment loading.***
> *Water quality initiatives will need to be redoubled under a changing climate in order to minimize worse-case scenarios such as fish kills, harmful blue-green algae blooms, or mobilization of sediments and nutrients and to prevent exacerbation of existing problems.*

Local Climate Changes

In an effort to determine actual temperature and precipitation conditions for the project area, long-term average annual and seasonal air temperature and total precipitation values were derived from official National Oceanic and Atmospheric Administration (NOAA) records for the weather recording station at Waukesha, Wisconsin. Due to its relative proximity to the project area, the records of this station may be considered typical of the entire watershed.

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[7] *The Water Resources Working Group (WRWG) included 25 members representing the Federal government, State government, the University of Wisconsin System, the Great Lakes Indian Fish and Wildlife Commission, and the Wisconsin Wetlands Association. Members were considered experts in the fields of aquatic biology, hydrology, hydrogeology, limnology, engineering, and wetland ecology in Wisconsin. Over the course of a year, the group convened to discuss current climate-related water resources research, potential climate change impacts, possible adaptation strategies, and future research and monitoring needs across the entire State of Wisconsin. For more details on climate change, impacts, adaptation, and resources visit* http://www.wicci.wisc.edu/water-resources-working-group.php.

[8] *Wisconsin Initiative on Climate Change Impacts, February 2011*, op. cit.

The Wisconsin State Climatology Office calculated a long-term annual average temperature of 46.5 degrees Fahrenheit (ºF) and total precipitation of 31.79 inches from years 1895-2007 for the Southeast Wisconsin climate division, which was a composite of multiple stations in this region of the State. A climate division has been defined by the National Climatic Data Center to be an area of the State that has relatively uniform climate characteristics using data from stations that record both temperature and precipitation. These regions, which were created in 1950, correspond to the Crop Reporting Districts of the U.S. Department of Agriculture and typically have boundaries corresponding to county and State boundaries, except in mountainous states where topographic features are used to determine the boundaries. The Southeast climate division is one of nine separate divisions in the State of Wisconsin.

The Wisconsin State Climatology Office further determined the long-term total precipitation and average temperatures for each season for southeastern Wisconsin for available data from 1985 to present. Seasonal total precipitation values include: Spring (March through May) 8.47 inches from 1895-2008; summer (June through August) 10.78 inches from 1895-2008; fall (September through November) 8.0 inches from 1895-2009; and 4.57 inches for winter (begins in December of previous year through February) from 1895-2005. Average temperatures for each season for Southeast Wisconsin were determined as follows: Spring (March through May) 44.7 F from 1895-2008; summer (June through August) 69.1 F from 1895-2008; fall (September through November) 50.0 F from 1895-2010; and 22.4 F in winter (begins in December of previous year through February) from 1895-2005.

Seasonal average temperature and total precipitation were calculated for the Waukesha station (station closest to the Pewaukee River watershed) for the period of record from 1950 through 2012 in the same seasonal breakdowns as discussed above for southeastern Wisconsin. The seasonal average temperatures of the Waukesha station were subtracted from the Southeast Wisconsin seasonal derived long-term average temperature and total precipitation in order to obtain departures from normal for this one station.

Normal conditions for the Waukesha station for average temperature and total precipitation were defined as being within an additional plus or minus 2ºF and two inches of total precipitation for each seasonal total precipitation and average temperature, respectively. For example, any total precipitations in the spring season ranging from 6.47 to 10.47 inches were considered normal and replaced by a zero to indicate normal spring season precipitation conditions to simplify the graph as shown in Figure 13. Similarly, average temperatures for the spring season ranging from 42.7 to 46.7ºF were considered normal and replaced by a zero to indicate normal spring season temperature conditions for purposes of graphing.

Pre- vs. Post-1980

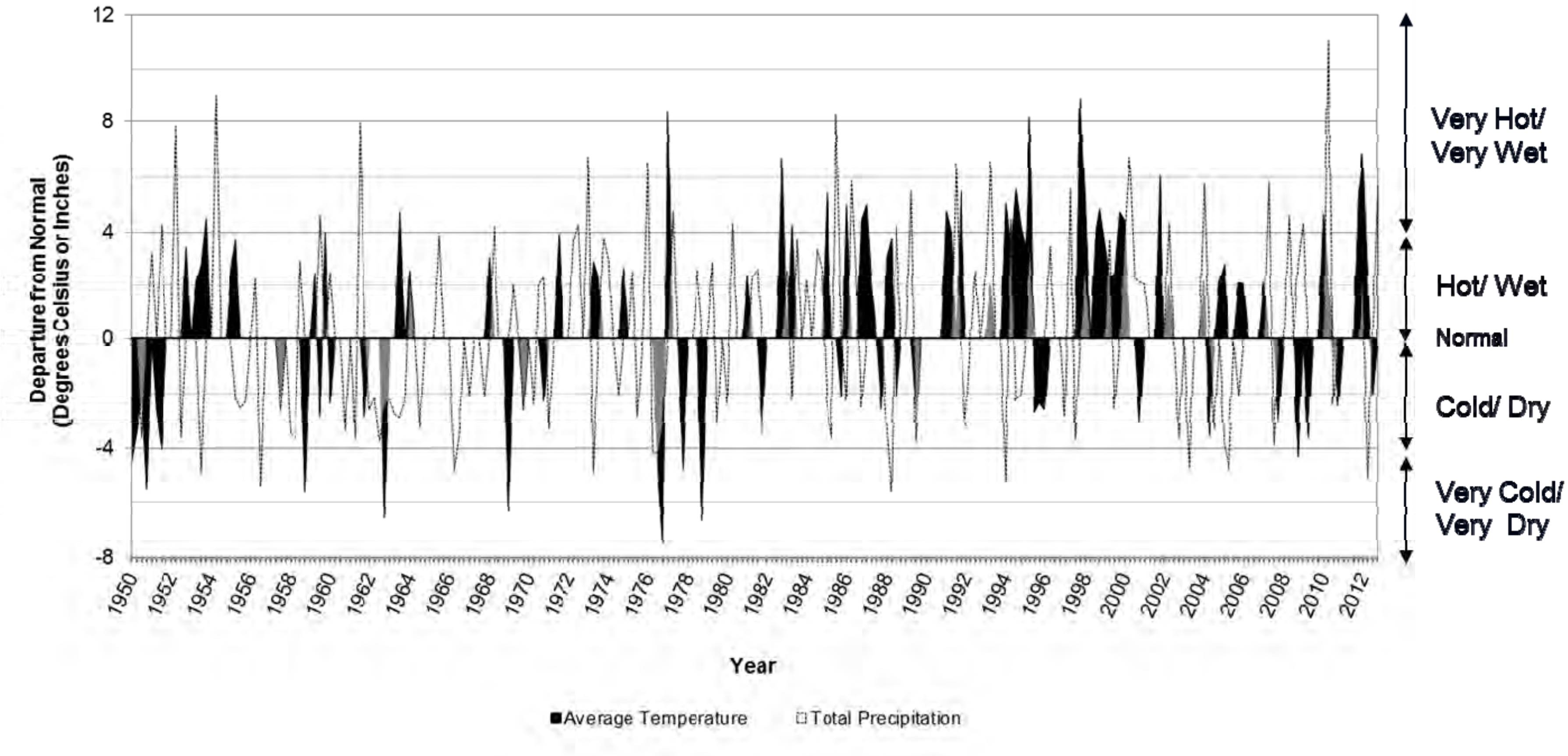
For purposes of this analysis, the 1950-1980 record was considered a base time period to compare with more recent changes in temperature and precipitation in this study between the years 1981-2012. This base period is consistent with previous studies at regional, national, and world scales.[9]

The mean annual air temperature and total precipitation at Waukesha increased from 46.6 to 47.5ºF and from 32.0 to 34.1 inches between pre-1980 and post-1980 years, respectively. Figure 13 shows that variability in average temperature and total precipitation is unpredictably high from season to season and year to year. Figure 13 distinguishes warm versus cold, as well as wet versus dry seasons among years, based upon the derived departures from normal. Based upon the resulting classifications, it is easy to see that there was a much higher proportion of warmer seasons among years post-1980, indicating that the past 32 years have been relatively warmer than the preceding years in the 63-year period of record. For example, 42 of the seasons between 1980 and

[9] *James Hansena, Makiko Satoa, and Reto Ruedy, "Perception of climate change," Proceedings of the National Academy of Sciences, Vol. 109 No. 37, E2415-E2423, September, 2012.* www.pnas.org/cgi/doi/10.1073/pnas.1205276109.

Figure 13

CALCULATED DEPARTURES FROM NORMAL IN AVERAGE TEMPERATURE AND TOTAL PRECIPITATION IN WAUKESHA COUNTY, WISCONSIN: 1950-2012



NOTE: Shaded gray areas indicate where temperature and precipitation values overlap. Data courtesy of NOAA National Climate Data Center for the Waukesha station in southeast Wisconsin. Data for the most recent year only includes up to spring season of 2012. Winter season begins in December of year indicated. Shaded grey areas indicate overlay between temperature and precipitation.

Source: Wisconsin State Climatology Office is affiliated with the Department of Atmospheric and Oceanic Sciences at the University of Wisconsin-Madison, 1225 W. Dayton St., Madison, WI 53706, URL is http://www.aos.wisc.edu/~sco/; *National Oceanic Atmospheric Association (2012), National Climatic Data Center, National Weather Service Milwaukee/Sullivan Wisconsin, Annual Climatological Data Publications, URL is* http://www.ncdc.noaa.gov/land-based-station-data/data-publications*; and, SEWRPC.*

2008, or about 33 percent of the period, were classified as hot to very hot compared to 16 of the seasons between 1950 and 1980, or about 13 percent of this period of record. Similarly, there was a higher proportion of wet seasons in the post-1980 period when about 28 percent were classified as wet to very wet. Each of the four seasons changes in temperature and precipitation pre- versus post- 1980 were further summarized in Appendix B. Similar to Figure 13, Appendix B shows that each season, except fall, is much warmer (i.e., contains a higher proportion of warmer categories) post-1980 compared to pre-1980. In contrast, total precipitation increases post-1980 seem to mostly be occurring in the fall and winter seasons, with only slight increases in the spring and summer seasons. This demonstrates that the Pewaukee River watershed is experiencing the same general shift to wetter and warmer conditions over the period of record as observed in other areas of the State of Wisconsin.[10]

Hence, these climatic conditions are drivers of water quality conditions within the Pewaukee River system and are important considerations for the protection of surface water and groundwater quality as future development occurs in this watershed. For example, higher air temperatures, which warm water and land surfaces, when combined with periods of decreased precipitation during the summer, can negatively affect surface water dissolved oxygen concentrations (see the "Effects of Urbanization and Agriculture on Instream Biological Communities" subsection below). Low dissolved oxygen concentrations are a major concern during the summer months for this watershed. Even short periods during which dissolved oxygen concentrations fall below 5.0 mg/l can cause significant decreases in the abundance and diversity of the aquatic organisms in streams. In addition, warmer and wetter winter seasons also can affect aquatic health and recreation. Winter temperatures are a major determinant of nonnative aquatic plant growth in lakes and streams in the Midwest. Warmer winters can provide advantages to nonnative species. For example, continued growth of Eurasian water milfoil (*Myriophyllum spicatum*) under the ice or early emergence following spring ice-out contributes to the degradation of the native aquatic plant community, impairment of water uses, and increased management costs and/or user conflicts. Warmer winters also may provide opportunities for colonization by other nonnative plant species, such as Hydrilla (*Hydrilla verticillata)* and fishes, among others (see Nonnative/Invasive Species section in Chapter IV of this report). Warmer winters also may result in decreased winter recreational opportunities, limiting ice fishing and snowmobiling due to unsafe or variable ice conditions, and/or increased flooding.

In addition to these changes, a couple of interesting changes in precipitation seem to be occurring in the post-1980 versus the pre-1980 time period. Specifically, as shown in Figure 14, there is a much stronger relationship between post-1980 annual precipitation in the summer and fall seasons than existed prior to 1980. This seems to indicate that total precipitation within a particular year is largely determined by the amounts of precipitation in the spring season. In other words, if the total amount of precipitation in the spring is lower than normal, it is very likely that total precipitation for that particular year will also be lower than normal. A second pattern also seems to have developed between summer and fall precipitation. As for the first relationship above, there is no statistically significant relationship between summer and fall precipitation prior to 1980. However, post-1980 there is a strong inverse relationship in precipitation between the summer and fall seasons, which indicates that when summers are dryer than normal, the following fall will tend to be wetter than normal. This relationship may prove to be a helpful tool in terms of planning for future projects, assuming that this relationship will continue to be a strong one in the future.

In general, the years 2011 and 2012, during which this project was conducted, were characterized by normal to below-average precipitation levels and above-normal temperatures. Most of the year in 2011, namely spring, summer, and fall, was characterized as within normal levels of total precipitation and average temperatures. In contrast, the winter of 2011 to 2012 had temperatures well above normal by 5.43ºF and although this winter was also considered to have normal total precipitation, there were well below normal levels of precipitation

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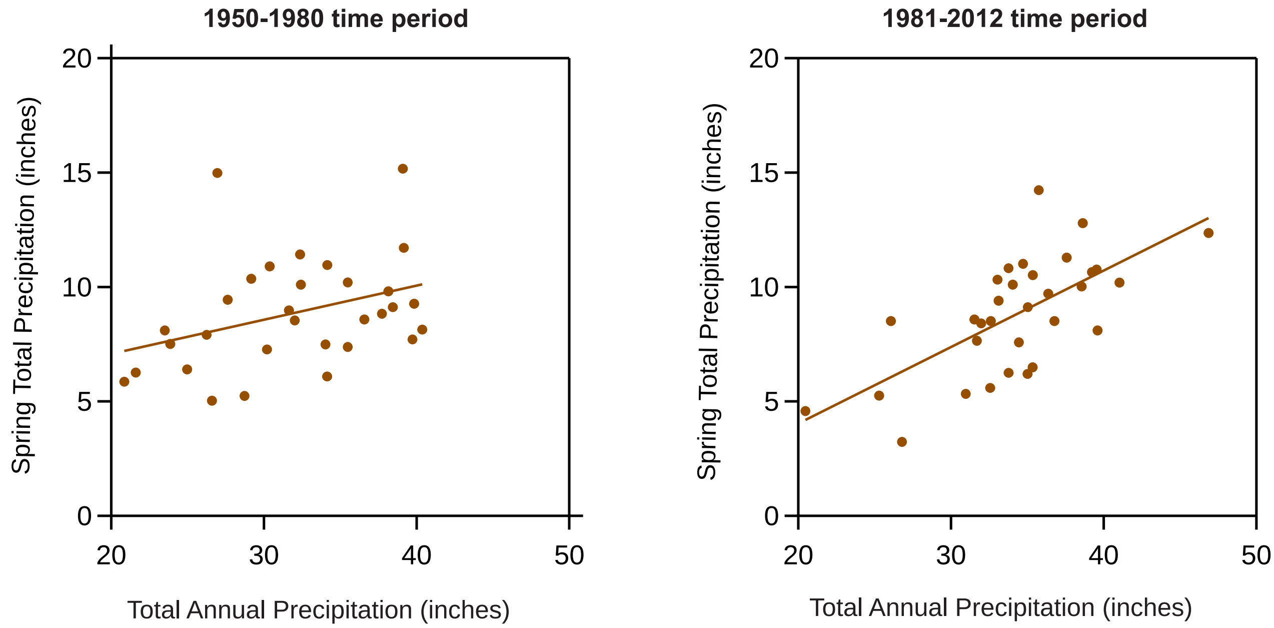
[10]*Wisconsin Academy of Sciences, Arts and Letters (WASAL),* Waters of Wisconsin: The Future of Our Aquatic Ecosystems and Resources, *Madison, Wisconsin, January 2003.*

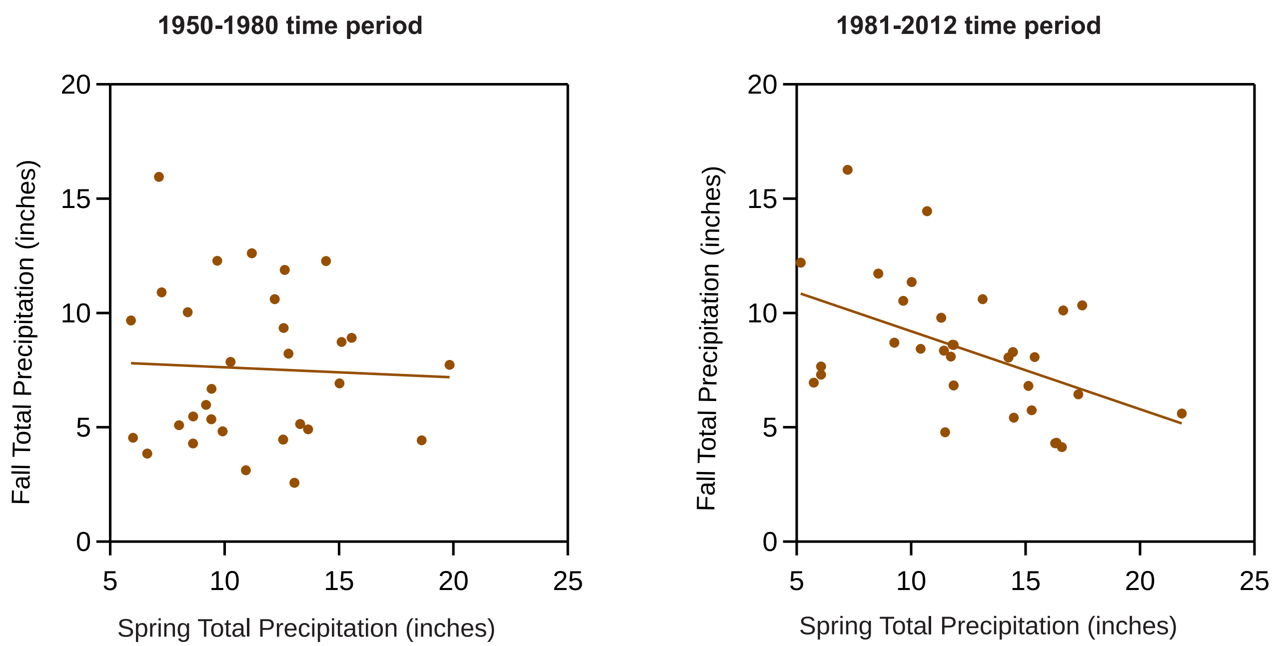
Figure 14

PRE- VERSUS POST-1980 CHANGES IN SEASONAL TOTAL PRECIPITATION AT THE NOAA WAUKESHA WEATHER RECORDING STATION: 1950-2012

Spring Total Precipitation



Fall Versus Summer Total Precipitation



Source: National Oceanic and Atmospheric Administration and SEWRPC.

as snowfall. That winter was followed by the warmest March on record for the U.S. and State of Wisconsin.[11] Wisconsin temperatures rose 15 to 30ºF above normal on most of the days between March 6 and 28. Maximum air temperatures during the month peaked in the lower to mid-80s on March 20 and 21 across the southern two-thirds of the State. This increase had a significant impact on water temperatures both locally throughout the Pewaukee River and Fox River as well as the Great Lakes region as shown in Figure 15. The surface water temperature of each of the Great Lakes increased above average conditions by about 3 to 5 degrees Celsius (ºC), (6.4 to 9.0ºF) within a period of about 14 days, which is incredible given the huge volumes of water each lake contains. Snowfall was well below normal, and there was no snow in southern Wisconsin after March 8. Trees, flowers, shrubs, bushes, and fruit orchards bloomed early and this period of unseasonably high temperatures also favored excessive growth of Eurasian Water Milfoil, an invasive aquatic plant, in lakes throughout southeastern Wisconsin. Overall, the average monthly temperatures were 13 to 16ºF above normal. This early warm-up was then followed up with a very hot July that was tied for the fourth warmest on record in Wisconsin, which was then followed by a summer-fall drought which ended in mid-October.[12] This caused streamflow levels within the Pewaukee River system to be well below normal during the period of this study. Hence, this early seasonal time series of air and water temperatures demonstrates how extreme temperature events can affect waterways at local, regional, and national scales. In addition, this hotter and dryer than normal year also had important implications concerning the water quality and biological assessments that were summarized in Chapter IV of this report.

GEOLOGY AND PHYSIOGRAPHY

The topographic elevations in the Pewaukee River watershed shown on Map 9 range from approximately 750 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29) along the lower two-thirds of the Pewaukee River and near the confluence of Pewaukee River with the Fox River in the southeastern portion of the watershed, up to over 1,125 feet above NGVD 29 in the northern and southwestern portions of the watershed—a variation of about 375 feet. Most of the high points in the watershed are part of the Inter-Lobate Kettle Moraine along the northern, western, and southern edges of the watershed surrounding Pewaukee Lake. The Inter-Lobate Kettle Moraine is one of the major physiographic and topographic features in the watershed and is part of much larger glacial landform features that were formed more than 10,000 years ago.[13]

Land slopes within the watershed range from less than 1 percent to greater than 20 percent. However, significant portions of the Pewaukee River watershed contain slopes exceeding 12 percent, with many such areas being located along the Kettle Moraine. About 2 percent of the total land area of the watershed has slopes of 20 percent or greater. About 7 percent of the total land area has slopes of between 13 and 19 percent. Poorly planned hillside development in these areas can lead to severe construction and post-construction erosion problems, and high maintenance costs associated with public infrastructure. Steeply sloped agricultural lands may make the operation of agricultural equipment difficult or even hazardous, while development or cultivation of steeply sloped lands is likely to result in erosion and sedimentation that negatively impact surface water quality. However, about three-fourths of the watershed has slopes of less than 6 percent.

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[11]*National Weather Service,* 2012 Wisconsin Yearly Weather Summary*, National and Oceanic Atmospheric Association.*

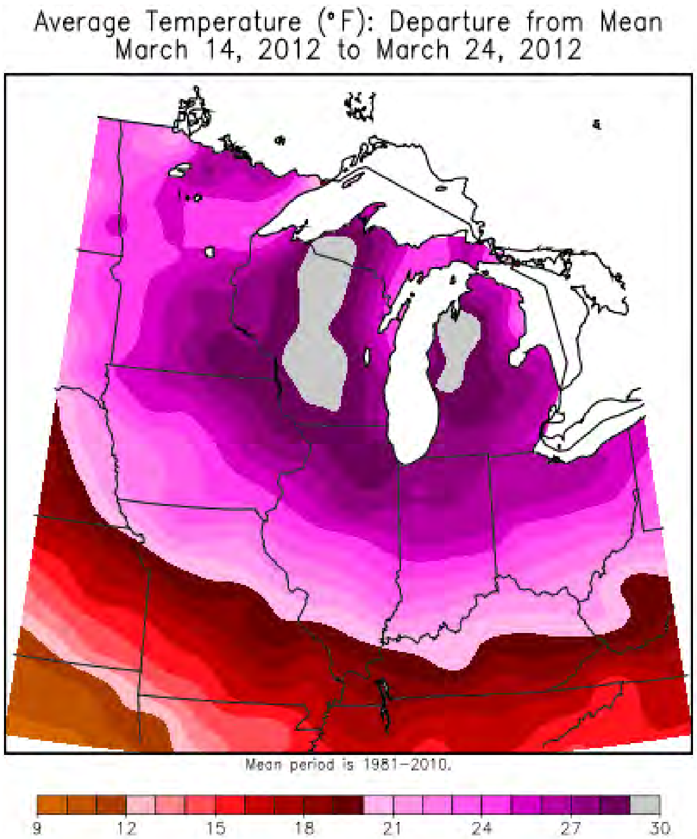
[12]*A drought emergency was declared for Waukesha County during the summer of 2012, News Release No. 0250.12; July 25, 2012,* http://usda.gov, http://droughtmonitor.unl.edu/archive.html*; U.S. Drought Monitor Archives,* http://water.weather.gov/precip/*; NOAA Advanced Hydrologic Prediction Service website.*

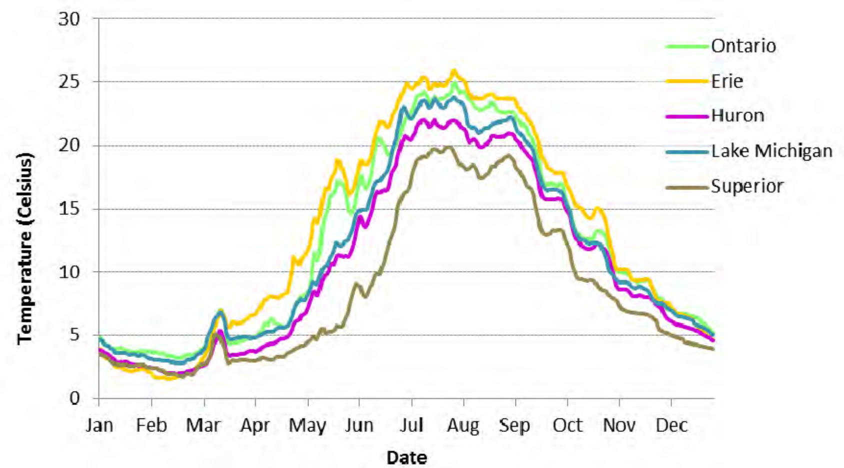
[13]*Waukesha County Department of Parks and Land Use-Land Resources Division,* Waukesha County Land and Water Resources Management Plan: 2006-2010*, March 2006.*

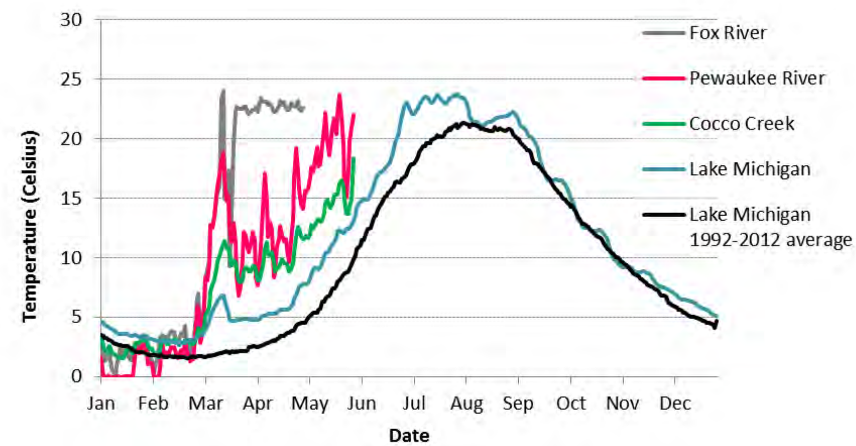
Figure 15

AVERAGE DAILY AIR AND WATER TEMPERATURES IN THE MIDWEST, GREAT LAKES, UPPER FOX RIVER, AND PEWAUKEE RIVER WATERSHED: 2012

The March early warming signature was observed across multiples scales throughout the Great Lakes region with nearly every waterbody peaking simultaneously on March 22





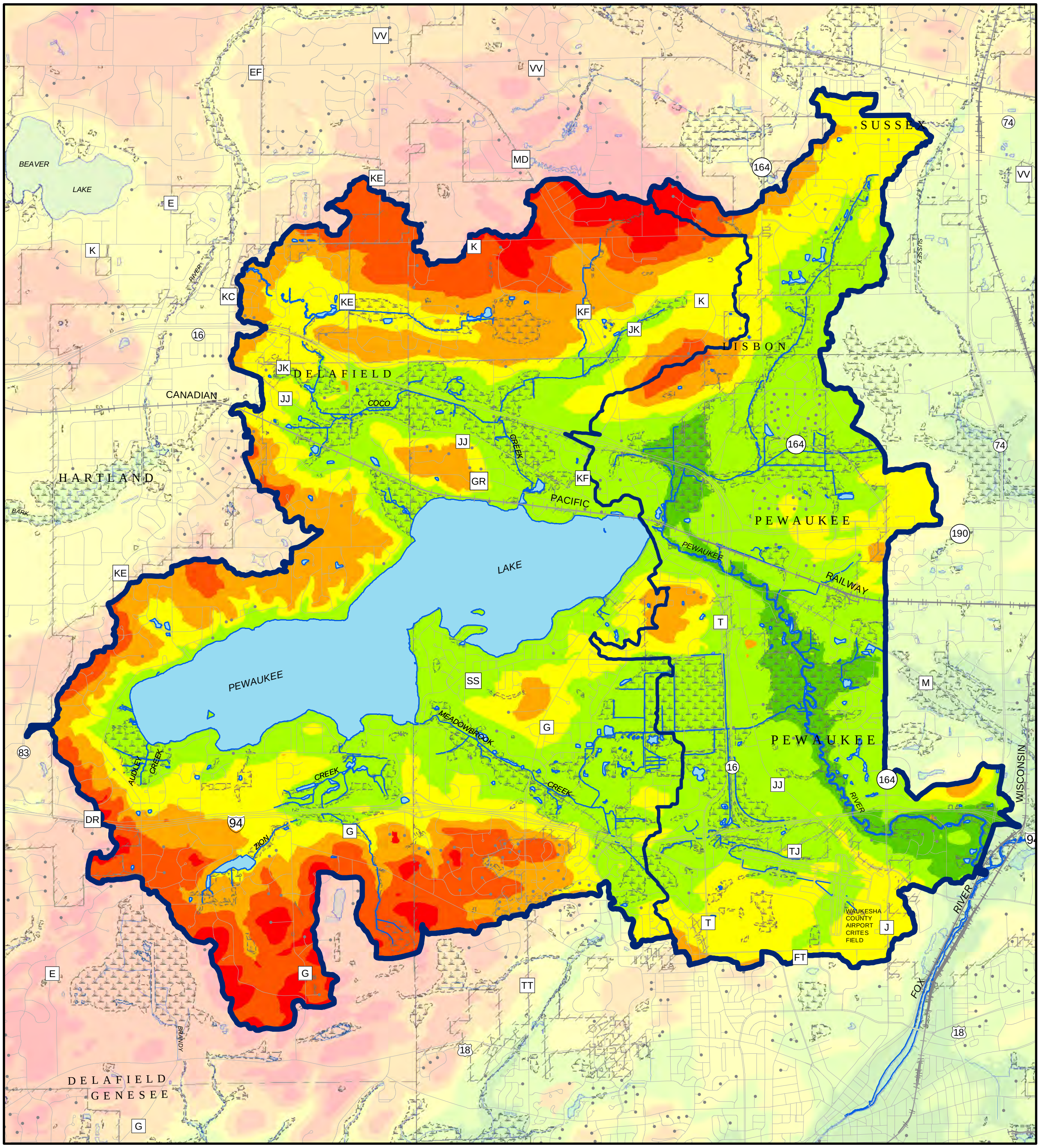


NOTE: 2012 was the warmest year ever recorded in the contiguous lower 48 states since 1895, according to NOAA.

Source: Midwestern Regional Climate Center, Illinois State Water Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign, Great Lakes Environmental Research Laboratory (GLERL) http://coastwatch.glerl.noaa.gov/statistic/statistic.html, *NOAA, and SEWRPC.*

Map 9

TOPOGRAPHIC AND PHYSIOGRAPHIC CHARACTERISTICS WITHIN THE PEWAUKEE RIVER WATERSHED



750 - 800	950 - 1000	SURFACE WATER
800 - 850	1000 - 1050	STREAM
850 - 900	1050 - 1125	WATERSHED BOUNDARY
900 - 950	ELEVATION IN FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM, 1929 ADJUSTMENT	SUBWATERSHED BOUNDARY

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

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

Bedrock Geology

The bedrock and surface deposits overlying the bedrock directly and indirectly affect the quantity and quality of surface water and groundwater in the Pewaukee River watershed, which is underlain by Niagara limestone (dolomite bedrock) that typically is located between 25 and 50 feet below the ground surface. However, there are some areas in the watershed where the bedrock is at the ground surface and visible as bedrock outcrops. The northeastern portion of the Pewaukee River watershed in the Village of Sussex and a portion of the Town of Lisbon has the shallowest bedrock at between 0 and 25 feet depth below the ground surface. Rock outcrops are most prevalent in this area, but can also be found in other portions of the watershed where the bedrock occurs at between 25 and 50 feet depth below the ground surface. Hence, there are three limestone quarries within or adjacent to the Pewaukee River watershed that include both the Vulcan Materials and Halquist Stone Companies in Sussex in the northeast and the Waukesha Lime & Stone Company just outside the southeast portion of the watershed along the Fox River.

The northern, western, and southern portions of the watershed contain the southern unit of the Inter-Lobate Kettle Moraine, which forms one of the dominant topographic features of the watershed as well as the watershed boundary. The depth to bedrock roughly corresponds to the increases in elevation in these areas. The Kettle Moraine, which is oriented in a generally northeast-southwest direction across western Washington, Waukesha, and Walworth Counties, is a complex system of kames (or crudely stratified conical hills); kettle holes (formed by glacial ice blocks that became separated from the ice mass, creating depressions and small lakes as the meltwater deposited material around the ice blocks); and eskers (long, narrow ridges of drift deposited in abandoned drainageways). The remainder of the watershed is covered by a variety of glacial landforms and features, including various types of moraines, drumlins, and outwash plains. The water from within the glacial sand and gravel deposits that characterize this landscape supplies the shallow wells and springs that occur within the watershed.

Fissures in the Niagara dolomite create water storages that are frequently tapped by moderately deep wells for water supply purposes. Underlying the Niagara dolomite is a relatively impervious layer of Maquoketa shale. In some pre-Pleistocene valleys in the western portions of Waukesha County, however, the Niagara dolomite is absent and the uppermost bedrock unit is the Maquoketa shale. Beneath the Maquoketa shale are dolomite and sandstone formations that constitute the "deep sandstone aquifer." This aquifer, however, is relatively unimportant in terms of its influence on the surface water resources of the County, since it does not intersect the surface drainage pattern (see the Groundwater Resources subsection below for more information). The general orientation of the aquifers within southeastern Wisconsin is shown in Figure 16.[14]

SOILS

The glaciers deposited a wide variety of soil-forming materials and sculpted many different landforms that influence soil type and stream hydrology in the Southeastern Wisconsin Region. Soil type, along with land slope, land use, and vegetative cover, are important factors determining the rate, amount, and quality of stormwater runoff and, consequently, stream and lake water quality. Soil texture and soil particle structure influence the permeability, infiltration rate, and erodibility of soils. Land slopes are important determinants of stormwater runoff velocities and therefore significantly influence the susceptibility of soils to erosion. The erosivity of the runoff can be moderated or modified by vegetation.

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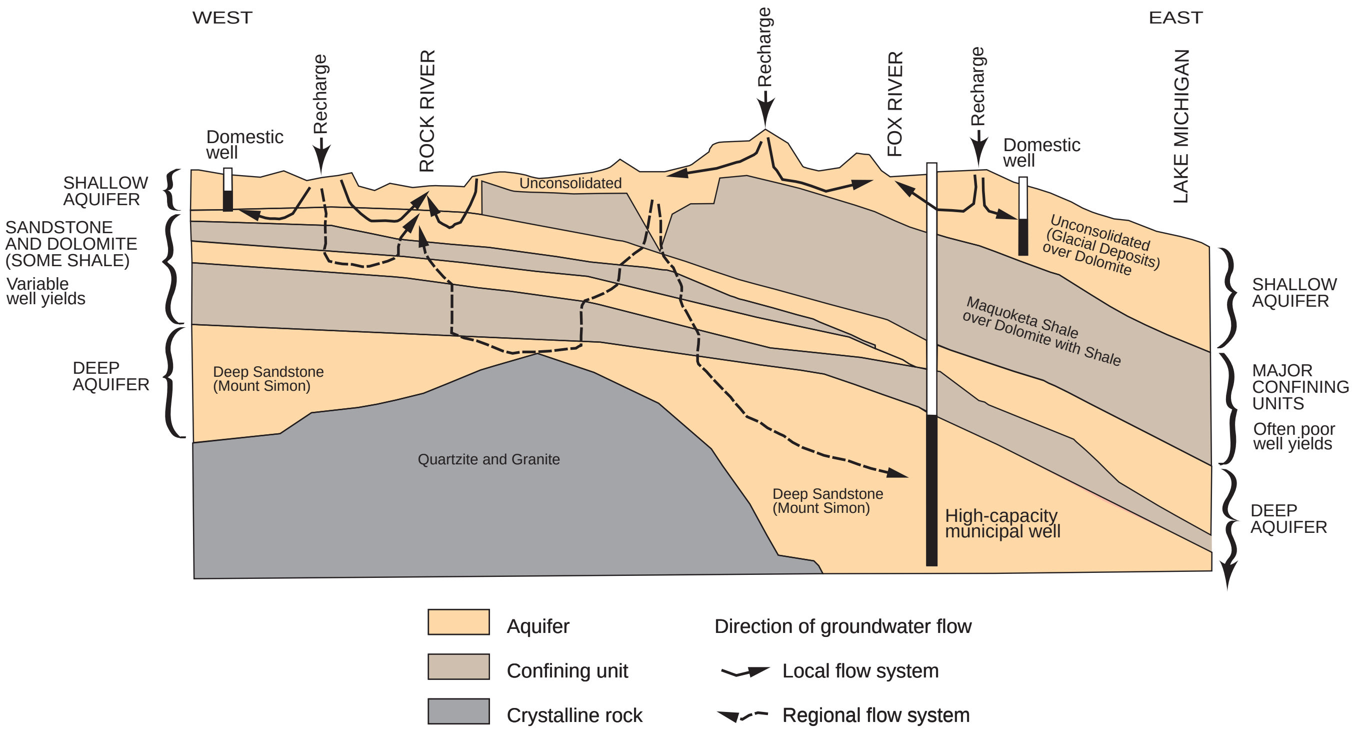
[14]*SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin, *June 2002.*

Figure 16

HYDROGEOLOGIC SECTION THROUGH SOUTHEASTERN WISCONSIN



Source: U.S. Geological Survey, University of Wisconsin-Extension, and SEWRPC.

There is only one main type of soil classification that constitutes the soil mantle within the Pewaukee River watershed: It is glacial in origin. This soil type can be further classified into four soil associations based upon the NRCS detailed soil survey of the region in 1971 that are summarized below:[15]

- Hochheim-Theresa association is comprised of well-drained soils that have a subsoil of clay loam and silty clay loam that was formed in thin loess and loam glacial till, on ground moraines.

- Pella, moderately shallow variant-Knowles association is comprised of poorly drained and well-drained soils that have a subsoil of silty clay loam or clay loam that is moderately shallow over dolomite bedrock.

- Fox-Casco association is comprised of well-drained soils that have a subsoil of clay loam. This association is moderately deep over sand and gravel and can be found on outwash plains and stream terraces.

- Rodman-Casco association is comprised of excessively- to well-drained soils that have a subsoil of clay loam and gravelly sandy loam. This association is shallow over gravel and sand.

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[15]*SEWRPC Planning Report No. 8,* Soils of Southeastern Wisconsin, *June 1966; see also U.S. Department of Agriculture Soil Conservation Service,* Soil Survey of Milwaukee and Waukesha Counties, Wisconsin, *July 1971.*

These soils generally range from poorly drained, organic soils to well drained, mineral soils. More specifically, the Hochheim-Theresa Association blankets 93.9 percent of the watershed, whereas the Pella, moderately shallow variant-Knowles Association covers 5.4 percent of the watershed. The Pella-Knowles association occurs where the bedrock is shallow in the northeastern portion of the watershed, and also in a small area associated with Zion Creek in the southwestern portion of the watershed. Minor portions of Rodman-Casco Association and of Fox-Casco Association cover 0.6 percent and 0.1 percent of the watershed, respectively.

Using the regional soil survey, these soils can be further subdivided into four main hydrologic groups; well-drained soils, moderately-drained soils, poorly-drained soils, and very poorly-drained soils. Due to the large proportion of the Pewaukee River watershed being comprised of the well-drained Hochheim-Theresa soil association, it is not surprising that this watershed contains about 68 percent moderately drained to well-drained soils. This result is consistent with the high to very high permeability along with moderate to very high groundwater recharge potential rankings of soils within this watershed.[16]

WATER RESOURCES

The Pewaukee River watershed covers about 38 square miles (about 24,380 acres). It is one of several subwatersheds that comprise the Upper Fox River watershed and it represents about 4 percent of the land area of that basin. The problems or threats facing the water resources of the Pewaukee River watershed are similar to those facing the Fox River; namely, potential excessive nutrient input, runoff from croplands and urban lands, introductions of pesticides and herbicides, filling of wetlands, extreme fluctuations of stream flow or low flow, temperature extremes, low dissolved oxygen, loss of fish and macroinvertebrate habitat, and barriers to fish and aquatic organism migration.[17]

Surface Water Resources

The Pewaukee River is approximately 11 miles in length, extending from its headwaters in the Village of Sussex to its confluence with the Fox River in the City of Pewaukee (see Map 2 in Chapter I of this report). The Pewaukee River watershed contains several perennial tributaries, the longest being Coco Creek at about five miles in length. The other perennial tributaries include Meadow Brook, Zion Creek, and Audley Creek. Pewaukee Lake and its associated subwatershed area is technically and functionally a tributary to the Pewaukee River. The mainstem of the Pewaukee River provides a wealth of opportunity for canoeing, kayaking, fishing, and bird watching, as well as scientific study among other uses. Coco Creek is a Class II trout stream.

The only lake within the Pewaukee River watershed is Pewaukee Lake, an impounded lake which is 2,446 acres in area and is the largest lake within Waukesha County. Hence, Pewaukee Lake provides some of the highest-quality boating and other lake-related recreation in the Southeastern Wisconsin Region, including a quality musky fishery. This mixture of high-quality lake and stream systems and associated recreational benefits has provided the unique framework from which the local communities have grown and thrived within the Pewaukee River watershed.

Runoff from Urban Development and Impervious Surfaces

As indicated above, urban land use in the Pewaukee River watershed is expected to continue to increase at least through 2035. In the absence of planning, such urbanization can create negative impacts on streams and lakes. Urbanization itself is not the main factor driving the degradation of the local waterbodies. Lakes and streams can survive and even flourish in urban settings with appropriate measures to control the impacts of urbanization. The

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

[17]*Wisconsin Department of Natural Resources, Publication No. PUBL-WT-701-2002,* The State of the Southeast Fox River Basin, *February 2002.*

Table 2

APPROXIMATE PERCENTAGE OF CONNECTED IMPERVIOUS SURFACES CREATED BY URBAN DEVELOPMENT

Type of Urban Development	Impervious Surface (percent)
Suburban-Density Residential	10-15
Low-Density Residential	20-25
Medium-Density Residential	25-30
High-Density Residential	30-50
Governmental and Institutional	40-75
Industrial	70-80
Commercial	85-95

Source: Natural Resources Conservation Service and SEWRPC.

main factors leading to the degradation of urban waterbodies include: the creation of large areas of connected impervious surfaces, the lack of adequate stormwater management facilities to control the quantity and quality of runoff, the proximity of development to waterbodies, loss of natural areas, and inadequate construction site erosion controls. These factors increase the potential for the occurrence of the negative water quality/quantity effects associated with urbanization. Good land use planning, creative site design, and the application of best management practices for construction site erosion control and post-construction stormwater management can greatly reduce the potential for urban development to negatively affect the surrounding environment.

Industrial and commercial land uses generally have significantly more impervious area than residential land uses, while smaller residential lots generally have proportionately more impervious surface than larger residential lots. Table 2 lists the approximate amounts of impervious surface created by residential, industrial, and commercial development. Although commercial and industrial developments generally have a larger percentage of impervious surface, lawns—which are the single largest use of the land area in residential developments—show some similarities to impervious surfaces. When lawns are compared to woodlands and cropland, they are found to contain less soil pore space (up to 15 percent less than cropland and 24 percent less than woodland), reducing their ability to infiltrate water. In many instances, considerable soil compaction occurs during grading of home sites, significantly reducing the perviousness of lawns. Compared to turf grass, native grasses, forbs, and sedges have significantly deeper root systems, which loosen the soil and create flow channels that increase infiltration capacity. Also, owing to excessive application of fertilizers and pesticides, urban lawns typically produce higher unit loads of nutrients and pesticide than do croplands.[18] [19]When new commercial or residential developments are built near streams, the area of driveways, rooftops, sidewalks, and lawns increases; the area of native plant growths and undisturbed soils decrease; and, the ability of the shoreland area to perform its natural functions (flood control, pollutant removal, wildlife habitat, and aesthetic beauty) is diminished. In the absence of mitigating measures, urbanization impacts the watershed not only by altering the ratio between stormwater runoff and groundwater recharge, but also through changing stream hydrology (i.e., increasing stormwater runoff volumes and peak flows and altering the baseflow regime). These changes are exacerbated by altering the seasonal thermal regimes in these flowing water systems and changing other characteristics of the streams, such as channel morphology, water quality/quantity, and biological diversity.

When urban development increases, the ratio of impervious surface area in a watershed to water surface area increases, which leads to a decrease in the amount of pervious surface area. For this reason alone, many researchers throughout the United States, including researchers at the WDNR, report that the amount of *connected* impervious surface is the best indicator of the level of urbanization in a watershed.[20] Connected impervious

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[18]*Center for Watershed Protection*, Impacts of Impervious Cover on Aquatic Systems, *Watershed Protection Research Monograph No. 1, March 2003, p. 7.*

[19]*2009 Wisconsin Act 9 created Section 94.643 of the* Wisconsin Statutes *which places restrictions on the use and sale of fertilizer containing phosphorus as well as on the use and sale of other turf fertilizers. Over time, it is anticipated that these restrictions on phosphorus in fertilizer will result in reduced loads of phosphorus in runoff from lawns.*

[20]*L. Wang, J. Lyons, P. Kanehl, and R. Bannerman, "Impacts of Urbanization on Stream Habitat and Fish across Multiple Spatial Scales,"* Environmental Management, *Vol. 28, 2001, pp. 255-266.*

surfaces have a direct hydraulic connection to a stormwater drainage system, and, ultimately, to a stream. The studies mentioned above have found that relatively low levels of urbanization, 8 to 12 percent connected impervious surface, can cause subtle changes in physical (increased temperature and turbidity) and chemical (reduced dissolved oxygen and increased pollutant levels) properties of a stream, leading to a decline in the biological integrity of the stream. For example, each 1 percent increase in watershed imperviousness can lead to an increase in water temperature of nearly 2.5°F.[21] While this temperature increase may appear to be small in magnitude, this small increase can have significant impacts on fish, such as trout and other biological communities that have a low tolerance to temperature fluctuations or require specific thermal ranges.

In the absence of mitigating measures, one of the consequences of urban development is the increase in the amount of stormwater that runs off the land surface rather than infiltrating into the groundwater system. A parking lot or driveway produces much more runoff than an undisturbed prairie or agricultural hay field. Furthermore, runoff traveling over the surface of a parking lot or driveway will pick up heavy metals, bacteria, pathogens, and other pollutants which otherwise might be removed as the stormwater is filtered through vegetation or infiltrated into the surface aquifer. Runoff traveling over such impervious surfaces bypasses the filtering action of the soil particles, soil microbes, and vegetation present above (stems and leaves) and below (roots) the soil surface. In addition, the location of the impervious surfaces determines the degree of direct impact they will have on a stream. There is a greater impact from impervious surfaces located close to streams—due to the fact that less time and distance exists wherein the polluted runoff can be naturally treated before entering into a stream. A study of 47 watersheds in southeastern Wisconsin indicated that one acre of impervious surface located near a stream could have the same negative effect on aquatic communities as 10 acres of impervious surface located farther away from the stream.[22]

Because urban lands located adjacent to streams have a greater impact on the biological community, an assumption might be made that riparian buffer strips located along the streambank could absorb some of the negative runoff effects attributed to urbanization. While riparian buffers do have a mitigating effect, streambank buffers may not be the complete answer to urban stormwater impacts within the watershed since most urban stormwater is delivered directly to the stream via storm sewers or engineered channels and enters the stream without passing through the buffer zone. Riparian buffers need to be combined with other management practices, such as infiltration facilities, detention basins, and grass swales, in order to adequately mitigate the effects of urban stormwater runoff. Combining practices into such a "treatment train" can provide a much higher level of pollutant removal, than single, stand-alone practices could achieve. In this regard, it is important to note that stormwater and erosion control treatment practices vary in their function, which in turn influences their level of effectiveness. Their location on the landscape, as well as their construction and maintenance, greatly influences their level of pollutant removal.

Researchers who evaluated 134 sites on 103 streams throughout the State of Wisconsin found that the amount of urban land use upstream of their sample sites had a negative relationship with the biotic integrity scores at the sites.[23] There appeared to be a threshold of about 10 percent directly connected impervious cover in the areas

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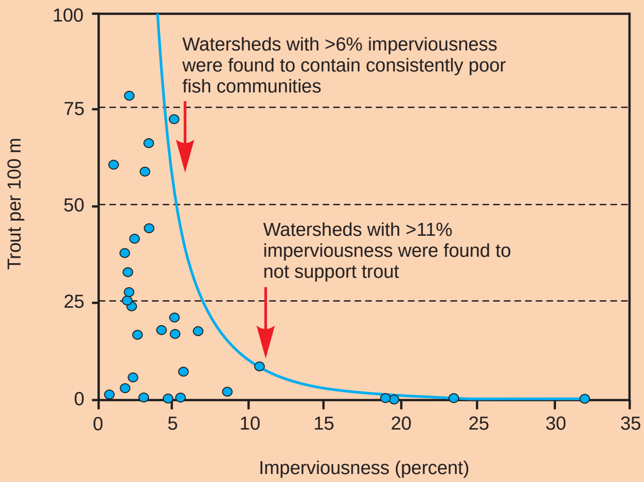
[21]*L. Wang, J. Lyons, and P. Kanehl, "Impacts of Urban Land Cover on Trout Streams in Wisconsin and Minnesota,* Transactions of the American Fisheries Society*, Vol. 132, 2003, pp. 825-839.*

[22]*L. Wang., J. Lyons, P. Kanehl, and R. Bannerman, "Impacts of Urbanization on Stream Habitat and Fish across Multiple Spatial Scales,"* Environmental Management*, Vol. 28, 2001, pp. 255-266.*

[23]*L. Wang, J. Lyons, P. Kanehl, and R. Gatti, "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams,"* Fisheries*, Volume 22, 1997.*

Figure 17

TROUT ABUNDANCE PER 100 METERS OF LINEAR STREAM DISTANCE AND PERCENT IMPERVIOUS SURFACES AMONG COLDWATER STREAM WATERSHEDS WITHIN WISCONSIN



Source: Wisconsin Department of Natural Resources.

tributary to the streams, beyond which Index of Biotic Integrity (IBI) scores declined dramatically.[24] The IBI is a measure of the quality of the fishery community and combines elements, such as abundance, diversity (number of different species), tolerance (ability of a species to tolerate pollution), feeding or trophic classifications (e.g., top carnivores, or fish that feed on other fish, vertebrates, or large aquatic insects), and healthy appearance (e.g., no deformities, eroded fins, or lesions). Fish IBI scores were found to be good to excellent below this threshold, but were consistently rated as poor to fair above this threshold. The researchers also found that habitat scores were not closely associated with degraded fish community attributes in the studied streams. Wisconsin researchers also found that the number of trout per 100 meters in coldwater streams dramatically decreased at a threshold of 6 percent imperviousness, and that no trout were observed in coldwater streams in watersheds with greater than 11 percent imperviousness (see Figure 17).[25]

A WDNR study examined 47 small streams in 43 watersheds in southeastern Wisconsin to retrospectively analyze fisheries and land use data acquired between 1970 and 1990.[26] Historical changes in land uses were determined from data provided by SEWRPC and the changes in the fishery were evaluated over the two decades. Streams that were already extensively urbanized as of 1970 had fish communities characterized as highly tolerant with low species richness.[27] As these areas urbanized even further, the fish communities changed little, as they were already considered to be degraded. In contrast, stream sites that had little urbanization (characterized by connected imperviousness) in 1970, but which were urbanizing by 1990, showed decreases in the quality of the fish community. This study further supported the finding that major differences occurred in the fisheries at the 10 percent connected impervious cover threshold, with poorer fisheries quality generally being reported for stream sites above this threshold. In addition, other studies in different eco-regions and using various techniques have supported these findings, suggesting that, as watersheds become highly urban, aquatic diversity becomes degraded.[28] In addition to increases in the amount of impervious land cover that are associated with urbanization,

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[24]*Directly connected impervious area is area that discharges directly to the stormwater drainage system without the potential for infiltration through discharge to pervious surfaces or facilities specifically designed to infiltrate runoff.*

[25]*Personal communication, L. Wang, Wisconsin Department of Natural Resources.*

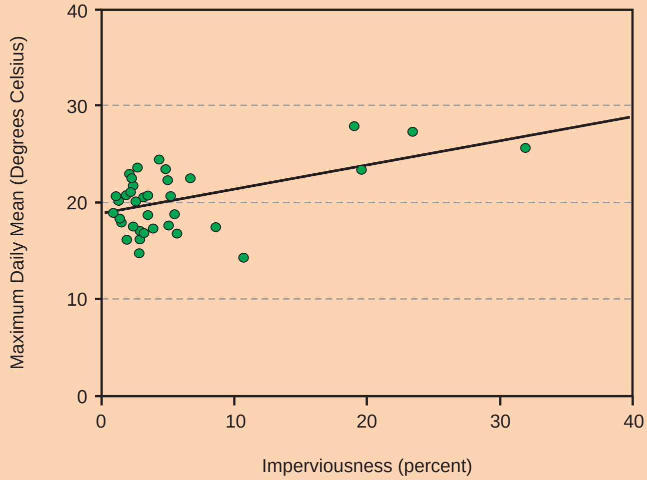
[26]*L. Wang, J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons, "Watershed Urbanization and Changes In Fish Communities In Southeastern Wisconsin Streams,"* Journal of the American Water Resources Association, *Volume 36, No. 5, 2000.*

[27]*Highly tolerant fishes can survive under degraded conditions, particularly low dissolved oxygen and high temperatures. More detail on tolerance and characterization of the fishery community in this watershed is provided in Chapter IV of this report.*

[28]*Center for Watershed Protection,* op. cit.

Figure 18

MAXIMUM DAILY WATER TEMPERATURES AND PERCENT IMPERVIOUS SURFACES AMONG COLDWATER STREAM WATERSHEDS WITHIN WISCONSIN



Source: Wisconsin Department of Natural Resources.

Table 3

OVERALL ESTIMATED PERCENT CONNECTED IMPERVIOUS SURFACE FOR THE PEWAUKEE RIVER WATERSHED

Watershed	2010	2035
Pewaukee River Subwatershed	19.3	26.4
Pewaukee Lake Subwatershed	9.1	12.6
Total Watershed	12.7	17.4

Source: SEWRPC.

urban development has often been accompanied by the alteration or loss of wetlands; disturbance or reduction in the size of riparian corridors; stream channel modification, including straightening and lining with concrete; and occasional spills of hazardous materials. All of these factors contribute to degradation of fish communities and of aquatic diversity.

A further important concern related to urban development is thermal pollution. Thermal pollution results when stormwater flows over heated surfaces, such as roads, rooftops, and parking lots, before entering streams. The main consequence of thermal pollution is oxygen depletion, because warm water cannot hold as much oxygen as cold water. As these oxygen-deficit events increase, the aquatic organisms living in the stream become more stressed, leading to decreased growth and reproduction, migration out of the system, and, in extreme cases, death of the aquatic organisms. Rainfall events that occur during the warmer summer months are more stressful to fish and other water dwelling organisms than rainfall at other times of the year, due to runoff being heated as it flows over sun-warmed impervious surfaces. When coupled with the chronic affects of reduced infiltration on baseflows to streams, these events can lead to significantly elevated temperatures in the flowing water systems. There is a direct relation between a coldwater stream's maximum daily water temperatures and the percentage of impervious surface (i.e., urban development) in the watershed (see Figure 18). Coldwater fish, such as brown trout, survive best in water temperatures less than 20°C. Temperatures a few degrees below the lethal limit of 25°C can still cause significant stress, eventually leading to illness, infection, and death.[29]

As noted above, the amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for evaluating the combined impacts of urbanization in the absence of mitigation. The Pewaukee River watershed overall had about 49 percent urban land use in 2010, which corresponds to approximately 12.7 percent directly connected imperviousness in the watershed; this is anticipated to increase to more than 17 percent by the year 2035 (see Table 3). That level of imperviousness is significantly above the threshold level of 6 to 11 percent at which negative biological impacts can be expected to occur in coldwater streams (see Figures 17 and 18). The PL subwatershed had about 29.4 percent urban land use in 2010, which corresponds to 9.1 percent directly connected imperviousness in the watershed. This is well within the threshold level at which negative biological impacts could be expected to occur. The planned 2035 development in the PL subwatershed is expected to exceed that threshold, with an estimated 12.6 percent connected impervious surface area. In contrast, the PR subwatershed has already greatly exceeded the 11 percent threshold at which negative biological impacts could be expected to occur. The PR subwatershed is currently estimated to contain

[29] *G.S. Becker,* Fishes of Wisconsin, *University of Wisconsin Press, 1983.*

19.3 percent directly connected impervious surface in 2010 and is planned to exceed 26 percent by year 2035 (see Table 3). This amount of development has often been associated with significant degradation of aquatic resources in other streams within southeastern Wisconsin.[30]

The data regarding the effects of runoff from urban development and impervious surfaces would suggest that the Pewaukee River subwatershed may exceed the threshold of being able to support a high-quality warmwater fish community and that the PL subwatershed, which currently supports a Class II trout stream (Coco Creek), may exceed the threshold of being able to support a coldwater trout community. Local stormwater management practices affecting runoff volume and quality are key to mitigating the consequences of development, one of which is the preservation of substantial riparian buffers (see Riparian Management Practices subsection below).

Runoff from Agricultural Development

In addition to the urban impacts discussed above, certain types of rural land use can also have negative impacts on riverine systems. For example, researchers in Wisconsin have found that the amount of agricultural land use upstream of sample sites had a negative relationship with biotic integrity scores. There appeared to be a threshold of about 50 percent agricultural land use, above which IBI scores declined dramatically.[31] A separate study looking at the effects of multi-scale environmental characteristics on the biota in agricultural streams in eastern Wisconsin demonstrated a strong negative correlation between fisheries IBI scores and increased proportions of agricultural land, ranging from 0 to 80 percent of the land surface within the studied watersheds, which indicates that, as the percentage of agricultural land increases, the resultant fishery community decreases in abundance and diversity.[32]

More than 70 percent of the Pewaukee River watershed was estimated to be in agricultural land use in 1950. As of 2010, agricultural land comprised about 24 percent of the land surface area within the watershed. The decline has been principally due to the conversion of agricultural land into residential subdivisions. The history of high agricultural land use combined with channel straightening or channelization that occurred in many creeks and streams throughout the Pewaukee River watershed has likely caused declines in fishery abundance and diversity as a result (see Stream Reaches and Habitat Conditions sections in Chapter IV of this report for more details). It is important to note that although the amount of agricultural land use has been reduced, there are still significant concerns related to sediment and nutrient loading into the waterways of the Pewaukee River system from agricultural practices (see below).

Riparian Management Practices

Studies of the effects of agricultural land use on biotic integrity scores have indicated a positive relationship between the fisheries IBI and increased agricultural riparian buffer vegetation width. This implies that, by analogy, the impacts of increased agricultural land use may also be mitigated by an increased width of riparian buffer, which, in turn, will act to protect the stream aquatic biota. A follow-up study investigating the influence of watershed, riparian corridor, and stream reach-scale characteristics on aquatic biota in agricultural watersheds found that the type(s) of land use within the watershed, the presence of riparian corridors, and the degree of fragmentation of vegetation were the most important variables influencing fish and macroinvertebrate abundance

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[30]*SEWRPC Technical Report No. 39,* Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds*, November 2007.*

[31]*L. Wang, J. Lyons, P. Kanehl, and R. Gatti, "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams,"* op cit*.*

[32]*F. Fitzpatrick, B. Scudder, B. Lenz, and D. Sullivan, "Effects of Multi-Scale Environmental Characteristics on Agricultural Stream Biota in Eastern Wisconsin,"* Journal of the American Water Resources Association, *Volume 37, No. 6, 2001.*

and diversity.[33] In addition, upland and riparian best management practices (BMPs) when combined significantly improved overall stream habitat quality, bank stability, instream cover for fishes, and fish abundance and diversity.[34] Upland BMPs include barnyard runoff controls, manure storage, contour plowing, and reduced tillage. Riparian BMPs include streambank fencing, streambank sloping, and limited streambank riprapping, Improvements were most pronounced at sites with riparian BMPs. At sites with limited upland BMPs installed, there were few improvements in water temperature or in the quality of fish community.

Around lakes, where development generally has a more urban character, stormwater management and runoff controls—such as the application of stormwater infiltration practices, onsite detention/retention of stormwater, adoption of good shorescaping measures, and shoreland management practices—offer similar benefits.[35] Wetlands adjacent to lakes and streams help enhance water quality conditions, while preserving desirable open space characteristics for residents to participate in a wide range of resource-oriented recreational activities. Protection of shoreland wetlands also helps to avoid the creation of new environmental and developmental problems as urbanization proceeds within the watershed. In parallel with such protection and preservation, the use of natural and native vegetation as shoreline protection is required pursuant to Chapter NR 328 of the *Wisconsin Administrative Code* as a best practice along lake shorelines where such measures are feasible. Recent studies of the potential impact of riparian landscaping activities on nutrient loadings to lakes in southeastern Wisconsin have suggested that urban residential lands can contribute up to twice the mass of phosphorus to lakes when subjected to an active program of urban lawn care than similar lands managed in a more natural fashion.[36] The application of agrochemicals to such lands, in excess of the plant requirements, therefore, results in enhanced nutrient loading directly to the adjacent waterbodies. To this end, the State of Wisconsin has promulgated guidance for turf nutrient management targeted at residential lands, parks, and high use areas, such as golf courses and parks.[37]

In addition to the protection of water quality, riparian buffers simultaneously protect wildlife including both aquatic and terrestrial habitats. Buffer zones adjacent to waterbodies such as lakes, rivers, and wetlands minimize the impacts of human activities on the landscape and contribute to recreation, aesthetics, and quality of life (see riparian buffer booklet in Appendix C). Riparian buffers are unique ecosystems that are exceptionally rich in biodiversity since they function as core habitat and travel corridors for many wildlife species including birds, fishes, amphibians, insects, reptiles, and plants. Fishery quality observed throughout the Pewaukee River watershed ranges from fair to excellent. This difference in quality can be attributed to a number of factors

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[33]*J. Stewart, L. Wang, J. Lyons, J. Horwatich, and R. Bannerman, "Influence of Watershed, Riparian Corridor, and Reach Scale Characteristics on Aquatic Biota in Agricultural Watersheds,"* Journal of the American Water Resources Association*, Volume 37, No. 6, 2001.*

[34]*L. Wang, J. Lyons, and P. Kanehl, "Effects of Watershed Best Management Practices on Habitat and Fish in Wisconsin's Streams,"* Journal of the American Water Resources Association*, Volume 38, No. 3, 2002.*

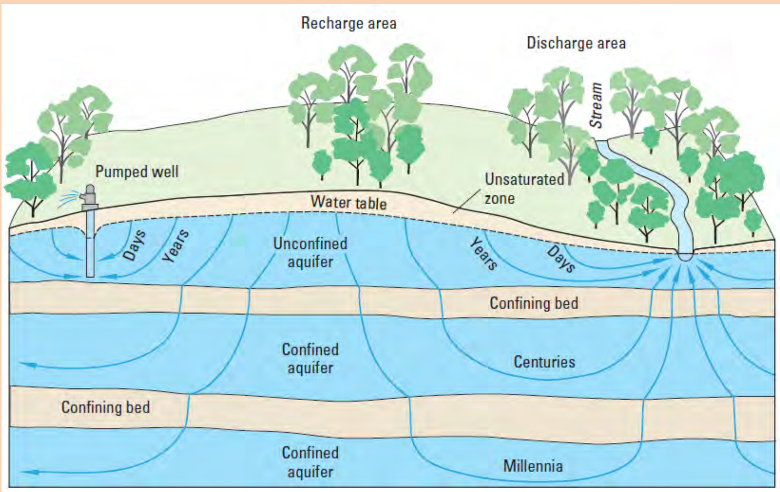
[35]*See University of Wisconsin-Extension, Publication No. GWQ045,* Storm Water Basins: Using Natural Landscaping for Water Quality and Esthetics*, 2005.*

[36]*U.S. Geological Survey Water-Resources Investigations Report No. 02-4130,* Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin*, July 2002.*

[37]*Wisconsin Department of Natural Resources, Technical Standard No. 1100,* Turf Nutrient Management, *2006; 2009 Wisconsin Act 9 created Section 94.643 of the* Wisconsin Statutes *which placed restrictions on the use and sale of fertilizer containing phosphorus as well as on the use and sale of other turf fertilizers, codifying in part the recommended land management measures set forth in Technical Standard No. 1100.*

Figure 19

GROUNDWATER FLOW PATHS IN A MULTI-AQUIFER GROUNDWATER SYSTEM



Groundwater flows from recharge areas at the water table to discharge locations at the stream and well. The residence time of groundwater can range from days to centuries to millennia.

Source: U.S. Geological Survey and SEWRPC.

including: position within the watershed and changes in instream channel features including discharge, groundwater inputs, substrates, and gradient; land use changes and limited measures to mitigate the adverse effects of land uses;[38] and extent of riparian buffers protecting lakes and streams (see Chapter IV of this report).

Groundwater Resources

Groundwater not only sustains lake levels and wetlands and provides the perennial base flow of streams, but it is also a major source of water supply. In general, there is an adequate supply of groundwater within the Region to support the growing population, agriculture, commerce, and viable and diverse industry. However, overproduction and water shortages may occur in areas of concentrated development and intensive water demand. The amount, recharge, movement, and discharge of groundwater is controlled by several factors, including: precipitation; topography; drainage; land use; soil; and, the lithology and water-bearing properties of rock units. All of the communities within the Pewaukee River watershed are dependent on groundwater for a potable water supply and for other commercial and industrial uses. Groundwater resources thus constitute an extremely valuable element of the natural resource base within the Pewaukee River watershed. The continued growth of population and industry within the watershed necessitates the wise development and management of groundwater resources. The U.S. Geological Survey (USGS) has released a report that presents concepts and tools to help water managers and others understand the effects of groundwater pumping on surface water (see below).[39] Much of the following information in this subsection is derived from that report.

Groundwater-Streamflow Interaction

As illustrated in Figure 19, groundwater and surface water systems are connected. The sources of water to streams are generally recognized to result from four processes that include: 1) precipitation that falls directly onto a stream, which is a relatively small component of total streamflow; 2) surface runoff (or overland flow) that travels

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[38]*The standards and requirements of Chapter NR 151 "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the* Wisconsin Administrative Code *are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of these rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.*

[39]*Barlow, P.M., and Leake, S.A.,* Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow, *U.S. Geological Survey Circular 1376, 2012, see website at* http://pubs.usgs.gov/circ/1376/.

"Streamflow depletion caused by pumping is an important water-resource management issue across the nation because of the adverse effects that reduced flows can have on aquatic ecosystems, the availability of surface water, and the quality and aesthetic value of streams and rivers."

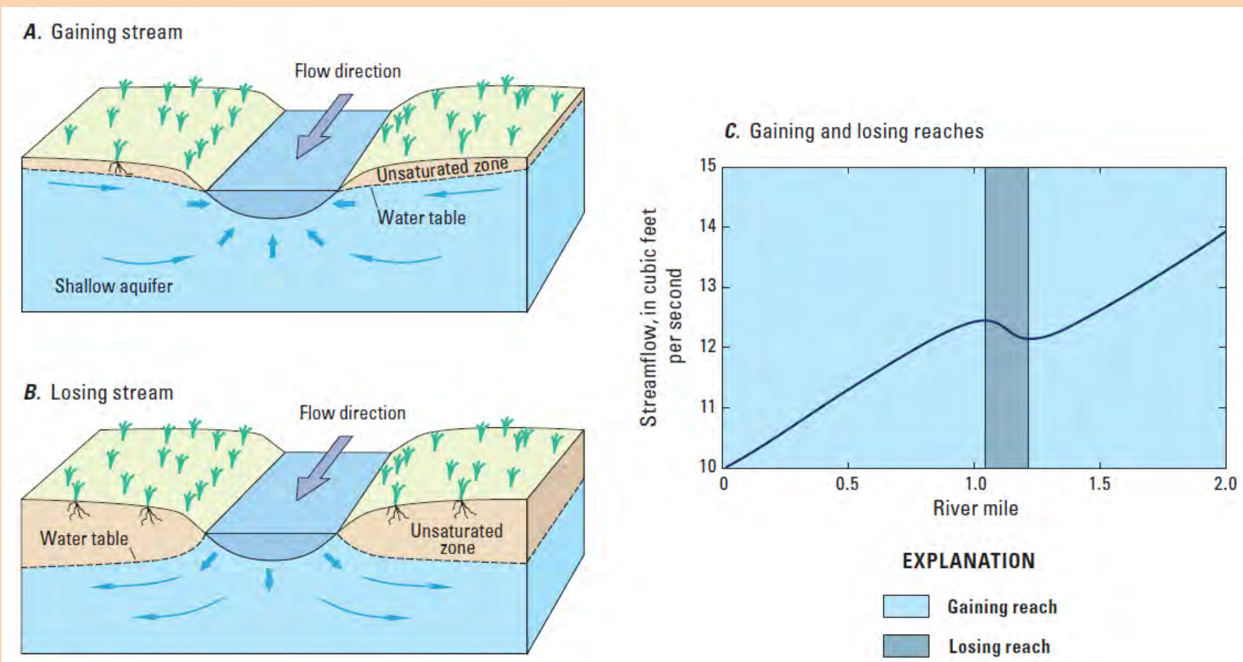
Source: Paul Barlow, USGS hydrologist, Press Release, "How Does Groundwater Pumping Affect Streamflow?," November 16, 2012.

over the land surface to a stream channel; 3) interflow (or subsurface storm flow) that moves through the upper soil layers to a stream channel; and 4) groundwater discharge, which is commonly referred to as base flow. Surface runoff and interflow are important during storm events, and their contributions typically are combined into a single term called the direct-runoff component of streamflow.[40] Groundwater, on the other hand, is most important for sustaining the flow of a stream during periods between storms and during dry times of the year and is often a substantial component of the total flow of a stream.

As shown in Figure 20, a stream gains water where groundwater is discharged into the stream through saturated streambed and streambank sediments, or permeable bedrock adjacent to the stream, wherever the altitude of the water table is greater than the altitude of the stream surface (see Figure 20, Part A). Conversely, a stream loses water wherever streamflow seeps into the underlying groundwater system wherever the elevation or altitude

Figure 20

HOW GROUNDWATER ELEVATIONS AFFECT GROUNDWATER AND STREAMFLOW INTERACTIONS: CONNECTED STREAM REACHES



Stream reaches connected with the adjoining groundwater elevation can exhibit gaining or losing conditions: A, Gaining stream reaches receive water from the groundwater system, whereas, B, losing reaches lose water to the groundwater system. C, Streamflow increases along the gaining reaches of a river and streamflow decreases along the losing reaches of a river when there is no direct surface-water runoff to the river.

Source: U.S. Geological Survey and SEWRPC.

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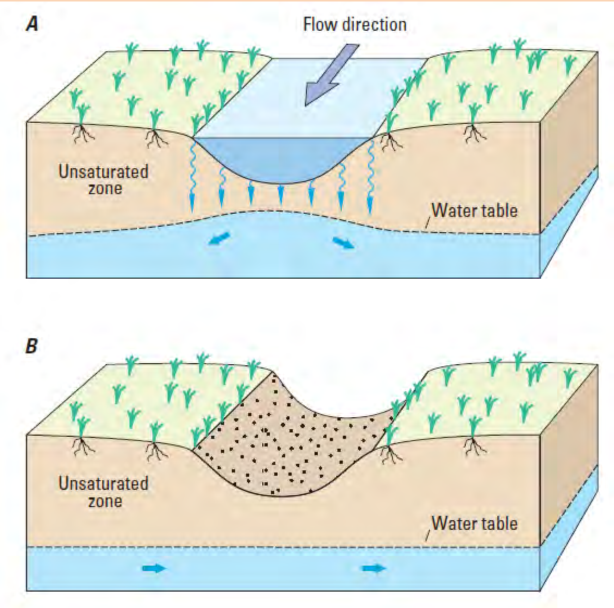
[40]*Barlow and Leake, 2012; Linsley, R.K., Jr., Kohler, M.A., and Paulhus, J.L.H., Hydrology for engineers (3rd edition), New York, McGraw-Hill, 508 p., 1982.*

Figure 21

GROUNDWATER AND STREAMFLOW INTERACTIONS DISCONNECTED STREAM REACHES



Disconnected stream reaches are separated from the groundwater system by an unsaturated zone. In other words, the water table is lower than the streambed. In A, streamflow is a source of recharge to the underlying groundwater system, but in B, streamflow and groundwater recharge have ceased and the streambed is dry.

Source: U.S. Geological Survey and SEWRPC.

of the stream surface is greater than the altitude of the adjoining water table (see Figure 20, Part B). Groundwater seeps and springs were observed and mapped throughout the Pewaukee River system (see the Hydrology/ Groundwater/Precipitation section in Chapter IV of this report). Stream reaches that receive groundwater discharge are called *gaining reaches* and those that lose water to the underlying aquifer are called *losing reaches*. The rate at which water flows between a stream and its adjoining aquifer depends on the hydraulic gradient between the two waterbodies and also on the hydraulic conductivity of geologic materials that may be located at the groundwater/ surface-water interface. A clay-lined streambed, for example, will tend to reduce the rate of flow between a stream and aquifer compared to a sandy or gravelly streambed. The graph in Figure 20 illustrates the effects of gaining and losing conditions on streamflow during a period of no direct surface-water runoff to a river. The graph shows that the rate of streamflow increases along gaining reaches and decreases along losing reaches. The graph also demonstrates that a stream can have both gaining and losing reaches simultaneously. This has been observed within the Pewaukee River system.

Moreover, because precipitation rates, pumping rates, and other hydrologic stresses vary with time, it is possible for a particular stream reach to switch from a gaining to a losing condition or from a losing to a gaining condition from one period to the next. Losing reaches can occur under conditions in which the underlying sediments are fully saturated, as shown in Figure 20, Part B, or when the sediments are unsaturated, as shown in Figure 21, Part A. In the case of the former, flow out of the stream into the underlying aquifer is dictated by elevation—water simply moves from a higher to a lower elevation. In the case of the latter, flow out of the stream is the result of concentration—water simply moves from an area of high concentration (the stream) to an area of low water concentration (the unsaturated soil beneath the streambed). A losing stream reach that is underlain by an unsaturated zone is said to be disconnected from the underlying aquifer.[41] Some stream reaches are ephemeral (they periodically become dry), and, as a consequence, flows between the stream and underlying aquifer may periodically cease (see Figure21, Part B). For example, during the drought conditions in the summer through fall of 2012 several small tributaries stopped discharging water to the Pewaukee River.

Groundwater Recharge

Recharge to groundwater is derived almost entirely from precipitation. The amount of precipitation (and snowmelt) that infiltrates at any location depends mainly on the permeability of the overlying soils, bedrock or other surface materials, including human-made surfaces. As development occurs, stormwater management practices can be instituted that encourage infiltration of runoff. However, it is important to note that such practices have generally not been required to be installed prior to 1990 in the Pewaukee River watershed. Therefore, so much of the urban development was not constructed to promote such infiltration (see Stormwater section in Chapter III of this report). Ideally, these practices need to be located on soils with permeable subsoils and

[41]*Winter, T.C., Harvey, J.W., Franke, O.L., and Alley, W.M.,* Ground water and surface water—A single resource, *U.S. Geological Survey Circular 1139, 1998.*

adequate groundwater separation to allow infiltration, but minimize the potential for groundwater contamination. This is described in more detail in Chapter V. Most of the precipitation that does infiltrate (either naturally or through a stormwater management practice) will generally only migrate within the shallow aquifer system and may discharge in a nearby wetland or stream system. This process helps support base flows, wetland vegetation, and wildlife habitat in these water resources. Therefore, as is the case for surface waters (lakes and streams), the quality of groundwater resources is clearly linked to the health and well-being of the biological communities (including humans) inhabiting those waters and their surrounding watersheds.[42]

Groundwater Pumping and Streamflow

Although the benefits of groundwater development are many, groundwater pumping can reduce the flow of water in connected streams and rivers—a process called streamflow depletion by wells.[43] Due to the connection and complex interactions between surface and groundwater, managing the effects of streamflow depletion by wells is challenging, particularly because of the significant time delays that often occur between when pumping begins and when the effects of that pumping are realized in nearby streams; in addition, there could be other local factors that control the timing, rates, and locations of streamflow depletion, as well. Nonetheless, managers should keep several important considerations in mind when trying to understand the relationship between streamflow and groundwater pumping:[44]

- Individual wells may have little effect on streamflow depletion, but small effects of many wells pumping within a basin can combine to produce substantial effects on streamflow and aquatic habitats.

- Basinwide groundwater development typically occurs over a period of several decades, and the resulting cumulative effects on streamflow depletion may not be fully realized for years.

- Streamflow depletion continues for some time after pumping stops because it takes time for a groundwater system to recover from the previous pumping stress. In some aquifers, maximum rates of streamflow depletion may occur long after pumping stops, and full recovery of the groundwater system may take decades to centuries.

- Streamflow depletion can affect water quality in the stream or in the aquifer. For example, in many areas, groundwater discharge moderates seasonal temperature fluctuations, cooling stream temperatures in the summer and warming stream temperatures in the winter, thus providing a suitable year-round habitat for fish. Reductions in groundwater discharge to streams caused by pumping can degrade these moderating effects.

- The major factors that affect the timing of streamflow depletion are the distance from the well to the stream and the properties and geologic structure of the aquifer.

- Sustainable rates of groundwater pumping near streams do not depend on the rates at which groundwater systems are naturally replenished (or recharged), but on the total flow rates of the streams and the amount of reduced streamflow that a community or regulatory authority is willing to accept.

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[42]*David Hambright, "Golden Algae & The Health of Oklahoma Lakes," LAKELINE, Volume 32(3), Fall 2012.*

[43]*Barlow, P.M., and Leake, S.A.,* Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow, *U.S. Geological Survey Circular 1376, 2012, see website at* http://pubs.usgs.gov/circ/1376/.

[44]*Barlow and Leake, 2012.*

These considerations illustrate the need to develop an interdisciplinary approach to manage surface and groundwater resources jointly so as to better understand and protect these resources within the Pewaukee River watershed.

Groundwater Modeling

A water supply system plan was recently developed by SEWRPC for the Southeastern Wisconsin Region to provide a sound framework for local water supply planning in the context of existing and planned future development within the Region in a manner consistent with the protection and wise use of the ground and surface water natural resources base.[45] That plan is the third component of the SEWRPC regional water supply planning program. The other two elements were the development of basic groundwater inventories[46] and the development of the regional groundwater model.[47]

In general, the regional aquifer simulation model was developed to enable characterization of water levels in the deep and shallow aquifers under historical, current, and planned conditions; to evaluate the effects of different groundwater management alternatives on surface water resources; and to provide a framework within which more-detailed "inset" models could be developed to investigate site-specific groundwater-related questions, including the possible effects of high-capacity wells on surface water resources. The model provides the capability of addressing the following questions:

- How does the quantity of water being removed from an aquifer by wells relate to that aquifer's supply?
- How much have humans altered the groundwater system?
- What effect does human alteration of the groundwater system have on surface waters?

In the deep aquifer, water levels have declined hundreds of feet since the 1800s as shown in Figure 22, Part A. In much of the Region, including the Pewaukee River watershed, water movement from the shallow sand and gravel and dolomite aquifer into the deep sandstone aquifer is limited by the Maquoketa shale, which forms a relatively impermeable barrier between the two aquifers. As a result, the rates of groundwater recharge to the deep aquifer are much less than the rates that water is being extracted by pumping. The drawdowns of the deep aquifer are indicative of a water budget deficit and are the combined result of pumping throughout southeastern Wisconsin as well as northeastern Illinois. In contrast, drawdowns in the shallow aquifer throughout the Region are much smaller (see Figure 22, Part B) despite the fact that nearly twice the amount of water is being extracted from it compared to the deep aquifer.[48] The reason for the lower drawdowns is that the shallow aquifer is unconfined in most places. It receives direct recharge from precipitation and is also linked directly to surface waterbodies as illustrated in Figure 19 above. Under natural conditions, most recharge to the shallow aquifer flows through the aquifer and discharges to surface waterbodies as baseflow. Pumping from the shallow aquifer for water supply purposes can reduce the natural groundwater discharge, intercepting it before it reaches surface waterbodies and then, after it has been treated, discharging it to those few rivers that receive wastewater effluent. It is even

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

[46]*SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin, *June 2002.*

[47]*SEWRPC Technical Report No. 41,* A Regional Aquifer Simulation Model for Southeastern Wisconsin, *June 2005.*

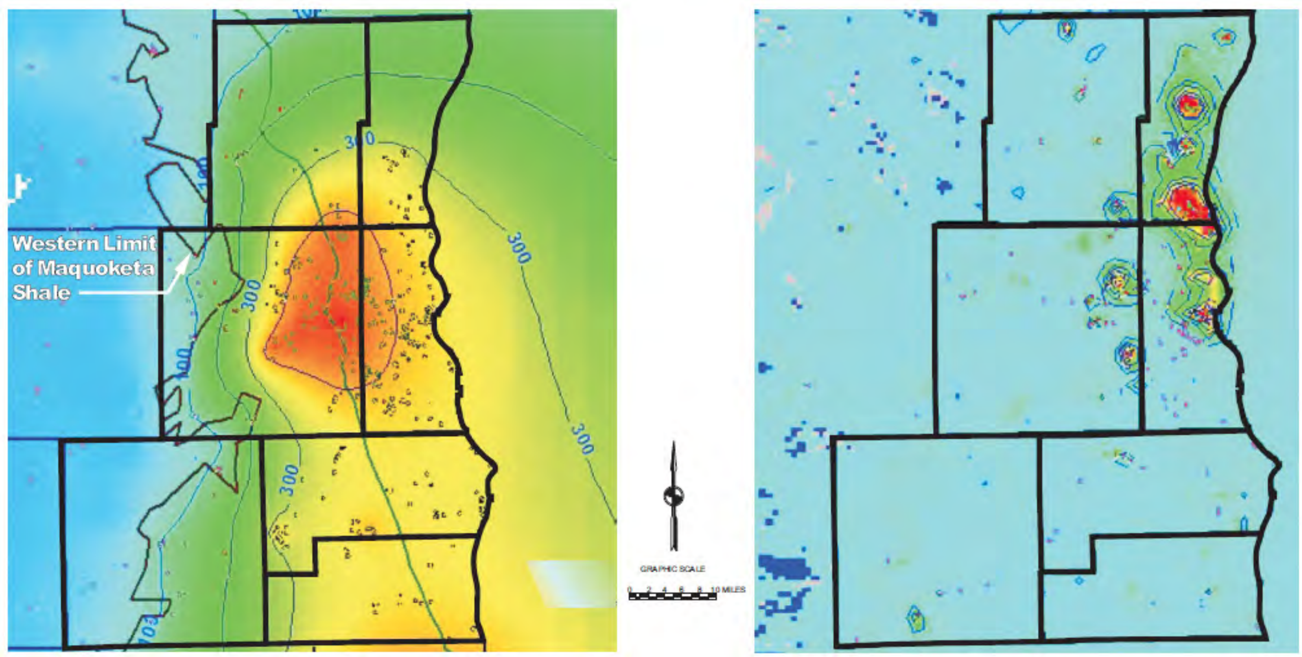
[48]*SEWRPC Technical Report No. 46,* Groundwater Budget Indices and Their Use in Assessing Water Supply Plans for Southeastern Wisconsin, *February 2010.*

Figure 22

SIMULATED GROUNDWATER DRAWDOWNS FOR THE SOUTHEASTERN WISCONSIN REGION BETWEEN 1860 AND 2000

A. Deep Aquifer—The red zones shows areas where the drawdowns are greater than 400 feet.

B. Shallow Aquifer—The red zones are areas where drawdowns are greater than 50 feet.



Source: U.S. Geological Survey and Wisconsin Geological and Natural History Survey, SEWRPC Technical Report No. 46, Groundwater Budget Indices and Their Use in Assessing Water Supply Plans for Southeastern Wisconsin, February 2010.

possible for pumping to reverse the natural groundwater discharge and induce water to flow out of surface waters and into the shallow aquifer. As a consequence, groundwater deficits in the shallow aquifer often do not manifest themselves as large drawdowns. Their effect, instead, is to reduce groundwater baseflow such as described above. In fact, in Figure 22, Part B, the large drawdowns all occur where the shallow aquifer is semi-confined by clay-rich glacial till. Clay particles are very small and tightly layered, severely limiting water movement. This is why they are often used to line ponds to prevent water leakage.

It is important to note that although the resolution of the regional groundwater models was considered sufficient and valid to compare differences in impacts resulting from alternative plans, it may not be sufficiently fine to predict site-specific impacts, or to resolve differences in impacts between surface water or groundwater features that are in close proximity to one another. Because the average grid cell size of the groundwater simulation model is over one-quarter square mile (about 2,500 feet on a side), the results, or output, from this regional modeling effort are not applicable for determining the impact of groundwater withdrawal on a site-specific basis. In other words, this regional model cannot specifically be used for local level groundwater supply planning purposes for the Pewaukee River watershed, because this area is too small. An evaluation of an area such as the Pewaukee River watershed would require a refinement of the model by the inclusion of more-detailed hydrogeologic data and a refinement of the model cell size.[49]

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[49]*The regional scale groundwater model has been specifically designed with a telescoping feature that allows for application to more-detailed investigation on specific geographic locations using more-refined inset models.*

One of the most accessible and effective tools developed as part of the water supply planning effort is the groundwater recharge potential map derived from a soil-water balance recharge model developed for the Southeastern Wisconsin Region.[50] Understanding recharge and its distribution is key to making informed land use decisions so that the groundwater needs of society and the environment can continue to be met. Unlike the regional model discussed above, this model contains a significantly reduced spatial grid size (about 100 feet on a side) that can actually be used for local level groundwater planning purposes. Therefore, these model results are generally applicable to the Pewaukee River watershed for identifying and protecting recharge areas that contribute most to baseflow of the lakes, streams, springs, and wetlands in the watershed. Protecting recharge areas is important to the goals of sustainable groundwater use and a healthy natural environment. Groundwater recharge potential was divided into four main categories defined as: low, moderate, high, and very high. Any areas that were not defined were placed into a fifth category as undefined. These undefined areas are most often associated with groundwater discharge, which is why they tend to be located adjacent to streams as shown on Map 10. Much of the Pewaukee River watershed can be considered to have moderate groundwater recharge potential (about 10,024 acres, or about 41 percent of the entire watershed area), as shown on Map 10. About 20 percent of the watershed was undefined and about 9 percent of the watershed was identified as having low recharge potential. The remaining nearly 30 percent of the watershed contains high and very high recharge potential. More importantly, more than twice the amount of the high and very high recharge lands are located within the PL subwatershed compared to the PR subwatershed.

In addition to the groundwater recharge potential tool summarized above, an entirely new fine-scale groundwater/surface water flow model has recently been constructed and calibrated to evaluate groundwater-flow patterns in the shallow aquifer system within the Upper Fox River watershed in southeastern Wisconsin. [51] As shown in Figure 23, the entire Pewaukee River watershed lies within the nearfield and farfield boundary conditions of the groundwater-surface water model. Unlike the regional model discussed above, this new model contains a significantly reduced grid size (about 125 feet on a side) that can actually be used for site-specific local level groundwater planning purposes. Therefore, these model results are generally applicable to the Pewaukee River watershed for quantifying fine-scale groundwater/surface water interactions in the shallow aquifer, defining sources and sinks of groundwater including recharge, boundary fluxes, interactions with surface water, and discharge to wells and quarries. Details of the major findings from this model can be found in the Hydrology/Groundwater/Precipitation section in Chapter IV of this report.

NATURAL RESOURCE BASE RELATED ELEMENTS

Many important interlocking and interacting relationships occur between living organisms and their environment. The destruction or deterioration of any one element may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects. Such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides low flows in rivers and streams. The destruction of woodland and other upland cover types, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes in isolation may not be overwhelming, the combined effects may lead eventually to the

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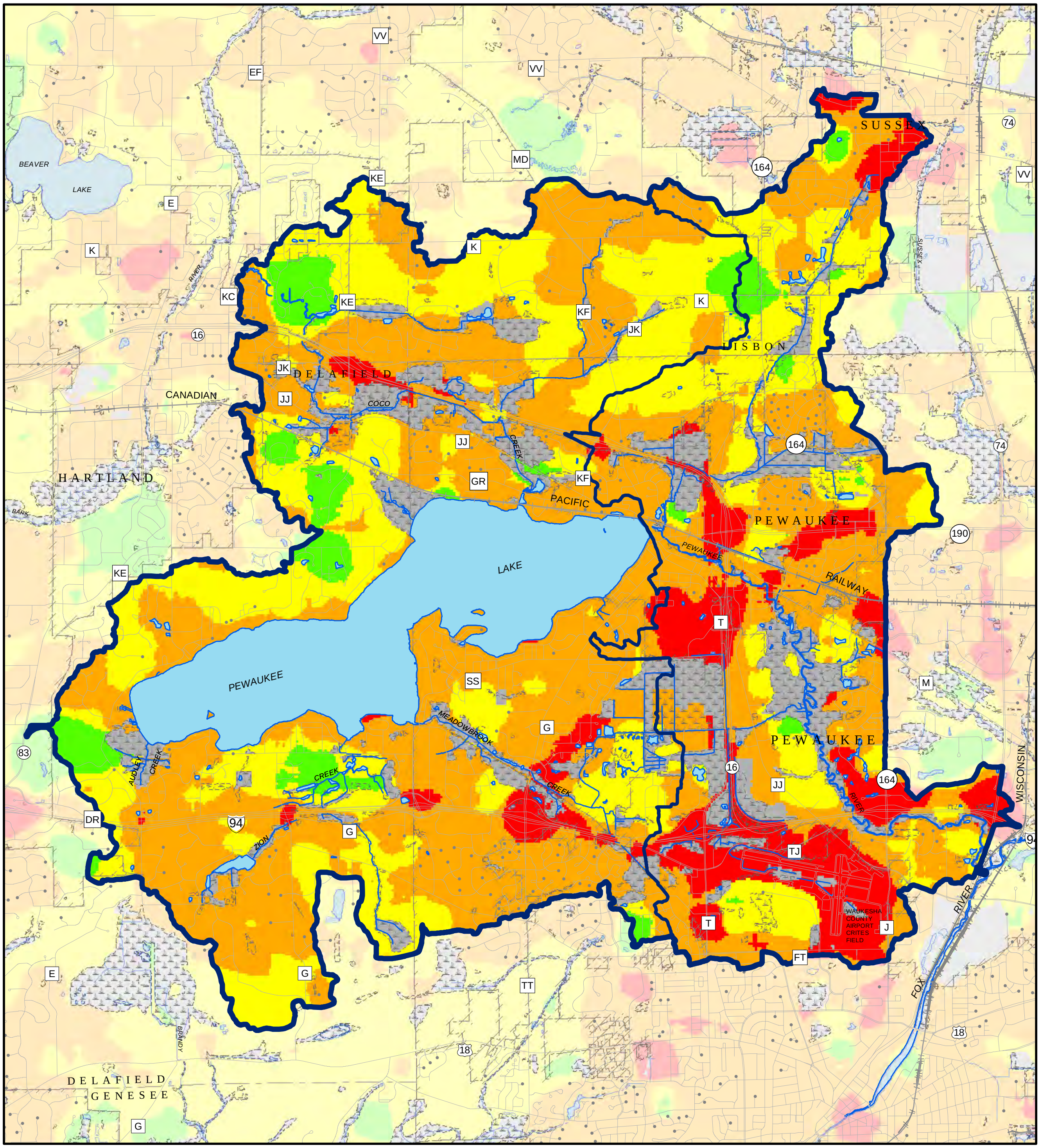
[50]*SEWRPC Technical Report No. 47,* Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water-Balance Model*, July 2008.*

[51]*D.T. Feinstein, M.N. Fienen, J.L. Kennedy, C.A. Buchwald, and M.M. Greenwood, "Development and application of a groundwater/surface-water flow model using MODFLOW-NWT for the Upper Fox River Basin, southeastern Wisconsin,"* U.S. Geological Survey Scientific Investigations Report 2012-5108*, 2012, 124 pages.*

Map 10

ESTIMATES OF GROUNDWATER RECHARGE POTENTIAL WITHIN THE PEWAUKEE RIVER WATERSHED



LOW
MODERATE
HIGH
VERY HIGH
UNDEFINED

SURFACE WATER
STREAM
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY

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

N

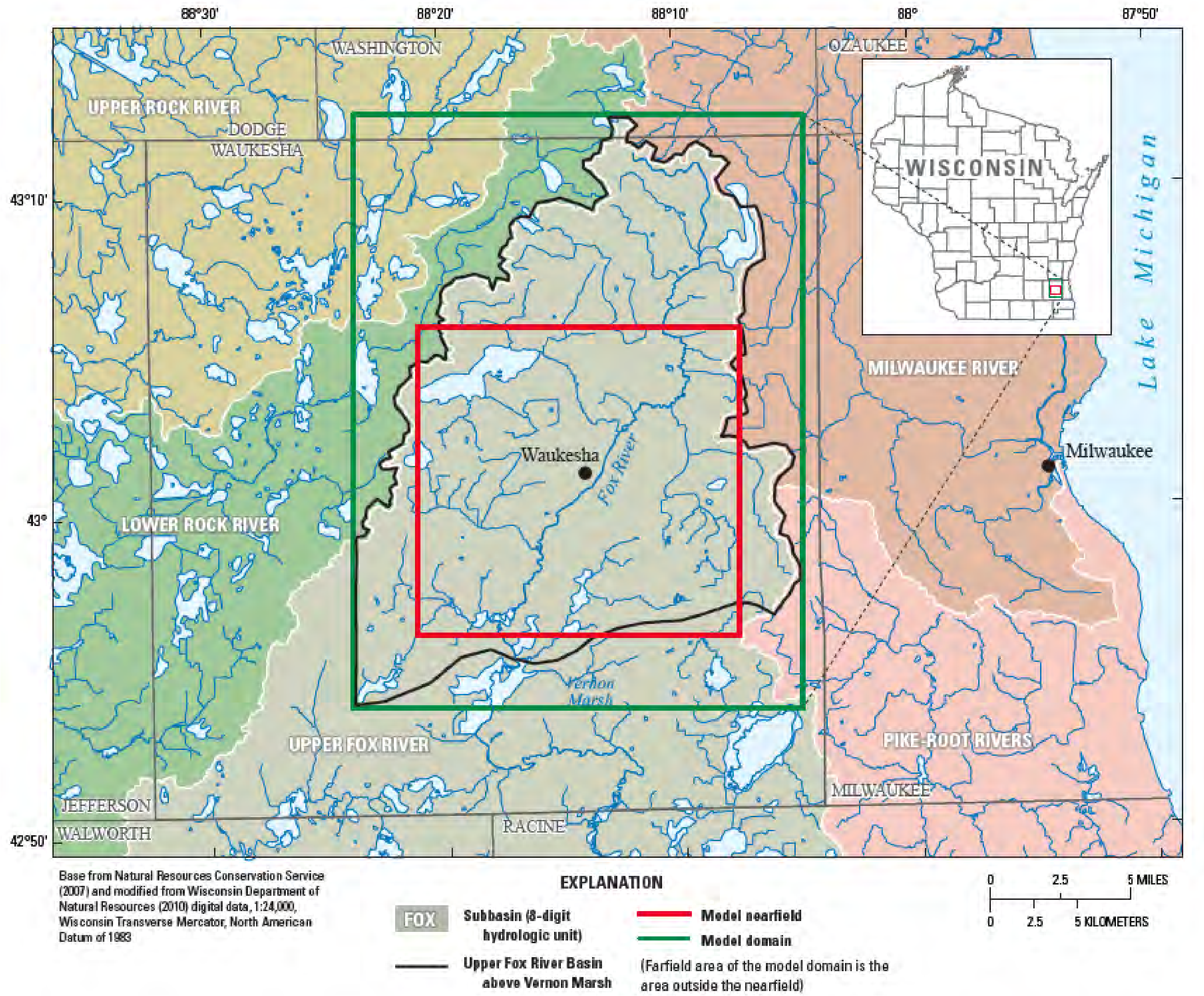
0 0.5 1 Miles

0 2,500 5,000 Feet

Source: Wisconsin Geological and Natural History Survey and SEWRPC.

Figure 23

STUDY AREA LIMITS FOR THE UPPER FOX RIVER BASIN, MODEL DOMAIN, AND MODEL NEARFIELD AREAS



Source: U.S. Geological Survey and SEWRPC.

deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the environmental corridors within the watershed area thus becomes apparent.

Primary Environmental Corridors

Primary environmental corridors (PEC) include a wide variety of important resource and resource-related elements. By definition, they are at least 400 acres in size, two miles in length, and 200 feet in width.[52] PEC encompassed about 5,883 acres, or about 25 percent of the Pewaukee River watershed, in 2010. These PECs

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

represent a composite of the best remaining elements of the natural resource base, and contain almost all of the best remaining woodlands, wetlands, and wildlife habitat areas in the watershed. PECs in the watershed are shown on Map 11. Although Pewaukee Lake is typically shown as open water, it is also important to note that the lakes, rivers and streams and the associated shorelands, including Pewaukee Lake, are in fact PECs, which is why they are shown as such on Map 11. In other words, the Lake and its associated shorelands are part of the highest quality natural resources within the Pewaukee River watershed. This is why management of the nearshore areas is vital to protecting and maintaining the quality and integrity of this resource (see Appendix C).

Secondary Environmental Corridors

Secondary environmental corridors (SEC) generally connect with the primary environmental corridors and are at least 100 acres in size and one mile long. In 2010, secondary environmental corridors encompassed about 567 acres, or just over 2 percent of the watershed. Secondary environmental corridors are remnant resources that have been reduced in size compared to the larger PEC as described above, due to land development for intensive urban or agriculture purposes. However, secondary environmental corridors contain a variety of resource elements that include facilitating surface water drainage, maintaining pockets of natural resource features, and providing corridors for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species. Secondary environmental corridors in the Pewaukee River watershed are shown on Map 11.

Isolated Natural Resource Areas

Smaller concentrations of natural resource features that have been separated physically from environmental corridors by intensive urban or agricultural land uses have also been identified. These natural resource areas, which are at least five acres in size, are referred to as isolated natural resource areas. Widely scattered throughout the watershed, isolated natural resource areas included about 694 acres, or about 3 percent, of the total study area in 2010. Isolated natural resource areas in the watershed are shown on Map 11.

Natural Areas and Critical Species Habitat Sites

Natural areas, as defined by the Wisconsin Natural Areas Preservation Council, are tracts of land or water so little modified by human activity, or sufficiently recovered from the effects of such activity, that they contain intact native plant and animal communities believed to be representative of the pre-European settlement landscape (see Map 8, Pre-Settlement Vegetation within the Pewaukee River Watershed: 1836). Natural areas are generally comprised of wetland or upland vegetation communities and/or complex combinations of both these fundamental ecosystem units (see the Wetlands and Uplands subsections below). In fact, some of the highest quality natural areas within the Southeastern Wisconsin Region are wetland complexes that have maintained adequate or undisturbed linkages (i.e., landscape connectivity) between the upland-wetland habitats, which is consistent with research findings in other areas of the Midwest.[53]

Natural areas have been identified for the seven-county Southeastern Wisconsin Region in SEWRPC Planning Report No. 42, "*A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*," published in September 1997, and amended in 2008 and 2010. This plan was developed to assist Federal, State, and local units and agencies of government, and nongovernmental organizations, in making environmentally sound land use decisions including acquisition of priority properties, management of public lands, and location of development in appropriate localities that will protect and preserve the natural resource base of the Region. Waukesha County uses this document to guide land use decisions.

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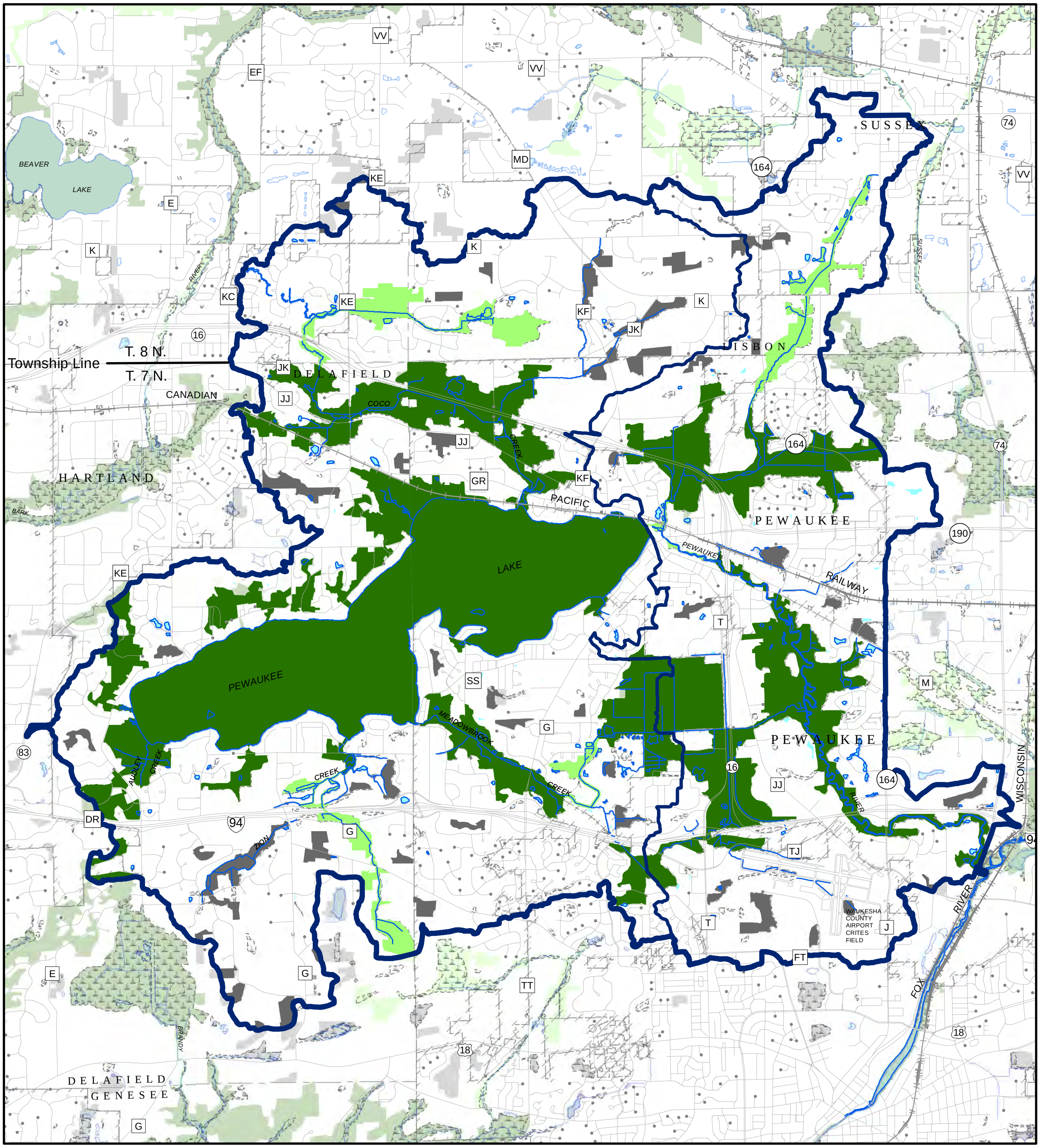
[53]*O. Attum, Y.M. Lee, J.H. Roe, and B.A. Kingsbury, "Wetland complexes and upland-wetland linkages: landscape effects on the distribution of rare and common wetland reptiles,"* Journal of Zoology*, Vol. 275, 2008, pages 245-251.*

Map 11

ENVIRONMENTAL CORRIDORS WITHIN THE PEWAUKEE RIVER WATERSHED: 2005 AND 2010



PRIMARY ENVIRONMENTAL CORRIDOR
SECONDARY ENVIRONMENTAL CORRIDOR
ISOLATED NATURAL RESOURCE AREA
SURFACE WATER
STREAM
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY

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

N

0 0.5 1 Miles
0 2,500 5,000 Feet

NOTE: Township 7 North contain 2010 corridors and Township 8 North contains 2005 corridors.
Source: SEWRPC.

The identified natural areas were classified into the following three categories:

1. Natural area of statewide or greater significance (NA-1);

2. Natural area of countywide or regional significance (NA-2); or

3. Natural area of local significance (NA-3).

Classification of an area into one of these three categories was based upon consideration of several factors, including the diversity of plant and animal species and community types present; the structure and integrity of the native plant or animal community; the extent of disturbance by human activity, such as logging, grazing, water level changes, and pollution; the frequency of occurrence within the Region of the plant and animal communities present; the occurrence of unique natural features within the area; the size of the area; and the educational value. The Pewaukee River watershed contains one natural area of countywide or regional significance (NA-2) and seven natural areas of local significance (NA-3). Most of the natural areas are wetlands associated with the tributaries of the Pewaukee River, largely within the Pewaukee Lake subwatershed. The natural areas and critical species habitats identified in the Pewaukee River watershed are shown on Map 12 and inventoried in Tables 4 and 5.

Critical species are defined as those species of plants and animals that are designated by the State of Wisconsin to be endangered, threatened, or of special concern. There are 20 such species known to occur in the watershed. They are listed in Table 6 and represent mussels, fish, reptiles, amphibians, birds, and plant species. Photos of each of these critical species and links to life history information are included in Figure 24.

Wetlands

Historically, wetlands were largely viewed as wastelands, presenting obstacles to agricultural production and development. Private interests as well as governmental institutions supported the transformation of wetlands into desired uses through large-scale draining and filling of wetland areas. This misunderstanding of the importance of wetlands led to dramatic wetland losses until scientific research revealed the value of wetlands. Wetlands are incredibly productive and biologically diverse ecosystems.[54] Wetlands are most known for their variety of plant life from submergent (plants growing underwater) species including algae to floating pond lilies to emergent cattails and bulrush to woody tamaracks, as just a few examples. Species of both aquatic and terrestrial wildlife communities that have been found to rely on, or are associated with, wetlands for at least part of their lives include: crustaceans, mollusks, and other aquatic insect larvae and adults; fishes, including forage fish and important gamefish species, such as trout, northern pike, and largemouth bass; amphibians; reptiles; mammals, including deer; and resident bird species, such as turkey and migrants, including sandhill or whooping cranes. Thus, wetlands help maintain biologically diverse communities of ecological and economic value.

In addition to maintaining biodiversity, wetlands provide a host of additional services that include storing floodwaters; filtering pollutants; improving water quality; protecting groundwater aquifers; serving as sinks, sources, or transformers of materials; and providing recreation sites for boating and fishing, to name a few.[55] This early recognition of the value and importance of wetlands has led to the creation of rules and regulations to

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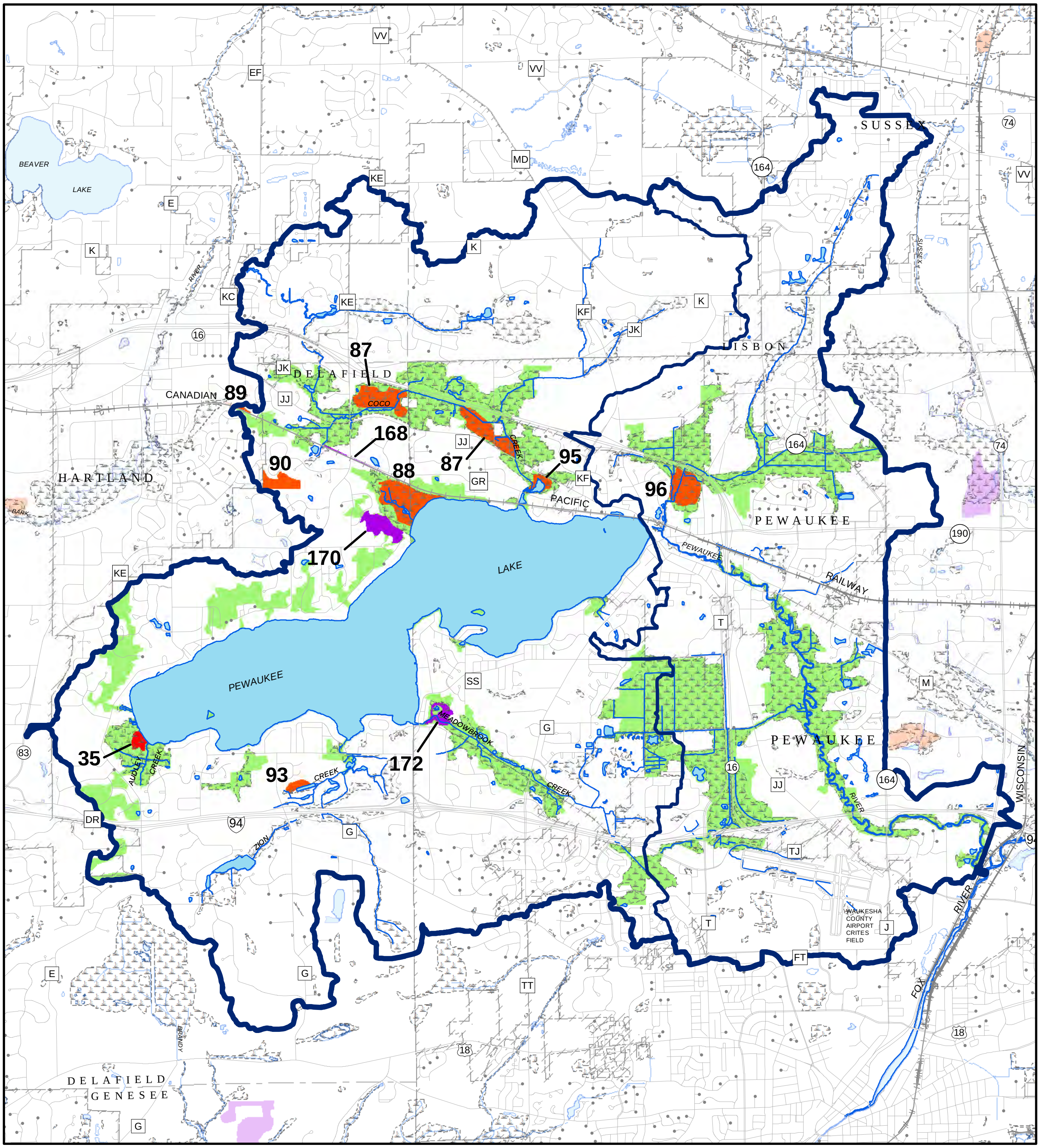
[54] *J.A. Cherry, "Ecology of Wetland Ecosystems: Water, Substrate, and Life," Nature Education Knowledge, Volume 3(10):16, 2012,* http://www.nature.com/scitable/knowledge/library/ecology-of-wetland-ecosystems-water-substrate-and-17059765.

[55] *Marsden Jacob Associates*, Literature Review of the Economic Value of Ecosystem Services that Wetlands Provide, *Final Report prepared for the Department of Sustainability, Environment, Water, Population and Communities, September 2012; The Ramsar Convention on Wetlands*, http://www.ramsar.org/cda/en/ramsar-july13-homeindex/main/ramsar/1%5E26239_4000_0__.

Map 12

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE PEWAUKEE RIVER WATERSHED: 2005



NATURAL AREA OF STATEWIDE OR GREATER SIGNIFICANCE (NA-1)

NATURAL AREA OF COUNTYWIDE OR REGIONAL SIGNIFICANCE (NA-2)

NATURAL AREA OF LOCAL SIGNIFICANCE (NA-3)

CRITICAL SPECIES HABITAT SITE

PRIMARY ENVIRONMENTAL CORRIDOR

88 IDENTIFICATION NUMBER (SEE TABLES 4 AND 5)

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

Source: SEWRPC.

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

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Table 4

NATURAL AREAS IN THE PEWAUKEE RIVER WATERSHED

Number on Map 12	Name	Type of Area	Ownership	Location	Acres Owned	Acres Proposed to Be Acquired	Total Acres	Proposed Acquisition Agency
35	Pewaukee Lake Access Fen	NA-2	Waukesha County	Town of Delafield	10	0	10	Existing County ownership
87	Capital Drive Sedge Meadow and Wet Prairie	NA-3	Pewaukee Lake Sanitary District, City of Pewaukee, and private	City of Delafield; City of Pewaukee	21	69	90	Pewaukee Lake Sanitary District
88	Pewaukee Lake Wetland	NA-3	Private	City of Pewaukee; Town of Delafield	0	65	65	Pewaukee Lake Sanitary District
89	Hartland Railroad Prairie	NA-3	Private	Village of Hartland	0	4	4	Village of Hartland
90	Prairie Wind Farm Woods	NA-3	Private	Town of Delafield	0	22	22	Private Conservancy Organization
93	Golf Cliff Ridge and Woods	NA-3	Private	Town of Delafield	0	8	8	Private Conservancy Organization
95	Pewaukee Sedge Meadow	NA-3	Private	City of Pewaukee	0	13	13	Pewaukee Lake Sanitary District
96	Pewaukee Park Sedge Meadow	NA-3	Private	Village of Pewaukee	0	42	42	Village of Pewaukee

NOTE: The map numbers correspond to those presented in the Regional Natural Areas Plan (SEWRPC Planning Report No. 42)

Source: SEWRPC.

Table 5

CRITICAL SPECIES HABITAT SITES LOCATED OUTSIDE OF NATURAL AREAS IN THE PEWAUKEE RIVER WATERSHED

Number on Map 12	Site Description	Acres	Classification	Status
168	Jungbluth Road Railroad Prairie	2	Plant	Threatened/Special Concern
170	Taylor Road Woods	30	Plant	Special Concern
172	Meadowbrook Prairie	16	Plant	Threatened

NOTE: The map numbers correspond to those presented in the Regional Natural Areas Plan (SEWRPC Planning Report No. 42)

Source: SEWRPC.

Table 6

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE PEWAUKEE RIVER WATERSHED: 2012

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Mussels			
Ellipse	*Venustaconcha ellipsiformis*	Not listed	Threatened
Round Pigtoe	*Pleurobema sintoxia*	Not listed	Special concern
Fish			
Lake Chubsucker	*Erimyzon sucetta*	Not listed	Special concern
Pugnose Shiner	*Notropis anogenus*	Not listed	Threatened
Reptiles and Amphibians			
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Special concern
Blanchard's Cricket Frog	*Acris crepitans blanchardi*	Not listed	Endangered
Blanding's Turtle	*Emydoidea blandingii*	Not listed	Special concern
American Bullfrog	*Lithobates catesbeiana*	Not listed	Special concern
Birds			
Black-Crowned Night-Heron	*Nycticorax nycticorax*	Not listed	Special concern/migrant[a]
Cerulean Warbler	*Dendroica cerulea*	Not listed	Threatened
Plants			
American Gromwell	*Lithospermum latifolium*	Not listed	Special concern
Autumn Coral-Root	*Corallorhiza odontorhiza*	Not listed	Special concern
Beaked Spikerush	*Eleocharis rostellata*	Not listed	Threatened
Butternut	*Juglans cinerea*	Not listed	Special concern
Hairy Beardtongue	*Penstemon hirsutus*	Not listed	Special concern
Hooker's Orchid	*Platanthera hookeri*	Not listed	Special concern
Kentucky Coffee-Tree	*Gymnocladus dioicus*	Not listed	Special concern
Prairie White-Fringed Orchid	*Platanthera leucophaea*	Federally threatened	Endangered
Small White Lady's-Slipper	*Cypripedium candidum*	Not listed	Threatened
Wafer-Ash	*Ptelea trifoliata*	Not listed	Special concern

[a]*Migrant (i.e., fully protected by Federal and State laws under the Migratory Bird Act).*

Source: Wisconsin Department of Natural Resources, Wisconsin State Herbarium, and SEWRPC.

Figure 24

ENDANGERED, THREATENED, AND SPECIAL CONCERN SPECIES PHOTOS IN THE PEWAUKEE RIVER WATERSHED: 2012

MUSSELS

Ellipse

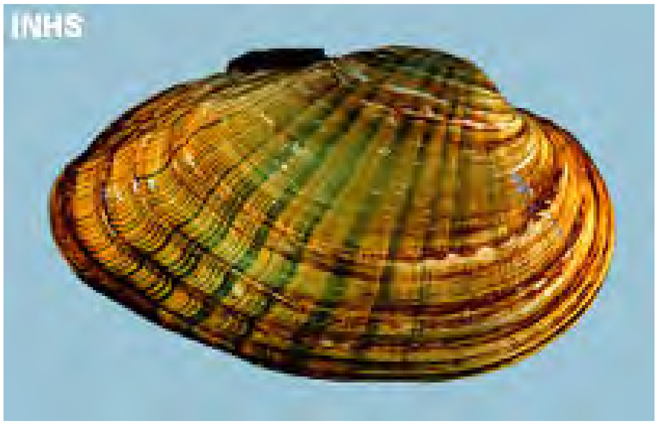


Photo © Illinois Natural History Survey.

Round Pigtoe

Photo © Illinois Natural History Survey.

FISH

Lake Chubsucker (side view adult)

Photo by John Lyons, WDNR.

Pugnose Shiner (side view adult)

Photo by John Lyons, WDNR.

REPTILES AND AMPHIBIANS

American Bullfrog (adult)

Photo by Carl D. Howe, Stow, MA USA. *(http://en.wikipedia.org/wiki/User:Cdhowe)*.

Blanchard's Cricket Frog (adult)

Photo by Wikipedia (*http://fr.wikipedia.org/wiki/Utilisateur:Pfinge*).

Figure 24 (continued)

REPTILES AND AMPHIBIANS (continued)

Blanding's Turtle (adult male)

Photo by Drew Feldkirchner, WDNR.

Blanding's Turtle (adult male, note the concave plastron)

Photo by Drew Feldkirchner, WDNR.

Butler's Gartersnake (juvenile)

Photo by Owen Boyle, WDNR.

Butler's Gartersnake (adult)

Photo by Owen Boyle, WDNR.

BIRDS

Black-Crowned Night Heron (juvenile)

Photo by D. Gordon and E. Robertson
(http://commons.wikimedia.org/wiki/User:Dger).

Black-Crowned Night Heron (adult)

Photo by Dick Daniel
(http://commons.wikimedia.org/wiki/User:DickDaniels).

Figure 24 (continued)

BIRDS (continued)

Cerulean Warbler

Photo by Mdf *(http://commons.wikimedia.org/wiki/User:Mdf).*

PLANTS

American Gromwell

Photo by Dan Carter, SEWRPC.

Autumn Coral-Root

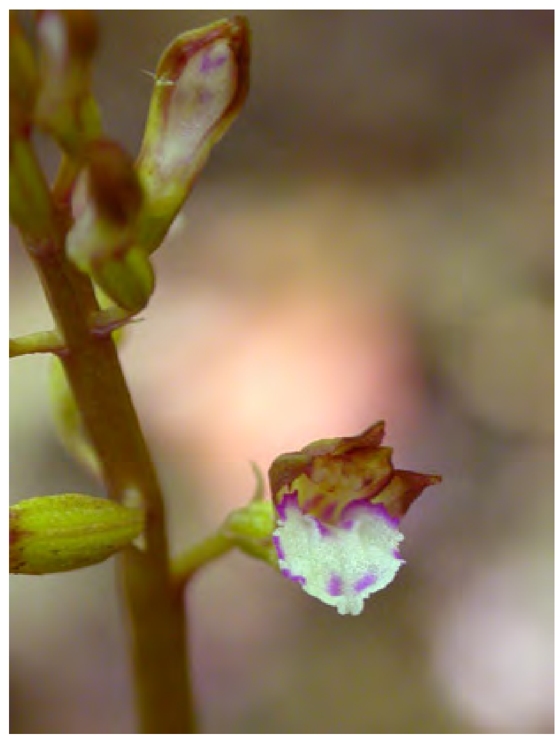


Photo by Drew Feldkirchner, WDNR.

Figure 24 (continued)

PLANTS (continued)

Beaked Spikerush

Photo by Steve D. Eggers.

Butternut

Photo by Dan Carter, SEWRPC.

Hairy Beardtongue

Photo by Suzan Campbell.

Hooker's Orchid

Photo by Andy Clark, WDNR.

Figure 24 (continued)

PLANTS (continued)

Kentucky Coffee-Tree

Photo by Dan Carter, SEWRPC.

Prairie White-Fringed Orchid

Photo by Dan Carter, SEWRPC.

Small White Lady's-Slipper

Photo by Dan Carter, SEWRPC.

Wafer-Ash

Photo by R. Schulenderg.

NOTE: Additional sources of information on taxonomy, identification, habitats, and life history characteristics can be found in the following website locations:
http://infotrek.er.usgs.gov/wdnr_fishes/index.jsp
http://dnr.wi.gov/topic/EndangeredResources/Animals.asp
http://www.npwrc.usgs.gov/resource/herps/amphibid/otherres.htm

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

protect wetlands globally, nationally (i.e., the Federal Clean Water Act of 1972), State-wide, and locally (see Chapter III for more details). Most recently, the U.S. Army Corp of Engineers and USEPA, in coordination with the U.S. Fish and Wildlife Service, WDNR, and SEWRPC, have updated the delineation of wetlands in areas of special natural resource interest for the entire regional area to protect these areas and their associated critical species habitats (see Advanced Delineation and Identification (ADID) wetlands section in Chapter III of this report).[56] These efforts are designed to protect or conserve wetlands and the ecosystem services they provide.

The term "ecosystem services" refers to any of the benefits that ecosystems—both natural and semi-natural—provide to humans.[57] In other words, the benefits of ecosystem services or function are broken down or classified by their relative abilities to provide goods and services that satisfy human needs, [58] either directly or indirectly, as shown for wetlands in Figure 25. For example, researchers have determined that the economic value of the various functions or services provided by wetland ecosystems exceeded that provided by any other system including lakes, streams, forests, and grasslands, and was second only to that provided by coastal estuaries.[59] Wetlands provide a wealth of ecosystem services; society stands to gain a great deal from wetland conservation. Therefore, it is essential to incorporate wetland conservation and restoration targets as part of this plan to guide management and policy decisions regarding the use and preservation of such ecosystems.

As indicated on Map 4 and quantified in Table 1, wetlands in the Pewaukee River watershed are mainly associated with the perennial and intermittent streams, and total approximately 2,800 acres, or about 11.5 percent of the watershed area. They are essentially transitional areas, possessing characteristics of both aquatic and terrestrial ecosystems. At the same time, they possess features unique unto themselves.

For regulatory purposes, the State of Wisconsin defines wetlands as areas where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions. Three specific characteristics of wetlands are evaluated when a wetland determination is made, including:[64]

- Hydrology that results in wet or flooded soils;

- Soils that are dominated by anaerobic (without oxygen, literally means living without air and is what produces the noxious smell) processes; and

- Rooted vascular plants, that are adapted to life in flooded, anaerobic environments.

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[56]*Pursuant to Section NR 103.04(4) of the Wisconsin Administrative Code, wetlands in areas of special natural resources interest includes those wetlands both within the boundary of designated areas of special natural resource interest and those wetlands which are in proximity to or have a direct hydrologic connection to such designated areas, which include Advanced Delineation and Identification study (ADID) areas. See SEWRPC Planning Report No 42,* Amendment to the Natural Areas and Critical Species Habitat Protection and Management Plan for the Southeastern Wisconsin Region, *December 2010.* http://www.sewrpc.org/SEWRPCFiles/Publications/pr/pr-042-natural-areas-crit-species-habitat-amendment.pdf?

[57]*Millennium Ecosystem Assessment,* Ecosystem services and human well-being: Wetlands and Water, *Synthesis. Report to the Ramsar Convention. Washington, DC: World Resources Institute. 2005. Online:* http://millenniumassessment.org/en/Global.html.

[58]*RDS. de Groot, M.A. Wilson, and RAM. Bauman's, "A typology for the classification, description and valuation of ecosystem functions, goods and services,"* Ecological Economics, *Vol. 41, 2000, pages 393-408.* http://www.sciencedirect.com/science/article/pii/S0921800902000897.

[59]*R.W. Costanzo,* et al., *"The value of the world's ecosystem services and natural capita,"* Nature, *Vol. 387, 1997, pages 253-260.*

Figure 25

RELATIONSHIP BETWEEN ECOSYSTEM SERVICES PROVIDED BY NATURAL AND CREATED WETLANDS AND THEIR VALUE IN DECISION MAKING[1]

Service	Examples of Goods and Services Derived	Estimated value (1994 US $/ac^{-1} yr^{-1})[a]
REGULATION SERVICES		
Water quality		
Erosion control and sediment retention	Sediment filtration and storage capabilities that prevent downstream migration of sediment and improve downstream water quality.	NA
Waste treatment	Reduction of excess nutrient, organic, and metal loadings reduced through microbial degradation and/or sorption to improve water quality. Reduction of runoff temperature via shading and water's heat capacity.	1,690
Nutrient cycling	Reduction of nitrogen and phosphorus concentrations through denitrification and biological uptake.	NA
Hydrologic regulation	Moderation of the rate, volume, and frequency of surface runoff to provide flood and storm surge protection.	1,860
Climate regulation		
Greenhouse gas regulation	Maintenance of air quality and CO_2/CH_4 balance (through C sequestration); regulation of gases also influences climate effects.	54
Microclimate regulation	Maintenance of a favorable climate (such as temperature, precipitation) for human habitation, health, and cultivation.	NA
Soil formation	Building of land surface through the accumulation of organic material in wetlands.	NA
HABITAT SERVICES		
Refugia	Maintenance of biological and genetic diversity through provision of suitable habitat for resident or migratory plant and animal species. Includes the maintenance of populations of commercially harvested species and biological pest control services. This diversity forms the basis of many other ecosystem services.	123
PRODUCTION SERVICES		
Food production	Production of fish, game, fruits for small-scale hunting/gathering or aquaculture.	104
Raw materials	Production of trees, peat, and other biomass appropriate for lumber, fuel, or fodder.	43
INFORMATION SERVICES		
Recreation	Provision of opportunities for hunting, bird-watching, hiking, or other recreational uses.	232
Cultural	Provision of opportunities for noncommercial uses, including the use of wetlands for school excursions/education and for scientific research. Aesthetic, artistic, and spiritual values are also included.	357

[1]Adapted from Costanza et al., 1997, and de Groot, 2006)

[2]Value estimates for each service taken from Costanza et al. (1997). A listing of NA for individual services indicates that a formal valuation of this service had not yet been conducted.

Ecosystem services are products of the structure (for example, plant and animal community composition) and processes (such as nutrient cycling and decomposition) that characterize an ecosystem such as a wetland. These services also include food and raw material provision, air and water purification, biodiversity maintenance, and aesthetic and other cultural benefits to humans. These services can be attributed economic, social, and ecological values. Ideally, the inherent value of these services will guide management and policy decisions regarding the use and preservation of ecosystems.

Source: Trisha L. Moore, William F. Hunt III, Urban Waterways: Stormwater Wetlands and Ecosystem Services*, North Carolina Cooperative Extension, 2011; Adapted from de Groot 2002 de Groot, R.S., Wilson, M.A., and Boumans, R.M., "A typology for the classification, description and valuation of ecosystem functions, goods and services," Ecological Economics 41: 393-408, 2002.*

It is important to note that these elements are the reason why wetlands pose severe limitations for urban development. In general, these limitations are related to the high water table, and the high compressibility and instability, low bearing capacity, and high shrink-swell potential of wetland soils. These limitations may result in flooding, wet basements, unstable foundations, failing pavements, and failing sanitary sewer and water lines. There are significant and costly onsite preparation and maintenance costs associated with the development of wetland soils, particularly in connection with roads, foundations, and public utilities.

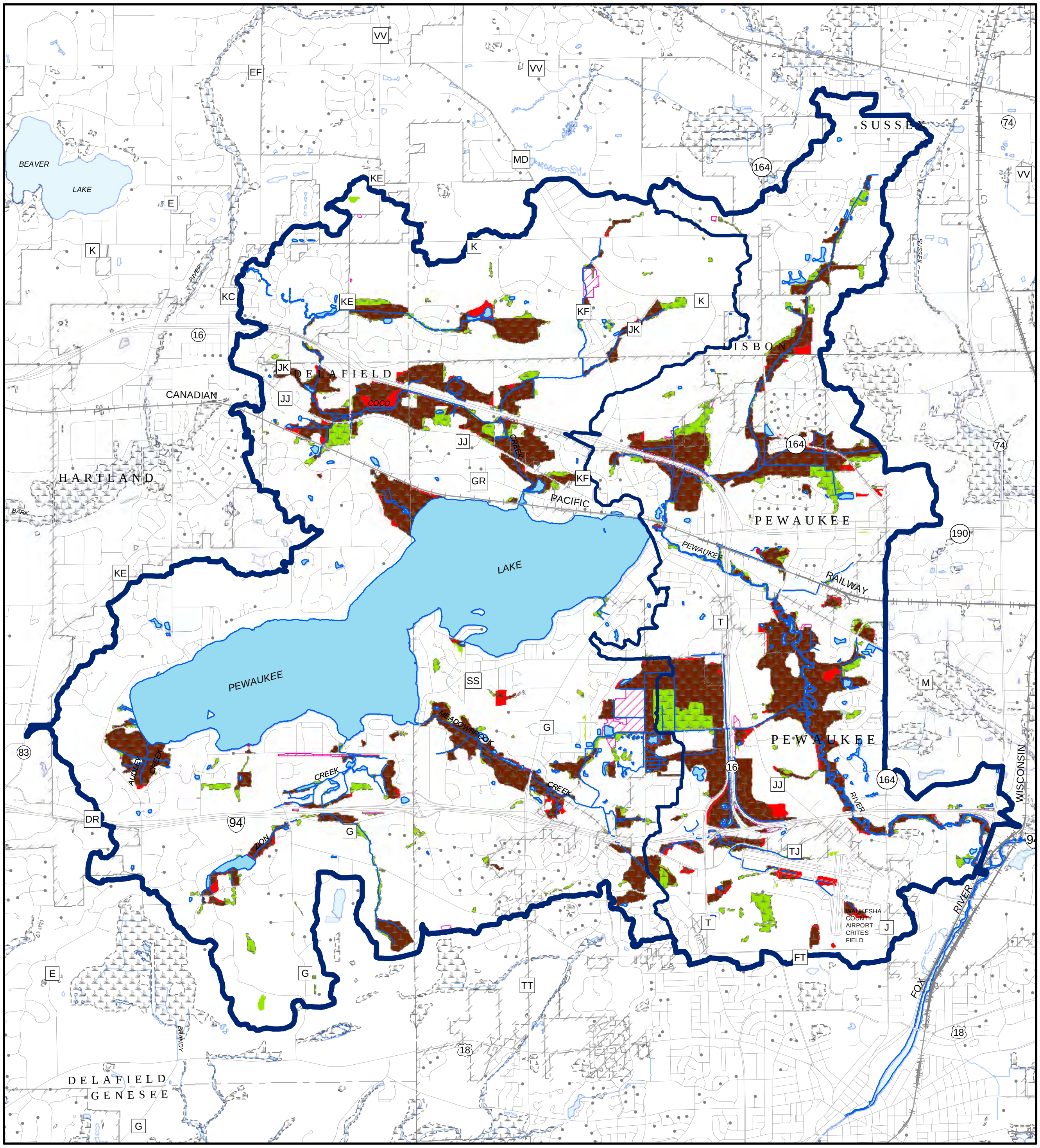
As part of the WDNR Wisconsin Wetland Inventory (WWI), beginning in the year 2005, the wetlands were mapped to a much finer scale and greater level of detail (more wetland categories) than under prior inventories. This change increased the accuracy and precision of mapped wetland boundaries throughout the Region. As a result of the changes to the mapping approach, however, year 2010 wetland inventory data are not comparable to data from the year 2000 and prior inventories. At the county and regional level, the most significant effect of the change is that more, smaller wetlands were able to be delineated, which led to an overall increase in the number and total acreage of wetlands. At the local scale of this study, there was an increase of almost 590 acres of wetland that was mostly due to an increase in the number of wetlands, historical wetlands converted to agricultural use through ditching and draining now reverting back to wetlands due to inactivity/abandonment of agricultural cultivation activities, and expansion of boundaries within pre-existing wetland areas as shown in Map 13. However, there was also significant loss of more than 200 acres of wetland due to urban development, primarily related to roadway construction and residential developments. Map 13 also shows that there are almost 90 acres of existing farmed wetland that currently exist within the Pewaukee River watershed. These areas contain significant potential as easily restorable areas to convert back to wetland in the future. In summary, despite the wetland losses compared to the year 2000, substantial wetland gains accounted for an increase of about 1.5 percent in wetland acres throughout the watershed. Although wetlands naturally change over time, the gains in wetland acreage within this watershed are more related to the changes in how they are mapped. These more accurate maps and associated mapping techniques will be far more effective in identifying and preserving wetlands for the future.

Map 14 shows that there are several unique types of wetland communities within the Pewaukee River watershed that include aquatic bed (submerged aquatic vegetation in less than six feet of water depth), emergent/wet meadow (herbaceous plants that stand above the surface of the water or soil), scrub/shrub (woody plants less than 20 feet tall), and forested (woody plants greater than 20 feet tall) types. There is also one additional category of farmed wetlands, that are technically still in agricultural use (see below), but are being mapped as part of this new inventory. Most surprising, although it may seem counterintuitive, more than 50 percent or 1,293 acres of Pewaukee Lake is functionally a submerged wetland. Although the aquatic bed is technically considered open water (i.e., the water elevation is below the ordinary high water mark), it contains the single largest contiguous wetland within the Pewaukee River watershed, which provides significant services that include erosion control and sediment retention, treatment or reduction of pollutant loadings, nutrient recycling through denitrification and biological uptake, habitat for wildlife, recreational, as well as aesthetic and cultural values. In other words, the ecosystem functions provided by this submerged wetland that provide goods (such as recreation) and services (such as pollutant reduction) represent the benefits that humans derive, directly or indirectly, from ecosystem functions.

As shown in Figure 25, estimated dollar values (based upon a willingness-to-pay) per acre per year have been developed for these services, which indicates that this submerged wetland contains an estimated value of nearly $5.8 million (1994 dollars) based upon its size. This valuation signifies the importance of this submerged wetland within Pewaukee Lake, both ecologically and economically. In addition, 2,798 acres of wetland (not including farmed wetland) is primarily wooded, with about 65 percent being combined scrub/shrub (44 percent) and forested (21 percent) wetland and the remaining 35 percent being emergent/wet meadow. This total acreage is estimated to provide an estimated value of about $12.5 million per year in ecosystem services, in addition to the aquatic bed wetlands. In conclusion, these wetlands combined are estimated to provide about $18.3 million annually in ecosystem services, demonstrating that public citizens and local municipalities are gaining a wealth of ecological and economical goods and services from the existing wetlands that have been protected within this watershed.

Map 13

WETLAND LOSSES AND GAINS WITHIN THE PEWAUKEE RIVER WATERSHED: 2000-2010



2000 and 2010 Wetlands (2290 acres)	SURFACE WATER
2000 Wetlands - Loss (206 acres)	STREAM
2010 Wetlands - Gain (587 acres)	WATERSHED BOUNDARY
Farmed Wetlands (84 acres)	SUBWATERSHED BOUNDARY

N

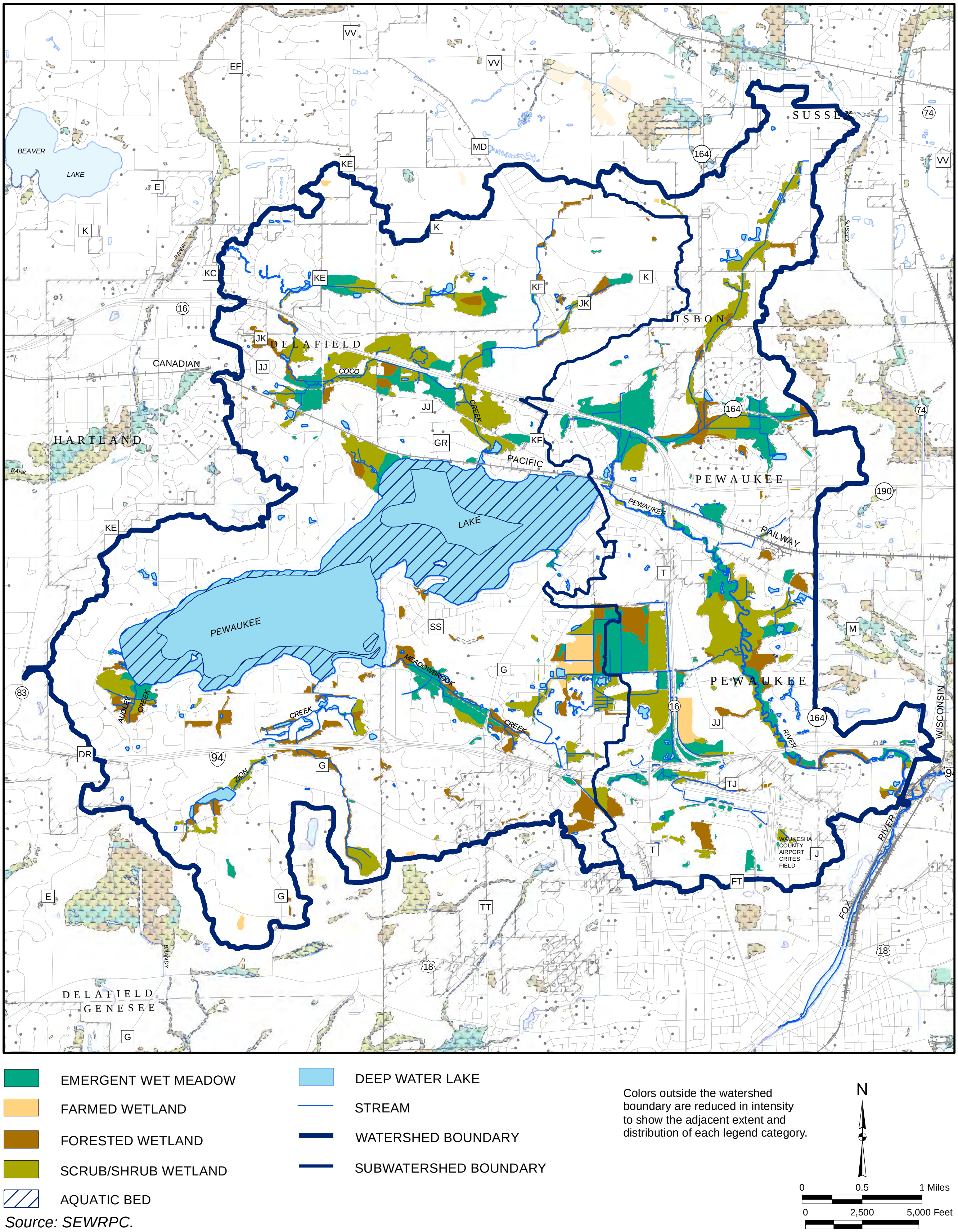
0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

Map 14

WETLAND COVER TYPES WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



Source: SEWRPC.

Uplands

Upland habitat is basically comprised of natural areas that are not defined as wetland. These areas are usually higher in elevation than wetlands and located outside wetlands further away from open water, and so they are not as wet as wetland. For example, as shown on Map 15, the upland areas within the Pewaukee River watershed are generally located outside of the transitional wetland areas. However, there are many exceptions to this gross attempt to broadly classify uplands that can be seen within the Pewaukee River watershed. Upland can sometimes be very difficult to distinguish from wetland, because these features form broad and complex mosaics or combinations across the landscape. It is precisely this combination and the linkages between these unique community types that provide the critical habitats to sustain healthy and diverse aquatic and terrestrial wildlife.

Much of the upland area within the Pewaukee River watershed was dominated by upland forest, primarily oak, as of 1836. This was cleared for agricultural crops and later developed for urban uses.[60] As can be seen in the 1941 aerial photos (see Figures 8 to 10), there were very few trees on the landscape after nearly 100 years of clear-cutting. In contrast, from 1941 to the present, there has been significant regrowth of deciduous forested lands throughout the watershed. Regrowth accounts for nearly 50 percent of all the upland lands identified in the 2005 WWI and nearly all of the upland forested woodlands—about 1,300 acres or 5 percent of the watershed area—as shown on Map 15. The remaining upland cover types include about 25 percent grassland and a nearly equal amount of brush (small diameter trees less than 20 feet in height), which is indicative of a much more open vegetation landscape than in the past. In some cases, this grassland is being managed as active pasture land, and is likely enrolled in the USDA Conservation Reserve Program (CRP) or equivalent program (see Chapter III for more details), and/or is in the middle of some type of crop rotation. There also were small portions of conifer and mixed (combinations of some or all of the others) upland communities.

Like wetlands ecosystems as described above, upland habitats also provide a variety of ecosystem services. Although researchers have determined that the economic value of these various functions or services provided by the upland forests and grasslands are not as great as the values for wetland ecosystems, these areas provide important services worth protecting.[61] More specifically, uplands provide these critical services, including: production of food, livestock, and crops; groundwater recharge and water quality; flood risk prevention; air quality protection; soil conservation; wildlife management potential through provision of critical breeding, nesting, resting, and feeding grounds (as well as refuge from predators for many species of upland game and nongame species; recreation), tourism, and education opportunities.

Another important contrast between upland and wetland is that the upland soils generally pose many fewer limitations for urban development. In general, uplands have a lower water table, lower compressibility and greater soil stability, greater bearing capacity, and lower shrink-swell potential than wetland soils. These conditions usually result in less flooding, dry basements, more stable foundations, more stable pavements, and less failure of sanitary sewer and water lines. Therefore, the development of upland soils requires significantly lower costs for onsite preparation and maintenance, particularly in connection with roads, foundations, and public utilities—which makes these areas highly desirable for urban development.

Therefore, it is important to incorporate upland conservation and restoration targets as part of this plan to guide management and policy decisions regarding the use and preservation of such ecosystems.

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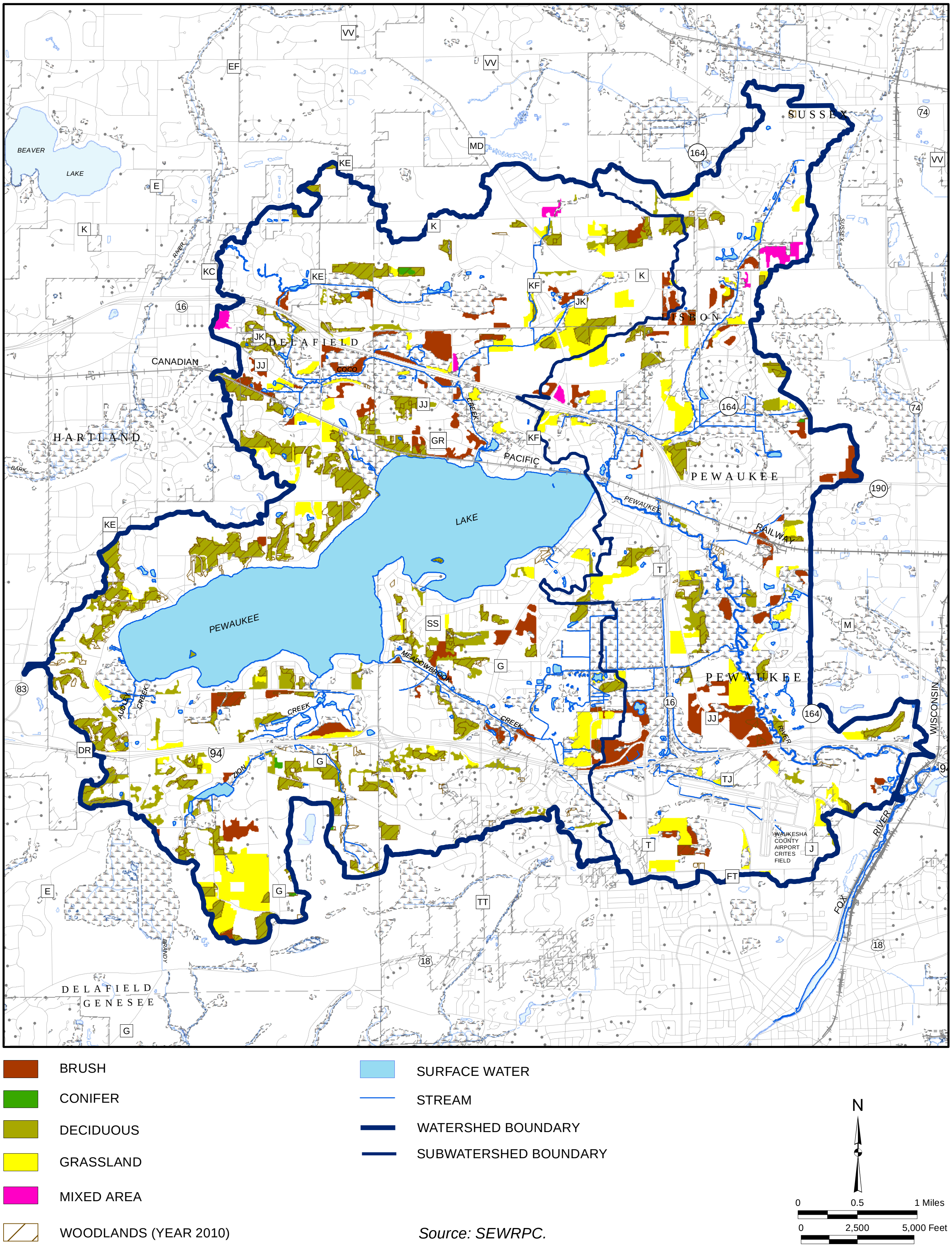
[60]*SEWRPC Planning Report No. 42*, op. cit.

[61]*R.W. Costanza, et al., "The value of the world's ecosystem services and natural capital,"* Nature, *Volume 387, 1997, pp. 253-260.*

Map 15

UPLAND COVER TYPES WITHIN THE PEWAUKEE RIVER WATERSHED: 2005



Source: SEWRPC.

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Chapter III

RELATED PLANS, REGULATIONS, AND PROGRAMS

RELATIONSHIP TO OTHER PLANS

The Pewaukee River Watershed Protection Plan is built upon preceding planning and resource management efforts, linking regional- and watershed-level plans with local level planning. This plan, therefore, will provide an integrated framework for future efforts to protect the land and water resources within the Pewaukee River watershed. This planning effort contributes to the environmentally sound management of these valuable resources in a coordinated manner that is compatible with watershedwide needs and resource management programs.

One of the first steps in the watershed planning process is the inventory, collation, and review of the recommendations of relevant, previously prepared reports and plans. These plans include recommendations and programs that address the interconnectedness of the natural resources of this watershed with those of the cities, towns, villages, and county within the watershed, and which focus on the immediacy and importance of natural resources at the community level. The plans that were collated and reviewed for input into this current planning program were generally most relevant to actions being taken or potentially undertaken by Waukesha County. In addition, selected plans prepared at the local level, including development plans, land use plans, park and open space plans, and water quality management plans, were considered. These plans and reports, which are described below, are listed in Table 7 and provide the basis for developing an integrated scheme for the sustainable management of the natural resources of the Pewaukee River watershed through the coordinated efforts of State, County, and local governments; special-purpose units of government; and community groups.

Land Use Plans

The areawide concerns that necessitate a regional planning effort in southeastern Wisconsin have their source in changing populations—size, composition, and distribution—and in the attendant urban development occurring within the Region. These areawide issues include: stormwater management and flooding; air and water pollution; increased demand for park and outdoor recreation facilities; the need to provide for adequate sewerage and water supply facilities; traffic congestion; and, underlying all of the foregoing, rapidly changing land use development. The year 2035 comprehensive regional land use plan, documented in Southeastern Wisconsin Regional Planning Commission (SEWRPC) Planning Report (PR) No. 48, provides an adopted framework for coordinating and guiding growth and development within the multijurisdictional urbanizing Region (see Table 7). A summary of the existing and planned land use conditions within the Pewaukee River watershed is set forth in Chapter II of this report. Within this planning umbrella, special-purpose plans provide more detail on specific issues of concern facing the County and local governments. These include stormwater, wastewater, and environmental management plans, which are briefly described below.

Table 7

LIST OF MANAGEMENT PLANS RELEVANT TO THE PEWAUKEE RIVER WATERSHED

Plan Type	Community	Plan and Date of Publication
Land Use	Regional	SEWRPC Planning Report No. 48, *A Regional Land Use Plan for Southeastern Wisconsin: 2035*, June 2006
	Waukesha County	SEWRPC Community Assistance Planning Report No. 209*, A Development Plan for Waukesha County, Wisconsin*, August 1996
	Village of Sussex	SEWRPC Community Assistance Planning Report No. 216, *A Land Use Plan for Waukesha county, Wisconsin,* December 1997
	Village of Hartland	SEWRPC Community Assistance Planning Report No. 254, *A Master Plan for the Village of Hartland: 2020, Waukesha County,* December 2004
	Town and Village of Pewaukee	SEWRPC Community Assistance Planning Report No. 76, *A Land Use Plan for the Town and Village of Pewaukee: 2000,* December 1982
Comprehensive Plans	City of Delafield	Yaggy Colby Associates, *City of Delafield 2030 Comprehensive Plan*, April 27, 2009
		City of Delafield and Yaggy Colby Associates, *City of Delafield Park and Recreation Plan*, June 7, 2010
	City of Pewaukee	City of Pewaukee, *Amendment to the City of Pewaukee Comprehensive Plan for the Year 2035, Neighborhood Plans for the City of Pewaukee: 2010-2035*, July 16, 2012
		City of Pewaukee, *City of Pewaukee Comprehensive Plan for the Year 2035*, April 20, 2009
		City and Village of Pewaukee, *Addendum to the Joint Comprehensive Park and Open Space Plan for the City and Village of Pewaukee, Waukesha County, Wisconsin*, March 2006
	City of Waukesha	City of Waukesha, *City of Waukesha, Wisconsin Comprehensive Plan*, November 4, 2009
		City of Waukesha, *A Park and Open Space Plan for the City of Waukesha: 2007*, June 5, 2007
	Village of Hartland	Waukesha County, *The Village of Hartland Comprehensive Development Plan: 2035*, June 22, 2009
		R.A. Smith & Associates, Inc., *Comprehensive Outdoor Recreation Plan, Village of Hartland, Wisconsin, 2007 Update*, February 2007
	Village of Pewaukee	Village of Pewaukee, *A Comprehensive Plan for the Village of Pewaukee: 2035*, August 2009
		City and Village of Pewaukee, *Addendum to the Joint Comprehensive Park and Open Space Plan for the City and Village of Pewaukee, Waukesha County, Wisconsin*, March 2006
	Village of Sussex	Vandewalle & Associates, *Addendum to the Comprehensive Plan, Sussex Downtown Design and Development Plan Update*, July 26, 2011
		HNTB, *Village of Sussex Comprehensive Plan: 2020*, March 25, 2003
		Schreiber/Anderson Associates, Inc., *Parks and Open Space Plan 2007 to 2011, Village of Sussex, Wisconsin*, August 2007
	Town of Delafield	Town of Delafield and Waukesha County, *Town of Delafield Smart Growth Plan, Waukesha County, Wisconsin*, August 11, 2009
		Town of Delafield, *Parks and Recreation Facilities Master Plan 2007-2012, Town of Delafield, Wisconsin*, December 12, 2006
	Town of Lisbon	Waukesha County, *A Comprehensive Development Plan for the Town of Lisbon–2035, Waukesha County, Wisconsin*, September 14, 2009
	Town of Merton	Town of Merton and MK Haroldson Planning Consultants, *Town of Merton, Waukesha County, Wisconsin, Comprehensive Land Use Plan–2035*, May 12, 2009
		Town of Merton, *Town of Merton Parks, Recreation and Open Space Plan: 2004*, December 2004
	Waukesha County	Waukesha County, *A Comprehensive Development Plan for Waukesha County, Waukesha County, Wisconsin*, February 24, 2009
		Waukesha County, *A Comprehensive Development Plan for Waukesha County, Waukesha County, Wisconsin; Appendix A, "Waukesha County Park and Open Space Plan,"* February 24, 2009

Table 7 (continued)

Plan Type	Community	Plan and Date of Publication
Stormwater Management	Village of Sussex	SEWRPC Community Assistance Planning Report No. 89, *A Stormwater Management Plan for the Village of Sussex, Waukesha County, Wisconsin,* October 1983
		Stormwater Management Master Plan, Village of Sussex, Waukesha County, Wisconsin, January 2011
	City of Pewaukee	*City of Pewaukee Storm Water Management Plan*, June 1999, Update June 2007
	City of Waukesha	*City of Waukesha Storm Water Management Plan*, is currently being developed by the Department of Public Works
	Village of Hartland	*Erosion Control and Stormwater Management Requirements, Village of Hartland, Wisconsin*, July 2005
Sanitary Sewer	City of Delafield	SEWRPC Community Assistance Planning Report No. 127, *Sanitary Sewer Service Area for the City of Delafield and the Village of Nashotah and Environs, Waukesha County, Wisconsin,* November 1992
	City (Town) of Pewaukee and Village of Pewaukee	SEWRPC Community Assistance Planning Report No 113, *Sanitary Sewer Service Area for the Town of Pewaukee Sanitary District No. 3, Lake Pewaukee Sanitary District, and Village of Pewaukee, Waukesha County, Wisconsin,* June 1985
	City of Waukesha	SEWRPC Community Assistance Planning Report No. 100, 2nd Edition*, Sanitary Sewer Service Area for the City of Waukesha and Environs, Waukesha County*, Wisconsin, March 1999
	Village of Hartland	SEWRPC Community Assistance Planning Report No.93, *Sanitary Sewer Service Area for the Village of Hartland, Waukesha County, Wisconsin*, April 1985
	Village of Sussex	SEWRPC Community Assistance Planning Report No. 84, 2nd Edition, *Sanitary Sewer Service Area for the Village of Sussex, Waukesha County, Wisconsin,* September 1994
Environmental	Regional	SEWRPC Planning Report No. 30, *A Regional Water Quality Management Plan for Southeastern Wisconsin—2000*, September 1978
		SEWRPC Memorandum Report No. 93, *A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report,* March 1995
		SEWRPC Planning Report No. 42*, A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin,* September 1997
		SEWRPC *Amendment to the Natural Areas and Critical Species Habitat Protection and Management Plan for the Southeastern Wisconsin Region*, December 2010
		SEWRPC Planning Report No. 5, *The Natural Resources of Southeastern Wisconsin*, June 1963
		SEWRPC Planning Report No. 8, *The Soils of Southeastern Wisconsin*, June 1966
		SEWRPC Technical Report No. 47, *Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water Balance Model,* July 2008
		SEWRPC Memorandum Report No. 188, *Troy Bedrock Valley Aquifer Model, Waukesha and Walworth Counties, Wisconsin,* November 2009
	Waukesha County	Waukesha County Department of Parks & Land Use-Land Resources Division, *Waukesha County Land and Water Resource Management Plan 2012 Update,* (This plan is also available for viewing and downloading at: *www.waukeshacounty.gov/landandwaterplan.)*
		SEWRPC Community Assistance Planning Report No. 156, *Waukesha County Animal Waste Management Plan,* August 1987
		SEWRPC Community Assistance Planning Report No. 159, *Waukesha County Agricultural Soil Erosion Control Plan,* June 1988
		SEWRPC Memorandum Report No. 145, *Lake and Stream Resources Classification Project for Waukesha County, Wisconsin: 2000,* November 2005
	Watershed	SEWRPC Planning Report No. 12, *A Comprehensive Plan for the Fox River Watershed,* Volume One, *Inventory Findings and Forecasts,* April 1969

Table 7 (continued)

Plan Type	Community	Plan and Date of Publication
Park and Open Space	Regional	SEWRPC Planning Report No. 27, *A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000,* November 1977
	Waukesha County	SEWRPC Community Assistance Planning Report No. 137, *A Park and Open Space Plan for Waukesha County,* December 1989
	City of Waukesha	SEWRPC Community Assistance Report No. 77, *A Wetland Protection and Management Plan for the City of Waukesha and Environs,* February 1983
	City of Waukesha and Town of Pewaukee	SEWRPC Community Assistance Planning Report No. 197, *A Wildlife Management Plan for the General Electric Company, Medical Systems Group, Lands, City of Waukesha and Town of Pewaukee, Waukesha County, Wisconsin,* June 1991
	Town and Village of Pewaukee	SEWRPC Community Assistance Planning Report No. 42, *A Park and Open Space Plan for the Town and Village of Pewaukee, Waukesha County, Wisconsin,* October 1980
Lake Planning	Pewaukee Lake	Wisconsin Department of Natural Resources Lake Use Report No. FX-2, *Pewaukee Lake, Waukesha County, Wisconsin,* 1970
		SEWRPC Memorandum Report No. 56, *A Lakefront Recreational Use and Waterway Protection Plan for the Village of Pewaukee*, March 1996
		SEWRPC Community Assistance Planning Report No. 58, 2nd Edition, *A Lake Management Plan for Pewaukee Lake*, *Waukesha County, Wisconsin,* May 2003
		Lake Pewaukee Sanitary District, *An Aquatic Plant Management Plan for Pewaukee Lake, Wisconsin,* January 1992
		Wisconsin Department of Natural Resources, *Pewaukee Lake, Waukesha County: Long-Term Trend Lake, 1986,* 1986
		Wisconsin Department of Natural Resources, *Pewaukee Lake, Waukesha County: Long-Term Trend Lake, 1987*, 1987
		Wisconsin Department of Natural Resources, *Pewaukee Lake Sensitive Area Study,* June 1994
		E.R. Schumacher*, Wisconsin Department of Natural Resources Fish Management Report No. 131, Creel Survey on Pewaukee and Nagawicka Lakes, Waukesha County, Summer 1982, February 1987*
Floodland Management	Village of Pewaukee	SEWRPC Community Assistance Planning Report No. 9, 2nd Edition, Floodland Information Report for the Pewaukee River, Village of Pewaukee. Waukesha County, Wisconsin, March 1985
		SEWRPC Community Assistance Report No. 14, *Floodland Management Plan for the Village of Pewaukee,* February 1978
	Village of Sussex	SEWRPC Community Assistance Planning Report No. 11, *Floodland Information Report for Sussex Creek and Willow Springs Creek,* March 1977

Source: SEWRPC.

Smart Growth Plans

In 1999 the Wisconsin Legislature enacted a new comprehensive planning law, set forth in Section 66.1001 of the *Wisconsin Statutes*. The new requirements supplement earlier provisions in the *Statutes* for the preparation of county development plans (Section 59.69(3) of the *Statutes*) and local master plans (Section 62.23 of the *Statutes*). The requirements, which are often referred to as the "Smart Growth" law, provide a new framework for the development, adoption, and implementation of comprehensive plans in Wisconsin. The law includes a "consistency" requirement, whereby zoning, subdivision, and official mapping ordinances adopted and enforced by counties, cities, villages, and towns must be consistent with the comprehensive plan adopted by the county or local unit of government. Under the comprehensive planning law (Section 66.1001(3) of the *Statutes*), the consistency requirement took effect on January 1, 2010. Waukesha County, in cooperation with the cities, towns, and villages, completed comprehensive land use plans in February 2009.[1] This plan provides an overall framework and point of departure for county and local planning efforts and is considered a refinement of the SEWRPC year 2035 regional land use plan.

Stormwater Management Plans

With the adoption of Chapter NR 216, “Storm Water Discharge Permits,” of the *Wisconsin Administrative Code*, stormwater planning and management has taken on greater significance as described in the Regulatory Standards section below. This enhanced awareness was further strengthened with the promulgation of Chapter NR 151, “Runoff Management,” and related provisions that set forth specific performance standards for stormwater management that must be met from urban-, nonurban-, and transportation-related land uses.

Sanitary Sewer Service Area Plans

The provision of public sanitary sewer service to appropriate densities of urban development within the Southeastern Wisconsin Region is a fundamental principle of the adopted regional water quality management plan. The regional water quality management plan, described below, provides the planning framework within which the need for sanitary sewerage services can be assessed and evaluated. Currently, the Pewaukee River watershed contains portions of four sanitary sewer service areas and is centered on the Fox River Water Pollution Control Commission’s sewer service area, which largely serves the City of Pewaukee, the Village of Pewaukee, and a portion of the City of Waukesha. Lands associated with the southern-most portion of the watershed are served by the City of Waukesha. The Village of Sussex and the Delafield Hartland Water Pollution Control Commission provide service to portions of the northeast and western-most areas of the watershed, respectively. The sanitary sewer serviced areas are documented in the SEWRPC Community Assistance Planning Report (CAPR) Nos. 84, 93, 100, 113, and 127 (see Table 7). These areas are shown on Map 6 in Chapter II of this report.

Environmental Management Plans

Regional Water Quality Management Plan

SEWRPC is the designated water quality planning agency for southeastern Wisconsin, pursuant to Section 208 of the Federal Water Pollution Control Act (P.L. 92-500), also known as the “Clean Water Act.” In 1979, the initial regional water quality management plan for southeastern Wisconsin, with a design year of 2000, was formally adopted as SEWRPC PR No. 30 (see Table 7). A status report on implementation of that plan was provided in SEWRPC Memorandum Report (MR) No. 93, published in 1995.

Under the adopted plan, the regional water quality management plan may be refined through the preparation of specific lake and stream management plans, such as this watershed protection plan.

Fox River Basin Water Quality Plan

As the State agency tasked with water resources management, the Wisconsin Department of Natural Resources (WDNR) prepares basin-level plans that guide the application of State resources for the major drainage basins across the State. The basin plan for the Fox River basin is set forth in WDNR Publication No. WT-701-01, *The State of the Southeast Fox River Basin*, published in 2002. This plan identified nine priority issues affecting the basin’s water resources, including the need to acquire basic inventory data on the state-of-the-basin; the impacts of land use changes on the water resources of the basin; the impacts of land use changes on the terrestrial resources of the basin; the need for consideration of groundwater recharge and quality; and the provision of recreational use opportunities. Of particular relevance to the Pewaukee River watershed are recommendations that implement Federal Phase I and Phase II stormwater permitting requirements for moderate- to large-size municipalities, and which promote compliance within municipalities with construction site erosion control ordinance requirements. In addition, recommendations relating to protection and enhancement of trout streams and coldwater fisheries, implementation of 100-foot-wide buffer zones along streamcourses, and protection of high-value habitat within the basin, complement actions recommended in this watershed protection plan.

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[1]*Waukesha County Department of Park and Land Use,* A Comprehensive Development Plan for Waukesha County, Waukesha County, Wisconsin*, February 2009.*

County Land and Water Resource Management Plan

The 1997 revisions to Chapter 92 of the *Wisconsin Statutes* require each county to develop a multi-year Land and Water Resource Management (LWRM) plan to address both rural and urban nonpoint source pollution problems. Chapter ATCP 50 of the *Wisconsin Administrative Code* contains details of the planning requirements.

The Waukesha County LWRM Plan 2006-2010 was approved by the Waukesha County Board and the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) in March 2006 and updated in 2012. This is a third-generation plan, intended to be an update to the initial LWRM plan which was adopted by the Waukesha County Board in February 1999. The LWRM plan outlines the conservation program priorities for the Waukesha County Parks and Land Use, Land Resources Division (LRD) for the next five years.

As shown in Table 7, other countywide plans developed by SEWRPC regarding environment-related topics include: animal waste management (CAPR No. 156), agricultural soil erosion (CAPR No. 159) and lake and steam resources classification (MR No. 145).

Park and Open Space Plans

The park and open space plans focus on the terrestrial resources and provision of public access to these resources. As with land use planning in general, county- and local-level park and open space planning is conducted within the framework of the Regional Park and Open Space Plan, initially published as SEWRPC PR No. 27 in 1977, with a design year of 2000. This plan was refined in the Waukesha County Park and Open Space Plan, published in 1989, as SEWRPC CAPR No. 137, and in the 1996 Waukesha County Development Plan (SEWRPC CAPR No. 209). A 2004 amendment to the Waukesha County Development Plan incorporates a greenway corridor concept, with guidelines for trail preservation and buffer zones. The principal park and open space sites within the Pewaukee River watershed are the Waukesha County Pewaukee Lake Access portion of Naga-waukee Park and portions of the Lake Country Trail system. The location of existing parkland as of year 2010 in the watershed is shown on Map 4 in Chapter II of this report under the "recreation" land use category.

Lake Management Plans

The Wisconsin Legislature has identified seven areas related to the development and protection of water resources and their attendant watersheds as the basis for evaluating the sensitivity of lakes and streams to human influences. Section 281.69(5)(b) of the *Wisconsin Statutes* defines these characteristics in terms of the size, depth, and shape of the waterbody; the size of the watershed; the quality of the water; the potential for recreational use; the potential for land development; the potential for nonpoint source pollution; and the type and size of the fish and wildlife populations in and around the waterbody. These attributes allow lakes and streams to be categorized into groups of varying sensitivities to human influences. A comprehensive lake management plan has been prepared for Pewaukee Lake within the Pewaukee River basin as listed in Table 7. This plan addresses both 1) current and forecasted water quality concerns facing the lake and 2) aquatic plant management for Pewaukee Lake and the Lake community in the context of its drainage basin. As such, this plan forms an important contribution to overall watershed planning.

WATER USE OBJECTIVES AND WATER QUALITY STANDARDS

Water quality standards are the basis for protecting and regulating the quality of surface waters. The standards implement portions of the Federal Clean Water Act by specifying the designated uses of waterbodies and setting water quality criteria to protect those uses. The standards also contain policies to protect high-quality waters and to protect waters from being further degraded. Water quality standards are established to sustain public health and public enjoyment of waters and for the propagation and protection of fish, aquatic organisms, and other wildlife.

Water quality standards consist of three elements: designated uses, water quality criteria, and anti-degradation policy. These are set forth in Chapters NR 102, "Water Quality Standards for Wisconsin Surface Waters," NR 103, "Water Quality Standards for Wetlands," NR 104, "Uses and Designated Standards and Secondary Values," NR 105, "Surface Water Quality Criteria for Toxic Substances," and NR 207, "Water Quality Antidegradation," of the *Wisconsin Administrative Code*. Under these chapters of the Code, Pewaukee Lake, Pewaukee River, and their associated tributaries, with the exception of Coco Creek and Zion Creek, are classified as warmwater sportfish.[2] Coco Creek is classified as a coldwater sportfish community, whereas, Zion Creek has been classified "limited aquatic life." The water use objectives established for the waters of the Pewaukee River watershed are shown on Map 16. The levels of pollution control needed to achieve the established water use objectives were initially identified in the SEWRPC Fox River watershed study and the regional water quality management plan,[3] and were refined in the Fox River watershed state-of-the-basin report.[4] These plans contain consistent recommendations on the levels of nonpoint source pollution controls needed to achieve water use objectives for the waterbodies within the Pewaukee River watershed.

None of the streams or tributaries within the Pewaukee River watershed are meeting their potential biological uses or the fishable and swimmable water use goals set for the waters of the United States in the Federal Clean Water Act.[5] Coco Creek has been identified to be partially meeting its potential biological use designation. The Pewaukee River, Meadowbrook Creek, and Zion Creek were reported as not meeting their potential biological uses. The cause or source of impairments identified by WDNR staff as part of their 2002 state-of-the-basin report for this watershed include ditching or channelization, hydrologic modification, cropland erosion, barnyard or excessive lot runoff, construction site erosion, urban stormwater runoff, unspecified nonpoint source pollution, and storm sewers. These have caused numerous impacts to the Pewaukee River and its tributaries in terms of degraded habitat (lack of cover, sedimentation, scouring, etc.), nutrient enrichment, temperature fluctuations or extremes, reductions in dissolved oxygen, sedimentation, stream flow fluctuations caused by land use development, bacteriological contamination, turbidity, and pesticide/herbicide toxicity.[6]

Despite these impairments, all of Coco Creek, beginning at CTH JJ (just upstream of Pewaukee Lake), has been designated by the WDNR as having the potential to support a Class I and Class II brown trout fishery.[7] A Class I trout stream is characterized as high-quality trout water that has sufficient natural reproduction to sustain the native or naturalized populations. Consequently, streams of this category do not require stocking of hatchery-raised trout. A Class II trout stream may have some natural trout reproduction, but not enough to utilize available food and space. Consequently, stocking is generally required to sustain a desirable sportfishery. In this regard, it should be noted that brown trout were collected by the WDNR staff from Coco Creek as recently as July 2011 (see the **Fisheries** section in Chapter IV of this report).

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[2]*Wisconsin Department of Natural Resources, Publication No. WR-366-94,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project, *June 1994.*

[3]*SEWRPC Planning Report No. 12,* A Comprehensive Plan for the Fox River Watershed, *Volume One,* Inventory Findings and Forecasts, *April 1969, and Volume Two,* Alternative Plans and Recommended Plan, *February 1970, as amended; and SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978, Volume Two,* Alternative Plans, *February 1979, and Volume Three,* Recommended Plan, *June 1979, as amended; SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

[4]*Wisconsin Department of Natural Resources, Publication No. PUBL-WT-701-2002,* The State of the Southeast Fox River Basin, *February 2002.*

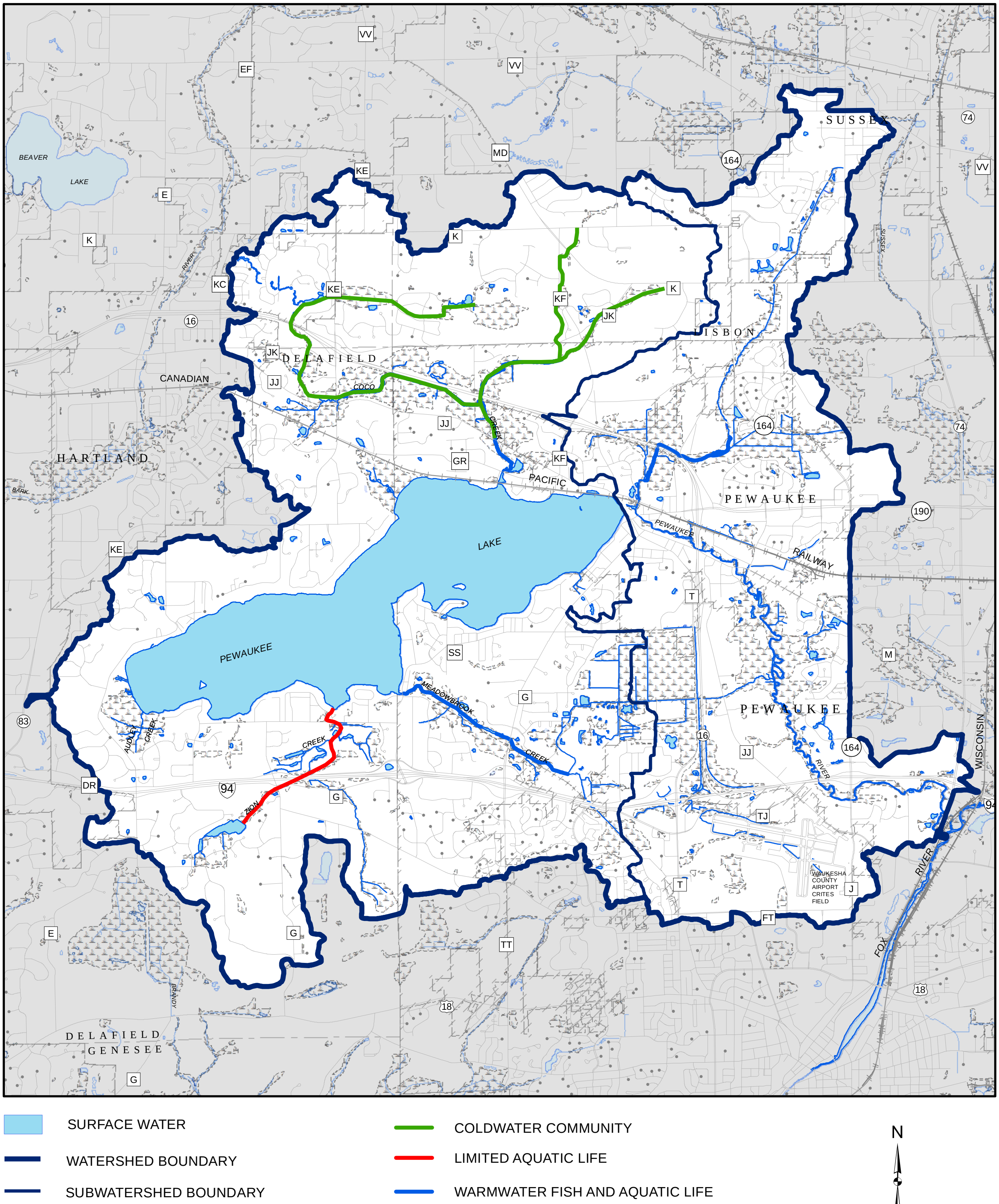
[5]*Wisconsin Department of Natural Resources, Publication No. PUBL-FH-806-2002, Wisconsin Trout Streams, April 2002.*

[6]Ibid.

[7]*Wisconsin Department of Natural Resources, Publication No. PUBL-WT-701-2002,* op. cit.

Map 16

CURRENT REGULATORY WATER USE CLASSIFICATIONS FOR SURFACE WATERS WITHIN THE PEWAUKEE RIVER WATERSHED



Source: SEWRPC.

Table 8

APPLICABLE REGULATORY WATER QUALITY CRITERIA FOR WATERBODIES WITHIN THE PEWAUKEE RIVER WATERSHED PROTECTION PLAN STUDY AREA

Water Quality Parameter	Designated Use Category[a]						Source
	Coldwater Community	Warmwater Fish and Aquatic Life	Limited Forage Fish Community (variance category)	Special Variance Category A[b]	Special Variance Category B[c]	Limited Aquatic Life (variance category)	
Temperature (^{o}F)	See Table 9					86.0	NR 102 Subchapter II
Dissolved Oxygen (mg/l)	6.0 minimum 7.0 minimum during spawning	5.0 minimum	3.0 minimum	2.0 minimum	2.0 minimum	1.0 minimum	NR 102.04(4) NR 104.04(3) NR 104.06(2)
pH Range (S.U.)	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	NR 102.04(4)[d] NR 104.04(3)
Fecal Coliform Bacteria (MFFCC)	- -	- -	- -	- -	- -	- -	NR 102.04(5) NR 104.06(2)
Geometric Mean	200	200	200	1,000	1,000	200	
Maximum	400	400	400	2,000	- -	400	
Total Phosphorus (mg/l)	- -	- -	- -	- -	- -	- -	NR 102.06(3) NR 102.06(4) NR 102.06(5) NR 102.06(6)
Designated Streams[e]	0.100	0.100	0.100	0.100	0.100	0.100	
Other Streams	0.075	0.075	0.075	0.075	0.075	- -	
Chloride (mg/l)	- -	- -	- -	- -	- -	- -	NR 105.05(2) NR 105.06(5)
Acute Toxicity[f]	757	757	757	757	757	757	
Chronic Toxicity[g]	395	395	395	395	395	395	

[a]*NR 102.04(1) All surface waters shall meet the following conditions at all times and under all flow conditions: substances that will cause objectionable deposits on the shore or in the bed of a body of water, floating or submerged debris, oil, scum or other material, and materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the State. Substance in concentrations or combinations which are toxic or harmful to humans shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[b]*As set forth in Chapter NR 104.06(2)(a) of the* Wisconsin Administrative Code.

[c]*As set forth in Chapter NR 104.06(2)(b) of the* Wisconsin Administrative Code.

[d]*The pH shall be within the stated range with no change greater than 0.5 unit outside the estimated natural seasonal maximum and minimum.*

[e]*Designated in Chapter NR 102.06(3)(a) of the* Wisconsin Administrative Code*. There are no designated streams in the Pewaukee River watershed.*

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

[g]*The chronic toxicity criterion is the maximum four-day concentration of a substance which ensures adequate protection of sensitive species of aquatic life from the chronic toxicity of that substance and will adequately protect the designated fish and aquatic life use of the surface water if not exceeded more than once every three years.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

The applicable water quality criteria for all water uses designated in the Pewaukee River watershed are set forth in Tables 8 and 9. Table 8 shows the applicable water quality criteria for all designated uses for five water quality parameters—dissolved oxygen concentration, pH, fecal coliform bacteria concentration, total phosphorus concentration, and chloride concentration. It also shows the water quality criterion for temperature that applies to limited aquatic life communities. Table 9 shows the water quality criteria for temperature for those streams that have a seven-day, 10-percent probability low flow (7Q10)[8] of less than 200 cubic feet per second (cfs). The 7Q10 of all of the streams in the Pewaukee River watershed is less than 200 cfs.

[8]*Seven-day consecutive low flow with an annual probability of occurrence of 10 percent.*

Table 9

AMBIENT, SUBLETHAL, AND ACUTE WATER QUALITY CRITERIA FOR TEMPERATURE (DEGREES CELSIUS) AMONG DESIGNATED USES FOR SMALL STREAMS[a]

Month	Designated Use Category and Associated Temperature Criterion[b]								
	Cold Water Communities			Warmwater Sportfish or Forage Fish Communities			Limited Forage Fish Communities		
	Ambient	Sublethal	Acute	Ambient	Sublethal	Acute	Ambient	Sublethal	Acute
January	1.7	8.3	20.0	0.6	9.4	24.4	2.8	12.2	25.6
February	2.2	8.3	20.0	1.1	10.0	24.4	3.9	12.2	26.1
March	3.9	10.6	20.6	3.3	11.1	25.0	6.1	13.9	26.7
April	8.3	13.9	21.1	8.9	12.8	26.1	10.0	17.2	27.2
May	13.3	17.2	22.2	14.4	18.3	27.8	15.0	21.1	28.9
June	16.7	19.4	22.2	18.9	24.4	28.9	17.8	25.0	29.4
July	17.8	19.4	22.8	20.6	27.2	29.4	20.6	27.2	30.0
August	17.2	18.3	22.8	19.4	27.2	28.9	20.0	26.1	30.0
September	13.9	15.6	22.2	15.6	22.8	27.8	17.2	22.8	29.4
October	9.4	11.7	21.1	10.0	16.1	26.7	12.8	17.2	28.3
November	5.0	8.9	20.6	4.4	9.4	25.0	7.8	12.2	26.7
December	2.8	8.3	20.6	1.7	9.4	24.4	4.4	12.2	26.1

[a]As set forth in Section NR 102.25 of the Wisconsin Administrative Code, small streams are waters with unidirectional 7Q10 flows less than 200 cubic feet per second. The 7Q10 flow is the seven-day consecutive low flow with a 10 percent annual probability of occurrence (10-year recurrence interval).

[b]The ambient, sublethal, and acute water quality temperature criterion specified for any calendar month shall be applied simultaneously to establish the protection needed for each identified fish and other aquatic life use. The sublethal criteria are to be applied as the mean daily maximum temperature over a calendar week. The acute criteria are to be applied as the daily maximum temperatures. The ambient temperature is used to calculate the corresponding acute and sublethal criteria and for determining effluent limitations in discharge permits under the Wisconsin Pollutant Discharge Elimination System.

Source: Wisconsin Department of Natural Resources and SEWRPC.

In addition to the numerical criteria presented in the tables, narrative standards apply to all waters. All surface waters must meet certain conditions at all times and under all flow conditions. Chapter NR 102 of the *Wisconsin Administrative Code* states that practices attributable to municipal, commercial, domestic, agricultural, land development or other activities shall be controlled so that all waters (including the mixing zone and the effluent channel) shall not degrade water quality of any substance or method to a level that would interfere with public rights in the waters of the State.

The State of Wisconsin has not promulgated numerical water quality criteria for some water quality constituents. Examples include total suspended solids, turbidity, and total nitrogen.

Since contaminants can and do accumulate in fishes, the WDNR in consultation with the State Department of Health Services provides annual updates for fish consumption advisories for all waters within the State. Fish are a healthy part of a well-balanced diet, but it is important to know where fish come from and the species or type of fish being eaten. These consumption advisories were developed to protect people's health while reducing their exposure to environmental contaminants and are available online along with a search tool to locate specific advisories for each county.[9] There are no special or more stringent advisories for Pewaukee River or Lake than are covered by general statewide advice.

[9]*WDNR, Choose Wisely: A Health Guide for Eating Fish in Wisconsin, 2013. Online:* http://dnr.wi.gov/topic/fishing/documents/consumption/FishAdvisoryWebLow2013.pdf

Under the anti-degradation policy to prevent the reduction of existing water quality, the WDNR has classified some waters of the State as designated Outstanding or Exceptional Resource Waters or designated wetlands of special natural resource interest in Chapter NR 102 and Chapter NR 103 of the *Wisconsin Administrative Code*, respectively. Although there are no designated Outstanding or Exceptional Resource Waters in the Pewaukee River watershed, there are substantial amounts of designated wetlands of special natural resource interest— about 3,140 acres of Advanced Delineation and Identification (ADID) wetlands as shown on Map 17. The ADID wetlands in southeastern Wisconsin "include lakes, streams, and wetlands" located in the 2005 primary environmental corridors and, in some cases, wetlands located within natural areas that are located outside the primary environmental corridors (see Map 17).[10] Presently, the ADID wetlands and related waters in and adjacent to navigable interstate waters provide the only Federal regulatory mechanism that may be used to protect wetland natural areas, critical species habitats, and related aquatic habitats.

STATE REGULATORY STANDARDS

Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*

Through 1997 Wisconsin Act 27, the State Legislature required the WDNR and DATCP to develop performance standards for controlling nonpoint source pollution from agricultural and nonagricultural land and from transportation facilities.[11] The performance standards are set forth in Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*, which became effective on October 1, 2002, and was revised in July 2004 and December 2010.

Agricultural Land Performance Standards

Performance standards relate to four areas of agriculture: cropland soil erosion control, soil loss from riparian lands, manure management, and nutrient management. The agricultural performance standards are:

- Soil erosion rates on all cropland (and pastures as of July 1, 2012) must be maintained at or below "T" (Tolerable Soil Loss).

- As of 2005, for high-priority areas, such as impaired or exceptional waters, and 2008 for all other areas, application of manure or other nutrients to croplands must be done in accordance with a nutrient management plan, designed to meet State standards for limiting the entry of nutrients into groundwater or surface water resources (this standard does not apply to applications of industrial waste, municipal sludge, or septage regulated under other WDNR programs, provided that the material is not comingled with manure prior to application).

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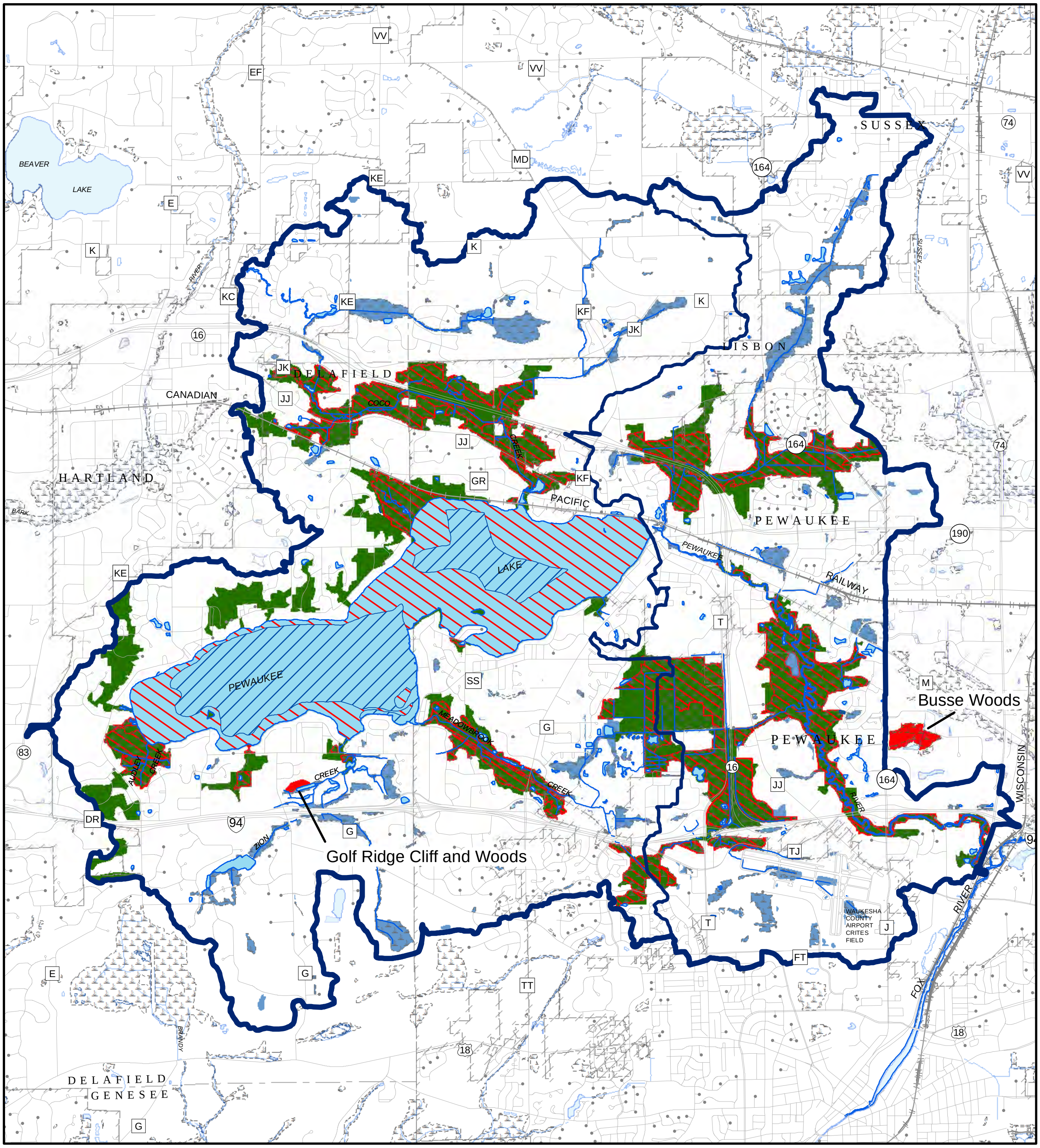
[10]*Under the Section 404(b)(1) Guidelines of the Clean Water Act, the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency, working in coordination with other Federal Agencies and the States, may identify certain wetlands and other waters that are generally unsuitable for the discharge of dredge and fill materials. Under these guidelines the Federal agencies have developed the Advanced Identification of Disposal Areas (ADID) in wetlands program (40 CFR 230.80). This program is an advisory procedure intended to add predictability to the Section 404 wetland permitting process and better account for the impacts of wetland losses from multiple projects within a geographic area.*

[11]*The State performance standards are set forth in the Chapter NR 151, "Runoff Management," of the* Wisconsin Administrative Code. *Additional code chapters that are related to the State nonpoint source pollution control program include: Chapter NR 152, "Model Ordinances for Construction Site Erosion Control and Storm Water Management;" 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 17

ADID WATERS (LAKES, STREAMS, AND WETLANDS) AND NON-ADID WETLANDS WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



ADID WETLANDS

ADID NATURAL AREAS

ADID LAKES OR PONDS

PRIMARY ENVIRONMENTAL CORRIDOR

OTHER WETLANDS

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

- Clean water runoff must be diverted away from contacting feedlots, manure storage facilities, and barnyards in water quality management areas (areas within 300 feet of a stream, 1,000 feet from a lake, or areas susceptible to groundwater contamination).

- All new or substantially altered manure storage facilities must meet current engineering design standards to prevent surface or groundwater pollution. In addition, inactive or unused manure storage facilities that are failing or leaking shall be properly upgraded, replaced, or closed.

The manure management prohibitions are:

- No direct runoff from animal feedlots to "waters of the State."

- No overflowing manure storage facilities.

- No unconfined manure piles in shoreland areas (areas within 300 feet of a stream, 1,000 feet from lakes).

- No unlimited livestock access to "waters of the State" where the livestock prevent sustaining an adequate vegetative cover.

In general, for land that does not meet the NR 151 standards and that was cropped or enrolled in the U.S. Department of Agriculture Conservation Reserve or Conservation Reserve Enhancement Programs as of October 1, 2002, agricultural performance standards are only required to be met if cost-sharing funds are available. Existing cropland that met the standards as of October 1, 2002, must continue to meet the standards. New cropland must meet the standards, regardless of whether cost-share funds are available.

The 2010 revision to NR 151 added new agricultural performance standards. The new performance standards include:

- A five- to 20-foot setback from the top of a surface water channel in agricultural fields within which no tillage is allowed for the purpose of maintaining streambank integrity and avoiding soil deposits into State waters;

- A limit on the amount of phosphorus that may run off croplands as measured by a phosphorus index; A prohibition against significant discharge of process water from milk houses, feedlots, and other similar sources; and

- A standard that requires crop and livestock producers to reduce discharges if necessary to meet a load allocation specified in an approved Total Maximum Daily Load (TMDL) by implementing targeted performance standards specified for the TMDL area using best management practices, conservation practices, and performance standards specified in Chapter ATCP 50 of the *Wisconsin Administrative Code*.

Chapter NR 243, "Animal Feeding Operations," of the *Wisconsin Administrative Code* sets forth rules for concentrated animal feeding operations and other animal feeding operations for the purpose of controlling the discharge of pollutants to waters of the State. Concentrated animal feeding operations are defined as livestock and poultry operations with more than 1,000 animal units. Animal units are calculated for each different type and size class of livestock and poultry. For example, facilities with 1,000 beef cattle, 700 milking cows, or 200,000 chickens each would be considered to have the equivalent of 1,000 animal units. All concentrated animal feeding operations and certain types of other animal feeding operations must obtain Wisconsin Pollutant Discharge Elimination System (WPDES) permits. In general, animal feeding operations are defined as feedlots or facilities, other than pastures, where animals are fed for a total of 45 days in any 12-month period.

Nonagricultural (urban) Land Performance Standards

The nonagricultural performance standards set forth in Chapter NR 151 encompass two major types of land development. The first includes standards for areas of new development and redevelopment, and the second includes standards for existing developed urban areas. The performance standards address the following areas:

- Construction sites for new development and redevelopment,
- Post-construction stormwater runoff for new development and redevelopment,
- Developed urban areas, and
- Nonmunicipal property fertilizing.

Chapter NR 151 requires municipalities to reduce the amount of total suspended solids (TSS) in stormwater runoff, as part of their Wisconsin Pollutant Discharge Elimination System permits for their municipal separate storm sewer system (MS4). Under Chapter NR 216, municipalities are required to reduce the amount of TSS in stormwater runoff by 20 percent from areas that have been developed as of October 2004, or to the maximum extent practicable, for areas that have been developed as of March 2008.

Chapter NR 151 also establishes schedules for reducing TSS from areas of existing development by 40 percent. The 2011Wisconsin Act 32, as reflected in Section 281.16(2)(am) of the *Wisconsin Statutes*, states that WDNR "may not enforce a provision in a rule that establishes a date by which a covered municipality must implement methods to achieve a specified reduction in the level of total suspended solids carried by runoff, if the provision requires the covered municipality to achieve a reduction of more than 20 percent."[12] The Section notes that the requirement does not apply to new development or redevelopment, and it states that a covered municipality that has achieved a total suspended solids reduction of more than 20 percent as of July 1, 2011, "shall to the maximum extent practicable maintain all of the best management practices that the municipality has implemented on or before July 1, 2011, to achieve that reduction." The effect of this law is to eliminate the requirement of NR 151 that a municipality with an MS4 permit under Chapters NR 151 and 216, "Storm Water Discharge Permits," must achieve a 40 percent reduction in TSS in runoff from areas of existing development by a specific date.[13]

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

In addition, regardless of whether a municipality is required to have a stormwater discharge permit under Chapter NR 216, Chapter NR 151 requires that, as of January 1, 2013, all construction sites that have one acre or more of land disturbance must discharge no more than five tons of sediment per acre per year. With certain limited exceptions, those sites required to have construction erosion control permits must also have post-development stormwater management practices to reduce the TSS load from the site by 80 percent for new

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[12]*The statute defines a "covered municipality" as one that has been issued an individual municipal separate storm sewer system (MS4) permit, or that is covered by a general MS4 permit.*

[13]*The requirements of Section 281.16(2)(am) of the* Wisconsin Statutes *are not included in the* Wisconsin Administrative Code.

development, 40 percent from parking lots and roads associated with redevelopment, and 80 percent for infill development. If it can be demonstrated that the solids reduction standard cannot be met for a specific site, TSS must be controlled to the maximum extent practicable.

Section NR 151.123 establishes peak discharge performance standards for new development. Under this section, best management practices shall "maintain or reduce the one-year, 24-hour and the two-year, 24-hour post-construction peak runoff discharge rates to the one-year, 24-hour and the two-year, 24-hour pre-development peak runoff discharge rates respectively, or to the maximum extent practicable."

Section NR 151.124 of the *Wisconsin Administrative Code* requires infiltration of post-development runoff from areas developed on or after October 1, 2004, subject to specific exclusions and exemptions. For development with less than 40 percent connected imperviousness ("low imperviousness"), 90 percent of the annual predevelopment infiltration volume is required to be infiltrated. However, no more than 1 percent of the area of the project site is required to be used as effective infiltration area. For development with connected imperviousness ranging from more than 40 percent up to 80 percent ("moderate imperviousness"), 75 percent of the annual predevelopment infiltration volume is required to be infiltrated. For development with connected imperviousness greater than 80 percent ("high imperviousness"), 60 percent of the annual predevelopment infiltration volume is required to be infiltrated. In the case of moderate and high imperviousness areas, no more than 2 percent of the project site is required to be used as effective infiltration area.

Setbacks from streams, lakes, and wetlands, as set forth in Section NR 151.125, are described below in the "Buffer Standards" subsection.

Recent State Actions Affecting Construction Erosion Control and Stormwater Management Standards
2013 Wisconsin Act 20, which was passed by the State Legislature, and signed into law by the Governor, established additional requirements related to construction erosion control and stormwater management that are not yet embodied in the *Wisconsin Administrative Code*. Those requirements are described below.

2013 Wisconsin Act 20 calls for:

- The Wisconsin Department of Safety and Professional Services to "establish statewide standards for erosion control at building sites that have a land disturbance that is less than one acre in area and that are for the construction of public buildings and buildings that are places of employment," and to "promulgate rules for the administration of construction site erosion control" consistent with the requirements of the Act,

- The WDNR to establish by rule uniform statewide standards for activities related to construction site erosion control at sites where one acre of land or more is disturbed,

- The WDNR to establish by rule uniform statewide standards for stormwater management,

- The WDNR to "prepare a model zoning ordinance for construction site erosion control … and for stormwater management in the form of an administrative rule," and

- Cities, villages, towns, or counties to comply with the uniform statewide construction site erosion control and stormwater management under any pertinent local zoning ordinance.

2013 Wisconsin Act 20 allows a municipality to establish ordinance provisions for stormwater management that are more restrictive than the uniform statewide standards if stricter standards are needed to control stormwater quantity or flooding or to comply with "[F]ederally-approved total maximum daily load requirements." Also, the uniform statewide standards are not required to be applied to municipal ordinance provisions relating to existing development or redevelopment.

Transportation Facility Performance Standards
Transportation facility performance standards that are set forth in Chapter NR 151 and in Chapter TRANS 401, "Construction Site Erosion Control and Storm Water Management Procedures for Department Actions," of the *Wisconsin Administrative Code* cover the following areas:

- Construction sites,
- Post-construction phase, and
- Developed urban areas.

The standards of TRANS 401 are applicable to Wisconsin Department of Transportation projects.

Municipal Stormwater Discharge Permits
The 1987 amendments to the Federal Clean Water Act established a Federal program for permitting stormwater discharges. The State of Wisconsin obtained certification from the USEPA which enabled the State to administer the stormwater discharge permitting program as an extension of the existing WPDES program. Section 283.33 of the *Statutes*, which provides authority for the issuance of stormwater discharge permits by the State, was enacted in 1993. The administrative rules for the State stormwater discharge permit program are set forth in Chapter NR 216 of the *Administrative Code*, which took effect on November 1, 1994, and was most recently repealed and replaced effective August 1, 2004.

In general, municipal separate storm sewer systems (MS4s), industrial facilities, and construction sites are required to obtain WPDES permit coverage under Subchapters I, II, and III of Chapter NR 216, respectively. The following entities are required to obtain discharge permits under Chapter NR 216:

1. An owner or operator of a municipal separate storm sewer system serving an incorporated area with a population of 100,000 or more as determined by the 1990 decennial census;

2. An owner or operator of a municipal separate storm sewer system notified by WDNR prior to August 1, 2004, that they must obtain a permit;

3. An owner or operator of a municipal separate storm sewer system located within an urbanized area as defined by the U.S. Bureau of the Census' latest decennial census survey;

4. An owner or operator of a municipal separate storm sewer system serving a population of 10,000 or more in a municipality with a population density of 1,000 persons or more per square mile as determined by the U.S. Bureau of the Census' latest decennial census survey;

5. Industries identified in Section NR 216.21,[14] including heavy and light manufacturers and associated transportation facilities, as well as operators in the mining, oil, and gas extraction industry. These facilities are separated into categories called "Tiers" based on their Standard Industrial Classification (SIC) code, which is now commonly replaced by NAICS codes; and

[14]*Depending on the type of industry, a statewide general permit or an individual permit may be issued. A holder of a general or an individual permit must prepare and implement a stormwater pollution prevention plan. The requirements for such a plan are set forth in Section NR 216.27.*

6. Construction sites where land disturbance of 1 acre or more will occur, except for those activities exempted under NR 216.42 such as those associated agriculture,[15] one- and two-family dwellings regulated by the Wisconsin Department of Safety and Professional Services DSPS, and Wisconsin Department of Transportation projects which are subject to the liaison cooperative agreement between the WDNR and the Wisconsin Department of Transportation.[16]

An MS4 municipal stormwater discharge permit to discharge all portions of the municipal separate storm sewer system to waters of the State was issued October 30, 2009, to members of the Upper Fox River Watershed Group, which includes the Cities of Pewaukee and Waukesha, Towns of Delafield and Lisbon, and Villages of Pewaukee and Sussex within the Pewaukee River watershed. The Towns of Brookfield and Waukesha also were included in the Upper Fox River Watershed Group, but they are outside the project watershed and were not considered further in this report. The permit specifically addresses Pewaukee Lake, the Pewaukee River, and Zion Creek, and their associated surface and ground waters. The Upper Fox River Watershed Group's permit sets forth conditions under which stormwaters may be discharged to waters of the State for purposes of achieving the water quality standards contained in chapters NR 102 through 105 and NR 140 of the *Wisconsin Administrative Code* through October 29, 2014.

These designated MS4 communities are required to reduce the urban pollutants entering the local waterways via their storm sewer systems by implementing programs such as: construction site and long-term stormwater control; illicit discharge screenings; information and education programs about stormwater that are targeted to the general public, developers, and internal staff; and improving municipal "good housekeeping" practices, including winter road management programs, public works yard inspections, and inventorying and maintaining existing storm-water facilities, including mapping their systems. Each municipality is required to submit an annual report for each calendar year summarizing and evaluating the programs being implemented and stating where improvements and cost effective changes should be made.

In cooperation with the WDNR, Waukesha County, Lake Pewaukee Sanitary District, and SEWRPC staffs, storm sewer system inventory information was obtained from each of the MS4 municipalities, as well as Waukesha County records, and combined into a composite map for the entire watershed (see Map 18). Although there are no specific mapping standards (i.e. formatting, labeling, coordinate system, etc.), each of these communities

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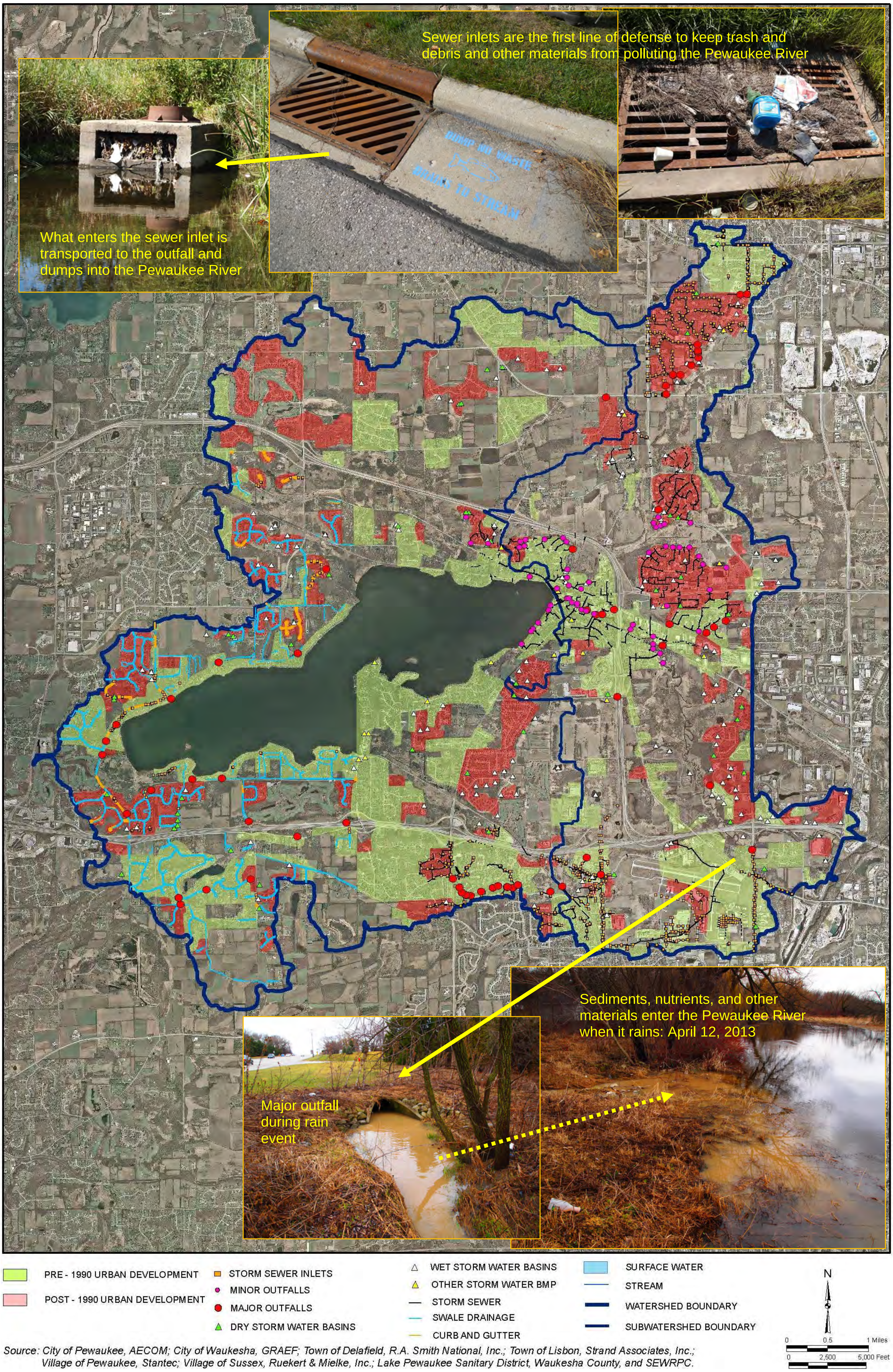
[15]*Agriculture is exempt from this requirement for activities such as planting, growing, cultivating, and harvesting crops for human or livestock consumption, and pasturing of livestock, as well as for sod farms and tree nurseries. However, agriculture is not exempt from the requirement to submit a notice of intent (NOI) for one or more acres of land disturbance for the construction of structures such as barns, manure storage facilities, or barnyard runoff control systems. Construction of an agricultural building or facility must follow an erosion and sediment control plan consistent with Section NR 216.46, including meeting the performance standards of Section NR 151.11.*

[16]*Public buildings and buildings that are places of employment are regulated by the Wisconsin DSPS under Chapter SPS 360, "Erosion Control, Sediment Control and Storm Water Management," of the Wisconsin Administrative Code. Section SPS 360.12 states that filing a notice of intent with the Wisconsin Department of Safety and Professional Services (DSPS) "for a construction site with one or more acres of land disturbing construction activity constitutes an application for coverage under a storm water construction site general permit issued by" WDNR. Coverage under the WDNR general permit is required by the U.S. Environmental Protection Agency in accordance with delegation of its Federal Clean Water Act permit authority to WDNR.*

Construction of one- and two-family dwellings is generally regulated by the Wisconsin DSPS. Chapter SPS 321, "Construction Standards," sets forth 1) erosion control procedures for construction of one- and two-family dwellings (see Section 321.125) and 2) post-construction stormwater management requirements according to Chapter NR 151 (see Section 321.126).

Map 18

STORM DRAINAGE SYSTEMS WITHIN THE PEWAUKEE RIVER WATERSHED FOR PRE- VERSUS POST-1990 URBAN LAND DEVELOPMENT: 2012



Source: City of Pewaukee, AECOM; City of Waukesha, GRAEF; Town of Delafield, R.A. Smith National, Inc.; Town of Lisbon, Strand Associates, Inc.; Village of Pewaukee, Stantec; Village of Sussex, Ruekert & Mielke, Inc.; Lake Pewaukee Sanitary District, Waukesha County, and SEWRPC.

is required to provide detailed and accurate inventories in a digital geographic information systems (GIS) software format for the following elements summarized below:

- Identification of all known municipal storm sewer system outfalls discharging to waters of the State or other municipal separate storm sewer system including minor and major outfalls (36 inches in diameter);[17]

- Location and permit number of any known discharge to the municipal separate storm sewer system that has been issued WPDES permit coverage by the WDNR;

- Location of structural stormwater facilities including detention basins, infiltration basins, and other manufactured treatment devices;

- Identification of publicly owned park, recreational areas, and other open lands;

- Location of municipal garages, storage areas and other public works facilities; and

- Identification of streets.

It is important to note that Map 18 was developed to show consistency of the stormwater information throughout the watershed as reported in 2011. This is not intended to show every element of the stormwater infrastructure in each community. Information on specific characteristics of municipal stormwater management systems can be located in individual reports for each community as documented in Table 7 above.

Since each of the MS4 communities compiled its inventories using different digital formats and categories, these GIS data files were integrated to the extent practicable by Waukesha County staff. The main categories include major outfalls, minor outfalls, storm sewers, and stormwater BMPs (wet basins, dry basins, and other) as shown on Map 18 and in Table 10 (see Appendix D for specific details). Another BMP category includes such practices as sediment traps, infiltration trenches, stormceptors (prefabricated, underground devices that separates oils, grease, and sediment from stormwater runoff from parking lots or streets), and rain gardens. Based upon this inventory data, there are a total of 65 major outfalls, 361 minor outfalls, 53 dry basins, 134 wet basins, and 45 other BMPs within the Pewaukee River watershed. The storm sewer lines shown on Map 18 include both culverts and gravity mains. In addition, some communities also mapped the sewer inlets, curb and gutter, and swale information, which helps to better understand how stormwater is routed across the landscape within portions of the watershed. This data was projected over the total extent of urban lands under pre- versus post-1990 conditions, because stormwater rules and practices began to be implemented more widely during the post-1990 period. Hence, nearly all of the stormwater BMPs on the landscape reside within the urban lands developed after 1990, although there are notable exceptions—particularly within the Village of Pewaukee.

Consequently, prior to 1990, most of the stormwater BMPs consisted of storm sewers, curb and gutter, and swales. In contrast, under post-1990 conditions, BMPs continue to utilize the aforementioned practices, but wet and dry stormwater detention basins became widely used for urban development. Nearly 200 of these wet and dry basins have been constructed since about 1990 and more continue to be constructed with each new development throughout the watershed, such as shown on Map 18 and in Figure 26. These basins can be wet or dry and are

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[17]*A major outfall is a municipal separate storm sewer outfall that meets one of the following criteria: 1) a single pipe with an inside diameter of 36 inches or more or equivalent conveyance (cross sectional area of 1,018 square inches) which is associated with a drainage area of more than 50 acres, or 2) an MS4 that receives stormwater runoff from lands zoned for industrial activity or from other lands with industrial activity that is associated with a drainage area of two acres or more.*

Table 10

STORM DRAINAGE SYSTEM INVENTORY SUMMARY AMONG MS4 COMMUNITIES WITHIN THE PEWAUKEE RIVER WATERSHED: 2010-2011

Community	Storm Drainage System Category					
		Outfalls		Best Management Practices (BMP)		
	Sewer Inlets	Minor	Major	Dry Basin	Wet Basin	Other
City of Pewaukee	26	94	18	4	11	0
City of Waukesha	659	88	4	11	62	7
Town of Delafield	121	20	18	16	25	0
Town of Lisbon	11	74	1	4	9	0
Village of Pewaukee	Not-reported	56	10	15	15	32
Village of Sussex	445	29	14	3	12	6
Total	**1,262**	**361**	**65**	**53**	**134**	**45**

Source: City of Pewaukee, AECOM; City of Waukesha, GRAEF; Town of Delafield, R.A. Smith National, Inc.; Town of Lisbon, Strand Associates, Inc.; Village of Pewaukee, STANTEC; Village of Sussex, Ruekert & Mielke, Inc.; Waukesha County PLU - Land Resources Division; and SEWRPC.

designed to capture the stormwater runoff water and release it at a reduced rate. Wet basins allow the total suspended solids particles, nutrients, and associated materials to settle out. Dry basins generally provide little control of nonpoint source pollution because they have no permanent pool for settling and subsequent storage of particulate pollutants. Stormwater is diverted into these basins prior to discharging into the surface water of the Lake or local tributaries and streams within the Pewaukee River system.

Urban nonpoint performance standards focus on controlling erosion from construction sites; managing post-construction runoff from parking lots, streets, buildings, and other impervious areas; promoting infiltration, maintaining vegetative buffers between impervious surfaces and water resources, and preventing polluted runoff through better land management. These standards are implemented through the county (and local) stormwater and erosion control ordinances for new development projects, and MS4 stormwater discharge permits for existing urban areas. Effective construction erosion control and abatement of nonpoint source pollution from urban areas rely on targeted information and education programs for developers, engineers, contractors, municipal staff, and the general public. To this end, Waukesha County has executed intergovernmental agreements with 25 local communities to implement a comprehensive stormwater education program to help communities meet this part of the MS4 permit mandate. In a rapidly developing area like Waukesha County, implementing the urban nonpoint performance standards represents the single largest workload for the Land Resources Division.[18]

Buffer Standards

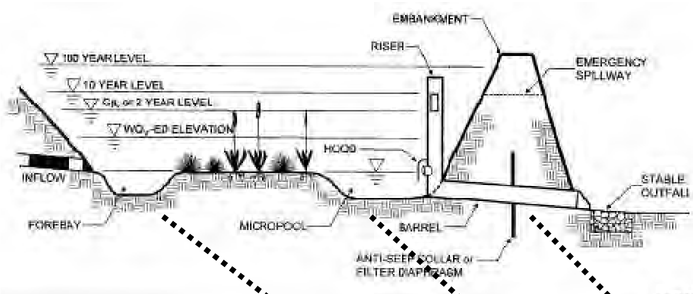
Riparian buffers are protected by a combination of Federal, State, county, and local municipal programs and regulations. For example, the Natural Resources Conservation Service (NRCS) technical standards continue to be applied through voluntary programs such as the Conservation Reserve Enhancement Program (CREP), which set minimum buffer widths based on program goals and technical standards. Administrative rules for redesign of the

[18]*Waukesha County Department of Parks & Land Use-Land Resources Division*, Waukesha County Land and Water Resource Management Plan 2012 Update.

Figure 26

STORMWATER WET DETENTION BASIN DESIGN AND CONSTRUCTION WITHIN THE PEWAUKEE RIVER WATERSHED AND PERCENT POLLUTANT REMOVAL EFFECTIVENESS: 2012

Wet basin schematic profile



Reported percent pollutant removal rates for wet basins

Pollutant	25th Percentile	Median	75th Percentile
Total suspended solids	54	78	90
Total phosphorus	39	49	76
Total nitrogen	16	32	40
Nitrate	12	28	66
Metals	25	48	71
Bacteria	48	70	92

Stormwater detention basins are designed and constructed as part of the associated development to manage both water volume and remove pollutants through settling and biological uptake before discharging into the surface waters of the Pewaukee River system.

Source: USEPA National Pollutant Discharge Elimination System (NPDES); © 2013 Microsoft Corporation, Pictometry Bird's Eye © 2012 MDA Geospatioal Services; and SEWRPC.

State nonpoint source pollution control program that began in 2000 led to the adoption of new buffer standards in 2011 with the revision of NR 151 and the establishment of a five- to 20-foot tillage setback in agricultural settings and a 10- to 75-foot impervious surface setback in urban settings (see "protective areas" around streams, lakes, and wetlands as summarized below). In addition, the provisions of County and local municipality floodland and shoreland zoning regulations also require setbacks from waterways that act as effective tools to protect riparian buffer lands, which are discussed in further detail below. The protective area setbacks are also included in the County's Storm Water Management and Erosion Control ordinance. Waukesha County also plans to incorporate the state tillage setback and/or buffer standard into the agricultural compliance evaluations.[19]

The nonagricultural performance standards set forth in Section NR 151.125 have developed specific setback requirements for designated "protective areas." A protective area is defined as an area of land that commences at the top of the channel of lakes, streams and rivers, or at the delineated boundary of wetlands, and that is the greatest of the following widths, as measured horizontally from the top of the channel or delineated wetland boundary to the closest impervious surface:

[19]*Waukesha County Department of Parks & Land Use-Land Resources Division*, Waukesha County Land and Water Resource Management Plan 2012 Update*, (page 70, under Goal 3.B.2).*

- 75 feet to protect higher quality areas that include: Chapter NR 102-designated Outstanding or Exceptional Resource Waters; Chapter NR 103-designated wetlands of special natural resource interest, which includes Advanced Delineation and Identification (ADID) wetlands as discussed above and shown on Map 17; as well as "*highly susceptible wetland*" types that include calcareous fens, sedge meadows, open and coniferous bogs, low prairies, coniferous swamps, lowland hardwood swamps, and ephemeral ponds;[20]

- 50 feet from perennial and intermittent streams, lakes, and wetlands (not designated as highly susceptible or less susceptible); and

- Minimum of 10 feet from less susceptible (degraded) wetlands and drainage channels with drainage areas greater than 130 acres.

The greatest protective area width shall apply where rivers, streams, lakes, and wetlands are contiguous. In other words, a stream or lake is not eligible for a lower protective area width even if it is contiguous to a less susceptible or degraded wetland.

Dam Regulation

Dams have a significant impact on water quality, wildlife, public safety, water rights issues, and land use in Wisconsin. Under Chapter 31 of the Wisconsin Statutes, which was created in 1917 under the Water Power Law, the WDNR has authority to regulate the location, construction, permitting, safety, operation, and maintenance of dams and bridges affecting navigable bodies of water. Chapter 31 also addresses alteration or repair of dams, dam transfer and removal, and water level and flow control.

Administrative rules governing dam design and construction standards are set forth in Chapter NR 333 of the *Wisconsin Administrative Code*. Chapter NR 335 covers the administration of the Municipal Dam Repair and Removal Grant Program; Chapter NR 330 provides standards for warning signs and portages for dams.

Spillway Capacity Requirements

The WDNR approved a failure analysis of the Pewaukee Dam in January 2005 and classified the dam as "high hazard." As the owner of the dam on Pewaukee Lake, the Village of Pewaukee adopted the dam failure floodplain in November 2008. Based on the high hazard rating, *Wisconsin Administrative Code* NR 333 requires that the Pewaukee Dam total spillway capacities be capable of passing the 1,000-year flood event without overtopping the dam. The Village then conducted an analysis of alternative to address the existing dam capacity, proposed modifications to provide the minimum hydraulic capacity, and prepared cost estimates for construction of the dam modifications.[21]

Based upon the results of the dam modification study, the dam spillway was reconstructed in the fall of 2010 (see Figure 27). The most notable features of the new spillway include replacing the downstream culverts with two box culvert outlet structures, as well as the spillway gate with a bottom draw gate that draws water from about four feet below the surface of Pewaukee Lake. In addition, the Village was required to increase the frequency of dam inspections, which are now conducted every two years. The reconstruction of this dam has not changed the required operating elevations of Pewaukee Lake. The summer water level is not to exceed 852.80 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29) from May 1 to October 1. The winter level is

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[20]*Note: Information on wetland types, including ephemeral ponds, is available from the WDNR by calling (608) 266-7012.*

[21]*R.A. Smith National, Design Report: Pewaukee Dam Modifications (Project No. 1090029), Prepared for Village of Pewaukee, Wisconsin, March 24, 2010.*

Figure 27

PEWAUKEE LAKE DAM OUTFALL

Pre-Construction

During Construction: October 18, 2010

Post-Construction: August 15, 2011

Source: Charlie Shong and SEWRPC.

not to exceed 852.20 above NGVD 29. Although there is no mandatory provision to maintain a minimum level of baseflow discharge at this outlet to sustain the Pewaukee River ecosystem downstream, the Village does keep the gate open at least 0.5 inch so that there is flow into the River.[22] The Village also monitors the outlet and remove any debris, particularly aquatic plants, to maintain unobstructed flows through the spillway. This was important in 2012 during the very dry conditions that were associated with high aquatic plant abundance and densities in Pewaukee Lake.

COUNTY AND LOCAL GOVERNMENT LAND USE REGULATIONS

The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their jurisdictions. Local zoning regulations include general, or comprehensive, zoning regulations and special-purpose regulations governing floodland and shoreland areas. General zoning and special-purpose zoning regulations may be adopted as a single ordinance or as separate ordinances; they may or may not be contained in the same document. Any analysis of locally proposed land uses must take into consideration the provisions of both general and special-purpose zoning. As already noted, the watershed includes portions of the City of Delafield, City of Pewaukee, City of Waukesha, and the Villages of Hartland, Pewaukee, and Sussex; and the Towns of Delafield, Lisbon, and Merton within Waukesha County, but note, that the Town of Pewaukee became the City of Pewaukee 13 years ago. The ordinances administered by these units of government are summarized in Table 11 and described in more detail below. In addition, since zoning regulations are often revised or updated, SEWRPC staff provide periodic summaries of the most up-to-date changes that can be read and downloaded at the following website location: *http://www.sewrpc.org/SEWRPCFiles/Community Assistance/ Smartgrowth/ fact_sheet_implementation_of_comp_plans.pdf.*

General Zoning

Villages in Wisconsin are granted comprehensive, or general, zoning powers under Section 61.35 of the *Wisconsin Statutes*. Counties are granted general zoning powers within their unincorporated areas under Section 59.69 of the

[22] *Personal Communication, David White, Engineer, Village of Pewaukee, August 2013.*

Table 11

LAND USE REGULATIONS WITHIN THE PEWAUKEE RIVER WATERSHED BY CIVIL DIVISION: 2010

Community	Type of Ordinance: General Zoning	Floodland Zoning	Shoreland or Shoreland-Wetland Zoning	Subdivision Control	Erosion Control and Stormwater Management
Waukesha County	Adopted	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Floodland and shoreland only	Adopted
City of Delafield	Adopted	Adopted	Adopted	Adopted	Adopted
City of Pewaukee	Adopted	Adopted	Adopted	Adopted	Adopted
City of Waukesha	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Hartland	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Pewaukee	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Sussex	Adopted	Adopted	Adopted	Adopted	Adopted
Town of Delafield	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Lisbon	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Merton	Adopted	County ordinance	County ordinance	Adopted	County ordinance

Source: SEWRPC.

Wisconsin Statutes. However, a county zoning ordinance becomes effective only in those towns that ratify the county ordinance. Towns that have not adopted a county zoning ordinance may adopt village powers, and subsequently utilize the village zoning authority conferred in Section 62.23. They are subject to county board approval where a general-purpose county zoning ordinance exists. Alternatively, a town may adopt a zoning ordinance under Section 60.61 of the *Wisconsin Statutes* where a general-purpose county zoning ordinance has not been adopted, but only after the county board fails to adopt a county ordinance at the petition of the governing body of the town concerned. General zoning is in effect in all communities within the Pewaukee River watershed.

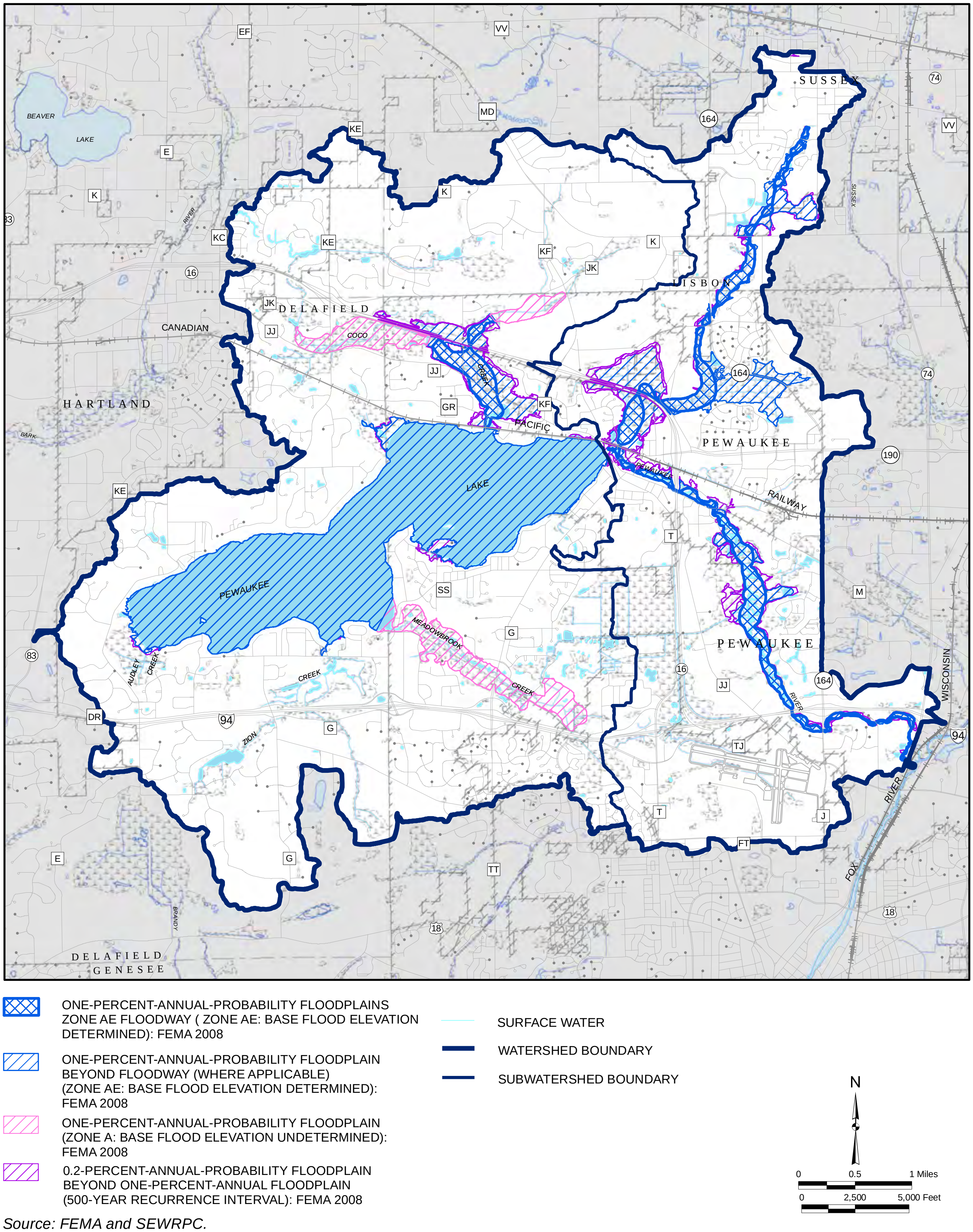
Zoning is used to regulate the use of land in Waukesha County in a manner that serves to promote the general welfare of citizens, the quality of the environment, and the conservation of resources, as well as to implement a land use plan. Zoning is the delineation of areas or zones into specific districts. It provides uniform regulations and requirements that govern the use, placement, spacing, and size of land and buildings. The Planning and Zoning Division of the Waukesha County Department of Parks and Land Use administers the zoning maps and the zoning ordinance for portions of the unincorporated areas of Waukesha County. The code is designed to provide standards for land development and to provide for adequate sanitation, drainage, safety, convenience of access, the preservation and promotion of the environment, property values, and general attractiveness of the area.

Floodland Zoning

Section 87.30 of the *Wisconsin Statutes* requires that villages and counties, with respect to their unincorporated areas, adopt floodland zoning to preserve the floodwater conveyance and storage capacity of floodplain areas and to prevent the location of new flood-damage-prone development in flood hazard areas. The minimum standards that such ordinances must meet are set forth in Chapter NR 116, “Wisconsin’s Floodplain Management Program,” of the *Wisconsin Administrative Code*. The required regulations govern filling and development within a regulatory floodplain, which is defined as the area that has a 1 percent annual probability of being inundated. The one-percent-annual-probability (100-year recurrence interval) floodplains within the Pewaukee River watershed are shown on Map 19. Under Chapter NR 116, local floodland zoning regulations must prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the one-percent-annual-probability peak flood flow. Local regulations must also restrict filling and development within the flood fringe, which is that portion of the floodplain located outside the floodway that would be covered by floodwater during the one-percent-annual-probability flood. Allowing the filling and development of the flood fringe

Map 19

FLOODPLAIN ZONES WITHIN THE PEWAUKEE RIVER WATERSHED: 2008



Source: FEMA and SEWRPC.

area, however, reduces the floodwater storage capacity of the natural floodplain, and may, thereby, increase downstream flood flows and stages. Map 16 shows floodplains designated as "Zone A" where the extent of the floodplain was based upon an approximate study that did not calculate specific flood stage elevations. The majority of these areas are associated with the small headwater tributary streams, particularly on Coco Creek and Meadowbrook Creek.

The Waukesha County ordinances related to shoreland and floodland protection recognize existing uses and structures and regulate them in accordance with sound floodplain management practices while protecting the overall water quality of stream systems. These ordinances are intended to: 1) regulate and diminish the proliferation of nonconforming structures and uses in floodplain areas; 2) regulate reconstruction, remodeling, conversion and repair of such nonconforming structures—with the overall intent of lessening the public responsibilities attendant to the continued and expanded development of land and structures inherently incompatible with natural floodplains; and 3) lessen the potential danger to life, safety, health, and welfare of persons whose lands are subject to the hazards of floods. Floodland zoning is in place for all the towns in Waukesha County (see Table 11). The Cities of Delafield, Pewaukee, and Waukesha, and the Villages of Hartland, Pewaukee, and Sussex have adopted their own floodland ordinances.

Shoreland Regulation

Shoreland zoning regulations play an important role in protecting water resources. Under Section 59.692 of the *Wisconsin Statutes*, within their unincorporated areas, counties in Wisconsin are required to adopt zoning regulations within statutorily defined shoreland areas, which are defined as those lands within 1,000 feet of the ordinary high water mark of a navigable lake, pond, or flowage; 300 feet of the ordinary high water mark of a navigable stream; or to the landward side of the floodplain, whichever distance is greater.[23]

Minimum standards for county shoreland zoning ordinances are set forth in Chapter NR 115, "Wisconsin's Shoreland Management Program," of the *Wisconsin Administrative Code*.[24] Chapter NR 115 sets forth minimum requirements regarding lot sizes and building setbacks; restrictions on cutting of trees and shrubbery; and restrictions on filling, grading, lagooning, dredging, ditching, and excavating that must be incorporated into county shoreland zoning regulations.[25] Because these are minimum requirements, counties may enact more restrictive ordinance provisions as appropriate. In addition, Chapter NR 115 requires that counties place all wetlands five acres or larger and within the statutory shoreland zoning jurisdiction area into a wetland conservancy zoning district to ensure their preservation after completion of appropriate wetland inventories by the WDNR.

[23]*Definitive determination of navigability and location of the ordinary high water mark on a case-by-case basis is the responsibility of the Wisconsin Department of Natural Resources.*

[24]*A revision to Chapter NR 115 of the* Wisconsin Administrative Code *was promulgated in January 2010. Chapter NR 115 includes the following note: "On September 12, 2010, the Secretary of the Department of Natural Resources signed an executive order extending the date by which a county must adopt or amend shoreland and subdivision ordinances to meet the revised standards in ch. NR 115. The date was extended to February 1, 2014."*

[25]*However, Chapter NR 115 includes the following note: "Effective April 17, 2012, 2011 Wisconsin Act 170 created s. 59.692 (2m), Stats., which prohibits a county from enacting, and a county, city, or village from enforcing, any provision in a county shoreland or subdivision ordinance that regulates the location, maintenance, expansion, replacement, repair, or relocation of a nonconforming building if the provision is more restrictive than the standards for nonconforming buildings under ch. NR 115; or the construction of a structure or building on a substandard lot if the provision is more restrictive than the standards for substandard lots under ch. NR 115. 2011 Wisconsin Act 170 also created other provisions that affect how a county regulates nonconforming uses and buildings, premises, structures, or fixtures under its general zoning ordinance."*

However, the rules regarding minimum lots sizes, building setbacks, and cutting of trees and shrubbery established in Chapter NR 115 for counties do not apply to cities and villages (except for newly annexed areas). Minimum standards for village shoreland-wetland zoning ordinances are set forth in Chapter NR 117, "Wisconsin's City and Village Shoreland-Wetland Protection Program," of the *Wisconsin Administrative Code*.

Shoreland zoning has the goal of protecting water quality, fish and wildlife habitat, recreation, and natural beauty. To accomplish these goals, the statewide minimum standards for county shoreland zoning ordinances in NR 115 create a 35-foot vegetated buffer strip and a 75-foot building setback around navigable waters, control the intensity of development around navigable waters, and protect wetlands within shorelands. Shoreland areas in unincorporated (town) areas are regulated by the county's shoreland zoning ordinance.

NR 117 requires cities and villages to protect wetlands located within the shoreland area. Under 2013 Wisconsin Act 80, city and village ordinances must also require a 50-foot building setback and a 35-foot vegetated buffer strip from the OHWM of navigable waters in areas annexed by the city or village after May 7, 1982, or incorporated after April 30, 1994, if the area annexed or incorporated was subject to a county shoreland zoning ordinance prior to the annexation or incorporation (see Shoreland Zoning Regulations in Annexed Lands below).

The basis for identification of wetlands to be protected under Chapters NR 115 and NR 117 is the Wisconsin Wetlands Inventory. Mandated by the State Legislature in 1978, this inventory resulted in the preparation of wetland maps covering each U.S. Public Land Survey township in the State. The inventory was completed for counties in southeastern Wisconsin in 1982 with the wetlands being delineated by the SEWRPC on its 1980, one-inch-equals-2,000-feet-scale aerial photography. SEWRPC staff, working in conjunction with the WDNR, subsequently completed updating that wetland inventory based on interpretation of 2005 color digital ortho-photography and field verification of selected wetland boundaries (see Wetlands section in Chapter II of this report for specific details).

County shoreland zoning ordinances are in effect in all unincorporated areas of Waukesha County. All of the incorporated municipalities within the Pewaukee River watershed have adopted shoreland-wetland zoning ordinances.

Shoreland Zoning Regulations in Annexed Lands

According to Section 59.692(7)(a) of the *Wisconsin Statutes*, county shoreland zoning regulations remain in effect in areas annexed by a city or village after May 7, 1982, or for a town which incorporated as a city or village after April 30, 1994, unless the ordinance requirements of the annexing or incorporating city or village are at least as stringent as those of the county. The only exception to this condition is if, after annexation, the annexing municipality requests the county to amend the county ordinance to delete or modify provisions that establish specified land uses or requirements associated with those uses. In such a situation, stipulations regarding land uses or requirements may be amended by the county.

Regulatory Programs for Wetlands

The determination of permissible, or potentially permissible, activities in wetlands within the Pewaukee River watershed may involve shoreland-wetland regulations as administered by the counties, cities, and villages, all under the oversight of the WDNR, pursuant to authorities set forth in Chapter 30 of the *Wisconsin Statutes*. Wetland water quality standards are set forth in Chapter NR 103, "Wetland Water Quality Standards," of the *Wisconsin Administrative Code*. The procedures and criteria for the application, processing, and review of State water quality certifications are set forth in Chapter NR 299, "Water Quality Certification." Chapter NR 103 applies to the discharge of dredged or fill materials to wetlands, among other provisions. These regulations are administered by the WDNR and in some cases jointly by the U.S. Army Corps of Engineers (USCOE) and U.S. Environmental Protection Agency (US EPA) pursuant to Section 404 of the Federal Clean Water Act. As a result of the January 9, 2001, ruling by the U.S. Supreme Court in the matter of Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers, No. 99-1178 ("SWANCC") certain isolated, nonnavigable, intrastate wetlands/waters are not under USCOE regulatory jurisdiction. However, such wetlands may be regulated under complementary State regulations. In addition to the State standards noted above, the U.S. Department of Agriculture (USDA) implements policies and programs regarding wetland protection and preservation that benefit farmers and the environment.

The minimum developable lot sizes for parcels that include wetlands are regulated by the various jurisdictions that have general zoning authority within the watershed in Waukesha County. For development adjacent to statutory wetlands, the Waukesha County ordinance specifies a minimum setback. There is currently no specified limit on the maximum area of impervious surface for development adjacent to statutory wetlands. However, recently adopted nonagricultural performance standards set forth in Section NR 151.125 specify impervious surface setback requirements for designated "protective areas" from streams, lakes, and wetlands as summarized in the Buffer Standards section above.

Subdivision Regulations

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

In accordance with Chapter 236 of the *Wisconsin Statutes*, the subdivision regulatory powers of counties are confined to unincorporated areas. City and village subdivision control ordinances may be applied to extra-territorial areas, as well as to their incorporated areas.[26] Counties have approval authority in the unincorporated areas and objecting authority in the incorporated areas. It is possible for both a county and a town to have concurrent jurisdiction over land divisions in unincorporated areas, or for a city or village to have concurrent jurisdiction with a town and county in the city and village extraterritorial plat approval areas. In the case of overlapping jurisdiction, the most restrictive requirements apply. Each community within the Pewaukee River watershed has adopted its own subdivision ordinance. The subdivision control ordinances adopted and administered by Waukesha County apply only to the unincorporated statutory shoreland areas of the County. Further, the Waukesha County Storm Water Management and Erosion Control Ordinance also contains certain cross-compliance provisions that directly affect the subdivision plat review and approval process in all unincorporated areas.

Construction Site Erosion Control and Stormwater Management Ordinances[27]

Stormwater management and erosion control ordinances help minimize water pollution, flooding, and other negative impacts of urbanization on downstream water resources (lakes, streams, wetlands, and groundwater) and property owners, both during and after construction activities. These ordinances are an important tool for accomplishing watershed protection goals because they apply to the entire watershed, not only a certain distance from the water resource.

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[26]*Under Section 236.02 of the* Wisconsin Statutes, *the extraterritorial plat approval jurisdiction is the area within three miles of the corporate limits of a first-, second-, or third-class city and within 1.5 miles of a fourth-class city or a village. The Cities of Pewaukee and Waukesha have extraterritorial zoning that applies within three miles and the City of Delafield and Villages of Hartland, Pewaukee, and Sussex have extraterritorial zoning that applies within 1.5 miles of each of these municipalities within the Pewaukee River watershed.*

[27]*See the subsection above on "Recent State Actions Affecting Construction Erosion Control and Stormwater Management Standards." The local responses to these actions were under consideration at the time of publication of this report.*

The *Wisconsin Statutes* grant authority to counties (Section 59.693), villages (Section 61.653), and towns (Section 60.627) in Wisconsin to adopt ordinances for the prevention of erosion from construction sites and the management of stormwater runoff. These ordinances generally apply to new development lands within their jurisdictions. A county ordinance would apply to all unincorporated areas and newly annexed lands, unless the annexing city or village enforces an ordinance at least as restrictive as the county ordinance. Towns may adopt village powers pursuant to Section 60.10 of the *Wisconsin Statutes* and subsequently utilize the authority conferred on villages to adopt their own erosion control and stormwater management ordinances. Pursuant to Section 60.627 of the *Wisconsin Statutes*, town construction site erosion control and stormwater management zoning requirements adopted under this section supersede county ordinances.

In the mid-1990s Waukesha County, through the Storm Water Advisory Committee, helped develop a State model ordinance for post-construction stormwater management, which was later merged into a single ordinance for erosion control and stormwater management. The County adopted the merged ordinance in 1998 and many local communities followed. All of the Cities and Villages in the Pewaukee River watershed also have adopted their own erosion control and stormwater ordinances.

Starting in August 2004, the LRD worked with the Waukesha County Storm Water Advisory Committee for seven months to rewrite the county ordinance to reflect the new performance standards and address a number of other implementation issues identified by the LRD. In March 2005, the Waukesha County Board adopted Chapter 14, Article VIII, "Storm Water Management and Erosion Control Ordinance of the Waukesha County Code."[28] Enforcement of this ordinance currently represents the largest workload for the LRD. It should be noted that local erosion control ordinances do not apply to single-family home construction as this is regulated under Chapter SPS 321 of the *Wisconsin Administrative Code*. Chapter SPS 321 supersedes all local ordinances. In June 2006, the LRD applied for status as an "authorized local program" by the WDNR under the provisions of NR 216.415 for regulating stormwater discharges from new construction sites within the jurisdiction of the County ordinance. In 2011, the WDNR authorized Waukesha County to issue NR 216 permit coverage on their behalf for projects within the County's jurisdiction. This streamlines the regulatory framework that land developers, contractors, and the County must work within to secure the necessary permits before beginning development or road projects.

Under the County ordinance, a series of triggers require a Storm Water Permit from the LRD. "Land disturbing activities" of a certain size require the preparation of an *erosion control plan* to reduce soil erosion and sedimentation during the construction and landscaping phases of a development. "Land development activities" generally result in the addition of impervious surfaces to the land (i.e., rooftops and pavement of at least one-half acre in size), and require the preparation of a *stormwater management plan* to control post-construction stormwater runoff. Erosion control plans and stormwater management plans both require Storm Water Permits. The ordinance establishes a series of technical design standards aimed to maintain predevelopment runoff patterns, peak flows, infiltration, water quality and the general hydrology of the site. While these standards may vary slightly between communities, the general intent and resulting best management practices on the landscape are usually similar.

Because stormwater management planning has a significant effect on onsite planning and land divisions, several provisions have been incorporated into the County ordinance to better coordinate stormwater planning with these other planning processes. One requires a "Preliminary Review Letter" from the LRD before certain zoning decisions or preliminary plat approval can be completed by the Planning and Zoning Division. Another requires a "Certification of Compliance" with the ordinance from the LRD before a Plat or Certified Survey Map can be

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[28] *A copy of the ordinance is available on the LRD's web page at:* http://www.waukeshacounty.gov/uploadedFiles/Media/PDF/Parks_and_Land_Use/Land_Conservation/Stormwater/Index_Docs/Final%202005%20Storm%20Water%20Ordinance%20-%20Waukesha%20Co%20Web%20Version.pdf.

approved for recording with the County Register of Deeds. These provisions have proved invaluable in avoiding conflicts between regulatory review processes and in promoting environmentally sound site planning for new developments.

Erosion Control for One- and Two-Family Dwelling Construction

Since the early 1990s, the Wisconsin Uniform Dwelling Code, formerly set forth in Chapter Comm 21 and currently set forth in Chapter SPS 321 of the *Wisconsin Administrative Code*, has included statewide erosion control requirements for one- and two-family homes. Specific construction site and erosion control requirements for unincorporated areas of Waukesha County have been promulgated under Chapter 14, Parks and Land Use, of the *County Code of Ordinances*.

Building Regulations

Waukesha County has incorporated several stormwater ordinance standards intended to prevent basement wetness and flooding in newly developed areas, even outside of zoned floodplains. For buildings designed for human occupation, these standards address flooding from surface water and wetness caused by groundwater seepage. For surface water, the standards use the peak water surface elevation produced by a 100-year, 24-hour design storm as a benchmark, requiring a 50-foot horizontal setback and a minimum two-foot vertical separation from this elevation to the ground surface at the lowest exposed portion of the building. For groundwater, the standards generally do not allow these buildings on hydric soils and require a minimum one-foot vertical separation between the seasonal high groundwater table and the proposed basement floor surface. These standards apply to all the unincorporated areas of the County. Requiring buildings to meet these standards helps protect the large investments of local homebuyers, while avoiding potential nuisance drainage issues and costly publicly funded solutions in the future. These restrictions have become more important in recent years as the living spaces of homes are often extended to finished lower levels.

Stormwater Facility Operation and Maintenance

As stormwater facilities become more complex, they will require more attention by end users. This is especially true for infiltration practices. Establishing an ongoing operation and maintenance program is critical to successful stormwater management. Waukesha County has developed a stormwater facility database that serves as a repository of design, construction, and maintenance information for stormwater best management practices under County jurisdiction. This database is being populated with new projects as they are permitted under the County ordinance. In addition, a process has been developed to populate the database with historical information about previously permitted projects. This database is also accessible to municipal engineers around the County and will serve as a source of information for the continued maintenance of stormwater facilities into the future.

Stormwater management maintenance agreements are now required through all local stormwater ordinances. These agreements include a detailed maintenance plan for each stormwater management practice and describe the owner's obligations for implementation. The agreements usually authorize the local community to enforce the maintenance provisions, using their special assessment powers if needed to ensure the work is done. Detailed as-built documentation is often recorded as an exhibit in the agreement and serves as a reference for future maintenance work. Documentation of inspections and maintenance activities are usually required to be submitted to the local community before a permit is closed and a financial assurance is released.

Most communities check stormwater facilities at the time of initial construction to establish conformance with permit requirements. However, the long-term maintenance of stormwater management practices is often the responsibility of private landowners. Consequently, many communities do not have proactive inspection programs, but may react to citizen complaints. Waukesha County has started to include a limited inspection service for existing stormwater practices through intergovernmental agreements with towns. Pursuant to Chapters NR 151 and NR 216 of the *Wisconsin Administrative Code,* the WDNR may require a landowner to maintain stormwater management practices.

Special Units of Government

Stormwater Utility Districts

Section 66.0827 of the *Wisconsin Statutes* permits towns, villages, and cities of the third and fourth class to establish utility districts for a number of municipal improvement functions. Funds for the provision of services within the district which are not paid for through special assessments are provided by levying a tax upon all property within the district. The establishment of utility districts requires a majority vote in towns and a three-fourths vote in villages. Prior to establishing such a district, the local governing bodies are required to hold a formal public hearing. The establishment of stormwater utility districts has become more common in recent years as a mechanism to implement stormwater management practices pursuant to Chapter NR 216 of the *Wisconsin Administrative Code*. Such districts install and maintain stormwater conveyance and management systems typically within subdivisions or other portions of municipalities where such services are required. To date, the City and Village of Pewaukee and the Village of Sussex are the only utility districts established in the Pewaukee River watershed.

Lake Pewaukee Sanitary District

General oversight of the Pewaukee Lake management activities is currently provided by the Lake Pewaukee Sanitary District with the advisory input from the City and Village of Pewaukee, and Town of Delafield. The Lake Pewaukee Sanitary District is a town sanitary district established under Chapter 60 of the *Wisconsin Statutes*, serving the Town of Delafield, and providing contract services to the City of Pewaukee. The Sanitary District provides lake management services including aquatic plant harvesting and shoreline cleanup for the Town of Delafield and for the City of Pewaukee. The District also purchases and manages land to protect water quality for Pewaukee Lake. For example, in March of 2013 the District obtained a $200,000 grant from the WDNR that was combined with $72,000 of its own funds to enable them to purchase and protect 26 acres of wetland and six acres of upland within the Pewaukee River watershed.[29]

In addition, the Lake Pewaukee Sanitary District also owns and maintains the sanitary sewer system around Pewaukee Lake. All wastewater from that system, however, is conveyed to the City of Brookfield for treatment. The sanitary sewer service area (see Map 6 in Chapter II of this report) includes a portion of the City of Pewaukee where the Sanitary District owns the sanitary sewer lines and pump stations.

Public Inland Lake Protection and Rehabilitation Districts

In order to maintain, protect, and improve the water quality of a lake and manage its watershed in an environmentally sound manner, the Wisconsin Legislature has authorized the creation of Public Inland Lake Protection and Rehabilitation Districts under Subchapter IV of Chapter 33 of the *Wisconsin Statutes*.[30] Similar to town sanitary districts, lake districts can be established by orders or resolutions adopted by a town, village, or county in response to the petition of the landowners within the boundary of the proposed district. Lake management districts are governmental bodies, and as such, have strictly defined boundaries. Lake districts have limited powers outside of their lake management functions.

The Pewaukee Lake Sanitary District is the only public inland lake management district in the Pewaukee River watershed. This organization depends on the cooperation of general purpose units of government to address many of the jurisdictional issues that affect the use of the lake.

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[29]*Melissa Graham, Living Reporter/Focus, "Grant Preserves Pewaukee Wetland," March 5, 2013.*

[30]*University of Wisconsin-Extension Publication No. G3818*, People of the Lakes: A Guide for Wisconsin Lake Organizations: Lake Associations and Lake Districts, *11th Edition, 2006.*

Nonprofit Conservation Organizations

In addition to governmental organizations, voluntary community organizations often participate in resource management projects. While they lack governmental authority, and both membership and payment of dues are voluntary, many of these nonprofit conservation organizations (NCOs) are influential in sustaining public interest in resource management issues and provide an important mechanism for public informational programming and involvement in communities. Many NCOs are incorporated under Chapter 181 of the *Wisconsin Statutes* and many are registered charitable organizations under Section 501(c)(3) of the Federal Internal Revenue Code. Several such organizations exist in the Pewaukee River watershed. In addition, incorporated lake or stream associations, meeting specific criteria established by the WDNR, may be eligible for cost-share grant funds under the lake or stream management and protection grant programs described below. For example, the Pewaukee River Partnership, which has led the effort in developing this planning study, is an NCO.

These organizations depend on the cooperation of general purpose units of government to address many of the jurisdictional issues that affect the use of the lake, and perform an important advocacy role in the basin. In addition, these organizations perform a vital role in community-based educational and informational programming, as discussed below.

RELATED CONSERVATION PROGRAMS

Coordination with Federal, State, regional, and local agencies is paramount to the protection of the land and water resources of the Pewaukee River watershed. The conservation programs mentioned below are vital to the successful implementation of this plan. The positive integration of programs and funding sources administered by the county and their cooperating agencies do the most toward accomplishing these goals.

Federal Programs

The U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS) has several programs directed at agricultural producers to alleviate cropland erosion, and to protect natural resources, as well as provide a financial incentive. The programs available to local producers and landowners are presented in Table 12 and summarized below. Four programs help to reduce erosion, protect wildlife habitat, restore wetlands, and improve water quality. All programs involve cost-share assistance from the Federal government, provided the landowner follows the prescribed practices of each program.

Conservation Reserve Program

The Conservation Reserve Program (CRP) and related State Conservation Reserve Enhancement Program (CREP) are voluntary programs for agricultural landowners that provide annual rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible farmland. The CRP goal is to reduce soil erosion, protect the nation's ability to produce food and fiber, reduce sedimentation in streams and lakes, improve water quality, establish wildlife habitat, and enhance forest and wetland resources. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as a prairie compatible noninvasive forage mix, wildlife plantings, trees, filter strips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract based on the agriculture rental value of the land, and up to 50 percent Federal cost-sharing is provided to establish vegetative cover practices. The program is administered by the USDA Farm Service Agency (FSA), with technical assistance provided by the NRCS. The NRCS works with landowners to develop their application, and to plan, design, and install the conservation practices on the land.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary conservation program that supports the production of agriculture and environmental quality as compatible goals. Through EQIP, farmers may receive financial and technical help with structural and management conservation practices on agricultural land. EQIP offers contracts for practice implementation for periods ranging from five to 10 years, and it pays up to 75 percent

Table 12

CHARACTERISTICS OF USDA FINANCIAL ASSISTANCE PROGRAMS

Program	Contract Length	Sign-Up Period	Cost-Share	Rental or Tillage Payments	Practices Suitable for Program	Amount of Land
Conservation Reserve Program (CRP)/Conservation Reserve Enhancement Program (CREP)	10, 15 years or as perpetual easements	Continuous or once a year	50 percent	A specified dollar amount per acre based upon soil type	Permanent pasture, buffer strips, grassed waterways, windbreaks, trees	Small sensitive areas along stream corridors to large tracts of land
Environmental Quality Incentives Program (EQIP)	Five to 10 years	Twice a year	Up to 75 percent	No-till practices only, with a 50-acre maximum	Livestock waste management, erosion and sediment control, habitat improvement, groundwater protection	Designed for the whole farm, not just small areas of the farm
Wildlife Habitat Incentives Program (WHIP)	10 years	Continuous	Up to 75 percent	- -	Instream structures for fish habitat, prairie restoration, wildlife travel lanes, wetland scrapes	Site- and species-specific, small to large areas, five-acre minimum
Wetland Reserve Program (WRP)	10 years, or 30 years and permanent easements	Continuous	Up to 100 percent	- -	Wetland restoration	20-acre minimum

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

of the costs of eligible conservation practices. Incentive payments and cost-share payments may also be made to encourage a farmer to adopt land management practices, such as nutrient management, manure management, integrated pest management, or wildlife habitat management.

Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program for people who want to develop or improve wildlife habitat on private lands. It provides both technical assistance and up to 75 percent Federal cost-sharing to help establish and improve wildlife habitat. Landowners agree to work with NRCS to prepare and implement a wildlife habitat development plan which describes the landowner’s goals for improving wildlife habitat, includes a list of practices and a schedule for installing them, and details the steps necessary to maintain the habitat for the life of the cost-share agreement. The WHIP emphasizes reestablishment of declining species and habitats, including prairie chickens, meadowlarks, sharp-tailed grouse, Karner blue butterfly, smallmouth bass, blue-winged teal, and many other species of grassland birds, reptiles, insects, and small mammals. Some of the opportunities are installing instream structures to provide fish habitat, restore prairie and oak savannahs, and brush management and control of invasive species.

Cost-shared practices include burning, seeding, and brush management of prairies, grasslands, and savannah; instream structures and bank stabilization in streams; and timber stand improvement and brush management on woodlots. Federal or State wildlife agencies or private organizations may provide additional funding or expertise to help complete a project. Contracts normally last a minimum of five years from the date the contract is signed and cost-sharing does not exceed $10,000. Eligible lands must be a minimum of five acres of agricultural or nonagricultural land, woodlots, pasture land, streambanks, and shorelands. Lands currently enrolled in other conservation programs are not eligible to participate in WHIP.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is another voluntary program designed to restore and protect wetlands on private property. It is an opportunity for landowners to receive financial incentives to restore wetlands that have been drained for agricultural purposes. Landowners who choose to participate in WRP may sell a conservation easement or enter into a cost-share restoration agreement with USDA to restore and protect wetlands. The landowner voluntarily limits future use of the land, yet retains private ownership. The landowner and NRCS develop a plan for the restoration and maintenance of the wetland. This program offers landowners three options; permanent easements, 30-year easements, and restoration cost-share agreements of a minimum 10-year duration.

Grasslands Reserve Program

The Grassland Reserve Program (GRP) is a voluntary program through the NRCS for landowners and operators to protect grazing uses and related conservation values by conserving grassland, including rangeland, pastureland, shrubland, and certain other lands. Participants voluntarily limit future development and cropping uses of the land while retaining the right to conduct common grazing practices and operations related to the production of forage and seed. The program offers eligible landowners and operators two options: permanent easements and rental contracts of 10-year, 15-year, or 20-year duration. For permanent easements, the GRP offers compensation up to the fair market value of the land concerned less the grazing value of the land. For rental contracts, the GRP provides annual payments of 75 percent of the grazing value established by the Federal Farm Service Agency, up to $50,000 to a single person or legal entity. Certain grassland easements or rental contracts may also be eligible for cost-share assistance of up to 50 percent of the cost to reestablish grassland functions and values where land has been degraded or converted to other uses. Payments of this cost-share assistance may not exceed $50,000 per year to a single person or legal entity.

Resource Conservation and Development

The Resource Conservation and Development (RC&D) program was established by the Federal Agricultural Act of 1962. This act directs the USDA to help units of government conserve and properly utilize all resources in solving local issues. Wisconsin has seven RC&Ds, covering all Wisconsin counties. Waukesha County is a member of the Town and Country RC&D area which was organized to cover 13 counties in southeastern Wisconsin. The Town and Country RC&D helps to facilitate the development and coordination of existing and innovative projects, and will assist in finding funding to implement them. Town and Country RC&D has helped promote agricultural, energy, water quality, and educational projects and programs throughout the Region.

The Pittman-Robertson Wildlife Restoration Program

The Pittman-Robertson Wildlife Restoration Program through the U.S. Fish and Wildlife Service provides grants to State fish and wildlife agencies for projects to restore, conserve, manage, and enhance wildlife and wildlife habitat. This program provides 75 percent Federal cost-share assistance for eligible projects and requires a 25 percent match from nonFederal sources. Eligible projects include identification, restoration, and improvement of areas of land or water adaptable as feeding, resting, or breeding places for wildlife.

The State Wildlife Grants Program

The U.S. Fish and Wildlife Service through the State Wildlife Grants Program provides Federal grant funds to State fish and wildlife agencies for the development and implementation of projects for the benefit of fish and wildlife and their habitats, including species that are not hunted or fished. Priority is placed on projects that protect species of greatest conservation concern. Two types of grants are made under this program: planning grants and implementation grants. Planning grants provide up to 75 percent Federal cost-share assistance for eligible projects and require a 25 percent match from nonFederal sources. Implementation grants under this program provide up to 50 percent Federal cost-share assistance for eligible projects and require a 50 percent match from nonFederal sources.

State Programs

Farmland Preservation Program

The DATCP and the Wisconsin Department of Revenue oversee the Farmland Preservation Program (FPP) across the State. This program allows agricultural landowners who meet certain eligibility requirements to file for tax credits. As a condition of receiving the tax credits, the land for which the credits are to be received must be farmed in accordance with soil and water conservation standards developed by counties and approved by the State of Wisconsin Land and Water Conservation Board. A farm plan for each landowner and farm involved is usually developed by the County or NRCS and ensures that through tillage practices, crop rotations, or other appropriate conservation practices soil erosion is being effectively reduced to at or below tolerable soil loss rates. Landowners who are found to be in noncompliance with the law must come into compliance with the rules, or they become ineligible to participate in the program. However, there are no exclusive agricultural zoning districts in the Pewaukee River watershed, so no lands are currently eligible for this program within this watershed.

Targeted Runoff Management Grant Program

The Targeted Runoff Management (TRM) Grant Program, in operation since 1999, was significantly revised effective January 1, 2011. Targeted Runoff Management Grants are administered under Chapters NR 153 and NR 154 of the *Wisconsin Administrative Code*. These grants provide technical and financial assistance to local governments for managing nonpoint source pollution. Most grants address agricultural problems. The agricultural project grants address many types of water resources, including impaired waters in areas with Total Maximum Daily Loads (TMDL), impaired waters outside TMDL areas, high-quality surface waters threatened by degradation and ground water protection and improvement. Agricultural projects can vary in scale, from small-scale projects addressing a single farm to larger-scale projects that address agricultural sources on a watershed basis. Projects that take place outside a TMDL area are required to implement the State's agricultural nonpoint source performance standards and prohibitions contained in Chapter NR 151. Projects designed to implement TMDLs may also implement practices that are not tied directly to achieving State standards and prohibitions as long as the management practices are required to achieve the goals of the TMDL. Targeted Runoff Management Grants also provide funding for a limited number of urban stormwater construction projects, but the urban TRM projects are restricted to TMDL areas. Only small-scale projects are available in urban areas.

All TRM grants provide 70 percent cost sharing for construction of management practices, with up to 90 percent cost sharing available for agricultural projects where the farmer qualifies for economic hardship. Large-scale TRM projects may also provide limited funding for staff support. Each year, the WDNR establishes caps on grant amounts consistent with available funding.

Urban Nonpoint Source and Storm Water Planning Program

Urban Nonpoint Source and Storm Water Planning Program (UNPS&SW) grant funds awarded under Chapter NR 155 of the *Wisconsin Administrative Code* are used to control polluted runoff in urban project areas. Funds are awarded for either planning or construction projects. The grant period is two years. Projects funded through this grant program are site-specific, serve areas generally smaller in size than a subwatershed, and are targeted to address high-priority problems. Eligible applicants include cities, villages, towns, counties, regional planning commissions, and special purpose districts such as lake districts, sewerage districts, and sanitary districts. In addition, an urban project area must meet at least one of the following criteria:

- An area with a residential population density of at least 1,000 people per square mile;
- Lands in either commercial or industrial use;
- A portion of a privately owned industrial site not covered by a WPDES permit issued under Chapter NR 216 of the *Wisconsin Administrative Code*; or
- A municipally owned industrial site (regardless of Chapter NR 216 permit requirements).

The maximum cost-share rate available for planning grants is 70 percent of eligible costs. The cap on the total State share for planning projects is $85,000. The maximum cost-share rate available for construction grants is 50 percent of eligible costs, with a total State share for a construction project of $150,000 and a potential grant of an additional $50,000 for land acquisition, with the approval of WDNR regional staff. Additional cost-share reimbursements may be available for project design and permanent easements costs, also with the approval of WDNR regional staff. Planning grants can be used to pay for a variety of eligible activities, including stormwater management planning for existing and new development, related information and education activities, ordinance and utility district development, and enforcement. Construction grants can be used to pay for the construction of best management practices to control stormwater pollution from existing urban areas. Projects may be eligible for funding whether or not they are designed to meet the performance standards identified in Section NR 151.13 of the *Wisconsin Administrative Code*. The highest priority in selecting projects under this program is given to projects that implement performance standards and prohibitions contained in Chapter NR 151 or that address waterbodies listed on the Federal Section 303(d) list of impaired waters.

Soil and Water Resource Management Program

The current Chapter ATCP 50, "Soil and Water Resource Management Program," became effective on October 1, 2002, and was most recently revised in April 2009. The administrative rule relates specifically to agricultural management programs. It establishes requirements and/or standards for:

- Soil and water conservation on farms;
- County soil and water programs, including land and water resource management plans;
- Grants to counties to support county conservation staff;
- Cost-share grants to landowners for implementation of conservation practices;
- Design certifications by soil and water professionals;
- Local regulations and ordinances; and
- Cost-share practice eligibility and design, construction, and maintenance.

Lake Management Planning and Protection Grant Programs

Lake management planning projects may be eligible for a 75 percent cost-share grant, up to $10,000 State-share under the Chapter NR 190 Lake Management Planning Grant Program, with implementation projects being eligible for a 50 percent cost-share grant under the Chapter NR 191 Lake Protection Grant Program. Lake management planning projects are further divided into small-scale projects of up to $3,500 and larger-scale projects of up to $10,000 State-share. The former are designed primarily to support lake water quality monitoring projects, although other planning activities are also eligible for funding.

Chapter NR 191 lake protection activities related to land acquisition and implementation of remedial measures identified in a WDNR-approved lake management plan may receive up to $200,000 in State cost-share funding, while ordinance development projects and diagnostic feasibility studies may be cost shared up to $100,000. These grants are available to local units of government, public inland lake protection and rehabilitation districts, lake sanitary districts, and qualified lake associations. In addition, counties are eligible to apply for funding to develop and implement local land and water management programs targeted to specific classes of lakes in response to various development and recreational use pressures. Grant awards may fund up to 75 percent of eligible project costs, not to exceed $50,000.

Additional funding for specific land acquisition activities may be available through the Knowles-Nelson Stewardship Program, created by the Wisconsin Legislature in 1989 and authorized under Chapters NR 50/51 of the *Wisconsin Administrative Code*. The program is intended to preserve valuable natural areas and wildlife habitat, protect water quality and fisheries, and expand opportunities for outdoor recreation. Similarly, the Recreational Boating Facilities Grant program, authorized under Chapter NR 7 of the *Wisconsin Administrative Code,* can provide additional funds for public recreational boating access, access site improvements, Eurasian water milfoil control, and establishment and/or marking of navigational channels, among other activities.

River Planning and Protection Grant Program

In a like manner to the lake grant programs, the Chapter NR 195 River Planning and Protection Grant program supports efforts of local governments to develop and implement river (and stream) management practices designed to minimize or mitigate human impacts on flowing water systems. Grant awards are made on a 75 percent cost-share basis to eligible units of government in amounts up to $10,000 for planning projects and $50,000 for management projects. Property acquisition, implementation of best management practices, and educational and informational programming are eligible projects under this program.

Aquatic Invasive Species Grant Program

The Chapter NR 198 Aquatic Invasive Species Control Grant awards may not exceed 75 percent of the project cost. Maximum grant awards depend upon the type of project being executed, with education, prevention and planning projects being limited to a maximum award of $150,000. Watercraft inspection program projects, conducted within this grant category are limited to a State share of $4,000 annually for each public boat launch facility, with the total project cost-share amount being less than or equal to the 75 percent State share. Early detection and response projects conducted under this grant program are limited to a maximum award of $20,000, and established population control projects to a maximum State share amount of $200,000. Education, prevention and planning projects can be funded as small-scale projects of up to $50,000 State cost-share or larger-scale projects of greater than $50,000 State cost-share.

Wisconsin Department of Natural Resources Clean Water Fund Program

The State Clean Water Fund Program (CWFP) provides financial assistance to municipalities for the planning, design, and construction of projects to control and treat urban stormwater runoff. Eligible applicants include cities, towns, villages, counties, town sanitary districts, public inland lake protection and rehabilitation districts, and metropolitan sewerage districts. Projects must be required by either a Wisconsin Pollutant Discharge Elimination System permit, a performance standard, or a plan approved by the WDNR. The primary purpose of an eligible urban runoff project must be to improve water quality. The program provides loans at an interest rate of 65 percent of the current CWFP market rate.

The Clean Water Fund Program also has a Small Loan Program that provides interest rate subsidies to municipalities that have loans from the State Trust Fund Loan Program for the planning, design, and construction of urban runoff projects with total estimated costs of $1 million or less.

Community Information and Education Programs

Community involvement and educational outreach is a key element of preserving the ecologically significant areas within the Pewaukee River watershed. Outreach is conducted by several active organizations within the watershed, including the Lake Pewaukee Sanitary District, land conservancy organizations, and citizen monitoring groups.

Monitoring and Evaluation Programs

Monitoring and evaluation program efforts are important to ensure program effectiveness and accountability in the expenditure of public funds. Measuring progress for nonpoint pollution control programs has been identified as a serious challenge in several State legislative audits since the late 1980s. Past program efforts have focused on tracking best management practices installed to control nonpoint pollution and associated expenditures. Actually measuring changes in water quality is the best way to track progress, but can be expensive. In addition, because of the high number of variables involved in monitoring water quality, it is often difficult to interpret the data. One solution to this problem is to encourage volunteer citizen monitoring.

Citizen Stream Monitors

For several years, groups such as the Water Action Volunteers (WAV), have held training sessions to teach interested citizens how to monitor streams for temperature, turbidity, dissolved oxygen, stream flow, and how to conduct biotic index and habitat assessments. The data collected is entered into an internet-accessible database that will be useful for monitoring future trends in stream condition. Eleven WAV monitoring stations are located in the Pewaukee River watershed, which has been monitored since around 2005 through 2007, depending on the site (see Water Quality section in Chapter IV of this report for more details).

Citizen Lake Monitoring Network

Wisconsin's Self-Help Lake Monitoring Program began in 1986 as one component of the WDNR Lake Management Program. The program is now included within the Citizen Lake Monitoring Network (CLMN) administered by the University of Wisconsin-Extension (UWEX) Lakes Partnership team. The CLMN is a data collection program implemented on approximately 1,000 of Wisconsin's 15,000 lakes, and it serves as a citizen education program about lakes in general. Each volunteer learns about his or her own lake(s) by collecting water quality data. These data are focused on Secchi-disk transparency measurements. The expanded program includes additional data collection necessary to support determination of Trophic State Indices (TSI values)—water samples for total phosphorus and chlorophyll-*a* analysis, which is conducted by the State Laboratory of Hygiene (SLOH)—as well as collection of temperature and dissolved oxygen concentration profiles. The data from both the basic and expanded programs are summarized in a detailed report provided to the volunteers at the end of each sampling season.

The Program was designed around a set of objectives designed to teach citizen volunteers about lake water quality sampling techniques along with some concepts of basic limnology, and to increase their understanding of their study lakes. Data are collected over time and analyzed for normal and seasonal variations and long-term trends, and are intended to help lake organizations and communities make sound lake management decisions. Pewaukee Lake is included in the Self-Help monitoring program.

Informational and Educational Programs

Various citizen-based organizations take an active interest in the Pewaukee River basin. These groups address a number of concerns facing the basin and its communities, both natural and human, through informational programming and management activities. Activities focus on the terrestrial and aquatic resources of the basin.

With respect to the terrestrial and wetland resources of the Pewaukee River basin, the Waukesha County Land Conservancy and Lake Pewaukee Sanitary District are working to preserve rare, threatened, and endangered species in and around Pewaukee Lake through partnerships with landowners and other interested stakeholders. The Waukesha County Environmental Action League (WEAL) helps to protect the natural resources of Waukesha County through local advocacy, public informational programs, newsletters, and the WEAL website. WEAL provides up-to-date information on environmental issues to the general public; teachers; county, city, and village officials; and State legislators. As previously mentioned in the Municipal Stormwater Discharge Permits section, each of the MS4 communities within the Pewaukee River watershed works with Waukesha County staff to implement their information and education programs, which are targeted specifically for developers, engineers, contractors, municipal staff, and the general public.

The Waukesha County Land Conservancy is a nonprofit, tax-exempt, nongovernmental conservation land trust whose goal is to protect natural resources through partnerships with private and public landowners. It is managed by a volunteer board of directors made up of local citizens who have a shared vision for preserving their communities' natural heritage. The Land Conservancy works in partnership with landowners and communities to permanently conserve natural resources.

Since its origin in 1992, the Waukesha County Land Conservancy has worked to preserve and manage environmentally significant lands in Waukesha County. With the assistance of professional biologists, naturalists and other land professionals, the Land Conservancy focuses on protecting the most environmentally significant remaining natural areas for the public benefit.

The goals of the Land Conservancy are achieved through:

- Establishing conservation easements,
- Accepting land donations,
- Purchasing land, and
- Working with public or private entities to protect environmentally sensitive sites.

Finally, the Lake Pewaukee Sanitary District supports a range of educational and informational programming activities at annual and periodic meetings, as well as in executing more active lake management functions.

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Chapter IV

BACKGROUND AND SUMMARY OF INVENTORY FINDINGS

INTRODUCTION

The health of a stream system is a direct reflection of its watershed. More specifically, changes in land and water use in a river basin affect the physical or chemical properties within streams, which in turn affects water quality, habitat, and resident biological communities. Hence, a stream's health is a result of the interaction of its physical, chemical, and biological components (see Figure 28).

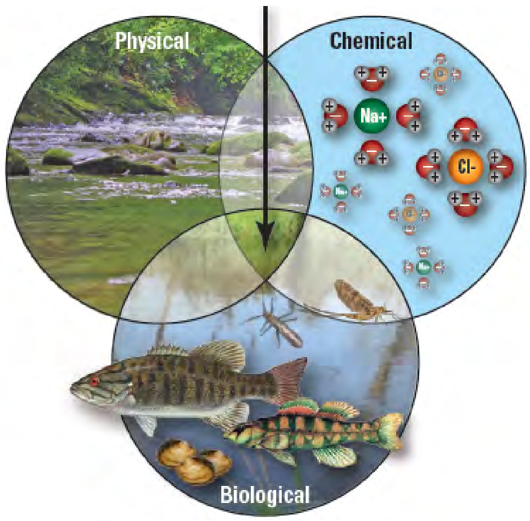
The condition of biological communities—which are collections of aquatic organisms—provides a direct measure of stream health. Reduced stream health is often associated with human-induced changes to the physical and chemical properties of streams that affect the condition of biological communities. Therefore, this chapter reports on how land and water management activities within the Pewaukee River watershed have influenced the physical, chemical, and biological properties of this stream system in order to develop effective management strategies aimed at restoring stream health.

This chapter presents an inventory and analysis of the surface waters and related features of the Pewaukee River watershed. Included is qualitative and quantitative information pertaining to 1) Physical Conditions—historical trends and current status of instream habitat quality within the Pewaukee River system; 2) Chemical Conditions—historical trends and potential limitations to water quality and fishery resources; and 3) Biological Conditions—fishes and other aquatic organisms and wildlife characteristics of the Pewaukee River, where available.

This chapter is based upon a combination of physical, chemical, and biological data collected for a variety of purposes and programs that include baseline monitoring by the Wisconsin Department of Natural Resources (WDNR); the National Water Quality Assessment (NAWQA) by the U.S. Geological Survey (USGS); research projects by local universities; the Lake Pewaukee Sanitary District; Waukesha County and other local municipalities; Pewaukee River Partnership members; citizen volunteers (i.e., Water Action Volunteers); and SEWRPC.

Figure 28

ECOLOGICAL STREAM HEALTH



This simple diagram shows that a stream's ecological health (or "stream health") is the result of the interaction of its biological, physical, and chemical components. Stream health is intact if (1) its biological communities (such as algae, macroinvertebrates, and fish) are similar to what is expected in streams under minimal human influence and (2) the stream's physical attributes (such as streamflow) and chemical attributes (such as salinity or dissolved oxygen) are within the bounds of natural variation.

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

Environmental Factors Influenced by Agriculture and Urban Land Use

USGS scientists recently found that stream health was reduced at the vast majority of streams assessed in agricultural and urban areas across the nation.[1] At least one of the three aquatic biological communities (algae, macroinvertebrates, and fish) was altered at 83 percent of the streams assessed. In contrast, nearly one in five streams in agricultural and urban areas was in relatively good health, signaling that it is possible to maintain stream health in watersheds with substantial land- and water-use development. Therefore, these researchers found that the degree of ecological health within a stream system is directly related to the degree of human induced changes in streamflow characteristics and water quality (nutrients and pesticides). Major findings and important implications of this study include:

- The presence of healthy streams in watersheds with substantial human influence indicates that it is possible to maintain and restore healthy stream ecosystems.

- Water quality is not independent of water quantity because flows are a fundamental part of stream health. Because flows are modified in so many streams and rivers, there are many opportunities to enhance stream health with targeted adjustments to flow management.

- Efforts to understand the causes of reduced stream health should consider the possible effects of nutrients and pesticides, in addition to modified flows, particularly in agricultural and urban settings.

More specifically, the land- and water-use activities associated with agricultural and urban land uses have been demonstrated to influence the hydrological, chemical, and physical factors of the streams, which are briefly described below and illustrated in Figure 29.[2]

Hydrologic Impacts

The natural timing, variability, and magnitudes of streamflow influence many of the key physical, chemical, and biological characteristics and processes of a healthy stream system. For example, recurring high flows from seasonal rainfall or snowmelt shape the basic structure of a river and its physical habitats, which in turn influences

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[1]*D.M. Carlisle and others*, The quality of our Nation's waters—Ecological health in the Nation's streams, *1993-2005: U.S. Geological Survey Circular 1391, 2013 (available online at:* http:// pubs.usgs.gov/circ/1391/*).*

[2]Ibid.

Figure 29

ILLUSTRATIONS OF THE DYNAMIC COMPONENTS OF NATURAL, AGRICULTURAL, AND URBAN STREAM ECOSYSTEMS

NATURAL STREAM ECOSYSTEM

AGRICULTURAL STREAM ECOSYSTEM

URBAN STREAM ECOSYSTEM

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

the types of aquatic organisms that can thrive. For many aquatic organisms, low flows impose basic constraints on the availability and suitability of habitat, such as the amount of the stream bottom that is actually submerged. The life cycles of many aquatic organisms are highly synchronized with the variation and timing of natural streamflows. For example, the reproductive period of some species like northern pike is triggered by the onset of spring runoff.

In general, human activities in agricultural settings alter the natural flow regime of streams and rivers through 1) subsurface drain tiles, which lower the water table and quickly route water to nearby streams; 2) ditching and straightening of headwater streams; and 3) irrigation, which supplements available water for crops. These changes can result in more rapid runoff, reduced streamflows during dry periods, and increased transport of sediments and pollutants. However, since there is a diversity of agricultural practices (see Figure 29, Agricultural Stream), the impacts to stream ecosystems can be highly variable.

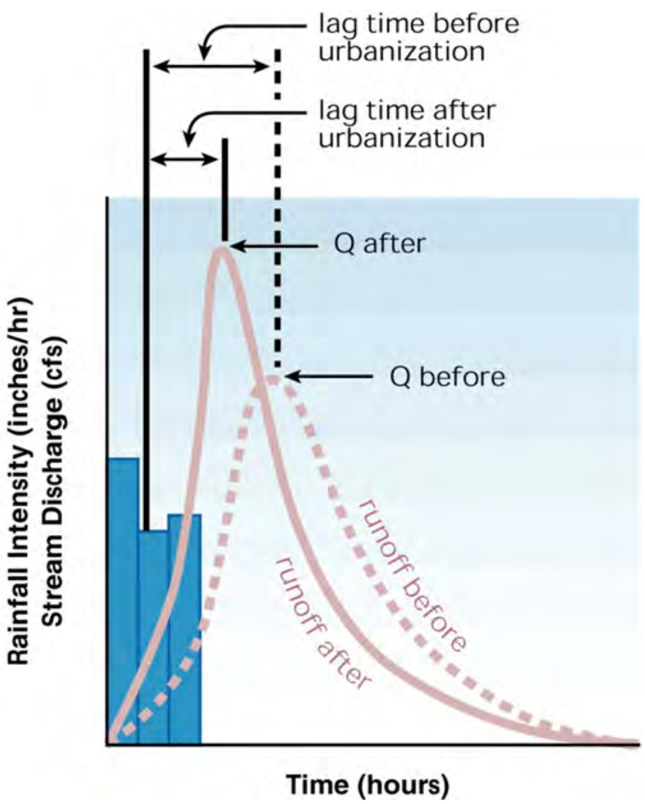
In an urban setting, Human activities change the movement of water in a watershed through introduction of increased impervious surfaces, such as pavement for roadways and parking lots, as well as buildings, all of which restrict the infiltration of precipitation into the groundwater system, combined with construction of artificial drainage systems (e.g., storm drains) that quickly move runoff to streams (see Figure 29 Urban Stream). These impervious surfaces can lead to increased storm runoff and higher and more variable peak streamflows, which scour the streambed or banks and degrade the stream channel. Reduced infiltration to groundwater can lead to diminished streamflows during dry periods, particularly in stream systems where groundwater is the main source of streamflow. In addition, larger populations in urban areas require greater demand, or water withdrawal, for public water supply, as well as industrial and commercial uses, which can also affect the natural flow regime of stream systems.

More specifically, recent research has shown that the hydrologic variables most consistently associated with changes in algal, invertebrate, and fish communities[3]

[3] *Personal Communication, Dr. Jeffrey J. Steuer, U.S. Geological Survey.*

Figure 30

A COMPARISON OF HYDROGRAPHS BEFORE AND AFTER URBANIZATION



Source: Federal Interagency Stream Restoration Working Group (FISRWG), Stream Corridor Restoration: Principles, Processes, and Practices, *October 1998.*

are average flow magnitude, high flow magnitude, high flow event frequency, high flow duration, and rate of change of stream cross-sectional area. As detailed in Chapter II of this report, the amounts of urban development within the watershed are at high enough levels to potentially be negatively affecting water quality and water quantity, and they are projected to increase. Therefore, the hydrology of this urbanizing stream system within the Pewaukee River watershed is a major determinant of stream dynamics and is a vital component of habitat for fishes and other organisms (see Figure 30).

To some degree, impervious surface impacts can be mitigated through implementation of traditional stormwater management practices and emerging green infrastructure technologies, such as pervious pavement, green roofs, rain gardens, bioretention, and infiltration facilities. Traditional stormwater management practices seek to manage runoff using a variety of measures, including detention, retention, and conveyance. Emerging technologies, in contrast, differ from traditional stormwater practices in that they seek to better mimic the disposition of precipitation on an undisturbed landscape by retaining and infiltrating stormwater onsite. A number of nontraditional, emerging low impact development (LID) technologies have been implemented throughout the Southeastern Wisconsin Region, including disconnecting downspouts; installing rain barrels, green roofs, and rain gardens; and constructing biofiltration swales in parking lots and along roadways. Experience has shown that these emerging technologies can be effective. For example, recent research has demonstrated that bioretention systems can work in clay soils with proper sizing, remain effective in the winter, and contribute significantly to groundwater recharge, especially when such facilities utilize native prairie plants.[4]

Location of impervious surfaces also determines the degree of direct impact they will have upon a stream. There is a greater impact from impervious surfaces located closer to a stream, due to the fact that there is less time and distance for the polluted runoff to be naturally treated before entering the stream. A study of 47 watersheds in southeastern Wisconsin found that one acre of impervious surface located near a stream could have the same

[4]*Roger Bannerman, WDNR and partners;* Menasha biofiltration retention research project, *Middleton, WI, 2008; N.J. LeFevre, J.D. Davidson, and G.L. Oberts,* Bioretention of Simulated Snowmelt: Cold Climate Performance and Design Criteria, *Water Environment Research Foundation (WERF), 2008; William R. Selbig and Nicholas Balster,* Evaluation of Turf Grass and Prairie Vegetated Rain Gardens in a Clay and Sand Soil: Madison, Wisconsin, Water Years 2004-2008, *In cooperation with the City of Madison and Wisconsin Department of Natural Resources, U.S. Geological Survey Scientific Investigations Report, in draft.*

negative effect on aquatic communities as 10 acres of impervious surface located further away from the stream.[5] Because urban lands located adjacent to streams have a greater impact on the biological community, an assumption might be made that riparian buffer strips located along the stream could absorb the negative runoff effects attributed to urbanization. Yet, riparian buffers may not be the complete answer since most urban stormwater is delivered directly to the stream via a storm sewer or engineered channel and, therefore, enters the stream without first being filtered by the buffer. Riparian buffers need to be combined with other management practices, such as detention basins, grass swales, and infiltration facilities, in order to adequately mitigate the effects of urban stormwater runoff. Combining practices into such a "treatment train" can provide a much higher level of pollutant removal, than can single, stand-alone practices. Stormwater and erosion treatment practices vary in their function, which in turn influences their level of effectiveness. Location of a practice on the landscape, as well as proper construction and continued maintenance, greatly influences the level of pollutant removal and runoff volume management.

Urbanization also creates other problems. Accumulations of trash and debris in urban waterways and associated riparian lands are unsightly and can cause physical and/or chemical (i.e., toxic) damage to aquatic and terrestrial wildlife. Sometimes debris can accumulate to such an extent that it may limit recreation and the passage of aquatic organisms and/or cause streambank erosion.

Chemical Impacts

The unique water chemistry requirements and tolerances of aquatic species help to define their natural abundance in a given stream, as well as their geographic distribution. Many naturally occurring chemical substances in streams and rivers are necessary for normal growth, development, and reproduction of biological communities. For example, sufficient dissolved oxygen in water is necessary for normal respiration. Dissolved oxygen concentrations in streams and rivers is determined, in part, by physical aeration processes influenced by the slope and depth of the stream, as well as the water temperature. Similarly, small amounts of nutrients (nitrogen, phosphorus, and silica) are necessary for normal growth of aquatic plants.

Human activities often contribute additional amounts of these naturally occurring substances, as well as other synthetic (manmade) chemicals to streams from point and nonpoint sources. Runoff from agricultural lands (see Agricultural Stream Ecosystem in Figure 29) may contain 1) sediment from soil erosion on tilled lands; 2) nutrients from the application of fertilizer and manure; 3) chloride and other salts from irrigation return flows; 4) pesticides used in the past and present to control insects, weeds, rodents, bacteria, or other unwanted organisms; and 5) other synthetic compounds used for varying purposes along with their degradates. Runoff from urban lands (see Urban Stream Ecosystem in Figure 29) may contain 1) sediment from construction activities; 2) nutrients and pesticides applied to lawns and recreational areas; and 3) petroleum compounds, trace metals, and deicing salts from roads and parking lots. Point sources include municipal and industrial wastewater effluent that, depending on the sources of wastewater and level of treatment, may contain different amounts of nutrients and other contaminants.

Physical Impacts

Physical habitat includes factors such as streambed substrates, water temperature, and large debris from streamside vegetation. Streambed substrates include the rocks, sediments, and submerged woody material in a stream. Streambed sediments may range in size and composition from large rocks to sand and silt that reflect the local geology. These substrates are important because they provide living space for many stream organisms. Stable substrates, such as cobbles and boulders, protect organisms from being washed downstream during high flows and, thus, generally support greater biological diversity than do less stable substrates, such as sand and silt. Water temperature is crucial to aquatic organisms because it directly influences their metabolism, respiration, feeding rate, growth, and reproduction. Most aquatic species have an optimal temperature range for growth and

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[5] *L. Wang, J. Lyons, P. Kanehl, and R. Bannerman, "Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales,"* Environmental Management, *Volume 28, 2001, pages 255-266.*

reproduction. Thus, their natural spatial and temporal distributions are largely determined by regional differences in climate and elevation along with more local effects from riparian (stream corridor) shading and groundwater influence. Water temperature also influences many chemical processes, such as the solubility of oxygen in water. The riparian zone is the land adjacent to the stream inhabited by plant and animal communities that rely on periodic or continual nourishment from the stream. The size and character of riparian zones are important to biological communities because these have a major influence on the amount of shelter and food available to aquatic organisms and the amount of sunlight reaching the stream through the tree canopy, which influences water temperature and the amount of energy available for photosynthesis. Riparian zones also influence the amount and quality of runoff that reaches the stream.

Land uses that affect streamflow, sediment availability, or riparian vegetation can alter physical habitats in streams. Some agricultural practices (see Agricultural Stream Ecosystem in Figure 29), such as conventional tillage near streambanks and drainage modifications, lead to increased sediment erosion, channelization, or removal of riparian vegetation. Increased sediment from erosion can fill crevices between rocks, which reduces living space for many stream organisms. As watersheds urbanize (see Urban Stream Ecosystem in Figure 29), some segments of streams are cleared, ditched, straightened, and enclosed to facilitate drainage and the movement of floodwaters. These modifications increase stream velocity during storms, which can transport large amounts of sediment, scour stream channels, and remove woody debris and other natural structures that provide habitats for stream organisms. In addition, culverts and ditches can be barriers to aquatic organisms that need to migrate throughout the stream network. Humans can alter natural stream temperature through changes in the amount and density of the canopy provided by riparian trees. In some extreme cases, streams in urban areas are routed through conduits and completely buried.

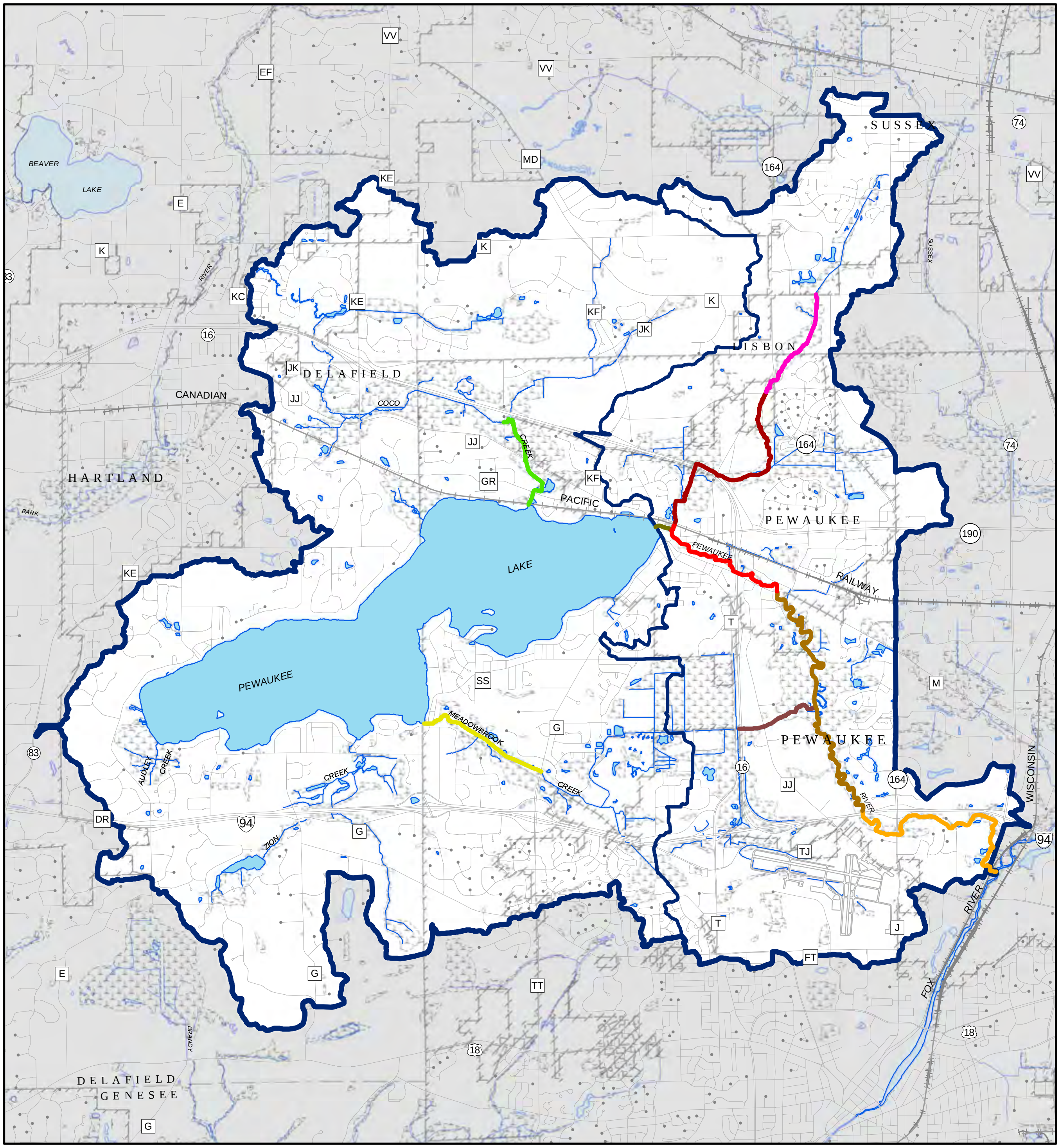
Pewaukee River Drainage Network

Water from rainfall and snowmelt flows into streams by one of two pathways: 1) either directly flowing overland as surface water runoff or 2) infiltrating into the soil, recharging the groundwater, and eventually reaching streams as baseflow. Ephemeral, or intermittent, streams generally flow only during the wet season or during large rainfall events. Perennial streams that flow year-round are primarily sustained by groundwater during dry periods. The surface water stream network within the Pewaukee River watershed is shown on Map 20. Eight assessment areas are identified within this watershed. In addition, the Pewaukee River was further divided into five discrete reaches, which were established based on a number of considerations that include gradient, sinuosity, dams, bridge and culvert crossings, and physical instream characteristics. An additional four reaches identified in this watershed include Coco Creek, Meadow Brook, CTH JJ tributary, and the Pewaukee Lake outlet (see Map 20 and Table 13). These reaches and assessment areas form the basis for the summary statistics and recommendations in this report.

Viewed from above, the network of water channels that form a river system typically displays a branch-like pattern as shown in Figure 31. A stream channel that flows into a larger channel is called a tributary of that channel. The entire area drained by a single river system is termed a drainage basin, or watershed. Stream size increases in the downstream direction as more and more tributary segments enter the main channel. A classification system based on the position of a stream within the network of tributaries, called stream order, was developed by Robert E. Horton and later modified by Arthur Strahler. In general, the lower stream order numbers correspond to the smallest headwater tributaries and are shown as the Order 1 or first-order streams as represented within the Pewaukee River watershed in Figure 31. Second-order streams (Order 2) are those that have only first-order streams as tributaries, and so on (see Figure 31). As water travels from headwater streams toward the mouth of larger rivers, streams gradually increase their width and depth and the amount of water they discharge also increases. It is important to note that more than 80 percent of the total length of Earth’s rivers and streams are headwater streams (first- and second-order) and the Pewaukee River watershed shows the same type of pattern. Although Pewaukee Lake is not a stream, it is technically a tributary to the Pewaukee River. If the dam had not been constructed, Pewaukee Lake would be considered a third-order stream, which is why it is labeled that way in Figure 31. The Pewaukee Lake Outlet combines with the Pewaukee River to form a fourth-order stream, and remains one to its confluence with the Fox River.

Map 20

STREAM REACHES SURVEYED WITHIN THE PEWAUKEE RIVER WATERSHED: 2012



PEWAUKEE RIVER MAINSTEM:

- PEWAUKEE 1
- PEWAUKEE 2
- PEWAUKEE 3
- PEWAUKEE 4
- PEWAUKEE 5

TRIBUTARIES:

- CTH JJ TRIBUTARY
- PEWAUKEE LAKE OUTLET
- COCO CREEK
- MEADOWBROOK CREEK

- SURFACE WATER
- STREAM (NOT SURVEYED)
- WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

Table 13

PHYSICAL CHARACTERISTICS OF MAINSTEM STREAM REACHES WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010

Stream Reach[a]	Reach Length (miles)		Sinuosity		Minimum Elevation (feet above NGVD29)	Maximum Elevation (feet above NGVD29)	Slope (percent)
	1941	2010	1941	2010			
Pewaukee River							
Pewaukee 1	2.44	2.18	1.37	1.23	811.8	835.6	0.207
Pewaukee 2	3.41	3.16	1.68	1.56	835.6	841.1	0.033
Pewaukee 3	1.48	1.34	1.33	1.20	841.1	843.8	0.038
Pewaukee 4	2.28	2.03	1.25	1.10	843.8	854.9	0.104
Pewaukee 5	2.30	2.31	1.10	1.10	854.9	877.5	0.318
Pewaukee Lake Tributaries							
Coco Creek	4.27	3.86	1.18	1.13	- -	- -	- -
Meadowbrook Creek........	2.64	3.26	1.05	1.26	- -	- -	- -

NOTE: Reach length and sinuosity for both 1941 and 2010 represent Coco Creek up to 0.24 mile past STH 16. Reach length and sinuosity for both 1941 and 2010 represent Meadowbrook Creek up to 0.35 mile past Milkweed.

[a]*See Map 20 for locations of surveyed portions of stream reaches.*

Source: SEWRPC.

Dams are often viewed as an interruption within the context of the normal continuum of characteristics from upstream to downstream within a natural stream system.[6] Pewaukee Lake and its associated dam interrupt the continuity of physical, chemical, and biological aspects of the river system.[7] For example, significant warming of surface waters within Pewaukee Lake can cause significant warming of waters discharging into the Pewaukee River in reaches downstream of the Lake outlet. However, it is important to note that the deeper areas of the lake also offer vast thermal refuges (i.e., cooler water temperatures) which have diverse high-quality habitats and spawning areas. In addition, the lake serves as the focal point of recreation within the Pewaukee River watershed.

To better understand stream systems and what shapes their conditions, it is important to understand the effects of both spatial and temporal scales. Streams can be theoretically subdivided into a continuum of habitat sensitivity to disturbance and recovery time, as shown in Figure 32.[8] Microhabitats, such as a handful-sized patch of gravel, are most susceptible to disturbance; river systems and watersheds are least susceptible. Furthermore, events that affect smaller-scale habitat characteristics may not affect larger-scale system characteristics, whereas large disturbances can directly influence both large- and smaller-scale features of streams. For example, on a small

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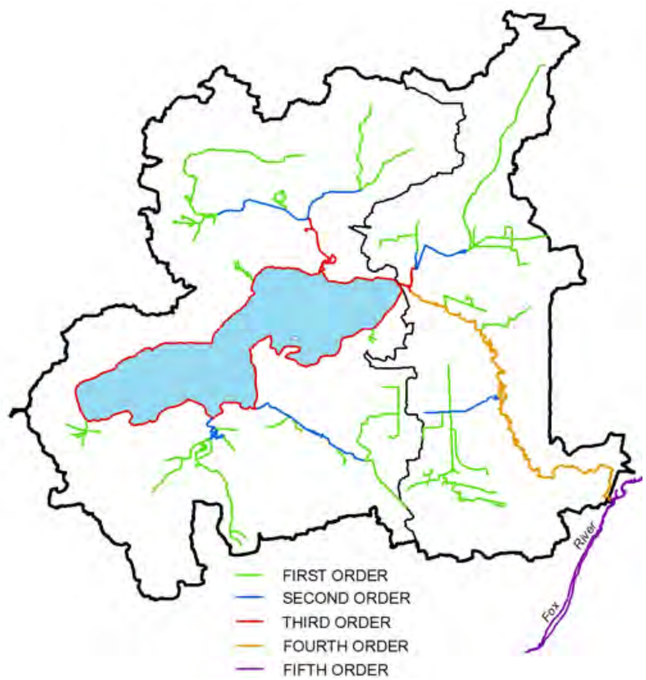
[6]*R.L. Vannote, G.W. Minshall, K.W. Cummings, J.R. Sedell, and C.E. Cushing, "The River Continuum Concept,"* Canadian Journal of Fisheries and Aquatic Sciences, *Volume 37, 1980, pages 130-137.*

[7]*J.V. Ward, and J.A. Stanford. "The serial discontinuity concept of lotic ecosystems," In Dynamics of Lotic Ecosystems (T.D. Fontaine and S.M. Bartell, editors), Ann Arbor Science Publishers, Ann Arbor, MI, 1983, pages 29-42.*

[8]*C.A. Frissell, et al., "A Hierarchical Framework for Stream Classification: Viewing Streams in a Watershed Context,"* Journal of Environmental Management, *Volume 10, 1986, pages 199-214.*

Figure 31

STREAM NETWORK PATTERN APPLIED TO THE PEWAUKEE RIVER BASED ON HORTON'S CLASSIFICATION SYSTEM



Source: Modified from Oliver S. Owen and others, Natural Resource Conservation: Management for a Sustainable Future*, and SEWRPC.*

spatial scale, deposition at one habitat site may be accompanied by scouring at another site nearby, but the reach or segment containing the habitat sites does not appear to change significantly. In contrast, a large-scale disturbance, such as a debris flood, is initiated at the segment level and reflected in all lower levels of the hierarchy (reach, habitat, microhabitat). Similarly, on a temporal scale, siltation of microhabitats may disturb the biotic community over the short term. However, if the disturbance is of limited scope and intensity, the system may recover quickly to pre-disturbance levels.[9]

The most important fundamental aspects of stream systems are 1) that the entire fluvial system is a continuously integrated series of physical gradients in which the downstream areas are longitudinally linked and dependent upon the upstream areas; and 2) that streams are intimately connected to their adjacent terrestrial setting—that is, the land-stream interaction is crucial to the functioning of stream ecosystem processes and this connectivity does not diminish in importance with stream size. In this regard, land uses have a significant impact on stream channel conditions and associated biological responses.[10]

As previously mentioned, the Pewaukee River system is somewhat unique in that Pewaukee Lake drains into the river through a controlled outlet, rather than the river flowing through the lake as is often the case. In this sense, Pewaukee Lake and its tributaries (Coco Creek, Meadowbrook Creek, Zion Creek, and Audley Creek) act as tributaries to the Pewaukee River. This connection to Pewaukee Lake is somewhat interrupted by the dam outlet, which controls Lake water levels. While fish and other aquatic life are at times able to travel through the Lake outlet into the River (particularly since it was reconstructed to be a bottom draw gate) it is difficult if not impossible for fish to migrate from the Pewaukee River into Pewaukee Lake. The abundant presence of the invasive zebra mussel in stretches of the Pewaukee River that approach the Pewaukee Lake outlet demonstrates the impact the Lake can have on the River. However, it is important to note that the lake does support a high-quality sport fishery and serves as a focal point of recreation within the Pewaukee River watershed.

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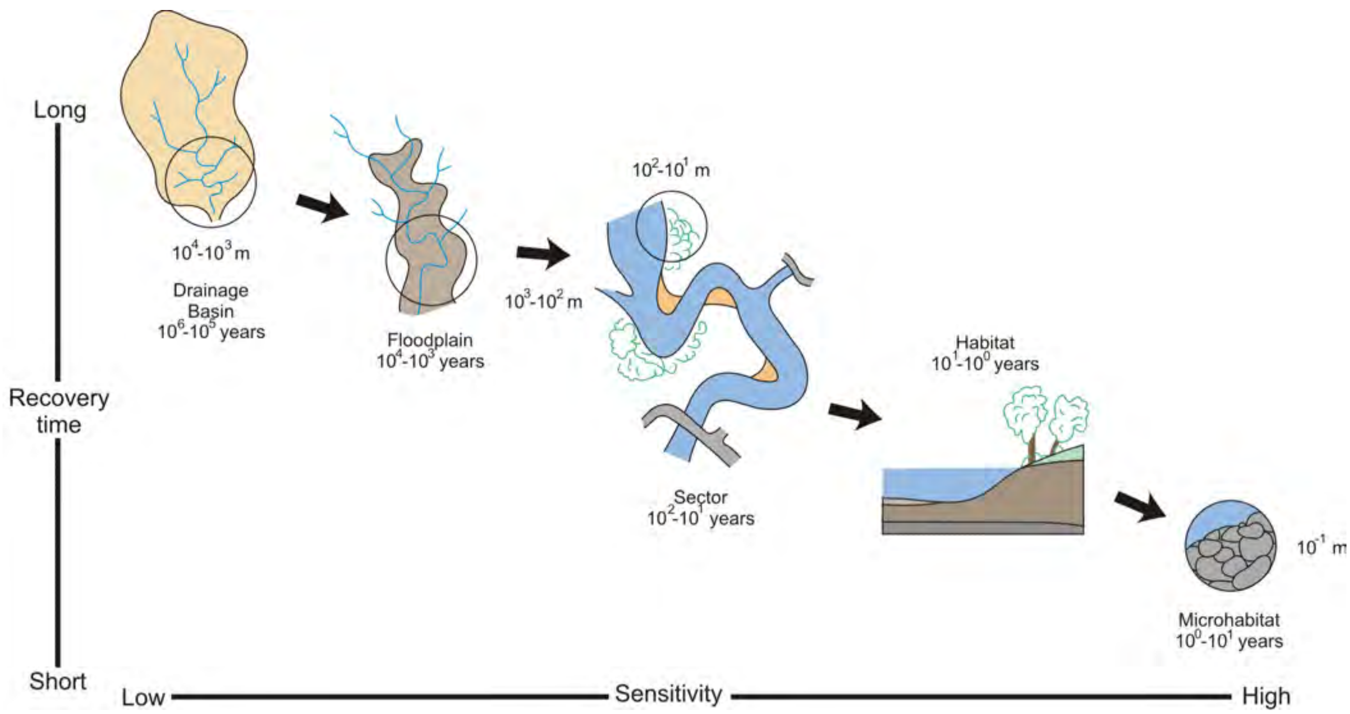
[9]*G.J. Niemi, et al., "An Overview of Case Studies on Recovery of Aquatic Systems From Disturbance,"* Journal of Environmental Management*, Volume 14, 1990, pages 571-587.*

[10]*Lizhu Wang, et al., "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams," Fisheries, Volume 22, Number 6, June 1997; Jana S. Stewart, et al., "Influences of Watershed, Riparian-Corridor, and Reach-Scale Characteristics on Aquatic Biota in Agricultural Watersheds,"* Journal of the American Water Resources Association*, Volume 37, Number 6, December 2001; Faith A. Fitzpatrick, et al., "Effects of Multi-Scale Environmental Characteristics on Agricultural Stream Biota in Eastern Wisconsin,"* Journal of the American Water Resources Association*, Volume 37, Number 6, December 2001.*

Figure 32

RELATION BETWEEN RECOVERY TIME AND SENSITIVITY TO DISTURBANCE FOR DIFFERENT HIERARCHICAL SPATIAL SCALES ASSOCIATED WITH STREAM SYSTEMS



Source: *C.A. Frissell and others, "A Hierarchical Framework for Stream Habitat Classification: Viewing Streams in a Watershed Context,"* Environmental Management*, Vol. 10, and SEWRPC.*

PHYSICAL CONDITIONS

SEWRPC staff conducted field inventories from March through May 2012 to quantitatively and qualitatively characterize the physical characteristics of the Pewaukee River watershed. Although a severe drought did occur in the summer of 2012, this survey preceded the timing of the drought by a couple of months, so the discharges at the time of this survey were considered to be within a normal range for this stream system. Both quantitative and qualitative measures were largely based upon the WDNR Baseline Monitoring protocols for instream fisheries habitat assessment.[11] A total of 406 cross sections surveys were obtained throughout the watershed and the number of transects ranged from 16 to 27 transects per mile, depending on the reach sampled as shown in Table 14 (see Appendix E). An additional 159 maximum water depths were recorded in pool habitats to assess number and quality in order to supplement information between cross sections where the full complement of data was collected. Physical parameters measured include water and sediment depth, substrate composition,

[11]*WDNR, Guidelines for Evaluating Habitat of Wadable Streams, Bureau of Fisheries Management and Habitat Protection, Monitoring and Data Assessment Section, Revised June 2000; Timothy Simonson, John Lyons, and Paul Kanehl, "Guidelines for Evaluating Fish Habitat in Wisconsin Streams,"* General Technical Report NC-164, *1995; and Lihzu Wang, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management, *Volume 18, 1998.*

Table 14

PHYSICAL HABITAT CHARACTERISTICS OF STREAM REACHES WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

Parameters	River Reach[a]								
	Pewaukee 1	Pewaukee 2	Pewaukee 3	Pewaukee 4	Pewaukee 5	CTH JJ Tributary[b]	Pewaukee Lake Outlet	Coco Creek[b]	Meadowbrook Creek[b]
Transects									
Number of Transects	40	50	26	43	25	20	4	19	20
Transects (number per mile)	18	16	18	19	24	27	- -	19	17
Habitat									
Composition									
Number of Pools per Mile	13.8	12.0	14.9	19.7	8.4	33.3	6.7	1.0	2.6
Number of Riffles per Mile	6.0	0.6	1.5	3.0	9.4	8.0	13.3	2.0	0
Pool/Riffle Ratio	2.3	20.0	9.9	6.6	0.9	4.2	0.5	0.5	- -
Average Width (feet)	29.0	29.2	29.9	13.8	5.3	8.3	78.5	10.1	24.5
Standard Deviation	8.2	7.9	12.2	8.1	2.5	2.9	57.0	6.9	9.8
Depth									
Average Pool Depth (feet)	2.8	2.9	2.3	2.0	1.1	2.2	1.2	2.4	1.7
Standard Deviation	0.7	0.7	0.5	0.4	0.2	1.1	0.0	0.6	0.8
Residual Pool Depth (feet)	1.7	1.8	1.8	1.3	0.7	1.7	0.76	2.0	2.1
Standard Deviation	0.8	0.7	0.5	0.4	0.2	1.2	- -	0.6	1.1
Average Riffle Depth (feet)	1.1	1.1	0.5	0.8	0.4	0.5	0.4	0.3	- -
Standard Deviation	0.3	0.0	0.1	0.2	0.1	0.1	0.0	0.1	- -
Average Run Depth (feet)	1.5	1.2	1.2	1.0	0.7	0.9	0.8	1.3	1.0
Standard Deviation	0.3	0.3	0.3	0.4	0.1	0.3	0.2	0.5	0.3
Substrate									
Flocculent Sediment Depth									
Average Depth (feet)	0.1	0.5	0.2	0.4	0.1	0.1	0.1	0.2	0.9
Maximum Depth (feet)	2.2	2.1	1.8	2.4	1.0	1.1	1.2	1.9	3.8
Composition[c]									
Muck (percent)	0	0	0	0	0	0	0	0	4
Clay(percent)	0	6	1	26	7	3	0	4	11
Peat (percent)	0	14	0	5	0	4	0	2	0
Silt (percent)	10	46	29	46	25	23	23	30	55
Sand (percent)	25	13	33	7	14	25	34	33	18
Gravel (percent)	30	11	23	8	12	23	25	23	11
Cobble (percent)	27	7	10	6	20	16	12	6	1
Boulder (percent)	8	3	4	2	11	6	6	2	0
Bedrock (percent)	0	0	0	0	11	0	0	0	0

Table 14 (continued)

Parameters	River Reach[a]								
	Pewaukee 1	Pewaukee 2	Pewaukee 3	Pewaukee 4	Pewaukee 5	CTH JJ Tributary[b]	Pewaukee Lake Outlet	Coco Creek[b]	Meadowbrook Creek[b]
Cover									
Undercut Banks									
Deep (percent >1.0 feet)	5	1	0	0	0	0	0	0	0
Moderate (percent >0.5 and ≤1.0 feet)	9	4	0	0	6	3	0	10	0
Shallow (percent <0.5 feet)	18	2	0	0	6	0	0	3	10
None (percent)	69	93	100	100	88	97	100	87	90
Amount of Cover									
High Abundance (percent)	20.0	8.0	8.0	30.2	20.0	35.0	0.0	10.5	30.0
Moderate Abundance (percent)	57.5	42.0	64.0	37.2	76.0	55.0	75.0	36.8	50.0
Low Abundance (percent)	22.5	50.0	28.0	32.6	4.0	10.0	25.0	52.6	20.0
None (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Woody Debris									
High Abundance (percent)	10.0	4.0	8.0	4.7	4.0	25.0	0.0	10.5	0.0
Moderate Abundance (percent)	32.5	32.0	24.0	27.9	32.0	45.0	50.0	26.3	25.0
Low Abundance (percent)	50.0	58.0	64.0	51.2	60.0	30.0	50.0	52.6	70.0
None (percent)	7.5	6.0	4.0	16.3	4.0	0.0	0.0	10.5	5.0
Macrophytes									
High Abundance (percent)	0.0	4.0	0.0	18.6	8.0	5.0	0.0	5.3	30.0
Moderate Abundance (percent)	0.0	24.0	4.0	18.6	0.0	5.0	25.0	10.5	30.0
Low Abundance (percent)	10.0	26.0	88.0	48.8	60.0	50.0	75.0	47.4	40.0
None (percent)	90.0	46.0	8.0	14.0	32.0	40.0	0.0	36.8	0.0
Algae									
High Abundance (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moderate Abundance (percent)	0.0	4.0	24.0	2.3	0.0	0.0	25.0	10.5	20.0
Low Abundance (percent)	42.5	32.0	48.0	23.3	36.0	35.0	75.0	26.3	35.0
None (percent)	57.5	64.0	28.0	74.4	64.0	65.0	0.0	63.2	45.0
Shading									
High Abundance (percent)	27.5	2.0	4.0	11.6	28.0	40.0	0.0	31.6	10.0
Moderate Abundance (percent)	22.5	8.0	24.0	14.0	20.0	15.0	50.0	15.8	10.0
Low Abundance (percent)	45.0	32.0	52.0	20.9	20.0	15.0	25.0	21.1	45.0
None (percent)	5.0	58.0	20.0	53.5	32.0	30.0	25.0	31.6	35.0
Obstructions									
Weir/Beaver Dams (total number)	0	1	0	0	1	0	0	0	2
Debris Jams (total number)	5	4	0	5	14	16	0	3	1
Road/Railway Crossings (total number)	6	1	5	4	12	3	0	8	4
Subtotal	11	6	5	9	27	19	0	11	7

Table 14 (continued)

Parameters	River Reach[a]								
	Pewaukee 1	Pewaukee 2	Pewaukee 3	Pewaukee 4	Pewaukee 5	CTH JJ Tributary[b]	Pewaukee Lake Outlet	Coco Creek[b]	Meadowbrook Creek[b]
Obstructions (continued)									
Reach Length Assessed (miles)	2.18	3.16	1.34	2.03	2.31	1.2	0.06	5.48	3.5
Total Obstructions (number per mile)	5.0	1.9	3.7	4.4	11.7	15.8	- -	2.0	2.0
Trash Sites (total number)	12	34	35	17	6	16	1	1	7
Trash-Tires (total number)	2	14	8	1	2	8	1	0	1
Stormwater Outlet Pipes (number)	8	4	16	7	1	1	0	0	0
Tributary Inlets (number)	1	26	5	5	2	3	0	1	4
Groundwater Springs/Seepage (number)	1	0	0	1	0	0	0	0	1
Qualitative Habitat Environmental Index (QHEI) Rating									
QHEI Score Range (minimum-maximum)	55-81	51-83	48-72	50-80	49-76	55-77	49-63	42-66	37-51
QHEI Quality Range (minimum-maximum)	Fair-excellent	Fair-excellent	Fair-good	Fair-excellent	Fair-excellent	Fair-excellent	Fair-good	Fair-good	Poor-fair

[a]*The numbers in parentheses indicate sample size.*

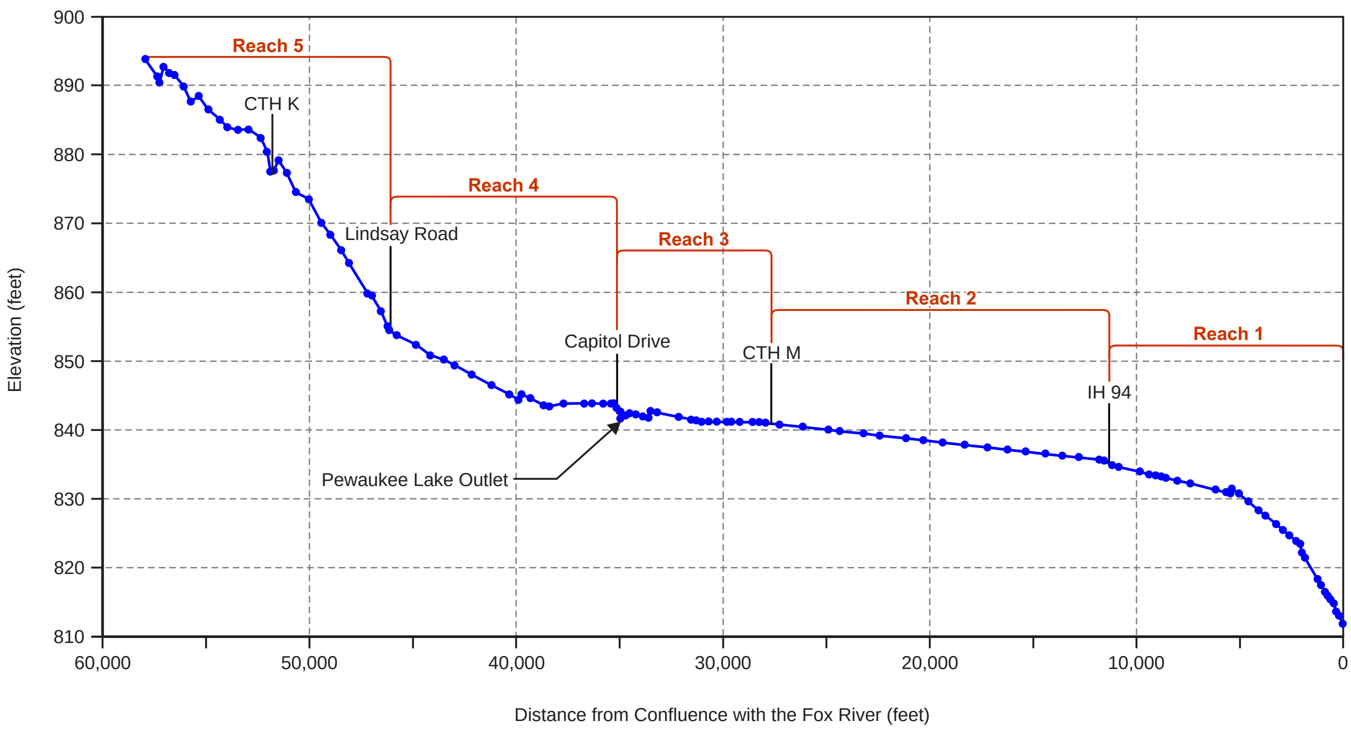
[b]*Only the lower portion, or about one mile, was assessed for the CTH JJ Tributary, Coco Creek, and Meadowbrook Creek systems.*

[c]*Based on generalized evaluation of substrate composition at each transect.*

Source: SEWRPC.

Figure 33

APPROXIMATE NORMAL WATER SURFACE ELEVATION PROFILES BY STREAM REACH IN THE PEWAUKEE RIVER WATERSHED: 2005



NOTE: Data were obtained from the 2005 Waukesha County digital terrain model in National Geodetic Vertical Datum (NGVD 29). In cases where the water surface elevation appears to increase from upstream to downstream, the plotted elevation may actually represent a localized land surface feature. These plots are intended to provide a general representation of stream slopes.

Source: SEWRPC.

undercut bank, bank slopes, and channel width. The remaining cover parameters were each qualitatively estimated as none, low, moderate, and high percent abundances based upon categories as defined in the Qualitative Habitat Evaluation Index (QHEI) methodology.[12]

Slope and Sinuosity

Stream characteristics, such as slope, length, and sinuosity are determined by a combination of geological history (i.e., glaciation) and human intervention (i.e., lake impoundments and channelization). Based upon this information, it was determined that there were five distinct stream reaches in the Pewaukee River as set forth on Map 20 and Figure 33. In addition, several of the major tributaries to Pewaukee Lake and River, including Coco Creek, Meadowbrook Creek, Pewaukee Lake Outlet, and CTH JJ tributary were also assessed as part of this project (see Map 20). The extent of the physical data collected within the Pewaukee River and other reaches within this watershed as part of this study is shown on Map 20.

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[12]*Edward T. Rankin, The Quality Habitat Evaluation Index [QHEI]: Rationale, Methods, and Application, State of Ohio Environmental Protection Agency, November 1989.*

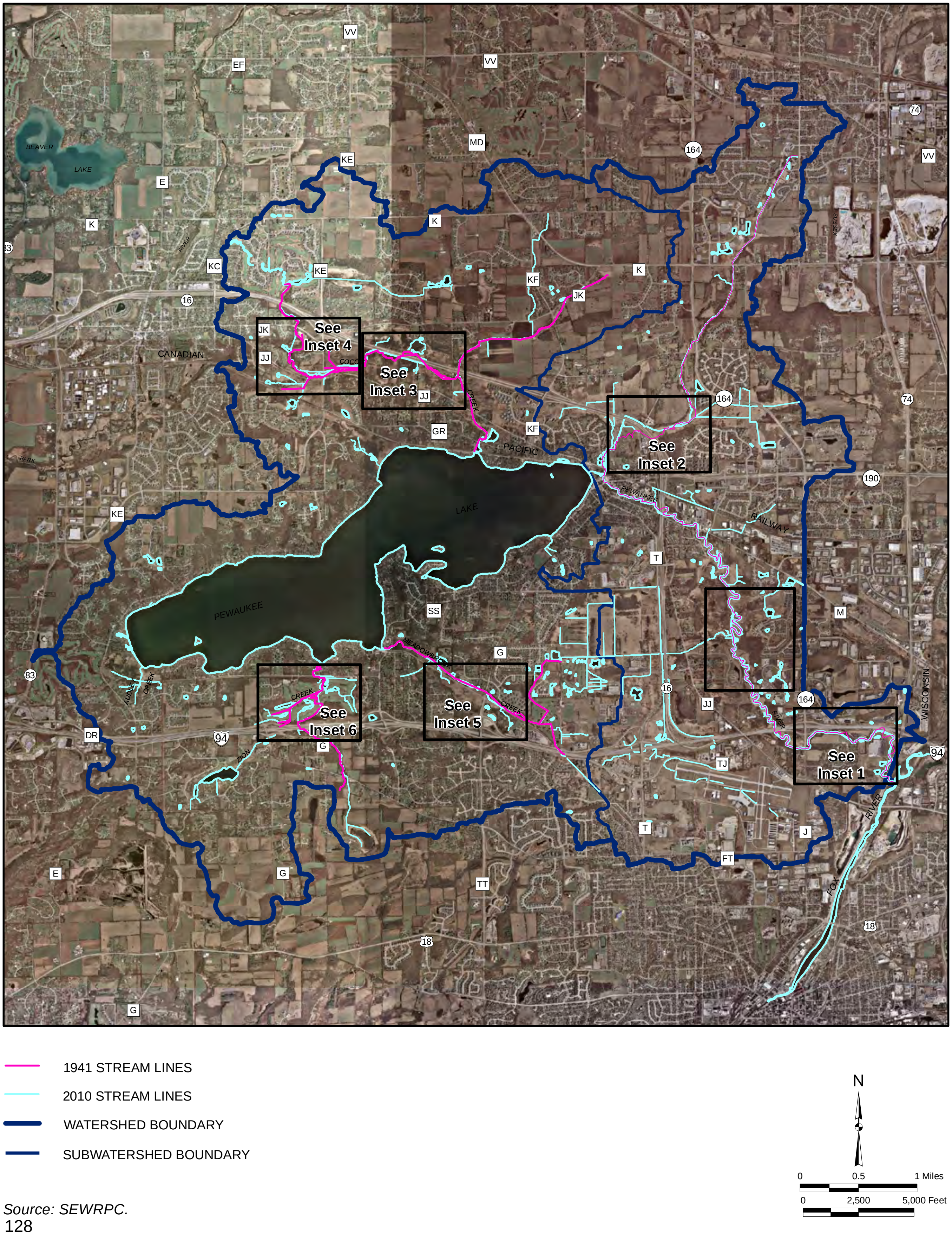
Healthy streams naturally meander or migrate across a landscape over time. Sinuosity is a measure of how much a stream meanders. It is defined as the ratio of channel length between two points on a channel to the straight-line distance between the same two points. Sinuosity or channel pattern can range from straight to a winding pattern, or meandering. Channelized sections of streams that have been straightened typically have low sinuosity or a number closer to one. Stream reaches within the Pewaukee River had sinuosities that range from 1.10 to 1.56 in 2010 as shown in Table 13, and include both channelized and nonchannelized segments. Comparison of the 1941 versus 2010 stream alignments as shown on Map 21 shows that this system, while already channelized in many reaches, was more sinuous in 1941, with sinuosities ranging from 1.10 to 1.68. Much of the loss in sinuosity occurred prior to 1941 from ditching or channel straightening to accommodate agricultural development. In contrast, post-1941 to 2010 ditching occurred to accommodate interstate, state trunk, county highways, and local road construction and urban development as seen in the series of insets shown on Map 21. Streams are transport systems for water and sediment and are continually eroding and depositing sediments, which causes the stream to migrate. When the amount of sediment load coming into a stream is equal to what is being transported downstream—and stream widths, depths, and length remain consistent over time—it is common to refer to that stream as being in a state of "dynamic equilibrium." In other words, the stream retains its physical dimensions (equilibrium), but those physical features are shifted, or migrate, over time (dynamic). For example, it is not uncommon for a low-gradient stream in Southeastern Wisconsin to migrate more than one foot within a single year. Reaches that were not channelized, particularly Pewaukee-2, still exhibit healthy meanders that have migrated only slightly over the nearly 70 years between 1941 and 2010 as shown on Map 21 (see Inset 1A). These comparisons, combined with onsite survey observations that generally indicated fairly stable streambed and streambanks, indicate that the Pewaukee River seems to be in a state of dynamic equilibrium. However, it is important to note that the Pewaukee River is well-connected to the floodplain and this floodplain, particularly within reach Pewaukee-2, is fairly extensive. This connection is critical and helps to protect the streambed and streambanks within the Pewaukee River by allowing flood flows to dissipate into the floodplain and reduce water velocities that would cause erosion, while at the same time allowing sediments and other pollutants to be deposited into the floodplain. In addition, the extensive floodplain and/or riparian buffer allows for the River system to naturally make adjustments to changes in discharge and sediment loads. It is also important to note that the extent of meandering increases with the area tributary to the stream reach, so as tributary area increases so does the width of the meander belt (see Appendix C).

The longitudinal slope of a channel is the ratio of elevation change between two points on the channel to the length of the channel between the same two points. Slope is an indicator of stream energy or power. The lower the slope, the lower the energy, and the slower the water flows. Stream slopes within mountainous stream systems are typically greater than 10 percent. However, slopes within the Pewaukee River reaches are more indicative of lowland streams found in Southeastern Wisconsin and do not exceed 1 percent, as shown in Table 13. Elevation profiles for each stream reach are shown in Figure 33.

In general, reaches Pewaukee-1 and Pewaukee-5 have the greatest slopes in the Pewaukee River (see Figure 33 and Table 13). These higher sloped reaches also contain the greatest proportions of larger substrates, including sands, gravels, cobbles, and boulders, compared to the other reaches, which are dominated by sand and organic substrates, such as silt and peat (see Table 14 and Figure 34). The Pewaukee-5 reach contains stretches of exposed bedrock which is typically found beneath a shallow layer of silty clay loam soils in the Pella-moderately shallow variant-Knowles soil association found throughout the reach, as discussed in Chapter II of this report. Relatively high slopes throughout this reach have allowed much of the shallow silty clay loam to be transported downstream, exposing the bedrock. The Pewaukee-2 and Pewaukee-3 reaches have a very gentle slope of 0.033 and 0.038 percent, respectively, which is also associated with decreased water velocities. As expected, the substrates in these reaches are dominated by clay and organic substrates, such as silt and peat, and also contain higher unconsolidated sediment depths compared to the other reaches.

Map 21

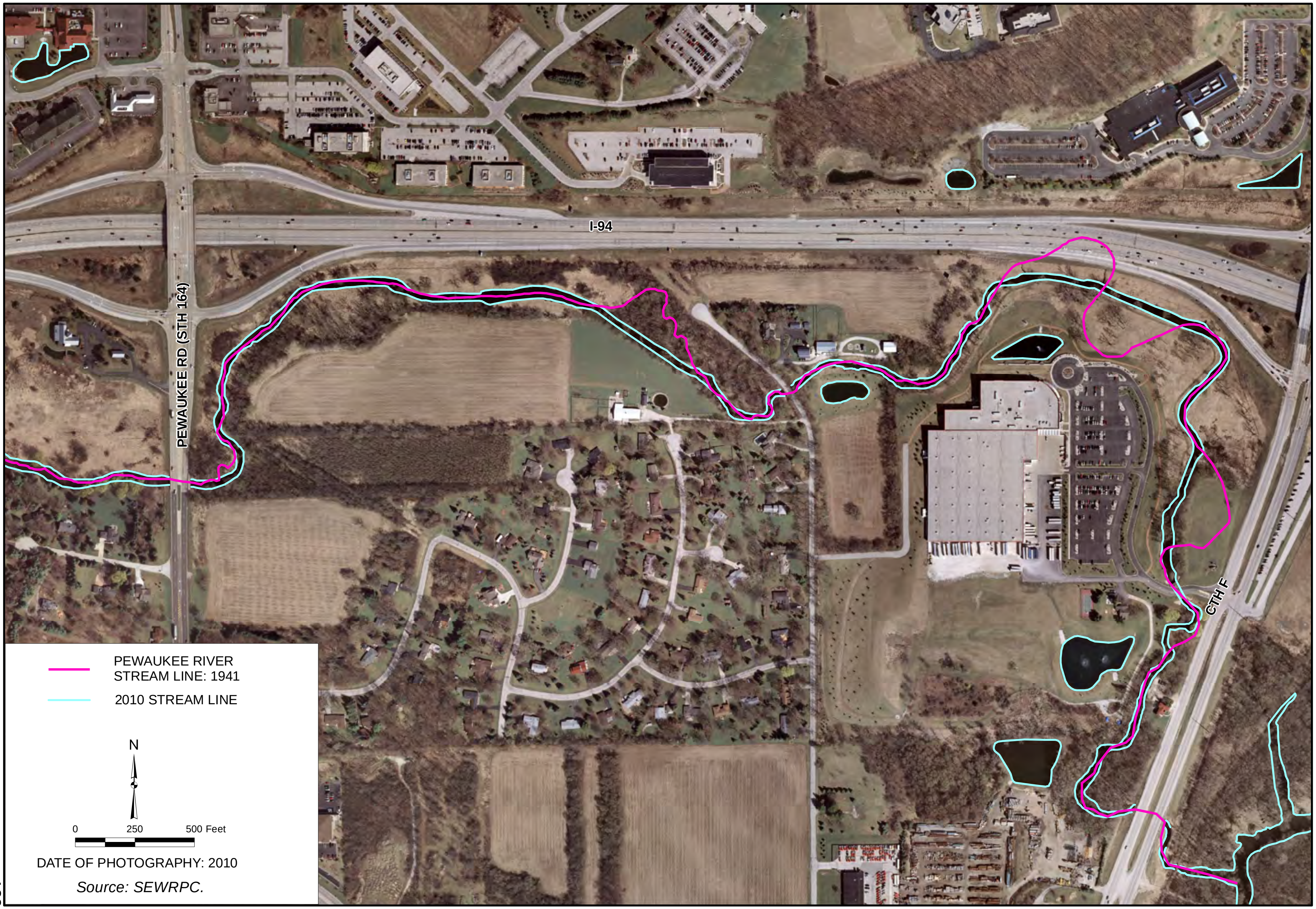
STREAM ALIGNMENTS WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010



Source: SEWRPC.

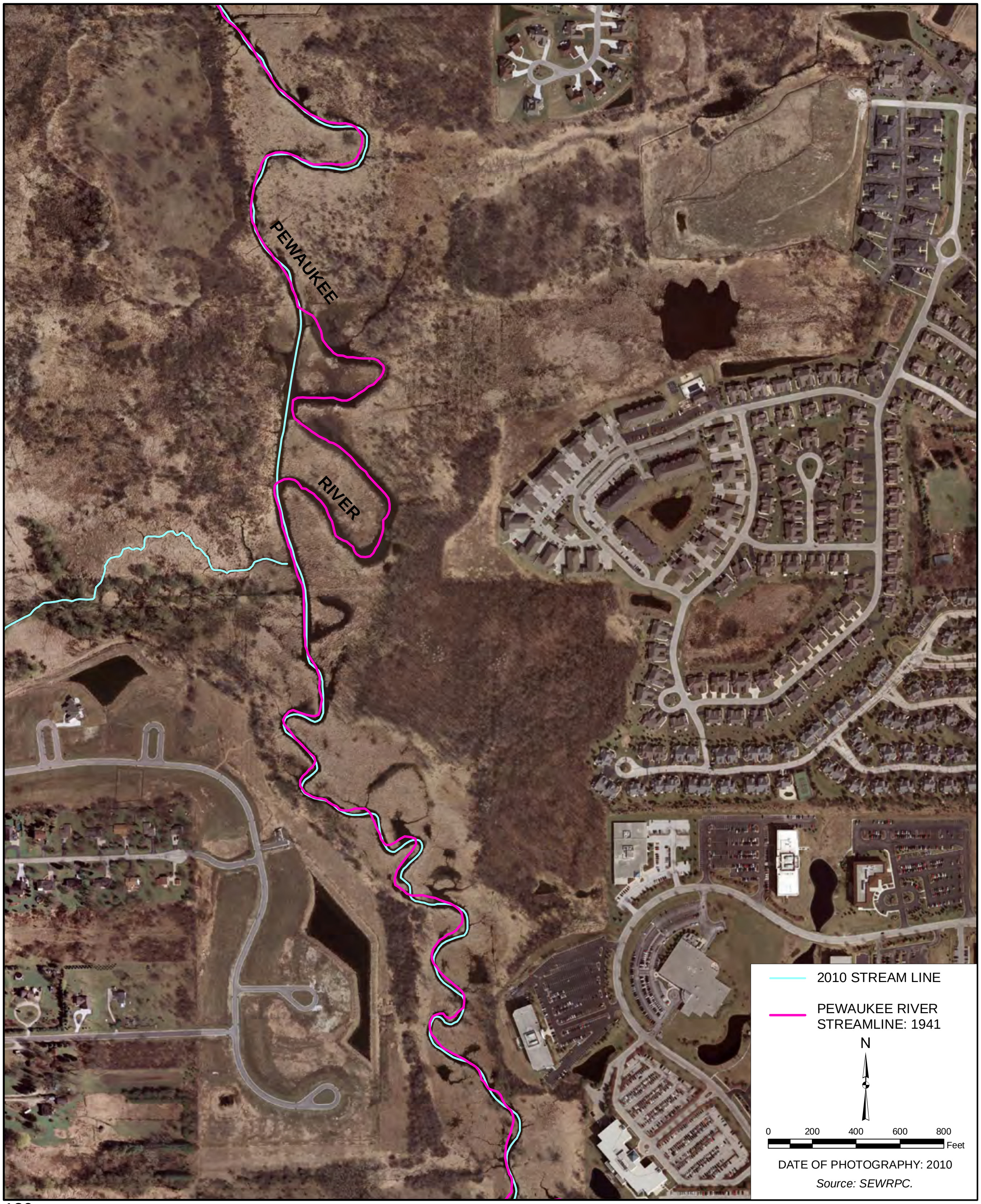
Inset 1 to Map 21

STREAM ALIGNMENTS WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010



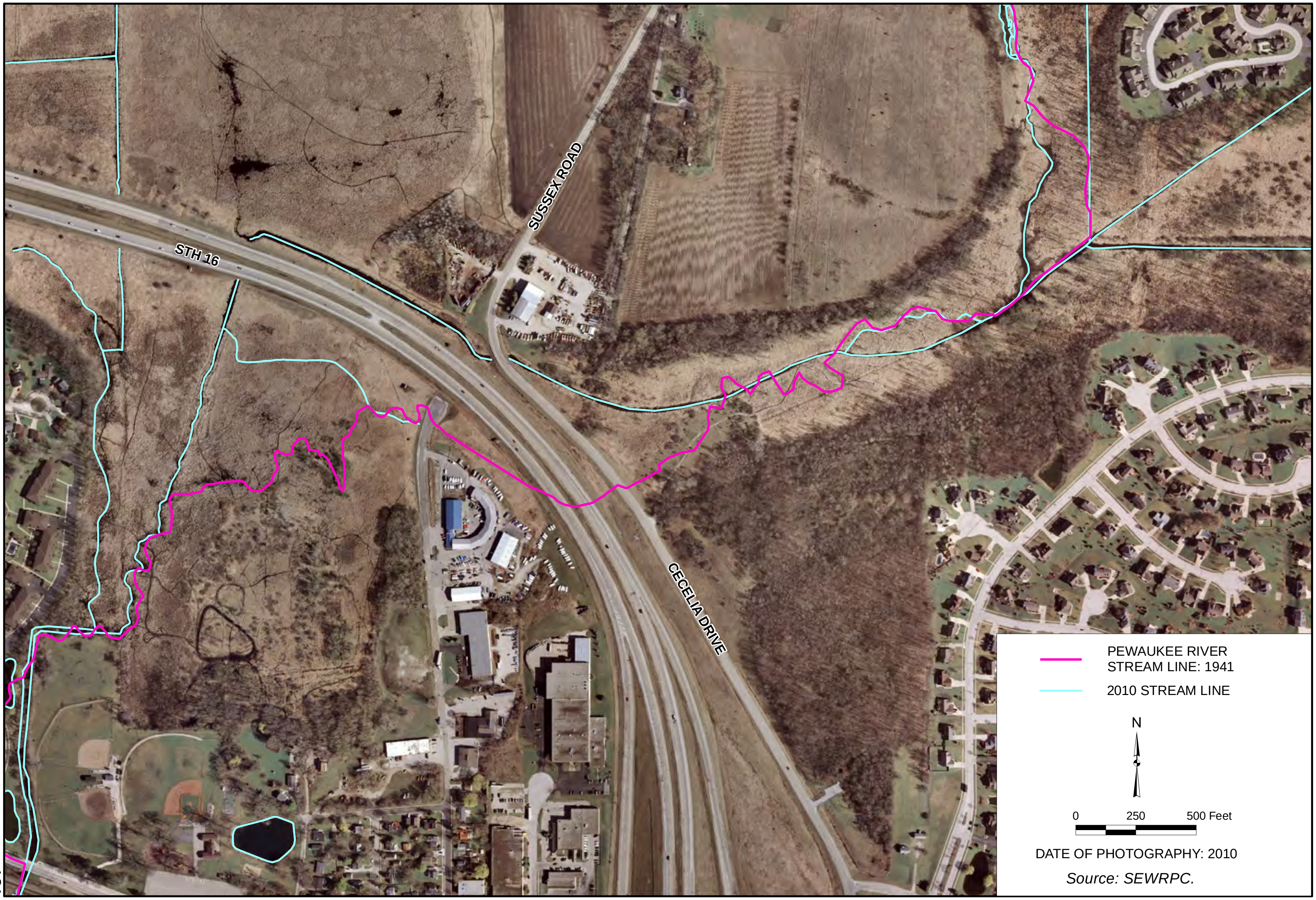
Inset 1a to Map 21

STREAM ALIGNMENTS WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010



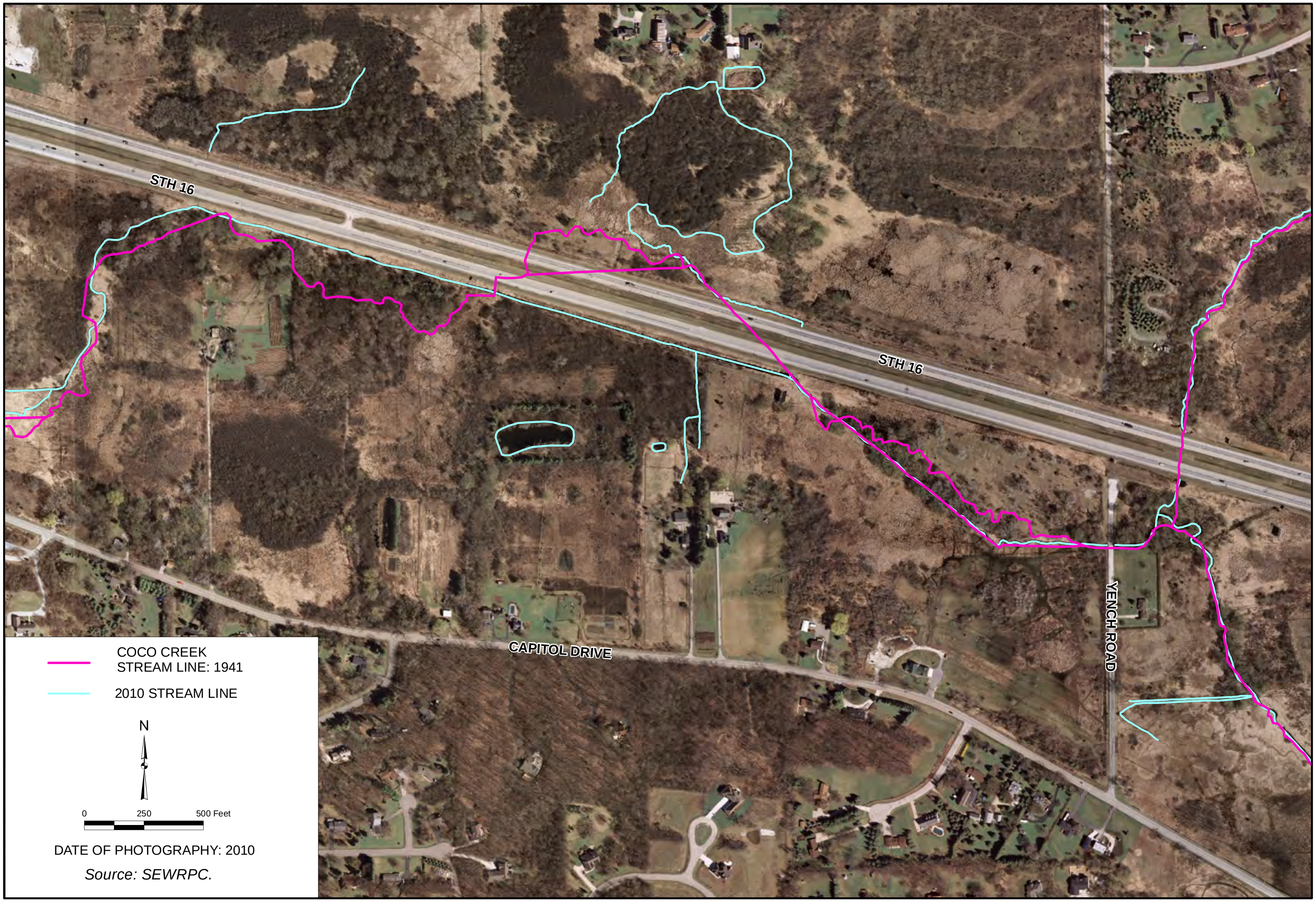
Inset 2 to Map 21

STREAM ALIGNMENTS WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010



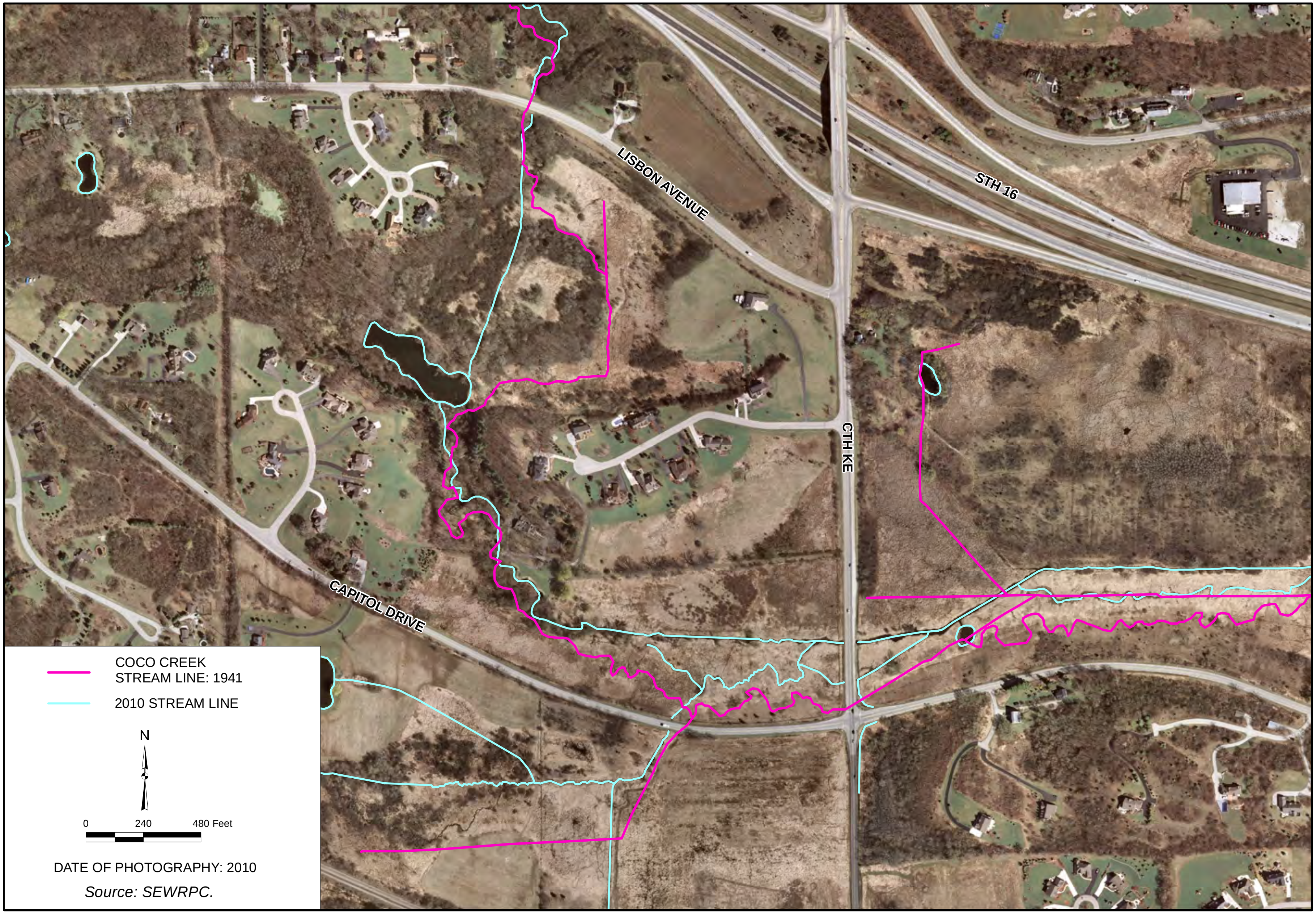
Inset 3 to Map 21

STREAM ALIGNMENTS WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010



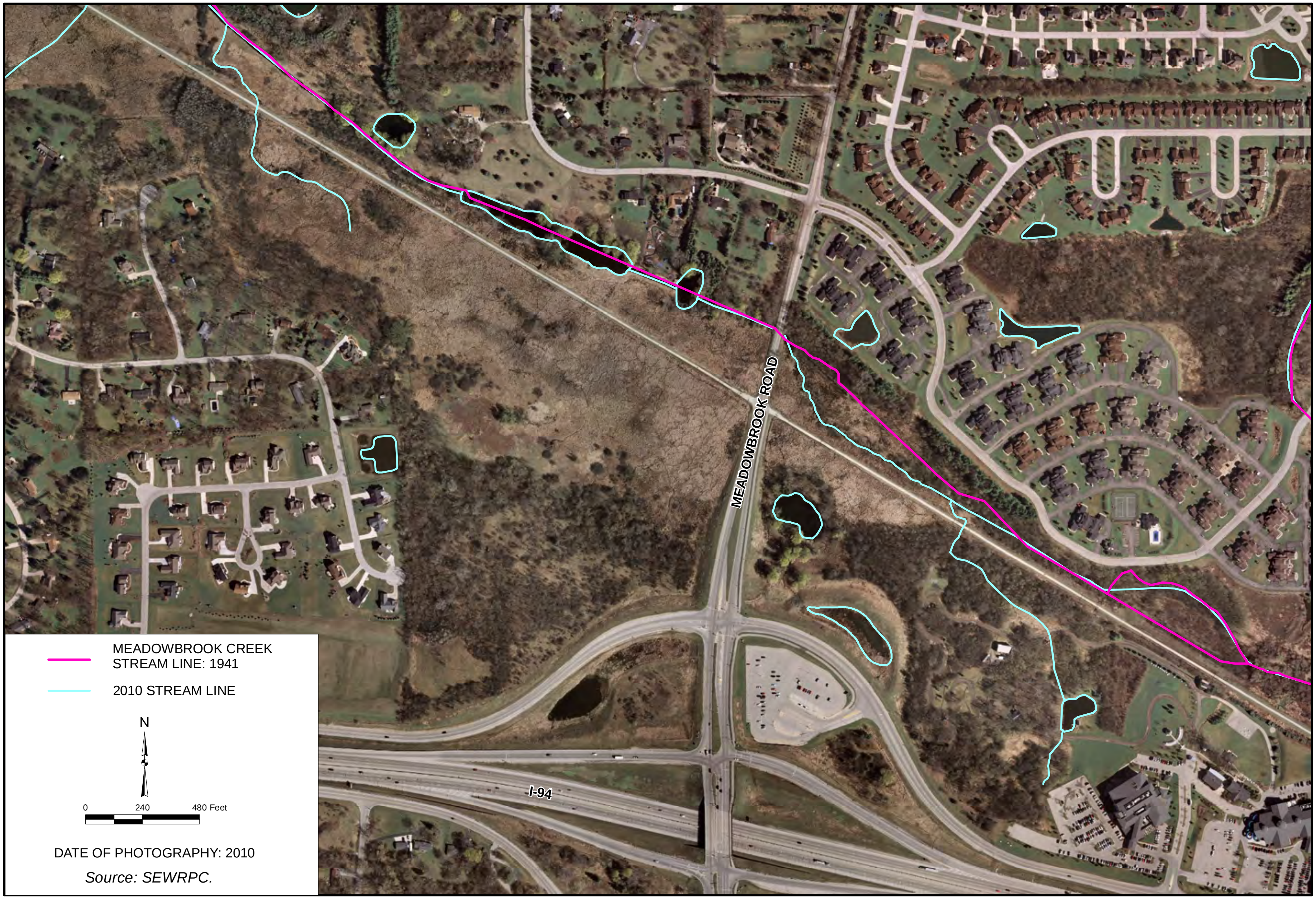
Inset 4 to Map 21

STREAM ALIGNMENTS WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010



Inset 5 to Map 21

STREAM ALIGNMENTS WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010

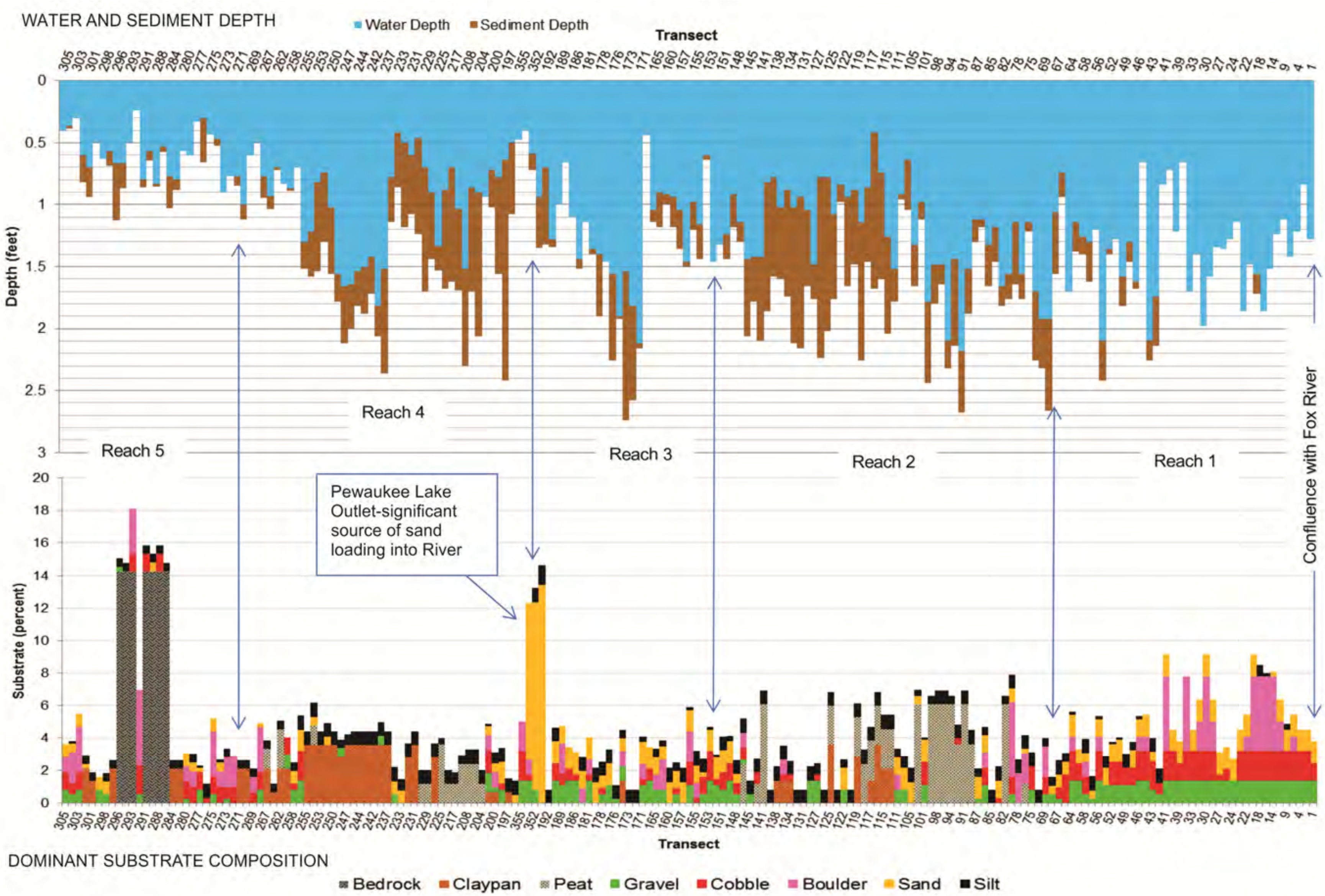


Inset 6 to Map 21

STREAM ALIGNMENTS WITHIN THE PEWAUKEE RIVER WATERSHED: 1941 AND 2010

Figure 34

MEAN WATER DEPTH, UNCONSOLIDATED SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION WITHIN THE PEWAUKEE RIVER: 2012



Source: SEWRPC.

Channelization

Straightening meandering stream channels or "channelization" was once a widely used and accepted technique in agricultural management. The U.S. Department of Agriculture National Resources Conservation Service (NRCS) (formerly Soil Conservation Service) cost shared such activities up to the early 1970s within southeastern Wisconsin.[13] The objectives of channelization were to reduce floods by conveying stormwater runoff more rapidly, to facilitate drainage of low-lying agricultural land, and to allow more efficient farming in rectangular fields. In many cases channelization was accompanied with the installation of drain tiles within the farm fields to better facilitate water movement off of the field. Through channelization and installation of drain tiles, farmers attempted to protect their crops by lowering the groundwater table and increasing the capacity to convey water downstream. In order to facilitate drainage, many channelized reaches were often dredged much deeper and wider than the pre-existing stream channel to increase the conveyance and storage capacity, which tends to produce areas that are characterized by slow moving, stagnant waterways. Many channelized reaches became long straight pools or areas of sediment deposition. Because the velocities within these reaches are too low to carry suspended materials, sediment particles settle out and accumulate. This is why many channelized reaches contain uniformly deep, unconsolidated, organic sediments. Channelization can also lead to instream hydraulic changes that can decrease or interfere with the connection between the channel and overbank areas during floods. This may result in reduced filtering of nonpoint source pollutants by riparian area vegetation and soils, as well as increased erosion of the banks. Channelization can lead to increased water temperature, due to the loss of riparian vegetation, and it can alter instream sedimentation rates and paths of sediment erosion, transport, and deposition. For example, the most heavily channelized sections of stream assessed in this study contained some of the greatest amounts of unconsolidated sediment deposition, particularly Meadowbrook Creek and Pewaukee-5 reaches. In addition to the loss of stream length, channel straightening causes a major decrease in the number of pool and riffle structures within the stream system. Pool-riffle sequences are often found in meandering streams, where pools occur at meander bends and riffles at crossover stretches.[14] Therefore, channelization activities, as traditionally accomplished without mitigating features, generally lead to a diminished suitability of instream and riparian habitat for fish and wildlife.

A comparison of aerial photographs from 1941 to 2010 indicates that nearly one stream-mile has been lost in the mainstem reaches of the Pewaukee River, but much more has been lost in the tributaries, including Coco Creek, Meadowbrook Creek, and Zion Creek (see Table 13 and Map 21). The actual distance of stream channel lost from the pre-settlement period is likely significantly greater, but because of a lack of aerial photography data prior to 1941, it is unknown where the original stream channel was located. Examination of the 1941 aerial photographs indicates that large sections of the streams within the watershed had already been straightened to facilitate the intense agricultural use of the land. Most of the remaining channelization that occurred after 1941 was to accommodate the construction of highways and local roads. This is particularly the case for reaches Pewaukee-1, where sections of the stream were channelized to accommodate the construction of IH 94 (see Inset 1 to Map 21), and Pewaukee-4, where the stream was straightened during construction of STH 16 (see Inset 2 to Map 21). Stretches of Coco Creek were also channelized during construction of STH 16, as well as for the expansion of local roadways (see Inset 3 and Inset 4 to Map 21). The Pewaukee-2 reach showed relatively little change over time, with any difference in this reach related to the natural meandering of the stream system. The Pewaukee-3 reach also showed little change from 1941 to 2010. However, it can be assumed that the stream had been channelized prior to 1941 to facilitate the development of the downtown area of the Village of Pewaukee. The Pewaukee-5 reach is the headwaters of the Pewaukee River and is intermittent throughout the year. A large portion of Pewaukee-5 was channelized before 1941 to allow for more efficient drainage of farm fields. Meadowbrook Creek was also channelized prior to 1941, most likely to allow for the draining of fields for cultivation. Later aerial photographs indicate that a series of inline ponds on Meadowbrook Creek were constructed sometime between 1963 and 1970. These ponds are still present today.

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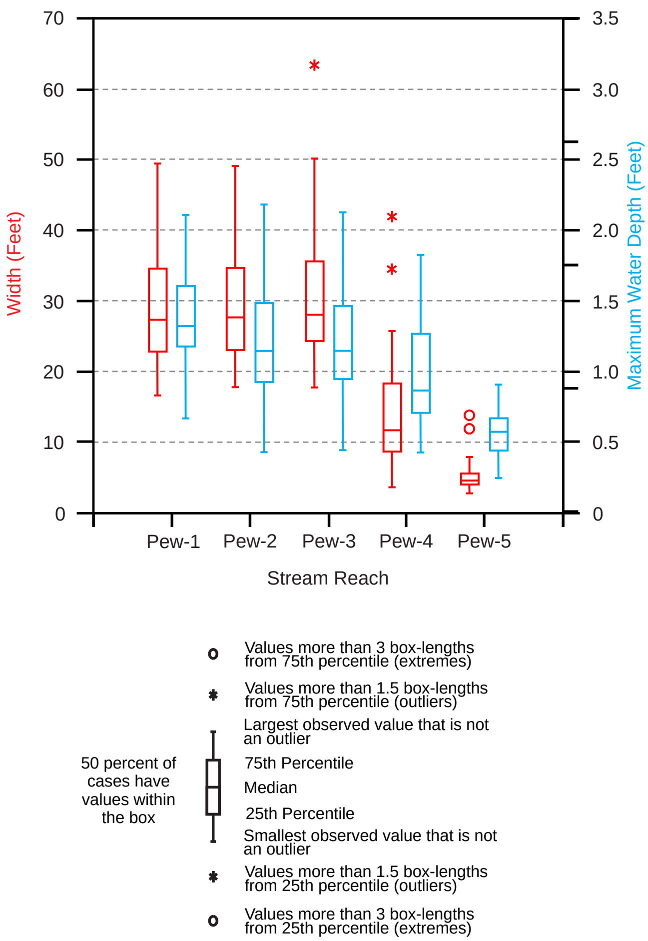
[13]*Personal Communication, Gene Nimmer, NRCS engineer.*

[14]*N.D. Gordon, et al.*, Stream Hydrology, *John Wiley and Sons, April 1993, page 318.*

Figure 35

STREAM WIDTH AND MEAN DEPTH AMONG REACHES IN THE PEWAUKEE RIVER WATERSHED: 2012



Source: SEWRPC.

Stream Reach Dynamics

There is a general increase in mean stream width and water depth among reaches in the Pewaukee River from upstream to downstream from Pewaukee-5 to Pewaukee-1 as shown in Figure 35. This figure shows increases in average width from less than 10 feet in the Pewaukee-5 reach to 15 feet in the Pewaukee-4 reach and to about 30 feet in the most downstream Pewaukee-3 through Pewaukee-1 reaches. It also shows that depths increase from about 0.5 foot to more than 2.0 feet. The abrupt increase or doubling in both width and depth starting at Pewaukee-3 is caused by the inflow from the Pewaukee Lake Outlet, which enters at the upstream end of this reach.

Although there is general pattern of increasing width and depth from upstream to downstream, there are some important disruptions in this pattern primarily due to several road crossings that have important implications for changes in water depth, unconsolidated sediment depth and substrate types as shown in Figure 34. Sand substrates do not dominate within the headwater reaches Pewaukee-4 or -5. Pewaukee-5 is dominated by gravel, cobble, and boulder substrates and flows over an outcropping of bedrock. Pewaukee-4 is dominated by claypan in the upper portion and peat in the lower portion of this reach and both these areas contain a significant amount of silt and unconsolidated sediments. It seems that there is a significant backwater effect at both Cecilia Drive and Capitol Drive, creating greater water and unconsolidated sediment depths upstream of each of these structures as shown in Figure 34. In contrast, it seems that there are substantial amounts of sand substrates entering the Pewaukee River from the Pewaukee Lake Outlet, which is likely the cause for sand substrates comprising a large portion of the Pewaukee-3 reach along with gravel and cobble substrates. However, STH 16 seems to be causing a backwater effect upstream of this structure, which is associated with the greatest amount of unconsolidated sediment deposition within this reach. Pewaukee-2 can best be described as a low gradient-wetland complex, so it is not surprising that this reach is dominated by organic silt, peat, and the deepest unconsolidated sediments within the entire river system. In contrast to Pewaukee-2, Pewaukee-1 is dominated by the largest substrates on the river system, including gravel, cobble, and boulder, with some sand substrates. Not surprisingly, average and maximum depths of unconsolidated sediment, which were loose sediments that SEWRPC staff could easily push a survey rod through, were closely associated with the presence of organic silt and peat substrates as shown in Table 14 and in Figure 34. Organic substrates are easily erodible, which is why the deepest areas within the Pewaukee River are comprised mostly of organic sediments.

The Pewaukee Lake Outlet is the most significant tributary to the Pewaukee River, which generally accounts for about 75 percent of the baseflow discharge of the Pewaukee River system. The Outlet is relatively short, so discharges only travel less than 500 feet before they merge into the Pewaukee River. As detailed in Chapter II of this report, the Pewaukee Lake dam outfall was reconstructed in the fall of 2010 to include a bottom

Figure 36

PEWAUKEE LAKE OUTLET CHANNEL CONDITIONS: 2012

UPPER PORTION

LOWER PORTION (AGGRADING CHANNEL)

Source: SEWRPC.

draw gate, which draws water from about four feet below the water surface of Pewaukee Lake. The eastern shoreline of Pewaukee Lake contains significant amounts of sand, which is the likely source of the sand in the Pewaukee Lake Outlet and reach Pewaukee-3. The streambed and streambanks are well armored with a mixture of gravel, cobble, and small boulders for the first approximately 200 feet downstream of the dam as shown in Figure 36. Although this upper 200 foot section is stable, it contains relatively limited water depths and habitat for fish and aquatic organisms. After about 200 feet, the channel width dramatically increases from about 30 feet to more than 120 feet wide for the remaining 300-foot length of the outlet channel to the confluence with the Pewaukee River. So, the Pewaukee Lake Outlet essentially loses the characteristics of a stream and becomes more like an impounded pond within the lower portion of this reach. This increase in width causes the water velocities to decrease significantly, which forces sediments to deposit in this area, because there is not enough energy to transport sediment downstream. Hence, this entire lower section has become aggraded. Aggradation involves the raising of the streambed elevation, an increase in width/depth ratio, and a corresponding reduction in both size and transport rate of bedload (i.e., sand depositing in the channel). Over-bank flows occur more frequently during less-than-high-water events, because there is a constriction of the stream channel at Oakton Bridge just downstream of this area. This situation is resulting in excess sand deposition in this aggrading section of the River. It is important to note that the Pewaukee River Partnership is aware of this problem and has been actively trying to reconstruct a more appropriately sized channel in this area using brush bundles, which can be seen in Figure 36, but this treatment has not been effective to date. The cause of aggradation is an increase in upstream sediment load from the Lake and the sediment size exceeds the transport capacity of the channel. Hence, the aggradation is a result of instability caused by over-widening of the channel with a resultant decrease in stream power and shear stress,

The sediment supply can have negative adverse effects on the biological community as well as other recreational uses in this area, but this largely depends on the corresponding adjustments of the channel to the increased load. An example of the aggradation occurring in this reach is shown in Figure 36. The obvious decline of fish habitat, elevated stream temperatures, and loss of biological function in this aggrading environment are negative consequences associated with this area and are a cause for concern in the Pewaukee River. Continued aggradation could lead to channel avulsion (complete abandonment and initiation of a new channel) and continued transport of sand loads into the Pewaukee River. Although sand is a natural substrate within the Pewaukee River, too much sand load can lead to smothering of the gravel, cobble, and boulder substrates that would degrade the fishery and aquatic life within this system.

Habitat Quality

The amount, quality, and diversity of available instream fisheries habitat range from fair to excellent within the Pewaukee River watershed based upon results of the QHEI that incorporates all of the dimensions described below and shown in Table 14. The Pewaukee-1, 2, 4, and 5 reaches contained the highest quality habitat with QHEI scores that ranged from fair to excellent. The Pewaukee-3 reach and Pewaukee Lake Outlet QHEI scores ranged from fair to good, mostly due to the combination of channelization and limited riparian buffers within a highly urban area. Although only the lower portion, or about one mile, was assessed for Meadowbrook Creek, Coco Creek, and the CTH JJ Tributary systems, these reaches had QHEI scores that were poor-fair, fair-good, and fair-excellent, respectively. It is important to note that the lowest habitat scores in all cases were associated with the modified sections of streams that were highly channelized. Although the streams continue to recover from past channelization, it is clear that the channelized segments continue to limit habitat quality and will not likely recover on their own without more intensive intervention.

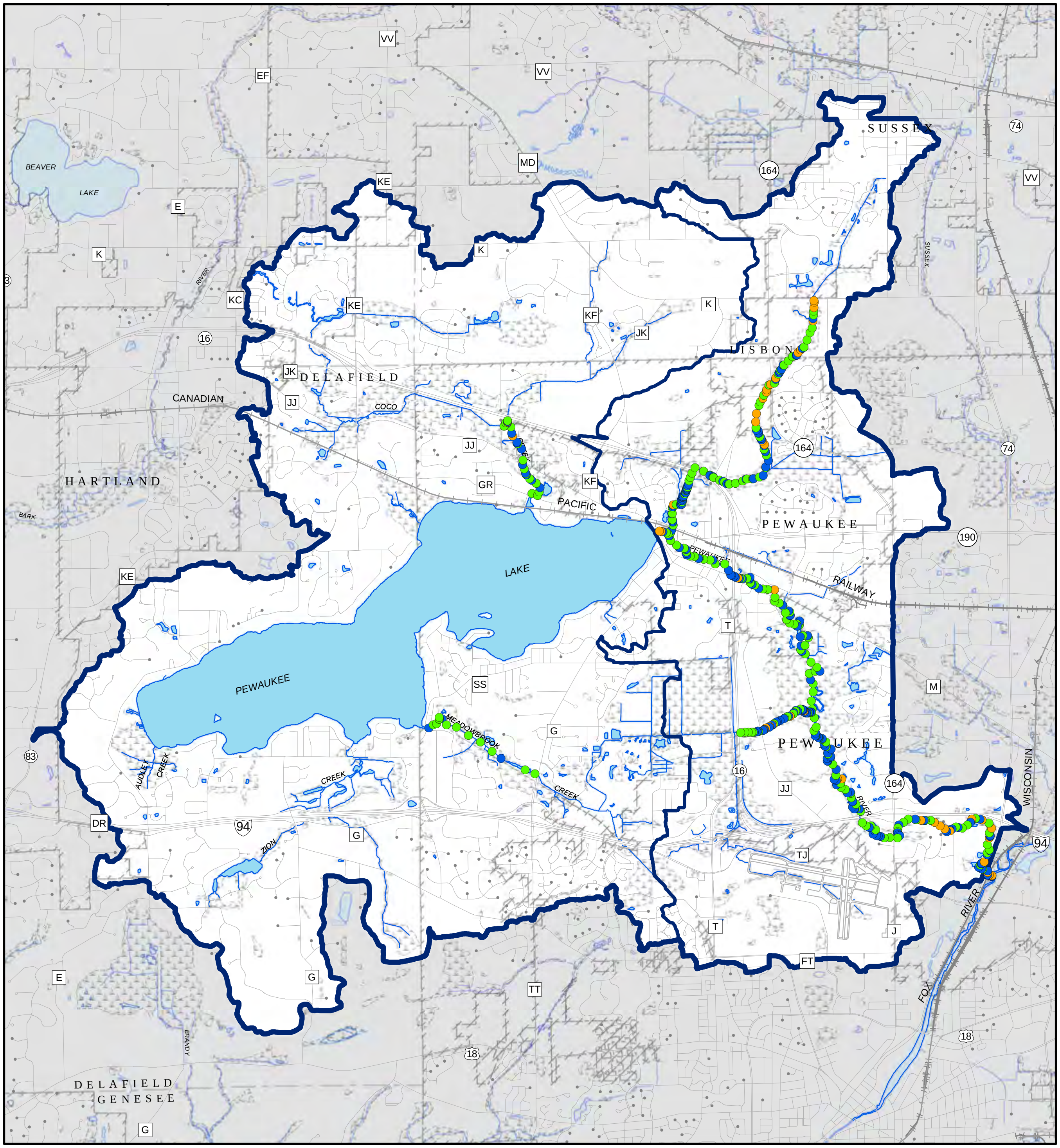
The overall distribution of instream habitat types as characterized by pools (deep water and slower water velocities), riffles (shallow water, large substrates, and higher water velocities), and runs (intermediate depth and water velocities) are shown on Map 22. Pool, riffle, and run habitat units are the fundamental instream features upon which the entire QHEI is based to determine overall habitat quality within the Pewaukee River watershed. The quality of habitat scores within the QHEI is predicated upon the presence and distribution of these discrete habitat types and their associated cover types, such as woody debris, undercut banks, boulders, and other substrates, submergent and emergent macrophyte vegetation, and overhanging riparian vegetation. As shown in Table 14 and Map 22, the diversity of the pool and riffle structure (i.e., number of pools compared to the number of riffles) is very poor in the middle reaches (Pewaukee-2,-3, and -4) of the Pewaukee River. In fact, only two riffles were found in each of the Pewaukee-2 and -3 reaches. Thus, riffle habitat availability is limited within these reaches. In contrast, the pool and riffle distribution is more balanced in the upstream Pewaukee-5 and downstream Pewaukee-1 reaches of the watershed.

In addition, several high-quality riffles were observed in the CTH JJ Tributary. Although this tributary does not provide as much flow to the Pewaukee River as does the Pewaukee Lake Outlet, it is a perennial tributary that was observed to be flowing throughout the drought of 2012. The mean width for this tributary was 8.3 feet; mean depths ranged from about 0.5 foot to more than 2.0 feet for the lower portion of this system to the confluence with the Pewaukee River. Figure 37 shows the relationship between water depth, sediment depth, and dominant substrate changes that show major changes or shifts in one or more of these physical characteristics due to past stream channelization in the upper portion of this reach where unconsolidated sediments accumulate. However, the lower section of this reach, downstream of the CTH JJ road crossing, contains a high proportion of gravel and cobble and in some cases boulder substrates, which were associated with the highest QHEI scores.

The general lack of riffle habitats within the middle reaches of the Pewaukee River is due to these areas being dominated by organic peat and silt substrates and deep pool and run habitats. Since riffle habitats are important spawning and feeding areas for many native fish species, the numbers and distribution of riffle habitats can affect fish species distribution. Therefore, maintaining access to the existing riffle habitats throughout the Pewaukee River system will be the key to protecting and enhancing the native fishery. For example, although the Pewaukee-2 reach has limited riffle habitats, it is connected to the CTH JJ Tributary that contains several riffle habitats. So, maintaining connections between the mainstem of the Pewaukee River and tributaries and access to key habitats is the key to protecting and maintaining a more diverse fishery.

Map 22

AQUATIC HABITAT TYPES SURVEYED WITHIN THE PEWAUKEE RIVER WATERSHED: 2012



POOL

RIFFLE

RUN

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

N

0 0.5 1 Miles

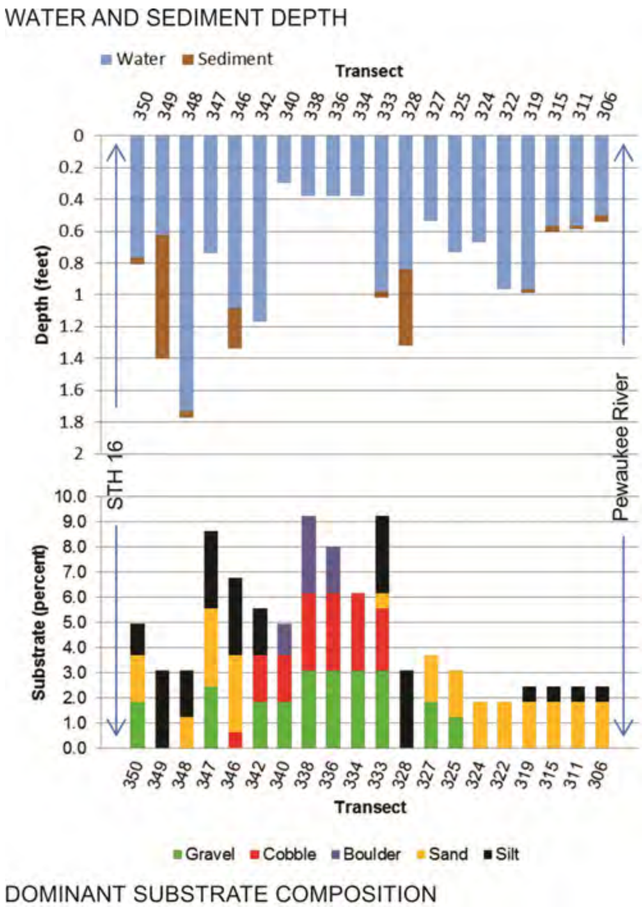
0 2,500 5,000 Feet

Source: SEWRPC.

NOTE: See Maps F-1 through F-8 and Table F-1 through F-3 for more details on instream habitat.

Figure 37

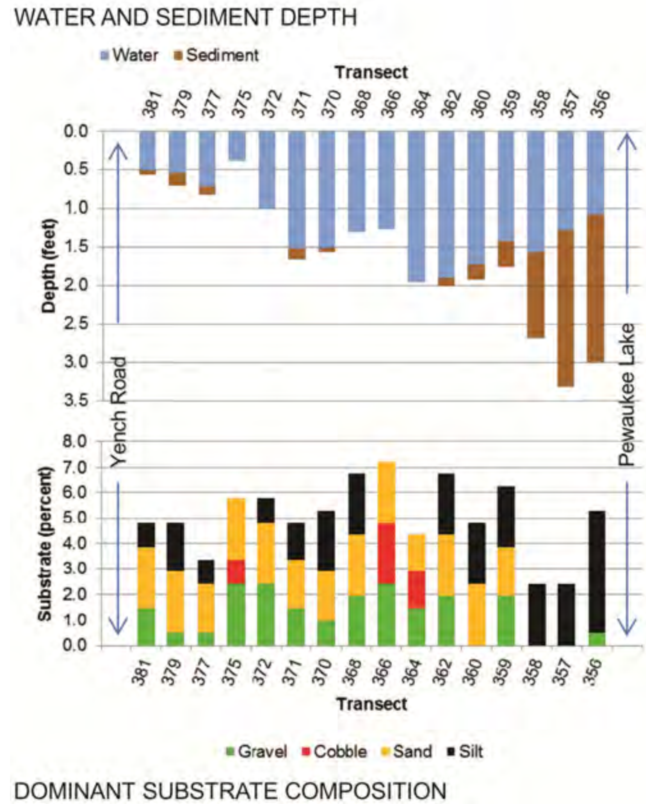
MEAN WATER DEPTH, UNCONSOLIDATED SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION WITHIN THE HWY JJ TRIBUTARY: 2012



Source: SEWRPC.

Figure 38

MEAN WATER DEPTH, UNCONSOLIDATED SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION WITHIN THE LOWER REACH OF COCO CREEK: 2012

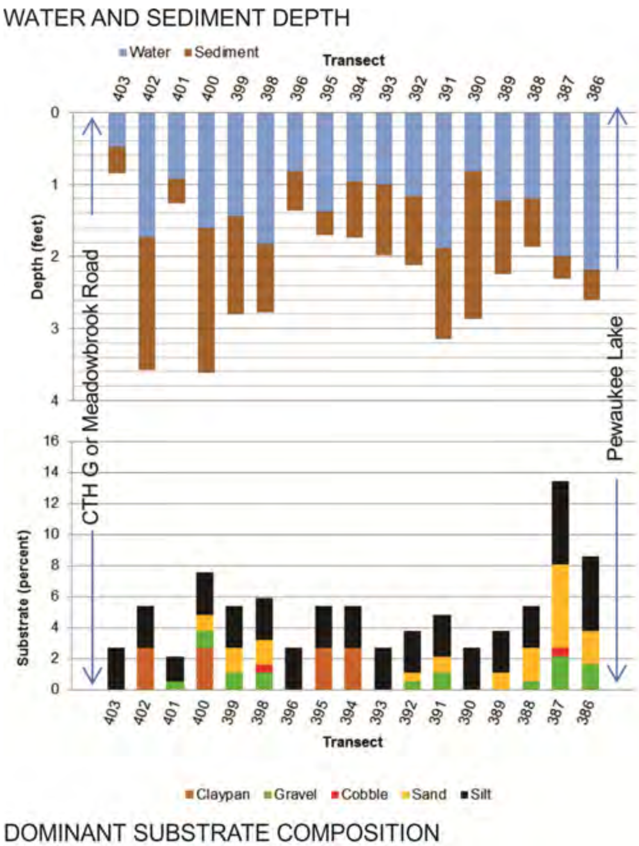


Source: SEWRPC.

In terms of the tributaries to Pewaukee Lake, no riffles were present in Meadowbrook Creek and only two were observed in Coco Creek. However, it is possible that there are riffle habitats further upstream of both Coco Creek and Meadowbrook Creek. The lower reaches of both of these tributaries have mean water depths that range from about one to two feet and have a good connection to Pewaukee Lake. However, while Coco Creek has an average width of 10.1 feet and is dominated by sand and gravel substrates (see Figure 38), Meadowbrook Creek is nearly twice as wide, with an average width of 24.5 feet, and is dominated by silt substrates (see Figure 39). Although both of these tributaries have been heavily channelized since long before 1941, Coco Creek exhibits a much better relationship between width and depth and overall habitat quality than Meadowbrook Creek, despite also having a subwatershed that is more than double the size of Meadowbrook Creek's subwatershed. Figure 39 shows that the unconsolidated sediment depths within this portion of the system range from about one to two feet over harder substrates, such as claypan or sand and gravel. These excessively wide and deep features associated with the lower portion of Meadowbrook Creek are likely the result of overly aggressive channel deepening and widening during the time of channelization. Therefore, despite the chance to recover from the effects of channelization for at least the past 72 years, Meadowbrook Creek continues to remain highly impaired. This is strong evidence that

Figure 39

MEAN WATER DEPTH, UNCONSOLIDATED SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION WITHIN THE LOWER REACH OF MEADOWBROOK CREEK: 2012



Source: SEWRPC.

Meadowbrook Creek will never recover from the effects of the channelization without intervention, which is not that uncommon in low gradient stream systems. In other words, it took heavy excavation equipment to channelize Meadowbrook Creek, so it will also require excavation equipment to recreate a more natural meandering stream with appropriate width and depth and pool and riffle habitats.

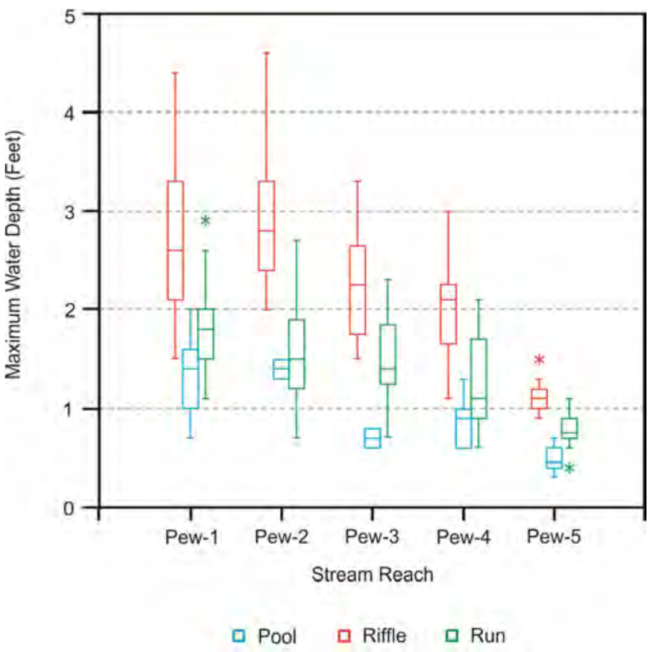
The maximum depths of pool, riffle, and run habitats also change from headwater areas to the confluence of the Fox River as shown in Figure 40. These differences indicate that although nominally the same types of habitat areas, the pools, riffles, and runs in the upper portions of the watershed effectively form smaller habitat areas than the corresponding habitat areas in the lower reaches of the watershed. These differences can affect and determine the biological community type, abundance, and distribution present within distinct hydrologic reaches, which, in effect, can result in significant differences in species composition within each of the reaches. The upstream reaches naturally contain a lower abundance and diversity of fishes compared to the downstream reaches, because these reaches contain less water volume. However, it is also important to note that these upstream areas provide vital spawning habitats for the sustained quality and productivity of the entire fishery within the Pewaukee River watershed.

Pool habitats are the opposite of riffle habitats, but they are also important components of fish habitat in streams, especially for larger fish, because their greater depth offers protection from predators, provides feeding areas, and provides refuge from high temperatures in the summer and cold temperatures in the winter. As shown in Figure 40, pool habitats are deepest within the two lowest Pewaukee-1 and -2 reaches, with more than 25 percent of the pools in these areas greater than three feet deep. The remaining three reaches contain pool depths that in general are much less than three feet in depth. Pools are often monitored to follow the effects of enhancement projects and natural stream processes, but variations of water depth with discharge can complicate assessment of changes in the depth and volume of pools. To subtract the effect of discharge on depth of pools, residual depth can be measured. Residual depth is the difference in water depth or bed elevation between a pool and the downstream water depth or bed elevation of the riffle crest (upstream edge of the riffle).[15] This residual dimension represents extreme low-flow conditions, which often determine the capacity of streams to produce fish, especially during summer months when water temperatures are highest.

[15]*Thomas E. Lisle, Using "residual depths" to monitor pool depths independently of discharge, Research Note PSW-394, Berkeley California, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, December 1987.*

Figure 40

MAXIMUM WATER DEPTH AMONG HABITAT TYPES AND REACHES IN THE PEWAUKEE RIVER WATERSHED: 2012

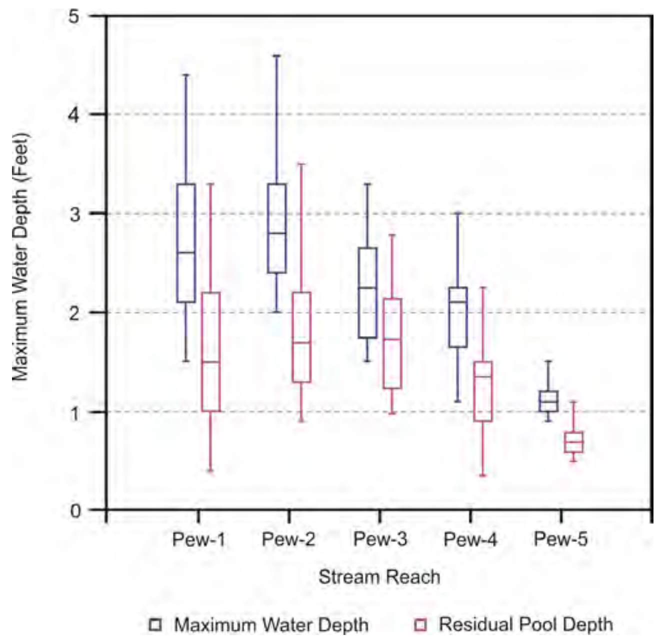


NOTE: See Figure 35 for description of symbols.

Source: SEWRPC.

Figure 41

RESIDUAL POOL DEPTH AMONG REACHES IN THE PEWAUKEE RIVER WATERSHED: 2012



NOTE: See Figure 35 for description of symbols.

Source: SEWRPC.

Residual pool depth was calculated by reaches in the Pewaukee River by subtracting the average water depths of all riffles within a reach from the maximum pool depth recorded within each individual pool. As shown in Figure 41, residual pool depths were highest within the Pewaukee-1 through 3 reaches, with more than 25 percent of the residual pool depths greater than 2.0 feet. A small percentage of residual pools within Pewaukee-1 and 2 even exceed 3.0 feet, indicating fish communities have access to a greater number and distribution of deep-water areas during low-flow conditions compared to the other reaches in Pewaukee River. These lower reaches also have the added benefit of being connected with the Fox River, which provides a potential avenue of protection if water levels get too low or stream temperatures get too high within these areas of the Pewaukee River. This connection also promotes maintenance of fish species abundance and diversity by providing access to many miles of additional habitats and large populations of diverse fish species to reproduce in and/or recolonize the Pewaukee River, as well as to provide genetic diversity through access to larger population sizes. In contrast, the Pewaukee-4 and 5 reaches contain the lowest residual pool depths compared to all other areas inventoried within the watershed (see Figure 41). This indicates that this section of stream would in general not contain many areas with depths greater than one foot and in most cases much less than one foot under low-flow conditions.

In addition to water width and depth, which are major determinants of pool, riffle, and run habitat quality scores as discussed above, the QHEI scores can be further enhanced by the presence of one or more of the following features: 1) fallen trees or branches (woody debris), 2) undercut banks, 3) boulders and other substrates, 4) submergent and emergent macrophyte vegetation, and 5) overhanging riparian vegetation, as shown in Figure 42. In general, the Pewaukee River was comprised of 4 to 50 percent low abundance of cover, 37 to 76 percent moderate abundance of cover, and 8 to 30 percent high abundance of cover types as shown in Table 14.

Figure 42

EXAMPLES OF INSTREAM COVER WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

Source: SEWRPC.

Boulders are considered to be one of the highest quality substrates in terms of providing good cover for fishes. However, all substrate types and their composition are important and contribute to overall habitat quality. Table 14 and Figure 34 show that there is a high diversity of substrates among reaches within the Pewaukee River watershed from smaller organic silt and peat, to sand and gravel, to larger cobbles and boulders. For more detail on substrate diversity, refer to the Stream Reach Dynamics subsection above.

The type and amounts of riparian vegetation are significant drivers of the types and amounts of instream cover which include woody debris, overhanging vegetation, shading, algae, and macrophytes. Instream large and small woody debris is an important component of stream ecosystems that provides essential food and habitat for aquatic organisms. Woody debris can affect channel morphology and form pools; retain organic matter, gravel, and sediment; influence invertebrate abundance; and provide cover and velocity refuge for fish.[16] Woody debris is

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[16]*B. Mossop and M.J. Bradford, Importance of large woody debris for juvenile Chinook salmon habitat in small boreal forest streams in the upper Yukon River basin, Canada,* Canadian Journal of Forestry Resources, *Volume 35, 2004, pages 1955-1966.*

very prevalent throughout the entire Pewaukee River system (see Map 23), which contained concentrations that ranged from 25 to 80 percent of moderate to high abundance of woody debris (see Table 14). Excessive woody debris can sometimes accumulate in some areas, causing debris jams that can function like a dam that may cause significant disruption in the stream sediment dynamics and can lead to localized flooding and bank stability problems. Given the overall high amount of wood within the river network, it is not surprising that there were a total of 48 debris jams were observed in every reach, except for Pewaukee-3. The highest amount of debris jams were observed in the CTH JJ Tributary and Pewaukee-5 reaches. The most significant or problem debris jams associated with streambank erosion were observed in multiple locations among the CTH JJ Tributary and Pewaukee-1, 2, and 5 reaches. Debris jams, particularly at road crossings, may inhibit fish movement to feeding and spawning areas, which was often observed at Structures 2 at CTH F and 4 at Busse Road (see Table F-1), which can lead to decreased reproductive success (see Stream Crossings and Dams section below). Therefore, it is important to periodically monitor these woody debris accumulations and either partially or completely remove them, as well as address any streambank erosion issues, where appropriate.

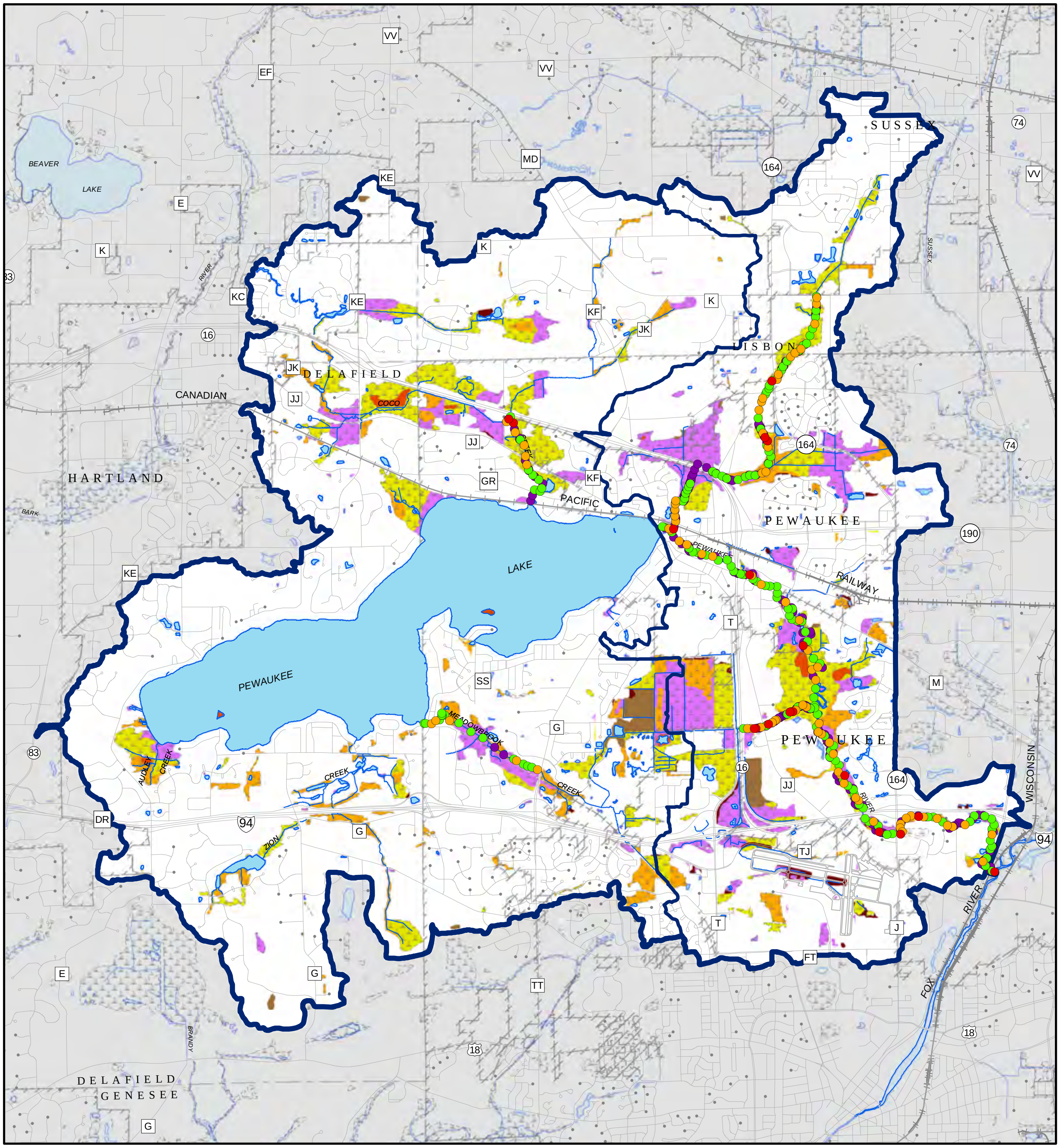
The high proportions of wooded riparian areas in most of the reaches throughout the watershed result in a high amount of shading. These shaded stream reaches have low percentages of algae and macrophytes, except for Pewaukee-4 and Meadowbrook Creek. In addition, the open canopy near the downtown Village of Pewaukee area at the upper portion of the Pewaukee-3 reach can develop excessive aquatic plant growth problems as shown in Figure 43.

Riparian zone and floodplain quality is another important dimension included within the QHEI scoring criteria to assess instream habitat quality. More specifically, greater extent or width of riparian (stream side) vegetation is associated with a greater quality and higher score for this feature. Riparian buffers greater than 50 meters (approximately 164 feet) from each streambank are necessary to obtain the highest scores for this dimension of the index. Riparian buffers are discussed more thoroughly in the Riparian Corridor Conditions section below, but, in general, riparian buffer width and floodplain quality range from poor to excellent within the Pewaukee River system. For example, the riparian buffer areas within the watershed have been significantly impacted particularly within the Pewaukee-1, Pewaukee-3, and lower portions of the Pewaukee-4 reaches, which is the primary reason that the cross sections within these areas contain the lowest QHEI scores within the entire Pewaukee River system. In contrast, the most extensive and highest quality floodplain area is within the Pewaukee-2 reach. Such areas allow high discharge events to dissipate across the landscape providing protection from flooding (while at the same time reducing) water velocities which protects the streambed and streambanks from erosion.

Although undercut banks are related to streambank stability, these are also areas of overhead protection for fishes and are ranked as an important habitat quality feature. The energy of flowing water in a stream is dissipated along the stream length by frictional resistance of the bed and banks, meanders, turbulence, streambank and bed erosion, and sediment resuspension. In general, increased urbanization may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour. Streambank erosion destroys aquatic habitat, spawning, and feeding areas; contributes to downstream water quality degradation by releasing sediments to the water; and provides material for subsequent sedimentation downstream, which, in turn, covers valuable benthic habitats, impedes navigation, and fills wetlands. These effects may potentially be mitigated by sound land use planning combined with proper stormwater management practices. Results indicate that undercut banks and streambank erosion are occurring in several areas, particularly the Pewaukee-3 and Pewaukee-1 reaches. The majority of undercut banks observed generally ranged from 0.5 to 1.0 foot in depth, but several sites within the Pewaukee-1 reach exceeded 1.0 foot in depth. The greatest percent of undercut banks and the deepest undercuts were located within the Pewuakee-1 reach, which contains the greatest slope and highest energy to scour undercut banks. It is also important to note that the majority of the upper portion of the Pewaukee-3 reach within the urbanized areas is largely protected or armored with stone or cement or bricks. This seems to indicate streambank erosion has been and continues to be an issue within this reach and that private residents, businesses, and local municipalities have addressed it in one way or another. For example, the Pewaukee River Partnership has been actively improving the downtown Village of Pewaukee area from the Pewaukee Lake Outlet

Map 23

QUALITATIVE DISTRIBUTION OF WOODY DEBRIS WITHIN STREAMS SURVEYED IN THE PEWAUKEE RIVER WATERSHED: 2012



NONE (0 PERCENT)

LOW (LESS THAN 25 PERCENT)

MODERATE (25 PERCENT TO 75 PERCENT)

HIGH (GREATER THAN 75 PERCENT)

EMERGENT WET MEADOW

FILLED/DRAINED WETLAND

FLATS/UNVEGETATED WET SOIL

FORESTED WETLAND

SCRUB/SHRUB

UPLAND

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

Figure 43

EXAMPLE OF EXCESSIVE AQUATIC PLANT GROWTH WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

Source: SEWRPC.

and River to Clark Street by armoring the streambanks with stone, debrushing shorelines of nuisance plants, and installing brush bundles, since the 1990s (see Figure 44). However, there is evidence of failing retaining walls, particularly just north and south of Oakton Bridge as shown in Figure 45.

Trash and Tires

Although the accumulation of trash and debris is not part of the QHEI scores as summarized above, these materials degrade the aesthetics of the river system and can cause physical and/or chemical (i.e., toxic) damage to aquatic and terrestrial wildlife. Therefore, Commission staff recorded and mapped the significant trash and debris that was encountered during the comprehensive survey conducted in the spring of 2012 as shown on Map 24 (with specific details in Appendix E, Maps E-9 through E-16 and Table E-4). The majority of trash was observed within the Pewaukee River, the CTH JJ tributary, and some portions of Coco Creek and Meadowbrook Creek. Nearly 30 automobile tires were found in the Pewaukee River, which made up the largest portion of trash found among the areas surveyed (see Map 24). Other types of trash included old wash machine parts, clothes, grocery bags, plastic bottles, and various construction materials.

Figure 44

STREAMBANK STABILIZATION PROJECT NORTH OF OAKTON BRIDGE: 1990

BEFORE PROJECT

POST PROJECT

Source: Charlie Shong, Pewaukee River Partnership.

Stream Crossings and Dams

Bridges and culverts can affect stream widths, water and sediment depths, velocities, and substrates. These structures also have the potential to pose physical and/or hydrologic barriers to fisheries and other aquatic organisms. Therefore, SEWRPC staff conducted an inventory of 50 structures throughout the Pewaukee River watershed, as summarized in Appendix F, that includes a description and photograph (see Figure F-1), location map (see Map F-1), condition, as well as a fish passage and navigation hazard rating (see Table F-1). Based upon this assessment conducted in 2012, the majority of the structures were identified to be passable, but 16 structures were considered partial barriers and two were complete barriers to passage. Several of these structures that have fish passage issues were also considered navigation hazards, which is addressed in the Recreational Conditions section below.

Eight of the structures rated as partial barriers and one complete barrier were located within the Pewaukee River that included the following structure numbers and associated River Miles (RM): 2 (RM 0.11), 8 (RM 5.83), 11 (RM 6.68), 14 (RM 7.54), 18 (RM 8.62), 20 (RM 8.74), 21 (RM 8.91), 25 (RM 9.59), and 27 (RM 9.79). Structure Number 18 is a drop structure that is acting like a dam at RM 8.62 and is a complete barrier to fish

Figure 45

STREAMBANK CONDITIONS DOWNSTREAM AND UPSTREAM OF OAKTON BRIDGE: 2012

DOWNSTREAM

EAST BANK (LOOKING DOWNSTREAM)

WEST BANK (LOOKING DOWNSTREAM)

UPSTREAM

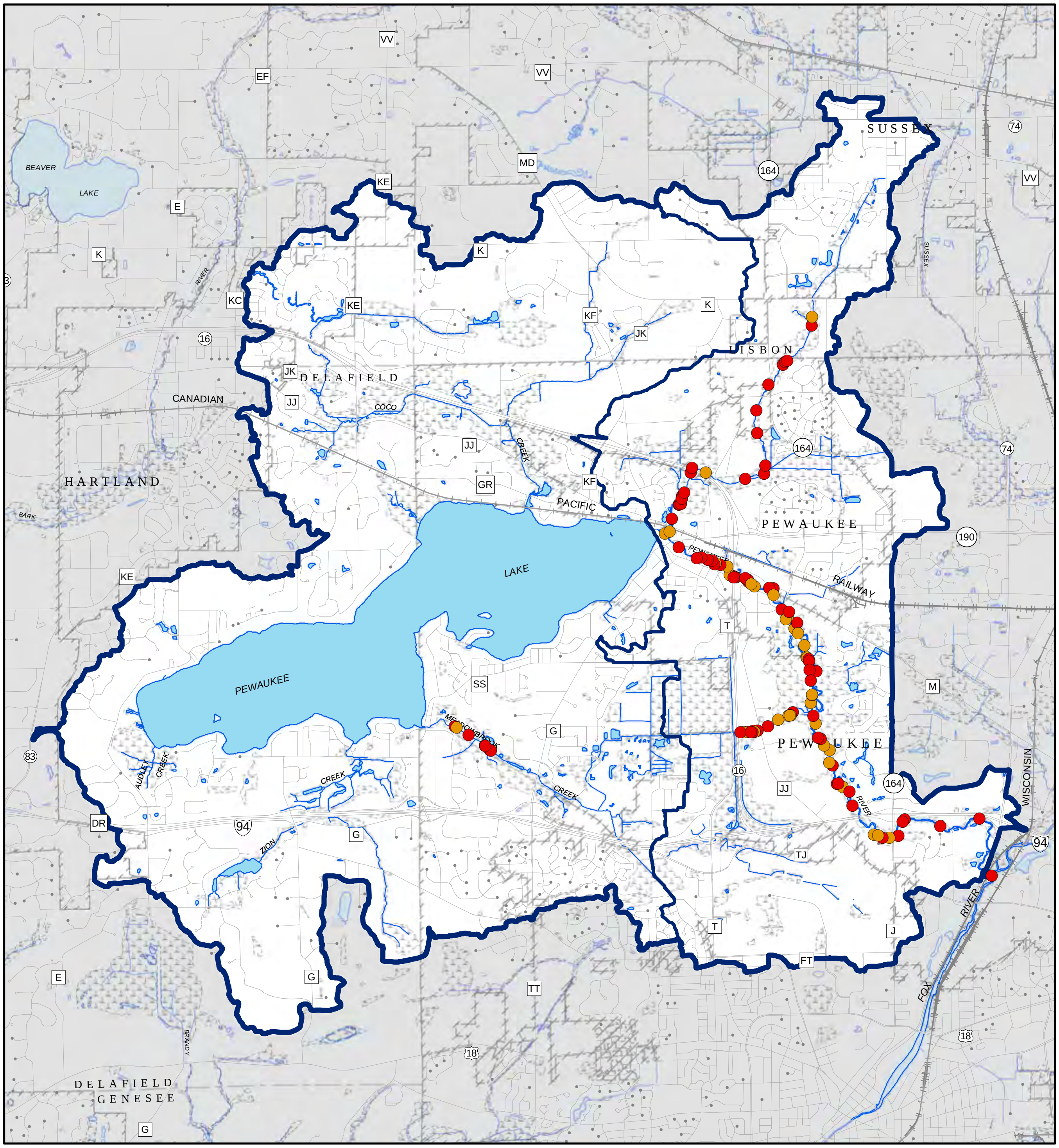
WEST BANK (LOOKING WEST)

WEST BANK (LOOKING WEST)

Source: SEWRPC.

Map 24

TIRES AND OTHER TRASH OBSERVED WITHIN THE PEWAUKEE RIVER WATERSHED: 2012



LOCATION OF TIRES IN STREAM

LOCATION OF OTHER TRASH IN STREAM

NOTE: See Appendix Map F-9 through Map F-16 for a more detailed look at trash, debris jams, beaver dams, and streambank erosion in each stream reach surveyed

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

passage. Structure numbers 8, 20, 21, 25, and 27 are only considered to be limiting fish passage under low-flow conditions, due to inadequate water depths. Although structures 8 and 11 are bridges and are well elevated above the Pewaukee River, the limited depths at these structures are due to a high amount of large stone that was placed on the streambed and streambanks underneath these bridges. This stone is causing a significant backwater effect under low-flow conditions that creates ponding and sediment deposition upstream of these structures (see Figure 34). Although the stone obstructions are certainly acting like dams, the water depths at these structures are likely only limiting fish passage during low-flow periods, so they were only considered partial barriers to fish passage. Hence, these crossings illustrate why it is important to be vigilant in the design construction and/or reconstruction of roadways, which can have unintended consequences to aquatic communities. This also is a good example of why it is important to continue to monitor all road crossings periodically in order to ensure that they have not accumulated debris and become barriers to fish and other aquatic organisms. In contrast, the most downstream structure, number 2, is limiting to passage due to high water velocities combined with the length of the culvert, which makes this structure difficult for passage during higher water discharge events.

Except for the one complete barrier on the Pewaukee Lake Outlet—the dam impounding Pewaukee Lake—the remaining structures in the other areas of the Pewaukee River watershed were considered partial barriers to fish passage under low-flow conditions. One partial barrier was located on the CTH JJ Tributary at structure number 29 (RM 0.53). Two partial barriers were identified on the Coco Creek at structure numbers 36 (RM 0.81) and 39 (RM 3.20). Two partial barriers also were located on the tributary to Coco Creek at structure numbers 41 (RM 0.04) and 42 (RM 1.34). Three partial barriers were observed on Meadowbrook Creek at structure numbers 44a (RM 1.45), 44b (RM 1.64), and 46 (RM 2.35). The descriptions and recommended actions for each of these structures are listed in Table F-1.

Because of the number of culverts within the Pewaukee River watershed, their combined impact on fish communities could potentially be significant.[17] Culverts tend to have a destabilizing influence on stream morphology that can create selective barriers to fish migration because swimming abilities vary substantially among species and size-classes of fish, affecting their ability to traverse the altered hydrologic regime within the culverts.[18] Fish of all ages require freedom of movement to fulfill needs for feeding, growth, and spawning. Such needs generally cannot be found in only one particular area of a stream system. These movements may be upstream or downstream and occur over an extended period of time, especially in regard to feeding. In addition, before winter freeze-up, fish tend to move downstream to deeper pools for overwintering. Fry and juvenile fish also require access up and down the stream system while seeking rearing habitat for feeding and protection from predators. The recognition that fish populations are often adversely affected by culverts has resulted in numerous designs and guidelines that have been developed to allow for better fish passage and to help ensure a healthy sustainable fisheries community.[19]

Beaver Activity

Beavers can cut trees and alter environments to a greater extent than any other mammal except humans. Their ability to increase landscape heterogeneity by felling trees and constructing impoundments and canals goes beyond their immediate needs for food and shelter. They can dramatically alter nutrient cycles and food webs in

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[17]*Thomas M. Slawski and Timothy J. Ehlinger, "Fish Habitat Improvement in Box Culverts: Management in the Dark?"* North American Journal of Fisheries Management, *Volume 18, 1998, pages 676-685.*

[18]*Stream Enhancement Research Committee, "Stream Enhancement Guide," Province of British of Columbia and the British Columbia Ministry of Environment, Vancouver, 1980.*

[19]*B.G. Dane,* A Review and Resolution of Fish Passage Problems at Culvert Sites in British Columbia, *Canada Fisheries and Marine Sciences Technical Report 810, 1978. Chris Katopodis, "Introduction to Fishway Design," Freshwater Institute Central and Arctic Region Department of Fisheries and Oceans, January, 1992.*

aquatic and terrestrial ecosystems by modifying hydrology and selectively removing riparian trees.[20] The activities of beavers in streams provides an example of a natural alteration to ecosystem structure and dynamics. Beaver activity may result in differing degrees of alterations that: 1) modify channel geomorphology and hydrology; 2) increase retention of sediment and organic matter; 3) create and maintain wetlands; 4) modify nutrient cycling and decomposition dynamics by wetting soils, altering the hydrologic regime, and creating anaerobic zones in soils and sediments; 5) modify the riparian zone, including the species composition and growth form of plants; 6) influence the character of water and materials transported downstream; and 7) modify instream aquatic habitat, which ultimately influences community composition (e.g., fish and macroinvertebrates) and diversity.[21]

Beaver dams are not permanent structures; without constant maintenance the dams will be breached and blowouts will occur. In addition, dams are frequently abandoned when beavers move on to new areas, depending on food and habitat availability. There is no set time frame within which beavers inhabit areas and maintain dams. It has been documented that dams can be maintained over long periods of time, or used only seasonally. It is likely that, under normal conditions, beaver dams are obstructions for most fish species in terms of upstream passage. Most fish species can go downstream without problems; however, it is unknown how passable beaver dams are under high flow conditions.

Beaver dams have been shown to enhance fisheries over watershedwide scales. When beaver impound streams by building dams, they substantially alter stream hydraulics in ways that benefit many fish species.[22] Early research suggested that beaver dams might be detrimental to fish, primarily by hindering fish passage, and it has been demonstrated that beaver dams seasonally restrict movement of fishes.[23] Until recently, it was common for fish managers to remove beaver dams. However, more than 80 North American fishes have been documented in beaver ponds, including 48 species that commonly use these habitats, and the beaver ponds' overall benefit to numerous fishes has been well documented, causing managers to rethink the practice of removing beaver dams.[24] In agricultural areas, beaver dams may impound water and submerge drain tile outlets, reducing the effectiveness of the tile systems and adversely affecting crops. Therefore, for the reasons cited above, this is a complicated and controversial issue, so decisions to remove beaver dams should be addressed on a case-by-case basis.

While there was notable beaver activity in terms of beaver chew and felled trees throughout the Pewaukee River system, only two beaver dams were observed on the Pewaukee River. The first was in Reach 2, and the second was in Reach 5. Meadowbrook Creek also contained two beaver dams.

Based on these observations it is probable that beaver dams were not likely to be significantly affecting the abundance and diversity of the fishery in Pewaukee River watershed during the time of this inventory, but they do have the potential to limit fish passage, particularly by northern pike trying to migrate into upstream tributaries to

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[20]*A.M. Ray, et al., Macrophyte succession in Minnesota beaver ponds,* Canadian Journal of Botany, *Volume 79, 2001, pages 487-499.*

[21]*R.J. Naiman, J.M. Melillo, J.E. Hobbie, Ecosystem alteration of boreal forest streams by Beaver (Castor canadensis),* Ecology*, Volume 67, 1986, pages 1254-1269.*

[22]*J.W. Snodgrass, and G.K. Meffe, Influence of beavers on stream fish assemblages: effects of pond age and watershed position,* Ecology*, Volume 79, 1998, pages 926-942.*

[23]*I.J. Schlosser, Dispersal, boundary processes, and trophic-level interactions in streams adjacent to beaver ponds,* Ecology*, Volume 76, 1995, pages 908-925.*

[24]*M.M. Pollock, et al., The importance of beaver ponds to coho salmon production in the Stillaguamish River Basin, Washington, USA,* North American Journal of Fisheries Management*, Volume 24, 2004, pages 749-760.*

lay their eggs. Therefore, it is important to continue to monitor beaver activity and take action where appropriate. These efforts should be particularly focused in the following locations: along migratory routes for northern pike spawning habitat, particularly Meadowbrook Creek and Coco Creek to the confluence with Pewaukee Lake; locations where structures may become threatened with flooding; and, where navigation can become obstructed, particularly at culverts and bridges.

Summary

In summary, the Pewaukee-1, 2, 4, and 5 reaches contained the highest quality habitat, ranging from fair to excellent. The Pewaukee-3 reach and Pewaukee Lake Outlet scores ranged from fair to good, mostly due to the combination of channelization and limited riparian buffers within a highly urban area. Although only the lower portion or about one mile was assessed for Meadowbrook Creek, Coco Creek, and the CTH JJ Tributary systems, these reaches contained habitat scores that ranged from poor-fair, fair-good, and fair-excellent, respectively. However, this analysis does indicate that there have been a number of modifications to the Pewaukee River system and that there are opportunities to improve habitat quantity and quality throughout the watershed (see Instream Restoration Priorities section in Chapter VI of this report).

Channelization has been extensive throughout the Pewaukee River watershed and this is one of the major determinants of limited instream habitat and biological condition—particularly in the headwaters of the Pewaukee River, as well as Coco Creek, Meadowbrook Creek, and the CTH JJ Tributary. In all cases despite having more than 70 to 100 years to recover from channelization, these reaches have not been able to redevelop more natural or appropriate sinuosities. Therefore, it is obvious that due to the low slopes or energies within this river system, the only way to restore stream function within this system is to physically reconstruct it. Reconstructing meanders or restoring a more natural sinuosity, particularly in low-gradient systems like the Pewaukee River, is one of the most effective ways to restore instream habitat and the ability of this system to transport sediment and to function more like a healthy river system. In particular, the highest priorities or best locations to restore stream function are where the pre-existing channel lengths that were cut off during channel straightening still exist. For example, several locations on the mainstem of the Pewaukee River in reach Pewaukee-2 and some more extensive reaches within Coco Creek, as shown on Map 21 (see Insets 3 and 4), that could easily be restored to flow back into the old channel with minimal effort and cost. Even if the old stream channel has been buried or cannot be determined, there are many opportunities to rehabilitate or increase stream sinuosities and associated habitat and stream function within these channelized sections of stream.

Streambank erosion does not seem to be an excessive problem throughout the majority of the Pewaukee River system. However, streambank erosion and undercut banks are an issue, particularly within Pewaukee-3 and Pewaukee-1 reaches.

HYDROLOGIC CONDITIONS

Modeled Groundwater and Surface Water Interactions

The Pewaukee River is one of several main tributaries that comprise the surface-water network of the Upper Fox River that were recently modeled to evaluate groundwater flow patterns in the shallow aquifer system within the Upper Fox River watershed in southeastern Wisconsin.[25] This report section summarizes data and model results applicable to the Pewaukee River watershed for quantifying groundwater/surface water interactions in the shallow aquifer, and defining sources and sinks of groundwater, including recharge, boundary fluxes, interactions with surface water, and discharge to wells and quarries. For example, one of the primary objectives of the Upper Fox River Basin model was to simulate base flow to the surface water network, which included results for both Pewaukee Lake and Pewaukee River, as summarized below.

[25] *D.T. Feinstein, M.N. Fienen, J.L. Kennedy, C.A. Buchwald, and M.M. Greenwood, "Development and application of a groundwater/surface-water flow model using MODFLOW-NWT for the Upper Fox River Basin, Southeastern Wisconsin, U.S. Geological Survey Scientific Investigations Report 2012-5108, 2012, 124 pages.*

Water Sources and Withdrawals
It is important to note that there is no discharge from wastewater-treatment plants (WWTPs) anywhere within the Pewaukee River system, so the only sources of discharge to the Pewaukee Lake and Pewaukee River are solely from precipitation that runs off the land surface or that infiltrates as recharge to the water table. Although there are no quarries within the boundaries of the Pewaukee River watershed, the contributing shallow groundwater areas that discharge into the quarry adjacent to Sussex Creek do extend into headwaters of the Pewaukee River and are reducing the amount of groundwater discharge to this area of Pewaukee River.

In 2005, about 34 million gallons per day (mgd) of groundwater were withdrawn for public, domestic, industrial, commercial, and agricultural uses in Waukesha County.[26] About 25 percent of that total is pumped by private domestic wells penetrating shallow aquifers, while the remaining 75 percent is extracted from high-capacity wells penetrating the shallow and deep aquifer systems primarily for public supply and industrial purposes. A high-capacity well is defined as withdrawing on average more than 0.1 mgd. However, it was estimated that shallow aquifer pumping within the Upper Fox River model domain totaled about 6.7 mgd, where the unconsolidated material and Silurian dolomite pumped at rates of 1.62 and 5.07 mgd, respectively distributed among a total of 99 separate high-capacity wells. The greatest concentration of pumping in the model domain, which included the Pewaukee River watershed, was from the dolomite wells in the eastern portion of the study area. In particular, a total of eight high-capacity wells were located within the Pewaukee River watershed as of year 2005. One high-capacity well is pumping from an unconsolidated deposit layer; the remaining seven high-capacity wells are pumping from the Silurian dolomite layer. The model output shows the extent and location of the high-capacity pumping wells on the shallow aquifer are primarily located in the lower portions of the Pewaukee River watershed. Based upon the reported proportions of groundwater withdrawal in Waukesha County, it also is likely that private domestic wells located within the Pewaukee River watershed can account for at least 25 percent of the total local groundwater supply from the shallow aquifers.[27] However, since the majority of domestic pumping is assumed to be returned to the shallow aquifer via mound and/or septic system infiltration, this element was not included in this modeling effort (see the “Groundwater Recharge” section below for further details).

Groundwater Recharge
The most important source for groundwater in southeastern Wisconsin is natural recharge to the water table. Recharge is variable over time and space. The *temporal variation* is caused by climatic variability, or more specifically, the timing and intensity of precipitation and temperature. These variables affect the processes of runoff, infiltration, and evapotranspiration. In general, higher recharge rates are correlated to higher amounts of precipitation, but specific recharge rates can be highly variable. The variability depends on a number of additional factors, such as the antecedent soil moisture, amount of snow or timing of frozen soil conditions, intensity and duration of rainfall, and the amount of evapotranspiration as controlled by temperature. The *spatial variation* of recharge depends on the land use, soil type, and land surface topography. Thus, land use planning plays an important role in protecting recharge areas.

The Upper Fox River Basin model identified recharge rates for each of the 27 drainage subbasins within the model domain, which ranged from 1.6 inches per year to 9.5 inches per year. These rate differences are primarily due to differences in soil type and surface topography as a result of the glaciers. The resulting recharge rates for the three subbasins within the Pewaukee River watershed were identified to range between 2.6 to 3.9 inches per year, which is consistent with previous studies for this part of Waukesha County.[28] It is important to note that

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

[27]*Feinstein, et al.,* op. cit.

[28]*SEWRPC Technical Report No. 48,* Shallow Groundwater Quantity Sustainability Analysis Demonstration For The Southeastern Wisconsin Region*, November 2009.*

Pewaukee Lake was assigned a recharge of zero, because this Lake is a sink for groundwater, not a source for groundwater. These recharge rates are estimates of long-term average rates and are not associated with any given year. As described above, they can be highly variable among seasons and years.

These rates are derived from the regional model developed for Southeastern Wisconsin and are consistent with the GIS-based water balance model for groundwater recharge potential as shown on Map 10 in Chapter II of this report. However, in addition to geologic features, the recharge potential Map 10 also accounts for land use (specifically year 2000 existing land use), which can significantly affect recharge potential. Recharge potential in the developed areas of the watershed is primarily medium or low, while undeveloped areas have a recharge potential mostly of high and very high.

Urban development also increases the runoff potential of lands and nearly all of the new urban developments within the Pewaukee River watershed are required to route stormwater runoff away to surface waters and not allowed to recharge into the ground. Despite new NR 151 requirements to infiltrate runoff for new developments where practicable, these development conditions still have the cumulative impact of reducing recharge compared to the nondeveloped conditions. They illustrate how land use changes can impact recharge potential and why this is such an important issue.

Soil water storage is secondary to land in controlling recharge potential. A low soil water storage allows infiltration to quickly pass through the soil and become recharge (e.g., large particles like sand and gravels). A high soil water storage holds the water longer (e.g., organic silts or clays), making it more available for transpiration. Where the soil water storage is medium in the developed areas, the recharge potential is more likely to be low. Where the soil water storage is low, the recharge potential is medium. Thus, in areas where urban development with significant impervious areas is coupled with a medium or high soil water storage, recharge potential would be expected to be low.[29]

Therefore, the high and very high recharge areas within the Pewaukee River watershed are located in open grassy areas, such as parks and other open lands; woodlands, as well as upland areas with sparse development (primarily agricultural lands); and soils with low runoff potential and low water storage capacity. If the parkland or agricultural lands were removed and replaced with residential, commercial, and industrial development without the provision of best management practices to promote infiltration, it is likely that the recharge potential would decrease from high or very high to medium. Therefore, land use planning has significant potential for maintaining or protecting recharge potential within this watershed.[30]

In addition to reducing rates of groundwater recharge, urban developments also have the potential to reduce the amounts of local groundwater levels and baseflows in surface waterbodies through the use of shallow aquifers (either Pleistocene sand and gravel or Silurian dolomite) for water supply. Wells developed in the shallow aquifers often provide sufficient yield, but can impact nearby surface-water resources and are generally more vulnerable to contamination than deeper bedrock wells. Communities tapping the shallow aquifer also face choices between using individual low-capacity household wells or developing a municipal water system with homeowners connecting to higher-capacity municipal wells. In some cases, these communities have an overall negative groundwater balance because sewage treatment plant effluent leaves the community via surface water. For example, a modeling simulation of shallow pumping was conducted for the Town the Lisbon to assess the potential relationship between development density (wells, homes, or water use per acre) and groundwater

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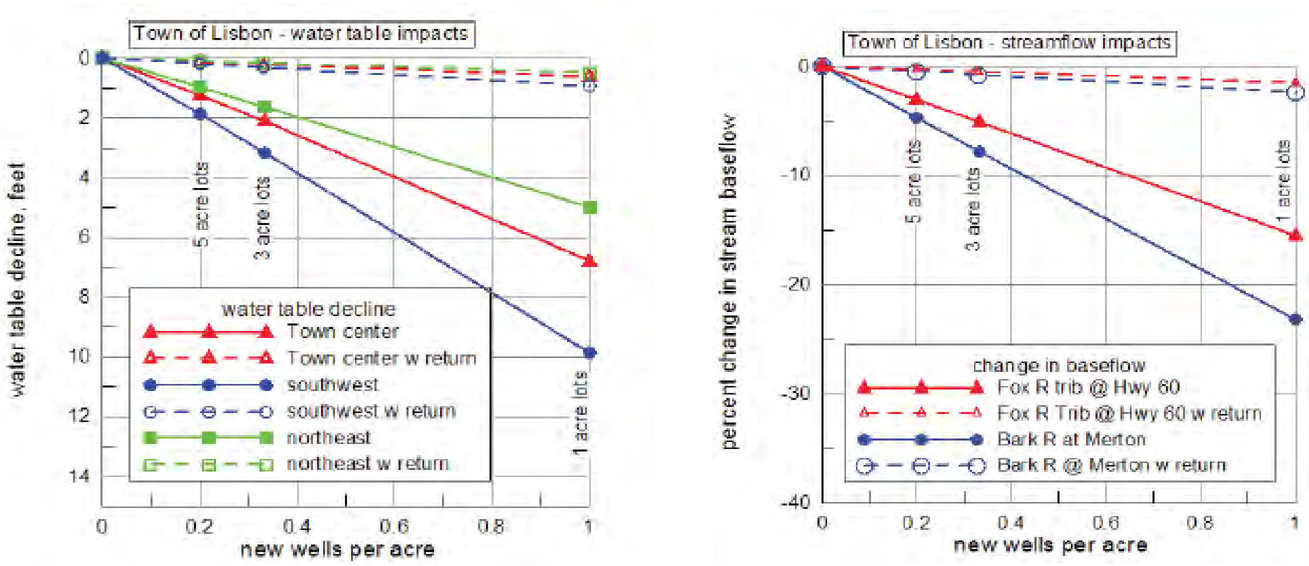
[29]*SEWRPC Technical Report No. 47,* Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water-Balance Model, *July 2008.*

[30]Ibid.

Figure 46

SIMULATED WATER-TABLE DECLINE AND BASEFLOW CHANGES WITHIN THE TOWN OF LISBON DEMONSTRATION AREA FOR VARIOUS LOT DENSITIES



Source: SEWRPC.

impacts, such as baseflow reduction and shallow aquifer drawdown.[31] The Town of Lisbon is just north of the Pewaukee River watershed and is contained within the same glacial Pleistocene deposits called the New Berlin Member,[32] which provides a good level of confidence in the potential comparability of this modeling scenario to the Pewaukee River watershed.

The detailed development simulations in the Town the Lisbon show that dense single-family subdivisions developed with onsite wells have the potential to impact groundwater levels and surface water flows, if wastewater is not returned to the aquifer from which the water supply is drawn. The magnitude of impacts depends on development density, the location of the development, and on the character of existing water resources. Not surprisingly, lot size, or density of wells, represents a critical control on groundwater impacts. Both drawdown and reductions in stream baseflows increase linearly as lot size decreases. Under the most aggressive development scenarios (0.5- or 1.0-acre lots, no return flow), simulated drawdowns beneath developed areas range from five to 10 feet, and baseflow reductions range from about 15 to 25 percent in nearby streams as shown in Figure 46. The reinfiltration of treated wastewater, or return flow, significantly mitigates the impacts of development on groundwater levels and baseflows. Assuming 90 percent wastewater return, simulated drawdowns under the most aggressive development scenarios (1.0-acre or smaller lots) decrease from five to 10 feet to less than one foot, and baseflow reductions decreased to less than 2.5 percent. In particular, small streams, springs, and wetlands are expected to be typically far more sensitive to local reductions in baseflow than are larger surface water features. In all cases, returning treated wastewater to the area of use largely mitigates these water quantity impacts. However, wastewater return flow might degrade local groundwater and surface water

[31]*SEWRPC Technical Report No. 48,* op. cit.

[32]*K.M. Syverson, L. Clayton, J.W. Attig, and D.M. Mickelson,* Lexicon of Pleistocene Stratigraphic Units of Wisconsin: Wisconsin Geographical and Natural History Survey, *Technical Report 1, 2011.*

quality. It must be recognized that sustainability of groundwater use must be considered within the context of the impacts of such use on the surface water features potentially impacted. Such consideration and associated analyses require underatanding of site-specific factors, such as surface water type, functions, and use objectives.

As identified in the regional water supply plan, in 2005 about one-third of the Pewaukee River watershed was served by public water utilities, and there were significant areas of urban development using private domestic wells pumping from the shallow aquifer.[33] Since the majority of the Pewaukee River watershed is sewered and/or is planned to be sewered as shown on Map 6 in Chapter II of this report, these domestic wells combined with routing wastewater to treatment plants could potentially have significant negative impacts to the local groundwater levels and baseflows in the Pewaukee River. There also are municipal wells developed in the shallow aquifer that could contribute to this situation. However, it is important to point out that the USGS Upper Fox River Basin model can be used to investigate different development scenarios (e.g., adding or taking out high-capacity wells, domestic wells, etc.) to help communities make land use decisions to balance water supply needs and water quality needs within this watershed.[34]

Water Budgets

Under the USGS Upper Fox River Basin study, it was calculated that the total base flow for the Upper Fox River Basin modeled network ranged from about 88.0 to 89 cubic feet per second at Vernon Marsh on the mainstem of the Fox River. About one-half of this total base flow (about 42 to 45 cubic feet per second) originates from among eight tributaries as shown in Table 15. Comparison among these major tributaries indicates that Pewaukee Lake and the Pewaukee River provide the greatest amount of baseflow (between 10.6 to 11.3 cubic feet per second) or about 25 percent of the total contribution from the major tributaries or about 10 percent of the entire flow to the Upper Fox River network. This demonstrates the importance of these waterbodies both locally and regionally within Southeastern Wisconsin.

In particular, Pewaukee Lake is a very unique component of this integrated surface water network of the Upper Fox River basin, which was modeled separately to simulate lake levels in terms of lake geometry and the balance of inflow and outflow of water to the Pewaukee River. The models simulate the stage of the lake, which partly controls the rate of the surface water outflow to the Pewaukee River. The elevation of the adjustable spillway weir was averaged to be about 852.35 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29) between January 2007 and August 2009, which allowed development of a rating curve. However, the Pewaukee Lake spillway discharge rating developed for the Upper Fox River Basin model is no longer valid, because the dam outlet was changed from a surface discharge weir gate to a bottom draw sluice gate. Fortunately, revised discharge calculations for the Pewaukee Lake spillway were developed for the new bottom draw sluice gate as shown in Figure 47. The outflow from the Lake also depends on discharges from tributaries into the Lake (Coco Creek, Meadowbrook Creek, Zion Creek, and other small streams), by groundwater discharge into the Lake, and by precipitation onto the Lake. The outflows from the Lake equal the inputs from the inflows minus what is lost to evaporation and some limited groundwater outflow. All of these terms are shown in Table 16 and are important to the overall lake water budget. Based upon this information it is possible to determine that Pewaukee Lake contributes a base flow of about 7.5 to 8.0 cubic feet per second, which comprises about 70 percent of the total discharge of the Pewaukee River (7.5-8.0 cfs divided by 10.6-11.3 cfs total Pewaukee Lake and River discharge). This outflow component is almost one-half of the approximately 16-cubic-feet-per-second increase in base flow estimated between the Watertown Road and Waukesha gauges. The remainder of this base-flow increase comes

[33]*SEWRPC Planning Report No. 52,* op. cit., *Volume One.*

[34]*D.T. Feinstein, et al. 2012-5108, these models are all public and archived with a data dictionary; URL:* http://pubs.usgs.gov/sir/2012/5108/index.html, *For additional information contact: Director, Wisconsin Water Science Center, U.S. Geological Survey, 8505 Research Way, Middleton, WI 53562,* http://wi.water.usgs.gov/

Table 15

SIMULATED BASE FLOW WITHIN THE UPPER FOX RIVER BASIN

Source	Fine-Favored Model (cubic feet per second)	Course-Favored Model (cubic feet per second)
Tributary Base Flow at Confluence with Fox River		
Fox Headwaters	2.1	2.1
Lannon Creek	1.2	1.2
Sussex Creek	5.6	5.8
Poplar Creek	2.5	2.9
Pewaukee Lake and Pewaukee River	10.6	11.3
Pebble Creek	5.9	6.0
Genesee Creek	7.1	7.0
Pebble Brook	7.6	8.0
Sum of Base Flow from Major Tributaries	42.5	44.1
Sum of Base Flow from Minor Tributaries	0.2	0.3
Sum of Tributary Flow to Fox River	42.7	44.5
Net Gain of Base Flow Along Main Trunk of Fox River	7.6	8.1
Contribution of Riparian Wetlands	3.7	3.4
Sum of Return Flow from Quarries	2.0	1.6
Added Flow from Wastewater Treatment Plants	31.9	31.9
Fox River Base Flow above Vernon Marsh	88.0	89.4

Source: U.S. Geological Survey.

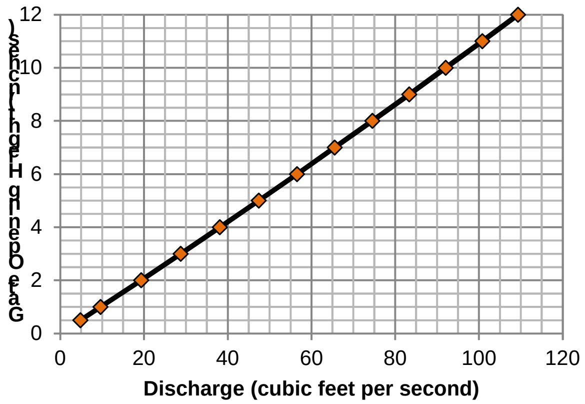
from the Pewaukee River and other inflows directly to the Fox River, which further demonstrates the importance of the Pewaukee River system to the Upper Fox River basin.

These modeled baseflows on the Pewaukee River are also in general agreement with the baseflow discharge measurements recorded on the Pewaukee River as part of the Water Action Volunteer monitoring, even after the installation of the new bottom sluice draw gate opening. However, it is important to note the discharges on the Pewaukee River have often been recorded to be less than 5.0 cubic feet per second during the summer months, particularly during the drought of 2012, which indicates that discharges can be very limiting in this river system.

Installation of the sluice gate spillway of Pewaukee Lake has provided a much greater level of control for the dam operator to balance the management of Pewaukee Lake levels versus discharges to the Pewaukee River. As shown in Figure 47, there is a direct linear relationship between the gate height opening and discharges into the Pewaukee Lake Outlet. The gate is maintained open at least 0.5 inch to provide a minimum baseflow discharge of about 4.9 cubic feet per second into the Pewaukee River during the summer. However, the gate was opened to 12 inches in spring 2013 for about 10 days, due to rising levels on the lake, which indicates that it was discharging more than 100 cfs as shown in Figure 48. Surprisingly, the velocity going past the gate appears to stay relatively constant, which was calculated to be 9.7 feet per second (fps) when opened to 0.5 inch and 9.1 fps when opened to 1.0 foot. Although these velocities are fairly consistent among the normal operation of the gate range of 0.5 to 12 inches, they also demonstrate why the streambed and streambanks within the Pewaukee Outlet need to be armored with fieldstone and riprap to protect from erosion and failure from the high-velocity discharges. On occasion, the gate has been opened to 18 inches for very short time periods (about five minutes) to flush accumulations of lake weeds and other debris that collect at the opening. Hence, one disadvantage of the new sluice gate as opposed to the old weir gate is that instead of material flowing over the weir they just pile up at the sluice gate, creating a significant obstruction that needs to be periodically flushed.

Figure 47

RELATIONSHIP BETWEEN THE BOTTOM DRAW SLUICE GATE OPENING AND PEWAUKEE LAKE OUTFLOW DISCHARGE



The calculation is based on the water surface elevation being at normal summer level. If the level is higher, the flows increase slightly, if the level is lower, the flows decrease.

Source: David White, Engineer, Village of Pewaukee, and SEWRPC.

Although the dam gate has been periodically opened up to provide adequate recreational discharges on the Pewaukee River for the annual "River Run" paddling event, there is no formal policy or provision to maintain discharges for recreational use or the minimum baseflow discharge. Although there are regulations requiring the maintenance of water levels on Pewaukee Lake, there are no such requirements to ensure adequate base flows in the Pewaukee River. Therefore, the management and needs of the Lake legally supersede the needs of the River, based upon existing requirements. A growing body of scientific evidence demonstrates that water management practices aimed at requiring some arbitrary "minimum" flows are inadequate to protect the structure and function of riverine systems.[35] Therefore, increasing numbers of scientists and managers agree that in order to protect freshwater biodiversity and maintain healthy rivers, it is vital to mimic components of natural flow variability which includes consideration of flow magnitude, frequency, timing, duration, rates of change and predictability of flow events, including floods and drought.[36] Hence, these relationships could be determined and a more dynamic management policy be pursued in order to better protect the biodiversity and maintain the goods and services that the Pewaukee Lake and Pewaukee River systems provide.

Finally, the Upper Fox River model allows mapping of areas where groundwater contributes flow 1) to surface water features and 2) to pumping wells and quarries as shown on Figure 49. The groundwater-contributing basins tend to extend beyond the western boundary of the Upper Fox River watershed and fall short of the eastern watershed boundary. Quarries and wells, which divert groundwater from its natural surface water sinks in selected areas, are shown on Figure 49. The calculated contributing groundwater basin areas, as well as sink areas for both Pewaukee Lake and Pewaukee River are shown on Figure 49. Although these simulated groundwater basins generally follow the surface watershed boundaries, there are some notable differences, particularly concerning the Pewaukee Lake contributing basin that extends beyond its surface watershed boundaries to the west and north. The implication of these modeling results is that these areas are important contributing areas for protection and maintenance of groundwater recharge and base flows of both Pewaukee Lake and the Pewaukee River.

Summary

The Pewaukee River streamflow is highly dependent upon groundwater discharge. Hence, it is also dependent upon recharge of the local shallow aquifer that ultimately discharges into the River. Recharge is variable over time and space and can range from less than an inch per year to more than 10 inches per year. This variation of

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[35] *D.H. Lytle, and N.L. Poff, "Adaptation to natural flow regimes,"* Trends in Ecology and Evolution, *Volume 19, 2004, pages 94-100.*

[36] *A.H. Arthington, S.E. Bunn, N.L. Poff, and R.J. Naiman, The challenge of providing environmental flow rules to sustain river ecosystems,"* Ecological Applications, *Volume 16, Number 4, 2006, pages 1311-1318.*

Table 16

SIMULATED STAGES AND WATER BUDGETS FOR PEWAUKEE LAKE

Simulated Results	Fine-Favored Model	Coarse-Favored Model
Stage (feet)	852.820	852.833
Inflow (cubic feet per second)		
Precipitation	9.33	9.33
Groundwater Inflow	2.53	2.60
Surface Water Inflow	4.28	4.54
Total	16.13	16.47
Outflow (cubic feet per second)		
Evaporation	8.45	8.45
Groundwater Inflow	0.16	0.08
Surface Water Inflow	7.52	7.94
Total	16.13	16.47

Source: U.S. Geological Survey.

recharge depends on land use, soil type, surface topography, and climatic variability, with increasing recharge rates associated with increasing precipitation rates.[37] Recharge can be altered by implementing land use and land development practices to promote open space and provide mitigating infiltration capacity, which gives land use planning an important role in protecting recharge areas and the ecological health of the connected surface waters within the Pewaukee River watershed. Hence, the recently developed recharge potential Map 10 in Chapter II of this report and contributing groundwater area on Figure 49 could both be used to help guide existing and planned land use decisions to protect sustained baseflow and the ecological health of the Pewaukee River and surrounding communities.[38] In addition, the communities within the Pewaukee River watershed could also utilize the Upper Fox River Basin model to help balance water supply demand and the effects of imperviousness resulting from future development, versus providing environmentally sustainable flows and recreational use opportunities for the Pewaukee River.

WATER QUALITY CONDITIONS

Water quality information summarized in this section includes data collected among 22 sampling sites throughout the Pewaukee River watershed (see Map 25) by the WDNR; Lake Pewaukee Sanitary District, Water Action Volunteers, and SEWRPC. The data monitoring efforts included a range of different parameters over sampling periods ranging from a single sample or season, to a year or multiple years (see Table 17). It is important to note that none of the water quality sampling projects to date has been conducted to simultaneously assess both the lake and stream ecosystems within the Pewaukee River watershed. Rather, monitoring has been targeted toward either the Lake or a reach of a stream and usually sampled at only one site over time, with several recent exceptions where multiple sites were sampled simultaneously throughout the Pewaukee River system by the Water Action Volunteers. Water quality data analysis for this study was limited to fall 2012. Water quality monitoring continues to be collected among several sites by the volunteer monitors and can be downloaded from the WDNR's Surface Water Integrated Monitoring System (SWIMS) database at the following link: *http://dnr.wi.gov/topic/surfacewater/swims/.*

[37]*SEWRPC Technical Report No. 47*, op. cit.

[38]Ibid.

Figure 48

HIGH WATER DISCHARGE ON THE PEWAUKEE LAKE OUTFLOW: APRIL 15, 2013

Source: Photos by Greg Shell.

Very few of the same water quality parameters were collected within and/or among Pewaukee Lake and streams within the Pewaukee River watershed consistently enough to be able to assess changes over time. For this study, dissolved oxygen, pH, total phosphorus, nitrite and nitrate nitrogen, chloride, and temperature parameters were used to assess water quality changes over time between Pewaukee Lake and streams within the watershed. Given the limitations noted above, comparison between the Lake and streams was necessarily limited. Since the Pewaukee Lake period of record is the most complete, the deep water monitoring station can be used or considered as a baseline of comparison between the tributary streams flowing into the Lake and the Pewaukee River, which receives discharges from the Lake. There is a significant dilution factor associated with the nutrient concentrations within Pewaukee Lake compared to the volumes of water with the River and there is a residence time of about two to three years within the Lake,[39] so comparisons and interpretations between the Lake and River need to keep this in mind. Therefore, comparisons between these waterbodies should focus less on actual concentration differences and more on relative rates or patterns of changes over time. There also are two stations, one on the Fox River just downstream of the confluence with the Pewaukee River, and one at RM 5.35 (Wisconsin Avenue) on the Pewaukee River ,that contain a fairly intact historical baseline of data from 1964 to 1975. During this early time period, wastewater effluent was being discharged into the Pewaukee and Fox Rivers and private septic systems around Pewaukee Lake were also discharging into the Lake until the 1980s, so this can be considered a worst case scenario for comparison to more recent sampling dates between 2005 and 2012.

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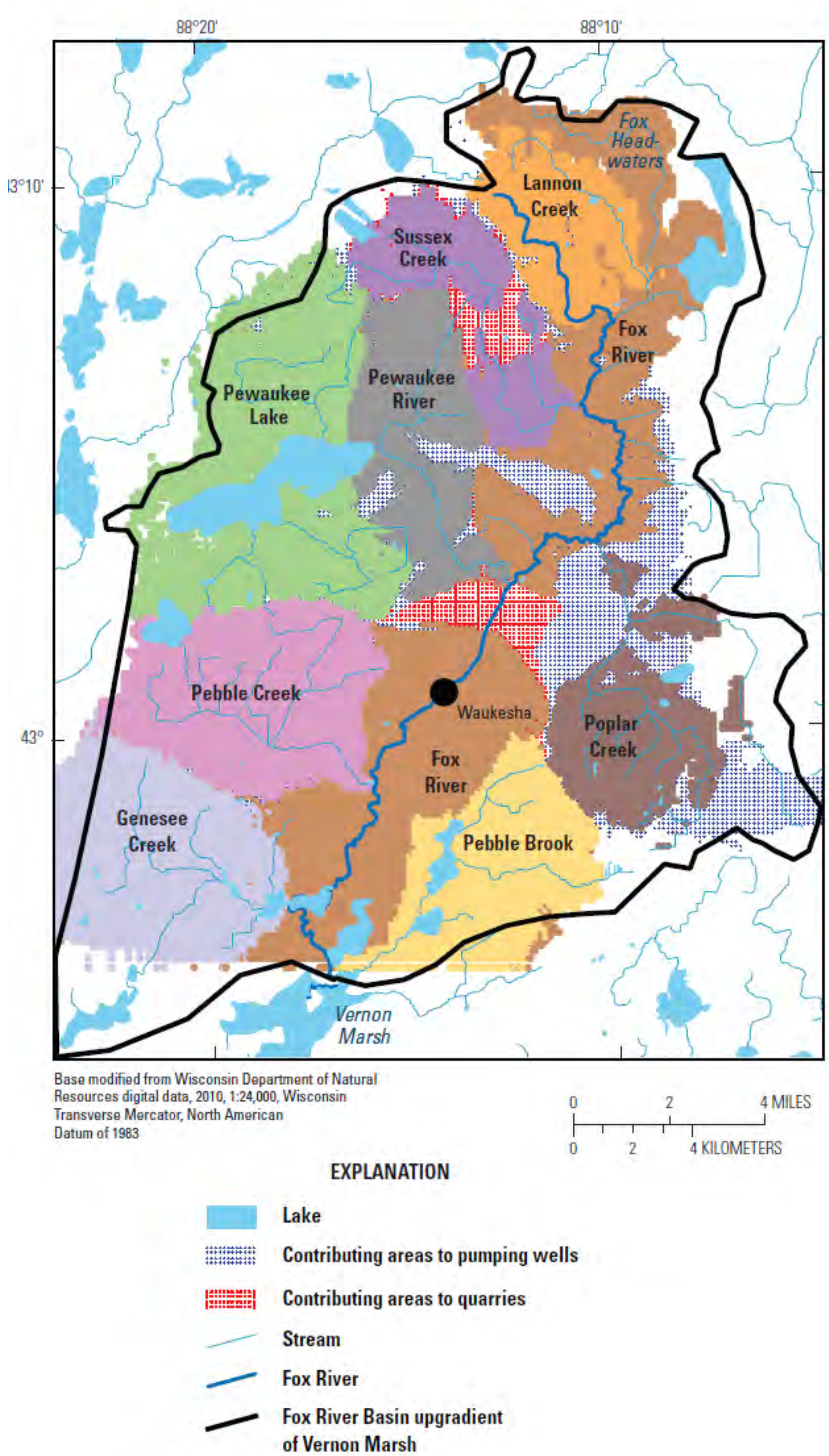
[39]*SEWRPC Community Assistance Planning Report No. 58, 2nd Edition,* A Lake Management Plan for Pewaukee Lake, *Waukesha County, Wisconsin, May 2003.*

Figure 49

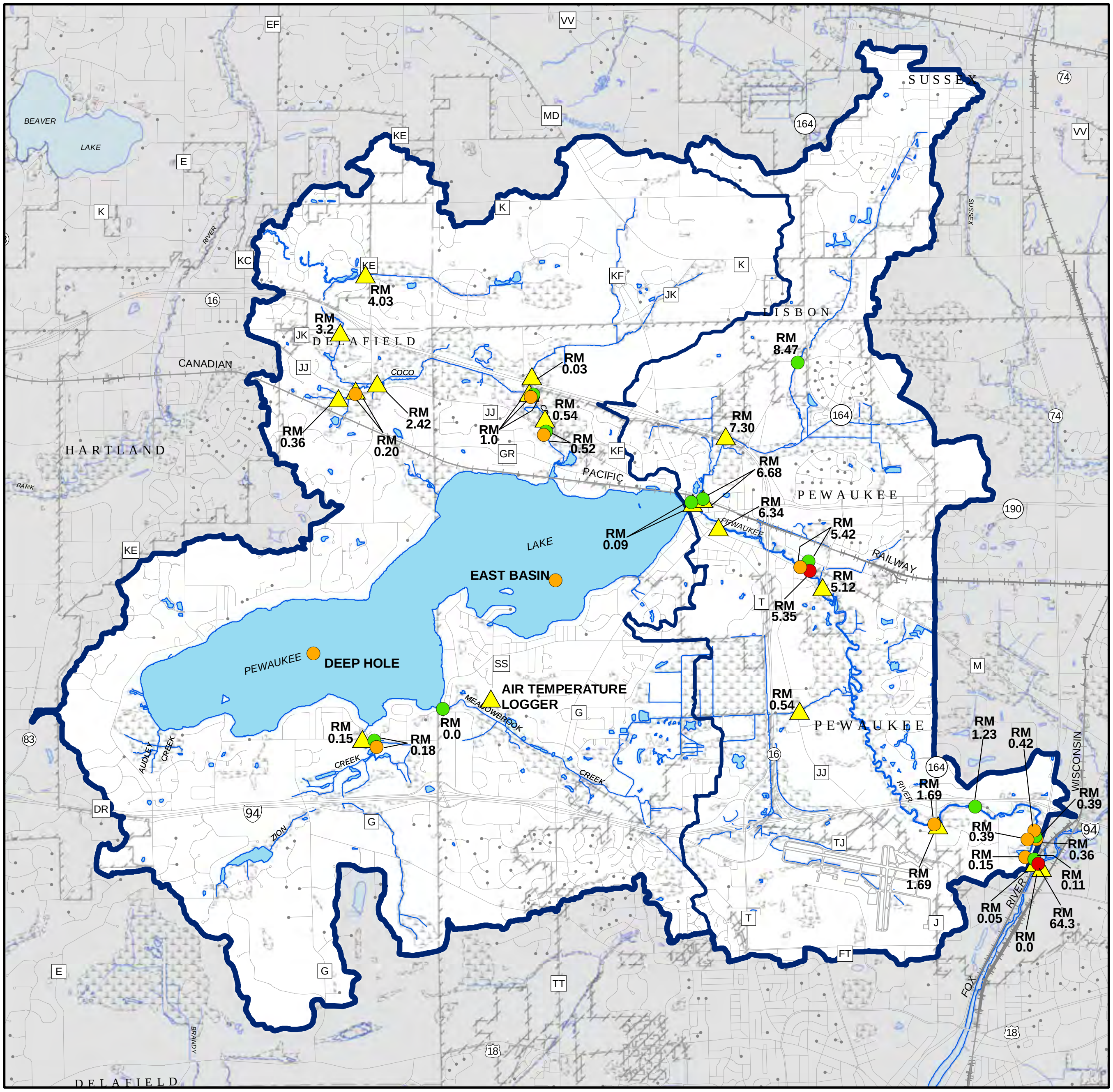
SIMULATED GROUNDWATER BASINS ASSOCIATED WITH SURFACE WATER FEATURES, QUARRIES, AND HIGH-CAPACITY WELLS (COARSE FAVORED MODEL OUTPUT)



Source: U.S. Geological Survey.

Map 25

WATER QUALITY ASSESSMENT SITES AND TEMPERATURE LOGGER SITES WITHIN THE PEWAUKEE RIVER WATERSHED



TEMPERATURE DATA LOGGER (see Table IV-6)

WATER ACTION VOLUNTEERS WATER QUALITY (see Table IV-5)

WDNR WATER QUALITY (see Table IV-5)

HISTORIC WATER QUALITY STATIONS (see Table IV-5)

RM 5.35 RIVER MILE DESIGNATION (see Tables IV-5 and IV-6)

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: Water Action Volunteers, Wisconsin Department of Natural Resources, and SEWRPC.

Table 17

WATER QUALITY SAMPLING SITES WITHIN THE PEWAUKEE RIVER WATERSHED: 1964-2012

Stream	Stream Reach	Location	Source of Data	Site Identification	River Mile (see Map 25)	Period of Record
Fox River	Fox River	Fox River at Pewaukee confluence	SEWRPC TR-17	FX-6	64.3[a]	1964-1975
Pewaukee River	Pewaukee 1					
		Downstream of CTH F	Water Action Volunteers	683228	0.11	05/26/2005 to 07/2/2012
		Upstream of CTH F	Wisconsin Department of Natural Resources	683209	0.15	08/20/1990 to 09/19/1990
		Upstream of CTH F	Wisconsin Department of Natural Resources	10037747	0.36	06/26/2012 to 08/20/2012
		Upstream of CTH F, near Steinhafel's	Wisconsin Department of Natural Resources	10030439	0.39	01/31/2011 to 09/27/2011
		Upstream of CTH F, near Steinhafel's	Water Action Volunteers	10030439	0.39	06/07/2007 to 06/07/2011
		Upstream of Steinhafel's entrance	Wisconsin Department of Natural Resources	10031806	0.42	11/29/2010 to 08/29/2011
		Between Busse Road and Pewaukee Road	Water Action Volunteers	10010563	1.23	06/17/2005 to 07/02/2012
		At Pewaukee Road	Wisconsin Department of Natural Resources	10034288	1.69	08/29/2011
	Pewaukee 2					
		Wisconsin Avenue	SEWRPC TR-17	FX-5	5.35	1964-1975
	Pewaukee 3					
		Upstream of Wisconsin Avenue	Wisconsin Department of Natural Resources	683311	5.42	08/20/1990 to 09/19/1990
		Upstream of Wisconsin Avenue	Water Action Volunteers	683311	5.42	01/24/2006 to 07/31/2012
		Downstream of Capitol Drive	Water Action Volunteers	10029788	6.68	06/14/2005 to 07/02/2012
	Pewaukee 4					
		Lindsey Road	Water Action Volunteers	10029789	8.47	05/24/2005 to 07/02/2012
Pewaukee Lake Outlet	Pewaukee Lake outlet					
		150 feet downstream of Pewaukee Lake outlet	Water Action Volunteers	10029787	0.09	06/23/2005 to 07/02/2012
Coco Creek	Coco Creek					
		At CTH JJ	Wisconsin Department of Natural Resources	683315	0.52	04/17/1990 to 09/19/1990
	Coco-Creek	At CTH JJ	Water Action Volunteers	683315	0.52	06/27/2005 to 07/02/2012
		At Yench Road (75m upstream)	Wisconsin Department of Natural Resources	10011876	1.0	05/23/2008 to 09/17/2008
		At Yench Road	Water Action Volunteers	10011876	1.0	08/28/2005 to 07/02/2012
Unnamed Tributary	Coco Creek					
		Unnamed tributary to Coco Creek	Wisconsin Department of Natural Resources	10030472	0.20	05/13/2009 to 09/09/2009
Zion Creek	Zion Creek					
		At Oakton Avenue	Wisconsin Department of Natural Resources	10029797	0.18	05/30/2012 to 07/23/2012
		At Oakton Avenue	Water Action Volunteers	10029797	0.18	06/29/2000 to 07/02/2012
Meadow Brook Creek	Meadow Brook Creek					
		At CTH SS	Water Action Volunteers	10030297	0.0	06/20/2005 to 07/02/2012

[a]*River mile for this site represents the distance from the former Wilmot Dam site in Kenosha County. The Wilmot Dam was removed in 1992.*

Source: Wisconsin Department of Natural Resources, Water Action Volunteers, and SEWRPC.

Dissolved Oxygen

The concentration of dissolved oxygen in water is a major determinant of the suitability of a waterbody as habitat for fish and other aquatic organisms because most aquatic organisms require oxygen in order to survive. Though tolerances vary by species, most aquatic organisms have minimum oxygen requirements.

Sources of dissolved oxygen to water include diffusion of oxygen from the atmosphere and photosynthesis by aquatic plants and suspended and benthic algae. Processes that remove dissolved oxygen from water include diffusion of oxygen to the atmosphere, respiration by aquatic organisms, and bacterial decomposition of organic material in the water column and sediment. Several factors can influence these processes, including the availability of light, the clarity of the water, the presence of aquatic plants, and the amount of water turbulence. Water temperature has a particularly strong effect for two reasons. First, as noted in the previous subsection, the solubility of most gasses in water decreases with increasing temperature. Thus as water temperature increases, the water is able to hold less oxygen. Second, the metabolic demands of organisms and the rates of oxygen-demanding processes, such as bacterial decomposition, increase with increasing temperature. As a result, the demands for oxygen in waterbodies tend to increase as water temperature increases.

The minimum dissolved oxygen standards for coldwater (trout) and warmwater streams, as set forth in Chapter NR 102 of the *Wisconsin Administrative Code*, are 6.0 and 5.0 mg/l, respectively. Minimum dissolved oxygen standards for coldwater streams are also designated to not be lower than 7.0 mg/l during the spawning season for trout species. Dissolved oxygen concentrations have a clear relationship with water temperature. Cold water can hold more dissolved oxygen than warmer water. As water becomes warmer it can hold less dissolved oxygen. If the water becomes too warm, dissolved oxygen levels may be suboptimal (i.e., less than 5.0 mg/l) for many species of fishes and other aquatic organisms. Because the warmest water temperatures occur in the summer, this is the most important time of the year for determining physiological limitations for aquatic organisms based on dissolved oxygen concentrations.

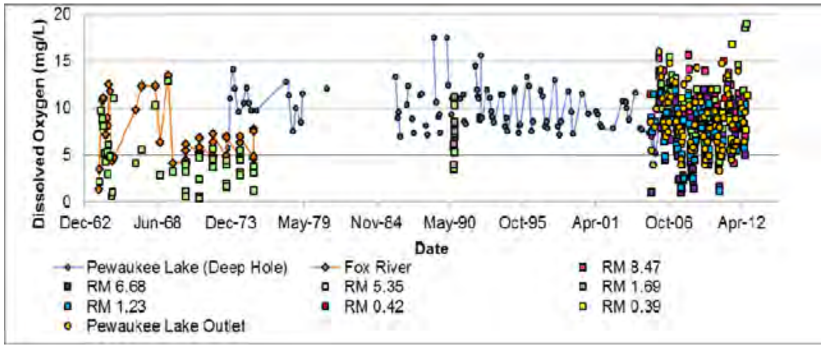
In general, dissolved oxygen concentration data were adequate to support a high-quality cold and warmwater fishery in the Pewaukee River watershed. For example, Coco Creek and its tributaries are achieving the coldwater standards and the majority of the remaining sites in the watershed are meeting the warmwater standard (see Figure 50 Parts A, B, and C). In addition, although Zion Creek is classified as a Limited Aquatic Life stream (see Map 16 in Chapter III of this report) for which the minimum dissolved oxygen standard is 1.0 mg/L, the data show that this Creek is consistently achieving the 5.0 mg/L standard (see Figure 50 Part C), which indicates a tremendous improvement in dissolved oxygen concentration since the stream was assigned a water use objective. Figure 50 Part A also shows some very poor dissolved oxygen concentrations in the Pewaukee River from 1964 through 1975, with the 5.0 mg/L standard rarely being exceeded. These concentrations were even worse than those in the Fox River; recent data indicates that these concentrations have greatly improved.

However, a few areas in the watershed may have limited dissolved oxygen concentrations. For example, Meadowbrook Creek seems to consistently fall below 2.0 mg/l and almost never achieves the 5.0 mg/L standard during the summer months, which indicates that this system is very limiting to fish and other aquatic organisms. This area contains a high amount of organic matter, which likely has a high biological oxygen demand in which oxygen is used up in the decomposition process. Decomposition of organic matter contained in this material, through chemical and especially biological processes, removes oxygen from the overlying water, lowering the dissolved oxygen concentration. In addition, there are a couple of sites on the Pewaukee River, in the headwaters at RM 6.68 and downstream site at RM 1.23, that were consistently below the warmwater standard in the summer months in both 2007 and 2008 (see Figure 50 Part B). However, this seems to have improved since 2008. Comparison of dissolved oxygen concentrations directly upstream versus downstream of the confluence of the Pewaukee Lake Outlet seems to indicate that discharges from Pewaukee Lake are having a positive effect on dissolved oxygen concentrations in the Pewaukee River. For example, in 2007 and 2008, concentrations in the Pewaukee River downstream of the Pewaukee Lake Outlet were markedly greater (i.e., greater than 5.0 mg/L) than concentrations upstream of the Outlet (see Figure 50 Part D).

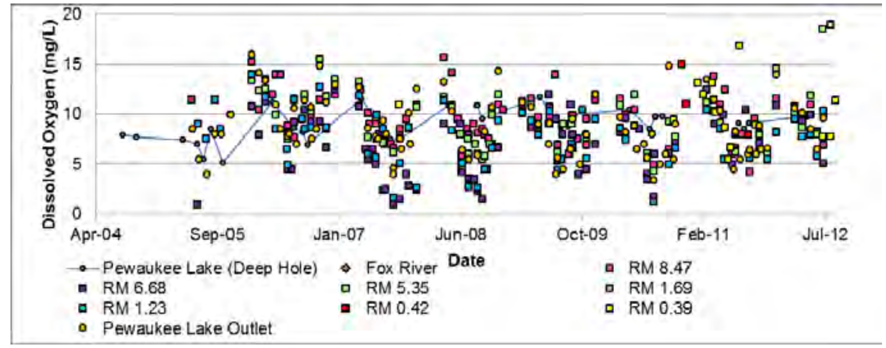
Figure 50

TOTAL DISSOLVED OXYGEN CONCENTRATIONS IN THE PEWAUKEE RIVER WATERSHED: 1964-2012

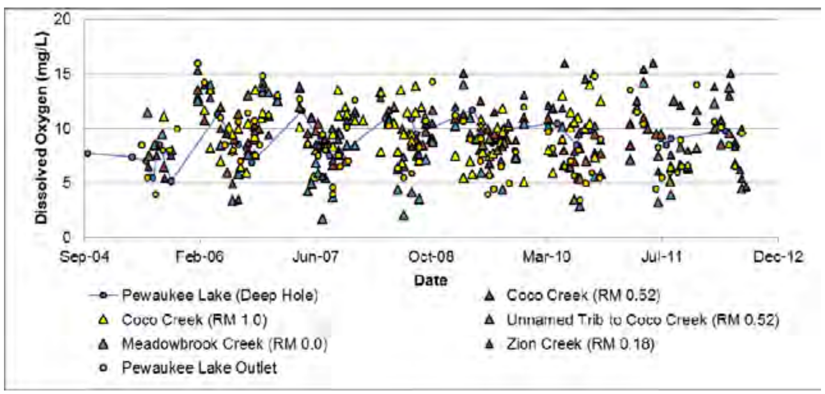
PART A–LAKE SURFACE VERSUS PEWAUKEE RIVER (1964 to 2012)



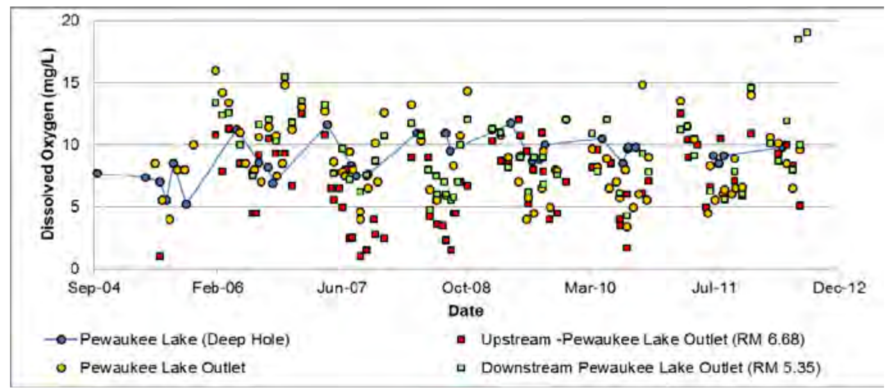
PART B–LAKE SURFACE VERSUS PEWAUKEE RIVER (2005 to 2012)



PART C–LAKE SURFACE VERSUS TRIBUTARIES (2005 to 2012)



PART D–LAKE OUTLET VERSUS PEWAUKEE RIVER (2005 to 2012)



NOTE: 140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: Water Action Volunteers, Wisconsin Department of Natural Resources, and SEWRPC.

The data show strong seasonal patterns to the concentrations of dissolved oxygen in both the Lake and River systems (see Figure 50 Part A). The concentrations of dissolved oxygen are highest during the winter, decline through spring, and reach a minimum during the summer months. They then rise through the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. The solubility of oxygen in water decreases with increasing temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer. In addition to the factors mentioned above, dissolved oxygen concentrations can also be affected by a variety of other factors, including the presence of aquatic plants, sunlight, turbulence in the water, and the amount and type of sediment.

The increases in concentrations of dissolved oxygen in the Pewaukee River represent a general improvement in water quality over time and the majority of samples indicate that the standard is being met, but there are often periods during the summer where the dissolved oxygen concentration has fallen below the 5.0 mg/L standard. The periodic low levels of dissolved oxygen potentially indicate that the system could be vulnerable to organic pollution. Consequently, issues of concern are limiting agricultural runoff and maintaining stormwater management systems that convey oxygen consuming substances.

pH

The acidity of water is measured using the pH scale. This is defined as the negative logarithm of the hydrogen ion (H^+) concentration, which is referred to as the standard pH unit or standard units (stu). It is important to note that each unit of the scale represents a change of a factor of 10. Thus the hydrogen ion concentration associated with a pH of 6.0 stu is 10 times the hydrogen ion concentrations associated with a pH of 7.0 stu. A pH of 7.0 stu represents neutral water. Water with pH values lower than 7.0 stu has higher hydrogen ion concentrations and is more acidic, while water with pH values higher than 7.0 stu has lower hydrogen ion concentrations and is less acidic.

Many chemical and biological processes are affected by pH. The solubility and availability of many substances are influenced by pH. For example, many metals are more soluble in water with low pH than they are in water with high pH. In addition, the toxicity of many substances to fish and other aquatic organisms can be affected by pH. Different organisms are capable of tolerating different ranges of pH, with most preferring ranges between about 6.5 and 8.0 stu.

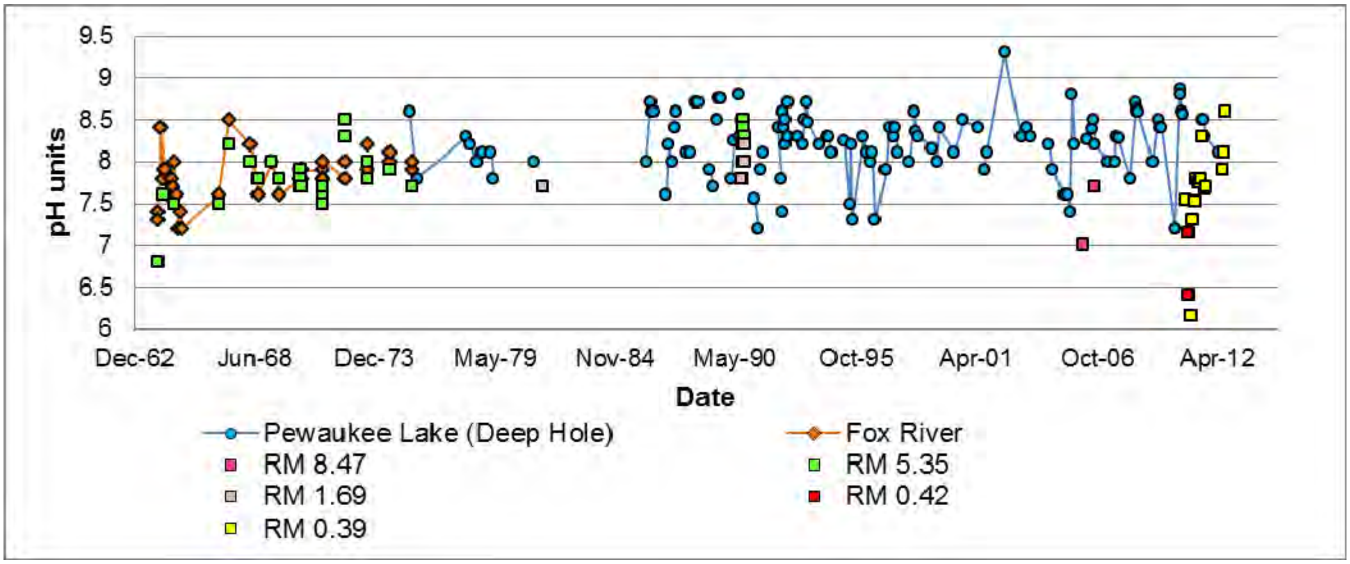
Several factors influence the pH of surface waters. Because of diffusion of carbon dioxide into water and associated chemical reactions, rainfall in areas that are not impacted by air pollution has a pH of about 5.6 stu. The pH of rainfall in areas where air quality is affected by oxides of nitrogen or sulfur tends to be lower. The mineral content of the soil and bedrock underlying a waterbody has a strong influence on the waterbody's pH. Because much of the Pewaukee River watershed is underlain by carbonate bedrock such as dolomite, pH in the waterbodies of the watershed tends to be between about 7.0 and 9.0 stu. Pollutants contained in discharges from point sources and in stormwater runoff can affect a waterbody's pH. Photosynthesis by aquatic plants, phytoplankton, and algae can cause pH variations both on a daily and seasonal basis.

The pH over the entire period of record across all stations and waterbodies generally ranged from about 7.5 to 8.5 stu. The pH for Coco Creek ranged slightly lower, from about 7.0 to 8.0 stu (see Figure 51). However, concentrations within Pewaukee Lake did tend to be higher than 8.5 stu during the summer months. These increases in summer pH are associated with increased dissolved oxygen concentrations. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. Summer and fall values of pH in Pewaukee Lake tend to be slightly lower than spring and winter values. While values of pH in these waterbodies were all within the range of 6.0 stu to 9.0 stu specified in Wisconsin's water quality criteria (see Table 8 in Chapter III of this report), there were a few winter samples collected in 2011 in the downstream reach of the Pewaukee River at RM 0.39 and RM 0.42 that were unusually

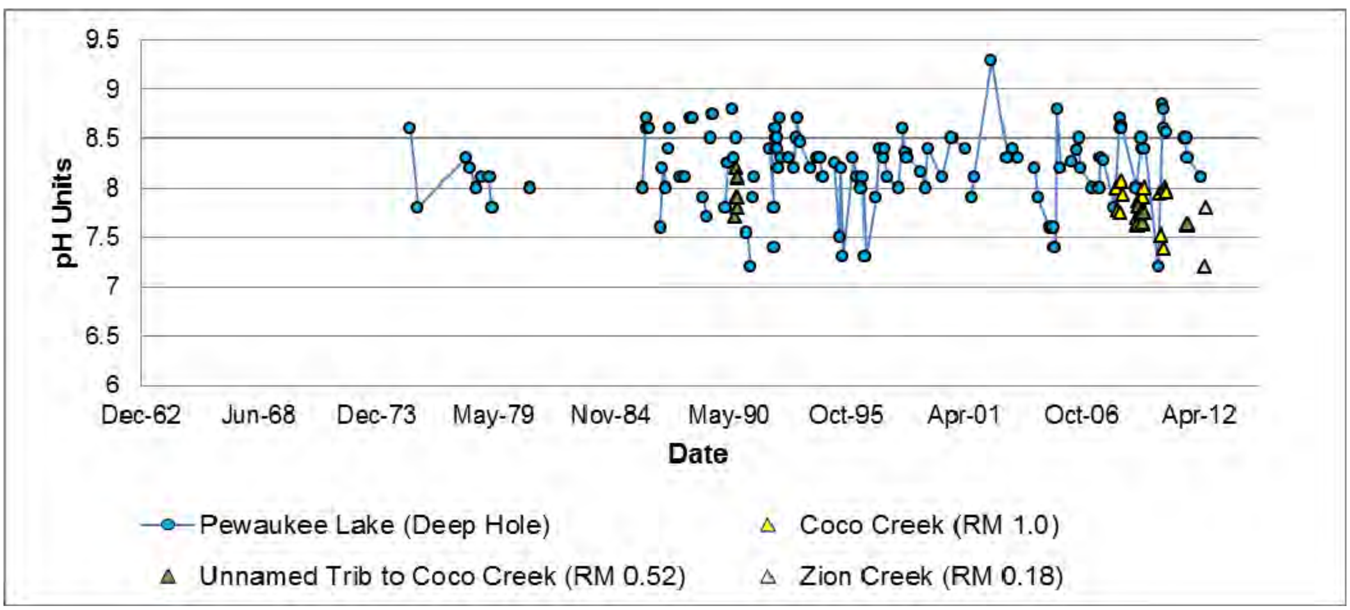
Figure 51

pH CONCENTRATIONS IN THE PEWAUKEE RIVER WATERSHED: 1964-2012

PEWAUKEE LAKE VERSUS PEWAUKEE RIVER AND FOX RIVER



PEWAUKEE LAKE VERSUS TRIBUTARIES



Source: Water Action Volunteers, Wisconsin Department of Natural Resources, and SEWRPC.

low at 6.15 and 6.4 stu, respectively. It is unknown why such low values were observed, but they could be associated with stormwater runoff from an adjacent parking lot and/or roadway in this area.

In summary, pH concentrations were generally shown to remain the same during the time period examined from 1964 to 2012 and did not exceed water quality criteria for this parameter. However, some recent low pH values are a cause for concern and these and other sites throughout the Pewaukee River watershed, which could be watched with continued monitoring.

Chloride

Chlorides of commonly occurring elements are highly soluble in water and are present in some concentration in all surface waters. Chloride is not decomposed, chemically altered, or removed from the water as a result of natural processes. Natural chloride concentrations in surface water reflect the composition of the underlying bedrock and soils, and deposition from precipitation events. Waterbodies in southeastern Wisconsin typically have very low natural chloride concentrations due to the dolomite bedrock found in the Region. These rocks are rich in carbonates and contain little chloride. Because of this, the sources of chloride to surface waters in the Pewaukee River watershed are largely anthropogenic, including sources such as salts used on streets, highways, and parking lots for winter snow and ice control; salts discharged from water softeners; and salts from sewage and animal wastes. Because of the high solubility of chloride in water, if chloride is present, stormwater discharges are likely to transport it to receiving waters. High concentrations of chloride can affect aquatic plant growth and pose a threat to aquatic organisms. Impacts from chloride contamination begin to manifest at a concentration of about 250 milligrams per liter and become severe at concentrations in excess of 1,000 milligrams per liter.[40]

Historical comparison of chloride concentrations from 1964 through 1975 indicate that concentrations are greater and more variable within the Pewaukee River and Fox River compared to Pewaukee Lake. However, any interpretations of this comparison are difficult, because the historic loads from the Village of Pewaukee WWTP no longer discharge into the Pewaukee River, since that plant has been decommissioned. Although no additional chloride data has been collected on the Pewaukee River since 1975, chloride concentrations have increased in Pewaukee Lake from about 30 mg/l in 1970s to about 80 mg/l in 1999, as shown in Figure 52. Therefore, chloride concentrations are likely increasing throughout the Pewaukee River and tributaries at an equal rate to the Lake as a minimum. This is consistent with the generally increasing trend in chloride concentrations in lakes within the Southeastern Wisconsin Region. Important sources of chlorides to lakes and streams in southeastern Wisconsin are anthropogenic in origin, and include salts used on streets and highways for winter snow and ice control, salts discharged from water softeners, and salts from sewage and animal wastes.

The recent concentrations reported within Pewaukee Lake are well below the WDNR standards for chronic chloride contamination (i.e., 395 mg/l) to protect fish and aquatic life. However, the increasing trend in chloride concentration is represents a decline in water quality for the entire Pewaukee River system, so this is an important issue of concern.

Nutrients

Nutrients are elements and compounds needed for plant and algal growth. They are often found in a variety of chemical forms, both inorganic and organic, which may vary in their availability to plants and algae. Typically, plant and algal growth and biomass in a waterbody are limited by the availability of the nutrient present in the lowest amount relative to the organisms' needs. This nutrient is referred to as the limiting nutrient. Additions of the limiting nutrient to the waterbody typically result in additional plant or algal growth. Phosphorus is usually, though not always, the limiting nutrient in freshwater systems. Under some circumstances nitrogen can act as the limiting nutrient.

Sources of nutrients to waterbodies include both sources within the waterbody and sources in the contributing watershed. Within a waterbody, mineralization of nutrients from sediment, resuspension of sediment in the streambed, erosion of streambed and banks, and decomposition of organic material can contribute nutrients. Nutrients can also be contributed by point and nonpoint sources within the watershed. Examples of point sources of pollution include sewage treatment plants and industrial discharges. Concentrations of some chemical forms of nutrients in discharges from point sources are subject to effluent limitations through the WPDES permit program

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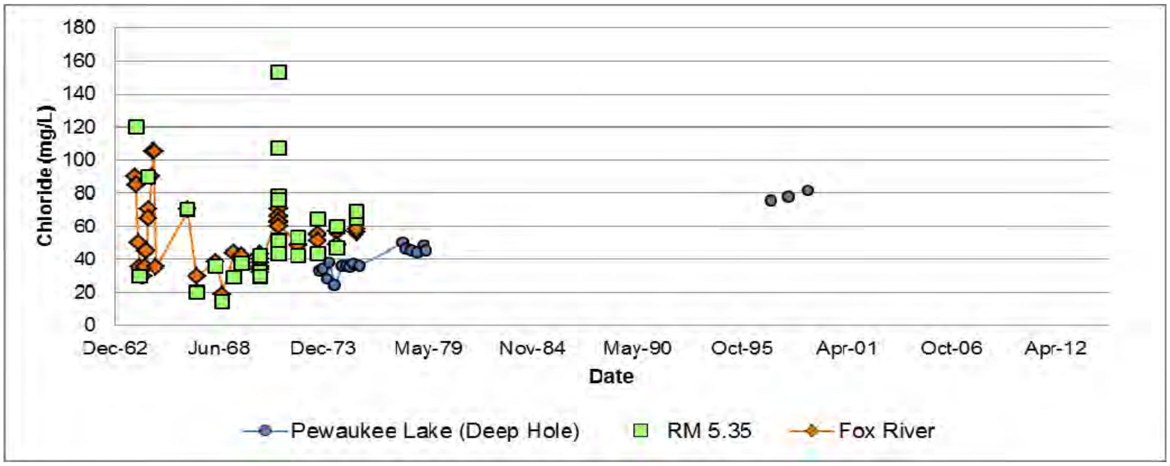
[40]*Frits van der Leeden, Fred L. Troise, and David Keith Todd,* The Water Encyclopedia, Second Edition, *Lewis Publishers, Inc., 1990.*

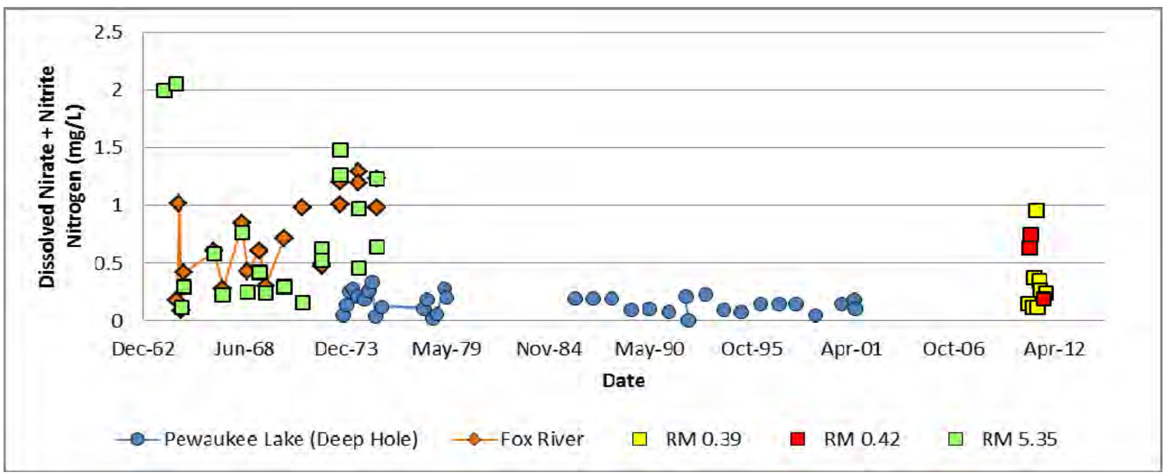
Figure 52

TOTAL CHLORIDE, NITROGEN, AND PHOSPHORUS CONCENTRATIONS IN THE PEWAUKEE RIVER WATERSHED: 1964-2012

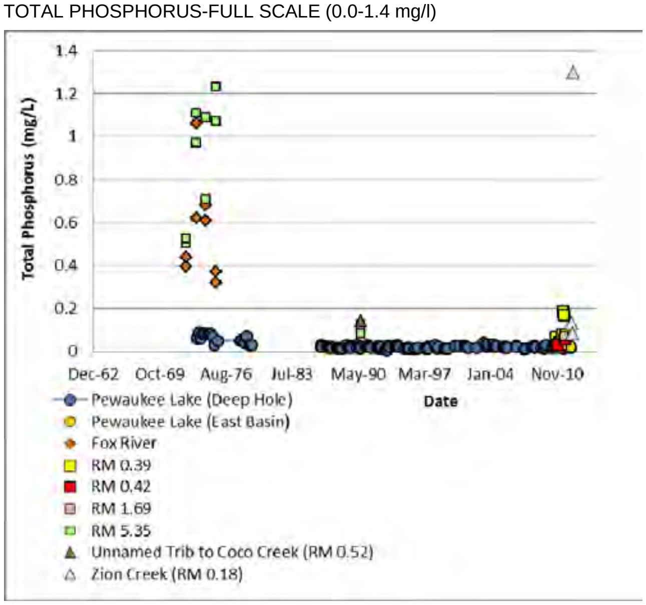
CHLORIDE



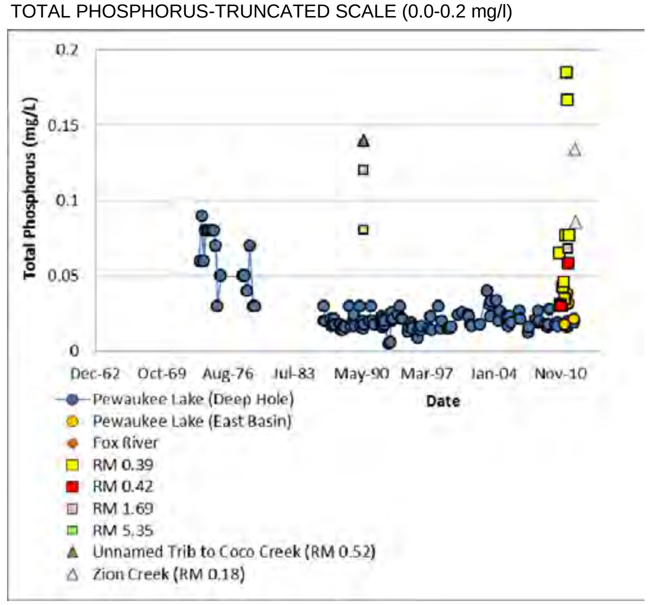
NITRATE-NITRITE NITROGEN



TOTAL PHOSPHORUS-FULL SCALE (0.0-1.4 mg/l)



TOTAL PHOSPHORUS-TRUNCATED SCALE (0.0-0.2 mg/l)



Source: Water Action Volunteers, Wisconsin Department of Natural Resources, and SEWRPC.

that limit the concentrations and amounts that can be discharged. A variety of nonpoint sources also contribute nutrients to waterbodies. Many BMPs for control of urban and rural nonpoint source pollution are designed to reduce discharges of nutrients.

Phosphorus

As noted above, phosphorus is usually, though not always, the limiting nutrient in freshwater systems. Two forms are commonly sampled in surface waters: total phosphorus and dissolved phosphorus. Total phosphorus consists of all of the phosphorus contained in material dissolved or suspended in water. Dissolved phosphorus consists of the phosphorus contained in material dissolved in water. In both these types, the phosphorus may be present in a variety of chemical forms. Because the degree of eutrophication in freshwater systems generally correlates more strongly with total phosphorus concentration than with dissolved phosphorus concentration, the State's water quality criteria are expressed in terms of total phosphorus and water quality sampling tends to focus more strongly on assessing total phosphorus concentrations than dissolved phosphorus concentrations. In rural settings, phosphorus from agricultural fertilizers or animal manure may be contributed through discharges from drain tiles or direct runoff into waterbodies. Phosphorus also may be contributed by poorly maintained or failing onsite wastewater treatment systems.

Phosphorus can be contributed to waterbodies from a variety of point and nonpoint sources. In urban settings, phosphorus from lawn fertilizers and other sources may be discharged through storm sewer systems and direct runoff into streams. It should also be noted that the State of Wisconsin has adopted a turf management standard limiting the application of lawn fertilizers containing phosphorus within the State.[41] This would be expected to reduce the amount of phosphorus discharged from urban settings. In 2010, the State also placed restrictions on the sale of some phosphorus-containing cleaning agents.[42]

Historical comparison of total phosphorus concentrations from 1964 through 1975 indicate that concentrations were greater and more variable within the Pewaukee River and Fox River compared to Pewaukee Lake. Despite those differences, these historical concentrations at all three locations consistently exceeded the State's applicable water quality criterion of 0.075 mg/l (see Table 8 in Chapter III of this report). This is mostly likely due to failing onsite wastewater treatment systems around Pewaukee Lake and sewage effluent inputs in the Rivers that contained high amounts of nutrients. However, the highest maximum recorded total phosphorus concentration ever observed within the Pewaukee River watershed was 1.3 mg/L on July 23, 2012, in Zion Creek. This observation indicates that Zion Creek remains impaired from excessive nutrient loading. Although the number of samples is very limited, in addition to Zion Creek, nearly every other station where data was collected within the last few years (including the Pewaukee River and Coco Creek) showed at least one sample where total phosphorus concentrations exceeded the State's applicable water quality criterion of 0.075 mg/l (see Figure 52). In contrast, Pewaukee Lake has not exceeded the phosphorus standard since sewers were installed around the lake in the late 1970s.

The incidences of elevated concentrations of total phosphorus at stations throughout the Pewaukee River indicate that phosphorus is a problem and an important water quality issue throughout this watershed.

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[41]*On April 14, 2009,* 2009 Wisconsin Act 9 *created Section 94.643 of the* Wisconsin Statutes *relating to restrictions on the use and sale of fertilizer containing phosphorus in urban areas throughout the State of Wisconsin.*

[42]*Section 100.28 of the* Wisconsin Statutes *bans the sale of cleaning agents for nonhousehold dishwashing machines and medical and surgical equipment that contain more than 8.7 percent phosphorus by weight. This statute also bans the sale of other cleaning agents containing more than 0.5 percent phosphorus by weight. Cleaning agents for industrial processes and cleansing dairy equipment are specifically exempted from these restrictions.*

Nitrogen

A variety of nitrogen compounds that act as nutrients for plants and algae are present in surface waters. Typically, only a small number of forms of nitrogen are examined and reported in water quality sampling. Total nitrogen includes all of the nitrogen in dissolved or particulate form in the water. It does not include nitrogen gas, which is not usable as a nutrient by most organisms. Total nitrogen is a composite of several different compounds which vary in their availability to algae and aquatic plants and in their toxicity to aquatic organisms. Common inorganic constituents of total nitrogen include ammonia, nitrate, and nitrite. These are the forms that most commonly support algal and plant growth. Total nitrogen also includes a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins that commonly occur in natural and polluted waters. These compounds are reported as organic nitrogen.

Nitrogen compounds can be contributed to waterbodies from a variety of point and nonpoint sources. In urban settings, nitrogen compounds from lawn fertilizers and other sources may be discharged through storm sewer systems and direct runoff into streams. Cross-connections between sanitary and storm sewer systems, illicit connections to storm sewer systems, and decaying sanitary and storm sewer infrastructure may contribute sanitary wastewater to waterbodies through discharges from storm sewer systems. In rural settings, nitrogen compounds from chemical fertilizers and animal manure may be contributed through discharges from drain tiles or direct runoff into waterbodies. Nitrogen compounds may also be contributed by poorly maintained or failing onsite wastewater treatment systems.

Occasionally, nitrogen acts as the limiting nutrient for algal and plant growth in freshwater systems. This usually occurs when concentrations of phosphorus are very high.

Historical comparison of nitrate-nitrite concentrations from 1964 through 1975 indicate that concentrations were greater and more variable within the Pewaukee River and Fox River than in Pewaukee Lake. These historical concentrations at both locations consistently exceeded 0.5 mg/l. Historical nitrate-nitrite concentrations were also elevated in Pewaukee Lake, mostly likely due to septic tank effluent inputs that contained high amounts of nutrients, but they never exceeded a concentration 0.5 mg/l. More recent nitrate-nitrite concentrations within the Lake are less than about 0.25 mg/l. Although there are fewer stations and samples of nitrogen data than collected for total phosphorus, the two downstream stations on the Pewaukee River indicate that there are elevated concentrations of nitrate-nitrite nitrogen very similar to the increased concentrations of total phosphorus.

The incidences of elevated concentrations of nitrate-nitrite nitrogen in the Pewaukee River are indicative that nitrogen is a problem and an important water quality issue in this watershed.

Water Temperature

Table 18 and Map 25 describe the site locations, river miles, and collection dates for temperature data used to characterize trends in the Pewaukee River watershed from 2008 through 2011. SEWRPC staff deployed continuous monitoring devices at 23 locations to measure water temperatures and one additional site to monitor air temperatures from 2010 through 2011. These devices were programmed to record temperature in hourly increments. Two stations on the Coco Creek system had additional years of continuous hourly monitoring data. The Coco Creek station at RM 1.04 had additional data from years 2008 through 2010, the Unnamed Tributary to Coco Creek station at RM 0.19 had additional data from year 2010.

Air temperatures are major determinants of water temperatures, which can be observed in the daily fluctuations that show the increase in temperature during the day and cooling at night (see Figure 53). Figure 53 also shows that the daily fluctuations and maximum temperatures overall are reduced in sections of stream with increased groundwater discharge, such as in reaches of Coco Creek compared to sites within the Pewaukee River or other tributaries. This series of plots also shows that water temperatures at a particular site are dependent upon both the current and preceding daily air temperature conditions. So, as daily temperatures increase over time, water temperatures within the streams tend to cumulatively get warmer.

Table 18

WATER AND AIR TEMPERATURE SAMPLING SITES WITHIN THE PEWAUKEE RIVER WATERSHED: 2008-2012

Stream	Stream Reach (see Map 20)	Location	River Mile (see Map 25)	Period of Record
Fox River	Fox River	Fox River at Pewaukee confluence	- -	10/15/2010 to 05/07/2012
Pewaukee River	Pewaukee 1	Pewaukee River upstream of confluence with the Fox River	0.05	10/15/2010 to 06/05/2012
		Downstream of STH 164	1.69	10/15/2010 to 06/05/2012
	Pewaukee 2	Downstream of CTH M (Wisconsin Avenue)	5.12	10/15/2010 to 06/05/2012
	Pewaukee 3	Upstream of Clark Street	6.34	10/15/2010 to 06/05/2012
		Downstream of Capitol Drive	6.68	10/15/2010 to 06/05/2012
	Pewaukee 4	Upstream of STH 16	7.30	10/15/2010 to 06/05/2012
Highway JJ Tributary	CTH JJ Tributary	Downstream of CTH JJ	0.54	10/15/2010 to 06/05/2012
Pewaukee Lake Outlet	Pewaukee Lake outlet	150 feet downstream of dam outlet	0.09	10/15/2010 to 03/20/2012
Coco Creek	Coco Creek	Bristlecone Pines Golf Course	4.03	10/15/2010 to 06/05/2012
		Downstream of CTH JK (Lisbon Avenue)	3.20	10/15/2010 to 060/5/2012
		Downstream of CTH KE	2.42	10/15/2010 to 06/05/2012
		Upstream of Capitol Drive	0.54	10/15/2010 to 06/05/2012
		Upstream of Yench Road	1.00	05/23/2008 to 10/13/2010 and 10/15/2010 to 06/05/2012[a]
Zion Creek	Zion Creek	At Oakton Avenue	0.15	10/15/2010 to 06/05/2012
Unnamed Tributary	Coco Creek 1	Downstream of STH 16	0.03	10/15/2010 to 06/05/2012
Unnamed Tributary	Coco Creek 2	Downstream of CTH JJ (Capitol Drive)	0.20	05/01/2010 to 1013/2010 and 10/15/2010 to 06/05/2012[b]
		Upstream of CTH JJ (Capitol Drive)	0.36	10/15/2010 to 06/05/2012
Air Temperature Logger	Labeled on Map	Pewaukee Lake Sanitary District	- -	10/15/2010 to 06/05/2012

[a]*Temperature data was collected at this site by Wisconsin Department of Natural Resources from May 23, 2008 to October 13, 2010, and by SEWRPC from October 15, 2010 to June 5, 2012.*

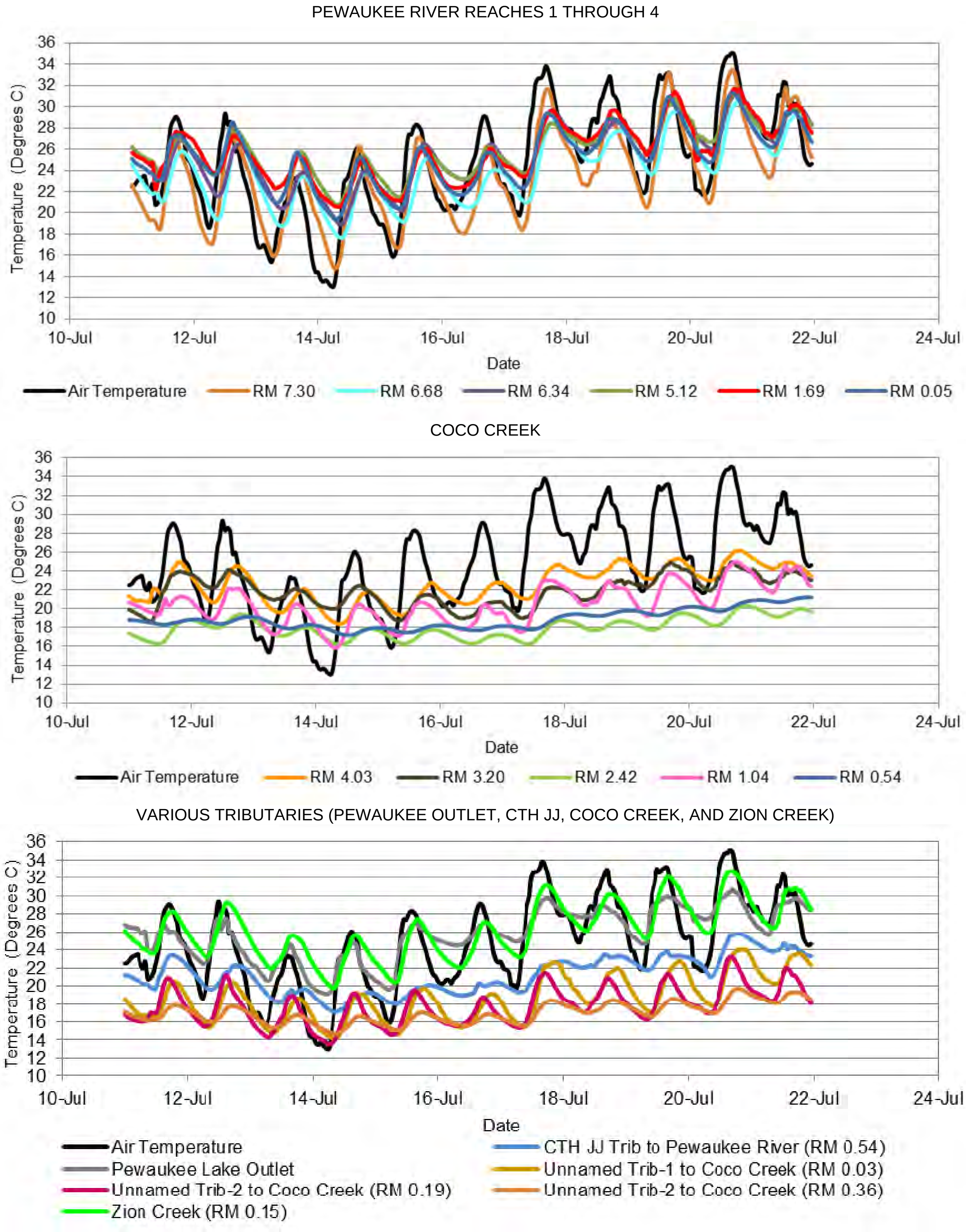
[b]*Temperature data was collected at this site by Wisconsin Department of Natural Resources from May 1, 2010 to October 13, 2010 and by SEWRPC from October 15, 2010 to June 5, 2012.*

Source: Wisconsin Department of Natural Resources, Water Action Volunteers, and SEWRPC.

In general, reaches within the Pewaukee River, Zion Creek, and the Pewaukee Lake Outlet contained the warmest sites. In contrast, Coco Creek and CTH JJ Tributary contained the coldest sites. Although the sites on the Pewaukee River are very similar in minimum and maximum daily temperatures, there are important and subtle changes from upstream to downstream. For example, the most upstream site at RM 7.3 achieves some of the warmest daily maximum temperatures during the day, but this site also cools down to the coldest minimum temperatures at night. This indicates that this site is receiving some groundwater inputs, but the small volumes of water in this portion of the stream are susceptible to heating during the day. Further evidence to support this observation is that the Water Action Volunteer site at Lindsey Road that is about a mile upstream of RM 7.3 was never recorded to exceed 26.8 degrees during summers from 2006 through 2012. This indicates that this site is

Figure 53

HOURLY WATER AND AIR TEMPERATURES AMONG SITES AND REACHES WITHIN THE PEWAUKEE RIVER WATERSHED: JULY 12-22, 2011



Source: SEWRPC.

receiving groundwater inputs. There is also a significant reduction in the daily maximum temperatures between RM 7.3 and RM 6.68, and there is a significant warming between RM 6.68 to RM 6.34. This warming can be due to number of factors that include inputs from the Pewaukee Lake Outlet channel, thermal heating from the ponding/backwater area at the confluence of the Pewaukee River and the Pewaukee Lake Outlet, and a fairly open canopy and exposure to thermal heating in the downtown area of the Village of Pewaukee. The area from RM 6.34 to RM 5.12 seems to vary between increasing and decreasing maximum daily temperatures. Between RM 5.12 and RM 1.69 there is a consistent increase in maximum daily temperatures. The decreased slopes and slower water velocities in this wetland complex and an open canopy combine to create conditions for increased heating in the summer. Between RM 1.69 and RM 0.05 maximum daily temperatures were variable, sometimes increasing and sometimes decreasing.

Due to the inability to recover the continuously recording temperature data logger at Meadowbrook Creek, it is not possible to compare the daily maximum temperatures of this system to other sites in the watershed. However, the samples collected by the Water Action Volunteers on this system indicate that the summer average temperature from 2006 through 2012 was 22.4 degrees Celsius and the maximum temperature recorded at Meadowbrook Creek was 28.5 degrees Celsius. This would indicate that this system is likely receiving groundwater input that is keeping the temperatures reduced in the Creek. This is supported by the cool headwater fishery classification (see the Fisheries Classification section below). More detailed temperature information would need to be collected to verify this.

As previously mentioned, Coco Creek is the only designated coldwater fishery within the Pewaukee River watershed. The remaining streams within the watershed are classified as warmwater streams (see Map 16 in Chapter III of this report). Based upon the acute water quality criteria for temperature, coldwater streams should not exceed a daily maximum of 22.2 degrees Celsius in June or 22.8 degrees Celsius in July or August. The stations at RM 0.54 and RM 2.42 on the mainstem of Coco Creek and the Unnamed Tributary-2 at RM 0.36 meet these criteria 100 percent of the time. The remaining tributary sites to Coco Creek at RM 1.04 generally meet the coldwater criteria for the summer months more than 95 percent of the time. In addition, the mainstem site on Coco Creek at RM 1.04 met the coldwater criteria for the summer months between 75 percent to more than 95 percent of the time over a four-year period from 2008 through 2011. In contrast, the two most upstream sites on the mainstem of Coco Creek at RM 3.20 and RM 4.03 only meet the summer month coldwater criteria about 50 percent of the time.

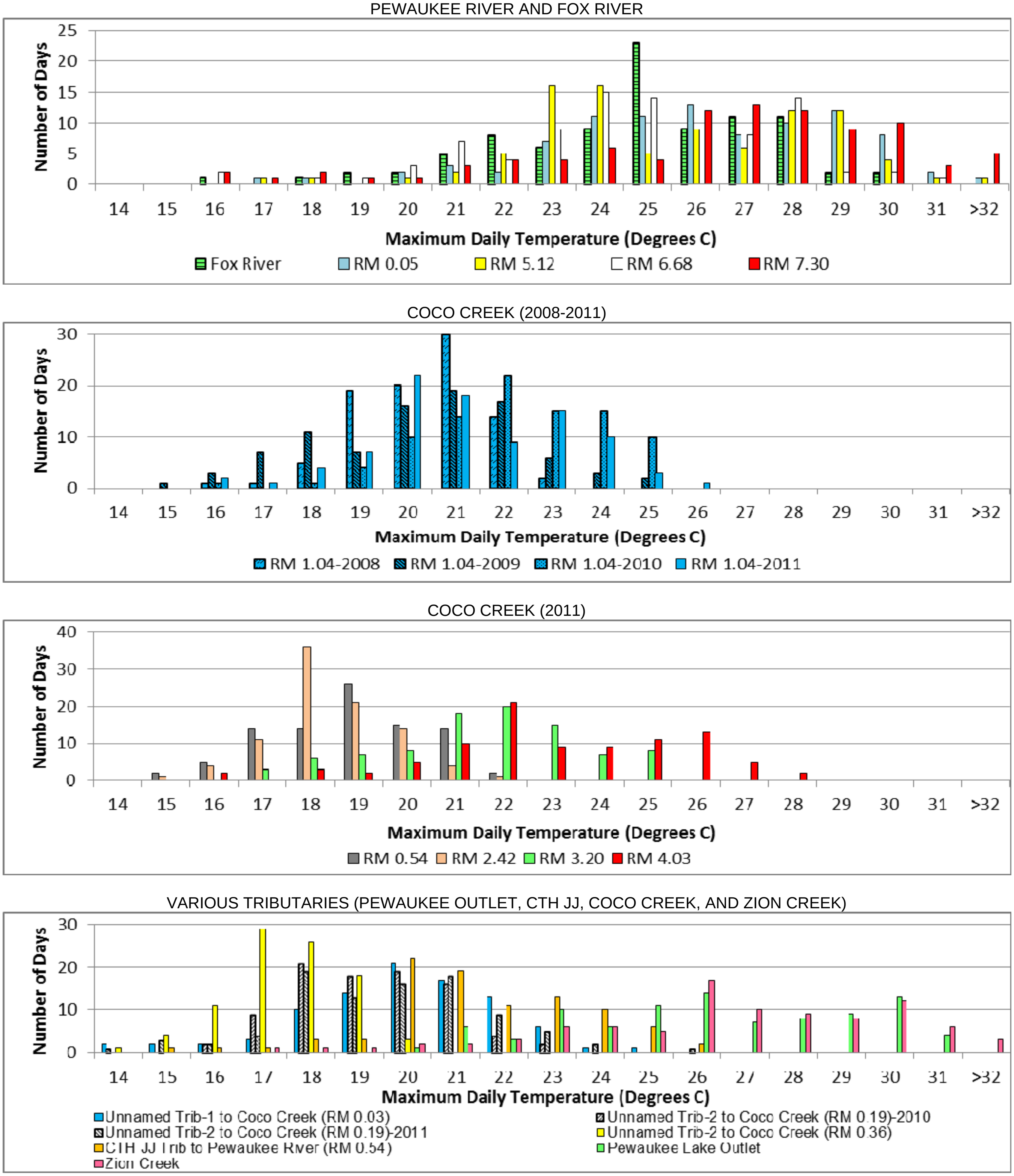
Brook trout and brown trout were recently found to not occur within streams where summer maximum daily water temperatures exceeded 27.6ºC,[43] which is also consistent with the fisheries survey findings summarized below. Based upon these findings it is possible to assess the thermal trout tolerance for each site and year as shown in Figure 54, which indicates that every site and year sampled on the mainstem and tributary of Coco Creek can be considered as “trout” streams likely capable of supporting trout (i.e., water temperatures are within thermal tolerance ranges for trout), except for the most upstream site at RM 4.03.

The acute water quality criteria for temperature in warmwater streams should not exceed a daily maximum of 28.9 degrees Celsius in June or August or 29.4 degrees Celsius in July. All stations sampled within the mainstem of the Pewaukee River are generally meeting these summer month warmwater criteria between 80 percent and more than 95 percent of the timeThe Pewaukee Lake Outlet and Zion Creek are meeting the criteria about 75 percent of the time. Most surprising, not only is the CTH JJ Tributary meeting the warmwater criteria 100 percent of the time, this site never exceeded 26 degrees Celsius, which means it is technically capable of supporting a coldwater trout fishery, as described above.

[43]*K.E. Wehrly, L. Wang, and M. Mitro, “Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation,”* Transactions of the American Fisheries Society, *Volume 139, 2007, pages 365-374.*

Figure 54

SUMMER MAXIMUM DAILY WATER TEMPERATURES AMONG SAMPLING SITES WITHIN THE PEWAUKEE RIVER WATERSHED: 2008-2011



Source: SEWRPC.

Water temperature data collected indicated that Coco Creek would be capable of supporting a sustainable salmonid fishery. As summarized within the fisheries section below, brook trout are stocked within the Pewaukee River annually, but this species has not been documented to be viable. No brook trout have shown to be collected or successfully reproduced within this subwatershed. It is possible that the temperatures greater than 20.0 and 25.0 ºC within this system are causing suboptimal growth and/or stress that can lead to decreased energy reserves to actually reproduce.[44] Temperature may also be inappropriate to induce spawning and/or for development of eggs after they are deposited into the stream channel. However, spawning and/or overwinter habitats may also be limiting. Before such relationships could be definitively established, they would have to be evaluated by assessments of brook trout population abundance and growth, integrated with more temperature and habitat monitoring.

Water temperature data collected also indicated that the Pewaukee River and associated tributaries would be likely to support a sustainable warmwater fishery. However, nearly all of the sites within the Pewaukee River are exceeding the daily maximum acute warmwater criteria for some portion of the summer months, which indicates that temperatures are likely impacting the quality of the fishery in this river. This seems to be consistent the general limited abundance and diversity of fishes in this system as discussed below.

Other Considerations

Urban development may increase the inputs of complex chemical mixtures typically found in runoff from impervious surfaces. These mixtures may include pesticides, nutrients, and hydrocarbons that are known to have harmful biological effects to aquatic organisms. Although limited data exists for nutrients, they were shown to be impacting water quality in the Pewaukee River and tributaries. So, it is also very likely that other pollutants, including pesticides and other hydrocarbons, are also loading into these streams, although no sampling data exists for these constituents.

Stream crossings act as direct conduits for nonpoint source pollution, especially in terms of the road runoff. Stream crossings also bisect riparian corridors, fragmenting the continuity of the corridor, which has also been shown to be associated with decreased water quality and biological diversity within watersheds. There are many crossings throughout the Pewaukee River, particularly in reaches 1, 3, and 5, as well as the CTH JJ Tributary (see Map 20). Consequently, the water quality impacts of roadways on the stream as a result of direct inflow from road crossings and stormwater inflows from tributary areas can be inferred. For example, stormwater runoff is likely to be a major source of chloride;[45] chloride concentrations have been shown to be increasing in every lake sampled throughout the Southeastern Wisconsin Region, as well as within Pewaukee Lake.[46]

Agricultural chemicals applied to fields can move to streams and groundwater. Other sources of chemicals include irrigation water or waste from animal feeding operations. Nutrients, primarily nitrogen and phosphorus, in streams can exceed natural levels when fertilizer infiltrates through the soil, reaching the groundwater that provides stream baseflow, or runs off the land surface. Excess nutrients can cause nuisance growth of algae and aquatic plants, which when they die and decompose can lead to low oxygen levels downstream. Pesticides are applied to control insect damage and growth of weeds or fungus, but can also harm aquatic organisms when they run off fields. The unnamed tributary to Coco Creek and the upper reaches of the Pewaukee River show elevated levels of nutrients impacting water quality in these agriculture-dominated areas of the watershed. So, it is also very likely that other pollutants, including pesticides and other chemicals related to agricultural management practices, are also loading into these streams, but no data exists for these constituents.

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[44]*George Becker,* Fishes of Wisconsin*, The University of Wisconsin Press, 1983.*

[45]*U.S. Environmental Protection Agency, "What You Should Know About Safe Winter Roads and the Environment," EPA 901-F-05-020, September 2005.*

[46]*SEWRPC Technical Report No. 39,* Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds, *November 2007.*

Existing Stormwater Management Systems

Installation and maintenance of appropriate stormwater best management practices (BMPs) are an important part of maintaining good water quality within the Pewaukee River watershed. Because they have been implemented over time, not all BMPs in the watershed were designed and constructed based on current technical standards. New BMPs in the watershed are designed based on current technical standards for stormwater management that include criteria intended to protect water quality. Older stormwater BMPs could have increased functionality for water quality improvement if modifications were made to bring them up to the current standards. Also, BMPs that promote infiltration of precipitation are important in the watershed for maintenance of stream baseflows and coldwater stream characteristics.

Research has shown that it is difficult to meet water quality requirements, particularly temperature criteria, with the current storm water control measure technologies.[47] Runoff from parking lots, particularly during summer storms, injects surges of hot water into receiving ponds and/or streams, which leads to temperature criteria exceedances.[48] Thus it is important to consider other factors in stormwater temperature management, such as the effect of parking lot composition (i.e., material) and layout on runoff temperatures, which could allow designers to reduce these impacts. For example, light-colored pavements can significantly reduce stormwater runoff temperatures compared to traditional black asphalt pavement, as well as shaded versus unshaded parking lots. Additionally, it is important to consider infiltration technologies when designing stormwater control measures such as bioretention, filter strips, sand filters, and permeable pavement, because infiltration greatly reduces the thermal load to streams.[49] It is important to note that paving decreases shallow groundwater flows, which both cold and warm water stream systems rely upon to maintain their baseflow temperatures. Hence, parking lots within the Pewaukee River watershed are likely contributing to increased runoff temperatures and resultant thermal loading to the River. This can be mitigated via tree placement and other green technologies to reduce this loading. In particular, several parking lots directly adjacent to the Pewaukee River near the Oakton Bridge crossing within the downtown area of the Village of Pewaukee are good candidates to reduce stormwater runoff and reduce thermal loading into the River.

In addition, some of the parking lots in the Pewaukee River watershed are constructed with asphalt, which requires sealants to be applied periodically in order to increase its longevity and enhance its appearance. However, recent research has determined that cold tar-based pavement sealants contain extremely high levels of polycyclic aromatic hydrocarbons (PAHs) compared to asphalt-based pavement sealants and other urban PAH sources such as vehicle emissions, used motor oil, and tire particles.[50] PAHs are an environmental health concern because several are probable human carcinogens and they are toxic to fish and other aquatic life. Since cold tar-based paved sealants can be a major source of PAHs to waterways in urban-dominated watersheds, these point source contaminants can be greatly reduced by using less toxic alternative sealants.

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[47]*Matthew P. Jones, William F. Hunt, and Ryan J. Winston, 2012, "Effect of Urban Catchment Composition on Runoff Temperature," Technical Note,* Journal of Environmental Engineering*, December, 1231-1236.*

[48]*Erich T. Hester and Kalen S. Bauman, 2012, "Stream and Retention Pond Thermal Response to Heated Summer Runoff from Urban Impervious Surfaces,"* Journal of the American Water Resources Association, *49(2): 328-342.*

[49]*Matthew P. Jones, et. al., 2012,* op. cit.

[50]*Peter C. Van Metre and Barbara J. Mahler, "PAH Concentrations in Lake Sediment Decline Following Ban on Coal-Tar-Based Pavement Sealants in Austin," Texas,* Environ. Sci. Technol.*, Publication Date (Web): June 16, 2014; Peter C. Van Metre and Barbara J. Mahler, "Contribution of PAHs from coal–tar pavement sealcoat and other sources to 40 U.S. lakes,"* Science of the Total Environment *409 (2010) 334–344; and, Barbara J. Mahler, Peter C. Van Metre, Thomas J. Bashara, Jennifer T. Wilson, and David A. Johns, "Parking Lot Sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons,"* Environ. Sci. Technol. *2005, 39, 5560-5566.*

Figure 55

EXAMPLES OF THE BENEFITS OF CONVERTING STORMWATER DETENTION BASINS WITH NATIVE VEGETATION IN THE PEWAUKEE RIVER WATERSHED: 2012

Source: Charlie Shong.

A variety of stormwater management features are located throughout the Pewaukee River watershed in the form of grassed swales, storm sewer inlets and outlets, curb and gutters, storm sewers, wet and dry detention basins, and rain gardens as shown on Map 18 in Chapter III of this report. It was determined that nearly 200 dry and wet detention basins have been constructed throughout the Pewaukee River watershed. These structures attract wildlife and they could be managed to improve or expand habitat for wildlife within the watershed. In addition, converting these mowed detention basins into native prairie and wetland natural areas can also improve water quality by discouraging geese and their associated feces from congregating around the edge of the water and eliminating the need to fertilize or water these native plants that are adapted to Wisconsin climate conditions (see Figure 55).

Figure 56

HIGH WATER DISCHARGE ON THE PEWAUKEE RIVER: APRIL 15, 2013

Source: Photos by Greg Shell.

In terms of habitat potential to improve wildlife, location is very important, particularly in urbanized river systems, such as the Pewaukee. Therefore, the stormwater detention basins directly adjacent to or within the riparian corridor have the greatest potential for access or use by organisms that need to migrate between the river and the detention basin or the lands within the corridor and the detention basin, such as frogs or salamanders. Hence, any detention basin that is not separated by a roadway cutting off or limiting safe access to the River and its riparian corridor could be managed to improve habitat and water quality by conversion from a traditional mowed lawn to native wetland and prairie natural areas.

Since all of these stormwater detention basins drain directly to the surface waters of the Pewaukee River system, any reduction in fertilizer (i.e., nutrient) and herbicide applications would be beneficial for both water quality and wildlife habitat.

SEWRPC staff found several pipes of various materials, including polyvinyl chloride (PVC), corrugated metal, and concrete, that were not previously identified and that discharge directly to the Pewaukee River. These structures were not included in the minor and major outfalls database provided by the municipal separate storm sewer system (MS4) communities within the Pewaukee River watershed as shown on Map 18 in Chapter III of this report. It is possible that some of these structures were forgotten. It is also possible that some of these structures were disconnected or are no longer functioning.

Flooding has been reported to be an important issue within the Pewaukee River watershed. Residents are concerned that this issue may become worse as agricultural lands are converted to urban land uses. As shown in Figure 56, even a modest spring flows in 2013 demonstrate why residents become concerned about potential flooding events on the Pewaukee River.

Summary

In summary, higher air temperatures lead to higher water temperatures, which have a major influence on fish and other ectothermic organisms in terms of their physiology, growth, and development, including reproduction in both lakes and streams within the Pewaukee River watershed.[51] High air temperatures, which warm water and land surfaces, when combined with periods of decreased precipitation during the summer, can also negatively affect surface water dissolved oxygen concentrations. Hence, low dissolved oxygen concentrations are a major

[51]*W.M. Tonn, and J.J. Magnuson, "Patterns in the Species Composition and Richness of Fish Assemblages in Northern Wisconsin Lakes,"* Ecology*, Volume 63, Number 4, 1982, pages 1149-1166; and G.W. Becker,* Fishes of Wisconsin, *University of Wisconsin Press, Madison, 1983.*

concern during the summer months, because even short periods of time where concentrations fall below 5.0 mg/l can cause significant decreases in the abundance and diversity of the aquatic organisms in lakes and streams. Figures 13 through 15 in Chapter II of this report show that the average temperature and precipitation can be highly variable from season to season and year to year, and both mean temperature and precipitation have been increasing. This is consistent with historical weather changes, as well as other indicators of warmer conditions, such as decreasing ice cover duration on lakes throughout the State of Wisconsin.[52] Fortunately, the Pewaukee River's discharge is supplemented by groundwater flow, which helps to mitigate temperature in critical summer periods, but this does not seem to be adequate on its own. As summarized above, discharge within the Pewaukee River watershed can be limiting and is highly dependent upon precipitation and groundwater recharge, which emphasizes that this system is vulnerable and that it will be important to protect the quality and quantity of groundwater as future development occurs in this subwatershed.

In addition, it is also important to minimize the human stressors related to land development that have the potential to negatively affect stream hydrology and water temperatures within the Pewaukee River watershed in both agricultural and urban areas. In particular, reductions in groundwater recharge may shift the thermal balance between warmer surface waters and cooler groundwater toward warmer conditions and reduce groundwater availability in general. Such a shift would have implications for the maintenance of warmwater and coldwater fish and aquatic communities in this system. While many of the factors controlling the quality of the aquatic environment in the Pewaukee River basin are limited by natural phenomena, human actions—such as maintaining or enhancing buffer widths, limiting road crossings, implementing appropriate stormwater management practices, limiting the spread of nonnative exotic invasive species, and protecting groundwater recharge—can and should be considered as critical elements in preserving and protecting the quality of this system.

Riparian Corridor Conditions

Healthy riparian corridors help to protect water quality, groundwater, fisheries and wildlife, and ecological resilience to invasive species, as well as reduce potential flooding of structures and harmful effects of climate change (see Appendix G).[53] The health of riparian corridors is largely dependent upon width (size) and continuity. Therefore, efforts to protect and expand the remaining riparian corridor width and continuity are the foundation for protecting and improving the fishery and recreation within the Pewaukee River watershed.

The provision of buffer strips along waterways represents an important intervention that addresses anthropogenic sources of contaminants. Even relatively small buffer strips provide a degree of environmental benefit, as suggested in Table 19 and Figure 57 and further discussed in Appendix C.[54] The Wisconsin Buffer Initiative (WBI) further developed two key concepts that are relevant to this plan: 1) riparian buffers are very effective in protecting water resources and 2) riparian buffers need to be a part of a larger conservation system to be most

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[52] *J.J. Magnuson, J. Krohelski, K. Kunkel, and D. Robertson, "Wisconsin's Waters and Climate: Historical Changes and Possible Futures,"* In Wisconsin's Waters: A Confluence of Perspectives, Transactions of the Wisconsin Academy of Sciences, Arts and Letters, *Volume 90, 2003.*

[53] *N.E. Seavy, et al., "Why Climate Change Make Riparian Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration, *Volume 27, Number 3, September, 2009, pages 330-338; "Association of State Floodplain Managers, Natural and Beneficial Floodplain Functions: Floodplain Management—More Than Flood Loss Reduction, 2008,"* www.floods.org/NewUrgent/Other.asp.

[54] *Data were drawn from A. Desbonnet, P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone – A Summary Review and Bibliography," CRC Technical Report No. 2064. Coastal Resources Center, University of Rhode Island, 1994.*

Table 19

EFFECT OF BUFFER WIDTH ON CONTAMINANT REMOVAL

Buffer Width Categories (feet)	Contaminant Removal (percent)[a]				
	Sediment	Total Suspended Sediment	Nitrogen	Phosphorus	Nitrate-Nitrogen
1.5 to 25					
Mean	75	66	55	48	27
Range	37-91	31-87	0-95	2-99	0-68
Number of Studies	7	4	7	10	5
25 to 50					
Mean	78	65	48	49	23
Range	- -	27-95	7-96	6-99	4-46
Number of Studies	1	6	10	10	4
50 to 75					
Mean	51	- -	79	49	60
Range	45-90	- -	62-97	0-99	- -
Number of Studies	5	- -	2	2	1
Greater than 75					
Mean	89	73	80	75	62
Range	55-99	23-97	31-99	29-99	- -
Number of Studies	6	9	8	7	1

[a]*The percent contaminant reductions in this table are limited to surface runoff concentrations.*

Source: University of Rhode Island Sea Grant Program.

effective.[55] However, it is important to note that the WBI limited its assessment and recommendations solely to the protection of water quality, and did not consider the additional values and benefits of riparian buffers. Research clearly shows that riparian buffers can have many potential benefits, such as flood control, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, and water temperature moderation, among others (see Appendix C). However, the nature of the benefits and the extent to which the benefits are achieved is very site-specific. Consequently, the ranges in buffer width for each of the buffer functions shown in Figure 57 are large. Buffer widths should be based on desired functions, as well as site conditions. For example, based upon a number of studies of sediment removal, buffer widths ranging from about 25 to nearly 200 feet achieved removal efficiencies of between 33 and 92 percent, depending upon local site differences such as soil type, slope, vegetation, contributing area size, and influent concentrations, to name a few. Figure 57 shows that for any particular buffer width, for example 75 feet, the buffer can provide multiple benefits, ranging from water temperature moderation to enhancement of wildlife species diversity. Benefits not shown in the figure include bank stabilization, which is an important concept in utilizing buffers for habitat protection (see Appendix C).

While it is clear from the literature that wider buffers can provide a greater range of values for aquatic systems, the need to balance human access and use with the environmental benefits to be achieved suggests that a 75-foot-wide riparian buffer provides a minimum width necessary to contribute to good water quality and a healthy aquatic ecosystem. In general, most pollutants are removed within a 75-foot buffer width. However, from an

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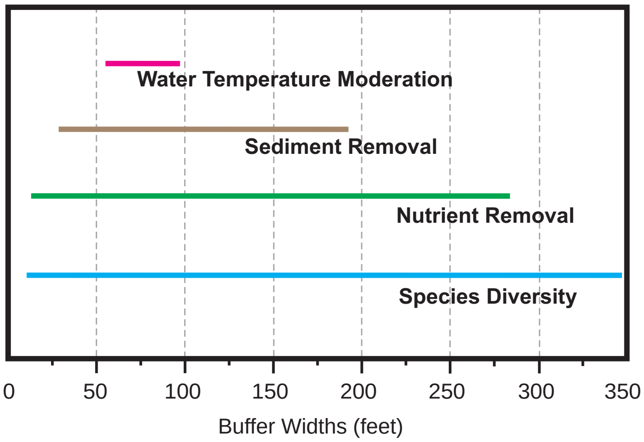
[55]*University of Wisconsin-Madison, College of Agricultural and Life Sciences,* The Wisconsin Buffer Initiative, *December 2005.*

Figure 57

RANGE OF BUFFER WIDTHS FOR PROVIDING SPECIFIC BUFFER FUNCTIONS



NOTE: Site-specific evaluations are required to determine the need for buffers and specific buffer characteristics.

Source: Adapted from A. J. Castelle and others, "Wetland and Stream Buffer Size Requirements-A Review," Journal of Environmental Quality, *Vol. 23.*

ecological point of view, 75-foot-wide buffers are inadequate for the protection and preservation of groundwater recharge or wildlife species. Riparian buffer strips greater than 75 feet in width provide significant additional physical protection of streamcourses, owing to their function in intercepting sediment and other contaminants mobilized from the land surface as a result of natural and anthropogenic activities. These wider buffers also serve to sustain groundwater recharge and discharge relationships, and biological benefit, as a result of the habitat available within the shoreland and littoral areas associated with streams and lakes.[56]

For example, the highest quality environmental corridors, natural areas, and vegetation communities are located within and adjacent to the riparian buffer network throughout the Pewaukee River watershed as shown on Map 26. In other words, the riparian buffers are a vital conservation tool that provides the connectivity among landscapes to improve the viability of wildlife populations within the habitats comprising the primary and secondary environmental corridors and isolated natural resource areas.[57] The vegetation community quality for 28 sites identified within the Pewaukee River watershed based upon the Floristic Quality Index (FQI),[58] a measure of plant species diversity and native community composition. This evaluation generally indicates that vegetation community quality range from poor to excellent, as shown on Map 26. The highest FQI ratings (in the excellent range) are associated with the mouths of Audley Creek and a small, unnamed tributary west of Coco Creek directly connected to Pewaukee Lake. Most of the other sites range from poor to good and it is important to note that all of these vegetation communities provide necessary habitat for a variety of wildlife.

As previously identified, healthy and sustained aquatic and terrestrial wildlife diversity is dependent upon adequate riparian buffer width and habitat diversity. Specifically, recent research has found that the protection of wildlife species is determined by the preservation or protection of core habitat within riparian buffers ranging from minimum 400-foot- to optimal 900-foot-wide buffers or greater as summarized in Appendix C. These buffer areas are essential for supporting healthy populations of multiple groups of organisms, including birds, amphibians, mammals, reptiles, and insects and their various life stages. For example, some species among birds, amphibians, turtles, snakes, and frogs have been found to need as much as 2,300 feet, 1,500 feet, 3,700 feet, 2,300 feet, and 1,900 feet buffer widths, respectively, for at least part of their life histories. Hence, preservation of

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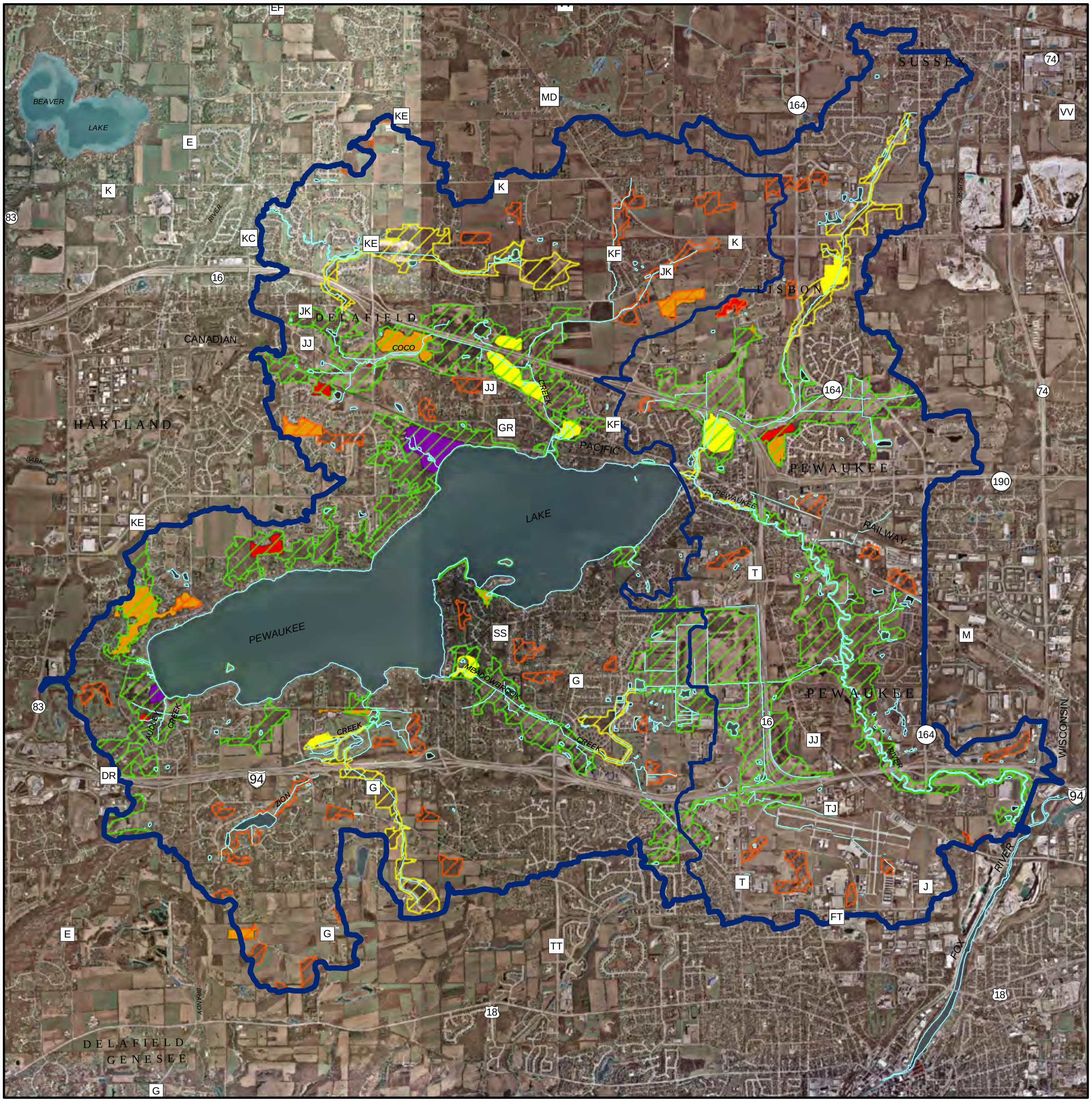
[56]*See, for example, Brian M. Weigel, Edward E. Emmons, Jana S. Stewart, and Roger Bannerman, " Buffer Width and Continuity for Preserving Stream Health in Agricultural Landscapes,"* Wisconsin Department of Natural Resources Research and Management Findings, *Issue 56, December 2005.*

[57]*Paul Beier and Reed F. Noss, "Do Habitat Corridors Provide Connectivity?,"* Conservation Biology, *Volume 12, Number 6, December 1998.*

[58]*T. Bernthal,* Development of a Floristic Quality Assessment Methodology for Wisconsin, *Final report to the U.S. Environmental Protection Agency Region V, June 2003.*

Map 26

PLANT COMMUNITY CONDITIONS WITHIN THE PEWAUKEE RIVER WATERSHED: 2012



PLANT COMMUNITY FLORISTIC QUALITY INDEX (FQI)

≥50 EXCELLENT

40-49 VERY GOOD

30-39 GOOD

20-29 FAIR

10-19 POOR

PRIMARY ENVIRONMENTAL CORRIDOR

SECONDARY ENVIRONMENTAL CORRIDOR

ISOLATED NATURAL RESOURCE AREAS

SURFACE WATER

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

riparian buffers to widths of up to 1,000 feet or greater represents the optimal condition for the protection of wildlife in the Pewaukee River watershed.[59]

Map 27 also shows the major natural cover types both within and outside of the existing riparian buffers distributed throughout the Pewaukee River watershed. This inventory shows that the riparian buffers are comprised of a variety of wetland, shallow marsh, deep marsh, prairie, grassland, shrubs, and forest vegetation communities. Each of these habitats is necessary to support the life history requirements of multiple wildlife species. For example, amphibians and reptiles have been reported to utilize numerous habitat types that include seasonal (ephemeral) wetlands, permanent wetlands (lakes, ponds, and marshes), wet meadows, bogs, fens, small and large streams, springs and seeps, hardwood forest, coniferous forest, woodlands, savannahs, grasslands, and prairies.[60] Hence, it is this mosaic of habitats and the ability of organisms to travel between them at the correct times in their lives to survive, grow, and reproduce, which is essential to support an abundant and diverse wildlife community throughout this watershed.

The development patterns and infrastructure that humans create on the landscape lead to a number of obstructions that can limit both the availability of wildlife habitat as well as the ability for organisms to travel between habitats. These obstructions are primarily a result of roadways, railways, and buildings that fragment the natural landscape. Therefore, an effective management strategy to protect wildlife abundance and diversity in the Pewaukee River watershed would be to maximize critical linkages between habitat areas on the landscape, ensuring the ability of species to access these areas. Examples of critical linkages include the following:

- Water’s edge (lake, pond, river, wetland) to terrestrial landscapes (i.e., riparian buffer width);
- Water’s edge to water’s edge (e.g., river to ephemeral pond, lake to ephemeral pond, permanent pond to ephemeral pond); and
- Habitat complexes or embedded habitats-Wetland to upland (e.g., seep to prairie) and upland to upland (e.g., grassland to woodland).

In addition, connecting the SEC land and multiple INRAs throughout the Pewaukee River watershed to the larger PEC areas, as well as building and expanding upon the existing protected lands, represent a sound approach to enhance the corridor system and wildlife areas within the watershed.

Existing and Potential Riparian Buffers

Map 28 shows the current status of existing and potential riparian buffers at the 75-foot, 400-foot, and 1,000-foot widths along the Pewaukee River and its major tributary streams. Buffers on Map 28 were primarily developed from 2010 digital orthophotographs and the 2010 WDNR Wisconsin Wetland Inventory within the Pewaukee River watershed, as well as inventories of primary and secondary environmental corridors and isolated natural resource areas. Polygons were created using geographic information system (GIS) techniques to delineate contiguous natural lands (i.e., nonurban and nonagricultural lands) comprised of wetland, woodland, and other

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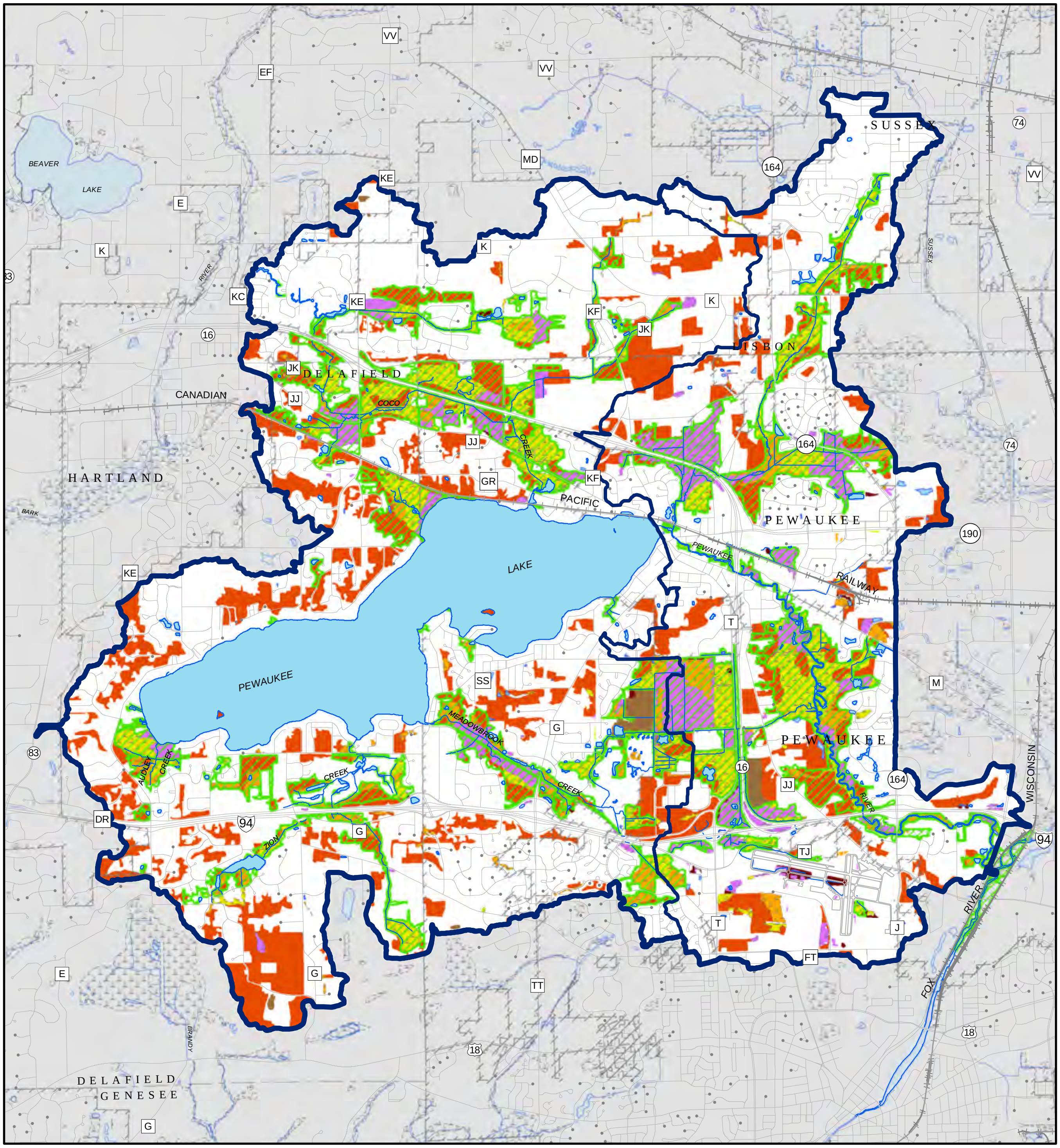
[59]*The shoreland zone is defined as extending 1,000 feet from the ordinary high water mark of lakes, ponds, and flowages and 300 feet from the ordinary high water mark of navigable streams, or to the outer limit of the floodplain, whichever is greater. To be consistent with this concept and to avoid confusion, the optimum buffer width for wildlife protection is defined as extending 1,000 feet from the ordinary high water mark on both sides of the lakes, ponds, and navigable streams in the watershed.*

[60]*Kingsbury, B.A. and J. Gibson (editors),* Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States, *Partners in Amphibian and Reptile Conservation Technical Publication HMG-1. 2nd Edition, 2012, 155 pages.*

Map 27

COVER TYPES AND RIPARIAN BUFFERS WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



WISCONSIN WETLAND INVENTORY CATEGORY:

- EMERGENT WET MEADOW
- FILLED/DRAINED WETLAND
- FLATS/UNVEGETATED WET SOIL
- FORESTED WETLAND
- SCRUB/SHRUB
- UPLAND
- RIPARIAN BUFFER
- SURFACE WATER
- STREAM
- WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY

N

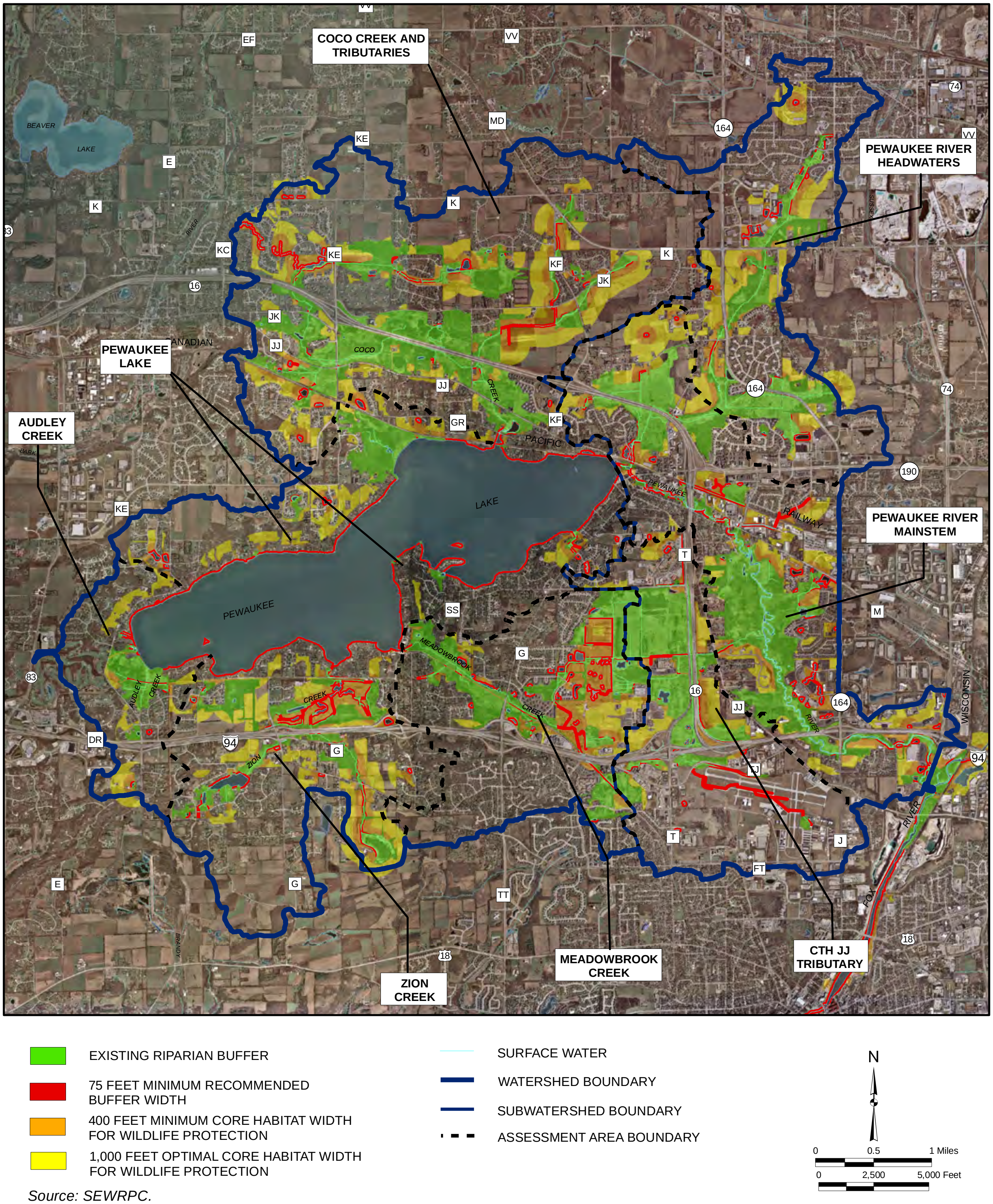
0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

Map 28

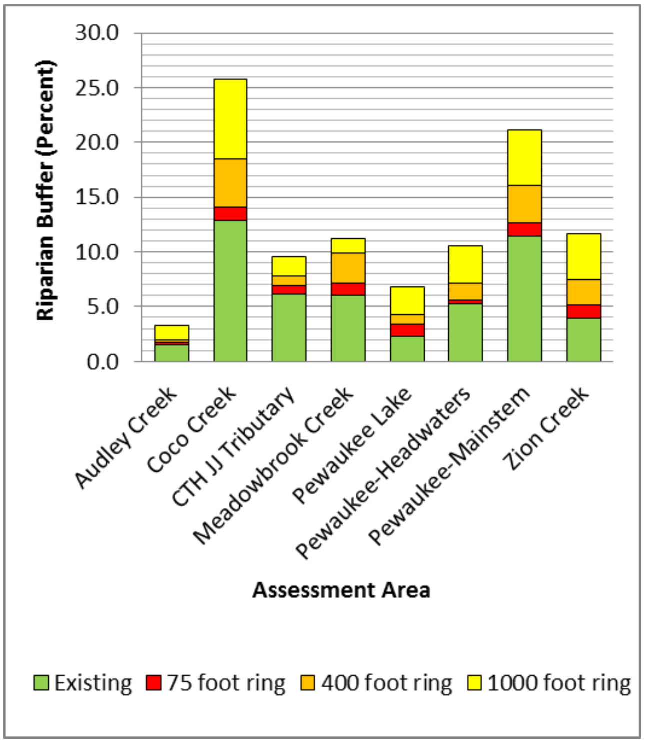
EXISTING RIPARIAN BUFFER AND POTENTIAL BUFFER ZONES WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



Source: SEWRPC.

Figure 58

PERCENT EXISTING AND POTENTIAL BUFFERS AMONG ASSESSMENT AREAS WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



Source: SEWRPC.

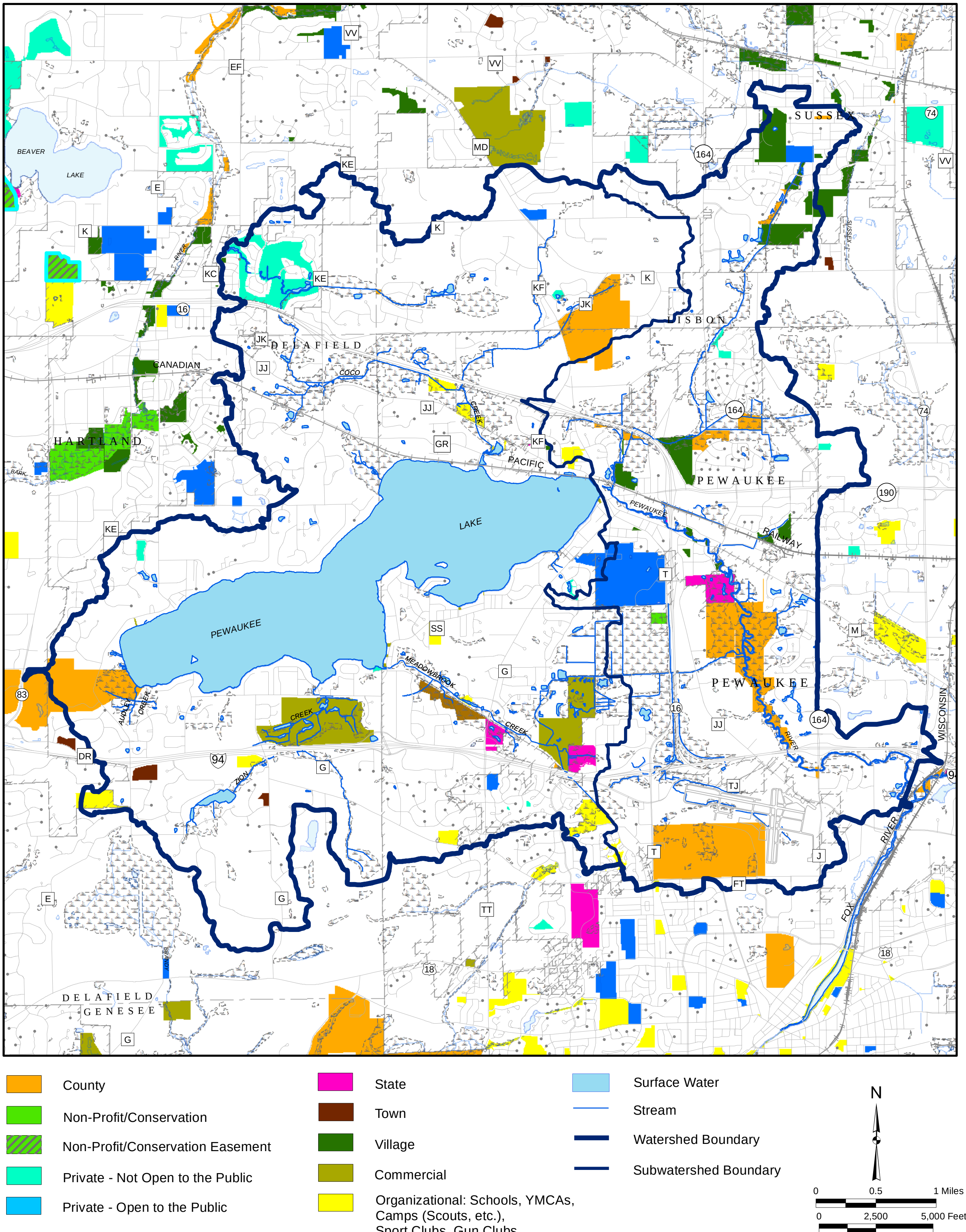
open lands adjacent to waterbodies. Those lands comprise a total of about 3,735 acres, or about 17 percent, of the entire Pewaukee River watershed area. Map 28 also shows the eight subwatershed assessment areas identified to help break down and analyze riparian buffers in the watershed, including Audley Creek, Coco Creek, CTH JJ Tributary, Meadowbrook Creek, Pewaukee Lake, Pewaukee River Headwaters, Pewaukee River Mainstem, and Zion Creek. As shown in Figure 58, the most extensive existing buffers were found within the Coco Creek and Pewaukee-Mainstem areas that comprised nearly one-half of all the buffers in the watershed, or approximately 26 and 23 percent of the total buffer area, respectively, as shown on Map 28. An additional approximately 35 percent of the total existing buffers is fairly equally distributed among the CTH JJ Tributary, Meadowbrook Creek, and Pewaukee-Headwaters assessment areas. The remaining 15 percent was located in the remaining three areas that include Zion Creek, Pewaukee Lake, and Audley Creek.

Comparison between the existing buffers versus the potential buffers at the 75-foot, 400-foot, and 1,000-foot widths throughout the Pewaukee River watershed indicates that the existing buffers contain some areas whose widths exceed 1,000 feet from the edge of the stream, which indicates they are providing significant water quality and wildlife protection (see Map 28). This is mostly due to the preponderance of wetlands abutting the streams. Nonetheless, a number of areas as shown on Map 28 have been encroachments into the riparian buffer to less than 400 feet (orange color) and 75 feet (red color) from the edge of the stream. In particular, the most significant encroachments into the riparian corridor within the 75-foot width are located around the perimeter of Pewaukee Lake and adjacent to Pewaukee River within the Village of Pewaukee. There are also several areas where the streams cross through agricultural land that also lacks riparian buffers greater than 75 feet in width. Based upon this analysis, Figure 58 shows that there is the potential to double the amount of riparian buffers throughout the watershed, adding about 3,811 acres. This also shows that the greatest potential to establish buffers exists within the Coco Creek, Pewaukee-Mainstem, and Zion Creek assessment areas, and there are opportunities to expand buffer protections in each of the remaining assessment areas.

Although the existing and potential buffers have been identified throughout the Pewaukee River watershed, it is important to recognize that some of these lands are more vulnerable to potential loss than others. For example, some of these buffer lands are protected through regulations and some are in some form of public ownership and already protected. Therefore, riparian buffer lands that are not within one of the following categories are considered to be vulnerable to potential loss over time: 1) open lands owned under public interest as shown on Map 29; 2) Federal Emergency Management Agency one-percent-annual-probability (100-year recurrence interval) regulatory floodway (AE Floodway Zone) as shown on Map 19 in Chapter III of this report; or 3) Advanced Delineation and Identification (ADID) wetlands as shown on Map 17 in Chapter III of this report. Approximately 19 percent of the lands within the riparian buffer areas are protected through public and private ownership. In addition, significant amounts of these riparian buffers are within the one-percent-annual-probability

Map 29

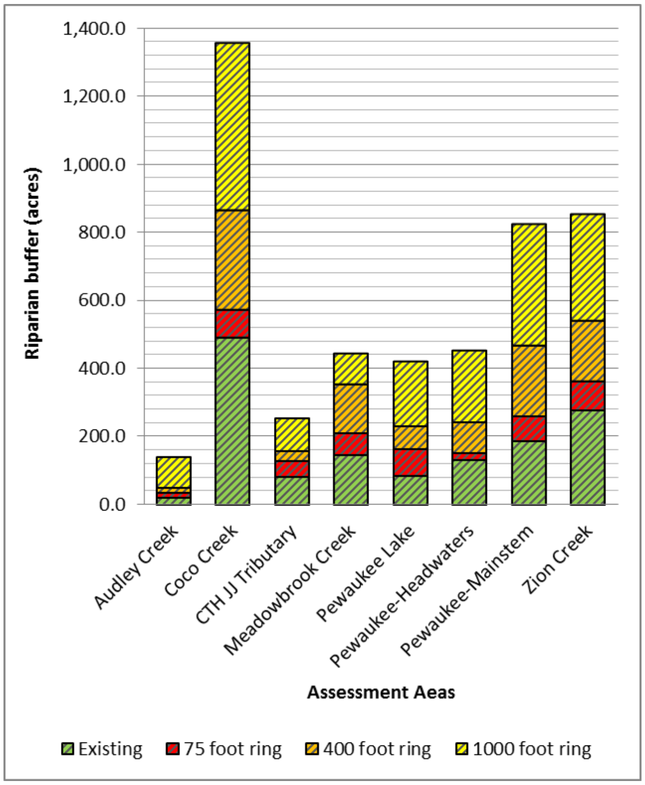
OPEN SPACE LANDS IN PUBLIC AND PRIVATE PROTECTION WITHIN AND ADJACENT TO THE PEWAUKEE RIVER WATERSHED



Source: SEWRPC.

Figure 59

ACRES OF VULNERABLE EXISTING AND POTENTIAL BUFFERS AMONG ASSESSMENT AREAS WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



Source: SEWRPC.

(100-year recurrence interval) regulatory floodway and/or within designated ADID wetlands, which provides additional protection for these areas. Based upon these criteria it was then possible to distinguish protected existing riparian buffer lands from vulnerable existing riparian buffer lands. In addition, it was also possible to distinguish protected versus vulnerable potential riparian buffer lands in the 75-foot, 400-foot, and 1,000-foot buffer width categories. Finally, the vulnerable existing and potential riparian buffer land acreages are summarized by assessment area and shown in Figure 59 and Map 32 in Chapter VI of this report. Figure 59 indicates that the greatest extent of the vulnerable existing riparian buffers and vulnerable potential riparian buffers are located within the headwater areas in Coco Creek, Meadowbrook Creek, and Zion Creek. However, there are opportunities to protect vulnerable existing and potential buffers within every assessment area throughout the Pewaukee River watershed. In conclusion, protection of these vulnerable areas would help to preserve water quality, wildlife, and recreational opportunities in the Pewaukee River watershed.

Riparian Buffer Protection and Prioritization Strategies

All riparian buffers provide some level of protection that is greater than if there were no buffer at all. However, wider buffers provide a greater number of functions (infiltration, temperature moderation, and species diversity) than narrower buffers. Therefore, it is important that existing buffers be protected and expanded where possible.

The riparian buffer network out to the 75-foot, 400-foot, and 1,000-foot widths as summarized above provides the framework upon which to protect and improve water quality and wildlife within the Pewaukee River watershed. This framework can be achieved through a combination of strategies that include land acquisition, regulation, and best management practices.

Land Acquisition

As summarized in Chapter II, not all of the corridors and associated natural areas are protected, and so it is recommended that the prioritization for acquisition of these lands (including PEC, SEC, and INRA, and NAs) should be based upon the following order of importance (in order from highest to lowest priority (see Map 36 in Chapter VI of this report):

1. Vulnerable existing riparian buffer (protect what exists on the landscape);

2. Vulnerable potential riparian buffer lands up to 75 feet wide (minimum level of protection);

3. Vulnerable potential riparian buffer lands up to 400 feet wide (minimum wildlife protection); and

4. Vulnerable potential riparian buffer lands up to 1,000 feet wide (optimum wildlife protection).

In addition, special consideration for the acquisition of vulnerable riparian buffers should be given to locations designated as having high to very high groundwater recharge potential as shown on Map 34 in Chapter VI of this report, as well as connecting and expanding critical linkages among habitat complexes to protect wildlife abundance and diversity. Furthermore, connecting the SEC land and multiple INRAs throughout the Pewaukee River watershed to the larger PEC areas, as well as building and expanding upon the existing protected lands, represents a sound approach to enhance the corridor system and wildlife areas within the watershed.

Regulation
Primary environmental corridors have a greater level of land use protections compared to secondary corridors, isolated natural resource areas, or designated natural areas. Therefore, the regulatory strategy to expand protections for vulnerable existing and potential riparian buffers would be to increase the extent of primary environmental corridor designated lands within the Pewaukee River watershed.

In particular, the Coco Creek, Meadowbrook Creek, and Zion Creek subwatersheds contain areas that have the greatest opportunity to expand primary environmental corridor designated lands. However, this can only be accomplished if there are sufficient natural resource features along the streams to meet the criterion for designation as a corridor and if the minimum area (400 acres), minimum length (two miles), and minimum width (200 feet) requirements for designation as a primary environmental corridor are met. Delineation of the one-percent-annual-probability (100-year) floodplains for each of these river systems, including their associated tributaries (see Existing Stormwater Management Systems subsection above) would increase the "point value" assigned to the lands along the streams. This could possibly enable their designation as primary environmental corridors, because primary environmental corridors are defined to include the one-percent-annual-probability (100-year) floodplain boundaries. Therefore, if these newly mapped floodplain boundaries are contiguous with existing primary environmental corridors, newly mapped floodplain areas would become PEC, which would expand this designation within the watershed. In other words, if the newly mapped floodplain boundaries were contiguous with existing PEC designated lands and included areas currently designated as either secondary environmental corridor or isolated natural resources areas, these would be upgraded to PEC. These lands would be automatically upgraded because they would already meet the minimum area and width criteria. In addition, since wetlands located within primary environmental corridors are considered to be wetlands of natural resource interest or ADID wetlands, these wetlands within each of these river systems would be protected from filling, and, thus, retain their riparian buffer functions.

Best Management Practices
Since a large portion of the vulnerable existing and potential riparian buffers are privately owned within urban and agricultural areas of the watershed, it is entirely up to the private landowner as to whether or not a buffer is established or trash is removed from the stream. In addition, although riparian buffers can be effective in mitigating the negative water quality effects attributed to urbanization and agricultural management practices, they cannot on their own address all of the pollutant problems associated with these land uses. Therefore, riparian buffers need to be combined with other management practices, such as infiltration facilities, detention basins, porous pavements, green roofs, and rain gardens, in order to mitigate the effects of urban stormwater runoff. In addition, riparian buffers need to be combined with other management practices, such as barnyard runoff controls, manure storage, contour plowing, constructing grassed waterways, and reduced tillage, to mitigate the effects of agricultural runoff. Therefore, the recommended best management land use practices to improve and protect water quality in both urban and agricultural areas are essential elements for the protection of water quality and quantity and wildlife within the Pewaukee River watershed.

Biological Conditions
The quality of streams and rivers is often assessed based on measures of the chemical or physical properties of water. However, a more comprehensive perspective includes resident biological communities. Guidelines to protect human health and aquatic life have been established for specific physical and chemical properties of

water and have become useful yardsticks for assessing water quality. Biological communities provide additional crucial information because they live within streams for weeks to years and therefore integrate through time the effects of changes to their chemical or physical environment.[61]

In addition, biological communities are a direct measure of stream health—an indicator of the ability of a stream to support aquatic life. Thus, the condition of biological communities, integrated with key physical and chemical properties, provides a comprehensive assessment of stream health. The presence and abundance of species in a biological community are a function of the inherent requirements of each species for specific ranges of physical and chemical conditions. Therefore, when changes in land and water use in a river basin cause physical or chemical properties of streams to exceed their natural ranges, vulnerable aquatic species are eliminated, and this ultimately impairs the biological condition and stream health.[62]

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristic of these areas are important determinants of the overall quality of the environment in the Pewaukee River watershed.

Fisheries Classification

In Wisconsin, high-quality warmwater systems are characterized by many native species, including cyprinids, darters, suckers, sunfish, and percids that typically dominate the fish assemblage. Pollution intolerant species (species that are particularly sensitive to water pollution and habitat degradation) are also common in such high-quality warmwater systems.[63] Pollution tolerant fish species (species that are capable of persisting under a wide range of degraded conditions) are typically present, but they do not dominate the fish fauna of these systems. Insectivores (fish that feed primarily on small invertebrates) and top carnivores (fish that feed on other fish, vertebrates, or large invertebrates) are generally common. Omnivores (fish that feed on both plant and animal material) also are generally common, but do not dominate. Simple lithophilous spawners (species that lay their eggs directly on large substrate, such as clean gravel or cobble, without building a nest or providing parental care for the eggs) are generally common.

The Pewaukee River system contains a variety of both warmwater and coldwater (Coco Creek) stream reaches (see the Water Temperature subsection above).[64] In contrast to warmwater streams, coldwater systems are characterized by few native species, with salmonids (trout) and cottids (sculpin) dominating, and they lack many of the taxonomic groups that are important in high-quality warmwater streams. An increase in fish species richness in coldwater fish assemblages often indicates environmental degradation. When degradation occurs, the small number of coldwater species is replaced by a larger number of more physiologically tolerant cool and warmwater species, which is the opposite of what tends to occur in warmwater fish assemblages.

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[61]*D.M. Carlisle and others,* The Quality of Our Nation's Waters—Ecological Health in the Nation's Streams, *1993–2005: U.S. Geological Survey Circular 1391, 2013 (available online at:* http:// pubs.usgs.gov/circ/1391/*).*

[62]Ibid.

[63]*John Lyons, "Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin," United States Department of Agriculture, General Technical Report NC-149, 1992.*

[64]*John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management, *Volume 16, May 1996.*

Table 20

PROPOSED WATER TEMPERATURE AND FLOW CRITERIA FOR DEFINING NATURAL STREAM BIOLOGICAL COMMUNITIES AND THE PROPOSED PRIMARY INDEX OF BIOTIC INTEGRITY (IBI) FOR BIOASSESSMENT

Natural Community	Maximum Daily Mean Water Temperature (˚F)	Annual 90 Percent Exceedence Flow (ft^3/s)	Primary Index of Biotic Integrity
Ephemeral	Any	0.0	N/A
Macroinvertebrate	Any	0.0-0.03	Macroinvertebrate
Cold Headwater	<69.3	0.03 -1.0	Coldwater Fish
Cold Mainstem	<69.3	>1.0	Coldwater Fish
Cool (Cold-Transition) Headwater	69.3-72.5	0.03-3.0	Headwater Fish
Cool (Cold-Transition) Mainstem	69.3-72.5	>3.0	Cool-Cold Transition Fish
Cool (Warm-Transition) Headwater	72.6-76.3	0.03-3.0	Headwater Fish
Cool (Warm-Transition) Mainstem	72.6-76.3	>3.0	Cool-Warm Transition Fish
Warm Headwater	>76.3	0.03-3.0	Headwater Fish
Warm Mainstem	>76.3	3.0-110.0	Warmwater Fish
Warm River	>76.3	>110.0	River Fish

Source: References for IBIs: Macroinvertebrate–Weigel 2003; Coldwater Fish–Lyons et al. 1996; Headwater Fish–Lyons 2006; Coolwater Fish–Lyons, in preparation; Warmwater Fish–Lyons 1992; River Fish–Lyons et al. 2001.

A stream model has recently been developed by the WDNR to classify stream reaches into their biotic community by fish occurrence and abundance, as well as the ecological conditions that largely determine the biotic community (i.e., stream flow and water temperature).[65] Although this model has some limitations, it does provide an objective, standardized, and ecologically meaningful framework to classify streams.[66] The proposed natural community classification has 11 natural community classes as summarized in Table 20, which have unique physical and biological characteristics as summarized below:[67]

Ephemeral—Channels with water flow only after precipitation events (i.e., no base flow). No fish and few or no aquatic invertebrates are present.

Macroinvertebrate—Very small, almost always intermittent (i.e., ceases flow for part of the year, although water may remain in the channel) streams. Few or no fish are present, but a variety of aquatic invertebrates are common, at least seasonally.

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[65]*John Lyons, "Patterns in the species composition of fish assemblages among Wisconsin streams,"* Environmental Biology of Fishes *Volume 45, 1996, pages 329-341.*

[66]*John Lyons, "Wisconsin Department of Natural Resources, An Overview of the Wisconsin Stream Model," January 2007.*

[67]*John Lyons, "Proposed temperature and flow criteria for natural communities for flowing waters," February 2008, updated October 2012.*

Cold Headwater—Small, perennial streams with cold summer temperatures. Collectively, coldwater fishes are usually abundant (catch rate of >100 fish per 100 m of stream length sampled) to common (10 to100 per 100 m), transitional fishes are common to absent, and warmwater fishes are absent. Because of the small size of the stream, trout populations consist almost exclusively of small fish (less than five inches) with larger fish absent except perhaps during spawning periods.

Cold Mainstem—Moderate to large but still wadable perennial streams with cold summer temperatures. Coldwater fishes are abundant to common, transitional fishes are common to absent, and warmwater fishes are absent. The size of the stream is sufficient to support trout in a wide range of sizes.

Cool (Cold-Transition) Headwater—Small, usually perennial streams with cold to cool summer temperatures. Coldwater fishes are common to uncommon (<10 per 100 m), transitional fishes are abundant to common, and warmwater fishes are uncommon to absent. Headwater species are abundant to common, mainstem species are common to absent, and river species are absent.

Cool (Cold-Transition) Mainstem—Moderate to large but still wadable perennial streams with cold to cool summer temperatures. Coldwater fishes are common to uncommon, transitional fishes are abundant to common, and warmwater fishes are uncommon to absent. Headwater species are common to absent, mainstem species are abundant to common, and river species are common to absent.

Cool (Warm-Transition) Headwater—Small, sometimes intermittent streams with cool to warm summer temperatures. Coldwater fishes are uncommon to absent, transitional fishes are abundant to common, and warmwater fishes are common to uncommon. Headwater species are abundant to common, mainstem species are common to absent, and river species are absent.

Cool (Warm-Transition) Mainstem—Moderate to large but still wadable perennial streams with cool to warm summer temperatures. Coldwater fishes are uncommon to absent, transitional fishes are abundant to common, and warmwater fishes are common to uncommon. Headwater species are common to absent, mainstem species are abundant to common, and river species are common to absent.

Warm Headwater—Small, usually intermittent streams with warm summer temperatures. Coldwater fishes are absent, transitional fishes are common to uncommon, and warmwater fishes are abundant to common. Headwater species are abundant to common, mainstem species are common to absent, and river species are absent.

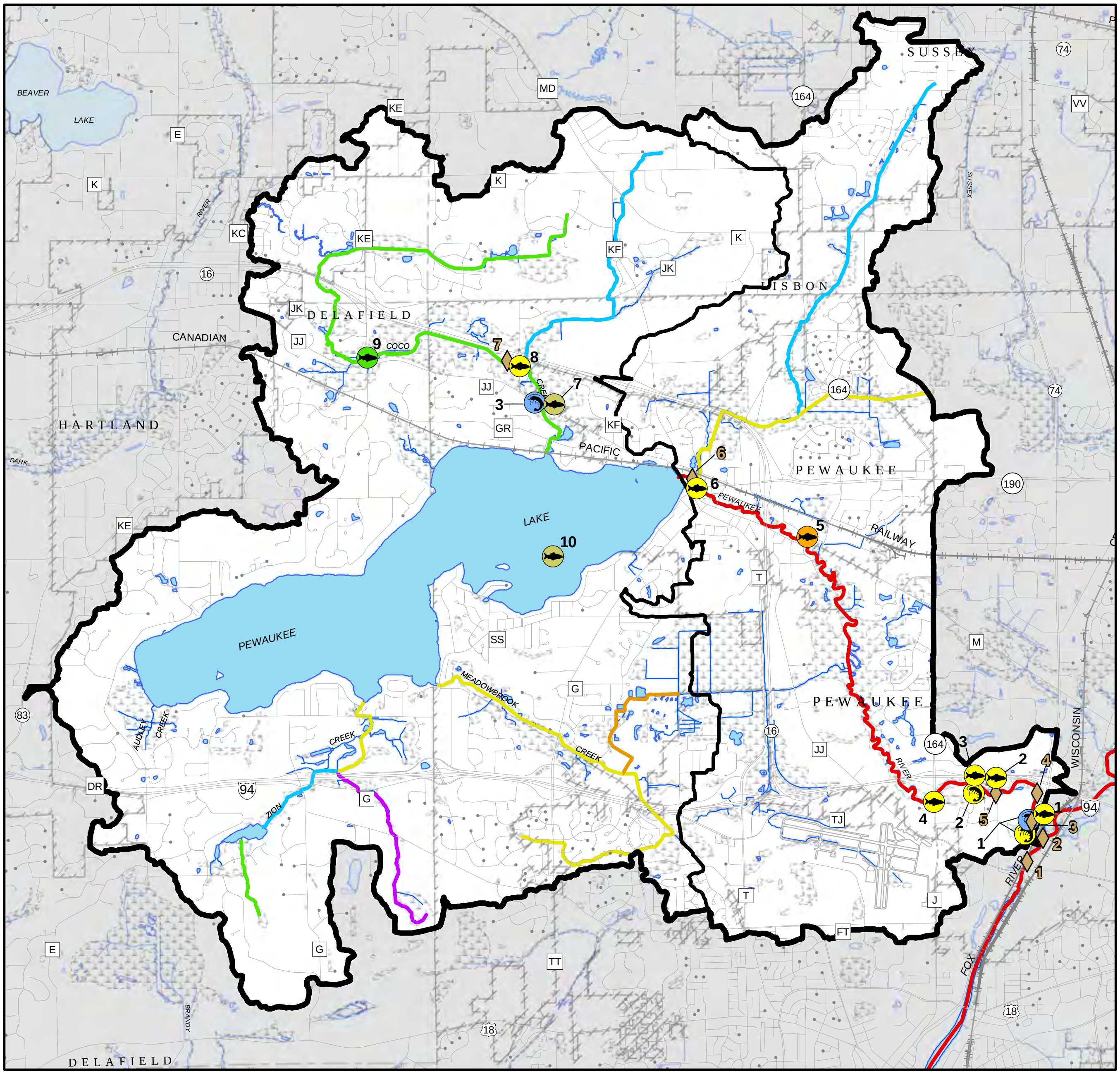
Warm Mainstem—Moderate to large but still wadable perennial streams with relatively warm summer temperatures. Coldwater fishes are absent, transitional fishes are common to uncommon, and warmwater fishes are abundant to common. Headwater species are common to absent, mainstem species are abundant to common, and river species are common to absent.

Warm Rivers—Nonwadable large to very large rivers with warm summer temperatures. Coldwater fishes are absent, transitional fishes are common to uncommon, and warmwater fishes are abundant to common. Headwater species are absent, mainstem species are common to uncommon, and river species are abundant to common.

Results of the stream model corroborate 1) the coldwater classification on Coco Creek, and 2) warmwater fishery classifications on the mainstem of the Pewaukee River—from the Pewaukee Lake Outlet to the confluence of the Fox River as shown on Map 30. However, this model also predicts the headwaters of Pewaukee River to be cool headwater that changes from a cold transitional to a warm transitional classification, which is generally supported by the water temperatures within this area. The cool headwater (cold transitional) classification was also predicted for the unnamed east branch of Coco Creek, which was also generally supported by water temperature data summarized above. Zion Creek was surprisingly classified as a cold headwater fishery to a cool headwater fishery. Although no temperature data are available for the headwaters of this system, the temperatures from the lower reaches of this creek indicate that this is more appropriately classified as a warm headwater stream.

Map 30

FISH, AQUATIC BUGS, AND MUSSEL SAMPLING LOCATIONS AND FISHERIES STREAM CLASSIFICATIONS WITHIN THE PEWAUKEE RIVER WATERSHED



FISH IBI RATING AND SITE ID (SEE TABLE IV-8)

9 GOOD

1 FAIR

5 POOR

7 UNRATED

AQUATIC BUGS HBI RATING AND SITE ID

1 GOOD TO VERY GOOD

2 FAIR

MUSSEL SAMPLING SITE AND SITE ID (see Table IV-11)

2

FISHERIES STREAM CLASSIFICATIONS (SEE TABLE IV-8)

COLD HEADWATER

COOL (COLD TRANSITION) HEADWATER

COOL (WARM TRANSITION) HEADWATER

WARM HEADWATER

WARM MAINSTEM

MACROINVERTEBRATE

SURFACE WATER

UNCLASSIFIED STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: Wisconsin Department of Natural Resources, Wisconsin Lutheran College, and SEWRPC.

In addition, the entire unnamed eastern branch of Zion Creek was ranked with a macroinvertebrate classification, which is probably appropriate, although no information exists to verify this classification. The stream model also predicted that Meadowbrook Creek transitions from a warm headwater to a cool headwater classification, although more information would need to be collected in order to verify these classifications.

Through calculation of the Index of Biotic Integrity (IBI), data on the fish community can provide insight into the overall health of the river ecosystem in this stretch. Fish catches can also reveal trends in the populations of rare and sport fish species. The overall goal of the monitoring is to better document the current status of this biologically unique piece of river and to provide an early warning of declines in environmental quality and fisheries associated with human development in the watershed. Due to the fundamental differences among warmwater, coolwater, and coldwater streams, a separate Index of Biotic Integrity was developed to assess the health of each of these types of streams.[68]

Based upon the fisheries assessments conducted between 1978 and the present in the Pewaukee River, the River seems to generally have improved from a very poor-fair to a fair warmwater fishery among several sites within the Pewaukee-1 reach. It is also possible that the Pewaukee-3 reach has decreased in quality from a fair classification in 1978 to a poor ranking in 2012, but these fishery surveys were not collected at the same location and the Pewaukee River was experiencing a severe drought in the summer of 2012, which makes it difficult to interpret the results of this information. However, a second survey conducted in 2012 further downstream that achieved a fair warmwater classification. This could mean that the Pewaukee-3 reach is either more degraded than the Pewaukee-1 reach or the Pewaukee-3 reach is more vulnerable to the impacts of decreased water levels, discharges, and elevated temperatures caused by the drought than the Pewaukee-1 reach. There is not enough information to interpret this further and there are no other sites where fisheries data have been collected to make any other comparisons. For example, despite the apparent decrease in fishery quality in the Pewaukee-3 reach, this is the only site where spottail shiner, a warmwater fish species that is sensitive to stream degradation, has been recorded to be present in both the 2012 and the 1978 samples. Therefore, it is recommended that these same sites continued to be monitored and that more locations be sampled throughout the Pewaukee River to better determine the quality and diversity of the fishery in this system.

Coco Creek was sampled in 1999 and 2011 and achieved a fair-good cool-cold transition IBI ranking and very poor-fair coldwater IBI scores. This seems to indicate that Coco Creek has a cool to coldwater fish assemblage, except for the absence of brook trout in those samples. Since brook trout are the only native stream-dwelling salmonid in the State of Wisconsin, the presence and abundance of brook trout dramatically improves the coldwater IBI scores, which is why the coldwater IBI scores were so poor. This does not mean that brook trout are not present in this system, it just means that they were not present in the samples collected. The temperature data summarized above indicate that Coco Creek has a high probability to support salmonids. For example, brown trout were collected in the most recent date sampled in 2011. However, it is a cause for concern that not a single brook trout was observed in either of thtse surveys and it is recommended that more surveys be conducted to determine the abundance and distribution of brook trout in Coco Creek.

Although the fish IBI is useful for assessing environmental quality and biotic integrity in streams, it is most effective when used in combination with additional data on physical habitat, water quality, macroinvertebrates, and other biota when evaluating a site.[69] Supplemental data for macroinvertebrates surveys conducted by the WDNR and Water Action Volunteer (WAV) are summarized below.

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[68]*John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management, *Volume 16, May 1996.*

[69]*John Lyons,* General Technical Report NC-149, op. cit.

Fish Species Diversity

A review of the fish data collected in the Pewaukee River between 1978 and 2012 indicates that the lower portions of the Pewaukee River have generally improved from seven to nine species per survey to about 14 to 15 species per survey in the more recent sample dates in 2011 and 2012 as shown in Table 21. The surveys indicate that this fishery contains a mixture of fish species that 1) are tolerant of pollution, 2) have an intermediate tolerance of pollution, and 3) are sensitive to pollution. The warmwater tolerant species assemblage includes green sunfish, yellow bullhead, black bullhead, common carp, and, most recently, a new record of bluntnose minnow. The warmwater intermediate assemblage includes hornyhead chub and common shiner species. However, the recent surveys included several more species that include bluegill, pumpkinseed, and largemouth bass—panfish and gamefish species that are highly sought by fisherman. Another good sign of a healthy fishery was the continued presence of spottail shiner in the Pewaukee-3 reach and rock bass in the downstream Pewaukee-1 reach, both of which are sensitive warmwater fish species. Two additional sensitive warmwater species, rainbow darter and smallmouth bass, were also observed in the most recent sampling in the downstream reach of the Pewaukee River—an excellent sign of a healthy warmwater fishery. In addition to these warmwater species, the following other transitional or coolwater species were found in the Pewaukee River: tolerant species-creek chub, central mudminnow, and white sucker; intermediate species-yellow perch, northern pike x muskellunge hybrid, and Johnny darter; and sensitive species-northern pike. The northern pike x muskellunge hybrid species are stocked in Pewaukee Lake, so this fish likely washed out of the Lake. In addition, numerous large adult carp were observed in the deepest areas of the Pewaukee-2 and Pewaukee-3 reaches during the time of the habitat surveys summarized above. SEWRPC staff also observed a northern pike in the CTH JJ Tributary.

A review of the fish data collected in Coco Creek between 2011 and 2012 indicates that the lower portions of the Creek were found to have between seven to nine species per survey. As previously mentioned, healthy coldwater streams are comprised of a lower number of species compared to healthy warmwater streams, so this low number of species is a good sign for Coco Creek. The surveys also indicate that this fishery contains a mixture of warmwater tolerant, transitional or coolwater species, and one sensitive coldwater species. The warmwater tolerant and intermediate species include yellow bullhead, green sunfish, golden shiner, fathead minnow, bluntnose minnow, pumpkinseed, largemouth bass, bluegill, common shiner, and hornyhead chub. Yellow bullhead, green sunfish, pumpkinseed, bluegill, and largemouth bass species are not usually found in high-quality coldwater streams, but since these are found in high abundance in Pewaukee Lake it is not unusual for these species to migrate up into the lower reaches of Coco Creek. The transitional or coolwater species observed in Coco Creek include white sucker, creek chub, central mudminnow, and yellow perch. Finally, brown trout were the only coldwater sensitive species found in Coco Creek.

Pewaukee Lake contains the most diverse and abundant fish community within the Pewaukee River watershed. The Lake has been observed to contain a warmwater assemblage of about 32 species and a transitional or coolwater assemblage of about 13 species, including two designated species of special concern (banded killifish and lake chubsucker) and one threatened species (pugnose shiner) (see Table 21). Historic fisheries records from WDNR files indicate that northern pike, walleye, and muskellunge have been stocked almost annually within Pewaukee Lake since 1972. Recent WDNR comprehensive surveys targeting muskellunge, walleye, largemouth bass, smallmouth bass, northern pike and panfish species from 2011 to 2012 in Pewaukee Lake are summarized below.[70]

- Muskellunge are not native to inland waters of Southeastern Wisconsin so their presence in Pewaukee Lake is the result of an intensive stocking program. Similarly, walleye and northern pike populations appear to be greatly affected by stocking practices in Pewaukee Lake.

[70]*Benjamin Heussner, Steven Gospodarek, and Andrew Notbohm, WDNR Comprehensive Survey Report of Pewaukee Lake, Waukesha County (WBIC 772000), 2012.*

Table 21

FISH SPECIES COMPOSITION BY PHYSIOLOGICAL TOLERANCE AND REACH IN THE PEWAUKEE RIVER WATERSHED: 1964-2012

Species According to Their Relative Tolerance to Temperature	Stream Reach (see Map 30)											
	Pewaukee 1					Pewaukee 3		Coco Creek				Pewaukee Lake
	Site 1[a]	Site 2		Site 3	Site 4	Site 5[b]	Site 6	Site 7[c]	Site 8		Site 9	Site 10
	2012	1978	1997	1997	2011	2012	1978	2006	1999	2011	2011	1964-2012
Coldwater												
Intermediate												
Brown Trout[d]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X	- -
Transitional												
Sensitive												
Blackchin Shiner	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Blacknose Shiner	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Muskellunge	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Northern Pike	- -	- -	- -	- -	X	- -	- -	- -	- -	- -	- -	X
Pugnose Shiner[e]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Intermediate												
Johnny Darter	- -	- -	X	X	X	- -	- -	- -	- -	- -	- -	X
Northern Pike x Muskellunge	- -	- -	X	X	- -	- -	- -	- -	- -	- -	- -	X
Walleye	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Yellow Perch	X	- -	- -	- -	X	- -	X	- -	X	X	X	X
Tolerant												
Brook Stickleback	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Central Mudminnow	- -	- -	- -	- -	- -	X	X	X	X	X	X	X
Creek Chub	- -	- -	X	X	- -	- -	- -	- -	X	- -	- -	X
White Sucker	X	X	X	X	X	- -	- -	- -	X	X	X	X
Warmwater												
Sensitive												
Rainbow Darter	X	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Rock Bass	X	X	X	X	X	- -	- -	- -	- -	- -	- -	X
Smallmouth Bass	X	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Spottail Shiner	- -	- -	- -	- -	- -	X	X	- -	- -	- -	- -	X
Intermediate												
Banded Killifish[f]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Bigmouth Shiner	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Black Crappie	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Bluegill	X	- -	- -	- -	X	- -	- -	- -	X	X	X	X
Bowfin	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Brook Silverside	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Brown Bullhead	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Common Shiner	X	X	X	X	X	- -	- -	- -	X	- -	- -	X
Emerald Shiner	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Freshwater Drum	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Grass Pickerel	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X

\Table 21 (continued)

Species According to Their Relative Tolerance to Temperature	Stream Reach (see Map 30)											
	Pewaukee 1					Pewaukee 3		Coco Creek				Pewaukee Lake
	Site 1[a]	Site 2		Site 3	Site 4	Site 5[b]	Site 6	Site 7[c]	Site 8		Site 9	Site 10
	2012	1978	1997	1997	2011	2012	1978	2006	1999	2011	2011	1964-2012
Warmwater (continued)												
Intermediate (continued)												
Hornyhead Chub	X	- -	X	X	X	- -	- -	- -	X	- -	- -	- -
Lake Chubsucker[f]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Largemouth Bass	X	- -	- -	- -	X	X	- -	- -	- -	- -	X	X
Longnose Gar	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Mimic Shiner	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Pumpkinseed	X	- -	- -	- -	X	- -	- -	- -	- -	X	X	X
Spotfin Shiner	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Tadpole Madtom	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Warmouth	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
White Bass	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
White Crappie	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Tolerant												
Black Bullhead	X	X	- -	- -	X	X	X	- -	- -	- -	- -	X
Bluntnose Minnow	- -	- -	- -	- -	X	X	- -	X	- -	- -	- -	X
Common Carp	X	X	X	X	X	X	X	- -	- -	- -	- -	X
Fathead Minnow	- -	- -	- -	- -	- -	- -	- -	- -	X	- -	- -	X
Golden Shiner	- -	- -	- -	- -	- -	- -	- -	- -	- -	X	- -	X
Goldfish	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X
Green Sunfish	X	X	- -	- -	X	X	X	- -	- -	X	X	X
Yellow Bullhead	- -	X	X	X	X	X	- -	- -	X	- -	- -	X
Total Number of Species	14	7	9	9	15	8	7	2	9	7	8	45
Warmwater IBI Qualitative Score	Fair	Very poor	Fair	Fair	Fair	Poor	Fair	- -	- -	- -	- -	- -
Cool-Cold Transition IBI Qualitative Score	- -	- -	- -	- -	- -	- -	- -	- -	Fair	Fair	Good	- -
Coldwater IBI Qualitative Score	- -	- -	- -	- -	- -	- -	- -	- -	Very poor	Very poor	Fair	- -

[a]*A portion of this survey was done for gamefish only. Largemouth Bass, Bluegill, and Yellow Perch species were only collected during this portion of the survey and are included in the total number of species at this site. For purposes of calculating IBI scores, only species collected during the "all species" portion of the survey were included.*

[b]*A portion of this survey was done for gamefish only. Largemouth Bass were only collected during this portion of the survey and are included in the total number of species at this site. For purposes of calculating IBI scores, only species collected during the "all species" portion of the survey were included.*

[c]*Sampling at this site was for a study focused on minnow species. Other nonminnow species sampled at this site were not recorded.*

[d]*This species is stocked by Wisconsin Department of Natural Resources fisheries management staff.*

[e]*Designated threatened species.*

[f]*Designated species of special concern.*

Source: Wisconsin Department of Natural Resources, Wisconsin Lutheran College, and SEWRPC.

- Stocking efforts have produced a muskellunge population density well above the Wisconsin statewide average. The 2011-2012 assessment resulted in a muskellunge population estimate of 0.62 fish per acre, which is one-tenth of a fish per acre higher than the previous estimate performed during the 1998 comprehensive assessment. The current assessment indicates muskellunge size structure is fairly balanced, with the vast majority of fish measuring 30 to 39 inches. Fish below 30 inches or over 40 inches were infrequently captured during the 2011-2012 assessment. The highlight of these fish was a 50.2-inch female muskellunge captured in 2012 that weighed over 40 pounds. Muskellunge in Pewaukee Lake grow at a rate faster than the Wisconsin statewide average. Mortality for muskellunge was calculated to be 46.6 percent beginning at age five or, 33.5 inches. Although this length is below the 40-inch minimum for angler harvest, angling pressure could contribute to this mortality rate as a result of added stress during warm-water months when musky are frequently targeted and susceptible to hooking mortality.

- Walleye populations in Pewaukee Lake have historically been low. Unfortunately, the 2011-2012 assessment showed little change as the number of adult walleye per acre was calculated to be 0.4 per surface acre. This estimate is lower than those of the 1998 and 1977 assessments and is likely a result of inconsistent stocking during the past decade. Average lengths, proportional stock density (PSD) and relative stock density (RSD) indicate a top-heavy walleye size structure stemming from a majority of older fish in the system. According to the 2011-2012 assessment, walleye grow quickly until age six when growth appears to slow significantly. The estimated annual walleye mortality rate is 51 percent beginning at age six or 21.1 inches.

- Largemouth bass were captured with mild success during the spring 2011 portion of the two-year comprehensive assessment. Average length and size structure has increased since the 1998 assessment but the largemouth in Pewaukee Lake are still of average size when compared to other Waukesha County lakes that have been surveyed recently. Like most species in Pewaukee Lake, largemouth bass grow at a rate that is faster than the Wisconsin statewide average.

- Smallmouth bass were also captured in spring 2011 but catch rates were lower when compared to largemouth. Average size and size structure have increased since the 1998 assessment. Pewaukee Lake's smallmouth are some of the largest in Waukesha County. More than 70 percent were at or above the 14-inch minimum length limit for angler harvest and several fish between 18 to 21 inches were captured.

- Northern pike fyke netting catch was low, indicating a significant drop in northern numbers since the 1998 assessment. An absence of stocking is likely the culprit for this reduction of northern pike numbers, although competition with muskellunge and a lack of spawning habitat may be contributing factors.

- Panfish were plentiful, but size structures were small during the 2011-2012 assessment. Small panfish size structure and over-abundance is a common problem in lakes, such as Pewaukee, that contain dense Eurasian water-milfoil beds. In addition to thick milfoil, angler selective harvest of larger panfish also may be a contributing factor.

Although not previously recorded, in spring 2013, northern pike were observed to have migrated upstream from Pewaukee Lake to spawn in the unnamed eastern branch of Coco Creek, as well as upstream to the unnamed tributary in the headwaters of Meadowbrook Creek. These observations indicate that good connections between the Lake and tributaries can facilitate production of northern pike in this system. Efforts should be geared toward protecting these native or naturalized spawning stocks to ensure and enhance the natural reproduction of these populations.

Mussels

Freshwater mussels are large bivalve (two-shelled) mollusks that live in the sediments of rivers, streams, and some lakes. Mussels are considered one of the most endangered families of animals in North America. These soft-bodied animals are enclosed by two shells made mostly of calcium and connected by a hinge. Mussels can typically be found anchored in the substrate, with only their siphons occasionally exposed. They typically favor sand, gravel, and cobble substrates. They play an important role in aquatic ecosystems by helping stabilize river bottoms; serving as natural water filters; providing excellent spawning habitat for fish; and serving as food for fish, birds, and some mammals. Live mussels and relic shells provide a relatively stable substrate in dynamic riverine environments for a variety of other macroinvertebrates, such as caddis flies and mayflies, and for algae.

Mussels require moving water to provide incoming food and oxygen and to eliminate waste. They draw in water from which they filter fine organic matter, such as algae and detritus. A single mussel can filter several gallons of water per day, which means mussels can improve water quality by removing sediment and associated contaminants from water. Many species are slow-growing and long-lived animals, surviving for as long as 100 years. Most mussel species are sessile, moving only short distances their entire life, maneuvering by way of a muscular fleshy foot extended from the shell. Movement is often triggered by changing water levels or other environmental conditions. During periods of stress (temperature extremes, drought, pollutants), many species will burrow deep into the sediment, sometimes surviving until the stressor has passed. Growth rings on mussel shells can determine their age; accumulating a defined line indicating a period of no growth, and these lines can be used to glean information about historical water quality and disturbance. Mussels serve as good indicators of ecosystem health because they are relatively long-lived and sessile, and depend on good water quality and physical habitat.

Mussels are viewed as important, sensitive indicators of changing environmental conditions. Water and sediment quality are important habitat criteria for mussels. Most species of freshwater mussels prefer clean running water with high oxygen content, and all species are susceptible to pollution, including pesticides, heavy metals, ammonia, and algal toxins. Mussels can be used to document changes in water quality over long periods of time since they are long-lived. Shells accumulate metals from both water and sediment, so testing heavy metal concentrations in shells can tell researchers when water in a given area was first contaminated. The presence or absence of a particular mussel species provides information about long-term water health. Because juvenile forms of mussels are more susceptible to pollution than the adult forms, finding juveniles with few adults nearby may indicate a newly colonized area. In general, having healthy diverse populations of mussels means the water quality is good.

The freshwater mussel has a unique life cycle, including a short parasitic stage attached to a fish.[71] Reproduction occurs when a male mussel releases sperm into the water column, which is siphoned into the female mussel to fertilize the eggs. Reproduction may be triggered by increasing water temperature and/or day length, and development and retention of larvae within the female may last from one to 10 months. Glochidia (immature mussels) are generally released from the female in spring and early summer (April to July). The glochidia (immature mussels) must attach to the gills of a fish to obtain nutrients from blood serum. Mussels need host fish to carry their young through the waterways in order for them to survive, grow, and disperse. Female mussels either release the glochidia into the water in a sac called a conglutinate (made to look like food for their host fish), wherein the glochidia can survive for only a short period of time without a fish host, or they have developed specific adaptations, including an enlarged mantle tissue flap that look like prey organisms (worms, insect larva, small fish, or crayfish) which attract a fish host looking for food. When fish nip at these structures which resemble potential food items, the female releases glochidia into the water column that attach to the gills or fins of the fish host. As parasites, glochidia are dependent on fish for their nutrition at this stage in their life. Some mussels

[71]*U.S. Geological Survey, "Ecological Status and Trends of the Upper Mississippi River System, 1998: A Report of the Long Term Resource Monitoring Program," April 1999, LTRMP 99-T001.*

may depend on only a single fish species, whereas others can parasitize many different fishes. The attachment of glochidia causes no problems for the host fish. After the glochidia take at least a two- to three-week ride on the fish as a benign parasite, they drop off and land in the bed of a new stretch of a stream, river, or lake where they may grow and stay for more than a half century. Mussels have a variety of fish host species, and can range in number from as little as one to as many as 35 for species found within the Pewaukee River watershed. Mussel characteristics and potential host fish species are shown in Table 22.

Exploitation, changing water quality, and invasive species all are threats to these invertebrates. Siltation, chemical pollution, loss of habitat through creation of impoundments, channelization or other stream modifications, predation, and impacts from invasive species are common factors responsible for the decline of freshwater mussels. Adult mussels are eaten by muskrats, otters, and raccoons; young mussels are eaten by ducks, wading birds, and fish. Historically, freshwater mussels were used by Native Americans as food, source materials for tools, and ornamental objects. They were also important commercially in modern society, beginning around the 1890s, when mussels were harvested and used in the manufacture of buttons for clothing.

Invasive species, such as zebra mussels, pose a significant threat to native mussel populations for several reasons. Their reproduction is much simpler than other freshwater mussels because they do not require a fish host; rather, they develop as planktonic organisms called veligers that drift in the current until they become large enough to attach to the stream bottom or another object. Zebra mussels produce thousands of veligers and can reproduce several times per year. Zebra mussels have the ability to attach to the shells of native mussels, allowing them to directly interfere with successful reproduction in addition to competing for food. Other invasive mussel species include the Asian clam and the quagga mussel, which will also compete with native mussels for habitat and food.

The Pewaukee River contains a diverse assemblage of mussels, with 14 species having been found, including the State of Wisconsin State-threatened ellipse (*Venustaconcha ellipsiformis*) and the State-special-concern round pigtoe (*Pleurobema sintoxia*) (see Map 30, Table 23, and Figure 60). The sample survey site 2 in the Fox River downstream of the Pewaukee River confluence is the most diverse, containing 12 of the mussel species found within the watershed. A total of seven sites were surveyed within the watershed (see Table 23). Differences in the total number of species between the reaches can be attributed to several possible reasons, including the abundance and diversity of fish host species—places with a more diverse fishery have mussel populations that are equally diverse—and the total number of samples. The Pewaukee Lake outlet also may contain fewer species than other reaches due to its smaller overall size.

Currently, the WDNR Bureau of Endangered Resources is working with citizen scientists to create a new mussel monitoring program to update the data on mussel distribution statewide. Researchers are enlisting the help of volunteers by contracting with schools, nature centers, and interested individuals, and are providing training to conduct stream surveys under the auspices of the Mussel Monitoring Program of Wisconsin.[72] Volunteers wade in the water and walk stream banks looking for live and dead mussels. Live mussels are identified and photographed before they are returned to the stream. Empty shells and dead specimens are collected along with information and photos that are sent to the mussel monitoring program at the WDNR central office. Identifying mussels can sometimes be tricky; basic shape, color, size, and beak structure are all used to determine the species. As with most invertebrates, there is some overlap between species description and even sexual dimorphism.

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[72] *Heather Kaarakka, Wisconsin Department of Natural Resources, "Several paths to build up mussels,"* Wisconsin Natural Resources Magazine, *June 2010 (*http://dnr.wi.gov/wnrmag/2010/06/mussels.htm).

Table 22

CHARACTERISTICS OF MUSSEL SPECIES FOUND TO OCCUR WITHIN THE PEWAUKEE RIVER WATERSHED

Species	Maximum Size	Habitat	Potential Host Fish Species[a]	
			Occur in Pewaukee River	Not Found in Pewaukee River
Creeper[b]	Four inches	Creeks, small streams, and occasionally large rivers in mud, sand, and gravel	Rock bass, yellow bullhead, black bullhead, rainbow darter, johnny darter, green sunfish, pumpkinseed, bluegill, creek chub, common shiner, bluntnose minnow, central mudminnow, yellow perch, largemouth bass, smallmouth bass	Northern redbelly dace, burbot, walleye, channel catfish, central stoneroller, brook stickleback, fantail darter, Iowa darter, blackside darter, logperch, longear sunfish, white crappie, black crappie, spotfin shiner, sand shiner, fathead minnow, fathead minnow
Cylindrical Papershell	3.5 inches	Creeks and small streams, in sand and mud; common headwater species	White sucker, bluegill, common shiner, largemouth bass, bluntnose minnow	Sea lamprey, mottled sculpin, spotfin shiner brook stickleback, Iowa darter, blacknose shiner, fathead minnow, black crappie
Ellipse[c]	Three inches	Sand, gravel, and small cobble in small to large streams	Johnny darter, rainbow darter	Mottled sculpin, slimy sculpin, greenside darter, orange throat darter, brook stickleback, Iowa darter, blackside darter, fantail darter, greenside darter, orange throat darter, logperch
Fatmucket	Five inches	Small streams to large rivers, as well as ponds and lakes in silt, sand, and gravel	Smallmouth bass, largemouth bass, yellow perch, bluntnose minnow, bluegill, green sunfish, rock bass, white sucker, pumpkinseed, common shiner	White bass, sauger, walleye, striped shiner, tadpole madtom, white crappie, black crappie, sauger, walleye, longear sunfish, sand shiner, warmouth, striped shiner
Fluted Shell	Seven inches	Medium sized streams to large rivers in mud, sand, and gravel. Occasionally in smaller streams.	Largemouth bass, pumpkinseed, common carp, bluegill, creek chub	Banded darter, northern hogsucker, longnose dace, central stoneroller, goldfish
Giant Floater	10 inches	Small streams to large rivers, ponds to lakes; silt, sand, and gravel	- -[d]	- -
Lilliput	1.5 inches	Rivers, ponds, and lakes in mud, sand, or gravel	Bluegill, green sunfish	Orangespotted sunfish, warmouth, white crappie
Paper Pondshell	Four inches	Silt or fine-grained sediments in small streams, lakes, and large ponds. Very tolerant of fine silt, and/or still waters.	Creek chub, green sunfish, pumpkinseed, bluegill, largemouth bass, yellow perch, rock bass, bullfrog	Longear sunfish, warmouth, banded killifish, spotfin shiner, black crappie, northern leopard frog, tiger salamander
Plain Pocketbook[b]	Seven inches	Small streams to large rivers in stable, compacted mud, through stable sand or gravel	Green sunfish, bluegill, smallmouth bass, largemouth bass, yellow perch	White crappie, tiger salamander, sauger, walleye
Round Pigtoe[b,e]	3-4 inches	Small to large streams in mud, sand, and gravel	Bluntnose minnow, bluegill	Northern redbelly dace, southern redbelly dace, spotfin shiner, central stoneroller
Spike	5.5 inches	Small stream to large rivers and occasionally in lakes; silt, sand, and gravel	- -	Gizzard shad, flathead catfish, white crappie, black crappie

Table 22 (continued)

Species	Maximum Size	Habitat	Potential Host Fish Species[a]	
			Occur in Pewaukee River	Not Found in Pewaukee River
Threeridge	Eight inches	Compacted mud, sandy or gravel areas of smaller streams to large rivers	Rock bass, northern pike, green sunfish, pumpkinseed, bluegill, largemouth bass, yellow perch	Shortnose gar, sauger, white bass, flathead catfish, warmouth, white crappie, black crappie
Wabash Pigtoe	Four inches	Creeks, small streams, and large rivers in mud, sand, and gravel	Bluegill	Silver shiner, white crappie, black crappie, creek chub
White Heelsplitter	Eight inches	Small streams to large rivers in mud, sand, and gravel	Common carp, green sunfish, largemouth bass	Gizzard shad, river redhorse, walleye, banded killifish, orangespotted sunfish, longnose gar, white crappie

[a]*This information is adapted from "A Field Guide to the Freshwater Mussels of Chicago Wilderness" and can be found at* www.fieldmuseum.org.

[b]*This species was found in the Fox River, just downstream of the confluence with the Pewaukee River.*

[c]*Designated threatened species.*

[d]*This mussel species is listed as having over 35 potential fish hosts that were not listed in the field guide referenced above.*

[e]*Designated species of special concern.*

Source: SEWRPC.

Table 23

MUSSEL SPECIES BY REACH IN THE PEWAUKEE RIVER WATERSHED: 2011

Species	Survey Location (see Map 30)						
	Fox River		Pewaukee 1			Pewaukee 3 and Pewaukee Lake Outlet	Coco Creek
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
	Fox River Upstream of Wonderland Tap	Fox River Downstream of Pewaukee River Confluence	Pewaukee River Downstream of Steinhafel's Driveway	Pewaukee River at Steinhafel's	Pewaukee River at Busse Road	Pewaukee River Downstream of Pewaukee Lake Outlet	Coco Creek at Yench Road
Creeper	- -	1	- -	- -	- -	- -	- -
Cylinder Paper Shells	- -	- -	- -	- -	- -	- -	5 (2)
Ellipse[a]	63 (1)	9	6	2	23	- -	- -
Fatmucket	17	6	- -	3	- -	- -	- -
Fluted Shell	18	50	- -	2	1	- -	- -
Giant Floater	13 (1)	52	- -	15 (4)	8 (1)	- -	8 (6)
Lilliput	2	- -	4	9	- -	- -	- -
Paper Pondshell	- -	1	- -	- -	- -	- -	- -
Pocketbook	14	5	- -	- -	- -	- -	- -
Round Pigtoe[b]	2	2	- -	- -	- -	- -	- -
Spike	71	57	2	1	- -	- -	- -
Threeridge	43	63	1	2	1	- -	- -
Wabash Pigtoe	7	15	- -	1	2	- -	- -
White Heelsplitter	10 (4)	13 (24)	- -	30 (10)	5	- -	- -
Zebra	- -	- -	- -	4	8	Many	- -
Total Number of Mussels	266	298	13	83	49	- -	13
Total Number of Species	11	12	4	10	7	1	2

NOTE: Number in parentheses indicates live specimens.

[a]*Designated threatened species.*

[b]*Designated species of special concern.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Macroinvertebrates

The Hilsenhoff Biotic Index[73] (HBI) and percent EPT (percent of families comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify macroinvertebrate and environmental quality using survey data from 1980 to 2010 in two locations in the Pewaukee River and one location in Coco Creek as shown on Map 30.

A total of seven macroinvertebrate surveys were conducted in the downstream reach of the Pewaukee River from 1980 to 2010. The site at CTH F (RM 0.11) was sampled two times in 1980 in the spring and fall, two times in 1990 in the spring, and one time in 2010 in the fall. It had corresponding HBI scores that ranged from poor-very poor, fair, and good-very good for each of these dates, respectively. Two samples collected at Busse Road (RM 1.02) in 1997 in the fall had HBI scores that both ranked as fair quality. Although data are only available for the most downstream reach of the Pewaukee River, the data does seem to show that the macroinvertebrate community

[73]*William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index, *University of Wisconsin- Madison, 1988.*

Figure 60

NATIVE MUSSEL SPECIES WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

Source: SEWRPC.

quality has improved from 1980 to present and generally indicate that current macroinvertebrate diversity and abundances are indicative of fair to good-very good water quality in the Pewaukee River. These sites also showed a general improvement in the percent of Ephemeroptera, Plecoptera, and Trichoptera (EPT) genera from 19 to 29 percent to about 35 to 46 percent—another indication that there has been an improvement in the abundance and diversity of macroinvertebrates from 1980 to present.[74]

A total of three macroinvertebrate surveys were conducted in the downstream reach of Coco Creek from 1990 to 1997. The site at CTH JJ (RM 0.52) was sampled one time in spring 1980 and two times in fall 1997 and each had corresponding HBI scores that ranged from good to very good for each of these dates and samples. Although there are only data for the most downstream reach of Coco Creek, the data does seem to generally indicate that current macroinvertebrate diversity and abundances are indicative of good to very good water quality in this Creek. These samples also showed that the percent of EPT genera ranged from about 43 to 67 percent, which is another indication that this downstream reach contained a healthy abundance and diversity of macroinvertebrates from 1990 to 1997.[75]

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[74]*M.T. Barbour, J. Gerritsen, B.D. Snyder, and J.B. Stribling,* Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, *Second Edition, EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999.*

[75]Ibid.

The Water Action Volunteers (WAV) Biotic Index also was used to classify the macroinvertebrate and environmental quality of the stream system using survey data from 2005 to 2012 among five sites within the Pewaukee River watershed, two sites on Coco Creek, one site on Meadowbrook Creek, and one site on Zion Creek.[76] The Pewaukee sites, from upstream to downstream, contained the following biotic index scores: RM 8.74—fair to good; RM 6.68—poor to fair; RM 1.23—fair; RM 0.11—fair to good; and the Pewaukee Lake Outlet RM 0.0—fair. These scores generally agree well with the WDNR HBI data above, but they also indicate that the middle reaches seem to have a less diverse macroinvertebrate community and associated decreased water quality compared to the upstream and downstream reaches.

The Coco Creek sites at RM 1.0 ranked as fair to good and RM 0.52 ranked as fair. The quality of these scores was significantly less than the HBI scores for Coco Creek summarized above, so this might indicate that this system has decreased in macroinvertebrate and water quality since 1997. Finally, the Zion Creek site showed that the biotic index ranged from poor to fair and the Meadowbrook Creek data show that this system is poor.

Wisconsin researchers have generally found that as the amount of human land disturbance increases, such as in the Pewaukee River watershed, the subsequent macroinvertebrate community diversity and abundance decreases, which is generally supported by the data in some areas of this watershed. In addition, the areas ranked with good scores indicates that there are good quality macroinvertebrates found in both the Pewaukee River and Coco Creek systems, which is likely a function of the integrity and continuity of riparian buffers greater than 75 feet adjacent to the streams (see Riparian Corridor Conditions subsection above). Such buffers provide significant buffering capacity and help reduce pollutant loadings and other human disturbances.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, a list of species observed during the field visits made for this project includes: whitetail deer, beaver, raccoon, opossum, squirrel, chipmunk, rabbit, green frog, Blanding's turtle, sandhill cranes, great blue herons, wild turkeys, and various songbirds (see Figure 61).

Bird surveys for areas within and adjacent to the Pewaukee River watershed were conducted from 1995 through 2012 by several sources that include the Wisconsin Breeding Bird Atlas, The Great Backyard Bird Count, and the Wisconsin Society of Ornithology (WSO). Based upon these surveys, from 40 to 76 species were observed, including resident, migrant, and breeding bird species. Hence, the presence of these numerous and diverse bird species is consistent with the overall high quality of the riparian buffer areas within the Pewaukee River watershed and emphasizes the need for careful management of lands to protect shrubland and forest habitats for these species (see Appendix H).

Exotic Invasive Species

Invasive plant and animal species can alter aquatic and terrestrial habitats to the point that they can no longer support native species assemblages, which is why it is important to prevent, remove, and/or control them to the extent practicable. For example, invasive plants such as reed canary grass can alter wetland habitats so severely that they cannot support amphibians and reptiles. In other cases, exotic animals can act as predators or parasites, or interfere with food resources that can reduce native species abundance and diversity and lead to local extirpations in some cases.

As previously mentioned, common carp, an exotic invasive species, have been found within the lower reaches of Pewaukee River and in Pewaukee Lake. Other exotic invasive species known to exist within the stream are the rusty crayfish and zebra mussel. Invasive aquatic plant species known to occur include Eurasian water milfoil and curly-leaf pondweed.

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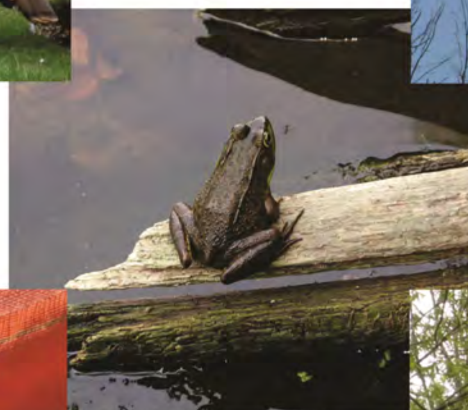
[76]*Water Action Volunteer Biotic Index Monitoring*
*(*http://clean-water.uwex.edu/wav/monitoring/biotic/index.htm*).*

Figure 61

WILDLIFE SPECIES WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

Wild Turkey

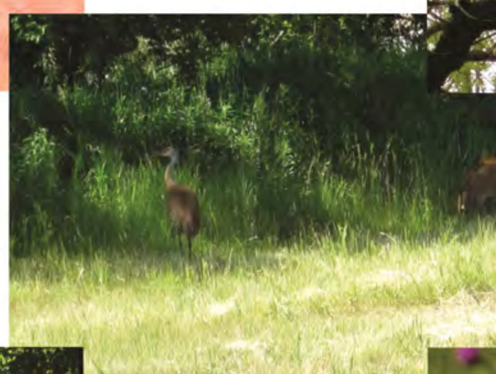
Blue Heron Rookery
(located near Simmons Woods)



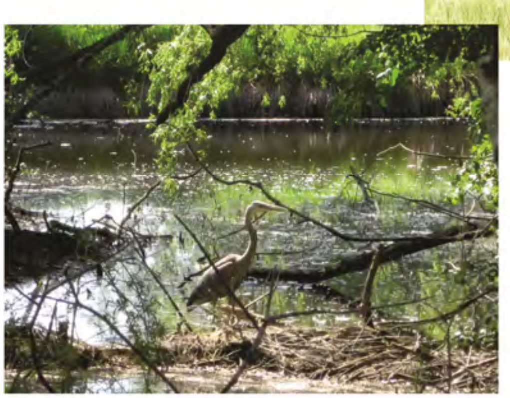
Green Frog

Eastern Garter Snake

Red-Tailed Hawk



Sandhill Crane



Great Blue Heron

Eastern Tiger Swallowtail

Source: SEWRPC.

Other invasive plant species include reed canary grass that is prevalent throughout the watershed, as shown on Map 31. Areas with phragmites infestations have also been located, and are shown on Map 31. Invasive terrestrial vegetation species found include: garlic mustard, European buckthorn, and purple loosestrife, which were found among the nonnative plants on streambanks and shoreland areas throughout the watershed (see Riparian Corridor Conditions subsection above.)

The current and potential new nonnative plant and animal invasive species continue to threaten the biological integrity of this stream ecosystem and need to be managed to the extent practicable to protect the function and structure of the existing wildlife habitats and recreational quality in this watershed. The WDNR, Waukesha County, the Lake Pewaukee Sanitary District, and the Pewaukee River Partnership—have conducted a variety of management programs in concert with the local communities to help control nonnative and invasive species within the watershed.

RECREATIONAL CONDITIONS

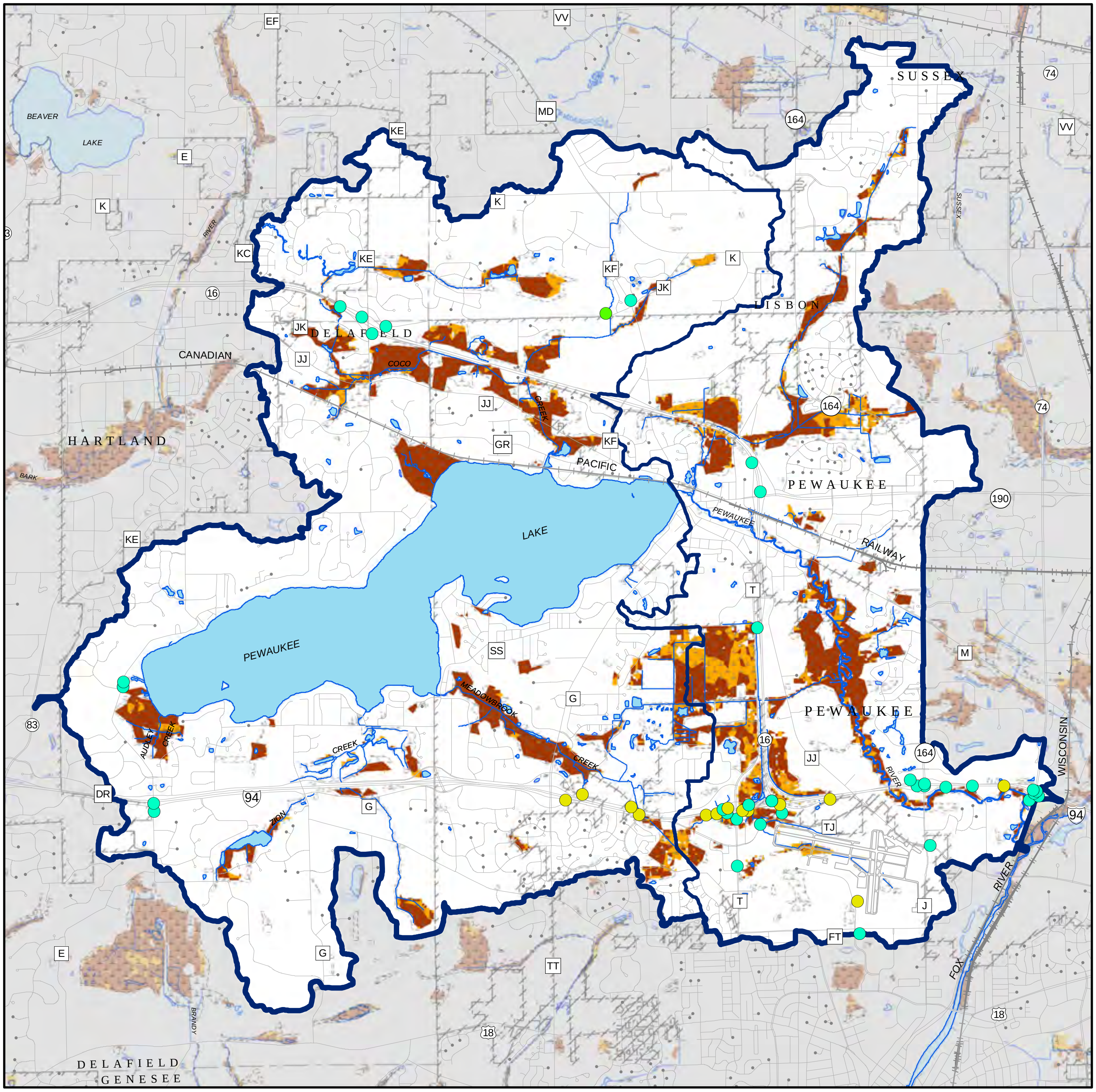
The Pewaukee River and its associated tributary streams, including Pewaukee Lake, form an important element of the natural resource base of the municipalities within the area. The location of these waterbodies within environmental corridors and open space areas provides an opportunity for people to utilize and enjoy these resources for recreational and aesthetic viewing purposes. Consequently, these resources can provide an essential avenue for relief of stressors among the human population and improve quality of life in neighborhoods throughout the area. Such water resources, and their associated recreational uses, also sustain industries associated with outfitting and support recreational and other uses of the natural environment, and, therefore, provide economic opportunities for the local communities. The Waukesha County Comprehensive Plan anticipates an increase in lands dedicated to recreational uses. Hence, recreational use is as important to the quality of life for residents as it is for the continued economic development for all the communities within this watershed.

As part of this planning effort, a recreational opportunity map was developed showing locations of access points, parks, and viewing areas for bird watching, as well as walking and riding trails, parks, golf courses, and parking locations throughout the Pewaukee River watershed (see Appendix I, Map I-1 and Table I-1). This map is designed to help potential users understand that there are numerous recreational opportunities within and adjacent to the Pewaukee River watershed. Increased recreational opportunities can lead to increased appreciation and ultimately stewardship of the water and land resources. For example, the local Kiwanis Club sponsors an annual "River Run" each spring which engages the entire local community, including businesses to come together and enjoy a canoe or kayak trip on the Pewaukee River. This event takes a lot of effort and it also promotes awareness of the ongoing efforts to protect and enhance recreation on this system. In addition, since safe recreational access was an important issue on this River, SEWRPC staff conducted a navigational hazards assessment on multiple structures on the Pewaukee River as summarized below.

One of the observations while putting this recreational map together was that there has been a loss of private boat launch sites on Pewaukee Lake and there are limited access points on the Pewaukee River. The loss of private launches on the Lake is primarily due to sales of residential developments. If this trend continues on the Lake, public access to the lake could become severely limited and loss of the remaining sites could result in the loss of ability to apply for recreational grants from the WDNR in the future. However, the Pewaukee River Partnership, Lake Pewaukee Sanitary District, and Village of Pewaukee have done an excellent job of improving both parking and access to Pewaukee Lake and River by purchasing and improving the Village parking lot in downtown Pewaukee on Oakton Road (at the former Sentry location), constructing new carry-on boat access at Riverside Drive (see Figure 62), and maintenance and construction of several boardwalk trails and decks. These collaborative efforts improve access and recreational opportunities for local residents and visitors to downtown Pewaukee, which enhances the quality of the recreational experience, supports local businesses as well as the economy of the entire community.

Map 31

DISTRIBUTION OF EXOTIC INVASIVE REED CANARY GRASS, PHRAGMITES, JAPANESE KNOTWEED, AND TEASEL WITHIN THE PEWAUKEE RIVER WATERSHED



WETLAND WITH LESS THAN 50 PERCENT OF REED CANARY GRASS COVER

WETLAND WITH MORE THAN 50 PERCENT OF REED CANARY GRASS COVER

PHRAGMITES OBSERVED LOCATIONS

JAPANESE KNOTWEED OBSERVED LOCATIONS

TEASEL OBSERVED LOCATIONS

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

NOTES: Data for reed canary grass cover within wetlands is from 2006. Surveys for phragmites, Japanese knotweed, and teasel were updated in 2011.

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

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: Southeastern Wisconsin Invasive Species Constortium, Inc., and SEWRPC.

Figure 62

CONSTRUCTION OF THE RIVERSIDE DRIVE CARRY-ON BOAT LAUNCH ON THE PEWAUKEE RIVER

NOTE: See Map 38 in Chapter VI for location. Completed in 2013.

Source: Photos by Charlie Shong.

Navigational Hazards

Bridges and culverts can be significant hazards to navigate through in low-flow conditions and can be extremely dangerous in higher flow periods. These conditions are primarily because road crossings were not necessarily designed to allow for the safe passage of watercraft. Therefore, SEWRPC staff conducted an assessment of each structure on the Pewaukee River up to structure number 14 at Cecilia Drive (which was considered a reasonable limit to navigate under normal low-flow conditions) to rate their ability to safely navigate a kayak or canoe, as shown in Table F-1. The results of this assessment indicate that all of the structures on the Pewaukee River can be safely navigated under normal or low-flow conditions, except structure numbers 12 at Capitol Drive, 13 at STH 16, and 14 at Cecilia Drive (see Table F-1). At low-flow conditions the underside of structures 12 and 13 are between two and three feet above the water surface, leaving no room to safely pass a canoe. Similarly, the sizes of the three culvert pipes of structure 14 make it impossible to navigate through, even at the lowest of flow conditions. It is possible that structure 12 could be easily portaged with minimal construction for entry and exit landings, as well as additional road crossing safety features. Unfortunately, highway traffic speeds and culvert length make portaging structure 13 impossible, thus replacement of this structure with culverts that have sufficient height to safely pass a canoe would be the only option if recreational watercraft are to navigate this stretch.

Chapter V

WATERSHED ISSUES AND CONCERNS

INTRODUCTION

Many issues of concern that impact the water quality and recreational use of the Pewaukee River system. These issues were identified using the information highlighted in Chapters II through IV of this report, as well as through consultations with the Pewaukee River Partnership Inc., and the *ad hoc* Pewaukee River Protection Plan Advisory Group (as discussed in Chapter I of this report). In general, the majority of the issues of concern are related to the existing and forecasted changes in land use in the Pewaukee River watershed. More specifically, they relate to the potential effects of these land use changes on the hydrology, groundwater recharge, water quality (including temperature, habitat, and bank stability) and aquatic and terrestrial wildlife community.

A primary consideration in the selection of issues of concern to be addressed was the degree to which the concerns could be mitigated by either structural or nonstructural measures that, functioning together as a watershed-based system, would be expected to achieve the agreed-upon water resource objectives. It is also important to note that the Advisory Group understands that the Pewaukee River and its environment contain many assets, as shown in Figure 63. Therefore, the goals, objectives, and issues addressed in this report emphasize protecting and further enhancing this valuable resource.

This chapter discusses the issues of concern within the watershed, which form the basis for the recommendations set forth in Chapter VI. These issues are discussed within the context of major project goals which were identified by the Pewaukee River Watershed Protection Plan Advisory Group. These goals are as follows:

- Protect and improve wildlife, land, surface water, and groundwater resources;
- Minimize impacts of land development by controlling agricultural and urban runoff pollution and flooding; and
- Build partnerships and inform the public to promote the protection and use of natural resources.

PROTECT AND IMPROVE WILDLIFE, LAND, SURFACE WATER, AND GROUNDWATER RESOURCES

The most fundamental element of this watershed protection plan is land use. The future distribution of urban and rural land uses will largely determine the character, magnitude, and distribution of nonpoint sources of pollution and, ultimately, the quality of surface waters and the associated environment in the Pewaukee River

Figure 63

PHYSICAL, CHEMICAL, BIOLOGICAL, AND RECREATIONAL ASSETS OF THE PEWAUKEE RIVER SYSTEM

BIOLOGICAL CHARACTERISTICS:

Generally fair to good stream health and wildlife habitat

Areas with both warmwater and coldwater fisheries

Fair diversity and abundance of mussels

Moderately abundant aquatic insect populations

Abundant and diverse wildlife including a Blue Heron rookery located within the watershed

Presence of threatened and endangered species, as well as special areas of concern

FAIR-GOOD QUALITY AND DIVERSITY OF INSTREAM HABITATS:

Good substrate and water depths

Healthy aquatic vegetation

Regions of woody cover

Areas of high-quality spawning habitat

Figure 63 (continued)

GOOD QUALITY AND DIVERSE RECREATIONAL EXPERIENCES:

Boating/Skiing

Canoeing

Hunting

Fishing

Wildlife Viewing

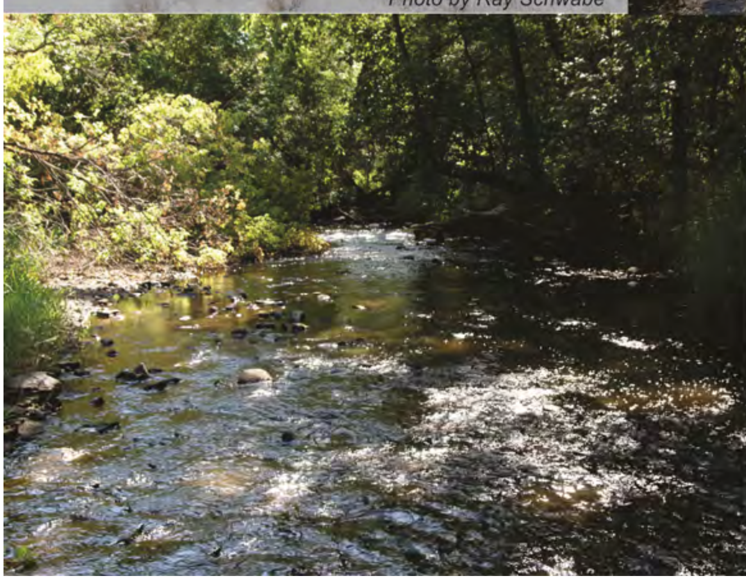
Golfing

Hiking/Biking

Picnicking

Public Access

Photo by Ray Schwabe



PHYSICAL AND CHEMICAL CHARACTERISTICS:

Well-connected floodplain in most areas

Stable streambed and banks

Some areas of extensive riparian buffers with good potential for expansion

Significant amount of infiltration areas/ groundwater recharge potential

High groundwater discharge

Areas with natural meanders, but channelization/ diversions have been significant

Source: Pewaukee River Watershed Protection Plan Advisory Group and SEWRPC.

watershed. Consequently, the selection of a land use plan for the study area is the first and most basic step in synthesizing the water quality plan. The process for developing the planned land use data that forms the foundation for the land use element of the plan is described in Chapter II of this report.

Land Management Measures

Objective—Preserve and protect environmentally sensitive areas such as designated natural areas, wetlands, fish and wildlife habitat, riparian buffers, and primary and secondary environmental corridors.

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

The delineation of these 12 natural resource and related elements on a map results in an essentially linear pattern of relatively narrow, elongated "environmental corridors," as designated by the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements. They are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors generally connect with the primary environmental corridors and are at least 100 acres in size and one mile long. In addition, smaller concentrations of natural resource features that have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

Given the fact that these areas are particularly important to the overall health of the watershed, the protection and further enhancement of these areas are a crucial part of this plan. It is therefore important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge, natural filtration, and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality could then, in turn, lead to a deterioration of the quality of the groundwater which serves as a source of domestic, municipal and industrial water supply, and provides base flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be significant, the combined effects of environmental changes may lead eventually to potentially permanent deterioration of the

[1]*The process of delineating environmental corridors and isolated natural resource areas as areas encompassing concentrations of natural resource base features such as wetlands, woodlands, and wildlife habitat areas, along with the resulting configuration of environmental corridors and isolated natural resource areas, is described in Chapter II of SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006.*

underlying and supporting natural resource base and of the overall quality of the environment. In short, the best course of action to protect the valuable resources contained in environmental corridors and natural resource areas is to prevent deterioration to the greatest extent possible.

As noted in Chapter II, the Pewaukee River watershed has been urbanizing rapidly since the 1950s, indicating that protection, maintenance, and expansion of environmental sensitive areas within the watershed must become a priorities. Partnerships between the WDNR, Waukesha County, Lake Pewaukee Sanitary District, Pewaukee River Partnership, and the cities, towns, and villages in the watershed have contributed to the maintenance of these areas on behalf of the citizens of Wisconsin and others. Encouraging and continuing the synergies between these various entities is an important issue to be considered, as it will affect the ability and willingness of the entities to protect and preserve the Pewaukee River corridor and its associated ecosystems for the benefit of the stakeholders living in and visiting the watershed.

Fisheries and Wildlife Enhancement

Objective—Protect lakes and streams to support a high-quality sustainable coldwater and warmwater fishery and associated aquatic community, habitat, and water quality.

Stream Corridor Management, and Fish and Wildlife Enhancement

The maintenance and rehabilitation of the warmwater and coldwater sport fishery, key natural resources in the Pewaukee River System watershed, are important issues to be considered in this protection plan. As described in Chapter IV of this report, the Pewaukee River and Pewaukee Lake are capable of supporting warmwater sport fish and water recreation use objectives. Additionally, Coco Creek, located in the northern part of the Pewaukee River watershed, is generally capable of supporting coldwater sport fish and partial water recreation use objectives. Based upon analysis and review of historic and recent fisheries surveys, summarized in Chapter IV of this report, fishery conditions in the Pewaukee River watershed demonstrate the ability to support both cold and warmwater fisheries that generally range from poor to good.

In order to best protect these resources, it should be noted that the watershed ecosystem is a continuum, including the stream, the Lake, and the surrounding lands. These features form the basic support system and structure for sustaining the wildlife, other natural resources and, most importantly, the local citizens who reside there. To sustain the ecology of the Pewaukee River watershed, actions should focus on the key natural resource features located throughout the watershed. Consequently, actions to preserve and enhance the interconnection between the watershed's ecosystems are important considerations. Such actions should focus on the restoration and management of habitats not only within the River and streams, but also within the Lake and the watershed as a whole.

A number of issues of concern specifically affect the quality of the fisheries resource and should be considered to ensure the continued maintenance and future production of the fishery. These issues are related to existing and planned changes in land use, and the associated effects of those land use changes on stream hydrology, groundwater recharge and discharge, water quality (including temperature), and aquatic habitat quality. Actions taken to manage land use, nonpoint source pollution, and stormwater runoff, together with environmental monitoring, complement and support actions necessary to sustain the fisheries and other aquatic life.

The Aquatic Organism recommendations set forth in Chapter VI were formulated as an outgrowth of the assessment of fish and aquatic life resources set forth in Chapter IV of this report. These recommendations are made to supplement or reinforce recommendations related to the control of urban and rural nonpoint sources of pollution, protection and maintenance of riparian buffers, and the restoration or rehabilitation of aquatic organism passage at selected road crossings. These actions would help to protect or reestablish a native warmwater and/or coldwater fishery where appropriate.

Groundwater Protection Measures

Objective—Preserve groundwater recharge areas and prevent groundwater contamination from stormwater infiltration practices.

The groundwater contamination potential of shallow aquifers in the Southeastern Wisconsin Region was mapped under the regional groundwater management planning program. As the groundwater contamination potential in the Pewaukee River watershed is considered to be predominantly moderate to high,[2] the groundwater contamination potential of the shallow aquifers is an issue to be considered in locating new development and/or redeveloping sites within the watershed.

Additionally, under the regional water supply planning process,[3] groundwater sustainability analyses were made for six selected demonstration areas, with each selected to represent a range of hydrogeological conditions. The areas were analyzed to provide guidance on the number of individual household wells that could be sustained without significant impacts on the shallow groundwater aquifer system. The study was also developed with the intent that the analytical results could be applied to the evaluation of similar developments throughout the Region. The groundwater sustainability guidance developed through this planning program is something that should be considered by municipalities in this watershed when they are completing local land use plans and when evaluating the sustainability of proposed developments.

These concerns are reflected in the Waukesha County Land and Water Resources Management Plan, [4] which recognizes the need to protect groundwater recharge areas and minimize the impacts of stormwater-borne contaminants on groundwater, under Goal 2 of the plan update. Consequently, consideration of groundwater protection and management remains an important issue in the Pewaukee River watershed.

Climate Change

Objective—Protect the system from the potential negative physical and biological impacts associated with climate change.

Global climate models indicate that climate change will have significant impacts on mid-latitude regions such as the Upper Midwest, but little is known about specific effects on Wisconsin's environment, economy, and human health, or how to address potential threats or opportunities. Effective responses will require the best available science and meaningful participation of public and private stakeholders. Therefore, the Wisconsin Initiative on Climate Change Impacts (WICCI) was formed in response to questions raised by a bipartisan committee of State legislators who want to know how climate change could impact their districts and constituents.[5] More than 40

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[2]*SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin, *June 2002. See especially Map 33 in Chapter VII of SEWRPC Technical Report No. 37.*

[3]*SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin, *December 2010and SEWRPC Technical Report No. 48,* Shallow Groundwater Quantity Sustainability Analysis Demonstration for the Southeastern Wisconsin Region, *November 2009.*

[4]*Waukesha County Department of Parks and Land Use,* Waukesha County Land and Water Resource Management Plan: 2006-2012, *2012 Update.*

[5]*Wisconsin Initiative on Climate Change (WICCI) assesses and anticipates climate change impacts on specific Wisconsin natural resources, ecosystems and regions; evaluates potential effects on industry, agriculture, tourism and other human activities; and develops and recommends adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers and other stakeholders. See website,* http://www.wicci.wisc.edu/about.php

scientists from the University of Wisconsin-Madison, the Wisconsin Department of Natural Resources, and other agencies and institutions met in June 2007 to explore ways to identify and measure the impacts of climate change and variability at local and regional scales. The group also discussed the development of adaptation strategies for Wisconsin ecosystem and natural resource management, agriculture, business, human health, and other vital components of quality of life. WICCI represents the outgrowth of these efforts.

Unlike the Governor's Global Warming Task Force, which targets mitigation of greenhouse gases (how humans affect the climate) WICCI focuses solely on the impacts of climate change—how the climate affects us and how to adapt to changes in climate.

WICCI is governed by a Science Council whose members are chosen from an array of disciplines within the University of Wisconsin System, the Wisconsin Department of Natural Resources, and other State and Federal agencies, universities, and institutions. The primary function of the Science Council is to organize and coordinate Working Groups that have the scientific expertise to assess climate change impacts pertinent to specific issues or areas of concern. An Operations and Outreach Unit in the Nelson Institute for Environmental Studies at UW-Madison facilitates the operations of the Science Council and is responsible for the outreach mission of WICCI. It also coordinates the activities of an Advisory Committee.

Specific working groups were created by the Science Council to conduct science-based assessments of potential climate change impacts on specific regions, ecosystems, communities, and industries in Wisconsin and to make recommendations on adaptation strategies. Scientists, experts, and practitioners work together in each group and have identified a number of concerns and potential mitigative measures that are further refined in Chapter VI of this report. Among these issues relative to the Pewaukee River system are coldwater fish and fisheries, human health, plants and natural communities, soil conservation, stormwater management,[6] water resources, and wildlife.

MINIMIZE IMPACTS OF LAND DEVELOPMENT BY CONTROLLING AGRICULTURAL AND URBAN RUNOFF POLLUTION AND FLOODING

All human activities upon the land surface result in some degree of mobilization of contaminants and modification of surface runoff patterns that can affect lakes and streams, their quality, and biotic condition. Many effects of human activities can be mitigated to a large extent through sound planning; the provision of sanitary sewer service; utilization of appropriate nonpoint source pollution abatement measures; and the actions of an informed public. Each of these issues forms an important element to be considered, and is discussed further below.

Urban Land Use Planning and Zoning Measures

Objective—Develop policies and install practices that reduce urban nonpoint source water pollution and help achieve the recommended water use objectives and supporting water quality standards for surface waters.

As noted above, a basic element of any water quality management effort is the promotion of sound land use development and management in the watershed. The type and location of future urban and rural land uses in the Pewaukee River watershed will determine, to a large degree, the character, magnitude, and distribution of nonpoint sources of pollution; the practicality of, as well as the need for, stormwater management; and, to some degree, the water quality of the streams of the watershed.

Chapter II of this report includes descriptions of the existing and planned land use patterns for the years 2000 and 2035, respectively, within the Pewaukee River watershed. The land use plan suggests that urban land uses,

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[6]*The SEWRPC staff serves on the Stormwater Management Working Group.*

especially residential development, within the watershed would increase during this time period. Much of this residential development is likely to occur on agricultural lands. Within these areas, it is envisioned that there also will be some infilling of existing platted lots and some back lot development, as well as the redevelopment and reconstruction of existing residential properties. Recent surveillance indicates that this type of development is currently occurring in the Pewaukee River watershed. Accordingly, given the potential impact of lakefront and riparian development and redevelopment throughout the watershed, future development proposals are an issue of concern, that should be evaluated for potential impacts on the Pewaukee River system as proposals are advanced.

In addition, the adopted regional and local land use and water quality management plans set forth management measures directed at urban and rural nonpoint source contaminants within the Pewaukee River watershed (see Table 7 in Chapter III of this report for a list of applicable plans). Sediment (and associated total phosphorus load) reduction goals for the Pewaukee River watershed called for up to by 80 percent for new development, 40 percent from parking lots and roads associated with redevelopment, and 80 percent for infill development in urban nonpoint source pollution loads as required by NR 151 of the *Wisconsin Administrative Code*. Recent studies of the potential impact of riparian landscaping activities on nutrient loadings to waterbodies in southeastern Wisconsin have suggested that urban residential lands can contribute up to twice the mass of phosphorus to a lake when subjected to an active program of urban lawn care, contrasted with similar lands managed in a more natural fashion.[7] The State of Wisconsin has enacted limitations on the application of fertilizers containing phosphorus, pursuant to 2009 Wisconsin Act 9, and has taken action to limit runoff and sediment transport from urban areas and transportation corridors under Chapter NR 151 of the *Wisconsin Administrative Code*. The adopted Waukesha County Land and Water Resources Management Plan specifically incorporates recommendations under Goal 1, calling for control of urban runoff pollution and flooding. Periodic review of requirements for the control of nonpoint source pollution is important and needs to be considered.

Stormwater and Floodland Management Measures

Objective—Preserve floodwater storage areas and control the quantity of runoff from new urban development.

The extent and placement of incremental urban development over the planning period is critical if the intensification of the existing and the creation of new flooding problems in the watershed are to be avoided. The legal requirements for, and extent and placement of, stormwater and flood mitigation infrastructure directly affects the hydrologic and hydraulic behavior of the streams within the watershed. In this respect, preservation of the primary environmental corridors is of particular importance and affects the hydrologic and hydraulic behavior of the stream system and also water quality conditions. Preservation of floodlands lying outside the environmental corridors in open uses is also critical, as is encouraging the use of floodland areas for outdoor recreational and open space activities. Hence, the improvement of stormwater management facilities, control of runoff from areas of future development, protection of wetlands, and the prevention of future development in floodprone areas are issues to be considered.

With respect to stormwater management, all of the municipalities in the watershed have adopted stormwater management ordinances, or have incorporated stormwater management requirements in multiple other ordinances, as indicated in Table 11 in Chapter III of this report. The Waukesha County ordinance reflects current best practices regarding the determination of stormwater flows and increased runoff volumes, mitigation of flooding potential, and the control of contaminants from land use activities. Periodic review of these ordinances and their provisions, to ensure they are current, should be undertaken on a regular basis to facilitate control of urban-source contaminants that would likely be delivered to the Pewaukee River system and to minimize the impacts of urban

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[7]*U.S. Geological Survey Water-Resources Investigations Report No. 02-4130,* Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin, *July 2002.*

runoff on the natural resources of the Pewaukee River watershed. This would be consistent with the provisions of Goal 2 of the Waukesha County Land and Water Resources Management Plan. Hence, management of runoff from urban areas is an issue to be considered.

Agricultural Pollution Control Measures

Objective—Promote the use of agricultural nonpoint pollution control practices to meet or exceed State and Federal standards.

Chapter III of this report contains a review of the State and local nonpoint pollution control standards that apply to agricultural operations, principally contained in Chapters NR 151 and ATCP 50 of the *Wisconsin Administrative Code*. Details of how these performance standards will be implemented in Waukesha County are set forth in the Waukesha County Land and Water Resource Management Plan (2006-2012).

One of the State performance standards requires the maintenance of cropland soil erosion rates at or below tolerable—or "T"—values.[8] This could be accomplished through a combination of practices, including, but not limited to, expanded conservation tillage, contour farming, crop rotations, and grassed waterways. The applicable measures are usually determined by the development of individual farm conservation plans, consistent with the recommendations set forth in the NRCS Technical Guide and Conservation Planning Manual. It should be noted, however, that maintaining erosion rates at "T" values may not adequately protect water quality from sediment delivery. Consequently, agricultural nonpoint source control measures remain an issue to be considered.

Buffers serve important water quality-related functions, including the removal of nonpoint source pollutants from both surface water and groundwater, reduction of instream water temperatures through shading of the stream channel, and maintenance of streambank stability, among others. In addition, riparian buffers provide habitat for a variety of aquatic and terrestrial wildlife and are essential components of environmental corridors. The riparian corridors form the nexus between the surface water and groundwater systems, including areas of groundwater discharge that coincide with the ability of streams to sustain economically important coldwater fish species, and with groundwater recharge areas that allow precipitation to infiltrate into the groundwater aquifers. While Waukesha County currently does not have a program for the establishment of riparian buffers, the County Land and Water Resources Management Plan recommends promoting buffers along all water resources for water quality, wildlife habitat, and groundwater recharge purposes, which is consistent with the Pewaukee River Watershed Advisory Group goal calling for control of agricultural runoff pollution.

Additionally, a literature review was recently conducted by SEWRPC as part of the update to the Regional Water Quality Management Plan to evaluate the effectiveness of riparian buffers in controlling nonpoint source pollution.[9] Based upon this review, it was determined that a general buffer width of 75 feet is appropriate for water quality modeling purposes in terms of representing: 1) a reasonably high level of effectiveness for the control of nitrogen, phosphorus, and total suspended solids; 2) practicality of implementation; and, 3) consistency with regulatory requirements such as structural setbacks (see Appendix O, "Riparian Buffer Effectiveness Analysis," in SEWRPC Planning Report No. 50). It is important to note that riparian buffers are only a single component of a comprehensive watershed management strategy. Strategies include other measures to control

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[8] *"T-value" is the tolerable soil loss rate—the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely. T-values are published for each soil type by the USDA Natural Resource Conservation Service in Chapter 2 of the Field Office Technical Guide. "Excessive" cropland erosion refers to erosion in excess of the tolerable rate, or T-value.*

[9] *SEWRPC Planning Report No. 50,* A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds, *December 2007.*

point and nonpoint sources of nutrients and sediments, protection of aquatic and terrestrial habitat, and management of floodwaters. Nevertheless, the establishment and maintenance of riparian buffers as well as the application of buffer requirements in the Pewaukee River basin are major issues to be considered.

Chapters NR 151 and ATCP 50 also contain certain provisions relating to the control of barnyard runoff, manure storage, and the application of nutrients on cropland and pastures. Reductions in agricultural loadings may be anticipated on a case by case basis as a result of the implementation of the State administrative rule provisions. Hence, control of runoff from agricultural areas remains an issue to be considered.

BUILD PARTNERSHIPS AND INFORM PUBLIC TO PROMOTE PROTECTION AND USE OF NATURAL RESOURCES

As part of the overall citizen informational and educational programming to be conducted in the Pewaukee River watershed, residents in, and visitors to, the watershed should be made aware of the value of the ecologically significant areas to the overall structure and functioning of the watershed ecosystems. Specifically, informational programming related to the protection of ecologically valuable areas in the watershed should focus on the need to maintain the integrity of riparian corridors, minimize the spread of nuisance aquatic species such as purple loosestrife, and utilize good urban housekeeping and yard care practices in order to mitigate and moderate the impacts of human activity on the watershed. Likewise, educational activities within the watershed's school districts should make use of the proximity of this waterway and focus on the unique attributes of the River system within the Region, particularly since many areas of the watershed have been designated fair to good habitat and water quality. In this regard, informational and educational programming is an issue to be considered.

Educational and informational brochures and pamphlets of interest to homeowners and others are available from the University of Wisconsin-Extension (UWEX), the WDNR, SEWRPC, the County Land and Water Resources Division, and many Federal agencies. The informational content of these brochures could be provided to homeowners through local media, the Internet, direct distribution, and/or targeted library and civic center displays. Many of the ideas contained in these publications can be integrated into ongoing, larger-scale activities, such as anti-littering campaigns, recycling drives, and similar environmentally focused activities. Within the school districts, much of the information contained in these publications could be used to supplement texts in environmental science, art, biology, and mathematics, among other subject areas. This is consistent with the recommendations set forth in the Waukesha County Land and Water Resource Management Plan related to monitoring water quality/flow of local streams and the Lake, and, hence, is an issue to be considered. Specifically, informational and educational programming in the following three areas should be considered, as summarized below: in school-based educational programming, in general community-based informational programming, and in specific informational programming in communities with municipal separate storm sewer (MS4) systems that are implementing State stormwater management permit requirements.

Targeted Educational Programming

Objective—Develop or expand land use and water quality information and education programs as needed to implement plan goals and objectives.

Promotion of local support for environmentally sensitive and sustainable measures can be enhanced through targeted educational programming. School-based programs that could be further utilized within the Basin include participation in programs such as Project WET, Project WILD, and Project Learning Tree (PLT). Given the importance of children to the future sustainability of our water resources, as well as their potential for influencing family members, these types of educational programs need to be considered.

Community-Based Informational Programming

Objective—Continue cooperation among community organizations and municipalities, and develop public participation opportunities.

Experience suggests that coordinating individual efforts is a valuable and useful element of an informational and educational program. Establishment of a stream-focused conservation organization can promote local support for river protection by providing a focal point for private residents, and an umbrella under which businesses and other nonprofit organizations may participate in a meaningful manner in stream protection activities. To this end, the Lake Pewaukee Sanitary District provides opportunities for public participation in decision-making processes, and has supported opportunities for shared decision-making such as the creation of citizen advisory committees, completion of memoranda of understanding with lake and river organizations within the Fox River basin, and support for rehabilitation activities that benefit all aspects of watershed management.

The Pewaukee River Partnership, Inc., established as a private, nonprofit watershed protection organization, continues to play a leading role in coordinating and garnering citizen and community participation in support of the implementation of stewardship activities to enhance the natural resources within the Pewaukee River Watershed.

Recreational Development

Objective—Promote, maintain, and expand safe recreational opportunities.

The Pewaukee River, its associated tributary streams, and Pewaukee Lake form an important element of the natural resource base of the municipalities within the area. The location of these waterbodies within environmental corridors and open space areas provides an opportunity for people to utilize and enjoy these resources for recreational and aesthetic viewing purposes. Consequently, these resources can provide an essential avenue for relief of stressors among the human population and improve quality of life in neighborhoods throughout the area. Such water resources, and their associated recreational uses, also sustain industries associated with outfitting and support recreational and other uses of the natural environment, and, therefore, provide economic opportunities for the local communities. The Waukesha County Comprehensive Plan anticipates an increase in lands dedicated to recreational uses. Hence, recreational use is an important issue to be considered.

SUMMARY

A number of priority issues of concern facing the Pewaukee River, the lake and the streams within the watershed, and the resident communities have been identified. While these issues generally fall within the three areas of concern initially identified by the Working Group—namely: protecting and improving wildlife, land, surface water and groundwater resources; minimizing impacts of land development by controlling agricultural and urban runoff pollution and flooding; and building partnerships to inform the public to facilitate protection and use of natural resources—the foregoing analysis suggests that there are 10 areas of priority concern that should be addressed in order to preserve and protect the environmental quality, the ecological structure and integrity of the Pewaukee River watershed, as well as public health, safety, and quality of life. These 10 areas are summarized as follows:

1. Preserve and protect environmentally sensitive areas such as designated natural areas, wetlands, fish and wildlife habitat, riparian buffers, and primary and secondary environmental corridors.

2. Protect the lake and streams to support a high-quality sustainable coldwater and warmwater fishery and associated aquatic community, habitat, and water quality.

3. Preserve groundwater recharge areas and prevent groundwater contamination from stormwater infiltration practices.

4. Protect the system from the potential negative physical and biological impacts associated with climate change.

5. Develop policies and install practices that reduce urban nonpoint source water pollution and help achieve the recommended water use objectives and supporting water quality standards for surface waters.

6. Preserve floodwater storage areas and control the quantity of runoff from new urban development.

7. Promote the use of agricultural nonpoint pollution control practices to meet or exceed State and Federal standards.

8. Develop or expand land use and water quality information and education programs as needed to implement plan goals and objectives.

9. Continue cooperation among community organizations and municipalities, and develop public participation opportunities.

10. Promote, maintain, and expand safe recreational opportunities.

Recommended priority actions to address these 10 elements are set forth in Chapter VI of this report.

Chapter VI

RECOMMENDATIONS

INTRODUCTION

This chapter provides project and management recommendations, as identified by the Southeastern Wisconsin Regional Planning Commission (SEWRPC), the Pewaukee River Partnership Inc., and the *ad hoc* Pewaukee River Watershed Protection Plan Advisory Group. The recommendations address the 10 priority concerns identified in Chapter V of this report. They are presented in the following categories:

1. Riparian Buffers,
2. Groundwater Recharge and Pollution,
3. Surface Hydrology,
4. Water Supply and Demand,
5. Water Quality,
6. Wildlife,
7. Aquatic Organisms,
8. Recreational Opportunities,
9. Land Use Planning,
10. Monitoring and Information, and
11. Education.

Table 24 indicates recommendation categories associated with each of the priority concerns identified in Chapter V of this report.

The recommendations set forth herein focus on those measures which are applicable to the stakeholders and agencies with jurisdiction within the Pewaukee River watershed. However, the general-purpose units of government within the Pewaukee River watershed—counties, villages, and towns—are specifically encouraged to adopt these recommendations and implement this protection plan, through local policies, practices, programs, and ordinances, where appropriate. In addition, many actions can be implemented by other stakeholders, including special purpose units of government, nonprofit conservation organizations, and individual citizens, as summarized in the "Roles and Responsibilities" subsection at the end of this chapter.

Table 24

CONNECTION BETWEEN IDENTIFIED ISSUES OF CONCERN AND THE RECOMMENDATION CATEGORIES

Priority Concerns	Recommendation Category
Preserve and protect environmentally sensitive areas such as designated natural areas, wetlands, fish and wildlife habitat, riparian buffers, and primary and secondary environmental corridors	All
Protect the lake and streams to support a high-quality sustainable coldwater and warmwater fishery and associated aquatic community, habitat, and water quality	Aquatic Organisms, Surface Hydrology, Riparian Corridors, Groundwater Recharge, Water Quality, Wildlife, Land Use Planning
Preserve groundwater recharge areas and prevent groundwater contamination from stormwater infiltration practices	Groundwater Recharge and Pollution Water Supply and Demand
Protect the system from the potential negative physical and biological impacts associated with climate change	All
Develop policies and install practices that reduce urban nonpoint source water pollution and help achieve the recommended water use objectives and supporting water quality standards for surface waters	Water Quality, Riparian Buffers Groundwater Recharge, Wildlife
Preserve floodwater storage areas and control the quantity of runoff from new urban development	Surface Hydrology, Groundwater Recharge, Water Quality
Promote the use of agricultural nonpoint pollution control practices to meet or exceed State and Federal standards	Groundwater Pollution, Water Quality, Wildlife
Develop or expand land use and water quality information and education programs as needed to implement plan goals and objectives	Education Monitoring and Information
Continue cooperation among community organizations and municipalities, and develop public participation opportunities	Education Monitoring and Information Recreation
Promote, maintain, and expand safe recreational opportunities	Recreation

Source: SEWRPC.

It is also understood that a certain level of prioritization of projects and programs will need to take place, particularly given the number of recommendations made in this protection plan. The “Prioritization of Projects” section of this chapter provides some basic guidance in this regard, while the “Cost Consideration and Funding Sources” section provides some guidance on the financial benefits of implementing these projects, as well as the kinds of funding sources that are available to help put the plan’s recommendations into action.

RECOMMENDATIONS

In order to facilitate the identification of potential projects and pinpoint where the recommendations should be implemented, recommendation maps related to buffer region development, groundwater recharge protection, stormwater management improvement, aquatic habitat enhancement, and recreational opportunities have been included with this chapter. These maps play an integral role in communicating the recommendations of this plan. As a result, the recommendations laid out in this chapter follow the following structure:

1. A brief summary of the recommendation category and the issues associated with that category,

2. An explanation of the targets associated with the issue,

3. An explanation of the recommendation map developed to guide the implementation of projects meant to address identified issues (see Maps 32 through 39 located at the end of this chapter), and

4. A list of recommended actions aimed at achieving each target.

It is important to note that the recommended actions, included as a subsection of each target, identify general recommendations for project types, while the maps indicate specifically where these projects should be located. Therefore, the two must be used in tandem in order to implement the recommendations of this plan. Each of the maps provides guidance on the recommendations and their interpretation in order to facilitate their use.

Climate Change

The main climate drivers (i.e., factors that may change or impact the resource) identified by the WRWG are large rainfall events, water availability, and warming temperatures. Subsequently, the U.S. Environmental Protection Agency (USEPA) has developed a much more comprehensive list of 26 climate indicators, which are subdivided among five categories that include: greenhouse gases; weather and climate; oceans; snow and ice; and, society and ecosystems.[1] A summary of the key points is provided in Appendix G in this report. That summary presents compelling evidence that many fundamental measures of climate in the United States are changing and having real effects on the human communities, which supports similar trends in Wisconsin as discussed above. All of these physical, chemical, and biological impacts are anticipated to affect food webs and, ultimately, the status of Wisconsin's rich water and fishery resources and the communities that depend upon them. In many cases, these impacts will call for policy changes. Therefore, the following list represents the first consensus-based attempt to develop water resources responses to climate change in Wisconsin. The impacts, in italics, are followed by adaptation strategies that were taken from the WRWG Executive Summary in the 2011 WICCI report.

Increased flooding will have impacts on urban infrastructure and agricultural land, especially in low-lying areas and large watersheds.

- Identify, map, and prioritize Potentially Restorable Wetlands (PRWs) in floodplain areas.
- Restore prior-converted wetlands in upland areas to provide storage and filtration, and to mitigate storm flows and nutrient loading downstream.
- Develop both long-term and short term changes to community infrastructure.

Increased frequency of harmful blue-green algal blooms due to nutrient-rich runoff, lake stratification, and changes in water levels.

- Increase monitoring of inland beaches and develop better prediction tools for blue-green algal toxins and associated water quality in order to improve predictive capacity.
- Support development of statewide standards for blue-green algal toxins and take appropriate action to protect public health.

Conflicting water use concerns based on increased demand for groundwater extraction due to variable precipitation projections and warmer growing season temperatures.

- Encourage large volume water users to locate in areas with adequate and sustainable water sources including large rivers or the Great Lakes.

[1]*USEPA*, Climate Change Indicators in the United States, *2012,online:* climateindicators@epa.gov

- Encourage rural and urban water conservation through incentives and regulation.

- Promote integrated water management by planning water use based on long-term projections of supply and demand and tying it to land use and economic growth forecasts.[2]

Changes in seepage lake levels due to variable precipitation, recharge, increased evapotranspiration (ET). There are additional implications for water chemistry, habitat, and shorelines.

- Enhance and restore shoreline habitat (coarse wood, littoral and riparian vegetation, bioengineered erosion control) to withstand variations in water levels.

- Enhance infiltration by reducing impervious surfaces in urban/riparian areas and changing land management practices, particularly in headwater areas.

- Change planning and zoning criteria for lakeshore development to account for changes in water levels.

- Adjust and modify expectations and uses of lakes, especially seepage lakes; recognize that some lakes are not suited for all uses.

Increased sediment and nutrient loading to surface waters during earlier and more intense spring runoff events.

- Resize manure storage facilities, wastewater facilities, stormwater drains, and infrastructure to accommodate increased storm flows to protect water quality.

- Reverse the loss of wetlands; restore prior-converted wetlands to provide storage and filtration by mitigating storm flows and nutrient loading.

- Protect recharge/infiltration areas and riparian buffers to reduce overland flow of polluted runoff.

- Incorporate water management strategies based on climate projections into farm-based nutrient management plans.

Increased spread of aquatic invasive species due to changes in hydrology, water temperatures, and warmer winter condition. The WICCI WRWG did not develop adaptation strategies for this impact. They recognized that such strategies would be developed and refined in the future.

In addition to these impacts and adaptation strategies, WICCI's Coldwater Fish & Fisheries Working Group conducted a statewide fisheries vulnerability assessment and adaptation strategy to lessen the impact of climate change.[3] This group of experts identified environmental management activities as the foundation of their adaptation strategy to offset the impacts of rising air temperatures and changes in precipitation and flow in streams associated with climate change. These activities include land, riparian, and water management and stream restoration to protect coldwater and warmwater habitats and fish populations throughout Wisconsin. These activities and associated recommendations are quoted below:

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[2]*Such an approach has already been developed for southeastern Wisconsin as documented in SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin, *December 2010.*

[3]*Wisconsin Initiative on Climate Change Impacts (WICCI), Coldwater Fish and Fisheries Working Group Report, December 2010.*

Land management and land use is key to the protection and restoration of stream and lake ecosystems and associated fishery communities (see the "Runoff from Urban Development and Impervious Surfaces" and "Runoff from Agricultural Development" subsections below):

- Reduce existing and/or limit creation of additional impervious surfaces and utilize best management practices where applicable.

- Protect environmentally sensitive lands.

- Utilize best management practices in agricultural and urban lands to reduce nonpoint source runoff pollution in riparian and upland areas of the watershed.

Riparian (land next to water) management is critical to stream management and protection. This area is the interface between a stream and land in its watershed and includes the streambank and land adjacent to the stream. These areas serve many functions, including nutrient reduction, flood mitigation, erosion protection, and shading (see Riparian Management Practices subsection for more details).

- Protect and expand riparian buffer width and continuity to protect water quality and fisheries.

- Encourage practices that promote infiltration of precipitation and recharge of groundwater inputs to streams and lakes to offset effects of climate change.

Water management is vital, as adequate groundwater resources will be critical to maintaining high-quality coldwater and warmwater streams threatened by a warming climate, and the direction of changes in precipitation will play a central role in water availability. Prolonged drought conditions will cause added stress to many over-utilized groundwater sources and may compound the effects of climatic warming on streams.[4]

- Groundwater recharge areas should be identified and protected to help sustain adequate baseflows to streams and water levels in lakes.

- Protection from groundwater pumping that reduces the water table is also essential. It is recommended that continued enforcement and strengthening of the laws governing groundwater use will be critical to protecting streams and associated fisheries impacted by climate change.

Stream restoration is a critical part of stream management in Wisconsin and generally involves the re-establishment of aquatic functions and related biological, chemical, and physical characteristics of streams that would have occurred prior to disturbance. Habitat restoration work has been successful at improving fish population numbers and size structure. Restoration may take many forms—narrow or deepen channels, which may help to maintain or further cool stream during summer; eroding streambanks, which can be re-sloped and revegetated to increase cover and shading to reduce water temperatures; streams can be reconnected to floodplains to dissipate energy from floods and reduce streambank erosion, protecting stream temperature and water quality; instream pool and riffle habitats and/or re-meandering, which can be reconstructed to increase habitats for spawning and provide protective deep water resting areas during low-flow summer conditions; dams or other obstructions, which can be removed to reduce thermal heating effects of the backwater to protect water temperatures and improve stream connectivity and access to spawning sites and provide for the ability to escape low-discharge conditions.

[4]*Both of the following recommendations by the WICCI Coldwater Fish & Fisheries Working Group are consistent with the recommendations set forth in the SEWRPC regional water supply plan, which includes a systems-level identification of groundwater recharge areas throughout the Southeastern Wisconsin Region.*

In summary, these activities collectively help to protect and improve the resiliency of aquatic ecosystems to buffer the impacts of future climate changes by restoring or simulating natural processes, ensuring adequate habitat availability, and limiting human impacts on resources.

Riparian Buffers and Corridors

Issue and Targets

Based upon the summary of the best available science, preservation and development of riparian buffers are keys to the existing and future economic, social, and recreational wellbeing of the Pewaukee River watershed and the residents living within it. Riparian buffers protect water quality, groundwater, fisheries, wildlife, and ecological resilience to invasive species, and reduce potential flooding of structures and the harmful effects of climate change.[5] Given the acceptance of facts, the question becomes "How much is enough?"

We have attempted to answer this question through an examination of the literature (as discussed in Chapter IV and Appendix C of this report), regional observation, and thorough analysis of the existing and potential buffers within the Pewaukee River watershed. This analysis has resulted in riparian buffer targets which, when achieved, will vastly improve the water quality, fishery, and recreation in the Pewaukee River. They are as follows:

Target 1: Protect and expand riparian buffer regions to the greatest extent practicable with a minimum 75-foot and optimum 1,000-foot width or greater goal.

The literature has revealed that a 75-foot regulatory shoreland setback width can provide highly productive instream habitat and significant pollution reduction (as high as 75 percent in some regions). Additionally, it has shown that the protection of a 400-foot minimum and 900-foot optimum riparian buffer width has significant benefits to wildlife populations. Given this information, and the fact that current regulatory shoreline zone is 1,000 feet as described in Chapter III of this report, it has been decided that the protection and expansion of riparian buffers to 1,000 feet from the ordinary high-water mark, or within the boundaries defined by floodplains or wetlands (whichever is greater) should be a major priority in this watershed.

Target 2: Protect and expand riparian buffers to encompass a total of 30 percent of the land area within the watershed.

It was determined that an overall goal for total riparian cover should be developed in order to provide guidance on "How much riparian buffer is enough?" To develop this target, SEWRPC staff looked to previous riparian buffer evaluations completed in the Region to determine the total percentages found in watersheds with high water quality and excellent stream habitat (e.g., Mukwonago). This review revealed a percentage of just under 30 percent total riparian cover, thereby leading to the target stated above.

According to our analysis, the Pewaukee River Watershed currently has buffer cover of about 17 percent. This means that the buffer development programs should aim to almost double the total amount of buffered regions. Although a more targeted approach (e.g., developing goals based on where development is located in subwatersheds) may be a more efficient approach to

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[5]*N.E. Seavy and others, "Why Climate Change Make Riparian Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration, *Volume 27(3): pages 330-338, September, 2009; "Association of State Floodplain Managers, Natural and Beneficial Floodplain Functions: Floodplain Management—More Than Flood Loss Reduction, 2008,"* www.floods.org/NewUrgent/Other.asp.

mitigating issues like pollution loading, it was decided that an overall watershed goal was more desirable because: 1) it allows for more flexibility in developing buffer regions in less developed areas, therefore making the goal more achievable; and 2) it provides more opportunities for expansion of existing buffer regions toward, and slightly beyond, the optimum "wildlife enhancement" width (i.e., 1,000 feet or above).

Target 3: Protect and increase continuity and connectivity of riparian buffer regions.

Fragmentation of riparian buffers by roads, railways, and utilities, combined with encroachment by development, impacts the structure and function of riparian corridors and their ability to adequately protect waterways and wildlife habitat. Stream crossings also tend to have a cumulative impact on a stream and associated lands, as well as an impact on the quality of water and the fishery. Therefore, it is important to reduce the linear fragmentation of the existing riparian buffers by either removing crossings where possible or at least not increasing the number of crossings of waterways within the Pewaukee River system, where practical. It is recognized, however, that police, fire protection, and emergency medical service access is an overriding consideration that must be applied in determining whether the objective of removing a crossing is feasible. This recommendation is only meant to apply to situations where more road crossings exist than are necessary to ensure adequate access for emergency services and efficient movement of traffic.

While, as discussed above, this plan generally recommends protecting and expanding riparian buffer regions to a minimum 75-foot width and an optimum 1,000-foot width goal, it is important to note that the presence of a buffer is always better than the absence of one, even if only to prevent some pollution or allow for better aquatic habitat. Therefore, it is recommended that all efforts be made to develop buffered areas, to the maximum extent practicable up to and beyond the optimum width. This can be achieved through a combination of strategies that include *land acquisition*, *regulation*, and *implementing best management practices* as summarized in the Riparian Buffer Protection and Prioritization Strategies section in Chapter IV of this report.

Recommendation Map

To guide the accomplishment of the riparian buffer targets above, Map 32 has been developed as a tool for project identification. This map highlights the existing riparian buffers, as well as the areas where buffer regions could potentially be expanded to 75 feet, 400 feet, and 1,000 feet (i.e., land areas within the 1,000 foot ideal buffer region which are not designated as urban development). The map also identifies the existing buffer regions and potential buffer areas, within the 1,000 optimum width core, that are currently designated as "vulnerable." Specifically, areas are designated as "vulnerable" when they are not located within the one-percent-annual-probability regulatory floodplain boundary; are not designated as wetland or primary environmental corridor; or are not under protected ownership.

This map provides individuals and organizations attempting to implement this plan with guidance on land areas that should be prioritized for protection either through land purchases, easements, and/or voluntary measures (i.e., vulnerable existing or potential buffer regions), and it provides guidance as to where buffers could potentially be established throughout the watershed. Additionally, the map indicates the regions within the watershed where large buffer areas (i.e., greater than 75 feet width) may not be feasible, thereby indicating where smaller buffers and other measures to protect the Pewaukee River ought to be implemented (e.g., buffers to the greatest extent possible, "green buildings," rain gardens, etc.).

Recommended Actions

Though the recommendation map does provide the information necessary to begin planning buffer protection and expansion projects, and in turn meet the three targets identified above, it is necessary to provide some guidance on the kinds of projects that are being recommended. Accordingly, the three targets are described below with their associated recommendations. Target 1 and 2 have been combined as many of the recommendations associated with these targets are the same.

Recommended Actions for Riparian Target 1 and Target 2: ***(i.e., Protect and expand riparian buffer areas to the greatest extent practicable with a minimum 75-foot and optimum 1,000-foot width goal; and Protect and expand riparian buffers to encompass a total of 30 percent of the land area within the watershed).***

A. Protection of existing buffer and potential regions and connections with emphasis on "vulnerable" existing buffers (see Map 32, Examples C and D).

- Land use regulation, public land acquisition via donation or purchase, establishment of conservation easements on critical lands, and subsequent protection of existing buffers and potential buffer regions which have been identified as vulnerable, including:

    - Purchase of lands by governmental, nongovernmental, or private organizations, or other private entities to expand buffers within the SEWRPC-delineated primary and secondary environmental corridors and isolated natural resources areas, especially along the River mainstem and tributary streams.

- Educational campaigns and general promotion of low-impact use of existing buffer regions;

- Continued application of limits on development in SEWRPC-delineated primary environmental corridors and extension of such limitations to secondary environmental corridors and isolated natural resource areas through County and municipal land use regulations, at the discretion of the appropriate unit of government. Consistent and effective application of the provisions in the existing regulatory framework. These include the U.S. Army Corps of Engineers permit program for wetlands, State wetland regulations, shoreland zoning requirements, and local zoning ordinances; and

- Enforcement of local zoning regulations to discourage development within the one-percent-annual-probability floodplain.

B. Maintain existing buffer regions (see Map 32, Example A).

- Eradication of purple loosestrife and other nonnative invasive species, to the extent possible, through partnerships between communities, schools, volunteer groups, service organizations, and local governments, and through participation in the Wisconsin Department of Natural Resources (WDNR) purple loosestrife beetle rearing program, (see Exotic Invasive Species section in Chapter IV of this report);

- Restoration of natural vegetation in buffer regions wherever needed.

C. Development of buffers wherever practicable (see Map 32, Example B) **with the goal of 1,000-foot width and 30 percent of land area being designated a protected buffer region.**

- Establishment of natural vegetation along perennial, intermittent, and ephemeral waterways in both urban and rural areas to the extent practicable up to a 1,000-foot width, preferably using native species, in accordance with WDNR and Natural Resources Conservation Service (NRCS) technical standards for filter strips and turf management as may be applicable, and SEWRPC guidance for riparian buffers (see Appendix C), including:

    - Establishment of buffers on public lands, on lands purchased with donations or grant funds, or on private lands on which conservation easements are acquired.

D. Buffer development to greatest extent practicable, as well as Best Management Practices (BMPs), in areas where there is low buffer potential (see Map 32, Example E).

- Consideration of adopting and enforcing shoreland setback requirements in the watershed and continuation of active enforcement of construction site erosion control and stormwater management ordinances;

- Provision of informational materials to shoreland property owners on the benefits of buffer areas and BMPs (see Stormwater Management section), including instructions on how to proceed with their implementation; and

- Establishment of incentive-based programs to encourage the use of BMPs and buffer development by shoreline property owners.

Recommended Actions for Riparian Target 3: ***(i.e., Protect and increase continuity and connectivity of riparian buffer regions to provide pathways for wildlife and improve overall quality of the Pewaukee River system).***

A. Establishment of connections and pathways to ensure connectivity and continuity in areas where buffer development is not feasible (see Map 32: Areas where there are gaps between existing and/or potential buffers).

- Removal of abandoned or nonessential roads where appropriate,

- Establishment of educational or incentive-based programs to encourage existing homes or businesses within the 1,000-foot zone to consider landscaping that would enhance wildlife by providing connections (see Appendix C) or lanes through the lots, as well as using native plants to provide cover and food for wildlife,

- Where possible, limit creation of new road crossings of the mainstem or tributaries within the Pewaukee River system, and

- Preservation and expansion, to the extent practicable, of small wetlands, woodlands, and prairies not identified as part of an environmental corridor or an isolated natural resource area and link such features by providing corridors connected to larger natural areas, as determined in county and local plans.

Groundwater Recharge and Pollution

Issue and Targets

Groundwater recharge within the Pewaukee River watershed supplies water to the shallow aquifers in the watershed, which, in turn, provide the baseflow to the River. Baseflow is invaluable to maintaining the natural hydrology and the overall health of the River, particularly during the droughts and low-flow conditions which occurred in 2012. This reality indicates that the maintenance and improvement of groundwater recharge is a crucial part of any plan developed to maintain or improve the conditions in the Pewaukee River watershed.

It is also important to note that, though infiltration into soils (i.e., groundwater recharge) does provide some level of pollution reduction, shallow aquifers are still vulnerable to pollution in general. In particular, within the Pewaukee watershed, there are specific areas to be concerned about within the high groundwater recharge areas, including: 1) golf courses and agricultural lands, as these areas could be potential sources of pollution due to over-fertilization and pesticide use; and 2) urban and residential areas, as these areas could be potential sources of urban runoff pollutants (e.g., gasoline, heavy metals, fertilizers and pesticides from lawn care), which can infiltrate to the groundwater during rain and snowmelt events. This pollution needs to be prevented to the greatest extent possible, as it contaminates the baseflow which enters the River and reduces water quality.

In order to assure the maintenance and improvement of groundwater recharge in the area, as well as to reduce nonpoint source pollution of the shallow aquifer, three major targets have been developed each with their own potential actions. They include:

Target 1: Preserve groundwater recharge areas and shallow aquifer levels in accordance with the regional water supply plan and mitigate the increases in pollution associated with future urban development, particularly in high recharge-designated areas.

Traditional urban development increases the area of impervious surfaces which, in the absence of green infrastructure or other land development measures to promote infiltration of runoff, reduces infiltration volumes into the shallow aquifer. This reduction in infiltration reduces the baseflows provided by the shallow groundwater systems. This loss of baseflow can lead to substantial loss in stream depth and volume, increased water temperatures, and increased potential for summer fish kills caused by low dissolved oxygen concentrations, as well as loss of the coldwater fishery. According to the 2035 planned land use data presented in Chapter II of this report, a high proportion of the planned land use changes are located in areas that have been designated as having high and very high groundwater recharge potential (shown on Map 33 located at the end of this chapter). This target essentially seeks to preserve recharge by either preventing urban development in high groundwater recharge areas (favoring instead the creation of open space and buffer areas, or encouraging the use of green technologies meant to maintain infiltration functions to the extent practicable, if urban development in these regions does take place. This target will also have the added benefit of mitigating the nonpoint source pollution of the River associated with urban development.

Target 2: Reduce the impact of current urban development on groundwater recharge and water quality.

Unfortunately, the amount of urban development within the Pewaukee watershed is currently at high enough levels to potentially be negatively affecting the water quality and water quantity in the Pewaukee River. However, implementing projects that seek to restore the natural flow patterns have the potential to mitigate these effects. This could involve a variety of measures, including better detention, retention, and infiltration and filtration, each of which attempt to mimic the disposition of precipitation on an undisturbed landscape.

Target 3: Prevent nonpoint source pollution from existing agricultural and recreational sources (e.g., golf courses) within high groundwater recharge areas.

Agricultural land use, as well as other land uses, like golf courses, has the potential to increase pollutant inputs into groundwater due to over-fertilization and pesticide use. This target seeks to promote nonpoint pollution control practices with the intent of mitigating pollution of groundwater.

Recommendation Map

Map 34, provided at the end of this chapter, is meant to be used as a tool for project identification as it relates to groundwater recharge maintenance and reestablishment, and associated groundwater pollution reduction in the Pewaukee River watershed. The map highlights the high groundwater recharge potential areas and explains the kinds of projects which should be undertaken in these areas. The map also highlights the vulnerable buffer areas in the Pewaukee watershed with the specific purpose of helping prioritize lands for purchase and/or protection. In particular, the areas that serve the dual purpose of protecting the River from pollution, as well as maintaining groundwater recharge, should be considered high priority for protection.

Recommended Actions

Map 34 is generally sufficient for identifying projects that should be completed in the Pewaukee River watershed to encourage maintenance of groundwater quality. Further details on the nature of these projects and programs (and what they are intended to achieve) are provided below.

Recommended Actions for Groundwater Target 1: ***(i.e., preserve groundwater recharge areas and shallow aquifer levels in accordance with the regional water supply plan and mitigate increases in pollution associated with future urban development, particularly in high recharge-designated areas).***

A. Prevent or limit urban development in high groundwater recharge areas (see Map 33: All development other than recreational located in the high groundwater recharge zone).

- The protection and preservation of groundwater recharge areas classified as having a high or very high recharge potential through conservation easements, land purchases or voluntary incentive based measures. Such protection should also incorporate preservation of environmental corridors, isolated natural resource areas, prime and other agricultural areas, and open lands that are associated with conservation developments and that facilitate recharge.

- Consideration of groundwater conditions when locating buildings. This should include review of development proposals to avoid locating structures and other infrastructure in areas prone to flooding as a result of high groundwater levels.[6]

- Consideration of groundwater impacts during the installation of sewer and water lines and other buried utilities which could intercept groundwater flows.

B. Reduce the impacts of future urban development (see Map 34: New development which is undertaken in high groundwater recharge areas) **on groundwater recharge quality and quantity.**

- Review, and update as necessary, local and County land use regulations to promote where appropriate conservation development practices that provide for the clustering of new development within the watershed so as to minimize nonpoint source pollution impacts on groundwater and to also minimize potential reductions in groundwater recharge and stream baseflow; and

- Maintenance of infiltration and recharge rates as close to existing rates as practicable by incorporating runoff management recommendations for enhancing infiltration using low-impact design standards in accordance with the regional water supply plan.[7,8] Some examples of infiltration techniques and low impact design include:

  - Bioretention cells
  - Curb and gutter elimination
  - Grassed swales

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[6]*See the* "Basement Wetness and Flooding Prevention Standards" *applied under the Waukesha County Storm Water Management and Erosion Control Ordinance.*

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

[8]*SEWRPC Technical Report No. 48,* Shallow Groundwater Quantity Sustainability Analysis Demonstration for the Southeastern Wisconsin Region, *November 2009.*

- Green parking design
- Infiltration trenches
- Permeable pavement
- Permeable pavers
- Rain barrels and cisterns
- Riparian buffers
- Sand and organic filters
- Soil amendments
- Stormwater planters
- Tree box filters
- Vegetated filter strips
- Vegetated roofs

- Protection of water resources when adding, improving, or upgrading urban infrastructure:

  - For planned road construction, ensure that adequate right-of-way land is purchased for the installation of state-of-the-art erosion control and post-construction stormwater management practices, without damaging adjacent sensitive areas;

  - For installation of sewer systems and other buried utilities, including proposed sanitary sewer extensions, ensure adequate erosion and sediment control techniques are used;

  - For all road, bridge and culvert construction or reconstruction, employ good planning and enforcement of erosion control and stormwater management practices; and

  - For collector streets and associated sidewalks and stormwater management systems, consider updating municipal design standards to reduce impervious surfaces and increase treatment of runoff through biofiltration and other practices.

Recommended Action for Groundwater Target 2: ***(i.e., Reduce the impact of current urban development on groundwater recharge and water quality)***

A. Encourage infiltration techniques to serve existing urban development (see Map 34, Example D).

- Increase infiltration of urban runoff where it can be accomplished and where it can be achieved without degrading groundwater quality;

- Improve of infiltration of rainfall and snowmelt through innovative BMPs that are associated with low-impact development, including bioretention and rain garden projects,[9] installation of rain barrels, etc.

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[9]*Roger Bannerman, WDNR and partners; Menasha biofiltration retention research project, Middleton, WI, 2008; N.J. LeFevre, J.D. Davidson, and G.L. Oberts, Bioretention of Simulated Snowmelt: Cold Climate Performance and Design Criteria, Water Environment Research Foundation (WERF), 2008; William R. Selbig and Nicholas Balster, Evaluation of Turf Grass and Prairie Vegetated Rain Gardens in a Clay and Sand Soil: Madison, Wisconsin, Water Years 2004-2008, In cooperation with the City of Madison and Wisconsin Department of Natural Resources, USGS Scientific Investigations Report, in draft.*

- Retrofitting current urban development (e.g., disconnection of downspouts; installation of porous pavement) to ensure infiltration.

- Consideration of pollution entering the groundwater through infiltration in the design of infiltration facilities such as infiltration trenches, infiltration basins, bioretention facilities, rain gardens, and grassed swales and in the design of stormwater detention basins, especially in areas with a shallow depth to groundwater. The WDNR has developed post-construction storm-water management technical standards which include provisions intended to protect ground-water quality. It is recommended that these standards be applied in the design of stormwater management facilities.

Recommended Action for Groundwater Target 3: ***(i.e., Prevent nonpoint source pollution from agricultural and recreational sources (e.g., golf courses) within high groundwater recharge areas).***

A. Implement pollution reduction measures in agricultural areas and other areas of potential nonpoint source pollution located in the high groundwater recharge areas in the watershed (see Map 34, Examples C and E).

- Evaluation of agricultural operations in the watershed for compliance with State standards for control of barnyard runoff, manure storage, and application of integrated nutrient and pest management practices, and undertake corrective measures. County and UWEX agricultural extension staff should work with landowners to secure cost-share funding required to install practices, such as those provided through the following NRCS programs:
    - Conservation Reserve Program (CRP);
    - Conservation Reserve Enhancement Program (CREP); and
    - Environmental Quality Improvement Program (EQIP);

- County staff, UWEX agricultural extension staff, and NRCS staff should work with landowners to control cropland erosion by reviewing and refining as necessary conservation plans intended to control cropland erosion rates to levels that meet or exceed the State standards.

- Consideration of agricultural drainage needs in any proposed practices for stream restoration, wetland restoration, nonpoint source pollution reduction, or flood control.

Surface Hydrology

Issue and Targets

Urban development brings with it significant changes in the landscape. These changes historically have included modification of the drainage pattern, hardening of surfaces, and alteration of groundwater infiltration, all of which can affect water quality and quantity. All of these changes generally increase the volume and rate of runoff from precipitation events. Historically, managing these increases in rates and volumes of runoff would often involve construction of storm sewer and/or open channel systems to convey stormwater as quickly and efficiently as possible to streams and ultimately to the Fox River. In recent years, however, flooding, water quality impairment, and environmental degradation have demonstrated the need for an alternative approach to stormwater management. Consequently, current stormwater management practices seek to manage runoff using a variety of measures, including detention, retention, infiltration, and filtration, better mimicking the disposition of precipita-tion on an undisturbed landscape.

Consequently, this protection plan includes recommendations related to stormwater management retrofitting, land use planning, and stream management in order to reduce the rates and volume of runoff, as well as reduce the effects that the high rates and volume of runoff have on the people that live in the watershed and on the River itself. To this end, two targets were developed:

Target 1: Maintain, or restore to the degree practicable, natural flow regimes to provide adequate baseflows and prevent or reduce flashiness, stream erosion, and habitat degradation.

Urbanization increases the area of impervious surfaces, which can lead to an increase in "flashiness" (or the rate at which flow responds to a precipitation event). This process subsequently affects streambank and streambed stability, increases pollutant loading, and changes sediment dynamics, which, in turn, degrade habitat availability and quality. Therefore, increased flashiness has been identified as a cause of degradation of aquatic communities. This target seeks to implement actions that will reduce the "flashiness" and reduce the associated streambank erosion and pollution. This includes buffer installation (which slows down water, as well as anchors soil, thereby preventing erosion), wetland restoration (which slows water down), and groundwater infiltration in urban areas.

Target 2: Preserve floodwater storage areas, mitigate flow increases and floodwater storage losses, and reduce the amount of development in unmapped floodplain areas.

The high-speed and high-volume runoff associated with impervious cover also leads to flooding, as the water from storm events enters the river system and floodplain more quickly than it would in a natural system. As with the process of reducing "flashiness," it is important to restore natural infiltration of precipitation into the groundwater system, which would reduce the volume of the water moving toward the River, and to restore wetlands, which can store runoff and floodwaters, reducing and delaying flood peaks. This target is also intended to reduce flooding and associated property damage and to promote the proper mapping of floodplains.

Recommendation Map

The important component for restoring surface hydrology to more-natural conditions is the reduction of flashiness and flooding, which can be achieved in part through installation of buffers and improvement of infiltration in urban areas. Therefore, many of the recommendations included in the section are represented on Map 32 (see Examples B and C) and Map 34 (see Example D). These maps identify potential buffer regions and urban areas to implement infiltration techniques.

Recommended Actions

Many of the recommendations necessary to meet the target of restoring surface hydrology to more-natural conditions are covered in the Riparian Targets 1 and 2, as well as Groundwater Targets 1 and 2. Therefore, these recommendations should be emphasized when implementing this plan, as they will serve dual purposes. Additionally, some recommendations have not yet been covered. A summary of these recommendations follows:

Recommended Actions for Hydrology Target 1: ***(i.e., Maintain, or restore to the degree practicable, natural flow regimes to provide adequate baseflows and prevent or reduce flashiness, stream erosion, and habitat degradation).***

A. Restore the natural surface hydrology by reducing impervious cover and associated runoff.

- It is recommended that the USGS Upper Fox River Basin model be used to investigate different development scenarios (e.g., adding or taking out high-capacity wells, domestic wells, etc.) to help communities make land use decisions to balance water supply needs, water quality needs, and possibly recreational needs within this watershed.[10]

[10] *D.T. Feinstein, et al. 2012-5108, these models are all public and archived with a data dictionary; URL:* http://pubs.usgs.gov/sir/2012/5108/index.html. *For additional information contact: Director, Wisconsin Water Science Center, U.S. Geological Survey, 8505 Research Way, Middleton, WI 53562,* http://wi.water.usgs.gov/.

- Consider revision of the current water level requirements for Pewaukee Lake to a more dynamic management policy that better mimics a more natural flow regime in order to better protect the biodiversity and maintain the goods and services that both the Pewaukee Lake and Pewaukee River systems provide.

- Implement recommendations associated with Groundwater Targets 1 and 2 that addresses reducing the negative hydrologic effects of urban development and installation of infiltration techniques.

- The recently developed recharge potential Map 10 in Chapter II of this report and contributing groundwater area on Figure 49 in Chapter IV of this report should be used to help guide existing and planned land use decisions to protect sustained baseflow and the ecological health of the Pewaukee River and surrounding communities.

B. Restore natural landscape elements that reduce the effects of flashiness and "slow down water."

- Implement recommendations associated with Riparian Targets 1 and 2.

- Protect existing wetlands and expand them where feasible, including the reestablishment of prior converted agricultural lands.

Recommended Actions for Surface Hydrology Target 2: ***(i.e., Preserve floodwater storage areas, mitigate flow increases and floodwater storage losses, and reduce the amount of development in unmapped flood-plain areas).***

A. Reduce the occurrence of flooding events.

- Implement recommendations associated with Groundwater Targets 1 and 2.

- Implement recommendations associated with Riparian Targets 1 and 2.

- Expand wetlands where feasible to allow for the water to be spread over a larger undeveloped surface (see Map 14 in Chapter II of this report to view current wetlands).

B. Make efforts to better manage the effects of flooding and prevent associated damage.

- Use of National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation-frequency information and the 2006 SEWRPC revised design storm temporal rainfall distribution in the calculation of flood elevations and the design of stormwater management infrastructure to more accurately reflect current conditions within the watershed and Southeastern Wisconsin Region;[11]

    - Local stormwater management ordinances should be updated to call for use of NOAA Atlas 14 precipitation-frequency information;

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[11]*National Oceanic and Atmospheric Administration,* Precipitation-Frequency Atlas of the United States, *Volume 8.0, Version 2.0; Midwestern States, 2013. The 2006 SEWRPC temporal distribution was developed in con-junction with the WDNR. That distribution and a link to NOAA Atlas 14 can be accessed at* http://www.sewrpc.org/SEWRPC/Environment/RainfallFrequency.htm.

- Development of new stormwater and floodland management facilities, or retrofitting of existing facilities as necessary, to minimize or prevent damage from events up to, and including, the one-percent-annual-probability flood;
    - Development and maintenance of up-to-date inventories and maps to identify areas and structures at risk of flooding;
- Delineation of the one-percent-annual-probability floodplain wherever approximate floodplain boundaries are delineated in the watershed, including the headwaters of Coco Creek, Zion Creek, Audley Creek, and Meadowbrook Creek. This is recommended to occur prior to the development of this land in order to promote sound development outside of the floodplain and not increase the risk or incidence of flooding in the Pewaukee River watershed.
- Consistent with local floodplain zoning ordinances, continue to regulate filling and development within the floodplain, so that connectivity with the stream system can be maintained.

Water Supply and Demand

Issue and Targets

Water supply withdrawals can affect surface water levels if wells are situated in proximity to surface waterbodies, including lakes and streams. Therefore, water conservation measures; groundwater recharge protection and enhancement measures; and implementation of high-capacity well development siting, monitoring, and impact mitigation protocols, as is recommended in the SEWRPC regional water supply plan, are imperative to minimize water use conflicts and ecosystem impairment in the Pewaukee River watershed.[12]

Additionally, the projected increase in residential land use and population growth within the Pewaukee River watershed, as described in Chapter II of this report (see Map 5 in Chapter II), will lead to an increased demand for water resources. Given that all of the water supplied within the Pewaukee watershed is groundwater, and that the groundwater also supplies crucial baseflow to the Pewaukee River, this increased demand will need to be balanced with the ecological needs of the River. To accomplish this balance, management of both water supply and demand are needed. Accordingly, the following targets were developed:

Target 1: Maintain and increase supply of groundwater wherever practicable.

In order to maintain and potentially increase the supply of groundwater, the maintenance and potential increase of the groundwater recharge in the Pewaukee watershed will become crucial. This reaffirms the need to assure that groundwater recharge is both protected and expanded, and further enforces the importance of achieving the recommendations highlighted in the Groundwater Recharge and Pollution recommendations section above.

Target 2: Reduce the demand for water through increasing awareness, encouraging/initiating conservation BMPs, and better monitoring water use.

In addition to protecting and enhancing groundwater recharge, for the purpose of maintaining and potentially increasing the supply of groundwater, it is also important to reduce the demand for water to offset the anticipated rise in population and the associated increase in water use

[12]*See State of Wisconsin Court of Appeals District II decision on appeal number 2008AP3170 dated June 16, 2010, which affirms that "…information from a scientist that the proposed well 'would cause adverse environmental impacts to the wetland and navigable surface waters of Lake Beulah'…" must be considered in the granting by the WDNR of municipal well permits.*

over the next 25 years. This is often best accomplished by water pricing mechanisms. This target also highlights educational and voluntary based measures which seek to meet this target.

Recommendation Map

The supply side of addressing this issue is maintaining and increasing groundwater recharge. Therefore, Map 34; provides guidance on where to implement these projects. The demand side of addressing this issue relates to reducing demand for groundwater supply throughout the watershed.

Recommended Actions

In order to provide a better understanding of what is meant by increasing supply and reducing demand, and provide an idea of where to begin, the following recommendations are provided:

Recommended Actions for Supply and Demand Target 1: ***(i.e., Maintain and increase supply of groundwater wherever practicable).***

- Implement recommendations associated with Groundwater Recharge Targets 1 and 2.

- As recommended in the regional water supply plan, studies should be conducted related to the siting of all new high-capacity wells, including analyses of potential impacts, and subsequent monitoring of the actual impacts of such wells on the shallow aquifer, existing wells, and surface waters. The siting studies should be designed to develop the necessary understanding of the hydrogeological system associated with each candidate site and to assess the likelihood of impacts of proposed wells upon nearby existing wells and surface waterbodies. The studies should include identification of significant potential negative impacts, needed mitigative actions, or site location revisions. Surface water and groundwater levels in the vicinity of new high-capacity wells in the shallow aquifer should be monitored before and after wells are constructed and placed into operation to establish a baseline including levels expected to be maintained in private wells and to develop performance and impact data during the test well phase of well development and during the subsequent operation of the well over time.

Recommended Actions for Supply and Demand Target 2: ***(i.e., Reduce the demand for water through increasing awareness, encouraging/initiating conservation BMPs, and better monitoring water use).***

- Implement educational projects to inform Pewaukee watershed residents of conservation practices like rain barrels and low-flow toilets and showerheads, and encourage their implementation through incentive-based programs and/or in-kind assistance.

- Implement a program to help the agricultural community reduce water consumption in the region and reduce water loss generally associated with irrigation practices.

- It is also recommended that the municipalities within the Pewaukee River watershed utilize the Upper Fox River Basin model to help balance water supply demand and the effects of imperviousness resulting from future development versus providing environmentally sustainable flows and recreational use opportunities for the Pewaukee River.

Water Quality

Issue and Targets

The overall water quality within the Pewaukee River watershed, as discussed in Chapter IV of this report, is generally good. However, specific constituents, such as pesticide metabolites and increasing chloride concentrations (from salt treatments on roads), indicate the potential vulnerability of this system to contamination. The major purpose of this section is to provide recommendations to reduce the amount of pollutants that contaminate the Pewaukee River system either through preventing the pollution from occurring at the source, or through improving the Pewaukee watershed's ability to treat the pollutants through natural processes. To this end the following targets were developed:

Target 1: Reduction of urban and agricultural pollution within the Pewaukee River watershed through pollution control at the source.

Pollution in the Pewaukee River watershed comes from two major sources: agricultural stormwater runoff and urban stormwater runoff. This target aims to reduce these pollutants at the source by either preventing the pollution from occurring in the first place or through collecting and treating runoff containing pollutants, thereby reducing the pollution load to the system.

Target 2: Maintain or naturalize currently installed stormwater management mechanisms to help mimic the "natural system" where feasible and to improve pollution reduction.

This target seeks to identify stormwater management systems which are candidates for modifications to increase their pollution reduction capabilities, where practicable, including converting dry detention basins to wet basins with permanent ponds or to infiltration basins, and adding features characteristic of natural systems.

Target 3: Increase pollution reduction ability of lands surrounding the Pewaukee River.

Natural systems, specifically wetlands and buffer regions, are particularly efficient at reducing pollution deposited into surface water systems. They both slow water down and allow for pollutants and sediments to settle prior to entering river or lake systems. Additionally, they are both highly productive systems which play a role in using and converting pollutants to nonharmful byproducts, therefore further reducing the harmful effects stormwater runoff. It has been shown that a buffer width of 75 feet can cause a 75 percent reduction in pollution under some conditions. This target seeks to both protect and increase the reaches of the River which are protected by buffers and wetlands to reduce current pollution and future pollution that could result from planned land use changes.

Recommendation Map

The first water quality target may be guided by Map 4 in Chapter II of this report, which indicates the current land uses in the watershed. This will help identify the urban and agricultural areas that should be targeted for pollution reduction programs. Additionally, Map 35, included at the end of this chapter, identifies stormwater management projects that have the potential to significantly contribute to reducing pollution in the Pewaukee River system. These projects relate to: better management of stormwater detention basins through "re-naturalization." This map also highlights potential projects in the downtown area, which is currently considered a problem area as it contributes a significant sediments and pollution to the Pewaukee River (see Chapter IV of this report for more details).

Recommended Actions

Various types of water quality improvement projects can be undertaken in the Pewaukee River watershed. These project types are detailed below:

Recommended Actions for Water Quality Target 1: ***(i.e., Reduction of urban and agricultural pollution within the Pewaukee River watershed through pollution control at the source).***

A. Reduce nonpoint source pollution from agricultural areas (shown on Map 4 in Chapter II of this report)

- Implementation of recommendations associated with Groundwater Targets 1 and 3 which seek to target agricultural runoff which may reach the groundwater;

- Management of stormwater runoff to meet, to the maximum extent practicable, the agricultural standards as established under Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*; and

- Implementation of programs to inform farmers of best management projects, the need for set-backs, good storage practices for manure, good tilling practices, and the dangers of over fertilization and over use of pesticides. These programs should emphasize maintaining or improving productivity while improving water quality.

B. Reduce nonpoint source pollution from urban areas (shown on Map 4 in Chapter II of this report)

- Implementation of recommendations associated with Groundwater Targets 1 and 3 to prevent groundwater pollution and the resulting contamination of baseflow;

- Preparation of detailed regional stormwater management plans addressing areas where future urban development is planned and areas of existing development where controls need to be upgraded to protect and maintain the quality of the water resources of the Pewaukee River system;

- Management of stormwater runoff to meet, to the maximum extent practicable, the nonagricultural standards for existing development, new development, and redevelopment as established under Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*;

- Promotion of good urban land management and housekeeping practices under the public informational programs being conducted under the conditions of the Wisconsin Pollutant Discharge Elimination System municipal separate storm sewer system (MS4) discharge permits. Such practices consist of fertilizer and pesticide use management, litter and pet waste controls, lawn watering, and management of leaf litter and yard waste;

- Promotion of urban nonpoint source pollution abatement through local stormwater management ordinances and through meeting the conditions of the (MS4) discharge permits for all permitted municipalities within the watershed. Stormwater management planning could be undertaken by municipalities to promote cost-effective urban nonpoint source pollution abatement;

- Reduction of chloride (salt) contamination resulting from road treatment and water softener discharge. Stormwater management and wastewater treatment practices do not remove dissolved chloride in runoff. As a consequence, concentrations of dissolved chloride in both surface waters and groundwaters are increasing, and special safeguards should be considered in order to avoid future adverse effects. Therefore, the following actions should also be considered:

  - Evaluation of existing road deicing and anti-icing programs with an emphasis on salt reduction; establishment of new road deicing and anti-icing programs aimed at reducing salt application in communities that do not have such reduction programs; and promotion of optimal application of deicing agents on commercial, industrial, governmental and institutional, airport, and residential properties. Review of alternative measures to manage snow and ice could involve consideration of alternatives such as salting intersections only, use of salt brine, substitution of less environmentally damaging anti-icing and deicing agents, and sand-salt mixtures where practicable to limit the introduction of chloride to surface water and groundwater in the Pewaukee River watershed;[13]

  - o Identification of spring seeps, spring boils, and/or stream reaches with high chloride concentrations and target them for pilot programs; and

  - o Consideration of the use of alternative technologies for softening potable water, such as reverse osmosis filters.

- Working cooperatively with area fueling and automotive service stations to decrease potentially contaminated runoff; and

- Implementation of State turf management standards on all lands including public lands in accordance with requirements of municipal permits under Chapter NR 216 of the *Wisconsin Administrative Code*.

- It is also recommended that cold tar-based asphalt sealants be avoided and less toxic asphalt-based pavement sealants or equivalent be used to protect asphalt parking lots and driveways. More information on choosing alternatives to coal tar-based pavement sealcoats can be found at the Minnesota Pollution Control Agency website: (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/great-lakes-coal-tar-sealcoat-pah-reduction-project/choosing-alternatives-to-coal-tar-based-pavement-sealcoats.html).

Recommended Actions for Water Quality Target 2: ***(i.e., Maintain or naturalize currently installed storm-water management mechanisms to help mimic the "natural system" where feasible and improve pollution reduction).***

A. Naturalization of dry and wet stormwater retention basins to improve their pollution reduction capabilities (see Map 35). This will also have the benefit of establishing good wildlife habitat, in addition to reducing pollution inputs to the River.

- All detention basins are recommended to be converted or managed as native wetland and prairie habitat that will also help improve water quality due to a reduced need for fertilizer or herbicide applications. Map 35 in Chapter VI of this report shows the stormwater detention basins identified as high and moderate priorities for either whole or partial conversion to native wetland and prairie to enhance water quality and wildlife habitat in the Pewaukee River.

- It is important to prevent, remove, and/or control invasive plants to the extent practicable.

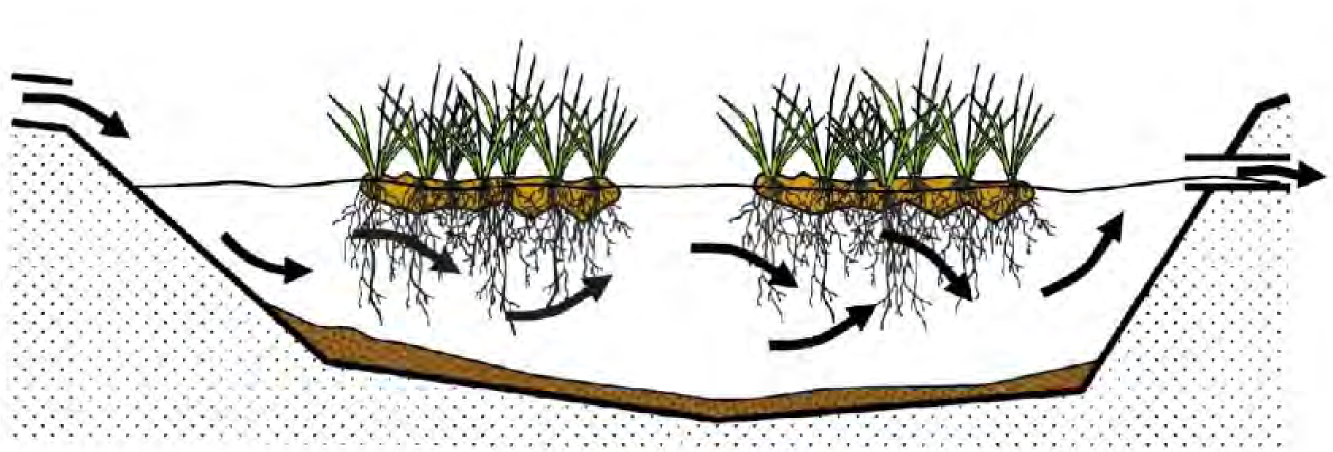
- Mowing, fertilizing, and use of pesticides should be eliminated or reduced in areas associated with dry and wet detention basin, where practicable.

- Consider installing floating island or floating treatment wetland technologies in existing and/or planned stormwater management designs, where applicable, as shown in Figure 64, to reduce nutrient and other pollutant loads from entering the Pewaukee River.

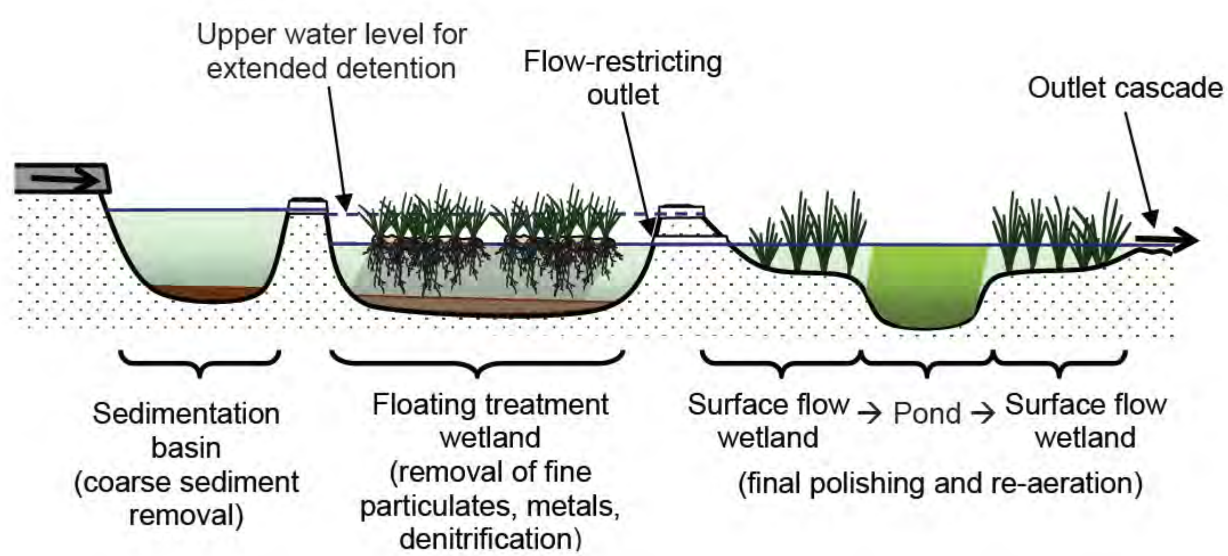
[13]*When considering alternative anti-icing and de-icing practices, the possible effects on biochemical oxygen demand and dissolved oxygen levels in receiving streams should be considered.*

Figure 64

SCHEMATIC OF FLOATING TREATMENT WETLAND (FTW) DESIGN APPLICATIONS



Emergent plants are grown within a floating artificially constructed material within a wet detention stormwater basin. The roots are directly in contact with the water column and can intercept suspended particles. The roots also provide a high surface area for microbiological activity that aid in adsorbing pollutants



Conceptual longitudinal cross-section through a “newly designed” stormwater treatment system incorporating floating wetlands, ponds, and surface flow wetlands (not to scale).

Source: Ian Dodkins; Anouska Mendzil; and Leela O’Dea, Floating Treatment Wetlands (FTWs) in Water Treatment: Treatment efficiency and potential benefits of activated carbon, Prepared for: FROG Environmental Ltd, March 2014; Headley, T.R. and C.C. Tanner, Constructed Wetlands With Floating Emergent Macrophytes: An Innovative Stormwater Treatment Technology, Critical Reviews in Environmental Science and Technology, 42:2261–2310, 2012.

- Consider formation of stormwater utility districts within local jurisdictions, and/or the adoption of an intergovernmental stormwater management entity. The districts and/or entity would have responsibility for stormwater management throughout the Pewaukee River watershed, and the authority to fund, implement, and maintain stormwater facilities and BMPs.

B. Mapping as well as investigation and subsequent repair, removal, or retrofitting of stream outfalls entering the river (as indicated on Map 35) **in order to reduce the direct runoff entering the river system.**

- It is recommended that a standard digital format, labelling, and coordinate system be developed for mapping stormwater infrastructure, in order to show consistency in stormwater management inventories among municipalities and/or compare and merge datasets at the scale of watersheds such as shown on Map 18 in Chapter III of this report. The mapping standards should consider using the following elements:

  - With regard to digital submittals, map items should be provided in a digital format georeferenced to the State Plane Coordinate System, Wisconsin South Zone, NAD 27, NGVD 29. Preferred formats include ESRI Geodatabase or AutoCAD .dxf.

  - With regard to mapping stormwater BMPs (points), attributes should include a unique BMP ID number, BMP Type (using the WDNR technical standards whenever possible), BMP Description, Drainage Area (acres), entity or person responsible for maintenance, Certifying/Design Engineer, Company and Date, In-Service Date, and Document Numbers for Recorded Maintenance Agreements.

  - Unique identification between swale and curb and gutter sections

  - Flow arrows for all conveyances and discharges from large BMPs (> 2 acres)

  - Standard alpha numeric numbering system for major outfalls and contributing drainage areas (i.e., start with first three letters of municipality, then assign letters to drainage areas, and numbers to outfalls)

  - Northing, Easting coordinates for major outfalls and BMPs

  - Uniquely identify areas not tributary to MS4, (i.e. riparian areas)

  - TMDL reach subbasin boundaries, if applicable.

- Conduct a study investigating the source of discharges from the high-priority outfalls identified on Map 35 to determine whether any outfalls or discharges can be eliminated.

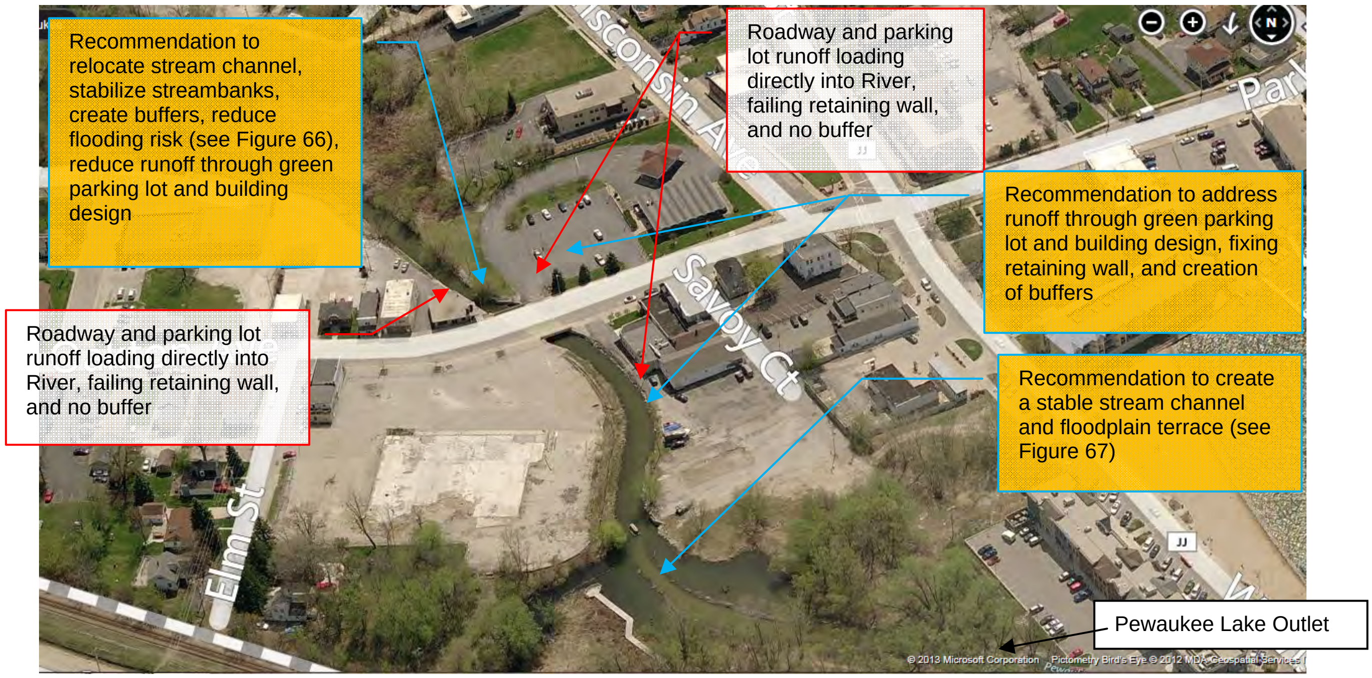
- Repair leaking outfalls, as identified on Map 35.

C. Completion of extensive modifications to the downtown area identified in the inset on Map 35 **to prevent the extensive erosion that results from that area, as described in Chapter IV of this plan. These measures would include:**

- Any efforts to reduce stormwater runoff and decrease flashiness of the Pewaukee River throughout the watershed should be a high priority to protect streambank and streambed stability and water quality, as well as potentially reduce flooding within this system. The Pewaukee-3 and -1 reaches and their associated erosion sites should be monitored and addressed if they become worse. In particular, the failing retaining walls just north and south of Oakton Bridge should be a high priority to address. As illustrated in Figures 65 and 66 these sites offer potential opportunities to reduce stormwater runoff as well as pollutant and thermal loads in this critical downtown Village of Pewaukee area that could include one or more measures as summarized below:

Figure 65

HIGH-PRIORITY PROBLEM AREAS AND OPPORTUNITIES TO PROTECT WATER QUALITY INCLUDING TEMPERATURES, STREAMBANK STABILITY, SEDIMENT TRANSPORT, AND FISHERIES HABITAT WITHIN THE PEWAUKEE RIVER WATERSHED: 2012



Source: Google Maps and SEWRPC.

- Improved parking lot design
- Retrofitting of parking lot for better infiltration
- Improvement of bank stability
- Redevelopment of bank slopes
- Retrofitting of parking lot
- Reconstruction of failed retaining wall
- Creation of buffers
- Green building design where practicable
- Installation of a floodplain terrace or bench (see Figures 66 and 67 for more details)
- Use of BMPs, particularly relating to snow removal and salt application.

Recommended Actions for Water Quality Target 3: ***(i.e., Increase pollution reduction ability of lands surrounding the Pewaukee River).***

- Implementation of recommendations associated with Riparian Targets 1 through 3 to the greatest extent practicable, targeting areas between sources of pollution and the River. For example:
  - Installation of 75-foot-wide minimum permanent vegetative buffers along perennial and intermittent streams where adjacent to cropland or livestock pastures.

Figure 66

TYPICAL CROSS SECTION TO ILLUSTRATE RECOMMENDATIONS AND POTENTIAL ALTERNATIVES DOWNSTREAM OF OAKTON BRIDGE: 2012

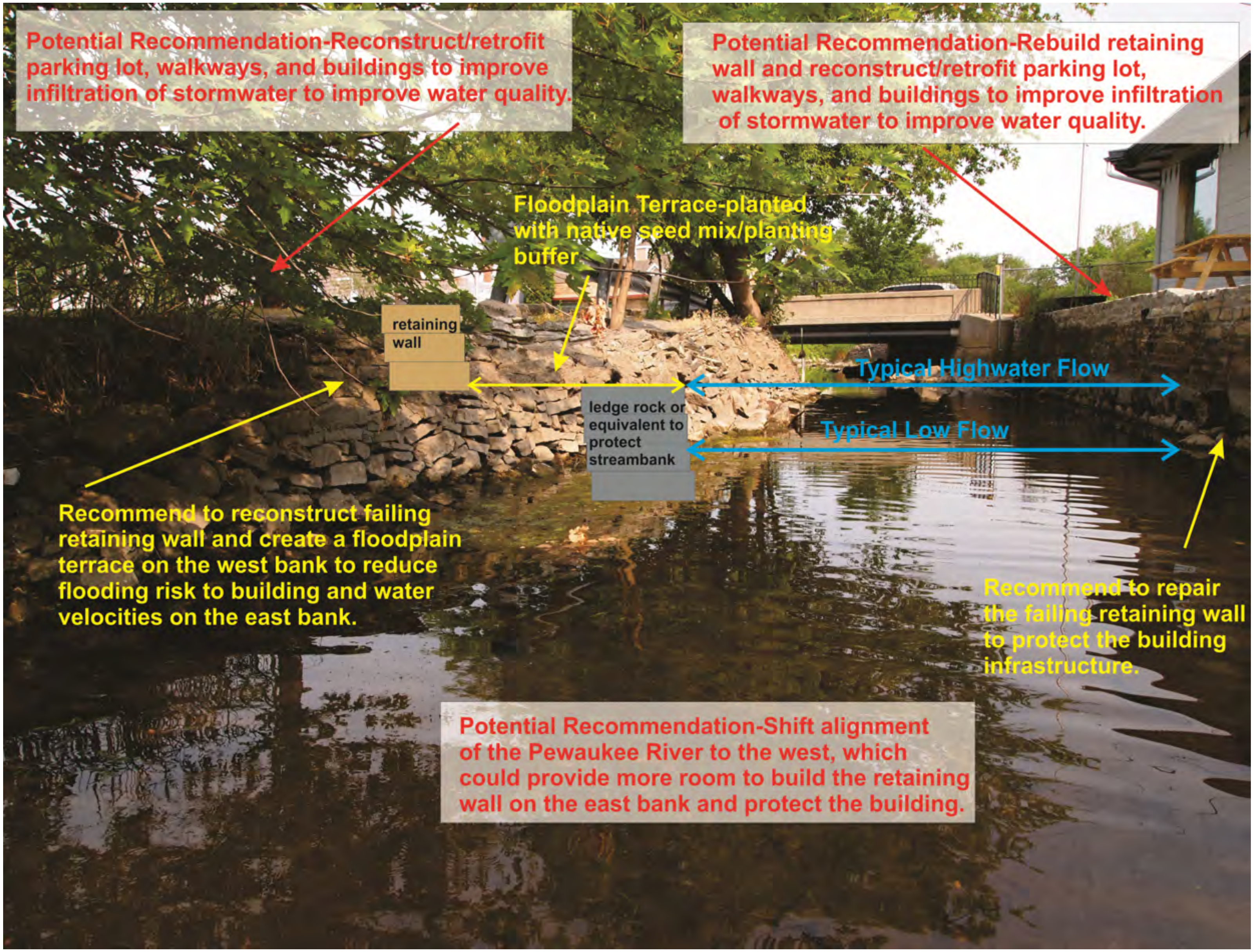


Figure 67

OFF-BANK ROCK TOE/FLOODPLAIN TERRACE STREAM RESTORATION TREATMENT

Source: Living Waters Consultants, Inc., www.LivingWatersConsultants.com, 1 South 132 Summit Ave., Suite 304 • Oakbrook Terrace, IL 60181, and SEWRPC.

- Restoration of undeveloped wetlands (i.e., farmed wetland) that were previously converted to agricultural uses. This could occur when lands are converted from rural to urban land uses, and funding can be obtained. Consideration should be given to reconnecting tributary streams and associated near shore lands with floodplains, and maintaining groundwater recharge if this occurs.

Wildlife

Issue and Targets

A healthy wildlife population, including deer, amphibians, birds, small mammals, etc., is the ultimate indication of a healthy watershed. This is largely due to the fact that wildlife populations require large, well-connected natural areas, which are also associated with high water quality and good aquatic habitat. Additionally, the presence of a healthy wildlife population also presents recreational opportunities, such as bird watching, hunting, and nature trekking, which encourage land users to have a healthy relationship with nature. In order to maintain and improve the wildlife populations in the Pewaukee watershed, the following three targets have been developed, each with specific recommendations:

Target 1: Preserve and expand wildlife habitat to the extent practicable.

This target seeks to protect and expand wildlife habitat so that wildlife can thrive.

Target 2: Reduce habitat fragmentation by preserving and further enhancing connections between buffer areas, open spaces, protected areas, and isolated natural areas.

Fragmentation (i.e., breaking wildlife habitat into pieces, preventing the movement of wildlife from one natural area to another, often caused by road development) is a major threat to wildlife populations in North America. This is due to loss of genetic diversity caused by limiting access to the variety of potential environments that wildlife can live in; road mortality; and noise and vibration, created by roads, which interferes with the ability of reptiles, birds, and mammals to communicate, detect prey, and avoid predators. This target seeks to mitigate these effects by maintaining and establishing connections between current and potential wildlife areas (e.g., buffer areas and open spaces), limiting establishment of new roads where practicable, and mitigating the adverse effects of new roads on habitat connections where practicable.

Target 3: Implement best management practices to enhance wildlife health.

In addition to habitat, there are also human practices which threaten wildlife in general. This goal seeks to reduce this threat either through the implementation of BMPs.

Recommendation Map

As discussed in Chapters IV and VI of this report, environmental corridor and natural area delineation is one of the most important tasks SEWRPC undertakes. These corridors identify the most pristine lands in the watershed and provide them with a certain level of legal protection from development (primary corridors receiving the most amount of protection and isolated natural areas receiving the least). These areas are crucial to wildlife maintenance and enhancement due to their continuity, size, and proximity to waterbodies. Map 36 is provided to guide wildlife enhancement activities toward protecting, enhancing, and connecting these precious resources. This map indicates the location of primary and secondary environmental corridors and isolated natural areas. It also indicates the vulnerable existing and potential buffer areas in the watershed, which are identified to provide guidance as to where buffer development and land purchase and easements should be focused when attempting to enhance wildlife.

In general, the goals of the recommendations included on Map 36 are to protect and expand environmental corridors to the extent feasible while maximizing connections between isolated natural areas and the corridors. Measures taken to carry out these recommendations will ultimately greatly benefit the wildlife in the Pewaukee River watershed.

Recommended Actions

As mentioned above, protection and expansion of environmental corridors and natural areas is an important part of wildlife enhancement. In addition, other recommended actions can help achieve this goal. These actions are highlighted below:

Recommended Actions for Wildlife Target 1: *(i.e., Preserve and expand wildlife habitat to the extent practicable).*

A. **Protection of vulnerable buffer and potential buffer areas within the environmental corridors** (see Map 36), **as well as establishment of buffers where feasible.**

- Implementation of recommendations associated with Riparian Targets 1 through 3, specifically focusing on expansion of buffers to the 400-foot minimum width for wildlife and the 1,000-foot optimum width for wildlife, particularly when located within the delineated environmental corridors;

- Implementation of recommendations associated with Groundwater Targets 1 through 3 and Surface Hydrology Targets 1 and 2 to maintain or restore historical flow regimes in streams;

- Implementation of recommendations associated with Water Quality Targets 1 through 3 to ensure healthy habitat in general;

- Protection of vulnerable buffer and potential buffer areas within the environmental corridors through land purchase or voluntary programs;

- Establishment of 400-feet to 1,000 feet of natural upland habitat adjacent to shoreline wetlands and streams; and

- Certain wetland and woodland areas have been identified for acquisition in the adopted regional natural areas and critical species habitat protection and management plan.[14] Implementation of these recommendations, in addition to those set forth in the adopted park and open space plan for Waukesha County,[15] would complement the protection and preservation of environmentally sensitive lands.

Recommended Actions for Wildlife Target 2: ***(i.e., Reduce habitat fragmentation by preserving and further enhancing connections between buffer areas, open spaces, protected areas, and isolated natural areas).***

A. **Establish connections between isolated natural areas, environmental corridors, and established buffers** (see Map 36)

- Implementation of recommendations associated with Riparian Target 3;

- Maintenance of connections between streams and overbank floodplains so as to continue to protect and preserve fish and wildlife habitat and water quality benefits, making use of open space lands, riparian corridors, and park lands in floodprone areas, as appropriate; and

- Educational or incentive-based programs meant to encourage existing homes or businesses within the 1,000-foot buffer zone to consider landscaping that would enhance wildlife by providing connections (see Appendix C) or lanes through the lots, as well as using native plants to provide cover and food for wildlife.

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[14]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997, and Amendment to Planning Report No. 42, December 2010.*

[15]*SEWRPC Community Assistance Planning Report No. 137,* A Park and Open Space Plan for Waukesha County, *December 1989, as amended in 1996 (CAPR No. 209), and in 2009 in the 2035 Waukesha County Comprehensive Development Plan.*

Recommended Actions for Wildlife Target 3: ***(i.e., Implement best management practices to enhance wildlife health).***

A. Implementation of BMPs aimed at maintaining wildlife, either by designated agencies on public and protected lands or through voluntary, educational, or incentive-based programs. Some of these BMPs include:

- ❖ Install fences to control livestock access to rivers, streams, wetlands, and other waterbodies. Consider alternative watering sources or concentrate livestock watering and shading needs in a small area, leaving the majority of habitat intact.

- ❖ Follow label directions and apply the minimum amounts necessary when using fertilizers, herbicides, and insecticides on agricultural lands, lawns or golf courses, and adequately buffer aquatic regions.

- ❖ Restore natural fire frequency, intensity, and seasonality to the extent practicable. Where feasible, favor burning over herbicides as a vegetation management tool, especially in drier upland ecosystems.

- ❖ Identify and protect embedded, adjacent, and sensitive habitat features such as seasonal wetlands, springs, caves, and rock outcroppings.

- ❖ Minimize soil disturbance (e.g., tire ruts, soil compaction) when using heavy equipment. Use low-pressure tires and limit equipment use to drier seasons or when ground is frozen.

- ❖ Meet or exceed State-recommended BMPs, including impervious setback requirements associated with the revision of NR 151 of the Wisconsin Administrative Code for the establishment of “protective areas” around streams, lakes, and wetlands.

- ❖ Incorporate missing habitat features back into the landscape. Loafing, basking, or escape structures may be absent. Consider strategically placing broken pieces of concrete pipe, plywood, downed trees, or rock, to provide more diverse habitat.

- ❖ Allow dead trees and other coarse woody materials to decompose naturally, and after timber harvests, leave residue, such as stumps, blow overs, logs, and dead standing snags.

- ❖ Formulate forest regeneration plans before harvesting activities start.

- ❖ Use native plant species from as local a source as possible when implementing restoration efforts. Implement management strategies to increase native flowering plants (which encourages healthy insect food base for amphibians) and prevent the introduction and spread of exotic species.

- ❖ Maintain a diversity of forest age classes, densities, and structures either within the same stand or among adjacent stands. Consider thinning, burning, and extended rotations to optimize the time herbaceous and shrub layer vegetation is available. Consider a mosaic of smaller, adjacent patches of varying management regimes.

- ❖ Leave large cull trees or patches of trees on harvested sites whenever practical.

- ❖ Use seasonal road closures to provide balance between species and habitat protection and maintaining traditional uses such as hunting and fishing.

- ❖ In areas managed for recreation, locate regularly used roads, trails, landings, and recreational facilities away from sensitive habitats, migration corridors, and transitional zones between adjacent habitats. Limit recreational access to as few points as is feasible.

- ❖ Avoid mowing wetlands, shorelines and ditches from mid-spring through mid-fall. When mowing fields, raise the mower deck to a height of at least eight inches.

- ❖ Use native species, wood chip berms, hay bales, and staggered siltation fencing for erosion control in areas surrounding wetlands and terrestrial buffers.

- ❖ Avoid precision land leveling where possible (in order to allow for shallow depressional wetlands of which are primary breeding habitats for many amphibians).

- ❖ Avoid storage of silage, manure, salts, and other contaminants near wetlands.

- ❖ Use effective nutrient management (timing, amounts, mechanisms of spreading), including considering crop rotation and burning to add nutrients rather than use of chemicals.

- ❖ Avoid the use of plastic mesh netting.

- ❖ Do not kill wildlife in general, particularly amphibians and reptiles. An added benefit of this is potential predation (e.g., snakes feed on rodents and mice and thus help with pest control).

- ❖ Spay and neuter cats and dogs and keep them indoors/under control (to prevent wildlife mortality).

- ❖ Control increases in predator populations (e.g., raccoons and foxes) in residential areas. These animals thrive in urban areas and feed on birds, reptiles, and amphibians, thereby reducing the wildlife population.

- ❖ Avoid introducing nonnative insects such as fire ants and flatworms by inspecting potted plants and landscaping materials.

- ❖ Use mountable road curbs, rather than vertical-faced curbs, to allow amphibians, reptiles, and other small wildlife to climb off of roads.

- ❖ Create compost piles in natural landscaping.

- Encourage agricultural landowners to enroll in Federal agricultural incentive programs such as the Conservation Reserve Program, the Wetland Reserve Program, the Wildlife Habitat Incentives Program, or the Landowner Incentive Program, which provide financial incentives to restore habitats.

- Investigate and consider the establishment of a Priority Amphibian and Reptile Conservation Area (PARCA).

Aquatic Organisms

Issue and Targets

Aquatic organisms, including fish, mussels, and insects, are essential to maintaining aquatic health by assuring an ecological balance with Pewaukee Lake, and are also the sources of extensive recreation (particularly as it relates to fisheries). In fact, recreational fishing is one of the more important economic activities within Pewaukee

Lake and the streams of the Pewaukee River watershed. In general, to maintain these assets within the Pewaukee River watershed it is important to ensure good aquatic habitat, as well as good water quality and quantity. In the interest of meeting this challenge, three targets were developed, including:

Target 1: Protect and enhance fish and aquatic organism habitat throughout the Pewaukee River watershed.

As aquatic organisms depend on aquatic habitat, it is very important to preserve and improve aquatic habitat wherever possible. This includes maintaining and improving, to the extent practical, the physical, chemical, and hydrologic characteristics within the Pewaukee River watershed, as well as the habitat integrity through preservation of riparian buffers, preservation and protection of spawning areas and riffles, and restoration of streambeds and banks where appropriate. As habitat among reaches and the connectedness of the stream system are improved over time, there will be improved aquatic organism populations and overall health.

Target 2. Maintain and restore fish and aquatic organism passage to the Fox River, Pewaukee Lake, and to the headwaters and tributaries in the Pewaukee River watershed.

The maintenance and continuity of both the game fish species of economic importance and those species on which they depend is associated to a large degree with the protection and restoration of appropriate habitat. To this end, efforts to remove obstructions to fish migration along the mainstem and tributaries of the Pewaukee River are key to the long-term maintenance and protection of the fishery. These obstructions are primarily due to culverts at roadways. As structures are removed or retrofitted over time to promote fish passage, there will be improved access to the highest-quality habitat areas for feeding, rearing, and spawning, leading to restoration of a more sustainable fishery within the watershed.

Target 3: Maintain and enhance a high-quality, sustainable fishery.

The Pewaukee River system contains some very good spawning and rearing areas for northern pike; these should be protected and expanded where applicable. This target seeks to maintain and expand where appropriate the most diverse and highest-quality aquatic communities within the Pewaukee River watershed (see Table 25) through protecting, maintaining, and enhancing these areas to maximize fish populations within the Pewaukee River and Pewaukee Lake.

Recommendation Map

To facilitate the enhancement of aquatic organism populations, SEWRPC staff walked the major streams within the Pewaukee River system and identified potential projects which, when implemented, could greatly improve aquatic habitat in the system. These projects, which are identified on Map 37, include: areas that are priorities for protection (current fish spawning habitat and riffles); areas that require maintenance (debris jam removal projects); areas that require rehabilitation (severe and moderate sources of erosion); and areas that require retrofitting or structure removal (fish passage barriers). Additionally, the map highlights projects in the downtown problem area, as discussed in Chapter IV and the “Water Quality” subsection of this chapter. The materials that support the creation of this map are included in Appendices E and F of this report.

Recommended Actions

Map 37 sets forth the recommended aquatic habitat actions. A summary list of the recommendations included on the map is provided below:

Recommended Actions for Aquatic Organism Target 1: ***(i.e., Protect and enhance fish and aquatic organism habitat throughout the Pewaukee River watershed).***

Table 25

FISH PASSAGE ASSESSMENT AT ROAD CROSSINGS, CALCULATED STREAM LENGTH BETWEEN STRUCTURES, AND BIOLOGICAL (FISH, INVERTEBRATES) AND HABITAT QUALITY DETERMINATIONS AMONG STREAM REACHES WITHIN THE PEWAUKEE RIVER WATERSHED: 1997-2012

Stream Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures	Number of Springs/ Seeps	Number of Tributaries	Fish Spawning Sites/Riffles	Fisheries IBI Rating	Aquatic Bugs HBI Rating	Mussel Species Abundance[a]	Habitat Quality
Pewaukee 1				0.05	0	0	2	- -	- -	- -	Good-Excellent
	0.05	No	Abandoned Canadian Pacific Railway	- -	- -	- -	- -	- -	- -	- -	- -
				0.06	0	0	1	- -	- -	- -	Good
	0.11	Yes	CTH F	- -	- -	- -	- -	- -	- -	- -	- -
				0.28	0	0	1	Fair	Fair-Very Good	Abundant	Good-Excellent
	0.39	No	Steinhafel's driveway	- -	- -	- -	- -	- -	- -	- -	- -
				0.63	0	0	4	Fair	- -	Abundant	Good-Excellent
	1.02	No	Busse Road	- -	- -	- -	- -	- -	- -	- -	- -
				0.67	1	0	5	Fair	Fair	Abundant	Good-Excellent
	1.69	No	STH 164 (Pewaukee Road)	- -	- -	- -	- -	- -	- -	- -	- -
				0.47	0	0	0	Fair	- -	- -	Fair-Good
	2.16	No	I-94	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2				3.19	0	24	2	- -	- -	- -	Fair-Excellent
	5.35	No	Wisconsin Avenue	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3				0.48	0	2	2	Poor	- -	- -	Fair-Good
	5.83	Yes	STH 16	- -	- -	- -	- -	- -	- -	- -	- -
				0.52	0	1	0	- -	- -		Fair-Good
	6.35	No	Clark Street	- -	- -	- -	- -	- -	- -	- -	- -
				0.20	0	1	0	- -	- -		Good
	6.55	No	Oakton Avenue	- -	- -	- -	- -	- -	- -	- -	- -
				0.13	0	0	0	Fair	- -	- -	Fair-Good
	6.68	Yes	Canadian Pacific Railway	- -	- -	- -	- -	- -	- -	- -	- -
				0.01	0	0	0	0	0	0	- -
	6.69	No	Capital Drive	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4				0.61	- -	1	1	- -	- -	- -	Fair-Excellent
	7.30	No	STH 16	- -	- -	- -	- -	- -	- -	- -	- -
				0.24	0	1	0	- -	- -	- -	Fair-Good
	7.54	Yes	Cecilia Drive	- -	- -	- -	- -	- -	- -	- -	- -
				0.58	0	2	0	- -	- -	- -	Good
	8.12	No	Private bridge 1	- -	- -	- -	- -	- -	- -	- -	- -

Table 25 (continued)

Stream Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures	Number of Springs/ Seeps	Number of Tributaries	Fish Spawning Sites/Riffles	Fisheries IBI Rating	Aquatic Bugs HBI Rating	Mussel Species Abundance[a]	Habitat Quality
Pewaukee 5				0.45	4	1	4	- -	- -	- -	Good-Excellent
	8.57	No	Private bridge 2	- -	- -	- -	- -	- -	- -	- -	- -
				0.05	0	0	0	- -	- -	- -	- -
	8.62	No	Private bridge 3	- -	- -	- -	- -	- -	- -	- -	- -
				0.00	0	0	0	- -	- -	- -	- -
	8.62	Yes	Private drop structure	- -	- -	- -	- -	- -	- -	- -	- -
				0.03	0	0	0	- -	- -	- -	Good
	8.65	No	Private bridge 4	- -	0	0	0	- -	- -	- -	- -
				0.09	0	0	1	- -	- -	- -	Good-Excellent
	8.74	Yes	Lindsey Road	- -	- -	- -	- -	- -	- -	- -	- -
				0.17	0	0	3	- -	- -	- -	Good-Excellent
	8.91	Yes	STH 164	- -	- -	- -	- -	- -	- -	- -	- -
				0.38	0	1	1	- -	- -	- -	Fair-Excellent
	9.29	No	Private bridge 5	- -	- -	- -	- -	- -	- -	- -	- -
				0.11	0	0	2	- -	- -	- -	Good-Excellent
	9.40	No	Private bridge 6	- -	- -	- -	- -	- -	- -	- -	- -
				0.15	0	0	0	- -	- -	- -	Fair-Good
	9.55	No	Private bridge 7	- -	- -	- -	- -	- -	- -	- -	- -
				0.04	0	0	0	- -	- -	- -	Good
	9.59	Yes	Private culvert 1	- -	- -	- -	- -	- -	- -	- -	- -
				0.04	0	1	1	- -	- -	- -	Excellent
	9.63	No	Private bridge 8	- -	- -	- -	- -	- -	- -	- -	- -
				0.16	0	0	0	- -	- -	- -	Fair
	9.79	Yes	Private culvert 2	- -	- -	- -	- -	- -	- -	- -	- -
				0.02	0	0	3	- -	- -	- -	Fair-Excellent
	9.81	No	CTH K (Lisbon Road)	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary				0.53	0	2	6	- -	- -	- -	Fair-Excellent
	0.53	Yes	CTH JJ (Bluemound Road)	- -	- -	- -	- -	- -	- -	- -	- -
				0.19	0	1	0	- -	- -	- -	Good
	0.72	No	STH 16	- -	- -	- -	- -	- -	- -	- -	- -
				0.05	- -	- -	- -	- -	- -	- -	- -
	0.77	No	CTH T	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee Lake Outlet				0.06	0	0	2	- -	- -	- -	Fair-Good
	0.06	Yes	Pewaukee Lake outlet	- -	- -	- -	- -	- -	- -	- -	- -

Table 25 (continued)

Stream Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures	Number of Springs/ Seeps	Number of Tributaries	Fish Spawning Sites/Riffles	Fisheries IBI Rating	Aquatic Bugs HBI Rating	Mussel Species Abundance[a]	Habitat Quality
Coco Creek				0.00	- -	- -	- -	- -	- -	- -	- -
	0.00	No	Canadian Pacific Railway	- -	- -	- -	- -	- -	- -	- -	- -
				0.11	0	0	0	- -	- -	- -	Poor-Fair
	0.11	No	Glacier Road	- -	- -	- -	- -	- -	- -	- -	- -
				0.41	0	0	0	- -	Good-Very Good	- -	Fair-Good
	0.52	No	CTH JJ	- -	- -	- -	- -	- -	- -	- -	- -
				0.29	0	0	1	- -	- -	- -	Good
	0.81	Yes	Private culverts	- -	- -	- -	- -	- -	- -	- -	- -
				0.19	0	2	0	- -	- -	- -	Good
	1.00	No	Yench Road	- -	- -	- -	- -	- -	- -	- -	- -
				1.43	- -	- -	- -	Fair	- -	Present	- -
	2.43	No	CTH KE	- -	- -	- -	- -	- -	- -	- -	- -
				0.77	- -	- -	- -	Good	- -	- -	- -
	3.20	Yes	CTH JK (Lisbon Avenue)	- -	- -	- -	- -	- -	- -	- -	- -
				0.36	- -	- -	- -	- -	- -	- -	- -
	3.56	No	STH 16	- -	- -	- -	- -	- -	- -	- -	- -
Tributary to Coco Creek				0.04	0	- -	1	- -	- -	- -	Fair-Good
	0.04	Yes	STH 16	- -	- -	- -	- -	- -	- -	- -	- -
				1.30	- -	- -	- -	- -	- -	- -	- -
	1.34	Yes	CTH KF	- -	- -	- -	- -	- -	- -	- -	- -
Meadow Brook Creek				0.00	- -	- -	- -	- -	- -	- -	- -
	0.00	No	CTH SS	- -	- -	- -	- -	- -	- -	- -	- -
				1.11	1	5	0	- -	- -	- -	Poor-Fair
	1.11	No	CTH G	- -	- -	- -	- -	- -	- -	- -	- -
				0.99	- -	- -	- -	- -	- -	- -	- -
	2.10	No	Fieldhack Drive	- -	- -	- -	- -	- -	- -	- -	- -
				0.25	- -	- -	- -	- -	- -	- -	- -
	2.35	Yes	Milkweed Lane	- -	- -	- -	- -	- -	- -	- -	- -
Zion Creek				0.04	- -	- -	- -	- -	- -	- -	- -
	0.04	No	Louis Avenue	- -	- -	- -	- -	- -	- -	- -	- -
				0.15	- -	- -	- -	- -	- -	- -	- -
	0.19	No	Oakton Avenue	- -	- -	- -	- -	- -	- -	- -	- -

Note: The gray shading indicates the location of a roadway or railway crossing, whereas the orange, green and blue colors indicate the biological or habitat quality rating within the reach of stream between two structures.

[a]*Mussel abundance data comes from surveys conducted in 2011. Surveys were only conducted at site-specific locations and do not reflect the abundance of mussels through the entire river system.*

Source: SEWRPC.

- Implementation of recommendations associated with Riparian Targets 1 through 3;

- Implementation of recommendations associated with Groundwater Targets 1 through 3;

- Implementation of recommendations associated with Surface Hydrology Targets 1 and 2; and

- Implementation of recommendation associated with Water Quality Targets.

- It is recommended that all of the trash and tires identified on Maps E-9 through E-16 in Appendix E be removed to improve the aesthetics and recreational experience of the Pewaukee River and to protect wildlife. In some cases trash is accumulating behind and/or integrated with woody debris jam obstructions; these sites will likely require more effort to address (see Map 37, Inset 2, for example).

- Problem woody debris jams should be removed either partially or completely where appropriate, as shown on Maps E-9 through E-16 in Appendix E, particularly those jams associated with streambank erosion and/or trash and debris. It is recommended to periodically monitor these woody debris accumulations mapped throughout the Pewaukee River watershed and dismantle and/or remove them when they become a problem.

- Seventeen structures were considered to be partial barriers and one structure was considered to be a complete barrier to fish passage throughout the Pewaukee River watershed. These are recommended to either be removed, replaced, or retrofitted to restore fish passage to the extent practicable (see Table F-1). Structure number 18 (RM 8.62) is a complete barrier to fish passage and is a high priority for removal. In terms of the remaining structures, priority for improving passage should be to restore connectivity and habitat quality between the Pewaukee River and the Fox River and between Coco Creek, Meadowbrook Creek, Zion Creek, and Audley Creek and Pewaukee Lake.

- It is also recommended that these structures, particularly the culverts that have more restrictive openings than bridges, be monitored periodically in order to ensure that they have not accumulated debris and become barriers to fish and other aquatic organisms.

- Protect and expand existing highest quality fishery and aquatic habitat within the Pewaukee River watershed as described in Chapter IV of this plan and shown in Table 25.

- Protect identified riffles and spawning areas (see Map 37, observed and potential northern pike spawning areas and potential riffle spawning habitat).

- Restore, enhance, and/or rehabilitate the identified "problem" stream channels through remeandering projects and streambank rehabilitation (see Map 37, Examples 3 and 4).

- Restore and stabilize failing streambanks to reduce sediment deposition into the River and the associated water pollution (see Map 37, moderate and severe streambank erosion sites).

- Expand riparian and instream clean-up efforts throughout the Pewaukee River system, such as those currently implemented by the Pewaukee River Partnership, Inc.

- It is recommended that the aggradation problem within the Pewaukee Lake Outlet be addressed using an Off-Bank Rock Toe/Floodplain Terrace stream restoration treatment or some equivalent (as illustrated in Figure 67) within the lower portion of this channel and the Pewaukee River downstream of the railway bridge to the abutments of the abandoned bridge footings. This type of treatment simultaneously allows for the re-creation of a more appropriate stream width and depth to improve stream channel conveyance, as well as stable floodplain terrace where excess sediments can deposit and promote vegetative growth. Vegetation can and should be planted to further help stabilize sediments outside of the Off-Bank Rock Toe, such as illustrated in Figure 67. Given time, this type of treatment has been shown to improve water temperatures, instream habitat, and fishery abundances. In essence, this would emulate the efforts using the brush bundles, except the stone will be more effective in maintaining a stable bank and terrace area for deposition. However, it is important to note that depending on the actual slopes, discharges, and water velocities at this site, it may be necessary to incorporate a riffle grade control structure or other treatment to ensure that it remains stable over time. In addition, the stone also should be sized large enough so that is will not be easily dismantled.

Recommended Actions for Aquatic Organism Target 2: ***(i.e., Maintain and restore fish and aquatic organism passage to the Fox River, Pewaukee Lake, and to the headwaters and tributaries in the Pewaukee River watershed).***

- Encourage development of plans for replacement and/or retrofitting obstructions at mainstem and tributary road crossings and implementation of improvements to aquatic organism passage over time as opportunities present themselves (e.g., structure failure, major blockage, or bridge reconstruction or replacement). The recognition that fish populations are often adversely affected by culverts has resulted in numerous designs and guidelines to allow for better fish passage and to help ensure a healthy sustainable fisheries community. These are summarized in Appendix F.[16]

    - Table 25 sets forth a list of the number of road crossings or obstructions for each subwatershed within the Pewaukee River watershed and the relationship of these features to fish passage, stream length, habitat quality, and biological quality sample sites.

    - These plans should be developed in partnership with the relevant municipality and/or the County Highway Department.

- Removal and/or retrofitting of obstructions identified on Map 37, accompanied by the restoration or re-creation of habitat within the stream and riparian corridor, as this is essential for resting, rearing, feeding, and spawning of fishes and other organisms. The description and recommended actions for each of these structures are listed in Table F-1.

- To the extent practicable, design and implement stormwater management and conveyance facilities that avoid enclosure of tributary streams, especially those identified as having significant and valuable biological and recreational uses.

- Consider annual or biannual surveys on the Pewaukee River system to assess capabilities to maintain fish passage at road crossings and to identify where actions need to be taken to improve passage.

    - Actions to improve passage would have to be coordinated with the WDNR, County Highway Department, local public works departments, and/or the Wisconsin Department of Transportation.

- Consider annual or biannual surveys on the Pewaukee River system to monitor beaver activity and address beaver dams that are obstructing aquatic organism passage, present impediments to navigation, or creating flooding conditions on a case-by-case basis as necessary.

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[16]*B.G. Dane, "A Review and Resolution of Fish Passage Problems at Culvert Sites in British Columbia," Canada Fisheries and Marine Sciences Technical Report 810, 1978. Chris Katopodis, "Introduction to Fishway Design," Freshwater Institute Central and Arctic Region Department of Fisheries and Oceans, January, 1992.*

- Remove the identified trash and debris built up within the stream channel (see Map 37, Moderate and Severe Debris Jams), particularly when it poses an impediment to fish passage.

Recommended Actions for Aquatic Organisms Target 3: ***(i.e., Maintain and enhance a high-quality, sustainable fishery).***

- Develop and implement plans for control and removal of nonnative species:
    - Continue carp eradication efforts on Pewaukee Lake and potential expansion of this effort to other lakes and mainstream reaches within the Pewaukee River system.
    - Reduce Eurasian water milfoil and curly leaf pondweed infestations, during plant harvesting operations.
- Continue stocking warmwater and coldwater gamefish species to supplement and enhance the fishery in the Lake and streams of the Pewaukee River system as appropriate. This includes the implementation of recommendations related to a walleye spawning site, as identified by WDNR in the 2011-2012 Pewaukee Lake Comprehensive survey. These recommendations are intended to increase recruitment of stocked and naturally reproduced walleye, as well as increase overall adult abundance. The specifics of these recommendation include:
    - Implement a walleye stocking plan that involves increasing the small fingerling stocking rate from the current 35 per acre to 100 per acre on an alternate-year basis. In opposite, alternating years, stock large fingerling walleye at the current recommended rate of 10 per acre. Large fingerling walleye stocking is known to provide greater recruitment, but at a much higher cost per fish. This option would only be feasible if sponsored by alternative funding sources, since the WDNR currently cannot fill these types of extended growth quotas due to increased demand and increased cost.
    - Implement an experiment to increase survival by holding small fingerling walleye in net pens, predator enclosures, or rearing ponds connected to the Lake and allowing them adapt to the Lake and grow without risk of predation. Specifically, a five-acre pond just north of the east basin of the Lake could be utilized as a rearing pond.
    - Monitor of the walleye population for contribution of stocked versus naturally reproduced fish to each year class through marking and recapture and fall electrofishing surveys.

Recreation

Issue and Targets

The Pewaukee River, Pewaukee Lake, and tributary streams form an important element of the natural resource base of the watershed. The location of the River and tributary streams within environmental corridors and open space areas provides an opportunity for people to utilize and enjoy these resources for recreational and aesthetic viewing purposes. Consequently, these resources can provide an essential avenue for relief of urban stressors among the population and improve quality of life in local neighborhoods and the entire watershed. Such uses also sustain industries associated with outfitting and support recreational and other uses of the natural environment, thereby providing economic opportunities for the local communities.

Recreational activity also has the added benefit of maximizing the investment of watershed residents in the health of the Pewaukee River through providing opportunities for residents to “build a relationship with the River.” This relationship can then influence residents and business owners to make an effort to implement BMPs and, in general, actively seek to maintain and/or improve the conditions of the River in which they enjoy recreating. This target aims to improve recreational opportunities and improve the recreational experience within the Pewaukee River in order to encourage people to build this relationship and ensure a culture which ultimately cares about the well being of the River.

Accordingly, in the interest of maintaining and encouraging recreational activities, two targets were developed. They are as follows:

Target 1: Improvement and expansion of recreational and associated educational opportunities.

In general, the River, tributary streams and their associated parkways are in close proximity to other economic and cultural resources of the watershed. This provides opportunities for linking recreation by connecting these landscape features through an integrated system of roads, trails, paths, and waterways. As embodied in the regional park and open space plan, the County and local open space plans, the County land and water resource management plan, and the County comprehensive development plan, the objective of this target is to maintain and expand access to the water resources of the Pewaukee River watershed, as well as to take advantage of the opportunities for education within those areas.

Target 2: Ensure maintenance and improvement recreational safety.

Several safety hazards are associated with recreational use of the Pewaukee River, both as it relates to human safety and the safety of the Pewaukee River itself (in relation to ecosystem health). This target is meant to manage the identified safety hazards through enforcement of regulations, reconstruction or elimination of safety hazards, and potential signage. In general, this target is meant to ensure that recreation undertaken in the Pewaukee River is enjoyable, without risking the integrity of the Pewaukee River system.

Recommendation Map

To facilitate the enhancement of recreation on the Pewaukee River, SEWRPC staff walked the River and identified major recreational hindrances and opportunities. These findings are summarized on Map 38, which includes recommendations related to: potential future bike and walking trails; potential walking bridges; potential access sites; navigational hazards; and potential sign locations. Additionally, the map identifies the lands in the areas owned by the State, Waukesha County, and the Village of Pewaukee in order to provide insight into who would need to be consulted when implementing a project in this area. The map also shows the FEMA 100-year floodplain, as these areas have some restrictions related to recreation that must be adhered to as described in *NR 116 of the Wisconsin Administrative Code*. Supporting material for this map is presented in Appendix E of this report.

Recommended Actions

All of the recommended actions related to recreational enhancement are included on Map 38. They are additionally listed as follows with short explanations:

Recommended Actions for Recreation Target 1: ***(i.e., Improvement and expansion of recreational and potential educational opportunities).***

A. Installation of new trails and access sites (see Map 38, potential access sites and potential trail and bike routes)

- It is recommended that the Pewaukee River Partnership continue to collaborate with local municipalities and WDNR and other organizations to maintain and improve recreational access within the Pewaukee River watershed.

- It is recommended that community park and recreation or county departments working with the WDNR consider purchase of the remaining private boat launch sites as they are offered for sale. Loss of the remaining sites will restrict public access in the watershed and could result in the loss of ability to apply for recreational grants from the WDNR in the future.

- Installation of access site A as shown on Map 38 to provide safe entrance and exit to the Pewaukee River upstream of a major navigational hazard.

- The current and potential new nonnative plant and animal invasive species continue to threaten the biological integrity of this stream ecosystem and need to be managed to the extent practicable to protect the function and structure of the existing wildlife habitats and recreational quality in this watershed.

- Installation of previously proposed biking and pedestrian trails, as highlighted on Map 39, including:

    - The SEWRPC 2010 proposed on- and off-road bike and pedestrian trails.

    - The proposed City of Pewaukee bike plan on- and off-road trails.

- Installation of new trails in the areas identified under this plan (see Map 38), including:

    - A connected, new, limited-use trail beginning at the Lake and following the River downstream to just beyond the proposed new access point at site A as shown on Map 38.

    - A new bike trail installed just east of the River with a connection to the aforementioned proposed trail.

B. Installation of signs to educate recreational users of the River. These should be installed at all current and potential access points to the Lake and River (see Map 38, Potential and Existing Access Points).

- Installation of interpretive signs to identify habitat types, trails, canoeing and fishing access areas, and the general state of the watershed. These signs should also be maximized for educational purposes to communicate the issues affecting the River and how every person can contribute to the solution.

Recommended Actions for Recreation Target 2: ***(i.e., Ensure maintenance and improve recreational safety).***

A. Improve safety for recreational users (see Map 38, major and general navigational hazards).

- With respect to the regulation and management of fishing, boating, and related water-based recreational opportunities offered in the Pewaukee River watershed, current levels of enforcement should be maintained and programs such as Operation Dry Water should be supported and expanded.[17]

- It is recommended that the three culvert pipes making up structure 14 be replaced with a single structure to accommodate adequate and safe navigation at both low-flow and high-flow conditions (as identified on Map 38).

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[17]*Operation Dry Water is a joint law enforcement program to prevent boat operators from driving while under the influence of alcohol. This is a national program is conducted in partnership with WDNR wardens, municipal boat patrols, the National Association of State Boating Administrators, and the U.S. Coast Guard (see* www.operationdrywater.org*).*

- In addition, two structures—number 1 (abandoned Canadian Pacific Railway bridge) and number 2 (culvert at CTH F)—are very dangerous to navigate under elevated or higher flow conditions and are recommended to be replaced. As a short-term solution, it is recommended that signs be posted in strategic locations along the Pewaukee River to warn watercraft operators of the potential danger at these crossings (as identified on Map 38).

- It is recommended that an access area be created for watercraft to safely exit the river upstream of the culvert at IH 94 as identified on Map 38, because the closest public access site to exit the Pewaukee River is several miles upstream.

    - As a long-term solution, these structures should be replaced to allow for safe navigation in both lower and higher flow conditions, which should include the ability to safely escape or climb out of a structure in an emergency.

    - As a short-term solution, it is recommended that signs be posted in strategic locations along the Pewaukee River to warn watercraft operators of the potential danger at these crossings.

- Consider removal of fences that impede navigation and create unsafe recreational conditions.

B. Prevent dangers associated with recreational use from affecting the River ecosystem.

- Recreational boating access users should be made aware of the presence of the exotic invasive species Eurasian water milfoil, zebra mussel, and rusty crayfish, among others. Measures to do so could include:

    - Appropriate signage placed at public and private recreational boating sites, and supplemental materials on the control of invasive species, should be made available to the public.

    - Materials should be provided to riparian households by means of mail drops or distribution of informational materials at public buildings, such as municipal buildings and public libraries.

    - Informational materials should be provided to nonriparian users at the entrances to all municipal public recreational boating access sites.

- Installation and maintenance of bins for disposal of plant materials and other refuse should be removed from watercraft using the public recreational boating access sites.

- Potential inspection of boats during high volume seasons should be considered in order to prevent the introduction of invasive species.

- Continued monitoring and removal of trash and debris from streams and the Lake are recommended.

Land Use Planning

Issue and Targets

As is apparent when examining many of the issues and targets described above, the most fundamental and basic element of this protection plan is the land use element. The distribution of urban and rural land uses will largely determine the character, magnitude, and distribution of nonpoint sources of pollution and, ultimately, the quality and quantity of the surface water and groundwater within the Pewaukee River watershed.

Considering the effect that land use decisions have on the status of the Pewaukee River, it was determined that recommendations should be developed related to regulating: land use changes; setback distances; buffer development; and BMPs, to maximize the effect one action can have on the entire watershed and the Pewaukee River in general. In short, the recommendations included in this section attempt to create an enabling legal environment within the Pewaukee River (i.e., a legal environment which encourages and even potentially mandates the implementation of the recommendations discussed above).

To achieve this "enabling environment," three targets were developed. They are as follows:

Target 1: Implementation of currently developed plans related to land use and environmental management within the Pewaukee River system.

As discussed in Chapter III of this report, several plans have been developed related to land use planning, water supply, and environmental management that relate to the Pewaukee River watershed. This target seeks to highlight which of these plans should be fully implemented to assure the health and well being of the Pewaukee River.

Target 2: Continued and improved implementation of current regulations that help meet the targets listed in this chapter.

Various regulations and zoning laws currently in place prevent, limit, or restrict urban development and agricultural uses in specific areas of the Pewaukee River. This target seeks to assure that these regulations are maintained and properly implemented.

Target 3: The introduction of a new regulatory framework which seeks to protect, preserve, and enhance the Pewaukee River system.

In addition to the regulations and plans are currently in place, there are also potential mechanisms and planning processes that could be implemented or investigated and which could greatly facilitate the accomplishment of the targets included above. This target is intended to encourage the investigation and potential implementation of some of these mechanisms.

Recommendation Maps

As these recommendations would ideally be applied on a municipal or full watershed basis, the civil division map (see Map 2 in Chapter I of this report) is the most useful map related to enforcement or establishment of regulations. This map provides an idea of which entities should be consulted when attempting to enact new regulations. In addition, it could also be useful to consult with the "Roles and Responsibilities" section of this chapter, to gain an idea of the role of a municipality versus the role of the County or the State.

Recommended Actions

The recommendations are included as a part of this plan to either reaffirm current regulatory structures and plans or to begin discussion of the measures that could ultimately solve many of the problems in the Pewaukee watershed, if properly implemented. The recommendations are as follows:

Recommended Actions for Land Use Planning Target 1: *(i.e., Implementation of currently developed plans related to land use and environmental management within the Pewaukee River system).*

- Integrate the Pewaukee River Watershed Protection Plan recommendations into regional and local-level development plans, including an updated comprehensive watershed management plan for the Fox River basin;[18] and

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[18]*The Fox River watershed study is documented in SEWRPC Planning Report No. 12,* A Comprehensive Plan for the Fox River Watershed*; Volume One,* Inventory Findings and Forecasts; *Volume Two,* Alternative Plans and Recommended Plan*, February 1970. See also WDNR, Publication No. PUBL-WT-701-02,* The State of the Southeast Fox River Basin*, February 2002.*

- Observe and implement the conservation and development guidelines set forth in Regional, County, and local land use and comprehensive plans, and the county land and water resource management plan, to protect environmentally sensitive lands as recommended in the regional natural areas and critical species habitat protection and management plan.

Recommended Actions for Land Use Planning Target 2: ***(i.e., Continued and improved implementation of current regulations which help meet the targets listed prior to this section).***

- Limit development within the SEWRPC-delineated primary and secondary environmental corridors and isolated natural resource areas, and promote connection of fragmented ecologically valuable lands by: connecting environmental corridors and isolated natural resource areas with other larger corridors and natural areas where practicable.

- Update and improve implementation of zoning standards to ensure preservation of targeted lands including:

    - Protection and enhancement of wetland areas through ordinance enforcement, appropriate zoning, development of setbacks and runoff management measures by requiring minimum 75-foot wetland setbacks for all proposed impervious surfaces or site grading.[19]

Recommended Actions for Land Use Planning Target 3: ***(i.e., The introduction of a new regulatory framework which seeks to protect, preserve, and enhance the Pewaukee River System).***

- Implement a "Pewaukee River Overlay Zoning District," or expand the "Environmental Corridor Overlay District"[20] by Waukesha County and the concerned cities, towns and villages. This Zoning District would designate zones along the stream corridors of the Pewaukee River for protection and would ideally extend the corridors 1,000 feet from significant streams and lakes or to the outer limit of the existing primary environmental corridor, whichever is greater. Within this zoning district, specific requirements would be established regarding existing and new urban and suburban development and agricultural lands. Things to consider when discussing this recommendation include:

    - Much of the land in this zone would include SEWRPC-delineated environmental corridor lands, SEWRPC-identified natural areas and critical species habitat, regulatory floodplains, shoreland wetlands, shoreland areas, drainageways, steeply sloped lands, and important uplands including prairie, woodlands, and other open lands. All, or portions of, these lands are currently

[19]*Chapter NR 151,* Runoff Management, *of the* Wisconsin Administrative Code, *currently requires protective zones adjacent to wetlands ranging from 10 to 75 feet in width, depending on the quality of the wetland. Thus, the overall recommendation of this watershed protection plan, in some cases, is more stringent than the existing or proposed requirements of NR 151.*

[20]*The purpose and intent of the Waukesha County Environmental Corridor District, as mapped or intended to be mapped, includes nonwetland/floodplain primary or secondary environmental corridors, and is intended to be used to preserve, protect, enhance, and restore significant woodlands, upland wildlife habitat areas, scenic overlooks, slopes exceeding 12 percent, and upland wooded areas, while also affording an opportunity to use the site for the limited residential purposes, in concert with the goal and intent of the Regional Land Use Plan or locally adopted plan, which suggests that residential densities in such areas not exceed one unit per five acres for all parcels which lie entirely within the Environmental Corridor. Where questions arise as to the exact location or boundary of an environmental corridor, the extent and location of such corridors shall be finally determined by infield investigation by the Zoning Administrator or his/her designee.*

included within conservancy zoning districts within which new development is already restricted. Consequently, implementation of the recommendation would be likely to have a minimal impact on existing development outside of the developed lake shore areas.

- Within the lake shore areas, rigorous enforcement of the regulatory 75-foot shoreland setback is recommended.

- Consideration should be given to encouraging the placement of vegetated riparian buffers within lake shore areas as part of the implementation of this overlay zoning district.

- Similar approaches have been adopted in the Village of Fontana on Geneva Lake through their environmental corridor overlay districts and the City of Milwaukee through their Milwaukee River Greenway Overlay Zone.

- This recommendation could be enabled by the formation of an intergovernmental task force to consider issues that would need to be addressed in establishing a “Pewaukee River Overlay Zoning District.” Such a task force would make recommendations to the units of government with zoning authority. Some issues that could be considered include:

  — The streams along which the District would be established;

  — A method for optimizing the extent of undeveloped riparian buffers that meets multiple water quality and habitat objectives;

  — The restrictions, if any, that would be imposed on existing development;

  — Logistics of how such a District can be accomplished without imposing an unnecessary financial burden on residents and other landowners within the District;

  — The requirements that would apply to agricultural lands;

  — The types and sizes of new development that would be permitted;

  — Required characteristics of new development (e.g., clustering, green infrastructure);

  — Required stormwater management approaches;

  — Building setbacks from water features that would be established within the 1,000-foot zone; and

  — What limits would there be on removal of vegetation and trees.

- Consider applying land use planning and regulatory tools to preserve productive farmland and agricultural businesses, while minimizing land use conflicts with urban areas.

- This watershed protection plan should be reviewed by Waukesha County; the Villages of Hartland, Pewaukee, and Sussex; the Towns of Delafield, Lisbon, and Merton; and the Cities of Delafield, Pewaukee, and Waukesha, and consideration given to incorporating pertinent recommendations into their “Smart Growth” comprehensive multi-jurisdictional and other local level plans;[21]

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

- Implement the recommendations in Surface Water Target 2, which relates to floodplain mapping, to potentially meet the criteria necessary to have the riparian lands along Coco Creek, Meadowbrook Creek, and Zion Creek designated as primary environmental corridors, therefore affording them better regulatory protection from development.

- Develop a stormwater management plan for the downtown area identified on Map 35 and Map 37. As discussed in the Surface Hydrology Target 1 and Water Quality Target 3, this plan should focus on the use of green technologies like green roofs, porous pavement, rain gardens, and rain barrels for the purpose of restoring the natural hydrology of the Pewaukee River system in that area.

Monitoring and Information

Issue and Targets

Monitoring and information collection programs are invaluable at helping planners, local officials, and community members better understand what is taking place within the Pewaukee River watershed. These kinds of programs can also provide a general idea of where management efforts should focus, can help better target management programs, can help determine project feasibility, and can help monitor the success of management projects. In order to achieve the monitoring and information needs of the Pewaukee River watershed, the following four targets were developed:

Target 1: Maintain and enhance current water quality and quantity monitoring programs.

It is critical to determine whether water quality and biological communities are improving or degrading. It is, therefore, important to establish the physical conditions of the streams and associated corridor lands, so that the response of those streams and lands to land use changes can be determined. Accordingly, this target seeks to maintain and expand existing monitoring efforts and research.

Target 2: Collect information necessary to effectively target management efforts.

In addition to general stream and lake water quality and quantity data, extensive targeted data collection can take place to better direct management efforts. For example, by monitoring chloride concentrations in outfalls draining into the Lake, the locations of the highest chloride concentrations can be determined and the areas draining to those outfalls can be targeted for salt reduction programs. This information has generally not been collected; this target seeks to gain this information through targeted monitoring and research programs.

Target 3: Collect logistical information required to effectively implement the recommendations of this plan.

Information related to issues such as project design and cost, legal structures, and zoning laws can greatly affect the effectiveness and feasibility of any proposed project. This target seeks to gain the information required to determine the feasibility of recommended projects, and thereby help determine the projects that can be implemented immediately and the projects that require further consideration.

Target 4: Develop and monitor "performance indicators" for each project/target that is undertaken as a part of this plan.

Any project that is undertaken should be designed with a level of monitoring in mind. Instream and in-lake monitoring may not indicate the effects of projects on parameters of interest for several years. This is especially true in lakes, as residence times (the average time it takes from the moment a molecule of water enters a lake system to when it flows out) can vary from less than two years to more than 50 years depending on depth, mixing, and flow. As a result, though a project may be intended to ultimately measurably improve the water quality of a waterbody, the visible effects of the project (e.g., water clarity and nutrient reduction) may not be immediately apparent. This target seeks to develop "performance indicators" that will indicate progress even in the initial phases of a project.

Target 5: Monitor and communicate all of the environmental projects being implemented in the Pewaukee River watershed.

It is important to keep track of all the projects that are undertaken in the Pewaukee River watershed as a result of the implementation of this plan. This will avoid repetition of efforts and ensure that all efforts are maximized to effect change. This target seeks to ensure this monitoring and its subsequent communication to policy makers, funding agencies, and community members.

Recommendation Maps

Many of the recommendations in this section apply to the entire watershed, therefore all of the maps included in this chapter (see Maps 32 through 38) indicate areas that should be targeted.

Recommended Actions

Following are the recommended actions related to monitoring and information:

Recommended Action for Monitoring and Information Target 1: ***(i.e., Maintain and enhance current water quality and quantity monitoring programs).***

A. Maintain current monitoring actions.

- Maintain current inventories on riparian buffer conditions and widths throughout the watershed and expand riparian buffer inventories along tributaries that have not been assessed.

- Continue coordination of terrestrial monitoring, sampling schedules, and sharing of data and results among government agencies, nongovernment agencies, citizen monitoring, and research institutions.

- Continue monitoring nonnative invasive species such as buckthorn, gypsy moth, emerald ash borer, and purple loosestrife, among other species identified or that may be identified in Chapter NR 40 of the *Wisconsin Administrative Code*.

- Continue and expand citizen and student monitoring efforts and maintenance of inventories for fish passage, habitat, aquatic organisms, and water quality.

    - Such efforts should be supported and integrated into the data collection and analysis process associated with the agency programs (e.g., WDNR).These programs form a vehicle for ongoing data collection that frequently extends beyond the specific project period, and can contribute both to enhanced civic awareness and to the education of youth.

B. Expand and improve current monitoring efforts.

- Monitor fish and macroinvertebrate populations to periodically evaluate the effectiveness of the lake and stream protection program, and to provide for early detection of, and response to, potential nonnative invasive species in the River and Lake.

- Expand terrestrial monitoring. Specifically, such monitoring would include periodic bird counts, transect sampling of upland habitat, and species counts of vegetation, invertebrates (e.g., butterflies, beetles), mammals, amphibians, and reptiles when possible.

- Adopt common quality assurance and quality control procedures among all implementing agencies completing monitoring, including:

    - Standardized monitoring programs, including agency programs such as the WDNR baseline monitoring program and the UWEX and other citizen-based monitoring programs, and

    - Common use of the WDNR Surface Water Integrated Monitoring System (SWIMS).

- As this plan is implemented, liaison with the ongoing WDNR and U.S. Geological Survey (USGS) monitoring programs is recommended, and modification of these programs is suggested so they can provide site-specific information on potential priority project areas within the Pewaukee River watershed. Where appropriate, these programs should include:

    - Collection, dissemination and analysis of data on a range of parameters, including physical (stream morphological and hydrologic data), chemical, and biological (fisheries and invertebrate population data) parameters, both before and after interventions.

- Identify and develop new monitoring sites in cooperation with citizen and other monitoring programs and sharing of knowledge with stakeholders.

Recommended Actions for Monitoring and Information Target 2: ***(i.e., Collect information necessary to effectively target management efforts).***

To better illustrate how targeted monitoring and research programs can help better direct projects and programs, ensuring more cost-effective projects, examples are given below for each recommendation category in Table 26.

- In addition to the information required above, it is recommended that a periodic review of the plan recommendations and the effectiveness of management measures be undertaken on a five- to 10-year cycle. This would help evaluate effectiveness and determine where funds should be spent in the future. Such a review should require the following actions:

    - Continue cooperation among agencies and organizations involved in implementing the necessary measures identified in the Pewaukee River Watershed Protection Plan, and refine these plans as necessary and appropriate based upon the outcomes of the implemented actions.

    - Evaluate site-specific management measures such as fish habitat and streambank stability treatments in the Pewaukee River using both quantitative and qualitative indicators.

    - Modify existing, and develop new, management measures as necessary and appropriate based upon the monitoring and assessment program findings.

    - Refine the watershed protection plan based upon both a qualitative and quantitative assessment of progress toward plan implementation.

Table 26

TARGETED MONITORING AND RESEARCH EXAMPLES FOR EACH RECOMMENDATION CATEGORY

Recommendation Category	Targeted Monitoring and Research Program Examples
Riparian Buffers	Expand riparian buffer inventories within tributaries not assessed to better direct protection and maintenance efforts
Groundwater and Surface Hydrology	Continue working toward understanding the interactions between groundwater, surface water, and wetlands in order to sustain conjunctive use of this hydrologic system, to minimize water use conflicts, and to ensure adequate allocation and quality of water to sustain the integrity of the coldwater and warmwater aquatic communities. This will help identify areas where Best Management Practice programs should be targeted
Water Supply and Demand	Collect information about where the highest use of water in the watershed takes place in order to better target conservation measures toward high-volume users
Water Quality	Monitor the outfalls identified in Map 35 for chloride and nutrient concentrations and determine the land area that each one serves. This will help target pollutant reduction programs
Wildlife	Conduct wildlife species surveys and vegetation surveys to identify high-value riparian buffer and/or environmental corridor lands throughout the Pewaukee River watershed. These areas would then become the focus of protection and reconnection with possible additional corridor lands
Aquatic Organisms	Explore unexplored reaches (e.g., Zion Creek) to identify areas for protection and rehabilitation
Land Use Planning	Conduct FEMA floodplain mapping for Zion, Meadowbrook, and Coco Creeks to avoid locating development in flood hazard areas
Education	Complete an investigation of the municipal officials or other groups that should be targeted for educational campaigns (e.g., developers who are currently looking to develop in the Pewaukee watershed, and municipal officials who are making development decisions)

Source: SEWRPC.

- A comprehensive monitoring and evaluation plan should be developed and implemented for the Pewaukee River watershed to assess the effectiveness and adequacy of existing and proposed watershed management measures and alternative strategies in meeting adopted goals and objectives. This plan should include:
    - Establishment of long-term biological monitoring goals and objectives for the watershed;
    - Continued gathering of accurate data for long-term study of stream and Lake health;
    - Continued coordination of sampling efforts between organizations;
    - Communication of monitoring results to stakeholders; and
    - Qualitative and quantitative assessment of actions.

Recommended Actions for Monitoring and Information Target 3: ***(i.e., Collect logistical information required to effectively implement recommendations).***

- Determine the feasibility of proposed projects in terms of cost, political will, implementing agencies, presence of information, and schedules. This could be done through:

- o Brainstorming meetings with relevant stakeholders and experts;
- o Literature reviews; and
- o Hiring a consultant to design projects and estimate project costs.

Recommended Actions for Monitoring and Information Target 4: ***(i.e., Develop and monitor "performance indicators" for each project/target that is undertaken as a part of this plan).***

Table 27 was developed to better illustrate what these performance indicators could look like. It provides some examples of potential indicators for the recommendation categories discussed in this chapter.

Recommended Actions for Monitoring and Information Target 5: ***(i.e., Monitoring and communication of all of the environmental projects being implemented in the Pewaukee River watershed).***

- Develop and implement a comprehensive monitoring and evaluation plan for the Pewaukee River watershed to assess the degree to which proposed watershed management measures meet the objectives of this protection plan.
- Maintain a geographic information system database of existing projects to monitor and improve water quality (e.g., riparian buffer width changes through purchase or easements or other types of agreements).
- Maintain a database which tracks all projects implemented in the Pewaukee River watershed that address the recommendations of this plan.
- Maintain a website to communicate the status of implementation of this plan.

Education

Issue and Target

In addition to the numerous recommended actions and potential projects identified above, many actions can be undertaken to help citizens, government officials, nongovernmental organizations (NGOs), and business owners understand watershed management, its importance, and how they can assist. Actions that seek to improve this understanding can help create an "enabling environment," under which affected and interested parties are more open to the implementation of the recommendations included in this plan. These actions should be targeted either to inspire action or to decrease resistance, depending on what is needed. Three targets were established to achieve this goal. They are as follows:

Target 1: Implementation of educational and communication programs targeting community members and River users.

Community members and River users have the ability to severely degrade or improve the conditions within the Pewaukee watershed. These individuals need to be targeted when attempting to increase the implementation of BMPs to mitigate pollution and promote infiltration, and attempting to reduce potential negative impacts of certain forms of recreational use. Additionally, community members and River users can be effective volunteers for monitoring and implementation of projects. This target seeks to influence these individuals to invest in the Pewaukee River through the implementation of BMPs or through volunteer work.

Target 2: Implementation of educational and communications programs targeting business owners, developers, and farmers.

Business owners, developers, and farmers can play significant roles in implementing practices to reduce water pollution and promote groundwater infiltration within the Pewaukee River watershed. This target seeks to promote efforts to protect the natural features of the Pewaukee watershed, and to spur action by these individuals to implement BMPs (e.g., reduced fertilizer use, green building).

Table 27

PERFORMANCE INDICATOR EXAMPLES FOR EACH RECOMMENDATION CATEGORY

Recommendation Category	Potential Performance Indicators
Riparian Buffers	The total acreage of land converted into buffers
	The total acreage of lands purchased for protection
Groundwater Recharge and Pollution	Number of infiltration facilities installed, drainage area controlled by stormwater practices that achieve quality and quantity control, area of permeable paving materials installed, acres of wetland and upland restored, area of low-impact development
	Number of rain gardens or rain barrels installed and downspouts disconnected, green roofs installed
Surface Hydrology	Total number of parking lots retrofitted with porous pavement
	Number of floodplain mapping projects initiated
Water Supply and Demand	Number of rain barrels installed
	Number of residents who attend educational workshops
Water Quality	Number of communities implementing road salt reduction programs; reduction in amount of road salt applied by municipalities
	Number of farmers implementing best management practices related to pesticide application
Wildlife	Number of unused roads converted to wildlife habitat
	Number of wildlife connections installed through residential properties
Aquatic Organisms	Number of river reaches targeted for debris jam removal
	Number of failed streambanks restored
Recreation	Number or signs installed throughout the Pewaukee River watershed
	Number of trailways initiated
Land Use Planning	Number, or land area, of new developments which include “green building designs”
Monitoring and Information	Number of monitored parameters added to the current community monitoring program (e.g., chloride, heavy metals, etc.)
Education and Institutional Strengthening	Number of schools which include educational materials related to the Pewaukee River watershed

Source: SEWRPC.

Target 3: Implementation of educational and communication programs targeting municipal officials and implementing agencies.

For the recommendations of this plan to be successfully implemented, the various implementing agencies in the Pewaukee River watershed must be aware of. Additionally, development of the plan provides a means to inform municipal officials—who could greatly influence the achievement of the recommendations in this plan—about issues related to river management, thereby increasing the likelihood that they would endorse the recommendations. This target seeks to both disseminate the information contained in this plan, as well as to inform municipal officials about rivers in general.

Recommendation Map
As with the recommendations presented in the monitoring section, many of these recommendations would apply to the entire watershed. Therefore all of the recommendation maps (see Maps 32 through Map 38) can be used to identify areas for targeting.

Recommended Actions
The recommended actions associated with education are listed and briefly explained as follows:

Recommended Action for Education Target 1: (*i.e., Implementation of educational and communication programs targeting community members and River users).*

- Continue promoting informational and educational activities intended to draw attention to the water resources in the Pewaukee River watershed, including activities such as: a) storm drain informational marking; b) volunteer stream water quality monitoring; c) distributing information on proper management of materials that may cause water pollution from sources such as automobiles, pets, household hazardous wastes, and household practices; d) promoting beneficial onsite reuse of composted leaves and grass clippings and proper use of lawn and garden fertilizers and pesticides; and e) promoting infiltration practices for residential stormwater runoff, such as "rain gardens."

- Continue Lake Pewaukee Sanitary District public awareness campaigns and citizen participation that contribute to an informed citizenry within the watershed, including provision of information not only of Lake interest but also relating to the streams of the watershed, in the Lake District newsletters, meetings, and other media outlets;

- Continue implementation of programs to inform and educate the public on invasive species issues.

- Encourage inclusion of river-oriented curricula in local schools. Promote river monitoring and storm drain informational marking in cooperation with community organizations such as the Pewaukee River Partnership, Inc.

- Create and erect signage identifying watershed boundaries or stream crossings on local roadways with appropriate permission to communicate watershed issues/value (as recommended in Recreation Target 1).

- Develop and distribute newsletters at municipal buildings and public libraries. Also consider distributing recycled paper placemats containing river access points and activities of interest to local restaurants.

- Sponsor a poster, photograph, essay, or video contest to promote awareness and protections of the Pewaukee River and its watershed. Solicit prizes and support from community businesses and/or service organizations.

- Identify activities appropriate to community youth and service organizations and share these with the leadership of these groups (e.g., Eagle Scout projects, community garden projects).

- Promote synergies with existing community activities and organizations such as recycling and public health, among others. Develop partnerships with the Wisconsin Department of Tourism and local tourism outlets and offices to promote river-oriented outdoor recreation. Partner with local businesses (e.g., bike shops, canoe liveries, ice cream parlors).

- Develop a "River Day" annual event to promote awareness of the ongoing efforts to protect and enhance fisheries and recreation. Encourage public access television stations to develop, obtain, and screen programs related to the natural history of the specific rivers.

- Compile an oral and/or photographic history of the River in partnership with the County historical society. Sponsor a River-oriented display in community centers and libraries that is focused on local neighborhoods.

Recommended Action for Education Target 2: ***(i.e., Implementation of educational and communications programs targeting business owners, developers, and farmers).***

- Promote and encourage, through meetings and educational outreach, the use of green infrastructure, monitoring of project implementation, and the maintenance of practices that support the health of the Lake and River. Encourage business owners to participate in awareness campaigns, including:
    - Create grocery bags, posters, and place mats with an awareness message;
    - Place revolving displays in various locations;
    - Educate employees on waste minimization and recycling;
    - Use natural landscaping and stormwater management in yards and parking areas.
- Encourage participation of builders and developers in:
    - Workshops on special and alternative design considerations supporting the preservation of the streams in the Pewaukee River watershed; use of erosion control and construction site stormwater management practices; and, environmentally friendly building, landscaping and conservation development practices (green building);
    - Informing clients about the process of making positive environmental choices with respect to remodeling, rebuilding, and constructing homes and other premises; and
    - Preserving green space, use of natural landscaping, and good housekeeping practices.
- Implement awareness campaigns aimed at reducing tillage practices that increase erosion, over fertilization, and pesticide use by farmers. This could be done through workshops and other educational venues (e.g., town meetings).
- Consider establishment of demonstration projects on private properties.

Recommended Actions for Education Target 3: ***(i.e., Implementation of educational and communication programs targeting municipal officials and implementing agencies).***

- Make efforts to provide input to municipal plan commissions on land use decisions affecting the Pewaukee River.
- Maintain contact with State, County, and local elected officials and inform them of concerns regarding protection of the Rivers and associated tributaries.
- Consider introduction of a program such as the Rock River Coalition “Send your Legislator Down the River” awareness program.
- Share inventory information with the County, municipalities, WDNR, and SEWRPC to incorporate into planning documents.
- Encourage participation of local government in:

- o Informational programming using workshops, informational packets, etc.;
- o Developing stewardship activities for watershed residents;
- o Minimizing and managing solid and hazardous waste;
- o Managing stormwater and preventing water pollution;
- o Street sweeping and leaf collection programs;
- o Using alternative salts and deicers;
- o Storm sewer and catch basin maintenance;
- o Naturalized highway and roadway plantings/maintenance.

- Encourage implementation of demonstration projects or sustainable landscaping in public parks.

IMPLEMENTATION CONSIDERATIONS

Funding and Cost Considerations

Cost Considerations

A major concern in the implementation of any river protection plan is that of cost. Much of the cost associated with this plan relates to the manner in which development occurs in the watershed. Implementation of the recommended plan would entail capital expenditures for stormwater management and water quality management measures within the watershed and along the lands riparian to the Pewaukee River and its tributaries. A New Hampshire study on the economic values of surface waters concluded that, even though the initial development costs to provide environmental protection features beyond what may typically be required may be slightly higher, these costs are generally viewed favorably by landowners and the community in general, as they contribute to preserving the ambience of the area and benefit property values and quality of life.[22]

Typically environmentally targeted recommendations, such as those included in this watershed protection plan, have minimal impact on the amount of construction activity within the affected area and have been shown, in one New Jersey case study, to have little effect on the local tax base.[23] There may be additional upfront costs for developers, but these may be recoverable costs by selling lots at a higher price. A Chesapeake Bay study of the effects of implementing environmental protection measures developed through watershed planning found that land values for developed land can increase by as much as 10 percent, and the value of vacant land by as much as 20 percent, as a result of the protection measures.[24] The Chesapeake Bay study notes that "residents benefited from the knowledge that public actions were taken to protect the environmental amenity in which they had already invested."

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[22]*Lisa Shapiro and Heidi Kroll,* A Study of the Economic Values of the Surface Waters of New Hampshire: Phase I Report, Preliminary Assessment of the Existing Literature, Data, and Methodological Approaches to Estimating the Economic Value of Surface Water, *August 2001;* Phase II Report, Estimates of Select Economic Values of New Hampshire Lakes, Rivers, Streams and Ponds, *June 2003.*

[23]*W.P. Beaton, "The Impact of Regional Land Use Controls on Property Values: the Case of the New Jersey Pinelands,"* Land Economics, *Volume 67, No. 2, pages 172-194, 1991.*

[24]*W.P. Beaton,* The Cost of Government Regulations, Volume 2, A Baseline Study for the Chesapeake Bay Critical Area, *Chesapeake Bay Critical Area Commission, Annapolis, MD, 216 pages, 1988.*

Other studies focusing strictly on stream corridors indicate that properties located adjacent to a stream buffer can increase in value by more than 30 percent due to the "sense of place" created by water, green space, and forested natural areas.[25] People interviewed for this study expressed a greater willingness to pay more to live near these protected natural resources. Additionally, by taking a proactive stance and installing stream buffers before pollutants degrade water quality, generally less money will need to be spent in the future on potentially costly remedial efforts. When these buffers also contain the entire one-percent-annual-probability (100-year recurrence interval) floodplain, they are a very cost-effective form of flood damage mitigation, both for communities and individual property owners.

Funding Sources

Funding for watershed management measures may be available as cost-share funding through:

1. The Chapter NR 50/51 Stewardship Grant Program,

2. The Chapter NR 120 Nonpoint Pollution Abatement Program in the form of Targeted Runoff Management (TRM) and Urban Nonpoint Source Water Pollution Abatement and Storm Water Management grants,

3. The Chapter NR 153/NR 154 Runoff Management Programs, and

4. The Chapter NR 195 River Protection Grant Program. Under Chapter NR 120.

Roles of Organizations

In addition to cost considerations, it is important to know which entities need to be included when implementing different projects. Implementation of the recommendation proposing the "Pewaukee River Overlay Zoning District," for example would require consultation with various entities, including municipalities and, potentially, the County. Additionally, projects to retrofit properties for "green technologies" would require permits that could be issued by various entities. This section seeks to provide an overview of the roles of the various entities, including permitting agencies and agencies which must be consulted during implementation.

Role of Waukesha County

The Waukesha County Department of Parks and Land Use, Land Resources Division (LRD) is the suggested lead agency for implementation of the watershed protection plan. In general, this agency continues to provide a coordinating role in cooperation with the appropriate local government units and State agencies. Specifically, the agency has oversight of shoreland, floodland, and shoreland/wetland zoning in unincorporated areas within the watershed.

The agency also regulates the installation and maintenance of all private onsite wastewater treatment systems and stormwater management facilities for new development in unincorporated areas. In addition, the Department has compiled, updated, and administered the implementation of the county land and water resources management plan,[26] which, together with the wetland regulations and the shoreland and floodland zoning functions, has immediate relevance to the Pewaukee River watershed and its development. The County has an additional direct role in the management of the Pewaukee River and its tributaries through the informational and educational programming it undertakes on a countywide basis.

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[25] *Mark R. Correl, Jane H. Lillydahl, and Larry D. Singell, "The Effects of Greenbelts on Residential Property Values: Some Findings on the Political Economy of Open Space,"* Land Economics*, Volume 54, No. 2, 1978.*

[26] *See Waukesha County Department of Parks and Land Use,* Waukesha County Land and Water Resource Management Plan: 2006-2012, *March 2006.*

Roles of Municipalities

Sound land management is an integral part of the maintenance and protection of the Pewaukee River watershed and its natural resources. While many of the recommended practices can be implemented by individual property owners, community-level action is predicated on the adoption and implementation of land use, stormwater management, and park and open space plans supported by appropriate zoning requirements. Many municipalities within the watershed have existing plans and ordinances in place, as described in Chapter III of this plan. Nevertheless, such plans and ordinances should be reviewed and periodically updated to ensure conformance with current best management practices and technologies. Consequently, it is recommended that local municipalities within the Pewaukee River watershed develop or update, and implement land use, park and open space, and stormwater management plans and ordinances consistent with the recommendations contained in this plan.

Role of the Wisconsin Department of Natural Resources

The WDNR is dedicated to the preservation, protection, effective management, and maintenance of Wisconsin's natural resources. It is responsible for implementing the laws of the State and, where applicable, the laws of the Federal government that protect and enhance the natural resources of the State. It is the agency charged with coordinating the many disciplines and programs necessary to protect the environment and to provide a full range of outdoor recreational opportunities for Wisconsin citizens and visitors. Part of the WDNR strategic plan is to work together with the public, organizations, and officials to provide Wisconsin with healthy, sustainable ecosystems. This mission is consistent with WDNR participation in the Pewaukee River Protection Plan Advisory Group.

The WDNR staff serves a variety of functions, including: legal enforcement and science-based management of waste, air, land, and water resources. Legal enforcement includes community and construction site stormwater runoff under Chapters NR 151, “Runoff Management,” and NR 216, “Storm Water Discharge Permits,” of the *Wisconsin Administrative Code*; agricultural performance standards under Chapter NR 151; control of nonnative species under Chapter NR 40; angling under Chapter NR 20; recreational boating under Chapter NR 7; and review of local implementation of wetland regulations and shoreland and floodplain zoning ordinances under Chapter 30 of the *Wisconsin Statutes* and associated section of the *Wisconsin Administrative Code*.

With respect to the Pewaukee River watershed, the WDNR staff is a critical and important partner for the implementation of policies and actions summarized in this plan, as well as the monitoring and evaluation of the watershed to help ensure the sustained protection and improvement of this resource. WDNR fisheries biologists are charged with protecting and managing the fishery, other aquatic biota, and their habitats. WDNR wildlife biologists have similar responsibilities with regard to terrestrial wildlife. In addition, WDNR property managers have responsibility for WDNR properties located within the watershed, including those located adjacent to the Pewaukee River Parkway. WDNR conservation wardens enforce State laws and regulations, especially those related to recreational boating, fishing, and hunting.

WDNR water management specialists have responsibility for wetland regulations and shoreland zoning issues, while WDNR water regulation and zoning engineers work cooperatively with the water management specialists and have specific responsibility for floodlands and dam safety issues. It is important to note that one or more of the recommended measures, particularly actions associated with any instream work, may require State permits, administered by the WDNR staff, prior to implementation. WDNR water resources management specialists can provide assistance in lake and river management and planning and water quality management, while WDNR financial assistance specialists and natural resources program specialists can advise on grants and related financial matters.

The WDNR staff also is responsible for a variety of other services that include: analyzing data, formulating and implementing management plans; assessing aquatic habitat; developing and implementing stream habitat mitigation, improvement, or restoration plans; and reviewing permit applications. To this end, WDNR research scientists conduct site-specific assessments and investigations into specific issues of concern. The case of the Pewaukee River system, WDNR researchers have conducted investigations into walleye populations, among other topics.

WDNR staff can assist communities and individuals with contacts in other State agencies, including the University of Wisconsin Extension lakes partnership. Through cooperative programs with Federal agencies, the WDNR staff also forms an important link to the resources provided through agencies such as the U.S. Department of Agriculture Natural Resources Conservation Service, U.S. Geological Service, and Fish and Wildlife Service, among others, that have responsibilities for, and administer grant programs with respect to agriculture, data acquisition and research, and goose management, respectively.

Role of the Public Inland Lake Protection and Rehabilitation District

Public inland lake protection and rehabilitation districts, or lake districts (or lake management districts), are special purpose units of government with responsibility for undertaking a program of protection and rehabilitation of a public lake. These districts can be created by municipalities, or by petition of landowners, pursuant to the process set forth in Chapter 33 of the *Wisconsin Statutes*. In the Pewaukee River watershed, lake district functions are provided by the Lake Pewaukee Sanitary District. The District is governed by a board of commissioners and has its own staff.

The Lake Pewaukee Sanitary District has developed a lake management plan which includes an aquatic plant management element, as noted in Chapter III of this plan. Aquatic plant management forms a major service provided by the Sanitary District, along with the maintenance of informational and educational programming and the WDNR Citizen Lake Monitoring Network program. Additionally, the District has undertaken an active conservation program which includes land purchase of wetlands adjacent to streams.

Role of the Nongovernmental Sector

The Pewaukee River Partnership, Inc. is a nongovernmental organization and an active partner with the local governments and Sanitary District in providing informational programming to the Pewaukee River communities, conducting public lectures, field days, and environmental management activities throughout the watershed.

Prioritization of Recommendations

Many recommendations are described within this chapter. The inevitable question that follows is “Where to begin?” This is a difficult question to answer, as many of the recommendations provided in this chapter require opportunities, which may or may not present themselves. Land purchase and protection, for example—a major recommendation throughout this plan—requires the opportunity to purchase lands from landowners who are willing to sell. Since these opportunities may not always be available, it is important to capitalize on them whenever possible.

Throughout this report, SEWRPC staff has attempted to provide some guidance on the “prioritization of projects” particularly through the “recommendation maps” (i.e., Maps 32, 34, 35, 36, 37, and 38), which indicate high-priority areas for management as they relate to each recommendation category. Additionally, emphasis should be placed on management efforts that contribute to the greatest number of targets. In particular, the accomplishment of the riparian buffer, groundwater recharge, and/or water quality targets, as described in this chapter, would contribute the most to meeting all of the other targets: good recreational opportunities, increased aquatic organism populations, wildlife enhancement, and restoration of surface water hydrology. Therefore, these three targets should be focused on.

It is also important to note that the installation of new regulatory frameworks (e.g., “green building techniques” in new developments) is often difficult to accomplish, yet can contribute a great deal to implementing each of the targets within this plan at a faster rate. Therefore, any opportunities to make these recommendations legally binding should take priority when available.

Finally, a further consideration is feasibility. Some of the recommendations, particularly those shown on Maps 35 and 37, contain projects that can be completed with minimal costs in terms of time or money (e.g., debris jam removal). These projects, therefore, should also take priority, as they can be conducted quickly, their value is generally recognized by municipalities and citizens, and they can potentially significantly improve fish passage and water quality.

In general, the answer to the question to “Where to begin?” is dependent on the implementing agency’s/person’s priorities. If fisheries are the main concern, the implementation of the aquatic organism targets should take priority. If the concern is water quantity during droughts, the groundwater recharge projects would likely take priority. Although this may be a subjective prioritization scheme, it was chosen because, in reality, many of the recommendations highlighted in this plan contribute to several different goals of the plan. Therefore, any action to implement this plan will promote the achievement of plan objectives.

In short, the plan strongly encourages implementers to get to work and make a contribution to the improvement of the Pewaukee River and its watershed.

SUMMARY AND CONCLUSION

The protection strategies in this plan are primarily based on preserving and enhancing existing resources through a combination of regulatory measures, restoration projects, and continued informational and outreach programming. These elements are necessary to help balance the needs of the Pewaukee River, and to accommodate the expected increases in development in the future.

The future protection of the Pewaukee River watershed will depend upon continued vigilance, cooperation, and partnership among the State and regional agencies, Waukesha County, municipalities, the Lake Pewaukee Sanitary District, nongovernmental organizations like the Pewaukee River Partnership Inc., and citizens to implement the recommendations of this plan. Implementation of the recommended measures will provide the water quality and habitat protection necessary to maintain and restore conditions in the watershed, preserve the natural beauty and ambience of the River and its ecosystems, and enable people’s enjoyment of the watershed today and in the future.

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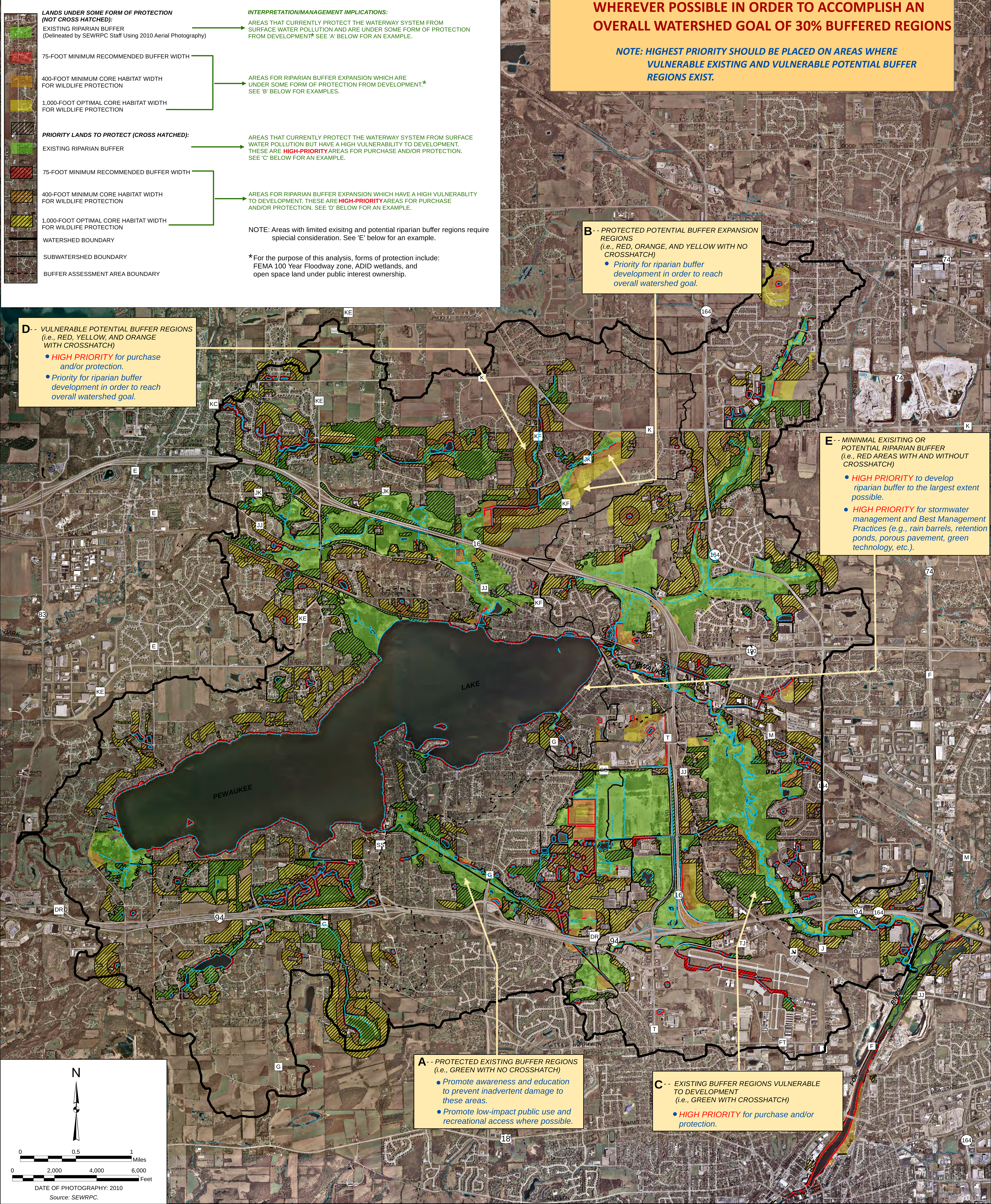
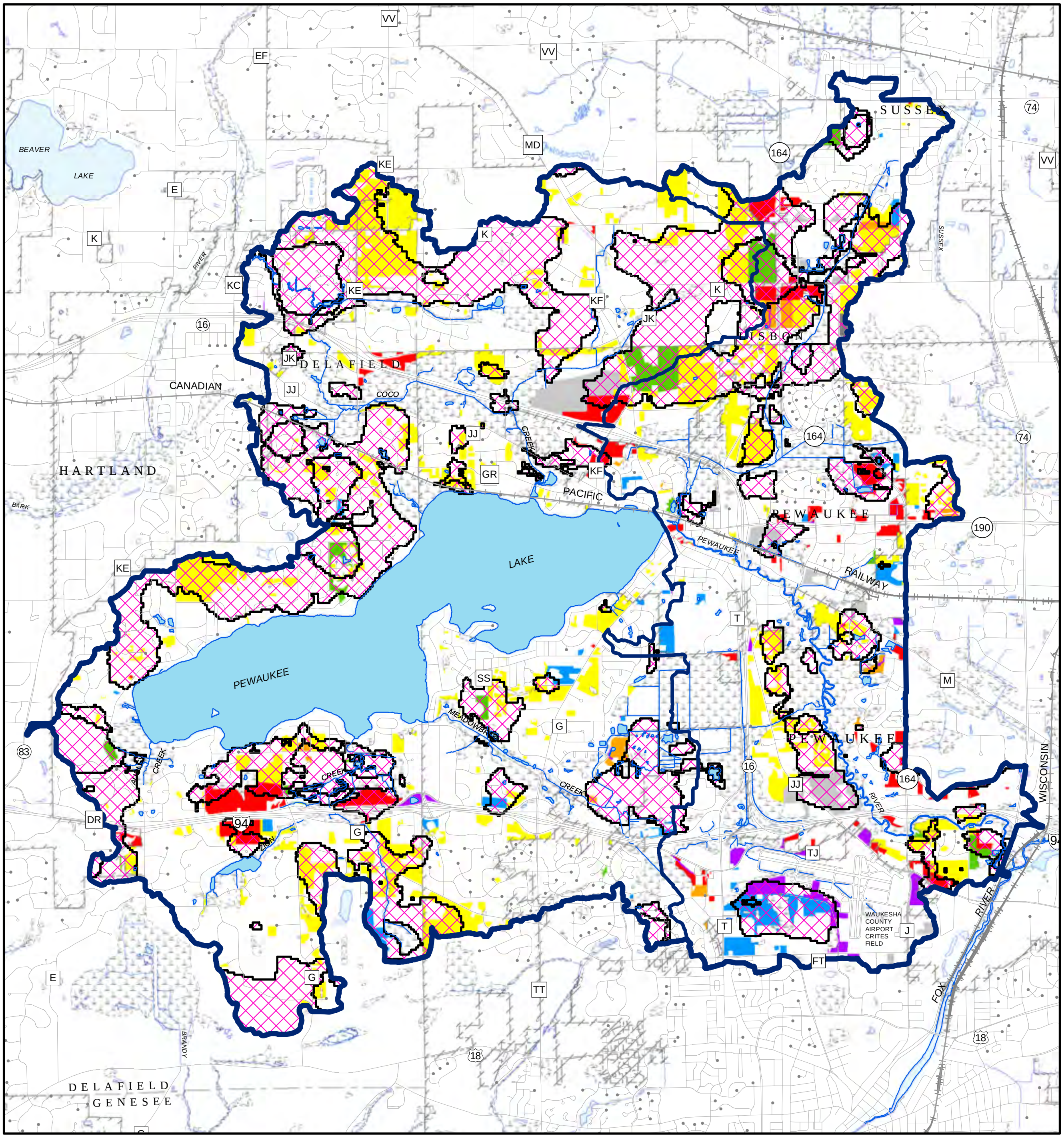
Map 32

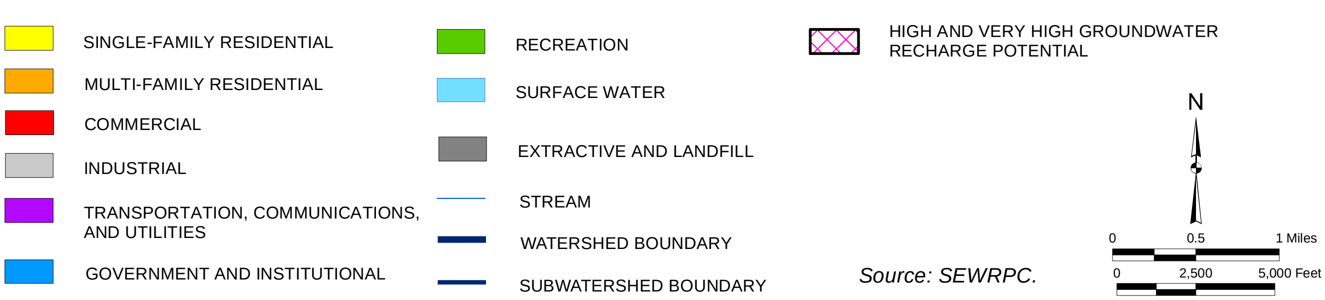
PROPOSED PRIORITY RIPARIAN BUFFER PROTECTION AREAS WITHIN THE PEWAUKEE RIVER WATERSHED: 2010



Map 33

AREAS OF HIGH GROUNDWATER RECHARGE AND 2010 AGRICULTURAL, OPEN LANDS, AND WOODLANDS IN URBAN USES UNDER 2035 LAND USE CONDITIONS WITHIN THE PEWAUKEE RIVER WATERSHED

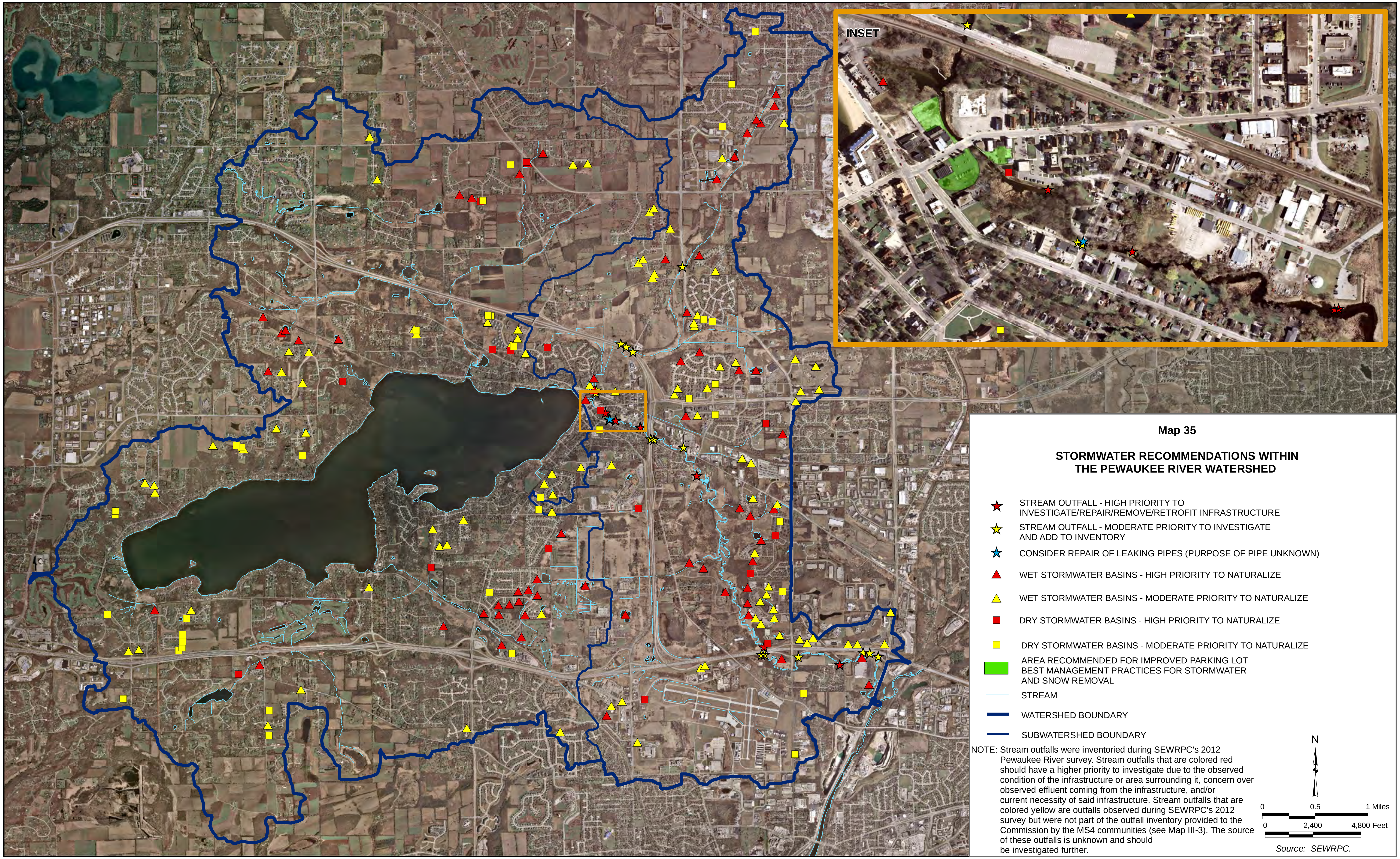




Source: SEWRPC.

Map 34

PROPOSED PRIORITY RIPARIAN BUFFER PROTECTION AREAS AND GROUNDWATER RECHARGE AREAS WITHIN THE PEWAUKEE RIVER WATERSHED

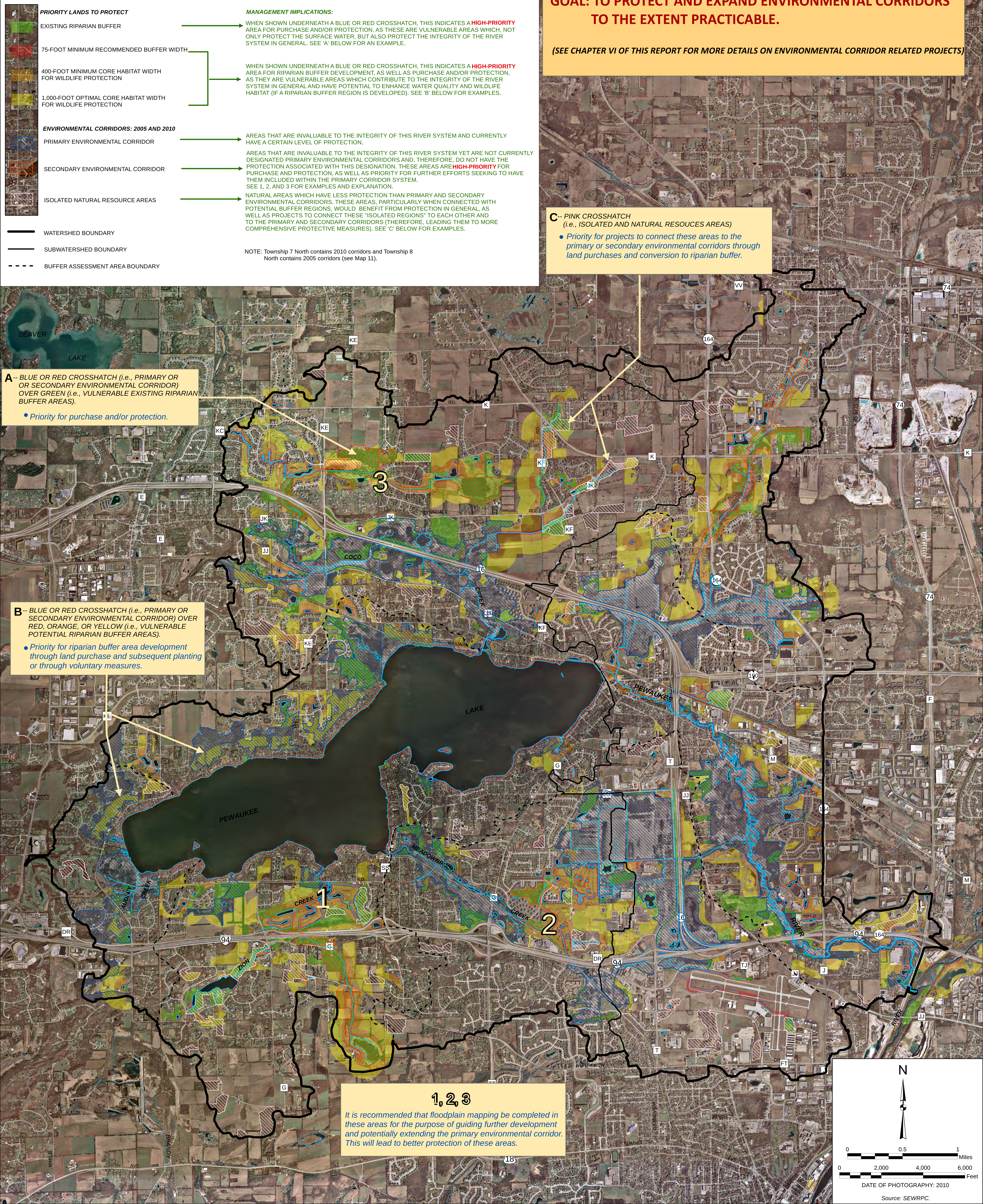


Map 35

STORMWATER RECOMMENDATIONS WITHIN THE PEWAUKEE RIVER WATERSHED

Map 36

PROPOSED PRIORITY RIPARIAN BUFFER PROTECTION AREAS AND ENVIRONMENTAL CORRIDORS WITHIN THE PEWAUKEE RIVER WATERSHED



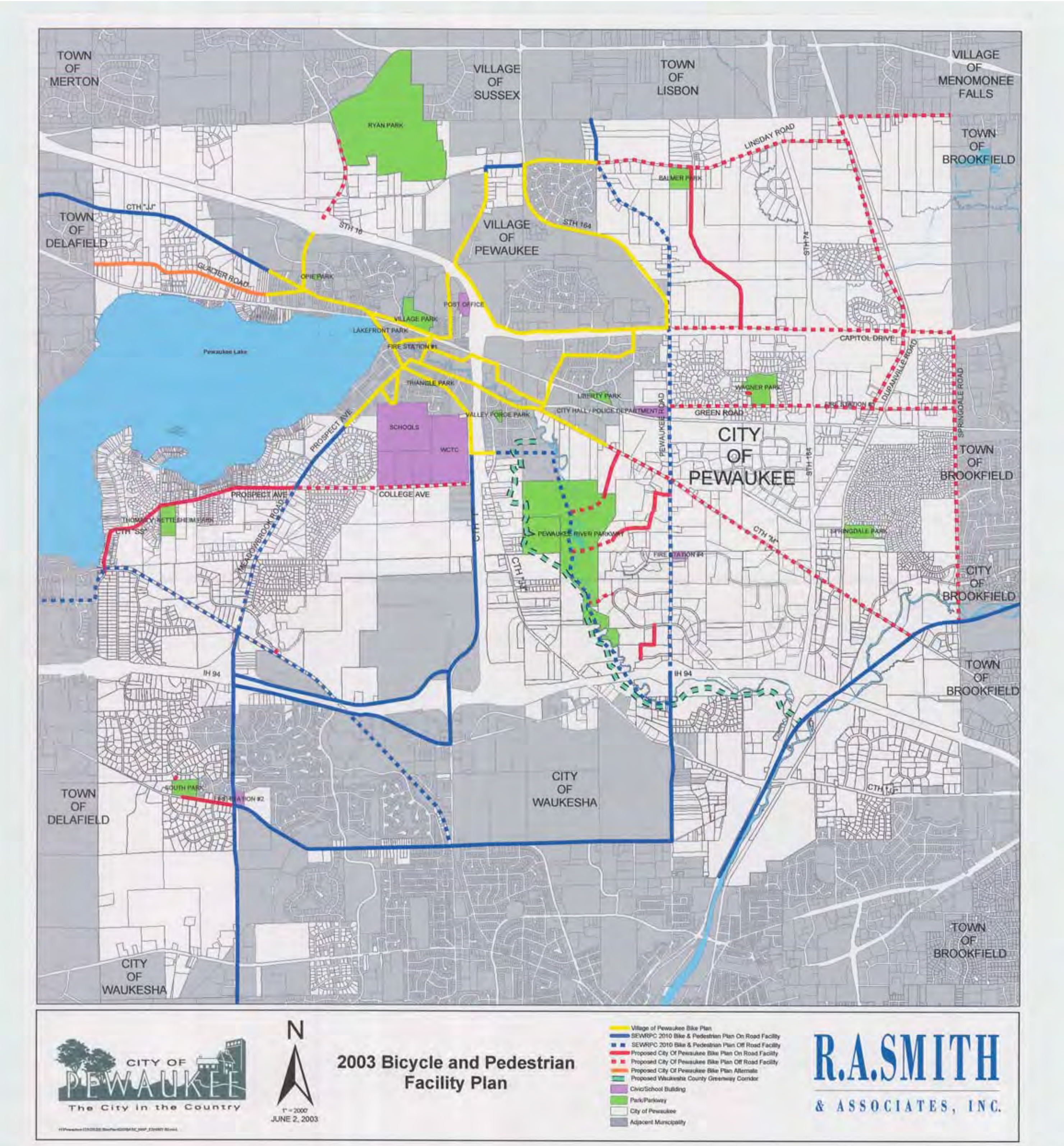
Map 37

PROPOSED AQUATIC HABITAT RECOMMENDATIONS WITHIN THE PEWAUKEE RIVER WATERSHED: 2010


GOAL: IMPROVE RECREATIONAL ACTIVITY ALONG THE PEWAUKEE RIVER
Map 38
EXISTING AND POTENTIAL RECREATIONAL OPPORTUNITIES ALONG THE PEWAUKEE RIVER
MANAGEMENT IMPLICATIONS:
EXISTING BOARDWALK
EXISTING TRAIL
PRIORITY FOR MAINTENANCE.
POTENTIAL TRAIL
POTENTIAL BIKE ROUTE (TO LAKE COUNTY TRAIL)
PRIORITY FOR TRAIL CREATION.
CANOE ROUTE
EXISTING ACCESS SITE
HIGH PRIORITY FOR SIGN INSTALLATION (EDUCATION AND/OR HAZARD WARNINGS).
POTENTIAL ACCESS SITE
HIGH PRIORITY FOR ACCESS SITE CONSTRUCTION AND SIGN INSTALLATION. SEE 'A' FOR AN EXAMPLE.
MAJOR NAVIGATIONAL HAZARD (SEE TABLE G-1)
GENERAL NAVIGATIONAL HAZARD (HIGH FLOW ONLY) (SEE TABLE G-1)
HIGH PRIORITY SITES FOR RECONSTRUCTION AND/OR HAZARD SIGNS. SEE 'B' FOR AN EXAMPLE.
POTENTIAL PEDESTRIAN BRIDGE
PRIORITY FOR BRIDGE DEVELOPMENT.
PARCEL BOUNDARY
STATE-OWNED
COUNTY-OWNED
VILLAGE-OWNED
INDICATES ENTITY THAT SHOULD BE CONTACTED TO PROCEED WITH PROJECT IN THIS AREA.
FEMA 100-YEAR FLOODWAY
FEMA 100-YEAR FLOODFRINGE
INDICATES AREAS WITH RESTRICTIONS ON TRAIL TYPES. SEE 'C' FOR AN EXAMPLE.
C -POTENTIAL TRAILS WITHIN THE FLOODWAY OR FLOODFRINGE
Priority for trail development in accordance with the restrictions which apply to this area (see Chapter VI for details)
A -POTENTIAL ACCESS SITE UPSTREAM FROM MAJOR NAVIGATIONAL HAZARD
Priority for access site development
HIGH PRIORITY for warning signs which indicate water levels and subsequent risk of downstream navigational hazards.
B -MAJOR NAVIGATIONAL HAZARD
HIGH PRIORITY for signage
HIGH PRIORITY for reconstruction
164
74
190
M
T
SS
JJ
16
94
TJ
J
13
14
12
6
2
1
N
0
500
1,000
2,000 Feet
DATE OF PHOTOGRAPHY: 2010
Source: Waukesha County and SEWRPC.

Map 39

BICYCLE AND PEDESTRIAN FACILITY PLAN: 2003



Source: R.A. Smith & Associates, Inc.

APPENDICES

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Appendix A

2010 AND 2035 LAND USE BY SUBWATERSHED

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Table A-1

LAND USE IN THE PEWAUKEE RIVER SUBWATERSHED: 2010-2035[a,b]

Category[c]	2010 Acres	2010 Percent of Total	2035 Acres	2035 Percent of Total	Change: 2010-2035 Acres	Change: 2010-2035 Percent
Urban						
Residential	1,548	6.3	2,184	9.0	636	41.1
Commercial	534	2.2	709	3.0	175	32.8
Industrial	349	1.4	539	2.2	190	54.4
Governmental and Institutional	359	1.5	563	2.3	204	56.8
Transportation, Communication and Utilities	1,718	7.1	2,117	8.7	399	23.2
Extractive	- -	- -	9	<0.1	9	>100
Recreational	178	0.7	282	1.2	104	58.4
Subtotal	4,686	19.2	6,403	26.3	1,717	36.6
Rural						
Agricultural and Open Lands	2,079	8.5	410	1.7	-1,669	-80.3
Wetlands[d,e]	1,438	5.9	1,438	5.9	0	0
Woodlands	207	0.9	159	0.6	-48	-23.2
Water	92	0.4	92	0.4	0	0
Subtotal	3,816	15.7	2,099	8.6	-1,717	-45.0
Total	8,502	34.9	8,502	34.9	0	- -

[a]*As approximated by whole U.S. Public Land Survey one-quarter sections.*

[b]*As part of the regional land use inventory for the year 2000, the delineation of existing land use was referenced to real property boundary information not available for prior inventories. This change, which is also reflected in the 2010 inventory, increases the precision of the land use inventory and makes it more usable to public agencies and private interests throughout the Region. As a result of the change, however, year 2000 and later land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the county and regional level, the most significant effect of the change is to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

[c]*Off-street parking of more than 10 spaces is included with the associated land use.*

[d]*It is important to note that farmed wetlands are included with the Agricultural and Open Lands category for the year 2010. However, if farmed wetland is adjacent to Primary Environmental Corridor (PEC) lands, it is included with the PEC lands category for the year 2035 planned land use, which would represent part of the reduction in the Agricultural and Open Lands category.*

[e]*As part of the Wisconsin Department of Natural Resources Wisconsin Wetland Inventory (WWI) beginning in the year 2005, the wetlands were mapped to a much finer scale and greater level of detail (more wetland categories) than prior inventories. This change increased the accuracy and precision of wetland mapping throughout the Region. As a result of the change, however, year 2010 wetland inventory data are not comparable with data from the year 2000 and prior inventories. At the County and Regional level, the most significant effect of the change is that more, smaller wetlands were able to be delineated, which led to an overall increase in the number and total acreage of wetlands. At the local scale of this study, the most significant wetland area increases were due to an increase in the number of wetlands, farmed wetlands reverting back to wetlands due to inactivity/abandonment of agricultural cultivation activities, and expansion of boundaries within pre-existing wetland areas. However, there was also significant loss of wetland due to urban development, primarily related residential housing and roadway construction.*

Source: SEWRPC.

Table A-2

LAND USE IN THE PEWAUKEE LAKE SUBWATERSHED: 2010-2035[a,b]

Category[c]	2010 Acres	2010 Percent of Total	2035 Acres	2035 Percent of Total	Change: 2010-2035 Acres	Change: 2010-2035 Percent
Urban						
Residential	4,659	19.1	5,635	23.1	976	20.0
Commercial	89	0.4	264	1.1	175	196.6
Industrial	38	0.1	136	0.6	98	257.9
Governmental and Institutional	117	0.5	207	0.8	90	76.9
Transportation, Communication and Utilities	1,612	6.6	2,051	8.4	439	27.2
Extractive	- -	- -	- -	- -	- -	- -
Recreational	650	2.7	786	3.2	136	20.9
Subtotal	7,165	29.4	9,079	37.2	1,914	26.7
Rural						
Agricultural and Open Lands	3,719	15.2	1,881	7.7	-1,838	-49.4
Wetlands[d,e]	1,360	5.6	1,360	5.6	0	0
Woodlands	1,087	4.5	1,011	4.1	-76	-7.0
Water	2,547	10.4	2,547	10.5	0	0
Subtotal	8,713	35.7	6,799	27.9	-1,914	-22.0
Total	15,878	65.1	15,878	65.1	0	- -

[a]*As approximated by whole U.S. Public Land Survey one-quarter sections.*

[b]*As part of the regional land use inventory for the year 2000, the delineation of existing land use was referenced to real property boundary information not available for prior inventories. This change, which is also reflected in the 2010 inventory. increases the precision of the land use inventory and makes it more usable to public agencies and private interests throughout the Region. As a result of the change, however, year 2000 and later land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the county and regional level, the most significant effect of the change is to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

[c]*Off-street parking of more than 10 spaces are included with the associated land use.*

[d]*It is important to note that farmed wetlands are included with the Agricultural and Open Lands category for the year 2010. However, if farmed wetland is adjacent to Primary Environmental Corridor (PEC) lands, it is included with the PEC lands category for the year 2035 planned land use, which would represent part of the reduction in the Agricultural and Open Lands category.*

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Source: SEWRPC.

Appendix B

AVERAGE TEMPERATURES AND PRECIPITATION BY SEASON PRE- VS. POST-1980

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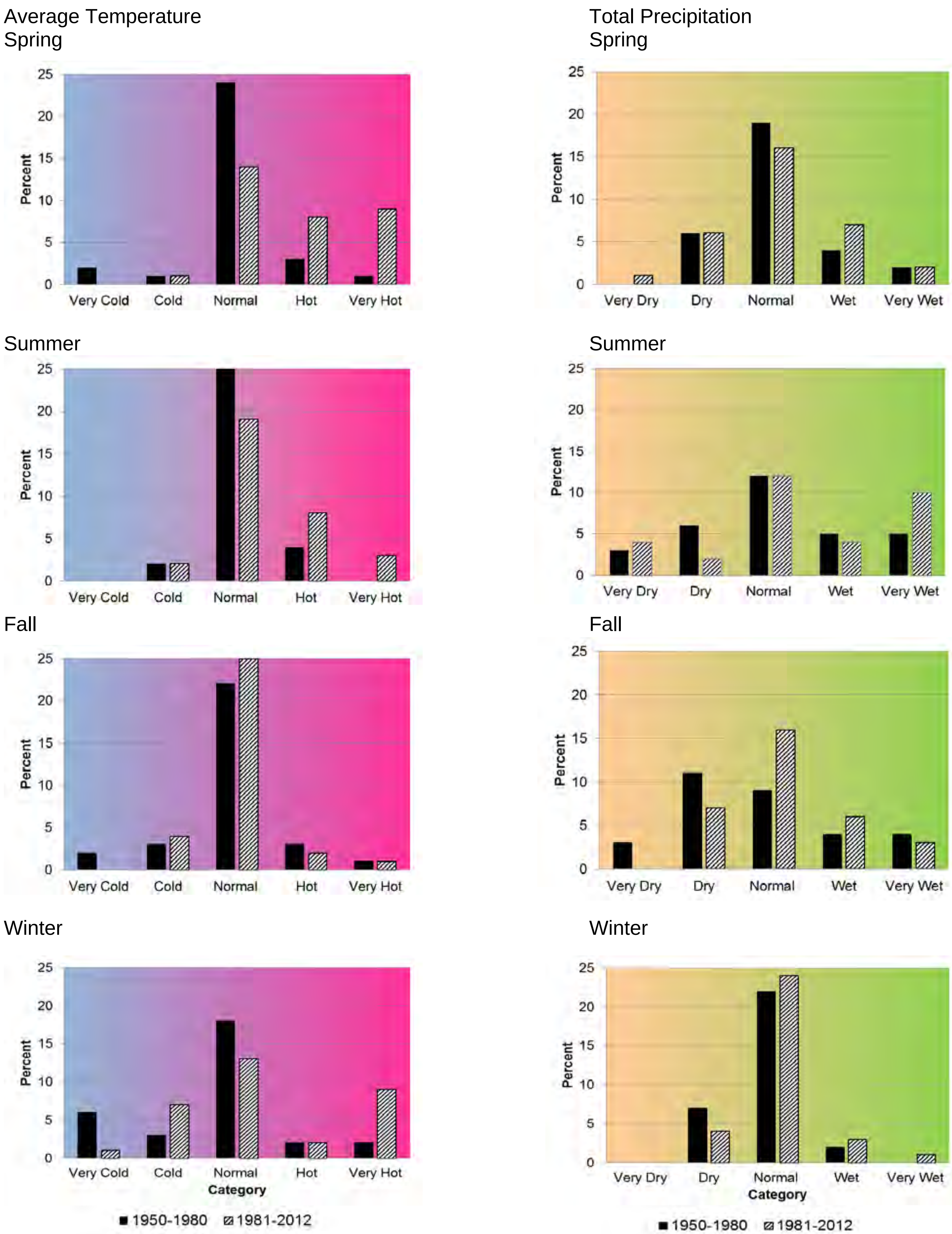
Figure B-1

SEASONAL AVERAGE TEMPERATURE AND TOTAL PRECIPITATION DEPARTURES FROM NORMAL AT THE NOAA WAUKESHA WEATHER RECORDING STATION: 1950-1980 vs. 1981-2012



Source: National Oceanic and Atmospheric Administration and SEWRPC.

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Appendix C

SEWRPC RIPARIAN BUFFER GUIDE NO. 1
"MANAGING THE WATER'S EDGE"

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Managing the Water's Edge

Making Natural Connections

Problem Statement:

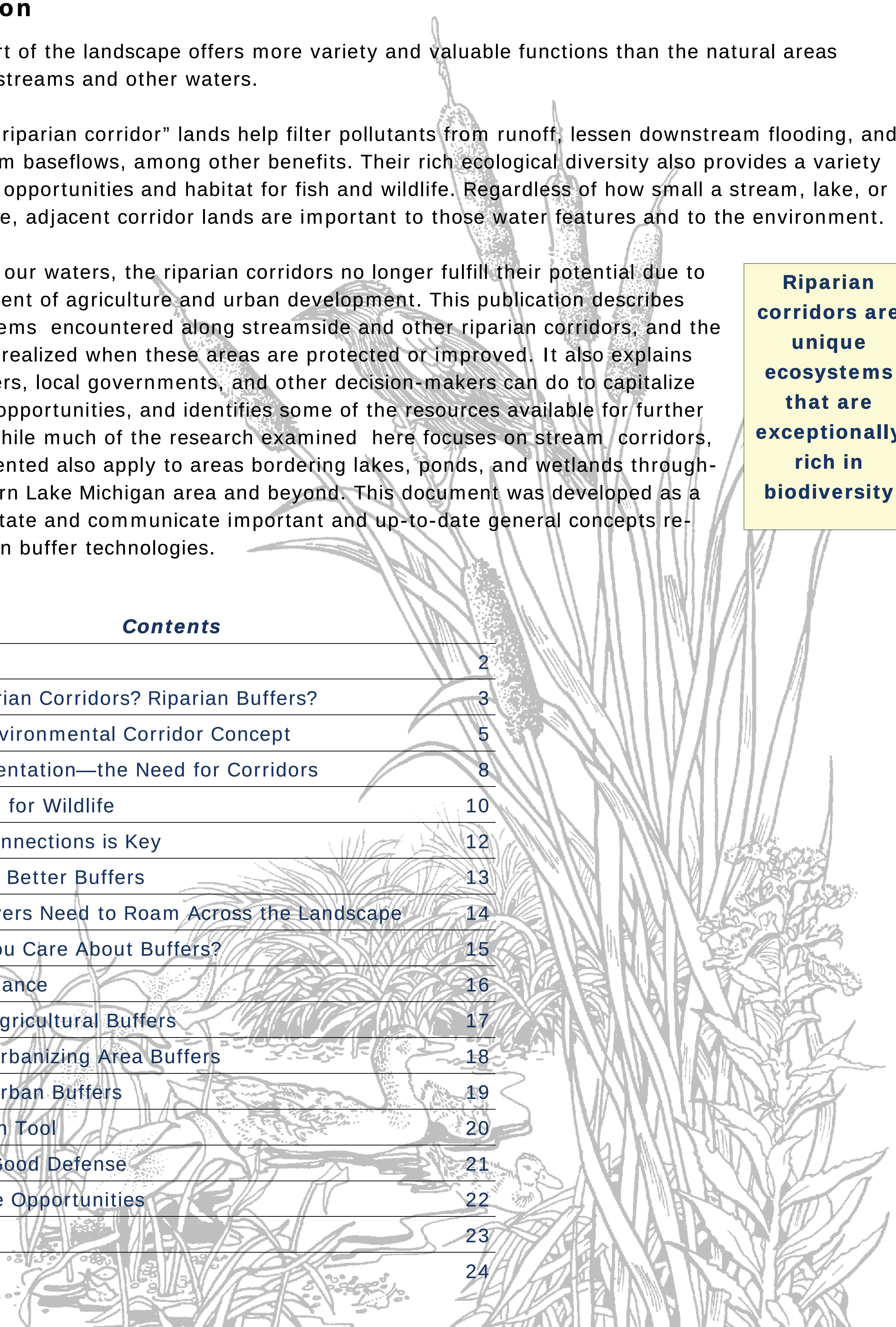
Despite significant research related to buffers, there remains no consensus as to what constitutes optimal riparian buffer design or proper buffer width for effective pollutant removal, water quality protection, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, augmentation of stream baseflow, and water temperature moderation.

Southeastern Wisconsin Regional Planning Commission

Our purpose in this document is to help protect and restore water quality, wildlife, recreational opportunities, and scenic beauty.

This material was prepared in part with funding from the U.S. Environmental Protection Agency Great Lakes National Program Office provided through CMAP, the Chicago Metropolitan Agency for Planning.

Introduction



Perhaps no part of the landscape offers more variety and valuable functions than the natural areas bordering our streams and other waters.

These unique "riparian corridor" lands help filter pollutants from runoff, lessen downstream flooding, and maintain stream baseflows, among other benefits. Their rich ecological diversity also provides a variety of recreational opportunities and habitat for fish and wildlife. Regardless of how small a stream, lake, or wetland may be, adjacent corridor lands are important to those water features and to the environment.

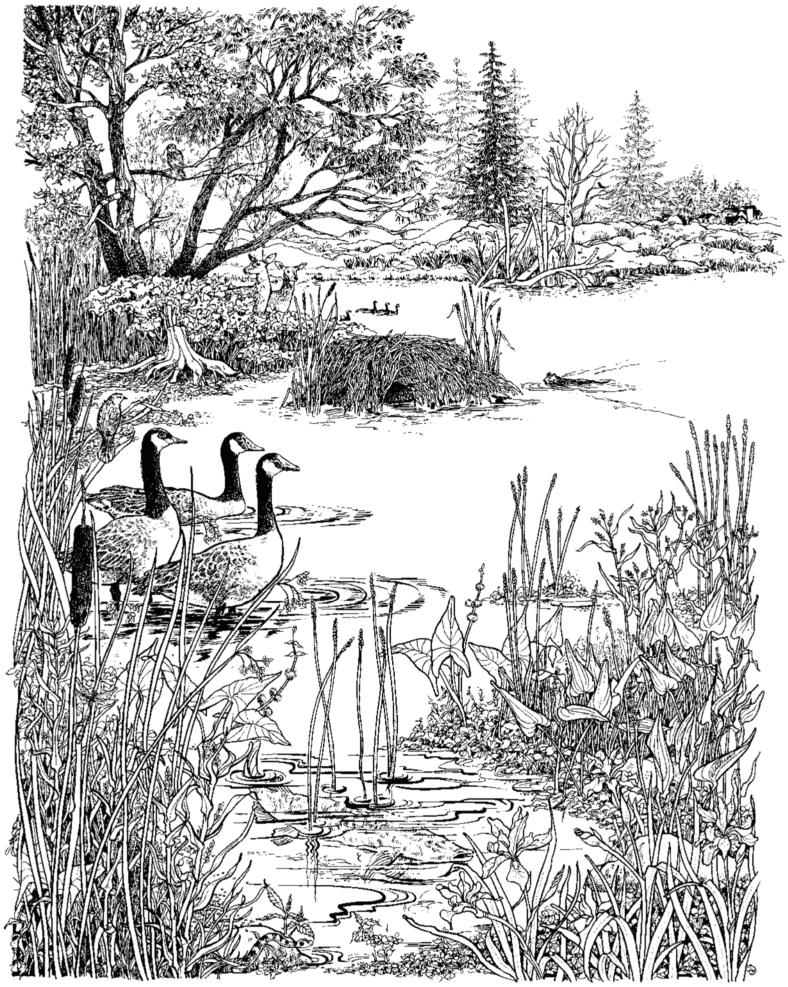
Along many of our waters, the riparian corridors no longer fulfill their potential due to the encroachment of agriculture and urban development. This publication describes common problems encountered along streamside and other riparian corridors, and the many benefits realized when these areas are protected or improved. It also explains what landowners, local governments, and other decision-makers can do to capitalize on waterfront opportunities, and identifies some of the resources available for further information. While much of the research examined here focuses on stream corridors, the ideas presented also apply to areas bordering lakes, ponds, and wetlands throughout the southern Lake Michigan area and beyond. This document was developed as a means to facilitate and communicate important and up-to-date general concepts related to riparian buffer technologies.

Riparian corridors are unique ecosystems that are exceptionally rich in biodiversity

Contents

What Are Riparian Corridors? Riparian Buffer Zones?

The word riparian comes from the Latin word *ripa*, which means bank. However, in this document we use riparian in a much broader sense and refer to land adjoining any water body including ponds, lakes, streams, and wetlands. This term has two additional distinct meanings that refer to 1) the "natural or relatively undisturbed" corridor lands adjacent to a water body inclusive of both wetland and upland flora and fauna and 2) a buffer zone or corridor lands in need of protection to "buffer" the effects of human impacts such as agriculture and residential development.



University of Wisconsin—Extension

The word buffer literally means something that cushions against the shock of something else (noun), or to lessen or cushion that shock (verb). Other useful definitions reveal that a buffer can be something that serves to separate features, or that is capable of neutralizing something, like filtering pollutants from stormwater runoff. Essentially, buffers and buffering help protect against adverse effects.

Riparian buffer zones function as core habitat as well as travel corridors for many wildlife species.

Riparian buffers are zones adjacent to waterbodies such as lakes, rivers, and wetlands that simultaneously protect water quality and wildlife, including both aquatic and terrestrial habitat. These zones minimize the impacts of human activities on the landscape and contribute to recreation, aesthetics, and quality of life. **This document summarizes how to maximize both water quality protection and conservation of aquatic and terrestrial wildlife populations using buffers.**

What Are Riparian Corridors? Riparian Buffer Zones?

Buffers **can** include a range of complex vegetation structure, soils, food sources, cover, and water features that offer a variety of habitats contributing to diversity and abundance of wildlife such as mammals, frogs, amphibians, insects, and birds. Buffers can consist of a variety of canopy layers and cover types including ephemeral (temporary-wet for only part of year) wetlands/seasonal ponds/spring pools, shallow marshes, deep marshes, wetland meadows, wetland mixed forests, grasslands, shrubs, forests, and/or prairies. Riparian zones are areas of transition between aquatic and terrestrial ecosystems, and they can potentially offer numerous benefits to wildlife and people such as pollution reduction and recreation.

In the water resources literature, riparian buffers are referred to in a number of different ways. Depending on the focus and the intended function of a buffer, or a buffer-related feature, buffers may be referred to as stream corridors, critical transition zones, riparian management areas, riparian management zones, floodplains, or green infrastructure.

It is important to note that within an agricultural context, the term buffer is used more generally to describe filtering best management practices most often at the water's edge. Other practices which can be interrelated may also sometimes be called buffers. These include grassed waterways, contour buffer strips, wind breaks, field border, shelterbelts, windbreaks, living snow fence, or filter strips. These practices may or may not be adjacent to a waterway as illustrated in the photo to the right. For example, a grassed waterway is designed to filter sediment and reduce erosion and may connect to a riparian buffer. These more limited-purpose practices may link to multipurpose buffers, but by themselves, they are not adequate to provide the multiple functions of a riparian buffer as defined here.

U.S. Department of Agriculture, Natural Resource Conservation Service, Ohio Office.

Beyond the Environmental Corridor Concept

The term "environmental corridors" (also known as "green infrastructure") refers to an interconnected green space network of natural areas and features, public lands, and other open spaces that provide natural resource value. Environmental corridor planning is a process that promotes a systematic and strategic approach to land conservation and encourages land use planning and practices that are good for both nature and people. It provides a framework to guide future growth, land development, and land conservation decisions in appropriate areas to protect both community and natural resource assets.

Environmental corridors are an essential planning tool for protecting the most important remaining natural resource features in Southeastern Wisconsin and elsewhere. Since development of the environmental corridor concept, there have been significant advancements in landscape ecology that have furthered understanding of the spatial and habitat needs of multiple groups of organisms. In addition, advancements in pollutant removal practices, stormwater control, and agriculture have increased our understanding of the effectiveness and limitations of environmental corridors. In protecting water quality and providing aquatic and terrestrial habitat, there is a need to better integrate new technologies through their application within riparian buffers.

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.

Beyond the Environmental Corridor Concept

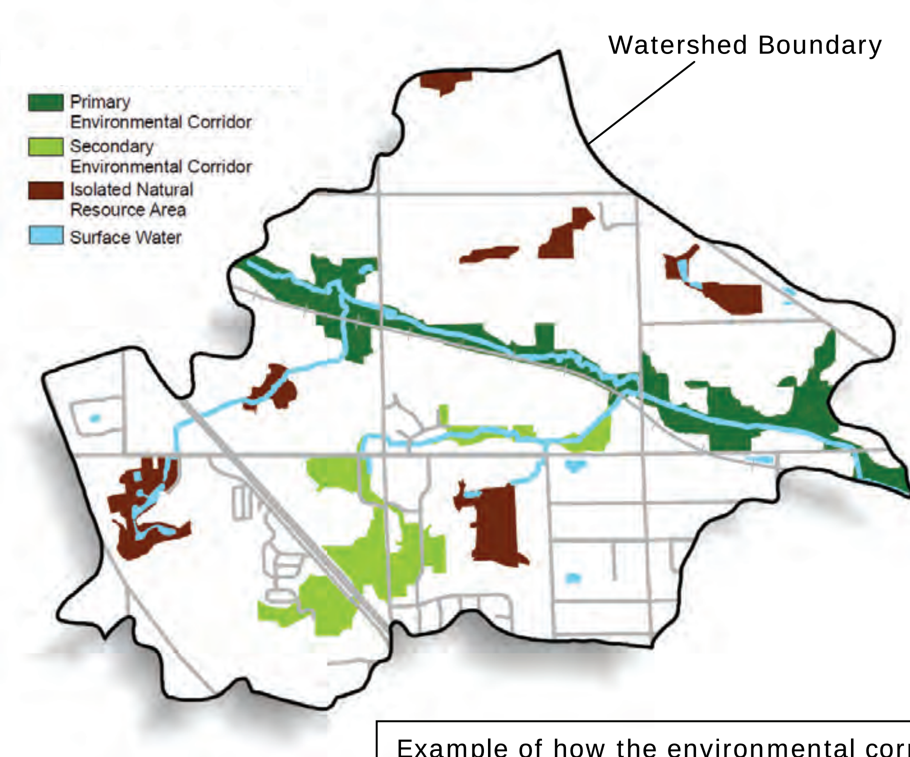
Environmental corridors are divided into the following three categories.

- **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 at least one mile long, unless serving to 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

Beyond the Environmental Corridor Concept

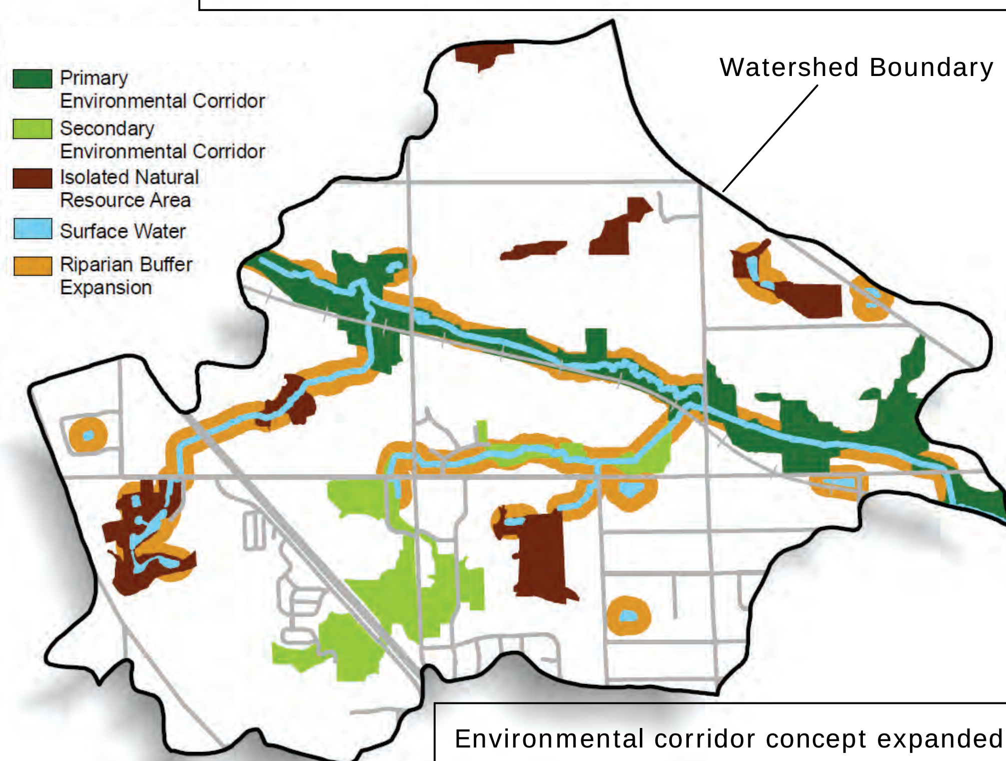


The Minimum Goals of **75** within a Watershed

75% minimum of total stream length should be naturally vegetated to protect the functional integrity of the water resources. (Environment Canada, How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great lakes Areas of Concern, Second Edition, 2004)

75 foot wide minimum riparian buffers from the top edge of each stream bank should be naturally vegetated to protect water quality and wildlife. (SEWRPC Planning Report No 50, A Regional Water Quality Management Plan for the Greater Milwaukee Watersheds, December 2007)

Example of how the environmental corridor concept is applied on the landscape. For more information see "Plan on It!" series **Environmental Corridors: Lifelines of the Natural Resource Base** at http://www.sewrpc.org/SEWRPC/LandUse/EnvironmentalCorridors.htm



Environmental corridor concept expanded to achieve the Goals of 75. Note the expanded protection in addition to the connection of other previously isolated areas.

Habitat Fragmentation—The Need for Corridors

Southeastern Wisconsin is a complex mosaic of agricultural and urban development. Agricultural lands originally dominated the landscape and remain a major land use. However, such lands continue to be converted to urban uses. Both of these dominant land uses fragment the landscape by creating islands or isolated pockets of wetland, woodland, and other natural lands available for wildlife preservation and recreation. By recognizing this fragmentation of the landscape, we can begin to mitigate these impacts.

New developments should incorporate water quality and wildlife enhancement or improvement objectives as design criteria by looking at the potential for creating linkages with adjoining lands and water features.

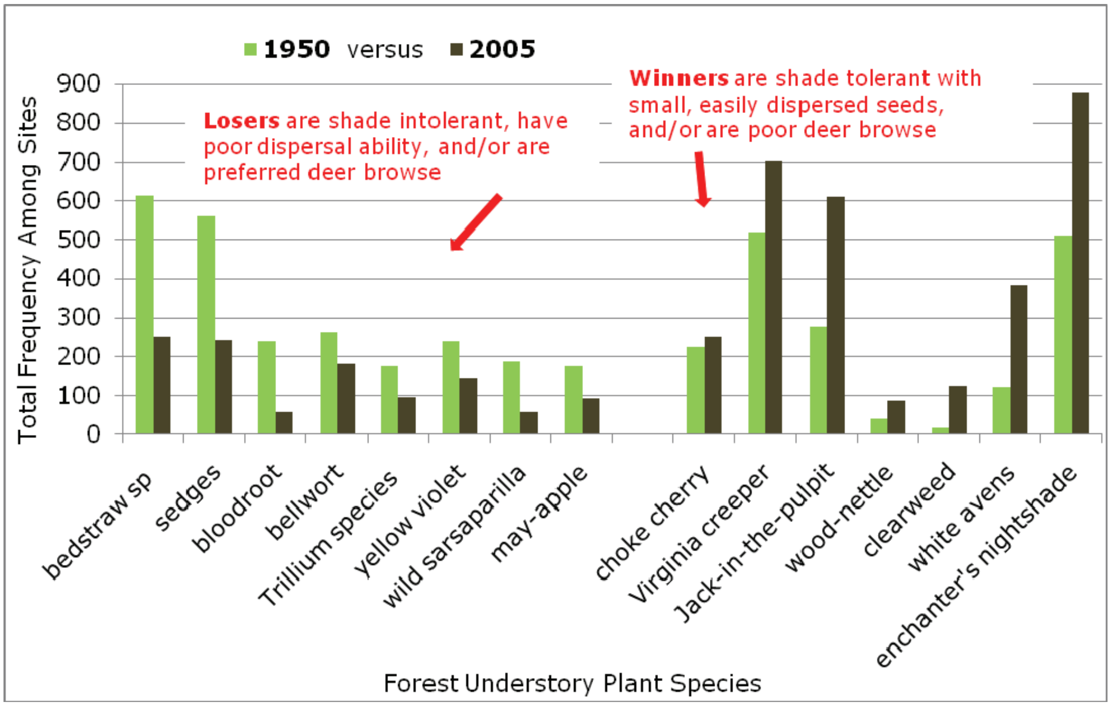
At the time of conversion of agricultural lands to urban uses, there are opportunities to re-create and expand riparian buffers and environmental corridors reconnecting uplands and waterways and restoring ecological integrity and scenic beauty locally and regionally. For example, placement of roads and other infrastructure across stream systems could be limited so as to maximize continuity of the riparian buffers. This can translate into significant cost savings in terms of reduced road maintenance, reduced salt application, and limited bridge or culvert maintenance and replacements. This simple practice not only saves the community significant amounts of money, but also improves and protects quality of life. Where necessary road crossings do occur, they can be designed to provide for safe fish and wildlife passage.

Overland travel routes for wildlife are often unavailable, discontinuous, or life endangering within the highly fragmented landscapes of Southeastern Wisconsin and elsewhere.

State Threatened Species: Blanding's turtle

Habitat Fragmentation—The Need for Corridors

Forest understory plant species abundance among stands throughout Southern Wisconsin



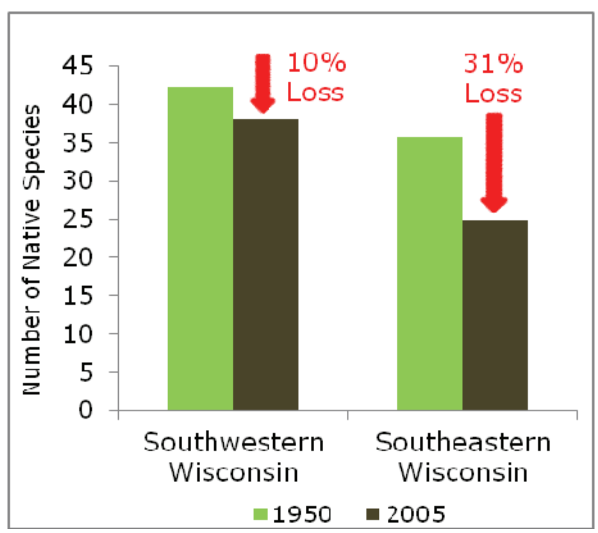
Forest fragmentation has led to significant plant species loss within Southern Wisconsin

(Adapted from David Rogers and others, 2008, Shifts in Southern Wisconsin Forest Canopy and Understory Richness, Composition, and Heterogeneity, Ecology, 89 (9): 2482-2492)

"...these results confirm the idea that large intact habitat patches and landscapes better sustain native species diversity. It also shows that people are a really important part of the system and their actions play an increasingly important role in shaping patterns of native species diversity and community composition. Put together, it is clear that one of the best and most cost effective actions we can take toward safeguarding native diversity of all types is to protect, enhance and create corridors that link patches of natural habitat."
Dr. David Rogers, Professor of Biology at the University of Wisconsin-Parkside

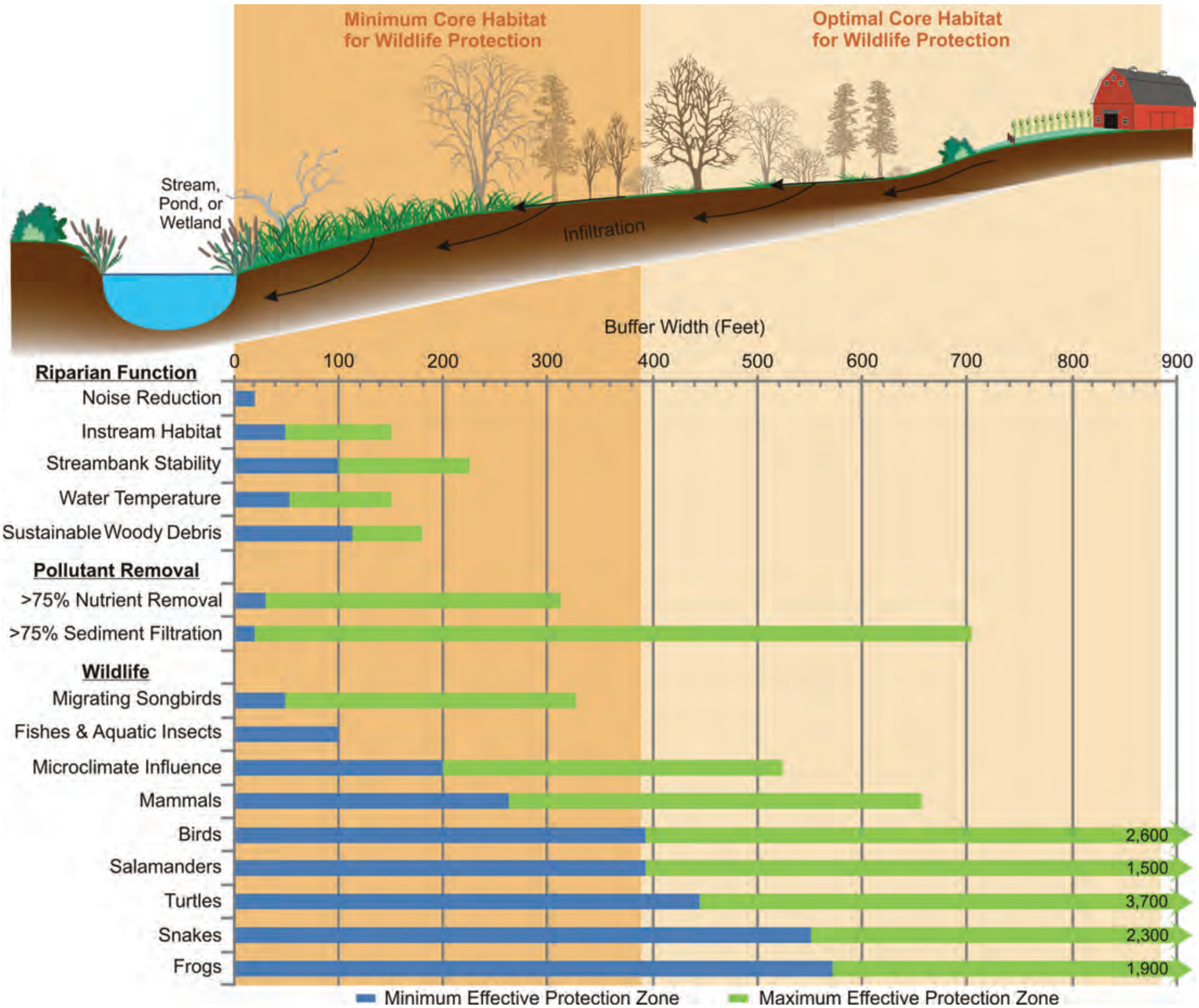
Since the 1950s, forests have increasingly become more fragmented by land development, both agricultural and urban, and associated roads and infrastructure, which have caused these forests to become isolated "islands of green" on the landscape. In particular, there has been significant loss of forest understory plant species over time (shrubs, grasses, and herbs covering the forest floor.) It is important to note that **these forests lost species diversity even when they were protected as parks or natural areas**.

One major factor responsible for this decline in forest plant diversity is that routes for native plants to re-colonize isolated forest islands are largely cut-off within fragmented landscapes. For example, the less fragmented landscapes in Southwestern Wisconsin lost fewer species than the more fragmented stands in Southeastern Wisconsin. In addition, the larger-sized forests and forests with greater connections to surrounding forest lands lost fewer species than smaller forests in fragmented landscapes.



Wider is Better for Wildlife

Why? Because buffer size is the engine that drives important natural functions like food availability and quality, access to water, habitat variety, protection from predators, reproductive or resting areas, corridors to safely move when necessary, and help in maintaining the health of species' gene pools to prevent isolation and perhaps extinction.



One riparian buffer size does not fit all conditions or needs. There are many riparian buffer functions and the ability to effectively fulfill those functions is largely dependent on width. Determining what buffer widths are needed should be based on what functions are desired as well as site conditions. For example, as shown above, water temperature protection generally does not require as wide a buffer as provision of habitat for wildlife. Based on the needs of wildlife species found in Wisconsin, the minimum core habitat buffer width is about 400 feet and the optimal width for sustaining the majority of wildlife species is about 900 feet. Hence, the value of large undisturbed parcels along waterways which are part of, and linked to, an environmental corridor system. The minimum effective buffer width distances are based on data reported in the scientific literature and the quality of available habitats within the context of those studies.

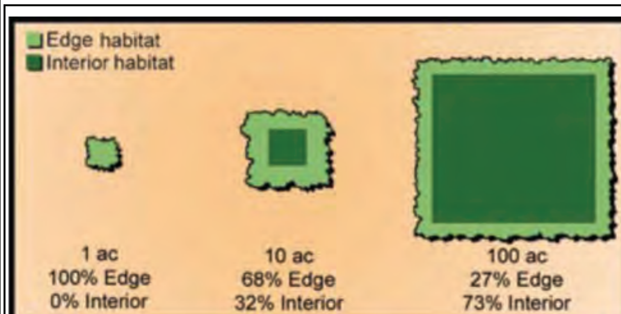
Wider is Better for Wildlife

Wildlife habitat needs change within and among species. **Minimum Core Habitat and Optimum Core Habitat distances were developed from numerous studies to help provide guidance for biologically meaningful buffers to conserve wildlife biodiversity.** These studies documented distances needed for a variety of biological (life history) needs to sustain healthy populations such as breeding, nesting, rearing young, foraging/feeding, perching (for birds), basking (for turtles), and overwintering/dormancy/hibernating. These life history needs require different types of habitat and distances from water, for example, one study found that Blanding's turtles needed approximately 60-foot-wide buffers for basking, 375 feet for overwintering, and up to 1,200 feet for nesting to bury their clutches of eggs. Some species of birds like the Blacked-capped chickadee or white breasted nuthatch only need about 50 feet of buffer, while others like the wood duck or great blue heron require 700-800 feet for nesting. Therefore, **understanding habitat needs for wildlife species is an important consideration in designing riparian buffers.**

Although *Ambystoma* salamanders require standing water for egg laying and juvenile development, most other times of the year they can be found more than 400 feet from water foraging for food.

Wisconsin Species	Mimimum Core Habitat (feet)	Optimum Core Habitat (feet)	Number of Studies
Frogs	571	1,043	9
Salamanders	394	705	14
Snakes	551	997	5
Turtles	446	889	27
Birds	394	787	45
Mammals	263	No data	11
Fishes and Aquatic Insects	100	No data	11
Mean	388	885	

This approach was adapted from *R.D. Semlitsch and J.R. Bodie, 2003, Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibian and Reptiles, Conservation Biology, 17(5):1219-1228.* These values are based upon studies examining species found in Wisconsin and represent mean linear distances extending outward from the edge of an aquatic habitat. The Minimum Core Habitat and Optimum Core Habitat reported values are based upon the mean minimum and mean maximum distances recorded, respectively. Due to a low number of studies for snake species, the recommended distances for snakes are based upon values reported by *Semlitsch and Bodie.*



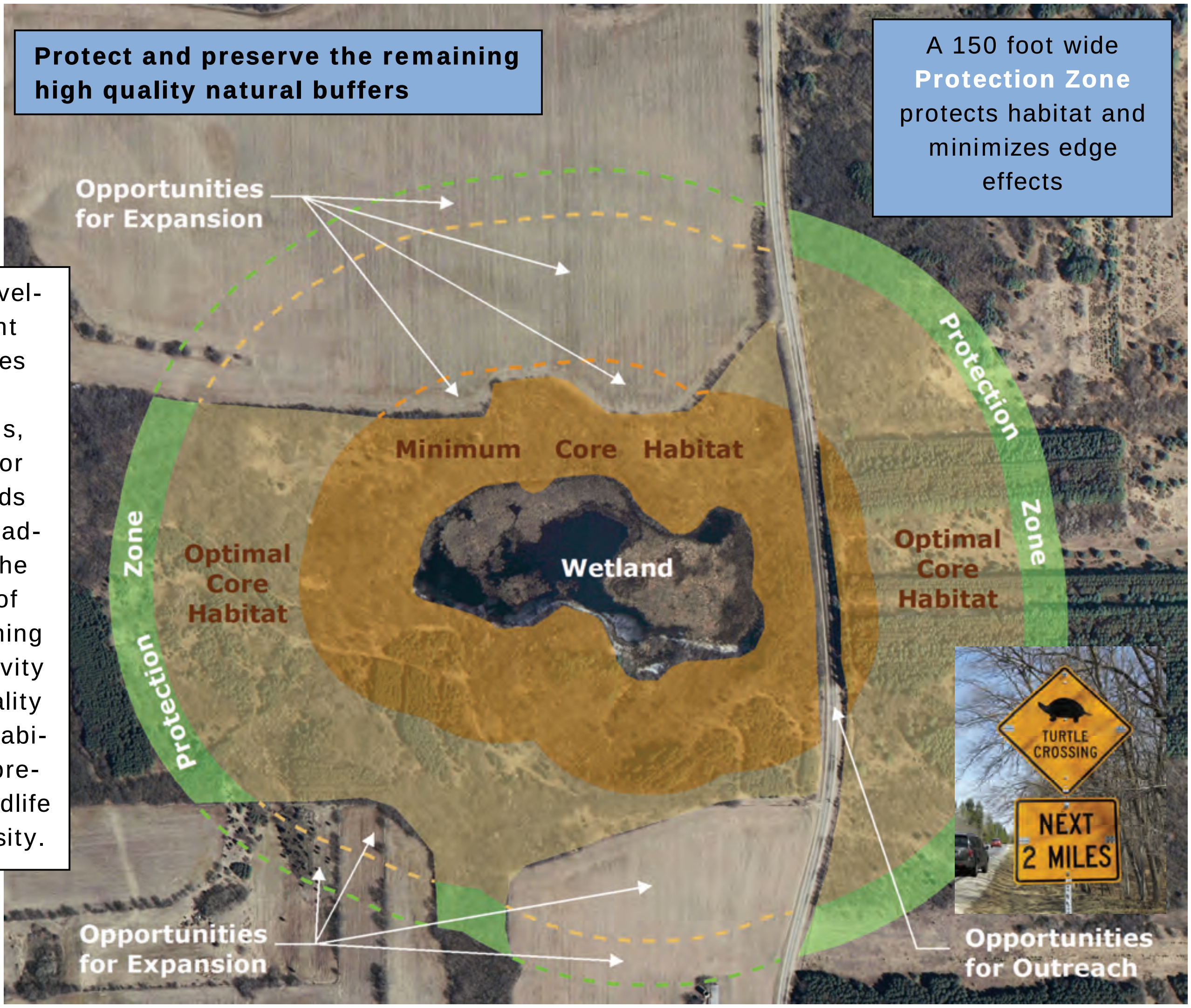
"***Large patches typically conserve a greater variety and quality of habitats, resulting in higher species diversity and abundance."*** *Larger patches contain greater amounts of interior habitat and less edge effects, which benefits interior species, by providing safety from parasitism, disease, and invasive species.*

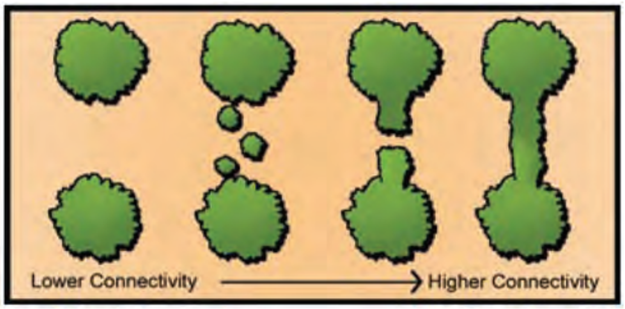
(Bentrup, G. 2008. Conservation buffers: design guidelines for buffers, corridors, and greenways. Gen. Tech. Rep. SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station)

Maintaining Connections is Key

Like humans, all forms of wildlife require access to clean water. Emerging research has increasingly shown that, in addition to water, more and more species such as amphibians and reptiles cannot persist without landscape connectivity between quality wetland and upland habitats. Good connectivity to upland terrestrial habitats is essential for the persistence of healthy sustainable populations, because these areas provide vital feeding, overwintering, and nesting habitats found nowhere else. Therefore, both aquatic and terrestrial habitats are essential for the preservation of biodiversity and they should ideally be managed together as a unit.

Land development practices near streams, lakes, or wetlands need to address the issue of maintaining connectivity with quality upland habitats to preserve wildlife biodiversity.



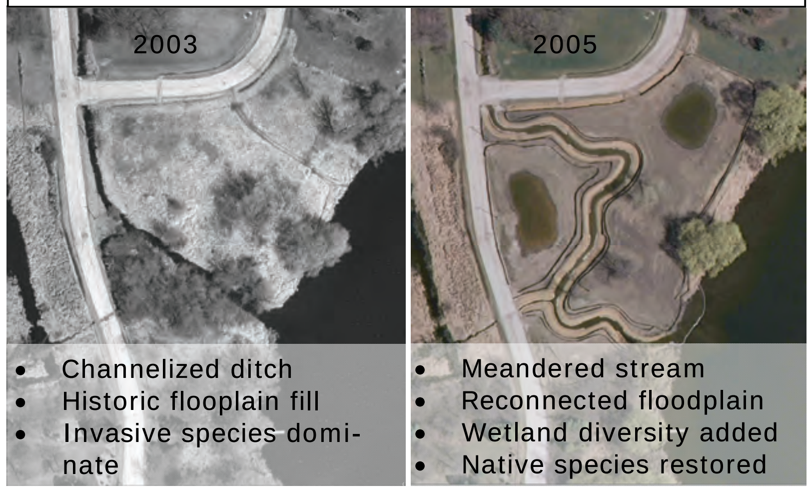


Increasing connectivity among quality natural landscapes (wetlands, woodlands, prairies) can benefit biodiversity by providing access to other areas of habitat, increasing gene flow and population viability, enabling recolonization of patches, and providing habitat (Bentrup 2008).

Basic Rules to Better Buffers

Protecting the integrity of native species in the region is an objective shared by many communities. The natural environment is an essential component of our existence and contributes to defining our communities and neighborhoods. Conservation design and open space development patterns in urbanizing areas and farm conservation programs in rural areas have begun to address the importance of maintaining and restoring riparian buffers and connectivity among corridors.

There are opportunities to improve buffer functions to improve water quality and wildlife habitat, even in urban situations

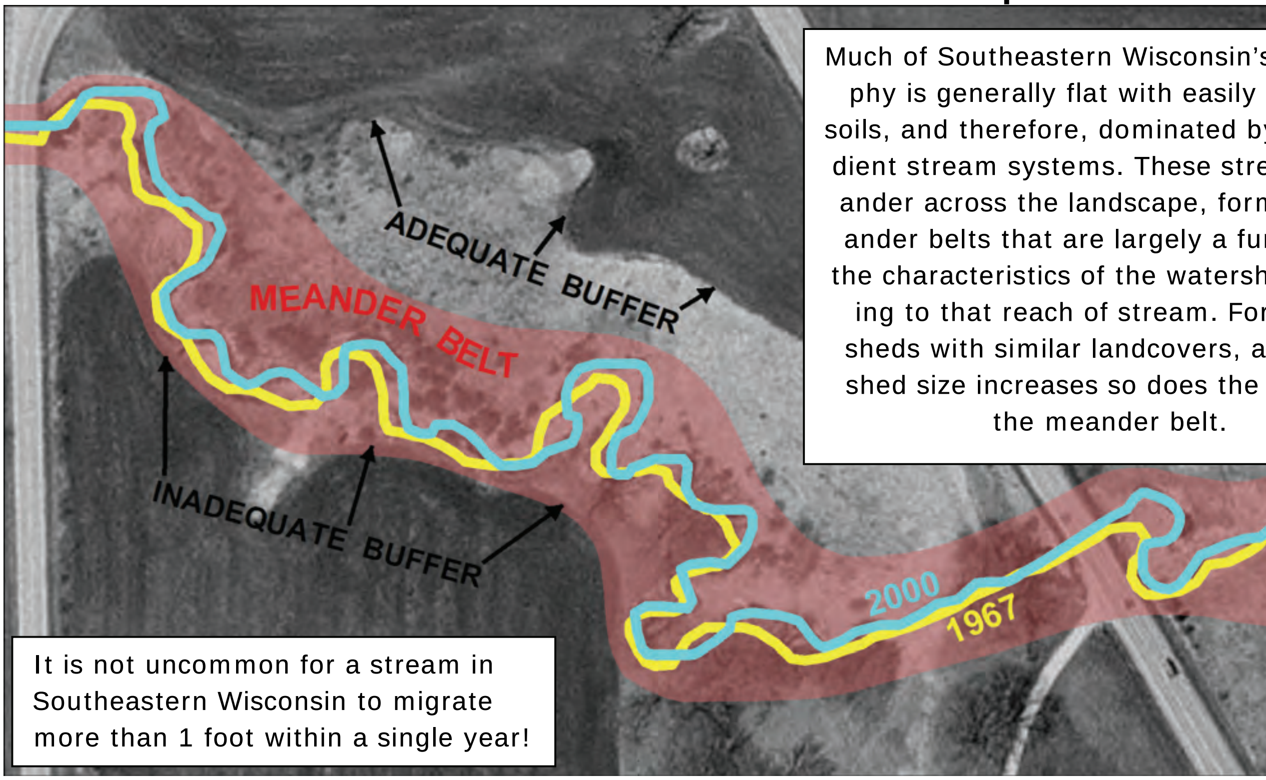


How wide should the buffer be? Unfortunately, there is no one-size-fits all buffer width adequate to protect water quality, wildlife habitat, and human needs. Therefore, the answer to this question depends upon the predetermined needs of the landowner and community objectives or goals. As riparian corridors become very wide, their pollutant removal (buffering) effectiveness may reach a point of diminishing returns compared to the investment involved. However, the prospects for species diversity in the corridor keep increasing with buffer width. For a number of reasons, 400- to 800-foot-wide buffers are not practical along all lakes, streams, and wetlands within Southeastern Wisconsin. Therefore, communities should develop guidelines that remain flexible to site-specific needs to achieve the most benefits for water resources and wildlife as is practical.

Key considerations to better buffers/corridors:

- Wider buffers are better than narrow buffers for water quality and wildlife functions
- Continuous corridors are better than fragmented corridors for wildlife
- Natural linkages should be maintained or restored
- Linkages should not stop at political boundaries
- Two or more corridor linkages are better than one
- Structurally diverse corridors (e.g., diverse plant structure or community types, upland and wetland complexes, soil types, topography, and surficial geology) are better than corridors with simple structures
- Both local and regional spatial and temporal scales should be considered in establishing buffers
- Corridors should be located along dispersal and migration routes
- Corridors should be located and expanded around rare, threatened, or endangered species
- Quality habitat should be provided in a buffer whenever possible
- Disturbance (e.g. excavation or clear cutting vegetation) of corridors should be minimized during adjacent land use development
- Native species diversity should be promoted through plantings and active management
- Non-native species invasions should be actively managed by applying practices to preserve native species
- Fragmentation of corridors should be reduced by limiting the number of crossings of a creek or river where appropriate
- Restoration or rehabilitation of hydrological function, streambank stability, instream habitat, and/or floodplain connectivity should be considered within corridors.
- Restoration or retrofitting of road and railway crossings promotes passage of aquatic organisms

Creeks and Rivers Need to Roam Across the Landscape



Much of Southeastern Wisconsin's topography is generally flat with easily erodible soils, and therefore, dominated by low gradient stream systems. These streams meander across the landscape, forming meander belts that are largely a function of the characteristics of the watershed draining to that reach of stream. For watersheds with similar landcovers, as watershed size increases so does the width of the meander belt.

It is not uncommon for a stream in Southeastern Wisconsin to migrate more than 1 foot within a single year!

Healthy streams naturally meander or migrate across a landscape over time. Streams are transport systems for water and sediment and are continually eroding and depositing sediments, which causes the stream to migrate. When the amount of sediment load coming into a stream is equal to what is being transported downstream—and stream widths, depths, and length remain consistent over time—it is common to refer to that stream as being in a state of **"dynamic equilibrium."** In other words the stream retains its physical dimensions (equilibrium), but those physical features are shifted, or migrate, over time (dynamic).

Room to Roam

Riparian buffer widths should take into account the amount of area that a stream needs to be able to self-adjust and maintain itself in a state of dynamic equilibrium. ... These are generally greater than any minimum width needed to protect for pollutant removal alone.

Streams are highly sensitive, and they respond to changes in the amounts of water and sediment draining to them, which are affected by changing land use conditions. For example, streams can respond to increased discharges of water by increased scour (erosion) of bed and banks that leads to an increase in stream width and depth—or "degradation." Conversely, streams can respond to increased sedimentation (deposition) that leads to a decrease in channel width and depth—or "aggradation."

Why Should You Care About Buffers?

Economic Benefits:

- Increased value of riparian property
- Reduced lawn mowing time and expense
- Increased shade to reduce building cooling costs
- Natural flood mitigation protection for structures or crops
- Pollution mitigation (reduced nutrient and contaminant loading)
- Increased infiltration and groundwater recharge
- Prevented loss of property (land or structures) through erosion
- Greater human and ecological health through biodiversity

Recreational Benefits:

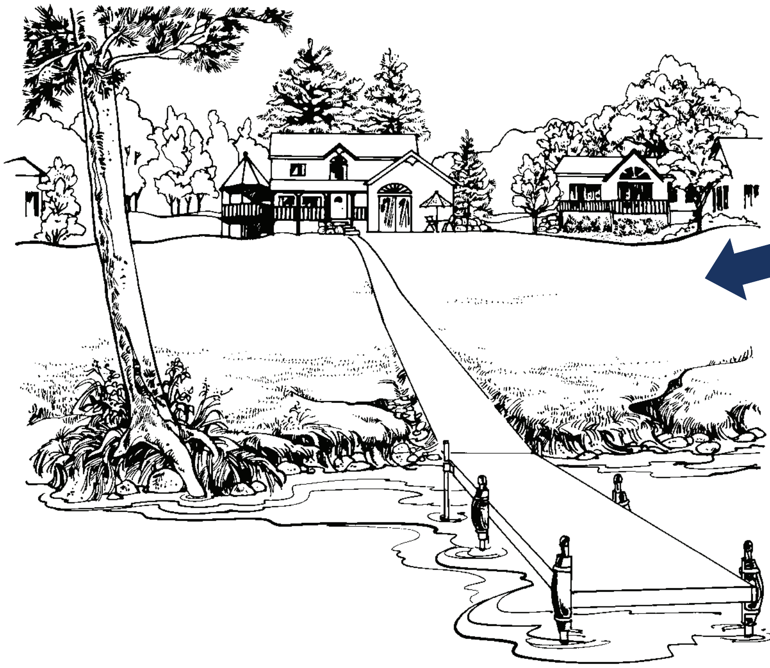
- Increased quality of the canoeing/kayaking experience
- Improved fishing and hunting quality by improving habitat
- Improved bird watching/wildlife viewing quality and opportunities
- Increased potential for expansion of trails for hiking and bicycling
- Opportunities made available for youth and others to locally reconnect with nature

Riparian buffers make sense and are profitable monetarily, recreationally, and aesthetically!

Social Benefits:

- Increased privacy
- Educational opportunities for outdoor awareness
- Improved quality of life at home and work
- Preserved open space/balanced character of a community
- Focal point for community pride and group activities
- Visual diversity
- Noise reduction

A Matter of Balance



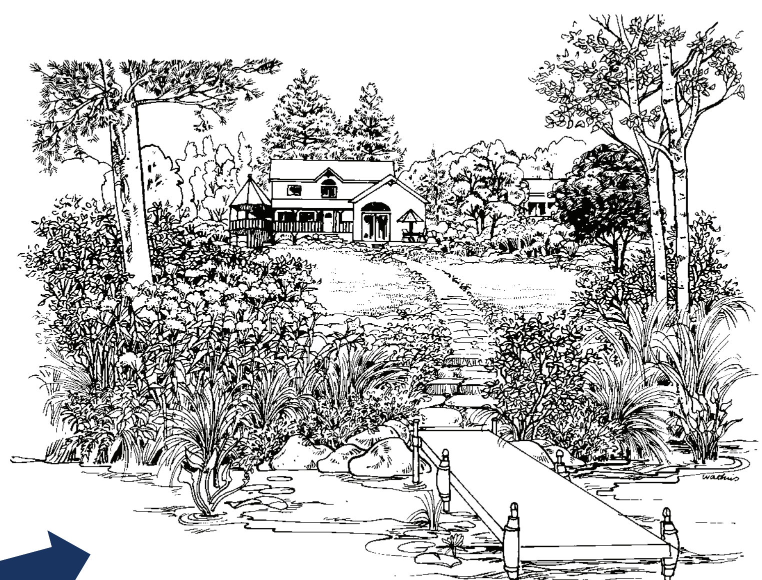
University of Wisconsin—Extension

Although neatly trimmed grass lawns are popular, these offer limited benefits for water quality or wildlife habitat. A single house near a waterbody may not seem like a "big deal," but the cumulative effects of many houses can negatively impact streams, lakes, and wetlands.

All the lands within Southeastern Wisconsin ultimately flow into either the Mississippi River or the Great Lakes systems. The cumulative effects of agriculture and urban development in the absence of mitigative measures, ultimately affects water quality in those systems. Much of this development causes increases in water runoff from the land into wetlands, ponds, and streams. This runoff transports water, sediments, nutrients, and other pollutants into our waterways that can lead to a number of problems, including flooding that can cause crop loss or building damage; unsightly and/or toxic algae blooms; increased turbidity; damage to aquatic organisms from reduced dissolved oxygen, lethal temperatures, and/or concentrations of pollutants; and loss of habitat.

Riparian buffers are one of the most effective tools available for defending our waterways. Riparian buffers can be best thought of as forming a living, self-sustainable protective shield. This shield protects investments in the land and all things on it as well as our quality of life locally, regionally, and, ultimately, nationally. Combined with stormwater management, environmentally friendly yard care, effective wastewater treatment, conservation farming methods, and appropriate use of fertilizers and other agrichemicals, **riparian buffers complete the set of actions that we can take to minimize impacts to our shared water resources.**

Lakeshore buffers can take many forms, which require a balancing act between lake viewing, access, and scenic beauty. Lakeshore buffers can be integrated into a landscaping design that complements both the structural development and a lakeside lifestyle. Judicious placement of access ways and shoreline protection structures, and preservation or reestablishment of native vegetation, can enhance and sustain our use of the environment.



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Case Study—Agricultural Buffers

Agricultural nonpoint source pollution runoff continues to pose a threat to water quality and aquatic ecosystems within Wisconsin and elsewhere. In an effort to address this problem, the Wisconsin Buffer Initiative was formed with the goal of designing a buffer implementation program to achieve science-based, cost-effective, water quality improvements (report available online at http://www.soils.wisc.edu/extension/nonpoint/wbi.php).

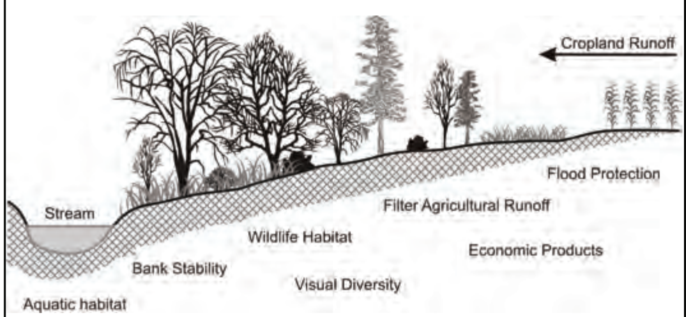
Challenge:
Buffers may take land out of cultivated crop production and require additional cost to install and maintain. Cost sharing, paid easements, and purchase of easements or development rights may sometimes be available to offset costs.

Benefits:
Buffers may offset costs by producing perennial crops such as hay, lumber, fiber, nuts, fruits, and berries. In addition, they provide visual diversity on the landscape, help maintain long-term crop productivity, and help support healthier fish populations for local enjoyment.

While it is true that riparian buffers alone may not always be able to reduce nutrient and sediment loading from agricultural lands, WBI researchers found that "...***riparian buffers are capable of reducing large percentages of the phosphorus and sediment that are currently being carried by Wisconsin streams. Even in watersheds with extremely high loads (top 10%), an average of about 70% of the sediment and phosphorus can be reduced through buffer implementation***." (*Diebel, M.J. and others, 2009, Landscape planning for agricultural nonpoint source pollution reduction III: Assessing Phosphorus and sediment reduction potential, Environmental Management, 43:69-83.*).

Federal and state natural resource agencies have long recognized the need to apply a wide range of Best Management Practices on agricultural lands to improve stream water quality. Although there are many tools available in the toolbox to reduce pollutant runoff from agricultural lands, such as crop rotations, nutrient and manure management, conservation tillage, and contour plowing, riparian buffers are one of the most effective tools to accomplish this task. Their multiple benefits and inter-connectedness from upstream to downstream make riparian buffers a choice with watershed-wide benefits.

Determine what benefits are needed.



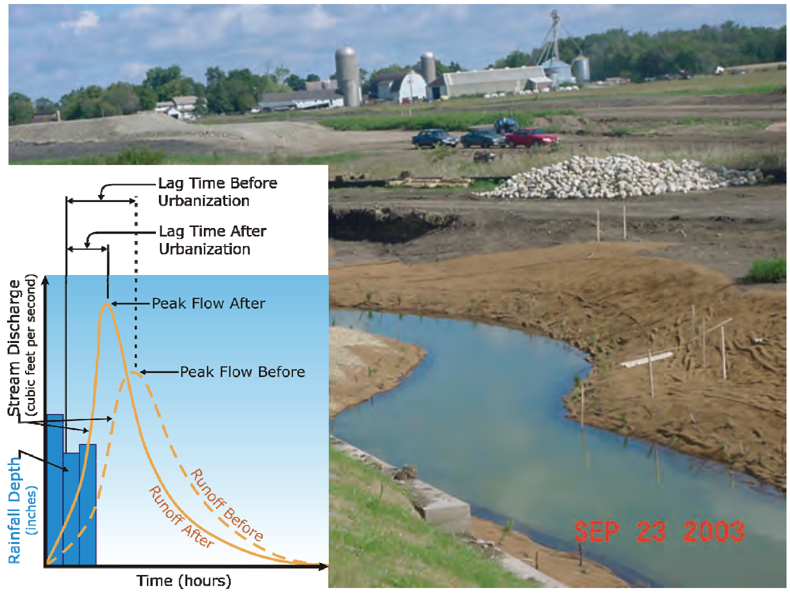
The USDA in *Agroforestry Notes* (AF Note-4, January 1997) outlines a four step process for designing riparian buffers for Agricultural lands:

1-Determine what buffers functions are needed
2-Identify the best types of vegetation to provide the needed benefits
3-Determine the minimum acceptable buffer width to achieve desired benefits
4-Develop an installation and maintenance plan

Drain tiles can bypass infiltration and filtration of pollutants by providing a direct pathway to the water and "around" a buffer. This is important to consider in design of a buffer system which integrates with other agricultural practices.

Case Study—Urbanizing Area Buffers

When development occurs near a waterbody, the area in driveways, rooftops, sidewalks, and lawns increases, while native plants and undisturbed soils decrease. As a result, the ability of the shoreland area to perform its natural functions (flood control, pollutant removal, wildlife habitat, and aesthetic beauty) is decreased. In the absence of mitigating measures, one the consequences of urban development is an increase in the amount of stormwater, which runs off the land instead of infiltrating into the ground. Therefore, **urbanization impacts the watershed, not only by reducing groundwater recharge, but also by changing stream hydrology** through increased stormwater runoff volumes and peak flows. This means less water is available to sustain the baseflow regime. The urban environment also contains increased numbers of pollutants and generates greater pollutant concentrations and loads than any other land use. This reflects the higher density of the human population and associated activities, which demand measures to protect the urban water system.



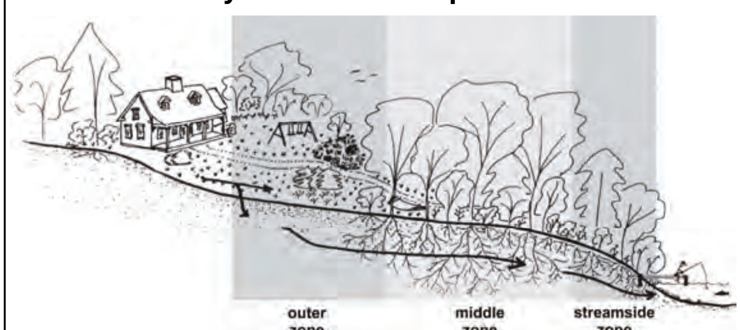
Comparison of hydrographs before and after urbanization. Note the rapid runoff and greater peak streamflow tied to watershed development. (Adapted from Federal Interagency Stream Restoration Working Group (FISRWG), Stream Corridor Restoration: Principles, Processes, and Practices, October 1998)

Mitigation of urban impacts may be as simple as not mowing along a stream corridor or changing land management and yard care practices, or as complex as changing zoning ordinances or widening riparian corridors through buyouts.

Challenge:
Urban development requires balancing flood protection, water quality protection, and the economic viability of the development.

Opportunities:
Buffers may offset costs by providing adequate space for providing long-term water quantity and water quality protection. In addition, they provide visual diversity on the landscape, wildlife habitat and connectedness, and help maintain property values.

Anatomy of an urban riparian buffer



The most effective urban buffers have three zones:

Outer Zone-Transition area between the intact buffer and nearest permanent structure to capture sediment and absorb runoff.

Middle Zone-Area from top of bank to edge of lawn that is composed of natural vegetation that provides wildlife habitat as well as improved filtration and infiltration of pollutants.

Streamside Zone-Area from the water's edge to the top of the bank or uplands that provides critical connection between water, wetland, and upland habitats for wildlife as well as protect streams from bank erosion

(Fact sheet No. 6 Urban Buffer in the series Riparian Buffers for Northern New Jersey)

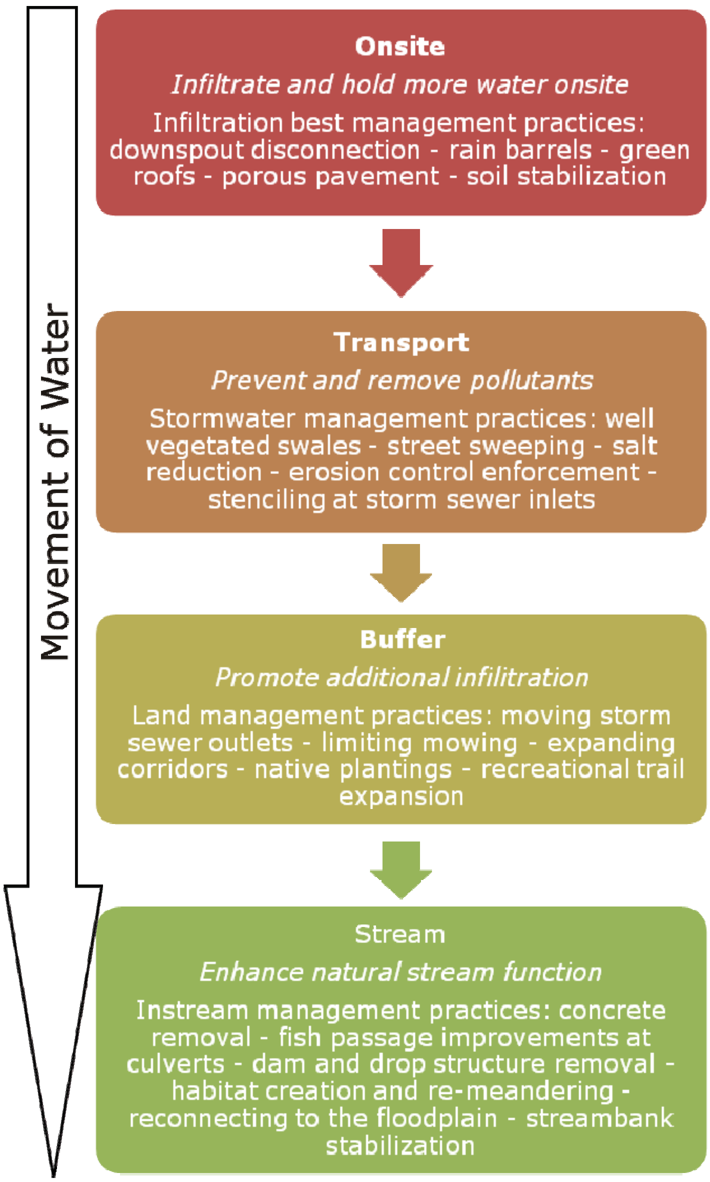
Case Study—Urban Buffers

Placement of riparian buffers in established urban areas is a challenge that requires new and innovative approaches. In these areas, historical development along water courses limits options and requires balancing flood management protection versus water quality and environmental protection needs. Consequently, some municipalities have begun to recognize the connections between these objectives and are introducing programs to remove flood-prone structures and culverts from the stream corridors and allow recreation of the stream, restoring floodplains, and improving both the quality of life and the environment.

In urban settings it may be necessary to limit pollution and water runoff before it reaches the buffer.

Challenge:
There are many potential constraints to establishing, expanding, and/or managing riparian buffers within an urban landscape. Two major constraints to establishment of urban buffers include:

1) **Limited or confined space to establish buffers** due to encroachment by structures such as buildings, roadways, and/or sewer infrastructure;
2) **Fragmentation of the landscape** by road and railway crossings of creeks and rivers that disrupt the linear connectedness of buffers, limiting their ability to provide quality wildlife habitat.



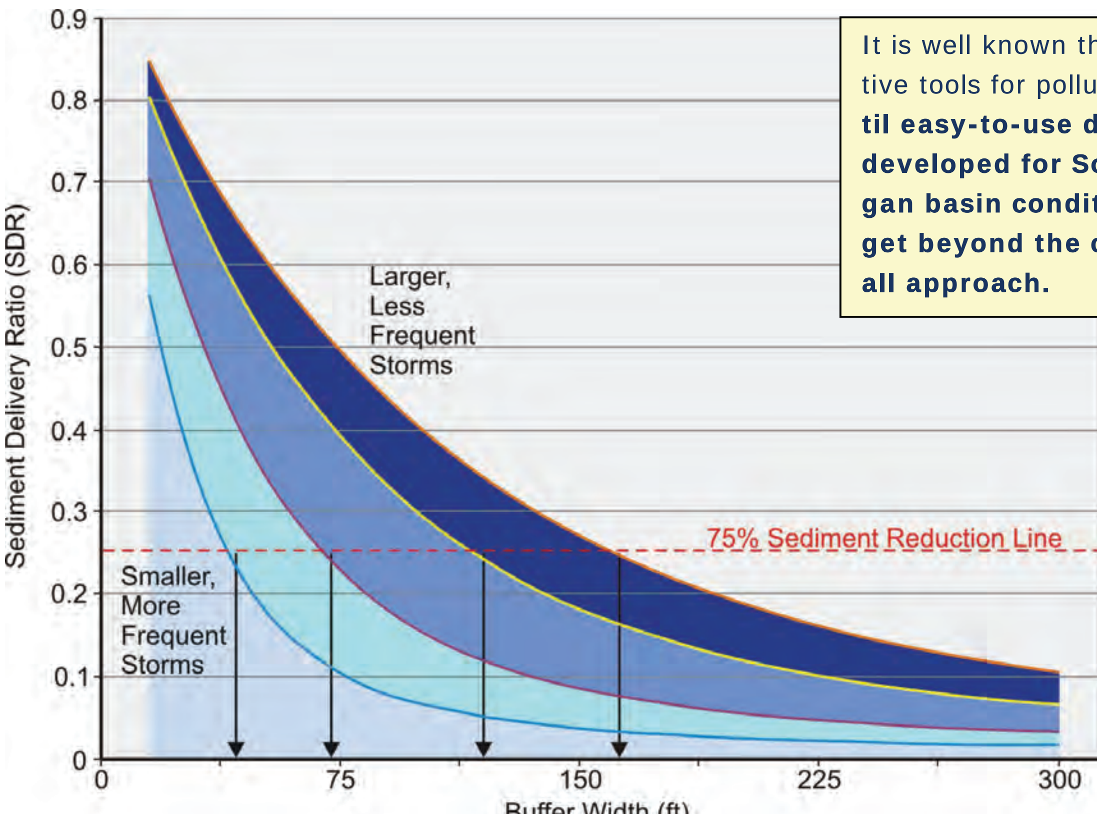
Much traditional stormwater infrastructure intercepts runoff and diverts it directly into creeks and rivers, bypassing any benefits of buffers to infiltrate or filter pollutants. This is important to consider in design of a buffer system for urban waterways, which begin in yards, curbsides, and construction sites, that are figuratively as close to streams as the nearest storm sewer inlet.

A Buffer Design Tool

Design aids are needed to help municipalities, property owners, and others take the "guesswork" out of determining adequate buffer widths for the purpose of water resource quality protection. While there are various complex mathematical models that can be used to estimate sediment and nutrient removal efficiencies, they are not easily applied by the people who need them including homeowners, farmers, businesses and developers.

To fill this gap, design aid tools are being developed using factors such as slope, soils, field length, incoming pollutant concentrations, and vegetation to allow the user to identify and test realistic buffer widths with respect to the desired percent pollutant load reduction and storm characteristics. By developing a set of relationships among factors that determine buffer effectiveness, the width of buffer needed to meet specific goals can be identified.

In the example below, 50-foot-wide buffers are necessary to achieve 75 % sediment removal during small, low intensity storms, while buffers more than 150 feet wide are necessary to achieve the same sediment reduction during more severe storms. Based on this information, decision-makers have the option of fitting a desired level of sediment removal into the context of their specific conditions. Under most conditions, a 75-foot width will provide a minimum level of protection for a variety of needs (SEWRPC PR No. 50, Appendix O.)



It is well known that buffers are effective tools for pollutant removal, but **until easy-to-use design aid tools are developed for Southern Lake Michigan basin conditions, we can never get beyond the current one size fits all approach.**

This generalized graph depicts an example of model output for an optimal buffer width to achieve a 75% sediment reduction for a range of soil and slope, vegetation, and storm conditions characteristic of North Carolina. *(Adapted from Muñoz-Carpena R., Parsons J.E.. 2005. VFSMOD-W: Vegetative Filter Strips Hydrology and Sediment Transport Modeling System v.2.x. Homestead, FL: University of Florida. http://carpena.ifas.ufl.edu/vfsmod/citations.shtml)*

Buffers Are A Good Defense

Today's natural resources are under threat. These threats are immediate as in the case of chemical accidents or manure spills, and chronic as in the case of stormwater pollution carrying everything from eroded soil, to fertilizer nutrients, to millions of drips from automobiles and other sources across the landscape. Non-native species have invaded, and continue to invade, key ecosystems and have caused the loss of native species and degradation of their habitats to the detriment of our use of important resources.

> ***"Riparian ecosystems are naturally resilient,*** *provide linear habitat connectivity, link aquatic and terrestrial ecosystems, and create thermal refugia for wildlife: all characteristics that can contribute to ecological adaptation to climate change."*
>
> *(N. E. Seavy and others, Why Climate Change Makes Riparian Restoration More Important Than Ever: Recommendations for Practice and Research, 2009, Ecological Restoration 27(3):330-338)*

A more subtle, but growing, concern is the case of stresses on the environment resulting from climate change. Buffers present an opportunity for natural systems to adapt to such changes by providing the space to implement protective measures while also serving human needs. **Because riparian buffers maintain an important part of the landscape in a natural condition, they offer opportunities for communities to adjust to our changing world.**

Well-managed riparian buffers are a good defense against these threats. In combination with environmental corridors, buffers maintain a sustainable reserve and diversity of habitats, plant and animal populations, and genetic diversity of organisms, all of which contribute to the long-term preservation of the landscape. Where they are of sufficient size and connectivity, riparian buffers act as reservoirs of resources that resist the changes that could lead to loss of species.

Refuge or protection from increased water temperatures as provided by natural buffers is important for the preservation of native cold-water, cool-water, and warm-water fishes and their associated communities.

Buffers Provide Opportunities

River, lake, and wetland systems and their associated riparian lands form an important element of the natural resource base, create opportunities for recreation, and contribute to attractive and well-balanced communities. These resources can provide an essential avenue for relief of stress among the population and improve quality of life in both urban and rural areas. Such uses also sustain industries associated with outfitting and supporting recreational and other uses of the natural environment, providing economic opportunities. Increasing access and assuring safe use of these areas enhances public awareness and commitment to natural resources. Research has shown that property values are higher adjoining riparian corridors, and that such natural features are among the most appreciated and well-supported parts of the landscape for protection.

We demand a lot from our riparian buffers!

Sustaining this range of uses requires our commitment to protect and maintain them.

Summary

The following guidance suggestions highlight key points to improve riparian corridor management and create a more sustainable environment.

Riparian corridors or buffers along our waters may contain varied features, but all are best preserved or designed to perform multiple important functions.

Care about buffers because of their many benefits. Riparian buffers make sense and are profitable monetarily, recreationally, aesthetically, as well as environmentally.

Enhance the environmental corridor concept. Environmental corridors are special resources which deserve protection. They serve many key riparian corridor functions, but in some cases, could also benefit from additional buffering.

Avoid habitat fragmentation of riparian corridors. It is important to preserve and link key resource areas, making natural connections and avoiding habitat gaps.

Employ the adage "wider is better" for buffer protection. While relatively narrow riparian buffers may be effective as filters for certain pollutants, that water quality function along with infiltration of precipitation and runoff and the provision of habitat for a host of species will be improved by expanding buffer width where feasible.

Allow creeks and rivers room to roam across the landscape. Streams are dynamic and should be buffered adequately to allow for natural movement over time while avoiding problems associated with such movement.

Consider and evaluate buffers as a matter of balance. Riparian buffers are a living, self-sustainable shield that can help balance active use of water and adjoining resources with environmental protection.

Agricultural buffers can provide many benefits. Riparian buffers in agricultural settings generally work well, are cost-effective, and can provide multiple benefits, including possibly serving as areas to raise certain crops.

Urban buffers should be preserved and properly managed. Though often space-constrained and fragmented, urban buffers are important remnants of the natural system. Opportunities to establish or expand buffers should be considered, where feasible, complemented by good stormwater management, landscaping, and local ordinances, including erosion controls.

A buffer design tool is needed and should be developed. Southeastern Wisconsin and the Southern Lake Michigan Basin would benefit from development of a specific design tool to address the water quality function of buffers. Such a tool would improve on the currently available general guidance on dimensions and species composition.

Buffers are a good defense. Combined with environmental corridors, riparian buffers offer a good line of defense against changes which can negatively impact natural resources and the landscape.

Managing the Water's Edge

MORE TO COME

Future editions in a riparian buffer planning series are being explored with the intent of focusing on key elements of this critical land and water interface. Topics may include:

- Information sharing and development of ordinances to integrate riparian buffers into existing land management plans and programs
- Integration of stormwater management practices and riparian buffer best management practices
- Application of buffers within highly constrained urban corridors with and without brownfield development
- Installation of buffers within rural or agricultural lands being converted to urban uses
- Utilization of buffers in agricultural areas and associated drainage systems
- Integration of riparian buffers into environmental corridors to support resources preservation, recreation and aesthetic uses
- Preservation of stream courses and drainageways to minimize maintenance and promote protection of infrastructure
- Guidance for retrofitting, replacement, or removal of infrastructure such as dams and road crossings, to balance transportation, recreation, aesthetic, property value, and environmental considerations.
- Protection of groundwater recharge and discharge areas
- Protection of high quality, sensitive coastal areas, including preservation of recreational potential

MORE INFORMATION

This booklet can be found at http://www.sewrpc.org/RBMG-no1 . Please visit the website for more information, periodic updates, and a list of complementary publications.

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Appendix D

DOCUMENTATION FOR DIGITAL STORM DRAINAGE SYSTEM DATASETS AMONG MS4 COMMUNITIES WITHIN THE PEWAUKEE RIVER WATERSHED

MS4 DATASETS WITH WATERSHED-WIDE COVERAGE

Storm Water Best Management Practices (BMP)
Village of Sussex StormPonds (polygons) was converted into point features by using ESRI ArcMap Feature to Point tool. The points were renamed VSussesStormPonds. The points were categorized by PondType, where "Dry" = dry, "Infiltration" = dry, "Raingarden"= dry and null = other;

City of Pewaukee Ponds_BMPs_2010 (points) was categorized by Type, where "Bioret" = dry, "CB" = other, "Dry" = dry, "Infilt" = dry, "Stmceptr" = other, "Unk_Pond" = other, "Wet" = wet and "Wetland" = wet;

Village of Pewaukee Ponds 2010 SLAMM (polygons) was converted into point features by using ESRI ArcMap Features to Point tool. The points were renamed VPewaukeePonds. The points were categorized by DNR_Status, where "Dry" = dry, "Model" = wet, "Natural" = wet, "No LTM Agreement" = wet, "Too New" = wet and "Too Shallow" = Dry;

Town of Delafield Pond (polygons) was converted into point features by using ESRI ArcMap Feature to Point too. The points were renamed TDelafieldPonds. The points were categorized by Detention where "Dry" = dry and "wet" = wet. Mapped storm water BMPs that were already in the County's BMP inventory were removed from the Town's dataset;

The Town of Lisbon uses the County's BMP database, so this information is provided through Waukesha County's Storm_Water_BMPs (see below).

City of Waukesha storm water management BMPs was mapped from the City of Waukesha NR 216 Annual Report for the Year 2010, AECOM 2011 where the coordinates of BMPs in the report were plotted as an event theme. The determination of wet, dry or other was done by Waukesha County staff based upon site conditions and aerial photo review.

Waukesha County Storm_Water_BMPs (points) were categorized by BMPFacilityTypeDesc where "Constructed Wetland" = wet, "Dry Detention Basin" = dry, "Grassed Swale" = dry, "Infiltration Basin" = dry, "Infiltration Trench/Structure" = dry, "Kettle" = dry, "Permanent Sediment Trap" = wet, "Rain Garden" = dry and "Wet Detention Basin" = wet.

Storm Pipes

Documentation for merging the storm water system storm pipes for the MS4 community datasets using ESRI ArcMap:

City of Waukesha – **StormGravityMain**
Town of Delafield – **GreaterThan24_Sewer, GreaterThan36_Sewer, SewerOutside & Sewer36_Outside**
Town of Lisbon – **st_culvert and st_sewer**
Village of Pewaukee – **stormpipedata2007**
Village of Sussex – **StormPipes**
City of Pewaukee – **StormSewersApprox2010**
Waukesha County – **County_Storm_Pipes**

Major Outfalls

Documentation for merging the storm water system major outfalls for the MS4 community datasets using ESRI ArcMap:

Waukesha County: County_Major_Outfalls
City of Pewaukee: StormSystemOutfalls2010 (definition query for Type = Major)
Village of Sussex: StormStructures (definition query for StrucType = OFM)
Town of Lisbon: Outfalls (definition query for Type = Major)
Town of Delafield: Major_Outfall (definition query for Type = Major”
City of Waukesha: StormDischargePoint (definition query for OutfallTyp = MAJOR)
Village of Pewaukee: Outfalls (definition query for Maj_Min = Major Outfall)

Outfalls were created by merging the datasets listed below:
Waukesha County: County DPLUoutlets
City of Pewaukee: StormSystemOutfalls2010 (definition query for Type not equal to Major)
City of Waukesha: StormDischargePoint (definition query for OutfallTyp not equal to MAJOR)
Town of Delafield: Storm_Points (definition query for Type = Coutfall or outfall)
Town of Lisbon: Outfalls (definition query for Type = Minor)
Village of Pewaukee: Outfalls (definition query for Maj_Min = Minor Outfall)
Village of Sussex: StormStructures (definition query for StructType = OF)

Waukesha County stormwater and erosion control plan Digital Submittal requirements:

In addition to a paper copy, provide site map items in a digital format georeferenced to the State Plane Coordinate System, Wisconsin South Zone, NAD 27, NGVD 29. Preferred formats include ESRI Geodatabase or AutoCAD.dxf.

With regard to <u>storm water BMPs</u>, the County database includes the following attributes: BMPNumber, ProjectName, BMPFacilityTypeDesc, BMPDescription, BMPDrainageArea, BMPMaintainedBy, MunicipalityDesc, BMPQuarterSection, BMPSection, BMPTownshipID, Watershed, Subwatershed, BMPCertificationPEName, BMPCertificationCompany, BMPCertificationDate, BMPInServiceDate, BMPStatusDesc, LastBMPInspectionDate, DocumentNumbers, GEONorthing, GEOEasting, BMPNextPlannedInspectionDate.

MS4 DATASETS WITHOUT WATERSHEDWIDE COVERAGE (SEWER INLETS, CULVERTS & STREET DRAINAGE)

City of Waukesha Inlets
StormInlets.shp
StormCatchBasin.shp

Village of Sussex Inlets and Culverts

StormStructures.shp

Inlets – StrucType = “CB” or “IN”

Culverts – StrucType = “EOP”

Town of Delafield Inlets and Culverts

StormSystem Feature Dataset, Storm_Points Feature Class

Culverts –TYPE = 'CULVERT'

Inlets – TYPE = 'CB'

Village of Pewaukee Swales

Final SLAMM Analysis Map to SEWRPC.mpk

Swale

Town of Delafield Street Drainage

Curb_Gutter_Drainage.shp

Swale_Drainage.shp

Undeveloped_Roadside.shp

Town of Lisbon Curb and Gutter

Curb and Gutter.shp

Source: City of Pewaukee, AECOM; City of Waukesha, GRAEF; Town of Delafield, R.A. Smith National, Inc.; Town of Lisbon, Strand Associates, Inc.; Village of Pewaukee, STANTEC; Village of Sussex, Ruekert & Mielke, Inc.; Waukesha County PLU -- Land Resources Division; and SEWRPC.

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Appendix E

INSTREAM HABITAT INVENTORY AMONG REACHES WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

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Table E-1

QUANTITATIVE INSTREAM COVER CHARACTERISTICS AMONG HABITAT TYPES WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Pewaukee 1	1	- -	21-Mar-12	2478640.0864	384688.8740	Riffle	Fast	3	3	0	0	3
Pewaukee 1	2	- -	21-Mar-12	2478520.7379	384732.7312	Riffle	Fast	3	1	0	0	1
Pewaukee 1	3	- -	21-Mar-12	2478444.24000	384738.085882	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	4	- -	21-Mar-12	2478451.6334	384832.2661	Riffle	Fast	2	0	0	0	1
Pewaukee 1	5	- -	21-Mar-12	2478458.103160	384898.345076	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	6	- -	21-Mar-12	2478229.7919	384953.5517	Run	Fast	3	1	0	1	3
Pewaukee 1	7	- -	21-Mar-12	2478185.197210	384969.984697	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	8	- -	21-Mar-12	2478056.877590	385049.888408	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	9	- -	21-Mar-12	2478128.2301	385142.1405	Run	Fast	3	2	0	1	2
Pewaukee 1	10	- -	21-Mar-12	2478160.735980	385203.491448	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	11	- -	21-Mar-12	2478179.655230	385228.340479	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	12	- -	21-Mar-12	2478295.4289	385299.6979	Riffle	Fast	2	1	0	1	3
Pewaukee 1	13	- -	21-Mar-12	2478429.071730	385605.623845	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	14	- -	21-Mar-12	2478439.4513	385704.6660	Run	Fast	2	1	0	1	1
Pewaukee 1	15	- -	21-Mar-12	2478564.116730	385786.663510	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	16	- -	22-Mar-12	2478551.761770	385823.495457	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	17	- -	22-Mar-12	2478529.0404	385829.5771	Run	Fast	2	1	0	1	1
Pewaukee 1	18	- -	22-Mar-12	2478440.5500	386069.0445	Run	Moderate	2	1	0	1	2
Pewaukee 1	19	- -	22-Mar-12	2478523.0843	386347.1352	Riffle	Fast	3	2	0	1	3
Pewaukee 1	20	- -	22-Mar-12	2478540.124330	386433.305589	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	21	- -	22-Mar-12	2478571.373280	386470.613585	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	22	- -	22-Mar-12	2478529.3071	386585.4562	Run	Moderate	1	1	0	1	1
Pewaukee 1	23	- -	22-Mar-12	2478618.7101	386782.3265	Riffle	Fast	1	1	0	1	1
Pewaukee 1	24	- -	22-Mar-12	2478499.6421	387024.6190	Run	Moderate	1	1	1	0	1
Pewaukee 1	25	- -	22-Mar-12	2478200.7799	387157.1788	Riffle	Fast	2	1	0	0	1
Pewaukee 1	26	- -	22-Mar-12	2478116.951940	387197.640018	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	27	- -	22-Mar-12	2477917.7955	387219.4982	Run	Fast	2	0	0	0	1
Pewaukee 1	28	- -	22-Mar-12	2477737.4179	387189.1374	Riffle	Fast	2	1	0	0	1
Pewaukee 1	29	- -	22-Mar-12	2477680.996450	387049.661640	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	30	- -	22-Mar-12	2477558.8327	386918.1284	Run	Moderate	2	1	0	1	2
Pewaukee 1	31	- -	22-Mar-12	2477329.6825	386784.3676	Run	Moderate	2	2	0	1	3
Pewaukee 1	32	- -	22-Mar-12	2477143.161240	386830.487209	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	33	- -	22-Mar-12	2477032.573535	386853.402190	Run	Fast	2	0	0	1	1
Pewaukee 1	34	- -	22-Mar-12	2476874.733630	386751.747209	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	35	- -	28-Mar-12	2476782.173440	386712.150176	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	36	- -	28-Mar-12	2476770.7991	386682.2979	Riffle	Fast	2	2	0	1	3
Pewaukee 1	37	- -	28-Mar-12	2476643.508370	386632.002698	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	38	- -	28-Mar-12	2476592.702370	386686.558363	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	39	- -	28-Mar-12	2476544.0588	386750.0225	Riffle	Fast	2	2	0	1	3
Pewaukee 1	40	- -	28-Mar-12	2476328.4247	386897.8926	Riffle	Moderate	2	1	0	0	3
Pewaukee 1	41	- -	28-Mar-12	2476092.5134	387053.0606	Riffle	Moderate	2	2	0	1	3
Pewaukee 1	42	- -	28-Mar-12	2475915.8225	387122.8698	Run	Slow	1	1	1	0	0
Pewaukee 1	43	- -	28-Mar-12	2475678.6071	387131.4351	Run	Slow	1	1	0	1	1

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Pewaukee 1	44	- -	28-Mar-12	2475623.30240	387122.95348	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	45	- -	28-Mar-12	2475494.6750	387133.0755	Riffle	Fast	2	2	0	1	2
Pewaukee 1	46	- -	28-Mar-12	2475263.7664	387150.8242	Run	Moderate	3	3	0	0	2
Pewaukee 1	47	- -	28-Mar-12	2475236.999700	387179.589201	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	48	- -	28-Mar-12	2474918.5279	387179.7998	Run	Slow	2	2	0	0	1
Pewaukee 1	49	- -	28-Mar-12	2474712.7002	387060.5255	Run	Slow	2	2	0	0	2
Pewaukee 1	50	- -	28-Mar-12	2474507.957190	386917.594647	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	51	- -	28-Mar-12	2474473.4382	386811.5634	Run	Slow	2	2	0	0	2
Pewaukee 1	52	- -	28-Mar-12	2474454.2949	386629.6825	Run	Slow	2	2	0	0	1
Pewaukee 1	53	- -	28-Mar-12	2474452.573770	386585.189143	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	54	- -	28-Mar-12	2474484.586830	386506.759182	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	55	- -	28-Mar-12	2474546.5444	386459.7964	Pool	Slow	2	2	0	0	1
Pewaukee 1	56	- -	28-Mar-12	2474457.1801	386354.0964	Run	Moderate	3	3	0	0	3
Pewaukee 1	57	- -	29-Mar-12	2474099.5404	386375.5482	Run	Slow	1	1	0	0	2
Pewaukee 1	58	- -	29-Mar-12	2473860.8479	386350.0344	Run	Slow	1	1	0	0	3
Pewaukee 1	59	- -	29-Mar-12	2473694.227190	386418.515264	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	60	- -	29-Mar-12	2473599.650280	386442.936147	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	61	- -	29-Mar-12	2473517.5825	386461.8816	Pool	Slow	3	3	0	0	2
Pewaukee 1	62	- -	29-Mar-12	2473365.049050	386526.569838	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	63	- -	29-Mar-12	2473446.419620	386681.780486	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	64	- -	29-Mar-12	2473477.5902	386716.7283	Run	Slow	2	1	0	0	1
Pewaukee 1	65	- -	29-Mar-12	2473269.6585	386907.0461	Run	Slow	2	2	1	0	1
Pewaukee 1	66	- -	29-Mar-12	2473200.883360	386818.320239	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 1	67	- -	29-Mar-12	2473058.2091	386907.5425	Run	Slow	1	1	1	0	1
Pewaukee 1	68	- -	29-Mar-12	2472887.9257	387043.2365	Run	Slow	1	1	0	0	0
Pewaukee 2	69	- -	2-Apr-12	387532.2227	387532.2227	Run	Slow	1	1	1	1	2
Pewaukee 2	70	- -	2-Apr-12	2472762.336670	387647.815627	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	71	- -	2-Apr-12	2472623.2917	387681.3231	Run	Slow	1	1	1	0	0
Pewaukee 2	72	- -	2-Apr-12	2472546.079230	387644.912090	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	73	- -	2-Apr-12	2472516.065180	387653.779854	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	74	- -	2-Apr-12	2472444.083370	387716.302367	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	75	- -	2-Apr-12	2472592.7835	387857.2315	Run	Slow	2	2	1	1	1
Pewaukee 2	76	- -	2-Apr-12	2472459.1932	387977.0535	Run	Slow	2	2	0	1	1
Pewaukee 2	77	- -	2-Apr-12	2472441.572550	387966.808099	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	78	- -	3-Apr-12	2472400.4512	388139.2513	Run	Slow	1	1	0	0	0
Pewaukee 2	79	- -	3-Apr-12	2472376.0979	388336.6788	Run	Slow	2	1	0	0	2
Pewaukee 2	80	- -	3-Apr-12	2472348.859150	388394.404357	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	81	- -	3-Apr-12	2472215.833500	388347.221052	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	82	- -	3-Apr-12	2472120.4554	388508.2463	Run	Slow	1	1	0	0	0
Pewaukee 2	83	- -	3-Apr-12	2471943.3918	388607.3190	Run	Slow	2	2	1	0	1
Pewaukee 2	84	- -	3-Apr-12	2471741.618240	388722.096615	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	85	- -	3-Apr-12	2471915.2157	388787.6490	Run	Slow	1	1	1	0	0
Pewaukee 2	86	- -	3-Apr-12	2471979.7231	388979.4990	Riffle	Moderate	3	3	0	0	3
Pewaukee 2	87	- -	3-Apr-12	2471788.3475	388986.3887	Riffle	Moderate	2	2	0	0	0
Pewaukee 2	88	- -	3-Apr-12	2471728.851860	388908.191715	Deep pool	- -	- -	- -	- -	- -	- -

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Pewaukee 2	89	- -	3-Apr-12	2471634.669960	388963.186028	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	90	- -	3-Apr-12	2471707.7863	389131.5981	Run	Slow	2	2	0	0	0
Pewaukee 2	91	- -	3-Apr-12	2471731.6284	389405.7334	Pool	Slow	1	1	0	0	2
Pewaukee 2	92	- -	3-Apr-12	2471565.9601	389621.1339	Run	Slow	1	1	1	0	0
Pewaukee 2	93	- -	4-Apr-12	2471338.489120	389763.820910	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	94	- -	4-Apr-12	2471325.7490	389781.3635	Pool	Slow	1	1	0	0	0
Pewaukee 2	95	- -	4-Apr-12	2471329.217490	389884.320012	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	96	- -	4-Apr-12	2471477.0433	389923.2589	Pool	Slow	2	2	0	0	1
Pewaukee 2	97	- -	4-Apr-12	2471470.107300	389979.945477	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	98	- -	4-Apr-12	2471368.6839	390056.6678	Run	Slow	1	1	0	0	0
Pewaukee 2	99	- -	4-Apr-12	2471341.302110	390126.673202	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	100	- -	4-Apr-12	2471494.4632	390288.1335	Pool	Slow	1	1	0	0	0
Pewaukee 2	101	- -	4-Apr-12	2471295.4607	390411.4965	Run	Moderate	2	2	0	1	1
Pewaukee 2	102	- -	4-Apr-12	2471238.750480	390429.487557	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	103	- -	4-Apr-12	2471184.556030	390531.925344	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	104	- -	4-Apr-12	2471259.9036	390613.7920	Run	Slow	1	0	0	0	0
Pewaukee 2	105	- -	4-Apr-12	2471101.8695	390726.2586	Run	Moderate	1	1	0	0	0
Pewaukee 2	106	- -	4-Apr-12	2471088.710420	390779.576424	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	107	- -	4-Apr-12	2470961.6237	390807.1128	Run	Moderate	2	2	1	0	1
Pewaukee 2	108	- -	4-Apr-12	2470940.380990	390802.905446	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	109	- -	4-Apr-12	2470918.545740	390838.498222	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	110	- -	5-Apr-12	2470854.734510	390891.388208	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	111	- -	5-Apr-12	2470807.9869	390889.7304	Run	Moderate	2	2	0	0	1
Pewaukee 2	112	- -	5-Apr-12	2470785.340950	390890.444312	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	113	- -	5-Apr-12	2469991.575480	395760.913902	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	114	- -	5-Apr-12	2470733.7220	391118.2513	Run	Moderate	1	1	0	0	0
Pewaukee 2	115	- -	5-Apr-12	2470835.9665	391269.5548	Run	Slow	1	2	0	0	1
Pewaukee 2	116	- -	5-Apr-12	2470759.7934	391688.2757	Run	Slow	1	1	0	0	0
Pewaukee 2	117	- -	2-May-12	2470657.7900	392066.5479	Run	Moderate	1	1	0	1	0
Pewaukee 2	118	- -	2-May-12	2470617.0444	392424.7838	Run	Moderate	1	1	0	1	0
Pewaukee 2	119	- -	2-May-12	2470691.1892	392818.8453	Run	Moderate	1	1	1	1	0
Pewaukee 2	120	- -	2-May-12	2470693.9648	393211.4256	Run	Moderate	2	2	1	1	0
Pewaukee 2	121	- -	1-May-12	2470574.244590	393382.030209	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	122	- -	1-May-12	2470516.1614	393655.2918	Run	Moderate	3	2	3	0	1
Pewaukee 2	123	- -	1-May-12	2470795.0201	393770.6026	Run	Slow	3	2	2	0	1
Pewaukee 2	124	- -	1-May-12	2470997.682720	393758.839822	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	125	- -	1-May-12	2470875.1672	393933.3572	Run	Slow	1	1			0
Pewaukee 2	126	- -	1-May-12	2470606.1051	394152.9637	Run	Slow	2	1	1	0	0
Pewaukee 2	127	- -	1-May-12	2470344.7008	394524.8796	Run	Slow	2	2	2	0	1
Pewaukee 2	128	- -	1-May-12	2470208.974650	394638.004731	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	129	- -	1-May-12	2470147.2094	394717.7670	Run	Moderate	3	3	2	0	1
Pewaukee 2	130	- -	1-May-12	2470156.127970	394880.026556	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	131	- -	1-May-12	2470335.7831	394913.3962	Run	Moderate	2	1	2	0	0
Pewaukee 2	132	- -	1-May-12	2470457.034850	395341.417366	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	133	- -	1-May-12	2470480.4639	395248.6977	Run	Slow	1	0	1	0	0

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Pewaukee 2	134	- -	1-May-12	2470237.4910	395339.7487	Run	Slow	1	1	1	0	0
Pewaukee 2	135	- -	1-May-12	2470124.114580	395295.251776	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	136	- -	1-May-12	2470087.5536	395806.9683	Run	Slow	1	1	0	0	1
Pewaukee 2	137	- -	1-May-12	2470098.611350	395964.599518	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	138	- -	1-May-12	2469975.1408	395854.9859	Run	Slow	2	2	2	1	0
Pewaukee 2	139	- -	1-May-12	2469991.575480	395760.913902	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	140	- -	1-May-12	2469864.2831	395837.7678	Run	Slow	2	1	2	1	0
Pewaukee 2	141	- -	12-Apr-12	2469653.0424	395891.8917	Run	Slow	2	1	2	1	0
Pewaukee 2	142	- -	12-Apr-12	2469521.0702	396057.1105	Run	Slow	2	1	2	1	0
Pewaukee 2	143	- -	12-Apr-12	2469658.681460	396214.166605	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	144	- -	12-Apr-12	2469685.385800	396243.787608	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	145	- -	12-Apr-12	2469663.1470	396374.2834	Run	Slow	2	1	2	1	0
Pewaukee 2	146	- -	12-Apr-12	2469616.172357	396430.196028	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	147	- -	12-Apr-12	2469469.1799	396361.5174	Run	Slow	2	1	3	2	0
Pewaukee 2	148	- -	13-Apr-12	2469359.1309	396648.4151	Run	Slow	2	2	2	2	1
Pewaukee 2	149	- -	13-Apr-12	2469348.426500	396688.676482	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 2	150	- -	13-Apr-12	2469192.7014	396768.4496	Run	Slow	1	0	2	1	1
Pewaukee 2	151	- -	13-Apr-12	2468973.5746	396859.3864	Run	Slow	1	1	2	1	1
Pewaukee 2	152	- -	13-Apr-12	2468994.4285	397047.7174	Run	Slow	1	1	1	1	2
Pewaukee 3	153	- -	13-Apr-12	2468984.5033	397358.4767	Riffle	Moderate	2	1	1	1	1
Pewaukee 3	154	- -	13-Apr-12	2468677.4311	397381.8122	Run	Slow	2	1	1	2	1
Pewaukee 3	155	- -	13-Apr-12	2468469.7901	397397.6429	Run	Slow	2	1	1	1	2
Pewaukee 3	156	- -	13-Apr-12	2468269.3056	397438.6520	Pool	Slow	2	2	1	2	2
Pewaukee 3	157	- -	17-Apr-12	2468101.0510	397564.9812	Run	Slow	2	1	1	0	1
Pewaukee 3	158	- -	17-Apr-12	2467989.645100	397613.671352	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	159	- -	17-Apr-12	2467913.0596	397681.0577	Run	Moderate	2	1	2	1	0
Pewaukee 3	160	- -	17-Apr-12	2467860.4049	397824.6965	Run	Slow	2	2	1	0	1
Pewaukee 3	161	- -	17-Apr-12	2467879.316580	397856.386417	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	162	- -	17-Apr-12	2467887.370700	397930.438763	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	163	- -	17-Apr-12	2467754.6735	397878.4904	Run	Moderate	3	3	1	1	2
Pewaukee 3	164	- -	17-Apr-12	2467559.930730	397862.789620	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	165	- -	17-Apr-12	2467495.3561	397874.4530	Run	Slow	1	1	1	1	1
Pewaukee 3	166	- -	17-Apr-12	2467411.542580	397885.009720	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	167	- -	17-Apr-12	2467353.8944	397900.7597	Riffle	Moderate	2	1	1	1	1
Pewaukee 3	168	- -	17-Apr-12	2467411.542580	397885.009720	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	169	- -	17-Apr-12	2467194.370110	397966.869136	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	170	- -	17-Apr-12	2467078.113460	398013.230920	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	171	- -	17-Apr-12	2467044.8724	398030.3497	Pool	Slow	1	1	1	1	0
Pewaukee 3	172	- -	17-Apr-12	2466939.5908	398246.5559	Pool	Slow	1	1	1	2	0
Pewaukee 3	173	- -	17-Apr-12	2466771.7578	398528.9267	Run	Slow	1	1	1	1	0
Pewaukee 3	174	- -	17-Apr-12	2466358.8603	398521.8690	Run	Slow	2	1	1	0	2
Pewaukee 3	175	- -	18-Apr-12	2466235.235880	398696.660983	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	176	- -	18-Apr-12	2466114.6977	398692.0035	Run	Slow	2	2	1	1	1
Pewaukee 3	177	- -	18-Apr-12	2465838.1284	398741.2495	Run	Slow	1	1	1	0	1

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Pewaukee 3	178	- -	18-Apr-12	2465651.1701	398779.9692	Run	Slow	2	2	1	0	3
Pewaukee 3	179	- -	18-Apr-12	2465603.203020	398748.472560	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	180	- -	18-Apr-12	2465436.4182	398853.0045	Run	Slow	1	1	0	0	2
Pewaukee 3	181	- -	18-Apr-12	2465252.2109	398876.9041	Run	Moderate	1	1	1	2	1
Pewaukee 3	182	- -	18-Apr-12	2465101.851330	398917.858048	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	183	- -	18-Apr-12	2465059.563030	398983.341512	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	184	- -	18-Apr-12	2465071.8504	399052.4099	Run	Slow	2	1	1	2	1
Pewaukee 3	185	- -	18-Apr-12	2465054.422290	399154.440580	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	186	- -	18-Apr-12	2464981.4365	399202.4198	Run	Slow	2	2	1	1	1
Pewaukee 3	187	- -	18-Apr-12	2464744.097780	399251.553574	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	188	- -	18-Apr-12	2464635.3204	399348.8365	Run	Moderate	2	2	1	1	1
Pewaukee 3	189	- -	23-Apr-12	2464378.1750	399545.6662	Run	Moderate	2	0	1	2	0
Pewaukee 3	190	- -	23-Apr-12	2464315.2410	399772.2412	Pool	Moderate	2	1	1	1	1
Pewaukee 3	191	- -	23-Apr-12	2464300.617700	399771.050567	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 3	192	- -	23-Apr-12	2464376.7307	399910.3846	Run	Moderate	3	3	0	0	2
Pewaukee 3	193	- -	23-Apr-12	2464404.701150	400002.939539	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	194	- -	23-Apr-12	2464480.0107	400235.3298	Run	Slow	2	2	1	0	1
Pewaukee 4	195	- -	23-Apr-12	2464473.505150	400370.098910	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	196	- -	23-Apr-12	2464462.559630	400437.552843	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	197	- -	23-Apr-12	2464445.2273	400484.6777	Run	Slow	2	2	1	0	2
Pewaukee 4	198	- -	23-Apr-12	2464435.631540	400735.374426	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	199	- -	23-Apr-12	2464438.2660	400745.5125	Run	Slow	2	2	0	0	3
Pewaukee 4	200	- -	24-Apr-12	2464455.8615	401009.0576	Run	Moderate	2	2	0	0	2
Pewaukee 4	201	- -	24-Apr-12	2464464.868680	401062.473181	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	202	- -	24-Apr-12	2464482.803030	401108.958652	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	203	- -	24-Apr-12	2464476.4408	401141.2745	Riffle	Fast	3	2	1	1	3
Pewaukee 4	204	- -	24-Apr-12	2464611.1594	401150.3785	Run	Moderate	1	1	0	0	1
Pewaukee 4	205	- -	24-Apr-12	2464801.5905	401147.0150	Run	Moderate	1	1	1	0	1
Pewaukee 4	206	- -	24-Apr-12	2464825.354180	401143.690210	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	207	- -	24-Apr-12	2464864.711060	401176.595000	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	208	- -	24-Apr-12	2464879.1749	401262.7005	Run	Slow	1	1	0	0	0
Pewaukee 4	209	- -	24-Apr-12	2464884.843890	401319.316499	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	210	- -	24-Apr-12	2464852.148420	401348.242951	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	211	- -	24-Apr-12	2464869.299630	401397.763849	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	212	- -	24-Apr-12	2464902.490840	401406.279252	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	213	- -	24-Apr-12	2464909.24542	401473.21645	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	214	- -	24-Apr-12	2464914.0932	401499.5360	Run	Moderate	1	1	1	0	0
Pewaukee 4	215	- -	24-Apr-12	2464910.301520	401514.917486	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	216	- -	24-Apr-12	2464944.854600	401544.054895	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	217	- -	24-Apr-12	2465003.2577	401638.5321	Run	Moderate	1	1	1	0	0
Pewaukee 4	218	- -	24-Apr-12	2465016.009640	401685.274757	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	219	- -	24-Apr-12	2465029.037170	401683.497529	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	220	- -	24-Apr-12	2465055.5378	401775.4429	Run	Moderate	1	1	1	0	0
Pewaukee 4	221	- -	24-Apr-12	2465072.269040	401798.831616	Deep pool	- -	- -	- -	- -	- -	- -

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Pewaukee 4	222	- -	24-Apr-12	2465080.609250	401812.329949	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	223	- -	24-Apr-12	2465087.208970	401858.758006	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	224	- -	24-Apr-12	2465098.794910	401888.517461	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	225	- -	24-Apr-12	2465124.0718	401934.8796	Run	Moderate	1	1	1	0	0
Pewaukee 4	226	- -	24-Apr-12	2465132.652120	401987.280386	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	227	- -	24-Apr-12	2465163.422400	402074.182116	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	228	- -	24-Apr-12	2465195.4483	402213.5142	Run	Slow	1	0	1	0	0
Pewaukee 4	229	- -	24-Apr-12	2465247.9416	402347.3748	Run	Slow	1	0	1	0	0
Pewaukee 4	230	- -	24-Apr-12	2465315.6813	402552.3570	Run	Slow	1	0	1	0	0
Pewaukee 4	231	- -	3-May-12	402794.7578	402794.7578	Run	Slow	1	0	1	0	0
Pewaukee 4	232	- -	3-May-12	2465845.4201	402632.2666	Run	Slow	1	0	1	0	0
Pewaukee 4	233	- -	3-May-12	2466121.9251	402464.0606	Run	Moderate	1	1	1	0	0
Pewaukee 4	234	- -	3-May-12	2466119.987090	402446.361161	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	235	- -	3-May-12	2466259.561620	402395.408179	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	236	- -	3-May-12	2466281.1400	402348.8948	Run	Moderate	1	1	1	0	1
Pewaukee 4	237	- -	9-May-12	2466533.3849	402248.6342	Run	Moderate	2	1	2	1	0
Pewaukee 4	238	- -	9-May-12	2466699.678520	402179.48702	Deep pool	- -					
Pewaukee 4	239	- -	9-May-12	2466747.7700	402140.4960	Run	Moderate	2	1	2	1	1
Pewaukee 4	240	- -	9-May-12	2466859.362250	402094.585618	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	241	- -	9-May-12	2466943.532690	402082.292336	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	242	- -	9-May-12	2466989.3394	402071.1198	Run	Moderate	3	0	3	1	0
Pewaukee 4	243	- -	9-May-12	2467250.3864	402100.2733	Run	Moderate	3	1	3	1	0
Pewaukee 4	244	- -	9-May-12	2467571.9442	402209.4420	Run	Moderate	3	1	3	1	0
Pewaukee 4	245	- -	9-May-12	2467720.372010	402288.459902	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	246	- -	9-May-12	2467753.8441	402296.3441	Run	Moderate	3	1	3	0	0
Pewaukee 4	247	- -	10-May-12	2468013.7261	402297.6449	Run	Moderate	3	1	3	0	0
Pewaukee 4	248	- -	10-May-12	2468042.467170	402307.905729	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	249	- -	10-May-12	2468320.0486	402380.2865	Run	Moderate	3	2	3	0	0
Pewaukee 4	250	- -	10-May-12	2468483.7406	402447.8044	Pool	Moderate	3	2	2	0	2
Pewaukee 4	251	- -	10-May-12	2468594.3588	402801.7423	Run	Moderate	3	1	3	2	0
Pewaukee 4	252	- -	10-May-12	2468601.891250	402827.995240	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	253	- -	10-May-12	2468706.8107	403112.9396	Pool	Moderate	2	1	2	1	0
Pewaukee 4	254	- -	10-May-12	2468612.4703	403336.2144	Run	Moderate	2	1	2	0	0
Pewaukee 4	255	- -	10-May-12	2468582.6554	403520.8187	Pool	Moderate	3	2	3	0	1
Pewaukee 4	256	- -	11-May-12	2468528.3832	403603.4035	Run	Slow	2	1	2	1	1
Pewaukee 4	257	- -	11-May-12	2468528.028860	403758.679731	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	258	- -	11-May-12	2468550.7700	403817.7049	Riffle	Moderate	3	3	1	0	3
Pewaukee 4	259	- -	11-May-12	2468438.9109	403968.0737	Riffle	Fast	3	3	1	0	3
Pewaukee 4	260	- -	11-May-12	2468406.503840	404031.133910	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	261	- -	11-May-12	2468394.760100	404111.521873	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	262	- -	11-May-12	2468340.0483	404166.0785	Run	Moderate	2	2	1	0	3
Pewaukee 4	263	- -	11-May-12	2468274.719660	404309.205861	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	264	- -	11-May-12	2468259.7545	404343.6001	Pool	Moderate	3	1	2	0	2
Pewaukee 4	265	- -	11-May-12	2468253.651790	404423.071119	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 4	266	- -	11-May-12	2468189.907820	404466.345310	Deep pool	- -	- -	- -	- -	- -	- -

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Pewaukee 4	267	- -	11-May-12	2468164.4318	404561.9383	Run	Moderate	2	0	2	0	0
Pewaukee 4	268	- -	11-May-12	2468136.9936	404828.5477	Riffle	Fast	2	1	0	1	2
Pewaukee 4	269	- -	11-May-12	2468179.1480	405194.4570	Riffle	Fast	2	2	0	1	1
Pewaukee 4	270	- -	11-May-12	2468293.0644	405553.7785	Run	Moderate	2	2	1	0	1
Pewaukee 4	271	- -	11-May-12	2468356.9196	405699.9272	Run	Moderate	2	2	1	0	2
Pewaukee 4	272	- -	11-May-12	2468460.7737	405875.3340	Riffle	Fast	2	1	1	0	0
Pewaukee 5	273	- -	14-May-12	2468511.3278	406015.0610	Run	Moderate	2	1	1	1	0
Pewaukee 5	274	- -	14-May-12	2468620.1671	406142.8137	Riffle	Moderate	2	1	1	1	0
Pewaukee 5	275	- -	14-May-12	2468643.4650	406257.1275	Riffle	Fast	2	1	1	1	3
Pewaukee 5	276	- -	14-May-12	2468741.9723	406467.2557	Run	Slow	3	3	0	0	3
Pewaukee 5	277	- -	14-May-12	2468808.9925	406492.4676	Riffle	Moderate	2	1	1	1	1
Pewaukee 5	278	- -	14-May-12	2468982.6303	406541.3156	Run	Moderate	2	2	1	0	1
Pewaukee 5	279	- -	14-May-12	2469044.079340	406722.707923	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 5	280	- -	14-May-12	2469034.9872	406770.6117	Riffle	Moderate	2	2	0	1	3
Pewaukee 5	281	- -	14-May-12	2469159.8065	406948.3590	Run	Moderate	2	1	1	0	0
Pewaukee 5	282	- -	14-May-12	2469184.493100	407011.395666	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 5	283	- -	14-May-12	2469214.640350	407061.992350	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 5	284	- -	14-May-12	2469250.1747	407109.6730	Run	Moderate	2	1	0	1	0
Pewaukee 5	285	- -	14-May-12	2469287.930560	407156.149970	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 5	286	- -	14-May-12	2469367.610190	407345.444539	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 5	287	- -	14-May-12	2469408.5550	407352.1148	Run	Moderate	2	1	0	0	1
Pewaukee 5	288	- -	14-May-12	2469590.7492	407545.8306	Run	Moderate	2	2	0	0	0
Pewaukee 5	289	- -	14-May-12	2469786.1028	407720.6065	Run	Moderate	2	2	0	0	2
Pewaukee 5	290	- -	16-May-12	2469944.825900	407788.213995	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 5	291	- -	16-May-12	2469965.1169	407809.1769	Pool	Moderate	2	1	1	0	1
Pewaukee 5	292	- -	16-May-12	2470036.9986	407895.5173	Riffle	Fast	2	2	0	1	2
Pewaukee 5	293	- -	16-May-12	2470142.8294	408036.6298	Riffle	Fast	2	1	1	0	2
Pewaukee 5	294	- -	16-May-12	2470219.502190	408081.574956	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 5	295	- -	16-May-12	2470297.7189	408137.1287	Run	Moderate	2	1	1	0	0
Pewaukee 5	296	- -	16-May-12	2470436.9804	408476.1270	Run	Moderate	3	1	0	1	0
Pewaukee 5	297	- -	16-May-12	2470561.5356	408795.6877	Run	Moderate	2	1	1	0	1
Pewaukee 5	298	- -	16-May-12	2470653.6870	409003.0954	Run	Moderate	3	2	1	0	3
Pewaukee 5	299	- -	16-May-12	2470695.2348	409315.7703	Riffle	Fast	3	1	3	0	2
Pewaukee 5	300	- -	16-May-12	2470696.401170	409430.045357	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee 5	301	- -	16-May-12	2470715.9684	409584.6750	Run	Slow	2	1	1	0	0
Pewaukee 5	302	- -	16-May-12	2470723.2512	409748.4578	Run	Slow	1	0	1	1	2
Pewaukee 5	303	- -	16-May-12	2470739.0904	409901.6300	Riffle	Fast	2	2	1	0	3
Pewaukee 5	304	- -	16-May-12	2470750.8312	410151.9281	Riffle	Moderate	2	2	1	0	3
Pewaukee 5	305	- -	16-May-12	2470726.8217	410221.2104	Riffle	Fast	3	1	3	0	3
HWY JJ Tributary	306	- -	9-Apr-12	2470648.0955	391960.2191	Run	Moderate	1	1	0	0	0
HWY JJ Tributary	307	- -	9-Apr-12	2470592.469620	391972.642607	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	308	- -	9-Apr-12	2470535.883120	391963.719725	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	309	- -	9-Apr-12	2470512.258490	391959.951360	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	310	- -	9-Apr-12	2470515.703690	391942.241093	Deep pool	- -	- -	- -	- -	- -	- -

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
HWY JJ Tributary	311	- -	9-Apr-12	2470469.7691	391922.1729	Run	Moderate	1	1	0	0	0
HWY JJ Tributary	312	- -	9-Apr-12	2470433.072630	391916.783467	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	313	- -	9-Apr-12	2470385.371930	391917.825788	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	314	- -	9-Apr-12	2470312.917680	391956.937258	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	315	- -	9-Apr-12	2470291.6113	391999.3588	Riffle	Fast	2	2	0	0	0
HWY JJ Tributary	316	- -	9-Apr-12	2470252.269840	392023.795720	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	317	- -	9-Apr-12	2470232.685560	392073.803494	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	318	- -	9-Apr-12	2470214.699050	392074.554149	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	319	- -	9-Apr-12	2470117.6910	392093.5282	Run	Moderate	2	2	1	0	0
HWY JJ Tributary	320	- -	9-Apr-12	2470003.934700	392016.298688	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	321	- -	9-Apr-12	2469925.195360	392028.360344	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	322	- -	9-Apr-12	2469918.9516	392007.8177	Run	Moderate	2	1	1	0	0
HWY JJ Tributary	323	- -	9-Apr-12	2469837.429130	391937.254227	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	324	- -	9-Apr-12	2469811.0158	391867.0615	Run	Moderate	2	2	1	0	3
HWY JJ Tributary	325	- -	9-Apr-12	2469678.7461	391785.8054	Riffle	Moderate	3	3	1	0	2
HWY JJ Tributary	326	- -	9-Apr-12	2469606.552300	391784.926119	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	327	- -	9-Apr-12	2469550.4514	391770.0557	Run	Moderate	3	3	1	0	1
HWY JJ Tributary	328	- -	9-Apr-12	2469432.9381	391691.1898	Run	Slow	3	1	3	0	1
HWY JJ Tributary	329	- -	9-Apr-12	2469395.308300	391670.445377	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	330	- -	9-Apr-12	2469225.311260	391595.396971	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	331	- -	9-Apr-12	2469114.218310	391539.310141	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	332	- -	9-Apr-12	2469053.392970	391517.710446	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	333	- -	9-Apr-12	2468953.6487	391436.6253	Run	Moderate	2	2	0	0	3
HWY JJ Tributary	334	- -	11-Apr-12	2468900.8910	391406.4866	Riffle	Moderate	2	2	0	1	3
HWY JJ Tributary	335	- -	11-Apr-12	2468867.430420	391377.089008	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	336	- -	11-Apr-12	2468776.8696	391314.1666	Riffle	Moderate	3	2	1	1	3
HWY JJ Tributary	337	- -	11-Apr-12	2468745.299430	391289.697779	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	338	- -	11-Apr-12	2468592.1423	391238.2008	Riffle	Fast	3	3	0	1	2
HWY JJ Tributary	339	- -	11-Apr-12	2468535.505880	391197.467977	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	340	- -	11-Apr-12	2468498.8117	391168.3716	Riffle	Fast	2	1	1	1	2
HWY JJ Tributary	341	- -	11-Apr-12	2468482.953170	391154.349296	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	342	- -	11-Apr-12	2468275.5520	391100.6762	Run	Slow	2	2	1	1	1
HWY JJ Tributary	343	- -	11-Apr-12	2468240.598990	391104.859894	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	344	- -	11-Apr-12	2468199.068240	391073.493159	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	345	- -	11-Apr-12	2468095.137670	391060.250403	Deep pool	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	346	- -	11-Apr-12	2468036.3264	391052.6287	Run	Slow	3	3	0	0	3
HWY JJ Tributary	347	- -	11-Apr-12	2467963.0362	391053.7186	Run	Slow	3	3	0	1	3
HWY JJ Tributary	348	- -	11-Apr-12	2467812.6133	391054.2911	Run	Slow	2	2	1	1	3
HWY JJ Tributary	349	- -	11-Apr-12	2467664.0155	391050.1930	Run	Slow	2	2	1	0	3
HWY JJ Tributary	350	- -	11-Apr-12	2467483.3489	391045.3361	Run	Moderate	2	1	2	0	0
Pewaukee Lake Outlet	351	- -	23-Apr-12	2464258.3022	399858.5392	Run	Moderate	2	2	1	1	0
Pewaukee Lake Outlet	352	- -	23-Apr-12	2464174.3568	399925.2675	Run	Moderate	2	2	2	1	1
Pewaukee Lake Outlet	353	- -	23-Apr-12	2464020.486698	399954.573494	Deep pool	- -	- -	- -	- -	- -	- -
Pewaukee Lake Outlet	354	- -	23-Apr-12	2464009.4969	399978.9406	Riffle	Moderate	1	1	1	1	2
Pewaukee Lake Outlet	355	- -	23-Apr-12	2463937.5220	400006.5950	Riffle	Moderate	2	1	1	2	2

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Coco Creek	356	- -	23-May-12	- -	- -	Pond	Slow	2	0	3	1	0
Coco Creek	357	- -	23-May-12	- -	- -	Pond	Slow	1	0	1	2	1
Coco Creek	358	- -	23-May-12	2458212.6512	401642.8848	Run	Slow	2	1	1	2	1
Coco Creek	359	- -	23-May-12	2458468.5818	401572.0352	Run	Slow	1	1	1	1	3
Coco Creek	360	- -	23-May-12	2458531.6266	401726.2960	Run	Slow	1	1	0	1	0
Coco Creek	361	- -	23-May-12	2458577.117340	401920.649286	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	362	- -	23-May-12	2458407.0465	402102.7772	Run	Slow	1	1	1	1	0
Coco Creek	363	- -	24-May-12	2458203.369070	402238.901930	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	364	- -	24-May-12	2458127.2449	402308.9920	Run	Slow	1	1	1	1	0
Coco Creek	365	- -	24-May-12	2457968.428260	402496.210143	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	366	- -	24-May-12	2457954.9447	402523.4637	Run	Slow	1	1	0	0	0
Coco Creek	367	- -	24-May-12	2457937.657000	402564.877985	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	368	- -	24-May-12	2457875.9337	402755.7766	Run	Slow	2	2	1	0	3
Coco Creek	369	- -	24-May-12	2457794.596260	402941.201379	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	370	- -	24-May-12	2457811.2386	403135.9995	Run	Slow	2	2	0	0	1
Coco Creek	371	- -	24-May-12	2457755.9812	403632.4369	Pool	Slow	2	2	0	0	1
Coco Creek	372	- -	24-May-12	2457593.4126	403863.3406	Run	Moderate	1	1	1	0	0
Coco Creek	373	- -	24-May-12	2457546.370380	403898.030830	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	374	- -	24-May-12	2457556.785710	403930.572760	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	375	- -	24-May-12	2457350.7618	404205.0456	Riffle	Fast	2	2	0	0	3
Coco Creek	376	- -	24-May-12	2457323.147070	404338.252719	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	377	- -	24-May-12	2457281.2157	404608.3591	Run	Moderate	3	3	0	0	3
Coco Creek	378	- -	24-May-12	2457112.287920	404761.279432	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	379	- -	24-May-12	2457073.3999	404778.4795	Run	Moderate	3	3	2	0	3
Coco Creek	380	- -	25-May-12	2457052.424190	404771.695093	Deep pool	- -	- -	- -	- -	- -	- -
Coco Creek	381	- -	25-May-12	2456968.4916	404646.5566	Run	Moderate	2	2	2	0	2
Tributary To Coco Creek	382	- -	24-May-12	2457061.919250	404794.560861	Run	Moderate	1	1	0	0	2
Tributary To Coco Creek	383	- -	24-May-12	2457121.201280	404813.530639	Riffle	Fast	1	1	0	0	3
Tributary To Coco Creek	384	- -	25-May-12	2457135.105780	404846.326178	Deep pool	- -	- -	- -	- -	- -	- -
Tributary To Coco Creek	385	- -	25-May-12	2457137.778020	404881.949794	Run	Slow	1	1	0	0	2
Meadowbrook	386	- -	22-May-12	2453324.6511	391273.0121	Estuary	Slow	2	1	2	0	0
Meadowbrook	387	- -	22-May-12	2453377.6829	391282.9199	Estuary	Slow	2	1	2	0	0
Meadowbrook	388	- -	22-May-12	2453634.0186	391253.1194	Pool	Slow	3	2	3	0	1
Meadowbrook	389	- -	22-May-12	2453839.6255	391390.8619	Run	Slow	2	2	2	1	3
Meadowbrook	390	- -	22-May-12	2453995.4762	391436.8432	Run	Slow	2	1	2	2	2
Meadowbrook	391	- -	22-May-12	2454226.5571	391646.8867	Pool	Slow	3	1	3	2	1
Meadowbrook	392	- -	17-May-12	2454432.5246	391401.8088	Run	Slow	2	2	2	0	1
Meadowbrook	393	- -	17-May-12	2454860.1851	391291.0577	Run	Slow	3	1	3	0	1
Meadowbrook	394	- -	17-May-12	2455400.8150	390918.4659	Run	Slow	3	1	3	1	1
Meadowbrook	395	- -	17-May-12	2455935.0239	390625.0187	Run	Slow	3	1	3	1	0
Meadowbrook	396	- -	22-May-12	2456450.1150	390218.8361	Run	Slow	3	0	3	2	0
Meadowbrook	397	- -	22-May-12	2456846.646387	389896.495841	Deep pool	- -	- -	- -	- -	- -	- -
Meadowbrook	398	- -	22-May-12	2457290.5146	389687.4277	Pond	Slow	1	1	1	1	1
Meadowbrook	399	- -	22-May-12	2457410.0327	389617.5535	Pond	Slow	2	2	1	1	1

Table E-1 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	River Mile	Sample Date	Longitude[b]	Latitude[b]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Meadowbrook	400	- -	22-May-12	2457716.5718	389463.0617	Pond	Slow	1	1	1	1	1
Meadowbrook	401	- -	22-May-12	2457909.0901	389393.3728	Run	Slow	2	1	1	0	0
Meadowbrook	402	- -	22-May-12	2458105.8286	389328.7266	Pond	Slow	1	1	1	2	1
Meadowbrook	403	- -	22-May-12	2458340.5282	389220.4316	Run	Slow	2	2	1	0	3
Tributary to Meadowbrook	404	- -	18-May-12	2454109.615770	391625.588183	Run	Slow	2	1	0	0	0
Tributary to Meadowbrook	405	- -	18-May-12	2454104.897280	391643.857832	Run	Slow	2	1	1	1	0
Tributary to Meadowbrook	406	- -	18-May-12	2454103.203380	391731.302867	Run	Moderate	1	1	1	0	2

NOTE: Instream cover variable rank numbers are defined as follows:

0 = None or Nearly Absent (< 5.0 percent)
1 = Low Abundance (5 to 25 percent)
2 = Moderate Abundance (25 to 75 percent)
3 = High Abundance (greater than 75 percent).

[a]*Cross-section surveys were not conducted in every pool habitat location, however maximum pool depths were recorded.*

[b]*These coordinates are in North American Datum (NAD) 1927 State Plane Wisconsin South Federal Information Processing Standard (FIPS) 4803.*

Source: SEWRPC.

Table E-2

QUANTITATIVE STREAMBANK AND BANKFULL CHARACTERISTICS AMONG HABITAT TYPES WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

		Left Bank				Right Bank				Bankfull							
Reach	Survey ID[a] (see Maps E-1 through E-8)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 1	1	2.8	1.5	0.54	- -	1.7	1.7	01.00	- -	43.2	2.5	2.4	2.0	2.7	2.2	2.40	2.7
Pewaukee 1	2	0.9	1.3	1.44	0.2	1.4	2.1	1.50	0.2	27.1	1.7	1.9	1.9	2.2	2.1	2.00	2.2
Pewaukee 1	3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	4	1.1	1.5	1.36	- -	0.8	2.0	2.50	1.5	20.5	1.9	2.1	2.2	2.2	2.3	2.10	2.3
Pewaukee 1	5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	6	1.1	1.5	1.36	- -	0.8	2.0	2.50	1.5	20.5	1.9	2.1	2.2	2.2	2.3	2.10	2.3
Pewaukee 1	7	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	9	0.5	2.1	4.20	0.4	2.7	1.3	0.48	- -	41.7	2.0	2.0	1.8	1.5	1.2	1.70	2.0
Pewaukee 1	10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	11	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	12	0.9	2.1	2.33	0.5	5.5	2.3	0.42	- -	34.1	2.4	2.1	2.2	2.5	2.6	2.40	2.6
Pewaukee 1	13	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	14	1.4	0.9	0.64	- -	1.2	2.4	2.00	0.3	19.3	1.9	2.1	2.3	2.5	2.6	2.30	2.6
Pewaukee 1	15	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	16	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	17	1.2	1.8	1.50	- -	4.7	2.8	0.60	- -	28.2	3.3	3.3	3.5	3.3	3.5	3.40	3.5
Pewaukee 1	18	2.8	1.5	0.54	- -	3.1	2.5	0.81	1.0	44.3	2.3	2.6	2.5	2.7	2.7	2.60	2.7
Pewaukee 1	19	0.5	3.4	6.80	2.0	4.6	3.0	0.65	- -	24.7	4.3	4.3	4.0	3.7	3.6	4.00	4.3
Pewaukee 1	20	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	22	0.7	2.6	3.71	0.4	1.5	1.9	1.27	0.2	23.3	2.7	2.7	2.8	2.8	2.7	2.70	2.8
Pewaukee 1	23	1.2	1.7	1.42	0.3	1.7	2.4	1.41	0.5	29.1	1.8	1.7	1.8	1.8	2.1	1.80	2.1
Pewaukee 1	24	1.8	2.0	1.11	- -	1.9	2.1	1.11	- -	38.0	2.1	2.1	2.0	2.1	2.2	2.10	2.2
Pewaukee 1	25	0.9	1.6	1.78	- -	0.6	1.7	2.83	0.1	27.2	1.8	1.7	1.9	2.0	2.0	1.90	2.0
Pewaukee 1	26	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	27	1.4	2.0	1.43	- -	1.2	2.1	1.75	0.5	25.3	2.2	2.2	2.3	2.3	2.3	2.30	2.3
Pewaukee 1	28	1.7	1.1	0.65	- -	0.4	2.5	6.25	2.0	19.3	2.1	2.2	2.4	2.6	2.7	2.40	2.7
Pewaukee 1	29	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	30	0.6	2.3	3.83	- -	0.8	1.8	2.25	0.7	29.6	2.8	2.8	2.6	2.6	2.4	2.60	2.8
Pewaukee 1	31	1.4	1.7	1.21	- -	2.0	1.7	0.85	- -	40.1	1.8	1.9	2.0	2.2	2.1	2.00	2.2
Pewaukee 1	32	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	33	1.0	1.1	1.10	- -	1.2	1.6	1.33	- -	20.4	2.0	2.1	2.3	2.5	2.3	2.20	2.5
Pewaukee 1	34	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	35	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	36	1.4	1.1	0.79	- -	2.4	1.4	0.58	- -	21.6	1.3	1.5	1.5	1.5	1.5	1.50	1.5
Pewaukee 1	37	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	38	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	39	2.2	1.9	0.86	- -	1.3	1.5	1.15	0.6	33.7	2.9	3.1	2.5	2.4	2.3	2.60	3.1

Table E-2 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 1	40	1.4	1.1	0.79	- -	1.0	1.1	1.10	0.2	28.4	1.6	1.6	1.6	1.6	1.6	1.60	1.6
Pewaukee 1	41	1.3	0.8	0.62	- -	2.3	1.1	0.48	- -	29.5	1.4	1.4	1.7	1.8	1.6	1.60	1.8
Pewaukee 1	42	1.9	1.6	0.84	- -	0.6	1.8	3.00	0.2	51.4	2.0	2.1	2.5	3.0	2.7	2.50	3.0
Pewaukee 1	43	1.3	1.6	1.23	- -	2.2	1.3	0.59	- -	49.4	2.9	2.9	2.8	2.5	1.9	2.60	2.9
Pewaukee 1	44	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	45	0.6	1.1	1.83	- -	0.9	1.6	1.78	- -	31.3	1.1	1.2	1.3	1.3	1.6	1.30	1.6
Pewaukee 1	46	0.9	1.9	2.11	- -	1.6	1.6	1.00	- -	30.5	2.2	2.2	2.7	2.8	2.4	2.50	2.8
Pewaukee 1	47	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	48	2.7	1.6	0.59	- -	1.1	2.1	1.91	- -	37.2	2.1	2.4	2.6	2.7	2.7	2.50	2.7
Pewaukee 1	49	1.6	2.0	1.25	- -	1.1	1.5	1.36	- -	33.3	3.0	3.0	2.8	3.0	2.3	2.80	3.0
Pewaukee 1	50	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	51	1.4	1.4	1.00	- -	0.9	2.6	2.89	- -	26.2	1.9	2.2	2.6	2.7	2.8	2.40	2.8
Pewaukee 1	52	3.5	1.5	0.43	- -	1.5	1.9	1.27	- -	30.1	2.4	2.7	2.7	2.7	2.8	2.70	2.8
Pewaukee 1	53	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	54	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	55	0.4	3.2	8.00	0.8	1.7	1.4	0.82	- -	21.6	3.7	3.6	3.2	3.2	2.2	3.20	3.7
Pewaukee 1	56	3.8	2.0	0.53	- -	3.5	2.1	0.60	- -	31.2	2.8	2.9	2.8	3.0	3.0	2.90	3.0
Pewaukee 1	57	5.5	1.5	0.27	- -	1.8	1.5	0.83	- -	43.9	1.6	1.7	2.2	2.7	2.8	2.20	2.8
Pewaukee 1	58	1.3	1.7	1.31	- -	3.1	1.4	0.45	- -	37.8	2.5	2.4	2.5	2.0	2.0	2.30	2.5
Pewaukee 1	59	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	60	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	61	3.4	1.9	0.56	- -	3.0	41.6	13.87	0.3	41.6	2.2	2.3	2.4	2.6	2.9	2.50	2.9
Pewaukee 1	62	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	63	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	64	1.4	2.7	1.93	- -	2.0	1.9	0.95	- -	27.4	3.4	3.3	3.2	3.2	3.1	3.20	3.4
Pewaukee 1	65	1.0	1.8	1.80	0.4	1.4	2.4	1.71	0.3	34.2	1.9	1.8	2.0	2.3	2.4	2.10	2.4
Pewaukee 1	66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 1	67	3.2	1.5	0.47	- -	4.3	2.0	0.47	- -	53.4	1.8	2.4	2.8	2.8	2.2	2.40	2.8
Pewaukee 1	68	0.6	2.6	4.33	- -	2.9	1.5	0.52	- -	34.3	3.6	3.8	3.8	2.6	2.0	3.20	3.8
Pewaukee 2	69	3.3	1.2	0.36	- -	0.8	1.6	2.00	- -	30.8	2.0	3.4	3.7	3.3	2.5	3.00	3.7
Pewaukee 2	70	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	71	0.4	1.5	3.75	- -	1.1	1.5	1.36	- -	31.6	2.7	2.9	3.2	3.1	2.9	3.00	3.2
Pewaukee 2	72	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	73	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	74	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	75	2.6	1.2	0.46	- -	0.5	2.2	4.40	0.5	22.7	2.0	2.1	2.1	2.2	2.3	2.10	2.3
Pewaukee 2	76	1.8	1.8	1.00	- -	5.0	2.0	0.40	- -	33.2	3.5	3.8	3.4	2.9	2.6	3.20	3.8
Pewaukee 2	77	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	78	2.0	1.5	0.75	- -	1.0	2.0	2.00	- -	37.2	1.8	2.0	2.4	2.8	2.8	2.40	2.8
Pewaukee 2	79	3.0	1.7	0.57	- -	1.9	1.7	0.89	- -	31.8	2.6	2.9	3.2	3.1	2.9	2.90	3.2
Pewaukee 2	80	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table E-2 (continued)

		Left Bank				Right Bank				Bankfull							
Reach	Survey ID[a] (see Maps E-1 through E-8)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 2	81	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	82	7.9	1.6	0.20	- -	2.8	2.6	0.93	- -	33.5	2.1	2.7	3.5	3.5	3.4	3.00	3.5
Pewaukee 2	83	1.8	1.9	1.06	- -	3.3	1.8	0.55	- -	25.4	3.1	3.1	2.7	3.0	2.3	2.80	3.1
Pewaukee 2	84	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	85	2.7	2.3	0.85	- -	0.5	2.4	4.80	- -	30.9	2.6	2.4	2.6	2.8	3.0	2.70	3.0
Pewaukee 2	86	1.9	1.9	1.00	- -	0.8	2.0	2.50	- -	25.7	2.7	2.8	2.7	3.0	2.9	2.80	3.0
Pewaukee 2	87	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	88	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	89	0.6	2.2	3.67	- -	1.7	2.0	1.18	- -	25.3	2.6	2.1	2.3	2.5	2.9	2.50	2.9
Pewaukee 2	90	2.4	2.1	0.88	- -	1.6	2.0	1.25	- -	28.9	2.7	3.1	3.2	3.3	3.1	3.10	3.3
Pewaukee 2	91	4.5	1.8	0.40	- -	0.5	2.8	5.60	0.4	23.2	2.8	3.8	4.0	4.5	3.9	3.80	4.5
Pewaukee 2	92	2.5	1.8	0.72	- -	2.4	2.1	0.87	- -	33.2	2.3	2.3	3.3	3.5	3.3	2.90	3.5
Pewaukee 2	93	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	94	0.5	2.5	5.00	- -	2.9	1.9	0.66	- -	21.7	3.9	4.4	3.9	3.3	2.8	3.70	4.4
Pewaukee 2	95	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	96	3.0	1.7	0.57	- -	0.9	2.9	3.22	1.2	26.3	2.2	2.8	3.6	3.4	3.6	3.10	3.6
Pewaukee 2	97	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	98	0.7	2.3	3.29	- -	1.6	2.1	1.31	- -	24.4	3.2	3.5	3.4	3.1	2.5	3.10	3.5
Pewaukee 2	99	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	100	3.5	2.0	0.57	- -	1.0	2.5	2.50	- -	24.5	3.1	3.3	3.8	3.7	3.2	3.40	3.8
Pewaukee 2	101	0.8	2.4	3.00	0.5	4.4	2.0	0.45	- -	23.7	2.9	3.0	3.0	2.8	2.2	2.80	3.0
Pewaukee 2	102	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	103	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	104	4.1	2.0	0.49	- -	1.6	2.0	1.25	- -	25.2	2.3	2.8	3.6	3.6	3.2	3.10	3.6
Pewaukee 2	105	5.1	1.8	0.35	- -	0.8	1.8	2.25	- -	35.9	1.9	1.6	1.7	2.1	2.5	2.00	2.5
Pewaukee 2	106	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	107	1.0	2.6	2.60	- -	6.6	1.9	0.29	- -	25.2	3.0	2.8	2.5	2.3	2.1	2.50	3.0
Pewaukee 2	108	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	109	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	110	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	111	3.3	2.5	0.76	- -	1.3	2.4	1.85	- -	30.2	3.6	4.1	3.9	3.5	3.0	3.60	4.1
Pewaukee 2	112	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	113	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	114	1.9	2.4	1.26	- -	1.7	1.3	0.76	- -	32.8	3.0	3.5	3.5	2.7	2.8	3.10	3.5
Pewaukee 2	115	2.4	2.2	0.92	- -	3.1	2.4	0.77	- -	42.5	2.2	2.1	2.8	2.6	2.5	2.40	2.8
Pewaukee 2	116	3.5	1.5	0.43	- -	3.5	1.4	0.40	- -	47.2	1.4	1.3	1.6	1.6	1.3	1.40	1.6
Pewaukee 2	117	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	118	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	119	0.4	1.5	3.75	- -	1.3	1.2	0.92	- -	45.2	0.6	1.7	2.0	1.8	1.5	1.50	2.0
Pewaukee 2	120	0.7	1.5	2.14	- -	0.9	1.8	2.00	- -	39.6	0.9	0.8	1.6	1.9	2.5	1.50	2.5
Pewaukee 2	121	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	122	1.3	2.6	2.00	- -	2.6	2.0	0.77	- -	31.0	2.0	2.4	2.5	2.5	2.4	2.40	2.5

Table E-2 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 2	123	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	124	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	125	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	126	2.2	2.2	1.00	- -	0.9	1.8	2.00	- -	35.8	2.4	2.1	2.5	2.5	2.3	2.40	2.5
Pewaukee 2	127	1.6	1.4	0.88	- -	0.3	2.2	7.33	- -	28.2	2.4	2.5	2.5	3.0	3.1	2.70	3.1
Pewaukee 2	128	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	129	3.4	1.2	0.35	- -	1.0	2.0	2.00	0.8	30.2	1.9	2.2	2.2	2.2	2.2	2.10	2.2
Pewaukee 2	130	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	131	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	132	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	133	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	134	11.2	1.3	0.12	- -	11.5	1.3	0.11	- -	71.2	1.5	1.7	1.8	1.8	1.6	1.70	1.8
Pewaukee 2	135	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	136	10.1	1.0	0.10	- -	13.5	1.1	0.08	- -	66.6	1.5	1.8	2.1	1.7	1.7	1.80	2.1
Pewaukee 2	137	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	138	2.9	1.4	0.48	- -	19.6	1.4	0.07	- -	69.4	1.5	1.6	1.9	2.3	1.7	1.80	2.3
Pewaukee 2	139	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	140	3.9	1.6	0.41	- -	12.1	1.6	0.13	- -	50.5	2.3	2.4	2.2	1.9	1.8	2.10	2.4
Pewaukee 2	141	0.8	1.5	1.88	- -	3.8	1.4	0.37	- -	42.6	2.7	2.9	2.5	2.3	2.0	2.50	2.9
Pewaukee 2	142	2.1	1.2	0.57	- -	2.1	1.4	0.67	- -	32.3	2.2	2.6	2.6	2.1	1.7	2.20	2.6
Pewaukee 2	143	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	144	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	145	5.9	1.4	0.24	- -	0.8	1.6	2.00	- -	35.5	1.7	2.0	2.6	3.2	2.4	2.40	3.2
Pewaukee 2	146	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	147	0.3	1.8	6.00	- -	4.0	1.4	0.35	- -	28.2	2.5	2.4	2.4	1.9	1.7	2.20	2.5
Pewaukee 2	148	5.0	1.5	0.30	- -	1.6	1.7	1.06	- -	44.1	2.0	2.2	2.2	2.4	2.3	2.20	2.4
Pewaukee 2	149	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 2	150	3.1	2.8	0.90	- -	2.1	1.8	0.86	- -	24.9	3.2	3.4	3.3	2.8	2.3	3.00	3.4
Pewaukee 2	151	2.0	1.3	0.65	- -	2.4	1.5	0.62	- -	32.7	2.5	2.5	2.4	2.3	2.2	2.40	2.5
Pewaukee 2	152	1.7	1.3	0.76	- -	1.3	1.9	1.46	- -	28.4	2.3	2.5	2.6	2.8	2.5	2.50	2.8
Pewaukee 3	153	2.4	1.9	0.79	- -	2.4	1.9	0.79	- -	29.6	2.1	2.3	2.3	2.3	2.3	2.30	2.3
Pewaukee 3	154	3.6	2.0	0.56	- -	2.9	1.7	0.59	- -	38.5	2.5	2.5	2.6	3.0	2.7	2.70	3.0
Pewaukee 3	155	3.8	2.1	0.55	- -	2.2	2.1	0.95	- -	33.8	3.0	2.8	2.7	2.8	2.5	2.80	3.0
Pewaukee 3	156	0.9	1.9	2.11	- -	1.7	1.8	1.06	- -	25.3	2.8	3.0	3.1	3.1	2.7	2.90	3.1
Pewaukee 3	157	2.5	1.6	0.64	- -	5.6	1.9	0.34	- -	34.1	2.5	2.8	2.8	2.5	2.0	2.50	2.8
Pewaukee 3	158	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	159	4.3	2.5	0.58	- -	2.9	25.3	8.72	- -	25.3	3.2	3.3	3.0	2.6	2.5	2.90	3.3
Pewaukee 3	160	5.1	2.5	0.49	- -	8.4	2.5	0.30	- -	34.8	3.0	3.3	3.1	3.2	2.8	3.10	3.3
Pewaukee 3	161	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	162	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	163	6.1	1.9	0.31	- -	2.0	2.2	1.10	- -	32.7	2.2	2.5	3.0	3.2	2.8	2.70	3.2

Table E-2 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 3	164	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	165	2.5	1.6	0.64	- -	3.9	2.0	0.51	- -	31.6	2.3	2.6	2.8	2.8	2.2	2.50	2.8
Pewaukee 3	166	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	167	0.8	2.0	2.50	- -	6.7	2.0	0.30	- -	31.8	2.1	2.0	2.2	2.1	2.2	2.10	2.2
Pewaukee 3	168	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	169	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	170	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	171	0.9	1.4	1.56	- -	0.8	1.6	2.00	- -	24.1	3.5	3.6	3.4	3.0	2.6	3.20	3.6
Pewaukee 3	172	0.4	1.7	4.25	- -	0.6	1.6	2.67	- -	46.6	2.0	2.7	3.2	2.4	1.7	2.40	3.2
Pewaukee 3	173	0.4	1.4	3.50	- -	0.9	1.6	1.78	- -	64.5	2.2	2.8	2.7	2.2	1.8	2.30	2.8
Pewaukee 3	174	1.9	1.2	0.63	- -	0.9	1.6	1.78	- -	40.3	3.1	3.1	3.1	2.3	2.2	2.80	3.1
Pewaukee 3	175	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	176	0.4	2.1	5.25	- -	1.2	1.6	1.33	- -	51.2	2.5	2.3	2.5	2.6	2.5	2.50	2.6
Pewaukee 3	177	1.7	1.6	0.94	- -	1.5	1.8	1.20	- -	40.1	2.2	2.4	2.8	3.4	3.0	2.80	3.4
Pewaukee 3	178	1.3	1.7	1.31	- -	3.6	1.6	0.44	- -	55.1	2.9	3.2	2.2	1.8	2.0	2.40	3.2
Pewaukee 3	179	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	180	5.1	2.1	0.41	- -	2.7	2.0	0.74	- -	43.4	2.9	2.8	2.8	2.9	2.7	2.80	2.9
Pewaukee 3	181	4.9	2.4	0.49	- -	2.4	2.1	0.88	- -	36.3	3.1	3.1	2.9	2.6	2.3	2.80	3.1
Pewaukee 3	182	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	183	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	184	2.2	1.4	0.64	- -	4.8	1.8	0.38	- -	34.7	2.0	2.5	2.8	3.3	2.8	2.70	3.3
Pewaukee 3	185	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	186	6.3	1.8	0.29	- -	4.0	1.9	0.48	- -	43.8	2.6	2.6	2.6	2.6	2.6	2.60	2.6
Pewaukee 3	187	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	188	2.8	1.7	0.61	- -	2.8	2.0	0.71	- -	30.6	2.0	2.0	2.1	2.1	2.2	2.10	2.2
Pewaukee 3	189	1.1	1.8	1.64	- -	1.9	1.6	0.84	- -	20.7	2.3	2.8	2.8	2.5	2.3	2.50	2.8
Pewaukee 3	190	1.3	1.3	1.00	- -	2.1	1.6	0.76	- -	28.6	2.5	2.7	2.4	1.3	1.4	2.10	2.7
Pewaukee 3	191	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 3	192	2.6	1.2	0.46	- -	5.9	1.7	0.29	- -	37.4	1.4	1.4	1.8	2.0	1.8	1.70	2.0
Pewaukee 3	193	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	194	2.9	1.5	0.52	- -	3.9	1.8	0.46	- -	41.2	1.5	1.6	2.2	1.8	2.1	1.80	2.2
Pewaukee 4	195	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	196	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	197	1.0	1.5	1.50	- -	3.9	30.6	7.85	- -	30.6	1.6	1.7	2.1	2.1	1.8	1.90	2.1
Pewaukee 4	198	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	199	0.9	1.4	1.56	- -	3.3	1.6	0.48	- -	22.2	1.5	2.2	2.2	2.2	2.0	2.00	2.2
Pewaukee 4	200	2.3	1.2	0.52	- -	2.0	1.3	0.65	- -	46.3	1.6	1.4	1.4	1.8	1.4	1.50	1.8
Pewaukee 4	201	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	202	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	203	3.0	1.1	0.37	- -	3.0	1.9	0.63	- -	16.1	1.3	1.8	2.0	2.1	2.2	1.90	2.2
Pewaukee 4	204	5.1	1.6	0.31	- -	3.7	1.6	0.43	- -	26.4	1.9	2.1	2.2	2.4	2.2	2.20	2.4

Table E-2 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 4	205	2.1	0.4	0.19	- -	0.9	1.5	1.67	- -	16.1	0.7	0.9	1.3	1.4	1.2	1.10	1.4
Pewaukee 4	206	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	207	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	208	0.5	1.1	2.20	- -	0.5	1.2	2.40	- -	10.1	1.5	2.2	2.7	2.4	1.6	2.10	2.7
Pewaukee 4	209	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	210	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	211	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	212	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	213	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	214	0.8	1.2	1.50	- -	0.8	1.1	1.38	- -	10.5	2.0	1.6	1.6	- -	- -	1.70	2.0
Pewaukee 4	215	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	216	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	217	0.4	1.0	2.50	- -	0.8	0.9	1.13	- -	13.1	1.3	1.4	1.4	1.5	1.5	1.40	1.5
Pewaukee 4	218	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	219	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	220	1.0	1.4	1.40	- -	1.0	0.7	0.70	- -	13.1	1.8	1.7	1.7	1.3	1.0	1.50	1.8
Pewaukee 4	221	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	222	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	223	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	224	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	225	1.0	1.7	1.70	- -	0.9	1.7	1.89	- -	9.2	2.6	2.5	2.1	- -	- -	2.40	2.6
Pewaukee 4	226	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	227	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	228	0.7	1.2	1.71	- -	0.5	1.2	2.40	- -	11.4	1.4	1.9	2.2	2.2	1.7	1.90	2.2
Pewaukee 4	229	1.3	1.9	1.46	- -	0.5	2.1	4.20	- -	15.8	2.3	2.2	2.2	2.3	2.2	2.20	2.3
Pewaukee 4	230	1.2	1.7	1.42	- -	3.3	1.7	0.52	- -	26.3	2.0	1.8	1.5	1.4	1.7	1.70	2.0
Pewaukee 4	231	0.7	0.9	1.29	- -	0.8	1.3	1.63	- -	25.2	1.2	1.2	1.4	1.3	1.2	1.30	1.4
Pewaukee 4	232	0.9	1.0	1.11	- -	2.4	1.2	0.50	- -	27.6	1.6	1.0	1.0	1.1	1.3	1.20	1.6
Pewaukee 4	233	0.8	1.0	1.25	- -	0.9	1.2	1.33	- -	20.8	1.2	1.2	1.3	1.1	1.1	1.20	1.3
Pewaukee 4	234	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	235	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	236	0.5	1.8	3.60	- -	1.1	1.5	1.36	- -	17.1	1.7	1.8	2.1	2.2	1.8	1.90	2.2
Pewaukee 4	237	2.1	1.7	0.81	- -	2.8	1.4	0.50	- -	19.1	1.8	2.1	2.3	2.4	1.6	2.00	2.4
Pewaukee 4	238	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	239	0.4	2.2	5.50	- -	1.4	2.3	1.64	- -	12.5	2.1	2.3	2.4	2.6	2.6	2.40	2.6
Pewaukee 4	240	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	241	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	242	0.5	1.8	3.60	- -	3.2	1.5	0.47	- -	15.7	1.8	2.0	2.2	2.0	1.7	1.90	2.2
Pewaukee 4	243	1.5	1.3	0.87	- -	2.2	1.5	0.68	- -	17.7	1.6	1.7	1.9	1.9	1.6	1.70	1.9
Pewaukee 4	244	0.8	2.2	2.75	- -	2.2	1.2	0.55	- -	15.2	2.2	2.0	1.8	1.8	1.6	1.90	2.2
Pewaukee 4	245	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	246	1.0	1.5	1.50	- -	1.8	1.7	0.94	- -	12.7	1.7	1.7	1.8	2.0	2.1	1.90	2.1

Table E-2 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 4	247	1.8	2.1	1.17	- -	0.8	1.7	2.13	- -	13.3	2.1	2.2	2.4	2.6	1.9	2.20	2.6
Pewaukee 4	248	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	249	2.2	1.5	0.68	- -	1.0	1.2	1.20	- -	12.4	2.0	2.1	1.7	1.9	1.7	1.90	2.1
Pewaukee 4	250	0.7	1.1	1.57	- -	2.2	0.7	0.32	- -	22.3	1.3	1.5	1.4	0.9	0.6	1.10	1.5
Pewaukee 4	251	3.9	1.3	0.33	- -	2.7	0.8	0.30	- -	23.8	1.7	1.3	1.2	1.0	1.0	1.20	1.7
Pewaukee 4	252	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	253	2.7	1.1	0.41	- -	1.4	1.1	0.79	- -	25.9	1.2	1.3	2.1	1.3	1.0	1.40	2.1
Pewaukee 4	254	0.5	1.3	2.60	- -	0.6	2.0	3.33	- -	11.2	1.6	1.6	2.0	2.2	2.1	1.90	2.2
Pewaukee 4	255	1.1	1.5	1.36	- -	1.5	1.3	0.87	- -	11.5	2.0	1.7	1.6	1.7	1.6	1.70	2.0
Pewaukee 4	256	5.6	0.7	0.13	- -	1.5	1.1	0.73	- -	30.8	0.8	0.8	1.1	1.2	1.3	1.00	1.3
Pewaukee 4	257	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	258	1.7	1.6	0.94	- -	1.6	1.2	0.75	- -	8.1	1.7	1.8	1.5	- -	- -	1.70	1.8
Pewaukee 4	259	1.2	1.0	0.83	- -	0.7	1.0	1.43	- -	5.1	1.4	1.5	1.3	- -	- -	1.40	1.5
Pewaukee 4	260	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	261	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	262	0.7	0.6	0.86	- -	0.7	0.9	1.29	- -	7.4	1.1	1.3	1.2	- -	- -	1.20	1.3
Pewaukee 4	263	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	264	0.5	0.6	1.20	- -	0.7	1.1	1.57	- -	5.6	1.0	1.3	1.4	- -	- -	1.20	1.4
Pewaukee 4	265	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	266	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 4	267	0.3	1.6	5.33	- -	0.9	0.9	1.00	- -	4.9	1.4	1.3	1.1	- -	- -	1.30	1.4
Pewaukee 4	268	0.7	1.3	1.86	- -	0.6	1.6	2.67	- -	6.2	1.6	1.4	1.6	- -	- -	1.50	1.6
Pewaukee 4	269	0.8	0.9	1.13	- -	1.4	0.9	0.64	- -	9.2	1.4	1.5	1.5	- -	- -	1.50	1.5
Pewaukee 4	270	0.6	1.1	1.83	- -	1.6	1.0	0.63	- -	7.2	1.5	1.7	1.2	- -	- -	1.50	1.7
Pewaukee 4	271	0.6	0.8	1.33	- -	0.8	1.0	1.25	- -	5.6	1.2	1.3	1.3	- -	- -	1.30	1.3
Pewaukee 4	272	0.4	1.8	4.50	- -	0.5	1.9	3.80	- -	5.4	1.7	1.9	2.0	- -	- -	1.90	2.0
Pewaukee 5	273	1.4	2.1	1.50	- -	0.5	1.6	3.20	- -	5.1	1.9	2.0	1.9	- -	- -	1.90	2.0
Pewaukee 5	274	1.0	1.2	1.20	- -	0.7	1.8	2.57	0.6	5.2	1.5	1.7	1.7	- -	- -	1.60	1.7
Pewaukee 5	275	0.5	0.8	1.60	- -	1.1	1.0	0.91	- -	6.4	1.0	1.0	1.1	- -	- -	1.00	1.1
Pewaukee 5	276	1.2	0.7	0.58	- -	6.0	0.9	0.15	- -	19.2	1.1	1.0	1.1	0.9	0.9	1.00	1.1
Pewaukee 5	277	0.3	1.2	4.00	0.4	0.7	1.0	1.43	- -	7.3	1.2	1.2	1.2	- -	- -	1.20	1.2
Pewaukee 5	278	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 5	279	0.5	0.9	1.80	- -	1.8	0.9	0.50	- -	6.7	1.2	1.1	1.3	- -	- -	1.20	1.3
Pewaukee 5	280	0.7	1.0	1.43	- -	1.2	0.8	0.67	- -	7.3	1.4	1.2	1.2	- -	- -	1.30	1.4
Pewaukee 5	281	0.3	1.5	5.00	- -	0.9	1.0	1.11	- -	4.7	1.7	1.6	1.3	- -	- -	1.50	1.7
Pewaukee 5	282	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -0	- -
Pewaukee 5	283	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 5	284	0.6	1.5	2.50	- -	0.4	1.7	4.25	0.3	4.7	1.6	1.8	2.1	- -	- -	1.80	2.1
Pewaukee 5	285	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 5	286	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 5	287	0.1	1.5	15.00	0.3	0.5	1.3	2.60	- -	5.3	1.6	1.5	1.4	- -	- -	1.50	1.6

Table E-2 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 5	288	0.2	1.6	8.00	0.7	0.5	1.1	2.20	- -	5.0	1.7	1.6	1.3	- -	- -	1.50	1.7
Pewaukee 5	289	0.3	0.8	2.67	- -	0.3	1.1	3.67	- -	4.6	1.0	1.3	1.4	- -	- -	1.20	1.4
Pewaukee 5	290	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 5	291	0.3	1.2	4.00	- -	0.7	1.4	2.00	0.3	5.7	1.4	1.7	1.7	- -	- -	1.60	1.7
Pewaukee 5	292	2.3	1.1	0.48	- -	1.0	1.2	1.20	- -	17.2	1.1	1.2	1.2	1.2	1.3	1.20	1.3
Pewaukee 5	293	0.8	0.8	1.00	- -	1.0	0.7	0.70	- -	6.6	1.0	1.0	1.0	- -	- -	1.00	1.0
Pewaukee 5	294	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 5	295	0.4	1.0	2.50	- -	0.6	1.3	2.17	- -	5.2	1.3	1.7	1.5	- -	- -	1.50	1.7
Pewaukee 5	296	0.2	1.8	9.00	- -	0.5	1.6	3.20	- -	4.2	1.7	1.9	1.6	- -	- -	1.70	1.9
Pewaukee 5	297	0.6	1.9	3.17	- -	0.9	1.8	2.00	- -	5.3	2.3	2.5	2.2	- -	- -	2.30	2.5
Pewaukee 5	298	1.8	1.9	1.06	- -	1.8	1.6	0.89	- -	6.6	2.2	2.2	2.1	- -	- -	2.20	2.2
Pewaukee 5	299	0.6	1.1	1.83	- -	2.0	1.0	0.50	- -	5.5	1.5	1.7	1.3	- -	- -	1.50	1.7
Pewaukee 5	300	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee 5	301	0.4	1.5	3.75	- -	0.4	1.6	4.00	0.5	4.8	1.7	1.9	1.8	- -	- -	1.80	1.9
Pewaukee 5	302	1.1	1.4	1.27	- -	1.5	1.3	0.87	- -	8.3	1.8	1.9	1.9	- -	- -	1.90	1.9
Pewaukee 5	303	0.8	1.0	1.25	- -	2.4	1.0	0.42	- -	11.0	1.3	1.5	1.3	- -	- -	1.40	1.5
Pewaukee 5	304	1.1	1.5	1.36	- -	2.5	1.6	0.64	- -	10.8	1.7	1.9	1.8	- -	- -	1.80	1.9
Pewaukee 5	305	0.1	1.0	10.00	- -	0.4	1.0	2.50	- -	6.0	1.2	1.2	1.2	- -	- -	1.20	1.2
HWY JJ Tributary	306	8.2	1.7	0.21	- -	4.2	1.6	0.38	- -	18.8	2.0	2.1	1.9	- -	- -	2.00	2.1
HWY JJ Tributary	307	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	308	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	309	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	310	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	311	3.8	1.8	0.47	- -	1.2	1.7	1.42	- -	10.4	2.0	2.3	2.1	- -	- -	2.10	2.3
HWY JJ Tributary	312	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	313	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	314	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	315	1.3	1.5	1.15	- -	0.9	1.9	2.11	- -	6.3	2.0	2.1	2.1	- -	- -	2.10	2.1
HWY JJ Tributary	316	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	317	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	318	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	319	0.7	1.3	1.86	- -	1.2	1.1	0.92	- -	6.4	1.7	1.9	2.1	- -	- -	1.90	2.1
HWY JJ Tributary	320	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	321	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	322	0.4	2.2	5.50	0.7	1.9	2.3	1.21	- -	5.9	2.4	2.5	2.5	- -	- -	2.50	2.5
HWY JJ Tributary	323	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	324	1.5	1.7	1.13	- -	0.9	1.9	2.11	- -	7.1	2.0	2.3	2.2	- -	- -	2.20	2.3
HWY JJ Tributary	325	1.0	1.5	1.50	- -	1.2	1.9	1.58	- -	9.6	2.0	2.0	2.1	- -	- -	2.00	2.1
HWY JJ Tributary	326	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	327	0.9	1.8	2.00	- -	1.6	1.8	1.13	- -	10.2	2.3	2.3	2.1	- -	- -	2.20	2.3
HWY JJ Tributary	328	1.2	2.0	1.67	- -	1.4	2.4	1.71	- -	12.8	2.3	2.3	2.3	2.3	2.3	2.30	2.3

Table E-2 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
HWY JJ Tributary	329	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	330	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	331	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	332	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	333	1.2	2.0	1.67	- -	1.2	1.9	1.58	- -	13.1	3.0	2.9	2.6	2.5	2.2	2.60	3.0
HWY JJ Tributary	334	1.7	1.1	0.65	- -	1.4	1.3	0.93	- -	17.6	1.5	1.3	1.4	1.4	1.7	1.50	1.7
HWY JJ Tributary	335	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	336	1.3	0.9	0.69	- -	1.1	0.9	0.82	- -	14.0	1.0	1.0	1.2	1.3	1.5	1.20	1.5
HWY JJ Tributary	337	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	338	2.9	1.0	0.34	- -	1.9	1.2	0.63	- -	14.7	1.1	1.3	1.4	1.4	1.4	1.30	1.4
HWY JJ Tributary	339	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	340	0.6	1.4	2.33	- -	3.0	1.3	0.43	- -	11.5	1.4	1.5	1.6	- -	- -	1.50	1.6
HWY JJ Tributary	341	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	342	0.6	1.9	3.17	- -	0.9	1.7	1.89	- -	11.0	2.5	2.5	2.3	- -	- -	2.40	2.5
HWY JJ Tributary	343	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	344	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	345	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
HWY JJ Tributary	346	1.3	1.7	1.31	- -	3.7	2.3	0.62	- -	15.6	2.3	2.9	3.3	3.2	2.7	2.90	3.3
HWY JJ Tributary	347	0.6	1.5	2.50	- -	3.0	1.8	0.60	- -	12.3	2.0	2.2	2.3	2.4	2.2	2.20	2.4
HWY JJ Tributary	348	0.7	2.5	3.57	- -	1.4	2.6	1.86	- -	9.3	4.0	4.0	3.9	- -	- -	4.00	4.0
HWY JJ Tributary	349	2.4	2.5	1.04	- -	2.1	2.6	1.24	- -	16.4	2.9	2.1	2.7	2.8	2.8	2.70	2.9
HWY JJ Tributary	350	0.7	1.7	2.43	- -	2.2	1.8	0.82	- -	11.3	2.4	2.4	2.2	- -	- -	2.30	2.4
Pewaukee Lake Outlet	351	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Pewaukee Lake Outlet	352	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Pewaukee Lake Outlet	353	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pewaukee Lake Outlet	354	3.5	1.4	.40	- -	7.0	1.4	0.20	- -	38.2	1.4	1.4	1.4	1.6	1.9	1.50	1.9
Pewaukee Lake Outlet	355	9.3	1.6	.17	- -	6.1	1.9	0.31	- -	46.1	1.5	1.6	1.8	1.9	2.4	1.80	2.4
Coco Creek	356	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Coco Creek	357	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Coco Creek	358	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Coco Creek	359	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Coco Creek	360	0.2	2.1	10.50	- -	0.6	1.7	2.83	- -	25.8	2.2	2.4	2.5	2.7	2.0	2.40	2.7
Coco Creek	361	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	362	0.5	1.8	3.60	- -	0.8	1.5	1.88	- -	18.8	2.8	2.9	2.7	2.9	1.9	2.60	2.9
Coco Creek	363	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	364	0.5	1.5	3.00	0.8	0.5	13.6	27.20	0.4	13.6	2.5	2.6	3.2	3.2	2.5	2.80	3.2
Coco Creek	365	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	366	0.4	1.7	4.25	0.7	0.5	1.9	3.80	0.5	12.1	1.9	2.0	2.1	2.1	2.0	2.00	2.1
Coco Creek	367	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	368	0.4	1.4	3.50	- -	0.0	1.1	- -	- -	17.0	2.1	2.3	2.3	2.1	2.1	2.20	2.3
Coco Creek	369	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table E-2 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (feet)	Length (feet)	Height (feet)	Slope	Undercut (feet)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Coco Creek	370	0.3	1.1	3.67	- -	0.6	1.1	1.83	- -	15.2	2.2	2.3	2.5	2.7	2.1	2.40	2.7
Coco Creek	371	0.5	1.7	3.40	- -	0.8	2.1	2.63	0.5	11.8	2.2	2.7	3.0	2.9	2.6	2.70	3.0
Coco Creek	372	0.3	2.0	6.67	- -	1.2	1.5	1.25	- -	11.4	2.3	2.4	2.3	2.3	2.2	2.30	2.4
Coco Creek	373	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	374	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	375	2.2	2.1	0.95	- -	3.6	2.1	0.58	- -	18.4	2.3	2.3	2.3	2.3	2.3	2.30	2.3
Coco Creek	376	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	377	1.7	2.2	1.29	- -	2.3	2.0	0.87	- -	16.2	2.6	2.5	2.9	3.0	2.5	2.70	3.0
Coco Creek	378	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	379	0.7	1.7	2.43	- -	1.4	1.7	1.21	- -	20.1	1.9	1.9	1.7	2.1	2.6	2.00	2.6
Coco Creek	380	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Coco Creek	381	1.2	1.4	1.17	- -	2.4	1.2	0.50	- -	17.5	1.6	1.7	1.7	1.6	1.5	1.60	1.7
Tributary to Coco Creek	382	0.6	1.1	1.83	- -	0.6	1.2	2.0	- -	5.7	1.6	1.6	1.4	- -	- -	1.53	1.6
Tributary to Coco Creek	383	1.2	1.1	0.92	- -	1.5	1.3	0.87	- -	3.6	1.3	1.3	1.2	- -	- -	1.27	1.3
Tributary to Coco Creek	384	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Tributary to Coco Creek	385	0.4	1.7	4.25	- -	0.7	1.5	2.14	- -	8.6	2.4	2.7	2.5	- -	- -	2.53	2.7
Meadowbrook	386	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Meadowbrook	387	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Meadowbrook	388	0.0	2.2	- -	- -	1.4	1.3	0.93	- -	47.5	2.2	2.1	2.1	2.3	1.8	2.10	2.3
Meadowbrook	389	1.8	0.9	0.50	- -	6.9	1.0	0.14	- -	35.6	2.2	2.6	2.1	1.6	1.2	1.90	2.6
Meadowbrook	390	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Meadowbrook	391	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Meadowbrook	392	0.4	1.5	3.75	- -	1.2	1.8	1.50	- -	24.5	1.7	2.0	2.3	2.4	2.3	2.10	2.4
Meadowbrook	393	0.3	1.2	4.0	- -	1.6	1.0	0.62	- -	28.5	1.5	1.6	1.7	1.6	1.6	1.60	1.7
Meadowbrook	394	0.4	1.0	2.50	- -	0.8	1.0	1.25	- -	34.4	1.2	1.5	1.4	1.2	1.0	1.30	1.5
Meadowbrook	395	0.3	1.5	5.0	- -	0.4	1.3	3.25	- -	18.9	1.7	1.9	2.1	2.1	1.8	1.90	2.1
Meadowbrook	396	0.3	1.6	5.33	- -	1.4	1.3	0.93	- -	16.7	1.8	1.9	2.0	1.8	1.7	1.80	2.0
Meadowbrook	397	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Meadowbrook	398	- -	- -	- -	- -	0.0	- -	- -	0.8	- -	- -	- -	- -	- -	- -	- -	0.0
Meadowbrook	399	- -	- -	- -	0.2	0.0	- -	- -	0.8	- -	- -	- -	- -	- -	- -	- -	0.0
Meadowbrook	400	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Meadowbrook	401	0.3	1.6	5.33	0.2	0.7	1.6	2.29	- -	21.4	1.8	2.0	2.5	2.5	2.2	2.20	2.5
Meadowbrook	402	- -	- -	- -	- -	0.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.0
Meadowbrook	403	2.1	1.2	0.57	- -	2.1	1.0	0.48	- -	15.3	1.3	1.5	1.5	1.4	1.3	1.40	1.5
Tributary to Meadowbrook	404	0.4	1.0	2.50	- -	0.5	1.2	2.40	- -	2.7	1.3	1.4	1.4	- -	- -	1.37	1.4
Tributary to Meadowbrook	405	0.2	1.1	5.50	- -	0.5	10.9	21.80	- -	10.3	1.0	1.2	1.0	1.0	1.1	1.06	1.2
Tributary to Meadowbrook	406	0.7	1.7	2.43	- -	4.5	0.8	0.18	- -	4.6	0.9	1.0	0.9	- -	- -	0.93	1.0

[a]*Cross-section surveys were not conducted in every pool habitat location, however maximum pool depths were recorded.*

Source: SEWRPC.

Table E-3

QUANTITATIVE INSTREAM LOW FLOW CHARACTERISTICS AMONG HABITAT TYPES WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 1	1	39.4	1.2	1.3	1.1	1.7	1.1	- -	- -	- -	- -	- -	1.30	1.7
Pewaukee 1	2	25.3	0.5	0.8	0.9	1.1	0.9	- -	- -	- -	- -	- -	0.80	1.1
Pewaukee 1	3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.9
Pewaukee 1	4	19.2	0.9	1.1	1.3	1.4	1.4	- -	- -	- -	- -	- -	1.20	1.4
Pewaukee 1	5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.9
Pewaukee 1	6	22.0	1.1	1.3	1.4	1.8	1.5	- -	- -	- -	- -	- -	1.40	1.8
Pewaukee 1	7	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 1	8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.3
Pewaukee 1	9	38.6	1.4	1.5	1.3	0.9	1.2	- -	- -	- -	- -	- -	1.30	1.5
Pewaukee 1	10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 1	11	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.9
Pewaukee 1	12	29.2	1.2	1.2	1.1	1.4	1.3	- -	- -	- -	- -	- -	1.20	1.4
Pewaukee 1	13	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 1	14	16.6	1.1	1.4	1.6	1.7	1.8	- -	- -	- -	- -	- -	1.50	1.8
Pewaukee 1	15	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.8
Pewaukee 1	16	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 1	17	22.1	1.8	1.8	2.0	1.8	1.9	- -	- -	- -	- -	- -	1.90	2.0
Pewaukee 1	18	38.8	1.3	1.7	1.5	1.7	1.6	- -	- -	- -	- -	- -	1.60	1.7
Pewaukee 1	19	21.2	2.0	1.9	1.5	1.1	0.9	- -	- -	- -	- -	- -	1.50	2.0
Pewaukee 1	20	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.2
Pewaukee 1	21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.5
Pewaukee 1	22	21.6	1.8	1.8	1.9	2.0	1.8	- -	- -	- -	- -	- -	1.90	2.0
Pewaukee 1	23	26.7	1.1	1.0	1.1	1.2	1.3	- -	- -	- -	- -	- -	1.10	1.3
Pewaukee 1	24	35.6	1.2	1.3	1.3	1.3	1.3	- -	- -	- -	- -	- -	1.30	1.3
Pewaukee 1	25	23.5	1.2	1.1	1.4	1.6	1.5	- -	- -	- -	- -	- -	1.40	1.6
Pewaukee 1	26	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.3
Pewaukee 1	27	23.4	1.3	1.4	1.4	1.3	1.3	- -	- -	- -	- -	- -	1.30	1.4
Pewaukee 1	28	17.2	1.2	1.4	1.7	1.8	1.8	- -	- -	- -	- -	- -	1.60	1.8
Pewaukee 1	29	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.8
Pewaukee 1	30	27.9	2.0	2.1	2.0	2.0	1.8	- -	- -	- -	- -	- -	2.00	2.1
Pewaukee 1	31	37.9	1.0	1.2	1.5	1.8	1.5	- -	- -	- -	- -	- -	1.40	1.8
Pewaukee 1	32	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 1	33	18.8	1.4	1.6	1.8	2.0	2.3	- -	- -	- -	- -	- -	1.80	2.3
Pewaukee 1	34	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4.2
Pewaukee 1	35	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
Pewaukee 1	36	18.8	0.6	0.7	0.7	0.7	0.6	- -	- -	- -	- -	- -	0.70	0.7
Pewaukee 1	37	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.3
Pewaukee 1	38	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 1	39	30.5	1.3	1.6	1.1	1.1	1.0	- -	- -	- -	- -	- -	1.20	1.6
Pewaukee 1	40	25.9	6.0	0.8	0.8	0.7	0.7	- -	- -	- -	- -	- -	1.80	6.0
Pewaukee 1	41	25.8	0.7	0.8	1.0	1.0	0.7	- -	- -	- -	- -	- -	0.80	1.0
Pewaukee 1	42	49.4	0.9	1.1	1.5	2.3	2.9	- -	- -	- -	- -	- -	1.70	2.9

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 1	43	46.7	2.6	2.5	2.4	1.8	1.2	- -	- -	- -	- -	- -	2.10	2.6
Pewaukee 1	44	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4.4
Pewaukee 1	45	30.0	0.5	0.7	0.7	0.7	0.7	- -	- -	- -	- -	- -	0.70	0.7
Pewaukee 1	46	28.5	1.3	1.5	1.9	2.0	1.4	- -	- -	- -	- -	- -	1.60	2.0
Pewaukee 1	47	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 1	48	33.5	0.8	1.2	1.5	1.6	1.4	- -	- -	- -	- -	- -	1.30	1.6
Pewaukee 1	49	31.0	1.6	1.7	1.6	1.9	1.1	- -	- -	- -	- -	- -	1.60	1.9
Pewaukee 1	50	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.7
Pewaukee 1	51	24.3	0.8	1.1	1.5	1.5	1.5	- -	- -	- -	- -	- -	1.30	1.5
Pewaukee 1	52	25.4	1.2	1.5	1.4	1.4	1.3	- -	- -	- -	- -	- -	1.40	1.5
Pewaukee 1	53	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 1	54	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
Pewaukee 1	55	20.2	2.5	2.5	2.2	2.2	1.1	- -	- -	- -	- -	- -	2.10	2.5
Pewaukee 1	56	24.3	1.1	1.3	1.2	1.3	1.1	- -	- -	- -	- -	- -	1.20	1.3
Pewaukee 1	57	37.3	0.5	0.8	1.4	1.9	1.9	- -	- -	- -	- -	- -	1.30	1.9
Pewaukee 1	58	33.5	1.4	1.4	1.5	1.1	0.9	- -	- -	- -	- -	- -	1.30	1.5
Pewaukee 1	59	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 1	60	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 1	61	35.5	0.7	1.0	1.1	1.4	1.5	- -	- -	- -	- -	- -	1.10	1.5
Pewaukee 1	62	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
Pewaukee 1	63	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.7
Pewaukee 1	64	23.8	1.8	1.8	1.7	1.7	1.5	- -	- -	- -	- -	- -	1.70	1.8
Pewaukee 1	65	32.3	0.5	0.5	0.5	1.1	1.1	- -	- -	- -	- -	- -	0.70	1.1
Pewaukee 1	66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.7
Pewaukee 1	67	45.7	0.5	1.1	1.5	1.5	0.7	- -	- -	- -	- -	- -	1.10	1.5
Pewaukee 1	68	31.2	2.2	2.5	2.6	1.5	0.8	- -	- -	- -	- -	- -	1.90	2.6
Pewaukee 2	69	26.7	1.0	2.4	2.7	2.2	1.3	- -	- -	- -	- -	- -	1.90	2.7
Pewaukee 2	70	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 2	71	30.3	1.3	1.7	2.0	1.9	1.6	- -	- -	- -	- -	- -	1.70	2.0
Pewaukee 2	72	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4.2
Pewaukee 2	73	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.7
Pewaukee 2	74	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.9
Pewaukee 2	75	19.8	1.0	1.1	1.1	1.2	1.3	- -	- -	- -	- -	- -	1.10	1.3
Pewaukee 2	76	26.5	1.8	2.2	1.8	1.2	0.8	- -	- -	- -	- -	- -	1.60	2.2
Pewaukee 2	77	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.5
Pewaukee 2	78	34.6	0.5	0.9	1.3	1.6	1.4	- -	- -	- -	- -	- -	1.10	1.6
Pewaukee 2	79	26.6	1.2	1.6	1.9	1.7	1.4	- -	- -	- -	- -	- -	1.60	1.9
Pewaukee 2	80	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 2	81	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4.1
Pewaukee 2	82	23.0	0.7	1.3	2.2	2.1	2.0	- -	- -	- -	- -	- -	1.70	2.2
Pewaukee 2	83	20.1	1.3	1.4	1.1	1.4	0.7	- -	- -	- -	- -	- -	1.20	1.4
Pewaukee 2	84	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.8
Pewaukee 2	85	27.6	1.2	1.1	1.3	1.4	1.6	- -	- -	- -	- -	- -	1.30	1.6
Pewaukee 2	86	22.8	1.0	1.2	1.0	1.3	1.1	- -	- -	- -	- -	- -	1.10	1.3
Pewaukee 2	87	23.3	1.2	0.7	1.0	1.2	1.5	- -	- -	- -	- -	- -	1.10	1.5

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 2	88	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 2	89	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.3
Pewaukee 2	90	25.4	0.9	1.6	1.7	1.8	1.6	- -	- -	- -	- -	- -	1.50	1.8
Pewaukee 2	91	18.8	1.2	2.2	2.4	2.9	2.2	- -	- -	- -	- -	- -	2.20	2.9
Pewaukee 2	92	28.9	0.8	0.9	1.7	2.0	1.8	- -	- -	- -	- -	- -	1.40	2.0
Pewaukee 2	93	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.5
Pewaukee 2	94	18.9	2.3	2.8	2.4	1.8	1.2	- -	- -	- -	- -	- -	2.10	2.8
Pewaukee 2	95													4.6
Pewaukee 2	96	22.9	0.7	1.3	2.0	1.7	1.7	- -	- -	- -	- -	- -	1.50	2.0
Pewaukee 2	97	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 2	98	22.7	1.5	1.9	1.7	1.5	0.8	- -	- -	- -	- -	- -	1.50	1.9
Pewaukee 2	99	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 2	100	20.4	1.4	1.6	2.2	2.1	1.6	- -	- -	- -	- -	- -	1.80	2.2
Pewaukee 2	101	18.8	1.1	1.2	1.2	1.0	0.4	- -	- -	- -	- -	- -	1.00	1.2
Pewaukee 2	102	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 2	103	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.4
Pewaukee 2	104	19.7	0.5	1.1	1.9	1.8	1.3	- -	- -	- -	- -	- -	1.30	1.9
Pewaukee 2	105	30.8	0.5	0.3	0.5	0.8	1.1	- -	- -	- -	- -	- -	0.60	1.1
Pewaukee 2	106	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.8
Pewaukee 2	107	17.8	1.4	1.3	1.0	0.6	0.3	- -	- -	- -	- -	- -	0.90	1.4
Pewaukee 2	108	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 2	109	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4.2
Pewaukee 2	110	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4.1
Pewaukee 2	111	25.1	1.3	2.0	1.9	1.5	0.9	- -	- -	- -	- -	- -	1.50	2.0
Pewaukee 2	112	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 2	113	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 2	114	28.8	1.0	1.6	1.7	1.0	1.0	- -	- -	- -	- -	- -	1.30	1.7
Pewaukee 2	115	37.2	0.4	0.5	1.3	0.9	0.6	- -	- -	- -	- -	- -	0.70	1.3
Pewaukee 2	116	41.1	0.4	0.3	0.5	0.7	0.2	- -	- -	- -	- -	- -	0.40	0.7
Pewaukee 2	117	42.0	0.7	0.8	1.1	1.0	0.7	- -	- -	- -	- -	- -	0.90	1.1
Pewaukee 2	118	34.3	0.8	1.2	1.3	1.4	1.0	- -	- -	- -	- -	- -	1.10	1.4
Pewaukee 2	119	43.5	0.8	0.8	1.2	1.0	0.6	- -	- -	- -	- -	- -	0.90	1.2
Pewaukee 2	120	38.0	0.2	0.4	1.1	1.3	1.7	- -	- -	- -	- -	- -	0.90	1.7
Pewaukee 2	121	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.8
Pewaukee 2	122	27.7	0.5	0.9	1.1	1.0	0.7	- -	- -	- -	- -	- -	0.80	1.1
Pewaukee 2	123	24.8	0.6	1.1	1.5	1.4	0.8	- -	- -	- -	- -	- -	1.10	1.5
Pewaukee 2	124	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 2	125	28.5	1.0	1.1	0.8	0.7	0.3	- -	- -	- -	- -	- -	0.80	1.1
Pewaukee 2	126	33.2	0.5	0.4	0.9	1.1	1.0	- -	- -	- -	- -	- -	0.80	1.1
Pewaukee 2	127	26.5	1.3	1.4	1.3	1.7	1.7	- -	- -	- -	- -	- -	1.50	1.7
Pewaukee 2	128	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.3
Pewaukee 2	129	26.3	0.8	1.2	1.2	1.1	0.9	- -	- -	- -	- -	- -	1.00	1.2
Pewaukee 2	130	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 2	131	39.7	0.7	1.1	1.1	1.3	0.5	- -	- -	- -	- -	- -	0.90	1.3
Pewaukee 2	132	33.1	0.5	0.7	1.4	1.4	1.1	- -	- -	- -	- -	- -	1.00	1.4

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 2	133	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.7
Pewaukee 2	134	49.1	0.6	1.0	1.2	0.9	0.7	- -	- -	- -	- -	- -	0.90	1.2
Pewaukee 2	135	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
Pewaukee 2	136	43.4	0.7	1.1	1.4	1.1	0.8	- -	- -	- -	- -	- -	1.00	1.4
Pewaukee 2	137	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 2	138	47.4	0.3	0.6	0.9	1.4	0.7	- -	- -	- -	- -	- -	0.80	1.4
Pewaukee 2	139	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.4
Pewaukee 2	140	34.7	0.9	1.1	0.9	0.7	0.5	- -	- -	- -	- -	- -	0.80	1.1
Pewaukee 2	141	37.9	1.6	1.9	1.5	1.3	0.8	- -	- -	- -	- -	- -	1.40	1.9
Pewaukee 2	142	28.0	1.5	1.9	1.8	1.2	0.7	- -	- -	- -	- -	- -	1.40	1.9
Pewaukee 2	143	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 2	144	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 2	145	28.9	0.6	1.1	1.7	2.3	1.5	- -	- -	- -	- -	- -	1.40	2.3
Pewaukee 2	146	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 2	147	24.4	1.5	1.5	1.4	0.8	0.5	- -	- -	- -	- -	- -	1.10	1.5
Pewaukee 2	148	37.5	0.7	1.0	1.0	1.1	0.8	- -	- -	- -	- -	- -	0.90	1.1
Pewaukee 2	149	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 2	150	20.0	1.3	1.6	1.6	1.1	0.6	- -	- -	- -	- -	- -	1.20	1.6
Pewaukee 2	151	28.3	1.4	1.5	1.4	1.3	1.0	- -	- -	- -	- -	- -	1.30	1.5
Pewaukee 2	152	25.4	1.2	1.5	1.6	1.7	1.3	- -	- -	- -	- -	- -	1.50	1.7
Pewaukee 3	153	25.0	0.3	0.6	0.6	0.8	0.7	- -	- -	- -	- -	- -	0.60	0.8
Pewaukee 3	154	31.7	0.9	1.0	1.1	1.6	1.2	- -	- -	- -	- -	- -	1.20	1.6
Pewaukee 3	155	28.0	1.1	1.0	1.0	1.1	0.7	- -	- -	- -	- -	- -	1.00	1.1
Pewaukee 3	156	22.7	1.2	1.5	1.7	1.7	1.2	- -	- -	- -	- -	- -	1.50	1.7
Pewaukee 3	157	26.0	1.1	1.3	1.4	1.0	0.4	- -	- -	- -	- -	- -	1.00	1.4
Pewaukee 3	158	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.8
Pewaukee 3	159	18.7	1.2	1.3	1.0	0.7	0.5	- -	- -	- -	- -	- -	0.90	1.3
Pewaukee 3	160	21.7	0.7	1.2	1.0	1.1	0.6	- -	- -	- -	- -	- -	0.90	1.2
Pewaukee 3	161	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.7
Pewaukee 3	162	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 3	163	24.0	0.4	0.7	1.2	1.3	0.9	- -	- -	- -	- -	- -	0.90	1.3
Pewaukee 3	164	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.5
Pewaukee 3	165	25.5	0.9	1.2	1.3	1.2	0.6	- -	- -	- -	- -	- -	1.00	1.3
Pewaukee 3	166	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.7
Pewaukee 3	167	24.3	0.4	0.4	0.6	0.4	0.4	- -	- -	- -	- -	- -	0.40	0.6
Pewaukee 3	168	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 3	169	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.4
Pewaukee 3	170	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.3
Pewaukee 3	171	22.6	2.4	2.6	2.3	1.9	1.4	- -	- -	- -	- -	- -	2.10	2.6
Pewaukee 3	172	45.8	1.3	2.3	2.6	1.8	1.1	- -	- -	- -	- -	- -	1.80	2.6
Pewaukee 3	173	63.4	1.4	2.0	2.0	1.5	0.8	- -	- -	- -	- -	- -	1.50	2.0
Pewaukee 3	174	37.5	2.2	2.2	2.3	1.5	1.3	- -	- -	- -	- -	- -	1.90	2.3
Pewaukee 3	175	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.9
Pewaukee 3	176	49.9	1.6	1.5	1.7	1.7	1.3	- -	- -	- -	- -	- -	1.60	1.7
Pewaukee 3	177	36.8	0.9	1.2	1.7	2.1	1.4	- -	- -	- -	- -	- -	1.50	2.1

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 3	178	50.2	1.7	2.2	1.3	0.9	0.9	- -	- -	- -	- -	- -	1.40	2.2
Pewaukee 3	179	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 3	180	35.6	1.4	1.4	1.5	1.4	1.1	- -	- -	- -	- -	- -	1.40	1.5
Pewaukee 3	181	29.6	1.5	1.6	1.3	0.9	0.4	- -	- -	- -	- -	- -	1.10	1.6
Pewaukee 3	182	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
Pewaukee 3	183	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 3	184	28.5	0.8	1.3	1.6	2.0	1.5	- -	- -	- -	- -	- -	1.40	2.0
Pewaukee 3	185	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.8
Pewaukee 3	186	34.6	1.2	1.2	1.2	1.0	0.9	- -	- -	- -	- -	- -	1.10	1.2
Pewaukee 3	187	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.9
Pewaukee 3	188	24.4	0.6	0.7	0.7	0.7	0.6	- -	- -	- -	- -	- -	0.70	0.7
Pewaukee 3	189	17.7	0.7	1.2	1.3	1.0	0.8	- -	- -	- -	- -	- -	1.00	1.3
Pewaukee 3	190	25.2	1.4	1.6	1.3	1.1	1.0	- -	- -	- -	- -	- -	1.30	1.6
Pewaukee 3	191	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.3
Pewaukee 3	192	28.5	0.5	0.5	0.9	1.0	0.6	- -	- -	- -	- -	- -	0.70	1.0
Pewaukee 3	193	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.7
Pewaukee 4	194	34.4	0.2	0.3	0.9	0.5	0.6	- -	- -	- -	- -	- -	0.50	0.9
Pewaukee 4	195	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
Pewaukee 4	196	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.3
Pewaukee 4	197	25.7	0.3	0.5	0.9	0.9	0.6	- -	- -	- -	- -	- -	0.60	0.9
Pewaukee 4	198	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.6
Pewaukee 4	199	18.2	0.4	1.0	1.0	0.9	0.6	- -	- -	- -	- -	- -	0.80	1.0
Pewaukee 4	200	41.9	0.8	0.6	0.7	1.0	0.5	- -	- -	- -	- -	- -	0.70	1.0
Pewaukee 4	201	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.8
Pewaukee 4	202	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.3
Pewaukee 4	203	10.4	0.3	0.8	1.1	1.2	1.3	- -	- -	- -	- -	- -	0.90	1.3
Pewaukee 4	204	18.4	0.7	0.9	1.0	1.1	0.8	- -	- -	- -	- -	- -	0.90	1.1
Pewaukee 4	205	13.8	0.5	0.6	1.0	1.2	1.0	- -	- -	- -	- -	- -	0.90	1.2
Pewaukee 4	206	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	207	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	208	9.7	0.9	1.6	2.1	1.9	1.1	- -	- -	- -	- -	- -	1.50	2.1
Pewaukee 4	209	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 4	210	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	211	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	212	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.9
Pewaukee 4	213	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
Pewaukee 4	214	9.3	1.3	0.9	0.9	- -	- -	- -	- -	- -	- -	- -	1.00	1.3
Pewaukee 4	215	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	216	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.3
Pewaukee 4	217	12.1	0.5	0.7	0.7	0.8	0.8	- -	- -	- -	- -	- -	0.70	0.8
Pewaukee 4	218	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	219	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.9
Pewaukee 4	220	11.4	1.1	1.1	1.1	0.7	0.4	- -	- -	- -	- -	- -	0.90	1.1
Pewaukee 4	221	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 4	222	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.4

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 4	223	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	224	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	225	8.1	1.6	1.4	1.0	- -	- -	- -	- -	- -	- -	- -	1.30	1.6
Pewaukee 4	226	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.4
Pewaukee 4	227	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Pewaukee 4	228	10.3	0.4	1.0	1.2	1.2	0.7	- -	- -	- -	- -	- -	0.90	1.2
Pewaukee 4	229	14.0	0.7	0.6	0.7	0.8	0.7	- -	- -	- -	- -	- -	0.70	0.8
Pewaukee 4	230	22.1	0.8	0.7	0.4	0.2	0.2	- -	- -	- -	- -	- -	0.50	0.8
Pewaukee 4	231	23.9	0.6	0.6	0.8	0.6	0.4	- -	- -	- -	- -	- -	0.60	0.8
Pewaukee 4	232	24.5	0.9	0.4	0.3	0.4	0.5	- -	- -	- -	- -	- -	0.50	0.9
Pewaukee 4	233	19.2	0.4	0.5	0.6	0.4	0.2	- -	- -	- -	- -	- -	0.40	0.6
Pewaukee 4	234	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.7
Pewaukee 4	235	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Pewaukee 4	236	15.7	0.5	0.7	1.0	1.1	0.6	- -	- -	- -	- -	- -	0.80	1.1
Pewaukee 4	237	14.5	1.2	1.6	1.8	1.9	1.1	- -	- -	- -	- -	- -	1.50	1.9
Pewaukee 4	238	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.6
Pewaukee 4	239	11.0	1.5	1.8	1.8	2.0	2.0	- -	- -	- -	- -	- -	1.80	2.0
Pewaukee 4	240	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 4	241	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 4	242	13.8	1.2	1.5	1.7	1.5	1.2	- -	- -	- -	- -	- -	1.40	1.7
Pewaukee 4	243	14.3	1.4	1.5	1.6	1.7	1.3	- -	- -	- -	- -	- -	1.50	1.7
Pewaukee 4	244	12.5	1.8	1.7	1.5	1.5	1.2	- -	- -	- -	- -	- -	1.50	1.8
Pewaukee 4	245	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.5
Pewaukee 4	246	10.3	1.5	1.5	1.6	1.8	1.8	- -	- -	- -	- -	- -	1.60	1.8
Pewaukee 4	247	11.6	1.5	1.7	1.8	2.0	1.3	- -	- -	- -	- -	- -	1.70	2.0
Pewaukee 4	248	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Pewaukee 4	249	9.1	1.6	1.8	1.4	1.6	1.4	- -	- -	- -	- -	- -	1.60	1.8
Pewaukee 4	250	19.8	1.0	1.2	1.4	0.9	0.6	- -	- -	- -	- -	- -	1.00	1.4
Pewaukee 4	251	16.6	1.2	0.8	0.7	0.5	0.5	- -	- -	- -	- -	- -	0.70	1.2
Pewaukee 4	252	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.6
Pewaukee 4	253	21.4	0.6	0.7	1.6	0.7	0.5	- -	- -	- -	- -	- -	0.80	1.6
Pewaukee 4	254	10.0	0.9	0.9	1.3	1.6	1.4	- -	- -	- -	- -	- -	1.20	1.6
Pewaukee 4	255	9.4	1.5	1.3	1.2	1.3	1.2	- -	- -	- -	- -	- -	1.30	1.5
Pewaukee 4	256	22.7	0.4	0.5	0.8	0.9	0.9	- -	- -	- -	- -	- -	0.70	0.9
Pewaukee 4	257	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.8
Pewaukee 4	258	5.8	0.9	1.0	0.7	- -	- -	- -	- -	- -	- -	- -	0.90	1.0
Pewaukee 4	259	3.6	0.9	0.9	0.7	- -	- -	- -	- -	- -	- -	- -	0.80	0.9
Pewaukee 4	260	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.4
Pewaukee 4	261	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.3
Pewaukee 4	262	6.3	0.6	0.8	0.7	- -	- -	- -	- -	- -	- -	- -	0.70	0.8
Pewaukee 4	263	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.4
Pewaukee 4	264	4.8	0.7	1.0	1.1	- -	- -	- -	- -	- -	- -	- -	0.90	1.1
Pewaukee 4	265	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.4
Pewaukee 4	266	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.7
Pewaukee 4	267	4.2	0.9	0.8	0.6	- -	- -	- -	- -	- -	- -	- -	0.80	0.9

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Pewaukee 4	268	5.0	0.6	0.4	0.5	- -	- -	- -	- -	- -	- -	- -	0.50	0.6
Pewaukee 4	269	7.1	0.6	0.6	0.6	- -	- -	- -	- -	- -	- -	- -	0.60	0.6
Pewaukee 4	270	5.8	1.0	1.3	0.7	- -	- -	- -	- -	- -	- -	- -	1.00	1.3
Pewaukee 4	271	4.6	0.7	0.8	0.8	- -	- -	- -	- -	- -	- -	- -	0.80	0.8
Pewaukee 4	272	4.4	0.6	0.8	0.9	- -	- -	- -	- -	- -	- -	- -	0.80	0.9
Pewaukee 5	273	4.4	0.9	0.9	0.9	- -	- -	- -	- -	- -	- -	- -	0.90	0.9
Pewaukee 5	274	3.6	0.3	0.5	0.6	- -	- -	- -	- -	- -	- -	- -	0.50	0.6
Pewaukee 5	275	4.9	0.4	0.4	0.5	- -	- -	- -	- -	- -	- -	- -	0.40	0.5
Pewaukee 5	276	11.9	0.4	0.4	0.4	0.2	0.1	- -	- -	- -	- -	- -	0.30	0.4
Pewaukee 5	277	6.1	0.4	0.3	0.3	- -	- -	- -	- -	- -	- -	- -	0.30	0.4
Pewaukee 5	278	4.5	0.6	0.5	0.7	- -	- -	- -	- -	- -	- -	- -	0.60	0.7
Pewaukee 5	279	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.9
Pewaukee 5	280	5.4	0.7	0.5	0.5	- -	- -	- -	- -	- -	- -	- -	0.60	0.7
Pewaukee 5	281	3.6	0.9	0.9	0.6	- -	- -	- -	- -	- -	- -	- -	0.80	0.9
Pewaukee 5	282	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.1
Pewaukee 5	283	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.1
Pewaukee 5	284	3.8	0.5	0.7	1.1	- -	- -	- -	- -	- -	- -	- -	0.80	1.1
Pewaukee 5	285	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.3
Pewaukee 5	286	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.5
Pewaukee 5	287	4.8	0.6	0.6	0.4	- -	- -	- -	- -	- -	- -	- -	0.50	0.6
Pewaukee 5	288	4.2	1.0	0.9	0.6	- -	- -	- -	- -	- -	- -	- -	0.80	1.0
Pewaukee 5	289	4.4	0.4	0.6	0.7	- -	- -	- -	- -	- -	- -	- -	0.60	0.7
Pewaukee 5	290	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.2
Pewaukee 5	291	4.8	0.6	0.9	0.9	- -	- -	- -	- -	- -	- -	- -	0.80	0.9
Pewaukee 5	292	13.8	0.1	0.2	0.3	0.3	0.3	- -	- -	- -	- -	- -	0.20	0.3
Pewaukee 5	293	5.1	0.5	0.5	0.5	- -	- -	- -	- -	- -	- -	- -	0.50	0.5
Pewaukee 5	294	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
Pewaukee 5	295	4.1	0.4	0.9	0.7	- -	- -	- -	- -	- -	- -	- -	0.70	0.9
Pewaukee 5	296	3.6	0.6	0.8	0.6	- -	- -	- -	- -	- -	- -	- -	0.70	0.8
Pewaukee 5	297	3.9	0.5	0.7	0.5	- -	- -	- -	- -	- -	- -	- -	0.60	0.7
Pewaukee 5	298	3.2	0.6	0.7	0.6	- -	- -	- -	- -	- -	- -	- -	0.60	0.7
Pewaukee 5	299	2.7	0.5	0.7	0.3	- -	- -	- -	- -	- -	- -	- -	0.50	0.7
Pewaukee 5	300	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
Pewaukee 5	301	4.2	0.6	0.8	0.7	- -	- -	- -	- -	- -	- -	- -	0.70	0.8
Pewaukee 5	302	5.7	0.5	0.7	0.6	- -	- -	- -	- -	- -	- -	- -	0.60	0.7
Pewaukee 5	303	7.8	0.3	0.4	0.2	- -	- -	- -	- -	- -	- -	- -	0.30	0.4
Pewaukee 5	304	7.3	0.3	0.4	0.4	- -	- -	- -	- -	- -	- -	- -	0.40	0.4
Pewaukee 5	305	5.5	0.4	0.4	0.4	- -	- -	- -	- -	- -	- -	- -	0.40	0.4
HWY JJ Tributary	306	5.6	0.5	0.6	0.4	- -	- -	- -	- -	- -	- -	- -	0.50	0.6
HWY JJ Tributary	307	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.1
HWY JJ Tributary	308	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1
HWY JJ Tributary	309	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.6
HWY JJ Tributary	310	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.2
HWY JJ Tributary	311	5.2	0.4	0.7	0.6	- -	- -	- -	- -	- -	- -	- -	0.60	0.7

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
HWY JJ Tributary	312	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.3
HWY JJ Tributary	313	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.5
HWY JJ Tributary	314	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.3
HWY JJ Tributary	315	4.2	0.5	0.6	0.6	- -	- -	- -	- -	- -	- -	- -	0.60	0.6
HWY JJ Tributary	316	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.8
HWY JJ Tributary	317	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.9
HWY JJ Tributary	318	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
HWY JJ Tributary	319	4.7	0.8	0.9	1.2	- -	- -	- -	- -	- -	- -	- -	1.00	1.2
HWY JJ Tributary	320	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.6
HWY JJ Tributary	321	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.6
HWY JJ Tributary	322	3.4	0.9	1.0	1.0	- -	- -	- -	- -	- -	- -	- -	1.00	1.0
HWY JJ Tributary	323	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.8
HWY JJ Tributary	324	5.1	0.4	0.8	0.8	- -	- -	- -	- -	- -	- -	- -	0.70	0.8
HWY JJ Tributary	325	7.6	0.7	0.7	0.8	- -	- -	- -	- -	- -	- -	- -	0.70	0.8
HWY JJ Tributary	326	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.4
HWY JJ Tributary	327	7.8	0.6	0.6	0.4	- -	- -	- -	- -	- -	- -	- -	0.50	0.6
HWY JJ Tributary	328	10.4	0.8	0.8	0.9	0.9	0.8	- -	- -	- -	- -	- -	0.80	0.9
HWY JJ Tributary	329	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.7
HWY JJ Tributary	330	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.8
HWY JJ Tributary	331	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
HWY JJ Tributary	332	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
HWY JJ Tributary	333	11.0	1.3	1.2	1.0	0.8	0.6	- -	- -	- -	- -	- -	1.00	1.3
HWY JJ Tributary	334	14.5	0.5	0.3	0.3	0.3	0.5	- -	- -	- -	- -	- -	0.40	0.5
HWY JJ Tributary	335	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.4
HWY JJ Tributary	336	11.6	0.1	0.2	0.4	0.5	0.7	- -	- -	- -	- -	- -	0.40	0.7
HWY JJ Tributary	337	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.6
HWY JJ Tributary	338	9.9	0.2	0.4	0.4	0.5	0.4	- -	- -	- -	- -	- -	0.40	0.5
HWY JJ Tributary	339	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.6
HWY JJ Tributary	340	8.4	0.2	0.4	0.3	- -	- -	- -	- -	- -	- -	- -	0.30	0.4
HWY JJ Tributary	341	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.2
HWY JJ Tributary	342	9.9	1.2	1.2	1.1	- -	- -	- -	- -	- -	- -	- -	1.20	1.2
HWY JJ Tributary	343	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4.8
HWY JJ Tributary	344	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4.8
HWY JJ Tributary	345	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	5
HWY JJ Tributary	346	10.8	0.6	1.2	1.5	1.3	0.8	- -	- -	- -	- -	- -	1.10	1.5
HWY JJ Tributary	347	8.7	0.6	0.8	0.8	0.9	0.6	- -	- -	- -	- -	- -	0.70	0.9
HWY JJ Tributary	348	7.4	1.8	1.8	1.6	- -	- -	- -	- -	- -	- -	- -	1.70	1.8
HWY JJ Tributary	349	12.2	0.6	0.8	0.5	0.6	0.6	- -	- -	- -	- -	- -	0.60	0.8
HWY JJ Tributary	350	8.3	0.9	0.8	0.6	- -	- -	- -	- -	- -	- -	- -	0.80	0.9
Pewaukee Lake Outlet	351	132.8	0.7	0.9	0.6	0.7	1.2	0.9	1.2	1.5	1.0	0.7	0.90	1.5
Pewaukee Lake Outlet	352	122.7	0.4	0.9	0.8	0.6	0.5	0.5	0.5	0.6	0.7	0.4	0.60	0.9
Pewaukee Lake Outlet	353	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.2
Pewaukee Lake Outlet	354	27.3	0.3	0.3	0.4	0.5	0.5	- -	- -	- -	- -	- -	0.40	0.5
Pewaukee Lake Outlet	355	31.2	0.1	0.3	0.5	0.5	1.0	- -	- -	- -	- -	- -	0.50	1.0

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Coco Creek	356	- -	1.2	2.2	1.6	0.9	1.0	0.8	0.9	0.9	0.8	0.5	1.10	2.2
Coco Creek	357	- -	1.7	2.3	1.3	0.5	0.6	- -	- -	- -	- -	- -	1.30	2.3
Coco Creek	358	- -	1.0	1.6	2.3	1.8	1.1	- -	- -	- -	- -	- -	1.60	2.3
Coco Creek	359	- -	0.6	1.6	1.8	1.7	1.4	- -	- -	- -	- -	- -	1.40	1.8
Coco Creek	360	25.0	1.4	1.7	2.0	2.1	1.4	- -	- -	- -	- -	- -	1.70	2.1
Coco Creek	361	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Coco Creek	362	17.5	2.1	2.3	2.0	2.1	1.0	- -	- -	- -	- -	- -	1.90	2.3
Coco Creek	363	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3.2
Coco Creek	364	12.6	1.7	1.8	2.4	2.3	1.6	- -	- -	- -	- -	- -	2.00	2.4
Coco Creek	365	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.9
Coco Creek	366	11.4	1.2	1.3	1.3	1.3	1.2	- -	- -	- -	- -	- -	1.30	1.3
Coco Creek	367	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Coco Creek	368	16.7	1.2	1.5	1.5	1.2	1.1	- -	- -	- -	- -	- -	1.30	1.5
Coco Creek	369	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.4
Coco Creek	370	14.3	1.3	1.5	1.7	1.8	1.2	- -	- -	- -	- -	- -	1.50	1.8
Coco Creek	371	10.7	1.0	1.6	1.9	1.7	1.4	- -	- -	- -	- -	- -	1.50	1.9
Coco Creek	372	9.9	1.0	1.1	1.0	1.0	0.9	- -	- -	- -	- -	- -	1.00	1.1
Coco Creek	373	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.6
Coco Creek	374	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3
Coco Creek	375	12.6	0.4	0.4	0.4	0.4	0.3	- -	- -	- -	- -	- -	0.40	0.4
Coco Creek	376	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1.5
Coco Creek	377	12.5	0.5	0.5	1.0	1.0	0.6	- -	- -	- -	- -	- -	0.70	1.0
Coco Creek	378	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.1
Coco Creek	379	17.7	0.5	0.4	0.2	0.6	1.0	- -	- -	- -	- -	- -	0.50	1.0
Coco Creek	380	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.8
Coco Creek	381	13.8	0.4	0.6	0.6	0.5	0.4	- -	- -	- -	- -	- -	0.50	0.6
Tributary to Coco Creek	382	5.7	0.5	0.5	0.3	- -	- -	- -	- -	- -	- -	- -	0.43	0.50
Tributary to Coco Creek	383	3.6	0.3	0.3	0.1	- -	- -	- -	- -	- -	- -	- -	0.23	0.30
Tributary to Coco Creek	384	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2
Tributary to Coco Creek	385	8.6	1.5	1.9	1.7	- -	- -	- -	- -	- -	- -	- -	1.70	1.90
Meadowbrook	386	- -	1.3	1.5	2.7	2.5	2.7	2.5	2.5	2.4	2.3	1.4	2.20	2.7
Meadowbrook	387	- -	1.1	1.3	2.0	2.2	2.7	2.5	2.5	2.6	2.0	1.0	2.00	2.7
Meadowbrook	388	45.9	1.1	1.3	1.3	1.4	0.9	- -	- -	- -	- -	- -	1.20	1.4
Meadowbrook	389	26.8	1.5	1.9	1.4	0.9	0.4	- -	- -	- -	- -	- -	1.20	1.9
Meadowbrook	390	- -	0.6	0.7	0.7	1.4	0.7	- -	- -	- -	- -	- -	0.80	1.4
Meadowbrook	391	- -	1.0	1.7	3.5	2.2	1.0	- -	- -	- -	- -	- -	1.90	3.5
Meadowbrook	392	23.2	0.7	1.1	1.3	1.5	1.2	- -	- -	- -	- -	- -	1.20	1.5
Meadowbrook	393	26.7	0.9	1.1	1.1	1.0	0.9	- -	- -	- -	- -	- -	1.00	1.1
Meadowbrook	394	33.2	1.0	1.2	1.1	0.8	0.7	- -	- -	- -	- -	- -	1.00	1.2
Meadowbrook	395	18.3	1.2	1.4	1.6	1.5	1.2	- -	- -	- -	- -	- -	1.40	1.6
Meadowbrook	396	15.2	0.8	0.9	1.0	0.8	0.6	- -	- -	- -	- -	- -	0.80	1.0
Meadowbrook	397	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.2
Meadowbrook	398	- -	1.3	1.8	2.2	2.1	1.7	- -	- -	- -	- -	- -	1.80	2.2
Meadowbrook	399	- -	0.7	1.4	1.8	2.0	1.3	- -	- -	- -	- -	- -	1.40	2.0

Table E-3 (continued)

Reach	Survey ID[a] (see Maps E-1 through E-8)	Low Flow												
		Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Depth-6 (feet)	Depth-7 (feet)	Depth-8 (feet)	Depth-9 (feet)	Water Depth-10 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Meadowbrook	400	- -	1.2	2.1	2.0	1.7	1.0	- -	- -	- -	- -	- -	1.60	2.1
Meadowbrook	401	20.5	0.5	0.8	1.3	1.2	0.8	- -	- -	- -	- -	- -	0.90	1.3
Meadowbrook	402	- -	1.4	2.5	2.1	1.6	1.0	- -	- -	- -	- -	- -	1.70	2.5
Meadowbrook	403	10.9	0.3	0.5	0.6	0.5	0.5	- -	- -	- -	- -	- -	0.50	0.6
Tributary to Meadowbrook	404	2.7	0.5	0.5	0.6	- -	- -	- -	- -	- -	- -	- -	0.53	0.6
Tributary to Meadowbrook	405	10.3	0.3	0.4	0.3	0.2	0.3	- -	- -	- -	- -	- -	0.30	0.4
Tributary to Meadowbrook	406	4.6	0.2	0.3	0.2	- -	- -	- -	- -	- -	- -	- -	0.23	0.3

NOTE: The number of points at which water depths were measured within a cross-section was dependent upon stream width. In general, if wetted width was less than 10 feet, only three points per transect were taken; for widths ranging from 10 to 75 feet, five to 10 points per transect were taken; and where width was greater than 75 feet, 10 points were taken.

[a]*Cross-section surveys were not conducted in every pool habitat location, however maximum pool depths were recorded.*

Source: SEWRPC.

Table E-4

TRASH OBSERVED IN STREAMS WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

Stream Reach	Map Identification Number (see Map E-9 through E-16)	Longitude[a]	Latitude[a]	Description
Pewaukee 1	1	2478669.37308	384664.14082	Hub cap and radio
	2	2478116.95194	387197.640018	Saucer sled
	3	2476396.55151	386870.654124	Laundry basket
	4	2474815.79778	387167.222428	Plastic 5 gallon bucket, near right streambank
	5	2474712.70022	387060.525463	Metal stove top and tire
	6	2474524.9168	386432.537874	Toilet seat
	7	2474128.21878	386353.792953	Tire, center of stream channel
	8	2473809.28602	386357.188615	Lawn chair cushion
	9	2473627.27556	386449.574585	Tire, near right streambank
	10	2473427.96788	386489.099113	Wheel rim, center of stream channel
Pewaukee 2	11	2472485.80408	387776.830461	Metal drum lid and other metal scraps
	12	2472348.85915	388394.404357	Metal drum, barbed wire fencing rolls on right streambank
	13	2472040.6452	388606.20249	Tire, center of stream channel
	14	2471802.29003	388745.902342	Plastic garbage can, on right streambank
	15	2471846.53666	388771.712001	Casserole dish, left side of channel; five gallon bucket, right side of channel
	16	2471608.07881	389571.822606	Two unidentified metal objects
	17	2471463.30154	389692.696708	Tire, left side of stream channel
	18	2471469.88584	390250.976431	Tire, center of stream channel
	19	2471229.31513	390463.450088	Tire, center of stream channel
	20	2471081.67468	390742.393427	Bathtub, center of stream channel
	21	2470961.62373	390807.112786	Plastic oil pan
	22	2470836.58954	391426.809381	Tire, center of stream channel
	23	2470742.67601	391777.323772	Wood pallet
	24	2470627.37014	392338.957163	Tire, center of stream channel; Blue sled, left streambank
	25	2470685.24174	392692.064069	Kiddie pool, center of stream channel
	26	2470686.19285	392713.180496	Tire, center of stream channel
	27	2470640.43376	393343.370509	Plastic kiddie pool, right side of stream channel
	28	2470571.55168	393807.59235	Piece of plastic pool, old bridge debris, left streambank
	29	2470886.96345	393757.875257	Plastic garbage can, left side of stream channel
	30	2470564.6324	394202.049566	Fiberglass tub
	31	2470532.99237	394293.689474	Pallet and five-gallon bucket, right streambank
	32	2470463.62539	394347.046323	Tire, left side of stream channel
	33	2470437.90267	394381.245074	Tire, left side of stream channel
	34	2470345.1522	394897.243714	Tire, left side of stream channel
	35	2470071.57532	395425.137343	Tire, center of stream channel
	36	2470018.19616	395896.380495	Rubbermaid tub and five-gallon bucket, left streambank
	37	2469912.36566	395634.484037	Tire, center of stream channel
	38	2469521.07018	396057.110488	Two road signs
	39	2469602.91713	396181.702431	Tire and part of failed wooden pier
	40	2469663.147	396374.28341	Kiddie pool
	41	2469342.64042	396489.146042	Sign and sign pole, center of stream channel

Table E-4 (continued)

Stream Reach	Map Identification Number (see Map E-9 through E-16)	Longitude[a]	Latitude[a]	Description
Pewaukee 3	42	2468984.47087	397138.226946	Tire at inlet of Wisconsin Ave. bridge
	43	2468980.59029	397427.330845	Small metal trough and push lawnmower
	44	2468789.26194	397452.517146	Street sign and boot
	45	2468148.51027	397526.898231	Tire tread, center of stream channel; Orange barrel base, left streambank
	46	2467987.38253	397615.111166	Tire and pallet
	47	2467885.53802	397712.717085	Metal watering can
	48	2467850.93179	397735.09204	Jar, bowl, beer bottles
	49	2467831.85932	397818.84417	Wire basket
	50	2467721.11808	397877.571086	Trash can lid
	51	2467295.98047	397922.675983	Tire, center of stream channel
	52	2467278.54941	397922.92303	Metal culvert wingwall and orange cone
	53	2467209.4252	397925.108393	Orange construction barrel base
	54	2467151.70813	397972.941302	Orange construction barrel base
	55	2467044.58104	398024.99566	Large semi tire, center of stream channel
	56	2466919.44678	398409.397122	Tire, right side of stream channel
	57	2466625.0435	398475.710966	Large metal plate and cylinder, center of stream channel
	58	2466404.46093	398531.594384	Tire and plastic bucket, center of stream channel
	59	2466347.99418	398522.038957	Plastic sled, right side of stream channel
	60	2466247.37857	398667.674493	Fishing net and basket, center of stream channel
	61	2466057.67882	398697.10324	Tarp, right side of stream channel
	62	2465783.81519	398805.474414	Large cardboard boxes, right side of stream channel
	63	2465574.76082	398767.618847	Ski pole and metal rake
	64	2464768.21125	399266.904594	Two five-gallon buckets, right streambank
	65	2464362.90465	399951.593185	Two tires, left side of stream channel; Rubber hose, right side of stream channel
Pewaukee 4	66	2464466.03305	400522.265928	Rubber bin lid, left side of stream channel
	67	2464769.53769	401146.163958	"Danger" snowmobile sign
	68	2464808.89424	401154.501868	"Stay on Trial or Stay Home" snowmobile sign
	69	2464864.71106	401176.595	Deicing salt bag
	70	2464902.49084	401406.279252	Deicing salt bag
	71	2464907.73984	401432.69849	Rain gutter
	72	2464927.24866	401525.933868	Tarps and large bag
	73	2465016.00964	401685.274757	Deicing salt bags
	74	2465308.56614	402569.134538	Black garbage bag with styrofoam
	75	2465359.07031	402783.289621	Plastic planting pot
	76	2465962.73413	402570.613537	Tire, left side of stream channel
	77	2467720.37201	402288.459902	Wood pallet
	78	2468560.58589	402509.126128	Wood pallet
	79	2468616.5031	402870.010576	Wood pallet
	80	2468259.35617	404324.310489	Large plastic planting pot
	81	2468214.1499	405329.485644	Plastic planting pot

Table E-4 (continued)

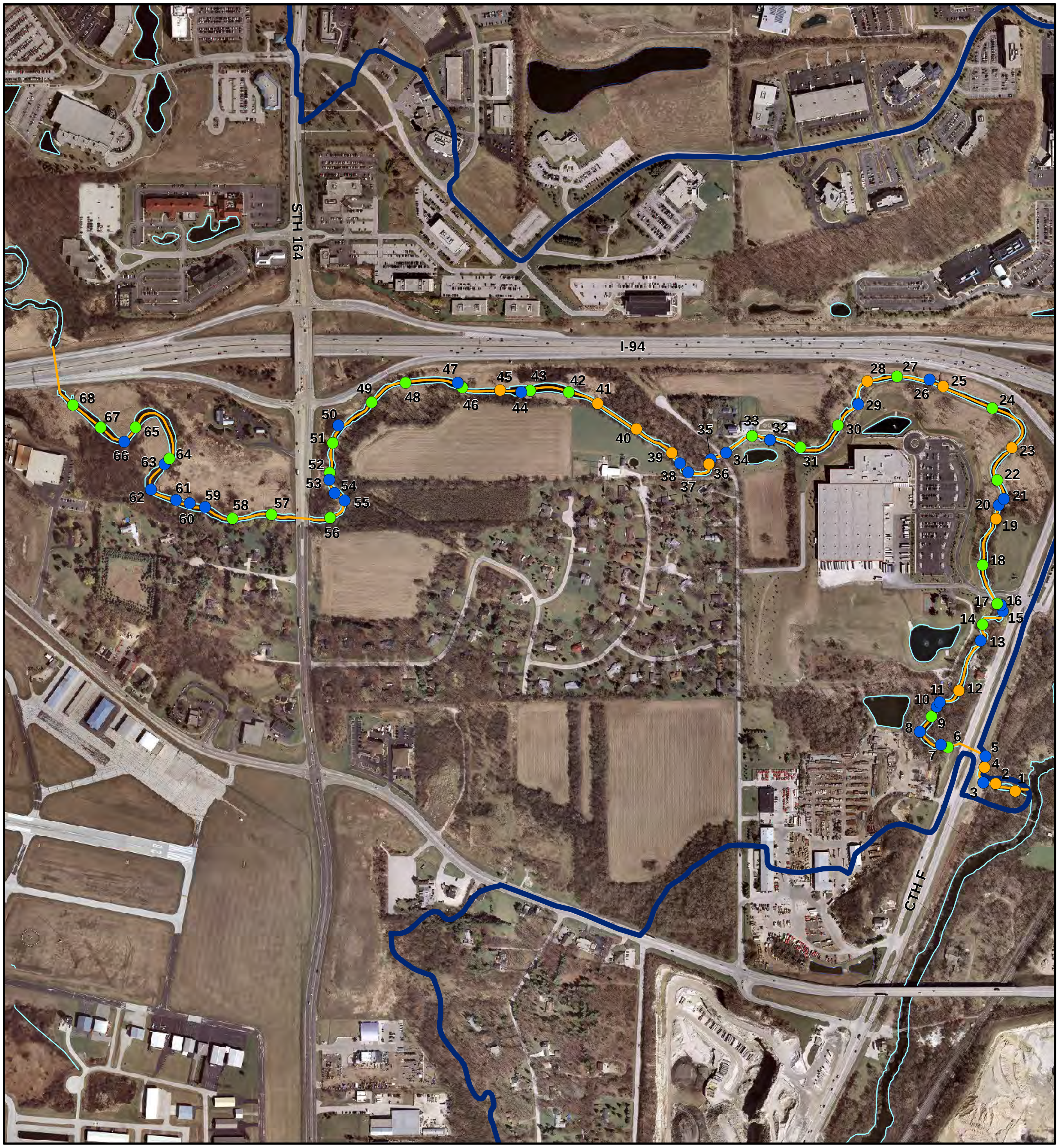
Stream Reach	Map Identification Number (see Map E-9 through E-16)	Longitude[a]	Latitude[a]	Description
Pewaukee 5	82	2468755.16522	406477.678886	Wood pallet
	83	2469387.97793	407344.681745	Metal patio end table
	84	2469490.4026	407481.96067	Wood planks/failed footbridge
	85	2469586.59302	407547.60588	Wood door
	86	2470674.14695	409103.906901	Wood pallet/ failed bridge
	87	2470690.73025	409486.547868	Two tires
CTH JJ Tributary	88	2467511.92033	391050.488284	Wood pallet
	89	2467636.67271	391043.050306	Tire in debris jam
	90	2467720.10988	391049.598194	Tire in debris jam
	91	2467838.60767	391071.183124	Tire
	92	2467963.03623	391053.718592	Tire, left side of stream channel
	93	2468036.32644	391052.628699	Plastic planting pot
	94	2468063.63051	391093.568578	Trash collecting behind fallen tree
	95	2468148.60377	391062.105715	Tire and styrofoam bait bucket in debris jam
	96	2468271.2469	391108.255885	Wooden plank
	97	2468726.45038	391286.826066	Bed sheet and bag
	98	2469180.41896	391591.761807	Coke bottles and bubble wrap (txs17)
	99	2469649.9049	391779.6676	Large tire
	100	2469710.64592	391796.713825	Tire
	101	2469740.66423	391792.640015	Tire
	102	2469840.09579	391921.328734	Garage door panel
Pewaukee Lake Outlet	103	2464166.72919	399866.744273	Tire
Meadowbrook Creek	104	2454827.19406	391294.905118	Orange construction barrel base
	105	2454910.16798	391249.542676	Tire, right side of stream channel
	106	2455430.63216	390923.077777	Large piece of aluminum siding
	107	2456158.36528	390449.826427	Wood pallet
	108	2456175.7724	390440.474412	Large sheet of aluminum siding
	109	2456393.04034	390253.054183	Large sheet of siding and wood pallet
	110	2456432.88147	390236.451526	Metal fence/gate

NOTE: Right and left streambank are always described based on the orientation of looking upstream.

Source: SEWRPC.

Map E-1

AQUATIC HABITAT TYPE WITHIN THE PEWAUKEE 1 STREAM REACH: 2012



POOL

RIFFLE

RUN

68 SURVEY ID (SEE TABLE F-1 THROUGH F-3)

PEWAUKEE 1 STREAM REACH

SURFACE WATER

SUBWATERSHED BOUNDARY

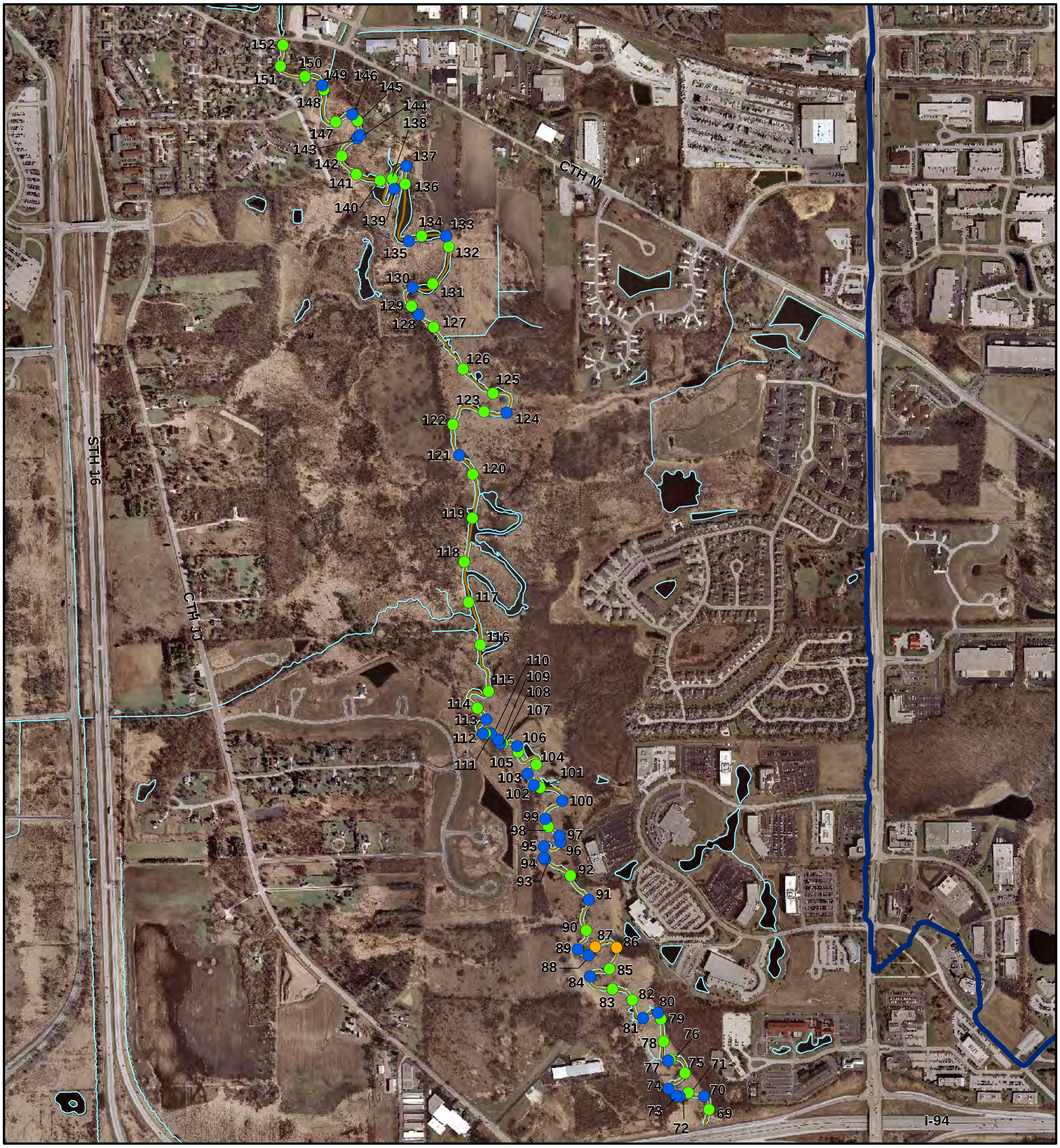
N

0 240 480 Feet

Source: SEWRPC.

Map E-2

AQUATIC HABITAT TYPE WITHIN THE PEWAUKEE 2 STREAM REACH: 2012



●	POOL	▬	PEWAUKEE 2 STREAM REACH
●	RIFFLE	▬	SURFACE WATER
●	RUN	▬	WATERSHED BOUNDARY
152	SURVEY ID (SEE TABLE F-1 THROUGH F-3)		

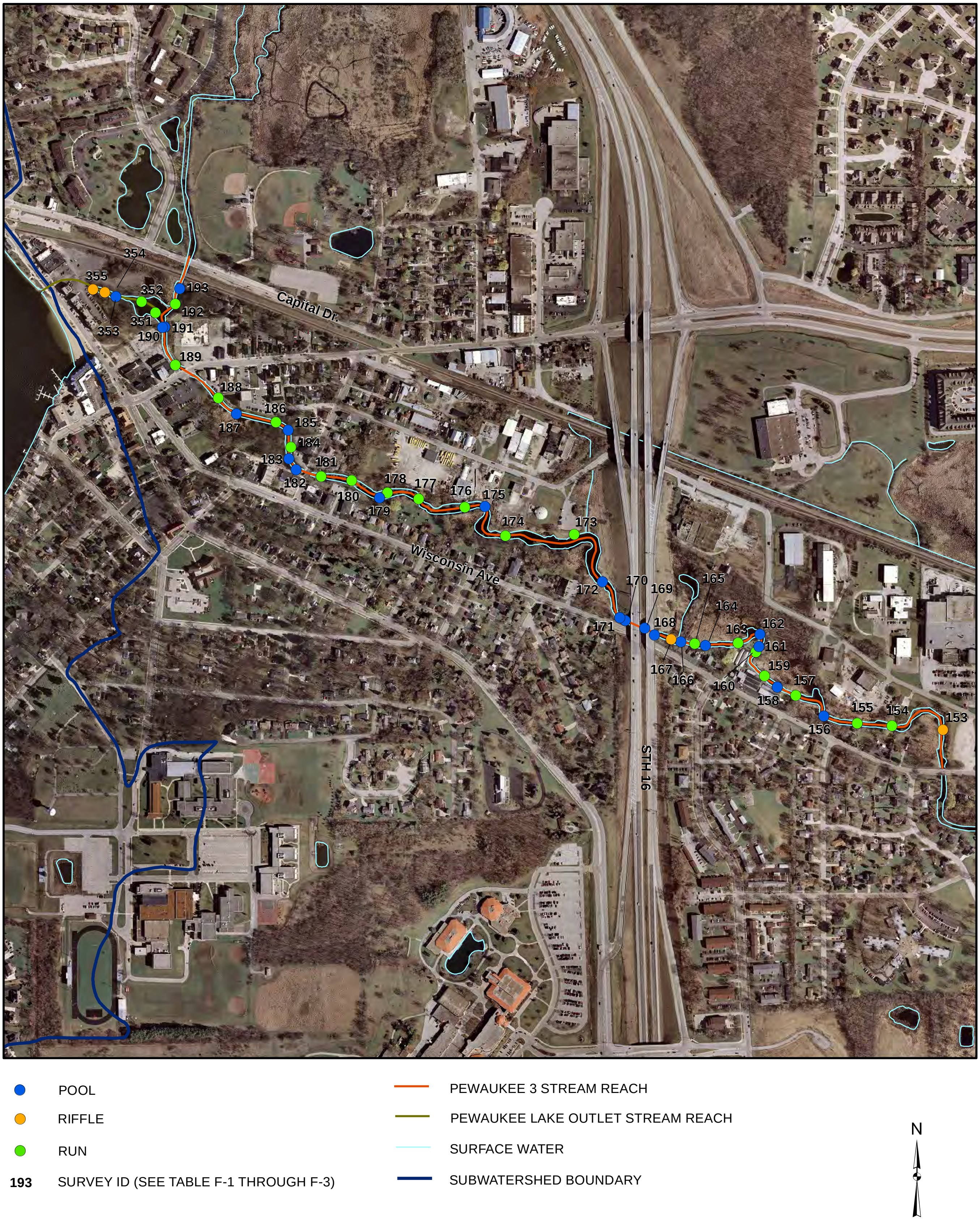
N

0 490 980 Feet

Source: SEWRPC.

Map E-3

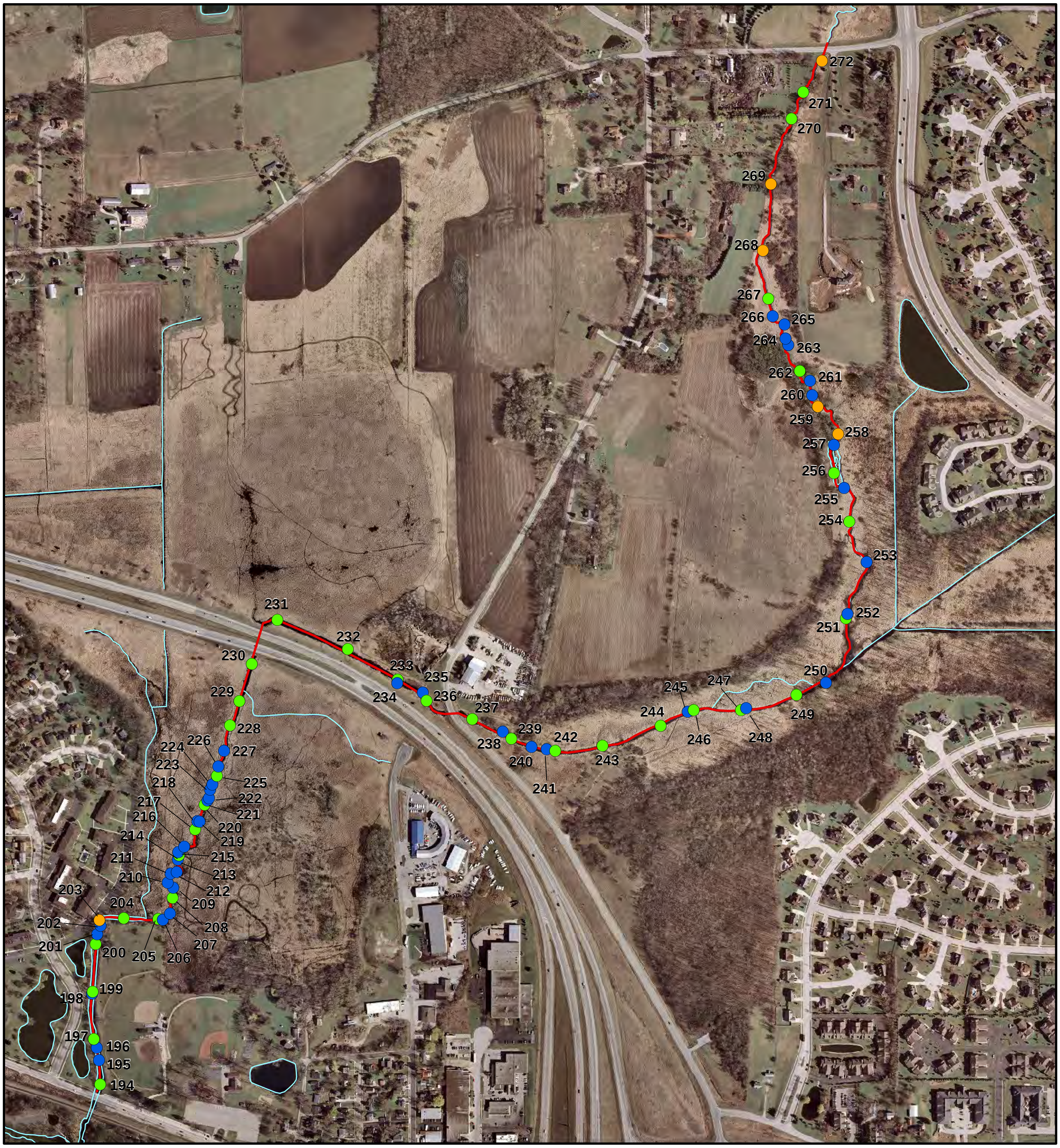
AQUATIC HABITAT TYPE WITHIN THE PEWAUKEE 3 AND PEWAUKEE LAKE OUTLET STREAM REACHES: 2012



Source: SEWRPC.

Map E-4

AQUATIC HABITAT TYPE WITHIN THE PEWAUKEE 4 STREAM REACH: 2012



POOL

RIFFLE

RUN

272 SURVEY ID (SEE TABLE F-1 THROUGH F-3)

PEWAUKEE 5 STREAM REACH

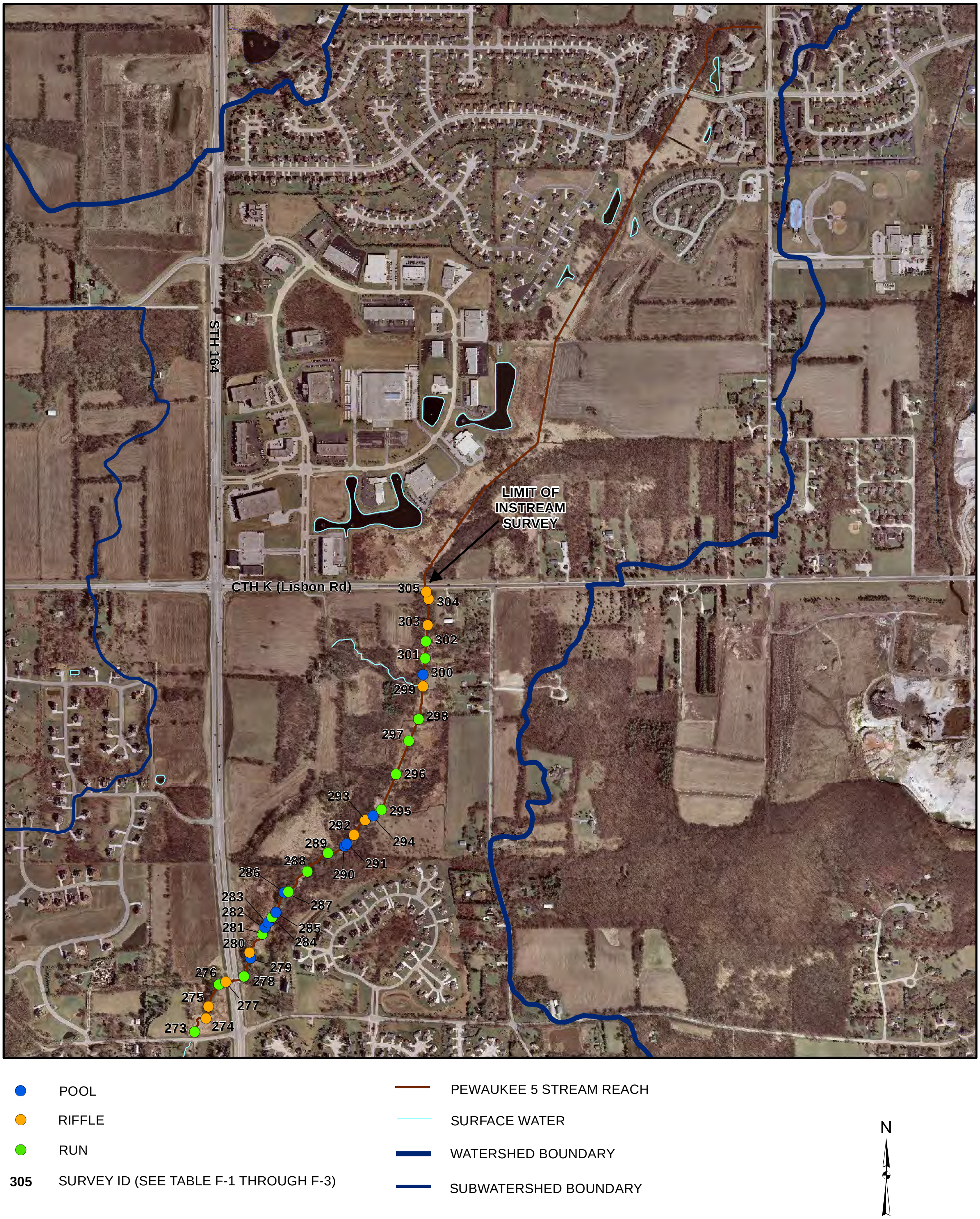
SURFACE WATER

N

0 250 500 Feet

Map E-5

AQUATIC HABITAT TYPE WITHIN THE PEWAUKEE 5 STREAM REACH: 2012



NOTE: The Pewaukee 5 stream reach was not surveyed for physical habitat conditions upstream of County Highway K.

Source: SEWRPC.

Map E-6

AQUATIC HABITAT TYPE WITHIN THE CTH JJ TRIBUTARY STREAM REACH: 2012

POOL

RIFFLE

RUN

350 SURVEY ID (SEE TABLE F-1 THROUGH F-3)

CTH JJ TRIBUTARY REACH

SURFACE WATER

N

0 250 500 Feet

Source: SEWRPC.

Map E-7

AQUATIC HABITAT TYPE WITHIN THE COCO CREEK STREAM REACH: 2012

POOL

RIFFLE

RUN

385 SURVEY ID (SEE TABLE F-1 THROUGH F-3)

COCO CREEK STREAM REACH

SURFACE WATER

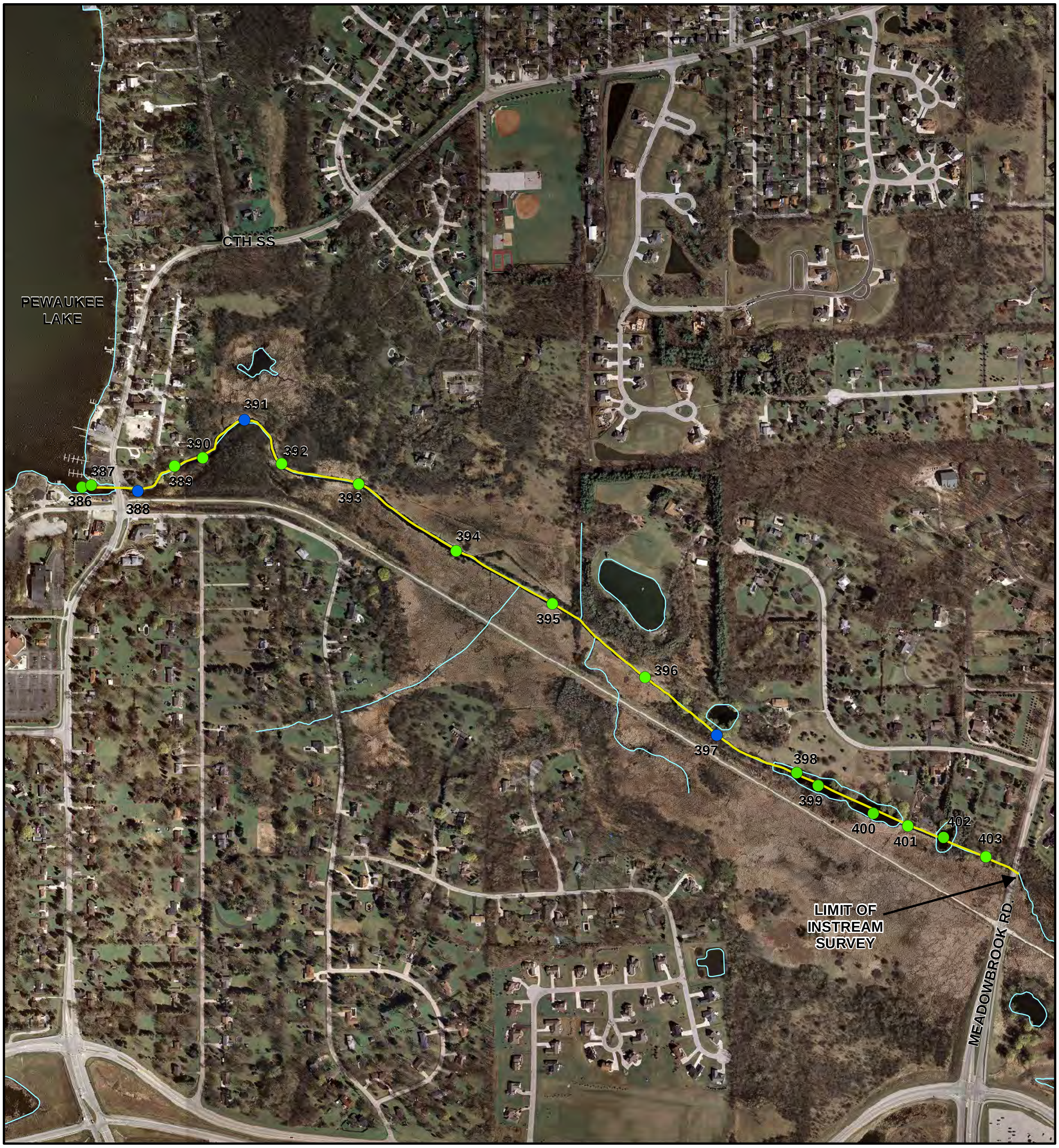
N

0 250 500 Feet

Source: SEWRPC.

Map E-8

AQUATIC HABITAT TYPE WITHIN THE MEADOWBROOK CREEK STREAM REACH: 2012



POOL

RIFFLE

RUN

MEADOWBROOK CREEK STREAM REACH

SURFACE WATER

403 SURVEY ID (SEE TABLE F-1 THROUGH F-3)

N

0 250 500 Feet

Source: SEWRPC.

Map E-9

TRASH, DEBRIS JAMS, BEAVER DAMS, AND STREAMBANK EROSION WITHIN THE PEWAUKEE 1 STREAM REACH: 2012

9 LOCATION OF TIRES IN STREAM (SEE TABLE F-4)

1 LOCATION OF OTHER TRASH IN STREAM (SEE TABLE F-4)

DEBRIS JAM

BEAVER DAM

SURFACE WATER

SUBWATERSHED BOUNDARY

STREAMBANK EROSION

N

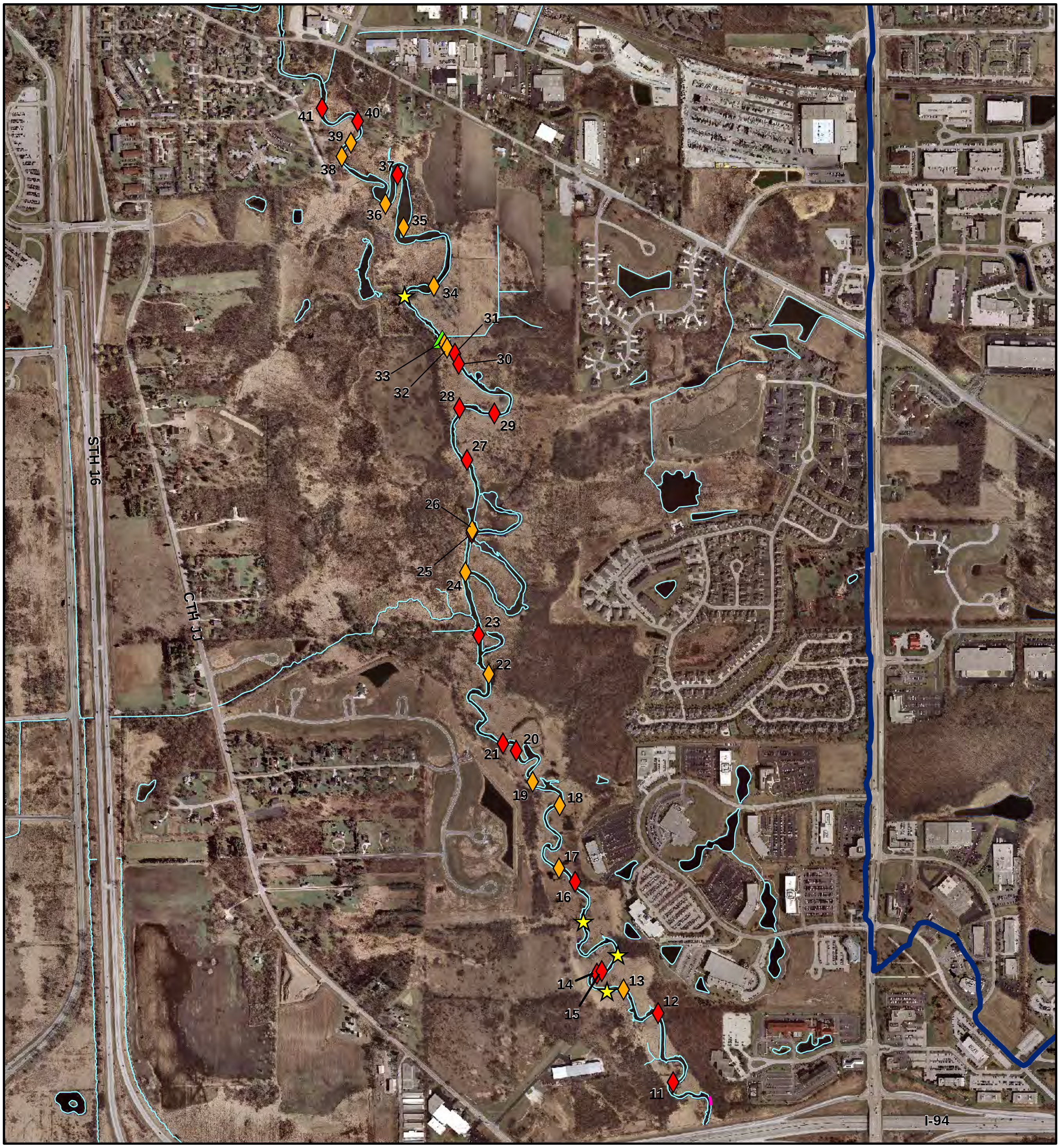
0 240 480 Feet

DATE OF PHOTOGRAPHY: 2010

Source: SEWRPC.

Map E-10

TRASH, DEBRIS JAMS, BEAVER DAMS, AND STREAMBANK EROSION WITHIN THE PEWAUKEE 2 STREAM REACH: 2012



13 LOCATION OF TIRES IN STREAM (SEE TABLE F-4)

11 LOCATION OF OTHER TRASH IN STREAM (SEE TABLE F-4)

DEBRIS JAM

BEAVER DAM

SURFACE WATER

WATERSHED BOUNDARY

STREAMBANK EROSION

N

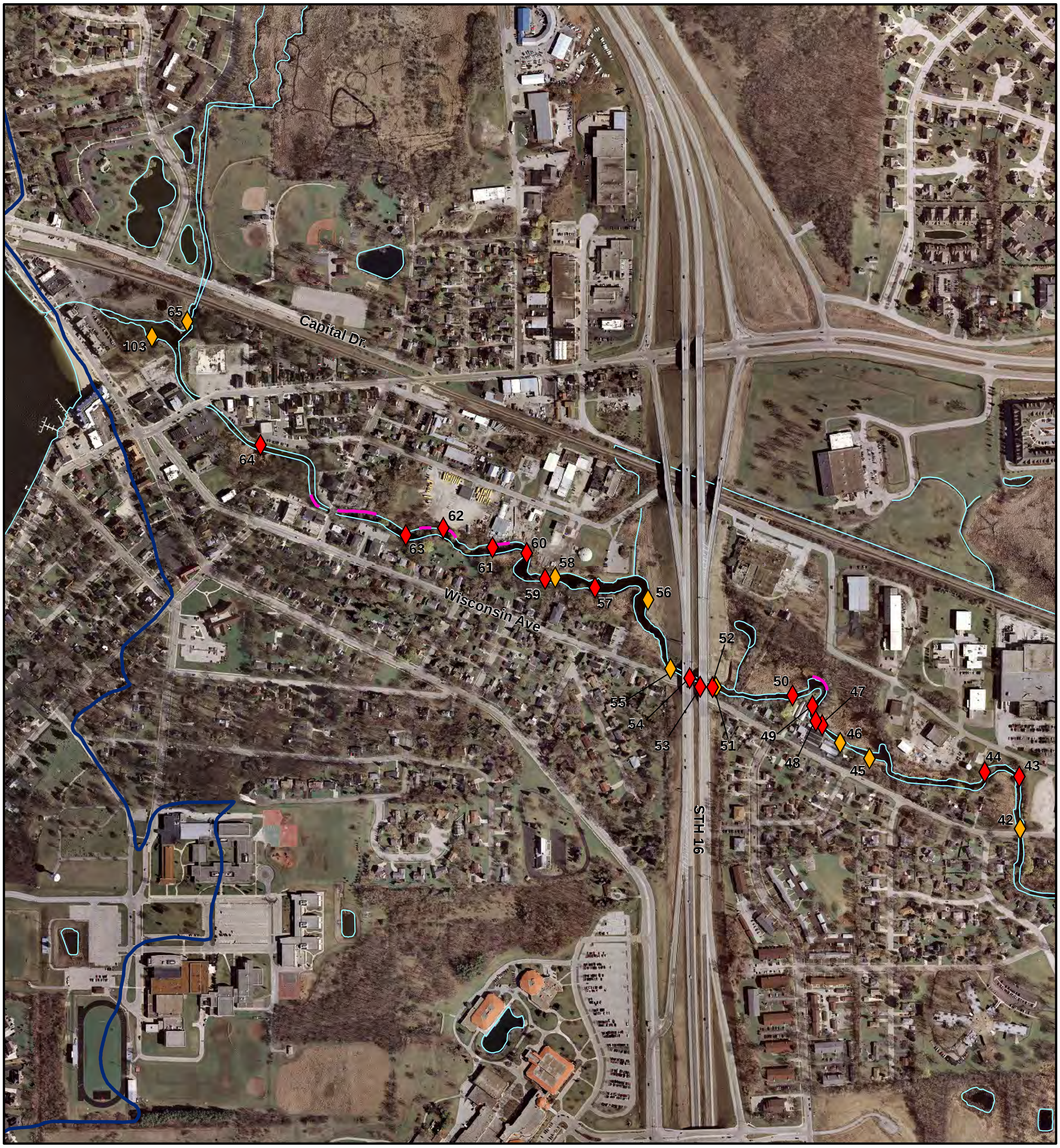
0 490 980 Feet

Source: SEWRPC.

DATE OF PHOTOGRAPHY: 2010

Map E-11

TRASH, DEBRIS JAMS, BEAVER DAMS, AND STREAMBANK EROSION WITHIN THE PEWAUKEE 3 STREAM REACH AND PEWAUKEE LAKE OUTLET: 2012



42 LOCATION OF TIRES IN STREAM (SEE TABLE F-4)

43 LOCATION OF OTHER TRASH IN STREAM (SEE TABLE F-4)

DEBRIS JAM

BEAVER DAM

SURFACE WATER

SUBWATERSHED BOUNDARY

STREAMBANK EROSION

N

0 240 480 Feet

DATE OF PHOTOGRAPHY: 2010

Source: SEWRPC.

Map E-12

TRASH, DEBRIS JAMS, BEAVER DAMS, AND STREAMBANK EROSION WITHIN THE PEWAUKEE 4 STREAM REACH: 2012

76 LOCATION OF TIRES IN STREAM (SEE TABLE F-4)

66 LOCATION OF OTHER TRASH IN STREAM (SEE TABLE F-4)

DEBRIS JAM

BEAVER DAM

SURFACE WATER

STREAMBANK EROSION

N

0 250 500 Feet

Source: SEWRPC.

DATE OF PHOTOGRAPHY: 2010

Map E-13

TRASH, DEBRIS JAMS, BEAVER DAMS, AND STREAMBANK EROSION WITHIN THE PEWAUKEE 5 STREAM REACH: 2012

87 LOCATION OF TIRES IN STREAM (SEE TABLE F-4)

82 LOCATION OF OTHER TRASH IN STREAM (SEE TABLE F-4)

DEBRIS JAM

BEAVER DAM

SURFACE WATER

WATERSHED BOUNDARY

SUBWATERSHED BOUNDARY

STREAMBANK EROSION

N

0 490 980 Feet

DATE OF PHOTOGRAPHY: 2010

Source: SEWRPC.

Map E-14

TRASH, DEBRIS JAMS, BEAVER DAMS, AND STREAMBANK EROSION WITHIN THE CTH JJ TRIBUTARY STREAM REACH: 2012

89	LOCATION OF TIRES IN STREAM (SEE TABLE F-4)		SURFACE WATER
88	LOCATION OF OTHER TRASH IN STREAM (SEE TABLE F-4)		STREAMBANK EROSION
	DEBRIS JAM		
	BEAVER DAM		

N

0 250 500 Feet

Source: SEWRPC.

DATE OF PHOTOGRAPHY: 2010

Map E-15

TRASH, DEBRIS JAMS, BEAVER DAMS, AND STREAMBANK EROSION WITHIN THE COCO CREEK STREAM REACH: 2012

89 LOCATION OF TIRES IN STREAM (SEE TABLE F-4)

88 LOCATION OF OTHER TRASH IN STREAM (SEE TABLE F-4)

DEBRIS JAM

BEAVER DAM

SURFACE WATER

STREAMBANK EROSION

N

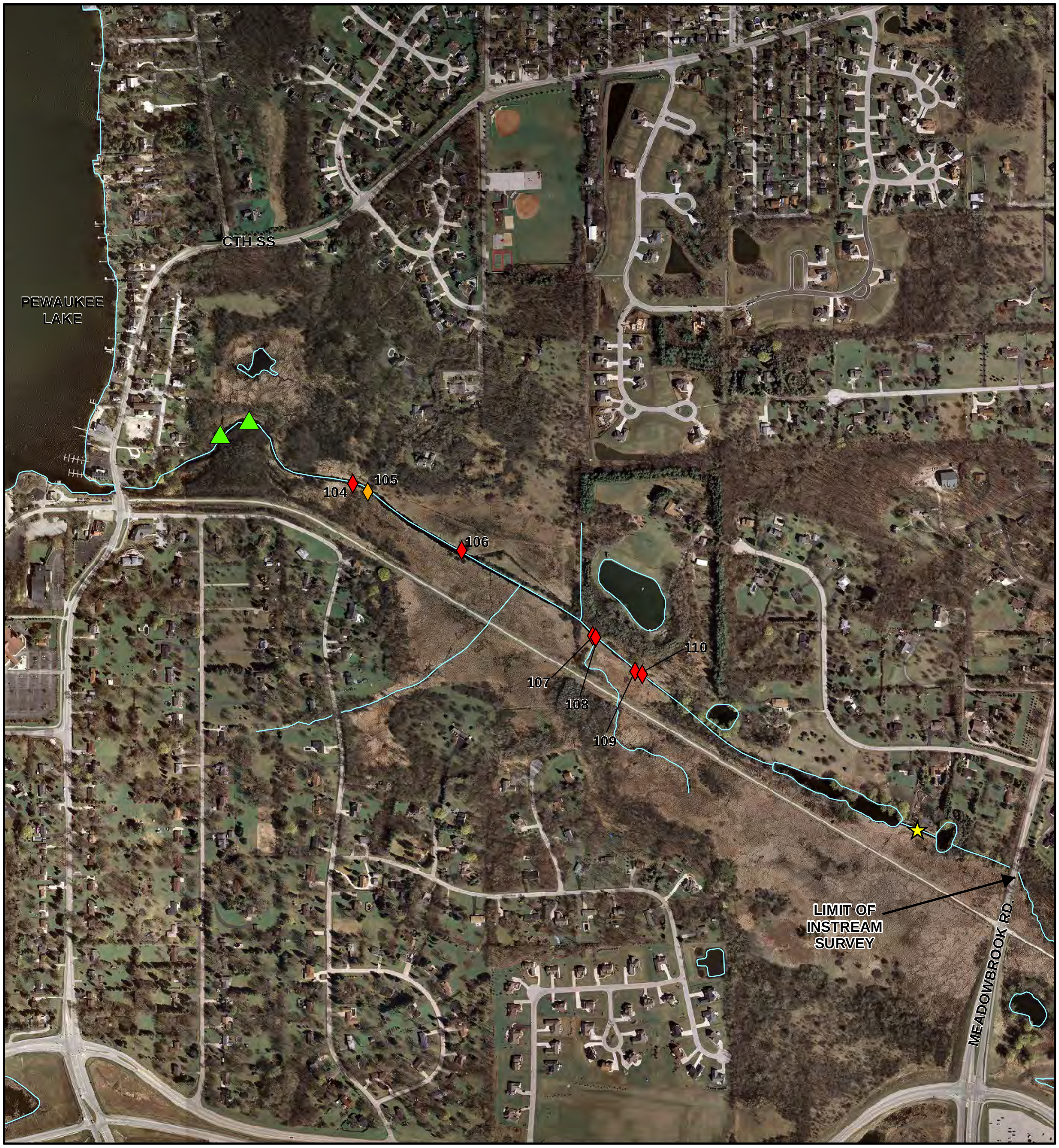
0 250 500 Feet

DATE OF PHOTOGRAPHY: 2010

Source: SEWRPC.

Map E-16

TRASH, DEBRIS JAMS, BEAVER DAMS, AND STREAMBANK EROSION WITHIN THE MEADOWBROOK CREEK STREAM REACH: 2012



105 LOCATION OF TIRES IN STREAM (SEE TABLE F-4)

104 LOCATION OF OTHER TRASH IN STREAM (SEE TABLE F-4)

DEBRIS JAM

BEAVER DAM

SURFACE WATER

STREAMBANK EROSION

N

0 250 500 Feet

Source: SEWRPC.

DATE OF PHOTOGRAPHY: 2010

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Appendix F

STREAM CROSSING DESCRIPTION, LOCATION, CONDITION, FISH PASSAGE, AND NAVIGATION RATING ASSESSMENT WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

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Table F-1

STRUCTURE DESCRIPTION, LOCATION, CONDITION, FISH PASSAGE AND NAVIGATION RATING ASSESSMENT WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

										Priority Rating and Recommendation Summary for Site			
Stream Reach	Structure Number on Map F-1 and Figure F-1	Description	Road Crossing	River Mile	Culvert/Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)	Embedded Depth (feet)	Fish Passage Rating	Recommended Actions	Navigation Hazard	Recommended Actions
Pewaukee 1	1	Metal/concrete/wood bridge with abutments	Abandoned Canadian Pacific Railway	0.05	8.6	Moderate	Fair	0.8	- -	Passable	Erosion control	Yes, during high flows	Replace and increase structure height to improve safety
	2	Two 10-foot-wide, 5.7-foot-high concrete box culverts	CTH F	0.11	144.0	Minor	Good	0.3	0.0	Partial barrier at high flows	Retrofit to reduce water velocities and provide resting areas	Yes, during high flows	Replace and increase structure height to improve safety
	3	Concrete open bottom arch culvert	Steinhafel's driveway	0.39	72.6	Stable	Good	0.6	- -	Passable	None	No	None
	4	Two 11-foot-wide, seven-foot-high corrugated metal pipe arch culverts	Busse Road	1.02	32.0	Stable	Partially rusted through on bottom of pipes, Lannon stone headwall failing in areas	1.2	0.1	Passable	General maintenance	No	General maintenance
	5	Concrete bridge with abutments	STH 164 (Pewaukee Road)	1.69	85.0	Stable	Fair	1.1	- -	Passable	None	No	None
	6	One 22.6-foot-wide, eight-foot-high concrete box culvert. Interior of culvert split into two cells	IH 94	2.16	265.0	Stable	Fair	2.0	1.0	Passable	None	Yes, during high flows	Replace and increase structure height to improve safety, consider signage warning
Pewaukee 2	7	Concrete bridge with abutments	Wisconsin Avenue	5.35	42.3	Stable	Top concrete span is crumbling on upstream and downstream ends, abutments and wingwalls in fair condition	0.8	- -	Passable	General maintenance	No	General maintenance
Pewaukee 3	8	Two concrete span bridges with abutments and side slopes	STH 16	5.83	170.0	Stable	Good	- -	- -	Partial barrier at low flows	Remove or reconstruct rock weir	No	None
	9	Concrete bridge with abutments	Clark Street	6.35	50.0	Minor	Good	0.9	- -	Passable	General maintenance (leaking pvc pipe running through structure)	No	None

Table F-1 (continued)

Stream Reach	Structure Number on Map F-1 and Figure F-1	Description	Road Crossing	River Mile	Culvert/Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)	Embedded Depth (feet)	Priority Rating and Recommendation Summary for Site			
										Fish Passage Rating	Recommended Actions	Navigation Hazard	Recommended Actions
Pewaukee 3 (conrinued)	10	Concrete bridge with abutments	Oakton Avenue	6.55	68.0	Stable	Good	1.2	- -	Passable	General maintenance needed on upstream and downstream Lannon stone headwalls	No	None
	11	Metal and concrete bridge with abutments	Canadian Pacific Railway	6.68	41.0	Minor	Fair	0.6	- -	Partial barrier at low flows	Remove or reconstruct rock weir	No	None
	12	Concrete bridge with abutments	Capital Drive	6.69	44.0	Stable	Good	0.6	- -	Passable	None	Yes, during low and high flow	Replace and increase structure height to improve safety,
Pewaukee 4	13	Two 9.6-foot-wide, five-foot-high concrete box culverts	STH 16	7.30	166.0	Stable	Good	0.8	1.1	Passable	None	Yes, during low and high flow	Replace and increase structure height to improve safety,
	14	Three 5.5-foot-wide, 3.2-foot-high concrete ellipse culverts	Cecilia Drive	7.54	75.0	Minor	Fair	1.6	1.0	Partial barrier	Debris removal, beaver dam removal, replace culverts with more appropriate capacity	Yes, during low and high flow	Replace and increase structure height to improve safety,
	15	Wood plank bridge	Private bridge 1	8.12	- -	- -	Poor	- -	- -	Passable	None	N/A	N/A
Pewaukee 5	16	Wood plank bridge	Private bridge 2	8.57	- -	- -	Fair	- -	- -	Passable	None	N/A	N/A
	17	Wood plank bridge	Private bridge 3	8.62	- -	- -	Fair	- -	- -	Passable	None	N/A	N/A
	18	Cinder block and Lannon stone drop structure	Private drop structure	8.62	- -	- -	Fair	- -	- -	Complete barrier	Remove drop structure	N/A	N/A
	19	Wood plank bridge	Private bridge 4	8.65	- -	- -	Failed	- -	- -	Passable	Remove or replace	N/A	N/A
	20	Two five-foot-wide, 3.4-foot-high corrugated metal pipe arch culverts	Lindsey Road	8.74	56.0	Stable	Fair	0.2	0.0	Partial barrier at low flows	Retrofit (upstream apron) or replace	N/A	N/A
	21	Two concrete bridges with abutments	STH 164	8.91	100.0	Stable	Good	0.4	- -	Partial barrier at low flows	Reconstruct a more appropriate channel width to increase water depths	N/A	N/A
	22	Wood plank bridge	Private bridge 5	9.29	6.9	Stable	Fair	0.7	- -	Passable	None	N/A	N/A
	23	Wood plank bridge	Private bridge 6	9.40	6.9	Stable	Fair	0.6	- -	Passable	None	N/A	N/A
	24	Wood plank bridge	Private bridge 7	9.55	6.2	Stable	Fair	0.6	- -	Passable	None	N/A	N/A
	25	One four-foot-diameter round concrete culvert	Private culvert 1	9.59	- -	- -	Good	0.1	0.0	Partial barrier at low flows	Remove or replace	N/A	N/A

Table F-1 (continued)

Stream Reach	Structure Number on Map F-1 and Figure F-1	Description	Road Crossing	River Mile	Culvert/Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)	Embedded Depth (feet)	Priority Rating and Recommendation Summary for Site			
										Fish Passage Rating	Recommended Actions	Navigation Hazard	Recommended Actions
Pewaukee 5 (continued)	26	Metal/wood plank bridge	Private bridge 8	9.63	9.0	Stable	Fair	0.3	- -	Passable	None	N/A	N/A
	27	One three-foot-diameter round corrugated metal culvert	Private culvert 2	9.79	- -	- -	Rusted through	0.2	0.3	Partial barrier at low flows	Remove or replace	N/A	N/A
	28	One two-foot-diameter; two three-foot-diameter round corrugated metal culverts	CTH K (Lisbon Road)	9.81	80.0	Minor	Fair	0.4	0.0	Passable	Debris removal, general maintenance	N/A	N/A
CTH JJ Tributary	29	One 10-foot-wide, eight-foot-high concrete box culvert	CTH JJ (Bluemound Road)	0.53	117.0	Stable	Good	0.1	0.0	Partial barrier at low flows	Remove or reconstruct rock cascade	N/A	N/A
	30	One 9.6-foot-wide, seven-foot-high corrugated metal pipe arch culvert	STH 16	0.72	148.0	Minor	Partially rusted through at bottom of culvert	0.3	0.2	Passable	General maintenance	N/A	N/A
	31	One 9.0-foot-wide, 6.6-foot-high corrugated metal pipe arch culvert	CTH T	0.77	115.5	Stable	Partially rusted through at bottom of culvert, wingwall failing	0.1	0.0	Passable	General maintenance	N/A	N/A
Pewaukee Lake Outlet	32	Two six-foot-wide, four-foot-high concrete box culverts	Pewaukee Lake outlet/dam	0.06	321.0	Stable	Good	N/A	0.0	Complete barrier to upstream migration	General maintenance to ensure discharge to Pewaukee River	N/A	N/A
Coco Creek	33	Metal and concrete bridge with abutments	Canadian Pacific Railway	0.00	40.9	Minor	Fair	3.3	- -	Passable	None	No	No
	34	Concrete bridge with abutments	Glacier Road	0.11	36.5	Stable	Good	2.6	- -	Passable	None	No	No
	35	Three seven-foot-wide, 4.7-foot-high corrugated metal pipe arch culverts	CTH JJ	0.52	46.0	Minor	Lannon stone wall surrounding culvert is failing	0.3	0.4	Passable	Debris removal, general maintenance	N/A	N/A
	36	One three-foot-diameter; one four-foot-diameter round corrugated metal culverts	Private culverts	0.81	14.0	Stable	Fair	0.4	0.0	Partial barrier at low flows	Remove	N/A	N/A
	37	One 5.6-foot-wide, 3.2-foot-high; one 5.6-foot-wide, two-foot-high corrugated metal pipe arch culverts	Yench Road	1.00	34.0	Stable	Lannon stone wall surrounding culvert is failing	1.0	0.5	Passable	General maintenance on structure headwall	N/A	N/A
	38	One eight-foot-wide, four-foot-high concrete box culvert	CTH KE	2.43	48.0	Stable	Good	1.0	1.5	Passable	None	N/A	N/A
	39	One 12.4-foot-wide, six-foot-high concrete box culvert	CTH JK (Lisbon Avenue)	3.20	84.6	Stable	Good	0.2	0.0	Partial barrier at low flows	Remove or reconstruct rock weir	N/A	N/A
	40	Two eight-foot-wide, six-foot-high concrete box culverts	STH 16	3.56	298.0	Stable	Good	0.2	0.0	Passable	Debris removal at inlet	N/A	N/A

Table F-1 (continued)

Stream Reach	Structure Number on Map F-1 and Figure F-1	Description	Road Crossing	River Mile	Culvert/Bridge Length (feet)	Ditch Erosion	General Condition	Limiting Water Depth (feet)	Embedded Depth (feet)	Priority Rating and Recommendation Summary for Site			
										Fish Passage Rating	Recommended Actions	Navigation Hazard	Recommended Actions
Tributary to Coco Creek	41	Four five-foot-diameter round concrete culverts	STH 16	0.04	200.0	Stable	Good	1.6	0.6	Partial barrier	Replace culverts with more appropriate capacity	N/A	N/A
	42	Two four-foot-diameter round corrugated metal culverts	CTH KF	1.34	94.0	Minor	Fair	0.2	0.2	Partial barrier at low flows	Remove boulder/cobble pile at inlet	N/A	N/A
Meadowbrook Creek	43	One 10-foot-wide, seven-foot-high corrugated metal pipe arch culvert	CTH SS	0.00	38.0	Moderate	Fair	1.6	0.0	Passable	General maintenance, erosion control at inlet	N/A	N/A
	44	One 5.3-foot-wide, 5.9-foot-high ellipse corrugated metal culvert	CTH G	1.11	58.7.0	Minor	Spancrete wall surrounding culvert is failing	3.0	0.1	Passable	General maintenance, debris clearing downstream of outlet	N/A	N/A
	44a	Man-made weir made of riprap and cobble	Man-made weir	1.45	- -	- -	- -	- -	- -	Partial barrier at low flows	Removal	N/A	N/A
	44b	Man-made weir made of riprap and cobble	Man-made weir	1.64	- -	- -	- -	- -	- -	Partial barrier at low flows	Removal	N/A	N/A
	45	One 10-foot-wide, six-foot-high concrete box culvert	Fieldhack Drive	2.10	65.0	Stable	Good	0.3	0.9	Passable	General maintenance, debris removal upstream	N/A	N/A
	46	One 10-foot-wide, six-foot-high concrete box culvert	Milkweed Lane	2.35	65.0	Minor	Good	0.1	0.2	Partial barrier at low flows	Erosion control at inlet	N/A	N/A
Zion Creek	47	Two six-foot-wide, 4.8-foot-high corrugated metal pipe arch culverts	Louis Avenue	0.04	35.7	Minor	Fair	1.7	0.5	Passable	Erosion control at inlet	N/A	N/A
	48	One eight-foot-wide, five-foot-high concrete box culvert	Oakton Avenue	0.19	52.6	Stable	Good	0.3	0.0	Passable	Monitor condition of adjacent Lannon stone walls	N/A	N/A

NOTE: The yellow and red colors indicate moderate and high priority ratings or problems to address fish passage and navigation hazards in the watershed.

Source: SEWRPC.

Figure F-1

STREAM CROSSINGS AND DAM LOCATIONS WITHIN THE PEWAUKEE RIVER WATERSHED: 2012

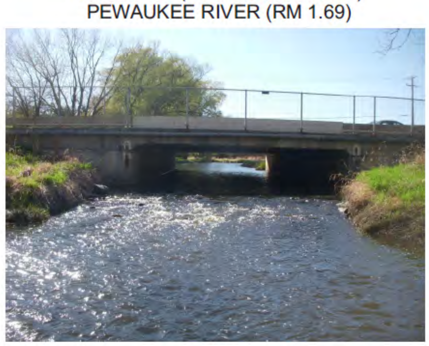
1- ABANDONED RAILROAD
PEWAUKEE RIVER (RM 0.05)

2- CTH F
PEWAUKEE RIVER (RM 0.11)

3- STEINHAFEL'S DRIVEWAY
PEWAUKEE RIVER (RM 0.39)

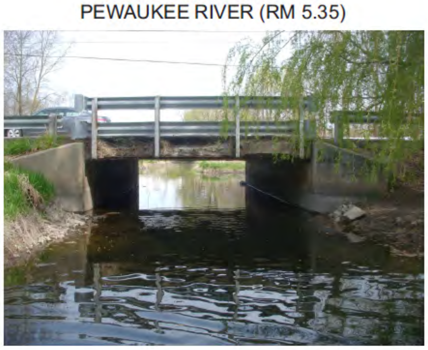
4- BUSSE ROAD
PEWAUKEE RIVER (RM 1.02)

5- STH 164 (PEWAUKEE ROAD)
PEWAUKEE RIVER (RM 1.69)

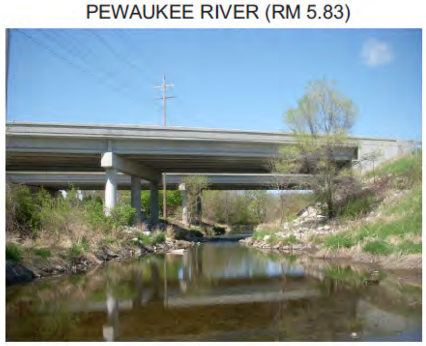


6- I-94
PEWAUKEE RIVER (RM 2.16)

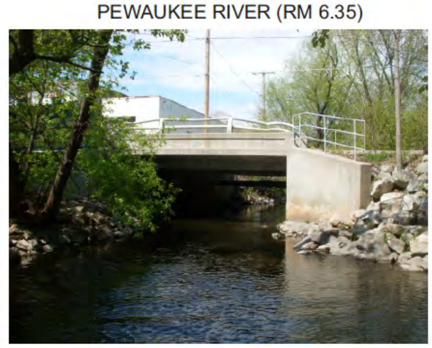
7- WISCONSIN AVENUE
PEWAUKEE RIVER (RM 5.35)



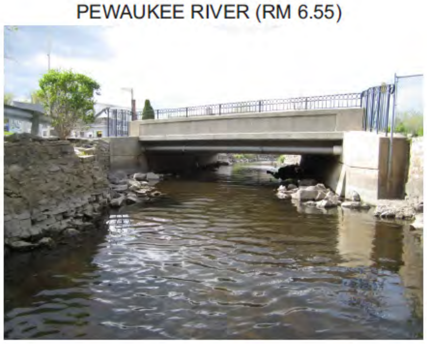
8- STH 16
PEWAUKEE RIVER (RM 5.83)



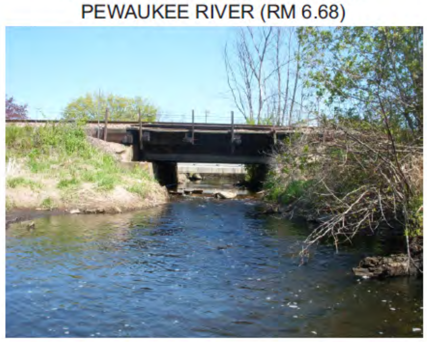
9- CLARK STREET
PEWAUKEE RIVER (RM 6.35)



10- OAKTON AVENUE
PEWAUKEE RIVER (RM 6.55)



11- CANADIAN PACIFIC RAILWAY
PEWAUKEE RIVER (RM 6.68)



12- CAPITOL DRIVE
PEWAUKEE RIVER (RM 6.69)

Figure F-1 (continued)

13- STH 16
PEWAUKEE RIVER (RM 7.30)

14- CECILIA DRIVE
PEWAUKEE RIVER (RM 7.54)

15- PRIVATE BRIDGE 1
PEWAUKEE RIVER (RM 8.12)

16-PRIVATE BRIDGE 2
PEWAUKEE RIVER (RM 8.57)

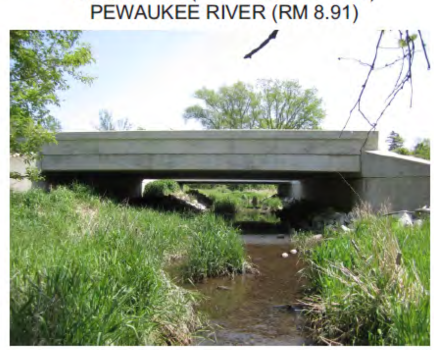
17- PRIVATE BRIDGE 3
PEWAUKEE RIVER (RM 8.62)

18- PRIVATE DROP STRUCTURE
PEWAUKEE RIVER (RM 8.62)

19- PRIVATE BRIDGE 4
PEWAUKEE RIVER (RM 8.65)

20-LINDSEY ROAD
PEWAUKEE RIVER (RM 8.74)

21- STH 164 (PEWAUKEE ROAD)
PEWAUKEE RIVER (RM 8.91)



22- PRIVATE BRIDGE 5
PEWAUKEE RIVER (RM 9.29)

23- PRIVATE BRIDGE 6
PEWAUKEE RIVER (RM 9.40)

24- PRIVATE BRIDGE 7
PEWAUKEE RIVER (RM 9.55)

Figure F-1 (continued)

25- PRIVATE CULVERT 1
PEWAUKEE RIVER (RM 9.59)

26-PRIVATE BRIDGE 8
PEWAUKEE RIVER (RM 9.63)

27- PRIVATE CULVERT 2
PEWAUKEE RIVER (RM 9.79)

28- CTH K (LISBON ROAD)
PEWAUKEE RIVER (RM 9.81)

29- CTH JJ (BLUEMOUND ROAD)
CTH JJ TRIBUTARY (RM 0.53)

30- STH 16
CTH JJ TRIBUTARY (RM 0.72)

31- CTH T
CTH JJ TRIBUTARY (RM 0.77)

32- PEWAUKEE LAKE OUTLET
PEWAUKEE LAKE OUTLET (RM 0.09)

33- CANADIAN PACIFIC RAILWAY
COCO CREEK (RM 0.00)

34- GLACIER ROAD
COCO CREEK (RM 0.11)

35- CTH JJ
COCO CREEK (RM 0.52)

36- PRIVATE CULVERTS
COCO CREEK (RM 0.81)

Figure F-1 (continued)


37- YENCH ROAD
COCO CREEK (RM 1.00)


38- CTH KE
COCO CREEK (RM 2.43)


39- CTH JK (LISBON AVENUE)
COCO CREEK (RM 3.20)


40- STH 16
COCO CREEK (RM 3.56)


41- STH 16
COCO CREEK TRIBUTARY (RM 0.04)


42- CTH KF (RYAN ROAD)
COCO CREEK TRIBUTARY (RM 1.34)


43- CTH SS
MEADOWBROOK (RM 0.00)


44- CTH G
MEADOWBROOK (RM 1.11)


45- FIELDHACK DRIVE
MEADOWBROOK (RM 2.10)


46- MILKWEED LANE
MEADOWBROOK (RM 2.35)

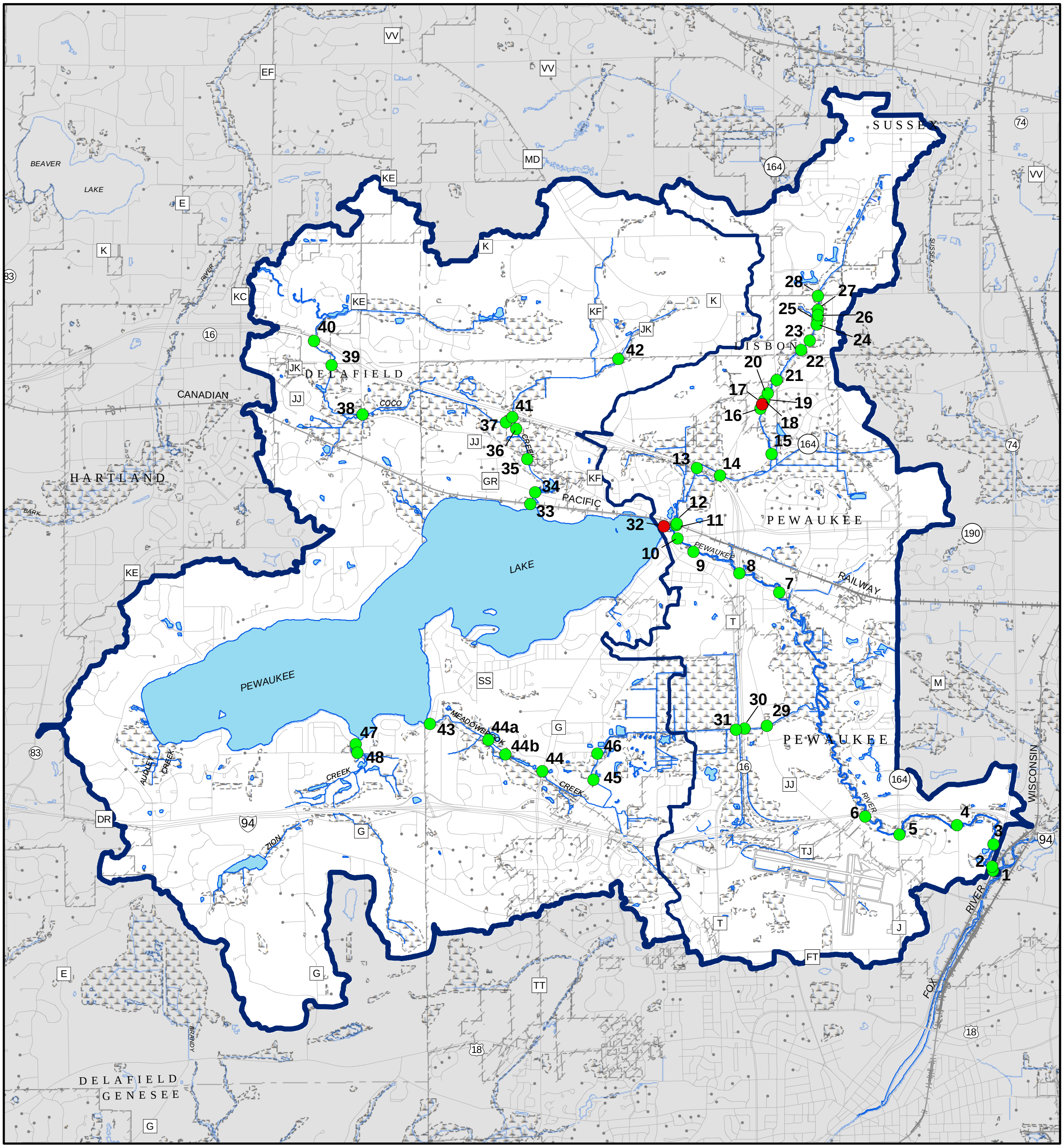

47- LOUIS AVENUE
ZION CREEK (RM 0.04)


48- OAKTON AVENUE
ZION CREEK (RM 0.19)

Source: SEWRPC.

Map F-1

STREAM CROSSINGS AND DAMS WITHIN THE PEWAUKEE RIVER WATERSHED: 2012



STREAM CROSSING

DAM/DROP STRUCTURE

15 STREAM CROSSING DESIGNATION (see Table F-1)

SURFACE WATER

STREAM

PEWAUKEE RIVER TOTAL DRAINAGE AREA

PEWAUKEE RIVER DIRECT DRAINAGE AREA

N

0 0.5 1 Miles

0 2,500 5,000 Feet

Source: SEWRPC.

CRITERIA AND GUIDELINES FOR STREAM CROSSINGS TO ALLOW FISH PASSAGE AND MAINTAIN STREAM STABILITY WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

TYPES OF CROSSINGS

- The number of stream crossings should be minimized.
- If a crossing is necessary, structures that maintain to the extent possible the existing streambed and bank conditions are preferable; therefore, bridges spanning streams are preferable to other structures.
- If a culvert is necessary, open bottom structures are preferable to closed bottom structures.
- If a closed bottom culvert is necessary, box culverts, elliptical, or pipe arch culverts are preferable to round pipe culverts, because round pipes generally reduce stream width to a much larger degree than the aforementioned structures, causing long-term upstream and downstream passage limitations (see physical considerations below).

BIOLOGICAL CONSIDERATIONS[1]

- Contact the area WDNR fisheries manager prior to design.[2]
- Species of fish present (coldwater, warmwater, threatened, endangered, species of special concern).
- Life stages to potentially be impacted (e.g., egg development within substrates should be avoided).
- Migration timing of affected species/ life stages (e.g., adult spawning times should be avoided).

PHYSICAL CONSIDERATIONS[3]

It is important to note that in order to achieve the minimum physical criteria outlined below, the culvert(s) will need to be oversized as part of the design to ensure adequate long-term fish passage as well as the ability to pass the design period rainfall event.

It may not be possible to achieve some of the minimum passage criteria below based upon specific on-site conditions or constraints. However, the closer the designed and completed culvert meet these criteria, the better the long-term passage and overall sustainability of the fishery will be in this region.

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[1]*British Colombia Ministry of Forests,* Fish-stream crossing guidebook, *For. Prac. Br., Min. For., http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/Guidetoc.htm, Victoria, B.C. Forest Practices Code of British Columbia guidebook, 2002.*

[2]*UW-Extension and WDNR,* Fish Friendly Culverts*, 2002.*

[3]*Washington Department of Fish and Wildlife, Habitat and Lands Program, Environmental Engineering Division,* Fish Passage Design at Road Culverts: A Design Manual for Fish Passage at Road Crossings, *Washington, March 3, 1999.*

COMPARISON OF UNDERSIZED AND ADEQUATELY SIZED AND PLACED CULVERTS

Undersized culvert.

Properly sized and placed culverts.

Source: Minnesota Department of Natural Resources.

Provide Adequate Depth

- Slope—Culvert should be installed with a slope that matches the riffle slope as measured in the thalweg[4] (see Minnesota DNR guidelines[5]).

- Water Depth—Depths should maintain the determined thalweg depth at any point within the culvert during low flow periods (see Minnesota DNR guidelines).

- Installation Below Grade—The culvert should be installed so that the bottom of the structure is buried to a depth equal to 1/6th the bankfull width of the stream (up to two feet) below the natural grade line elevation of the stream bottom (see Minnesota DNR guidelines). The culvert should then be filled to stream grade with natural substrates. The substrates should consist of a variety of gravel ranging from one to four inches in diameter and either mixed with nonuniformly laid riprap or uniformly placed alternate riprap baffles, large enough to be stable during the culvert design discharge, which will ensure stability of substrates during high-flow events.

Provide Adequate Width

- Width—Culvert width shall match the bankfull width (minimum) of the existing channel.

- Offsetting Multiple Culverts—The number of culverts used should be minimized. However, if multiple culverts are necessary, it is recommended that the culvert inverts be offset vertically and only one culvert be designed to provide passage during low-flow conditions and the additional culverts be used to pass the higher flow events (see figure above). Therefore, the low-flow culvert will be the only culvert, in a series of two or more culverts, designed to provide fish passage during low flows and shall meet the physical requirements of passage above.

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[4]*The thalweg is the lowest point of the streambed.*

[5]*Minnesota DNR, Best Practices for Meeting DNR General Public Waters Work Permit GP 2004-0001, March 2006.*

Provide Adequate Resting Areas

- Length—Culverts that exceed more than 75 feet in length need to provide additional resting areas (e.g., installation of baffles or weirs) within the culvert to facilitate passage.[6]

Inlet and Outlet Protection

- Align the culvert with the existing stream alignment (e.g., 90 degree bends at the inlet or outlet should be avoided, even though this will increase culvert length, see Minnesota DNR guidelines).

- The low-flow culvert should be centered on the thalweg of the channel to ensure adequate depths inside the culvert.

- Provide grade control where there is potential for head-cuts that could degrade the channel.

- It may be necessary to install riprap protection on the outside bank below the outlet to reduce bank erosion during high-flow events.

[6]*Thomas Slawski and Timothy Ehlinger, "Habitat Improvement in Box Culverts: Management in the Dark?,"* North American Journal of Fisheries Management, *Volume 18:676-685, 1998.*

Road/Stream Crossing Inspection Data Sheet

Site ID: __________

Name of Observer(s)____________________________ **Date**____________

GPS coordinates (lat/long.) ______________________________ OR **T/R**__________ **Sec**____ ¼____

Road Name___________________________ **Road Number** ________ **Structure ID** ________

Stream Name________________________________ **Road type** State County Town Private Federal Other

Land Use In Surrounding Area: (circle all that apply)
Forest Wetland Open/Field Pasture Cultivated Urban Other

Additional comments about location (milepost, etc.)**:**

Road Surface (circle all that apply) Paved Gravel Native **Road Width** ______ft. **with shoulders** ______ft.

Erosion of road near crossing? Y N
(if YES, also fill out Section F)

Is there a trash rack or beaver prevention structure? Y N

Evidence of crossing blow-out? Y N **Evidence of beaver activity? Y N**

Structure Type (circle one) Culvert Bridge Ford No Structure

A. Crossing Characteristics:

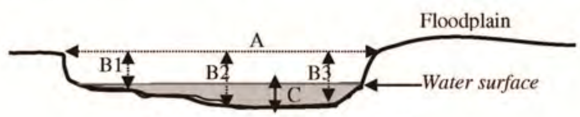
		Inlet/Upstream	Outlet/Downstream	Comments/Notes
Embankment or Side Slopes (not applicable to Fords)	Protection	vegetation armor other	vegetation armor other	
	Erosion *(if Y, fill out Section F)*	Y N	Y N	
Channel	Aligned	Y N	Y N	
	Pool present	Y N	Y N	
	Pool scour width	ft.	ft.	
	Pool water depth (max.)	ft.	ft.	
	Protection	armor other none	armor other none	
Ditch	Present	Y N	Y N	
	Protection	vegetation armor other	vegetation armor other	
	Connected to stream	Y N	Y N	
	Erosion *(if Y, fill out Section F)*	Y N	Y N	

B. Stream Measurements (*See standard procedure in instruction sheet*)**:**

A: Bankfull Width _________feet

B: Bankfull Depth (left to right facing downstream)
B1:______feet B2:______feet B3:______feet

C: Water depth _______ feet



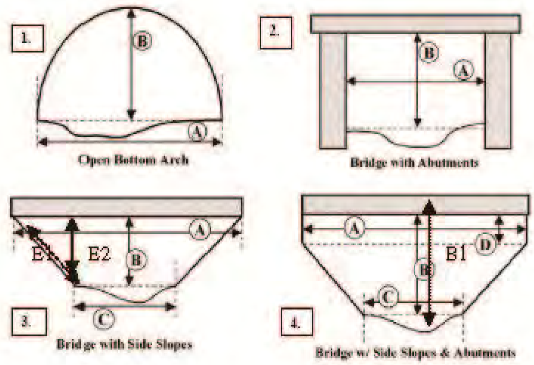
Cross-section of stream channel

Flow conditions: overbank at bankfull below bankfull very low none

Fish present? Y N

page 1
4/2/2007

E. Bridge Characteristics (For multiple cells see below):



Bridge Type (# from diagram) _______

Bridge Surface Material:

Wood	Open decking? Y N
Concrete	Asphalt
Metal	other __________

Bridge Measurements:

A: Span ______feet Width (parallel to stream) ______feet

B: Bottom of beam to water surface _______feet

B1: Bridge Rise (bottom of beam to stream bed) _______feet

C: Stream width _______feet

D: Bottom of beam to top of embankment _______feet

E: Side Slopes (facing downstream):

Left bank: E1_______feet E2______feet **Right Bank**: E1______feet E2______feet

Present at inlet (circle all that apply): Wingwalls Apron Other _______________
Present at outlet (circle all that apply): Wingwalls Apron Other _______________

Condition of Structure: Deteriorating **Y or N**
If yes, where (check all that apply)? ☐ Abutments ☐ Decking ☐ Wingwalls ☐ Other__________________

Multiple Bridge Cells
NOTE: *(number multiple bridge cells (usually separated by abutments) from left to right facing downstream. Fill in sections above for bridge cell # 1 and use this section for remaining cells)*

Bridge Cell #	A (ft.)	B (ft.)	B1 (ft.)
2			
3			
4			

F. Erosion Properties – *(fill out all that apply, add other locations in blank rows. Other locations to note may include prominent erosion along stream banks within 50' of crossing.)*

Location of Erosion	Erosion Dimensions (feet)			Material Eroded (clay, silt, sand, gravel, loam, sandy loam, OR gravelly loam)	Erosion Reaching Stream? (Y/N)	Comments
	Length	Width	Depth			
Road approach *(left, facing downstream)*						
Road approach *(right, facing down stream)*						
Ditch(s) *(upstream side of road)*						
Ditch(s) *(downstream side of road)*						
Road over crossing (or bridge deck)						
Culvert inlet embankment						
Culvert outlet embankment						
Bridge Side slopes *(left, facing downstream)*						
Bridge Side slopes *(right, facing down stream)*						

If erosion occurs on the approaches or in the ditches, is there opportunity (room) to install road drainage measures?
Y **N**

G. Site Sketches (Identify road crossing, stream, flow direction, issues, and location and direction of photos):

↑ **N**

Comments: *(Provide additional information such as invasive plants present, spillways present, etc)*

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Appendix G

USEPA CLIMATE INDICATORS BROCHURE: 2012

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United States Environmental Protection Agency

Climate Change Indicators in the United States, 2012

EPA's *Climate Change Indicators in the United States, 2012*, presents compelling evidence that many fundamental measures of climate in the United States are changing. Temperatures are rising, snow and rainfall patterns are shifting, and more extreme climate events—like heavy rainstorms and record-high temperatures—are already affecting society and ecosystems. Similar changes are occurring around the world. EPA's report presents 26 indicators, which are organized into the five categories listed at right.

Observed Changes

Greenhouse Gases: Greenhouse gas emissions are increasing as a result of people's activities. Consequently, average concentrations of these heat-trapping gases in the atmosphere are also increasing.

Weather and Climate: Average U.S. and global temperatures are increasing. Other attributes of weather and climate, such as precipitation, drought, and tropical cyclone activity, are changing.

Oceans: The oceans are getting warmer. Sea levels are rising around the world, and the oceans are becoming more acidic.

Snow and Ice: The extent of Arctic sea ice is declining. Glaciers in the United States and around the world are generally shrinking, while snowfall and snow cover in the United States have decreased overall.

Society and Ecosystems: Ragweed pollen season is lengthening, as is the growing season for crops. Winter habitats of bird species have shifted northward as temperatures have risen.

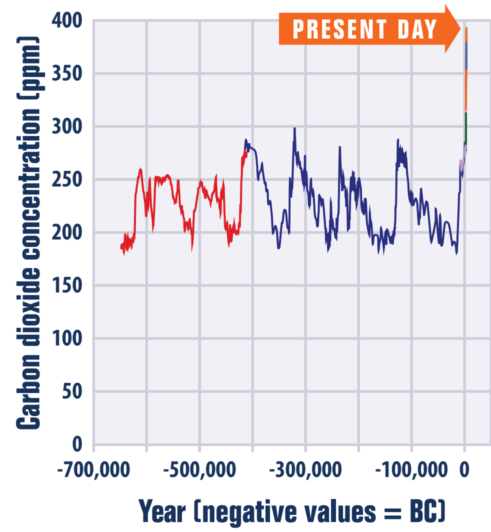
Climate Change In

Atmospheric Concentrations of Greenhouse Gases

Before the industrial era began in the late 1700s, global carbon dioxide concentrations in the atmosphere measured approximately 280 parts per million (ppm). Concentrations have risen steadily since then, reaching 391 ppm in 2011—a 40 percent increase. Current global atmospheric concentrations of carbon dioxide are unprecedented compared with the past 650,000 years.

Global Atmospheric Concentrations of Carbon Dioxide Over Time

~650,000 years ago to present

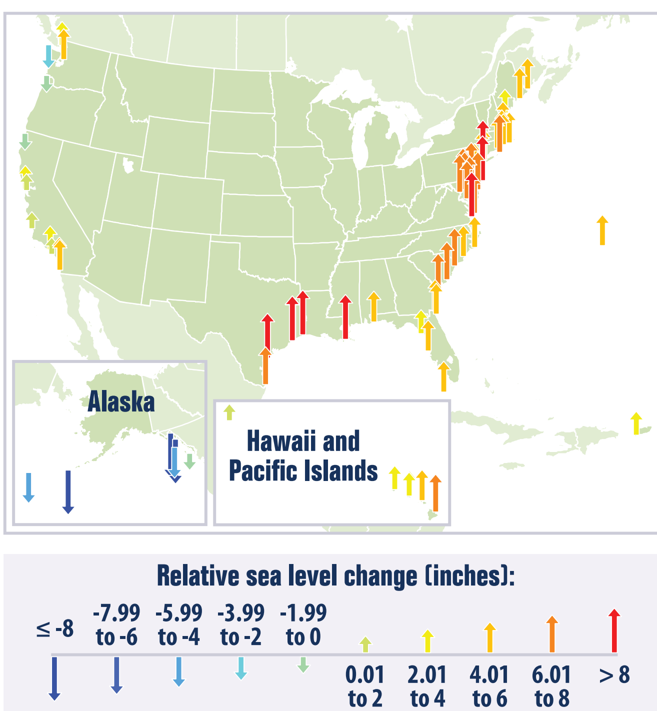


Data source: Compilation of 12 underlying datasets

Sea Level

As temperatures rise, seawater warms up and expands, and ice melts. This raises sea level worldwide. Sea level rose relative to the land along much of the U.S. coastline between 1960 and 2011, particularly along the Mid-Atlantic and Gulf Coasts. Some parts of the Gulf Coast have registered a relative sea level rise of more than 8 inches since 1960.

Relative Sea Level Change Along U.S. Coasts, 1960–2011

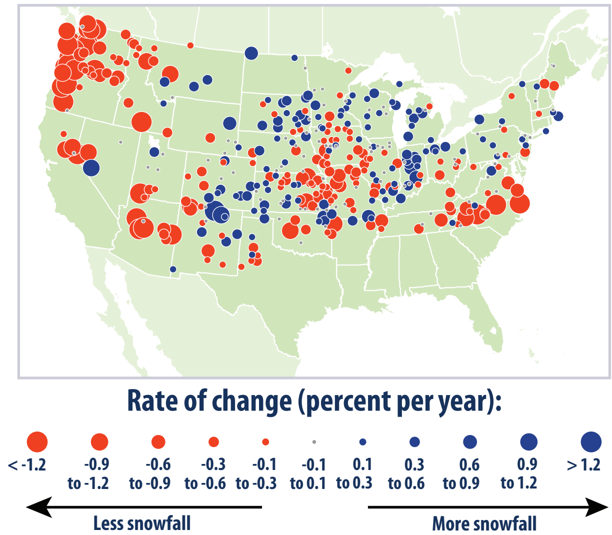


Data source: NOAA, 2012

Snowfall

With warming temperatures and changing weather patterns, snowfall amounts have decreased in many parts of the country (as indicated by the red circles on the map), with 57 percent of weather stations showing a decline. The Pacific Northwest has seen the largest consistent decline in snowfall, but some regions have experienced modest increases, including areas near the Great Lakes.

Change in Total Snowfall in the Contiguous 48 States, 1930–2007

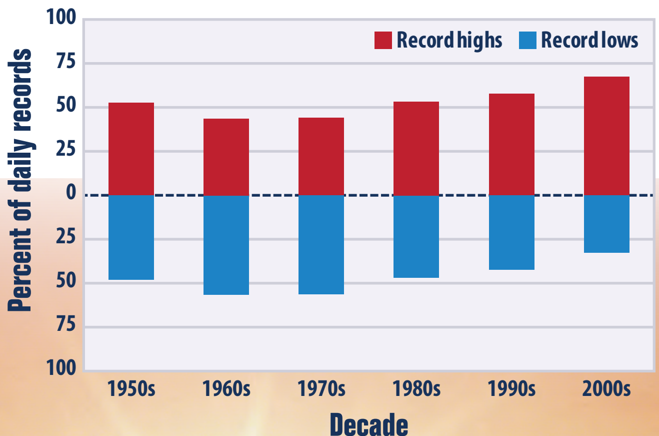


Data source: Kunkel et al., 2009

High and Low Temperatures

Since the 1970s, record-setting daily high temperatures have become more common than record lows across the United States. The most recent decade had twice as many record highs as record lows.

Record Daily High and Low Temperatures in the Contiguous 48 States, 1950–2009

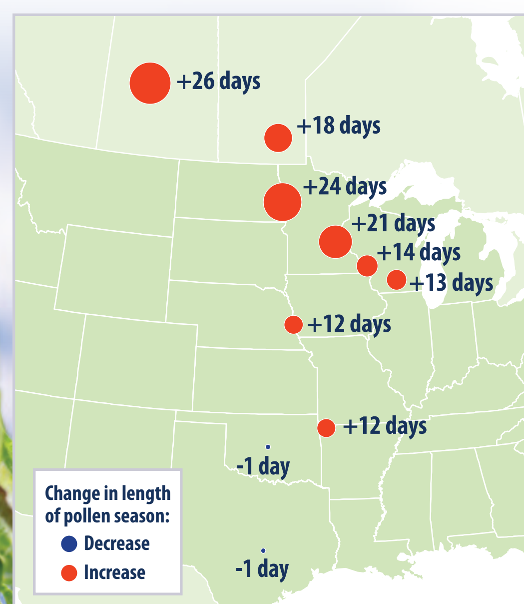


Data source: Meehl et al., 2009

Ragweed Pollen Season

The length of the ragweed pollen season is closely related to the timing of the first fall frost, which is occurring later than it used to in northern areas. Since 1995, the ragweed pollen season has grown longer at eight of the 10 locations studied. The red circles represent a longer pollen season, with larger circles indicating larger changes.

Change in Ragweed Pollen Season, 1995–2011



Data source: Ziska et al., 2012

2012 Climate Indicators

Greenhouse Gases

U.S. Greenhouse Gas Emissions

Global Greenhouse Gas Emissions

Atmospheric Concentrations of Greenhouse Gases

Climate Forcing

Weather and Climate

U.S. and Global Temperature

High and Low Temperatures

U.S. and Global Precipitation

Heavy Precipitation

Drought

Tropical Cyclone Activity

Oceans

Ocean Heat

Sea Surface Temperature

Sea Level

Ocean Acidity

Snow and Ice

Arctic Sea Ice

Glaciers

Lake Ice

Snowfall

Snow Cover

Snowpack

Society and Ecosystems

Streamflow

Ragweed Pollen Season

Length of Growing Season

Leaf and Bloom Dates

Bird Wintering Ranges

Heat-Related Deaths

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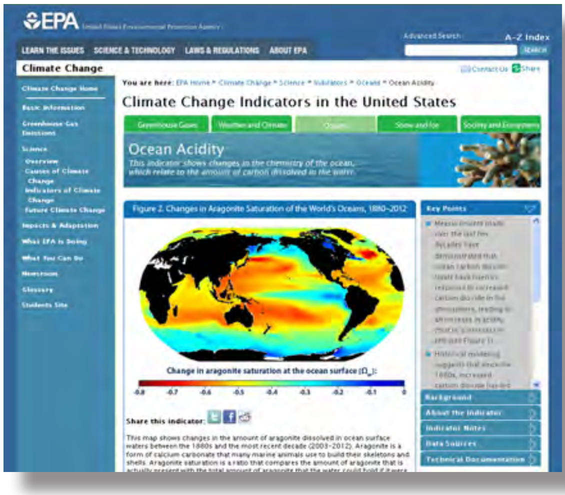
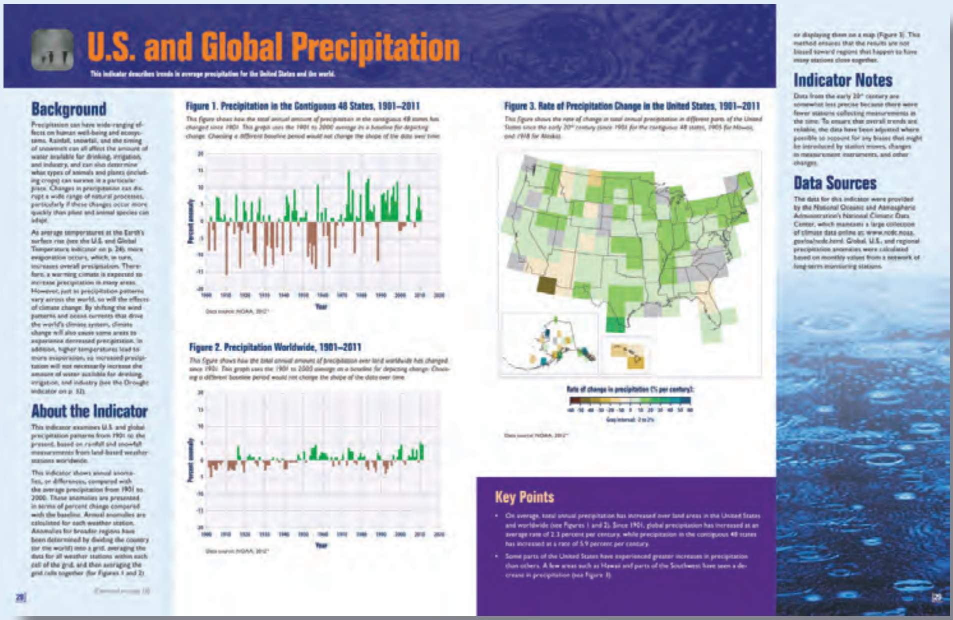


For each of the 26 indicators, the report presents graphics depicting changes over time, key points about what the graphics show, background on how the indicator relates to climate change, and information about how the indicator was developed.

The website also features technical documentation that provides additional details about each indicator. Visitors to the website can share report content through social media outlets like Facebook and Twitter.

A print version of the report is available by request or for download from the website.



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December 2012 EPA 430-F-12-032

Appendix H

BIRDS KNOWN OR LIKELY TO OCCUR IN THE PEWAUKEE RIVER WATERSHED

		Year-Round Observations	Wisconsin Breeding Bird Atlas			The Great Backyard Bird Count		Wisconsin Society of Ornithology (WSO)		Federal and State
Scientific (family) and Common Name	Scientific Name	Waukesha County	Sussex Quad	Hartland Quad	Waukesha Quad	Hartland	Waukesha	Abundance	Status	Status
Podicipedidae										
Pied-Billed Grebe	*Podilymbos podiceps*	B, M	- -	- -	- -	- -	X	Common	- -	- -
Ardeidae										
Great Blue Heron	*Ardea herodias*	B, M	X	- -	X	- -	X	Common	SC	SC
Green Heron	*Butorides striatus*	B, M	X	X	- -	- -	- -	Common	- -	- -
Anatidae										
Mute Swan	*Cygnus olor*	B, R, W	- -	X	- -	- -	X	Uncommon	- -	Alien
Snow Goose	*Chen caerulescens*	M	- -	- -	- -	- -	- -	Uncommon	- -	- -
Canada Goose	*Branta canadensis*	B, M, R, W	X	X	X	X	X	Common	- -	- -
Wood Duck	*Aix sponsa*	B, M	X	X	X	- -	- -	Common	- -	- -
Mallard	*Anas platyrhynchos*	B, R	X	X	X	X	X	Common	- -	- -
Blue-Winged Teal	*Anas discors*	B, M	- -	X	- -	- -	- -	Common	SGCN	- -
Common Goldeneye	*Bucephala clangula*	M, W	- -	- -	- -	- -	X	Common	SC	SC
Hooded Merganser	*Lophodytes cucullatus*	B, M	- -	- -	- -	- -	- -	Common	- -	- -
Common Merganser	*Mergus merganser*	M, W	- -	- -	- -	- -	X	Common	- -	SC
Accipitridae										
Bald Eagle	*Haliaeetus leucocephalus*	M	- -	- -	- -	X	X	Common	SGCN, SC	SC,FTHR
Cooper's Hawk	*Accipiter cooperii*	B, R	X	X	X	X	X	Common	- -	- -
Sharp-Shinned Hawk	*Accipiter striatus*	B, M, R	- -	- -	- -	X	X	Common	- -	- -
Northern Harrier	*Circus cyaneus*	B, R	- -	- -	- -	X	X	Common	SGCN	SC
Broad-Winged Hawk	*Buteo platypterus*	B, M	- -	- -	- -	- -	- -	Common	- -	- -
Red-Tailed Hawk	*Buteo jamaicensis*	B, R	X	X	X	X	X	Common	- -	- -
Northern Goshwak	*Accipiter gentiles*	R	- -	- -	- -	- -	- -	Uncommon	SGCN, SC	SC
Red-shouldered Hawk	*Buteo lineatus*	B, M, R	- -	X	- -	- -	- -	Uncommon	SGCN, THR	STHR
Rough Legged Hawk	*Buteo lagopus*	M, W	- -	- -	- -	- -	X	Common	- -	- -
Falconidae										
American Kestrel	*Falco sparverius*	B, R	X	- -	X	- -	- -	Common	- -	- -
Phasianidae										
Wild Turkey	*Meleagris gallopavo*	B, R	X	X	- -	X	X	Common	- -	- -
Grey Partridge	*Perdix perdix*	R	- -	- -	- -	- -	- -	Uncommon	- -	Alien
Ring-Necked Pheasant	*Phasianus colchicus*	B, R	X	X	Probable[a]	X	X	Common	- -	Alien

NOTE: The following abbreviations are used in this table:

B = Breeding: Nesting species
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R = Resident: Present Year Round

Status abbreviations for WSO:

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SC = Special Concern
END = Endangered
THR = Threatened

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Appendix H (continued)

Scientific (family) and Common Name	Scientific Name	Year-Round Observations	Wisconsin Breeding Bird Atlas			The Great Backyard Bird Count		Wisconsin Society of Ornithology (WSO)		Federal and State
		Waukesha County	Sussex Quad	Hartland Quad	Waukesha Quad	Hartland	Waukesha	Abundance	Status	Status
Rallidae										
Virginia Rail	*Rallus limicola*	B, M	- -	- -	X	- -	- -	Common	- -	- -
Common Moorhen	*Gallinula chloropus*	B, M	- -	Probable[a]	- -	- -	- -	- -	- -	SC
Gruidae										
Sandhill Crane	*Grus canadensis*	B	Probable[a]	- -	X	X	X	Common	- -	- -
Charadriidae										
Killdeer	*Charadrius vociferus*	B, M	X	X	X	- -	- -	Common	- -	- -
Scolopacidae										
Spotted Sandpiper	*Actitis macularia*	B, M	- -	- -	Probable[a]	- -	- -	Common	- -	- -
American Woodcock	*Scolopax minor*	B, M	X	X	Probable[a]	- -	- -	Common	SGCN	- -
Laridae										
Ring-Billed Gull	*Larus delawarensis*	R	- -	- -	- -	X	X	Common	- -	- -
Herring Gull	*Larus argentatus*	R	- -	- -	- -	- -	X	Common	- -	- -
Columbidae										
Rock Dove	*Columba livia*	B, R	X	X	X	X	X	Common	- -	Alien
Mourning Dove	*Zenaida macroura*	B, R	X	X	X	X	X	Common	- -	- -
Strigidae										
Eastern Screech Owl	*Otus asio*	B, R	X	X	X	- -	X	Common	- -	- -
Great Horned Owl	*Bubo virginianus*	B, R	X	X	X	X	X	Common	- -	- -
Snowy Owl	*Nyctea scandiaca*	W, M	- -	- -	- -	- -	X	Uncommon	- -	- -
Barred Owl	*Strix varia*	B, R	- -	Probable[a]	- -	- -	- -	Common	- -	- -
Short-Eared Owl	*Asio flammeus*	R, PB	- -	- -	- -	- -	- -	Uncommon	SGCN, SC	SC
Northern Saw-Whet Owl	*Aegolius acadicus*	Bp, M, R	- -	- -	Probable[a]	- -	- -	Common	- -	- -
Caprimulgidae										
Common Nighthawk	*Chordeiles minor*	B, M	- -	- -	X	- -	- -	Common	SC	- -
Apodidae										
Chimney Swift	*Chaetura pelagica*	B, M	X	X	X	- -	- -	Common	- -	- -
Trochilidae										
Ruby-Throated Hummingbird	*Archilochus colubris*	B, M	X	X	X	- -	- -	Common	- -	- -
Alcedinidae										
Belted Kingfisher	*Ceryle alcyon*	B, M	X	- -	X	X	X	Common	- -	- -

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		Waukesha County	Sussex Quad	Hartland Quad	Waukesha Quad	Hartland	Waukesha	Abundance	Status	Status
Picidae										
Red Bellied Woodpecker	*Melanerpes carolinus*	B, R	X	X	X	X	X	Common	- -	- -
Downy Woodpecker	*Picoides pubescens*	B, R	X	X	X	X	X	Common	- -	- -
Hairy Woodpecker	*Picoides villosus*	B, R	X	X	X	X	X	Common	- -	- -
Pileated Woodpecker	*Dryocopus pileatus*	B, R	- -	- -	- -	- -	- -	Common	- -	- -
Northern Flicker	*Colaptes auratus*	B, M, R	X	X	X	X	X	Common	- -	- -
Tyrannidae										
Eastern Wood-Pewee	*Contopus virens*	B, M	X	X	Probable[a]	- -	- -	Common	- -	- -
Yellow-Bellied Flycatcher	*Empidonax flaviventris*	- -	- -	- -	- -	- -	- -	Common	- -	- -
Acadian Flycatcher	*Empidonax virescens*	B, M	X	- -	- -	- -	- -	Uncommon	SGCN	STHR
Alder Flycatcher	*Empidonax alnorum*	Bp, M	- -	- -	Probable[a]	- -	- -	Common	- -	- -
Willow Flycatcher	*Empidonax traillii*	B, M	X	X	- -	- -	- -	Common	SGCN	- -
Least Flycatcher	*Empidonax minimus*	B, M	X	Probable[a]	- -	- -	- -	Common	SGCN	- -
Eastern Phoebe	*Sayornis phoebe*	B, M	X	X	X	- -	- -	Casual/ accidental; not regular	- -	- -
Great Crested Flycatcher	*Myiarchus crinitus*	B, M	X	X	Probable[a]	- -	- -	Common	- -	- -
Eastern Kingbird	*Tyrannus tyrannus*	B, M	X	X	X	- -	- -	Common	- -	- -
Alaudidae										
Horned Lark	*Eremophila alpestris*	Bp, M, R	Probable[a]	- -	- -	- -	X	Common	- -	- -
Hirundinidae										
Purple Martin	*Progne subis*	B, M	- -	X	- -	- -	- -	Common	SC	- -
Tree Swallow	*Tachycineta bicolor*	B, M	X	X	X	- -	- -	Common	- -	- -
Northern Rough-Winged Swallow	*Stelgidopteryx serripennis*	B, M	X	X	- -	- -	- -	Common	- -	- -
Cliff Swallow	*Petrochelidon pyrrhonota*	B, M	X	X	- -	- -	- -	Common	- -	- -
Barn Swallow	*Hirundo rustica*	B, M	X	X	X	- -	- -	Common	- -	- -
Corvidae										
Blue Jay	*Cyanocitta cristata*	B, R	X	X	X	X	X	Common	- -	- -
American Crow	*Corvus brachyrhynchos*	B, R	X	X	X	X	X	Common	- -	- -
Common Raven	*Corvus corax*	R	- -	- -	- -	- -	- -	Common	- -	- -
Paridae										
Tufted Titmouse	*Baeolophus bicolor*	B, R	- -	- -	- -	X	X	Common	- -	- -
Black-Capped Chickadee	*Parus atricapillus*	B, R	X	X	X	X	X	Common	- -	- -

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		Waukesha County	Sussex Quad	Hartland Quad	Waukesha Quad	Hartland	Waukesha	Abundance	Status	Status
Sittidae										
Red-Breasted Nuthatch	*Sitta canadensis*	B, R	- -	- -	- -	X	X	Common	- -	- -
White-Breasted Nuthatch	*Sitta carolinensis*	B, R	X	X	X	X	X	Common	- -	- -
Certhiidae										- -
Brown Creeper	*Certhia americana*	B, M	X	- -	- -	X	- -	Common	- -	- -
Troglodytidae										
Carolina Wren	*Thryothorus ludovicianus*	- -	- -	- -	- -	- -	X	Uncommon	- -	- -
House Wren	*Troglodytes aedon*	B, M	X	X	X	- -	- -	Common	- -	- -
Winter Wren	*Troglodytes troglodytes*	M	- -	- -	- -	- -	- -	Common	- -	- -
Sedge Wren	*Cistothorus platensis*	B, M	- -	- -	- -	- -	- -	Common	- -	- -
Marsh Wren	*Cistothorus palustris*	B, M	- -	- -	Probable[a]	- -	- -	Common	- -	- -
Sylviidae										
Blue-Gray Gnatcatcher	*Polioptila caerulea*	B, M	X	X	X	- -	- -	Common	- -	- -
Turidae										
Eastern Bluebird	*Sialia sialis*	B, M	X	X	X	X	- -	Common	- -	- -
Veery	*Catharus fuscescens*	B, M	- -	X	- -	- -	- -	Common	SGCN	- -
Wood Thrush	*Hylocichla mustelina*	B, M	X	X	- -	- -	- -	Common	SGCN	- -
American Robin	*Turdus migratorius*	B, M	X	X	X	X	X	Common	- -	- -
Mimidae										
Gray Catbird	*Dumetella carolinensis*	B, M	X	X	X	- -	- -	Common	- -	- -
Brown Thrasher	*Toxostoma rufum*	B, M	- -	X	X	- -	- -	Common	- -	- -
Bombycillidae										
Bohemian Waxwing	*Bombycilla garrulus*	- -	- -	- -	- -	- -	- -	Uncommon	- -	- -
Cedar Waxwing	*Bombycilla cedrorum*	B, M, R	X	X	X	X	X	Common	- -	- -
Sturnidae										
European Starling	*Sturnus vulgaris*	B, R	X	X	X	X	X	Common	- -	Alien
Vireonidae										
Yellow-Throated Vireo	*Vireo flavifrons*	B, M	Probable[a]	- -	- -	- -	- -	Common	SC	- -
Blue-Headed Vireo	*Vireo solitarius*	B	- -	- -	- -	- -	- -	Common	- -	- -
Warbling Vireo	*Vireo gilvus*	B, M	X	Probable[a]	Probable[a]	- -	- -	Common	- -	- -
Red-Eyed Vireo	*Vireo olivaceus*	B, M	X	X	Probable[a]	- -	- -	Common	- -	- -
Philadelphia Vireo	*Viero philadelphicus*	M	- -	- -	- -	- -	- -	Common	SC	- -

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Appendix H (continued)

Scientific (family) and Common Name	Scientific Name	Year-Round Observations: Waukesha County	Wisconsin Breeding Bird Atlas: Sussex Quad	Wisconsin Breeding Bird Atlas: Hartland Quad	Wisconsin Breeding Bird Atlas: Waukesha Quad	The Great Backyard Bird Count: Hartland	The Great Backyard Bird Count: Waukesha	Wisconsin Society of Ornithology (WSO): Abundance	Wisconsin Society of Ornithology (WSO): Status	Federal and State: Status
Parulidae										
Blue-Winged Warbler	*Vermivora pinus*	B	X	X	- -	- -	- -	Common	SGCN	- -
Yellow Warbler	*Dendroica petechia*	B, M	X	X	Probable[a]	- -	- -	Common	- -	- -
Chestnut-Sided Warbler	*Dendroica pensylvanica*	B, M	X	- -	- -	- -	- -	Common	- -	- -
American Redstart	*Setophaga ruticilla*	B, M	X	- -	- -	- -	- -	Common	- -	- -
Prothonotary Warbler	*Protonotaria citrea*	Bp, M	- -	Probable[a]	- -	- -	- -	Common	SGCN, SC	SC
Ovenbird	*Seiurus aurocapillus*	B, M	X	X	- -	- -	- -	Common	- -	- -
Common Yellowthroat	*Geothlypis trichas*	B, M	X	X	Probable[a]	- -	- -	Common	- -	- -
Thraupidae										
Scarlet Tanager	*Piranga olivacea*	B, M	Probable[a]	X	- -	- -	- -	Common	- -	- -
Cardinalidae										
Dickcissel	*Spiza americana*	B, M	- -	- -	- -	- -	- -	Common	SGCN	SC
Northern Cardinal	*Cardinalis cardinalis*	B, R	X	X	X	X	X	Common	- -	- -
Rose-Breasted Grosbeak	*Pheucticus ludovicianus*	B, M	X	X	X	- -	- -	Common	- -	- -
Indigo Bunting	*Passerina cyanea*	B, M	X	X	Probable[a]	- -	- -	Common	- -	- -
Emberizidae										
Eastern Towhee	*Pipilo erythrophthalmus*	B, M	X	X	X	- -	- -	Common	- -	- -
American Tree Sparrow	*Spizella arborea*	M, M	- -	- -	- -	X	X	Common	- -	- -
Clay-Colored Sparrow	*Spizella pallida*	M	- -	- -	- -	- -	- -	Common	- -	- -
Chipping Sparrow	*Spizella passerina*	B, M	X	X	X	- -	- -	Common	- -	- -
Field Sparrow	*Spizella pusilla*	B, M	X	X	Probable[a]	- -	- -	Common	SGCN	- -
Savannah Sparrow	*Passerculus sandwichensis*	B, M	X	X	X	- -	- -	Common	- -	- -
Henslow's Sparrow	*Ammodramus henslowii*	Bp, M	- -	Probable[a]	- -	- -	- -	Uncommon	SGCN, THR	STHR
Fox Sparrow	*Passerella iliaca*	M	- -	- -	- -	- -	- -	Common	- -	- -
Song Sparrow	*Melospiza melodia*	B, M, R	X	X	X	- -	X	Common	- -	- -
Swamp Sparrow	*Melospiza georgiana*	B, M	X	X	- -	- -	X	Common	- -	- -
White-Throated Sparrow	*Zonotrichia albicollis*	M, R	- -	- -	- -	X	- -	Common	- -	- -
White-Crowned Sparrow	*Zonotrichia leucophrys*	M	- -	- -	- -	- -	X	Common	- -	- -
Lark Sparrow	*Chondestes grammacus*	M	- -	- -	- -	- -	X	Common	SGCN	SC
Dark-Eyed Junco	*Junco hyemalis*	M, W	- -	- -	- -	X	- -	Common	- -	- -
Icteridae										
Bobolink	*Dolichonyx oryzivorus*	B, M	X	- -	Probable[a]	- -	- -	Common	SGCN	- -
Red-Winged Blackbird	*Agelaius phoeniceus*	B, M, R	X	X	X	X	X	Common	- -	- -
Eastern Meadowlark	*Sturnella magna*	B, M	X	X	Probable[a]	- -	- -	Common	SGCN	- -
Common Grackle	*Quiscalus quiscula*	B, M, R	X	X	X	- -	X	Common	- -	- -
Brown-Headed Cowbird	*Molothrus ater*	B, M, R	X	X	X	- -	- -	Common	- -	- -
Orchard Oriole	*Icterus spurius*	Bp, M	- -	- -	- -	- -	- -	Common	- -	SC
Northern (Baltimore) Oriole	*Icterus galbula*	B, M	X	X	X	- -	- -	Common	- -	- -

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Scientific (family) and Common Name	Scientific Name	Waukesha County	Sussex Quad	Hartland Quad	Waukesha Quad	Hartland	Waukesha	Abundance	Status	Status
Fringillidae										
Purple Finch	*Carpodacus purpureus*	R	- -	- -	- -	X	X	Common	- -	- -
House Finch	*Carpodacus mexicanus*	B, R	X	X	X	X	X	Common	- -	- -
Pine Siskin	*Carduelis pinus*	B, M, R, W	- -	- -	X	X	X	Common	- -	SC
American Goldfinch	*Carduelis tristis*	B, R, W	X	X	X	X	X	Common	- -	- -
White-Winged Crossbill	*Loxia leucoptera*	M, R, W	- -	- -	- -	- -	X	Uncommon	- -	- -
Passeridae										
House Sparrow	*Passer domesticus*	B, R, W	X	X	X	X	X	Common	- -	Alien
	Total Number of Species	- -	73	70	52	40	53	- -	- -	- -
	Total Number of Species, Including Probable Species	- -	77	76	68	40	53	- -	- -	- -

NOTE: The following abbreviations are used in this table:

B = Breeding: Nesting species
Bp = Probable Breeding
M = Migrant: Spring and/or fall transient
W = Wintering: Present January through February
R = Resident: Present Year Round

Status abbreviations for WSO:

SGCN = Species of Greatest Conservation Need
SC = Special Concern
END = Endangered
THR = Threatened

Status abbreviations for Federal and State:

SC = Special Concern
FTHR = Federally Designated Threatened Species
STHR = State-Designated Threatened Species
Alien = Nonnative Bird Species

[a]*Probable* = *Multiple singing or territorial birds detected within a block on one day; Birds observed in and around nesting habitats during breeding seasons; Singing male observed at same location on at least two occasions for seven or more days; Defensive breeding activity observed; Courtship behavior observed between a pair of birds; Bird is observed visiting the same likely nest site repeatedly, but cannot be considered confirmed due to cavity nesters or shrub nesting species that fly into the same thicket and disappear on several occasions; Confirmed habitant due to cavity nesters or for a shrub-nesting species; Agitated behavior or anxiety calls from adults observed; Nest building by wrens or excavations of cavities by woodpeckers observed.*

Source: *Samuel D. Robbins, Jr.,* Wisconsin Birdlife, Population & Distribution, Past and Present*, 1991; John E. Bielefeldt, Racine County Naturalist; Wisconsin Department of Natural Resources; National Audubon Society;* Wisconsin Breeding Bird Atlas*; Stanley Temple, John Cary and Robert Rolley,* Wisconsin Birds, A Seasonal and Geographical Guide, Second Edition*, 1997; Tory Peterson,* Peterson Field Guides, Eastern Birds*, 1980; The Great Backyard Bird Count is led by the Cornell Lab of Ornithology and National Audubon Society, with Canadian partner Bird Studies Canada and sponsorship from Wild Birds Unlimited.* http://www.birdsource.org/gbbc/whycount.html*.1998-2012; Wisconsin Breeding Bird Atlas is led by University of Wisconsin-Green Bay and Wisconsin Society for Ornithology.* http://www.uwgb.edu/birds/wbba/data/quadlist.asp*. 1995-2000. Wisconsin Society for Ornithology checklist is led by the Classification Committee of the American Ornithologists' Union, William P. Mueller, WSO Education Chair, as well as the Records Committee of the Wisconsin Society for Ornithology.* http://wsobirds.org/files/Records/Checklist/Checklist-09122012.pdf*. 2012.*

Appendix I

OUTDOOR RECREATIONAL OPPORTUNITIES IN AND NEAR THE PEWAUKEE RIVER WATERSHED

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Table I-1

OUTDOOR RECREATIONAL OPPORTUNITIES IN THE PEWAUKEE RIVER WATERSHED

Recreational Activity	Location	Fee	Description/Features
Parks			
1. Iron Wood Golf Course	W270 N6166 Moraine Drive Sussex, WI	Yes	18-hole course. Includes a club house, golf carts, full-length driving range, and two putting greens
2. Armory Park	W237 N5930 Maple Avenue Sussex, WI	No	28 acres, includes volleyball courts, soccer fields, basketball courts, baseball diamonds, nature trails, restrooms and shelter accommodations. Open daily: sunrise to 9 p.m.
3. Village Park	W244 N6067 Weaver Drive Sussex, WI	No	75 acres, baseball diamonds, sledding hills, nature trails, playground, picnic area, tennis and volleyball courts, disc golf course, restrooms and shelter accommodations. Open daily: sunrise to 11 p.m.
4. Melinda Weaver Park	W239 N6046 Maple Avenue Sussex, WI	No	Two acres, basketball and tennis courts. Open daily: sunrise to 9 p.m. Free parking on street
5. Ryan Park	Off CTH KF/Ryan Road and Lynndale Road	No	Roughly 200 acres, dog trails, horse trails, hiking trails. Parking is available
6. Richard J. Opie Park	450 West Street. Just north of Pewaukee Lake	No	Picnic area, basketball court and playground. Building to rent out is available
7. Village Beach/Lake Front Park	222 W. Wisconsin Street. Downtown Pewaukee, WI. Right on Pewaukee Lake	No	ADA accessible, nature areas, picnic area, restrooms and shelter available. Summer months allow for swimming at the beach
8. Pewaukee Village Park	325 Capitol Drive. Downtown Pewaukee, WI	No	ADA accessible, baseball, softball fields, tennis, volleyball and basketball courts, picnic area, nature trails, shelter and restrooms. Parking is available
9. Liberty Park	440 Concord Road, Pewaukee, WI	No	Softball, soccer and baseball fields, as well as tennis, volleyball and basketball courts. Picnic area, playground and portable toilets. Parking is available
10. Valley Forge Park	206 Morris Street, Pewaukee WI	No	Baseball and softball fields, basketball court, playground and portable toilets
11. Peffer Park	330 Main Street, Pewaukee, WI	No	Playground and picnic area
12. Pebble Valley Park	2565 Pebble Valley Road Waukesha, WI	No	38 acres, baseball field, basketball courts, picnic area and playground
13. South Park	N5 W27300 Northview Road Pewaukee, WI	No	ADA accessible, baseball, softball and soccer fields, along with basketball, volleyball and tennis courts. Picnic area, playground, and restrooms available
14. Willow Run Golf Course	N12 W26506 Golf Road Pewaukee, WI	Yes	18-hole, par 71 course with driving range, putting and chipping greens. Pro shop and restaurant conveniently located on the course, as well
15. West Park/Nettesheim Park	N26 W27497 Prospect Avenue Pewaukee, WI. between Ash Street and Oak Street	No	ADA accessible, baseball and softball fields, basketball and tennis courts, volleyball court, picnic area, playground, soccer field as well as restrooms and shelter. Parking is available
16. Sports Commons	Corner of Maple Avenue and Silvernail Road, Pewaukee, WI	No	Baseball and softball fields, playground, skate park and pavilion available
17. Elmhurst Park	Elmhurst Road. (CTH G). Just south of IH 94. Delafield, WI	No	5.5 acres, jogging path, picnic tables, shelter, and playground
18. Western Lakes Golf Course	W287 N1963 Oakton Road Pewaukee, WI	Yes	18-hole championship course. Offers golf carts, golf shop, practice facility, driving range, practice bunker, and chipping greens
19. Naga-Waukee Park/Golf course	Park: 651 STH 83, Hartland, WI Golf Course: STH 83 and CTH E	Yes	This park spans the land between Nagawicka Lake and Pewaukee Lake. Includes camping, boating, swimming, fishing, picnic areas, and Ice Age nature trails. Golf course is an 18-hole championship course with three sets of Tees for all skill levels. Park open daily: sunrise to 10 p.m.

Table I-1 (continued)

Recreational Activity	Location	Fee	Description/Features
Parks (continued)			
20. Bristlecone Pines	1500 E Arlene Drive Hartland, WI	Yes	World-class course. 7,006-yard, 18-hole golf course
21. Joliet Park	1010 Dona Road, Hartland, WI	No	1.6 acres, one softball field, playground and picnic facility
22. Simmons Woods	889 Cecilia Drive Pewaukee, WI	No	50 acres, includes beautiful nature trails, picnic area, portable toilets, and shelter. Parking is available
23. Frame Park	701 E. Moreland Boulevard Waukesha, WI	No	Picnic areas, paved trails, playground, and rental accommodations for use along the Fox River. Open daily: sunrise to sunset
24. Barstow Plaza	210 NW Barstow Street Waukesha, WI	No	Adjacent to Frame Park, along the Fox River
Boat Launches			
1. Pewaukee Lake Boat Ramp at Naga-Waukee Park	Located in Naga-Waukee Park, west end of Pewaukee Lake	Yes	Paved ramp, ADA accessible, restrooms available, boarding dock
2. Sports Dock Bar and Grill Boat Access	W278 N2345 Prospect Avenue Pewaukee, WI	Yes	Paved boat ramp and boarding dock. No personal watercraft
3. City of Pewaukee Boat Launch	End of Lakeview Boulevard, north of CTH SS	Yes	Paved ramp, ADA accessible, and restrooms
4. Boehm's Boat and Bait	W270 N2807 Elm Avenue Pewaukee, WI. South shoreline of Pewaukee Lake	Yes	Private paved ramp
5. Smokey's Bait Shop	129 Park Avenue Pewaukee, WI	Yes	Paved ramp. Boat, canoe, and kayak rentals. Slips available for yearly rental
Hiking/Biking Trails			
A. Bugline Trail	Trailhead in Menomonee Falls, WI, adjacent to post office. Trail runs through Sussex, WI	No	12-mile-long recreational trail. Crushed Lannon stone and dirt path that runs through forest, residential, farmland and prairie areas. Wheelchair accessible, allows biking, horseback riding, and walking
B. Simmons Woods Trail	889 Cecilia Drive Pewaukee, WI	No	1.5-mile trail looping through Simmons Woods includes an 800-foot handicapped-accessible boardwalk through wetland
C. Existing Paths along Pewaukee River	Just off Capitol Drive and River Street in downtown Pewaukee, WI	No	Walking trails that allow for quiet scenic views along the Pewaukee River
D. Lake County Recreational Trail	Trailhead in Cushing Park, off STH 83 in Delafield, WI	No	Eight-mile crushed limestone and paved trail that runs between Landsberg trailhead and Cushing Park, Delafield. Allows bikers, hikers, and joggers. Intersects with Ice Age trail just west of STH 83
E. Bikeway Route in Hartland, WI.	Runs from Cardinal Lane to E. Capitol Drive Hartland, WI	No	Paved bike route runs through downtown Hartland, Wisconsin
F. Ice Age Trail, Hartland Segment	Foxwood Drive to Centennial Park, Hartland WI	No	Ice Age trail traces the terrain that was along the glacier's edge in Wisconsin. The trail shown on this map is the Hartland Segment- a 6.9-mile, mostly paved trail. Visit *www.iceagetrail.org* for more trail information
G. Fox River Trail	Trailhead starts 701 E. Moreland Boulevard Waukesha, WI	No	Six-mile paved trail that runs through the City of Waukesha along the Fox River. Starts in Frame Park and continues south to CTH H in Fox River Park
H. Bike Route	Bike Route runs along County Road TT- from Lake County Recreation Trail to STH 18	No	2.5-mile bike route on CTH TT down to STH 18. May be difficult to navigate around I-94 amd CTH TT on and off ramps.

Table I-1 (continued)

Recreational Activity	Location	Fee	Description/Features
Boardwalks			
1. Simmons Woods	889 Cecilia Drive Pewaukee, WI	No	800-foot wheelchair-accessible boardwalk which runs through Simmons Woods wetland. Educational exhibits describing local geology, wildlife, historic Pewaukee River characteristics, and more
2. Pewaukee River Boardwalk	Off Hickory Street in Pewaukee, WI	No	Boardwalk that skirts through a nicely wooded area along the Pewaukee River
3. Pewaukee Lake Outlet Boardwalk	Off Wisconsin Avenue in downtown Pewaukee, WI	No	Boardwalk located in downtown Pewaukee off Wisconsin Avenue along the confluence of the Pewaukee Lake outlet and the Pewaukee River
Fishing			
1. Lakefront Pier	Off Wisconsin Avenue Pewaukee, WI	No	Accessible fishing pier east end of Pewaukee Lake
2. Frame Park	Frame Park, Waukesha, WI	No	Shore fishing in Frame Park, downtown City of Waukesha
3. City of Pewaukee Boat Launch Pier	End of Lakeview Boulevard North of CTH SS	No	Fishing pier located right near the boat launch, along south shore of Pewaukee Lake
Canoe Route			
Pewaukee River	Downtown Pewaukee to the Fox River	No	Canoe almost six miles from downtown Pewaukee through beautiful wetland areas providing excellent wildlife viewing. Canoe all the way to Frame Park on the Fox River
Wildlife Viewing			
Blue Heron Rookery	Simmons Woods Boardwalk	No	Every summer Great Blue Herons like to nests high in tall trees with their young. A dense population, or colony, of Blue Herons and their nests can be viewed while walking along the Simmons Woods boardwalk

Source: City of Pewaukee, Wisconsin Department of Natural Resources, University of Wisconsin-Extension, and SEWRPC.

Map I-1

OUTDOOR RECREATIONAL OPPORTUNITIES NEAR THE PEWAUKEE RIVER WATERSHED

Source: Wisconsin Department of Natural Resources and SEWRPC.