COMMUNITY ASSISTANCE
PLANNING REPORT NO. 330

A RESTORATION PLAN FOR THE OAK CREEK WATERSHED

VOLUME 1: CHAPTERS 1 – 5

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

KENOSHA COUNTY
Aloysius Nelson
John O'Day
Robert W. Pitts

RACINE COUNTY
Jonathan Delagrave
James A. Ladwig
Peggy L. Shumway

MILWAUKEE COUNTY
Donna Brown-Martin
Theodore Lipscomb, Sr.
Adam M. Tindall-Schlicht

WALWORTH COUNTY
Charles L. Colman,
Chairman
Brian E. Holt
Mary Knipper

OZAUKEE COUNTY
Thomas H. Buestrin
Natalia Minkel-Dumit
Gustav W. Wirth, Jr.,
Secretary

WASHINGTON COUNTY
Jeffrey D. Schleif
Daniel S. Schmidt
David L. Stroik,
Treasurer

WAUKESHA COUNTY
Michael A. Crowley,
Vice-Chairman
James T. Dwyer
Dewayne J. Johnson

ADVISORY GROUP FOR THE OAK CREEK WATERSHED RESTORATION PLAN

Robert Anderson
Philip Beiermeister
Benjamin Benninghoff
Timothy Detzer
Greg Failey
Jacob Fincher
Dave Giordano
Craig Helker
Laura Herrick
Jeffrey Katz
Julie Kinzelman
Mary Jo Lange
Janette Marsh
Glen Morrow
Cheryl Nenn
Brian Russart
Tom Slawski
Timothy Thur
Kyle Vandercar
Jennifer Wright

Titles and affiliations of members can be found in Appendix B of this report

Special acknowledgement is due to Mr. Stevan Keith, former Principal Environmental Engineer and County Conservationist, Milwaukee County Environmental Services who served on the Advisory Group for much of the planning process.

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION STAFF

Kevin J. Muhs, PE, AICP .... Executive Director
Benjamin R. McKay, AICP .... Deputy Director
Joel E. Dietl, AICP .... Chief Land Use Planner
Laura K. Herrick, PE, CFM .... Chief Environmental Engineer
Christopher T. Hiebert, PE .... Chief Transportation Engineer
Elizabeth A. Larsen, SPHR, SHRM-SCP .... Director of Administration
Eric D. Lynde .... Chief Special Projects Planner
Rob W. Merry, PLS .... Chief Surveyor
Nakeisha N. Payne .... Public Involvement and Outreach Manager
Dr. Thomas M. Slawski .... Chief Biologist

Special acknowledgement is due to Dr. Joseph E. Boxhorn, Principal Planner; Aaron W. Owens, Senior Planner; Megan A. Beauchaine, Planner; Laura K. Herrick, PE, CFM, Chief Environmental Engineer; Dr. Justin P. Poinsatte, Senior Specialist Biologist; Julia C. Orlowski, PE, CFM, Engineer; James M. Mahoney, PE, Engineer; Zijia Li, PE, Engineer; Patricia L. Bouchard, GIS Applications Specialist; Dale J. Buser, PE, PH, Principal Specialist; Dr. Dan Carter, Former Principal Specialist-Biologist; Anna Cisar, Former Research Analyst; Megan I. Deau, Senior Graphic Designer; Frank G. Fierek, Senior Specialist; Timothy R. Gorsegner, GIS Specialist; Karin M. Hollister, PE, Principal Engineer; Zachary P. Kron, Senior Specialist-Biologist; Ronald Scerbicke, Former Research Aide; Dr. Thomas Slawski, Chief Biologist; Kathryn E. Sobottke, Principal Specialist; Kimberly A. Walsh, Former Research Aide; and Emma Weiss-Burns, Former Research Analyst for their contributions to the conduct of this study and the preparation of this report.

COMMUNITY ASSISTANCE PLANNING REPORT
NUMBER 330

OAK CREEK WATERSHED FUTURE

A RESTORATION PLAN FOR THE OAK CREEK WATERSHED

VOLUME 1: CHAPTERS 1 – 5

Prepared by the
Southeastern Wisconsin Regional Planning Commission
W239 N1812 Rockwood Drive
P.O. Box 1607
Waukesha, Wisconsin 53187-1607
www.sewrpc.org

The preparation of this publication was financed in part through planning funds provided by Milwaukee County Parks, City of South Milwaukee, Milwaukee Metropolitan Sewerage District, and Fund for Lake Michigan.
The contents of this report do not necessarily reflect the official views or policy of these organizations.

Milwaukee County PARKS

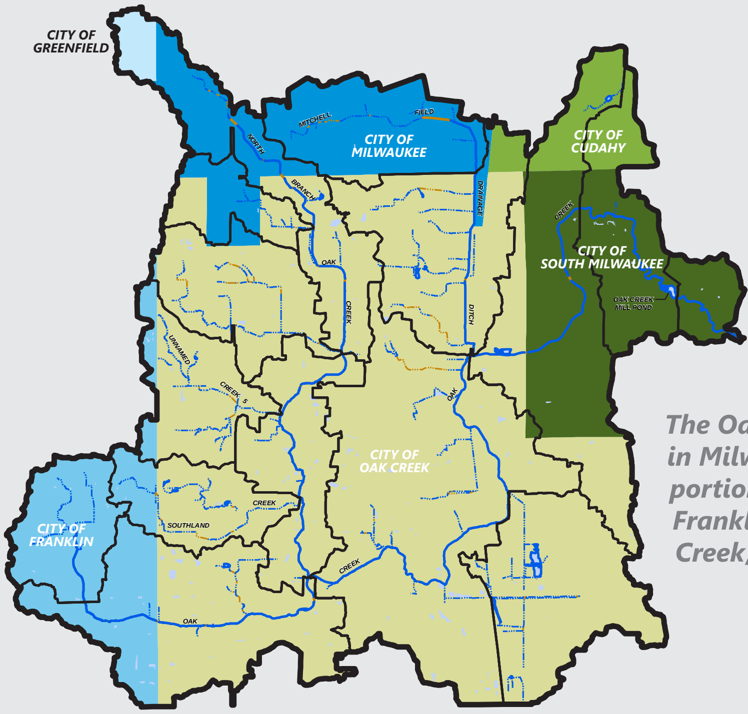
city of South Milwaukee Proud Past ... Promising Future

MMSD PARTNERS FOR A CLEANER ENVIRONMENT

Fund for Lake Michigan

December 2021

EXECUTIVE SUMMARY



OAK CREEK WATERSHED FUTURE

The Oak Creek watershed is located in Milwaukee County and includes portions of the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee.

PURPOSE

The Oak Creek Watershed Restoration Plan (Plan) is a comprehensive resource developed to provide a set of specific, targeted recommendations to improve Oak Creek, its tributaries, and the watershed as a whole. The recommendations are for focused implementation over the next thirty years, but the Plan is comprehensive in scope and it is likely that it will be implemented well beyond that timeframe.

The Plan is coordinated with other recent plans and recommendations. Notably, the 2007 SEWRPC regional water quality management plan update provides comprehensive recommendations related to land use, pollution abatement, and water quality management that are directly related to the Oak Creek watershed. This Plan includes a detailed review of the implementation status of these recommendations.

This Plan is also intended to meet the U.S. Environmental Protection Agency's Nine Key Elements for a Watershed Plan. The elements specify requirements that include identifying the sources of pollutants, describing watershed management measures and timeline for implementation, estimating costs, setting milestones and criteria for plan progress, and providing information and education.

The four focus areas for this Plan include water quality, habitat, recreational access and use, and targeted flooding. A review for these focus areas was also completed specifically for the Mill Pond and Mill Pond dam near the downstream end of the watershed in the City of South Milwaukee. This Plan was developed in consultation with an Advisory Group of experts and interested parties. Stakeholders participated through the project webpage and numerous public meetings.

The Oak Creek Watershed Restoration Plan seeks to preserve, restore, and enrich the natural environment by focusing on these four areas:

- Water Quality
- Habitat Conditions
- Recreational Access and Use
- Flooding

A RESTORATION PLAN FOR THE OAK CREEK WATERSHED

PLAN SUMMARY

The Oak Creek Watershed Restoration Plan is divided into six chapters and 21 appendices. The first three chapters provide background on how the Plan was developed, prior work that has been completed in the watershed that relates to this Plan, and a general characterization of the watershed.

The fourth Plan chapter provides a detailed inventory of the state of the watershed based on research, field surveys, and existing data. Major findings for each category are summarized below.

Stream Characteristics

Commission staff surveyed about 22 miles of Oak Creek, North Branch Oak Creek, and the Mitchell Field Drainage Ditch inventorying and geolocating stream components such as channel and water dimensions, habitat types, streambank erosion, outfalls, culverts and bridges, large debris jams, and large trash items. Historical modifications to the stream channels, the loss of wetlands, and increases in impervious surfaces due to rapid urbanization have led to many impairments to Oak Creek and its tributaries. Impairments include excessive streambed and bank erosion, disconnection of the streams from a functional floodplain, excessive sedimentation, and loss of critical instream and terrestrial habitat. In addition, impediments to aquatic organism passage between Oak Creek, its tributaries, and Lake Michigan have contributed to a relatively poor-quality aquatic organism community.

Commission staff conducted instream surveys to assess the existing conditions of the waterways. This included an assessment of habitat conditions and an inventory of the physical attributes and infrastructure associated with the stream system.

Water Quantity

Flows on Oak Creek are very flashy and adversely impact the streams of the watershed. Stream and stormwater flooding impacts are scattered throughout the watershed.

Mill Pond and Dam

The Mill Pond has significant sediment accumulation that has adversely impacted its water quality, fishery, and recreational use. The Mill Pond dam is in good condition, except that its maintenance sluice gate is inoperable.

Surface Water Quality

While instream levels of pH and concentrations of total suspended solids and some heavy metals have improved, high concentrations of fecal indicator bacteria, total phosphorus, total nitrogen, and chloride are present and constitute ongoing water quality problems. Low concentrations of dissolved oxygen are present in some tributaries and the upper reaches of Oak Creek, which is another water quality problem.

High levels of bacteria have been found in streams within the Oak Creek watershed. Potential sources of bacteria include wildlife, pet waste, or cross-connections between sanitary and storm sewers. The presence of dry-weather flow from stormwater outfalls may be an indication of illicit connections to the storm sewer system

Biological Conditions

While the quality of the biological community in some reaches of the mainstem of Oak Creek has improved, the watershed contains poor to fair quality fish and aquatic macroinvertebrate communities, reflecting the combined effects of poor water quality, habitat alteration, and habitat fragmentation.

Recreational Access and Use

Commission staff conducted various recreational use surveys to better understand the patterns of outdoor recreation throughout the watershed. The existing 1,165 acres of County Parkway, 12 miles of Oak Leaf Trail, the many acres of parks and open spaces, the Mill Pond warming house, and fishing access offer good opportunities for outdoor recreation along Oak Creek. Interested plan participants expressed a desire for additional recreational opportunities including high quality trails that support walking, hiking, and bicycling and restoration of the Mill Pond area.

The Oak Creek watershed contains many miles of recreational trails, including over 12 miles of Oak Leaf Trail and over nine miles of Forked Aster trails that support walking, hiking, biking, and other passive recreational uses.

Fishing is an important recreational activity in the Oak Creek watershed. The most popular fishing locations are located between the Creek's confluence with Lake Michigan and the Mill Pond dam. During the fall, this stretch is known for its salmon and brown trout runs.

The fifth chapter of the Plan summarizes the goals and management objectives to improve conditions in the watershed. These goals and objectives were used to develop the Plan recommendations.

PLAN RECOMMENDATIONS

The sixth and final Plan chapter summarizes the recommendations to improve conditions related to water quality, habitat, recreational access and use, flooding, and the Mill Pond and dam in the Oak Creek watershed. This includes a list of projects to be implemented over time. Recommendations include the following types of projects.

Water Quality

The Plan includes recommendations to address water pollution from point sources and urban and rural runoff. A major emphasis is placed on installing green infrastructure. The Plan also includes recommendations for implementing innovative runoff management practices to address specific pollutants such as phosphorus and pathogens. In addition, the Plan offers example stormwater management projects to retrofit current infrastructure for both water quantity and quality improvements.

Strategies to Reduce Pollution from Urban Runoff:

Grassed swales	Rain barrels	Fertilizer application controls
Bioretention facilities	Soil amendments	Pet litter and debris controls
Rain gardens	Pervious pavement	Iron enhanced sand filters
Green roofs	Stormwater treatment facilities	Riparian buffers
Native landscaping	Storm sewer systems	Regenerative stormwater conveyance
Cisterns	Leaf and lawn waste management	Nuisance waterfowl control

Recommended Water Quality Monitoring Includes Analyzing Indicators Related To:

Dissolved oxygen	Metals	Phosphorus	Water flow
Fecal indicator bacteria	Nitrogen compounds	Stream invertebrates	Water temperature
Fish	Organic compounds	Suspended solids	Water transparency

Habitat

Recommended actions include re-establishing natural surface water hydrology; protecting, restoring, expanding, and connecting riparian buffers; restoring and connecting wildlife habitat; restoring the quality and diversity of instream habitat; mitigating the negative impacts on aquatic and terrestrial ecosystems that are associated with climate change; and reducing trash and debris within the stream channels and riparian areas.

A well-connected floodplain can provide many beneficial functions related to water quality, aquatic and terrestrial wildlife habitat, and flood reduction. Many stream reaches within the Oak Creek watershed have been disconnected from their floodplains through channelization and erosion of the streambeds. An important recommendation in this Plan is to improve the connection of streams to a functional floodplain.

Recreational Access and Use

Recommended actions include providing a better connected trail system to both local and regional trail systems; continue to expand passive recreational opportunities throughout the watershed; pursue opportunities for voluntary acquisitions of lands adjacent to publicly owned open spaces; additional access sites for fishing; examine additional uses for the Mill Pond warming house; and continue to strive for equal access and use of recreational facilities for all interested users.

Targeted Flooding

Due to the scattered nature of flooding concerns, solutions should be evaluated on a case-by-case basis as opportunities arise. Retaining runoff onsite as much as possible and protecting areas for infiltration and flood storage is also recommended.

Mill Pond and Dam

Five alternatives and one optional spillway enhancement are summarized to improve the Mill Pond and dam area. Sediment core sampling in the Mill Pond is recommended to refine the alternatives.

The final chapter also provides details regarding Plan implementation, including public participation, measuring plan success—including water quality monitoring, a schedule and interim milestones, and potential funding sources.

The Oak Creek Watershed Restoration Plan can be accessed online at:
www.sewrpc.org/OakCreekWRP

For more information please contact
lherrick@sewrpc.org

VOLUME 1: CHAPTERS 1 – 5

VOLUME 2: CHAPTER 6

VOLUME 3: APPENDICES

LIST OF FIGURES

LIST OF MAPS

LIST OF TABLES

INTRODUCTION 1

Credit: SEWRPC Staff

1.1 PURPOSE OF PLAN

The health of a river system is usually a direct reflection of the use and management of the land within its watershed. Human activities within a watershed affect, and are also affected by, surface water and groundwater quality and quantity and habitat conditions. In the Oak Creek watershed the effects of human activities on water quality often tend to overshadow natural influences. Oak Creek, its tributaries, and associated wetlands are important warmwater resources located in Milwaukee County in Southeastern Wisconsin that have historically shown and continue to show signs of degradation. The problems of this watershed typify those found in areas experiencing changing land use patterns and water resource-related problems that have a direct effect on the property and general welfare of the residents of the watershed. The purpose of this plan is to provide a set of specific, targeted recommendations that can be implemented to address improvements for a set of watershed focus issues with the overall goal of restoring and improving the water resources of the Oak Creek watershed.

This watershed restoration plan was prepared in the context of the Southeastern Wisconsin Regional Planning Commission's (SEWRPC)[1] regional water quality management plan update for the greater Milwaukee watersheds (RWQMPU),[2] which was prepared in coordination with, and largely incorporates, the Milwaukee Metropolitan Sewerage District's (MMSD) 2020 facilities plan.[3] This plan builds upon the findings and recommendations of the 2007 SEWRPC RWQMPU to provide specific, targeted recommendations to address four focus issues: water quality, recreational access and use, habitat conditions, and targeted stormwater drainage and flooding issues. In addition, this plan addresses the status of the Oak Creek Mill Pond and the associated dam, considering their relationship to multiple focus issues. The applicable planning objectives, principles, and standards applied under the RWQMPU, and set forth in Chapter VII and Appendix G of SEWRPC PR No. 50,[4] are also adopted for use under this watershed restoration planning effort.

---

[1] *The acronyms and abbreviations used in this report are defined in Appendix A.*

[2] *SEWRPC Planning Report No. 50 (PR No 50), A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds, December 2007.*

[3] *Milwaukee Metropolitan Sewerage District, MMSD 2020 Facilities Plan, June 2007.*

[4] *SEWRPC Planning Report No. 50, op. cit.*

The Oak Creek watershed restoration plan is designed to assist local units of government, State and Federal agencies, nongovernmental organizations, and private landowners in identifying actions that will restore and benefit the natural assets of the watershed. By implementing the actions identified in this plan, results will be achieved that preserve, restore, and enrich the natural environment.

This watershed restoration plan has been prepared to meet the U. S. Environmental Protection Agency's (USEPA) nine minimum elements for a watershed-based plan (see USEPA Watershed Plan Requirements sections below). This plan is also designed to serve as a practical guide for the management of water resources within the Oak Creek watershed and for the management of the land surfaces that drain, directly and indirectly, to Oak Creek and its tributaries.

The Oak Creek Watershed

The U.S. Geological Survey (USGS) has divided and subdivided the watersheds of the United States into successively smaller hydrologic units that are identified by unique hydrologic unit codes (HUCs). The Oak Creek watershed is classified as a HUC 12 watershed with the unique code of 04040020102. As shown on Map 1.1, the Oak Creek watershed encompasses about 28 square miles in Milwaukee County. The mainstem of the Creek originates in the City of Franklin and flows approximately 13.8 miles in a generally easterly direction through the Cites of Franklin, Oak Creek, and South Milwaukee to its confluence with Lake Michigan in the City of South Milwaukee. The Creek has two major tributaries—the North Branch of Oak Creek and the Mitchell Field Drainage Ditch. Both originate in the City of Milwaukee and flow in southerly directions to their confluences with the mainstem of Oak Creek in the City of Oak Creek. The North Branch of Oak Creek is approximately 5.8 miles long and is located in the western portion of the watershed. The Mitchell Field Drainage Ditch is approximately 3.3 miles long and is located in the north-central portion of the watershed.

The watershed is highly urbanized. Urban development comprises over half of the watershed area under existing conditions; however, agricultural and open lands are scattered throughout the watershed. Under planned land use conditions, it is forecasted that the watershed would be essentially completely developed in urban uses, except for primary environmental corridors, consisting predominately of woodlands, wetlands, and floodplain.

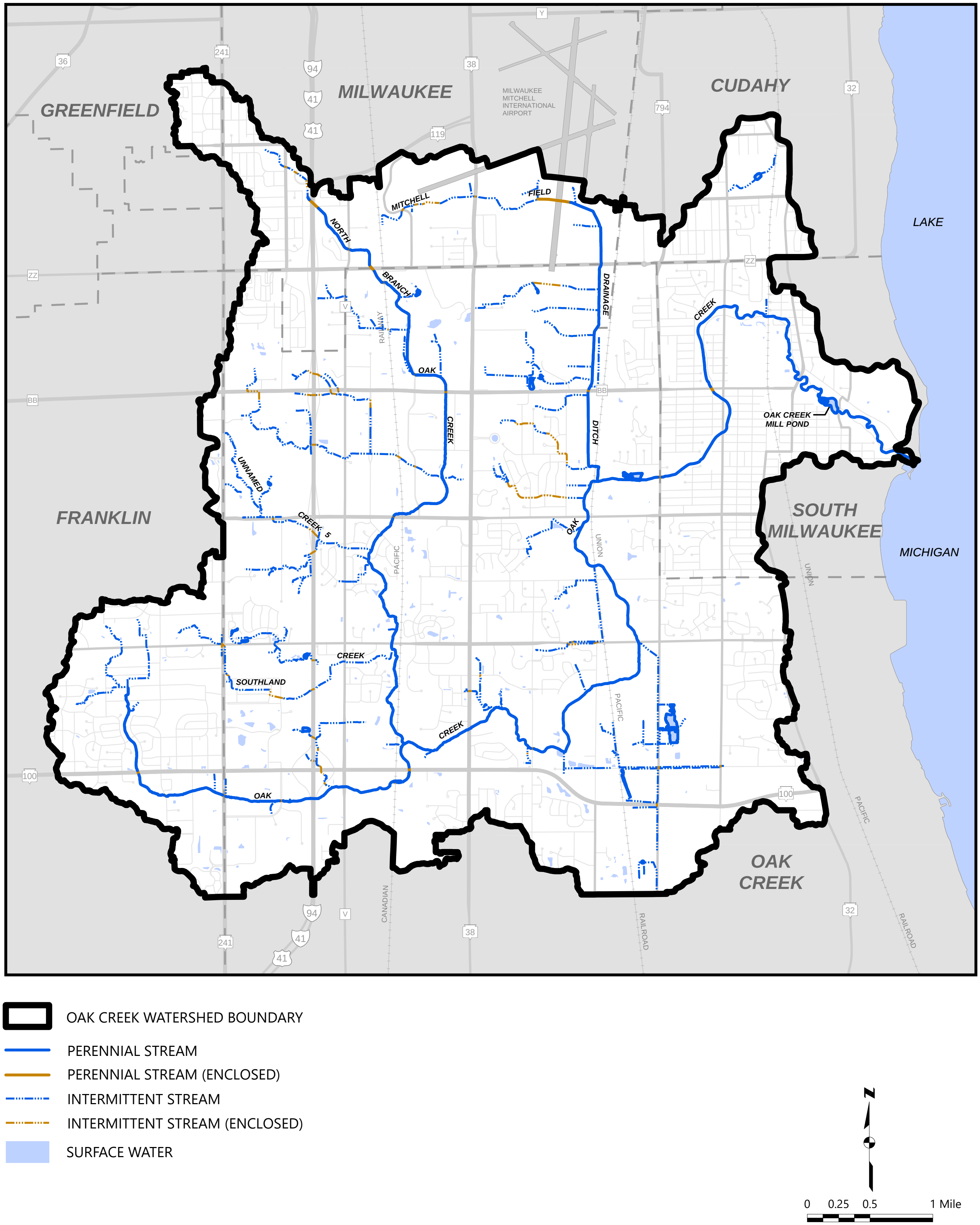
A number of problems have been identified in the Oak Creek watershed that restrict its potential uses and threaten its ecological integrity.[5] The mainstem of Oak Creek is considered impaired pursuant to the Federal Clean Water Act because of chronic toxicity to aquatic organisms related to an unidentified pollutant, chronic and acute toxicity to aquatic organisms related to concentrations of chloride that exceed applicable water quality criteria, and the presence of a degraded biological community due to high concentrations of total phosphorus. In addition, the Wisconsin Department of Natural Resources (WDNR) proposed in 2018 that the North Branch of Oak Creek be added to the State's list of impaired waters because of chronic and acute toxicity to aquatic organisms due to concentrations of chloride that exceed applicable water quality criteria. Surface waters in much of the watershed contain high concentrations of bacteria that indicate contamination with fecal material, especially during the months of May through October when many people are actively engaged in outdoor recreational activities. The Oak Creek watershed supports a poor quality fishery. The fish community contains relatively few species of fishes, is trophically unbalanced, as the stream contains few or no top carnivores, and is dominated by fish species that are tolerant of degraded conditions. Streambed and streambank erosion occur in the mainstem and major tributaries of the Creek. Aquatic and terrestrial invasive species are present at many locations in the watershed and may be displacing native species and degrading habitat.

USEPA Watershed Plan Requirements

In 1987, Congress enacted the Section 319 of the Clean Water Act, which established a national program to control nonpoint sources of water pollution. Section 319 grant funding is available to states, tribes, and territories for the restoration of impaired waters and to protect unimpaired/high quality waters. Watershed plans funded by Clean Water Act Section 319 funds must address nine key elements that the USEPA has

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

Map 1.1
The Oak Creek Watershed: 2018



Source: SEWRPC

identified as critical for achieving improvements in water quality.[6] In addition, projects implemented using Federal funds provided under Section 319 of the Clean Water Act must directly implement a watershed-based plan that the USEPA has determined to be consistent with the nine key elements. Thus, a finding of consistency with the nine key elements is a significant benefit to implementing the Oak Creek watershed restoration plan in that it would make projects recommended under the plan eligible for Federal funding. The nine key elements from the USEPA Nonpoint Source Program and Grants Guidelines for States and Territories are as follows:

1. Identification of causes of impairments and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.

2. Estimates of the load reductions expected from management measures.

3. Descriptions of the nonpoint source management measures that will need to be implemented to achieve load reductions in Element 2, and a description of the critical areas in which those measures will be needed to implement the plan.

4. Estimates of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement the plan.

5. An information and education component used to enhance public understanding of the plan and encourage the public's early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

6. A reasonably expeditious schedule for implementing the nonpoint source management measures identified in the plan.

7. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

8. A set of criteria that can be used to determine whether load reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under element 8.

1.2 PLANNING PROCESS

The Oak Creek watershed restoration plan was developed in response to a request from Milwaukee County, the City of South Milwaukee, and the MMSD. The planning effort was directed by Milwaukee County and the City of South Milwaukee and completed by SEWRPC staff. Funding for the planning effort was provided by MMSD, the City of South Milwaukee, Milwaukee County, the Fund for Lake Michigan, and SEWRPC.

Focus Issues

Focus issues are those general themes related to the critical concerns of the watershed. An individual focus area reflects a set of issues and problems related to one another through some desired use or state that the public has for the resource. Thus, these focus areas constitute a linkage between conditions in the watershed and the use by the public of water resources.

The focus issues that this watershed restoration plan addresses are derived from two sources. First, they reflect the findings of the 2007 RWQMPU for the greater Milwaukee watersheds.[7] As previously noted,

---

[6] *U.S. Environmental Protection Agency (USEPA), Handbook for Developing Watershed Plans to Restore and Protect Our Waters, USEPA 841-B-08-002, March 2008.*

[7] *SEWRPC Technical Report No. 39, op. cit.; SEWRPC Planning Report No. 50, op. cit.*

the RWQMPU identified several problems in the Oak Creek watershed that restrict potential uses of the resource and threaten its ecological integrity. Second, the focus issues reflect themes that emerged from a series of discussions by interested parties, including elected officials, State and local government staff, nongovernmental organizations, landowners, and residents.

The identification of focus issues related to the Oak Creek watershed began at two intergovernmental meetings convened in 2011 by Patricia Jursik, who at that time was the Milwaukee County Supervisor for a portion of the watershed. The results of those meetings are summarized in a January 10, 2012, SEWRPC staff memorandum entitled *Approaches to Addressing Water Resource-Related Issues in the City of South Milwaukee in the Oak Creek Watershed*. The staff memorandum identifies the following general issues of concern:

- Debris and sediment accumulations in the Oak Creek channel
- Streambank erosion
- City and County maintenance responsibilities within the Oak Creek channel
- Flooding of low-lying areas, such as the South Milwaukee High School athletic fields, and washouts of the foot bridge near Beech Street that connects the neighborhoods west of Oak Creek to the High School/Middle School campus
- Sanitary sewer backups into basements
- The effects of land use changes throughout the watershed on sedimentation, streambank erosion, stormwater runoff, flooding, and sanitary sewer backups
- The condition of the Mill Pond dam impoundment along the Creek in the City of South Milwaukee
- Lake Michigan bluff stability at a location in Grant Park where significant bluff erosion is occurring[8]

Many of those issues were also raised during a January 8, 2015, meeting at South Milwaukee City Hall that was convened by South Milwaukee Mayor Erik Brooks and former Supervisor Jursik. Participants at this meeting included elected officials from Milwaukee County and municipalities located in the Oak Creek watershed; staff from Milwaukee County, municipalities located in the watershed, the MMSD, the WDNR, and SEWRPC; members of local nongovernmental organizations active in the watershed; representatives of potential funding agencies; and members of the public. Based on the input from those who attended the January 2015 meeting, the following four major focus issues emerged for this watershed restoration plan:

- Water quality
- Recreational access and use
- Habitat conditions
- Targeted stormwater drainage and flooding issues

In addition, the plan will address the status of the Mill Pond impoundment and the associated dam due to their relationship to multiple focus issues.

Advisory Group

The Oak Creek watershed restoration plan was developed through a collective effort on the part of a number of agencies and organizations under the overall direction of Milwaukee County and the City of South Milwaukee. The agencies and organizations involved include the City of Racine Public Health Department, the WDNR, Milwaukee County, the MMSD, the municipalities of the Oak Creek watershed, the Root-Pike

[8] *This bluff stability issue occurs at locations outside of the Oak Creek watershed and, therefore, is not addressed under this plan.*

Watershed Initiative Network (Root-Pike WIN),[9] and SEWRPC. The plan was developed under the guidance of the Oak Creek Watershed Restoration Plan Advisory Group. The Advisory Group was created specifically for the purpose of reviewing draft plan chapters during plan development. Its membership includes elected and appointed officials, agency personnel, and citizens knowledgeable in land and water resource matters. The membership of the Advisory Group is documented in Appendix B.

The Advisory Group met periodically over the course of the planning effort to provide input on the plan. Advisory Group meetings were held on February 7, 2018; November 14, 2018; October 30, 2019; June 23, 2020; November 17, 2020; May 18, 2021; July 29, 2021; and August 25, 2021. The Advisory Group reviewed each chapter of the plan in draft form and provided comments and recommendations, which were addressed in the final plan.

Outreach to Stakeholders and the Public

The planning effort included periodic watershed stakeholder meetings to update those interested in watershed issues of the progress on the plan and to present summaries of ongoing planning activities. Those meetings were held at locations within the watershed and were open to the public. Organizations and individual citizens with an interest in the watershed were notified using interested party lists developed by the Root-Pike WIN and others. Attendance at those meetings by members of the Advisory Group was encouraged.

Presentations were made to the public at stakeholder meetings summarizing the content of draft chapters and reporting on progress. These meetings were held on April 12, 2016; August 30, 2016; April 26, 2017; March 8, 2018; December 13, 2018; December 12, 2019; December 9, 2020; June 23, 2021; and September 29, 2021.

A webpage describing the watershed restoration project was provided on the SEWRPC website.[10] This website could also be accessed through links on the Root-Pike WIN website. Copies of agendas and minutes from Advisory Group meetings and presentations, draft chapters of the plan report, and other materials related to the planning effort were placed on this webpage in downloadable form. The webpage also included a comment screen on which members of the public could ask questions and submit comments on the draft plan.

1.3 PLAN FORMAT AND ORGANIZATION

This report documents a watershed restoration plan for the Oak Creek watershed. It is organized into six chapters.

Following this initial introductory chapter, Chapter 2 summarizes and describes the recommendations of the RWQMPU as they relate to the Oak Creek watershed, indicates how these recommendations relate to the focus areas of this plan, and evaluates the implementation status of the recommendations. It also sets forth an inventory and review of recent and ongoing watershed management programs and initiatives in the Oak Creek watershed that are related to the focus areas of this plan. This review describes those plans, programs, and initiatives that have recently been undertaken, or are currently ongoing, by State and local governments and private entities, with a view toward integrating those efforts that are consistent with, and complement, this plan's focus areas.

Chapter 3 presents information on the natural and man-made features of the watershed, including a description of the natural resource base and environmentally sensitive areas, land use data, and demographics. This characterization represents a refinement and updating of the inventories presented in the RWQMPU.[11]

[9] *The Root-Pike Watershed Initiative Network area of interest includes the Oak Creek, Pike River, and Root River watersheds and the Lake Michigan direct drainage area from the mouth of Oak Creek at Lake Michigan south to the Wisconsin-Illinois state line.*

[10] *This can be accessed at www.sewrpc.org/SEWRPC/Environment/Restoration-Plan-Oak-Creek-Watershed.htm.*

[11] *SEWRPC Technical Report No. 39, op. cit.*

Chapter 4 presents an inventory and analysis of those watershed characteristics most relevant to the four focus issues. This characterization includes discussion of physical conditions of the surface water system, existing surface water quality, and habitat and biological conditions in the Oak Creek watershed. In addition, the inventory includes analysis of data collected as part of two projects conducted in support of this planning effort. These projects include collection of water quality data by the City of Racine Public Health Department with assistance from staff at the University of Wisconsin-Parkside under a project funded by the Fund for Lake Michigan and collection of aquatic biological community data by the WDNR.

Chapter 5 provides a description of the goals and management objectives for the Oak Creek watershed restoration plan. These goals and objectives establish targets to be achieved by implementing the watershed restoration plan and steps related to the focus issues that must be implemented to meet the long-term goals established in the RWQMPU. Establishing targets breaks the long-term goals into manageable pieces, helps determine the specific steps necessary to achieve a goal, and facilitates the development of measures to track progress.

Chapter 6 presents the plan recommendations to guide activities for the restoration of the watershed. This chapter presents the management efforts selected to meet the targets identified in the previous chapter. For each recommended action, it also identifies the primary land uses that the action addresses and prioritizes those geographical areas and locations in the watershed where the action should be implemented. This chapter also presents strategies designed to assist the implementing entities in converting the plan into actions, policies, and programs and provides guidance on prioritizing the recommendations for implementation. Finally, the chapter identifies the agencies responsible for implementing elements of the plan, presents estimates of the resources—such as technical and financial assistance—required to implement elements of the plan, and identifies potential sources of such support.

Credit: SEWRPC Staff:

PRIOR AND ONGOING STUDIES, PLANS, PROJECTS, AND PROGRAMS 2

2.1 INTRODUCTION

The Oak Creek watershed restoration plan refines and details the recommendations of the 2007 regional water quality management plan update for the greater Milwaukee watersheds (RWQMPU)[12],[13] as they pertain to the Oak Creek watershed. Since efforts to implement the recommendations of the RWQMPU have been ongoing for over a decade, reviewing the implementation status of these recommendations is an important step in developing this watershed restoration plan.

While this plan represents a refinement of the RWQMPU as it relates to the Oak Creek watershed, it must be recognized that findings and recommendations of a number of other planning efforts and goals and objectives of actions undertaken by a number of recent, current, and ongoing natural resource management programs and efforts also bear upon the focus issues addressed by this plan. To promote effective and sound management of land and water resources, it is important that management activities be conducted in a coordinated manner that takes into account both the needs of the watershed and the objectives and goals of the various programs, initiatives, and efforts involved in natural resource management within the watershed. Achieving this coordination requires that the findings and recommendations of related plans and the goals and objectives of relevant management programs and efforts be taken into account in the design of this watershed restoration plan. Where goals and objectives are consistent with the RWQMPU and where they address the focus issues for this watershed restoration plan, it may be desirable to integrate them into this plan. Thus, it is important to inventory, collate, and review the recommendations of relevant reports and plans and of relevant recent, current, and ongoing management programs and efforts.

This chapter summarizes the recommendations of the RWQMPU that pertain to the Oak Creek watershed and reviews the status of their implementation. In addition, this chapter also reviews other plans and programs that address the Oak Creek watershed and summarizes the recommendations and efforts from those plans and programs that pertain to the four focus areas of this watershed restoration plan.

[12] *SEWRPC Planning Report No. 50,* A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds, *December 2007.*

[13] *The acronyms and abbreviations used in this report are defined in Appendix A.*

2.2 REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE (RWQMPU)

The RWQMPU updated the initial regional water quality management plan[14] for six watersheds, including the Oak Creek watershed. The RWQMPU addressed three major elements of the original regional water quality management plan: the land use element, the point source pollution abatement element, and the nonpoint source pollution abatement element. The point source pollution abatement element addresses those sources of pollution that enter surface waters through discharge at discrete locations such as outfalls or pipes. The nonpoint source pollution abatement element addresses those sources of pollution that enter surface water through runoff from land surfaces. In addition, the updated plan considered several issues that were not considered in the initial plan, including instream and riparian habitat conditions and groundwater management. The RWQMPU planning effort was conducted in conjunction and coordination with the development of the Milwaukee Metropolitan Sewerage District's (MMSD) 2020 Facilities Plan (MMSD 2020 FP).

The RWQMPU made numerous recommendations that are relevant to the Oak Creek watershed. These recommendations fall into eight broad areas:

- Land Use
- Point Source Abatement Measures
- Nonpoint Source Pollution Abatement—Rural Control Measures
- Nonpoint Source Pollution Abatement—Urban Control Measures
- Instream Water Quality Management Measures
- Inland Lake Water Quality Management Measures
- Auxiliary Water Quality Management Measures
- Groundwater Management Measures

Table 2.1 summarizes the recommendations of the RWQMPU as they relate to the Oak Creek watershed. In addition, the table indicates which recommendations relate to each of the four focus areas of the Oak Creek watershed restoration plan: water quality, recreational access and use, habitat conditions, and targeted stormwater drainage and flooding issues.

Summary of Targeted and General Recommendations for the Oak Creek Watershed

Land Use Element

The land use element of the RWQMPU included both an inventory of existing development in the year 2000 and the identification of planned year 2020 development. In addition, projections of buildout land use conditions were developed for municipalities located within the MMSD planning area.

Year 2020 and buildout population and land use estimates were initially developed by the SEWRPC staff and the communities served by the MMSD based on future land use information provided by those communities. Those initial year 2020 populations and land development assessments were used for sizing the conveyance components of MMSD's Metropolitan Interceptor System. Planned land use data and population forecasts from the SEWRPC 2020 regional land use plan[15] were applied for communities in the study area that are not served by MMSD.

---

[14] *SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; Volume Three,* Recommended Plan, *June 1979.*

[15] *SEWRPC Planning Report No. 45,* A Regional Land Use Plan for Southeastern Wisconsin: 2020, *December 1997.*

Table 2.1
Relationship of Recommendations of the Regional Water Quality Management Plan Update to Focus Areas of the Oak Creek Watershed Restoration Plan

	Focus Area			
Recommendation	Water Quality	Recreation	Habitat	Flooding
Land Use				
Develop according to approved local land use plans	--	X	X	X
Preserve primary environmental corridors in essentially open space uses	X	X	X	X
Consider preserving secondary environmental corridors and isolated natural resource areas in essentially open space uses	X	X	X	X
Preserve all identified natural areas and critical species habitat sites in public or public-interest ownership	--	X	X	X
Preserve, to the extent practicable, all farmland covered by Class I and Class II soils	--	--	--	--
Point Source Pollution Abatement Measures				
Refine sanitary sewer service areas	X	X	--	--
Continue operation and maintenance of MMSD and South Milwaukee wastewater treatment plants	X	X	--	--
Construct and maintain local sanitary sewer systems	X	X	--	--
Evaluate the need to reduce infiltration and inflow of clearwater into sanitary sewers	X	X	--	--
Implement Capacity, Management, Operations, and Maintenance (CMOM) programs	X	X	--	--
Continue to regulate wastewater treatment plant and industrial discharges under the Wisconsin Pollutant Discharge Elimination System (WPDES) program	X	X	--	--
Consider changes in the method of applying corrosion control in municipal water systems to limit phosphorus loading	X	--	--	--
Nonpoint Source Pollution Abatement-Rural Control Measures				
Implement practices to reduce soil loss from cropland to rates below the tolerable soil loss rate, "T"	X	--	X	--
Apply manure and supplemental nutrient to cropland in accordance with nutrient management plans	X	X	--	--
Increase crop and pasture riparian buffers to minimum 75-foot widths	X	X	X	X
Limit the number of stream crossings and configure crossings to minimize fragmentation	--	X	X	X
Convert marginally productive agricultural lands to wetland or prairie conditions	X	X	X	X
Implement county-enforced inspection and maintenance programs for private onsite wastewater treatment systems constructed after counties adopted private sewage system programs	X	X	--	--
Institute voluntary programs to inventory and inspect private onsite wastewater treatment systems constructed before counties adopted private sewage system programs	X	X	--	--
Nonpoint Source Pollution Abatement-Urban Control Measures				
Implement construction erosion control and urban nonpoint source controls consistent with standards in NR 151	X	X	X	--
Implement programs to detect and eliminate illicit discharges and control pathogens that are harmful to human health	X	X	--	--
Conduct human health and ecological risk assessments to address pathogens in stormwater runoff	X	X	--	--
Implement chloride reduction programs	X	--	--	--
Implement fertilizer management programs	X	--	--	--
Implement pet litter management programs	X	X	--	--
Implement beach and riparian litter and debris programs	X	--	X	--
Conduct targeted research on bacteria and pathogens and research on stormwater best management practice techniques and programs	X	X	--	--

Table continued on next page.

Table 2.1 (Continued)

Recommendation	Focus Area: Water Quality	Recreation	Habitat	Flooding
Instream Water Quality Management Measures				
Implement projects called for under the Milwaukee County stream assessment study	X	--	X	--
Prepare abandonment and riverine area restoration plans for dams	X	--	X	--
Limit the number of culverts, bridges, drop structures, and channelized stream segments and incorporate measures to allow for passage of aquatic organisms	--	--	X	X
Remove abandoned bridges and culverts	--	--	X	X
Protect remaining stream channels, including small tributaries and shoreland wetlands	X	--	X	--
Restore wetlands, woodlands, and grasslands adjacent to stream channels and establish minimum buffers 75 feet in width	X	X	X	X
Restore and enhance stream channels	X	--	X	--
Monitor fish and macroinvertebrate populations	X	--	X	--
Consider more intensive fisheries manipulation measures where warranted, based upon specific goals developed in detailed local-level planning	--	X	X	--
Inland Lake Water Quality Measures				
Implement recommendations of the Milwaukee County park pond and lagoon management plan	X	X	X	--
Conduct aquatic plant surveys in those lakes in which plant management activities are being conducted	--	--	X	--
Establish long-term monitoring stations in inland lakes	X	X	--	--
Auxiliary Water Quality Management Measures				
Implement waterfowl control programs, where necessary	X	X	--	--
Continue, support, and institute household hazardous waste collection programs	X	--	--	--
Continue, support, and institute collection programs for unused and expired medications	X	--	--	--
Conduct assessments and evaluations of the significance for human health and wildlife of the presence of pharmaceuticals and personal care products in surface waters	X	--	--	--
Continue and support programs to reduce the introduction and spread of exotic and invasive species	--	--	X	--
Document and monitor the occurrence and spread of exotic and invasive species	--	--	X	--
Continue and support current surface water quality monitoring programs	X	X	--	--
Establish long-term fisheries, macroinvertebrate, and habitat monitoring stations	X	X	X	--
Continue efforts to facilitate consolidation of data from different monitoring programs	X	X	X	--
Continue and expand citizen-based monitoring efforts, with an emphasis on filling geographical data gaps	X	X	X	--
Maintain and update RWQMPU/MMSD 2020 Facility Plan water quality models	X	--	--	X
Groundwater Management Measures				
Maintain important groundwater recharge areas	X	--	X	X
Consider groundwater sustainability guidance from the regional water supply plan in evaluating the sustainability of proposed developments and local land use planning	X	--	X	--
Develop and implement utility-specific water conservation programs	X	--	X	--
Consider the potential impacts on groundwater quality of stormwater management facilities	X	--	--	--

Source: SEWRPC

When data from the SEWRPC 2035 regional land use plan[16] became available, 2020 land use and population estimates for the MMSD communities were revised and used to develop the wastewater storage and treatment components called for under the recommended MMSD 2020 facilities plan, which is incorporated in the regional water quality management plan. Similarly refined population estimates were used for the 2020 condition evaluation of all of the public sewage treatment plants in the study area. Revised 2020 industrial and commercial land use estimates were also applied for developing nonpoint source pollution loads used in modeling the instream water quality conditions under revised future year 2020 and recommended water quality plan conditions.

The RWQMPU makes several recommendations related to land use. It recommends that:

- Primary environmental corridors be preserved in essentially natural, open uses, forming an integrated system of open space lands. Under the RWQMPU, development within the primary environmental corridors would be limited to essential transportation and utility facilities, compatible outdoor recreation facilities, and rural-density residential development in upland corridor areas not encompassing steep slopes. Several measures are in effect that help ensure the preservation of environmentally significant areas in the Oak Creek watershed.

- The preservation of secondary environmental corridors and isolated natural resource areas be encouraged and that counties and communities consider the preservation of these areas in the preparation of county and local land use plans.

- All of the identified natural areas and critical species habitat sites designated for acquisition under the regional natural areas and critical species habitat plan (specified sites not in existing public or public-interest ownership) be preserved.[17]

- To the extent practicable, the most productive farmland, identified as farmland covered by agricultural capability Class I and Class II soils as classified by the U.S. Natural Resources Conservation Service (NRCS) be preserved.[18] Class I soils are those that have few to slight limitations that may restrict their use for cultivation. Class II soils are those that have moderate limitations that may either reduce the choice of plants that can be grown in them or require moderate conservation practices. Examples of limitations that can restrict the choice of plants or require conservation practices include susceptibility to erosion, excess water due to poor drainage or the presence of a high water table, presence of a shallow rooting zone, low moisture holding capacity, or high salinity.

Point Source Pollution Abatement Plan Subelement

The RWQMPU includes recommendations related to public wastewater treatment plants (WWTPs) and associated sewer service areas, private wastewater treatment plants, and other point sources of water pollution. The RWQMPU reiterates the initial regional water quality management plan's recommendation that all sanitary sewer service areas be refined. Unrefined sewer service areas are the product of systems level planning and are normally generalized in nature. The refining process determines a precise sewer service area boundary that is consistent with local land use plans and development objectives. Reports documenting the refined sewer service area include detailed maps of environmentally significant lands within the sewer service area. The refining process is conducted by the community concerned, with the assistance of SEWRPC staff. Following adoption by the designated management agency for the WWTP, local sewer service area plans are considered for adoption by the Regional Planning Commission as formal amendments to the regional water quality management plan. The Commission then forwards the plans to the Wisconsin Department of Natural Resources (WDNR) for approval.

---

[16] *SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2005.*

[17] *SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997; amended December 2010.*

[18] *The plan does envision that some Class I and Class II farmland that is located in the vicinity of existing urban service areas will be converted to urban use as a result of planned expansion of those urban service areas. This is a matter of balancing objectives for the preservation of productive farmland with objectives for the orderly and efficient provision of urban facilities and services. The plan also anticipates the development of lands beyond planned urban service areas that have been committed to low-density and suburban-density residential development through subdivision plats and certified surveys. This may be expected to result in the additional loss of Class I and Class II farmland.*

The RWQMPU recommends that both the MMSD and the City of South Milwaukee maintain and operate WWTPs. It recommends that the MMSD upgrade its WWTPs according to its 2020-FP. The RWQMPU recommends that the City of South Milwaukee implement several improvements and upgrades to its WWTP that the City agreed to in a court-ordered stipulation issued in June 2004. Those improvements included increasing the raw sewage pump capacity to meet a design peak flow of 30 million gallons per day (mgd) with the largest unit out of service, installing two new secondary clarifiers, and replacing the ultraviolet disinfection system.

Within the service areas described, the RWQMPU recommends that municipalities construct and maintain local sewer systems. In the Oak Creek watershed, this recommendation applies to all of the municipalities that are wholly or partially located in the watershed. The Cities of Cudahy, Franklin, Greenfield, Milwaukee, and Oak Creek are served by MMSD, while, as noted above, the City of South Milwaukee is served by its own WWTP. The plan also calls for the municipalities operating local sewerage systems to evaluate the need to reduce clearwater infiltration and inflow into sewers and implement Capacity, Management, Operations, and Maintenance (CMOM) programs. CMOM is a program initiated by the U.S. Environmental Protection Agency (USEPA) that provides a framework for municipalities to identify and incorporate widely-accepted wastewater industry practices to better manage, operate, and maintain collections systems; investigate capacity constrained areas of the collection system; and respond to sanitary sewer overflow events. MMSD rules require that the communities within its service area implement CMOM programs. The RWQMPU also recommends eliminating discharges from all points of sewerage flow relief in sewerage systems to natural waterbodies (i.e., overflows).

The RWQMPU recommends continued regulation of WWTP and industrial discharges to surface waters through the Wisconsin Pollutant Discharge Elimination System (WPDES) program, with effluent concentrations of pollutants being controlled to acceptable levels on a case-by-case basis through the operation of the WPDES.

An additional point source issue identified under the RWQMPU is that of phosphorus loads from some industrial noncontact cooling water discharges. The industries involved do not normally add phosphorus to their cooling waters. Phosphorus is contained in the source water used for cooling because some utilities such as the Cities of Cudahy, Milwaukee, and South Milwaukee add orthophosphate or polyphosphate as a corrosion control agent to prevent certain metals such as lead from leaching from distribution systems and building plumbing materials into the treated water. Recognizing the public health benefits involved, it is not recommended that the water utilities end their current corrosion control practice. It is, however, recommended that water utilities serving the watershed further consider an alternative technology that does not result in increased phosphorus loading if such a technology is both effective in controlling corrosion in pipes and cost-effective for the utility to implement.

Nonpoint Source Pollution Abatement Subelement

Recommended Rural Nonpoint Source Pollution Control Measures

The RWQMPU includes recommendations for rural nonpoint source pollution control measures for the Oak Creek watershed that are generally consistent with the Milwaukee County land and water resource management plan.[19]

The RWQMPU calls for practices to reduce soil loss from cropland to be expanded to attain erosion rates less than or equal to "T," the maximum average annual rate of soil loss that can occur without significantly affecting crop productivity, by 2020. This could be accomplished through a combination of practices, including, but not limited to, expanded conservation tillage, grassed waterways, and riparian buffers. The applicable measures should be determined by developing farm management plans that are consistent with the county land and water resource management plans.[20]

[19] *SEWRPC Community Assistance Planning Report No. 312,* A Land and Water Resource Management Plan for Milwaukee County: 2012-2021, *August 2011.*

[20] *The recommended rural nonpoint source control measures in the RWQMPU were based upon, and incorporated, agricultural performance standards from Chapter NR 151, "Runoff Management," of the* Wisconsin Administrative Code *that were in effect from 2004 through 2007 when the RWQMPU was being developed. NR 151 was revised in 2010, with the revision taking effect January 1, 2017. The current agricultural performance standards are described later in this chapter.*

The RWQMPU recommends that manure and any supplemental nutrients be applied to cropland in accordance with a nutrient management plan consistent with the requirements of Sections ATCP 50.04, 50.48, and 50.50 and Section NR 151.07 of the *Wisconsin Administrative Code*.

Based on a review of the literature related to the effectiveness of riparian buffers in controlling nonpoint source pollution, the RWQMPU concludes that a minimum 75-foot riparian buffer width along each side of streams flowing through current crop and pasture land is optimal for the control of nonpoint source pollution. The plan update recommends that:

- In general, where existing riparian buffers adjacent to crop and pasture lands are less than 75 feet in width, they be expanded to a minimum of 75 feet on each side of the waterway

- The procedures for targeting buffers to locations where they would be most effective as developed under the Wisconsin Buffer Initiative be considered in the implementation of the riparian buffers recommendations made herein[21]

- Opportunities to expand riparian buffers beyond the recommended 75-foot width be pursued along high-quality stream systems, including those designated as outstanding or exceptional resource waters of the State, trout streams, or other waterways that support and sustain the life cycles of economically important species such as salmon, walleye, and northern pike

- The number of stream crossings be limited and configured to minimize fragmentation of streambank habitat

The RWQMPU recommends converting a total of 10 percent of existing farmland and pasture to either wetland or prairie conditions. The focus of this effort should be on marginally productive lands, which are defined as agricultural lands other than those designated as Class I and Class II lands by the NRCS. Consistent with this, the RWQMPU identified candidate areas to be given first consideration when identifying marginally productive lands to be converted to wetlands and prairies. Candidate areas that were identified in the Oak Creek watershed are shown on Map 2.1. In the Oak Creek watershed, the RWQMPU identified approximately 189 acres of candidate wetland or prairie areas.

The RWQMPU recommends, at a minimum, implementing county-enforced inspection and maintenance programs for all new or replacement private onsite wastewater treatment systems (POWTS) constructed after the date on which the counties adopted private sewage system programs, instituting voluntary county programs to inventory and inspect POWTS that were constructed prior to the dates on which the counties adopted private sewage system programs, and the WDNR and the counties in the RWQMPU study areas work together to strengthen oversight and enforcement of regulations for disposal of septage and to increase funding to adequately staff and implement such programs.[22]

Recommended Urban Nonpoint Source Pollution Control Measures

The RWQMPU recommends several best management practices to abate urban nonpoint source pollution. In some instances, the plan includes measures that go beyond what would be required to meet the performance standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*.

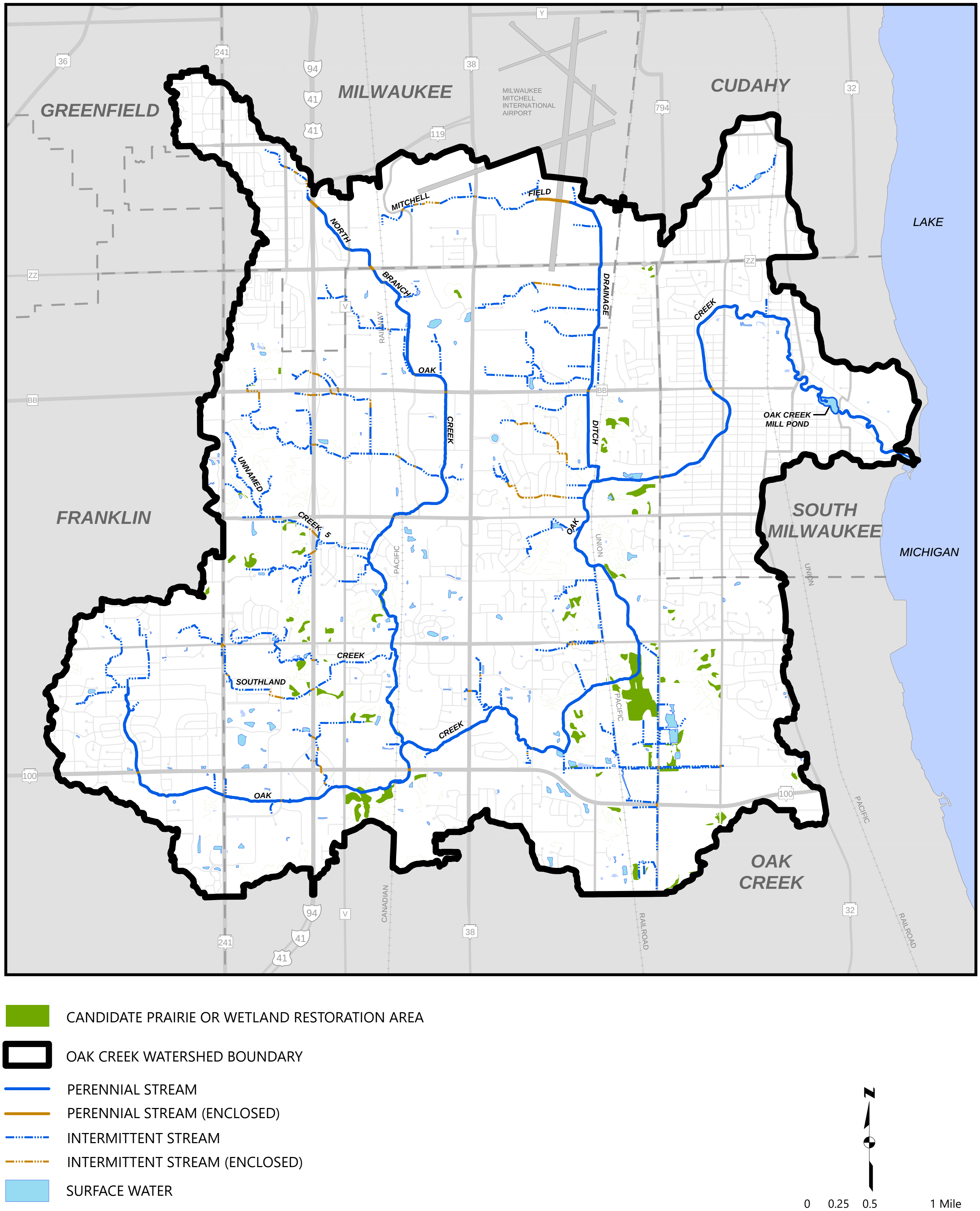
The RWQMPU recommends implementing urban nonpoint source pollution controls that are consistent with the standards of Chapter NR 151. [23] By implementing controls to meet these standards, municipalities will address control of construction site erosion; control of stormwater pollution from areas of existing and

[21] *College of Agriculture & Life Sciences, University of Wisconsin-Madison,* The Wisconsin Buffer Initiative, *December 2005.*

[22] *As described in more detail later in this chapter, the City of Franklin has an ordinance implementing a POWTS management program.*

[23] *The recommended urban nonpoint source pollution control measures in the RWQMPU were based upon and incorporated nonagricultural performance standards from Chapter NR 151, "Runoff Management," of the* Wisconsin Administrative Code *that were in effect from 2004 through 2007 when the RWQMPU was being developed. NR 151 was revised in 2010, with revisions taking effect January 1, 2011. The current nonagricultural performance standards are described later in this chapter.*

Map 2.1
Potential Prairie or Wetland Restoration Areas in the Oak Creek Watershed Identified in the Regional Water Quality Management Plan Update



Source: SEWRPC

planned urban development, redevelopment, and infill; and infiltration of stormwater runoff from areas of new development. Urban best management practices that could be installed to control nonpoint source pollution from existing or new development include 1) runoff infiltration/evapotranspiration and/or pollutant filtration devices such as grassed swales, infiltration basins, bioretention facilities, rain gardens, green roofs, and porous pavement; 2) stormwater treatment facilities, such as wet detention basins, constructed wetlands, sedimentation/flotation devices; and 3) maintenance practices such as vacuum sweeping of roads and parking lots.

To address fecal indicator bacteria and the risks posed to human health from the pathogens whose presence can be indicated by these bacteria, the RWQMPU recommends enhanced urban illicit discharge control and/or innovative methods to identify and control possible pathogen sources in stormwater runoff from all urban areas in the RWQMPU study area, including the Oak Creek watershed. To address the threats to human health and degradation of water quality resulting from human-specific pathogens and viruses entering stormwater systems, the plan recommends that each municipality in the study area implement a program consisting of:

- Enhanced storm sewer outfall monitoring to test for fecal coliform bacteria in dry- and wet-weather discharges

- Molecular tests for the presence or absence of human-specific strains of *Bacteroides*, an indicator of human fecal contamination, at outfalls where high fecal coliform counts are found in the initial dry-weather screenings

- Additional dry-weather screening upstream of outfalls where human-specific strains of *Bacteroides* are found to be present, with the goal of isolating the source of the illicit discharge

- Elimination of illicit discharges that were detected through the program described in the preceding three steps

It was anticipated that the program outlined above would also identify cases where illicit connections are not the primary source of bacteria, indicating that stormwater runoff is the main source. To adequately assess the appropriate way to deal with such bacteria sources (and the potentially associated pathogens), the RWQMPU recommends that human health and ecological risk assessments be conducted to address pathogens in stormwater runoff.

Water quality monitoring data set forth in the technical report that accompanied the RWQMPU indicated that chloride concentrations in the streams of the RWQMPU study area are increasing over time.[24] The chloride is likely from multiple sources, including sodium chloride and calcium chloride applied for ice and snow control on roads and parking lots, and discharges from water softener systems to either 1) POWTS that discharge to groundwater and, ultimately, to streams and lakes as baseflow, or 2) public wastewater treatment plants that discharge to surface waters. The RWQMPU makes several recommendations to reduce the amount of chlorides introduced into the environment. It recommends that the municipalities and counties in the study area continue to evaluate their practices regarding the application of chlorides for ice and snow control and strive to obtain optimal application rates to ensure public safety without applying more chlorides than necessary for that purpose. It also recommends that municipalities consider alternatives to current ice and snow control programs, such as applying a sand/salt mix to local roads along with enhanced street sweeping in the spring of the year to remove accumulated sand. It recommends implementing education programs to provide information about 1) alternative ice and snow control measures in public and private parking lots and 2) optimal application rates in such areas. The RWQMPU recommends implementing education programs to provide information about alternative water softening media and using more efficient water softeners that regenerate water based upon the amount of water used and the quality of the water.

The RWQMPU recommends that the use of low- or no-phosphorus fertilizers be encouraged in areas tributary to inland lakes and ponds and that consideration be given to adopting low- or no-phosphorus

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

fertilizer ordinances in those areas. It also recommends that information and education programs required under municipal WPDES stormwater discharge permits promote voluntary practices that optimize urban fertilizer application consistent with the requirements of WDNR Technical Standard No 1100, "Interim Turf Nutrient Management." One key provision of these standards calls for no application of fertilizer within 20 feet of a waterbody.

Other urban nonpoint source pollution control measures recommended in the RWQMPU include:

- Existing litter and debris control programs along the urban streams of the RWQMPU study area be continued and that opportunities to expand such efforts be explored.

- All municipalities in the study area have pet litter control ordinance requirements and that these requirements be enforced.

- Targeted research on bacteria and pathogens and research and implementation of stormwater best management practice (BMP) techniques and programs be supported. As part of this recommendation the plan also calls for support for research to develop and apply more direct methods of identifying sources of pathogens important to human health.

Instream Water Quality Management Measures Subelement

The RWQMPU recommends several instream water quality management measures that apply to the Oak Creek watershed.

In 2004, Milwaukee County assessed the stability and fluvial geomorphic character of streams in several watersheds within the County including the Oak Creek watershed.[25] This study report set forth and prioritized projects for concrete lining removal, channel rehabilitation, and fish passage improvement. The RWQMPU recommends implementing the projects called for under the Milwaukee County stream assessment study over time in a manner consistent with the need to provide flood protection and consistent with the stream rehabilitation recommendations of the regional plan update.

The RWQMPU recommends that abandonment and associated riverine area restoration plans be prepared as part of the design of new or reconstructed dams and prior to abandonment of existing dams. It also recommends that any dam removals specifically include provisions to protect upstream reaches from erosion and downstream reaches from sedimentation by prohibiting excessive sediment transport from the impoundment during and after dam removal.[26]

Culverts, bridges, drop structures, and channelized stream segments fragment and limit connectivity within stream habitat and ecosystems. The RWQMPU recommends that, to the extent practicable, these stream crossings and management strategies be limited. It also recommends that where such crossings are required, they be designed to allow the passage of aquatic organisms in addition to the passage of water, especially under low flow conditions.

The RWQMPU made several recommendations regarding the protection and enhancement of fisheries. These are consistent with actions recommended by WDNR for habitat improvement of stream systems.[27]

---

[25] *Inter-Fluve, Inc.,* Milwaukee County Stream Assessment, *prepared for Milwaukee County, September 24, 2004.*

[26] *The RWQMPU does not recommend the removal of any specific dams within the Greater Milwaukee watersheds, including the Oak Creek watershed. The RWQMPU recommends that the process for construction, operation, and abandonment of constructed waterbodies such as those resulting from dams should involve a public process with consultation and participation of a range of stakeholders, including riparian residents.*

[27] *Wisconsin Department of Natural Resources,* A Review of Fisheries Habitat Improvement Projects in Warmwater Streams with Recommendations for Wisconsin, *Technical Bulletin No. 169, 1990.*

The RWQMPU recommends:

- To the extent practicable, protecting remaining natural stream channels, including small tributaries and shoreland wetlands that provide habitat for the continued survival, growth, and reproduction of a sustainable fishery throughout the RWQMPU study area

- Restoring wetlands, woodlands, and grasslands adjacent to stream channels and establishing minimum buffers, 75 feet in width, on either side of streams to reduce pollutant loads entering streams and protect water quality

- Restoring, enhancing, and/or rehabilitating stream channels to provide increased quality and quantity of available fisheries habitat—through improving water quality, shelter/cover, food production, and spawning opportunities—by management measures that include but are not limited to:

    - Minimizing the number of stream crossings and other obstructions to limit fragmentation of stream reaches

    - Stabilizing stream banks to reduce erosion

    - Limiting instream sedimentation and selectively removing excessive silt accumulations

    - Reestablishing instream vegetation and bank cover to provide fish with food, spawning areas, shelter from predators, and protection from floods

    - Realigning channelized reaches of streams and removing concrete lining to provide heterogeneity in depth (e.g., alternating riffle and pool habitat), velocity or flow regime, and bottom substrate composition

    - As opportunities arise when roadways crossing streams are replaced or reconstructed, removing or retrofitting obstructions such as culverts, dams, and drop structures that limit the maintenance of healthy fish and macroinvertebrate populations

- Monitoring fish and macroinvertebrate populations to evaluate the effectiveness of the water quality management program

- Considering more intensive fisheries manipulation measures—such as removing exotic carp species and/or stocking of gamefish or other native species—where warranted based upon specific goals and objectives established for each project site, reach, or subwatershed through detailed local level planning

The plan also recommends that the locations for carrying out the recommended stream restoration measures be identified with the guidance and direct involvement of the WDNR, based upon site-specific field evaluations.

Inland Lake Water Quality Measures Subelement

The RWQMPU makes several recommendations for inland lake water quality management that apply to ponds in the Oak Creek watershed. The plan recommended:

- Implementation of the recommendations of the Milwaukee County park pond and lagoon plan[28]

- That aquatic plant surveys be conducted in those lakes in which aquatic plant management activities are being conducted

- That long-term water quality monitoring stations be established in inland lakes

[28] *Milwaukee County Environmental Services,* Milwaukee County Pond & Lagoon Management Plan, *June 2005.*

Auxiliary Water Quality Management Measures Subelement

The RWQMPU makes numerous auxiliary recommendations addressing several water quality issues.

The plan update recognizes that waterfowl, especially gulls, can be a significant source of fecal coliform bacteria in surface waters. It recommends implementing programs to discourage numbers of waterfowl that are high enough to cause water quality problems or generate complaints as a result of congregating near beaches and other water features. Measures that could be implemented in these programs include expanded use of informational signs regarding the negative aspects of feeding waterfowl; ordinances prohibiting the feeding of waterfowl; covered trash receptacles at beaches and water features; vegetative buffers along shorelines that discourage gulls and geese from congregating; and other, innovative measures, such as dogs trained to disperse waterfowl.

The RWQMPU makes the following recommendations related to household hazardous and pharmaceutical wastes:

- That the existing collection programs for household hazardous wastes be continued and supported and that those communities not served by such programs consider developing and instituting such programs

- That assessments and evaluations be made of the significance to adversely impact human health and to aquatic and terrestrial wildlife from the presence of pharmaceuticals and personal care products in surface waters

- That periodic collections of expired and unused prescription medications be conducted

The RWQMPU makes two recommendations regarding exotic and invasive species:

- That programs to reduce the introduction and spread of exotic and invasive species, including programs to educate the public, be supported and continued

- That the occurrence and spread of exotic and invasive species be monitored and documented

The plan evaluated existing water quality monitoring and data collection programs and characterized gaps in the available data. It found that relatively few data were available from tributary streams throughout the RWQMPU study area. To address monitoring needs in the watershed, the RWQMPU makes the following recommendations:

- That the surface water quality monitoring programs currently being conducted by the MMSD, WDNR, and U.S. Geological Survey (USGS) be supported and continued

- That long-term fisheries, macroinvertebrate, and habitat monitoring stations be established in streams, ideally at sites where water quality is also being monitored

- That efforts to facilitate consolidation of data from various monitoring programs be continued

- That citizen-based monitoring efforts be continued and expanded, with an emphasis on filling geographical gaps in existing data

Finally, the RWQMPU recommends periodic maintenance and updating of the water quality models developed under the RWQMPU/MMSD 2020 FP.

Groundwater Management Element

Three of the RWQMPU recommendations regarding groundwater management grew directly out of SEWRPC's regional water supply planning program, which was in progress during the time that the RWQMPU was being prepared.[29] As part of the regional water supply planning program, the most important groundwater

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

recharge areas within the Southeastern Wisconsin Region were identified and mapped.[30] The RWQMPU recommends considering important groundwater recharge areas for preservation or for development with corresponding stormwater management practices that are directed toward maintaining the natural hydrology. The RWQMPU recommends that consideration be given to following the recommendations of the regional water supply plan regarding maintenance of these areas. Under the regional water supply planning process, groundwater sustainability analyses were made for six selected demonstration areas, representing a range of hydrogeologic conditions.[31] These areas were analyzed to provide guidance on the density of individual household wells or shared common wells that could be installed without creating significant impacts on the shallow groundwater system. The RWQMPU recommends that municipalities consider groundwater sustainability guidance results developed under the groundwater sustainability study in evaluating proposed developments and in conducting local land use planning and that water utilities develop and implement utility-specific water conservation programs.

The RWQMPU also recommends that the design of stormwater management facilities that directly or indirectly involve infiltration of stormwater consider the potential impacts on groundwater quality, and that the provisions intended to protect groundwater quality in the WDNR's post-construction stormwater management technical standards be applied in the design of stormwater management facilities.

Status of Implementation of Recommendations of the RWQMPU in the Oak Creek Watershed

The recommendations made in the RWQMPU include a series of management strategies designed to improve surface water quality conditions in the Oak Creek watershed. As indicated above, these strategies include measures related to land use, point source pollution abatement, nonpoint source pollution abatement, instream and inland lake water quality management, groundwater management, and other issues. Efforts to implement the RWQMPU have been ongoing for several years.

To formulate a restoration plan for the Oak Creek watershed, it is important to assess the current status of implementation of the RWQMPU. There are several reasons to do this. Assessing the status of implementation enables an evaluation of how much progress toward the goals of the RWQMPU has been made since the plan was issued. Identifying areas in the watershed where projects implementing specific recommendations have been completed, are in process, or are planned can be useful for targeting locations for future projects. This identification can also indicate locations where recent efforts can be expanded or used as a basis for future actions, which can be especially important for the sorts of projects that act incrementally to produce reductions in pollutant loads to waterbodies, with resultant improvements in water quality. Alternatively, identification of areas where projects implementing specific recommendations have been completed, are in process, or are planned can also assist the process of identifying other portions of the watershed that have not received sufficient attention in the implementation of the specific recommendations. Assessing the status of plan implementation can also point out those specific recommendations that may require more attention in implementation. Finally, assessing the status of implementation at this juncture makes it possible to apply the lessons learned from recent implementation efforts to the identification and prioritization of recommendations under this watershed restoration plan.

In the assessment of the status of implementation of the RWQMPU, the recommendations are grouped into three broad categories: recommendations that reflect, in whole or in part, existing regulatory requirements; recommendations that are in various stages of implementation; and recommendations that have not yet been implemented.

Existing Regulatory Management Strategies

Table 2.2 shows the recommendations of the RWQMPU that reflect existing, ongoing regulatory requirements. The table also indicates the relevant regulations in the *Wisconsin Administrative Code, Wisconsin Statutes,* and local ordinances. It is important to note that some of the recommendations listed in the table are only partially addressed by existing regulations. The following descriptions will note where this is the case.

---

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

[31] *SEWRPC Technical Report No. 48,* Shallow Groundwater Quantity Sustainability Analysis Demonstration for the Southeastern Wisconsin Region, *November 2009.*

Table 2.2
Summary of Existing Regulatory Management Strategies Identified in the Regional Water Quality Management Plan Update

	Focus Area Primarily Addressed					
Recommendation or Management Strategy	Water Quality	Recreational Use and Access	Habitat Condition	Flooding	**Responsible and Participating Organizations**	**Relevant Regulations**
Develop according to approved comprehesive plans	X	X	X	X	Municipalities	66.1001 STATS[a]
Refine sanitary sewer service areas	X	X	--	--	Municipalities, SEWRPC, WDNR	NR 110 for public systems SPS 382 for private systems[b]
Continue operation and maintenance of the MMSD and South Milwaukee wastewater treatment plants	X	X	--	--	MMSD, City of South Milwaukee	NR 208, NR 210 and WPDES permit conditions
Evaluate the need to reduce infiltration and inflow of clearwater into sanitary sewers	X	X	--	--	MMSD, municipalities	NR 110.09; NR 210.23: Section 3.015 MMSD rules
Implement Capacity, Management, Operations, and Maintenance (CMOM) programs	X	X	--	--	MMSD, municipalities	NR. 210.23 and Section 3.105 MMSD rules
Continue to regulate wastewater treatment plant and industrial discharges under the Wisconsin Pollutant Discharge Elimination System (WPDES)	X	X	--	--	MMSD, City of South Milwaukee, WDNR	Regulated through WPDES program (NR 200-299)
Apply manure and supplemental nutrient to cropland in accordance with nutrient management plans[c]	X	X	--	--	Agricultural operators, Milwaukee County, DATCP, WDNR, NRCS	ATCP 50.04, ATCP 50.08, ATCP 50.48, ATCP 50.50, NR 151.07
Implement county-enforced inspection and maintenance programs for private onsite wastewater treatment systems constructed after counties adopt private sewage system programs	X	X	--	--	WDNR, Wisconsin Department of Safety and Professional Services, Municipalities	SPS 383.255, SPS 383.54, Section 190-28 Franklin Municipal Code
Implement construction erosion control and urban nonpoint source pollution controls consistent with standards in NR 151	X	X	X	--	WDNR, Milwaukee County, municipalities	NR 151; NR 216; MMSD Chapter 13; municipal ordinances
Implement fertilizer management programs[d]	X	--	--	--	Milwaukee County, WDNR	NR 151.13, NR 151.14, 94.643 STATS
Implement pet litter management programs	X	X	--	--	Milwaukee County, municipalities, UWEX	County and municipal ordinances[e]
Conduct aquatic plan surveys in those lakes in which aquatic plant management activities are being conducted	--	--	X	--	Milwaukee County, municipalities, lake associations	A common permit condition for aquatic plant management permits issued under NR 107 and NR 109
Continue and support programs to reduce the introduction and spread of exotic and invasive species	--	--	X	--	WDNR, Milwaukee County, municipalities	Some aspects are regulated under NR 40 and ATCP 21, municipal ordinances

Table continued on next page.

Table 2.2 (Continued)

Recommendation or Management Strategy	Focus Area Primarily Addressed: Water Quality	Recreational Use and Access	Habitat Condition	Flooding	Responsible and Participating Organizations	Relevant Regulations
Water utilities develop and implement utility-specific water conservation plans	X	--	X	--	Water utilities	Required for withdrawals from surface water and groundwater in Great Lakes Basin under NR 852
Consider the potential impacts on groundwater quality in the design of stormwater management facilities	X	--	--	--	WDNR, WisDOT, municipalities, Milwaukee County	NR 151.12, NR 151.124, NR 151.24 NR 151.244, Trans 401.106

[a] *Section 66.1001(3) of the* Wisconsin *Statutes requires that county and local general zoning ordinances; county, city, and village shoreland and floodplain zoning ordinances; county and local subdivision ordinances; and local official mapping ordinances enacted or amended on or after January 1, 2010 be consistent with the comprehensive plan adopted by the unit of government enacting or amending the ordinance.*

[b] *NR 110.08(4) and SPS 382 require that sewer service areas conform with the areawide water quality management plan.*

[c] *Compliance required to be eligible for cost-share funding.*

[d] *Includes the State ban on fertilizers containing phosphorus.*

[e] *Milwaukee County's ordinance applies to any animal under a person's control in parks and trails. Municipal ordinances vary among jurisdictions.*

Source: SEWRPC

Land Use Element

Develop According to Approved Land Use Plans

The RWQMPU was developed under the assumption that local communities will develop according to the recommendations given in approved local land use plans. This is partially addressed by existing regulatory requirements. In 1999, the Wisconsin Legislature enacted legislation that greatly expanded the scope and significance of comprehensive plans within the State. The legislation, often referred to as the State's "Smart Growth" law, provides a new framework for the development, adoption, and implementation of comprehensive plans by regional planning commissions and by counties, cities, villages, and towns. The law is set forth in Section 66.1001 of the *Wisconsin Statutes,* which also defines the elements that a comprehensive plan must contain. One of the required elements is a land use element that includes "a compilation of objectives, policies, goals, maps, and programs to guide future development and redevelopment of public and private property."

The law does not require the adoption of county and local comprehensive plans; however, Section 66.1001(3) of the *Statutes* requires that county and local general zoning ordinances; county, city, and village shoreland and floodplain zoning ordinances; county and local subdivision ordinances; and local official mapping ordinances enacted or amended on or after January 1, 2010, be consistent with the comprehensive plan adopted by the unit of government enacting or amending the ordinance.

All of the cities that are wholly or partially located in the Oak Creek watershed have adopted comprehensive plans. Because all of the municipalities in Milwaukee County are incorporated as cities or villages, the County has not prepared a comprehensive plan.

Point Source Pollution Abatement Measures

Refining of Sanitary Sewer Service Areas

As previously described, the RWQMPU recommends that unrefined sanitary sewer service areas in the Oak Creek watershed be refined. This has regulatory implications because Chapter NR 110, "Sewerage Systems," of the *Wisconsin Administrative Code*, requires that sanitary sewer extensions and sewerage system facility plans be in conformance with the approved areawide water quality management plan. The sanitary sewer service areas within the Cities of Franklin and Oak Creek within the Oak Creek watershed have been refined. Areas served by MMSD in the Cities of Cudahy, Greenfield, and Milwaukee have not been refined. In addition, the City of South Milwaukee's sanitary sewer service area has not been refined.

Since the completion of the RWQMPU, a second-generation sewer service area plan has further refined the sanitary sewer service area for the City of Franklin, including portions of the Oak Creek watershed. The existing sanitary sewer service areas in the Oak Creek watershed are described in Chapter 3 of this report.

Continue Operation and Maintenance of MMSD and City of South Milwaukee Wastewater Treatment Plants

The RWQMPU recommends that both the MMSD and the City of South Milwaukee continue to operate and maintain their respective WWTPs. Both of the MMSD plants and the City of South Milwaukee plants are currently operating under discharge permits issued through the WPDES and are operated subject to conditions set forth in those permits.

Evaluate the Need to Reduce Infiltration and Inflow and Implement CMOM Programs

The RWQMPU recommends that the municipalities operating local sewerage systems evaluate the need to reduce clearwater infiltration and inflow into sewers and implement CMOM programs that provide a framework for municipalities to identify and incorporate widely accepted wastewater industry practices in order to better manage, operate, and maintain collections systems; investigate capacity constrained areas of the collection system; and respond to sanitary sewer overflow events. Section NR 210.23 of the *Wisconsin Administrative* Code requires that all owners of sanitary sewage collection systems develop and implement CMOM programs by August 1, 2016. This section requires that such programs include implementing all feasible steps to eliminate excessive infiltration and inflow of clearwater into sanitary sewers. Section NR 110.09 of the *Wisconsin Administrative* Code requires that facilities planning for wastewater treatment facilities include an analysis to determine whether excessive infiltration and inflow exists in the sewerage system. The contents of this analysis are specified in sections NR 110.09(5) an NR 100.09(6). In addition, Section 3.105 of MMSD's rules requires that the communities within its service area operating sewer systems tributary to MMSD's system establish and implement CMOM programs. This rule also requires that the communities develop and implement infiltration and inflow management plans.

Continued Regulation of WWTP and Industrial Discharges Through the WPDES Permit Program

The RWQMPU recommends continued regulation of WWTP and industrial discharges to surface waters through the WPDES program, with effluent concentrations of pollutants being controlled to acceptable levels on a case-by-case basis through the operation of the WPDES program. Sections 283.31(1) and 283.33 of the *Wisconsin Statutes* require a permit for the legal discharge of any pollutant into the waters of the State, including groundwater. This State pollutant discharge permit system was established by the Wisconsin Legislature in direct response to the requirements of the Federal Clean Water Act. While the Federal law envisioned requiring a permit only for the discharge of pollutants into navigable waters, in Wisconsin permits are required for discharges from point sources of pollution to all surface waters of the State and, additionally, to land areas where pollutants may percolate, seep to, or be leached to groundwater.

Rules relating to the WPDES are set forth in Chapters NR 200 through 299 of the *Wisconsin Administrative Code*. The following types of discharges require permits under Chapter NR 200, "Application for Discharge Permits and Water Quality Standards Variances":

- The direct discharge of any pollutant to any surface water
- The discharge of any pollutant, including cooling waters, to any surface water through a storm sewer system not discharging to publicly owned treatment works
- The discharge of pollutants other than from agricultural uses for the purpose of disposal, treatment, or containment on land areas, including land disposal systems such as ridge and furrow, irrigation, and ponding systems
- Discharge from an animal feeding operation where the operation causes the discharge of a significant amount of pollutants to waters of the State and the owner or operator of the operation does not implement remedial measures as required under a notice of discharge issued by the WDNR under Chapter NR 243, which deals with animal waste management

Certain discharges are exempt from the permit system as set forth under Chapter NR 200, including discharges to publicly owned sewerage works, some discharges from vessels, discharges from properly functioning marine engines, and discharges of domestic sewage to septic tanks and drain fields. The latter are regulated under another chapter of the *Wisconsin Administrative Code*. Also exempted are the disposal of septic tank pumpage and other domestic waste, also regulated under another chapter of the *Wisconsin Administrative Code*; the disposal of solid wastes, including wet or semi-liquid wastes, when disposed of at a site licensed pursuant to another chapter of the *Wisconsin Administrative Code*; and discharges from private alcohol production systems.

Discharges related to a variety of municipal and industrial activities may be permitted under the WPDES permit system. Particular facilities may be permitted either under an individual permit to the owner or operator of the facility or under a Statewide general permit.

Individual permits are issued to specific facilities that generate wastewater from unique types of activities, have complex mixtures of pollutants, or have physical-chemical treatment systems. Municipal and privately owned WWTPs are generally permitted under individual permits. Conditions for individual permits include effluent limitations for pollutants that are discharged and monitoring and reporting requirements. Individual permits include a compliance schedule that specifies the actions needed to be taken for the facility to remain in compliance with permit conditions and the dates by which these actions must be completed. Individual permits are issued for a five-year term. To maintain coverage beyond the end of the term, permittees must reapply at least 180 days prior to expiration of the permit.

Statewide general permits are used to cover groups of facilities that generate wastewater from relatively simple operations having similar types and amounts of pollutants. Coverage under a general permit is conferred by completing and submitting a request-for-coverage form to the appropriate WDNR regional office. Compliance with the limitations contained in a general permit must be attained at the time coverage is granted. As of January 2018, the State had issued 27 different WPDES general permits, covering a variety of activities and discharges. Examples of these include general permits for noncontact cooling water, swimming pool facilities, hydrostatic test water, ballast water discharge, and stormwater from industrial facilities. It is important to note that an individual facility may need to be covered under more than one general permit, depending on the different types of waste streams that the facility discharges. General permits contain effluent limitations for pollutants associated with the covered discharges and monitoring and reporting requirements. These permit conditions vary according to the category of general permit. For some general permits, the WDNR has developed standard discharge monitoring reporting forms.

Nonpoint Source Pollution Abatement—Rural Control Measures

Nutrient Management Plans and Nutrient Application

Among the rural nonpoint source pollution abatement measures in the RWQMPU was a recommendation that manure and supplemental nutrients to cropland be applied in accordance with approved nutrient management plans. Starting in 2005 for high-priority areas such as impaired or exceptional waters, and in 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. Requirements related to these plans are set forth in Section ATCP 50.04(3) of the *Wisconsin Administrative Code*. In general, for land that does not meet the NR 151 performance 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 since October 1, 2002 must meet the standards, regardless of whether cost-share funds are available.

Inspection and Maintenance Programs for Private Onsite Wastewater Treatment Systems (POWTS)

As previously described, the RWQMPU recommends that, at a minimum, implementing county-enforced inspection and maintenance programs for all new or replacement private onsite wastewater treatment systems (POWTS) constructed after the date on which the counties adopted private sewage system programs. It also recommends instituting voluntary county programs to inventory and inspect POWTS that were constructed prior to the dates on which the counties adopted private sewage system programs.

At the State level, the Wisconsin Department of Safety and Professional Services has established rules regulating POWTS set forth in Chapter SPS 383, "Private Onsite Wastewater Treatment Systems," of the *Wisconsin Administrative Code*. Much of the regulation is performed by counties and, in counties with population of 500,000 or more, by municipalities. SPS 383.255 requires counties with populations of less than 500,000 and municipalities located in counties with populations of 500,000 or more to develop and implement comprehensive maintenance programs for POWTS within their jurisdictions. These counties and municipalities are referred to as governmental units. These programs are to include:

- Conducting, completing, and maintaining an inventory of all POWTS located within the governmental unit's jurisdiction

- A process that accepts and records inspections, evaluation, maintenance, and servicing reports submitted by owners of POWTS or their agents

- A process that notifies owners of POWTS who are delinquent in meeting reporting requirements

- A process that includes measures meant to ensure that required inspection, evaluation, maintenance, and servicing of POWTS are performed and reported

- Annual reporting to the Wisconsin Department of Safety and Professional Services

The units of government are required to complete the inventory by October 1, 2017, and have the other elements of the programs in place by October 1, 2019.

For POWTSs installed or constructed on or after July 1, 2000, SPS 383.54 requires submission of a management plan to the governmental unit as part of a plan for installation, construction, or replacement of or addition to a POWTS. This management plan is to include servicing and maintenance requirements, including servicing frequency requirements of the components of the system. In addition to the frequency given in the management plan, servicing is required to occur when the combined volume of sludge and scum in an anaerobic treatment tank (septic tank) equals one-third of the tank's volume. The owner or the owner's agent is required to report to the governmental unit within 30 days of required inspections, evaluations, maintenance, or servicing.

For POWTSs existing prior to July 1, 2000, servicing is also required to occur when the combined volume of sludge and scum in an anaerobic treatment tank (septic tank) equals one-third of the tank's volume. In addition, those systems that include a treatment or dispersal component utilizing in situ soil are required to be visually inspected at least once every three years to determine whether wastewater or effluent is ponding on the surface of the ground. The owner or the owner's agent is required to report to the governmental unit within 30 days of required inspections, evaluations, maintenance, or servicing.

The City of Franklin has an ordinance implementing a POWTS management program. This program requires that inspection and servicing of systems be conducted on a three-year cycle and that the City provide notification to owners of POWTS that their systems are due for inspection and servicing. It should be noted that the Cities of Greenfield, Milwaukee, Oak Creek, and South Milwaukee have enacted ordinances that require that new construction or buildings currently served by POWTS that are adjacent to streets or easements with public sanitary sewer service connect to such service.

Nonpoint Source Pollution Abatement—Urban Control Measures

Implementation of Construction Erosion Control and Urban Nonpoint Source Pollution Controls Consistent with the Performance Standards in NR 151

The nonagricultural performance standards set forth in Chapter NR 151 encompass two major types of land management. The first type includes standards for areas of new development and redevelopment. The second type includes standards for 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
- Nonmunicipal property fertilizing

NR 151 requires counties and local units of government in urbanized areas, which are identified based on population density, to obtain a WPDES stormwater discharge permit as required under Chapter NR 216.02. As a result of these requirements, Milwaukee County and all of the municipalities that are located in the Oak Creek watershed have applied for, and have been issued, stormwater discharge permits. These permit holders were required to reduce the amount of total suspended solids in stormwater runoff from areas of existing development that were in place as of October 2004 by 20 percent, or to the maximum extent practicable, by March 10, 2008.

Permitted municipalities are also required to 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.

In addition to the standards given in NR 151, units of government within the MMSD service area are required to comply with Chapter 13, "Surface Water and Storm Water Rules," of the MMSD rules. This Chapter requires governmental units in MMSD's service area to:

- Manage land use and activities in their jurisdictions to minimize debris and sediment from creating obstructions at outfalls or other structures in watercourses

- Remove debris and sediment that obstructs stormwater outfalls or other drainage structures

- Submit annual reports to the District that provide watershed, drainage, and development information

- Establish which developments and redevelopments must comply with the peak runoff management requirements set forth in Section 13.11 of the MMSD rules

- Submit stormwater management plans for all eligible development and redevelopment projects

In general, developments and redevelopments must provide stormwater management plans and comply with the runoff management requirements if they are in the District's ultimate sewer service area (except for certain riparian areas immediately adjacent to Lake Michigan) that either call for an increase of one-half acre or more of new impervious area or for demolition or construction during redevelopment that disturbs an area larger than two acres. Communities in MMSD's service area are required to have stormwater management ordinances that are consistent with Chapter 13 and to update the ordinances to include amendments to Chapter 13.

Fertilizer Management Programs

As previously discussed, the RWQMPU recommends encouraging the use of low- or no-phosphorus fertilizers in areas tributary to inland lakes and ponds and that consideration be given to adopting low- or no-phosphorus fertilizer ordinances in those areas. It also recommends that information and education programs required under municipal WPDES stormwater discharge permits promote voluntary practices that optimize urban fertilizer application consistent with the requirements of WDNR Technical Standard No. 1100, "Interim Turf Nutrient Management."

Sections NR 151.13 and 151.14 of Chapter NR 151 of the *Wisconsin Administrative Code* set forth fertilizer performance standards for municipal and nonmunicipal properties with more than five acres of pervious surface where fertilizer is applied. These standards call for fertilizer application to be done "in accordance with site-specific nutrient application schedules based upon appropriate soil tests." These standards are required to be followed in municipalities with WPDES stormwater discharge permits.

Section 94.643 of the *Wisconsin Statutes,* which became effective on April 1, 2010, after completion of the RWQMPU, places restrictions on the use, sale, and display of fertilizers containing phosphorus. This statute prohibits applying fertilizer to turf that is labeled as containing phosphorus or available phosphate except for:

- Applying such fertilizer to establish grass, using seed or sod, during the growing season in which the person using the fertilizer began establishing the grass

- Applying fertilizer to an area where the soil is deficient in phosphorus as shown in a soil test performed by a laboratory no more than 36 months before the application

The statute restricts the sale of fertilizers containing phosphorus to agricultural uses and the two uses described in the preceding paragraph. It also prohibits the display of fertilizers containing phosphorus.

Pet Litter Management

As previously discussed, the RWQMPU recommends that all municipalities, including those in the Oak Creek watershed, have pet litter control ordinance requirements and that these requirements be enforced. Milwaukee County has enacted an ordinance regarding control of pet litter in County parks and trails. This ordinance requires that the owner, caretaker, or person in control of an animal immediately remove pet litter when it is deposited, wrap it, and properly dispose of it. The ordinance also requires that anyone bringing an animal into a County park or trail also bring an item or device for removing pet litter. This ordinance applies to any animal brought into a County park or trail.

Most of the municipalities in the Oak Creek watershed have pet litter management ordinances. Only two communities—the Cities of Greenfield and Oak Creek—lack such ordinances. The requirements of these municipal ordinances vary. Most require that the owner, caretaker, or person in control of an animal immediately remove and properly dispose of pet litter deposited by an animal under their control on any public property or private property other than that belonging to owner, caretaker, or person in control of the animal. A few of these ordinances apply only to public property or parks and trails. Most, although not all, of these ordinances require that, when an animal is off its owner's or caretaker's premises, the owner or caretaker have an item or device for removing pet litter in his or her possession. The animals that are covered by these ordinances also varies by jurisdiction. Some municipalities have ordinances that apply to any animals while others have ordinances that apply specifically to dogs or dogs and cats.

It should be noted that the University of Wisconsin-Extension has developed educational materials related to pet waste management.[32]

Inland Lake Water Quality Management Measures

Aquatic Plant Surveys for Lakes in Which Plant Management Activities Are Being Conducted

As previously described, the RWQMPU recommends conducting aquatic plant surveys in those lakes in which plant management activities are being conducted. This recommendation is partially implemented under existing regulations. Aquatic plant management activities are regulated under two chapters of the *Wisconsin Administrative Code*. Chapter NR 107, "Aquatic Plant Management," regulates the application of chemical treatment for the management of aquatic plants. Chapter NR 109, "Aquatic Plants: Introduction, Manual Removal and Mechanical Control Regulations," regulates manual removal and mechanical control of aquatic plants. It also regulates the use of biological control agents. With some exceptions, a permit is required for most aquatic plant management activities.

Neither of these chapters specifically requires conducting an aquatic plant survey; however, they do require that the permit application include descriptive information of the plants or plant communities proposed to be managed. For chemical treatment, NR 107.04(2)(e) requires that the permit application include a description of the plant community causing the use impairment in the waterbody. Similarly, for manual removal and mechanical control of aquatic plants, NR 109.04(2)(f) requires that the permit application include a description of the aquatic plants to be controlled or removed. Under an additional provision of NR 109, the WDNR may require that an application for a permit for manual removal and mechanical control of aquatic plants include an aquatic plant management plan that describes how the aquatic plants will be introduced, controlled, removed, or disposed. The items that are required to be presented and discussed in such a plan are given in NR 109.09(2) and include a physical, chemical, and biological description of the waterbody. Under these provisions, completing an aquatic plant survey has been a common permit condition for applications for permits to conduct aquatic plant management activities under NR 107 and NR 109.

Auxiliary Water Quality Management Measures

Exotic and Invasive Species Management

As described above, the RWQMPU recommends that programs to reduce the introduction and spread of aquatic and terrestrial exotic and invasive species, including programs to educate the public, be supported and continued. Several State regulations address this recommendation.

Chapter NR 40, "Invasive Species Identification, Classification and Control," of the *Wisconsin Administrative Code* sets forth rules regarding the identification, classification, and control of invasive species. Chapter 40 lays out three major requirements as described below.

First, NR 40 creates a comprehensive system with criteria to classify invasive species into two categories: prohibited species and restricted species. A prohibited species is one that the WDNR has determined is likely to survive and spread if introduced to the State, but that is not found in the State or that region of the State where the species is listed as prohibited, except for isolated individuals or small populations of terrestrial species or species that are isolated to a specific watershed in the State or Great Lakes. Prohibited species are those for which Statewide or regional eradication or containment may be feasible. A restricted

[32] *University of Wisconsin-Extension, "Pet Waste and Water Quality," UWEX Publication GWQ006, 1999.*

species is one that the WDNR has determined is already established in the State or that region of the State where the species is listed as restricted and for which Statewide or regional eradication or containment may not be feasible. Both categories represent species that cause or have the potential to cause economic or environmental harm or harm to human health.[33] With some exceptions, NR 40 bans the transport, possession, transfer, and introduction of prohibited species. It also bans the transport, transfer, and introduction of restricted species. In addition, it bans the possession of restricted fish and crayfish species.

Second, NR 40 contains provisions enabling the WDNR to take action to control or eradicate invasive prohibited species that are present, but not yet established. With landowner permission or a judicial inspection warrant, the WDNR may inspect for, sample, and control prohibited species only. Persons found responsible for a prohibited species' presence on property they own, control, or manage may be ordered to carry out approved control measures. If a control order is not followed, and the WDNR takes control measures, the WDNR may seek cost-recovery. Control of restricted species is encouraged under NR 40, but not required.

Third, NR 40 requires taking preventive measures that address common pathways that may allow invasive species to spread. In general, the preventive measures are not species specific. Examples of preventive measures include the requirement that aquatic plants and animals be removed from, and that draining water from any vehicle, boat, boat trailer, or boating and fishing equipment when such vehicle or equipment is removed from a waterbody or from the waterbody's bank or shore. It should be noted that Section NR 19.055 of Chapter NR 19, "Miscellaneous Fur, Fish, Game and Outdoor Recreation," of the *Wisconsin Administrative Code*, also requires that boats, boat trailers, boating equipment, and fishing equipment be immediately drained when they are removed from an inland or outlying waterbody or the waterbody's bank or shore. This requirement extends to water in any bilge, ballast tank, bait bucket, live well, or other container.

Section NR 45.045 of Chapter NR 45, "Use of Department Properties," of the *Wisconsin Administrative Code*, requires that any firewood brought into State parks or other State-managed lands be from Wisconsin, be from within 25 miles of the State-owned property, and be from outside any quarantine areas, unless the State-owned property is also within the quarantine area.[34] As an alternative, firewood that is sold by Wisconsin certified firewood dealers has been treated to eliminate pests and diseases. This firewood may be brought onto State property. The Wisconsin Department of Agriculture, Trade & Consumer Protection (DATCP) has certification procedures for firewood dealers.

Management of several invasive species that are considered agricultural pests may also be addressed under the DATCP's authority to control pests on agricultural lands and agricultural business premises. These controls are set forth in Chapter ATCP 21, "Plant Inspection and Pest Control," of the *Wisconsin Administrative Code*. Under the rules in this chapter, DATCP may issue a quarantine order prohibiting the movement of any pest or any plant, pest host, or pest-harboring material that may transmit or harbor a pest. In addition, DATCP may issue a pest abatement order requiring the destruction or removal or pests, plants, pest hosts, or pest-harboring material within 10 days or the issuance of the order, if in DATCP's judgment such an order is necessary to prevent or control a hazard to plant or animal life in the State.

ATCP 21 also contains measures specifically addressing particular pest species, most of which are considered either prohibited species or restricted species under NR 40. Examples of invasive species addressed under this authority include both Asian and European gypsy moth; pine shoot beetle; African and Africanized honeybees; hemlock woolly adelgid; emerald ash borer; Asian longhorned beetle; and *Phytophthora ramorum*, the fungus that causes sudden oak death. The details of measures set forth in ATCP 21 vary by pest species. The materials subject to the prohibitions below differ with the particular pest species. In general, these rules prohibit anyone from:

---

[33] *In addition to the categories of invasive species regulated under NR 40, the WDNR maintains two lists of unregulated invasive species. The first consists of a caution list of species which are not found in the State that may have shown evidence of invasiveness in similar environments in other states and could potentially spread in Wisconsin. Additional information is needed to determine whether species on the caution list belong in another category. The second list consists of nonrestricted species which may have beneficial uses, but also may have adverse environmental, recreational, or economic impacts or cause harm to human health. Most of the nonrestricted species have already integrated into Wisconsin's ecosystems and Statewide control or eradication is not practical or feasible.*

[34] *The Oak Creek watershed is located entirely within quarantine areas for both gypsy moth and emerald ash borer.*

- Importing the pest organisms or materials that may harbor or transmit the pest organisms into the State from regulated, quarantined, or infested areas designated by the State or the U.S. Department of Agriculture
- Moving materials that may harbor or transmit the pest organisms from any regulated, quarantined, or infested areas designated by the State or the U.S. Department of Agriculture, unless the material has been inspected and certified in written certification by a pest control officer from the State of origin as either
  - Originating from noninfested premises and having not been exposed to the pest organism
  - Being free from the pest organism
  - Having been effectively treated to destroy the pest organism
  - Having been produced, processed, stored, handled, or used under conditions which preclude effective transmission of the pest organism

At the local level, management of invasive species may be addressed through municipal ordinances. A few municipalities in the watershed have ordinances that specifically address invasive species. The Cities of Franklin and Greenfield have ordinances that define certain invasive plant species as noxious weeds and require that these species be controlled along with other noxious weeds. Most of the municipalities in the watershed have noxious weed ordinances. While the content of these ordinances vary among the communities, they generally define certain plant species as noxious weeds and require their destruction or control. Some of these ordinances, such as those of the Cities of Milwaukee and Oak Creek, specifically relate to plant species that cause hay fever or skin rashes.

<u>Groundwater Management Measures</u>

Utility-Specific Water Conservation Programs

As previously noted, the RWQMPU recommends that water utilities develop and implement utility-specific water conservation programs. For water utilities withdrawing water from surface water or groundwater sources in the Great Lakes Basin, including the Oak Creek watershed, this recommendation is partially implemented through the requirements of Chapter NR 852, "Water Conservation and Water Use Efficiency," of the *Wisconsin Administrative Code.* This chapter requires mandatory water conservation programs for all new and increased withdrawals and diversions of water from sources in the Great Lakes Basin after December 8, 2008. It does not require water conservation for existing facilities at their pre-December 8, 2008 level of water withdrawal.

The rule classifies new withdrawals and diversions into three tiers, based upon the daily average amount of water withdrawn, whether the new or increased withdrawal constitutes a diversion of water from the Great Lakes basin, and whether the new or increased withdrawal would result in an average water loss through consumptive use or diversion of more than 2 million gallons per day. The measures that are required to be implemented vary by tier. For all new or increased withdrawals by utilities withdrawing an average of 100,000 gallons per day or more, the utility is required to develop a water conservation plan, conduct a water use audit, develop a leak detection and repair program, measure their sources of water, and educate their staff and customers about their water conservation activities. Utilities withdrawing more than an average of 1 million gallons per day, seeking a new or increased diversion of Great Lakes water, or making withdrawals that result in an average water loss of more than 2 million gallons per day are required to implement additional conservation and efficiency measures. Under the rule, conservation and efficiency measures that require retrofitting are optional.

Consider the Potential Impact on Groundwater Quality in the Design of Stormwater Management Facilities

As previously noted, the RWQMPU recommends that the design of stormwater management facilities that directly or indirectly involve infiltration of stormwater consider the potential impacts on groundwater quality, and that the provisions in the WDNR's post-construction stormwater management technical standards intended to protect groundwater quality be applied in the design of stormwater management facilities. These recommendations are addressed by regulations contained in Chapters NR 151, "Runoff

Management," and Trans 401, "Construction Site Erosion Control and Storm Water Management Procedures for Department Actions," of the *Wisconsin Administrative Code*. Chapter NR 151 sets forth post-construction performance standards for new development and redevelopment and infiltration performance standards for both nonagricultural (urban) areas and transportation facilities.[35] Trans 401 sets forth post-construction performance standards for those transportation facilities that are regulated by the Wisconsin Department of Transportation. These performance standards include several elements that are intended to protect groundwater quality:

- They prohibit the infiltration of runoff that originates from certain types of source areas that can be expected to contribute contaminants that could degrade groundwater quality. Examples of these source areas include fueling and vehicle maintenance areas, storage and loading areas from certain types of industrial facilities, and rooftop and parking areas of certain types of industrial facilities.

- They prohibit the infiltration of runoff that originates from certain types of source areas in close proximity of landscape features that can cause groundwater to be susceptible to contamination. Examples of these include prohibitions against infiltrating any runoff within 1,000 feet upgradient or 100 feet downgradient of karst features and infiltrating runoff from commercial, industrial, and institutional land uses or regional devices for one- and two-family residential development within 400 feet of a community water system or 100 feet of a private well.

- They specify required soil characteristics and separation distances between the bottom of an infiltration system and the elevation of seasonal high groundwater or the top of bedrock. These specified soil characteristics and separation distances depend upon the source of the runoff.

- They prohibit the infiltration of runoff in areas where contaminants of concern are present in the soil through which infiltration will occur.

- They require pretreatment prior to infiltration of runoff from parking lots and new road construction in commercial, industrial, and institutional areas.

- They require that infiltration systems shall, to the extent technically and economically feasible, minimize the level of pollutants infiltrating to groundwater and to maintain compliance with the preventive action limits for groundwater pollutants promulgated by the WDNR.[36]

Other Management Strategies that are in Various Stages of Implementation

Table 2.3 summarizes the recommendations of the RWQMPU that have been or are being implemented to some degree in the Oak Creek watershed.

<u>Land Use Element</u>

Preserve Primary Environmental Corridors in Essentially Natural Open Space Uses

The current protection status of primary environmental corridors in the watershed is shown on Map 2.2. About 744 acres, or 100 percent, of the primary environmental corridors in the Oak Creek watershed are protected, or substantially protected, through one or more of the following means:

- Public interest ownership, including publicly owned lands, privately held lands owned by conservancy organizations and other privately held lands that were in compatible outdoor recreational use, and surface water

- Joint State-local floodplain and shoreland-wetland zoning

---

[35] *The post-construction performance standard for new development and redevelopment in nonagricultural (urban) areas is set forth in NR 151.12. The infiltration performance standard for nonagricultural (urban) areas is set forth in NR 151.124. The post construction performance standard for transportation facilities is set forth in NR 151.24. The infiltration performance standard for transportation facilities is set forth in NR 151.244.*

[36] *Preventive action limits are groundwater quality criteria. They are set forth in Chapter NR 140, "Groundwater Quality," of the* Wisconsin Administrative Code.

Table 2.3
Management Strategies Recommended in the Regional Water Quality Management Plan Update that are in Various Stages of Implementation

Recommendation or Management Strategy	Focus Area Primarily Addressed: Water Quality	Recreational Use and Access	Habitat Condition	Flooding	Responsible and Participating Organizations[a]
Land Use Element					
Preserve primary environmental corridors in essentially natural open space uses	X	X	X	X	Milwaukee County, Municipalities
Consider preserving secondary environmental corridors and isolated natural resource areas in essentially natural open space uses	X	X	X	X	Milwaukee County, Municipalities
Preserve all identified natural areas and critical species habitat sites in public or public interest ownership	X	X	X	X	Milwaukee County, Municipalities
Preserve, to the extent practicable, all farmland covered by Class I and Class II soils	--	--	--	--	Milwaukee County, Municipalities, DATCP
Point Source Pollution Abatement Measures					
Refine sanitary sewer service areas	X	X	--	--	MMSD, Municipalities
Construct and maintain local sanitary sewer systems	X	X	--	--	Municipalities
Nonpoint Source Pollution Abatement-Rural Control Measures					
Implement practices to reduce soil loss from cropland to rates below the tolerable soil loss rate, "T"	X	--	--	--	Milwaukee County, DATCP, WDNR, NRCS
Increase crop and pasture riparian buffers to a minimum of 75-foot widths on each side of streams	X	X	X	X	Milwaukee County, MMSD, DATCP, WDNR, USFSA, NRCS, Land Trusts
Limit the number of stream crossings and configure crossings to minimize fragmentation	--	X	X	X	Milwaukee County, DATCP, WDNR, USDA, WisDOT
Nonpoint Source Pollution Abatement-Urban Control Measures					
Implement programs to detect and eliminate discharges and control pathogens that are harmful to human health	X	X	--	--	Municipalities, WDNR
Implement chloride reduction programs	X	--	--	--	Milwaukee County, Municipalities, WDNR, WisDOT
Implement fertilizer management programs	X	--	--	--	Milwaukee County, Municipalities, WDNR, UWEX
Implement beach and riparian litter and debris control programs	X	X	X	--	Milwaukee County, Municipalities, WDNR, UWEX
Instream Water Quality Management Measures					
Implement projects called for under the Milwaukee County stream assessment study	X	--	X	--	Milwaukee County
Limit the number of culverts, bridges, drop structures, and channelized segments and incorporate design measures to allow for passage of aquatic organisms	--	X	X	X	Milwaukee County, Municipalities, MMSD, WDNR, WisDOT
Remove abandoned bridges and culverts	--	--	X	X	Milwaukee County, Municipalities, MMSD, WDNR, WisDOT
Protect remaining stream channels, including small tributaries and wetlands	X	--	X	--	Milwaukee County, Municipalities, MMSD, WDNR, WisDOT

Table continued on next page.

Table 2.3 (Continued)

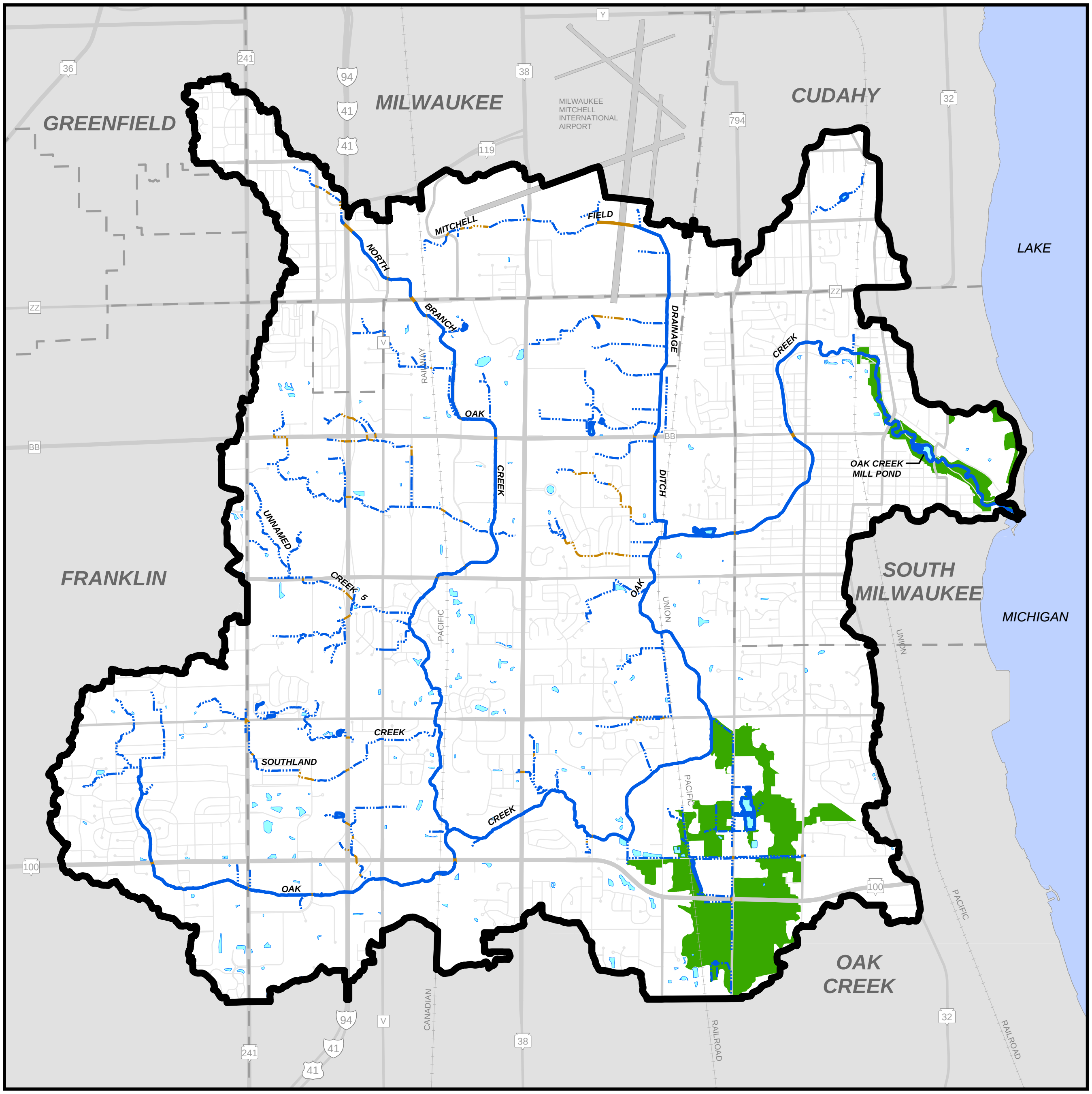
Recommendation or Management Strategy	Focus Area Primarily Addressed: Water Quality	Recreational Use and Access	Habitat Condition	Flooding	Responsible and Participating Organizations[a]
Instream Water Quality Management Measures (continued)					
Restore wetlands, woodlands, and grasslands adjacent to stream channels and establish minimum 75-foot-wide buffers on each side	X	X	X	X	Milwaukee County, Municipalities, MMSD, WDNR, WisDOT
Restore and enhance stream channels	X	--	X	--	Milwaukee County, Municipalities, MMSD, WDNR, WisDOT
Monitor fish and macroinvertebrate populations	X	--	X	--	WDNR, MMSD
Consider more intensive fisheries manipulation measures where warranted based upon specific goals developed in detailed local level planning	--	X	X	--	WDNR
Inland Lake Water Quality Management Measures					
Implement recommendations of the Milwaukee County park pond and lagoon management plan	X	X	X	--	Milwaukee County
Auxiliary Water Quality Management Measures					
Continue, support, and institute household hazardous waste collection programs	X	--	--	--	Milwaukee County, MMSD, DATCP
Continue, support, and institute collection programs for unused and expired medications	X	--	--	--	Milwaukee County, MMSD, Municipalities
Continue and support programs to reduce the introduction and spread of exotic and invasive species	--	--	X	--	WDNR, UWEX, Milwaukee County
Document and monitor the occurrence and spread of exotic and invasive species	--	--	X	--	WDNR, Milwaukee County
Continue and support current surface water quality monitoring programs	X	X	--	--	MMSD, WDNR, USGS
Establish long-term fisheries, macroinvertebrate, and habitat monitoring stations	X	X	X	--	WDNR, MMSD, USGS
Continue and maintain citizen-based monitoring efforts, with an emphasis on filling geographic data gaps	X	X	X	--	WDNR, UWEX, Milwaukee County
Maintain and update RWQMPU/MMSD 2020 Facility Plan water quality models	X	--	--	X	SEWRPC
Groundwater Management Measured					
Maintain important groundwater management areas	X	--	X	X	Milwaukee County, Municipalities

[a] *Abbreviations for organizations are:*

DATCP = Wisconsin Department of Agriculture, Trade and Consumer Protection
MMSD = Milwaukee Metropolitan Sewerage District
NRCS = Natural Resources Conservation Service
SEWRPC = Southeastern Wisconsin Regional Planning Commission
USDA = U.S. Department of Agriculture
USFSA = U.S. Farm Services Agency
USGS = U.S. Geological Survey
UWEX = University of Wisconsin-Extension
WDNR = Wisconsin Department of Natural Resources
WisDOT = Wisconsin Department of Transportation

Source: SEWRPC

Map 2.2
Protection of Primary Environmental Corridors in the Oak Creek Watershed: 2015



PROTECTED THROUGH PUBLIC-INTEREST OWNERSHIP OR PUBLIC REGULATION

OAK CREEK WATERSHED BOUNDARY

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: SEWRPC

- State administrative rules governing sanitary sewer extensions within planned sanitary sewer service areas

- Local land use regulations

Consider Preserving Secondary Environmental Corridors and Isolated Natural Resource Areas in Essentially Natural Open Space Uses

The RWQMPU encourages preserving secondary environmental corridors and isolated natural areas and recommends that counties and communities consider preserving these areas in the preparation of county and local land use plans. Some secondary environmental corridor sites and isolated natural resource areas in the Oak Creek watershed are in protective ownership. Example of these sites include portions of the Oak Creek Parkway.

Preserve All Identified Natural Areas and Critical Species Habitat Sites in Public or Public Interest Ownership

The RWQMPU recommends preserving of all identified natural areas and critical species habitat sites. As called for under the regional natural areas and critical species habitat protection and management plan,[37] the RWQMPU recommends acquiring those sites not in existing public or public-interest ownership. The identified natural areas and critical species habitat sites in the Oak Creek watershed and their current and recommended protection status are shown on Map 2.3. The status of implementation of the RWQMPU recommendations for placing these sites in protective ownership was assessed as part of the 2010 amendment to the regional natural areas and critical species habitat protection and management plan. This status is indicated in Table 2.4. There are 11 natural areas and 12 critical species habitat sites that are wholly or partially located within the Oak Creek watershed. The total area of these sites is 609 acres, with 521 acres located within the watershed. As of 2010, 364 acres were in protective ownership. The regional natural areas and critical species habitat protection and management plan, as amended, recommends that an additional 213 acres be acquired and placed in protective ownership.

<u>Point Source Pollution Abatement Measures</u>

Construct and Maintain Local Sanitary Sewer Systems

As discussed previously, the RWQMPU recommends that all of the municipalities in the watershed construct and maintain local sanitary sewer systems. These jurisdictions have all constructed such systems and perform maintenance on an ongoing basis.

<u>Nonpoint Source Pollution Abatement—Rural Control Measures</u>

These RWQMPU recommendations for controlling nonpoint source pollution in rural areas include:

- Implementing practices to reduce soil loss from cropland to attain erosion rates less than or equal to "T," the maximum average annual rate of soil loss that can occur without significantly affecting crop productivity

- Establishing minimum 75-foot-wide riparian buffers along each side of streams flowing through current crop and pasture land

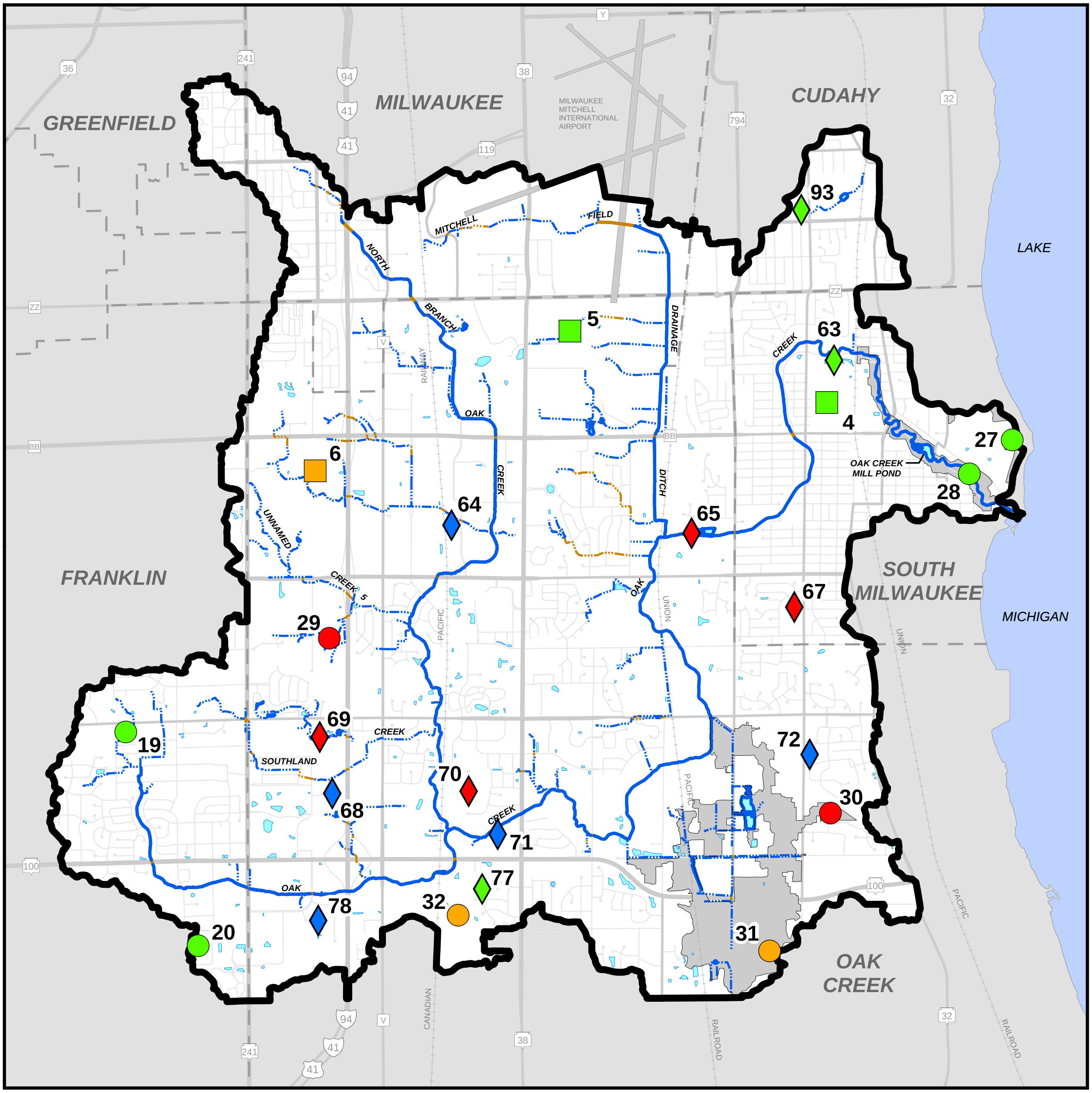
- Limiting the number of stream crossings and configuring crossings to minimize fragmentation of stream habitat

The Environmental Services Unit of the Milwaukee County Department of Administrative Services operates as the County's land conservation department. It has been pursuing implementation of these recommendations both through projects on County-owned lands and by providing cost-share assistance and technical assistance to land owners to install practices that address soil erosion and agricultural nonpoint source pollution.

---

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

Map 2.3
Protection Status of Natural Areas and Critical Species Habitat Sites in the Oak Creek Watershed



CURRENT STATUS AND PLAN PROTECTION

	NA-1 SITE	NA-2 SITE	NA-3 SITE	CSH SITE
ENTIRELY UNDER PROTECTIVE OWNERSHIP/ PROTECTIVE OWNERSHIP TO BE RETAINED	(NONE)			
PARTIALLY UNDER PROTECTIVE OWNERSHIP/ REMAINDER OF SITE TO BE ACQUIRED	(NONE)			
NOT UNDER PROTECTIVE OWNERSHIP/ ENTIRE SITE TO BE ACQUIRED	(NONE)	(NONE)		
NOT UNDER PROTECTIVE OWNERSHIP/ TO BE PRESERVED TO THE EXTENT PRACTICABLE WITHOUT PROTECTIVE OWNERSHIP	(NONE)	(NONE)	(NONE)	

PRIMARY ENVIRONMENTAL CORRIDOR

OAK CREEK WATERSHED BOUNDARY

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

4 REFERENCE NUMBER (SEE TABLE 2.4)

0 0.25 0.5 1 Mile

Note: Map numbers are those assigned in the Milwaukee County map in the Amendment to SEWRPC Planning Report No. 42, Natural Areas and Critical Species Habitat Protection and Management Plan for the Southeastern Wisconsin Region, December 2010

Source: SEWRPC

Table 2.4
Protection Status of Natural Areas and Critical Species Habitat Sites in the Oak Creek Watershed: 2018

Number on Map 2.3[a]	Name	Class[b]	Area (acres)	Area in Watershed (acres)	Area in Protective Ownership (acres)	Areas in Private Ownership (acres)	Area to Be Acquired (acres)[c]
4	Rawson Woods Park	NA-2	23	23	23	0	0
5	Cudahy Woods	NA-2[d]	47	47	47	0	0
6	Falk Park Woods	NA-2	78	78	71	7	7
19	Franklin Woods[e]	NA-3	34	34	37	0	0
20	Fitzsimmons Road Woods	NA-3	39	13	39	0	0
27	Grant Park Woods South	NA-3	45	14	45	0	0
28	Oak Creek Parkway Woods	NA-3	24	28	28	0	0
29	Barloga Woods[f]	NA-3	64	64	64	0	0
30	Wedge Woods	NA-3	17	17	0	17	17
31	Oak Creek Low Woods	NA-3	68	33	31	37	37
32	Ryan Road Woods	NA-3	42	42	42	0	0
		Subtotal	481	393	427	61	61
63	Oak Creek Parkway Bike Trail Woods	CSH	2	2	2	0	0
64	Industrial Park Mesic Woods	CSH	5	5	0	5	0
65	Camelot Park Woods	CSH	15	15	15	0	15
67	Blakewood School Woods	CSH	1	1	1	0	1
68	Meyers Woods	CSH	10	10	0	10	0
69	Puetz Road Woods	CSH	22	22	0	22	22
70	Wood Creek Woods	CSH	27	27	0	27	27
71	Howell Avenue Woods	CSH	21	21	0	21	0
72	Fittshur Wetland	CSH	6	6	0	6	0
77	Ryan Road Upland Woods-East	CSH	4	4	4	0	0
78	Truck Stop Woods	CSH	11	11	0	11	0
93	Cudahy Park Woods	CSH	4	4	4	0	0
		Subtotal	128	128	26	102	65
		Total	609	521	453	163	126

[a] *Map numbers are those assigned in the Milwaukee County map in the Amendment to SEWRPC Planning Report No. 42,* Natural Areas and Critical Species Habitat Protection and Management Plan for the Southeastern Wisconsin Region, *December 2010.*

[b] *NA-1 sites are areas of Statewide significance. These areas contain excellent examples of nearly complete and relatively undisturbed plant and animal communities which are believed to resemble those present prior to European settlement.*

NA-2 sites are areas of regional significance. These areas are so designated either because they show evidence of a limited amount of human disturbance or because they are of the highest quality but have less areas than that required for the NA-1 ranking.

NA-3 sites are areas of local significance. While these areas are substantially altered by human activities, they may contain excellent wildlife habitat or provide refuge for native plant species which no longer exist in the surrounding region due to land use activities.

CSH sites are critical species habitat sites.

[c] *As recommended in the 2010 amendment to the regional natural areas and critical species habitat protection plan.*

[d] *This site is also a designated State natural area.*

[e] *Also known as Puetz Road Woods.*

[f] *The name of this natural area has recently been changed. It was previously known as Esch-Honadel Woods.*

Source: SEWRPC

Nonpoint Source Pollution Abatement—Urban Control Measures

Programs to Detect and Eliminate Discharges and Control Pathogens That Are Harmful to Human Life

As previously described, the RWQMPU recommends enhanced urban illicit discharge control and/or innovative methods to identify and control possible pathogen sources in stormwater runoff from all urban areas in its study area, including the Oak Creek watershed. This recommendation is intended to address fecal indicator bacteria, the presence of which may indicate risks to human health from pathogens. As part of the sampling it conducted in support of the development of this watershed restoration plan, the City of

Racine Public Health Department (RHD) examined over 100 stormwater outfalls in the watershed for dry weather flow. The RHD performed microbial source tracking on samples collected from those outfalls with dry weather flow in which the flow contained high concentrations of fecal indicator bacteria.

Chloride Reduction Programs

The RWQMPU recommendations to reduce the amount of chlorides introduced into the environment include:

- Evaluating deicing practices by counties and municipalities to obtain optimal application rates to ensure public safety without applying more chlorides than necessary for that purpose

- Considering alternatives to current ice and snow control programs

- Implementing education programs to provide information about alternative ice and snow control measures in public and private parking lots and optimal deicer application rates in such areas

- Implementing education programs to provide information about alternative water softening media and the use of more efficient water softeners

A number of efforts have been made to reduce the use of chlorides in deicing. In 2017, Milwaukee Riverkeeper sponsored a snow and ice control workshop that focused on salt use reduction for private contractors maintaining parking lots.

Fertilizer Management Programs

As described previously, the RWQMPU recommends that information and education programs required under municipal WPDES stormwater discharge permits promote voluntary practices that optimize urban fertilizer application consistent with the requirements of WDNR Technical Standard No 1100, "Interim Turf Nutrient Management." Several programs provide information and education regarding fertilizer application and management to residents of the Oak Creek watershed. The Root-Pike Watershed Initiative Network (WIN) and the Southeastern Wisconsin Watersheds Trust, Inc. conduct the Respect Our Waters program, an educational program providing information with the long-term goal of reducing polluted runoff and improving water quality in local waterways. This program is sponsored by 50 counties and municipalities, including Milwaukee County and all of the municipalities in the Oak Creek watershed. The WDNR and the University of Wisconsin-Extension also provide educational materials regarding urban fertilizer management.

Beach and Riparian Litter Debris Control Programs

As previously noted, the RWQMPU recommends that existing litter and debris control programs along the urban streams of the study area be continued and that opportunities to expand such efforts be explored. In the Oak Creek watershed, Friends of the Mill Pond and Oak Creek Watercourse, Inc. sponsors annual spring and fall clean ups to remove trash and debris from selected areas along Oak Creek.

Instream Water Quality Management Measures

Implement Projects Called for Under the Milwaukee County Stream Assessment Study

The RWQMPU recommends that the projects called for under the Milwaukee County stream assessment study be implemented over time in a manner consistent with the need to provide flood protection and consistent with the stream rehabilitation recommendations of the regional plan update. Milwaukee County has been pursuing funding to implement projects recommended by this assessment.

Culverts, Bridges, Drop Structures, and Channelized Stream Segments

The RWQMPU recommends limiting the installation of culverts, bridges, drop structures, and channelized stream sections, removing them where possible, and retrofitting them to allow the passage of fish and other aquatic organisms. Two crossings have been removed from streams in the Oak Creek watershed. A private drive bridge on the mainstem of Oak Creek upstream of S. 35th Street was removed in 2004 or 2005. Another private drive bridge on the North Branch of Oak Creek downstream of Weatherly Drive was also removed. Since 2002, 13 bridges and culverts have been replaced along the major streams in the watershed: ten on the mainstem of Oak Creek, two on the North Branch of Oak Creek, and one on the Mitchell Field Drainage Ditch. At least one of these structures includes aquatic organism passage features. The culvert on the mainstem of Oak Creek at the northernmost crossing of W. Ryan Road was replaced in 2006. The replacement culvert incorporates baffles along the invert that decrease flow velocity and increase water depth, facilitating the passage of fish and other aquatic organisms.

Protect Remaining Natural Stream Channels

The RWQMPU recommends that to the extent practicable, remaining natural stream channels, including small tributaries and shoreland wetlands that provide habitat for the continued survival, growth, and reproduction of a sustainable fishery throughout the study area, be protected. No specific examples of implementation of this recommendation were identified within the Oak Creek watershed.

Restore Wetlands, Woodlands, and Grasslands Adjacent to
Stream Channels and Establish Minimum 75-Foot-Wide Buffers

As previously noted, the RWQMPU recommends restoring wetlands, woodlands, and grasslands adjacent to stream channels and establishing buffers that are a minimum of 75 feet in width on each side to reduce pollutant loads entering the stream and protect water quality. Some projects conducted by the Milwaukee County Department of Parks, Recreation and Culture (DPRC) address this recommendation. DPRC has recently conducted a reforestation project within Grant Park. It has also recently conducted native planting projects in Copernicus and Grant Parks.

Restore and Enhance Stream Channels

Several recent projects have addressed the RWQMPU recommendations to restore, enhance, and/or rehabilitate stream channels. From 2013 through 2015, an approximately 1,100-foot section of steam channel within a tributary to Oak Creek was relocated and restored in conjunction with road construction at the IH 94 interchange at Ryan Road. This project included wetland mitigation within an adjacent stormwater pond. From 2013 through 2015, over 1,900 linear feet of stream channel were relocated and restored within tributaries to the North Branch of Oak Creek in association with road construction along IH 94 at Drexel Avenue. This project included a specialized culvert designed to allow fish passage under both low- and high-flow conditions and wetland mitigation in an adjacent residential area.

Monitor Fish and Macroinvertebrate Populations

The RWQMPU recommends that monitoring fish and macroinvertebrate populations to evaluate the effectiveness of the water quality management program. The WDNR conducts monitoring of these organisms in the Oak Creek watershed, and the most recent monitoring was conducted in 2015. In 2004 and 2007, fish and macroinvertebrate data were also collected at two sampling stations along the mainstem of the Oak Creek in Milwaukee County as part of the MMSD Corridor Study.[38]

The Milwaukee County DPRC conducts natural history inventories and wildlife surveys in County parks and natural areas. Parks and natural areas within the Oak Creek watershed that have been recently examined include Cudahy Park, Cudahy Nature Preserve, Copernicus Park, Esch-Honadel Woods, Grant Park, Maitland Park, the Oak Creek Parkway, and Rawson Woods.

Consider More Intensive Fisheries Manipulation Measures Where
Warranted Based Upon Specific Goals Developed in Detailed Local Level Planning

As part of its fisheries management programs, the WDNR considers the appropriate management measures for fisheries in the Oak Creek watershed. The WDNR annually stocks catchable-size rainbow trout In the Oak Creek Mill Pond under its Southeast Region Urban Fishing Program.

<u>Inland Lake Water Quality Management Measures</u>

Implement Recommendations of the Milwaukee County Park Pond and Lagoon Management Plan

The RWQMPU recommends implementing the recommendations of the Milwaukee County park pond and lagoon management plan. Milwaukee County has been pursuing funding to implement projects recommended under the plan.

---

[38] *U.S. Geological Survey Scientific Investigations Report No. 2007-5084,* Water Quality Characteristics for Selected Sites within the Milwaukee Metropolitan Sewerage District Planning Area, Wisconsin: February 2004-September 2005, *2007; U.S. Geological Survey Scientific Investigations Report No. 2010-5166,* Biological Water Quality Assessment of Selected Streams within the Milwaukee Metropolitan Sewerage District Planning Area of Wisconsin: 2007, *2010.*

Auxiliary Water Quality Management Measures

Continue, Support, and Institute Household Hazardous Waste Collection Programs

MMSD has three Milwaukee County collection facilities that are open two to three days per week throughout the year. In addition, the MMSD sponsors periodic mobile collection events for Milwaukee County residents. Five of these events spread over seven days were held in 2017.

Continue, Support, and Institute Collection Programs for Unused and Expired Medications

Two types of programs have been developed that are implementing this RWQMPU recommendation in the Oak Creek watershed. First, several jurisdictions have established drop-off sites or drop boxes where residents may dispose of expired or unused medications. These sites are usually located at law enforcement offices. In the Oak Creek watershed, collection sites have been established at police departments in the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee. In addition, collection sites have been established in some pharmacies. For example, Walgreens Pharmacies have installed safe medication disposal kiosks at five of their locations in Milwaukee County. Second, mail-back programs for disposal of expired or unwanted medications also serve residents of the watershed. As part of a two-year pilot program, postage-paid drug disposal envelopes are available to the public at 10 Milwaukee area CVS Pharmacy locations, the Milwaukee and Cudahy Police Departments, and the MMSD's main office.

Continue and Support Programs to Reduce the Introduction and Spread of Exotic and Invasive Species

In addition to the regulatory approaches previously described, there are a number of ongoing efforts for reducing the introduction and spread of exotic and invasive species in the Oak Creek watershed. The DPRC conducts aquatic plant management activities in park ponds and lagoons for aquatic invasive plants such as Eurasian water milfoil. Management efforts are conducted on an as-needed basis. DPRC also conducts terrestrial invasive plant management and removal activities in parks and natural areas of the Milwaukee County Park System. The methods used depend on the particular invasive species and the biological community in which they are located. These methods include mowing, prescribed burns, hand removal, mechanical removal, and application of herbicides. Many of DPRC's activities in the management of invasive species are conducted in cooperation with partner groups. The Park People of Milwaukee County, an umbrella organization of park friends groups, park watch groups, and neighborhood associations concerned with specific parks of the Milwaukee County Park System, coordinates weed-out events in the Milwaukee County Park System. The annual weed-out events held in Grant Park by the Friends of Grant Park are an example of this. This coordination includes recruiting volunteers and providing onsite tools and training. Other recent partners include Americorps, the Student Conservation Association, the Boy Scouts and Girl Scouts, and service learning programs at local colleges and universities.

During 2013 and 2014, DPRC established release sites in Grant Park and the Oak Creek Parkway for beetles intended to control purple loosestrife, an exotic plant that invades wetlands.

Document and Monitor the Occurrence and Spread of Exotic and Invasive Species

In recent years, several ongoing efforts have addressed the RWQMPU recommendation to document and monitor the occurrence and spread of exotic and invasive species.

As part of its field activities, the WDNR documents the occurrence of exotic and invasive species. In addition, in 2003 and 2004, the Department used satellite data to map the degree to which wetlands in the State are infested with reed canary grass.[39] Distributions of several invasive species are documented on the Department's surface water data viewer, an internet-based mapping utility.[40] The Department has also implemented an internet-based reporting system for citizens and other agencies to report occurrences of invasive species.[41]

As part of its activities, the Milwaukee County DPRC has conducted natural resource inventories for natural areas management units within the Park System, which include inventories of invasive species. Parks and

---

[39] *Wisconsin Department of Natural Resources,* Mapping Wisconsin Wetlands Dominated by Reed Canary Grass, *Phalaris arundinacea* L.: A Landscape Level Assessment, *Final Report to the U.S. Environmental Protection Agency, October 2008.*

[40] *The surface water data viewer can be accessed at dnr.wi.gov/topic/surfacewater/swdv.*

[41] *The WDNR online reporting system can be accessed at dnr.wi.gov/topic/Invasives/report.html.*

natural areas within the Oak Creek watershed that have been recently examined include Cudahy Park, Cudahy Nature Preserve, Copernicus Park, Esch-Honadel Woods, Grant Park, Maitland Park, the Oak Creek Parkway, and Rawson Woods. In addition, DPRC staff have conducted surveys for aquatic invasive species in the Oak Creek Mill Pond and ponds in Grant Park and the Oak Creek Parkway.

In 2011, volunteers under the direction of the Southeastern Wisconsin Invasive Species Consortium (SEWISC)—a coalition of local units of government; Federal, State, and local government agencies; businesses; land trusts; and nongovernmental organizations that promotes efficient and effective management of invasive species throughout Kenosha, Milwaukee, Ozaukee, Racine, Sheboygan, Walworth, Washington, and Waukesha Counties— conducted roadside surveys for the presence and population sizes of four invasive plant species: common teasel (*Dipsacus sylvestris*), cut-leaf teasel (*Dipsacus laciniatus*), giant reed grass (*Phragmites australis*), and Japanese knotweed (*Polygonum cuspidatum*). This survey covered all roads with lane markings within the eight counties served by SEWISC. As part of this effort, surveys were also performed on areas in or near primary and secondary environmental corridors and isolated natural resource areas.

Continue and Support Current Surface Water Quality Monitoring Programs

The RWQMPU recommends that the surface water quality monitoring programs currently being conducted by the MMSD, WDNR, and USGS be supported and continued. While there have been some changes to sampling sites and sampling frequencies in response to budget considerations, these monitoring programs continue to operate in the Oak Creek watershed.

Establish Long-Term Fisheries, Macroinvertebrate, and Habitat Monitoring Stations

As noted previously, the RWQMPU recommends establishing long-term fisheries, macroinvertebrate, and habitat monitoring stations in streams—ideally at sites where water quality is also being monitored. As part of its 2015 monitoring efforts, the WDNR monitored fish and macroinvertebrate populations at the sample sites in the watershed that had been previously sampled for fish and macroinvertebrates.

Continue and Maintain Citizen-Based Monitoring Efforts, with an Emphasis on Filling Geographic Data Gaps

Activities implementing this recommendation have included: 1) some citizen-based water quality monitoring conducted by Milwaukee Riverkeeper in the Oak Creek watershed, mostly as a part of the WDNR/University of Wisconsin-Extension (UWEX) Level 3 Water Action Volunteers Program and through 2) a DPRC citizen-scientist program that focuses on Milwaukee County parks and natural areas. This program includes using volunteers to conduct wildlife surveys and monitoring of biota in ephemeral and other wetlands.

Maintain and Update RWQMPU/MMSD 2020 FP Water Quality Models

The RWQMPU recommends periodic maintenance and updating of the water quality models developed under the RWQMPU/MMSD 2020 FP. As part of its ongoing activities, SEWRPC has been maintaining and updating these models.

<u>Groundwater Management Measures</u>

Maintain Important Groundwater Recharge Areas

As previously discussed, the RWQMPU recommends that consideration be given to following the recommendations of the regional water supply plan regarding maintenance of groundwater recharge areas. The regional water supply plan recommended preserving and protecting of groundwater recharge areas having a high or very high recharge potential.[42] Such protection may be largely achieved through implementing of the adopted design year 2035 regional land use plan and supporting municipal comprehensive plans, since these plans recommend preserving of environmental corridors, isolated natural resource areas, and prime and other agricultural areas that facilitate recharge. The plan estimated that, within the Southeastern Wisconsin Region, about 76 percent of the highly rated and very highly rated recharge areas may be expected to be preserved by inclusion in environmental corridors, isolated natural resource areas, and prime and other agricultural areas identified for preservation in the adopted regional land use plan.

---

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

VISION 2050, an update to the year 2035 regional land use plan, was adopted by the Regional Planning Commission in 2016.[43] VISION 2050 also recommends preserving environmental corridors, isolated natural resource areas, and prime agricultural lands. In addition, the pattern of planned urban lands developed under the land use element of VISION 2050 assumed that enclaves of open land, including areas of wetlands and woodlands located outside of environmental corridors and isolated natural resource areas, would remain in developed areas resulting in a higher percentage of high and very-high recharge potential areas being preserved (over 90 percent).

Management Strategies Recommended by the RWQMPU that Are Not Yet Implemented

Some recommendations of the RWQMPU have not yet been implemented in the Oak Creek watershed. These are summarized in Table 2.5.

2.3 FLOOD MITIGATION AND STORMWATER PLANS

MMSD Oak Creek Phase 1 Watercourse Management Plan

The Milwaukee Metropolitan Sewerage District published Phase I of a Watercourse Management Plan for Oak Creek in 2000.[44] This plan was developed to identify flooding issues in the Oak Creek watershed, estimate potential structural damages, and analyze potential alternatives to resolve these flooding problems. Evaluations were done for each subwatershed, including the Oak Creek mainstem, the North Branch of Oak Creek, and the Mitchell Field Drainage Ditch.

Hydrologic and hydraulic models of the watershed were developed to determine the extent of the flooding problem and to analyze alternative solutions. Four watercourse alternatives were evaluated for their potential to mitigate damages during floods with annual probabilities of 1-percent or greater. The alternatives evaluated include constructing regional storage facilities, constructing levees or berms, conveyance improvements, and acquiring or floodproofing structures located in the 1-percent-annual probability floodplain.

The Oak Creek Phase 1 Watercourse Management Plan recommends floodproofing and acquiring several structures to mitigate impacts of flood with probabilities of 1-percent or greater. This proved to be the most cost effective option due to the scattered nature of the flood-prone structures in the watershed. The plan also recommends implementing regulations for new development to control stormwater runoff increases, preserving natural storage in the watershed, evaluating existing drop structures for potential removal, and investigating sewer capacity problems caused by low outfalls.

Subsequently, SEWRPC agreed to provide MMSD with an update for the Oak Creek Phase 1 Watercourse Management Plan completed in 2000.[45] The SEWRPC study updates the structural damage estimates and recommendations of the Phase 1 plan. The hydrologic and hydraulic models for the North Branch of Oak Creek were updated to include new survey information. New flood damage estimates were calculated to approximate the costs of direct and indirect damages in 2010 dollars. This update also identified critical use facilities that would likely become flooded in a 0.2-percent-annual-probability event, and listed major roads that could become flooded to a depth of at least 1.5 feet, blocking emergency vehicle access. In addition, three stormwater detention basins that were constructed as part of the IH-94 North-South Freeway reconstruction project were evaluated in the models to determine whether the basins would make any significant changes in flooding. The evaluation found that these basins somewhat reduced flood flows and attendant flood stages, resulting in slightly reduced estimated flood damage costs. The changes due to the presence of the basins did not reduce flood elevations sufficiently to remove any structures from the 1-percent-annual probability floodplain.

---

[43] *SEWRPC Planning Report No. 55,* Vision 2050: A Regional Land Use and Transportation Plan for Southeastern Wisconsin, *July 2017.*

[44] *Camp Dresser & McKee, Oak Creek Phase 1 Watercourse System Management Plan, Milwaukee Metropolitan Sewerage District, August 2000.*

[45] *SEWRPC Memorandum Report No. 198, Oak Creek Updated Phase 1 Watercourse Management Plan, (draft).*

Table 2.5
Management Strategies Recommended for Implementation in the Regional Water Quality Management Plan Update But Not Yet Implemented

	Focus Area Primarily Addressed				
Recommendation or Management Strategy	Water Quality	Recreational Use and Access	Habitat Condition	Flooding	Responsible and Participating Organizations[a]
Consider changes in the method of applying corrosion control in municipal water systems to limit phosphorus loading	X	--	--	--	Municipalities
Convert marginally productive agricultural lands to wetland or prairie conditions	X	X	X	X	Milwaukee County, WDNR, Land Trusts
Conduct human health and ecological risk assessments to address pathogens in stormwater runoff	X	X	--	--	MMSD, Municipalities
Conduct targeted research on bacteria and pathogens and research on stormwater best management practice techniques and programs	X	X	--	--	MMSD, Municipalities
Prepare abandonment and river restoration plans for dams	X	--	X	--	Milwaukee County, WDNR
Establish long-term monitoring stations in inland lakes	X	X	--	--	Milwaukee County, WDNR
Implement waterfowl control programs, where necessary	X	X	--	--	Milwaukee County, Municipalities
Conduct assessments and evaluations of the significance for human health and wildlife of the presence of pharmaceuticals and personal care products in surface waters	X	--	--	--	MMSD, USGS
Continue efforts to facilitate consolidation of data from different monitoring programs	X	X	X	--	MMSD, WDNR, UWEX, USGS, USEPA
Expand citizen-based monitoring efforts, with an emphasis on filling geographical data gaps	X	X	X	--	UWEX, WDNR
Consider groundwater sustainability guidance from the regional water supply plan in evaluating the sustainability of proposed development and local land use planning	X	--	X	--	Municipalities

[a] *Abbreviations for organizations are:*

MMSD = Milwaukee Metropolitan Sewerage District
USFSA = U.S. Farm Services Agency
USGS = U.S. Geological Survey
UWEX = University of Wisconsin-Extension
WDNR = Wisconsin Department of Natural Resources

Source: SEWRPC

This update also analyzed alternative plans for managing floodwater along the North Branch of Oak Creek near S. 13th Street and W. College Avenue. The alternative plans include replacing or adding capacity to the Canadian Pacific Railway culvert; adding flood storage at Maitland Park; floodproofing, elevating, and/or acquiring and demolishing structures in the floodplain; and cleaning out the channel. The evaluation of the alternatives for effectiveness of protection, ability to implement, and cost determined that the alternative consisting of structure floodproofing, elevation, and/or acquisition and demolition would protect structures from floods up to the 1-percent-annual probability event, and would be relatively easy to implement, while incurring the lowest cost.

City of Oak Creek Stormwater Management Master Plan

The stormwater management master plan adopted by the City of Oak Creek in 2002 was developed to provide alternatives, recommendations, and implementation strategies for water quality and quantity issues, as well as to minimize the impact of stormwater runoff from existing and future developments.[46] The master

[46] *City of Oak Creek,* Stormwater Management Master Plan, *December 2001.*

planning area comprises the entire City of Oak Creek, which includes a majority of the Oak Creek watershed and portions of the Root River watershed and the Lake Michigan direct drainage area. Major sections within the plan include stormwater management objectives and guidelines, an inventory of physical features within the study area, a hydrologic/hydraulic analysis, a water quality analysis, and recommendations related to stormwater flooding alternatives, water quality improvement alternatives, and implementation priorities.

The stormwater management master plan provides a set of design guidelines for elements of the stormwater management system in the City. Under these guidelines, a minor stormwater drainage system shall be designed to convey the 10-percent-annual-probability (10-year recurrence interval) critical duration storm. A major open channel drainage system shall be designed to convey the 1-percent-annual-probability (100-year recurrence interval), 24-hour duration storm. Culverts and bridges shall be designed to convey the 10-percent-annual-probability flood discharge for minor and collector streets, the 2-percent-annual-probability (50-year recurrence interval) flood flow for arterial streets and highways, and the 1-percent-annual-probability flood flow for freeways, expressways, and railways. Culverts and bridges shall also be designed, as feasible, to facilitate fish passage. Dikes and floodwalls shall not be constructed to facilitate new development within the regulatory FEMA floodplain.

Water quality goals in the stormwater management plan include reducing suspended solids and phosphorus loads by 50 percent for existing urban development and reducing suspended solids loads by 90 percent for future urban development.[47]

The City of Oak Creek Stormwater Management Master Plan included the following inventory summary of existing physical features of the study area.

- Drainage facilities such as storm sewers, watercourses, detention basins, and culverts locations
- Flooding and drainage problem locations
- Existing and future land use conditions
- Industrial discharge permits
- A climate summary
- Soils classification, with soils in the areas consisting predominantly of poorly drained group C soils
- Groundwater table depths
- Wetland resource classifications
- Waste disposal site locations
- Stream classifications and water quality conditions

The hydrologic and hydraulic analysis methodology and results are presented in the stormwater management plan. Both existing 1995 and planned 2020 land use conditions were evaluated. The plan includes the FEMA 1-percent-annual-probability floodplain maps and identifies areas with flooding problems. It also evaluated existing storm sewer capacities for the 50-percent-annual-probability and 10-percent-annual-probability storm events. Seven City of Oak Creek storm sewer systems were identified as under capacity for the 10-percent-annual-probability storm event, with two of these systems surcharging above manholes, resulting in street flooding. Flood and drainage solution recommendations include constructing regional detention facilities, channel modifications and diversions, storm sewer improvements, structure floodproofing, and structural relocations. The plan also recommends a stringent on-site detention policy for future developments.

---

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

The water quality analysis for the Master Plan was conducted using the Source Loading and Management Model (SLAMM). Pollutant loading was calculated for the 579 subbasins in the City that were delineated as part of the hydrologic analysis. The plan summarizes and maps annual loadings for total suspended solids (TSS), total phosphorous, particulate lead, particulate copper, and particulate zinc. This water quality analysis found that commercial and industrial lands contribute 63 percent of the pollution loading, while comprising only 16 percent of the land cover.

Pollution reduction alternatives are presented in the stormwater plan in three categories: source control, volume reduction, and storage and treatment. Due to physical limitations within the City such as high groundwater levels and poorly drained soils, and limited effectiveness of certain pollution control practices, only a small selection of potential water quality improvement practices are recommended. Recommendations for City-wide implementation include enforcement of erosion control and stormwater management ordinances; public education programs for fertilizer, composting, lawn clipping disposal, and waste disposal; support for the Milwaukee County Hazardous Response Team; coordination between municipalities on stormwater management efforts; weekly sweeping of streets with curbs during spring and fall; catch basin cleaning twice per year or when sumps are 30 to 40 percent full; and development of a "Business Partnership Program for Clean Water." Recommendations for subbasin-level improvements include wet detention basins, constructed wetlands, and streambank stabilization. The Master Plan estimated that implementation of all the water quality recommendations will result in an annual TSS load reduction of 42 percent to the receiving streams.

City of Franklin Stormwater Management Plan

The City of Franklin originally developed a stormwater management plan in 1993. This plan was updated in 2002.[48] The plan serves to provide a comprehensive guide for expansion and development of the stormwater management system in the City. The stormwater planning area encompasses the entire City of Franklin, which includes portions of Oak Creek and North Branch of Oak Creek subwatersheds, as well as portions of the Root River watershed. The plan includes an engineering analysis of stormwater quantity and quality for each stormwater subbasin in the City. In particular, the plan quantifies runoff rates and volumes resulting from the 1-percent-annual-probability storm event for each subbasin. The plan also used a spreadsheet approximation of SLAMM to estimate pollutant loads including sediment, phosphorous, lead, copper, and zinc for each subbasin. The plan contains guidance for stormwater quantity management criteria, nonpoint source pollution control specifications, recommendations for drainage system improvements, new development requirements, stormwater pond maintenance guidelines, and natural resources conservation and restoration considerations.

Stormwater Management Regulation

The discharge of stormwater by municipalities is regulated through the WPDES permit program. All of the municipalities within the Oak Creek watershed have applied for and received municipal separate storm sewer (MS4) discharge permits from the WDNR. These permits require that the municipalities reduce the discharge of polluted stormwater runoff by implementing stormwater management programs with best management practices. Examples of activities required as part of a municipality's MS4 program include:

- Public education and outreach programs to encourage the public and businesses to modify their behavior and procedures to reduce stormwater pollution
- Public involvement to encourage participation from individuals in activities to prevent stormwater pollution
- Illicit discharge detection and elimination programs to identify, prevent, and eliminate discharge of waste materials other than from stormwater from storm sewer systems
- Construction site erosion control ordinances to prevent sediment-laden water from construction sites from discharging into waterbodies
- Post-construction stormwater management ordinances to ensure that newly developed and redeveloped areas include measures to control pollutants, control peak flows in watercourses and maintain infiltrations

[48] *City of Franklin,* Stormwater Management Plan Update, *December 2002.*

- Control of total suspended solids in stormwater from existing areas
- Adoption of practices to prevent pollutants from municipally-owned transportations infrastructure, maintenance areas, storage yards, salt and sand storage areas, and waste transfer stations from entering the storm sewer system

2.4 OTHER PLANS, PROJECTS, AND PROGRAMS

As noted in the introductory section of this chapter, effective and sound management of land and water resources requires that coordinated management activities take into account the objectives and goals of the various programs, initiatives, and efforts involved in natural resource management within the watershed. Achieving this coordination requires that the findings and recommendations of related plans and the goals and objectives of relevant management programs and efforts be considered in the design of this watershed restoration plan and integrated into this plan where appropriate. Thus, an important step to be undertaken is the inventory, collation, and review of the recommendations of relevant previously prepared reports and plans and of relevant recent, current, and ongoing management programs and efforts. This section presents a summary of plans and programs that were reviewed.

Plans

A number of plans address the natural resources of the Oak Creek watershed. These plans include recommendations and programs that address the interconnectedness of the natural resources of the Oak Creek watershed with those of the cities and Milwaukee County within the watershed and that focus on the importance of natural resources at the community level. Elements of these plans directly or indirectly address the focus issues that constitute the emphasis of this plan.

The plans that were collated and reviewed for input into this current planning effort were relevant to actions undertaken or to potentially be undertaken by a variety of entities, including County and local governments, special purpose units of government, and community groups. They include plans that were drafted to specifically address the Oak Creek watershed, as well as regional and subregional plans that include the Oak Creek watershed. Selected plans prepared at the local level were considered, including local comprehensive plans, land use plans, park and open space plans, lake and water quality management plans, and sewer service area plans for individual communities or special-purpose units of government. Because a goal of this planning effort is to develop specific, targeted recommendations for the Oak Creek watershed, this review also included consideration of plans that are relatively narrow in scope. Examples of these include management plans pertaining to particular parks. The identified, pertinent plan reports, which are described below, are listed in Table 2.6. They provide the basis for developing an integrated scheme for the restoration and sustainable management of the natural resources of the Oak Creek watershed through the coordinated efforts of State, County, and local governments, special-purpose units of government, and community groups.

The inventory set forth in Table 2.6 includes plans addressing a variety of issues including land use, flood control, stormwater drainage and management, sanitary sewer service areas, and parks and open space.

Regional Land Use Plan

The regional land use plan provides a long-term guide to land use development and open space preservation in the Southeastern Wisconsin Region and serves as a basis for other elements of the regional plan, including the regional transportation plan, park and open space plan, water quality management plan, and water supply plan.[49] The regional land use plan has been refined and detailed locally through the preparation and adoption of local comprehensive plans. All of the municipalities in the Oak Creek watershed have prepared and adopted comprehensive plans.[50]

Regional and local flood control, stormwater drainage, and stormwater management plans were discussed in the previous section of this chapter.

---

[49] *SEWRPC Planning Report No. 55,* op. cit.

[50] *Because all of the municipalities in Milwaukee County are incorporated as either cities or villages, the County has not prepared or adopted a comprehensive plan.*

Table 2.6
List of Management Plans Relevant to the Oak Creek Watershed

Plan Type	Community	Plan and Date of Publication
Land Use	Regional	SEWRPC Planning Report No. 55, *Vision 2050: A Regional Land Use and Transportation Plan for Southeastern Wisconsin,* July 2017
	City of Cudahy	City of Cudahy, *City of Cudahy 2020 Comprehensive Plan,* December 15, 2009
	City of Franklin	City of Franklin Department of City Development, *City of Franklin 2025 Comprehensive Master Plan,* September 2009
	City of Greenfield	Vandewalle & Associates, *City of Greenfield Comprehensive Plan 2008,* November 2008
	City of Milwaukee[a]	City of Milwaukee Department of City Development, *Milwaukee Comprehensive Plan: Citywide Policy Plan,* March 2010 City of Milwaukee Department of City Development, *Milwaukee Comprehensive Plan: An Area Plan for the Southeast Side,* October 2008 SEWRPC Memorandum Report No. 224, *MKE Aerotropolis Development Plan: A Shared Vision for the Communities Around the Airport,* February 2017 City of Milwaukee Department of City Development, *South 27th Street Strategic Action Plan: A Part of the Southeast and Southwest Side Area Plans,* March 2017
	City of Oak Creek	Vandewalle & Associates, *2020 Vision-A Comprehensive Plan for the City of Oak Creek,* Volume I, *Inventory and Analysis Report,* April 14, 1999; Volume II, *Community Visioning Results,* August 25, 1999; Volume III, *Plan Recommendations,* April 1, 2002
	City of South Milwaukee	City of South Milwaukee, *City of South Milwaukee Comprehensive & Downtown Plan Update,* May 2016
Stormwater Drainage, Stormwater Management, and Flood Control	Milwaukee County	Milwaukee County Office of Emergency Management, *Milwaukee County Hazard Mitigation Plan 2016,* September 2016
	MMSD	SEWRPC Community Assistance Planning Report No. 130, *A Stormwater Drainage and Flood Control Policy Plan for the Milwaukee Metropolitan Sewerage District,* March 1989 SEWRPC Community Assistance Planning Report No. 152, *A Stormwater Drainage and Flood Control System Plan for the Milwaukee Metropolitan Sewerage District,* December 1990 Milwaukee Metropolitan Sewerage District, *Oak Creek Phase 1 Watercourse Management Plan,* August 2000
	City of Franklin	Bonestroo, Rosene, Anderlik, & Associated, *City of Franklin Stormwater Management Plan Update-2002,* 2002
	City of Greenfield	AECOM, *City of Greenfield Stormwater Utility Manual,* August 2009, updated January 2010
	City of Milwaukee	SEWRPC Community Assistance Planning Report No. 261, *A Flood Mitigation Plan for the City of Milwaukee, Milwaukee County, Wisconsin,* April 2003 SEWRPC Community Assistance Planning Report No. 282, *City of Milwaukee All Hazards Mitigation Plan (2nd edition),* June 2012 CH2MHill, *Green Streets Stormwater Management Plan,* March 2013.
	City of Oak Creek	City of Oak Creek, *Stormwater Management Master Plan,* December 10, 2001 SEWRPC Community Assistance Planning Report No. 274, *Flood Mitigation Plan of the City for Oak Creek, Milwaukee County, Wisconsin,* April 2004
Sanitary Sewer	City of Franklin	SEWRPC Community Assistance Planning Report No. 176, *Sanitary Sewer Service Area for the City of Franklin, Milwaukee County, Wisconsin, (2nd edition)* June 2011, as amended
	City of Oak Creek	SEWRPC Community Assistance Planning Report No. 213, *Sanitary Sewer Service Area for the City of Oak Creek, Milwaukee County, Wisconsin,* July 1994, as amended
Environmental	Regional	SEWRPC Planning Report No. 30, *A Regional Water Quality Management Plan for Southeastern Wisconsin,* Volume One, *Inventory Findings,* September 1978; Volume Two, *Alternative Plans*, February 1979; Volume Three, *Recommended Plan,* June 1979 SEWRPC Memorandum Report No. 93, *A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report,* March 1995 SEWRPC Planning Report No. 42, *A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for South Eastern Wisconsin,* September 1997 SEWRPC Planning Report No. 50, *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds,* December 2007[b] SEWRPC, *Amendment to the Natural Areas and Critical Species Habitat and Management Plan for the Southeastern Wisconsin Region,* December 2010
	MMSD	Milwaukee Metropolitan Sewerage District, *Regional Green Infrastructure Plan,* June 2013 Milwaukee Metropolitan Sewerage District, *Using Green Infrastructure to Enhance Urban Biodiversity in the MMSD Planning Area,* December 11, 2018

Table continued on next page.

Table 2.6 (Continued)

Plan Type	Community	Plan and Date of Publication
Environmental (continued)	Watershed	SEWRPC Planning Report No. 36, *A Comprehensive Plan for the Oak Creek Watershed,* August 1986 Wisconsin Department of Natural Resources, *The State of the Root-Pike Basin,* WDNR PUBL WT-700-2002, May 2002 Wisconsin Department of Natural Resources, *Oak Creek Frontal Lake Michigan TWA WQM Plan 2017: Oak Creek (SE05) HUC: 040400020102,* WDNR Water Quality Bureau, EGAD #3200-2017-11, September 1, 2017
	Milwaukee County	SEWRPC Community Assistance Planning Report No 282, *A Land and Water Resource Management Plan for Milwaukee County: 2012-2021,* August 2011
Park and Open Space	Regional	SEWRPC Planning Report No. 27, *A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000,* November 1977
	Milwaukee County	SEWRPC Community Assistance Planning Report No. 132, *A Park and Open Space Plan for Milwaukee County,* November 1991 Milwaukee County Department of Parks, Recreation, and Culture, *Milwaukee County Trails Network Plan,* 2007. Milwaukee County Department of Parks, Recreation, and Culture, *Oak Creek Parkway Ecological Restoration & Management Plan: 2016-2025,* updated December 6, 2016. City of Milwaukee and Milwaukee County Department of Parks, Recreation, and Culture, *Copernicus Park Master Plan,* December 2014. Milwaukee County Department of Parks, Recreation, and Culture, *Falk Park Ecological Restoration & Management Plan: 2016-2025,* updated January 18, 2017. Milwaukee County Department of Parks, Recreation, and Culture, *Rawson Woods Ecological Restoration & Management Plan: 2017-2026,* updated February 27, 2017. Milwaukee County Department of Parks, Recreation, and Culture, *Barloga Woods Ecological Restoration and Management Plan: 2016-2025,* updated January 15, 2018. Milwaukee County Department of Parks, Recreation, and Culture, *Cudahy Nature Preserve Ecological Restoration and Management Plan: 2018-2027,* 2018.
	MMSD	The Conservation Fund, Applied Ecological Services, Resource Data, Heart Lake Conservation Associates, and Velasco and Associates, *Milwaukee Metropolitan Sewerage District Conservation Plan,* October 2001 SEWRPC Memorandum Report No. 152, *A Greenway Connection Plan for the Milwaukee Metropolitan Sewerage District,* December 2002
	City of Franklin	City of Franklin Planning Department, *City of Franklin Comprehensive Outdoor Management Plan 2025,* April 4, 2011
	City of Greenfield	Stantec Consulting Services, *City of Greenfield, Wisconsin Comprehensive Outdoor Recreation Plan: 2017-2022,* July 2017
	City of Milwaukee	City of Milwaukee Department of Community Development, *City of Milwaukee Comprehensive Outdoor Recreation Plan: 2016-2021,* September 2016
	City of Oak Creek	City of Oak Creek, *City of Oak Creek Park & Open Space Plan: 2013,* December 17, 2013, amended April 15, 2014

[a] *The City of Milwaukee's comprehensive plan consists of a citywide policy plan and 13 area plans that address specific neighborhoods or districts of the City. Only those plans pertaining to areas that include portions of the Oak Creek watershed are included in this inventory.*

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

Source: SEWRPC

Sanitary Sewer Service Area Plans

Sanitary sewer service area plans identify the boundary of the area within which sanitary sewer service may be extended. The plans also identify the extent of environmentally sensitive lands wherein sanitary sewer extensions will generally be prohibited. These sensitive lands include all primary environmental corridors and those portions of secondary environmental corridors and isolated natural resource areas comprised of wetlands, 1-percent-annual-probability floodplain, shoreland areas, and areas with steep slopes of 12 percent or greater. Within the sensitive areas, sewered development is confined to limited recreational and institutional uses and unsewered rural-density (one dwelling unit per five acres) residential development in upland areas. Currently, all of the Oak Creek watershed is contained within planned sewer service areas. The planned sewer service areas in the Oak Creek watershed are described in Chapter 3 of this report.

MMSD 2050 Facilities Plan

The MMSD is currently developing a 2050 Facilities Plan (2050-FP), which will address long range planning through the year 2050 from an asset management perspective. Major asset areas to be addressed in the Facilities Plan include the two MMSD water reclamation (wastewater treatment) facilities, the MMSD conveyance and deep tunnel system, the District's administrative buildings, and watercourses under MMSD jurisdiction. The conveyance system and watercourse portions of the 2050 Facilities Plan are most relevant to this watershed planning effort. It is anticipated that elements of the 2050-FP related to the conveyance system will address reductions in combined and separate sewer overflows. Similarly, it is anticipated that 2050-FP elements related to the jurisdictional watercourses will address long-term plans for green infrastructure, stream corridor maintenance, and flood mitigation. As of October 2018, it was expected that MMSD will begin to release draft 2050-FP documents for public review some time in 2019.

MMSD Conservation Plan

The MMSD has also conducted planning relative to open space preservation and greenway connection. The District completed and adopted a conservation plan that identifies land parcels that are recommended to be protected for multiple purposes, including flood reduction potential and stormwater management benefits, as well as wildlife habitat, water quality, and recreational benefits.[51] The MMSD conservation plan identified 165 sites, including 42 high-priority sites, for protection through public acquisition or conservation easements, throughout the Menomonee River, Root River, and Oak Creek watersheds within the District. The District later adopted a greenway connection plan that identified potential greenway corridors connecting, and typically downstream of, the isolated parcels identified in the MMSD conservation plan.[52] The conservation plan also synthesized the results of other related open space planning efforts undertaken in the MMSD area to date, resulting in a comprehensive Districtwide greenway connection plan having flood mitigation benefits as well as a wide range of other environmental benefits. Several of the sites identified for acquisition in the conservation plan are along either the mainstem of Oak Creek or the Mitchell Field Drainage Ditch.

MMSD Green Infrastructure Plan

The MMSD has developed a green infrastructure plan for its planning area.[53] This planning area includes the entire Oak Creek watershed. In developing this plan, the District undertook a detailed data analysis of the opportunities and constraints for implementing green infrastructure strategies. Extensive data collection and mapping were conducted as part of this planning effort. These analyses include quantification of the numbers of roads, buildings, and parking lots in the planning area that can be treated with green infrastructure.

The objectives of the MMSD green infrastructure plan include:

1. Capturing the first 0.5 inch of rainfall from impervious surfaces with green infrastructure
2. Striving toward a rainwater harvest goal of capturing the first 0.25 gallon per square foot of area over the watershed for reuse
3. Complementing MMSD's Private Property Infiltration and Inflow Program and Integrated Regional Stormwater Management Program
4. Helping municipalities and other entities prioritize green infrastructure actions
5. Helping to meet receiving water quality standards by acknowledging watershed restoration plan recommendations
6. Meeting MMSD's Wisconsin Pollutant Discharge Elimination System (WPDES) discharge permit requirements for green infrastructure volume capture

---

[51] *The Conservation Fund; Applied Ecological Services, Inc., Heart Lake Conservation Associates; Velasco and Associates; and K. Singh and Associates,* Conservation Plan, Technical Report Submitted to Milwaukee Metropolitan Sewerage District, *October 31, 2001.*

[52] *SEWRPC Memorandum Report No. 152,* A Greenway Connection Plan for the Milwaukee Metropolitan Sewerage District, *December 2002.*

[53] *Milwaukee Metropolitan Sewerage District,* Regional Green Infrastructure Plan, *June 2013.*

As part of its approach to meeting these objectives, the plan developed watershed-specific recommendations for installing green infrastructure over the plan implementation period of 2014 through 2035. These recommendations were based on individual characteristics of each watershed. Specific recommendations for the Oak Creek watershed include:

- Porous pavement: Installing or retrofitting porous pavement equivalent to 730 average city blocks (3,650 acres) having 25 percent porous pavement[54]
- Bioretention areas/rain gardens: Installing bioretention areas and rain gardens equivalent to 12,000 150-square foot rain gardens
- Stormwater trees: Planting nine new trees per average city block
- Green roofs: Installing or retrofitting 1,000 buildings with green roofs[55]
- Cisterns: Installing cisterns with a capacity of 1,000 gallons at 150 large buildings[56]
- Native landscaping: Converting an area equivalent to 100 average city blocks (500 acres) to native landscaping
- Rain barrels: Installing one rain barrel at 7,100 homes
- Soil amendments: Adding amendments to soil over an area equivalent to 100 average city blocks (500 acres)

MMSD Urban Biodiversity Plan

The MMSD has developed an urban biodiversity plan for its planning area.[57] This planning area includes the entire Oak Creek watershed. This plan is intended to help preserve and restore biodiversity in the MMSD planning area through the application of green infrastructure. The plan evaluates green infrastructure practices for their ability to enhance biodiversity. In addition, it identifies goals and strategies for enhancing urban biodiversity by making recommendations for incorporating biodiversity into green infrastructure and other projects; identifying high priority conservation and rehabilitation areas; and suggesting future areas for research, monitoring, education, and outreach.

Milwaukee County Land and Water Resource Management Plan (CAPR 312)

The 1997 revisions to Chapter 92, "Soil and Water Conservation and Animal Waste Management," of the *Wisconsin Statutes* require each county to develop a multi-year land and water resource management plan (LWRM) to conserve long-term soil productivity, protect the quality of related natural resources, enhance water quality, and focus on soil erosion problems. The LWRM plans address both rural and urban nonpoint source pollution problems. Chapter ATCP 50, "Soil and Water Resource Management Program," of the *Wisconsin Administrative Code* sets forth details of the planning requirements. These plans serve as work plans for the counties' land conservation departments.

The Milwaukee County LWRM Plan for 2012-2021 was approved by the Milwaukee County Board in June 2011 and the Wisconsin Land and Water Conservation Board in August 2011.[58] This is a third-generation plan, updating the initial LWRM plan that was adopted in 2001 and a subsequent updated plan that was adopted in 2006. The LWRM plan is intended to guide the activities of the County Environmental Services Division in its efforts to protect and improve land and water resources within the County. The plan goals

---

[54] *For purposes of the MMSD green infrastructure plan, the area of the average city block was estimated to be five acres.*

[55] *The plan estimates the average size of a green roof to be 5,000 square feet.*

[56] *The plan defines large buildings with those with roof areas greater than 6,500 square feet.*

[57] *Milwaukee Metropolitan Sewerage District,* MMSD Planning Area Urban Biodiversity Plan: Draft for Ad Hoc Committee Review, *July 14, 2017.*

[58] *SEWRPC Community Assistance Planning Report No. 312,* A Land and Water Resource Management Plan for Milwaukee County: 2011-2021, *August 2011.*

include improving water quality through reducing the delivery of sediment and nutrients to surface waters; protecting, maintaining, and restoring land and water resources; enhancing Lake Michigan bluff protection initiatives; maintaining the existing information network and land information web portal; and limiting the introduction and reducing the spread of invasive species. In 2016, the Wisconsin Land and Water Conservation Board extended approval of this plan until 2021.

Regional Natural Areas and Critical Species Habitat Protection and Management Plan

The regional natural areas and critical species habitat protection and management plan for the Southeastern Wisconsin Region was undertaken to identify the most significant remaining natural areas, including remnants of the pre-European-settlement landscape and other areas vital to the maintenance of endangered, threatened, and rare plant and animal species in the Region.[59] Under the plan, natural areas are defined as tracts of land or water so little modified by human activity, or which have sufficiently recovered from the effects of such activity, that they contain intact native plant and animal communities believed to be representative of pre-European-settlement landscapes. Critical species habitats are defined as additional tracts of land or water that support endangered, threatened, or rare plant or animal species. The plan recommends that each of the identified natural areas and critical species habitat sites be protected and preserved to the maximum extent practicable as urban and rural development in the Region proceeds. The plan provides descriptive information for each natural area and critical species habitat site, along with recommended means for preservation. The plan was updated and revised in 2010 in a major plan amendment.[60] This amendment incorporated changes in the regional landscape, new findings concerning natural areas and critical species habitat sites, and updated recommendations for the protection of the identified natural areas and critical species habitat sites. The protection status of natural areas and critical species habitat sites in the Oak Creek watershed is described in Chapter 3 of this report.

Milwaukee County Park and Open Space Plan

The regional park and open space plan consists of two basic elements: an open space preservation element and an outdoor recreation element.[61] The open space preservation element consists of recommendations for preserving primary environmental corridors within the Region. The outdoor recreation element consists of a resource-oriented outdoor recreation plan providing recommendations for the number and location of large parks, recreation corridors to accommodate trail-oriented activities and water-access facilities, and an urban outdoor recreation plan providing recommendations for the number and distribution of local parks and outdoor recreational facilities required in urban areas of the Region.

Milwaukee County has prepared a park and open space plan.[62] This plan refines, details, and extends the regional park and open space plan. Major recommendations of the Milwaukee County park and open space plan related to Oak Creek include:

- Extension of the existing recreational corridor along the mainstem of Oak Creek
- Public acquisitions of land to link sections of the parkway along the Creek
- Public acquisitions of land to link the parkway along Oak Creek to adjacent parkways along the Root River and Lake Michigan

---

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

[60] *SEWRPC,* Amendment to the Natural Areas and Critical Species Habitat Protection and Management Plan for the Southeastern Wisconsin Region, *December 2010*.

[61] *SEWRPC Planning Report No. 27,* A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000, *November 1977.*

[62] *SEWRPC Community Assistance Planning Report No. 132,* A Park and Open Space Plan for Milwaukee County, *November 1991. The Regional Planning Commission is currently working with the Milwaukee County Department of Parks, Recreation & Culture to prepare an updated County park and open space plan.*

Local Park and Open Space and Comprehensive Outdoor Recreation Plans

Park and open space and comprehensive outdoor recreation plans have also been prepared, and in some cases updated, for several municipalities within the watershed. These plans are intended to help local governments meet Federal and State requirements for securing grants to help preserve parks and open space land and develop recreational facilities. Local park and open space and comprehensive outdoor recreation plans for communities in the Oak Creek watershed are listed in Table 2.6.

Milwaukee County Trails Network Plan

Milwaukee County has prepared a trails network plan.[63] This plan identifies trail corridors for potential development and provides guidance to the County Parks Department and other entities for trail development and future land acquisitions. The plan provides guidelines for designing, constructing, and maintaining trails within the County. In the Oak Creek watershed, the plan proposes two additions to the County's existing Oak Leaf Trail. One proposed addition would extend the existing trail along the mainstem of Oak Creek from near S. Howell Avenue to a point near the confluence with the North Branch of Oak Creek. The second proposed addition would extend the existing Oak Leaf Trail from a point where it crosses W. Puetz Road west of the mainstem of Oak Creek toward, and into, Bender Park.

Milwaukee County Pond and Lagoon Management Plan

Milwaukee County parklands include 68 lakes, ponds, and lagoons comprising over 120 acres of surface water.[64] These waterbodies enhance park aesthetics while providing recreational opportunities, including fishing, boating, and ice skating. In addition, some of these lakes, ponds, and lagoons provide stormwater detention, which serves to improve water quality in receiving waters. Concerns about water quality and aesthetics have arisen as degraded conditions along some lagoon shorelines have become more apparent. Residents have also expressed concern over the impacts of poor water quality on fishing and on human health of exposure to water in the ponds. In response to these concerns, Milwaukee County developed a park pond and lagoon management plan.[65] The objectives of this plan were to evaluate water quality conditions in representative ponds, identify and prioritize pond needs and set long-term goals, identify water quality management objectives, compare observed conditions to water quality objectives, and recommend long-term and short-term management actions.

The study identified several issues related to the Milwaukee County park lakes, ponds, and lagoons, including shoreline erosion; the presence of nuisance algae and aquatic plants, related to high nutrient loadings; elevated concentrations of fecal indicator bacteria; litter; the presence of rough fish; and siltation. The plan made three general recommendations for all County park lakes, ponds, and lagoons:

- Identify and deploy alternative management strategies to mowing grass to short lengths directly adjacent to these waterbodies
- Pursue grant funding for shoreline stabilization projects
- Continue water quality monitoring of these waterbodies to document conditions both before and after restoration projects

Individual Milwaukee County Park Plans

The Milwaukee County Department of Parks, Recreation & Culture has developed management plans for specific County parks or natural areas. These plans provide specific recommendations for management and restoration of park and natural area sites. Parks in the Oak Creek watershed for which these plans

---

[63] *Milwaukee County Department of Parks, Recreation, and Culture,* Milwaukee County Trails Network Plan, *2007.*

[64] *These ponds include the Oak Creek Mill Pond and the Oak Creek Parkway Pond.*

[65] *Milwaukee County Environmental Services, 2005,* op. cit.

have been developed include: Barloga Woods,[66] Cudahy Nature Preserve,[67] Falk Park,[68] the Oak Creek Parkway,[69] and Rawson Woods.[70]

The Milwaukee County park management plans identify potential ecological threats and set management objectives for the parks and natural areas that they cover. They also recommend and present costs for specific projects within management units of the sites. While the recommended projects vary among the parks and management units within the parks, common projects include removing and controlling invasive plant species; reforesting areas impacted by emerald ash borer; conducting surveys and monitoring of vegetation, wildlife, and ephemeral ponds; forest stand improvement; planting of native trees and shrubs to convert surrogate grasslands to forest; maintaining designated hiking trails; and trash and litter removal.

The Milwaukee County Department of Parks, Recreation & Culture in partnership with the City of Milwaukee developed a master plan for improvements to Copernicus Park.[71] Goals of this plan that relate to the focus areas of the Oak Creek watershed restoration plan include mitigating localized flooding in the neighborhood of the park, improving park safety, and promoting environmental, economic, and social sustainability. The plan includes a design for improvements to be made in the park. Elements of this design related to the focus areas of the Oak Creek watershed restoration plan include:

- Constructing stormwater mitigation facilities
- Improving sewer infrastructure
- Restoring lawn and trees
- Removing invasive plants
- Steambank grading and stabilization
- Planting native riparian and woodland vegetation

The plan is intended to be implemented in three phases and includes an implementation schedule and cost estimates. After this plan was developed it was determined that sufficient flood storage was created within the stream channel that there is no longer a need to create stormwater detention within Copernicus Park.

WDNR 2002 State of the Root-Pike River Basin (Oak Creek Portion)

As the State agency tasked with water resources management, the WDNR prepares basin-level plans that guide the application of State resources to the major drainage basins of the State. The Oak Creek watershed is a part of the Root-Pike Basin, which also contains the Root River, Pike River, and Pike Creek watersheds, and the adjacent direct drainage area to Lake Michigan. The plan for the Root-Pike basin provided an overview of the land and water resource quality and identified challenges facing the resources in these watersheds and recommended actions to be taken by the WDNR and its partners.[72] It also summarized

[66] *Milwaukee County Department of Parks, Recreation & Culture,* Barloga Woods Ecological Restoration and Management Plan: 2016-2025, *updated January 15, 2018.*

[67] *Milwaukee County Department of Parks, Recreation & Culture,* Cudahy Nature Preserve Ecological Restoration & Management Plan: 2018-2027, *2018.*

[68] *Milwaukee County Department of Parks, Recreation & Culture,* Falk Park Ecological Restoration and Management Plan: 2016-2025, *updated January 18, 2017.*

[69] *Milwaukee County Department of Parks, Recreation & Culture,* Oak Creek Parkway Ecological Restoration and Management Plan*, 2019.*

[70] *Milwaukee County Department of Parks, Recreation & Culture,* Rawson Woods Ecological Restoration and Management Plan: 2017-2026, *updated February 27, 2017.*

[71] *City of Milwaukee and Milwaukee County Department of Parks, Recreation and Culture,* Copernicus Park Master Plan, *December 2014.*

[72] *Wisconsin Department of Natural Resources,* The State of the Root-Pike Basin, *WDNR PUBL WT-700-2002, May 2002.*

the codified, and potentially achievable, water use objectives for streams and lakes of the watersheds. The monitoring and management recommendations in this plan pertaining to the Oak Creek watershed include:

- Encouraging the implementation of urban nonpoint source best management practices
- Encouraging buffer strip development for stream bank stabilization
- Conducting baseline surveys on streams within the watershed
- Assessing sediment delivery, sediment transport, and stream bank erosion within the watershed
- Evaluating, assessing, and improving aquatic and riparian habitat in cooperation with the MMSD and their ongoing flood management improvement projects
- Conducting aquatic habitat and sediment assessments above and below the Mill Pond dam and the Oak Creek drop structures
- Evaluating the Mill Pond dam and Oak Creek drop structures for removal
- Evaluating and implementing aquatic habitat restoration and water quality improvement practices where practicable
- Forming partnerships with schools and community organizations to assess and improve the water quality of Oak Creek
- Assessing impacts and improvements to water quality within communities subject to NR 216, "Storm Water Discharge Permits," municipal stormwater permitting requirements

WDNR Oak Creek FLM TWA WQM Plan 2017

The WDNR issued a water quality management plan update for the Oak Creek watershed in 2017.[73] This plan updates information set forth in the Department's Root-Pike Basin plan for the Oak Creek watershed. The updated information includes the description of characteristics of the watershed and the summary of codified, and potentially achievable, water use objectives for streams and lakes of the watershed. In addition, the plan presents results of a targeted watershed assessment that was conducted in the watershed in 2015. This assessment included monitoring of fish and macroinvertebrate communities, collection and analysis of water chemistry samples, and qualitative assessments of stream habitat at locations in the watershed. Management recommendations set forth in this plan include:

- Working with local area experts and WDNR staff from multiple programs to identify areas throughout the watershed where stream habitat can be restored and connectivity improved
- Working with partners and State grant programs to encourage local entities to seek funds to support habitat restoration and corridor continuity
- Identifying the primary sources of phosphorus and chlorides in the watershed by monitoring, investigations, and, potentially, modeling
- Investigating and pursuing local runoff management and river grants to help initiate management actions that reduce inputs of pollutants such as phosphorus and chloride into the water resources
- Identifying potential partners and stakeholders to participate in an overall awareness and behavioral change program in the watershed that results in reduced erosion and phosphorus inputs

[73] *Wisconsin Department of Natural Resources,* Oak Creek Frontal Lake Michigan TWA WQM Plan 2017: Oak Creek (SE05) HUC: 040400020102, *WDNR Water Quality Bureau, EGAD #3200-2017-11, September 1, 2017.*

In addition, the plan recommends actions in the areas of management priorities, restoration goals, and monitoring and assessment and recommends management priorities for actions by the WDNR and external partners.

Projects

In addition to the significant planning work completed for the Oak Creek watershed, numerous projects have been completed that address focus areas of this watershed restoration plan. These projects are described below.

1000 Friends of Wisconsin Prioritizing Codes and Ordinances for Green Infrastructure Project

Since 2012, 1000 Friends of Wisconsin has been working with municipalities in Southeastern Wisconsin to audit, revise, and prioritize municipal codes and ordinances that prohibit or inhibit more widespread use of green infrastructure. The use of green infrastructure can reduce erosion and contamination of waterbodies resulting from stormwater runoff; however, provisions in municipal codes and ordinances can create barriers to installing and using green infrastructure. Through this project, 1000 Friends of Wisconsin reviewed select local codes and ordinances and identified the provisions that created barriers to implementing green infrastructure. Outcomes of this project were that it:

- Clearly outlined barriers to green infrastructure that exist in current codes and ordinances that either prohibited or inhibited greater adoption of green infrastructure

- Increased the potential for green infrastructure-friendly revisions of codes by prioritizing codes for municipalities

- Further enhanced the ability of the municipalities to advance code and ordinance revisions by providing new language for the revisions tailored to their needs

The project initially focused on nine municipalities located in the Menomonee River watershed. As a result of the success of this initial project, the review of codes and ordinances was expanded to include an additional 19 municipalities in Southeastern Wisconsin. Municipalities in the Oak Creek watershed that participate in this project include the Cities of Cudahy, Franklin, Greenfield, Milwaukee, and Oak Creek. Since 2016, Clean Wisconsin has continued the initiative begun by 1000 Friends of Wisconsin. Clean Wisconsin has been working with the participating municipalities to update municipal ordinances and codes.

Drexel Town Square Development

In 2016, the Drexel Town Square project redeveloped an 85-acre former brownfield site to create a downtown core near the intersection of E. Drexel Avenue and S. Howell Avenue in the City of Oak Creek. This redevelopment incorporated an extensive network of green infrastructure practices to capture and manage stormwater. Stormwater management features of this development include restoring a 17-acre portion of the site to wetland and upland prairie conditions, enhancing an existing upland forest, creating three stormwater ponds, installing a bioswale system to capture and treat runoff, and installing permeable pavement at the parking lot serving the new City Hall and Library. In addition, three floating wetland islands were installed in one of the stormwater ponds. These islands are designed to remove suspended solids and nutrients from water being treated in the pond. They also provide additional habitat for native plants. The species planted in and around the ponds were also chosen to discourage the presence of nuisance waterfowl. The wetland restoration included installing trails, benches, and a boardwalk to provide public access.

Grant Park Bioblitz

On June 10, 2016, the Milwaukee Public Museum in partnership with 21 other organizations including several Wisconsin Universities and nature centers, the WDNR, the Friends of Grant Park, and the Milwaukee County Parks conducted a bioblitz in Grant Park. A bioblitz is an intensive 24-hour field survey that attempts to identify and record all of the species present in a given area. The species identified that day are dependent on the scientists available, the weather experienced, and the season selected. This survey of Grant Park identified 976 species, including 10 that had not been previously reported at this site.

Recent, Current, and Ongoing Programs and Initiatives Active and/or Available in the Oak Creek Watershed

MMSD Greenseams

MMSD's Greenseams program is an innovative flood management program that reduces flooding risks and impacts from polluted stormwater runoff by permanently protecting key lands. It constitutes implementation of the MMSD conservation plan that was discussed above.[74] The program makes voluntary purchases of undeveloped, privately-owned properties in areas that are expected to have major growth and in open space areas along streams, lakes, and wetlands. On some Greenseams properties, activities have been conducted to restore lands that were previously in agricultural land uses to their pre-European settlement vegetation. Following restoration, these properties are able to absorb more rain and snow melt, reducing and slowing down the flow of runoff into nearby waterbodies. In addition, these sites act as buffers to nearby waterbodies, filtering out nutrients and pollutants from water entering the waterbodies. Greenseams also preserves wildlife habitat and creates recreational opportunities. MMSD has contracted with The Conservation Fund to run the Greenseams program. As of 2018, the Greenseams program has acquired 145 acres in the Oak Creek watershed.

Land Trusts and Conservancies

Land trusts and conservancies are private, nonprofit organizations that work to conserve land—such as sensitive natural areas, farmland, ranchland, water sources, cultural resources, or notable landmarks. Land trusts work in partnership with landowners and communities to permanently conserve natural resources. These organizations use a variety of tools to accomplish their mission. For example, the land trust may acquire land through purchase or donation. Once acquired, the land trust may retain ownership or pass ownership to a third party, such as a unit of government, which will protect and manage the land. Alternatively, the land trust may purchase or otherwise acquire conservation easements on privately owned land. In a conservation easement, the owner of the land gives up some of the rights associated with the land. For example, under a conservation easement, the landowner may give up the right to build structures on the land, while retaining the right to grow crops. Future owners of the land will be bound by the terms of the conservation easement. Finally, land trusts conduct and participate in stewardship of such lands, managing the land for preservation, recreational use, wildlife habitat, or other purposes.

There are two land trusts and conservancies active in the Oak Creek watershed. The Milwaukee Area Land Conservancy is active in Milwaukee County, and in the Oak Creek watershed it has acquired and protected about 25 acres of Fitzsimmons Woods. The Oak Creek watershed is also served by the Prairie Enthusiasts. This land trust has not conducted any land acquisition or easement projects in the Oak Creek watershed.

Community-Based Monitoring Programs

In addition to the long-term monitoring programs conducted by government agencies described previously in this chapter, several citizen-based volunteer monitoring programs have been active, or could potentially be active, in the Oak Creek watershed. Community-based or citizen-based water quality monitoring programs can obtain data on waterbodies that may otherwise go unmonitored. In addition, community-based monitoring efforts can provide a variety of data that may be useful for conducting watershed management activities. Finally, community-based monitoring can act to increase awareness and understanding of local water quality issues.

Table 2.7 lists several active or potential community-based environmental monitoring programs for the Oak Creek watershed. Although the Oak Creek watershed is not the focus of any of these programs, some of them have conducted monitoring activities at sites within its boundaries. As previously noted, Milwaukee Riverkeeper has conducted some community-based water quality monitoring in the Oak Creek watershed, mostly as a part of the WDNR/UWEX Level 3 Water Action Volunteers Program. In addition, the Southeastern Wisconsin Invasive Species Consortium has conducted surveys of invasive plants in the watershed from cars along road-based routes. The Wisconsin Frog and Toad Survey has also used road-based routes.

---

[74] *The Conservation Fund; Applied Ecological Services, Inc., Heart Lake Conservation Associates; Velasco and Associates; and K. Singh and Associates,* op. cit.; *SEWRPC Memorandum Report No. 152,* op. cit.

Table 2.7
Active and Potential Community-Based and Volunteer Monitoring Programs in the Oak Creek Watershed

Name	Sponsors	Monitoring Scope	Activity in the Oak Creek Watershed[a] Historical	Recent
Bumble Bee Watch	Xerces Society of Invertebrate Conservation	Document species distribution and trends for native bumble bees	N	Y
Firefly Watch	Boston Museum of Science, Tufts University, Fitchburg State College	Population trends and status of fireflies	N	N
Great Backyard Bird Count	Cornell Laboratory of Ornithology, National Audubon Society	Population status and trends of birds	N	N
Milwaukee County Parks Bird Window Strike Monitoring	Milwaukee County Parks	Monitoring of risks of bird window strikes at park facilities	N	Y
Milwaukee County Parks Rusty Patch Bumble Bee Monitoring	Milwaukee County Parks	Document species distribution and trends for bumble bees	N	Y
Milwaukee County Parks Wetland Monitoring	Milwaukee County Parks	Population status and trends of amphibian and invertebrate species in wetlands	N	Y
Monarch Larva Monitoring Project	University of Minnesota	Distribution and abundance of breeding monarch butterflies	N	N
Mussel Monitoring Program of Wisconsin	WDNR	Distribution and status of mussel populations	N	N
Project FeederWatch	Cornell Laboratory of Ornithology	Population status and trends of birds	N	N
Project RED	River Alliance of Wisconsin	Early detection of invasive species	N	N
Water Action Volunteers	UWEX, WDNR, Milwaukee Riverkeeper	Water quality parameters in streams and rivers	N	Y
Wisconsin Bird Monitoring	Wisconsin Bird Conservation Initiative	Population status and trends of birds	N	N
Wisconsin Breeding Bird Survey	Wisconsin Society for Ornithology	Population status and trends of birds	Y	Y
Wisconsin Christmas Bird Count	National Audubon Society	Population status and trends of birds	N	N
Wisconsin Citizen Lake Monitoring Network	UWEX, WDNR, Wisconsin Lakes	Water clarity, some water chemistry, invasive species	N	N
Wisconsin eBird	Cornell Laboratory of Ornithology, Wisconsin Bird Conservation Initiative, WDNR	Population distribution, status, and trends of birds	N	N
Wisconsin Frog and Toad Survey	WDNR, USGS, North American Amphibian Monitoring Program	Population trends and species distribution of frogs and toads	N	N
Wisconsin Odonata Survey	WDNR, Wisconsin Dragonfly Society	Distribution and status of dragonfly and damselfly populations	N	N
Wisconsin Rare Plant Monitoring Program	WDNR	Distribution and trends of rare plants	N	N
Wisconsin Turtle Conservation Program	WDNR	Document species distribution and high mortality locations along roads for turtles	N	N

[a] *Historical activity indicates the existence of monitoring data from the program prior to 2007; recent activity indicates the existence of monitoring data in or after 2007.*

Source: SEWRPC

Some support for community-based monitoring in the State is provided by the Wisconsin Citizen-Based Monitoring Network. This group is a collaboration of monitoring groups, users of monitoring data, and others designed to improve the efficiency and effectiveness of community-based monitoring by providing coordination, communications, technical and financial resources, and recognition to the Wisconsin community-based monitoring community.

Milwaukee County Parks Community Science Program

The Milwaukee County Parks Natural Area Program currently runs three community science programs. The first program addresses bird mortality resulting from window strikes. Using a rapid architectural bird-risk assessment developed by the University of Wisconsin-Milwaukee, County Parks Natural Areas staff evaluated park buildings and facilities for the collision risks they posed to birds. Out of 70 facilities evaluated, 27 were rated as potentially high-risk for bird collisions. These facilities include the Grant Park Clubhouse, the Oakwood Park Clubhouse, and the Falk Park Pavilion in the Oak Creek watershed. Volunteers in this program are trained to monitor these high-risk facilities. The data from this program could potentially be used to retrofit facilities to reduce bird mortality and to better manage habitat adjacent to these buildings.

The second program monitors the rusty patched bumble bee (*Bombus affinis*), an insect listed on the Federal endangered species list. This species has recently been detected in and near several Milwaukee County parks. Natural Areas staff has inventoried potential bumble bee habitat within the Milwaukee County Park System. Under this program, volunteers are assigned to gather data on all bumble bee species present at a site, using the Bumble Bee Watch protocol. Data from this program will contribute to a better understanding of the factors causing the decline of bumble bee populations and help to guide future land management decisions. Potential survey sites on parkland within the Oak Creek watershed include Falk Park, Grant Park, Oakwood Park, Rawson Woods, and several sections of the Oak Creek Parkway.

Finally, the Natural Areas Program has implemented a wetland monitoring program. Park Department staff and volunteers working in this program monitor amphibian and invertebrate populations in wetlands including ephemeral ponds, larger marshes, and lagoons. To date, this program has documented 77 ephemeral ponds in the Oak Creek watershed. Data collected through this program is incorporated into the Parks Department's wildlife monitoring database and is used to guide current and future habitat management decisions.

Rain Barrel Programs

Several programs serving the Oak Creek watershed promote and support installing rain barrels to collect and store rain water that would otherwise run off roofs and lawns of homes. Information on installing, using, and maintaining rain barrels is available on the websites of the City of Milwaukee,[75] MMSD,[76] and UWEX.[77] Root-Pike WIN has provided rain barrels to some participants of its Green Yards, Cleaner Waters workshops. Several government agencies and nonprofit entities in and around the Oak Creek watershed have available for purchase rain barrels and diverter kits for diverting water from roof drains. These include the City of Milwaukee, Keep Greater Milwaukee Beautiful, the Milwaukee County Zoo, MMSD, and the Milwaukee Community Service Corps. Rain barrels are also available for purchase from several commercial sources in the area.

Education Programs

Stormwater Education Programs

Since 2012, Root-Pike WIN and the Southeastern Wisconsin Watersheds Trust, Inc. (Sweet Water) have been conducting the Respect Our Waters campaign, a multi-year marketing initiative to educate area residents on actions that they can take to reduce water pollution associated with stormwater runoff. This initiative has included a television advertising campaign using 30-second spots. These spots emphasize the importance of removing yard debris, cleaning up pet litter, using fertilizers and other yard chemicals responsibly, and preventing motor oil and other fluid from leaking from automobiles. This initiative also includes grassroots outreach, with Sweet Water and Root-Pike WIN conducting educational activities at community events. During these events, Sweet Water and Root-Pike WIN distribute pet waste bags, provide native plants for rain gardens, and conduct giveaways of rain barrels and Milorganite fertilizer. This initiative is funded by Sweet Water in conjunction with over 50 municipalities, including the members of the Southeastern Wisconsin Clean Water Network and the WDNR. As of 2018, Milwaukee County and all six of the municipalities in the Oak Creek watershed were participating in the Respect Our Waters campaign.

---

[75] *This can be accessed at: city.milwaukee.gov/ImageLibrary/Groups/cityGreenTeam/Stormwater/FINAL_BunkeRWHGuide_designR1_withAcknowledgements_Sept2017.pdf.*

[76] *This can be accessed at: www.mmsd.com/what-we-do/green-infrastructure/rain-barrels.*

[77] *This can be accessed at: fyi.uwex.edu/sewraingardens/other-stuff.*

As part of the Respect Our Waters activities, Root-Pike WIN has been conducting a targeted runoff pollution campaign. This campaign identified areas in the watersheds that Root-Pike WIN serves that act as runoff pollution hotspots. Mailers that explain the pollution issue and describe solutions were sent directly to households in the hotspot areas. As part of this project, two areas were targeted in the Oak Creek watershed: one along the mainstem of Oak Creek in the City of South Milwaukee and a second along the downstream portions of the North Branch of Oak Creek in the City of Oak Creek.

In partnership with UWEX, Root-Pike WIN conducts workshops on topics related to reducing contributions of polluted stormwater to area waterbodies. Recent events include composting workshops and Greener Yards, Cleaner Waters workshops, which focus on the causes of polluted runoff and on landscaping and yard care practices that can reduce contributions of pollutants to waterbodies.

The UWEX also provides online educational materials related to stormwater runoff.[78]

<u>Nature Centers</u>
Nature centers offer a variety of educational programs related to natural history, natural resources, and environmental issues. While each of these centers offers a unique set of programming, common programs include offering field trip opportunities for school groups; providing nature and environmental education programs for visitors; conducting natural history and environmental education programs for adults and families; offering summer day camps for school-aged children; providing training and resources for educators; and providing materials for self-guided activities, such as nature study. Nature centers may also sponsor or conduct citizen-based science programs, provide nature-based programs to support merit badge programs or scouting organizations, or provide professional continuing education for teachers.

While no nature centers are located within the Oak Creek watershed, Wehr Nature Center is located nearby in Whitnall Park in the City of Franklin. The center's 220-acre facility includes Mallard Lake, a variety of wetlands that are accessible via a boardwalk, restored oak savanna and prairie habitats, maple and oak woodlands, over five miles of hiking trails, a visitor center, and an outdoor amphitheater. Wehr Nature Center is the primary environmental education facility of the Milwaukee County Park System, and it provides a number of programs, including:

- Field trips for school groups, including opportunities for homeschooled students
- Natural history education programs for adults and families
- Nature hikes
- Citizen-based science
- Training and resources for educators

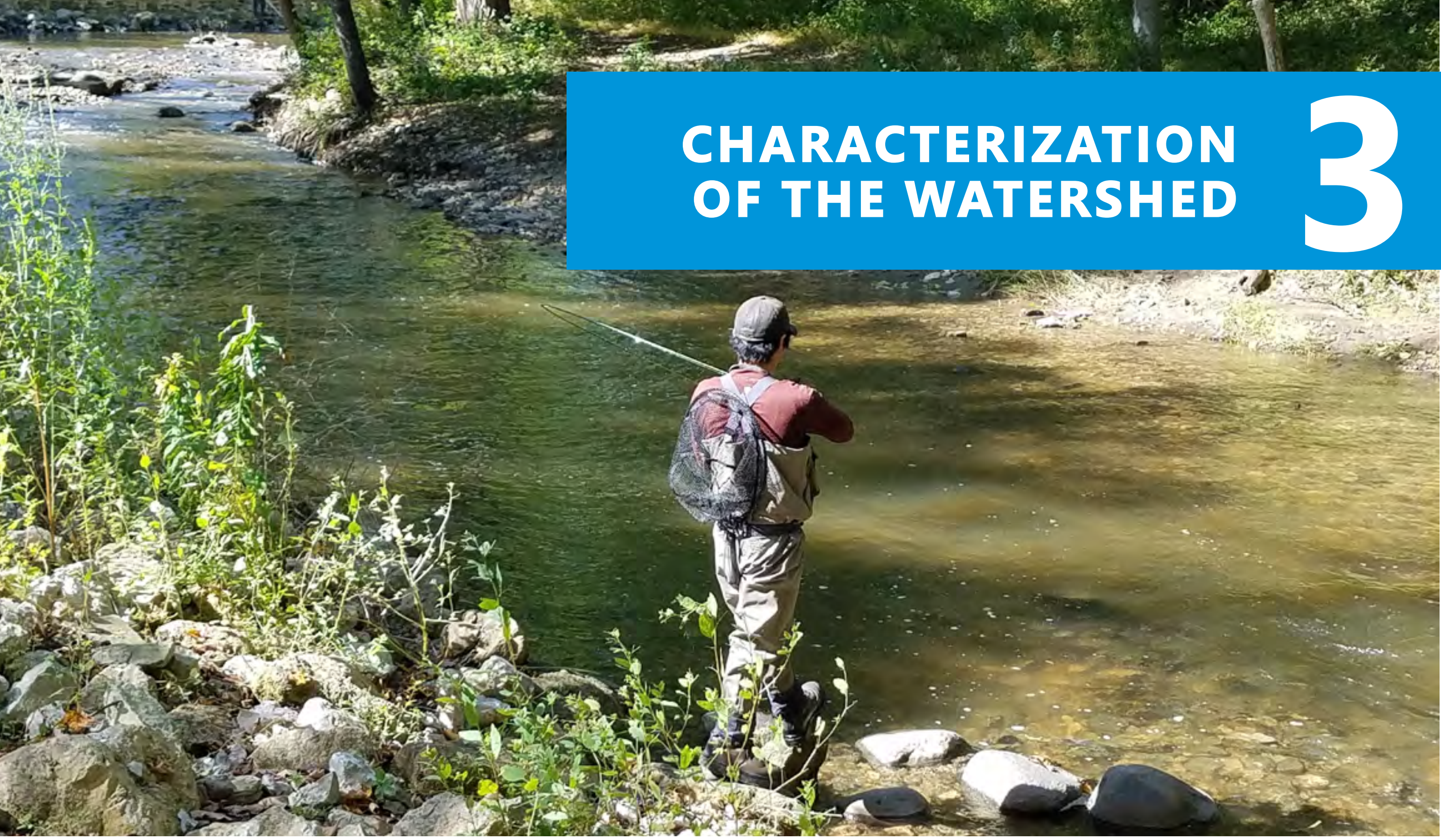
Wehr Nature Center also conducts the Nature in the Parks program. This is a collaborative effort of the Center, the University of Wisconsin-Cooperative Extension Service, and the Milwaukee County Park System. This program provides field trips, summer camps, and other youth programs in parks, schools, libraries, and other sites throughout Milwaukee County. These programs incorporate outdoor experiences, as often as possible.

Integration of Prior and Ongoing Work with this WRP
The Oak Creek watershed restoration plan refines and details pertinent recommendations of the regional water quality management plan. It is intended to provide comprehensive guidance for the management of water resources in the watershed relative to the four focus areas of water quality, recreational use and access, habitat conditions, and flooding. To achieve this, it is desirable to synthesize the findings and recommendations of previous plans and studies that address this watershed and integrate those that address the four focus areas into this watershed restoration plan. Such integration will ensure consistency among plans that are currently active. An additional result of this integration is that currently active recommendations addressing the four focus areas will be presented in a single document.

---

[78] *These materials can be accessed at: clean-water.uwex.edu/pubs.*

Thus, this watershed restoration plan draws upon the findings and recommendations presented in the plans and studies inventoried in Table 2.6 and, where appropriate, integrates them into its recommendations. In some instances, such findings and recommendations are incorporated as expressed in the documents in which they were originally presented. In other instances, findings and recommendations have been refined and detailed, extended, or otherwise modified based upon analyses presented in this plan, subsequent studies, or other relevant information.



CHARACTERIZATION OF THE WATERSHED 3

Credit: SEWRPC Staff

3.1 INTRODUCTION

Information on the natural and constructed features of a watershed is essential to sound planning for water quality, habitat, and floodplain management and for providing recreational access. Watershed topography, local hydrology, and soil types influence rates and volumes of runoff, which affect instream water quality, the composition of plant and animal communities, and flooding conditions. The water quality-related problems of a watershed, and their solutions, are primarily a function of the human activities taking place within it and the ability of the natural resource base to sustain those activities. Streams and lakes are also susceptible to water quality and habitat degradation due to human activities within the watershed, which can interfere with desired water uses and are often difficult and costly to correct. Because of this, land uses and population levels in the watershed are important considerations in planning for protecting, restoring, and managing the water resources in the watershed.

This chapter presents information on the natural resource and human-made features of the Oak Creek watershed including a description of the natural resource base and environmentally sensitive areas, land use data, and demographics. This collection of information helps to establish a factual, existing conditions base upon which the watershed planning process may proceed. The characterization of the Oak Creek watershed presented in this chapter represents a refinement and updating of the inventories presented in the Southeastern Wisconsin Regional Planning Commission (SEWRPC)[79] comprehensive plan for the Oak Creek watershed[80] and the SEWRPC regional water quality management plan update for the Greater Milwaukee watersheds (RWQMPU).[81]

---

[79] *The acronyms and abbreviations used in this report are defined in Appendix A.*

[80] *SEWRPC Planning Report No. 36,* A Comprehensive Plan for the Oak Creek Watershed, *August 1986.*

[81] *SEWRPC Planning Report No. 39,* Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds, *November 2007 and SEWRPC Planning Report No. 50,* A Regional Water Quality Management Plan for the Greater Milwaukee Watersheds, *December 2007 and SEWRPC Planning Report No. 39.*

3.2 ASSESSMENT AREAS

The Oak Creek watershed is comprised of five subwatersheds, as shown on Map 3.1. These include the Lower, Middle, and Upper Oak Creek subwatersheds, which make up the mainstem of Oak Creek, and the North Branch Oak Creek subwatershed and the Mitchell Field Drainage Ditch subwatershed, which are the main tributary streams to the mainstem of Oak Creek.

Hydrologic-hydraulic and water quality modeling that was conducted as part of the regional water quality plan update for the greater Milwaukee watersheds (RWQMPU)[82] required that subwatersheds be further subdivided into hydrologic subbasins. Hydrologic subbasins are the basic "building blocks" for simulating the hydrologic-hydraulic response of the watershed. A total of 70 subbasin areas were delineated in the watershed for simulation modeling in the RWQMPU. These subbasins were delineated to encompass areas tributary to streams, drainageways, and storm sewers using topographic mapping supplemented with street grade data and information on the location, configuration, and elevation of storm sewer systems.

To facilitate analysis for this watershed restoration planning effort, the watershed was divided into 15 "assessment areas." These assessment areas correspond to groupings of the RWQMPU hydrologic subbasins within the subwatersheds that are described above. The groupings were defined based on sites where historical stream flow and water quality data were available, or at points located upstream or downstream of known sources of pollution. The assessment areas are shown on Map 3.2 and their areas are quantified in Table 3.1.

The following are brief descriptions of the 15 assessment areas that make up the Oak Creek watershed. Further details on these areas, including land use, water quality data, biological assessments, channel conditions, and habitat assessment are examined later in this report.

Grant Park Ravine Assessment Area

The most downstream reach in the watershed, this assessment area covers 286 acres and contains 0.9 stream miles of the mainstem of Oak Creek in the City of South Milwaukee. The Creek flows through a steep ravine in Milwaukee County's Grant Park, from the Oak Creek Mill Pond dam downstream to its confluence with Lake Michigan. This assessment area is completely contained within the City of South Milwaukee. In this assessment area, the Creek is well-buffered from roadways and other development by natural vegetation. This area is popular for recreational activities including fishing, biking, birding, photography, and hiking. The majority of the land in this assessment area is characterized as recreational, residential, and industrial land uses.

Lower Oak Creek—Mill Pond Assessment Area

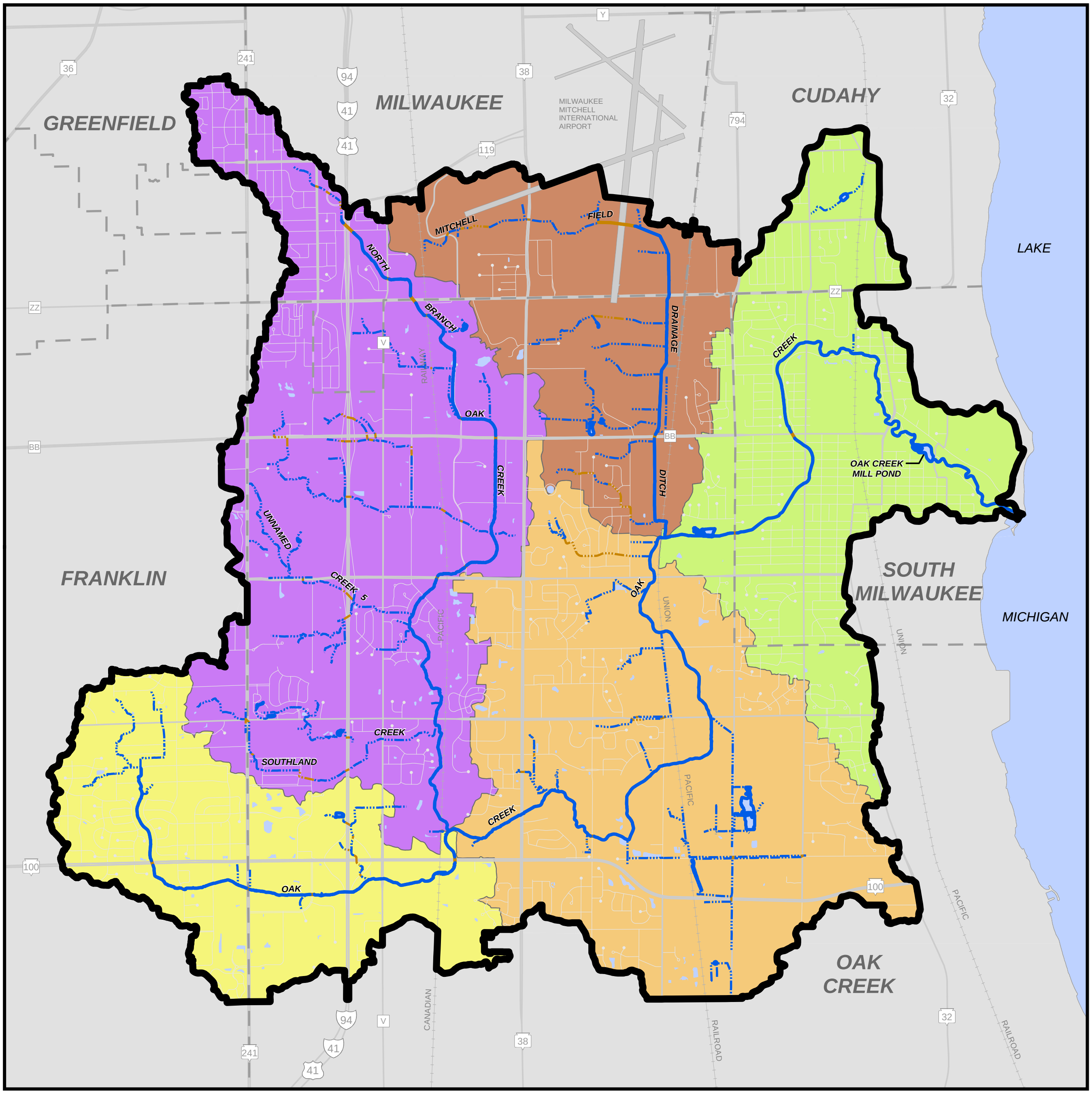
This assessment area covers 932 acres and contains 1.8 stream miles of the mainstem of Oak Creek, flowing from 15th Avenue downstream to the Mill Pond dam in the City of South Milwaukee. This assessment area is located within the Cities of Cudahy and South Milwaukee. This stretch of Creek is relatively well buffered by the Milwaukee County Oak Creek Parkway. This area is popular for biking along the Parkway, and fishing and birdwatching near the Mill Pond. A U.S. Geological Survey (USGS) continuous streamflow monitoring gage is located near the most upstream crossing in this assessment area (15th Avenue). This assessment area is predominantly developed in single-family and multifamily residential land uses, with some commercial and industrial uses as well.

Lower Oak Creek Assessment Area

This assessment area covers 2,046 acres and contains 2.4 stream miles of the mainstem of Oak Creek, flowing from the confluence with the Mitchell Field Drainage Ditch in the City of Oak Creek, downstream to 15th Avenue in the City of South Milwaukee. This assessment area is located within the Cities of Cudahy, Oak Creek, and South Milwaukee. The Creek in this area is relatively well-buffered by the Milwaukee County Oak Creek Parkway. There are short reaches of concrete-lined channel found in this assessment area. This area is largely developed with residential land use, with small pockets of commercial, industrial, governmental, and agricultural uses.

[82] *SEWRPC Planning Report No. 50,* op. cit.

Map 3.1
Subwatersheds Within the Oak Creek Watershed

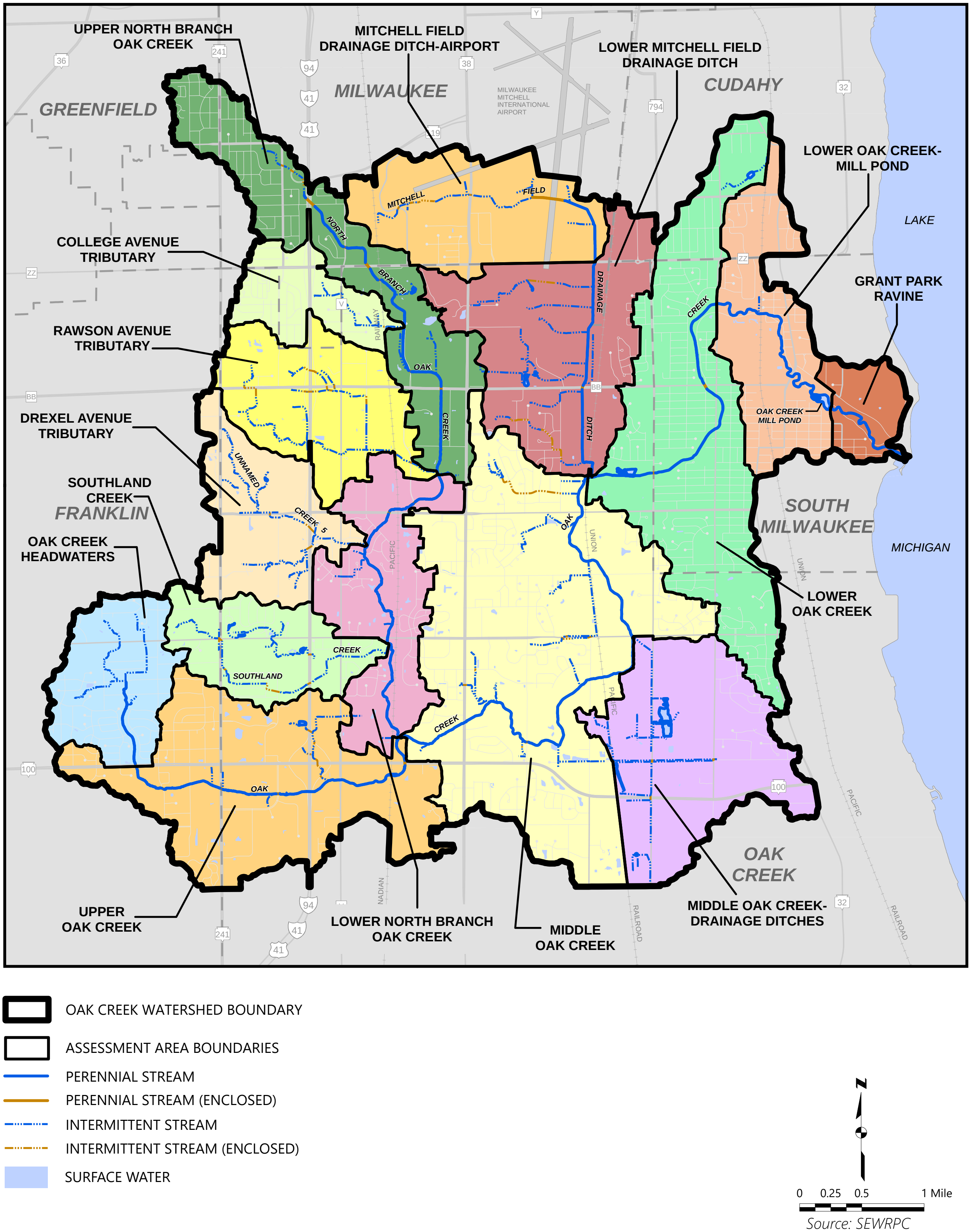


LOWER OAK CREEK SUBWATERSHED
MIDDLE OAK CREEK SUBWATERSHED
UPPER OAK CREEK SUBWATERSHED
NORTH BRANCH OAK CREEK SUBWATERSHED
MITCHELL FIELD DRAINAGE DITCH SUBWATERSHED
OAK CREEK WATERSHED BOUNDARY
PERENNIAL STREAM
PERENNIAL STREAM (ENCLOSED)
INTERMITTENT STREAM
INTERMITTENT STREAM (ENCLOSED)
SURFACE WATER

0 0.25 0.5 1 Mile

Source: SEWRPC

Map 3.2
Assessment Areas Within the Oak Creek Watershed



Source: SEWRPC

Middle Oak Creek Assessment Area

This is the largest assessment area covering 3,256 acres and containing 4.6 stream miles of the mainstem of Oak Creek, flowing from the confluence with the North Branch of Oak Creek downstream to the confluence of the Mitchell Field Drainage Ditch. There are several unnamed tributaries and drainage ditches that flow into this reach of Oak Creek. The entire assessment area is within the City of Oak Creek. This area has the largest amount of remaining agricultural and open space land uses along the mainstem of Oak Creek, as well as pockets of single- and multifamily residential development.

Table 3.1
Assessment Areas in the Oak Creek Watershed

Assessment Area[a]	Acres
Mainstem	
Grant Park Ravine	286
Lower Oak Creek – Mill Pond	932
Lower Oak Creek	2,046
Middle Oak Creek Drainage Ditches	1,372
Middle Oak Creek	3,256
Upper Oak Creek	1,827
Oak Creek Headwaters	706
Mitchell Field Drainage Ditch	
Lower Mitchell Field Drainage Ditch	1,443
Mitchell Field Drainage Ditch – Airport	1,010
North Branch Oak Creek	
Lower North Branch Oak Creek	978
Upper North Branch Oak Creek	1,257
Southland Creek	696
Drexel Avenue Tributary	814
Rawson Avenue Tributary	968
College Avenue Tributary	453
Total	18,044

[a] *Assessment areas are shown on Map 3.2.*

Source: SEWRPC

Middle Oak Creek—Drainage Ditches Assessment Area

This assessment area covers 1,372 acres and contains about 5.3 miles of unnamed roadside drainage ditches that flow into the mainstem of Oak Creek near Puetz Road. The entire assessment area is within the City of Oak Creek. This area consists of mostly agricultural and other open space land uses, with large areas of wetland.

Upper Oak Creek Assessment Area

This assessment area covers 1,827 acres and contains 2.7 stream miles of the mainstem of Oak Creek, flowing from Ryan Road in the City of Franklin, downstream to the confluence with the North Branch of Oak Creek, in the City of Oak Creek. This assessment area is located within the Cities of Franklin and Oak Creek. This assessment area has a mix of agricultural, industrial, and residential land uses and contains a portion of the Interstate Highway 94 (IH 94) corridor.

Oak Creek Headwaters Assessment Area

The furthest upstream assessment area of Oak Creek's mainstem covers 706 acres and contains 2.3 stream miles of Oak Creek's headwaters, flowing from its intermittent origins just north of Puetz Road, downstream to Ryan Road, in the City of Franklin. The entire assessment area is located within the City of Franklin. Most of the assessment area is developed with residential land uses.

Lower Mitchell Field Drainage Ditch Assessment Area

This assessment area covers 1,443 acres and contains 1.8 stream miles of the Mitchell Field Drainage Ditch tributary to the mainstem of Oak Creek. This reach flows from College Avenue downstream to the confluence with the mainstem of Oak Creek, mostly within the City of Oak Creek. This assessment area also contains small portions of the Cities of Milwaukee and Cudahy. There are several unnamed tributaries and drainage ditches that flow from west to east into the Mitchell Field Drainage Ditch. This area has a significant amount of open space land and also contains some pockets of residential, commercial, industrial, and airport land uses.

Mitchell Field Drainage Ditch—Airport Assessment Area

This assessment area covers 1,010 acres and contains about 2.3 stream miles of the Mitchell Field Drainage Ditch and several unnamed drainage ditches, all of which are within the Milwaukee Mitchell International Airport property. This assessment area is located within the Cities of Milwaukee and Oak Creek. Significant portions of the stream within this assessment area are enclosed under Airport runways.

Lower North Branch Oak Creek Assessment Area

This assessment area covers 978 acres and contains 2.8 stream miles of the North Branch of Oak Creek, flowing from just upstream of Drexel Avenue to its confluence with the mainstem of Oak Creek in the City of Oak Creek. This assessment area is located entirely within the City of Oak Creek. The North Branch of Oak Creek is the largest tributary of Oak Creek. Assessment areas directly contributing streamflow to the Lower

North Branch assessment area include the Upper North Branch Oak Creek, Rawson Avenue Tributary, the Drexel Avenue Tributary, and the Southland Creek Tributary. This assessment area has a mix of industrial, residential, governmental, agricultural, and other open space land uses.

Upper North Branch Oak Creek Assessment Area

This assessment area covers 1,257 acres and contains 3.5 stream miles of the North Branch of Oak Creek, flowing from its headwaters located northwest of IH 94 in the City of Milwaukee, downstream to just north of Drexel Avenue, where it flows into the Lower North Branch of Oak Creek. The assessment area includes portions of the Cities of Greenfield, Milwaukee, and Oak Creek, and contains a mix of industrial, commercial, residential, and open space land uses. A small portion of the IH 94 corridor crosses this assessment area. This assessment area receives contributing flow from the College Avenue Tributary assessment area.

Southland Creek Assessment Area

This assessment area covers 696 acres and contains 2.4 stream miles of Southland Creek which flows in a west to east direction from its headwaters in the City of Franklin to its confluence with the North Branch of Oak Creek in the City of Oak Creek, about 0.75 miles east of IH 94. This assessment area is located within the Cities of Franklin and Oak Creek. An unnamed, intermittent stream tributary to Southland Creek is also contained in this assessment area. The major land use in this area is agricultural and other open lands, with pockets of residential and commercial development and some IH 94 corridor.

Drexel Avenue Tributary Assessment Area

This assessment area covers 814 acres and contains about 3.8 stream miles of perennial and intermittent unnamed streams. The main stream in this assessment area flows southeast from its headwaters near S. 27th Street and crosses Drexel Avenue and IH 94 before flowing into the North Branch of Oak Creek just upstream of Willow Heights Park, in the City of Oak Creek. The assessment area also includes a small portion of the City of Franklin. This area has mostly agricultural, woodland, and other open lands, with small pockets of residential and commercial development. A portion of the IH 94 corridor transects this assessment area.

Rawson Avenue Tributary Assessment Area

This assessment area covers 968 acres and contains about 4.3 stream miles of intermittent unnamed streams. The assessment area is almost entirely contained within the City of Oak Creek, with a small portion within the City of Franklin. The main unnamed stream in this area flows in a south-southeastern direction, originating north of Rawson Avenue and crossing IH 94, S. 13th Avenue, and S. 6th Avenue before joining the North Branch of Oak Creek downstream of Marquette Avenue. This assessment area contains a mix of industrial, residential, commercial, agricultural and other open land uses and contains a portion of the IH 94 corridor.

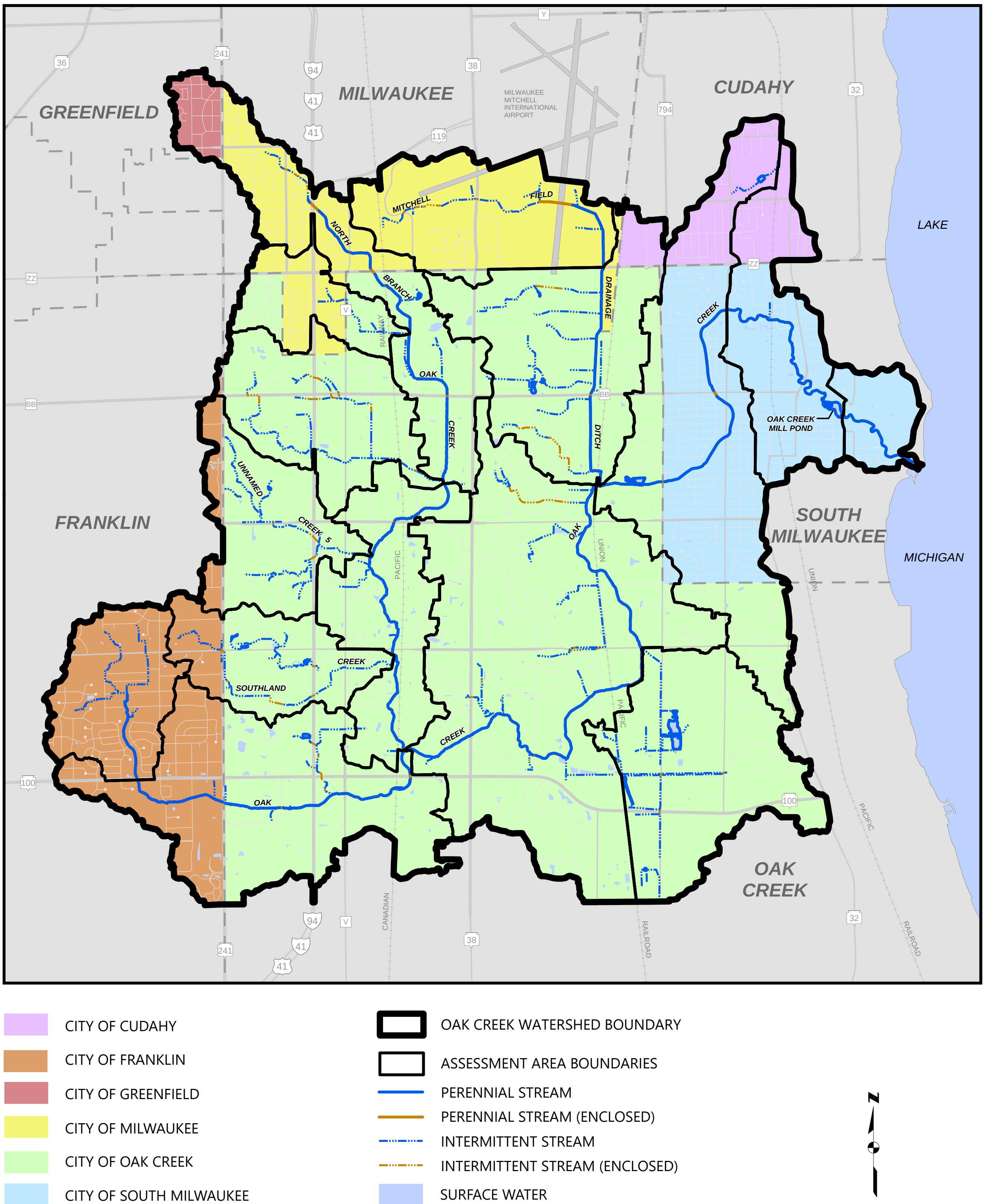
College Avenue Tributary Assessment Area

This assessment area covers 453 acres and contains about 1.25 stream miles of unnamed intermittent stream that originates to the west of IH 94 and flows southeast across S. 13th Avenue and into the North Branch of Oak Creek at S. 6th Street near the Milwaukee Area Technical College Oak Creek campus. This assessment area contains portions of the Cities of Milwaukee and Oak Creek and has a mix of residential, commercial, industrial, and open space land uses and contains a portion of the IH 94 corridor.

3.3 CIVIL DIVISIONS

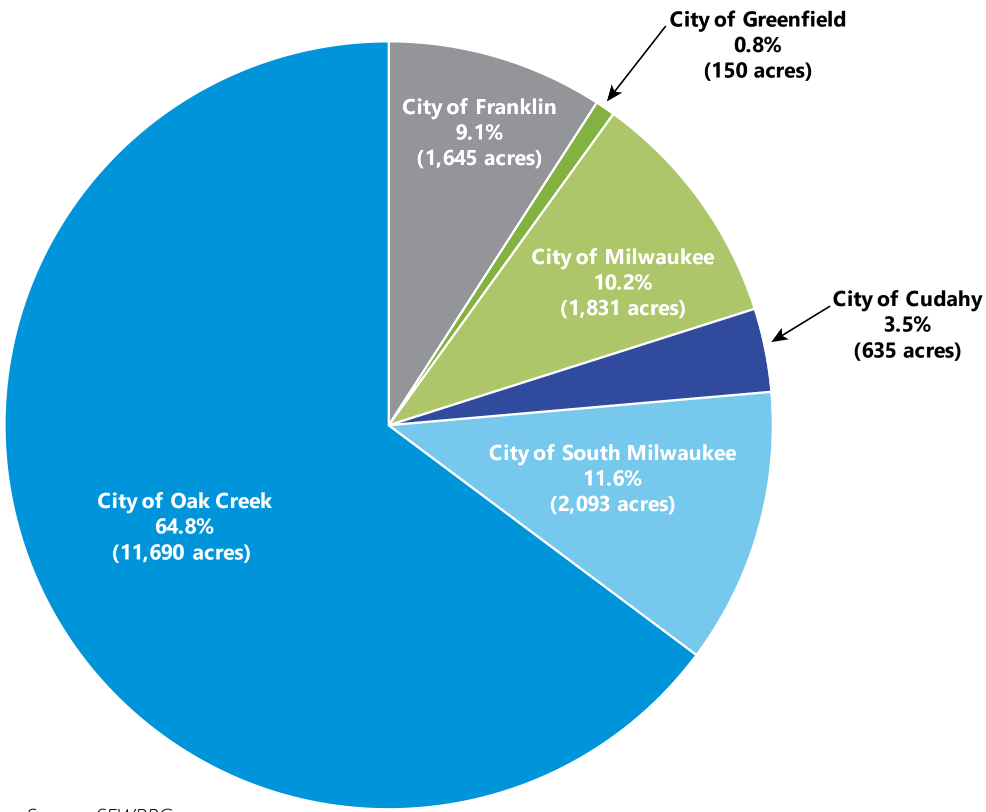
Superimposed over natural boundaries, such as watershed and subwatershed boundaries, is a pattern of local and political boundaries. As shown in Map 3.3, the Oak Creek watershed lies entirely within Milwaukee County and includes portions of the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee. Geographic boundaries of the civil divisions within the watershed are an important factor because they form the basic foundation of the public decision-making framework within which intergovernmental, environmental, and development issues may be addressed. The proportions of the watershed within the jurisdiction of each city are set forth in Figure 3.1.

Map 3.3
Civil Divisions Within the Oak Creek Watershed: 2018



Source: SEWRPC

Figure 3.1
Civil Divisions Within the Oak Creek Watershed: 2018



Source: SEWRPC

Jurisdictional Roles and Responsibilities

Natural resources in the United States are protected to various extents under Federal, State, and local law. The Clean Water Act regulates surface water quality at the national level. In Wisconsin, the Wisconsin Department of Natural Resources (WDNR) has the authority to administer the provisions of the Clean Water Act. The U.S. Environmental Protection Agency (USEPA), U.S. Army Corps of Engineers, Natural Resources Conservation Service (NRCS), and the U.S. Fish and Wildlife Service work with the WDNR to protect natural lands, wetlands, and threatened and endangered species. The Federal Safe Drinking Water Act applies to all public water supply systems and helps to protect surface and groundwater resources.

The local governments in the Oak Creek watershed have ordinances regulating land development and protecting surface waters. The 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 zoning regulations governing floodplain 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. The ordinances administered by the units of government within the Oak Creek watershed are summarized in Table 3.2.

Other governmental entities with watershed jurisdictional or technical advisory roles include: the USGS, the Wisconsin Department of Agriculture, Trade, and Consumer Protection (WDATCP); the University of Wisconsin-Extension; the Milwaukee Metropolitan Sewerage District (MMSD); the Milwaukee County Department of Transportation and Public Works—Architecture, Engineering, and Environmental Services Division; the Milwaukee County Department of Parks, Recreation, and Culture; and SEWRPC.

Table 3.2
Land Use Regulations Within the Oak Creek Watershed

Community	General Zoning	Floodplain Zoning	Shoreland or Shoreland Wetland Zoning	Subdivision Control	Erosion Control and Stormwater Management
Milwaukee County[a]	None	None	None	None	None
City of Cudahy	Adopted	Adopted	Adopted	Adopted	Adopted
City of Franklin[b]	Adopted	Adopted	Adopted	Adopted	Adopted
City of Greenfield	Adopted	Adopted	Adopted	Adopted	Adopted
City of Milwaukee	Adopted	Adopted	Adopted	Adopted	Adopted
City of Oak Creek	Adopted	Adopted	Adopted	Adopted	Adopted
City of South Milwaukee	Adopted	Adopted	Adopted	Adopted	Adopted

[a] *All communities in Milwaukee County are incorporated and contain land use regulations specified in this table.*

[b] *The City of Franklin Unified Development Ordinance contains all land use regulations specified in this table.*

Source: SEWRPC

Floodplain Zoning

Section 87.30 of the *Wisconsin Statutes* requires that cities, villages, and counties, with respect to their unincorporated areas, adopt floodplain zoning to preserve the floodwater conveyance and storage capacity of the 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 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 1-percent-annual-probability (100-year recurrence interval) floodplain areas within the Oak Creek watershed are shown on Map 3.4. Under Chapter NR 116, local floodplain zoning regulations must prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the 1-percent-annual-probability peak flood flow. Local regulations must also restrict filling and development within the flood fringe area, which is that portion of the floodplain located outside of the floodway that would be covered by floodwater during a 1-percent-annual-probability flood. However, permitting the filling and development of the flood fringe area without requiring the provision of compensatory storage to replace the floodwater storage volume lost through filling, reduces the floodwater storage capacity of the natural floodplain, and may, thereby, increase downstream flood flows and stages. All cities within the Oak Creek watershed have adopted floodplain zoning ordinances.[83]

A small area of floodplains in the City of Cudahy is designated as "Zone A" where the extent of the floodplain was determined based upon an approximate study that did not calculate specific flood stage elevations. All remaining floodplains in the watershed were developed under detailed studies for which flood flows and base flood elevations were determined (see Map 3.4). All floodplains in the watershed were delineated under the September 2008 Federal Flood Insurance Study for Milwaukee County.[84]

Shoreland Regulation

The State Water Resources Act of 1965 provides for the regulation of shoreland uses along navigable waters to assist in water quality protection and pollution abatement and prevention. In Section 59.692(1) of the *Wisconsin Statutes*, the Legislature defines shorelands as the area lying within the following distances from the ordinary high water mark of all natural lakes and of all streams, ponds, sloughs, flowages, and other waters which are navigable under the laws of the State of Wisconsin: 1,000 feet from a lake, pond, flowage, or glacial pothole lake, and 300 feet from a stream or to the landward side of the floodplain, whichever is greater.[85]

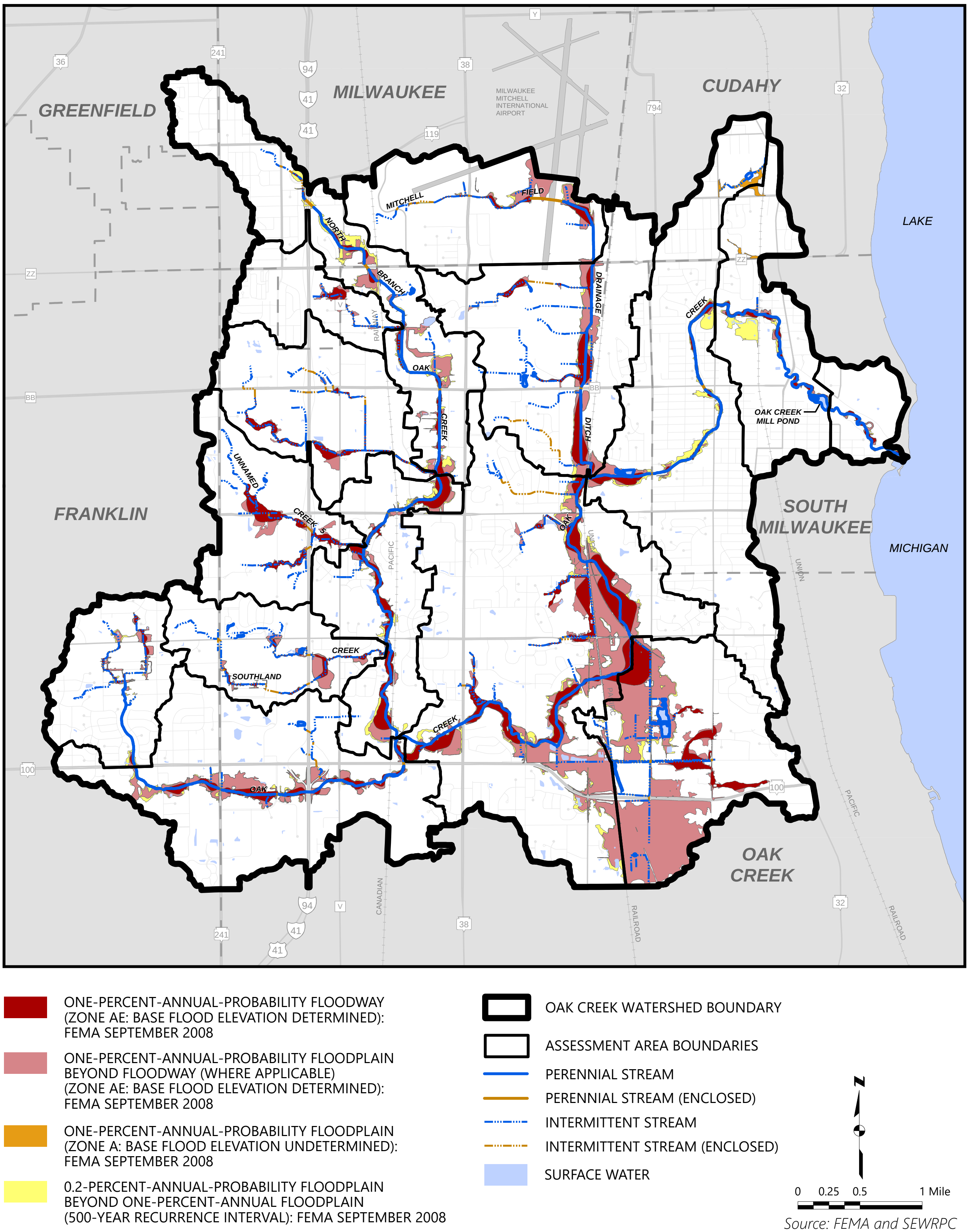
---

[83] *Although all municipalities within the watershed have adopted floodplain ordinances, this does not preclude development within the regulatory floodplains of the Oak Creek watershed.*

[84] *Federal Emergency Management Agency,* Flood Insurance Study—Milwaukee County, Wisconsin and Incorporated Areas, *September 2008.*

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

Map 3.4
Floodplain Designations Within the Oak Creek Watershed: Effective Date September 2008



Source: FEMA and SEWRPC

Section 281.31 of the *Wisconsin Statutes* specifically authorizes municipal zoning regulations for shorelands. This Statute defines a municipality as a county, city, or village. The shoreland regulations authorized by this Statute have been defined by the WDNR to include land subdivision controls and sanitary regulations. The purposes of zoning, land subdivision, and sanitary regulations in shoreland areas include the maintenance of safe and healthful conditions in riverine areas; preventing and controlling water pollution; protecting spawning grounds, fish, and aquatic life; controlling building sites, placement of structures, and land use; and preserving shore cover and natural beauty.

The standards and criteria for shoreland ordinances are set forth in Chapter 115, Wisconsin's Shoreland Protection Program, of the *Wisconsin Administrative Code.* These standards and criteria include restrictions on lot sizes, including a minimum average width of 65 feet and minimum area of 10,000 square feet for lots served by public sanitary sewer and a minimum average width of 100 feet and a minimum area of 20,000 square feet for lots not served by public sanitary sewer; building setbacks, including a typical minimum setback of 75 feet from the ordinary high water mark of any surface waterbody; the cutting of trees and shrubbery; and filling, grading, and dredging.

Cities and villages are required to zone proactively those wetlands shown on the Wisconsin Wetland Inventory maps that are five acres or larger in size and are within the shoreland zone. Chapter NR 117, Wisconsin's City and Village Shoreland-Wetland Protection Program, of the *Wisconsin Administrative Code* sets forth rules regarding shoreland-wetland zoning for cities and villages. The criteria concerning permitted uses, functional values and uses, and State review and oversight are, for the most part, the same as for county shoreland-wetland zoning. Permitted uses within the shoreland-wetland zoning district include hiking, hunting, trapping, harvest of wild crops, silviculture, pasturing of livestock, cultivation of crops provided that such "cultivation can be accomplished without filling, flooding, or artificial drainage of the wetland," repair of existing drainage systems, construction of certain utility lines, and construction and maintenance of duck blinds, piers, docks and walkways "provided that no filling, flooding, dredging, draining, ditching, tiling, or excavating is done."

In the past cities and villages were allowed to adopt shoreland zoning standards more restrictive than those contained in NR 115. Currently, requirements in 2015 Wisconsin Act 55 do not allow jurisdictions to regulate a matter in a shoreland zoning ordinance more restrictively that the matter is regulated by a State shoreland zoning standard. This requirement also applies to regulation of shoreland wetlands. However, this does not prohibit cities and villages from protecting wetlands outside of the shoreland zoning area. The WDNR retains oversight responsibility for the implementation and enforcement of Chapters NR 115 and NR 117. In addition, the Department must review and approve all shoreland and shoreland-wetland zoning ordinances, determine compliance, and monitor the rule.

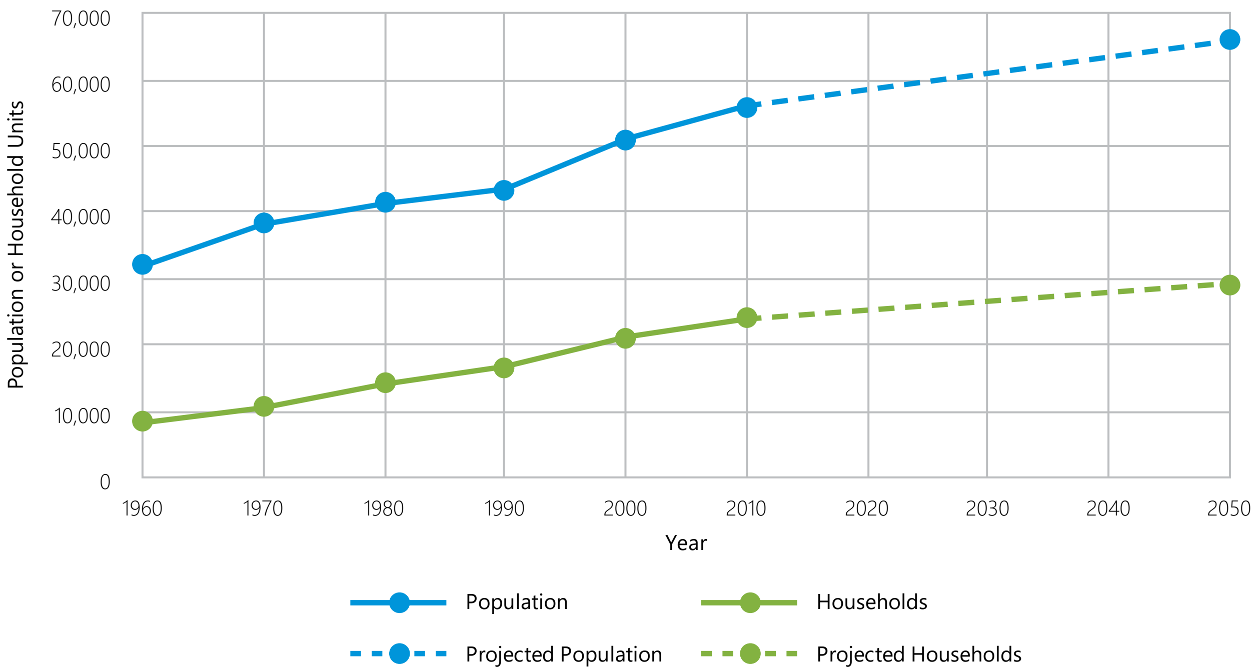
All cities within the Oak Creek watershed have adopted shoreland and shoreland-wetland zoning ordinances.

3.4 POPULATION AND HOUSEHOLDS

Data on estimated population and numbers of households in the Oak Creek watershed from 1960 to 2010, and projections for 2050, are shown in Figure 3.2. From 1960 to 2010, the resident population grew from about 32,000 to 56,000 individuals while the number of households grew from about 8,300 to more than 24,000. The greatest increase in both population and the number of households occurred between 1990 and 2000, however there has been a steady growth in both population and households since 1960 as shown in Figure 3.2. Based upon the adopted regional land use plan,[86] the population and number of resident households in the Oak Creek watershed are projected to continue to increase through the year 2050, which is consistent with the planned land use changes as shown in Table 3.3.

[86] *SEWRPC Planning Report No. 55,* VISION 2050: A Regional Land Use and Transportation Plan for Southeastern Wisconsin, *July 2017.*

Figure 3.2
Populations and Households Within the Oak Creek Watershed: 1960-2050



Note: Watershed area approximated by whole U.S. Public Land Survey quarter sections.

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

3.5 LAND USE

An important concept underlying the watershed planning effort is that land use development must be adjusted to the ability of the underlying natural resource base to sustain such development. The type, intensity, and spatial distribution of land uses determine, to a large extent, the resource demands within a watershed. The demands upon water resources can be correlated directly with the quantity and type of land use in the watershed. The same is true of the deterioration of water quality. The existing land use pattern can best be understood within the context of its historical development. This section presents information on past land use, existing land use, and planned land use within the Oak Creek watershed.

Changes in Land Use Over Time

Historically, before European settlement in the mid-1800s, the landscape within the Oak Creek watershed consisted largely of maple-basswood forest, which could be characterized by continuous, often dense, canopies of deciduous trees and understories of shade adapted shrubs and herbs. Also prevalent in the pre-settlement landscape, particularly in the eastern portion of the watershed near Lake Michigan, were beech-maple forests, consisting of mostly American beech and sugar maple trees. Other natural habitats included wetland complexes buffering large portions of the stream channels in the watershed, and pockets of oak forest, lowland hardwood forest, and conifer swamp. The extent of these pre-settlement habitat types in the Oak Creek watershed, derived from the original 1836 land surveyor's records, is shown on Map 3.5.

The soil that covered a significant portion of the watershed was considered less productive than some other portions of the Southeastern Wisconsin Region at the time. In some areas of the watershed the soil contained many boulders, varying in size from a few pounds to several tons.[87] Despite this fact, in large portions of the watershed, natural vegetation and forests were eventually cleared to make room for farming. Efforts were made to open up wetlands to cultivation through ditching and draining of wet soils. This land conversion had significant consequences on water quality and wildlife habitat within the Oak Creek watershed.

[87] *Lieutenant Col. Jerome A. Watrous and the Western Historical Association,* Memoirs of Milwaukee County, Volume 1, *1909*.

Table 3.3
Projected Changes in Land Use Within the Oak Creek Watershed: 2015 and Planned Conditions[a]

Land Use Categories	Percent of Watershed 2015	Percent of Watershed Under Planned Conditions	Percent Change[b]
Urban			
Residential			
Single-Family, Rural Density[c]	0.4	0.3	-0.1
Single-Family, Suburban Density[d]	0.0	0.0	--
Single-Family, Low Density[e]	9.4	11.8	+2.4
Single-Family, Medium Density[f]	11.5	12.3	+0.8
Single-Family, High Density[g]	2.0	2.1	+0.1
Multifamily	4.0	4.7	+0.7
Residential Subtotal	27.3	31.2	+3.9
Commercial	4.6	8.8	+4.2
Industrial	4.7	7.8	+3.1
Governmental and Institutional	4.0	4.6	+0.6
Transportation, Communication, and Utilities	20.4	22.6	+2.2
Recreational	3.9	4.0	+0.1
Urban Subtotal	64.9	79.0	+14.1
Nonurban			
Agricultural	9.2	3.6	-5.6
Other Open Lands	13.1	4.6	-8.5
Wetlands	7.3	7.3	--
Woodlands	4.7	4.7	--
Water	0.5	0.5	--
Extractive	0.3	0.3	--
Landfill	0.0	0.0	--
Nonurban Subtotal	35.1	21.0	-14.1

Note: Off-street parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Planned conditions are based on local government comprehensive plans.*

[b] *Percent change is relative to the total watershed area*

[c] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[d] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[e] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[f] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

[g] *High density residential reflects 7 or more dwelling units per net residential acre.*

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee and SEWRPC

By 1963, agricultural and other open lands dominated the landscape, accounting for over 57 percent of the land within the Oak Creek watershed.[88] From that point forward, agricultural land use slowly declined in the watershed, but was still the largest use of land as recently as 1980, when 45 percent of the land was used for agriculture or other open land uses.

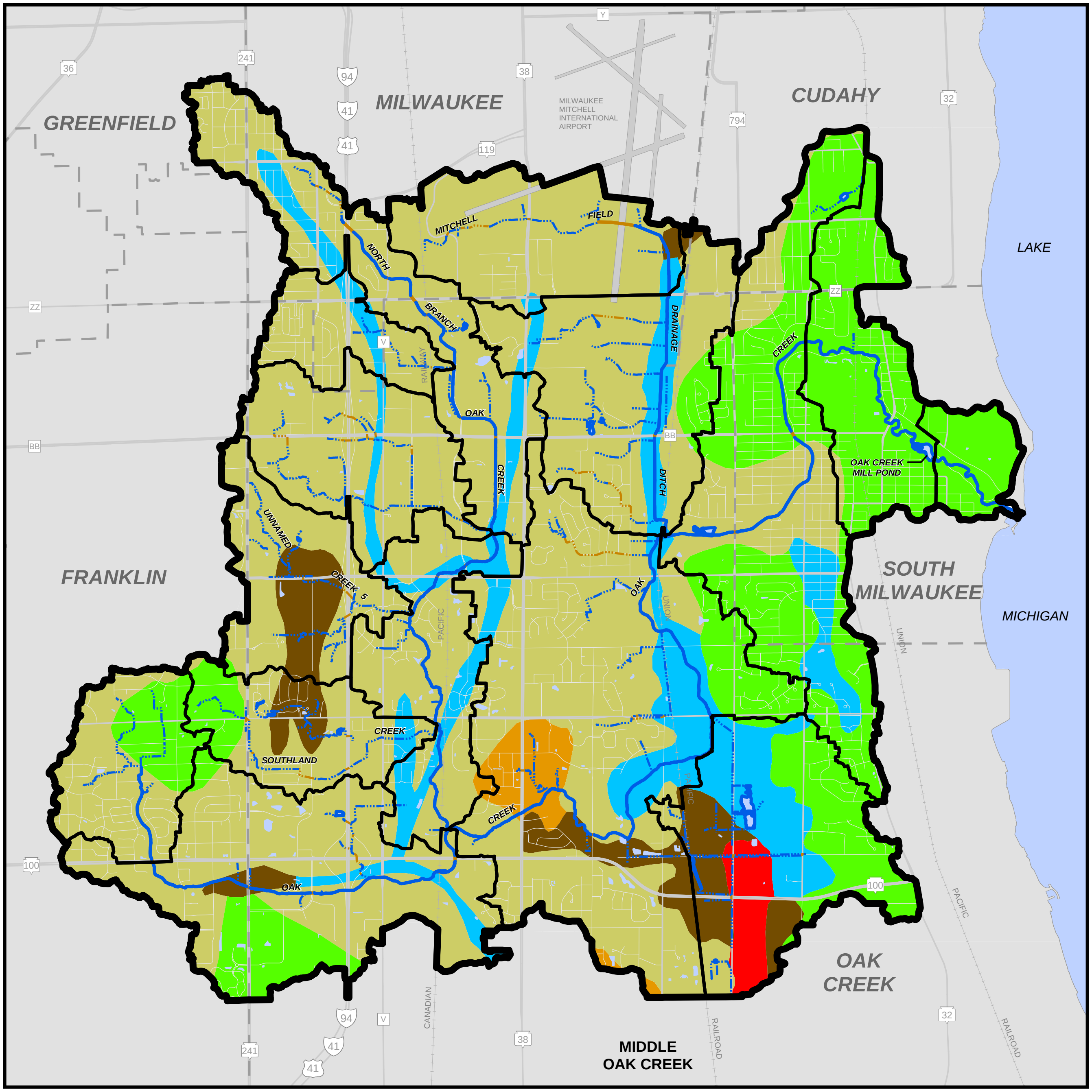
Historical Urban Growth

Historical urban growth within the Oak Creek watershed is shown on Map 3.6. In 1840, early settlers built a saw mill a short distance upstream from Oak Creek's confluence with Lake Michigan.[89] The saw mill derived power from a dam built on Oak Creek that provided a fall of twelve feet. This dam was also used to drive a small grist-mill in the area. Early urban growth (pre-1900) in the watershed was focused in a small area

[88] *1963 is the first year that SEWRPC completed a detailed land use analysis for the Southeastern Wisconsin Region.*

[89] Memoirs of Milwaukee County, Volume 1, op. cit.

Map 3.5
Presettlement Vegetation Within the Oak Creek Watershed: 1836



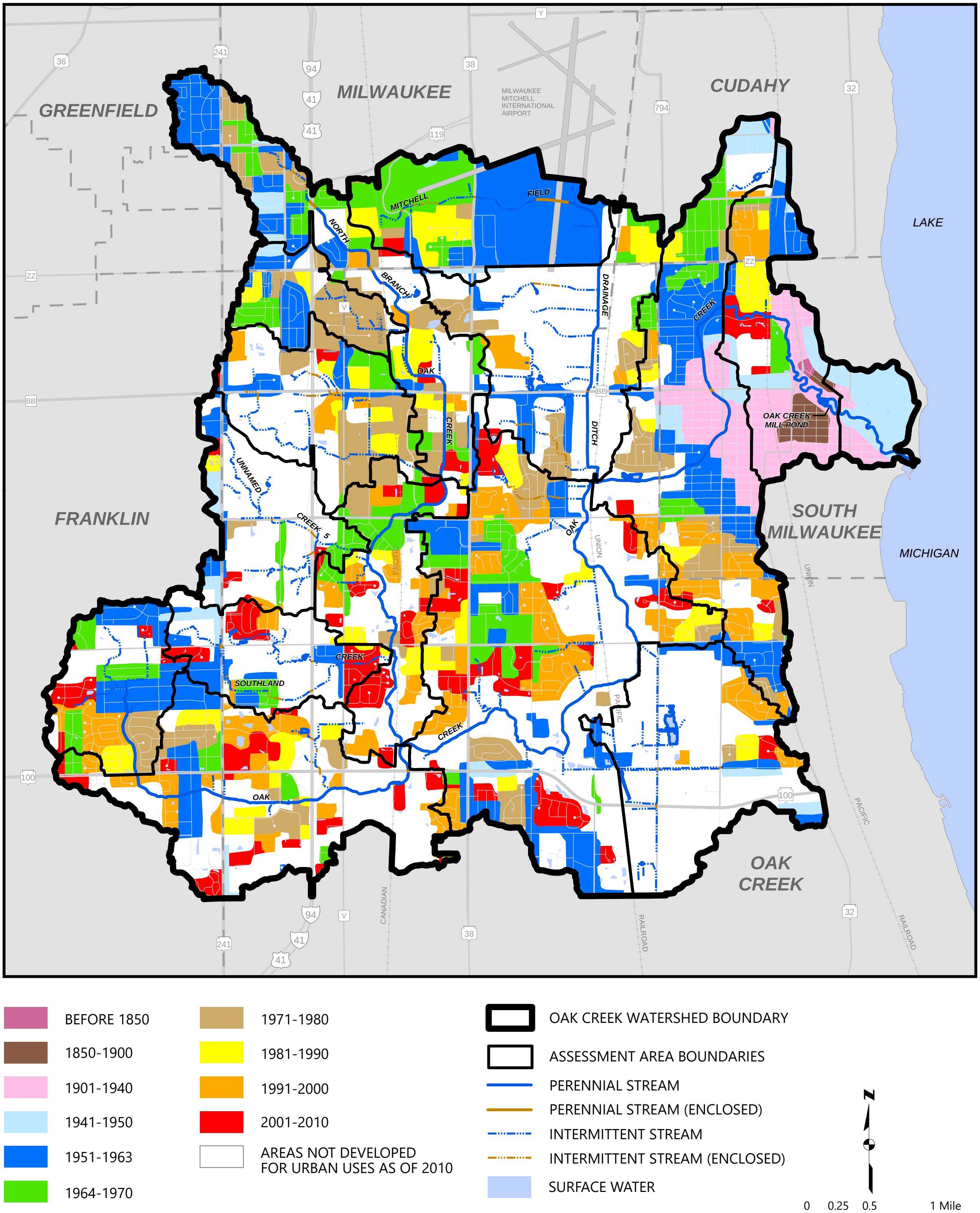
OAK FOREST	OAK CREEK WATERSHED BOUNDARY
MAPLE-BASSWOOD FOREST	ASSESSMENT AREA BOUNDARIES
BEECH-MAPLE FOREST	PERENNIAL STREAM
LOWLAND HARDWOOD FOREST	PERENNIAL STREAM (ENCLOSED)
CONIFER SWAMP	INTERMITTENT STREAM
WETLANDS	INTERMITTENT STREAM (ENCLOSED)
	SURFACE WATER

Note: The vegetation area features on this map have been interpreted from original surveyor's records and current topographic maps to illustrate the type and areal extent of native vegetation that occurred in this region in 1836.

0 0.25 0.5 1 Mile

Source: SEWRPC

Map 3.6
Historical Urban Growth Within the Oak Creek Watershed: 1850-2010



Source: SEWRPC

northwest of the location of the current dam and mill pond, and a larger area to the southwest of the mill pond in what is now the City of South Milwaukee. Between 1901 and 1940, most of the urban growth in the watershed continued to be focused in the City of South Milwaukee, with several small pockets of development in the Cities of Cudahy, Franklin, Milwaukee, and Oak Creek. The period between 1951 and 1970 saw the largest expansion of urban development throughout the watershed when the extent of urban development increased from about 8 percent to almost 33 percent of the watershed. The decades of the 1980s, 1990s, and 2000s experienced increased urban development within the watershed of 5.2, 8.6, and 5.9 percent, respectively. By 2010, 61.2 percent of the watershed had been developed with urban uses.

Existing and Planned Land Use

This section characterizes existing land use conditions as of the year 2015 and examines changes in land use anticipated to occur based on local government comprehensive plans. The types, intensity, and spatial distribution of land uses within the Oak Creek watershed are important elements in natural resource management and are important considerations in developing and implementing this restoration plan.

Existing Land Use: 2015

Map 3.7 shows existing land use for the Oak Creek watershed and Tables 3.4 through 3.7 set forth existing land use data, expressed as areas and percentages for the assessment areas and the entire watershed.

Map 3.8 shows the percentage of urban land uses within each assessment area in the watershed. The data set forth in Tables 3.4 through 3.7, and shown graphically on Map 3.8, indicate that the watershed is heavily urbanized, with nearly 65 percent of the watershed in urban land uses, and about 35 percent still in rural and other open space land uses as of the year 2015. Twelve of the fifteen assessment areas have a majority of the land in urban uses. In five assessment areas—the Lower Oak Creek-Mill Pond, the Lower Oak Creek, the Oak Creek Headwaters, the Mitchell Field Drainage Ditch-Airport, and the College Avenue Tributary—urban land uses account for over 80 percent of the land within the assessment area. In five additional assessment areas—the Grant Park Ravine, the Middle Oak Creek, the Upper Oak Creek, the Lower North Branch Oak Creek, and Upper North Branch Oak Creek—urban land uses account for over 60 percent of the land within the assessment area. Three assessment areas—the Middle Oak Creek-Drainage Ditches, the Lower Mitchell Field Drainage Ditch, and the Drexel Avenue Tributary have the majority of their land in non-urban land uses.

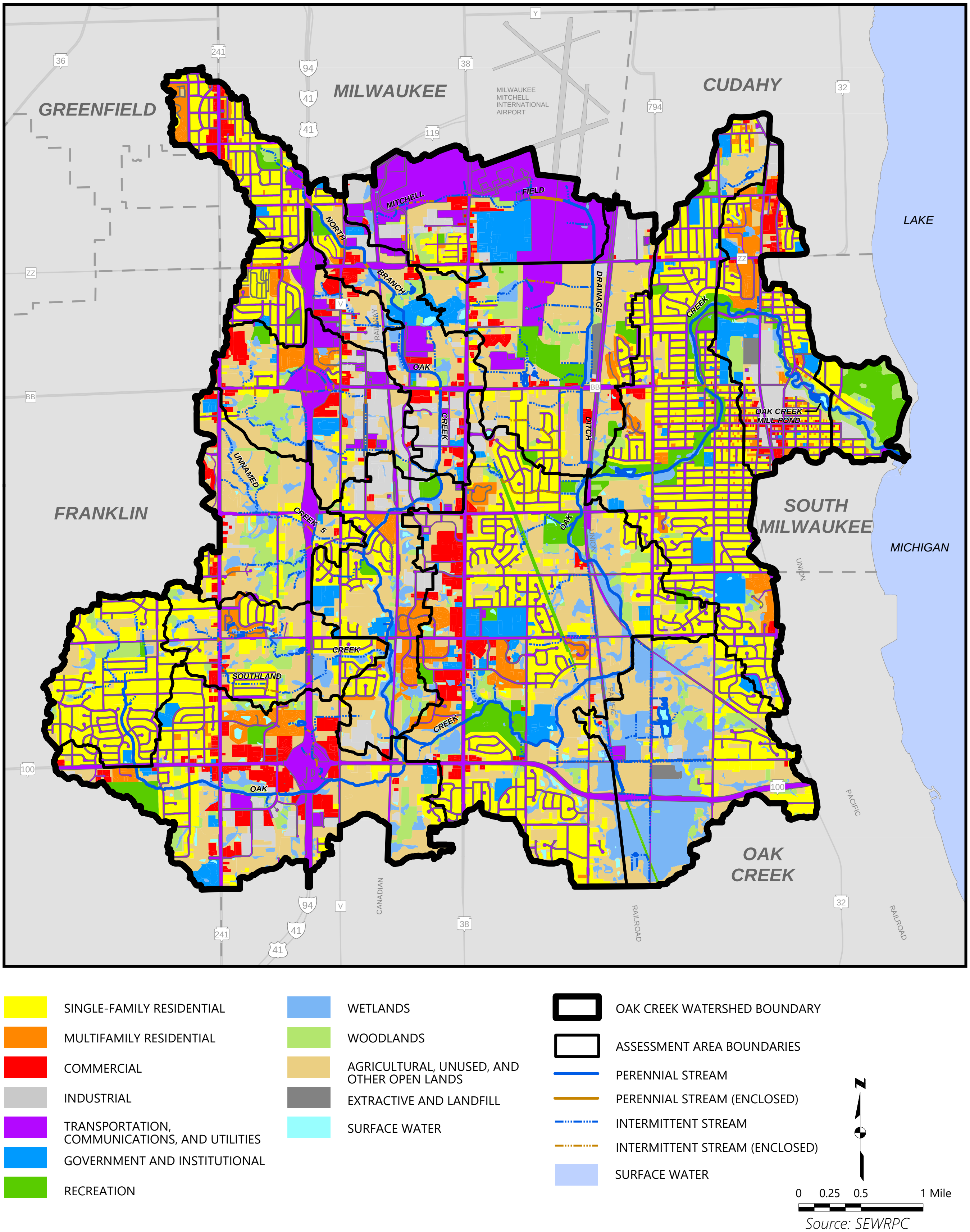
Residential development comprised the largest category of land uses in the watershed, accounting for 4,931 acres, or about 27.3 percent of the watershed. Wetlands accounted for 1,324 acres, or about 7.3 percent of the watershed, and woodlands accounted for 848 acres, or about 4.7 percent of the watershed. There were 1,664 acres, or about 9.2 percent of the watershed, in agricultural land uses.

Planned Land Use

Planned land use in the Oak Creek watershed is shown on Map 3.9 and summarized in Tables 3.8 through 3.11, expressed as area and percentages for each assessment areas and the entire watershed. Under planned land use conditions, about 14,254 acres, or 79 percent of the watershed, are anticipated to be in urban land uses, an increase of about 22 percent from year 2015 existing conditions, as shown in Table 3.11. The percent of anticipated urban development for each assessment area is shown graphically on Map 3.10. The increase in urban development is anticipated to result from increases in residential, commercial, and industrial development. (see Tables 3.7 and 3.11). All of the increases in urban development are anticipated to result in a loss of 1,014 acres of agricultural laned, 1,529 acres of other open lands, and five acres of woodlands. Map 3.11 graphically depicts the agricultural land, woodlands, and other open lands in 2015 that are expected to be converted to urban uses under planned conditions.

It is anticipated that all assessment areas within the watershed, except the Grant Park Ravine assessment area, will experience increases in the levels of urban development based on local government comprehensive plans. Comparison of Tables 3.3 through 3.10 indicate that the number of assessment areas in the watershed with greater than 80 percent urban development is expected to increase from five in 2015 to seven under planned conditions (also see Map 3.10). Only one of the 15 assessment areas—the Middle Oak Creek Drainage Ditches—is anticipated to have more rural land uses than urban development. Four assessment areas are anticipated to experience an increase of urban development of greater than 20 percentage

Map 3.7
Existing Land Use Within the Oak Creek Watershed: 2015



Source: SEWRPC

Table 3.4
Land Use in Assessment Areas Within the Oak Creek Mainstem Subbasins: 2015

	Grant Park Ravine		Lower Oak Creek Mill Pond		Lower Oak Creek		Middle Oak Creek		Middle Oak Creek Drainage Ditches		Upper Oak Creek		Oak Creek Headwaters		Mainstem Subbasins
Land Use Categories	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	**Total Acres**
Urban															
Residential															
Single-Family, Rural Density[a]	0	0.0	0	0.0	1	0.0	25	0.8	12	0.9	11	0.6	4	0.6	53
Single-Family, Suburban Density[b]	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Single-Family, Low Density[c]	13	4.5	0	0.0	54	2.6	426	13.1	177	12.9	169	9.3	318	45.2	1,157
Single-Family, Medium Density[d]	26	9.1	123	13.2	647	31.6	426	13.1	57	4.2	108	5.9	126	17.8	1,513
Single-Family, High Density[e]	21	7.3	76	8.2	224	10.9	0	0.0	0	0.0	0	0.0	0	0.0	321
Multifamily	4	1.4	129	13.8	94	4.6	137	4.2	0	0.0	85	4.7	0	0.0	449
Residential Subtotal	64	22.3	324	35.2	1,020	49.7	1,014	31.2	246	18.0	373	20.5	448	63.6	3,393
Commercial	1	0.3	70	7.5	20	1.0	164	5.0	3	0.2	202	11.1	0	0.0	460
Industrial	11	3.8	112	12.0	12	0.6	36	1.1	18	1.3	94	5.1	0	0.0	283
Governmental and Institutional	1	0.3	75	8.0	129	6.3	148	4.5	8	0.6	60	3.3	5	0.7	426
Transportation, Communication, and Utilities	27	9.4	189	20.5	441	21.6	476	14.6	157	11.4	330	18.1	111	15.7	1,731
Recreational	114	40.2	28	3.0	146	7.1	179	5.5	11	0.8	59	3.2	3	0.4	540
Urban Subtotal	218	76.3	802	86.2	1,768	86.3	2,017	61.9	443	32.3	1,118	61.3	567	80.4	6,933
Nonurban															
Agricultural	0	0.0	0	0.0	39	1.9	433	13.3	247	18.0	208	11.4	25	3.5	952
Other Open Lands	1	0.3	32	3.4	132	6.5	412	12.7	154	11.2	306	16.7	42	5.9	1,079
Wetlands	14	4.9	32	3.4	63	3.1	270	8.3	431	31.4	86	4.7	27	3.8	923
Woodlands	52	18.2	43	4.6	38	1.9	97	3.0	69	5.0	92	5.0	43	6.1	434
Water	1	0.3	6	0.6	6	0.3	27	0.8	12	0.9	17	0.9	2	0.3	71
Extractive	0	0.0	17	1.8	0	0.0	0	0.0	16	1.2	0	0.0	0	0.0	33
Landfill	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Nonurban Subtotal	68	23.7	130	13.8	278	13.7	1,239	38.1	929	67.7	709	38.7	139	19.6	3,492
Total	286	--	932	--	2,046	--	3,256	--	1,372	--	1,827	--	706	--	10,425

Note: Offstreet parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[b] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[c] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[d] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

[e] *High density residential reflects 7 or more dwelling units per net residential acre.*

Source: SEWRPC

Table 3.5
Land Use in Assessment Areas Within the Mitchell Field Drainage Ditch Subbasin: 2015

Land Use Categories	Lower Mitchell Field Drainage Ditch Acres	Lower Mitchell Field Drainage Ditch Percent of Area	Mitchell Field Drainage Ditch – Airport Acres	Mitchell Field Drainage Ditch – Airport Percent of Area	Subbasin Total Acres
Urban					
Residential					
Single-Family, Rural Density[a]	1	0.1	1	0.1	2
Single-Family, Suburban Density[b]	0	0.0	0	0.0	0
Single-Family, Low Density[c]	72	5.0	9	0.9	81
Single-Family, Medium Density[d]	72	5.0	39	3.9	111
Single-Family, High Density[e]	0	0.0	0	0.0	0
Multifamily	20	1.4	5	0.5	25
Residential Subtotal	165	11.5	54	5.4	219
Commercial	51	3.5	32	3.2	83
Industrial	85	5.9	70	6.9	155
Governmental and Institutional	34	2.4	112	11.1	146
Transportation, Communication, and Utilities	263	18.2	651	64.4	922
Recreational	101	7.0	3	0.3	104
Urban Subtotal	699	48.5	922	91.3	1,621
Nonurban					
Agricultural	228	15.8	0	0.0	228
Other Open Lands	339	23.5	54	5.3	393
Wetlands	59	4.1	15	1.5	74
Woodlands	97	6.7	19	1.9	116
Water	5	0.3	0	0.0	5
Extractive	16	1.1	0	0.0	16
Landfill	0	0.0	0	0.0	0
Nonurban Subtotal	744	51.5	88	8.7	832
Total	1,443	--	1,010	--	2,453

Note: Offstreet parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[b] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[c] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[d] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

[e] *High density residential reflects 7 or more dwelling units per net residential acre.*

Source: SEWRPC

points (expressed relative to the entire watershed area) including the Upper Oak Creek (increase of 20.3 percentage points), the Lower Mitchell Field Drainage Ditch (increase of 31.2 percentage points), the Drexel Avenue Tributary (increase of 25.2 percentage points), and the Rawson Avenue Tributary (increase of 20.2 percentage points).

Urban Development and Impervious Surface

Urban land uses in the Oak Creek watershed have been increasing since the first SEWRPC land use inventory was conducted in 1963, and are expected to continue to increase based on local comprehensive plans (see Figure 3.3). When urban development in a watershed increases, the amount of impervious surface area increases. Many researchers throughout the United States, including researchers at the WDNR, report that the amount of connected impervious surface area is the best indicator of the level of urbanization in a watershed.[90] Directly connected impervious surface areas are areas that discharge directly to the

[90] *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.*

Table 3.6
Land Use in Assessment Areas Within the North Branch Oak Creek Subbasin: 2015

Land Use Categories	Lower North Branch Oak Creek		Upper North Branch Oak Creek		Southland Creek		Drexel Avenue Tributary		Rawson Avenue Tributary		College Avenue Tributary		Subbasin Total Acres
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	
Urban													
Residential													
Single-Family, Rural Density[a]	1	0.1	1	0.1	2	0.3	4	0.5	1	0.1	0	0.0	9
Single-Family, Suburban Density[b]	0	0	0	0	0	0.0	0	0.0	0	0.0	0	0.0	0
Single-Family, Low Density[c]	73	7.5	56	4.5	198	28.5	78	9.6	51	5.3	1	0.2	457
Single-Family, Medium Density[d]	75	7.7	226	18.0	42	6.0	20	2.5	2	0.2	90	19.9	455
Single-Family, High Density[e]	0	0	0	0	0	0.0	0	0.0	2	0.2	46	10.2	48
Multifamily	102	10.4	54	4.3	31	4.5	5	0.6	36	3.7	22	4.9	250
Residential Subtotal	251	25.7	337	26.9	273	39.3	107	18.5	92	9.5	159	35.2	1,219
Commercial	14	1.4	110	8.8	15	2.2	35	4.3	77	8.0	31	6.8	268
Industrial	133	13.6	100	8.0	1	0.1	14	1.7	133	13.7	31	6.8	412
Governmental and Institutional	43	4.4	63	5.0	3	0.4	10	1.2	23	2.4	6	1.3	148
Transportation, Communication, and Utilities	128	13.1	298	23.5	111	15.9	134	16.5	221	22.8	135	29.8	1,027
Recreational	24	2.5	22	1.8	0	0.0	0	0.0	11	1.1	6	1.3	63
Urban Subtotal	593	60.7	930	74.0	403	57.9	300	36.9	557	57.5	368	81.2	3151
Nonurban													
Agricultural	99	10.1	1	0.1	70	10.1	207	25.4	107	11.1	0	0.0	484
Other Open Lands	162	16.5	230	18.2	99	14.2	146	17.9	174	18.0	72	15.9	883
Wetlands	78	8.0	50	4.0	65	9.3	69	8.5	52	5.4	13	2.9	327
Woodlands	37	3.8	41	3.3	57	8.2	88	10.8	75	7.7	0	0.0	298
Water	9	0.9	5	0.4	2	0.3	4	0.5	3	0.3	0	0.0	23
Extractive	0	0.0	0	0	0	0.0	0	0.0	0	0.0	0	0.0	0
Landfill	0	0.0	0	0	0	0.0	0	0.0	0	0.0	0	0.0	0
Nonurban Subtotal	385	39.3	327	26.0	293	42.1	514	63.1	411	42.5	85	18.8	2,015
Total	978	--	1,257		696	--	814	--	968	--	453	--	5,166

Note: Offstreet parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[b] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[c] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[d] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

[e] *High density residential reflects 7 or more dwelling units per net residential acre.*

Source: SEWRPC

Table 3.7
Land Use In Assessment Areas Within the Oak Creek Watershed: 2015

Land Use Categories	Oak Creek Mainstem Subbasins Total Acres	Mitchell Field Drainage Ditch Subbasin Total Acres	Oak Creek North Branch Subbasin Total Acres	Watershed Total	
				Total Acres	Percent of Total Area
Urban					
Residential					
Single-Family, Rural Density[a]	53	2	9	64	0.4
Single-Family, Suburban Density[b]	0	0	0	0	0.0
Single-Family, Low Density[c]	1,157	81	457	1,695	9.4
Single-Family, Medium Density[d]	1,513	111	455	2,079	11.5
Single-Family, High Density[e]	321	0	48	369	2.0
Multifamily	449	25	250	724	4.0
Residential Subtotal	3,493	219	1,219	4,931	27.3
Commercial	460	83	268	825	4.6
Industrial	283	155	412	850	4.7
Governmental and Institutional	426	146	148	720	4.0
Transportation, Communication, and Utilities	1,731	922	1,027	3,672	20.4
Recreational	540	104	63	707	3.9
Urban Subtotal	6,933	1,621	3151	11,705	64.9
Nonurban					
Agricultural	952	228	484	1,664	9.2
Other Open Lands	1,079	393	883	2,355	13.1
Wetlands	923	74	327	1,324	7.3
Woodlands	434	116	298	848	4.7
Water	71	5	23	99	0.5
Extractive	33	16	0	49	0.3
Landfill	0	0	0	0	0.0
Nonurban Subtotal	3,492	832	2,015	6,339	35.1
Total	10,425	2,453	5,166	18,044	--

Note: Offstreet parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[b] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[c] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[d] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

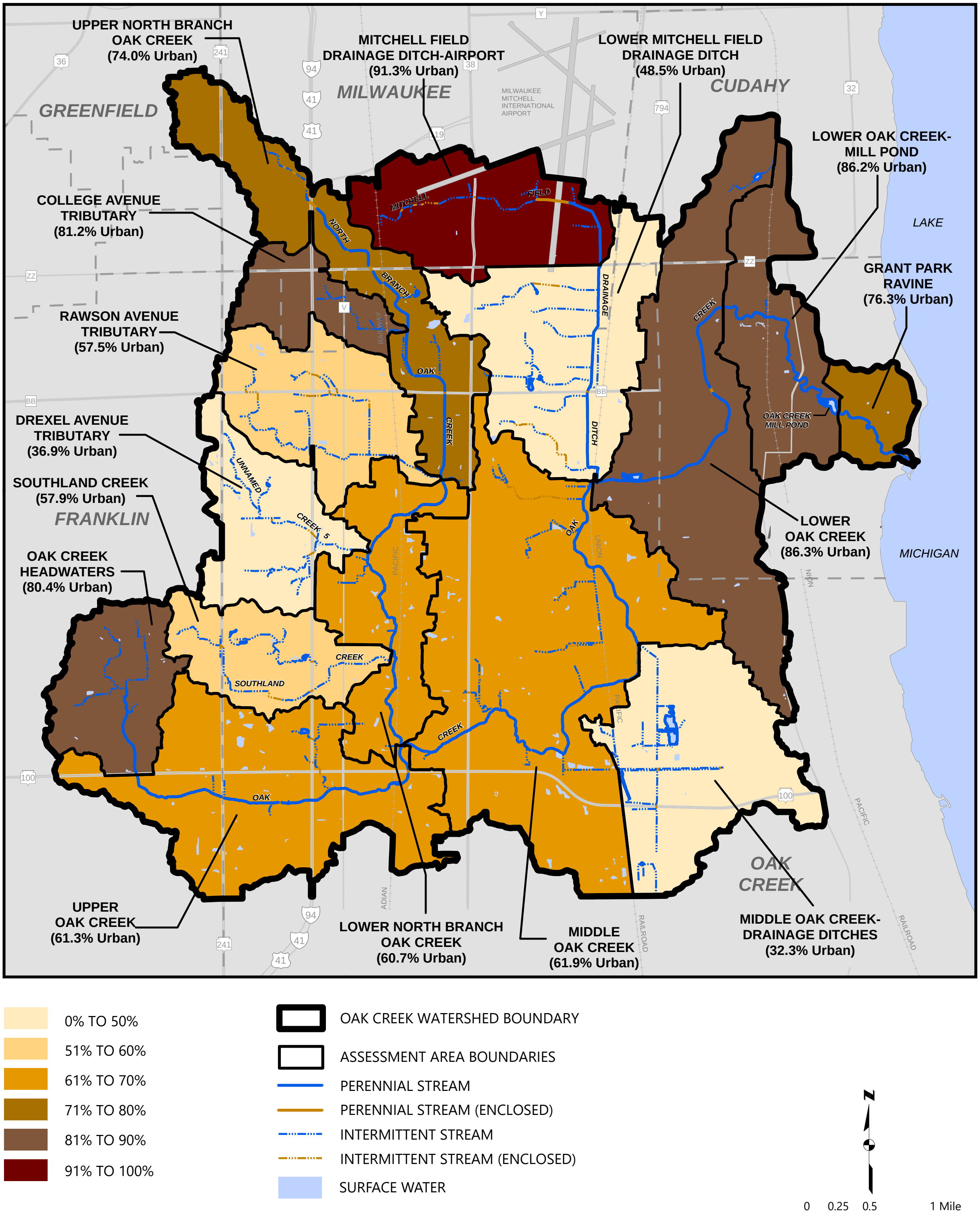
[e] *High density residential reflects 7 or more dwelling units per net residential acre.*

Source: SEWRPC

stormwater drainage system, and, ultimately to a stream, without the potential for infiltration through discharge to pervious surfaces or facilities specifically designed to infiltrate runoff. Studies have found that impervious surfaces:

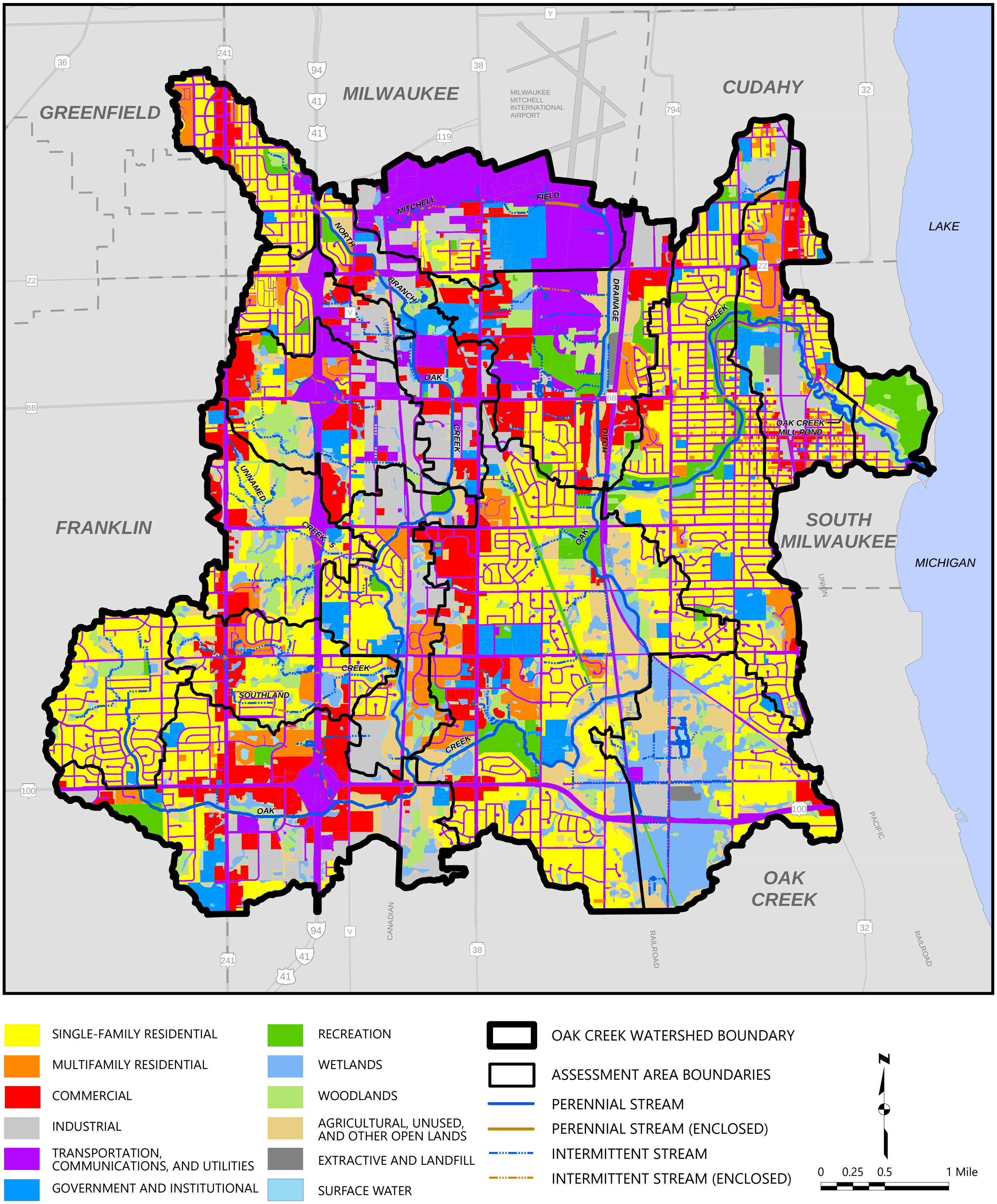
- Contribute to hydrologic changes that degrade waterways
- Are a major component of intensive land uses that generate pollution
- Prevent natural pollution attenuation or removal in the soil by preventing infiltration
- Serve as an efficient conveyance system transporting pollutants to waterways

Map 3.8
Percent Urban Land Uses Within Assessment Areas in the Oak Creek Watershed: 2015



Source: SEWRPC

Map 3.9
Planned Land Use Within the Oak Creek Watershed



Note: Planned conditions are based on local government comprehensive plans.

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee and SEWRPC

Table 3.8
Planned Land Use in Assessment Areas Within the Oak Creek Mainstem Subbasins[a]

	Grant Park Ravine		Lower Oak Creek Mill Pond		Lower Oak Creek		Middle Oak Creek		Middle Oak Creek Drainage Ditches		Upper Oak Creek		Oak Creek Headwaters		Mainstem Subbasins
Land Use Categories	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	**Total Acres**
Urban															
Residential															
Single-Family, Rural Density[b]	0	0.0	0	0.0	1	0.0	22	0.7	9	0.7	3	0.2	4	0.6	39
Single-Family, Suburban Density[c]	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Single-Family, Low Density[d]	13	4.5	0	0.0	78	3.8	559	17.2	267	19.5	187	10.2	354	50.2	1,458
Single-Family, Medium Density[e]	26	9.1	123	13.2	670	32.8	471	14.5	61	4.4	112	6.1	126	17.8	1,589
Single-Family, High Density[f]	21	7.3	78	8.4	228	11.1	0	0.0	0	0.0	0	0.0	0	0.0	327
Multifamily	4	1.4	135	14.5	103	5.0	171	5.3	0	0.0	85	4.7	0	0.0	498
Residential Subtotal	64	22.3	336	36.1	1,080	52.7	1,223	37.7	337	24.6	387	21.2	484	68.6	3,911
Commercial	1	0.3	80	8.6	28	1.4	249	7.6	23	1.7	358	19.6	0	0.0	739
Industrial	11	3.8	119	12.8	67	3.3	54	1.7	87	6.3	243	13.3	0	0.0	581
Governmental and Institutional	1	0.3	75	8.0	132	6.5	161	4.9	8	0.6	93	5.1	5	0.7	475
Transportation, Communication, and Utilities	27	9.4	189	20.3	454	22.2	525	16.1	183	13.3	350	19.2	120	17.0	1,848
Recreational	114	40.2	28	3.0	146	7.1	182	5.6	11	0.8	59	3.2	3	0.4	543
Urban Subtotal	218	76.3	827	88.8	1,907	93.2	2,394	73.6	649	47.3	1,490	81.6	612	86.7	8,097
Nonurban															0
Agricultural	0	0.0	0	0.0	7	0.3	268	8.2	132	9.6	59	3.2	0	0.0	466
Other Open Lands	1	0.3	7	0.8	25	1.2	200	6.1	63	4.6	86	4.7	22	3.1	404
Wetlands	14	4.9	32	3.4	63	3.1	270	8.3	431	31.4	86	4.7	27	3.8	923
Woodlands	52	18.2	43	4.6	38	1.9	97	3.0	69	5.0	89	4.9	43	6.1	431
Water	1	0.3	6	0.6	6	0.3	27	0.8	12	0.9	17	0.9	2	0.3	71
Extractive	0	0.0	17	1.8	0	0.0	0	0.0	16	1.2	0	0.0	0	0.0	33
Landfill	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Nonurban Subtotal	68	23.7	105	11.2	139	6.8	862	26.4	723	52.7	337	18.4	94	13.3	2,328
Total	286	--	932	--	2,046	--	3,256	--	1,372	--	1,827	--	706	--	10,425

Note: Offstreet parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Planned conditions are based on local government comprehensive plans.*

[b] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[c] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[d] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[e] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

[f] *High density residential reflects 7 or more dwelling units per net residential acre.*

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee and SEWRPC

Table 3.9
Planned Land Use in Assessment Areas Within the Mitchell Field Drainage Ditch Subbasin

Land Use Categories	Lower Mitchell Field Drainage Ditch Acres	Lower Mitchell Field Drainage Ditch Percent of Area	Mitchell Field Drainage Ditch – Airport Acres	Mitchell Field Drainage Ditch – Airport Percent of Area	Subbasin Total Acres
Urban					
Residential					
Single-Family, Rural Density[b]	0	0.0	1	0.1	1
Single-Family, Suburban Density[c]	0	0.0	0	0.0	0
Single-Family, Low Density[d]	58	4.0	11	1.1	69
Single-Family, Medium Density[e]	96	6.7	45	4.5	141
Single-Family, High Density[f]	0	0.0	0	0.0	0
Multifamily	32	2.2	3	0.3	35
Residential Subtotal	186	12.9	60	6.0	246
Commercial	254	17.6	39	3.9	293
Industrial	113	7.8	94	9.3	207
Governmental and Institutional	47	3.3	115	11.4	162
Transportation, Communication, and Utilities	443	30.8	660	65.2	1,103
Recreational	106	7.3	3	0.3	109
Urban Subtotal	1,149	79.7	971	96.1	2,120
Nonurban					0
Agricultural	39	2.7	0	0.0	39
Other Open Lands	78	5.4	5	0.5	83
Wetlands	59	4.1	15	1.5	74
Woodlands	97	6.7	19	1.9	116
Water	5	0.3	0	0.0	5
Extractive	16	1.1	0	0.0	16
Landfill	0	0.0	0	0.0	0
Nonurban Subtotal	294	20.3	39	3.9	333
Total	1,443	--	1,010	--	2,453

Note: Offstreet parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Planned conditions are based on local government comprehensive plans.*

[b] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[c] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[d] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[e] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

[f] *High density residential reflects 7 or more dwelling units per net residential acre.*

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee and SEWRPC

Research over the last 20 years shows a strong relationship between the connected imperviousness of a drainage basin and the health of receiving streams.[91] Studies have found that relatively low levels of urbanization—8 to 12 percent connected impervious surface—can cause subtle changes in physical (flashy flows, increased water temperatures and turbidity) and chemical (reduced dissolved oxygen and increased

[91] *Wang, L., 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 36(5):1173-1189, 2000; Wang, L., J. Lyons, P. Kanehl, and R. Gatti. "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams," Fisheries 22(6):6-12, 1997; Arnold, C., and C.J. Gibbons. "Impervious Surface Coverage. The Emergence of a Key Environmental Indicator," Journal of the American Planning Association 62(2):243-258, 1996; Schueler, T., Site Planning for Urban Stream Protection. Center for Watershed Protection, 1995; Ellicot, MD; Masterson, J.P., and R.T. Bannerman. "Impacts of Stormwater Runoff on Urban Streams in Milwaukee, Wisconsin," National Symposium on Water Quality, American Water Resources Association. Middelburg, VA, 1994; and Schueler, T., "The Importance of Imperviousness," Watershed Protection Techniques 1:100-111, 1994.*

Table 3.10
Planned Land Use in Assessment Areas Within the North Branch Oak Creek Subbasin[a]

Land Use Categories	Lower North Branch Oak Creek		Upper North Branch Oak Creek		Southland Creek		Drexel Avenue Tributary		Rawson Avenue Tributary		College Avenue Tributary		Subbasin Total Acres
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	
Urban													
Residential													
Single-Family, Rural Density[b]	1	0.1	0	0.0	2	0.3	4	0.5	0	0.0	0	0.0	7
Single-Family, Suburban Density[c]	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Single-Family, Low Density[d]	78	8.0	38	3.0	239	34.4	168	20.5	85	8.8	0	0.0	608
Single-Family, Medium Density[e]	109	11.1	228	18.1	42	6.0	20	2.5	4	0.4	90	19.9	493
Single-Family, High Density[f]	0	0.0	0	0.0	0	0.0	0	0.0	3	0.3	46	10.1	49
Multifamily	116	11.9	56	4.5	47	6.8	16	2.0	54	5.6	22	4.9	311
Residential Subtotal	304	31.1	322	25.6	330	47.5	208	25.5	146	15.1	158	34.6	1,468
Commercial	23	2.4	184	14.6	65	9.3	107	13.1	148	15.3	34	7.5	561
Industrial	199	20.2	177	14.1	0	0.0	16	2.0	166	17.1	66	14.6	624
Governmental and Institutional	53	5.4	72	5.7	6	0.9	15	1.8	33	3.4	6	1.3	185
Transportation, Communication, and Utilities	139	14.2	316	25.1	133	19.1	160	19.7	248	25.7	140	30.9	1,136
Recreational	24	2.5	22	1.8	0	0.0	0	0.0	11	1.1	6	1.3	63
Urban Subtotal	742	75.8	1,093	86.9	534	76.8	506	62.1	752	77.7	410	90.5	4037
Nonurban													0
Agricultural	35	3.6	0	0.0	8	1.1	77	9.5	25	2.6	0	0.0	145
Other Open Lands	77	7.9	68	5.4	32	4.6	70	8.6	61	6.3	30	6.6	338
Wetlands	78	8.0	50	4.0	65	9.3	69	8.5	52	5.4	13	2.9	327
Woodlands	37	3.8	41	3.3	55	7.9	88	10.8	75	7.7	0	0.0	296
Water	9	0.9	5	0.4	2	0.3	4	0.5	3	0.3	0	0.0	23
Extractive	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Landfill	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Nonurban Subtotal	236	24.2	164	13.1	162	23.2	308	37.9	216	22.3	43	9.5	1,129
Total	978	--	1,257	--	696	--	814	--	968	--	453	--	5,166

Note: Offstreet parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Planned conditions are based on local government comprehensive plans..*

[b] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[c] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[d] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[e] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

[f] *High density residential reflects 7 or more dwelling units per net residential acre.*

Source: Cities of Cudahy, Franklin, Greenfield, Oak Creek, Milwaukee, and South Milwaukee and SEWRPC

Table 3.11
Planned Land Use In Assessment Areas Within the Oak Creek Watershed[a]

Land Use Categories	Oak Creek Mainstem Subbasins Total Acres	Mitchell Field Drainage Ditch Subbasin Total Acres	Oak Creek North Branch Subbasin Total Acres	Watershed Total	
				Total Acres	Percent of Total Area
Urban					
Residential					
Single-Family, Rural Density[b]	39	1	7	47	0.3
Single-Family, Suburban Density[c]	0	0	0	0	0.0
Single-Family, Low Density[d]	1,458	69	608	2135	11.8
Single-Family, Medium Density[e]	1,589	141	493	2223	12.3
Single-Family, High Density[f]	327	0	49	376	2.1
Multifamily	498	35	311	844	4.7
Residential Subtotal	3,911	246	1,468	5,625	31.2
Commercial	739	293	561	1593	8.8
Industrial	581	207	624	1412	7.8
Governmental and Institutional	475	162	185	822	4.6
Transportation, Communication, and Utilities	1,848	1,103	1,136	4087	22.6
Recreational	543	109	63	715	4.0
Subtotal	8,097	2,120	4037	14,254	79.0
Nonurban	0	0	0		
Agricultural	466	39	145	650	3.6
Other Open Lands	404	83	338	825	4.6
Wetlands	923	74	327	1,324	7.3
Woodlands	431	116	296	843	4.7
Water	71	5	23	99	0.5
Extractive	33	16	0	49	0.3
Landfill	0	0	0	0	0.0
Subtotal	2,328	333	1,129	3,790	21.0
Total	10,425	2,453	5,166	18,044	--

Note: Offstreet parking area is included with the associated land use. Wetlands associated with specific land uses were grouped in the wetland category except for farmed wetlands which were grouped as agricultural land use.

[a] *Planned conditions are based on local government comprehensive plans.*

[b] *Rural density residential reflects less than 0.2 dwelling units per acre.*

[c] *Suburban density residential reflects 0.2 – 0.6 dwelling units per net residential acre.*

[d] *Low density residential reflects 0.7 – 2.2 dwelling units per net residential acre.*

[e] *Medium density residential reflects 2.3 – 6.9 dwelling units per net residential acre.*

[f] *High density residential reflects 7 or more dwelling units per net residential acre.*

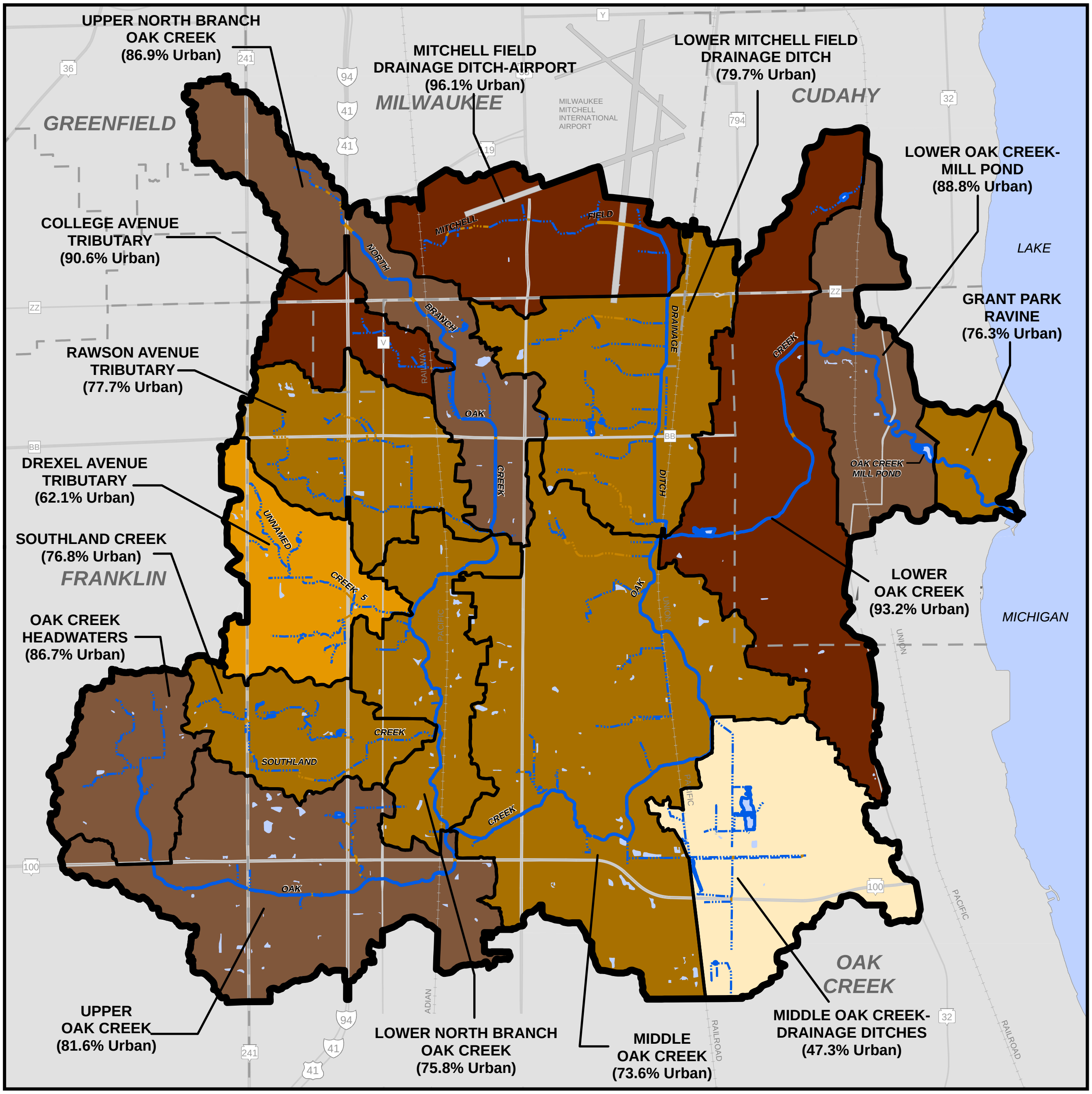
Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee and SEWRPC

pollutant levels) properties of a stream, leading to a decline in the biological integrity. For example, each 1 percent increase in watershed imperviousness can lead to an increase in water temperature of nearly 2.5°F.[92] While this temperature increase may appear to be small in magnitude, it can have significant impacts on fish (such as trout) and other biological communities that have a low tolerance to temperature fluctuations or that require specific thermal ranges.

The amount of directly connected impervious surface in a watershed can be estimated by applying a land use-specific connected impervious factor for each urban land use development type. The Oak Creek watershed

[92] *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.*

Map 3.10
Percent Planned Urban Land Uses Within Assessment Areas of the Oak Creek Watershed



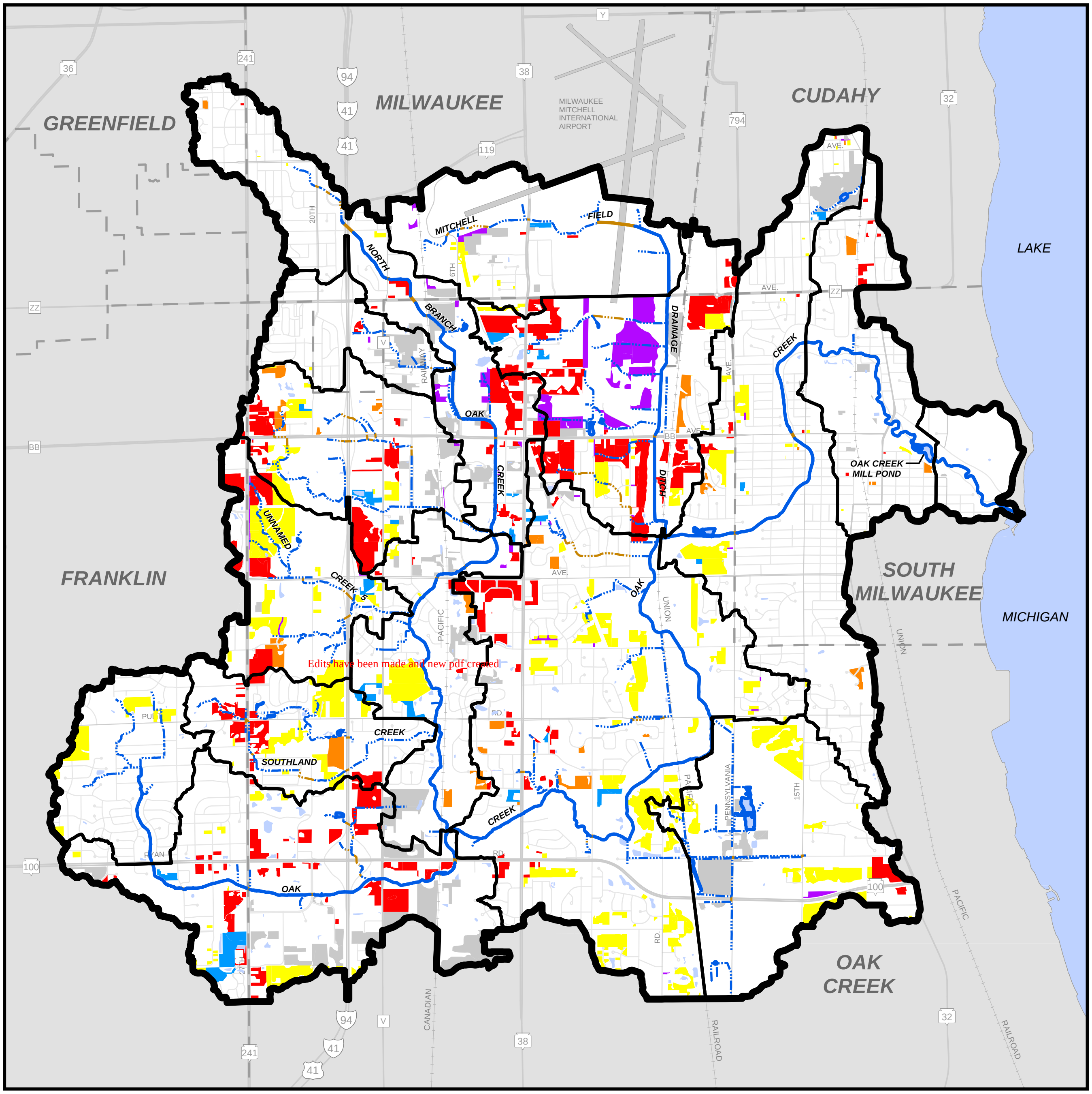
0% TO 50%	OAK CREEK WATERSHED BOUNDARY
51% TO 60% (NONE)	ASSESSMENT AREA BOUNDARIES
61% TO 70%	PERENNIAL STREAM
71% TO 80%	PERENNIAL STREAM (ENCLOSED)
81% TO 90%	INTERMITTENT STREAM
91% TO 100%	INTERMITTENT STREAM (ENCLOSED)
	SURFACE WATER

0 0.25 0.5 1 Mile

Note: Planned conditions are based on local government comprehensive plans.

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee and SEWRPC

Map 3.11
Locations Where Existing Year 2015 Agricultural Lands, Open Lands, and Woodlands are Projected to be Converted to Urban Land Uses Under Planned Conditions



PLANNED LAND USE

- SINGLE-FAMILY RESIDENTIAL
- MULTI-FAMILY RESIDENTIAL
- COMMERCIAL
- INDUSTRIAL
- TRANSPORTATION, COMMUNICATIONS, AND UTILITIES
- GOVERNMENT AND INSTITUTIONAL

- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

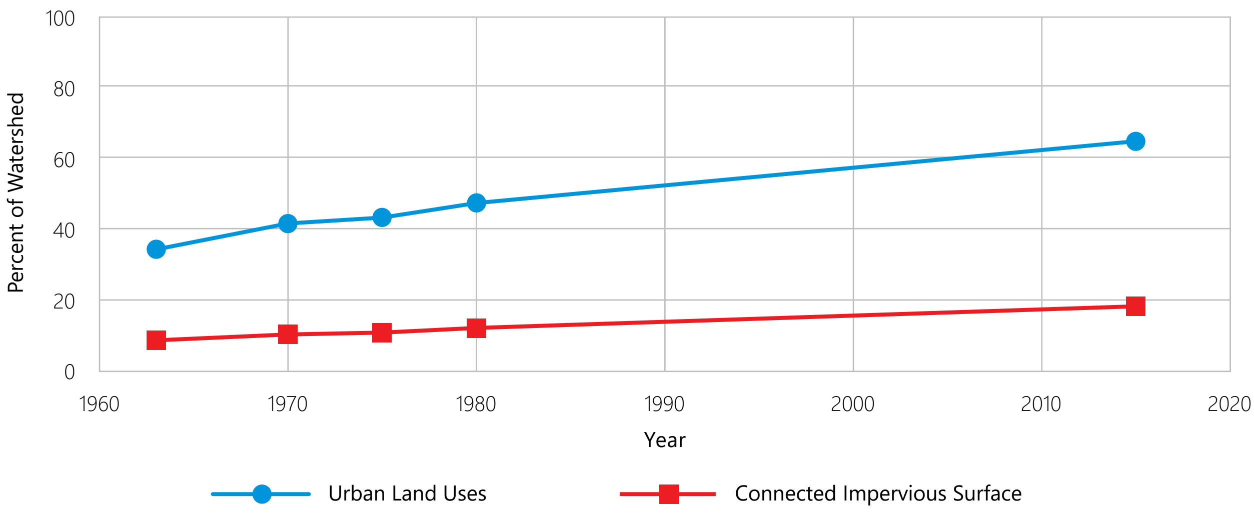
N

0 0.25 0.5 1 Mile

Note: Planned conditions are based on local government comprehensive plans.

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee and SEWRPC

Figure 3.3
Urban Land Uses and Connected Impervious Surface Within the Oak Creek Watershed: 1963-2015



Source: SEWRPC

had about 34.4 percent urban land uses in 1963,[93] which approximately corresponds to 8.7 percent directly connected imperviousness in the watershed. As of 2015, the watershed had about 64.9 percent urban land overall, corresponding to about 18.3 percent directly connected imperviousness (see Figure 3.3 and Table 3.12). That level of imperviousness is well above the threshold at which changes in properties of streams can occur, as described above. These changes have likely led to a decline in the biological integrity of the streams in the Oak Creek watershed and will be discussed in further detail in Chapter 4 of this report.

Table 3.12 sets forth estimated connected impervious area percentages by assessment area for existing year 2015 and planned land use conditions. The 2015 connected impervious area percentages by assessment area range from a low of 6.7 percent in the Middle Oak Creek-Drainage Ditches assessment area to a high of 31.4 percent in the Mitchell Field Drainage Ditch-Airport assessment area. Projections for the connected impervious area percentages for planned conditions range from a low of 10.9 percent in the Grant Park Ravine assessment area to a maximum of 34.1 percent in the Upper Oak Creek assessment area. Under 2015 conditions, all assessment areas except the Middle Oak Creek-Drainage Ditches assessment area have connected impervious area percentages above the 8 percent lower bound of the threshold level at which changes in stream properties may occur in the absence of mitigating measures on the landscape. Under planned conditions, all assessment areas are expected to have connected impervious area percentages above 8 percent.

These estimated levels of connected impervious surface in the Oak Creek watershed indicate that local stormwater management practices affecting runoff volume and water quality, such as those promoting detention, infiltration, green infrastructure projects, and preserving and expanding riparian buffers, will be crucial to mitigate the consequences of continued urban development within this watershed.

Sanitary Sewer Service Areas

The existing areas that are served by sanitary sewers and the extent of urban development not served by public sewerage systems within the Oak Creek watershed are shown on Map 3.12. Under existing conditions, approximately 60 to 70 percent of the watershed area is served by public sanitary sewerage systems. The remaining unserved areas are mostly made up of primary and secondary environmental corridor or agricultural and other open lands that have not been developed for urban uses. The small enclaves of urban development that are not served by sanitary sewerage systems are shown in red on Map 3.12, and total about 52 acres, or 0.2 percent of the watershed. These small areas consist of mostly low-density and rural density residential, commercial, and wholesaling and storage land uses. Urban development in these areas is likely to be served by onsite sewage disposal systems. In addition, some buildings located within the

[93] *SEWRPC Planning Report No. 36,* op. cit.

sanitary sewer service area are not connected to the sewer system and are still served by onsite sewage disposal systems. An onsite sewage disposal system may be a conventional septic tank; a mound system; a holding tank; or an alternative system, such as an aerobic treatment unit or sand filter.

Table 3.12
Estimated Percent of Connected Impervious Surface Within Assessment Areas of the Oak Creek Watershed: 2015 and Planned Conditions

Assessment Area[a]	2015	Planned Conditions[b]
Mainstem		
Grant Park Ravine	11	11
Lower Oak Creek – Mill Pond	29	31
Lower Oak Creek	19	21
Middle Oak Creek Drainage Ditches	7	12
Middle Oak Creek	15	19
Upper Oak Creek	21	34
Oak Creek Headwaters	12	13
Mitchell Field Drainage Ditch		
Lower Mitchell Field Drainage Ditch	15	31
Mitchell Field Drainage Ditch – Airport	31	34
North Branch Oak Creek		
Lower North Branch Oak Creek	20	26
Upper North Branch Oak Creek	25	34
Southland Creek	11	19
Drexel Avenue Tributary	11	21
Rawson Avenue Tributary	24	34
College Avenue Tributary	25	31
Total Watershed	18	25

[a] *Assessment areas are shown on Map 3.2.*

[b] *Planned conditions are based on local government comprehensive plans.*

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee, and SEWRPC

Transportation

The transportation system within the Oak Creek watershed provides the basis for moving goods and people into, out of, and through the watershed. Road culverts and bridges can have a major influence on the hydrology and habitat of a stream, and the connectivity to upstream and downstream areas for both aquatic and terrestrial wildlife. The need for deicing products to maintain safe functionality of roads and airports during the winter season can have an impact on water quality conditions in both surface and groundwater resources within a watershed. In addition, runoff from roadways can carry other contaminants from automobiles.

If designed and planned correctly, road construction projects often present opportunities to incorporate improvements to stream channel hydrology, habitat, and aquatic and terrestrial wildlife migration. However, when the health of nearby streams, rivers, and lakes are not sufficiently considered, roads and related construction projects can have negative consequences. Thus, a basic understanding of the existing transportation system within the Oak Creek watershed is a factor to consider while preparing a restoration plan for the watershed.

Arterial Streets and Highways

The western assessment areas of the Oak Creek watershed are traversed in a north-south direction by Interstate Highway 94 (IH 94). IH 94 is a major corridor used extensively for freight transport as well as daily commutes. Major north-south arterials within the watershed include STH 241 (South 27th Street), STH 38 (Howell Avenue), and STH 32 (Chicago Avenue). Major east-west arterials include STH 100 (Ryan Road), Puetz Road, Drexel Avenue, CTH BB (Rawson Avenue), and CTH ZZ (College Avenue). The watershed also contains many collector and land access streets serving residential neighborhoods.

Airports

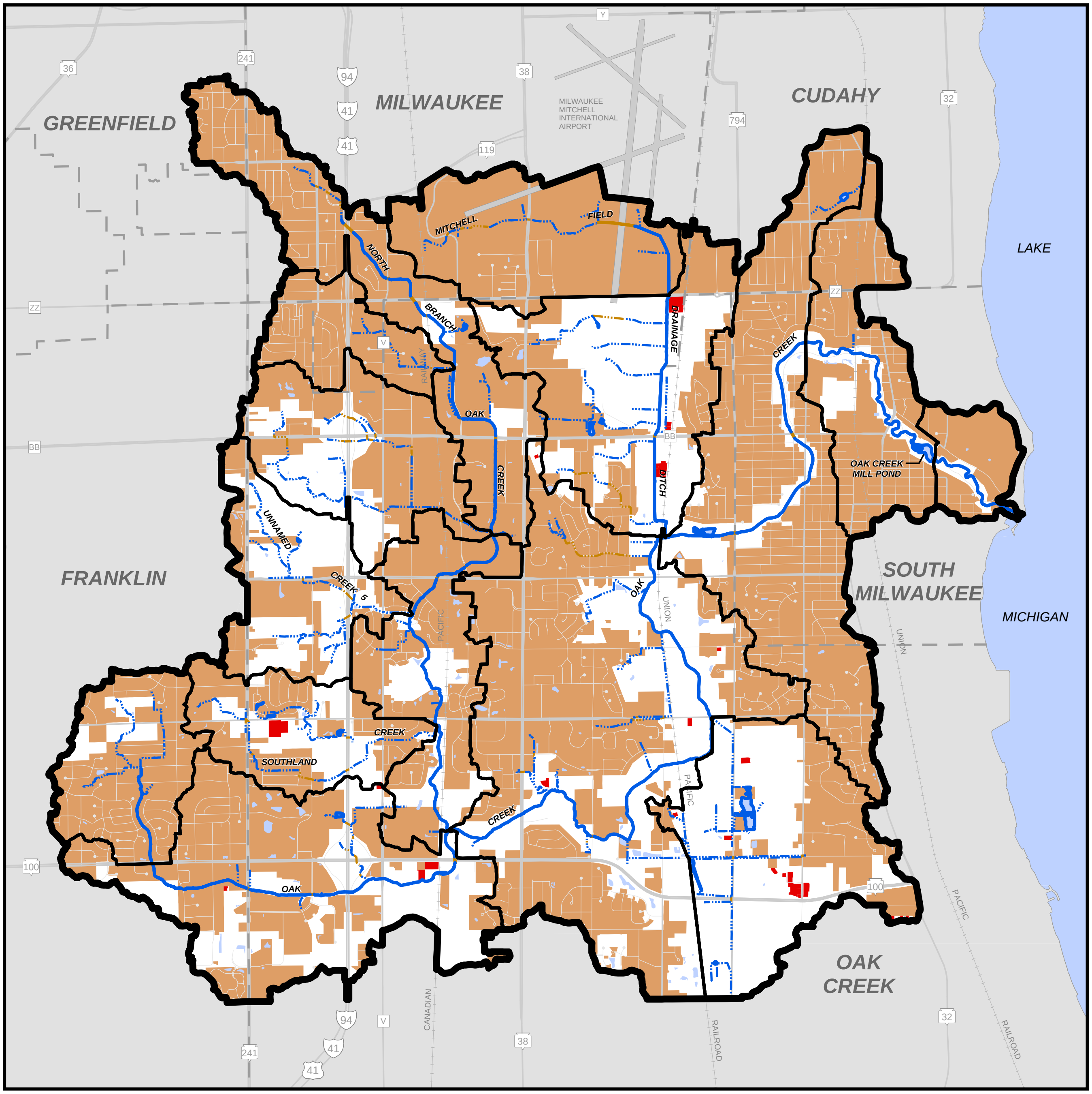
Part of Milwaukee Mitchell International Airport property lies within the northern portion of the Oak Creek watershed. Milwaukee Mitchell International Airport is the largest airport in the State and serves more than 4 million passengers per year. The Mitchell Field Drainage Ditch traverses the southern portion of the runway areas of the airport and is a major tributary to the mainstem of Oak Creek.

3.6 CLIMATE AND CLIMATE CHANGE

Climate, which is the long-term weather conditions in an area, is an important to consider in assessing the current conditions of the Oak Creek watershed and planning for the future health of its water resources. Recent assessments have documented changes in Wisconsin's climate over the late 20th century.[94]

[94] *For example, Christopher J. Kucharik, Shawn P. Serbin, Steve Vavrus, Edward J. Hopkins, and Melissa M. Motew, "Patterns of Climate Change across Wisconsin from 1950-2006,"* Physical Geography, *Volume 31, pages 1-28, 2010.*

Map 3.12
Areas Served by Sanitary Sewer Within the Oak Creek Watershed: 2010



AREA SERVED BY SANITARY SEWER

EXTENT OF URBAN DEVELOPMENT NOT SERVED BY PUBLIC SEWERAGE SYSTEMS

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

0 0.25 0.5 1 Mile

Source: SEWRPC

Projections of Wisconsin's future climate based on downscaled data from 14 global climate models indicate that additional changes will occur through the 21st century.[95] The following sections describe the changes that have occurred in Wisconsin's climate since 1950 and the changes that are projected to occur by the middle of the 21st century.

Air Temperature

Based on the 30-year average temperature data during the period of 1981 to 2010 from the official NOAA National Weather Service records, the average annual temperature at Milwaukee Mitchell International Airport was 47.8 degrees Fahrenheit. Average annual temperatures in Wisconsin increased over the last half of the 20th century. Between 1950 and 2006, average annual temperature in the State increased by 1.1°F.[96] In the vicinity of the Oak Creek watershed, the increase was between 1.5 and 2.0°F. Much of this increase in average annual temperature occurred in the form of higher night-time low temperatures. For example, over the period 1950 through 2006, the average number of days in which the daily low temperature fell below 0°F decreased by about six days per year. The greatest increase in temperatures occurred during winter and spring months. Depending on location within the Oak Creek watershed, average winter temperatures increased by 3.0 to 3.5°F over this period.

The consensus of downscaled results from climate models is that average annual temperatures will continue to increase through the 21st century.[97] Depending on location, the models project that average annual temperatures in Wisconsin will increase by between 4.0°F and 9.0°F over the period 1980 through 2055. This increase is projected to be on the order of 5.5°F in the vicinity of the Oak Creek watershed. The greatest changes are estimated to occur during the winter months, with average winter temperatures being projected to increase by about 7.5°F. By contrast, average temperatures in the watershed during the summer are projected to increase by about 5.5°F. Changes in extreme temperatures will accompany these changes in average temperature. The frequency of extreme daily high temperatures is also predicted to increase based on modeling results. The average number of days per year with daily high temperatures greater than 90°F is currently about 12 in southern Wisconsin. This is likely to double to about 25 days per year by 2055. By contrast, the frequency of extreme daily low temperatures is expected to decrease. The average number of days per year with daily low temperatures below 0°F is currently about 15 in southern Wisconsin. This is projected to decrease to about nine days per year by 2055.

Precipitation

Based on the 30-year average precipitation data during the period of 1981 to 2010 from the official NOAA National Weather Service records, the average annual precipitation at Milwaukee Mitchell International Airport was 34.8 inches. Average annual precipitation in Wisconsin increased over the last half of the 20th century. Between 1950 and 2006, average annual precipitation in the State increased by about 3.1 inches.[98] It should be noted that there was substantial variability in the change in average annual precipitation across the State, with some areas experiencing increases up to 7.0 inches, while areas in parts of northern Wisconsin experienced decreases in annual precipitation. Areas within the Oak Creek watershed experienced annual precipitation increases over this period of between 4.5 and 6.0 inches. Much of the increase in average precipitation occurred during autumn months. In the Oak Creek watershed, average precipitation during autumn months increased between 2.0 and 2.5 inches over the period from 1950 through 2006. Increases in precipitation also occurred to a lesser degree during winter, spring, and summer.

The frequency and magnitude of heavy precipitation events has also been increasing in Wisconsin. Extreme rainfall patterns in the City of Madison illustrate this trend. Between 2001 and 2010, there were 24 days in

---

[95] *Wisconsin Initiative on Climate Change Impacts,* Wisconsin's Changing Climate: Impacts and Adaptation*, Nelson Institute for Environmental Studies, University of Wisconsin-Madison and Wisconsin Department of Natural Resources, 2011. Downscaling is an analysis approach that enables climatological data generated by Intergovernmental Panel on Climate Change general circulation models developed at a relatively coarse geographic scale (e.g., climate change data for several large regions in an entire state) to be modified to represent a finer geographic scale (e.g., at the scale of a county or watershed).*

[96] *Kucharik and others, 2010,* op. cit.

[97] *Wisconsin Initiative on Climate Change, 2011,* op. cit.

[98] *Kucharik and others, 2010,* op. cit.

which 2.0 inches or more of precipitation fell in a single event. This is twice the previous maximum of 12 days with 2.0 inches or more of precipitation, which occurred in the decade between 1951 and 1960.

The consensus from downscaled results of climate models predict several changes in precipitation through the 21st century.[99] Most of the models project an increase in average annual precipitation in Southeastern Wisconsin of about 1.5 to 2.0 inches. The models indicate that the amount of precipitation falling during winter is likely to increase by about 25 percent. Due to the projected increase in temperatures, it is estimated that a greater amount of precipitation occurring during the winter will fall as rain rather than snow.[100] This will be accompanied by both an increase in the likelihood of freezing rain events and decreases in snow depth and snow cover. Model projections also show that Wisconsin will receive more precipitation and more frequent and intense precipitation events during the spring, especially during early spring. As in winter, it will become more likely for early spring precipitation to fall as rain rather than snow. The total amount of precipitation occurring during the summer is not projected to change much, but the models also indicate that the frequency of intense rainfall events will increase. In southern Wisconsin, the frequency of precipitation events in which two or more inches fall in a 24-hour period is expected to increase from about 12 events per decade to 15 events per decade by the middle of the 21st century. These changes will be concentrated in the spring and fall. The projections also indicate that the magnitude of the heaviest precipitation events will also increase. The shift to more heavy rainfall events but little change in total summertime precipitation implies that more dry days will occur in Wisconsin during the summer. More dry days, coupled with higher summer temperatures and the increases in evapotranspiration that may result from higher temperatures, may lead to an increase in the likelihood of summer droughts.

Effects of Climate Change on Water Resources

Climate directly affects water resources and such resources can serve as indicators of climate change at various temporal and spatial scales. The Wisconsin Initiative on Climate Change Impacts (WICCI) has concluded that projected future climate conditions may influence the quantity and quality of the State of Wisconsin's water resources. 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 3.4). The differences reflect local variations in land use, soil type and surface deposits, groundwater characteristics, and runoff and seepage responses to precipitation that illustrates the importance of considering the potential climate change effects on local hydrologic conditions and as part of a watershed restoration plan strategy.

Climate change appears 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 the water cycle. As shown in Figure 3.5, most of the water entering the landscape arrives as precipitation (rain and snowfall) that falls directly on waterbodies; or 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 discharging into lakes, wetlands, and streams. Even in the absence of climate change, when one part of the system is affected, all other parts are impacted. For example, an overdrawn groundwater aquifer used to irrigate crops or to provide potable water supply can lead to a reduction or complete loss in discharge of a local stream. More importantly, climate change exposes the vulnerabilities of water availability within a given area, and this vulnerability is proportional to how much humans have altered how water moves through the water cycle (e.g., through reducing groundwater recharge potential during land development and/or withdrawals from aquifers). This vulnerability becomes particularly evident during periods of prolonged drought conditions.

As discussed above, downscaled climate models predict that there will be an increase in annual precipitation in Southeastern Wisconsin, as well as an increase in precipitation falling as rain rather than snow due to higher temperatures. In addition, the frequency and magnitude of rainfall events is projected to increase. The combination of the above projections will likely lead to higher peak stream flows that can often lead to increased streambank erosion and sediment transport, as well as increases in nutrients and other pollutants entering the streams. While intense rainfall events are expected increase, there is projected to be little

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

[100] *Michael Notaro, David J. Lorenz, Daniel Vimont, Stephen Vavrus, Christopher Kucharik, and Kristie Franz, "21st Century Wisconsin Snow Projections Based on Operational Snow Model Driven by Statistically Downscaled Climate Data,"* International Journal of Climatology, *Volume 31, pages 1615-1633, 2011.*

change in total summertime precipitation, implying that there will be longer stretches of dry weather. These periods of dry weather could lead to decreased summertime baseflows, and when combined with warmer air temperatures, may produce increased water temperatures that can have a harmful impact on fish and other aquatic life. Streambank erosion and water temperatures within the Oak Creek watershed will be discussed in further detail in Chapter 4 of this report.

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 potential impacts to hydrologic processes and resources.[101] 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 as summarized below:

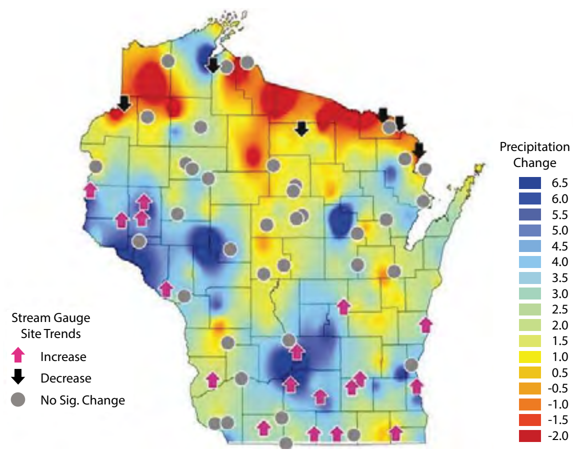
- Minimize threats to public health and safety by anticipating and managing for extreme events through effective planning.

- 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. Examples include 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 for humans and the environment.

- Maintain, improve, or restore water quality under a changing climate regime by promoting actions to reduce nutrient and sediment loading.

Figure 3.4
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: Water Resources Working Group of the Wisconsin Initiative on Climate Change Impacts and SEWRPC

Changing climatic conditions are drivers of water quality conditions within the Oak Creek system and these adaptation strategies are important considerations for the protection of surface water and groundwater quality and quantity as future development occurs within this watershed.

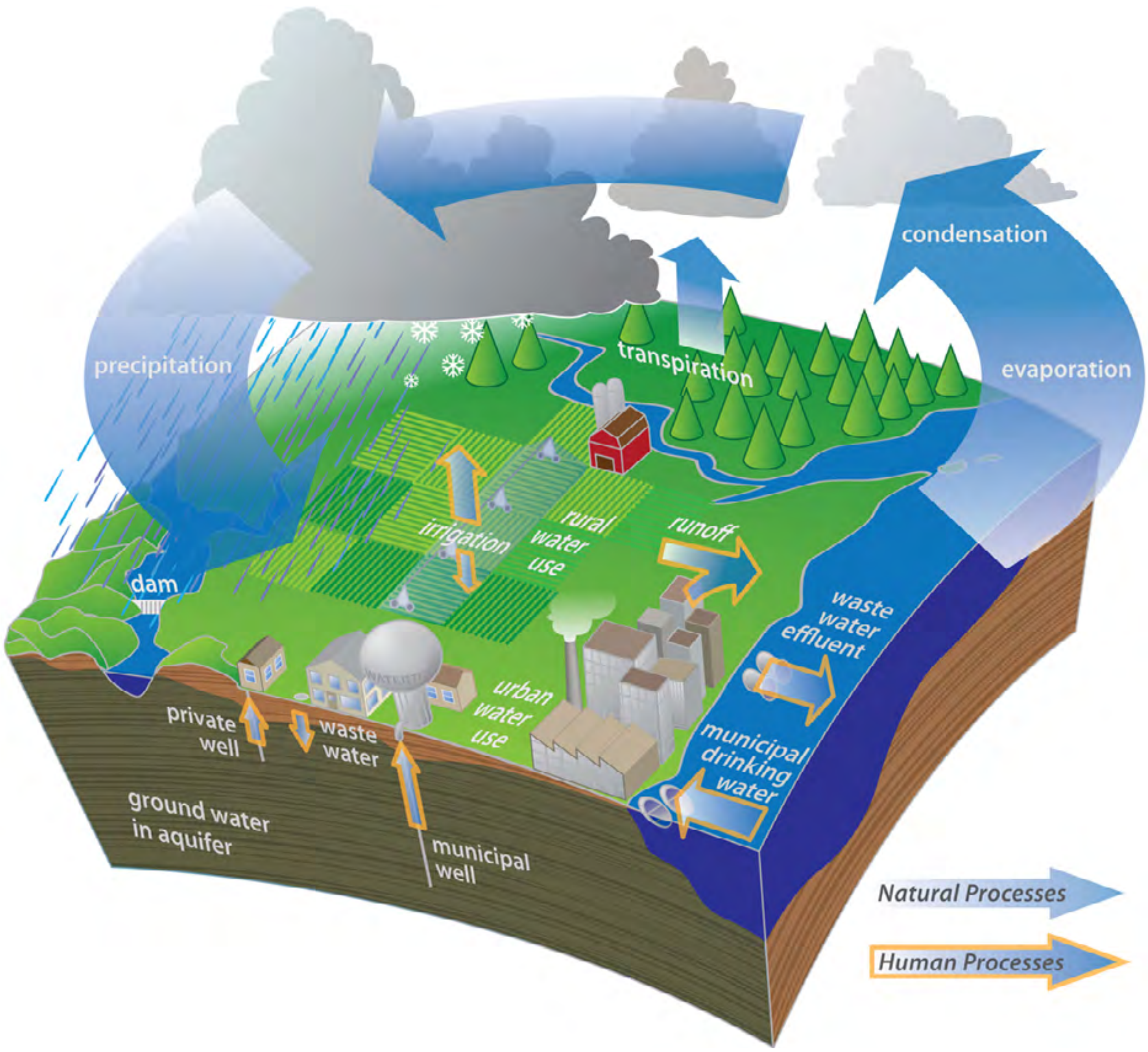
3.7 TOPOGRAPHY AND GEOLOGY

Topography is an important consideration in watershed planning since it is one of the most important factors determining the hydrologic response of a watershed to rainfall and snowmelt events. Topographic considerations enter into the selection of sites and routes for public utilities such as sewerage and water supply systems, flood control facilities, and roads. Topographical features, particularly slopes, have a direct bearing on the potential for soil erosion and the accumulation of sediment on the beds of surface waters.

Glaciation has largely determined the topography and physical geography of the Southeastern Wisconsin Region. Glacial deposits overlying the bedrock formations form the surface topography of the watershed,

[101] *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. For more details on climate change, impacts, adaptation, and resources visit www.wicci.wisc.edu/water-resources-working-group.php.*

Figure 3.5
Hydrologic Cycle of Water Movement



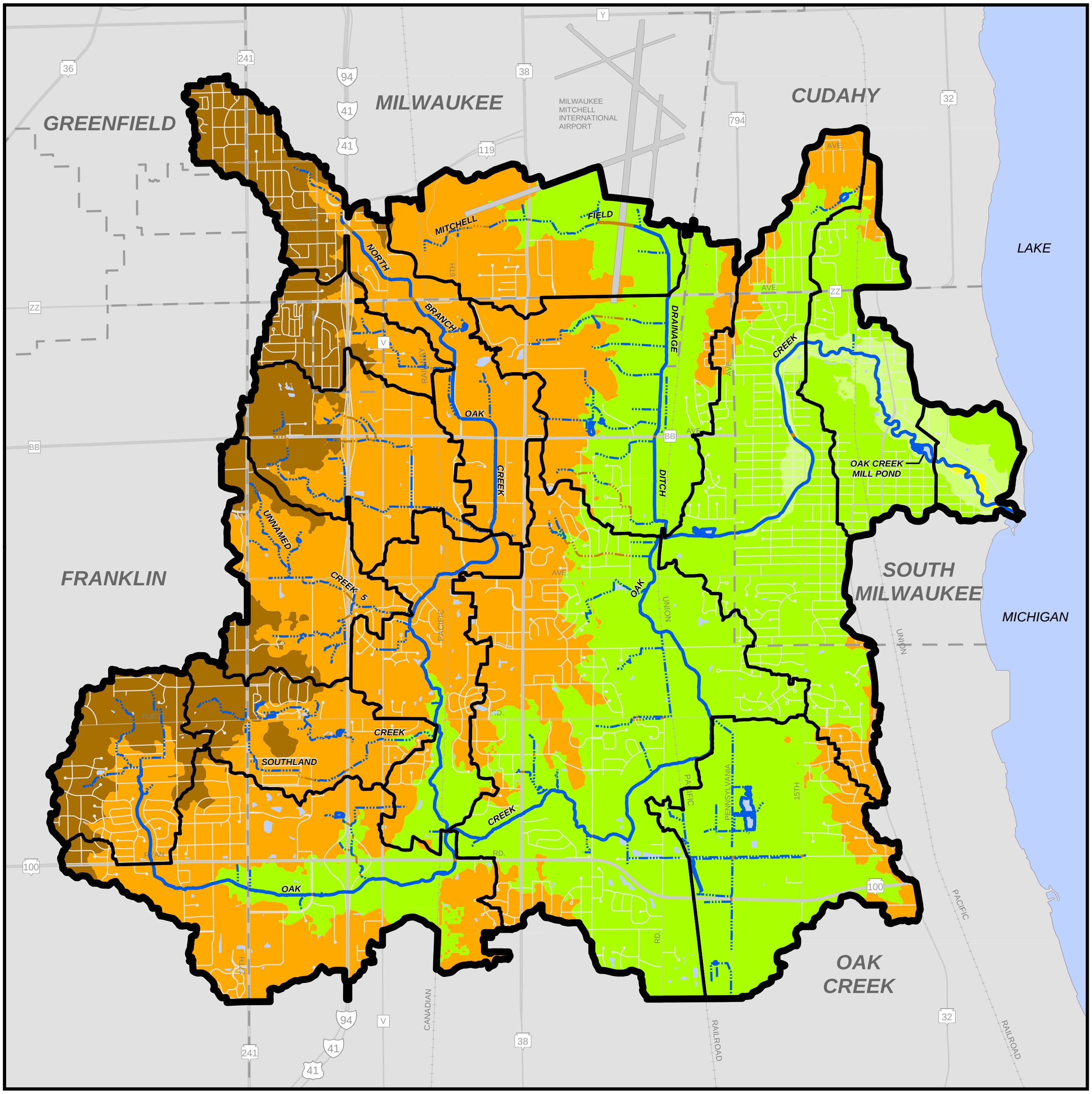
This schematic shows how human processes associated with land use development affect the natural processes of how water moves through its different states of the hydrologic cycle. Water returns to the atmosphere through evaporation (process by which water is changed from liquid to vapor), sublimation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

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

consisting primarily of gently sloping ground moraine. The generalized topographic elevations within the Oak Creek watershed are shown on Map 3.13. Generalized surface elevations range from 575 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29) near the confluence of Oak Creek with Lake Michigan to about 775 feet above NGVD 29 in the Upper North Branch Oak Creek assessment area, a variation of about 200 feet.

Bedrock and surface deposits directly and indirectly affect the quantity and quality of surface waters in the Oak Creek watershed. Discharge from groundwater is the source of baseflows in streams of the watershed. Especially at low flows, stream water chemistry reflects the influence of the composition of the bedrock and surface deposits. The surface deposits in the watershed consist of unconsolidated sediments that were deposited by glaciers during the Pleistocene glaciations that ended about 11,000 years ago. These are mostly unsorted tills consisting of sand, silt, clay, gravel, and boulders.

Map 3.13
Generalized Surface Elevations Within the Oak Creek Watershed



ELEVATION IN FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM, 1929 ADJUSTMENT

- 575
- 625
- 675
- 725
- 775

- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: SEWRPC

The Oak Creek watershed is underlain by Niagara dolomite, a sedimentary rock similar to limestone. This dolomite bedrock layer slopes downward in an easterly direction. Map 3.14 shows that the bedrock is located between 50 to 300 feet below the unconsolidated surficial deposits within the watershed.

3.8 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 and characteristics, along with land slope, surrounding land use, and vegetative cover are important factors in determining erosion potential and runoff in a watershed.

Soil data for the Oak Creek watershed was obtained from the NRCS SSURGO soils database. The soils within the Oak Creek watershed can be classified into three soil associations that are described below:

- Ozaukee-Morley-Mequon association is comprised of well-drained to somewhat poorly drained soils that have a subsoil of silty clay loam and silty clay. This association is formed in glacial till consisting of thin loess and silty clay loam and is found on glacial moraines.

- Montgomery-Martinton-Hebron-Saylesville association is comprised of poorly drained to well-drained soils that have a subsoil of clay to clay loam. This association consists of nearly level, wet soils that lie on flats and in depressions and are intermingled with better drained soils in slightly higher areas.

- Houghton-Palms-Adrian association is comprised of very poorly drained organic soils in marshy depressions over old lakebeds or on floodplains. These soils have mostly formed from dead and decaying remains of plants.

The dominant soil type within the watershed is the Ozaukee-Morley-Mequon group, composing nearly 90 percent of the soils. The remaining soils include the Mongomery-Martinton-Hebron association and Houghton-Palms-Adrian association, each comprising about 5 percent of the watershed and occurring only within the Middle Oak Creek and Middle Oak Creek—Drainage Ditches assessment areas.

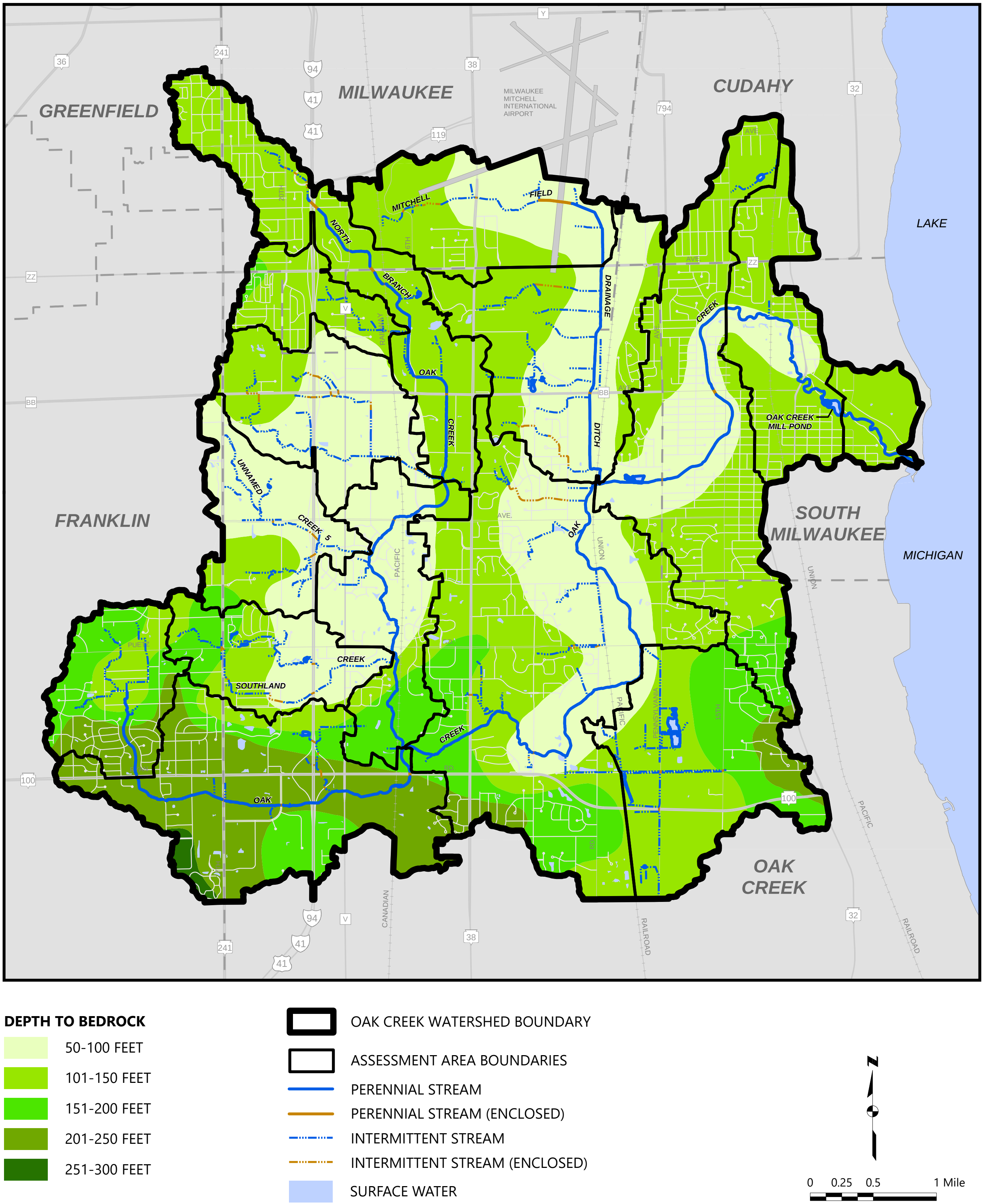
Hydrologic Soil Group

Soils are classified into hydrologic soil groups based on soil infiltration and transmission rate (permeability). Hydrologic soil groups along with land use, management practices, and hydrologic condition determine a soil's runoff curve number as established by NRCS. Runoff curve numbers are used to estimate direct runoff from rainfall. There are four hydrologic soil groups: A, B, C, and D. Descriptions of runoff potential, infiltration rate, and transmission rate of each group are shown in Table 3.13. Some soils fall into a dual hydrologic soil group (A/D, B/D, and C/D) based on their hydraulic conductivity and the water table depth. The first letter applies to the drained condition (lower water table) and the second letter applies to the undrained condition. Table 3.14 summarizes the percent of each hydrologic soil group present in each of the watershed assessment areas, and Map 3.15 shows the distribution of the groups. The dominant hydrologic soil groups in the Oak Creek watershed are Group C (48 percent of the watershed) and Group C/D (37 percent of the watershed). This composition suggests that the majority of the soils in the watershed have a moderately high to high runoff potential and are considered to be poorly to very poorly drained.

Hydric Soils

Soils that are saturated with water or that have a water table at or near the surface are known as hydric soils, and they pose significant limitations for most types of development. High water tables often cause wet basements and poorly functioning absorption fields for private onsite waste treatment systems. The excess wetness may also restrict the growth of landscaping plants and trees. Wet soils also restrict or prevent the use of land for crops, unless the land is artificially drained. Map 3.16 shows the locations of hydric soils within the Oak Creek watershed, as identified by NRCS. The land areas covered by hydric soils total 2,221 acres, or 12.3 percent of the watershed. Although such areas are generally unsuitable for development, they may serve as important locations for restoration of wetlands, wildlife habitat, and stormwater retention.

Map 3.14
Depth to Bedrock Within the Oak Creek Watershed



Source: Wisconsin Geological and Natural History Survey and SEWRPC

Soil Erodibility

The susceptibility of a soil to wind and water erosion depends on soil type and slope. Coarse-textured soils, such as sand, are more susceptible to erosion than fine textured soils, such as clay. Land slope steepness affects the velocity, and accordingly, the erosive potential of rain and snowmelt runoff. As slopes increase, the rate of soil erosion increases. Soils with slopes that are above 2 percent are prone to erosion without proper management. Land areas that are greater than 6 percent slope are of most concern for soil erosion. Highly erodible lands are those areas in the watershed that have slopes between 6 and 12 percent; areas with greater than 12 percent slope are considered to have very highly erodible soils.[102] Soils in areas of greater than 6 percent slope are difficult to manage, not only for agriculture, but also for urban development.

Table 3.13
Description of Hydrologic Soil Groups

Hydrologic Soil Group	Runoff Potential	Infiltration Rate	Transmission Rate
A	Low	High	High
B	Moderately Low	Moderate	Moderate
C	Moderately High	Low	Low
D	High	Very Low	Very Low

Source: Natural Resources Conservation Service

Map 3.17 shows soil slopes and erodible lands in the Oak Creek watershed. The slopes of the soils are classified into four major groups: slight slopes (less than 2 percent), moderate slopes (2 to 5 percent), steep slopes (6 to 12 percent), and very steep slopes (greater than 12 percent). Approximately 15.6 percent of the watershed is characterized as having slight slopes, 74.2 percent as having moderate slopes, 9.5 percent as having steep slopes, and 0.7 percent as having very steep slopes. The steepest slopes in the watershed are found within the Lower Oak Creek—Mill Pond and Grant Park Ravine assessment areas where slopes are as steep as 38 percent.

3.9 NATURAL RESOURCE 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. In certain areas of Southeastern Wisconsin groundwater serves as a source of domestic, municipal, and industrial water supply as well as providing baseflows in rivers and streams. The destruction of woodland and other upland cover types, which may have taken hundreds or thousands of years to mature, may result in soil erosion and stream siltation, more rapid runoff and increased flooding, as well the local extinction of native plants and animals. Although the effects of any one of these environmental changes in isolation may not be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment. The need to protect and preserve the natural areas and environmental corridors with their associated complexes of wetland, upland, and critical species habitats within the watershed is, thus, apparent. The following sections describe the important natural resource elements present within the Oak Creek watershed.

Environmental Corridors

Remaining natural resource elements and resource-related features, when mapped on the landscape, concentrate in an essentially linear pattern of relatively narrow, elongated areas that have been termed "environmental corridors". SEWRPC has identified two types of these corridors, primary environmental corridors (PEC) and secondary environmental corridors (SEC). In addition, SEWRPC has identified smaller concentrations of natural resource features that, though isolated from the environmental corridors, still constitute natural resource areas of significant value. These are referred to as isolated natural resource areas (INRAs). Protecting the environmental corridors and INRAs from intrusion by incompatible land uses, and, thereby, from degradation and destruction of their functions, is one of the principal objectives of this watershed restoration plan. The PECs, SECs, and INRAs in the Oak Creek watershed are shown on Map 3.18.

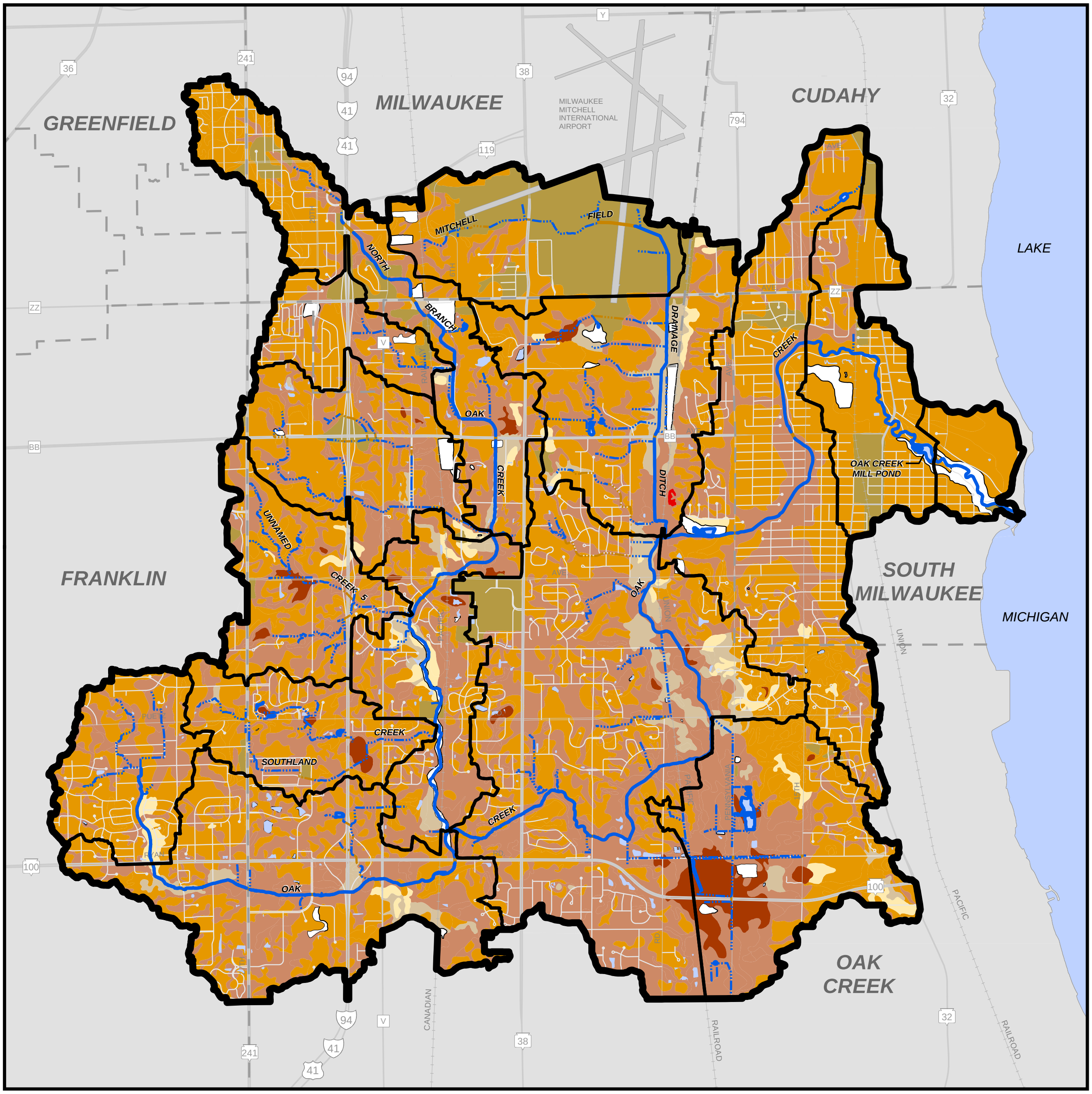
[102] *Outagamie County Land Conservation Department, Nonpoint Source Implementation Plan for the Plum and Kankapot Creek Watersheds, 2014.*

Table 3.14
Hydrologic Soil Group Composistion by Assessment Area

Hydrologic Soil Group	Oak Creek Mainstem							Mitchell Field Drainage Ditch		North Branch of Oak Creek						Watershed (% of area)
	Grant Park Ravine (% of area)	Lower Oak Creek – Mill Pond (% of area)	Lower Oak Creek (% of area)	Middle Oak Creek (% of area)	Middle Oak Creek – Drainage Ditches (% of area)	Upper Oak Creek (% of area)	Oak Creek Headwaters (% of area)	Lower Mitchell Field Drainage Ditch (% of area)	Mitchell Field Drainage Ditch – Airport (% of area)	Lower North Branch Oak Creek (% of area)	Upper North Branch Oak Creek (% of area)	Southland Creek (% of area)	Drexel Avenue Tributary (% of area)	Rawson Avenue Tributary (% of area)	College Avenue Tributary (% of area)	
A	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	<1
A/D	0	0	0	1	13	0	0	1	0	1	1	4	3	<1	0	2
B	0	0	1	1	3	1	5	2	0	5	1	0	2	1	<1	1
B/D	0	0	0	6	3	4	0	10	0	7	3	<1	<1	2	53	3
C	81	75	63	35	35	45	62	48	29	35	58	54	51	54	35	48
C/D	0	9	32	54	44	48	33	30	7	46	26	40	43	37	9	37
D	1	12	3	3	<1	<1	0	6	63	3	8	2	1	4	3	7
Unclassified	18	4	1	<1	1	1	<1	2	1	3	3	<1	0	2	0	2

Source: Natural Resources Conservation Service and SEWRPC

Map 3.15
Hydrologic Soil Groups Within the Oak Creek Watershed



GROUP A: WELL DRAINED SOILS

GROUP A/D: WELL DRAINED SOIL/VERY POORLY DRAINED SOIL
WELL DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM, VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED

GROUP B: MODERATELY DRAINED SOIL

GROUP B/D: MODERATELY DRAINED SOIL/VERY POORLY DRAINED SOIL
MODERATELY DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM, VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED

GROUP C: POORLY DRAINED SOILS

GROUPS C/D: POORLY DRAINED SOILS/VERY POORLY DRAINED SOILS
POORLY DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM, VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED

GROUP D: VERY POORLY DRAINED SOILS
VERY HIGH RUNOFF POTENTIAL

UNDEFINED SOILS

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

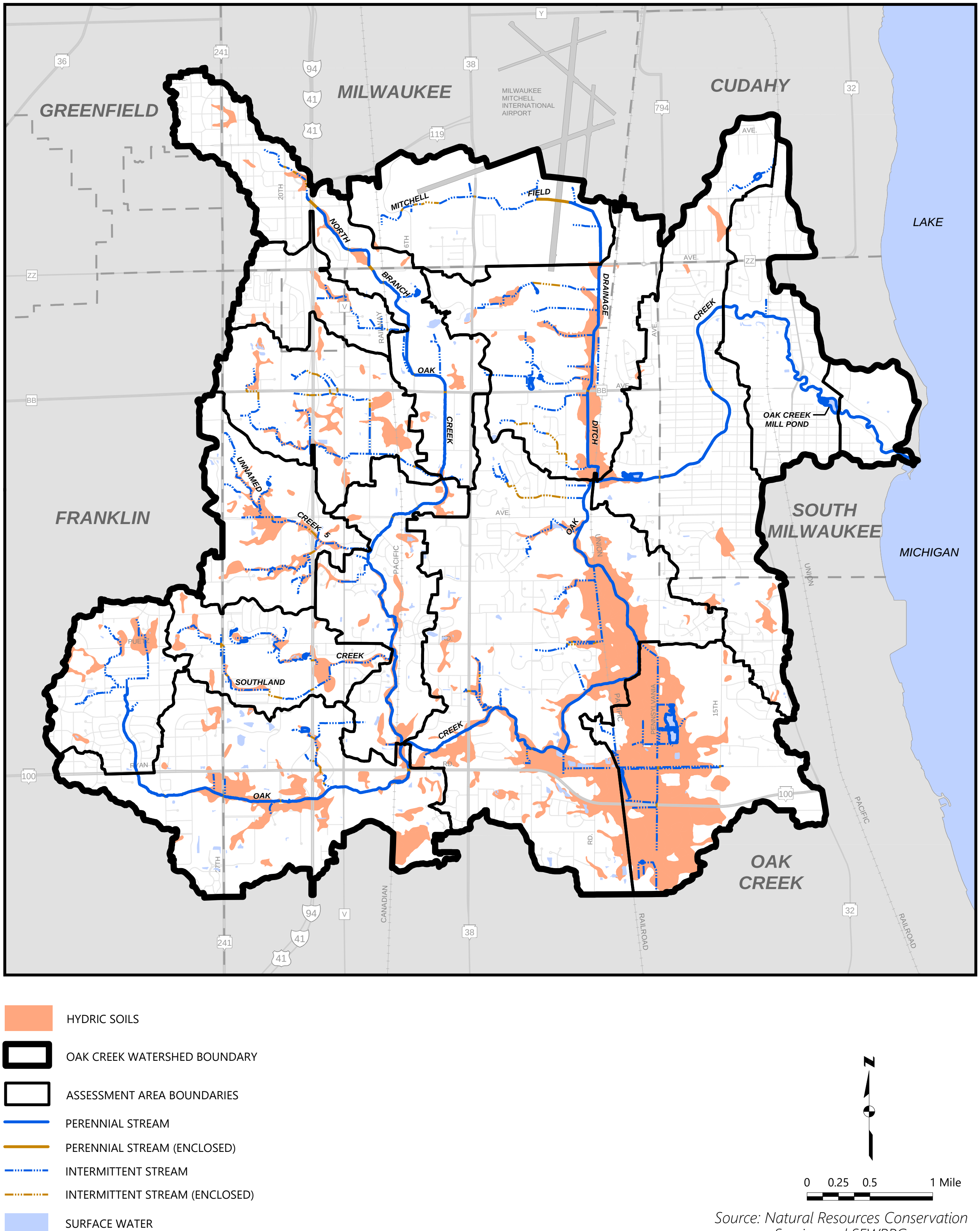
INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

0 0.25 0.5 1 Mile

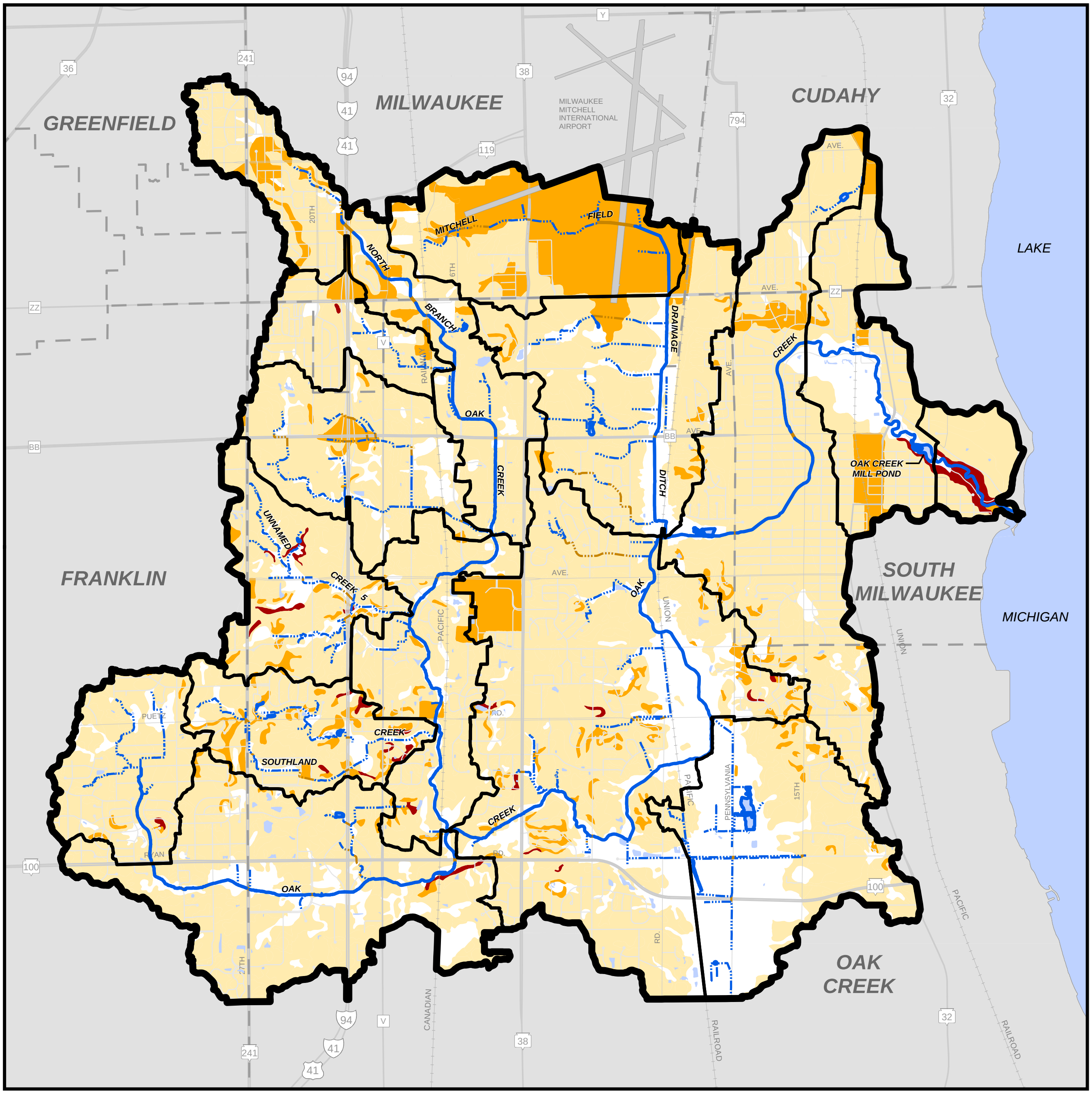
Source: Natural Resources Conservation Service and SEWRPC

Map 3.16
Hydric Soils Within the Oak Creek Watershed



Source: Natural Resources Conservation Service and SEWRPC

Map 3.17
Soil Slopes and Erodible Lands Within the Oak Creek Watershed



SLIGHT SLOPES (LESS THAN 2 PERCENT)	OAK CREEK WATERSHED BOUNDARY
MODERATE SLOPES POTENTIALLY HIGHLY ERODIBLE LAND (2 TO 5 PERCENT)	ASSESSMENT AREA BOUNDARIES
STEEP SLOPES HIGHLY ERODIBLE LAND (6 TO 12 PERCENT)	PERENNIAL STREAM
VERY STEEP SLOPES VERY HIGHLY ERODIBLE LAND (GREATER THAN 12 PERCENT)	PERENNIAL STREAM (ENCLOSED)
	INTERMITTENT STREAM
	INTERMITTENT STREAM (ENCLOSED)
	SURFACE WATER

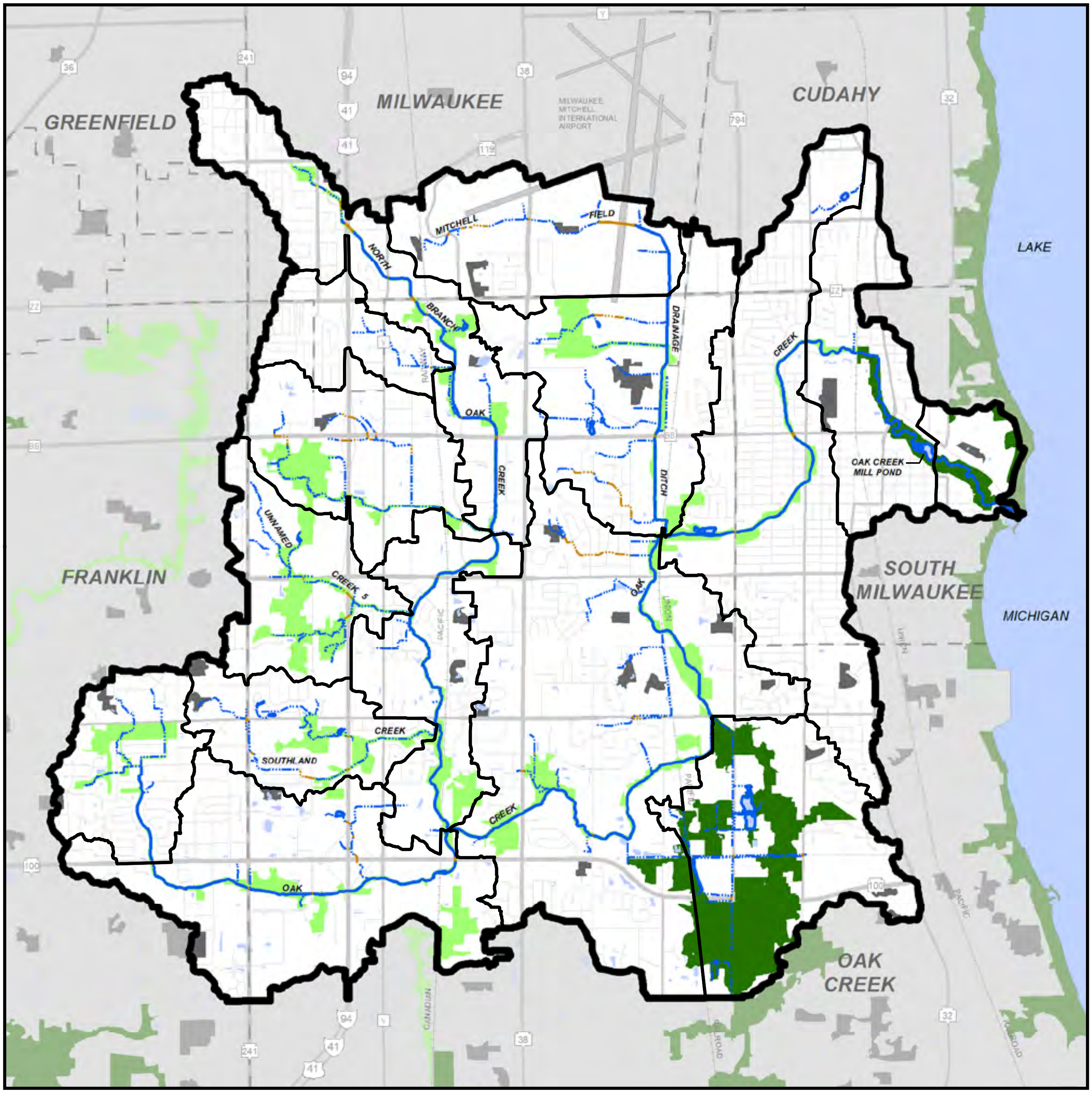
Note: Estimations of erodible lands shown on this map assume no erosion management measures are in place. Many areas shown on this map may either be developed in urban uses or have erosion management meaures installed.

N

0 0.25 0.5 1 Mile

Source: Natural Resources Conservation Service and SEWRPC

Map 3.18
Environmental Corridors Within the Oak Creek Watershed: 2015



PRIMARY ENVIRONMENTAL CORRIDOR

SECONDARY ENVIRONMENTAL CORRIDOR

ISOLATED NATURAL RESOURCE AREA

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

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: SEWRPC

Primary Environmental Corridors

PECs 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.[103] As shown on Map 3.18, the PECs in the Oak Creek watershed are located along the lower reaches of the mainstem of Oak Creek in the Lower Oak Creek—Mill Pond and Grant Park Ravine assessment areas, and in the Middle Oak Creek and Middle Oak Creek Drainage Ditches assessment areas, encompassing an area of the largest remaining wetlands and woodlands in the watershed. Primary environmental corridors accounted for 744 acres, or about 4.1 percent of the total watershed area in 2015. These lands represent a composite of the best remaining elements of the natural resource base in the watershed, and contain the best remaining connected uplands, wetlands, and wildlife habitat areas (see "Natural Areas and Critical Species Habitat Sites" subsection below) in the watershed.

Secondary Environmental Corridors

SECs are at least 100 acres in size and one mile long. As shown on Map 3.18, the SECs in the Oak Creek watershed are located along most of the mainstem of Oak Creek, the entire North Branch of Oak Creek, a portion of the Mitchell Field Drainage Ditch, and along several unnamed and intermittent tributary streams. These SECs encompassed 1,304 acres, or about 7.2 percent of the total watershed area in 2015. These corridors contain a variety of resource elements, often remnant resources from PECs that have been developed for intensive agricultural or urban purposes. SECs facilitate surface water drainage, maintain pockets of natural resource features, and provide corridors for wildlife movement, as well as for the movement and dispersal of seeds for a variety of plant species.

Isolated Natural Resource Areas

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 natural resource areas, which are at least five acres in size, are referred to as INRAs and are shown on Map 3.18. Widely scattered throughout the watershed, INRAs covered about 250 acres, or about 1.4 percent of the total study area in 2015. These areas should be protected and preserved in their natural state whenever possible and linked to primary and secondary environmental corridors when opportunities exist.

Natural Areas and Critical Species Habitat Sites

Natural areas, as defined by the Wisconsin Natural Areas Preservation Council, are tracts of land or waters 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 presettlement vegetation on Map 3.5). As such, these are generally exceptionally biodiverse and irreplaceable natural resource elements for which protection and stewardship are of critical importance. Natural areas are generally comprised of wetland or upland vegetation communities and/or complex combinations of both of these fundamental ecosystem units. 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.[104]

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 acquiring priority properties, managing public lands, and allowing development in appropriate locations that will protect and preserve the natural resource base of the Region.

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

[104] *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.*

The identified natural areas were classified into three categories:

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

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

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 and rarity of plants, animals, and natural community types present; the structural 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 Oak Creek watershed has 12 identified natural areas totaling nearly 390 acres (see Map 3.19). Three of the natural areas are categorized as being of countywide or regional significance (NA-2) and nine of the natural areas are categorized as local significance (NA-3). The 12 natural areas are listed in Table 3.15 and further profiled in Appendix C.

Critical species are defined as those species that are considered to be endangered, threatened, or of special concern by the State or Federal government. There are 42 critical species known to occur within the Oak Creek watershed. These critical species are listed in Table 3.16. Critical species habitats sites are tracts of land that include abiotic and biotic factors necessary for the long-term support of the critical species population. The regional natural areas plan amendment identified 128 acres of critical species habitats sites within the Oak Creek watershed. SEWRPC staff are continually evaluating habitat areas and incorporating reputable occurrences of critical species made by others in the Region. Since publishing the plan amendment in 2010, these surveys conducted by SEWRPC staff, Milwaukee County Parks staff, and others have led to the identification of an additional 1,044 acres of critical species habitat within the Oak Creek watershed for a total of 1,172 acres. The critical species habitat sites identified in the 2010 plan amendment as well as the additional areas identified as of February 2017 are shown on Map 3.19.

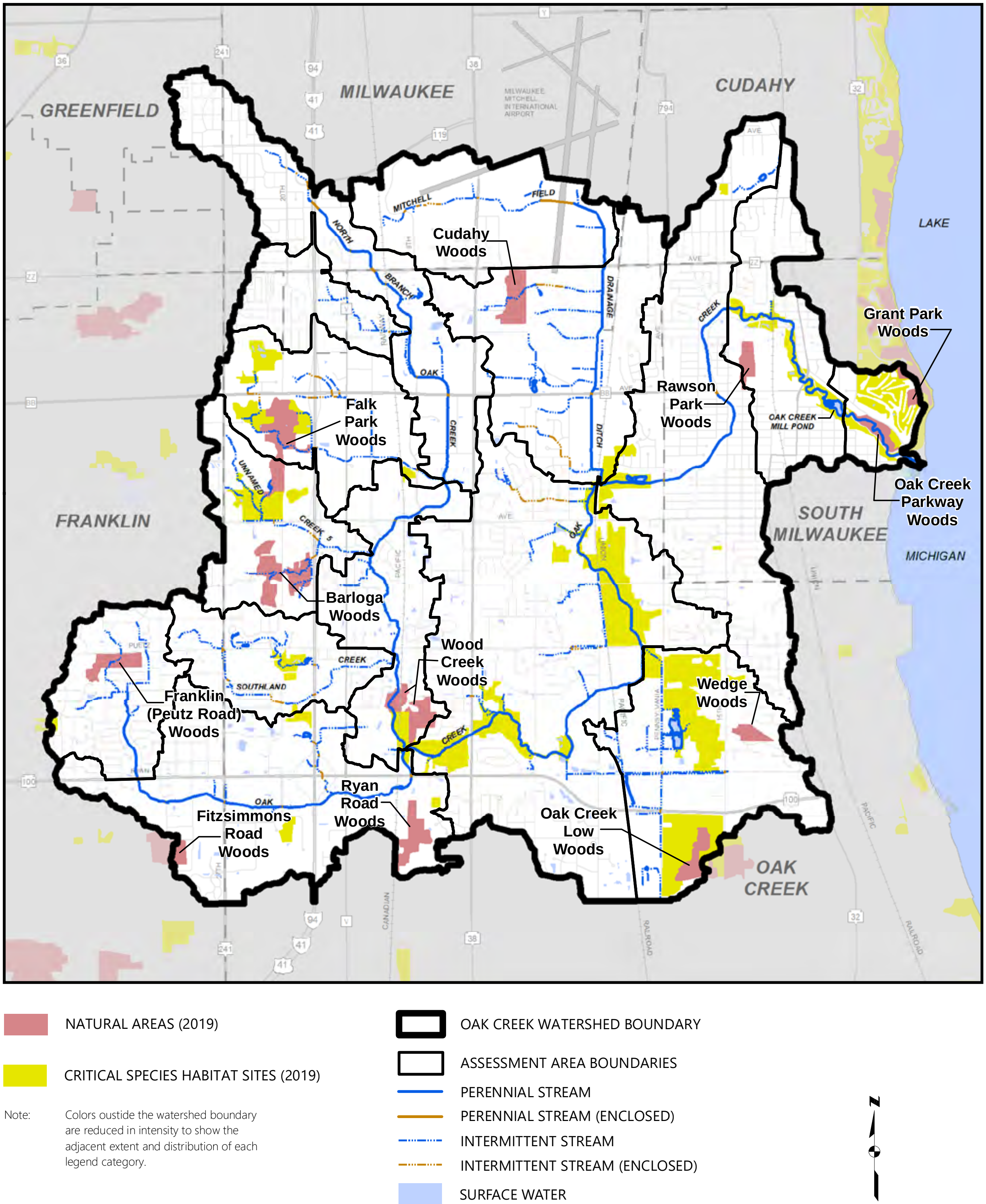
Wetlands

Wetlands form at the transition between surface water, groundwater, and land resources. Wetlands are areas that are inundated or saturated by surface water or groundwater at a frequency, and with a duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally occur in depressions and near the bottom of slopes, particularly along lakeshores and streambanks, and on large land areas that are poorly drained. Wetlands may, however, under certain conditions, occur on slopes and even on hilltops. They provide essential breeding, nesting, sanctuary, and feeding grounds for birds; offer escape cover for many forms of fish and wildlife; and provide the environmental conditions required by hundreds of plant species. In addition, wetlands perform an important set of natural functions that include: water quality protection; stabilization of lake levels and streamflows; reduction in stormwater runoff by providing areas for floodwater impoundment and storage; and protection of shorelines from erosion.

The location, extent, and types of wetlands within the Oak Creek watershed are shown on Map 3.20. These wetland areas are defined based on the Wisconsin Wetland Inventory originally completed for the Southeastern Wisconsin region in 1982, and then updated to the year 2015 as part of the regional land use inventory. The land area covered by wetlands within the watershed and each assessment area is presented in Tables 3.4 through 3.7. In total, wetlands within the watershed encompassed about 1,324 acres, or 7.3 percent of the area of the watershed, in 2015. Wetlands comprise between 1.5 and 10 percent of the land in most of the assessment areas of the watershed; however the Middle Oak Creek-Drainage Ditches assessment area has 31 percent of its land classified as wetland.

The wetlands in the Oak Creek watershed can be further characterized by the Wisconsin Wetland Inventory vegetated class categories that describe the uppermost layer of vegetation that covers 30 percent or more of a particular wetland. Below are descriptions of the main wetland types and acreages of each category found within the watershed:

Map 3.19
Natural Areas and Critical Species Habitat Sites Within the Oak Creek Watershed



Source: SEWRPC

Table 3.15
Natural Areas Within the Oak Creek Watershed

Name[a]	Owner	Acreage
Cudahy Nature Preserve	Milwaukee County	47
Falk Park Woods	Milwaukee County and Private	78
Rawson Park Woods	Milwaukee County and City of South Milwaukee	23
Barloga Woods	Milwaukee County and Private	64
Fitzsimmons Road Woods	Milwaukee County and Milwaukee Area Land Conservancy	39[b]
Franklin (Puetz Road) Woods	City of Franklin	34
Grant Park Woods – South	Milwaukee County	45[c]
Oak Creek Low Woods	Milwaukee County and Private	68[d]
Oak Creek Parkway Woods	Milwaukee County	24
Ryan Road Woods	Milwaukee County and Private	42
Wedge Woods	Private	17
Wood Creek Woods	Milwaukee County and Private	49

Note: Natural areas within the Oak Creek watershed are further profiled in Appendix C.

[a] *Site names correspond to the areas shown on Map 3.19.*

[b] *13 acres are within the Oak Creek watershed.*

[c] *14 acres are within the Oak Creek watershed.*

[d] *33 acres are within the Oak Creek watershed.*

Source: SEWRPC

- Forested wetlands (670 acres) are mostly made up of woody plants that are taller than 20 feet. Dominant vegetation in these areas includes ash trees (dying or dead), elm, silver maple, boxelder, eastern cottonwood, and quaking aspen.

- Emergent/wet meadows (454 acres) are mostly made up of herbaceous plants which stand above the surface of the water or soil. Dominant vegetation in these areas include cattail, most sedges and grasses, stinging nettle, bulrush, arrowhead, and pickerel weed.

- Scrub/shrub wetlands (168 acres) are mostly made up of woody plants that are less than 20 feet tall. Dominant vegetation in these areas include willows, dogwoods, buckthorn, and young hardwood trees.

- Flats/unvegetated wet soil (25 acres) are exposed wet soils which do not support vegetation. This class of wetland is typically found within agricultural fields.

- Open water wetlands (6 acres) are lakes and ponds with a depth of six feet or less as well as unvegetated river sloughs.

- Filled or drained wetlands (1 acre).

Wetlands are constantly changing in response to changes in drainage patterns and climatic conditions. While wetland inventory mapping provides a sound basis for area-wide planning, it should be viewed as a starting point to be supplemented with detailed field investigations for regulatory purposes. The highest quality wetlands within the watershed fall within the natural areas identified in SEWRPC's natural areas and critical species habitat protection and management plan[105] and are further described and characterized with photos in Appendix C of this report.

The Oak Creek watershed also contains ephemeral wetlands/ponds. These are depressional wetlands that are hydrologically isolated from other waterbodies and temporarily hold water in the spring and early summer, or after heavy rains. Periodically these wetlands dry up, often in mid- to late-summer. Ephemeral wetlands

[105] *SEWRPC Planning Report No. 42, A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, September 1997, amended December 2010.*

Table 3.16
Endangered and Threatened Species and Species of Special Concern Within the Oak Creek Watershed: 2018

Common Name	Scientific Name	Status Under the U.S. Endangered Species Act	Wisconsin Status	Source
Crustaceans				
Prairie Crayfish	*Procambarus gracilis*	Not listed	Special concern	Milwaukee County Parks
Insects				
Plains Emerald Dragonfly	*Somatochlora ensigera*	Not listed	Special concern	WDNR Natural Heritage Inventory
Rusty Patched Bumble Bee	*Bombus affinis*	Endangered	Endangered	USFWS
Reptiles and Amphibians				
Blanding's Turtle	*Emydoidea blandingii*	Species of Concern	Special concern	WDNR Natural Heritage Inventory
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Special concern	WDNR Natural Heritage Inventory, SEWRPC
Plains Garter Snake	*Thamnophis radix*	Not listed	Special concern	WDNR Natural Heritage Inventory
Birds				
Acadian Flycatcher	*Empidonax virescens*	Not listed	Threatened	Milwaukee County Parks and the Cornell Lab of Ornithology eBird
American Bittern	*Botaurus lentiginosus*	Not listed	Special concern	Cornell Lab of Ornithology eBird Project
American Black Duck	*Anas rubripes*	Not listed	Special concern	Cornell Lab of Ornithology eBird Project
American Woodcock	*Scolopax minor*	Not listed	Special concern	Milwaukee County Parks and the Cornell Lab of Ornithology eBird
Bell's Vireo	*Vireo bellii*	Not listed	Threatened	Milwaukee County Parks and the Cornell Lab of Ornithology eBird
Black-Crowned Night-Heron	*Nycticorax nycticorax*	Not listed	Special concern	WDNR Natural Heritage Inventory
Bobolink	*Dolichonyx oryzivorus*	Not listed	Special concern	Cornell Lab of Ornithology eBird Project
Brewer's Blackbird	*Euphagus cyanocephalus*	Not listed	Special concern	Cornell Lab of Ornithology eBird Project
Caspian Tern	*Hydroprogne caspia*	Not listed	Endangered	Cornell Lab of Ornithology eBird Project
Cerulean Warbler	*Setophaga cerulea*	Species of Concern	Threatened	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project
Common Goldeneye	*Bucephala clangula*	Not listed	Special concern	Cornell Lab of Ornithology eBird Project
Common Nighthawk	*Chordeiles minor*	Not listed	Special concern	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project
Common Tern	*Sterna hirundo*	Species of Concern	Endangered	Cornell Lab of Ornithology eBird Project
Dickcissel	*Spiza americana*	Not listed	Special concern	Cornell Lab of Ornithology eBird Project
Eastern Meadowlark	*Sturnella magna*	Not listed	Special concern	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project
Eastern Whip-Poor-Will	*Antrostomus vociferus*	Not listed	Special concern	SEWRPC
Forster's Tern	*Sterna forsteri*	Not listed	Endangered	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project

Table continued on next table.

Table 3.16 (Continued)

Common Name	Scientific Name	Status Under the U.S. Endangered Species Act	Wisconsin Status	Source
Birds (continued)				
Great Egret	*Ardea alba*	Not listed	Threatened	Cornell Lab of Ornithology eBird Project
Hooded Warbler	*Setophaga citrina*	Not listed	Threatened	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project
Least Flycatcher	*Empidonax minimus*	Not listed	Special concern	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project
Peregrine Falcon	*Falco peregrinus*	Not listed	Endangered	Cornell Lab of Ornithology eBird Project
Piping Plover	*Charadrius melodus*	Endangered	Endangered	Cornell Lab of Ornithology eBird Project
Purple Martin	*Progne subis*	Not listed	Special concern	Cornell Lab of Ornithology eBird Project
Ruby-Crowned Kinglet	*Regulus calendula*	Not listed	Special concern	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project
Rusty Blackbird	*Euphagus carolinus*	Not listed	Special concern	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project
Swainson's Thrush	*Catharus ustulatus*	Not listed	Special concern	Milwaukee County Parks and the Cornell Lab of Ornithology eBird Project
Yellow-Headed Blackbird	*Xanthocephalus xanthocephalus*	Not listed	Special concern	Cornell Lab of Ornithology eBird Project
Plants				
Black Haw Viburnum	*Viburnum prunifolium*	Not listed	Special concern	SEWRPC
Blue-Stem Goldenrod	*Solidago caesia*	Not listed	Endangered	SEWRPC
Downy Willow-Herb	*Epilobium strictum*	Not listed	Special concern	WDNR Natural Heritage Inventory
False Hop Sedge	*Carex lupuliformis*	Not listed	Endangered	SEWRPC
Golden-Seal	*Hydrastis canadensis*	Not listed	Special concern	SEWRPC
Handsome Sedge	*Carex formosa*	Not listed	Threatened	SEWRPC
Heart-Leaved Skullcap	*Scutellaria ovata*	Not listed	Special concern	SEWRPC
Ravenfoot Sedge	*Carex crus-corvi*	Not listed	Endangered	SEWRPC
Waxleaf Meadowrue	*Thalictrum revolutum*	Not listed	Special concern	WDNR Natural Heritage Inventory

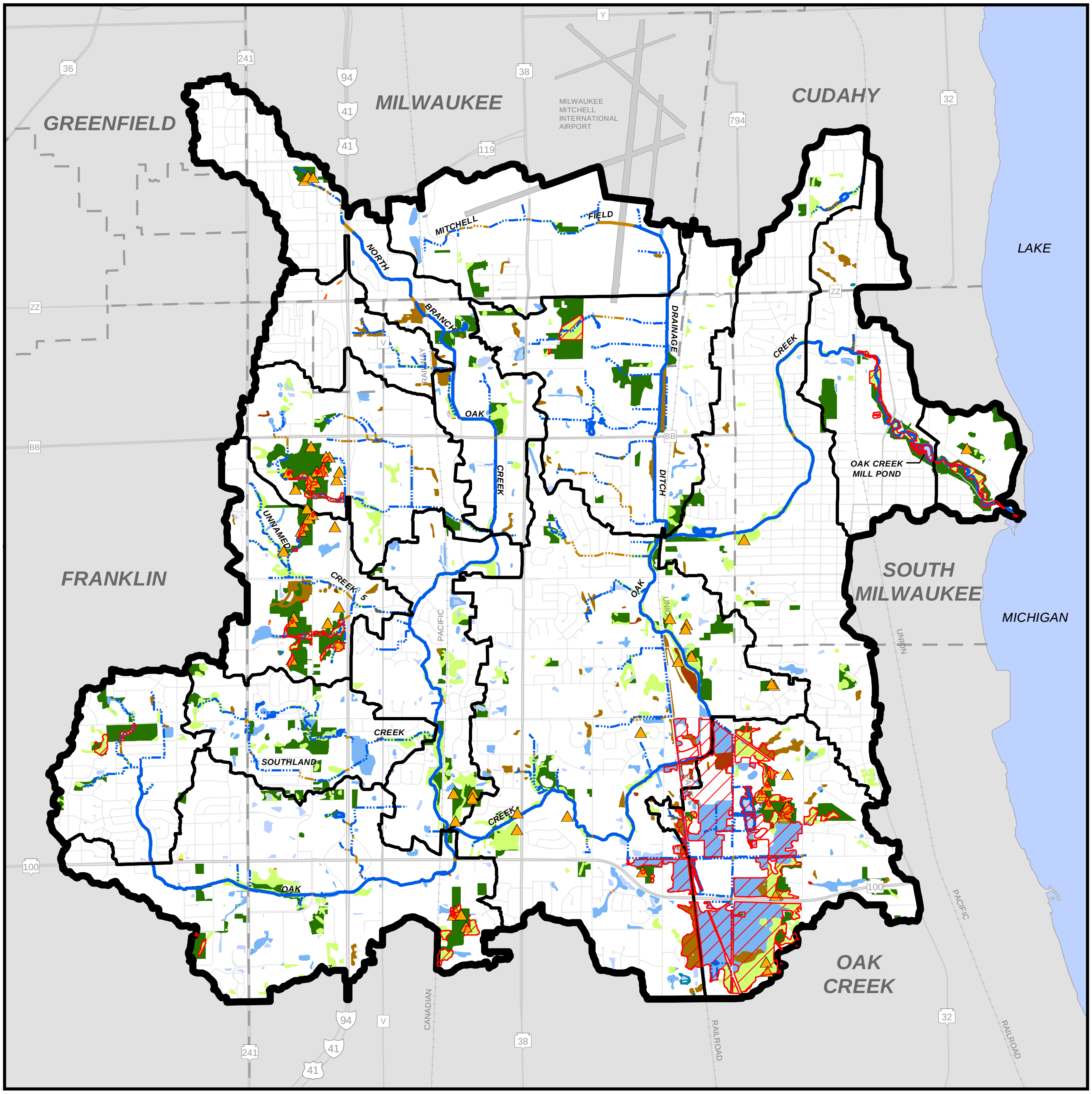
Note: No mammal or fish endangered species, threatened species, or species of special concern are currently found within the watershed.

Source: Cornell Lab of Ornithology eBird Project, Milwaukee County Parks, U.S. Fish and Wildlife Service, Wisconsin Department of Natural Resources, and SEWRPC

are free of fish, which makes them important breeding habitat for certain amphibian and invertebrate species. These habitats are typically smaller than two acres, with some being as small as six to 12 feet across. It should be noted that ephemeral wetlands can be difficult to define, identify, and protect because they tend to be small, isolated, and dry during certain times of the year. Milwaukee County Parks staff have identified 71 ephemeral ponds within the Oak Creek watershed (see Map 3.19).

Wetlands located within the PECs have been designated as Advanced Delineation and Identification (ADID) wetlands under Section 404(b)(1) of the Federal Clean Water Act and are deemed generally unsuitable for the discharge of dredge and fill material. There are about 598 acres of ADID wetlands within the Oak Creek watershed (see Map 3.20). These wetlands have additional protections from being filled and from being encroached upon by future development. The nonagricultural performance standards set forth in Section NR 151.125 of the *Wisconsin Administrative Code*, require establishment of a 75-foot protective area from impervious surfaces adjacent to these higher-quality wetlands. This

Map 3.20
Wetland Types, Ephemeral Ponds, and Woodlands Within the Oak Creek Watershed



WETLAND TYPES

- FORESTED WETLANDS
- EMERGENT/WET MEADOWS
- SCRUB/SHRUB
- FLATS/UNVEGETATED WET SOIL
- OPEN WATER WETLANDS
- EPHEMERAL WETLANDS/PONDS IDENTIFIED BY MILWAUKEE COUNTY PARKS STAFF
- ADID WETLANDS (2005)
- FILLED/DRAINED WETLANDS
- WOODLANDS (UPLAND)
- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

0 0.25 0.5 1 Mile

Source: SEWRPC

designated protective area boundary is measured horizontally from the delineated wetland boundary to the closest impervious surface.[106]

Woodlands

With sound management, woodlands serve a variety of beneficial functions. In addition to contributing to clean air and water and regulating surface water runoff, woodlands support diverse communities of plants and animals and provide recreational opportunities and aesthetic values that enhance quality of life. The destruction of woodlands, particularly on hillsides, can contribute to excessive stormwater runoff, siltation of lakes and streams, and loss of wildlife habitat. Woodlands identified under the 2015 SEWRPC land use inventory are shown on Map 3.20. The lands that are covered by woodlands within the Oak Creek watershed and each assessment area is set forth in Tables 3.4 through 3.7. In 2015, woodlands encompassed 848 acres, or about 4.7 percent of the area of the watershed.[107] The highest quality woodlands within the watershed fall within the natural areas identified in SEWRPC's natural areas and critical species habitat protection and management plan[108] and are further described and characterized with photos in Appendix C of this report.

3.10 WATER RESOURCES

The surface water resources within the Oak Creek watershed include streams, ponds, wetlands, and flooded gravel pits, and form one of the most important elements of the natural resource base of the watershed. Their contribution to the economic development, recreational activity, and aesthetic quality of the watershed are immeasurable. The groundwater resources of the Oak Creek watershed are hydraulically connected to the surface water resources and provide the baseflow of the streams. Lake Michigan is the main source of water supply for domestic, municipal, and industrial users in the watershed. The protection, enhancement, and proper development of these invaluable water resources constitute the basis for this watershed restoration plan.

Historical Stream Channel and Wetlands

Water resources are not static and can change greatly over time. One of the most variable features of the watershed is its stream system, which can have widely fluctuating discharges, stages, and geometry. When available, information from original land surveys can be an important tool to provide a best estimation of the shapes, sizes, and lengths of surface water features prior to European settlement. It should be noted, however, that these surveys, and maps drawn based on them, represent an approximation of what was present on the landscape at the time, and not an exact representation as would be possible with today's surveying and map-making technology.

Land surveyors conducted the first official Federal government survey of the area containing the Oak Creek watershed in 1837. The survey was done to divide the vast public domain into salable-sized lots that could be sold by the government to encourage settlement. The basic units of the public land survey are six-mile square townships that are further subdivided into one-mile square sections. These units were established by surveyors walking the grid and marking points that indicated each corner of the square sections, known as section corners, and the mid-point along each side of the sections, known as quarter-section corners. These markers established townships, sections, and quarter sections that are still used in surveys of the Region today.

To document their work, the surveyors kept books of field notes that became the official record of the surveys. These field notes include descriptions of features of the land including notes on the major timber and vegetation types present, and identification of locations where a surveyor entered or left a field or wetland, and where a surveyor encountered a stream or lake. Where the surveyors encountered a body of water of significant size along a section line, they set a meander post at the shoreline. Once these meander posts were set on all the section lines that intersected the lake or river, the shoreline was surveyed by connecting the bended corners by tangential lines. When surveys were completed for a township, a map laying out the locations and shapes of larger streams, lakes, and wetlands was drawn using the surveyed posts and field notes.

---

[106] *Runoff from impervious surfaces located within the protective area must be adequately treated with stormwater best management practices.*

[107] *These data include upland woods only, not lowland woods, such as tamarack swamps, which are classified as wetlands.*

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

The map drawn from the 1837 survey can be compared to maps from subsequent surveys to show relative changes in the watershed. Additional surveys were conducted for U.S. Geological Survey quadrangle maps published in 1891, 1901, and 1958. Examination of historical 1937 aerial photos[109] can also be used to compare changes within the watershed to streams, rivers, and wetlands as the watershed became more influenced by human impacts on the land. The original 1837 survey plat map, and the 1891 and 1958 USGS quadrangle maps are shown in Figure 3.6.[110] The historical stream lines have been darkened and the current Oak Creek watershed boundary has been superimposed for reference.

The most apparent difference between the 1837 and 1891 survey maps and more recent maps is the lack of discernable channels on the older maps in the locations of the Mitchell Field Drainage Ditch and the North Branch Oak Creek. The earlier survey maps show an elongated wetland complex that runs the length of where the present-day Mitchell Field Drainage Ditch flows. The 1891 map shows this wetland complex extending west to a location near the headwaters of the present-day North Branch Oak Creek. Interestingly, the 1891 survey also shows large wetland complexes extending outside of the current watershed boundary, both to the north into the Kinnickinnic River watershed, and to the south into the Root River watershed. The topography in the latter area near the Root River watershed is very flat, indicating that the Oak Creek/ Root River watershed boundary is fluid and could shift based on installation of agricultural drain tiles, maintenance of drainage channels, or even changes in amounts of precipitation.

Perhaps the most interesting difference between the 1837 survey map and the twentieth century maps is the presence of a stream channel in the area of what is now the headwaters of the mainstem of Oak Creek flowing east and then south before flowing into the Root River. If this connection to the Root River was accurate, it no longer existed by the time that the 1891 USGS quadrangle map was drawn (see Figure 3.6). It is unclear whether this difference reflects more accurate mapping in 1891 or was the result of hydrologic changes brought on by anthropogenic alterations on the landscape.

Examination of historical aerial photos indicate that by 1937 the watershed had been greatly altered by settlement and conversion of the land to agricultural uses. Much of the land that was reported in the 1837, 1891, and 1901 surveys as wetland was drained to the newly constructed channels that are today known as the Mitchell Field Drainage Ditch and the North Branch of Oak Creek. These alterations to the landscape are confirmed by the 1958 U.S. Geological Survey quadrangle map. As shown in Figure 3.6, by 1958, the mainstem of Oak Creek and its major tributaries, the Mitchell Field Drainage Ditch and the North Branch of Oak Creek appear with mostly the same geometry and location as they do in the present day. It should be noted that there have been additional minor channel alterations, channel straightening, and channel deepening that has occurred since 1958. A more detailed comparison of the historical stream channels to the current stream channels, and further discussion of specific channel alterations are provided in Chapter 4 of this report.

Geographic information systems (GIS) analysis indicates that the total acreage of wetlands has decreased from 3,805 acres in 1891 to about 1,324 acres in 2015, a decrease of about 65 percent. It should be noted that several wetland complexes in 1891, shown in Figure 3.6, extended beyond the current day watershed boundary as discussed above.

Current Surface Water Features

River and stream systems can have widely fluctuating discharges and stages. The stream system of the Oak Creek watershed receives a relatively uniform flow of water from the shallow groundwater reservoir underlying the watershed. This groundwater discharge constitutes the baseflow of the streams. Agricultural drain tiles also contribute to this baseflow. The streams also receive surface water runoff from rainfall and snowmelt. This runoff, combined with the baseflow, can sometimes cause the streams to leave their channels and occupy the adjacent floodplains in areas where the streams have not been deeply channelized.

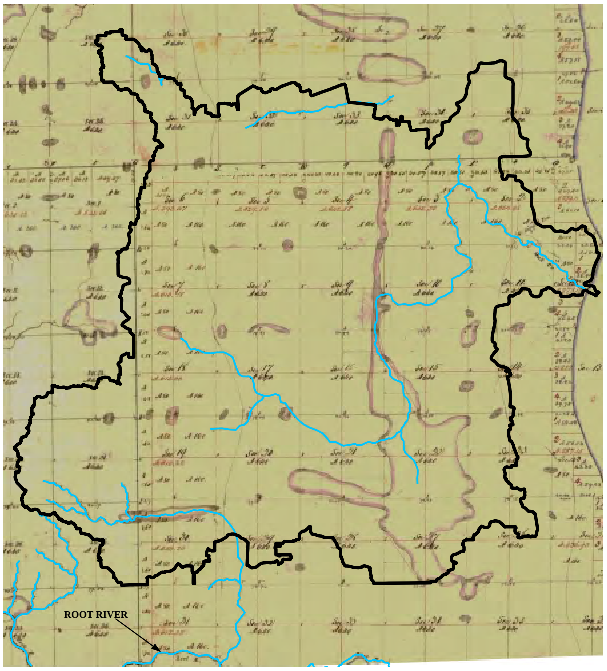
---

[109] *Historical aerial photos were obtained online from the Wisconsin State Cartographer's Office, Historic Aerial Imagery Finder website at maps.sco.wisc.edu/WHAIFinder.*

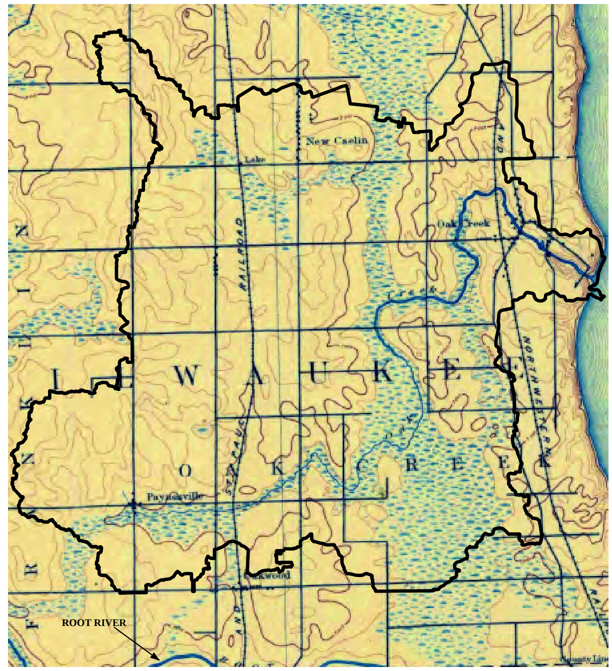
[110] *The presence and locations of surface water features shown on the 1901 USGS quadrangle map did not differ appreciably from those shown on the 1891 map. The locations of the surface water features visible on the 1937 historical aerial photographs were similar to those shown on the 1958 USGS quadrangle maps.*

Figure 3.6
Comparison of Surface Water and Wetland Features from Historical Maps of the Oak Creek Watershed: 1837, 1891, and 1958

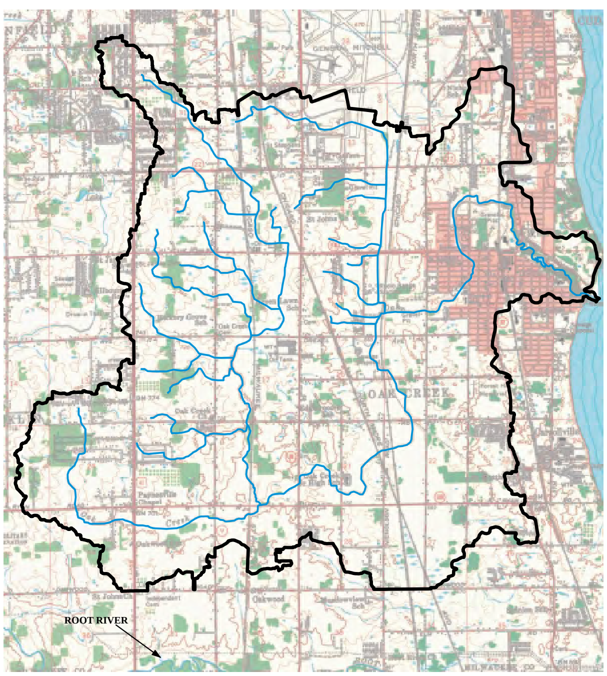
Historical 1837 Plat Map



Historical 1891 USGS Quad Map



Historical 1958 USGS Quad Map



Note: The 2015 watershed boundary has been superimposed on all three maps for comparison purposes only.

Source: Wisconsin Board of Commissioners of Public Lands, U.S. Geological Survey, and SEWRPC

Perennial streams maintain at least a small continuous flow throughout the year. Within the watershed there are 21.3 miles of such perennial streams. The watershed contains an additional 41 miles of intermittent streams, or those streams that only flow during certain times of the year when smaller upstream waters are flowing and when groundwater and precipitation runoff provide enough water for streamflow. During dry periods, these intermittent streams may not have flowing surface water. Intermittent streams can provide important spawning and feeding habitat for some fish and aquatic life at specific times of the year.

The mainstem of Oak Creek is approximately 14.5 miles in length, extending from its intermittent headwaters in the City of Franklin to its confluence with Lake Michigan in the City of South Milwaukee. There are two major tributary streams that flow into Oak Creek's mainstem: the North Branch of Oak Creek and the Mitchell Field Drainage Ditch. The North Branch of Oak Creek is approximately 6.3 miles in length, flowing from its intermittent headwaters northwest of IH 94 in the City of Milwaukee, to its confluence with the mainstem of Oak Creek just north of Ryan Road in the City of Oak Creek. The Mitchell Field Drainage Ditch is approximately 4.2 miles in length, flowing from the westernmost portion of General Mitchell International Airport to its confluence with the mainstem of Oak Creek in the City of Oak Creek. Some portions of the Mitchell Field Drainage Ditch within the Airport property are considered to be intermittent.

There are approximately 109 acres of open water ponds within the Oak Creek watershed, a majority of which are stormwater detention basins constructed during urban development to capture water during storm events. The Oak Creek Mill Pond is an approximately five-acre constructed impoundment maintained by a dam located at Mill Street in the City of South Milwaukee.

Groundwater

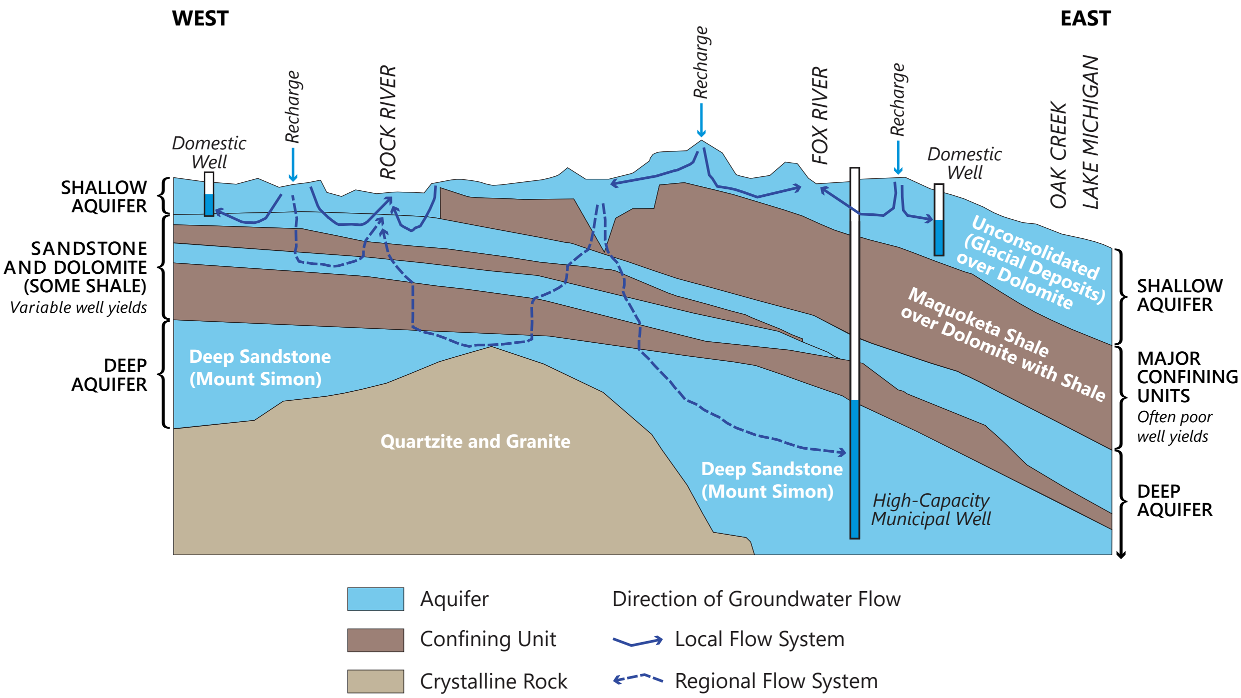
All of the communities within the Oak Creek watershed use Lake Michigan as their source for potable water supply and for commercial and industrial uses; however, groundwater sustains pond levels and wetlands and provides the perennial baseflow for streams within the watershed. Thus, groundwater resources constitute an important element of the natural resource base within the watershed. The amount, movement, recharge, 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. The continued growth of population and industry within the watershed necessitates the wise development and management of groundwater resources.

Groundwater occurs in three major aquifers that underlie the Oak Creek watershed and lands adjacent to the watershed. From the land's surface downward they are: 1) the sand and gravel deposits in the glacial drift; 2) the shallow dolomite layers in the underlying bedrock; and 3) the deeper sandstone, dolomite, siltstone, and shale strata. Because of their proximity to the land's surface and their hydraulic interconnection, the first two aquifers are commonly referred to collectively as the "shallow aquifer," while the latter is referred to as the "deep aquifer" or the "sandstone aquifer." Within the Oak Creek watershed, the shallow and deep aquifers are separated by the Maquoketa shale, which forms a relatively impermeable barrier between the two aquifers (see Figure 3.7).

Groundwater quality conditions can be impacted by sources of pollution such as infiltration of stormwater runoff, landfill leachate, agricultural fertilizer and pesticide runoff, manure storage and application sites, chemical spills, leaking surface or underground storage tanks, and onsite sewage disposal systems. Compared to the deep aquifer, the shallow aquifers are more susceptible to pollution from the surface because they are nearer to the source, thus minimizing the potential for dilution, filtration, and other natural processes that tend to reduce the potential detrimental effects of pollutants. The potential for groundwater pollution in the shallow aquifer is dependent on the depth to groundwater, the depth and type of soils through which the polluted water must percolate, the location of groundwater recharge areas, and the subsurface geology. Map 3.21 shows the depth to shallow groundwater within the Oak Creek watershed.

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 were generally not required to be installed prior to 1990 in the Oak Creek watershed. Ideally, practices that promote infiltration need to be located on soils with permeable subsoils and adequate

Figure 3.7
Conceptual Hydrogeologic Cross Section Through Southeastern Wisconsin



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

groundwater separation to allow infiltration, but minimize the potential for groundwater contamination. 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 discharge in a nearby wetland or stream system. This process helps support baseflows, wetland vegetation, and wildlife habitat in these water resources. As is the case for surface waters (lakes and streams), the quality of groundwater resources is clearly linked to the health of the biological communities (including humans) inhabiting those waters and their surrounding watersheds.[111]

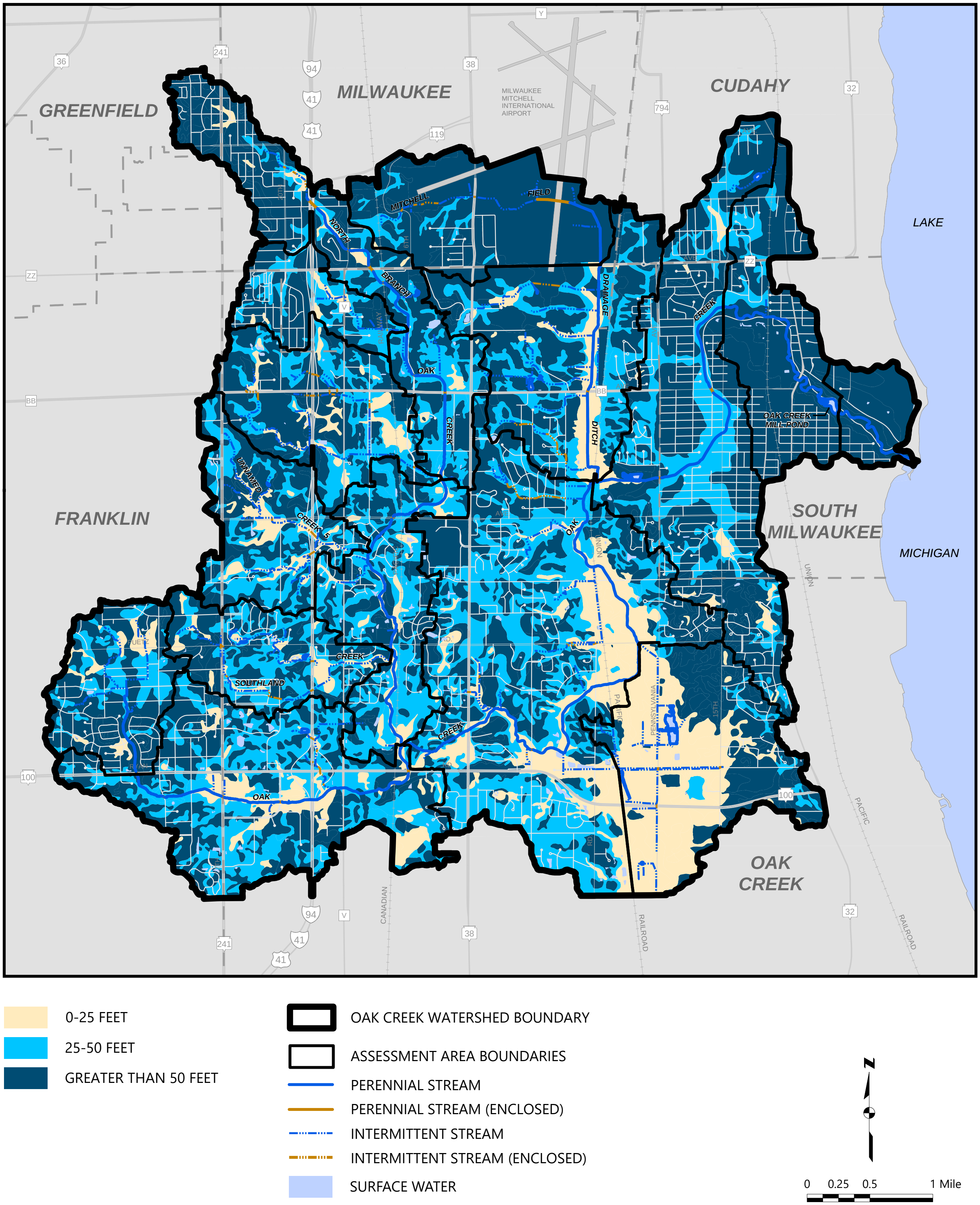
Understanding recharge and its distribution is key to making informed land use decisions so that the groundwater needs of society and the environment can continue to be met. Fortunately, a groundwater recharge potential map derived from a soil-water balance recharge model was developed under the SEWRPC water supply planning program for the Southeastern Wisconsin Region. Groundwater recharge potential in the Oak Creek watershed is shown on Map 3.22. This map can be used for identifying and protecting recharge areas that contribute the most to the baseflow of the ponds, streams, springs, and wetlands in the Oak Creek watershed.[112]

Groundwater recharge potential was divided into four main categories defined as low, moderate, high, and very high. Any areas that were not defined in the modeling were placed into a fifth category as undefined. These undefined areas make up about 5.4 percent of the Oak Creek watershed and are most often associated with groundwater discharge, which is why they tend to be located adjacent to streams and within wetland areas, as shown on Map 3.22. Much of the Oak Creek watershed can be considered to have either low (32.3 percent) or moderate (46.1 percent) groundwater recharge potential. Groundwater recharge potential is considered to be high in about 14.1 percent of the watershed and very high in about 2.1 percent of the watershed. Preserving recharge areas, particularly those located on agricultural and other open lands that have not yet been developed, is an important goal for protecting water resources in the Oak Creek watershed.

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

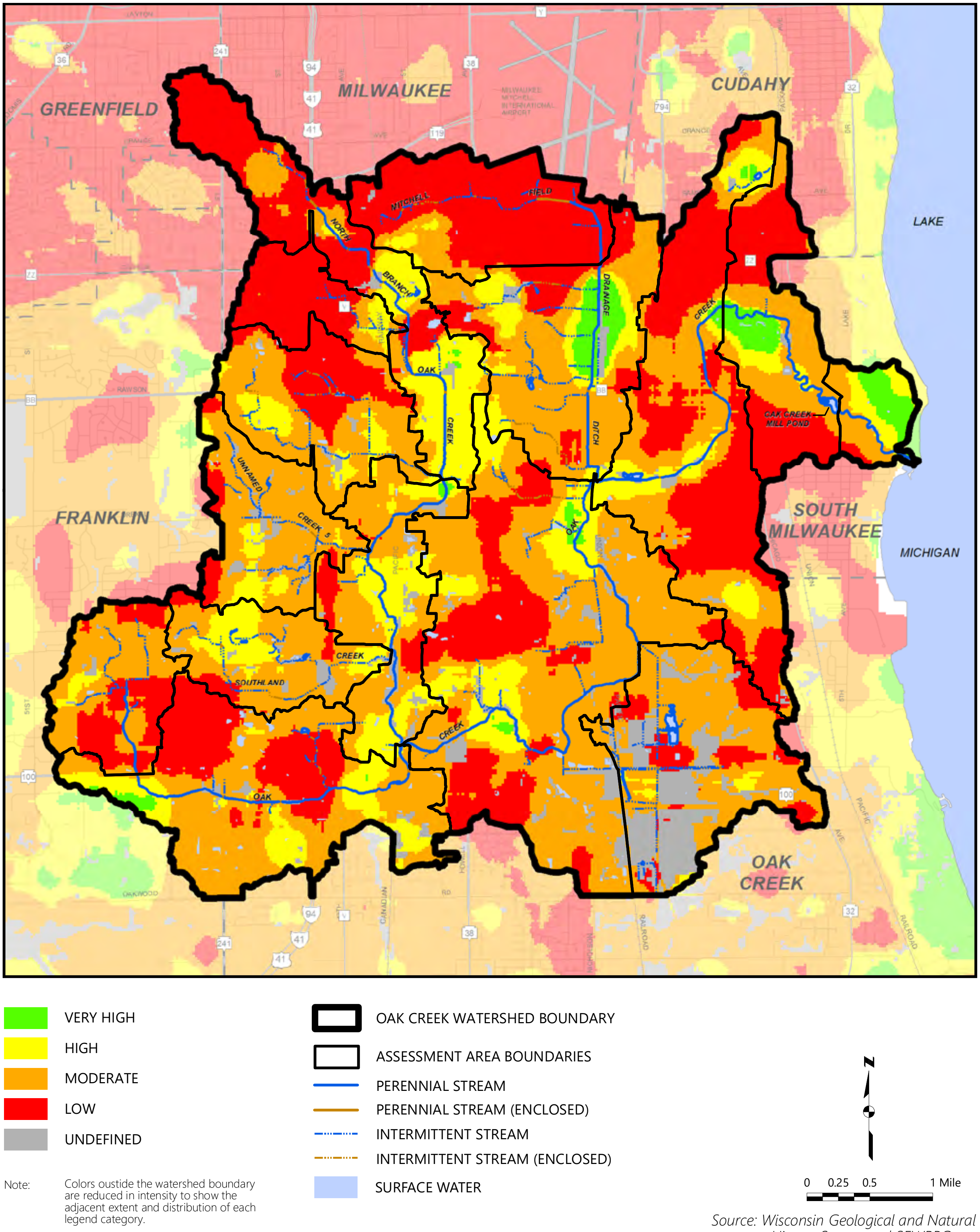
[112] *SEWRPC Technical Report No. 47*, Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water-Balance Model, *July 2008.*

Map 3.21
Depth to Groundwater Within the Oak Creek Watershed



Source: Natural Resources Conservation Service and SEWRPC

Map 3.22
Estimates of Groundwater Recharge Potential Within the Oak Creek Watershed



Source: Wisconsin Geological and Natural History Survey and SEWRPC

INVENTORY FINDINGS 4

Credit: SEWRPC Staff

4.1 INTRODUCTION

The health of a stream system is a direct reflection of its watershed. The interaction of a stream's physical, chemical, and biological components determines its ecological health (see Figure 4.1). Reduced stream health is often associated with human-induced changes that influence the physical and chemical properties of streams and the lands that surround them. Changes in the land use and hydrology of a watershed commonly result in degradation of water quality and habitat, and in turn, the degradation of the resident biological communities.

This chapter presents an inventory and analysis of the surface waters and related features of the Oak Creek watershed. Included is qualitative and quantitative information pertaining to 1) Physical Conditions—the fluvial geomorphology and hydrology of the watershed, historical trends and current status of instream habitat quality, and inventory and condition of near-stream or instream infrastructure within the Oak Creek system; 2) Chemical Conditions—historical trends and potential limitations to water quality and fishery resources; and 3) Biological Conditions—status of the fishery, other aquatic organisms, and wildlife of the Oak Creek watershed. Describing and inventorying the current physical, chemical, and biological conditions of the watershed is essential to developing effective management strategies aimed at restoring stream health.

Environmental Factors Influenced by Urban and Agricultural Land Use

U.S. Geological Survey (USGS)[113] scientists recently found that stream health was reduced at the vast majority of streams assessed in urban and agricultural areas across the nation.[114] The 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. Major findings and important implications of that study include:

---

[113] *The acronyms and abbreviations used in this report are defined in Appendix A.*

[114] *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 (online: pubs.usgs.gov/circ/1391).*

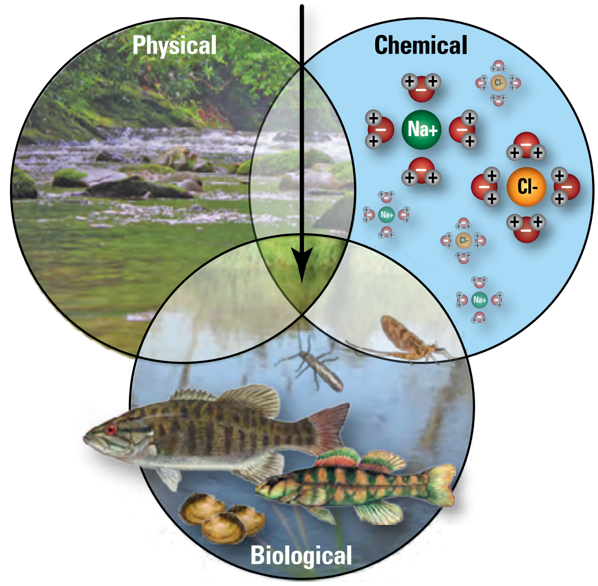
- The presence of healthy streams in a watershed with substantial human influence indicates that it is possible to maintain and restore healthy stream ecosystems

- 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 hydrologic, chemical, and physical factors of streams, which are briefly described below and illustrated in Figure 4.2.

Figure 4.1
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 Carlisle, D.M., Meador, M.R., Short, T.M., Tate, C.M., Gurtz, M.E., Bryant, W.L., Falcone, J.A., and Woodside, M.D., 2013, The Quality of our Nation's Waters—Ecological Health in the Nation's Streams, 1993–2005, U.S. Geological Survey Circular 1391, p. 2, pubs.usgs.gov/circ/1391, and SEWRPC

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 influence 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; 3) withdrawals from shallow groundwater by wells, which can reduce the amount of baseflow to streams and rivers; and 4) 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 Agricultural Stream Ecosystems in Figure 4.2), the impacts to stream ecosystems can be highly variable.

The Oak Creek watershed is heavily urbanized, and urban land use in the watershed is expected to continue to increase between the present and 2050. In the absence of planning, such urbanization can create adverse impacts on stream hydrology. In an urban setting, human activities have altered the natural flow regime of streams through the introduction of increased impervious surfaces, such as buildings and pavement for roadways and parking (see Table 3.12 in Chapter 3 of this Report). This increased imperviousness restricts the infiltration of precipitation into the groundwater system and when combined with construction of artificial drainage systems (e.g., storm sewers) that quickly move runoff to streams (see Urban Stream Ecosystems in Figure 4.2), impervious surfaces can lead to higher and more variable peak streamflow (see Figure 4.3). Reduced infiltration to groundwater can lead to diminished streamflow during dry periods. In addition, increased peak streamflow can scour the streambed and banks and degrade the stream channels.

Recent research has shown that the hydrologic variables most consistently associated with changes in algal, invertebrate, and fish communities[115] are average flow magnitude; high flow magnitude, frequency, and duration; and how rapidly the stream changes its width in response to changes in flow. As discussed in the previous Chapter, researchers have found that relatively low levels of urbanization can cause subtle changes in the properties of a stream.[116] The level of urban development within much of the Oak Creek watershed is substantial enough to potentially have negative effects on water quality and water quantity, and the amount of urbanization is also projected to increase. Table 3.12 sets forth the percentage of connected impervious area within each assessment area for existing year 2015 and planned land use conditions.

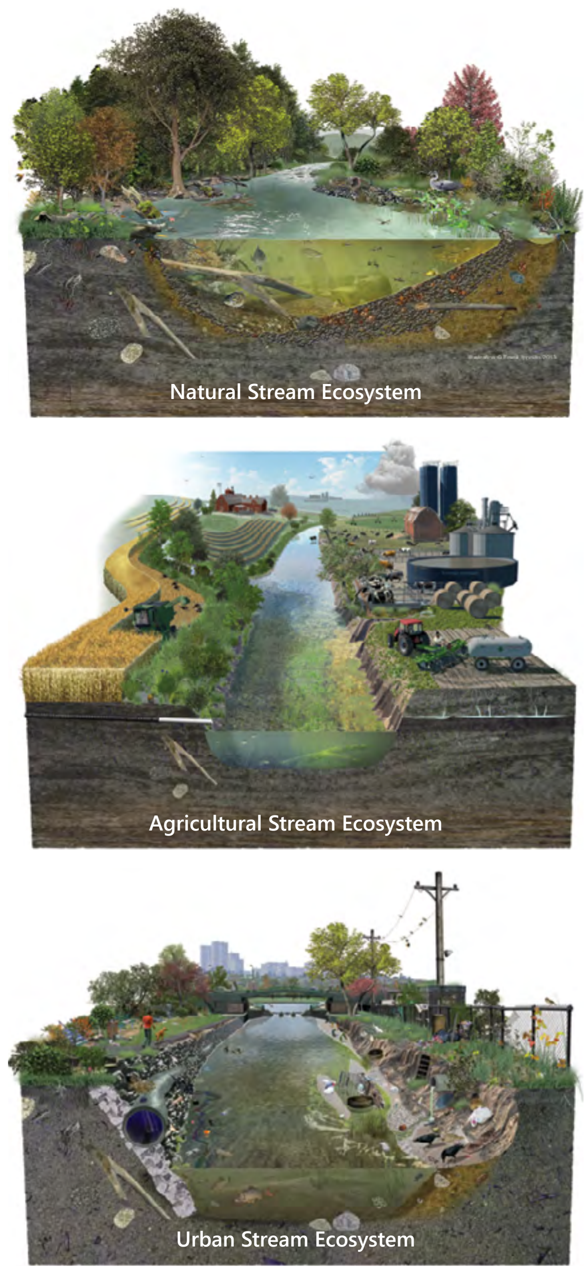
The location of impervious surfaces determines the degree of direct impact they will have on a stream. There is a greater impact from impervious surfaces located close to a stream because there is less time and distance for the polluted runoff to be naturally treated before entering a stream. A study 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 further away from the stream.[117]

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 are determined by the water temperature and by physical aeration processes influenced by the slope and depth of the stream. Similarly, small amounts of nutrients, such as 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 (human-made) chemicals, to streams from point and nonpoint sources. Runoff from agricultural lands (see Agricultural Stream Ecosystem in Figure 4.2) may contain:

Figure 4.2
Illustrations of the Dynamic Components of Natural, Agricultural, and Urban Stream Ecosystems



Source: Illustration by Frank Ippolito, www.productionpost.com. Modified from Carlisle, D.M., Meador, M.R., Short, T.M., Tate, C.M., Gurtz, M.E., Bryant, W.L., Falcone, J.A., and Woodside, M.D., 2013, The Quality of our Nation's Waters—Ecological Health in the Nation's Streams, 1993–2005, *U.S. Geological Survey Circular 1391, p. 28, pubs.usgs.gov/circ/1391, and SEWRPC*

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

[116] *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.*

[117] *L. Wang, J. Lyons, and P. Kanehl, and R. Bannerman,* op. cit.

- Sediment from soil erosion on tilled lands

- Nutrients from the application of fertilizer and manure

- Pesticides and herbicides used in the past and present to control insects, weeds, rodents, bacteria, or other unwanted organisms

Runoff from urban lands (see Urban Stream Ecosystem in Figure 4.2) may contain:

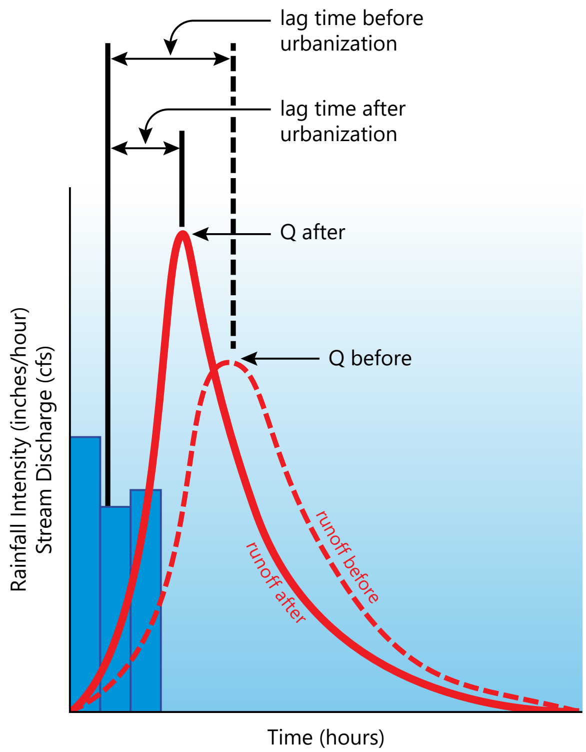
- Sediment from construction activities

- Nutrients, pesticides, and herbicides applied to lawns and recreational areas

- Petroleum compounds, trace metals, and deicing salts from roads and parking lots

Point sources include facilities that discharge 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.

Figure 4.3
A Comparison of Hydrographs Before and After Urbanization



Source: *Federal Interagency Stream Restoration Working Group (FISRWG),* Stream Corridor Restoration: Principles, Processes, and Practices, *p. 15, October 1998*

Physical Impacts

Physical habitat includes factors such as streambed substrates, water temperature, and large woody debris from streamside vegetation. 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 reproduction. Thus, their 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 availability of oxygen in water for fish and other aquatic life.

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 the riparian zones are important to biological communities because these have a major influence on the amount of shelter and food available to aquatic organisms. The character of the riparian zone also determines 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 alter the physical habitats in streams. Some agricultural practices (see Agricultural Stream Ecosystem in Figure 4.2), 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 and cobble in the streambed, which reduces the amount of living space for many stream organisms. As watersheds urbanize (see Urban Stream Ecosystem in Figure 4.2), some segments of streams may be cleared, ditched, straightened, enclosed, or lined with concrete to facilitate drainage and the movement of floodwaters. These modifications may increase streamflow velocity during storms as a result of disconnection from their floodplains, thus not allowing the stream to spill over its banks to naturally dissipate energy. As a result of one or more of these modifications above, shear stress on stream bed and banks can increase scour and promote failure, sediment transport can be increased, and coarse woody structure and other natural features that provide habitat and/or food for stream organisms may be removed from the stream.

Other physical impacts to riverine habitat include culverts and ditches that can be barriers to aquatic organisms that need to migrate throughout the stream network. Also, humans, invasive pests, and disease can alter natural stream temperature through changes in the amount and density of the canopy provided by riparian trees. Finally, in some extreme cases, streams in urban areas may be routed through pipes and completely buried.

Beneficial Functions that Healthy Streams Provide for Terrestrial Landscapes

While most of this introduction describes how surrounding land uses can impact streams, it is important to note that a healthy stream system can also have many beneficial impacts on adjacent terrestrial landscapes, the biota that inhabit them, and even humans that visit or live in the watershed. A few of the beneficial functions that healthy stream systems provide include:

- Breeding and rearing habitat for insects, amphibians, and other organisms that spend early life stages in aquatic environments and later life stages in terrestrial environments. This habitat is provided within the stream channel as well as in out-of-bank ephemeral wetlands and ponds in the surrounding floodplains.
- Food and water for terrestrial organisms.
- Nutrient rich sediment for uptake by floodplain vegetation.
- Environments that harbor denitrifying bacteria in stream sediments and out-of-bank ephemeral wetlands and ponds that assist in nutrient cycling.
- Floodwater storage and flood control.
- Groundwater recharge and discharge.
- Moderation of temperatures of surrounding landscapes through evapotranspiration.
- Better mental and physical health and well-being for residents by reducing stress, providing educational and recreational opportunities, and improving the aesthetics of a community.

4.2 PHYSICAL CHARACTERISTICS OF STREAMS WITHIN THE OAK CREEK WATERSHED

Two of 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 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 the stream ecosystem and hydrologic processes, and this connectivity does not diminish in importance with stream size. In this regard, land uses and modifications in watershed hydrology have a significant impact on stream channel conditions and associated biological responses.[118] These fundamentals should be kept in mind when analyzing the physical characteristics of the streams within the Oak Creek watershed.

For the purposes of this study's analyses, the watershed has been divided into 15 assessment areas based on a number of considerations including combinations of hydrologic subbasins, sites of historical stream flow and water quality data, stream gradient, presence of culvert or bridge crossings, and instream physical characteristics. The extent of these assessment areas are described in Chapter 3 of this Report and form the basis for the summary statistics discussed in detail within this section, and summarized in Table 4.1.

[118] *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.*

Table 4.1
Summary of Physical Conditions Among Assessment Areas Within the Oak Creek Watershed: 2016-2017

	General				Streambank Conditions				Obstructions				Inputs		
Principal Streams and Assessment Areas	Area (acres)	Principal Stream Length (miles)	Slope of Streambed (feet/mile)	Stream Length Assessed (miles)	Length of Stream Disconnected from Floodplain[a] (miles)	Percent of Stream Disconnected from Floodplain	Length of Eroded Streambanks (feet)	Percent of Stream Length with Eroded Banks	Stream Crossings Total Number Surveyed (per mile)	Dams, Weirs, or Drop Structures	Large Woody Debris Jams	Large Trash and Debris Sites	Stormwater Outfalls Total Number (number per mile)	Draintile Outfalls Total Number	Tributary Inlets
Oak Creek Mainstem															
Grant Park Ravine	286	0.9	33.9	0.9	0.3	33.3	1,403	26.6	3 (3.3)	0	0	0	25 (27.8)	0	0
Lower Oak Creek – Mill Pond	932	1.8	13.7	1.8	0.7	28.7	1,341	14.1	7 (3.9)	1	10	20	38 (21.1)	0	1
Lower Oak Creek	2,046	2.4	7.5	2.4	2.3	95.8	1,646	13.0	9 (3.8)	2	5	9	60 (25.0)	0	2
Middle Oak Creek	3,256	4.6	4.1	4.6	3.8	82.6	3,014	12.4	12 (2.6)	0	18	33	22 (4.8)	27	14
Middle Oak Creek – Drainage Ditches	1,372	5.3	--	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1 (0.2)	0	N/A
Upper Oak Creek	1,827	2.7	12.5	2.7	0.7	25.9	999	6.8	15 (5.5)	0	15	8	25 (9.3)	11	5
Oak Creek Headwaters	706	2.3	30.5	1.0	0.7	74.0	748	14.2	11 (11)	4	3	3	12 (5.2)	3	3
Mitchell Field Drainage Ditch															
Lower MFDD	1,443	1.8	6.7	1.8	1.7	94.4	1,183	12.5	3 (1.7)	0	22	4	11 (6.1)	6	6
MFDD – Airport	1,010	2.3	20.7	0.0	N/A	N/A	N/A	N/A	8 (3.5)[b]	N/A	N/A	N/A	23 (10.0)	N/A	N/A
North Branch Oak Creek															
Lower NBOC	978	2.8	12.2	2.8	0.9	32.1	1,558	10.5	7 (2.5)	0	13	24	18 (6.4)	12	9
Upper NBOC	1,257	3.5	11.6	3.5	1.5	42.9	1,019	5.5	18 (5.1)	0	8	13	31 (8.9)	1	5
Southland Creek	696	1.8[c]	25.3	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 (0.0)	N/A	N/A
Tributary to Southland	--	0.7[c]	32.6	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 (0.0)	N/A	N/A
Drexel Avenue Tributary[d]	814	1.3[c]	18.5	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 (0.0)	N/A	N/A
Tributary to Drexel Avenue Tributary	--	0.6[c]	41.7	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 (0.0)	N/A	N/A
Rawson Avenue Tributary[e]	968	2.0[c]	25.0	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29 (14.5)	N/A	N/A
Tributary to Rawson Avenue Tributary	--	0.7[c]	20.1	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0 (0.0)	N/A	N/A
College Avenue Tributary[f]	453	0.8[c]	22.7	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4 (5.0)	N/A	N/A

Note: N/A = Not Assessed.

[a] *Includes lengths of stream partially and fully disconnected from their floodplains.*

[b] *This number was derived from examination of aerial photography. Stream crossing surveys were not conducted by SEWRPC field crew in the Mitchell Field Drainage Ditch—Airport assessment area.*

[c] *Stream length includes only the extent of stream with a detailed flood model in the Milwaukee County Flood Insurance Study (FIS).*

[d] *Drexel Avenue Tributary is referred to as N7 Tributary in the Milwaukee County FIS and flows from north of Drexel Avenue to the confluence with the North Branch Oak Creek. The tributary to the Drexel Avenue Tributary is referred to as the N7A Tributary in the Milwaukee County FIS.*

[e] *Rawson Avenue Tributary is referred to as N5 Tributary in the Milwaukee County FIS and flows from north of Rawson Avenue south and west, across Interstate Highway 94 to the confluence with the North Branch Oak Creek. The tributary to the Rawson Avenue Tributary is referred to as the N4 Tributary in the Milwaukee County FIS.*

[f] *College Avenue Tributary is referred to as N2 Tributary in the Milwaukee County FIS.*

Source: SEWRPC

Drainage Network

Water from rainfall and snowmelt flows into streams within the Oak Creek watershed by one of three pathways: 1) flowing overland and entering the streams directly as surface water runoff, 2) flowing overland to storm sewer inlets, drain tiles, or ditches and swales, and entering the streams at their outfalls, or 3) 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 Oak Creek watershed is shown on Map 3.2 in Chapter 3 of this Report, where the intermittent reaches are shown as dashed blue lines, perennial streams as solid blue lines, and underground reaches of both intermittent and perennial streams are shown as orange dashed and solid lines, respectively.

There are three main streams within the Oak Creek watershed and multiple unnamed tributaries. The primary streams within the watershed include the mainstem of Oak Creek, North Branch Oak Creek, and the Mitchell Field Drainage Ditch. The mainstem of Oak Creek travels over 15 miles from its headwaters just north of Puetz Road and the Franklin Woods Nature Center in the City of Franklin and flows in a general west to east direction to its confluence with Lake Michigan near Grant Park. Assessment areas containing the mainstem of Oak Creek include (from downstream to upstream): the Grant Park Ravine, Lower Oak Creek—Mill Pond, Lower Oak Creek, Middle Oak Creek, Upper Oak Creek, and the Oak Creek Headwaters assessment areas (see Map 3.2). Much of the mainstem of Oak Creek has been channelized and straightened, typically with a trapezoidal shaped cross-section.[119]

North Branch Oak Creek and the Mitchell Field Drainage Ditch are the main tributaries flowing into the mainstem of Oak Creek. North Branch Oak Creek is over six miles of mostly perennial stream and flows south from its headwaters west of Interstate Highway 94 (IH 94) in the City of Greenfield, to its confluence with the Oak Creek mainstem, north of Ryan Road. There is one named tributary (Southland Creek) and multiple unnamed tributaries that flow into North Branch Oak Creek. For the purposes of this Report, these unnamed tributaries will be referred to by the name of the assessment areas in which they are located and include (from upstream to downstream) the College Avenue Tributary and the Rawson Avenue Tributary. The next most downstream tributary, located in the Drexel Avenue Tributary assessment area, has been referred to in other reports and some databases as Unnamed Creek 5. Southland Creek is the most downstream tributary to North Branch Oak Creek. In addition to the separate assessment areas for each of its tributaries, North Branch Oak Creek is divided into two assessment areas: the Lower North Branch Oak Creek and the Upper North Branch Oak Creek assessment areas (see Map 3.2). The upper reaches of North Branch Oak Creek receive a large amount of stormwater inputs directly from industrial parking lots. Most of North Branch Oak Creek is also channelized with trapezoidal shaped cross-sections, however the most downstream reach meanders through a mature beech and oak forest and exhibits a lesser degree of channelization.[120]

The Mitchell Field Drainage Ditch is over four miles of perennial and intermittent stream originating on the far western edge of Milwaukee Mitchell International Airport (MMIA) and first flows east through MMIA property and then south to its confluence with the mainstem of Oak Creek, which is just north of Drexel Avenue in the City of Oak Creek. Several unnamed tributaries flow into the Mitchell Field Drainage Ditch from the west. The Mitchell Field Drainage Ditch is divided into two assessment areas: The Lower Mitchell Field Drainage Ditch and the Mitchell Field Drainage Ditch—Airport assessment areas (see Map 3.2). All of the Mitchell Field Drainage Ditch has been straightened and channelized in either trapezoidal shaped ditches or in underground culvert (through much of MMIA property). Historic down-cutting in the Lower Mitchell Field Drainage Ditch has lowered the channel bed by as much as 5 feet near MMIA.[121]

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., mill pond impoundments and channelization). A stream is a transport system for water and sediment, and it is continually eroding and depositing sediments, which

[119] *Inter-Fluve, Inc.,* Milwaukee County Stream Assessment, Final Report, *September 2004*.

[120] *Ibid*.

[121] *Ibid*.

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." These streams retain their physical dimensions (equilibrium), but those physical features shift, or migrate, over time (dynamic). For example, it is not uncommon for a low-gradient stream in Southeastern Wisconsin to laterally migrate more than one foot within a single year.

The longitudinal slope of a channel is the ratio of elevation change between two points on the channel bed 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. Slopes within mountainous stream systems are typically greater than 10 percent, or an elevation drop of more than 528 feet per mile. Slopes within streams in the Oak Creek watershed are more typical of the lowland streams found in Southeastern Wisconsin and generally do not exceed 1 percent, or a drop in elevation of less than 53 feet per mile.

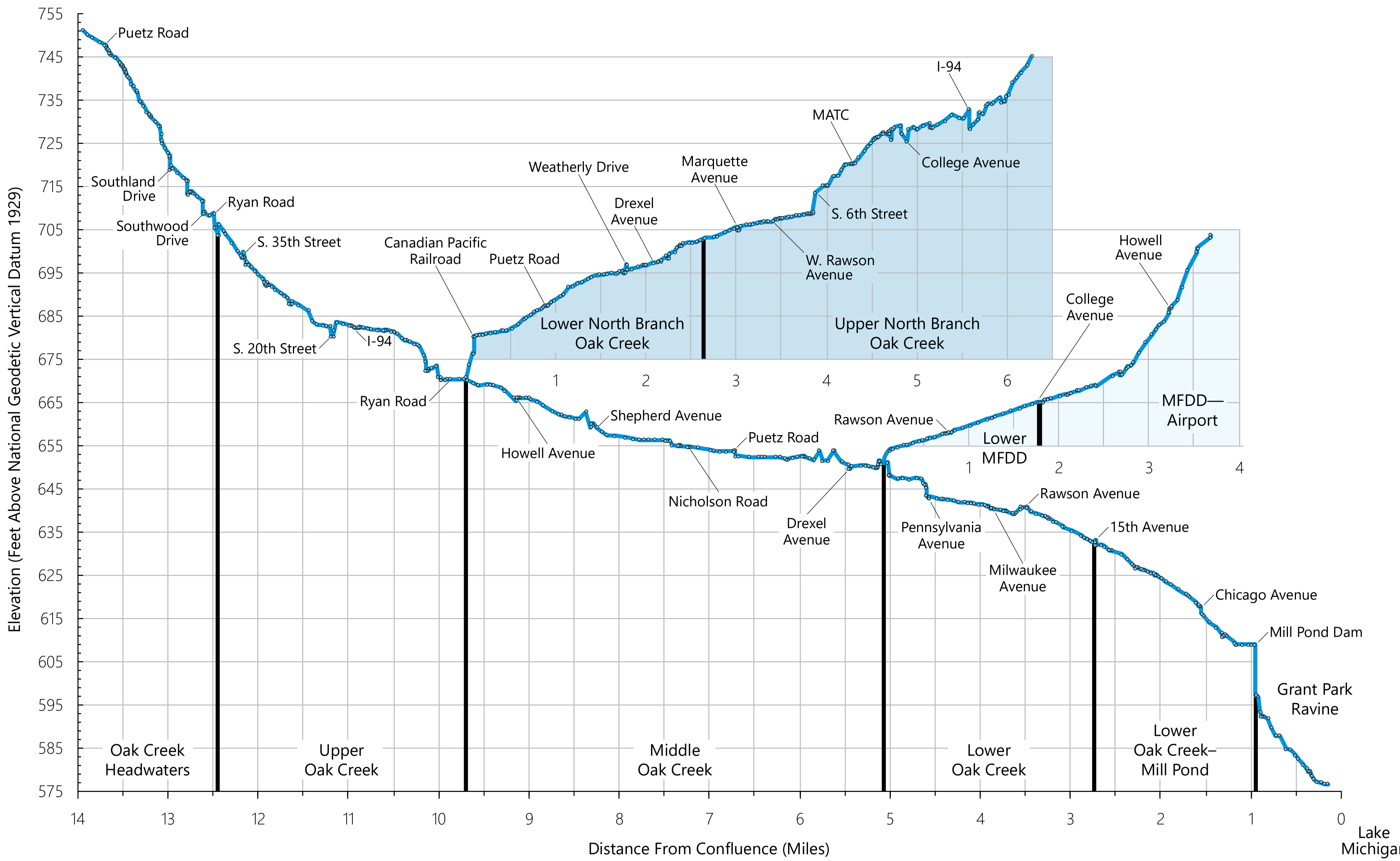
As shown in Figure 4.4, and quantified in Table 4.2, the channel slopes within the Oak Creek watershed vary greatly. Channel slopes in stream reaches of the Oak Creek watershed range between 0.08 and 0.79 percent, generally well below 1 percent. The steepest reaches of the mainstem of Oak Creek occur in the Grant Park Ravine (33.9 feet per mile) and the Oak Creek Headwaters (30.5 feet per mile) assessment areas. There are also relatively steep gradients in the Lower Oak Creek—Mill Pond assessment area (13.7 feet per mile), the upstream reaches of the Upper Oak Creek assessment area, the upper portions of the Mitchell Field Drainage Ditch through MMIA property, and the tributaries that flow into North Branch Oak Creek (tributary slopes range from 18.5 to 41.7 feet per mile) as quantified in Table 4.2 and shown graphically on Figure 4.4. The middle portions of the mainstem Oak Creek (Middle and Lower Oak Creek assessment areas), the lower portions of the Mitchell Field Drainage Ditch, and most of North Branch Oak Creek have much gentler gradients, ranging from 4.1 to 12.2 feet per mile.

All other hydraulic factors being equal or similar, steep channel slopes result in high streamflow velocities and shorter runoff times, whereas flat slopes produce lower velocities and longer runoff times. Stream slopes can also be an indicator of the types of substrates that might be found in certain reaches of streams. Larger and heavier types of substrates tend to be found in steeper reaches, and finer substrates tend to be found in low gradient[122] reaches where they are able to settle out of the slower moving water column. As would be expected, the reaches with the lowest channel slopes in the Oak Creek watershed exhibited the greatest accumulations of fine sediments. In contrast, the reaches with the steepest gradients were dominated by larger substrates such as sands, gravels, cobbles, or boulders (a more detailed examination of the distribution of substrates and sediment accumulations can be found in the Streambed Materials section below).

Healthy streams naturally meander across a landscape over time. Sinuosity is a measure of how much a stream meanders and is defined by a ratio of channel length between two points on a channel to a straight-line distance between the same two points. Sinuosity or channel pattern can range from a straight line to a winding pattern, or meandering. Channelized sections of streams that have been straightened typically have low sinuosity (i.e., a number closer to one). Much of the loss in sinuosity in streams within the Oak Creek watershed most likely occurred in the late part of the 19th century and early part of the 20th century from ditching or channel straightening to accommodate agricultural development. Other channelized streams within the watershed were ditched to better accommodate urban development, including the construction of IH 94 that crosses the western portion of the watershed from north to south. The sinuosities of the three principal stream reaches within the Oak Creek watershed are reported by assessment area for the years 1958 and 2015 in Table 4.2. As indicated in the table, stream sinuosities have changed very little since 1958. Sinuosities within the watershed ranged from 1.0 (a straight line) in the Lower Mitchell Field Drainage Ditch, to a maximum of 1.33 in the Lower Oak Creek—Mill Pond assessment area where the stream has a series of tight meanders upstream of the Mill Pond.

[122] *Stream reaches with slopes less than or equal to 26.4 feet per mile (0.5 percent) are considered to be low gradient reaches.*

Figure 4.4
Channel Bottom Profiles for Oak Creek and Select Tributaries



Source: SEWRPC

Table 4.2
Estimated Slope and Sinuosity of Selected Stream Reaches Within the Oak Creek Watershed: 1958 and 2015

Assessment Area and Stream Reach[a]	Sinuosity[b]		Slope (feet/mile)
	1958	2015	2015
Mainstem			
Grant Park Ravine	1.23	1.21	33.9
Lower Oak Creek – Mill Pond	1.32	1.33	13.7
Lower Oak Creek	1.02	1.02	7.5
Middle Oak Creek Drainage Ditches	--	--	--
Middle Oak Creek	1.03	1.04	4.1
Upper Oak Creek	1.04	1.04	12.5
Oak Creek Headwaters	1.06	1.06	30.5
Mitchell Field Drainage Ditch			
Lower Mitchell Field Drainage Ditch	1.00	1.01	6.7
Mitchell Field Drainage Ditch – Airport	1.03	1.03	20.7
North Branch Oak Creek			
Lower North Branch Oak Creek	1.05	1.04	12.2
Upper North Branch Oak Creek	1.05	1.02	11.6
Southland Creek	--	--	25.3
Tributary to Southland Creek	--	--	32.6
Drexel Avenue Tributary	--	--	18.5
Tributary to Drexel Avenue Tributary	--	--	41.7
Rawson Avenue Tributary	--	--	25.0
Tributary to Rawson Avenue Tributary	--	--	20.1
College Avenue Tributary	--	--	22.7

[a] *Assessment areas are shown on Map 3.2.*

[b] *Sinuosity was derived from the streamlines shown on the U.S. Geological Survey Quadrangle Map for 1958 and from orthophotographs from spring 2015.*

Source: SEWRPC

Channel Modifications, Channelization, and Disconnected Floodplain

As discussed in Chapter 3, maps drawn from surveys conducted in the mid and late 1800's show large wetland complexes occupied the areas of the Mitchell Field Drainage Ditch and North Branch Oak Creek. At the time of the surveys no discernable channels were indicated. It is likely that these streams were the result of channels being dug to drain the wetlands in these areas in order to cultivate the land (see Figure 3.6). Poor surface drainage in the watershed made it necessary to install tile underdrains to permit efficient agricultural operations. Because of the individual manner and the long period of time over which such drainage systems were installed, it is not possible to determine precisely the total tile-drained area. However, drain tile outfalls were observed at numerous locations in the watershed, indicating that subsurface drainage of land is widespread. It is unclear how many of these drain tile systems are still functioning today.

Modifications to stream channels usually include one or more of the following changes to the natural stream channel: channel straightening; channel deepening and lowering of the channel profile; channel widening; placement of a concrete channel invert and/or sidewalls; installation of dams, weirs, or drop structures; and construction or reconstruction of road bridges and culverts. In some instances, the natural channel may be relocated or completely enclosed in an underground conduit. Much of the stream system of the Oak Creek watershed was substantially modified in the late 19th and early 20th centuries for agricultural drainage purposes. As urbanization began to occur in the lower portions of the watershed, more modifications were implemented to assist in urban flood control. Many times, these modifications to the natural channel were done in an attempt to achieve a more hydraulically efficient waterway and to lower flood stages and reduce flood damages.

With the exception of the lower 5,000 feet, almost the entire length of the mainstem of Oak Creek has been modified to some degree. The channel modifications have been made over a long period of time by numerous public and private entities, and consequently, adequate records are not available to identify all of the stream reaches modified. Map 4.1 shows the extent of known human-made channel modifications along the three principal stream channels in the Oak Creek watershed, and the agency that led the effort. Some of the channel modifications could be considered minor and may not be readily apparent to the casual observer. These minor modifications could include localized clearing and widening and scattered straightening. There have also been major modifications that are readily apparent to the casual observer that include continuous and extensive deepening, widening and straightening, and some major relocations of stream channels.[123]

Large stretches of the mainstem of Oak Creek, North Branch Oak Creek, and Mitchell Field Drainage Ditch have been straightened and channelized with a trapezoidal cross-section. Small reaches of the mainstem Oak Creek and the unnamed tributary in the Rawson Avenue Tributary assessment area have had concrete channel bottom and/or side slopes installed (see Map 4.1 for locations). Figure 4.5 shows reaches of Oak Creek near 16th Avenue in the City of South Milwaukee where concrete side slopes have been installed. Examination of historical aerial photographs show the mainstem of Oak Creek between STH 38 (Howell Avenue) and STH 100 (Ryan Road) was relocated sometime between 1970 and 1975 when both highways were expanded from two lanes to four lanes. Relocating Oak Creek shortened the length of the North Branch Oak Creek and moved the confluence of the two streams about 1,000 feet to the north of the original confluence (see Figure 4.6). Similarly, a stretch of Oak Creek was relocated near IH 94 during its construction in the mid-1960s (see Figure 4.6).

The current day North Branch Oak Creek and Mitchell Field Drainage Ditches have sinuosities near one, indicating they are very straight. The upstream reaches of North Branch Oak Creek are also extremely incised, especially through Copernicus Park, and the remainder of the channel is trapezoidal with mainly grass-lined slopes. The upstream portions of the Mitchell Field Drainage Ditch consist of either grass-lined ditch or conduit running through MMIA. Downstream from MMIA, this tributary has also been channelized with some areas experiencing historical incision that has lowered the channel bed by as much as five feet.[124]

Channel modifications typically come at a high ecological and aesthetic cost. For example, channelizing a stream channel can reduce the diversity of habitat types (pool/riffle ratios) needed for survival of aquatic organisms. Channelized streams that have been over-excavated in width and depth can create slow baseflow water velocities that make deposition of silt more likely. Over-excavation and depositing spoils on the banks of the channel can disconnect a stream from its floodplain, decreasing the natural floodplain's storage capabilities to disperse flood waters and decrease their destructive energy, and allow pollutants to settle out across the floodplain. Increased streamflow velocities can be expected to result, leading to streambank and streambed erosion. Peak flood discharges may also be increased and could lead to new downstream flooding problems.

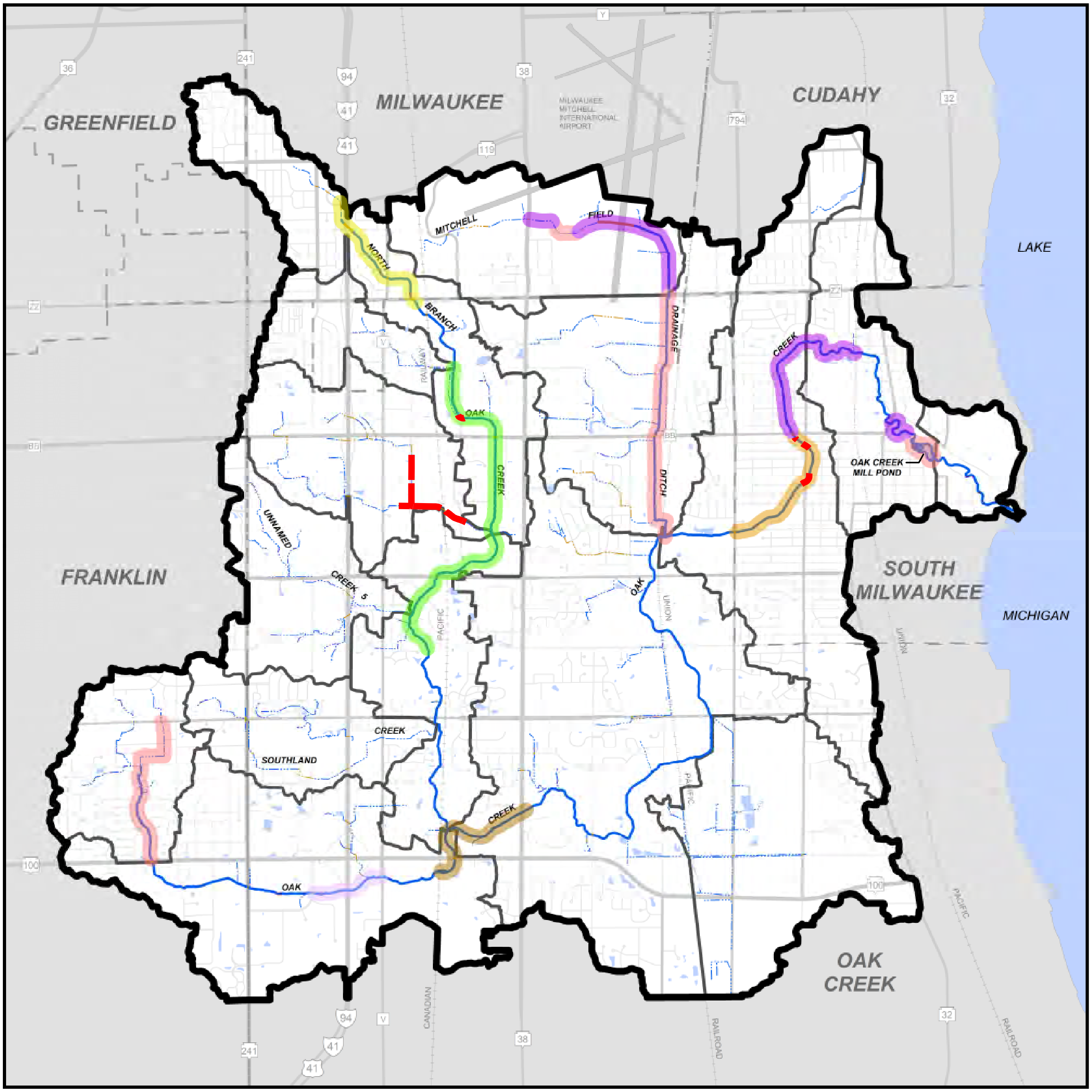
Floodplain connectivity can be evaluated in several ways, such as the bank height ratio (see Figure 4.7), entrenchment ratio, or stage/discharge relationships. Components to calculate bank height ratios (BHR) were measured at transect surveys where the streams were observed to be disconnected from the floodplain. The reach of Oak Creek that flows through the Grant Park Ravine assessment area was observed to have the best connection to the floodplain overall and had stable BHRs (see Figure 4.7 for photo of the well-connected floodplain in this assessment area). BHRs for surveyed streams in all other assessment areas ranged from stable to highly unstable, all having at least several sites with BHRs well over threshold for highly unstable streams (see Table 4.3 for BHRs and Figure 4.7 for photo example of severely disconnected floodplain). Map 4.2 generally characterizes the floodplain connectivity of stream reaches along the three principal streams within the Oak Creek watershed based on Commission staff observations. It is estimated that 55, 38, and 41 percent of the total length of the Oak Creek, North Branch Oak Creek, and the lower portions of the Mitchell Field Drainage Ditch, respectively, are at least partially disconnected from the floodplain. In these disconnected areas, floodplain functionality is greatly hindered.

---

[123] *SEWRPC Planning Report No. 36*, A Comprehensive Plan for the Oak Creek Watershed*, August 1986*.

[124] *Inter-Fluve, Inc., 2004,* op. cit.

Map 4.1
Known Channel Modifications Within the Oak Creek Watershed



CONCRETE LINED BANKS AND/OR CHANNEL BOTTOM

MODIFICATIONS MADE BY MILWAUKEE COUNTY

MODIFICATIONS MADE BY THE CITY OF MILWAUKEE

MODIFICATIONS MADE BY MMSD, THE CITY OF SOUTH MILWAUKEE, AND MILWAUKEE COUNTY

MODIFICATIONS MADE BY MMSD AND THE CITY OF OAK CREEK

MODIFICATIONS MADE BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION

MODIFICATIONS MADE BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION AND THE CITY OF OAK CREEK

OTHER MODIFICATIONS OBSERVED BY SEWRPC STAFF

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: SEWRPC

Streambank Erosion

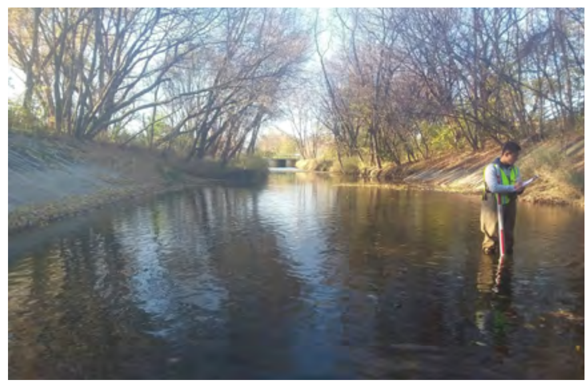
It is common for steam channels within stable stream systems to move within their floodplains both laterally and vertically over long periods of time, balancing the movements of sediments throughout the process. A stream reach is said to be in dynamic equilibrium when the sediment load leaving the reach is equal to the load entering the reach. A stream channel can be in balance with the hydrologic and sediment influences or can be in rapid transition as a result of changes in the watershed or within the stream corridor itself.[125] Streambank erosion can also be part of the natural processes within a stable stream, where erosion is balanced by deposition of sediment on floodplains (when the connection between stream and floodplain is still intact) and depositional bars within the channel itself. Streambank erosion can provide needed bed material, provide the channel diversity offered by coarse woody structure entering the stream, and promote varied aquatic habitats. Urban river systems such as in the Oak Creek watershed, however, are often in various states of disequilibrium. Excessive streambank erosion that is often associated with heavily altered and unstable riverine systems can contribute to water quality degradation by releasing too much sediment (and associated nutrients) to the water, leading to downstream sedimentation and degraded aquatic habitat. In addition, severe erosion in urban areas can also threaten vital infrastructure near the channel such as roads and stormwater infrastructure, so proximity to such infrastructure will also be considered when determining which streambank sites within the Oak Creek watershed should be remediated. These priority sites will be described in detail in Chapter 6 of this Report.

Commission staff inventoried streambank erosion along the three principal streams within the Oak Creek watershed by walking the streams with a tablet enabled with GPS and ESRI's Collector for ArcGIS application. Approximately 13.9 miles of the mainstem of Oak Creek; 6.3 miles of North Branch Oak Creek; and about 1.8 miles (about half the length) of the Mitchell Field Drainage Ditch were assessed for streambank erosion. Information on soil type, average and maximum erosion height, average depth of erosion, and length of eroded bank were collected. Photos were also taken to document each site. The lateral recession rates were estimated using the criteria in Table 4.4, and soil density was determined by soil type using photos, general soil maps, and NRCS Technical Guidance documents.[126] General locations of streambank erosion sites inventoried by Commission staff and their estimated lateral recession rates are shown

Figure 4.5
Examples of Concrete Lined Channels Along the Mainstem of Oak Creek, City of South Milwaukee

Looking Upstream from 16th Avenue Towards 15th Avenue

Looking Downstream from 15th Avenue Crossing (16th Avenue Triple Cell Culvert in Background)



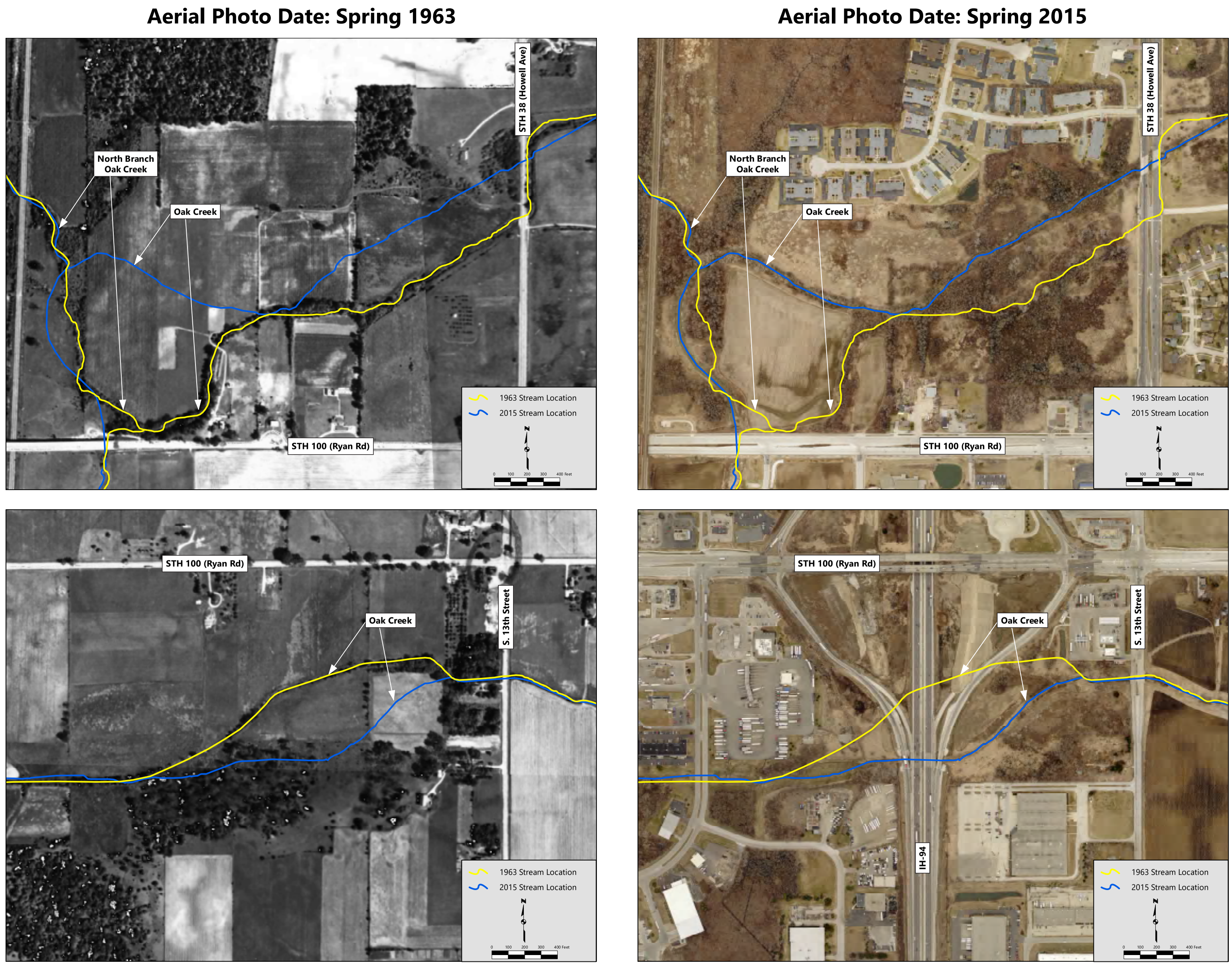
Looking Upstream (Southwest) Towards 15th Avenue Crossing (Taken From Milwaukee Avenue Bridge)

Source: SEWRPC

[125] *Ibid.*

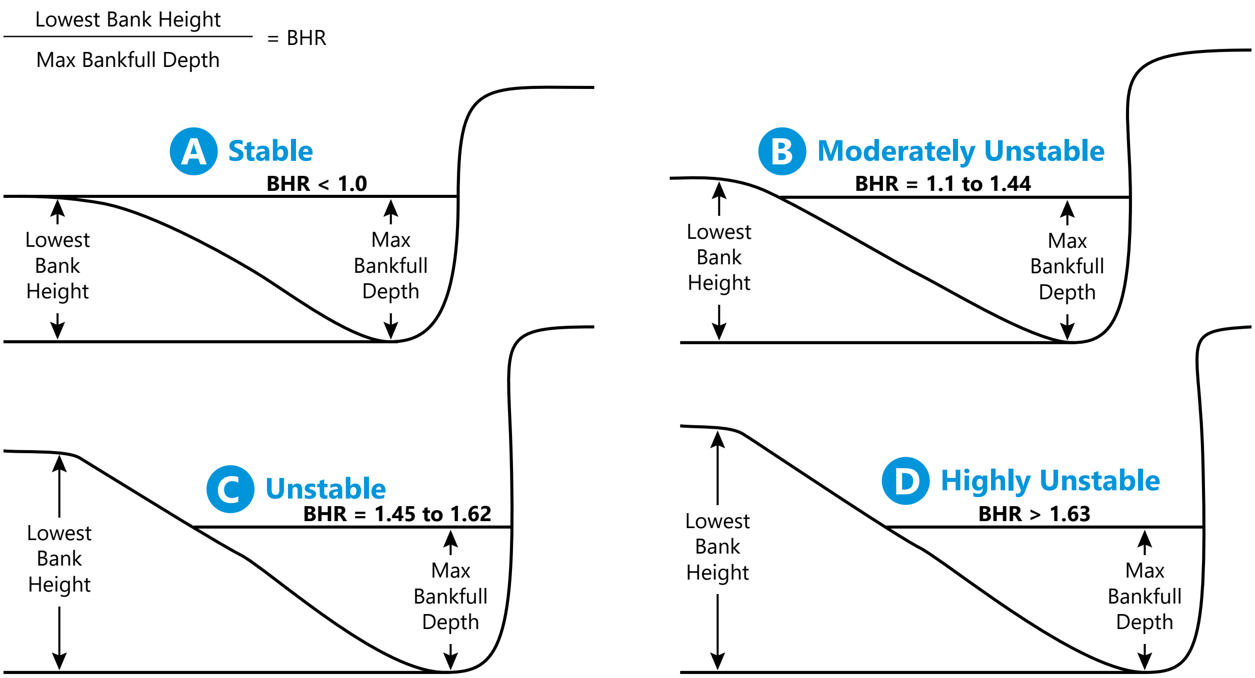
[126] *Natural Resources Conservation Service (NRCS),* Streambank Erosion. Field Office Technical Guide, *November 2003.*

Figure 4.6
Major Channel Modifications Related to State Highway and Interstate Highway Expansion Projects



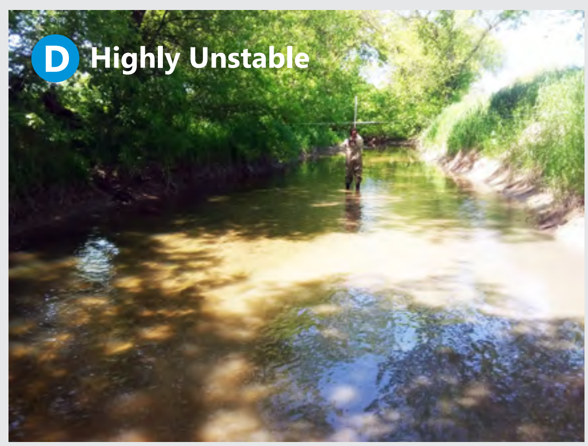
Source: SEWRPC

Figure 4.7
Bank Height Ratio (BHR) Schematic



Grant Park Ravine Assessment Area
Connected (Functional) Floodplain and Stable BHR

Middle Oak Creek Assessment Area
Severely Disconnected (Non-Functional) Floodplain and Highly Unstable BHR



Source: W. Barry Southerland, Fluvial Geomorphologist, NRCS, and SEWRPC

on Map 4.3.[127] The total length of erosion, percent of streambanks experiencing erosion, number of erosion sites in each lateral recession rate category, and estimates of annual pollutant loads that can be expected to result from current streambank erosion conditions are summarized in Table 4.5.

Streambank erosion within the Oak Creek watershed can be considered excessive at some locations. The significant erosion that was observed is likely the result of increased peak flows related to changes in land

[127] *Appendix F Maps F.13 through F.35 show the detailed locations of each streambank erosion site. These maps also indicate where minor streambank erosion was observed. While minor streambank erosion was noted, these sites were excluded from pollutant loading models and from reported total lengths of erosion.*

use, increased impervious surfaces throughout the watershed, channel straightening, and other channel modifications that have disconnected the streams from their floodplains. All of these watershed alterations have led to hydraulic scour of the channel bed and especially the toe of the banks. A total of 147 streambank erosion sites were observed during SEWRPC's field reconnaissance, totaling about 2.4 miles, or 5.6 percent of the streambanks assessed within the Oak Creek watershed.[128] Of the 147 eroding streambanks, 33 (2,341 linear feet) were estimated to have slight lateral recession (0.01-0.05 feet per year), 82 (6,951 linear feet) moderate lateral recession (0.06-0.2 feet per year), 31 (3,139 linear feet) severe lateral recession (0.3-0.5 feet per year), and one (171 linear feet) very severe lateral recession (greater than 0.5 feet per year) (see Table 4.5).

Table 4.3
Range of Bank Height Ratios at Transect Surveys

Assessment Area and Stream Reach[a]	Bank Height Ratios	Ranking
Mainstem		
Grant Park Ravine	>1.0	Stable
Lower Oak Creek – Mill Pond	>1.0 to 2.6	Stable to Highly Unstable
Lower Oak Creek	>1.0 to 2.1	Stable to Highly Unstable
Middle Oak Creek	>1.0 to 4.0	Stable to Highly Unstable
Upper Oak Creek	>1.0 to 3.9	Stable to Highly Unstable
Oak Creek Headwaters	>1.0 to 4.9	Stable to Highly Unstable
Mitchell Field Drainage Ditch		
Lower Mitchell Field Drainage Ditch	>1.0 to 7.1	Stable to Highly Unstable
North Branch Oak Creek		
Lower North Branch Oak Creek	>1.0 to 2.6	Stable to Highly Unstable
Upper North Branch Oak Creek	>1.0 to 3.4	Stable to Highly Unstable

[a] *Assessment areas are shown on Map 3.2.*

Source: SEWRPC

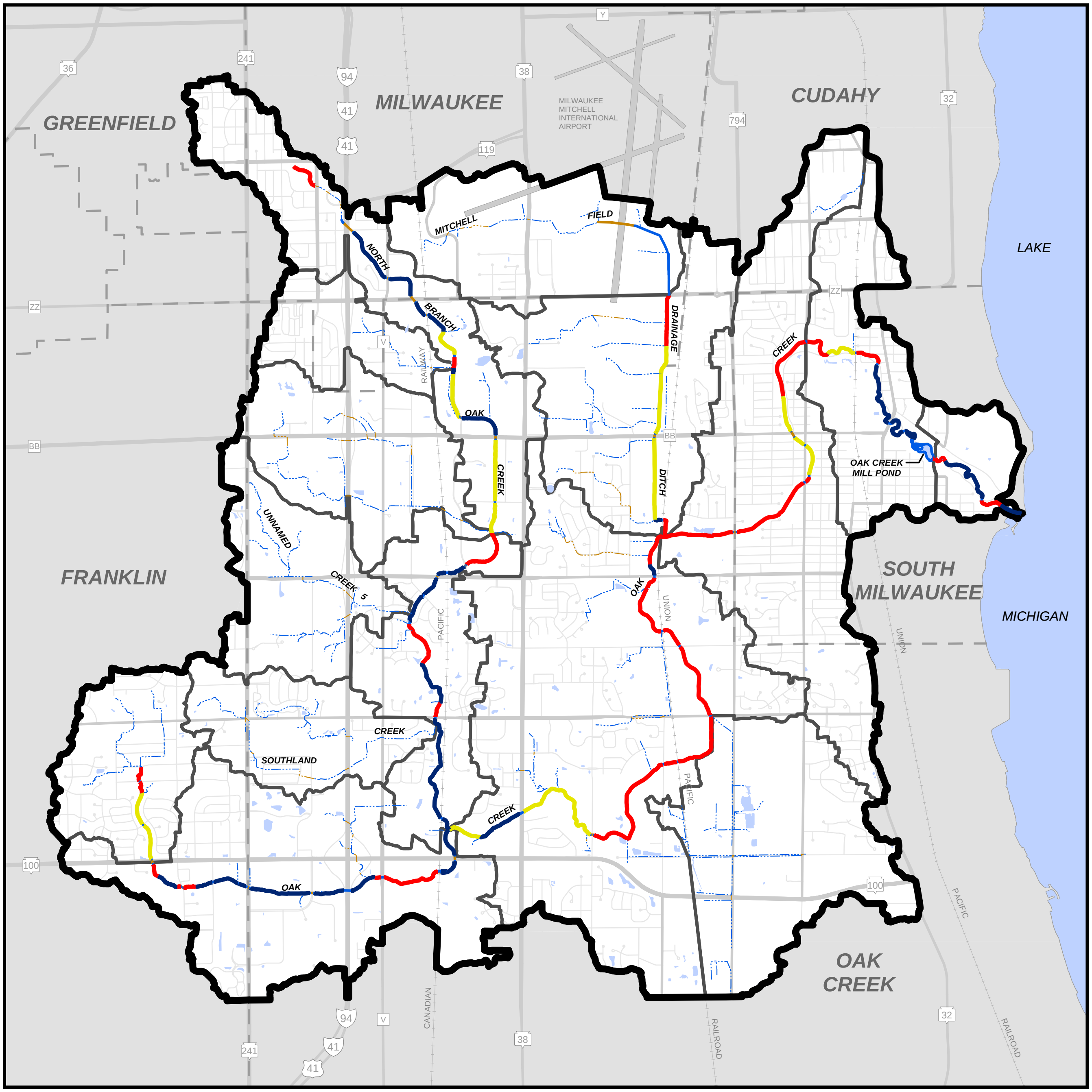
Annual pollutant loads for the inventoried streambank erosion sites were estimated using the U.S. Environmental Protections Agency's (USEPA) Spreadsheet Tool for Estimating Pollutant Loads (STEPL), and are summarized by assessment area in Table 4.5 and reported for each individual erosion site in Appendix D. The inventoried erosion throughout the watershed is estimated to annually contribute about 698 tons of sediment containing about 420 pounds of phosphorus, 1,090 pounds of nitrogen, and 2,180 pounds of biochemical oxygen demand. The Grant Park Ravine assessment area had the highest percentage of its banks actively eroding and is estimated to contribute the greatest sediment load in the watershed (197.5 tons). This is largely due to the presence of one very severe erosion site that is shown in Figure 4.8. The Middle Oak Creek assessment area had the most individual active erosion sites (39 sites) as well as the most sites considered to have severe lateral recession (7 sites). Figure 4.8 shows examples of erosion sites for each of the categories of lateral recession. Further analysis related to pollutant loading and the proportion of total pollutant loads that can be attributed to streambank erosion are presented in Chapter 5 of this Report. Priority streambank erosion sites in the watershed and their potential recommended remedies are discussed further in Chapter 6 of this Report.

Stormwater and Other Outfalls

A large portion of the principal streams within the Oak Creek watershed benefit from being adjacent to publicly owned lands. The mainstem of Oak Creek, in particular, benefits from flowing through the Milwaukee County Parks and Parkway system which provides extensive stream buffering, despite being located in a very densely urbanized area. The benefit provided by the parkway system is reduced by the fact that many storm sewers bypass the riparian corridor by completely or partially passing through the parkway lands discharging directly to the streams. Discharges from stormwater outfalls will typically contain pollutants washed off of impervious surfaces on the landscape and can also contribute to streambed and streambank erosion within the channel. In some instances, discharges may also contain bacteria originating from cross-connections between the sanitary and storm sewer systems, illicit discharges into the storm sewer system, or degrading sewer system infrastructure. Understanding where these outfalls are located and where their effluent discharge into the stream systems can help in the assessment of water quality issues and indicate where best management practices or retrofits are likely to be most effective. Sources of certain pollutants can also sometimes be tracked backwards from an outfall to the land area that drains to it, indicating where upland best management practices might be most effective. Knowledge of the condition of the outfalls can help municipalities that own the infrastructure to remedy issues affecting the functionality of particular outfalls and, potentially, large portions of their stormwater systems.

[128] *These lengths separately include both streambanks (left and right).*

Map 4.2
Floodplain Functionality Among Surveyed Stream Reaches Within the Oak Creek Watershed



FLOODPLAIN CONNECTIVITY

- DISCONNECTED (FLOODPLAIN NOT FUNCTIONING)
- PARTIALLY DISCONNECTED (FLOODPLAIN FUNCTIONING PARTIALLY)
- MOSTLY CONNECTED (FLOODPLAIN FUNCTIONING)
- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

STREAMS NOT ASSESSED

- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

0 0.25 0.5 1 Mile

Source: SEWRPC

Table 4.4
Streambank Erosion Lateral Recession Rate Descriptions

Lateral Recession Rate (feet per year)	Category	Description
0.01-0.05	Slight	Some bare bank, but active erosion not readily apparent. Some rills, but no vegetative overhang. No exposed tree roots.
0.06-0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang. Some exposed tree roots, but no slumps or slips.
0.3-0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross section becomes U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains, and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross section is U-shaped.

Source: Natural Resources Conservation Service

As part of the instream survey conducted in 2016 and 2017, Commission staff inventoried the location and attributes of encountered outfalls.[129] Data collected included the pipe size, material composition of the outfall, and an assessment of the general condition of each outfall. The assessment of general condition took into account the condition of the outfall structure itself, the amount of sediment buildup within the outfall, and erosion adjacent to the outfall. Any flows coming from the outfall at the time of the survey were noted (an analysis and discussion related to dry weather flow from outfalls and bacterial levels in streams can be found later in Chapter 4). Photos of each outfall were also collected to further document existing outfall conditions and assist in future identification. During the survey, Commission staff encountered a total of 136 outfalls discharging into, or near, surveyed portions of Oak Creek, North Branch Oak Creek, and the Mitchell Field Drainage Ditch.

In addition to the outfalls that were inventoried by Commission staff, municipalities with MS4 stormwater discharge permits are required to keep an inventory of known substantial outfalls within their service areas. Shapefiles and associated attributes of these municipal inventories were provided by Milwaukee County and the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee for analysis in this Report. The City of Racine Public Health Department also located selected stormwater outfalls as part of their assessment of the impact of outfalls on the water quality of the Oak Creek watershed.[130] Commission staff analyzed all available inventories to integrate information on identical and unique outfalls into one master inventory. A summary of this inventory is provided in Table 4.6. The complete inventory of outfalls is provided in Appendix Table E.1, locations of outfalls are shown on Appendix Map E.1, and where available, photographs of each outfall are provided in Appendix Figure E.1. A total of 299 outfalls were inventoried within the Oak Creek watershed, 45 of which are in poor or failed condition. It should be noted that there are likely a significant number of outfalls within the watershed that do not appear in this inventory because they are located on streams that were not surveyed, they were obstructed from view during the instream surveys, or they are not included in municipal records. Some of the outfalls in the inventory also may not be functional, either due to structural failures or intentional disconnections from storm sewer systems.

Stream Reach Dynamics

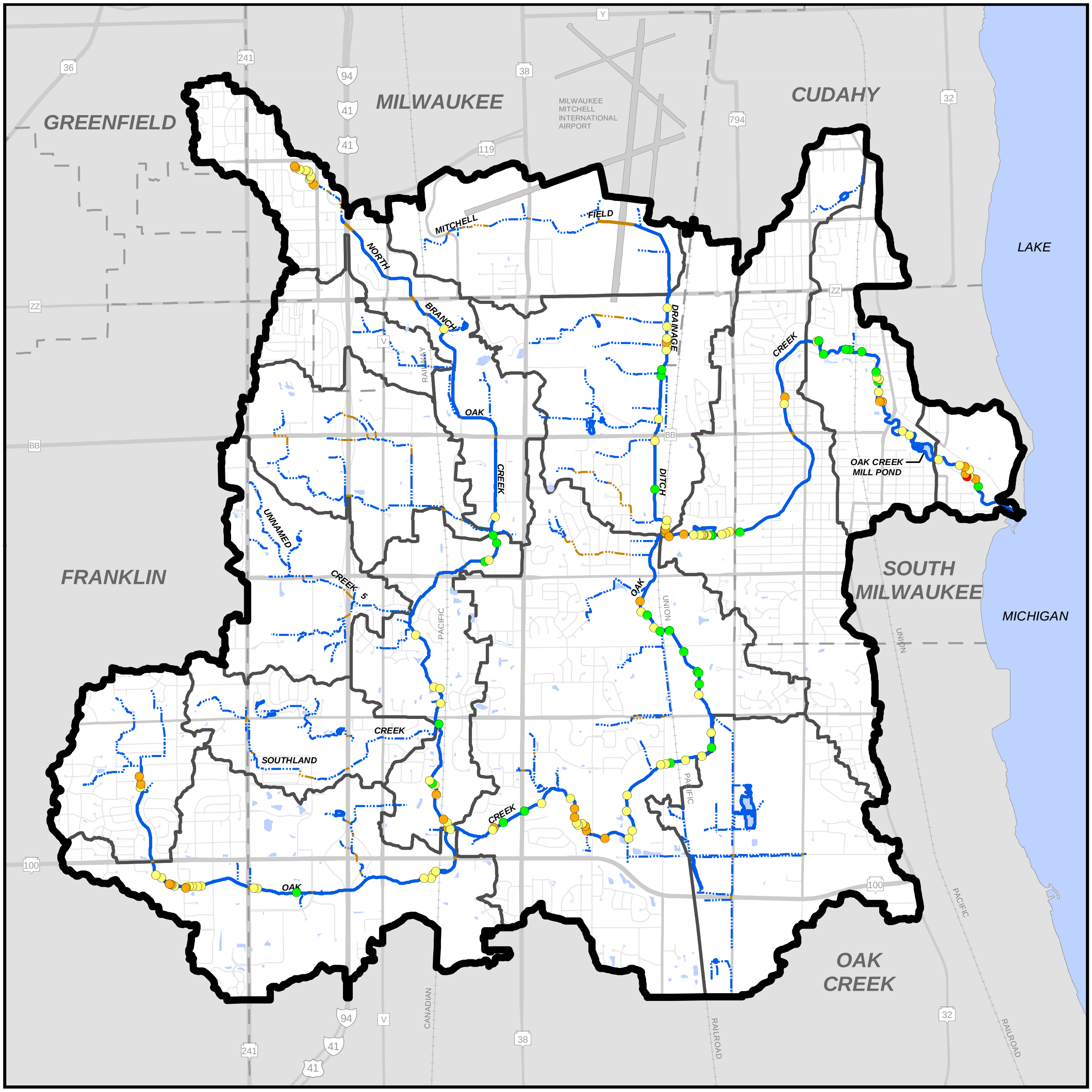
To better understand stream systems and what shapes their conditions, it is important to understand the effects of both spatial and temporal scales. Streams can be theoretically subdivided into a continuum of habitat sensitivity to disturbance and recovery time as shown in Figure 4.9.[131] Microhabitats, such as a handful-sized patch of gravel, are most susceptible to disturbance; entire watersheds or drainage basins are least susceptible. Furthermore, events that affect smaller scale habitat characteristics may not affect

[129] *Not all outfalls encountered during the instream survey could be confirmed as stormwater outfalls.*

[130] *Kwabena Agyenim Boateng and Julie Kinzelman,* Assessment of the Impact of Storm Water Outfalls on the Oak Creek, *Master's Thesis, University of Surrey, Guildford, Surrey, United Kingdom, August 2016. This work was part of a study conducted by the City of Racine Public Health Department.*

[131] *Adapted from 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.*

Map 4.3
Locations and Lateral Recession Severity of Observed Streambank Erosion Within the Oak Creek Watershed: 2016-2017



LATERAL RECESSION RATE

- SLIGHT (0.01 - 0.05 FT/YR)
- MODERATE (0.06 - 0.2 FT/YR)
- SEVERE (0.3 - 0.5 FT/YR)
- VERY SEVERE (>0.5 FT/YR)

Note: Streambank erosion locations are mapped in more detail by Assessment Area in Appendix F.

- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: SEWRPC

Table 4.5
Streambank Erosion Statistics for Surveyed Streams Within the Oak Creek Watershed: 2016-2017

Assessment Area	Number and Length of Eroding Streambanks (feet)	Percent of Stream Length with Eroded Banks[a]	Number of Erosion Sites by Lateral Recession Rate				Annual Pollutant Loads From Streambank Erosion			
			Slight	Moderate	Severe	Very Severe	Sediment (tons/year)	Phosphorus (lbs/year)	Nitrogen (lbs/year)	Biochemical Oxygen Demand (lbs/year)
Mainstem										
Grant Park Ravine	9 (1,403)	26.6	1	4	3	1	197.5	104.6	271.7	543.4
Lower Oak Creek – Mill Pond	15 (1,341)	14.1	7	6	2	0	34.8	21.4	55.6	111.2
Lower Oak Creek	17 (1,646)	13.0	3	10	4	0	39.2	29.2	75.9	151.9
Middle Oak Creek	39 (3,014)	12.4	13	19	7	0	126.1	79.1	205.3	410.8
Upper Oak Creek	19 (999)	6.8	1	15	3	0	34.8	21.5	55.9	111.8
Oak Creek Headwaters	3 (748)	14.2	0	1	2	0	96.9	59.7	155.1	310.2
Mitchell Field Drainage Ditch										
Lower Mitchell Field Drainage Ditch	15 (1,183)	12.5	3	9	3	0	43.0	26.6	69.1	138.3
North Branch Oak Creek										
Lower North Branch Oak Creek	17 (1,558)	10.5	5	8	4	0	69.3	42.7	110.8	221.7
Upper North Branch Oak Creek	13 (1,019)	5.5	0	10	3	0	56.8	35.0	90.9	181.8
Watershed Total (Surveyed Portion)	147 (12,911)	11.3	33	82	31	1	698.0	419.5	1,089.6	2,179.5

Note: Annual pollutant loads from streambank erosion sites were estimated using the Environmental Protection Agency's Spreadsheet Tool for Estimating Pollutant Loads (STEPL). Statistics for each individual streambank erosion site can be found in Appendix D.

[a] *Percentage of streambanks eroding is calculated using the total length of both (left and right) streambanks that were surveyed.*

Source: SEWRPC

Figure 4.8
Examples of Lateral Recession Rate Categories for Streambank Erosion Surveyed in the Oak Creek Watershed

Streambank Erosion Site 114
Lower North Branch Oak Creek Assessment Area

Streambank Erosion Site 3
Grant Park Ravine Assessment Area

Streambank Erosion Site 144
Upper North Branch Oak Creek Assessment Area

Streambank Erosion Site 4
Grant Park Ravine Assessment Area

Source: SEWRPC

larger-scale system characteristics, whereas large disturbances can directly influence both large- and smaller-scale features of streams. For example, on a small spatial scale, deposition at a 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 larger-scale disturbance, such as a large debris jam, is initiated at the reach 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.[132]

The methodology for the instream habitat surveys that the Commission staff conducted of the principal streams of the Oak Creek watershed is rooted in the concepts described above. Transect surveys conducted at an individual habitat scale can paint a picture of conditions at that particular habitat site, and when analyzed collectively, can tell a story about conditions at larger scales (reach and watershed scales). In other

[132] *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.*

Table 4.6
Summary of Inventoried Outfalls in the Oak Creek Watershed

Assessment Area	Number of Outfalls	Number of Outfalls in Poor or Failed Condition[a]
Mainstem		
Grant Park Ravine	25	2
Lower Oak Creek – Mill Pond	38	13
Lower Oak Creek	60	10
Middle Oak Creek Drainage Ditches	1	--[b]
Middle Oak Creek	22	0
Upper Oak Creek	25	3
Oak Creek Headwaters	12	0
Mitchell Field Drainage Ditch		
Lower Mitchell Field Drainage Ditch	11	--
Mitchell Field Drainage Ditch – Airport	23	--[b]
North Branch Oak Creek		
Lower North Branch Oak Creek	18	4
Upper North Branch Oak Creek	31	13
Southland Creek	0	--[b]
Drexel Avenue Tributary	0	--[b]
Rawson Avenue Tributary	29	--[b]
College Avenue Tributary	4	--[b]
Total	299	45

Note: Details and photographs of individual outfalls can be found in Appendix E.

[a] *Only outfalls that were inventoried during SEWRPC's instream survey were assessed for condition.*

[b] *SEWRPC staff did not conduct instream surveys in this assessment area. Therefore, none of the outfalls were assessed for condition.*

Source: Milwaukee County; the Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee; and SEWRPC

words, these surveys can help determine what the impacts of land use practices are at a localized site-specific scale within the streams and help assess watershed-wide, cumulative impacts of human activities on the streams and their biota. Temporally, these surveys also provide a snapshot in time and can be used as a baseline for future studies and comparison to past biological quality assessments.

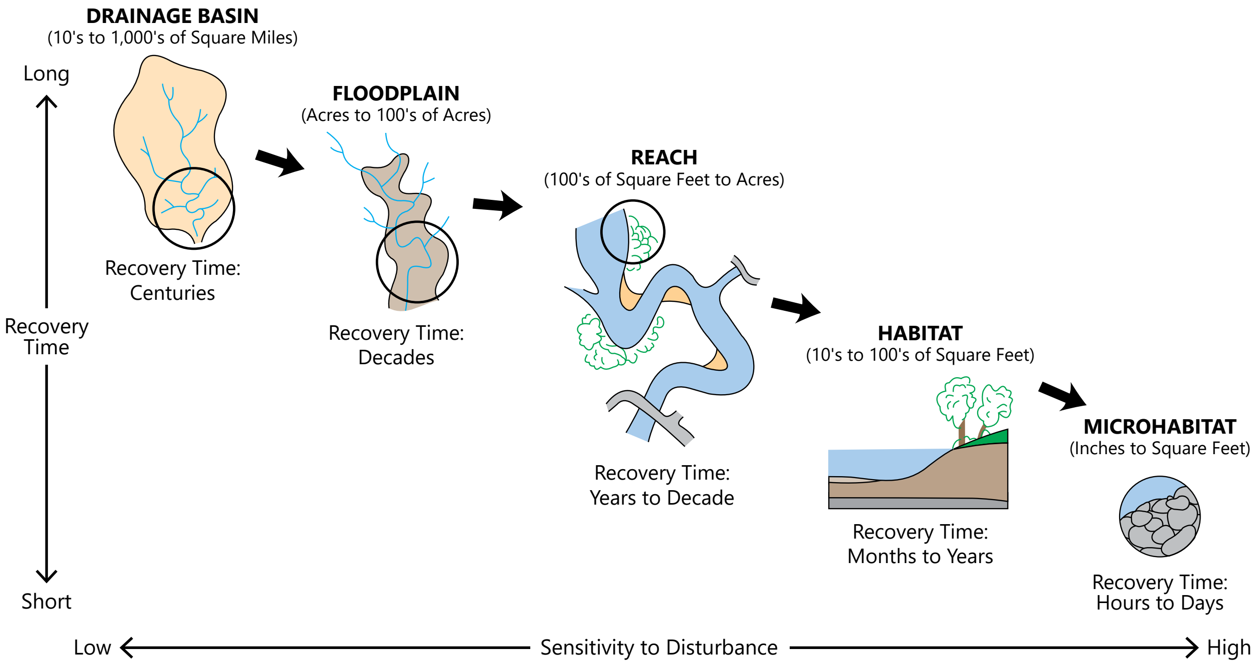
Transect survey locations were chosen where pool, riffle, or run habitats were either representative of the stream reach or, in contrast, where there were noticeable differences in channel reach characteristics. A total of 162 transect surveys were conducted by Commission staff from July through November 2016, and May through September 2017. These transect surveys included 112 (8 per mile surveyed) conducted on the mainstem of Oak Creek, 39 (6.2 per mile surveyed) on North Branch of Oak Creek, and 11 (6.4 per mile surveyed) on the portion of the Mitchell Field Drainage Ditch downstream of College Avenue. Physical parameters that were quantitatively measured at each transect survey included water and sediment depth, bank slope, presence and depth of undercut banks, water width, bankfull width, and bankfull depth. Qualitative measures collected at transect surveys included habitat type (pool, riffle, or run), substrate composition, general flow velocity, presence of channel shading, presence of fish cover, and the primary fish cover types. In order to supplement information between transect surveys, width and maximum depth measurements were taken at an additional 467 deep pool and 340 riffle habitat locations. The discussion below of various stream reach dynamics analyzes the results of these surveys.

Instream Habitat Types

The overall distribution of instream habitat types as characterized by pools (deep water and slower water velocities), riffles (shallow water, large substrates, higher water velocities), and runs (intermediate depth and water velocities) are shown by assessment area on Maps F.1 through F.12 in Appendix F.[133] The quantity and distribution of pool, riffle, and run habitat units are fundamental metrics upon which overall instream habitat

[133] *Due to the amount of data represented in these maps, it was necessary to split some of the assessment area maps into several reaches.*

Figure 4.9
Relationship Between Recovery Time and Sensitivity to Disturbance for Different Hierachical Spatial Scales Associated with Stream Systems



Source: Adapted from C.A. Frissell, W.J. Liss, C.E. Warren, and M.D. Hurley, "A Hierarchical Framework for Stream Habitat Classification: Viewing Streams in a Watershed Context," Environmental Management 10: 199-214, *1986, and SEWRPC*

quality can be assessed. Riffle habitats typically have shallow and faster moving water that flows over larger substrates, adding oxygen to the water. Riffles provide cover for macroinvertebrates and are important spawning and feeding areas for many native fish species, and therefore the numbers and distribution of riffles can affect fish species distribution. Pool habitats are characterized by deeper and slower moving water and typically contain finer substrates that are allowed to settle out of the water column. Pool habitats are also important components of the fish habitat in streams, especially for larger fish, because their greater depth offers protection from predators, feeding areas, and refuge from high temperatures in the summer and cold temperatures in the winter. Equal numbers of pool and riffle habitats is considered optimal for most fish species and for biological diversity in general. Thus, healthy streams have a pool-riffle ratio near 1:1 in any given reach.

The general habitat characteristics are given for stream reaches in each assessment area in Table 4.7. The diversity of pool and riffle structures in the downstream portion of the mainstem of Oak Creek is relatively good, with the Grant Park Ravine (23 pools and 21 riffles per mile) and Lower Oak Creek—Mill Pond (23 pools and 24 riffles per mile) assessment areas having a pool-riffle ratios near one. The diversity of pool-riffle structures decrease slightly in the Lower Oak Creek (14 pools and 10 riffles per mile) and Middle Oak Creek (21 pools and 11 riffles per mile) assessment areas, where widespread channelization has led to a marked decrease in the numbers of pools and riffles per mile when compared to downstream reaches. Pool-riffle diversity seems to improve within the Upper Oak Creek assessment area, which contained the highest number of pools and riffles per mile (26 pool and 29 riffles) of any mainstem assessment area and a pool-riffle ratio of 0.9. In the Oak Creek Headwaters assessment area, diversity of habitat types decreases where there are more than two times the number of riffle habitats than pool habitats, which is likely attributable to the lower quantity of water in headwater streams. In the tributary streams that were surveyed, there were almost two times more pools than riffles in both the Lower North Branch Oak Creek and Lower Mitchell Field Drainage Ditch. The Upper North Branch Oak Creek exhibited the fewest pool and riffle habitats per mile (9 pools and 3 riffles per mile), as well as the poorest pool-riffle ratio of 2.7. This poor habitat diversity within the tributary streams speaks to the highly modified stream channels.

Table 4.7
Instream Habitat Characteristics of Surveyed Stream Reaches Within the Oak Creek Watershed: 2016-2017

	Mainstem						**Mitchell Field Drainage Ditch**	**North Branch Oak Creek**	
Principal Streams and Assessment Areas	Grant Park Ravine	Lower Oak Creek – Mill Pond	Lower Oak Creek	Middle Oak Creek	Upper Oak Creek	Oak Creek Headwaters	Lower Mitchell Field Drainage Ditch	Lower North Branch Oak Creek	Upper North Branch Oak Creek
Transects									
Number of Transects	5	12	20	43	24	8	11	25	14
Transects per Mile	6.3	5.2	8.3	9.3	8.6	8.0	6.1	8.9	4.0
Habitat Composition									
Number of Pools per Mile	22.5	22.6	14.2	20.9	26.1	14.0	31.1	35.4	9.4
Number of Riffles per Mile	21.3	24.3	10.0	11.1	28.6	34.0	18.3	19.3	3.4
Pool/Riffle Ratio	1.1	0.9	1.4	1.9	0.9	0.4	1.7	1.8	2.7
Average Wetted Width (feet)	20.8	18.7	24.7	18.9	8.0	6.7	11.2	16.4	7.7
Depth									
Mean Maximum Pool Depth (feet)	2.1	2.7	3.2	2.5	1.5	1.1	2.0	2.0	1.5
Residual Pool Depth (feet)[a]	1.6	2.2	2.6	2.0	1.2	1.0	1.8	1.7	1.4
Mean Maximum Run Depth (feet)[b]	--	1.4	1.9	1.8	0.9	0.5	0.9	1.1	0.9
Mean Maximum Riffle Depth (feet)	0.5	0.5	0.6	0.5	0.3	0.1	0.2	0.3	0.1
Substrates									
Sediment Depth[b]									
Mean Depth (feet)	0.0	0.04	0.2	0.5	0.4[c]	0.1	0.5	0.2	0.6
Maximum Depth (feet)	0.5	0.6	1.7	3.8	1.8[c]	0.9	3.2	1.3	2.9
Composition[b]									
Clay (percent)	0.0	1.2	1.0	17.5	14.9	27.3	0.8	9.4	4.4
Silt (percent)	7.8	9.9	16.7	35.1	31.2	12.7	30.3	15.2	40.6
Sand (percent)	10.9	28.5	38.3	27.9	35.1	34.5	36.1	37.9	31.9
Gravel (percent)	36.0	28.5	27.7	13.3	18.8	25.5	21.3	25.3	11.0
Cobble (percent)	29.7	25.0	10.5	3.6	0.0	0.0	1.7	11.5	3.3
Boulder (percent)	12.5	6.4	5.3	0.2	0.0	0.0	0.0	0.7	0.0
Rubble (percent)	3.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Muck (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8
Peat (percent)	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0
Plant Detritus (percent)	0.0	0.5	0.5	2.2	0.0	0.0	4.9	0.0	0.0

[a] *Residual pool depth was estimated by assessment areas within the Oak Creek watershed by subtracting the mean maximum water depths of all riffles within a reach from the maximum pool depth recorded within each individual pool.*

[b] *Constituent only measured at transect habitat survey.*

[c] *Sediment depth measurements were not collected in the downstream-most reach of the Upper Oak Creek assessment area from STH 100 to the confluence with North Branch Oak Creek because sediment was too deep to safely measure. Therefore, both mean and maximum sediment depths for the Lower Oak Creek assessment area are assumed to be significantly higher than reported in this table.*

Source: SEWRPC

Stream Widths and Water Depths

The size of streams typically increases in an upstream to downstream direction. In unmodified systems, streams gradually increase their width and depth and the amount of water they convey as tributary streams enter the main channel. This pattern applies to a portion of the mainstem of Oak Creek but is not followed along its whole length. Graphically, these trends are shown using box plots. An explanation of box plot symbols in is given in Figure 4.10.

There is a general increase in stream width and maximum water depths from the Upper Oak Creek—Headwaters assessment area through the Lower Oak Creek assessment area (see Table 4.7 and Figure 4.11). However, this trend reverses downstream of the Lower Oak Creek assessment area, where the stream widths and depths decrease in the Lower Oak Creek—Mill Pond assessment area. Stream depths also decrease in the Grant Park Ravine assessment area; however, stream widths increase slightly. Stream widths in this downstream-most assessment area are still, on average, almost four feet less than those in the Lower Oak Creek assessment area.

Figure 4.11 shows the statistics for the water widths and maximum water depths measured at all transect surveys[134] in each assessment area along the mainstem of Oak Creek. As shown in Figure 4.11, mean stream widths increase from less than 10 feet in both the Oak Creek—Headwaters and Upper Oak Creek assessment areas to almost 25 feet in the Lower Oak Creek assessment area. They then decrease to about 20 feet in the Mill Pond and Grant Park Ravine assessment areas, respectively. Similarly, mean water depths increase from about 0.4 feet in the Headwaters assessment area to almost 1.0 foot in the Upper Oak Creek assessment area, and double again to more than 2.0 feet in the Lower Oak Creek assessment area, before decreasing to about 1.5 feet in the Mill Pond and Grant Park Ravine assessment areas. It should be noted that stream width and depth data is only available for the Grant Park Ravine assessment area from about 1,200 feet upstream of the confluence with Lake Michigan, where the backwater of the Lake starts to take effect and make the stream unwadeable. Similarly, width and depth measurements were not taken where Oak Creek flows through the Mill Pond.

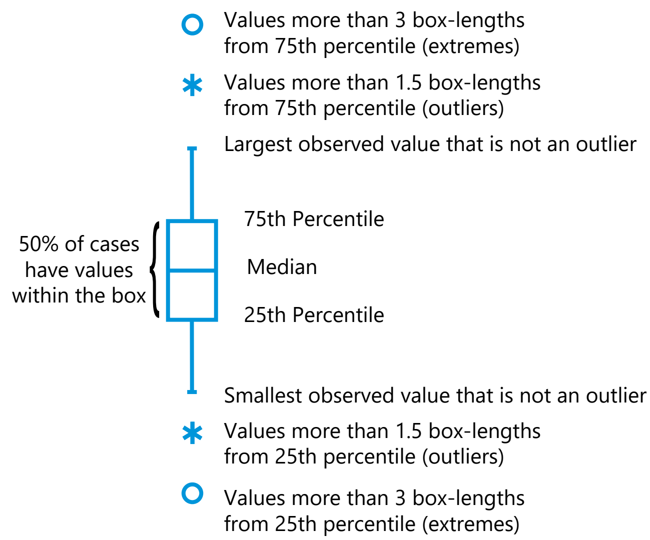
The abrupt increase in both width and depth in the Middle Oak Creek and Lower Oak Creek assessment areas may be explained by at least three factors. First, the inflow of the North Branch Oak Creek, which enters at the upstream end of the Middle Oak Creek assessment area, and Mitchell Field Drainage Ditch, which enters at the upstream end of the Lower Oak Creek assessment area, substantially increase the flows in these reaches, thus it may be expected that stream width and depth would also increase to accommodate the increased flows. Second, as shown in Figure 4.4 and Table 4.2, the Middle and Lower Oak Creek assessment areas have the most gradual slopes when compared to the other mainstem assessment areas. Gradual slopes can contribute to slower velocities and deeper streams. Downstream of the Lower Oak Creek assessment area, stream slopes almost double in the Mill Pond assessment areas (7.5 to 13.7 feet per mile) and more than double again from the Mill Pond to the Grant Park Ravine assessment areas (13.7 to 33.9 feet per mile). This may help to explain the shallower stream depths observed in these downstream-most assessment area reaches, even though they carry larger volumes of water than upstream reaches. Third, modifications to the stream channel in the middle and lower assessment areas likely included channelization, channel widening, and channel deepening. This is supported by Map 4.2, which shows that the greatest concentration of stream reaches that are disconnected from their floodplain occur within the Middle Oak Creek and Lower Oak Creek assessment areas. Often spoils from channelization projects are deposited on the banks, severing the stream-floodplain connection.

Water width and maximum water depths for the assessment area reaches of North Branch Oak Creek and Mitchell Field Drainage Ditch are shown in Figure 4.12. North Branch Oak Creek follows the typical trend of width and water depths increasing from upstream to downstream, with the water width more than doubling from a mean of almost eight feet in the Upper North Branch Oak Creek assessment area to more than 16 feet in the Lower North Branch Oak Creek assessment area. The mean maximum water depths also increase from upstream to downstream, but only by about 0.2 feet. For the Mitchell Field Drainage Ditch, only the Lower Mitchell Field Drainage Ditch assessment area was surveyed due to accessibility issues on the portion within MMIA property. Stream widths for the Lower Mitchell Field Drainage Ditch varied from 4 to almost 19 feet,

[134] *For habitat types surveyed between transect surveys, Figure 4.11 also included water widths at each surveyed riffle habitat. Maximum water depths are included for riffle and pool habitats.*

with a mean width of just over 11 feet. Mean maximum water depths within this assessment area varied greatly from a maximum of 4.5 feet in the deepest pool to several instances of 0.1 feet in shallow riffle habitats, with a mean maximum depth of 1.3 feet.

Figure 4.10
Explanation of Symbols in Box Plot Figures



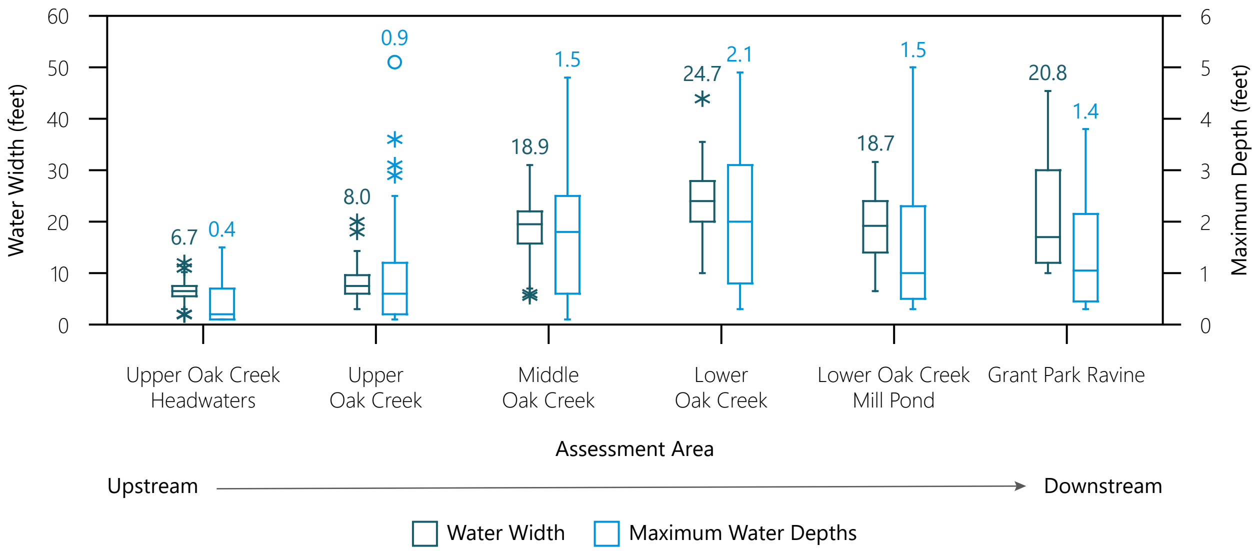
Source: SEWRPC

The maximum depths of pool, riffle, and run habitats also vary from headwater areas to the confluence with Lake Michigan. These differences indicate that although the same types of habitat occur in the upstream reaches as the downstream reaches, the pools, riffles, and runs in the upper portions of the watershed effectively offer smaller habitat areas than corresponding habitat areas in the lower reaches of the watershed. These differences 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. Upstream reaches naturally contain a lower abundance and diversity of fishes compared to downstream reaches because these reaches contain less water volume. However, it is important to note that these upstream areas provide vital spawning habitats for the sustained quality and productivity of the entire fishery of the Oak Creek watershed upstream of the Mill Pond dam (any fish downstream of the dam are completely disconnected from these upstream areas).

Trends in maximum water depths are broken down by habitat types in Figure 4.13 for Oak Creek and Figure 4.14 for North Branch Oak Creek and the Mitchell Field Drainage Ditch, and mean maximum depths are quantified in Table 4.7. Mean maximum riffle depths were observed to be relatively similar throughout most of the mainstem Oak Creek, averaging about one-half foot in the Grant Park Ravine through the Middle Oak Creek assessment areas. The remaining upstream portions of Oak Creek as well as the surveyed portions of North Branch Oak Creek and Mitchell Field Drainage Ditch had mean maximum riffle depths ranging from 0.1 to 0.3 feet. A greater variation in mean maximum water depths were observed in both pool and run habitat types. The deepest pool habitats are within the middle portions of the watershed. More than 25 percent of the pools in the Middle Oak Creek and Lower Oak Creek—Mill Pond assessment areas are greater than three feet deep, while in the Lower Oak Creek assessment area almost 25 percent of the pools are greater than four feet deep. Meanwhile, more than 75 percent of pool depths in the Upper Oak Creek assessment area and all pools in the Headwaters assessment area are less than two feet deep.

Monitoring pools can assist with measuring the effectiveness of stream restoration projects as well as natural stream processes. However, variations in water depth associated with differing amounts of discharge can complicate assessment of changes in the depth and volume of pools. To remove the effect of discharge on the depth of pool habitats, residual pool depths can be measured. This measurement also represents extreme low-flow conditions, and can often determine the capacity of streams to support and produce fish, especially during summer months when water temperatures are highest and drought conditions can lead to extremely low flows in streams. Residual pool depth can be estimated by subtracting the water depth or bed elevation of a riffle crest (upstream edge of the riffle) from the water depth or bed elevation of the upstream pool. Residual pool depth was estimated by stream reach in the assessment areas within the Oak Creek watershed by subtracting the mean maximum water depths of all riffles within a reach from the maximum pool depth recorded for each individual pool. Comparison of maximum pool depths and estimated residual pool depths and trends among assessment areas for Oak Creek are shown in Figure 4.15, and for the surveyed tributary streams in Figure 4.16. These figures indicate the range of pool depths that can be expected during normal summer flows (shown in dark blue) and extreme low flow conditions (shown in light blue) in each assessment area. The mean residual pool values were also calculated for each assessment area reach and are reported in Table 4.7. More than half of the pool depths within the Middle Oak Creek,

Figure 4.11
Water Width and Maximum Water Depth by Assessment Area
Along the Mainstem of Oak Creek: 2016-2017



Note: See Figure 4.10 for description of box plot symbols.

Numbers above box plots represent the mean for all measurements in associated assessment area.

The data represented in this figure for the Lower Oak Creek – Mill Pond assessment area does not include measurements within the Mill Pond itself. See "Oak Creek Mill Pond and Dam" under Section 4.3 ("Water Quantity Conditions") later in this chapter for more details on historical and recent conditions of the Mill Pond.

Source: SEWRPC

Lower Oak Creek, and Lower Oak Creek—Mill Pond were estimated to be about equal to or greater than two feet during extreme low-flow periods, with some pool depths approaching four feet in extreme low-flow conditions. These estimated residual pool depths are likely to be sufficient to sustain most fish species that occur within Oak Creek during these relatively infrequent extreme conditions. Most residual pool depths in the Upper Oak Creek and Oak Creek—Headwaters assessment areas, as well as all of the tributary reaches, are below two feet in depth, which likely contributes to the low abundances and dominance of tolerant fishes in these areas. It is vitally important for many fish species to have uninhibited access to deeper pools, thus maintaining connections between reaches with shallow residual pools and those with deep water areas is especially important during extreme low-flow conditions.

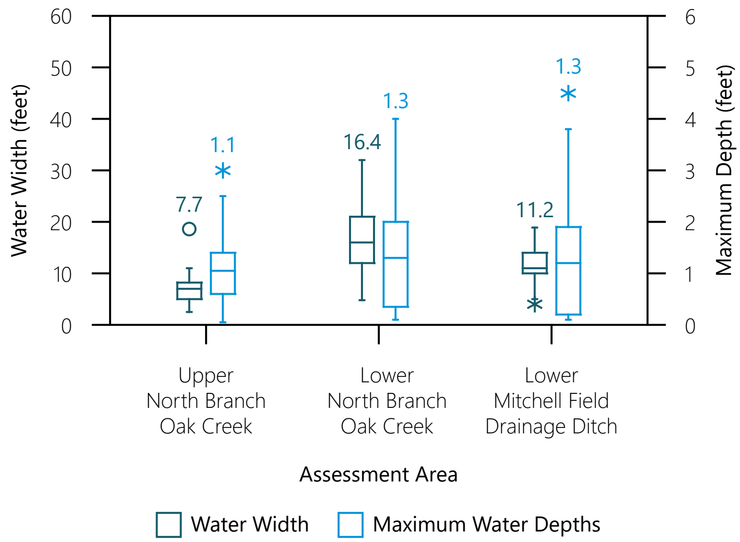
While Figure 4.15 shows that residual pool depths within the Grant Park Ravine assessment area are below two feet in depth, it should be noted that the connection of this reach of Oak Creek to Lake Michigan allows fish to seek refuge in the deeper waters of the Lake when necessary. The implications of the connection of Oak Creek to Lake Michigan, and the association with a more diverse fish assemblage in this assessment area is discussed further in the section on biological conditions later in this Chapter.

Streambed Materials

Streambed substrates include the rocks, sediments, and submerged decomposing plant and woody material in a stream. Streambed substrates may range in size and composition from large boulders 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. Steeper sloped stream reaches typically contain the greatest proportions of larger substrates including gravels, cobbles, and boulders compared to lower sloped reaches that are typically dominated by sand and organic substrates such as silt. Dominant substrate types were recorded typically at five points per transect for the 163 transect surveys along Oak Creek, North Branch Oak Creek, and the portions of the Mitchell Field Drainage Ditch downstream of College Avenue. The discussion below generally characterizes the trends in sediment depth and substrate composition observed during the 2016 and 2017 instream surveys.

Figure 4.17 shows the relationship between water depth, unconsolidated sediment depth, and dominant substrate types at each surveyed transect along Oak Creek.[135] Dominant substrate compositions for each assessment area of Oak Creek are presented in Figure 4.18. The two downstream-most reaches of the mainstem Oak Creek, Lower Oak Creek—Mill Pond and Grant Park Ravine, had minimal unconsolidated sediment accumulation and were dominated by larger substrates such as gravel and cobble.[136] These assessment areas also had the largest occurrence of boulders compared to elsewhere in the watershed. More substantial unconsolidated sediment accumulations were observed in the Lower Oak Creek assessment area, where silt substrates were observed more often and the mean maximum unconsolidated sediment depth at transects approached a half foot. Sand, gravel, and silt were the most dominant substrates at transects in the Lower Oak Creek assessment area, which also included either cobble or boulder substrates at about 15 percent of the surveyed sites (see Figures 4.17 and 4.18).

Figure 4.12
Water Width and Maximum Water Depth by Assessment Area Along Principal Tributary Streams: 2016-2017



Note: See Figure 4.10 for description of box plot symbols.

Numbers above box plots represent the mean for all measurements in associated assessment area.

Source: SEWRPC

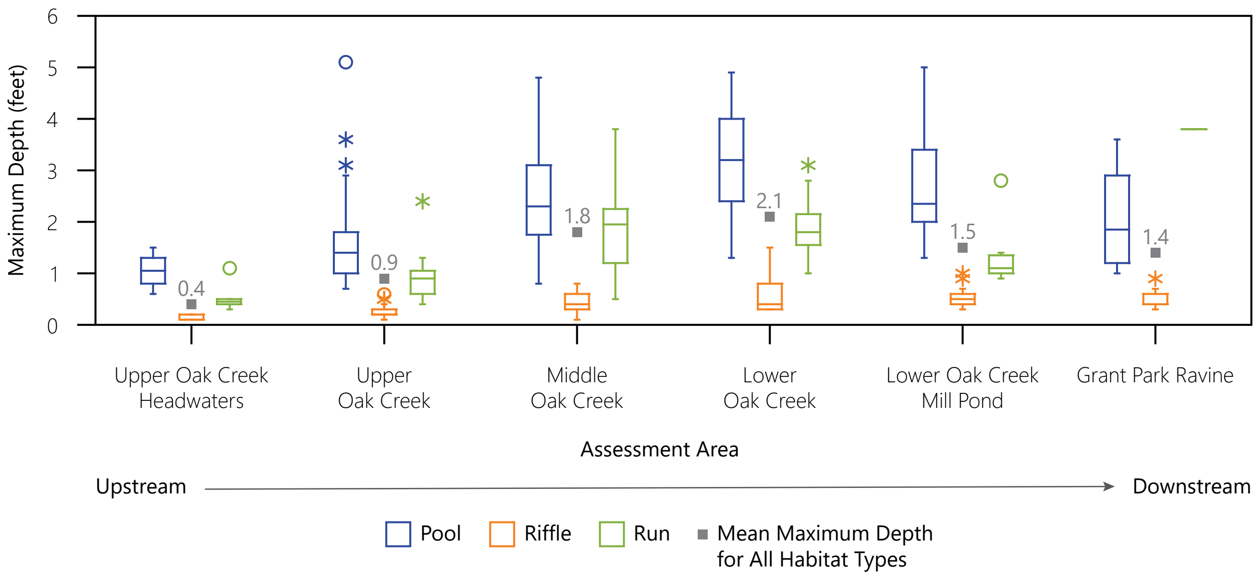
The Middle Oak Creek and Upper Oak Creek assessment areas exhibited the largest concentration of unconsolidated sediment accumulations, which coincided with some of the largest proportions of silt substrates in the watershed and underlying layers of claypan (see Figure 4.17).[137] Clay in this instream survey can be described more accurately as a claypan, which is a dense, compact, low permeability layer in the bottom of the stream having a much higher clay content than the overlying material, from which it is separated by a sharply defined boundary and/or is fully exposed. Claypans are usually hard when dry, and plastic and sticky when wet. The mean maximum sediment depths at surveyed transects within these areas was nearly one foot, with a maximum measurement of 3.6 feet. Large accumulations of silts and sands within the Middle Oak Creek assessment area may be partially explained by low channel slopes that slow water velocities and allow for finer sediments to fall out of the water column. In addition, this assessment area has a large proportion of stream channel that is disconnected from the floodplain, which can lead to more streambank erosion and doesn't allow for fine substrates to settle out over the floodplain during extreme flows. The deepest unconsolidated sediment accumulations likely occur in the downstream-most reach of the Upper Oak Creek assessment area. Exact depths of sediment in this reach are unknown because staff were unable to safely walk in the channel without getting stuck in the excessive sediment deposits. While it is unknown exactly how deep the unconsolidated sediment is in this stretch, it can be assumed to be well over three feet deep. This 1,000 feet of channel downstream of the Ryan Road crossing was highly modified in the 1970's as part of Ryan Road (STH 100) and Howell Avenue (STH 38) expansion projects, as discussed in the channel modifications section above, and shown in Figure 4.6. As part of this project, the confluence of the mainstem of Oak Creek and North Branch

[135] *Unconsolidated sediments discussed here and in Figure 4.17 and Figure 4.19 were comprised mostly of silt substrates and occasionally a silt/sand mixture. This unconsolidated sediment is typically overlain on coarser substrates and/or "claypan".*

[136] *Sediment measurements within the Mill Pond were not included in this assessment and are not shown on Figure 4.17.*

[137] *In the project area, most clayey sediment exposed at the surface is diamicton of the Oak Creek Formation.*

Figure 4.13
Maximum Water Depth Among Habitat Type and Assessment Areas Along the Mainstem of Oak Creek: 2016-2017



Note: See Figure 4.10 for description of box plot symbols.

The data represented in this figure for the Lower Oak Creek – Mill Pond assessment area does not include measurements within the Mill Pond itself. See "Oak Creek Mill Pond and Dam" under Section 4.3 ("Water Quantity Conditions") later in this chapter for more details on historical and recent conditions of the Mill Pond.

Source: SEWRPC

Oak Creek was relocated about 1,000 feet north. It is likely that slopes of this relocated channel are not sufficient to transport the amount of sediment entering the stream.

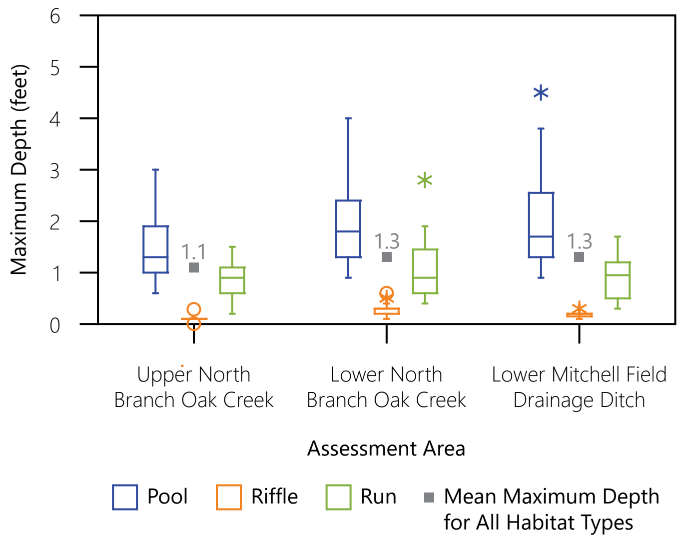
Significantly less unconsolidated sediment accumulation was observed in the Oak Creek—Headwaters assessment area, where sand, gravel, and claypan dominated the substrate composition. The mean maximum sediment depth in this assessment area was under 0.2 feet, however sediment approaching one foot in depth was observed at one transect.

Figure 4.19 shows the relationship between water depth, unconsolidated sediment depth, and dominant substrate types at each surveyed transect along North Branch Oak Creek and lower portions of the Mitchell Field Drainage Ditch. Dominant substrate compositions for each surveyed assessment area for these principal tributary streams are presented in Figure 4.20. Unconsolidated sediment accumulations generally increased in an upstream direction on North Branch Oak Creek. The Lower North Branch Oak Creek assessment area had a mean maximum sediment depth of 0.3 feet and a maximum observed sediment depth of 1.3 feet at a transect downstream of Wildwood Drive. The lower portions of North Branch Oak Creek were dominated by sand and gravel, and also contained claypan, cobble, and silt substrates at between nine and 15 percent of surveyed locations. Much greater unconsolidated sediment accumulations were observed in the Upper North Branch Oak Creek assessment area, where mean maximum sediment depths were near one foot, and were the second highest in the entire watershed. A maximum unconsolidated sediment depth of almost three feet was observed in this assessment area in a highly modified reach upstream of Rawson Avenue. Silt and sand were the dominant substrates in the Upper North Branch Oak Creek assessment area and were found at 40 percent and 32 percent of surveyed locations, respectively. The Lower Mitchell Field Drainage Ditch also had a mean maximum unconsolidated sediment depth of nearly one foot and an overall maximum sediment depth of over three feet observed in an area impacted by beaver dams, just upstream of Rawson Avenue. The dominant substrates in the Lower Mitchell Field Drainage Ditch assessment area were sand, silt, and gravel. The portions of the Mitchell Field Drainage Ditch upstream of College Avenue and within MMIA were not surveyed and substrate compositions are unknown.

Bankfull Conditions

Low flow discharges, commonly referred to as low-water discharge, sustained discharge, or fair-weather discharge, generally describe conditions when a stream's flow is primarily sustained by groundwater discharge. Bankfull conditions are defined by the discharge that occurs when water just begins to leave the channel and spread onto the floodplain and are strongly influenced by precipitation and runoff. The bankfull discharge is considered to be the channel-forming discharge, or effective discharge.[138] The quantity and movement of both water and sediment is what determines channel dimension and shape, and effective discharge is the amount of water (volume per unit of time) that transports the most sediment over the long term for any given stream system. Bankfull channel dimensions are important characteristics of stream power and also correspond to the stream's ability to transport sediments. The effective discharge typically occurs only a few times annually and is generally defined as the 67-percent-annual-probability (1.5-year recurrence interval) flow event.[139]

Figure 4.14
Maximum Water Depth Among Habitat Type and Assessment Areas Along Principal Tributary Streams: 2016-2017



Note: See Figure 4.10 for description of box plot symbols.

Source: SEWRPC

In theory, the bankfull height of a stream can be determined by finding the point at which the flow of water leaves the banks of the channel. In practice, however, these measurements can be difficult to determine, especially in entrenched stream types and highly modified streams such as those found in the Oak Creek watershed. Channelized streams often have banks that are much higher than would naturally occur. Often, during construction of these channelized reaches, spoils are deposited on the channel banks, making them excessively tall. The following characteristics were used as indicators to estimate bankfull conditions along the principal streams within the Oak Creek watershed:[140]

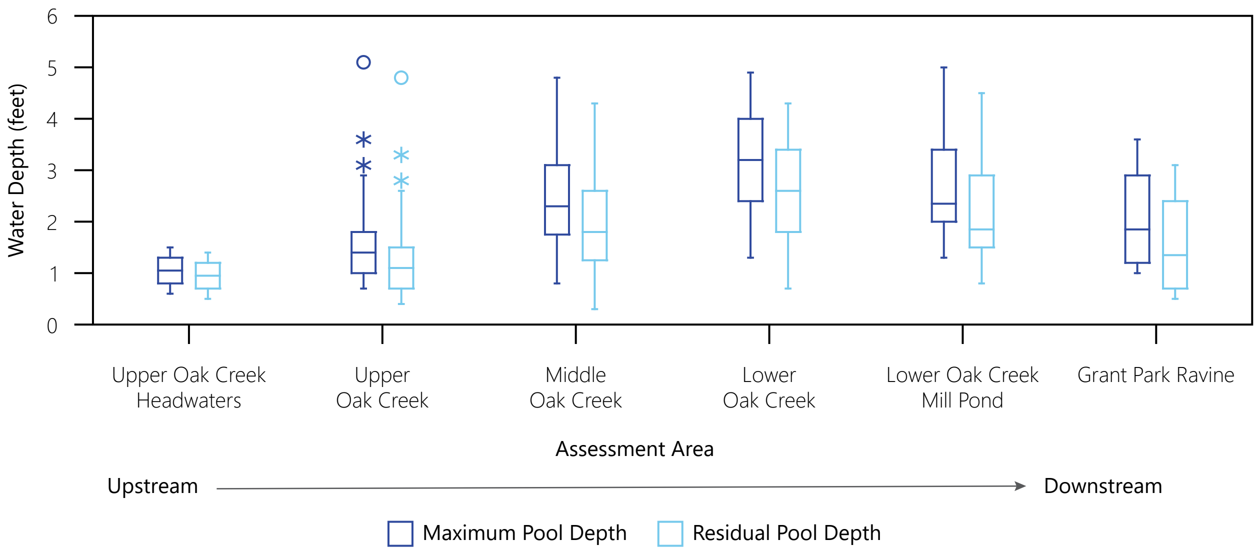
- *Breaks in Slope*: The abrupt slope-break from the stream channel to the low and flat floodplain on the lower of the two banks. This indicator is usually only present in unmodified stream channel.
- *Vegetation:* The line between lower areas that are either bare or have herbaceous plants, and higher areas with woody plants can sometimes indicate the bankfull edge.
- *Soils:* A transition within a streambank from cobble, gravel, sands, and/or silts to soil can sometimes be an indicator of bankfull height. Above the bankfull level, leaf litter and other organic matter may be visible within the soil.
- *Point Bars and Undercut Banks:* Often on the inside of meander bends, sediment will build up and form a point bar. The top of such a bar can be an indicator of bankfull height. Similarly, on the outside of bends, the stream will often undercut the bank and expose root mats. The upper extent of the undercut can also be an indicator of bankfull height.
- *Stain Lines on Boulders or Rocks:* The highest mineral stain on a stable rock or boulder may be an indicator of bankfull height.

[138] *Leopold, L. B,* A View of the River. *Cambridge: Harvard University Press, 1994.*

[139] *V.T. Chow,* Open-Channel Hydraulics*, McGraw Hill, New York, 1998.*

[140] *State of California Water Boards, Surface Water Ambient Monitoring Program (SWAMP),* Field Procedures, 8th Edition, *2006.*

Figure 4.15
Comparison of Maximum Pool Depths and Estimated Residual Pool Depths Among Oak Creek Assessment Areas: 2016-2017



Note: See Figure 4.10 for description of box plot symbols.

The data represented in this figure for the Lower Oak Creek – Mill Pond assessment area does not include measurements within the Mill Pond itself. See "Oak Creek Mill Pond and Dam" under Section 4.3 ("Water Quantity Conditions") later in this chapter for more details on historical and recent conditions of the Mill Pond.

Source: SEWRPC

- *Moss or Lichen:* The lowest line of lichen or moss growth on rocks, boulders, or tree trunks may be an indicator of bankfull height.
- *Adjacent Indicators:* Indicators at the transect survey site can be compared to upstream and/or downstream indicators of bankfull to extrapolate bankfull height at that location.

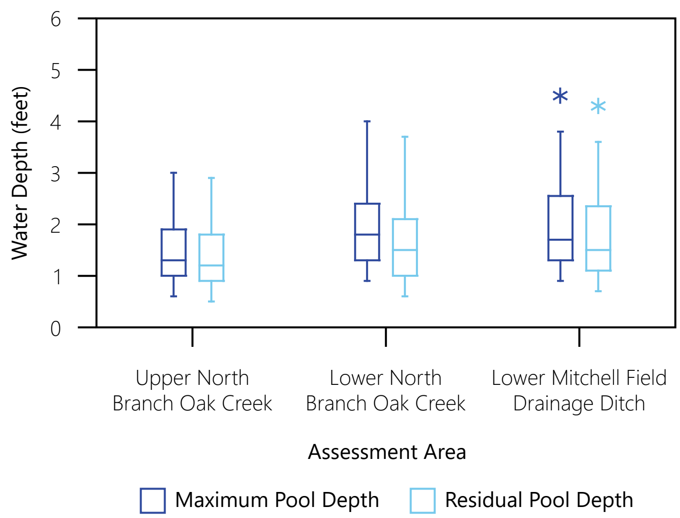
Figure 4.21 shows the estimated dimensions of bankfull width and maximum bankfull depth (measured from the thalweg)[141] among transect surveys along the mainstem of Oak Creek. As may be expected, Figure 4.21 shows that the bankfull dimensions of Oak Creek's mainstem generally increase among reaches from upstream (Oak Creek—Headwaters) to downstream (Grant Park Ravine) as drainage area increases. Mean bankfull channel width dimensions by assessment area show steady increase from under 10 feet in the Oak Creek—Headwaters to about 29 feet in the Lower Oak Creek assessment area, before declining slightly to 28.3 feet in the Lower Oak Creek—Mill Pond assessment area, and then rising significantly to over 43 feet in the Grant Park Ravine assessment area. Mean maximum bankfull depths show a similar pattern, steadily increasing from a mean of 1.3 feet in the Headwaters assessment area to a mean of about 3.0 feet in the Lower Oak Creek assessment area before declining slightly to 2.4 feet in the Lower Oak Creek—Mill Pond assessment area, and rising slightly to 2.6 feet in the Grant Park Ravine assessment area. Although the expected general linear increases in bankfull dimensions from upstream to downstream are present in this analysis, the apparent decrease in bankfull dimensions moving downstream from the Lower Oak Creek to the Lower Oak Creek—Mill Pond assessment area is slightly unusual. As discussed above, there have been significant channel modifications along Oak Creek, specifically within the middle reaches of the watershed. The difficulty of locating true bankfull dimensions in modified stream channels could be a factor in the slightly unusual variations observed.

Figure 4.22 shows the estimated dimensions of bankfull width and maximum bankfull depths among transect surveys on North Branch Oak Creek and the lower portions of the Mitchell Field Drainage Ditch, downstream of College Avenue and the Airport property. Similar to the mainstem of Oak Creek, these

[141] *The thalweg is a line connecting the lowest points of successive cross-sections along the course of a stream channel.*

tributary streams show a general increase in both bankfull width and depths moving from upstream to downstream. Mean bankfull channel width dimensions by assessment area increase from slightly over ten feet in the Upper North Branch Oak Creek assessment area to about 18 feet in the Lower North Branch Oak Creek assessment area. Likewise, mean maximum bankfull depths increase from about 1.5 feet in the Upper assessment area to about 1.7 feet in the Lower North Branch Oak Creek assessment area. The Lower Mitchell Field Drainage Ditch assessment area has an estimated average bankfull width of about 14 feet and a mean maximum bankfull depth of about 1.5 feet. Most of the surveyed reaches along these tributary streams exhibit highly modified characteristics.

Figure 4.16
Comparison of Maximum Pool Depths and Estimated Residual Pool Depths Among Tributary Stream Assessment Areas: 2016-2017



Note: See Figure 4.10 for description of box plot symbols.

Source: SEWRPC

The force that flowing water exerts on the bed and banks of a stream channel is known as shear stress. Shear stress is related to the depth of flow and the slope of the channel bottom, with deeper water and steeper sloped channels supplying greater force. At any point in a stream channel, there is a combination of water depth and channel bottom slope that will lead to bed and/or bank scour (or erosion).[142] Based upon channel slope and bankfull depths of flow, the size of substrates that the mainstem of Oak Creek is able to transport ranged from fine gravel (4.0 to 8.0 millimeters in diameter) in the Middle Oak Creek assessment area; to medium gravel (8.0 to 16.0 millimeters in diameter) in the Oak Creek Headwaters, Upper Oak Creek, Lower Oak Creek, and Lower Oak Creek—Mill Pond assessment areas; and coarse gravel (16 to 64 millimeters in diameter) in the Grant Park Ravine assessment area. In tributary reaches, the size of substrates that the streams were estimated to be able to transport ranged from medium gravel in both the Upper and Lower North Branch Oak Creek assessment areas, to fine gravel in the Lower Mitchell Field Drainage Ditch assessment area.

The bankfull channel dimensions and associated discharge are important factors when considering potential projects to restore streambed and/or streambanks, restore the stream-floodplain connection and floodplain functionality, and to improve fisheries habitat within the Oak Creek watershed, all of which will be discussed in further detail in Chapter 6 of this Report. The bankfull width and depth dimensions presented in this section are estimates and should be used as a general overview of conditions in the watershed. A trained hydrologist should be consulted to determine correct stream restoration design parameters and goals for specific stream restoration projects within the watershed. It is also important to note that channel forming discharge and bankfull channel dimensions can change, particularly as a watershed becomes more urbanized. Greater urbanization is associated with greater amounts of impervious surfaces, which increase runoff that can lead to increased discharge and stream power, causing the stream to increase in size in response (erode its streambed and streambanks). Monitoring bankfull channel conditions over time is also a good way to track a stream's ability to maintain its dimensions and whether it is in equilibrium.

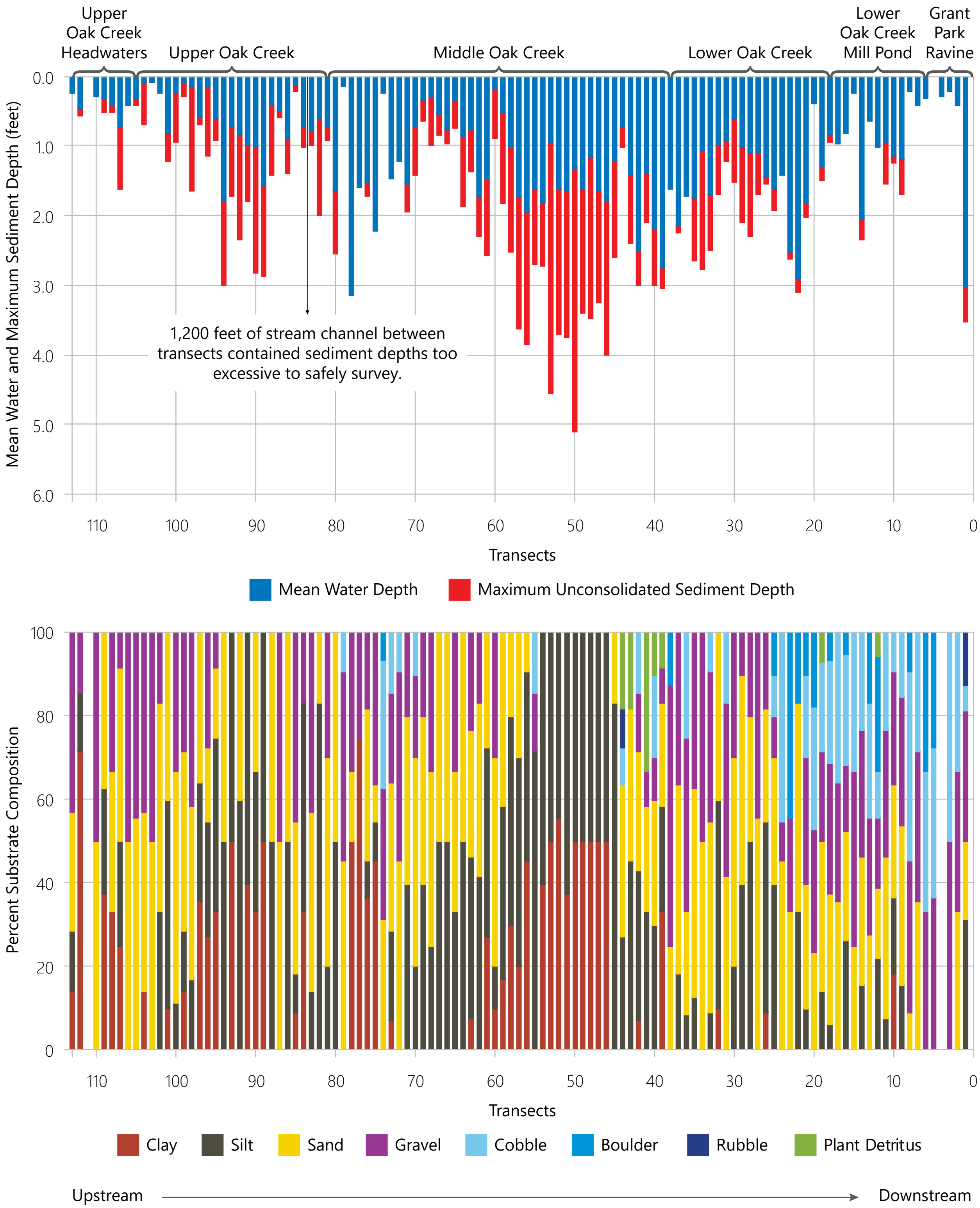
Habitat Quality Conditions

Riparian Buffers

As described in Chapter 3, primary environmental corridors (PEC), secondary environmental corridors (SEC), isolated natural resource areas (INRA), designated natural areas (NA), and critical species habitat sites (CSHS) are distributed throughout the Oak Creek watershed. The highest-quality environmental corridors, NAs, and CSHS are located within and adjacent to the stream system and other water bodies; however, these areas may

[142] *A. Ward, J. D'Ambrosio, and J. Wittner, "Channel-Forming Discharges,"* The Ohio State University-Extension, Fact Sheet Agriculture and Natural Resources, *Report No. AEX-445-03, 2008.*

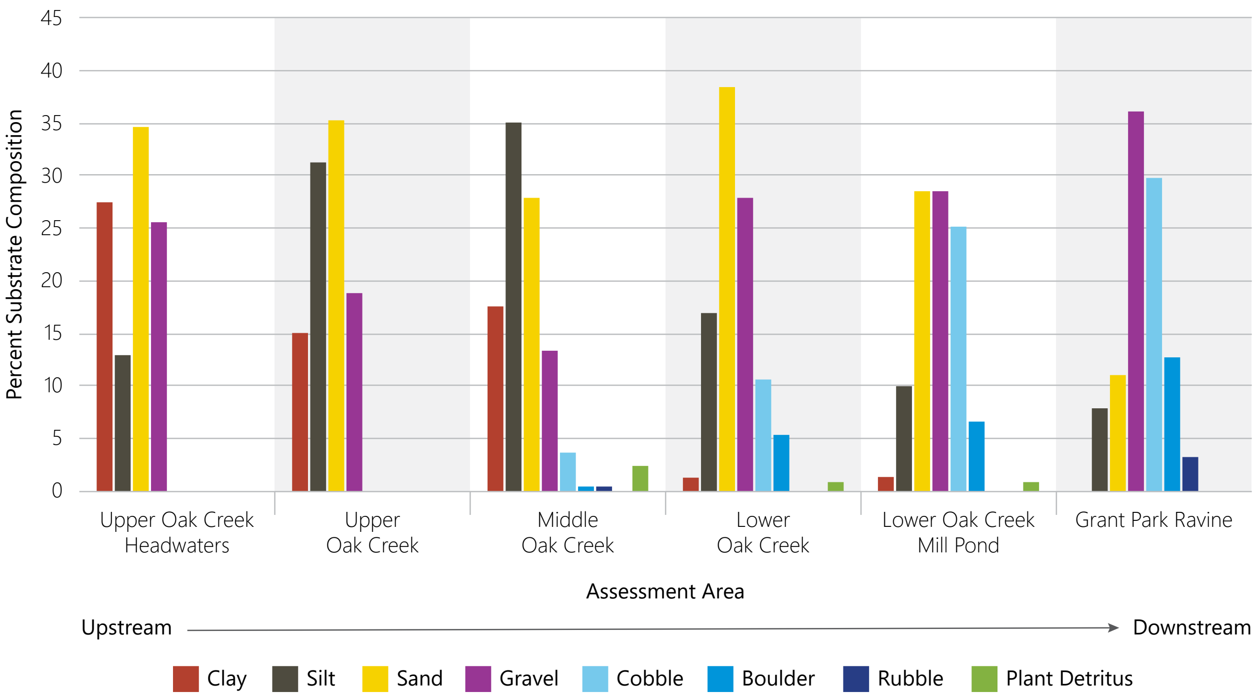
Figure 4.17
Mean Water Depth, Maximum Unconsolidated Sediment Depth, and Dominant Substrate Composition at Transects along Oak Creek: 2016-2017



Note: The data represented in this figure for the Lower Oak Creek – Mill Pond assessment area does not include measurements within the Mill Pond itself. See "Oak Creek Mill Pond and Dam" under Section 4.3 ("Water Quantity Conditions") later in this chapter for more details on historical and recent conditions of the Mill Pond.

Source: SEWRPC

Figure 4.18
Dominant Substrate Compositions by Assessment Areas Along Oak Creek: 2016-2017



Note: The data represented in this figure for the Lower Oak Creek – Mill Pond assessment area does not include measurements within the Mill Pond itself. See "Oak Creek Mill Pond and Dam" under Section 4.3 ("Water Quantity Conditions") later in this chapter for more details on historical and recent conditions of the Mill Pond.

Source: SEWRPC

not always be considered to be riparian buffer lands as they can sometimes be disconnected from water bodies by roads, parking lots, and other development, or simply by mowed and manicured lawns. Riparian buffers are continuously connected to the water's edge by "natural" landscapes. These landscapes can consist of a variety of canopy layers and cover types including ephemeral (wet for only part of the year) wetlands and ponds, shallow marshes, deep marshes, wetland meadows, wetland mixed forests, grasslands, shrubs, upland forests, and/or prairies. Riparian buffers can include a range of complex vegetation structure, soils, food sources, and abundance of wildlife such as mammals, amphibians, insects, and birds.[143] Riparian buffers help to protect water quality, groundwater, fisheries, and wildlife; provide ecological resilience to invasive species; reduce potential flooding of structures; and limit the harmful effects of climate change.[144] The functionality of riparian corridors is largely dependent upon width perpendicular to the stream and continuity. Therefore, efforts to protect and expand the remaining riparian corridor width and continuity are the foundation for protecting and improving the fishery, wildlife, and potential recreation within the Oak Creek watershed.

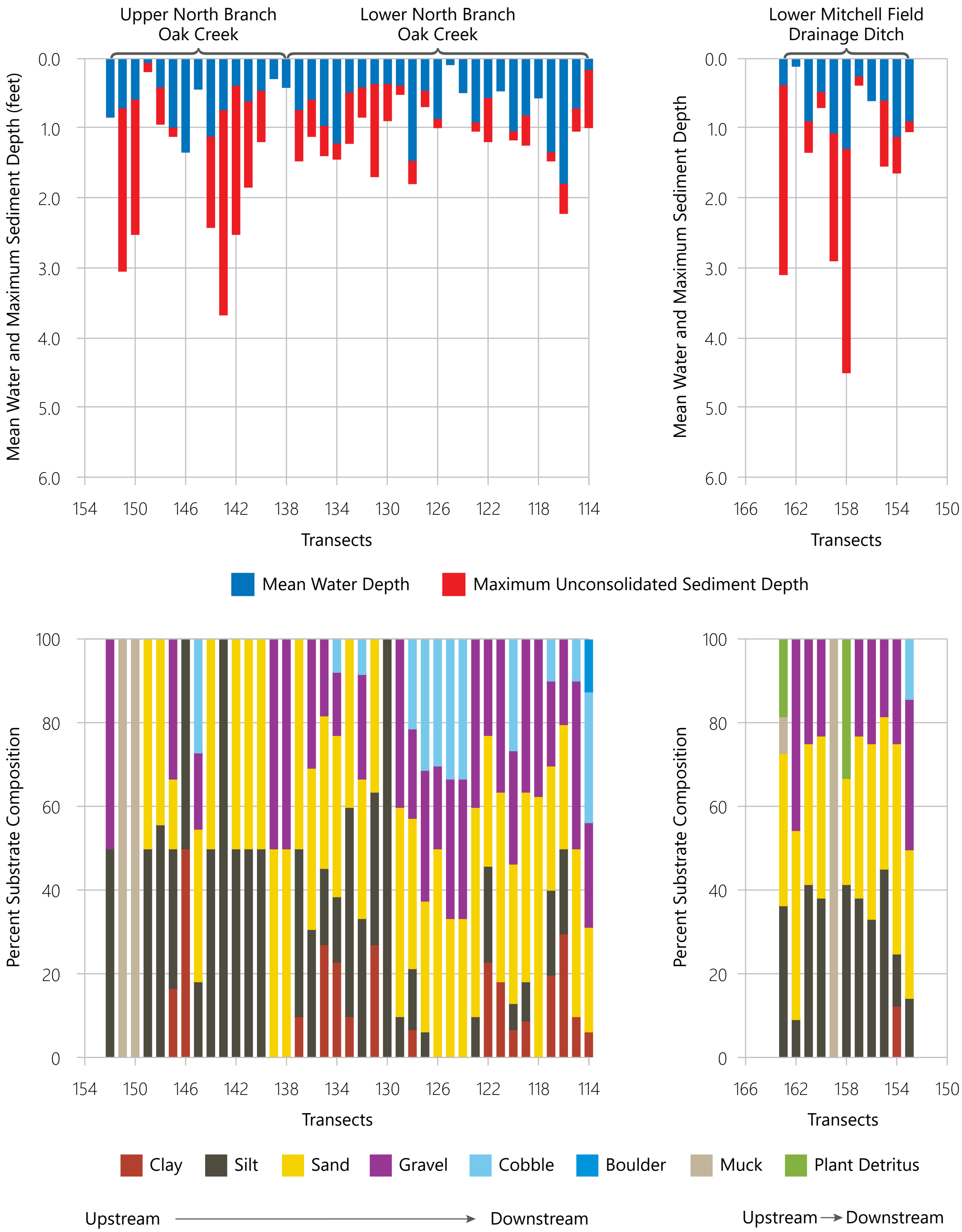
Riparian buffer areas along waterways can mitigate anthropogenic sources of contaminants. Even relatively small buffer areas provide a degree of environmental benefit, as suggested in Table 4.8 and Figure 4.23 and further discussed in Appendix G. The Wisconsin Buffer Initiative (WBI) further developed 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 part of a larger conservation system to be most effective.[145] However, it is important to

[143] *SEWRPC Riparian Buffer Management Guide No. 1,* Managing the Water's Edge; Making Natural Connections, *2010.*

[144] *N.E. Seavy, et al., "Why Climate Change Makes Riparian Buffer Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration, *Volume 27, Number 3, 2009, pages 330-338; and* Natural and Beneficial Floodplain Functions: Floodplain Management—More than Flood Loss Reduction*, Association of State Floodplain Managers, 2008.*

[145] *University of Wisconsin—Madison, College of Agricultural and Life Sciences,* The Wisconsin Buffer Initiative, *December 2005.*

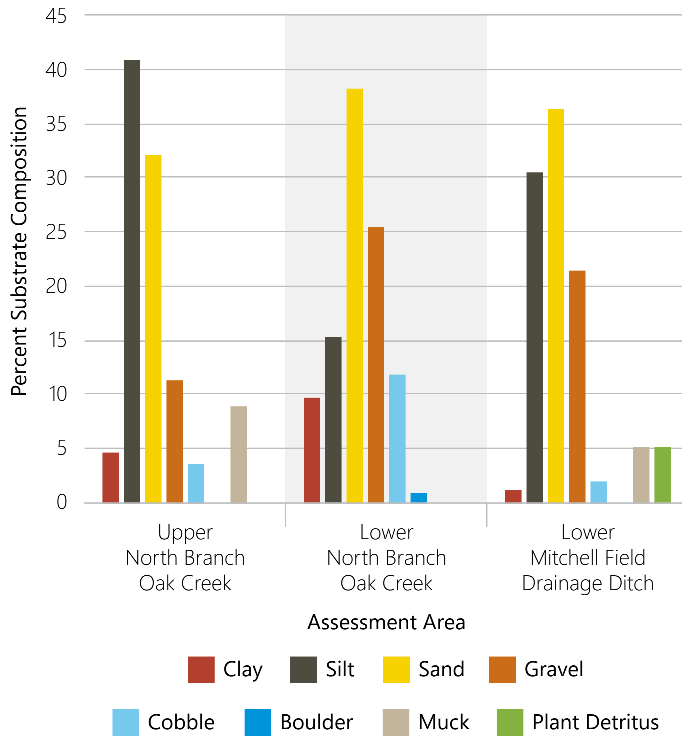
Figure 4.19
Mean Water Depth, Maximum Unconsolidated Sediment Depth, and Dominant Substrate Composition at Transects Along Principal Tributary Streams to Oak Creek: 2016-2017



Source: SEWRPC

note that the WBI limited its assessment and recommendations to protecting 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 mitigation, preventing channel bank erosion, providing fish and wildlife habitat, enhancing environmental corridors, and moderating water temperature (see Appendix G). The nature of the benefits and the extent to which the benefits are achieved is site-specific. Consequently, the ranges in buffer width for each of the functions shown in Table 4.8 and Figure 4.23 are large. Buffer widths should be based on desired functions, as well as site conditions. For example, based upon a number of studies, buffer widths ranging from about 25 feet to nearly 200 feet achieved sediment removal efficiencies of between 33 and 92 percent, depending upon local site conditions such as soil type, slope, vegetation, contributing area, and influent concentrations. It should be noted that the water quality benefits achieved from riparian buffers within highly urban areas is tempered by the fact that many storm sewer outfalls discharge directly to the streams of the watershed, completely, or partially, bypassing the riparian corridor.

Figure 4.20
Dominant Substrate Compositions by Assessment Area Along Principal Tributary Streams: 2016-2017



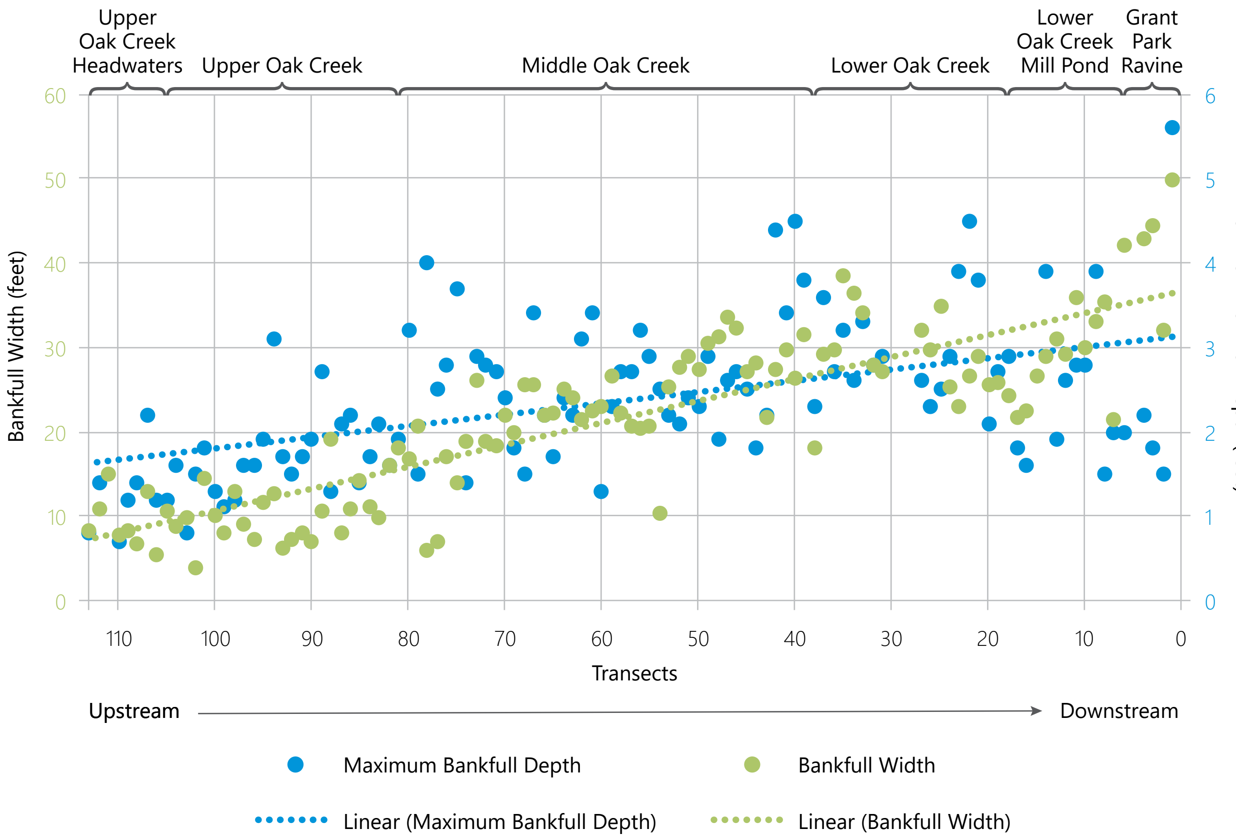
Source: SEWRPC

Still, it is clear from the literature that wider buffers can provide a greater range of values for aquatic systems, even in urban watersheds. The need to balance human access and use with 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 ecological point of view, 75-foot-wide buffers are inadequate for protecting and preserving groundwater recharge as well as habitat for wildlife species. Riparian buffer strips greater than 75 feet in width provide significant additional physical protection of streams by intercepting additional sediment and other contaminants mobilized from the land surface. They also provide biological benefit by creating habitat within the shoreland and littoral areas associated with streams and lakes.[146] Recent research has found that the protection of wildlife species is determined by the preserving or protecting of core habitat within riparian buffers with widths ranging from a minimum of 400 feet to an optimal 900 feet or greater (as summarized in Appendix G). These buffer areas are essential for supporting heathy populations of multiple groups of organisms including birds, amphibians, mammals, reptiles, and insects in their various life stages. Some species of birds, amphibians, turtles, snakes, and frogs have been found to need buffer widths of 1,000 feet, or greater, for at least part of their life cycle. Therefore, preserving riparian buffers to widths of up to 1,000 feet or greater represents the optimal condition for protecting wildlife in the Oak Creek watershed.[147]

[146] *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.*

[147] *The shoreland zone is defined in Wisconsin Administrative Code NR 115 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.*

Figure 4.21
Bankfull Width and Bankfull Maximum Depth Conditions Among Transect Surveys Along the Mainstem of Oak Creek: 2016-2017



Note: The data represented in this figure for the Lower Oak Creek – Mill Pond assessment area does not include measurements within the Mill Pond itself. See "Oak Creek Mill Pond and Dam" under Section 4.3 ("Water Quantity Conditions") later in this chapter for more details on historical and recent conditions of the Mill Pond.

Source: SEWRPC

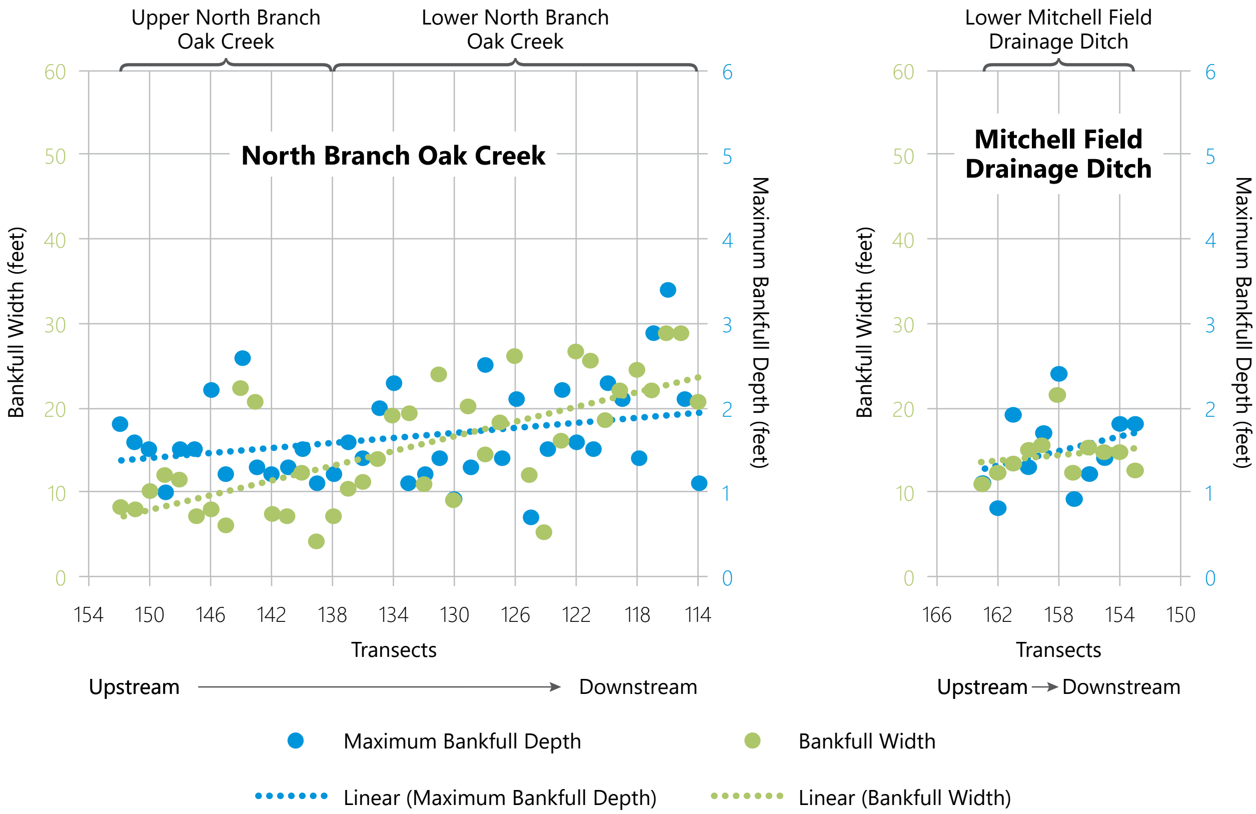
Existing and Potential Riparian Buffers

Map 4.4 shows the year 2015 status of riparian buffers in the Oak Creek watershed. Existing riparian buffer areas were primarily developed by analyzing 2015 digital orthophotographs, with the assistance of 2015 Wisconsin Wetland Inventory and inventories of PEC, SEC, and INRA. Polygons were digitized using ESRI ArcGIS to delineate contiguous natural lands (i.e., undeveloped, uncultivated, and unmowed lands) comprised of wetland, woodland, grasslands, prairies, and other open lands adjacent to waterbodies. Those lands comprise a total of 3,201 acres, or about 17.7 percent of the total land area within the Oak Creek watershed.

Map 4.5 shows the current status of existing riparian buffer areas as well as areas that could potentially become riparian buffer areas by restoring and naturalizing the land and vegetation. The potential buffer areas shown on Map 4.5 represent areas that are currently not developed in urban land uses, but do not exhibit the natural, undisturbed vegetative cover that can provide beneficial water quality and habitat functions. These are areas that can be targeted to be restored to more natural functioning environments and reconnected contiguously to existing riparian buffer areas. The potential riparian buffer areas include those areas along waterbodies needed to meet the 75-foot minimum recommended buffer width (shown in red), areas needed to achieve the 400-foot minimum core habitat width for wildlife protection (shown in orange), and areas needed to achieve the 1,000-foot optimal core habitat width for wildlife protection (shown in yellow).[148] Figure 4.24 shows the percent of each assessment area that is made up of existing riparian buffer (green) and the percent of each assessment area that is potentially available to restore to functioning riparian buffer lands (red, orange, and

[148] *Maps G.1 through G.22 in Appendix G show these areas at a more detailed scale by individual assessment area.*

Figure 4.22
Bankfull Width and Bankfull Maximum Depth Conditions at Transect Surveys Along Principal Tributary Streams to Oak Creek: 2016-2017



Source: SEWRPC

Table 4.8
Effect of Buffer Width on Contaminant Removal

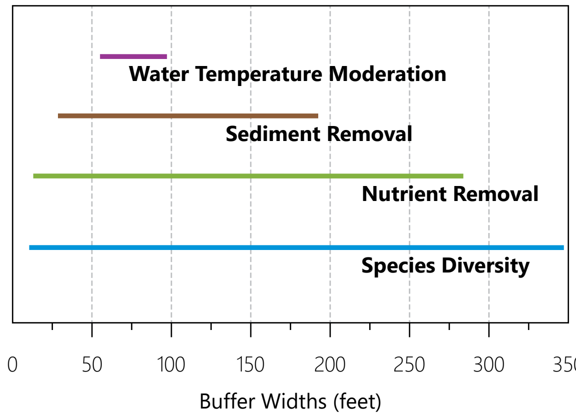
Buffer Width Categories (feet)	Contaminant Removal (percent)[a]				
	Sediment	Total Suspended Sediment	Nitrogen	Phosphorus	Nitrate-Nitrogen
1.5 to 25					
Mean	75	66	55	48	27
Range	37-91	31-87	0-95	2-99	0-68
Number of Studies	7	4	7	10	5
25 to 50					
Mean	78	65	48	49	23
Range	--	27-95	7-96	6-99	4-46
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 yellow). The acreage of each of these areas, as well as the percentage of the areas currently meeting the 75-foot minimum buffer width, are presented in Table 4.9.

As shown in Figure 4.24, existing riparian buffer lands made up 20 percent or more of the land area in the Grant Park Ravine, Middle Oak Creek, Middle Oak Creek—Drainage Ditches, and Oak Creek Headwaters assessment areas along the mainstem of Oak Creek; and the Southland Creek, Drexel Avenue Tributary, and Rawson Avenue Tributary assessment areas in the North Branch Oak Creek subwatershed. Both assessment areas along the Mitchell Field Drainage Ditch contained less than 20 percent of their lands currently functioning as riparian buffers, with only 1.5 percent of the land in the assessment area that contains the airport property considered to be functioning riparian buffer lands. Comparison between the existing buffers and the potential buffers shown on Map 4.5 indicates that the existing buffers contain several areas whose widths exceed 1,000 feet from the edge of a stream or pond, which indicates they are providing significant water quality and wildlife protections. This achievement is mostly due to the protection of land owned by the Milwaukee County Parks system, which owns 950 acres, or approximately 30 percent, of the existing riparian buffer in the watershed.

Figure 4.23
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.

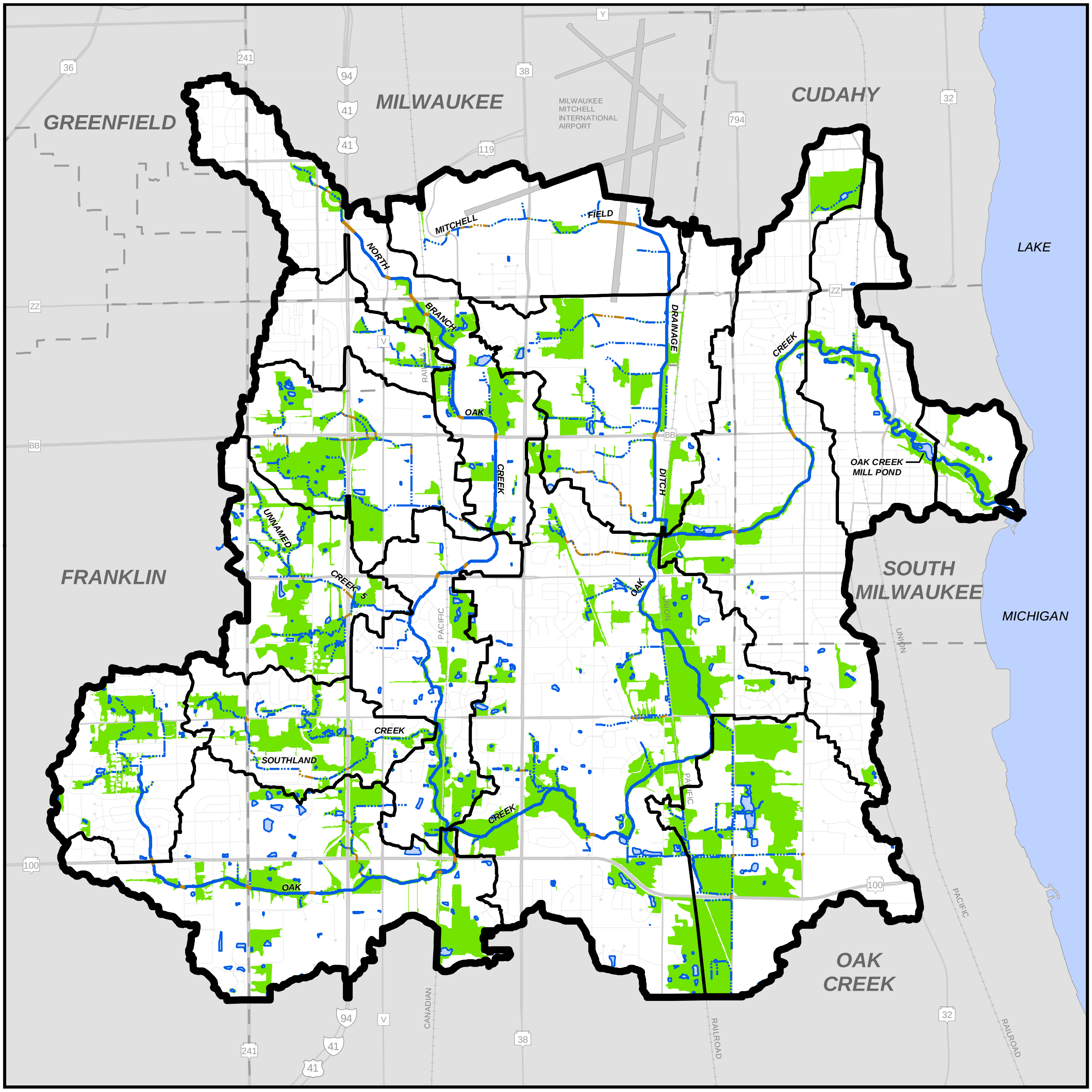
Source: *Adapted from A. J. Castelle and others, "Wetland and Stream Buffer Size Requirements-A Review,"* Journal of Environmental Quality, *Vol. 23.*

In contrast, encroachments into the riparian lands can be found in assessment areas throughout the watershed. There are significant amounts of land that are not meeting the 75-foot minimum recommended buffer width (shown in red on Map 4.5), much less the 400-foot minimum core habitat width for wildlife protection, or the 1,000-foot optimum core habitat width for wildlife protection (shown in orange, and yellow, respectively). As shown in Figure 4.25 and Table 4.9, between 49 and 79 percent of riparian lands in Oak Creek mainstem assessment areas meet at least the 75-foot minimum recommended buffer width. Encroachment into the riparian buffer is more pronounced in the North Branch Oak Creek and Mitchell Field Drainage Ditch subwatersheds. The percentage of riparian land meeting the minimum recommended buffer width within the assessment areas of the North Branch Oak Creek subwatershed ranges from 46 to 61 percent. The Mitchell Field Drainage Ditch assessment areas have the least amount of riparian lands meeting the minimum protection width, ranging from 16 to 39 percent of riparian lands (see Figure 4.25 and Table 4.9). To help achieve desired water quality improvements throughout the Oak Creek watershed, the percentage of land adjacent to waterbodies achieving the 75-foot minimum buffer width should approach at least 75 percent watershed-wide. This recommendation will be further discussed in Chapter 6 of this Report.

Depending on the degree of existing urbanization, some assessment areas within the Oak Creek watershed have more potential for riparian buffer expansion than others. The Lower Oak Creek—Mill Pond, Lower Oak Creek, Oak Creek Headwaters, College Avenue Tributary, and Mitchell Field Drainage Ditch—Airport assessment areas all have less than seven percent of their land available for riparian buffer expansion. Conversely, the Grant Park Ravine, Upper Oak Creek, Lower North Branch Oak Creek, Drexel Avenue Tributary, and Lower Mitchell Field Drainage Ditch assessment areas all have more than 20 percent of their lands potentially available for riparian buffer expansion (see Table 4.9).

Although existing and potential buffers have been identified throughout the Oak Creek 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 already in a form of public or protected private ownership. Therefore, riparian buffer lands and potential riparian buffer expansion 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 ownership; 2) Federal Emergency Management Agency 1-percent-annual-probability (100-year recurrence interval) regulatory floodway (AE Floodway Zone); and 3) Advanced Delineation and Identification (ADID) wetlands.

Map 4.4
Extent of Existing Riparian Buffer Areas Within the Oak Creek Watershed: 2015



EXISTING RIPARIAN BUFFERS (DELINEATED BY SEWRPC STAFF USING 2015 DIGITAL ORTHOPHOTOGRAPHY)

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

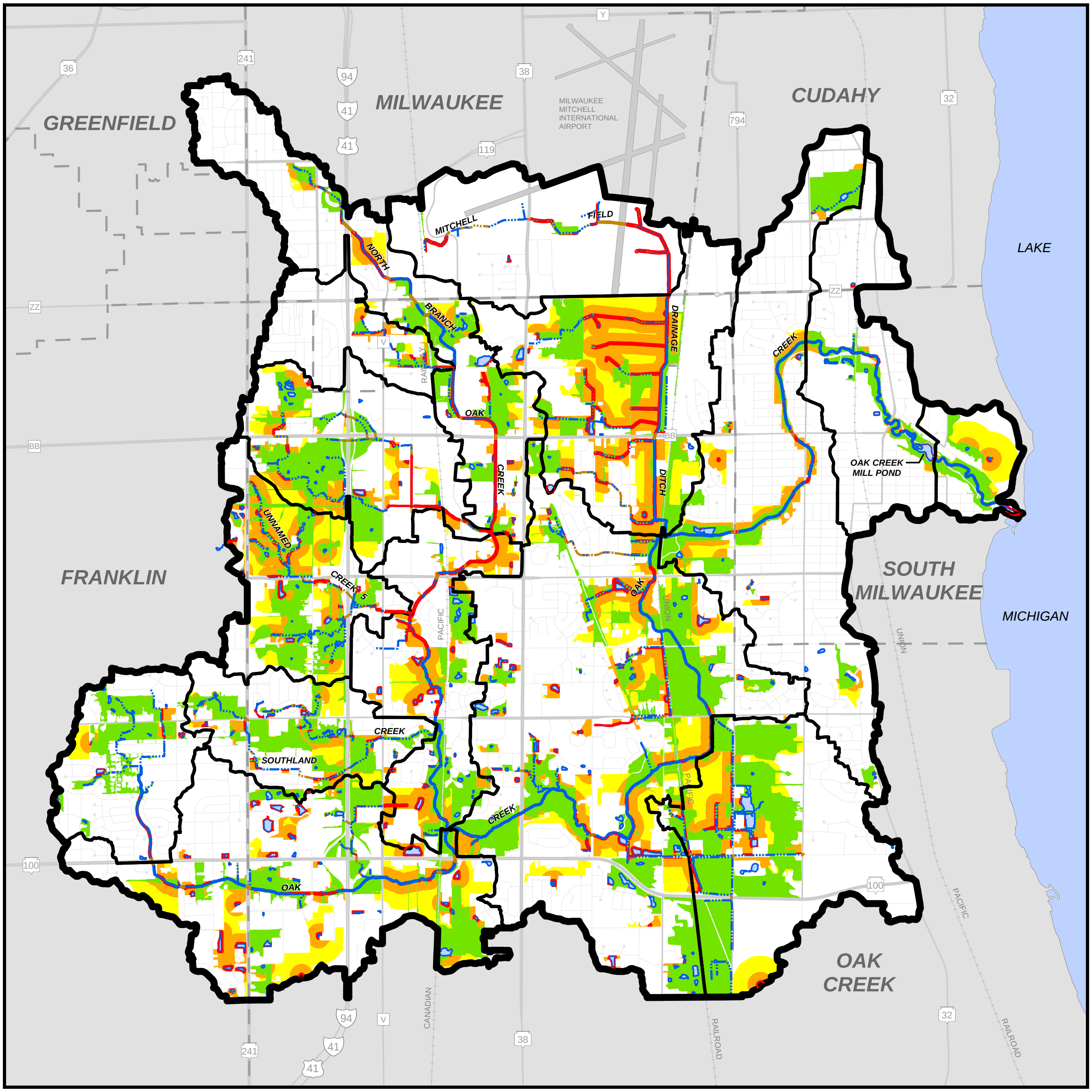
SURFACE WATER

Note: See Appendix Maps G.1 through G.21 for detailed view of existing riparian buffer lands by assessment area.

0 0.25 0.5 1 Mile

Source: SEWRPC

Map 4.5
Existing and Potenial Riparian Buffer Areas Within the Oak Creek Watershed: 2015



EXISTING RIPARIAN BUFFERS (DELINEATED BY SEWRPC STAFF USING 2015 DIGITAL ORTHOPHOTOGRAPHY)	OAK CREEK WATERSHED BOUNDARY
75-FOOT MINIMUM RECOMMENDED BUFFER WIDTH	ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)
400-FOOT MINIMUM CORE HABITAT WIDTH FOR WILDLIFE PROTECTION	PERENNIAL STREAM
1,000-FOOT OPTIMAL CORE HABITAT WIDTH FOR WILDLIFE PROTECTION	PERENNIAL STREAM (ENCLOSED)
	INTERMITTENT STREAM
	INTERMITTENT STREAM (ENCLOSED)
	SURFACE WATER

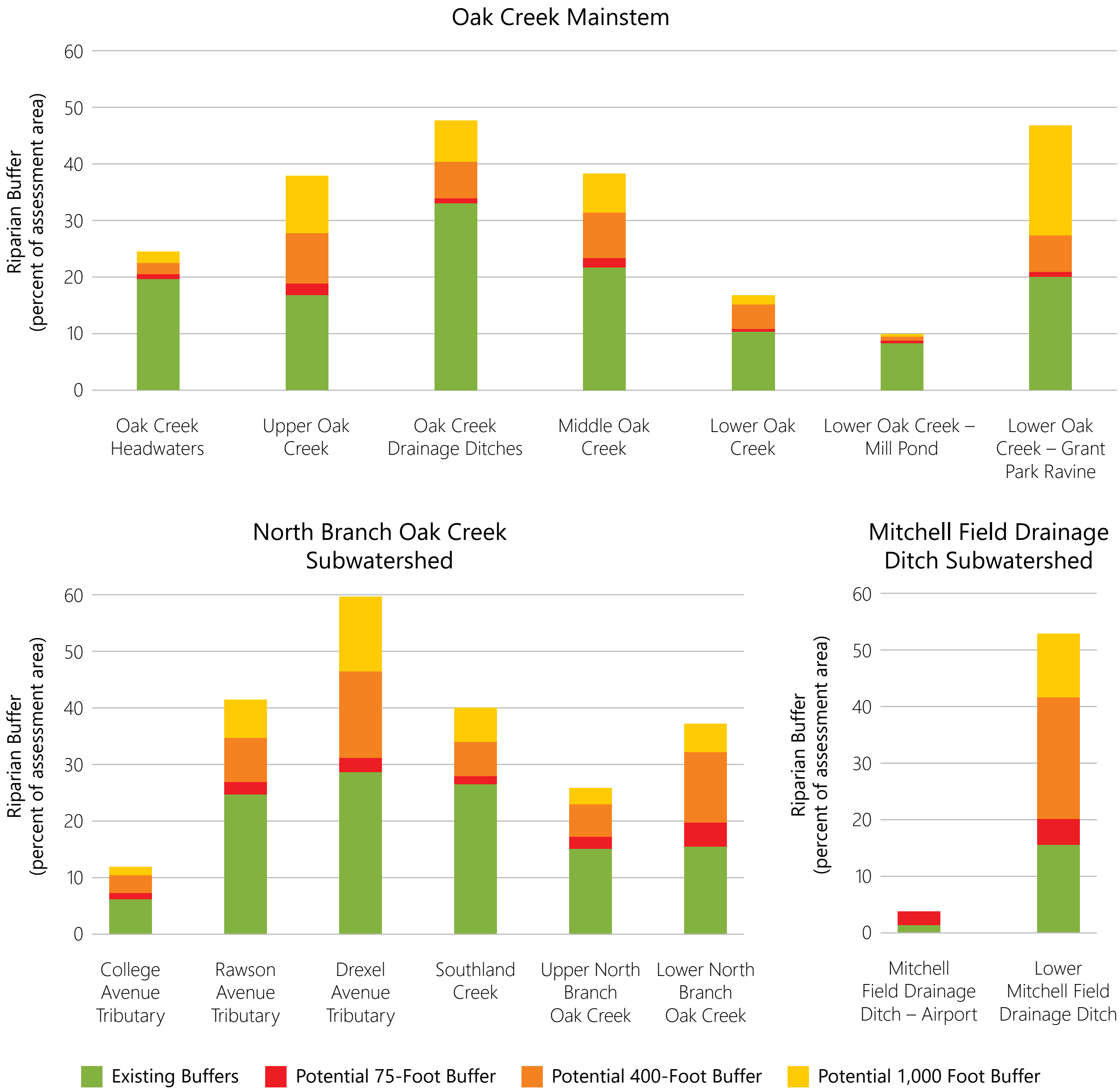
Note: See Appendix Maps G.1 through G.21 for detailed view of existing and potential riparian buffer lands by assessment area.

N

0 0.25 0.5 1 Mile

Source: SEWRPC

Figure 4.24
Percent Existing and Potential Riparian Buffers Within Assessment Areas of the Oak Creek Watershed: 2015



Source: SEWRPC

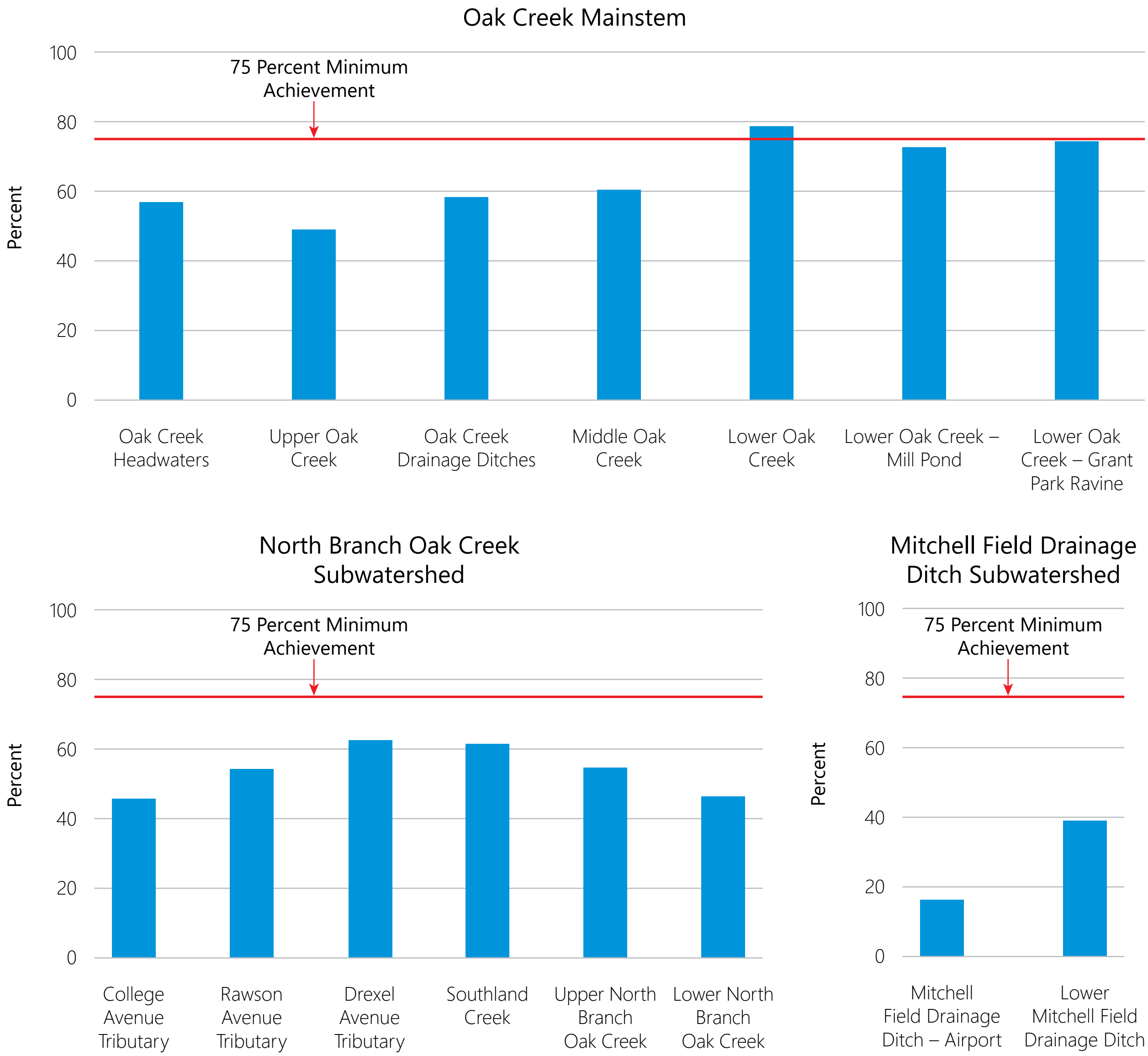
Approximately 38 percent of the existing riparian buffers within the watershed are protected through public interest ownership. In addition, significant amounts of the existing riparian buffers are within the 1-percent-annual-probability (100-year recurrence interval) regulatory floodway and/or within designated ADID wetlands, which provides additional protection for these areas. Based upon these criteria, it was possible to distinguish protected existing riparian buffer lands from vulnerable existing riparian buffer lands. It was also possible to distinguish protected versus vulnerable potential riparian buffer lands in the 75-foot, 400-foot, and 1,000-foot width categories. Map 4.6 shows existing and potential riparian buffer areas within the watershed, with those areas that are more vulnerable to loss shown with a black hatched line. Analysis indicates that about 52 percent of the existing riparian buffer areas within the watershed are vulnerable to loss. When considering potential riparian buffer lands, about 55 percent of potential 75-foot buffer areas, 65 percent of potential 400-foot buffer areas, and 69 percent of 1,000-foot buffer areas are considered vulnerable to loss.

Table 4.9
Existing and Potential Riparian Buffers Within Assessment Areas of the Oak Creek Watershed: 2015

			Potential Buffer Expansion Areas			
Assessment Area	**Existing Buffer (acres)**	**Percent of Buffer Area Meeting 75-Foot Minimum Buffer Width**	Potential 75-Foot Buffer Width (acres)	Potential 400-Foot Width Buffer Width (acres)	Potential 1,000-Foot Width Buffer Width (acres)	Percent of Land Area That Could Potentially Become Riparian Buffer
Mainstem						
Grant Park Ravine	57	74	2	19	56	27
Lower Oak Creek – Mill Pond	77	73	2	8	1	1
Lower Oak Creek	205	79	7	94	32	7
Middle Oak Creek Drainage Ditches	450	58	16	89	99	15
Middle Oak Creek	697	61	54	276	222	17
Upper Oak Creek	303	49	39	168	181	21
Oak Creek Headwaters	139	57	5	14	16	5
Mitchell Field Drainage Ditch						
Lower Mitchell Field Drainage Ditch	228	39	66	309	164	37
Mitchell Field Drainage Ditch – Airport	15	16	24	0	0	2
North Branch Oak Creek						
Lower North Branch Oak Creek	153	46	40	125	46	22
Upper North Branch Oak Creek	190	55	29	70	36	11
Southland Creek	186	61	10	42	43	14
Drexel Avenue Tributary	234	63	21	123	108	31
Rawson Avenue Tributary	239	54	23	77	62	17
College Avenue Tributary	28	46	5	15	6	6
Total Watershed	3,201	55	343	1,429	1,072	16

Source: SEWRPC

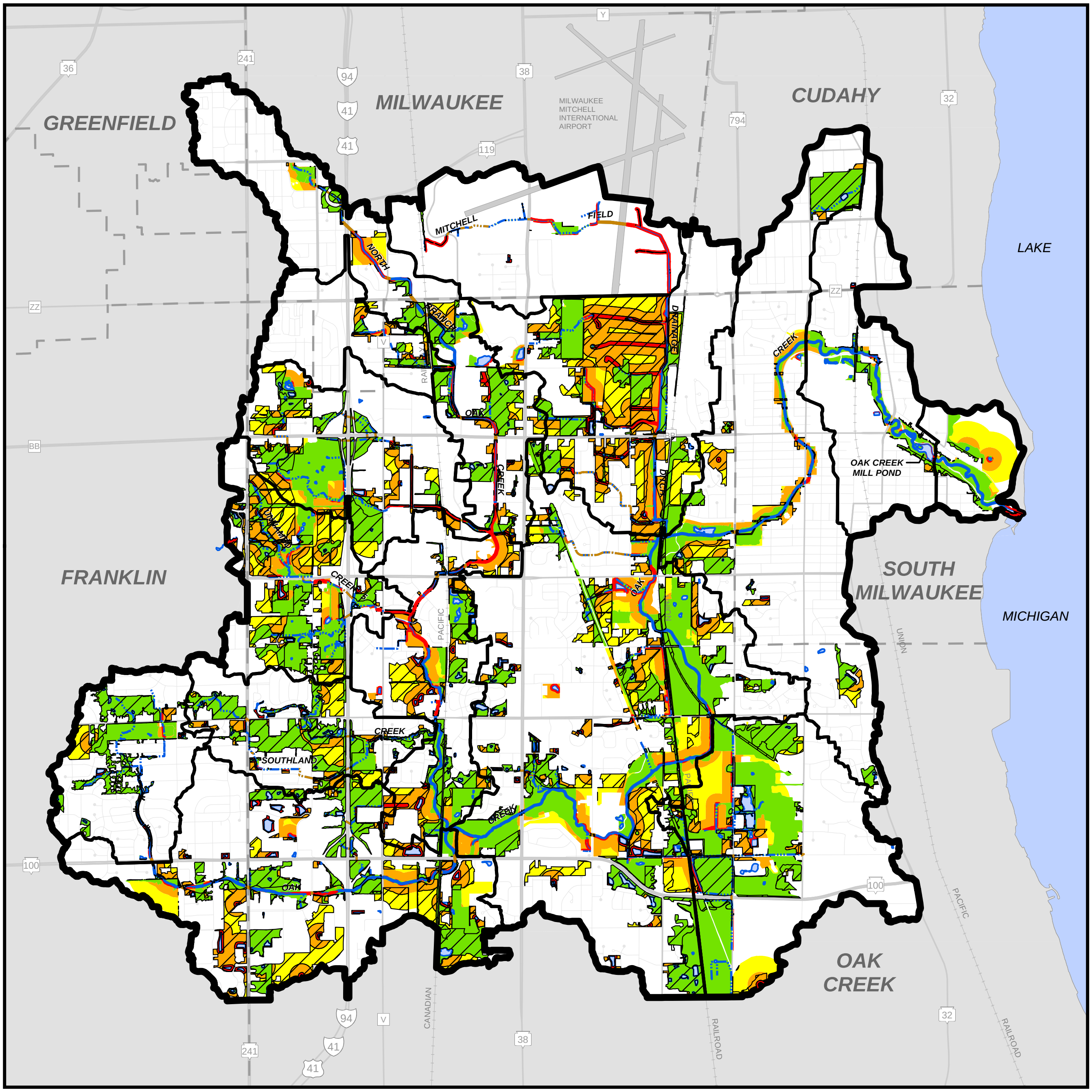
Figure 4.25
Percent of Riparian Buffer Areas Meeting the 75-Foot Minimum Recommended Buffer Width Among Assessment Areas of the Oak Creek Watershed: 2015



Source: SEWRPC

Another way to analyze areas of existing and potential riparian buffers that are vulnerable to loss is to examine planned land uses. Map 3.11 in Chapter 3 of this Report shows areas where year 2015 agricultural lands, open lands, and woodlands are projected to be converted to urban uses under planned land use conditions. Map 4.7 shows these areas superimposed over the existing and potential riparian buffer areas. According to this analysis, 610 acres (about 19 percent) of the existing riparian buffer areas are anticipated to be converted to urban uses under planned conditions. Likewise, 75 acres (22 percent) of potential 75-foot buffer areas; 602 acres (42 percent) of potential 400-foot buffer areas; and 548 acres (51 percent) of potential 1,000-foot buffer areas are projected to be converted to urban land uses. It is important to note that planned land use mapping can be rather coarse and is subject to change. Furthermore, because an area is projected to be converted from an agricultural, open space, or woodland land use to urban uses does not necessarily mean the riparian buffer areas will be lost. With proper planning, urban development can occur while still protecting vital riparian buffer lands.

Map 4.6
Vulnerable and Protected Riparian Buffer Areas Within the Oak Creek Watershed: 2015



LANDS UNDER SOME FORM OF PROTECTION (NOT CROSS HATCHED)

- EXISTING RIPARIAN BUFFERS (DELINEATED BY SEWRPC STAFF USING 2015 DIGITAL ORTHOPHOTOGRAPHY)
- 75-FOOT MINIMUM RECOMMENDED BUFFER WIDTH
- 400-FOOT MINIMUM CORE HABITAT WIDTH FOR WILDLIFE PROTECTION
- 1,000-FOOT OPTIMAL CORE HABITAT WIDTH FOR WILDLIFE PROTECTION

VULNERABLE LANDS (CROSS HATCHED)

- EXISTING OR POTENTIAL RIPARIAN BUFFER LANDS WITH NO FORM OF PUBLIC INTEREST OWNERSHIP

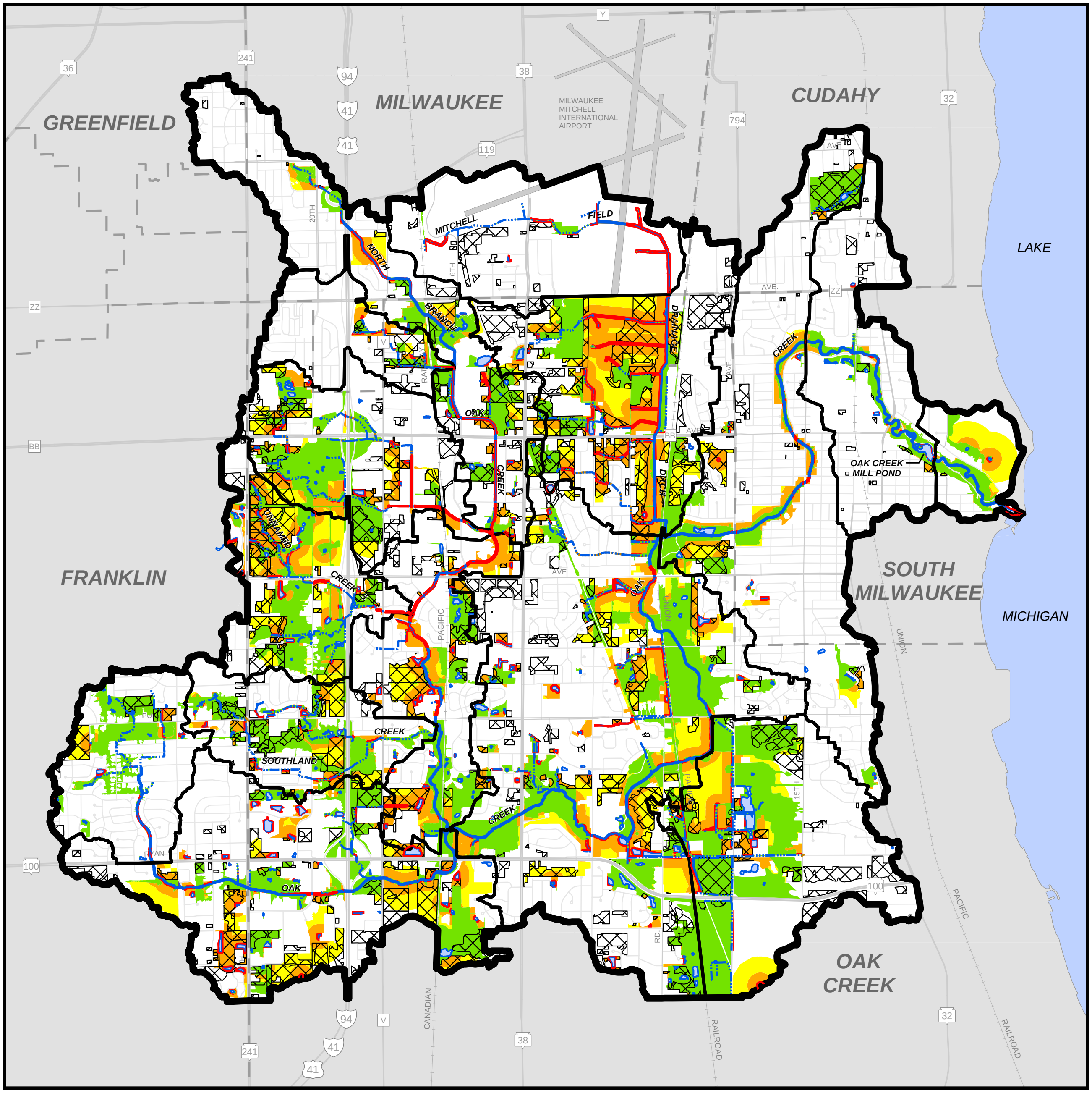
- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

Note: See Appendix Maps G.1 through G.21 for detailed view of vulnerable existing and potential riparian buffer lands by assessment area.

0 0.25 0.5 1 Mile

Source: SEWRPC

Map 4.7
Existing and Potential Riparian Buffer Areas in Relation to Areas Where Existing Year 2015 Agricultural Lands, Open Lands, and Woodlands are Projected to be Converted to Urban Uses Under Planned Land Use Conditions



2015 AGRICULTURAL LANDS, OPEN LANDS, AND WOODLANDS THAT ARE PROJECTED TO BE CONVERTED TO URBAN USES UNDER PLANNED LAND USE CONDITIONS

EXISTING RIPARIAN BUFFERS (DELINEATED BY SEWRPC STAFF USING 2015 DIGITAL ORTHOPHOTOGRAPHY)

75-FOOT MINIMUM RECOMMENDED BUFFER WIDTH

400-FOOT MINIMUM CORE HABITAT WIDTH FOR WILDLIFE PROTECTION

1,000-FOOT OPTIMAL CORE HABITAT WIDTH FOR WILDLIFE PROTECTION

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

Note: Projected land use categories for areas expected to be converted to urban uses can be seen on Map 3.11

N

0 0.25 0.5 1 Mile

Source: SEWRPC

Biological Characteristics of Riparian Buffer Areas

As noted above, many PEC, SEC, INRA, NA, and CSHS are associated with the riparian buffer network throughout the watershed (see Map 4.8 and Map 4.9). Not only do riparian buffers make up much of the environmental corridor, NA, and CSHS lands, but in some cases, they provide critical links between these areas. In this sense, riparian buffers are a vital conservation tool that provides connectivity among different landscapes to improve the viability of wildlife populations within the habitats comprising these high-quality areas.[149]

Map 4.10 shows the major wetland cover types both within and outside of the existing riparian buffer areas based upon the Wisconsin Department of Natural Resources (WDNR) 2015 wetland inventory. This inventory indicates that 960 acres, or about 30 percent, of the existing riparian buffers in the Oak Creek watershed are comprised of a variety of wetland types including emergent wet meadow (280 acres), forested wetlands (534 acres), scrub/shrub (126 acres), flats and unvegetated wet soil (17 acres), and open water wetlands (3 acres). Also shown on Map 4.10 are locations of ephemeral ponds that have been identified by Milwaukee County Parks staff. Of the 71 ephemeral ponds identified within the Oak Creek watershed, 65 are encompassed by existing riparian buffer lands. These habitats help 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, marshes), wet meadows, bogs, fens, small and large streams, springs and seeps, hardwood forest, coniferous forest, woodlands, savannahs, grasslands and prairies.[150] 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 that is essential to support an abundant and diverse wildlife community throughout the Oak Creek watershed.

In addition to being essential wildlife habitat, wetlands provide water quality benefits and flood mitigation. According to the USEPA, at any given point a typical one-acre wetland can store about one million gallons of water.[151] Comparison of the amount of mapped wetlands between today's conditions and the historical conditions shown on Figure 3.6 in Chapter 3 of this Report, indicate just how much wetland area has been lost. Restoring wetlands, particularly as riparian buffer, can provide water storage, reduce sediment and phosphorus loading, and provide additional wildlife habitat. Restorations can also be targeted in agricultural areas where frequent crop damage occurs due to flooding. Using the WDNR potentially restorable wetlands GIS layer, potential wetland restoration sites in the Oak Creek watershed were evaluated for their feasibility for restoration based on location and size. Any site that was located in an area of existing or ongoing development was eliminated. Map 4.11 shows the areas in the watershed with conditions that are favorable to be restored to wetlands in relation to the existing and potential riparian buffer areas. There are a total of 632 acres of potentially restorable wetlands within the watershed, and 322 acres, or 51 percent, of which are within existing riparian buffer lands. In addition, there are 46 acres of potentially restorable wetlands within the 75-foot potential riparian buffer areas, 139 acres within the 400-foot potential riparian buffer areas, and 39 acres within the 1,000-foot potential riparian buffer areas.

Milwaukee County owned Oak Creek Parkway lands that are within the Oak Creek watershed total 817 acres, about 80 percent of which are considered to be existing riparian buffer lands. Vegetative cover surveys conducted from 2008 to 2019 by Milwaukee County Parks staff have delineated the following cover types within the Oak Creek Parkway: floodplain forest (lowland hardwood forest), shrub-carr, upland shrubs, surrogate grasslands, mesic prairie (planted), southern sedge meadow, southern mesic forest, small evergreen plantings, open water, agricultural lands, and degraded habitat. Map 4.12 shows these cover types for the Oak Creek Parkway lands, both within and outside of existing riparian buffer lands. Of the 650 acres of existing riparian buffer lands within the Oak Creek Parkway, about 34 percent are considered floodplain forest, 19 percent are surrogate grassland, and 14 percent are southern mesic forest. Emergent marsh, southern dry forest, upland shrubs, and shrub carr cover types all make up less than 5 percent of the riparian buffer lands within the Oak Creek Parkway. Another 122 acres, or about 19 percent, of the riparian buffer areas within the Parkway were considered to be disturbed or degraded habitat. Degraded habitat is

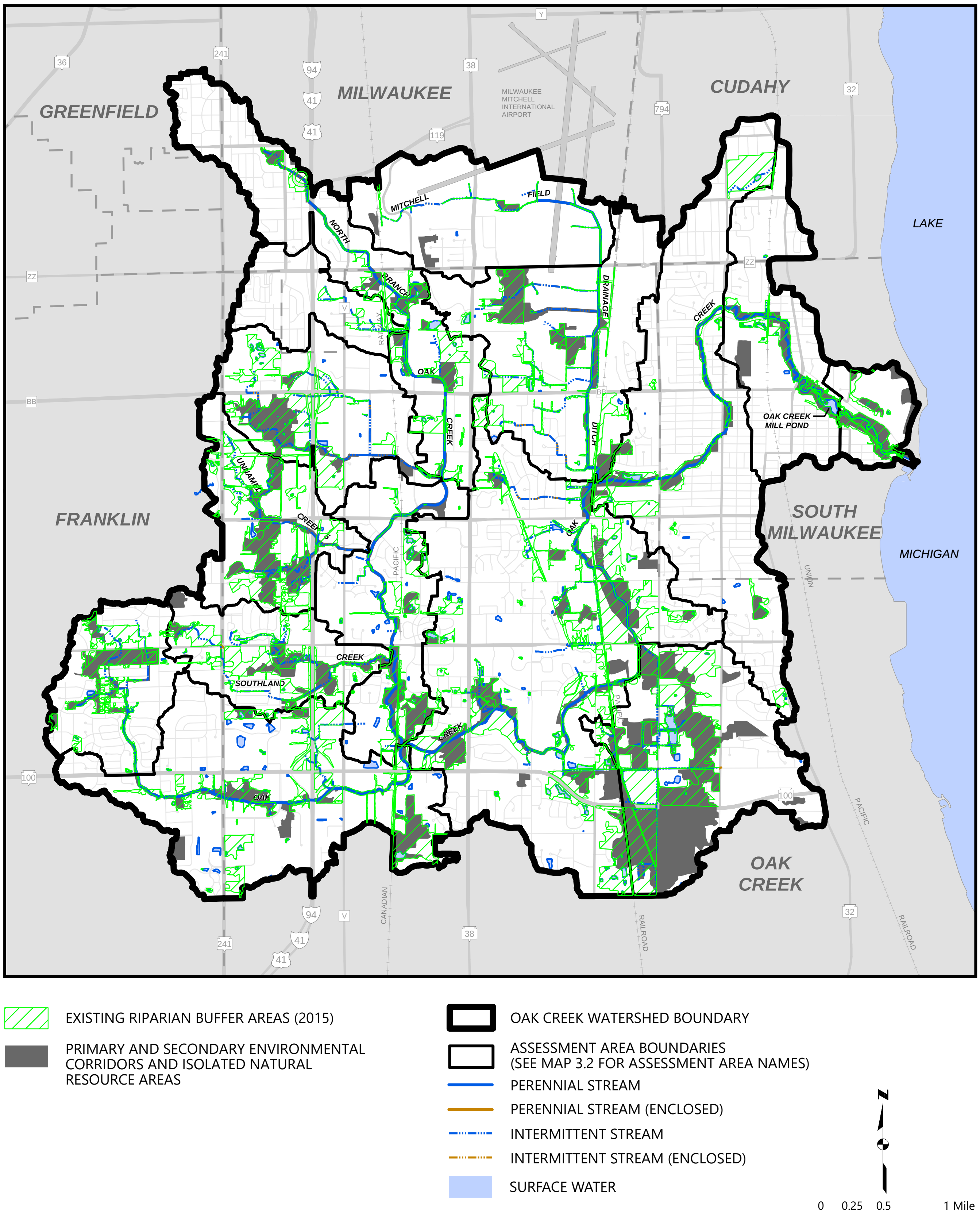
---

[149] *Paul Beier and Reed F. Noss, "Do Habitat Corridors Provide Connectivity?"* Conservation Biology, *Volume 12, Number 6, December 1998.*

[150] *Kingsbury, B.A. and Gibson, J. (editors),* Habitat Management Guidelines for Amphibian and Reptiles of the Midwestern United States, *Partners in Amphibian and Reptile Conservation Technical Publication HMG-1, 2nd Edition, 2012.*

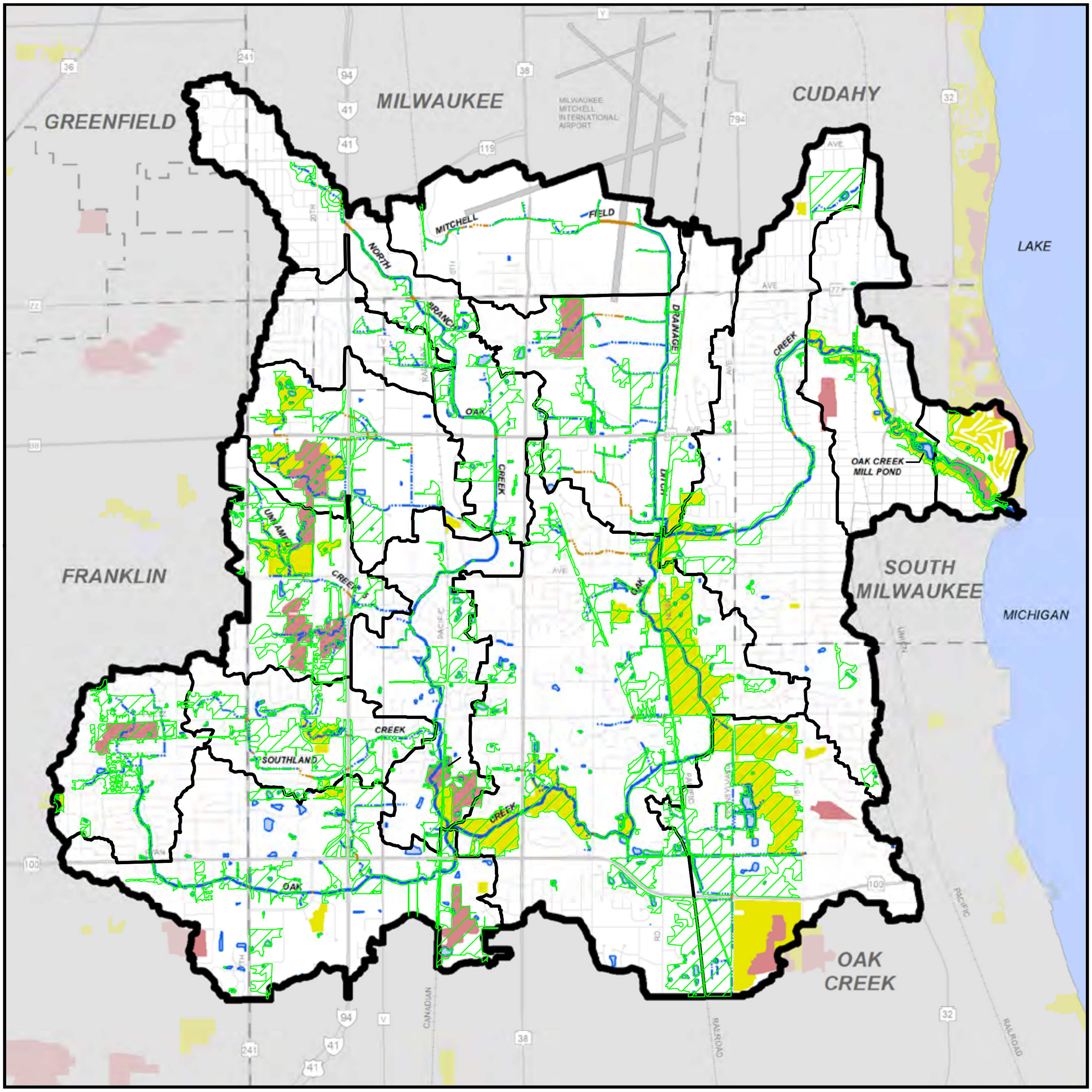
[151] *U.S. Environmental Protection Agency (USEPA),* Wetlands: Protecting Life and Property from Flooding, *May 2006, USEPA843-F-06-001.*

Map 4.8
Environmental Corridors in Relation to Existing Riparian Buffers Within the Oak Creek Watershed: 2015



Source: SEWRPC

Map 4.9
Natural Areas and Critical Species Habitat Sites in Relation to Existing Riparian Buffers in the Oak Creek Watershed



EXISTING RIPARIAN BUFFER AREAS (2015)

NATURAL AREAS (2019)

CRITICAL SPECIES HABITAT SITES (2019)

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

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES
(SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

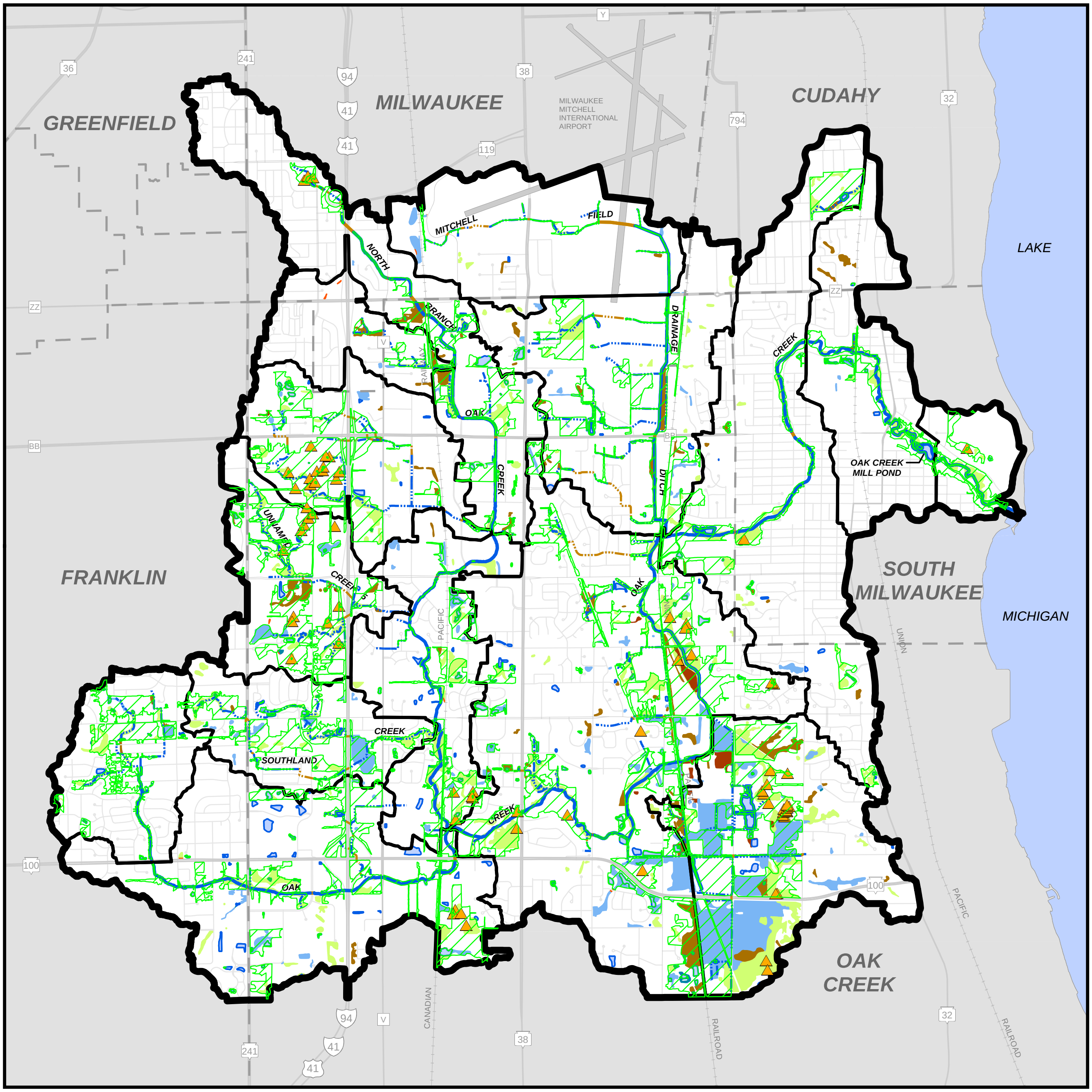
SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: SEWRPC

Map 4.10
Wetland Types and Ephemeral Ponds in Relation to Existing Riparian Buffers Within the Oak Creek Watershed



WETLAND TYPES

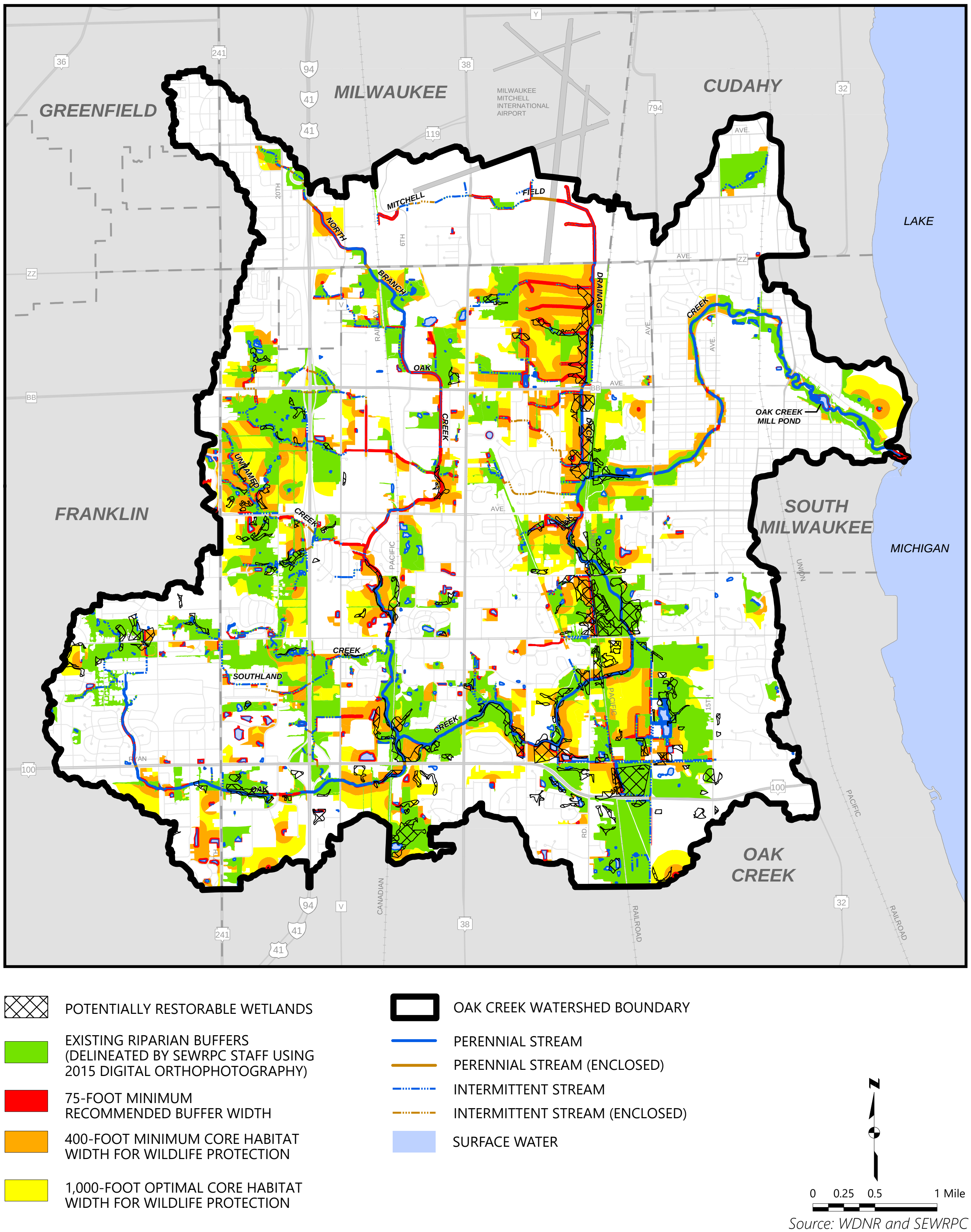
- FORESTED
- EMERGENT/WET MEADOWS
- SCRUB/SHRUB
- FLATS/UNVEGETATED WET SOIL
- OPEN WATER
- EPHEMERAL WETLANDS/PONDS IDENTIFIED BY MILWAUKEE COUNTY PARKS STAFF
- FILLED/DRAINED WETLANDS
- EXISTING RIPARIAN BUFFER AREAS (2015)
- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

N

0 0.25 0.5 1 Mile

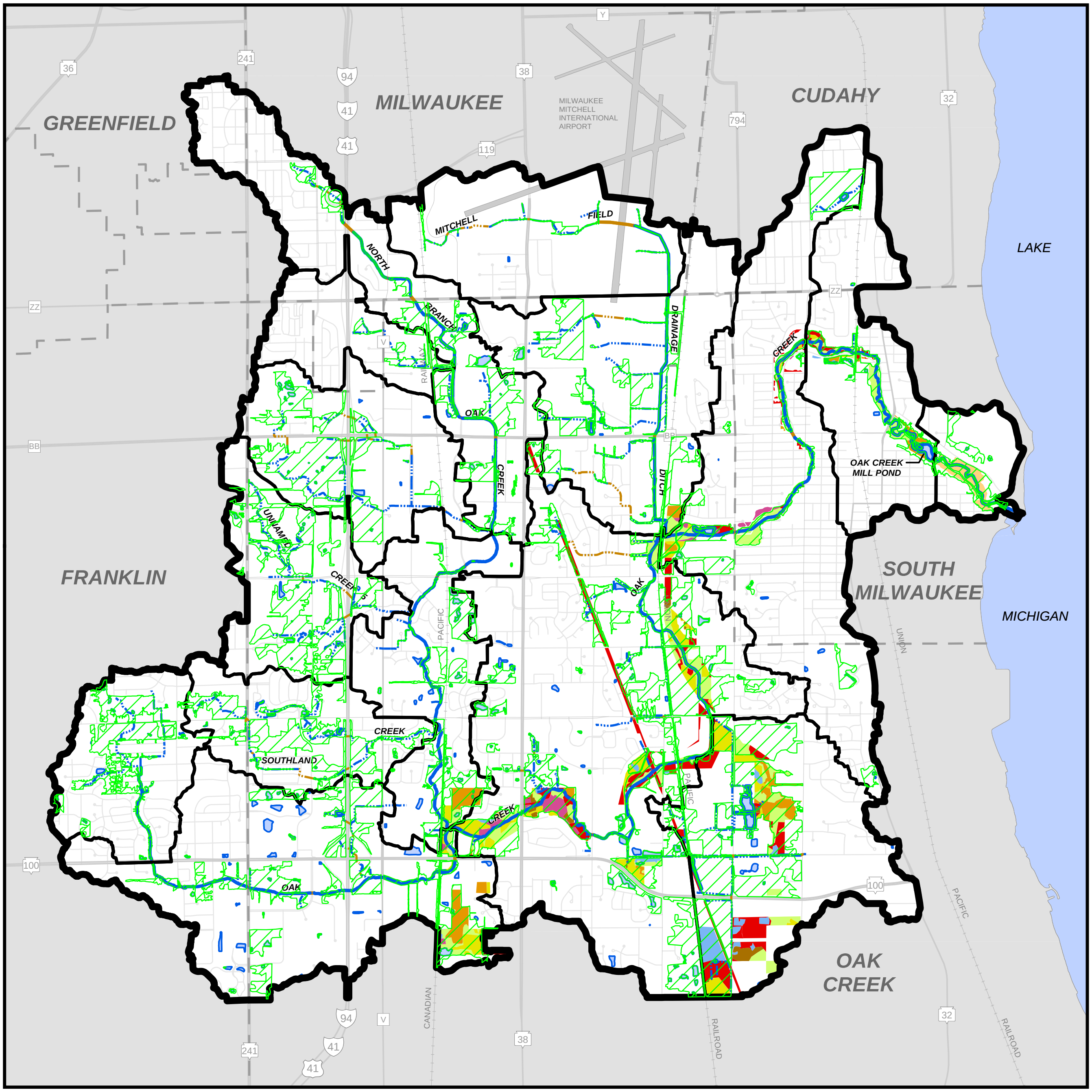
Source: WDNR, Milwaukee County Parks, and SEWRPC

Map 4.11
Existing and Potential Riparian Buffer Areas in Relation to Potentially Restorable Wetlands



Source: WDNR and SEWRPC

Map 4.12
Cover Types Within Milwaukee County's Oak Creek Parkway Lands in Relation to Existing Riparian Buffers



COVER TYPES DELINEATED WITHIN MILWAUKEE COUNTY'S OAK CREEK PARKWAY LANDS

- DISTURBED/DEGRADED
- EMERGENT MARSH
- FLOODPLAIN FOREST
- SHRUB CARR
- SOUTHERN DRY FOREST
- SOUTHERN MESIC FOREST
- SURROGATE GRASSLANDS
- UPLAND SHRUBS

- EXISTING RIPARIAN BUFFER AREAS (2015)
- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: Milwaukee County Parks and SEWRPC defined by Milwaukee County Parks as having vegetative cover types that consist of 75 percent or greater coverage by non-native herbaceous and woody invasive species. It should be noted that the amount of degraded habitat is likely much higher as these classifications were last assessed prior to the extensive degradation that has occurred within the floodplain forests of the Oak Creek Parkway caused by emerald ash borer infestations.

The floodplain forest community within the Oak Creek Parkway has a high composition of ash trees (predominantly green ash) as shown on Map 4.13. Milwaukee County Parks natural areas staff have observed high levels of ash mortality and decline throughout the corridor. The rapid decline of floodplain forest canopy is significantly altering habitat quality within these riparian buffer lands as the increased sunlight penetrating to the forest floor is allowing invasive species, particularly common buckthorn and reed canary grass, to rapidly spread into areas that were previously too shaded for optimal growth.[152] The Oak Creek Parkway lands also include extensive areas of riparian buffer within the 100-year floodplain including wetlands that have been ecologically compromised to some extent by dense stands of reed canary grass, non-native cattails, and common buckthorn.

Stream Crossings, Dams, and Drop Structures and Their Effects on Aquatic Organisms

The streams within the Oak Creek watershed have well over 100 structure crossings. Bridges, culverts, dams, weirs, and drop structures can affect stream widths, water and sediment depths, velocities, and substrate composition. These structures also have the potential to pose physical and/or hydrological barriers to the movement of fish and other aquatic organisms. Along the reaches of streams surveyed by Commission staff in 2016 and 2017, 90 stream crossings were encountered. Stream crossings assessed included 62 structures along Oak Creek, 25 structures along North Branch Oak Creek, and three structures along the Lower Mitchell Field Drainage Ditch. Included in these stream crossings were 44 culverts, 41 bridges, one major dam, and four concrete drop structures (see Table 4.10).[153] Assessments of these structures included gathering general characteristics such as structure type, material, and measurements; inlet and outlet conditions; substrates, water depths, and flow conditions within the structure; general structure condition; and an assessment of potential fish passage impediments.[154] The general characteristics and photos for each surveyed stream crossing are provided in Appendix H.

The locations of all assessed stream crossings are shown on Map 4.14. Stream crossings that were assessed to be fish passage impediments are symbolized in red and those that were assessed to be potential (or partial) impediments are shown in yellow. Along Oak Creek there were eight stream crossings determined to be impediments to fish passage and eight stream crossings considered to be potential (or partial) fish passage impediments to some species of fish. Along North Branch Oak Creek there were four crossings assessed to be fish passage impediments and two crossings that were determined to be a potential (or partial) impediments. Assessments of stream crossings along the Mitchell Field Drainage Ditch only included the three structures downstream of MMIA, and all were assessed to be passable for fish. Structure measurements, conditions, fish passage ratings, description of any problems, and recommended actions for each assessed stream crossing are provided in Appendix Table H.1.

The combined impact of stream crossings, particularly of culverts, on fish communities in streams within the Oak Creek watershed could potentially be significant. 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 of fish, affecting their ability to traverse the altered hydrologic regime within the culverts (see Figure 4.26).[155] Fish of all ages require freedom of movement to fulfill their 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 may occur over an extended period

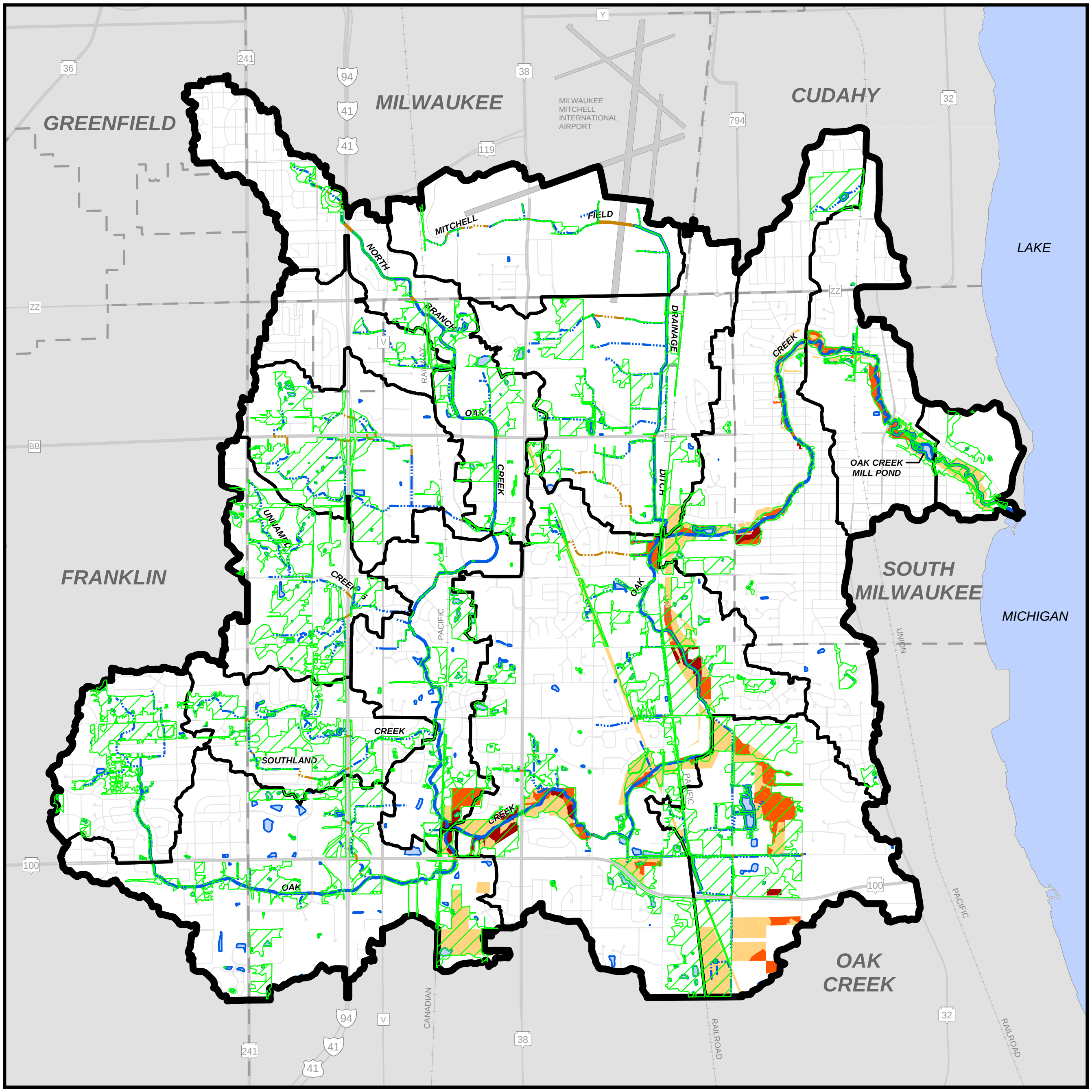
[152] *Milwaukee County Parks, 2019,* op. cit.

[153] *Analysis of previous studies and aerial photographs indicated that there were eight additional stream crossings or enclosures within the Milwaukee Mitchell International Airport property that were not surveyed by Commission staff but are included in the numbers presented in Table 4.10.*

[154] *Assessment of fish passage impediments were based on the best professional judgement of Commission staff.*

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

Map 4.13
Percent of Ash Tree Cover Within Milwaukee County's Oak Creek Parkway Lands in Relation to Existing Riparian Buffers Within the Oak Creek Watershed



PERCENT OF OAK CREEK PARKWAY CANOPY COMPOSED OF ASH TREES

- 0 to 25 PERCENT
- 25 TO 50 PERCENT
- 50 TO 75 PERCENT
- EXISTING RIPARIAN BUFFER AREAS (2015)

- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: Milwaukee County Parks and SEWRPC

Table 4.10
Summary of Stream Crossings Along Oak Creek, North Branch Oak Creek, and Mitchell Field Drainage Ditch: 2016-2017

	Structure Type					Fish Passage Impediments[a]	
Assessment Area	Culverts	Bridges	Dams	Drop Structures	Total	Passage Impediments	Potential (or Partial) Impediments
Mainstem							
Grant Park Ravine	0	3	0	0	3	0	0
Lower Oak Creek – Mill Pond	0	7	1	0	8	1	0
Lower Oak Creek	2	7	0	0	9	0	1
Middle Oak Creek	2	10	0	0	12	0	3
Upper Oak Creek	9	6	0	0	15	3	4
Oak Creek Headwaters	11	0	0	4	15	4	0
Mainstem Subtotal	24	33	1	4	62	8	8
Mitchell Field Drainage Ditch							
Lower Mitchell Field Drainage Ditch	2	1	0	0	3	0	0
Mitchell Field Drainage Ditch – Airport[b]	8	0	0	0	8	N/A	N/A
Mitchell Field Drainage Ditch Subtotal	10	1	0	0	11	--	--
North Branch Oak Creek							
Lower North Branch Oak Creek	4	3	0	0	7	1	0
Upper North Branch Oak Creek	14	4	0	0	18	3	2
North Branch Oak Creek Subtotal	18	7	0	0	25	4	2
Total	52	41	1	4	98	12	10

[a] *Some fish passage obstructions may not be directly related to the crossing structure itself, but occur within or near the structure.*

[b] *Stream crossings were not assessed by SEWRPC staff within the Milwaukee Mitchell International Airport. Information provided in this table is based on previous studies and examination of aerial photography.*

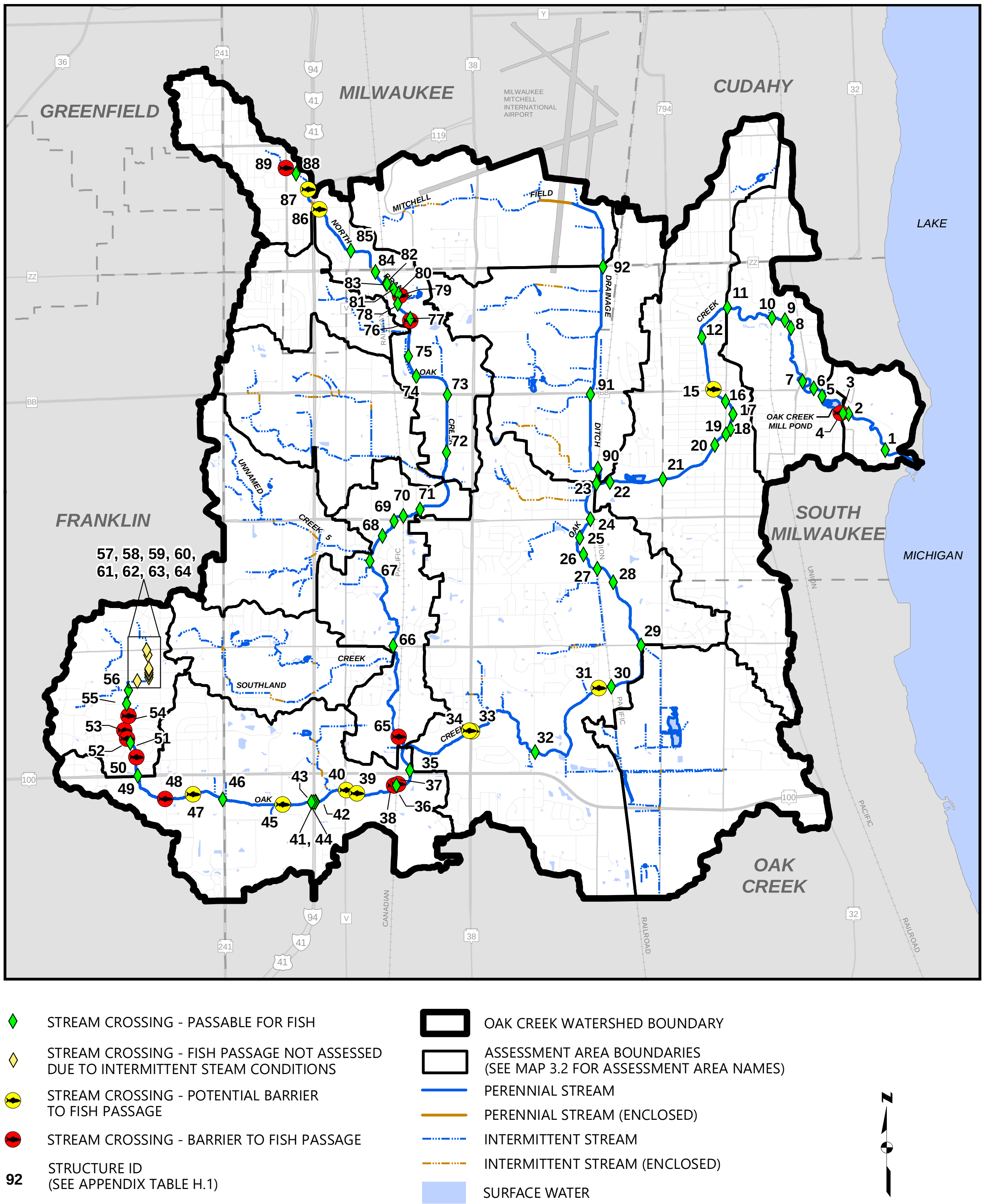
Source: SEWRPC

of time, especially in regard to feeding. In addition, before winter freeze-up, fish tend to move downstream while seeking habitat for rearing, feeding, and protection from predators.[156] Impediments to fish movement can severely limit the abundance and diversity of fish assemblages within stream systems. Thus, it is vitally important to the health of the fishery within the Oak Creek watershed to maintain hydrologic connections up and down the mainstem of Oak Creek as well as to the smaller tributary streams of the watershed. The assessments described in this section aim to highlight impediments at stream crossings that have likely fragmented the connectivity of the stream systems with the goal of improving connections to available high-quality habitat.

There are a variety of ways by which stream crossing structures in this watershed may impede or prevent the movement of fish or other animals. Some structures, such as the Mill Pond dam (structure number 4), the concrete drop structures upstream of Ryan Road in the Oak Creek headwaters assessment area (structure numbers 50, 52, 53, and 54), and the Canadian Pacific Railway crossing (structure number 65) on North Branch Oak Creek (about 0.1 miles upstream of the confluence with Oak Creek) all have significant elevation drops from the water surface upstream of the structure to the water surface elevation downstream of the structure, creating a physical barrier to most fish species attempting to move upstream (see Figure 4.27 and Map 4.14). The Mill Pond dam, and its predecessor structures, have been barriers to natural migration of fish species between the stream system and Lake Michigan (for both fish native and non-native to Wisconsin) for much longer than the earliest recorded fish sample taken in 1910. Lake Michigan is home to a diverse fishery and there is presently no way for the Oak Creek fishery to naturally restore itself upstream of the Mill Pond dam in its current configuration. Comparison of fish assemblages upstream and downstream of the dam can be found in the biological conditions section later in this Chapter.

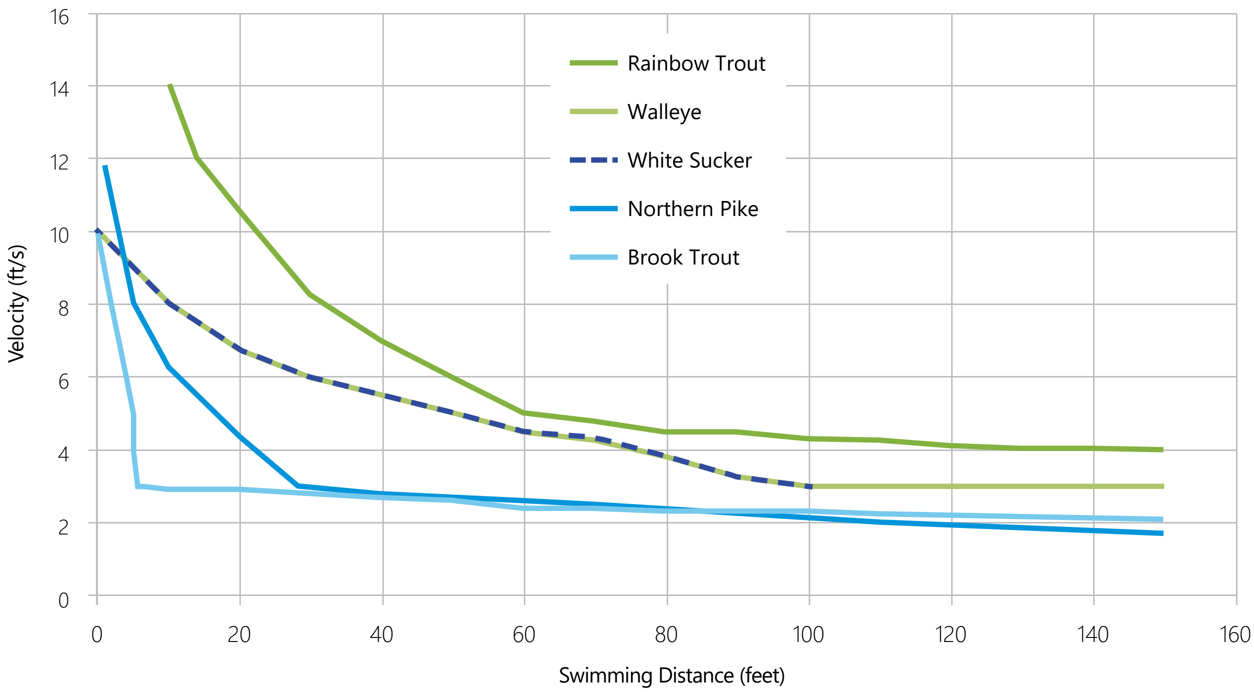
[156] *B.G. Dane,* A Review and Resolution of Fish Passage Problems at Culvert Sites in British Columbia, *Canada Fisheries and Marine Sciences Technical Report 810, 1978.*

Map 4.14
Stream Crossings and Fish Passage Assessment for Surveyed Streams in the Oak Creek Watershed: 2016-2017



Source: SEWRPC

Figure 4.26
Relationship Among Species Between Water Velocity and Fish Swimming Ability (Distance Between Resting Areas)



Source: Ontario Ministry of Natural Resources, Environmental Guidelines for Access Roads and Water Crossings, *Toronto, Ontario, 1988, and SEWRPC*

Other stream crossings, such as the Rawson Avenue and 16th Avenue culvert (structure number 15), are considered fish passage impediments due to their excessive length, in this case about 250 feet. Culverts this long often present passage problems for species of fish that are weaker swimmers as water velocities tend to increase within the structure. Long culverts typically offer very little, if any, larger substrates within the structure to provide for necessary resting spots. Many fish species are unable to swim for long distances without stopping to recover (see Figure 4.26). There are many culverts in the watershed where flow velocities may be troublesome for some species of fish. Additional structures in the watershed were considered to be potential fish passage impediments due to limiting water depths, even when observed during fair-weather flow periods. Absence of a narrower low-flow channel can result in water depths too shallow to allow passage for fish and other organisms, as was observed in structure numbers 33, 34, 40, 47, and 72 (see Figure 4.28 and Map 4.14).

Some structures may not present fish passage impediments themselves, but debris or sediment accumulation, or rock placement within or near the structure may present passage difficulties. This was the case for structure numbers 31, 48, 55, 67, 76, 79, and 89 (see Figure 4.29 and Map 4.14).

Finally, there are several structures in the watershed that have been abandoned and are obviously no longer used or necessary. Some of these structures are severely failing and present safety hazards in addition to impeding fish migration. Included in this category are structure numbers 39, 79, 81, and 82 (see Map 4.14).

Coarse Woody Habitat and Debris Jams

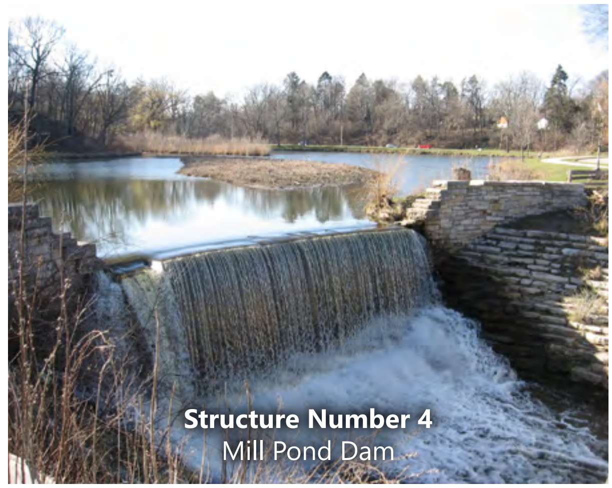
Branches, tree limbs, root wads, and entire trees that fall into or collect along streams are commonly referred to as coarse woody habitat (CWH). CWH plays a vital role in hydraulic, geomorphic, and biological function of streams and floodplains including those within the Oak Creek watershed. Instream CWH is an important component of stream ecosystems and helps control the shape of the channel while providing essential food and habitat for aquatic organisms. In addition, CWH can affect channel morphology and help to form pool habitats; retain organic matter, gravel, and sediment; influence invertebrate abundance; and provide cover and velocity refuge for fish. Contrary to popular belief, CWH can often help prevent erosion by slowing down water as well as armoring banks and preventing down cutting.[157] In most cases, removal of CWH can be detrimental to fish and other aquatic organism habitats downstream. By removing CWH, sedimentation can occur in pools and on top of gravels that are located downstream. Gravels that are covered by sediment become unsuitable for invertebrates and as sites for fish spawning.

In some cases, coarse wood can combine with trash and debris to form massive jams that span the entire width of the stream and extend completely to the bed of the channel. These large debris jams can persist for decades in some cases and have the potential to promote bank erosion, bed scour, localized road flooding, and in some extreme cases initiate the stream cutting a completely new channel potentially putting infrastructure at risk. Some bridges and roadway culverts have the potential to be blocked by debris accumulations, which act to impede flow and can also act as obstructions for fish trying to pass these areas to get to upstream or downstream resting, feeding, and spawning areas. Culvert stream crossings are particularly vulnerable to this, as shown in Figure 4.30.

The occurrence of pests and diseases affecting tree populations is an emerging issue within Southeastern Wisconsin and has had great impact on the riparian corridors adjacent to Oak Creek and other streams within the watershed. Of particular concern is the rapid emergence and spread of the emerald ash borer. Deceased ash trees killed by emerald ash borer are plentiful within the riparian lands adjacent to most of the streams within the watershed, particularly in Milwaukee County parkland along the Oak Creek parkway in the Middle Oak Creek, Lower Oak Creek, and Lower Oak Creek—Mill Pond assessment area (see Figure 4.31 and Map 4.13). As these trees continue to die, it can be expected that the amount of large woody material that enters Oak Creek and its tributaries will increase.

Commission staff encountered debris jams of varying size and impact along surveyed streams during their surveys in 2016 and 2017. Staff observed 51 debris jams along Oak Creek, 21 along North Branch Oak Creek, and 22 along the lower portion of the Mitchell Field Drainage Ditch (see Table 4.1). Locations of these inventoried debris jams are shown on Maps F.13 through F.35 in Appendix F. Many of the debris jams observed were created by trees that had recently fallen and were causing minor accumulations of debris but were still allowing the majority of stream

Figure 4.27
Examples of Fish Passage Impediments Caused by Significant Elevation Drops in Structures


Structure Number 4
Mill Pond Dam


Structure Number 65
Canadian Pacific Railroad


Structure Number 52
Concrete Weir Crossing Oak Creek

Note: See Map 4.14 for location of stream crossings.

Source: SEWRPC

[157] *B. Massop and M.J. Bradford, "Importance of Large Woody Debris for Juvenile Chinook Salmon Habitat in Boreal Forest Streams in the Upper Yukon River Basin,* Canadian Journal of Forestry Resources*, Vol. 35, 2004, pp. 1955-1966.*

flow to easily pass (see Figure 4.32). While these minor jams were not a problem at the time of survey, and actually provide excellent fish habitat, they can accumulate debris and escalate in severity. The most severe jams were observed within the Middle Oak Creek, Lower Oak Creek, and Lower Oak Creek—Mill Pond assessment areas (see Figure 4.33). Several of these severe debris jams were close to six feet in height and caused substantial backwater impacts. Municipalities seemed to be proactive in removing severe debris jams that accumulated at bridges and culverts within the watershed, as Commission staff observed sites that had previously been accumulating debris had been cleared, including at the Shepherd Avenue culvert (shown in Figure 4.30). However, large debris jams at many locations that are not as easily accessible can remain for years. Debris jams of this nature can potentially act as impediments to fish passage. There were 37 debris jams observed by Commission staff that appeared to have the potential to impede fish movement to some degree. Locations of these jams are shown on Map 4.15.

Figure 4.28
Example of Fish Passage Impediments Caused by Limiting Water Depths at Stream Crossings

Note: See Map 4.14 for location of stream crossings.

Source: SEWRPC

A series of debris jams within Oak Creek just upstream of the Mill Pond persisted over many years causing sediment to accumulate to the point where a blockage formed across the channel, forcing the Creek to cut a new channel in close proximity to the Oak Creek Parkway road. The sediment accumulation that blocks the original channel is shown in Figure 4.34. Examination of aerial photographs suggests that the new channel may have formed sometime between 2005 and 2007. As of 2018, this series of debris jams still blocked the original channel and the majority of the flow is diverted through the new channel along the road. Bank erosion near the Oak Creek Parkway has been observed. Considering the amount of deceased ash trees observed within the riparian lands along the mainstem and major tributaries of the watershed, debris jams can be expected to increase and become more troublesome in the future.

Beaver Activity and Beaver Dams

Beavers can alter environments to a greater extent than any other mammal besides humans. Their ability to increase landscape heterogeneity by felling trees and constructing impoundments and canals goes beyond their immediate needs for food and shelter. The activities of beavers in streams provide 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 of plants; 6) influence the character of water and materials transported downstream; and 7) modify instream aquatic habitat, which ultimately influences community composition (i.e., fish and macroinvertebrates) and diversity.[158]

Beaver dams are not permanent structures and without constant maintenance the dams will eventually 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 on the other hand, they may only be used seasonally. It is likely that under normal conditions beaver dams are impediments for most fish species in terms of upstream passage.

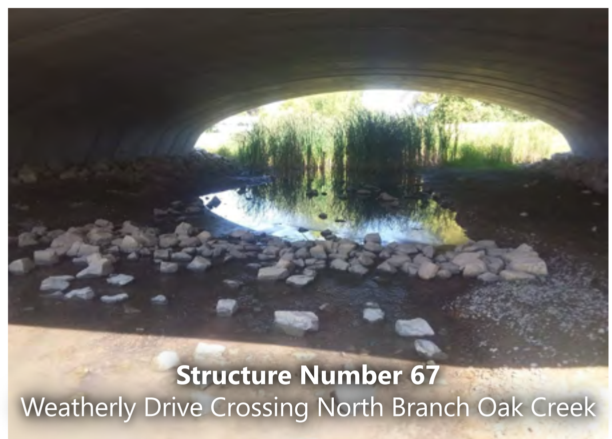
[158] *R.J. Naiman, J.M. Melillo, J.E. Hobbie, "Ecosystem alteration of boreal forest streams by beaver (Castor Canadensis),"* Ecology*, Volume 67, 1986, pages 1254-1269.*

Early research suggested that beaver dams might be detrimental to fish, primarily by hindering fish passage and restricting movement of fishes.[159] Until recently, it was common for fish managers to remove beaver dams. However, recent research has shown that beaver dams can enhance fisheries over watershed-wide scales. When beaver impound streams by building dams, they substantially alter stream hydraulics in ways that benefit many fish species.[160] More than 80 North American fishes have been documented in beaver ponds, including 48 species that commonly use these habitats.[161] In agricultural areas, beaver dams may impound water and submerge drain tile outlets, reducing the effectiveness of the tile systems and adversely affecting crops. Impounded water from beaver dams can also flood roadways and removal is necessary in such cases. Decisions to remove beaver dams should be addressed on a case-by-case basis.

There was notable beaver activity scattered throughout the surveyed reaches of Oak Creek and its tributaries that included beaver chew, felled trees, and a total of eight beaver dams. Beavers tend to construct a series of several dams on a stream to achieve the desired amount of backwater, and this was what was observed by Commission staff. A beaver dam was observed on the mainstem of Oak Creek near Puetz Road as well as the nearby drainage ditch that enters Oak Creek near Puetz Road (see Map F.20). These dams have since been removed by the City of Oak Creek public works department. Another series of three beaver dams were observed on North Branch Oak Creek upstream of Drexel Avenue (see Map F.30). Conditions observed in 2017 suggested that these dams were not immediately endangering flooding of the roadway and there was enough open land to accommodate any effects they may have. However, the area of these three beaver dams should be monitored.

The most significant beaver activity observed by Commission staff was a series of dams on the Mitchell Field Drainage Ditch near Rawson Avenue and is shown in Figure 4.35 (see Map F.34 for locations). The largest and most upstream dam was about 680 feet upstream of Rawson Avenue. Water levels behind this dam were likely raised more than two feet and were beginning to inundate a gravel roadway serving community garden plots owned by Milwaukee County. Two other dams were found about 250 feet upstream from Rawson Avenue and about 125 feet

Figure 4.29
Examples of Potential Fish Passage Impediments Caused by Debris or Sediment Accumulation or Rock Placement Within or Near Stream Crossings



Note: See Map 4.14 for location of stream crossings.

Source: SEWRPC

[159] *I.J. Schlosser, Dispersal, "Boundary Processes, and Trophic-Level Interactions in Streams Adjacent to Beaver Ponds,"* Ecology, *Volume 76, 1995, pages 908-925.*

[160] *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.*

[161] *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.*

downstream from Rawson Avenue. Commission staff noted that these impoundments contained large deposits of sediment. On a subsequent visit to this stream, staff observed that the three beaver dams had been removed.

Trash in Streams

Accumulation of trash and debris degrades the aesthetics of the streams within the watershed 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. Trash accumulations also give the general public a negative impression of the stream as a resource with the potential for rehabilitation. Therefore, Commission staff recorded and mapped the significant trash and debris encountered during the comprehensive instream survey of Oak Creek, North Branch Oak Creek, and the lower portions Mitchell Field Drainage Ditch. The number of sites where large trash items were observed within or near stream channels are reported in Table 4.1 and their locations are shown by assessment area on Maps F.13 through F.35 in Appendix F. A total of 73 locations were observed where large trash items were within or adjacent to the Oak Creek stream channel, 27 locations in North Branch Oak Creek, and four locations in the lower portion of the Mitchell Field Drainage Ditch.[162] The most common type of trash encountered were car tires, with at least 79 tires observed within surveyed streams. A particularly high concentration of car tires was observed in the Upper North Branch Oak Creek assessment area, where 32 automobile tires were observed in a quarter mile reach downstream of an auto salvage yard near College Avenue. Other large trash items observed included multiple shopping carts, trash cans, construction barrels, televisions, various furniture pieces, plastic buckets, and car parts, among other items.

Overall Stream Habitat Scoring

Low-gradient streams are characterized by a channel bottom slope of about 0.005 feet/foot (about 26 feet/mile) or lower. The Oak Creek—Headwaters and Grant Park Ravine assessment areas have gradients slightly above this threshold, but the Oak Creek system as a whole can be considered low-gradient. Undisturbed high quality low-gradient streams tend to lack riffles and have relatively slow currents, small substrate particle sizes, and well-developed meandering channel morphology. Such streams often flow through wetlands and may have very soft, unconsolidated substrates and poorly defined channels in some cases. These characteristics have made low-gradient streams

Figure 4.30
Large Debris Accumulations on Oak Creek at the Shepherd Avenue Culvert: 2016

Source: SEWRPC

Figure 4.31
Stands of Deceased Ash Trees Along Oak Creek: 2017

Source: SEWRPC

[162] *The numbers reported indicate locations at which large trash items were observed. There may be multiple large trash items at an individual site.*

ideal candidates for channelization for agricultural development along with installation of tiles to improve drainage. This has occurred over time to a large portion of streams in the Oak Creek watershed. Much of the agricultural land in the watershed has since been converted to urban uses, but the stream system still retains most of the modifications that were done when the land was cleared for cultivation in the late 19th and early 20th centuries.

Figure 4.32
Example of a Minor Debris Jam Along Oak Creek: 2016

Source: SEWRPC

The low gradient stream habitat index incorporates several habitat variables that are well established as strongly influencing fish communities and biotic integrity.[163] Those habitat variables include percent and age of channelization, instream cover, bank erosion, sinuosity, standard deviation of thalweg depth, and riparian buffer vegetation. Instream cover can include several features such as undercut banks, overhanging vegetation, woody debris, cobble and boulders, and emergent and/or submergent aquatic plants. The standard deviation in thalweg depth is a measurement of the variability of water depths, which is a good measure of the variability of stream channel morphology. Greater variability of water depths is reflected in greater diversity of pool, riffle, and run habitat units within a stream reach, and their associated differences in water depth, velocity, and substrate diversity. For example, channelized or straightened streams tend to have uniform conditions, whereas meandering streams tend to have a greater variety of habitats. Diverse habitat generally supports more species, a greater variety of life-stages, and higher abundance of fish. The results of the stream habitat index scores are shown in Table 4.11 for the mainstem of Oak Creek and in Table 4.12 for the assessment areas tributary to Oak Creek. It is important to note that the low-gradient stream habitat index is only one way to assess instream habitat quality in the Oak Creek watershed and should not be interpreted without the analysis of the stream survey data provided in the previous sections of this chapter.

Examining the habitat scores across the assessment areas of the Oak Creek watershed shows that all areas where there are available data have strong scores for the relatively low amount of bank erosion, the variability of water depths, and age of channelization.[164] The mainstem Oak Creek assessment areas were all in the fair-to-good range for riparian buffer coverage (see Table 4.11). The assessment areas within the North Branch Oak Creek subwatershed ranged from fair-to-good riparian buffer coverage, while the Mitchell Field Drainage Ditch assessment areas ranged from fair buffer coverage in the Lower Mitchell Field Drainage Ditch to poor in the Mitchell Field Drainage Ditch—Airport (see Table 4.12).

Many of the streams within the watershed are heavily channelized, which is reflected in the low habitat scores both in the sinuosity of the streams and the percent of channelization.[165] The portions of Oak Creek that flow through the Grant Park Ravine and Lower Oak Creek—Mill Pond assessment areas are the only stream reaches in the watershed that have sinuosities that are considered to be "good" based on the low-gradient stream habitat scores. The stream reach within the Oak Creek Headwaters is considered to

[163] *L. Wang, J. Lyons, and P. Kanehl, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management, *Volume 18, pages 775-785, 1998.*

[164] *Although the age of channelization is generally associated with an improvement in the biological integrity of a stream (because the ecosystem has had time to recover from this disturbance) there can be constraining factors that limit this improvement. Hence, factors such as non-functional floodplain connections and armored banks can influence the ability of a channel to recover on its own, no matter the length of time that has passed since channelization has taken place.*

[165] *While higher sinuosity ratios are typically indicators of a lower percentage of channelization, there can be exceptions. For example, the portion of Oak Creek within the Lower Oak Creek—Mill Pond assessment area is more sinuous than the reach of Oak Creek through the Grant Park Ravine, yet the Lower Oak Creek—Mill Pond portion of stream has experienced greater amounts of channelization. This is due to the fact that ravine streams (as are seen within the Grant Park Ravine assessment area) that have steeper gradients tend to be straighter by nature.*

have “fair” sinuosity, and all other stream reaches that were assessed, both on the mainstem and tributary streams, are ranked poor.

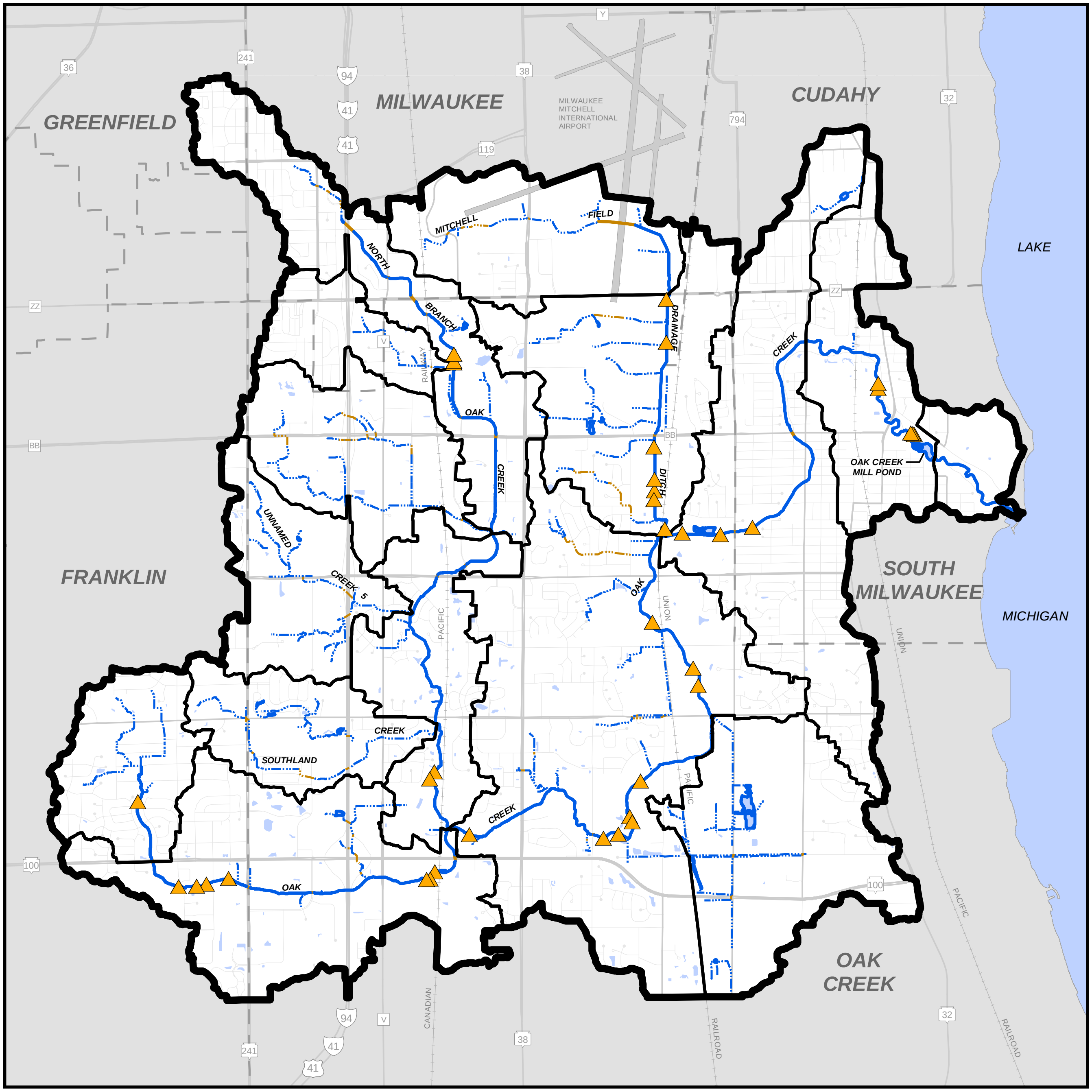
Instream cover is an essential component of a healthy stream ecosystem. It provides shelter for aquatic organisms, prevents excessively high water temperatures, and inhibits eutrophication. The type and amounts of riparian vegetation are significant drivers of the types and amounts of instream cover. The instream cover quality of surveyed streams within the watershed was ranked based on instream observations by Commission staff. These observations considered, on a reach basis, the amount of available cover, diversity of cover types (including boulders, cobbles, overhanging vegetation, submergent and emergent vegetation, woody debris, and undercut banks), and amount of stream shading. Instream cover was assessed to be of “good” quality in the Lower Oak Creek—Mill Pond and the Grant Park Ravine assessment areas, while the remaining reaches of Oak Creek were assessed to have “fair” instream cover (see Table 4.11). The instream cover ranged from “fair” in the Lower North Branch Oak Creek assessment area to “poor” quality in the Upper North Branch Oak Creek assessment area. The instream cover in Lower portion of the Mitchell Field Drainage Ditch was assessed to be in “poor” condition (see Table 4.12).

Overall, total stream habitat scores for the mainstem of Oak Creek assessment areas ranged from “excellent” to “fair” based on the indices presented above and shown in Table 4.11. Note that the Grant Park Ravine assessment area, which is the stream reach least impacted by channelization in this watershed, received the highest quality instream habitat score. Total stream habitat scores for the tributary stream reaches (for which enough data were available to calculate a score) ranged from “fair” to “poor” as shown in Table 4.12. These stream habitat scores are also generally consistent with the findings of fisheries and macroinvertebrate surveys conducted throughout the watershed and discussed in detail below in the biological conditions section. It is important to note that lower overall habitat scores were almost always associated with the most highly modified reaches. Although some reaches of streams within the Oak Creek watershed show some signs of recovery from past anthropogenic modifications, these reaches will likely not recover in a reasonable amount of time without further human intervention.

Figure 4.33
Examples of Severe Debris Jams Along Oak Creek: 2016-2017

Source: SEWRPC

Map 4.15
Debris Jams That Could Potentially Impede Fish Passage Along Surveyed Streams in the Oak Creek Watershed: 2016 and 2017



OBSERVED DEBRIS JAMS THAT ARE POTENTIAL FISH PASSAGE IMPEDIMENTS (2016-2017)

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

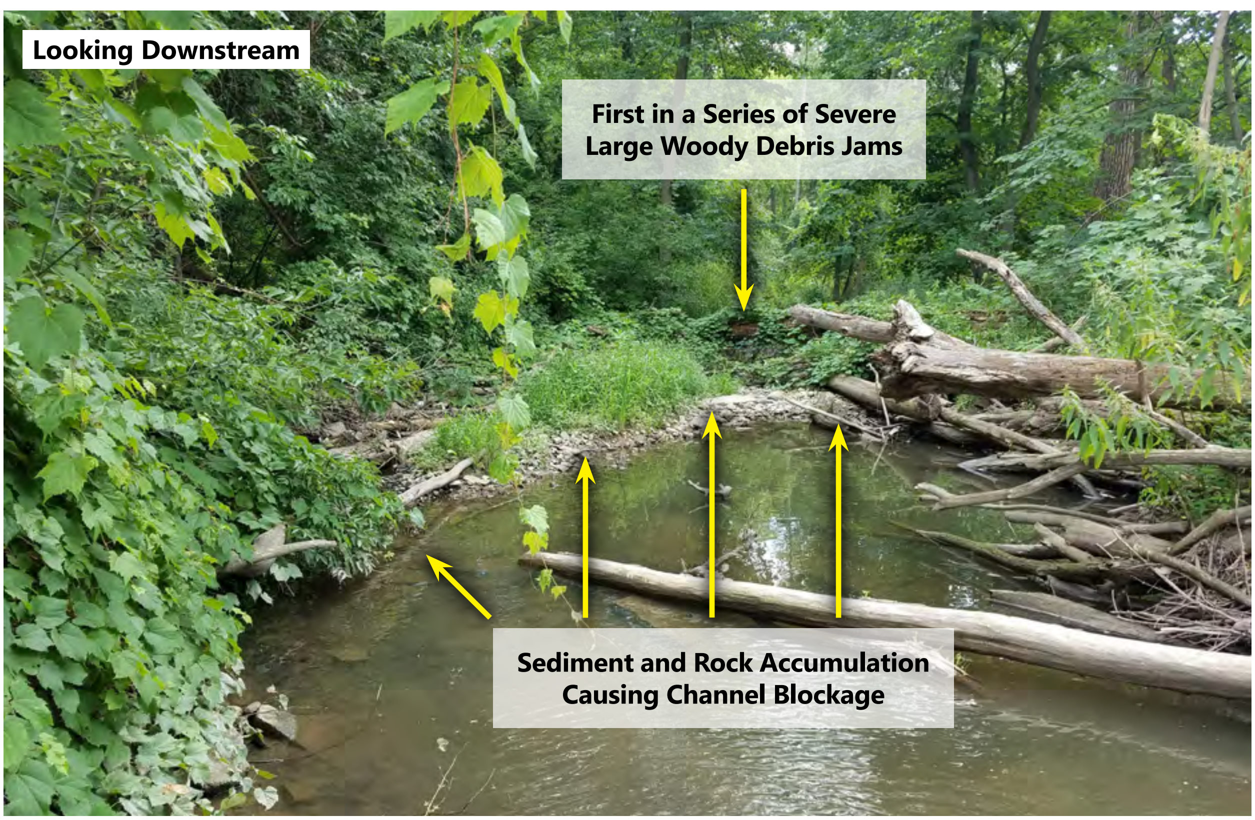
SURFACE WATER

Note: See Appendix Maps F.13 through F.35 for all observed debris jams

0 0.25 0.5 1 Mile

Source: SEWRPC

Figure 4.34
Sediment and Rock Accumulation and Channel Blockage Caused by a Series of Severe Debris Jams on Oak Creek Upstream of the Mill Pond: 2016



Source: SEWRPC

4.3 WATER QUANTITY CONDITIONS

Lake Michigan Water Levels

The mouth of Oak Creek is influenced by Lake Michigan water levels as well as wind and wave levels on the Lake. The mean monthly water levels on Lake Michigan for years 1918 to 2018 are included in Figure 4.36. For reference the figure includes the long term (1918-2018) mean Lake Michigan water level elevation of 578.84 feet in International Great Lakes Datum 1985 (IGLD85).[166]

Lake Michigan water levels have historically cycled and are currently on a rising trajectory (see Figure 4.36). With a few exceptions, when compared to the long term mean elevation, Lake Michigan had an above average water level period from approximately 1968 to 1998, and then below average water levels from approximately 1998 to 2014. The record low water level occurred in year 2013 (576.02 feet IGLD85). The June 2019 mean Lake Michigan water level was recorded as 581.76 feet IGLD85, indicating a 5.7-foot Lake level rise in approximately six years. A rapid rise of this caliber for Lake Michigan water levels has been experienced at other times within the period of record (see Figure 4.36). The record maximum mean monthly Lake Michigan water levels were set in year 2020 for the months of January through August and 1986 for the months September through December, with the highest Lake Michigan mean monthly water level recorded as 582.35 feet IGLD85 in October 1986.

Streamflow Conditions

The only continuous streamflow gage in the Oak Creek watershed is the U.S. Geological Survey (USGS) water stage recording Station No. 04087204, which is located on the left bank of Oak Creek's mainstem approximately 25 feet downstream of the 15th Avenue bridge in South Milwaukee. The gage is located approximately 2.8 miles upstream from the Oak Creek confluence with Lake Michigan. This gage has been in continuous operation since October 1963 and is a continuous water stage recorder, recording water level data every 15 minutes.

Mean monthly flow data for Station No. 04087204 are summarized in Figure 4.37. This figure summarizes the average monthly mean flows as well as the maximum monthly mean flows for the Oak Creek gage period of record.[167] For water years 1964 through 2017, the gage data indicate that Oak Creek average monthly mean flows did not exceed 52 cubic feet per second (cfs), and the maximum monthly mean flows did not exceed 207 cfs. It was also noted that the highest maximum mean monthly flows for Oak Creek for the period of record occurred in March, April, June, and July, while the lowest mean monthly flows for the period of record occurred in August through November.

Figure 4.35
Beaver Dams Observed Along the Mitchell Field Drainage Ditch: September 21, 2017

About 680 Feet Upstream of Rawson Avenue

About 250 Feet Upstream of Rawson Avenue

About 125 Feet Downstream of Rawson Avenue

Source: SEWRPC

[166] *Elevations in feet IGLD85 can be converted to elevations in feet National Geodetic Vertical Datum 1929 (NGVD29) by adding 0.53 feet (IGLD85 + 0.53 = NGVD29).*

[167] *The water year runs from October 1 of the preceding year through September 30 of the designated water year.*

Table 4.11
Stream Habitat Criteria Scores for Mainstem Oak Creek Assessment Areas: 2016-2017

Habitat Criterion	Grant Park Ravine	Lower Oak Creek – Mill Pond	Lower Oak Creek	Middle Oak Creek	Upper Oak Creek	Oak Creek Headwaters
Channelization Percent (score)	1-5 (6)	10-20 (3)	90-100 (0)	90-100 (0)	90-100 (0)	50-60 (3)
Channelization Age in Years (score)	>50 (15)	>50 (15)	>50 (15)	>50 (15)	>50 (15)	>50 (15)
Instream Cover (score)	Good (24)	Good (18)	Fair (12)	Fair (7)	Fair (12)	Fair (7)
Bank Erosion Percent[a] (score)	26.6 (7)	14.1 (9)	13.0 (9)	12.4 (9)	6.8 (10)	14.2 (9)
Sinuosity (score)	1.21 (5)	1.33 (9)	1.02 (0)	1.04 (0)	1.04 (0)	1.06 (4)
Thalweg Depth Standard Deviation (score)	0.98 (10)	0.92 (10)	0.98 (10)	0.96 (10)	0.71 (10)	0.37 (9)
Buffer Vegetation—Percent of Buffers Meeting 75 Foot Minimum Width[b] (score)	74 (8)	73 (8)	79 (8)	61 (6)	49 (4)	57 (5)
Total Habitat Score	Excellent (75)	Good (72)	Fair (54)	Fair (47)	Fair (51)	Fair (52)

Note: Background colors indicate the low-gradient stream habitat score given to each assessment area: Poor (red), Fair (yellow), Good (green), and Excellent (blue). See Map 3.2 for the location of each assessment area.

[a] *Only principal streams in each assessment area were surveyed and some reaches were not surveyed in their entirety. See Table 4.1 for length of streams that were surveyed in each assessment area.*

[b] *Commission staff used a more restrictive 75 foot minimum buffer width as part of this criteria rather than the 33 foot (10 meter) buffer width from stream edge as is used in the original index (see citation below for more details). Percent buffer vegetation is determined by the amount of land covered with relatively undisturbed vegetation (woodland, shrub, meadow, wetland) within 75 feet of each streambank. This includes buffered lands adjacent to all streams and ponds within the assessment area.*

Source: Adapted from L. Wang, J. Lyons, and P. Kanehl, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams," North American Journal of Fisheries Management, *Volume 18, pages 775-785, 1998 and SEWRPC*

Table 4.12
Stream Habitat Criteria Scores for Tributary Assessment Areas: 2016-2017

	North Branch Oak Creek						Mitchell Field Drainage Ditch (MFDD)	
Habitat Criterion	Lower NBOC	Upper NBOC	Southland Creek	Drexel Avenue Tributary	Rawson Avenue Tributary	College Avenue Tributary	Lower MFDD	MFDD Airport
Channelization Percent (score)	61-75 (0)	90-100 (0)	61-75 (0)	40-60 (3)	40-60 (3)	90-100 (0)	100 (0)	100 (0)
Channelization Age in Years (score)	>50 (15)	>50 (15)	>50 (15)	>50 (15)	>50 (15)	>50 (15)	>50 (15)	>50 (15)
Instream Cover (score)	Fair (15)	Poor (0)	N/A	N/A	N/A	N/A	Poor (1)	N/A
Bank Erosion Percent[a] (score)	10.5 (9)	5.5 (10)	N/A	N/A	N/A	N/A	12.5 (9)	N/A
Sinuosity (score)	1.04 (0)	1.02 (0)	N/A	N/A	N/A	N/A	1.01 (0)	1.03 (0)
Thalweg Depth Standard Deviation (score)	0.78 (10)	0.61 (10)	N/A	N/A	N/A	N/A	0.96 (10)	N/A
Buffer Vegetation—Percent of Buffers Meeting 75 Foot Minimum Width[b] (score)	46 (4)	55 (5)	61 (6)	63 (6)	54 (5)	46 (4)	39 (3)	16 (0)
Total Habitat Score	Fair (53)	Poor (40)	Incomplete[c]	Incomplete[c]	Incomplete[c]	Incomplete[c]	Poor (38)	Incomplete[c]

Note: Background colors indicate the low-gradient stream habitat score given to each assessment area: Poor (red), Fair (yellow), Good (green), and Excellent (blue). See Map 3.2 for the location of each assessment area.

N/A = Not Assessed.

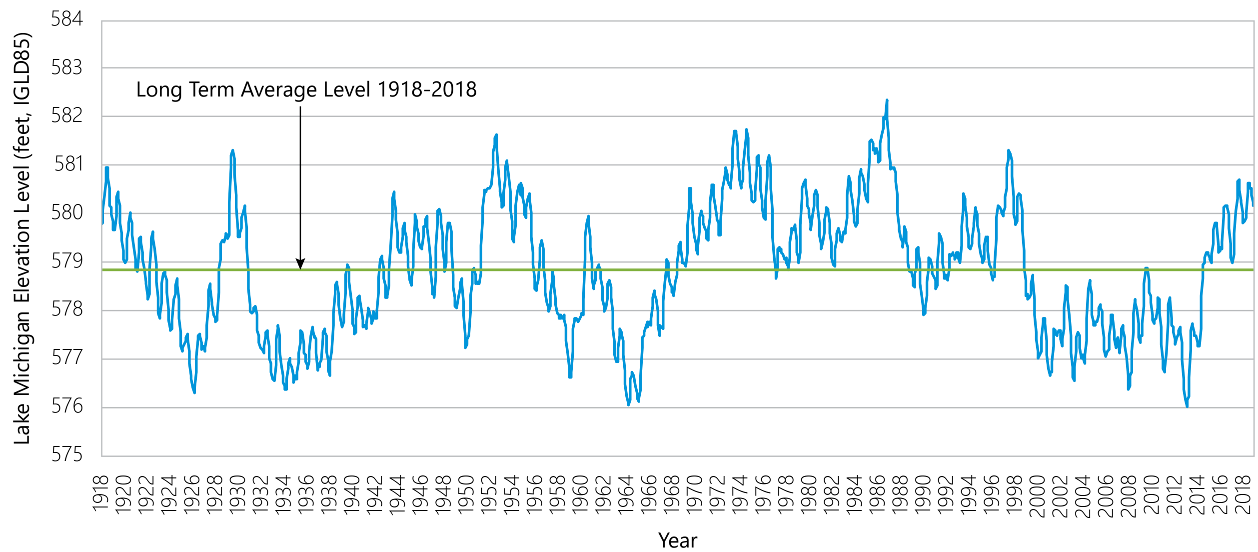
[a] *Only principal streams in each assessment area were surveyed and some reaches were not surveyed in their entirety. See Table 4.1 for length of streams that were surveyed in each assessment area.*

[b] *Commission staff used a more restrictive 75 foot minimum buffer width as part of this criteria rather than the 33 foot (10 meter) buffer width from stream edge as is used in the original index (see citation below for more details). Percent buffer vegetation is determined by the amount of land covered with relatively undisturbed vegetation (woodland, shrub, meadow, wetland) within 75 feet of each streambank. This includes buffered lands adjacent to all streams and ponds within the assessment area.*

[c] *A total habitat score could not be completed for these assessment areas due to a lack of data for some index criteria.*

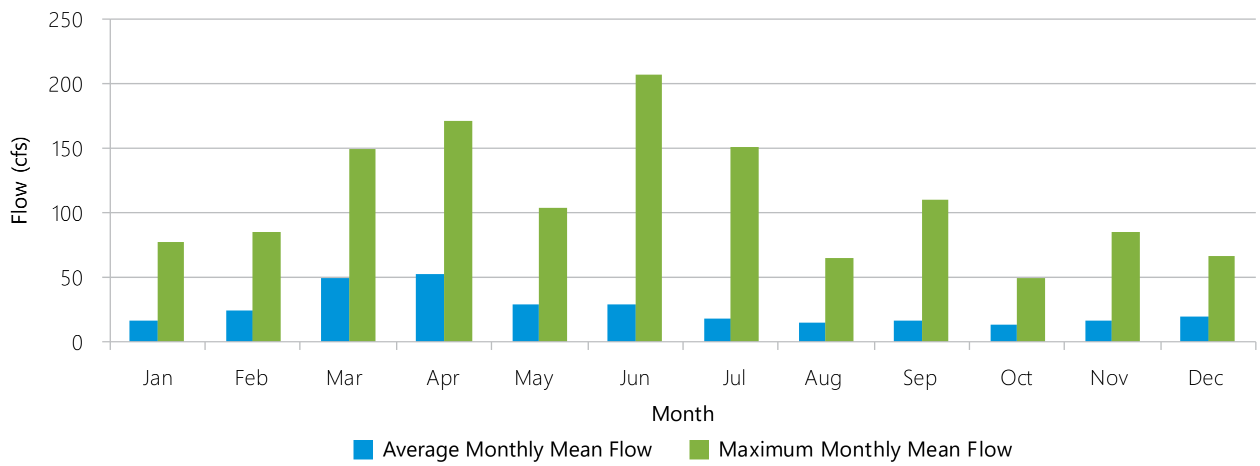
Source: Adapted from L. Wang, J. Lyons, and P. Kanehl, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams," North American Journal of Fisheries Management, *Volume 18, pages 775-785, 1998 and SEWRPC*

Figure 4.36
Lake Michigan Mean Monthly Water Levels: 1918-2018



Source: USACE Detroit District and SEWRPC

Figure 4.37
Average Monthly Mean and Maximum Monthly Mean Flow for Oak Creek at 15th Avenue: 1964-2017

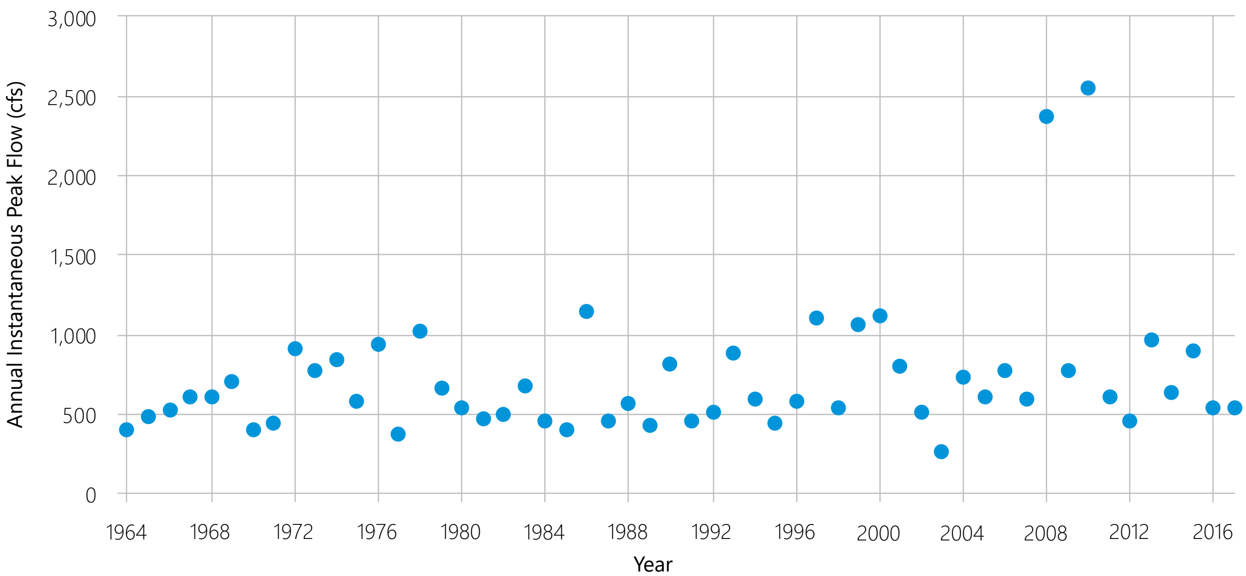


Source: U.S. Geological Survey and SEWRPC

Additional data for Station No. 04087204 include flow exceedance statistics computed by the USGS for the period of record. Based on the period of record, the Oak Creek mainstem at 15th Avenue has a 90 percent exceedance flow of 2 cfs, a 50 percent exceedance flow of 8 cfs, and a 10 percent exceedance flow of 52 cfs. Put another way, 10 percent of the recorded flows at that USGS gage from 1964 to 2016 were 2 cfs or less, 50 percent of the recorded flows were 8 cfs or less, and 90 percent of the recorded flows were 52 cfs or less. These flow values provide context for baseflow conditions on the mainstem of Oak Creek at 15th Avenue.

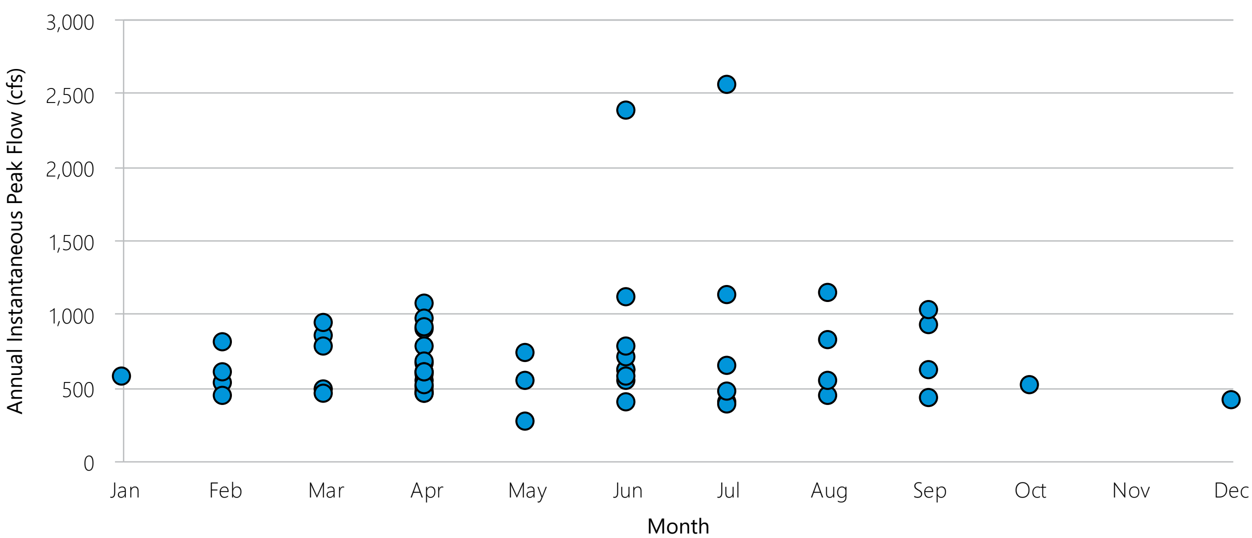
Annual instantaneous peak flows for USGS Gage Station No. 04087240 are summarized in Figures 4.38 and 4.39. These are the annual instantaneous maximum flows recorded at the gage during the 54 year period of record from water year 1964 through 2017. Annual peak flows at the Oak Creek gage were below 1,150 cfs with two exceptions. The exceptions were the peak flows for the June 2008 and July 2010 floods, which had maximum peaks of 2,370 cfs and 2,550 cfs, respectively. Figure 4.39 shows the 54 annual peak flows included in Figure 4.38 by the month in which they occurred. February through April

Figure 4.38
Annual Instantaneous Peak Flows for Oak Creek at 15th Avenue: Water Years 1964-2017



Source: U.S. Geological Survey and SEWRPC

Figure 4.39
Annual Peak Flows by Month for Oak Creek at 15th Avenue: Water Years 1964-2017

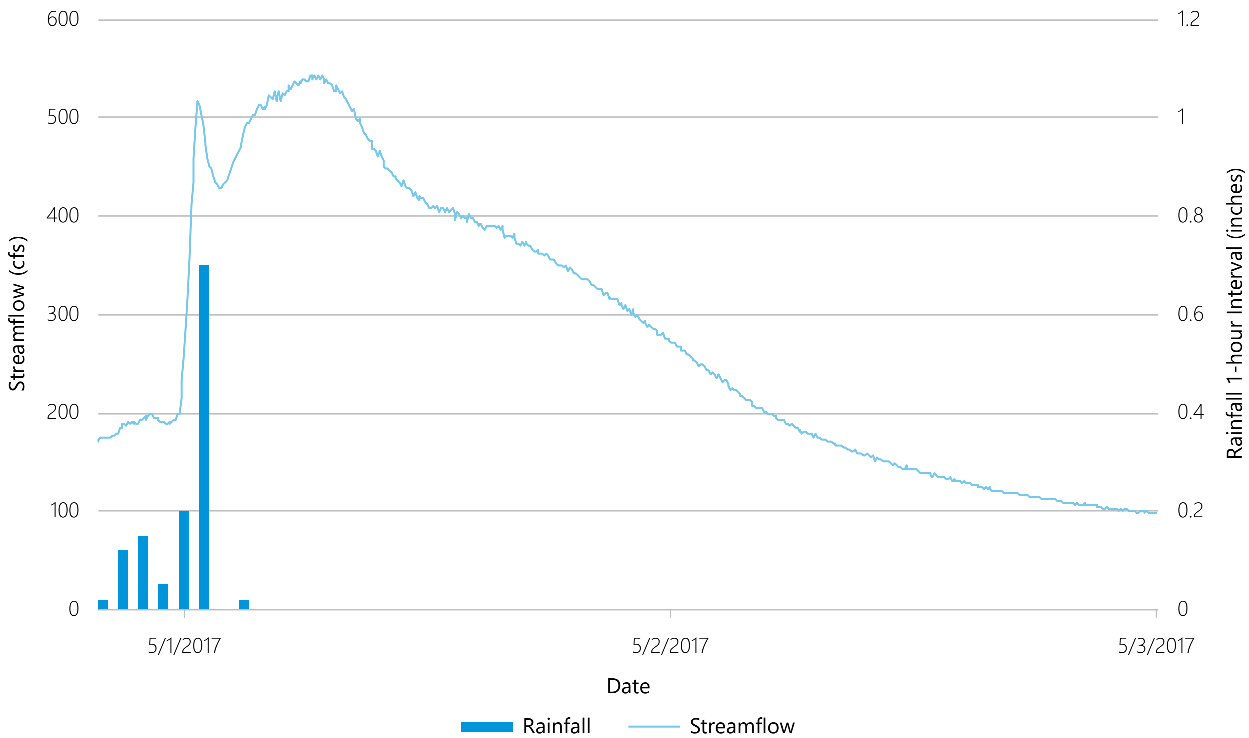


Source: U.S. Geological Survey and SEWRPC

accounted for 25 of the annual peaks observed, while May through July included 18 of the 54 annual peaks and the two largest peak flows. Minimal annual peak flows occurred in the months of October through January for the 54 year period of record.

An individual storm event is shown in Figure 4.40 to illustrate the typical storm response for the contributing drainage area to the 15th Avenue USGS gage location on Oak Creek. Included in the figure is the April 30, 2017 to May 2, 2017 storm event hydrograph for USGS Gage Station No. 04087240 as well as the corresponding hourly rainfall data from the Milwaukee Metropolitan Sewerage District (MMSD) rainfall gage located at the South Shore Water Reclamation Facility. This particular rainfall event is smaller than a 1-percent-annual-probability storm, but the watershed response is similar for larger rainfall events. As is shown in the figure, urban runoff utilizing storm sewers that discharge at or just upstream of 15th Avenue

Figure 4.40
Storm Event for Oak Creek at 15th Avenue: April 30, 2017 to May 2, 2017



Source: U.S. Geological Survey, Milwaukee Metropolitan Sewerage District, and SEWRPC

reach the stream almost immediately, producing the first peak flow (520 cfs). Then runoff from the rest of the watershed reaches the stream gage location, producing the second, later, and more gradual peak (540 cfs) followed by a corresponding gradual flow decline typical of a large contributing drainage area.

The Milwaukee County Flood Insurance Study (FIS), effective September 26, 2008, includes flood frequency information for Oak Creek at 15th Avenue. These discharges were determined using output from a Hydrologic Simulation Program – FORTRAN model with weather data from 1940 through 1997. The FIS discharges estimated for Oak Creek at 15th Avenue are shown in Table 4.13.

Seasonal Differences in Streamflow

Figure 4.41 shows the seasonal pattern of streamflow in Oak Creek at the stream gage at 15th Avenue over the period of record, October 1963 through December 2017. The average daily discharge data were disaggregated into months and the flow value for the 10th percentile, 25th percentile, 50th percentile (median), 75th percentile, and 90th percentile ranks were determined for each month.[168] The 50th percentile ranks indicate typical flow conditions at this gage and show a strong seasonal pattern. This pattern begins in January, when the flow in the stream is relatively low. From January through March, flow increases rapidly in response to snowmelt and spring rains. Peak flow typically occurs in March. Following this, flow decreases over late spring and summer. This decrease results from a number of factors, including the end of snowmelt, increases in evapotranspiration due to higher temperatures, and increased infiltration of precipitation due to thawed soil conditions. The lowest flows of the year usually occur in September for Oak Creek. Flow then increases relatively slowly over the fall and winter, reaching a second peak in December. The peak that occurs in December is typically much lower than the peak that occurs in March.

[168] *A percentile rank is the percentage of values which are lower than a given value. For example, the 10th percentile represents the upper boundary of the lowest 10 percent of the data. The interpretation of this statistic is that on 10 percent of the dates in this month during the period of record, average daily discharge at this gage was less than or equal to this value. Similarly, the 90th percentile represents the upper boundary of the lowest 90 percent of the data and is interpreted in a similar manner.*

The other percentile ranks shown in Figure 4.41 indicate how discharge at this site can vary from the typical pattern described in the last paragraph. The distance between the 10th and 90th percentile lines shows how variable discharge is during any month, with greater vertical distance between the two lines indicating more variability. Discharge at the Oak Creek gage at 15th Avenue is much more variable during late winter and spring than during the rest of the year.

Table 4.13
2008 Milwaukee County FIS Summary of Discharges

Annual Probability of Occurrence (percent)	Flow Oak Creek at 15th Avenue (cfs)
10.0	1,360
2.0	1,850
1.0	2,070
0.2	2,610

Source: Federal Emergency Management Agency and SEWRPC

The seasonal variations in discharge shown in Figure 4.41 can exert a strong influence on the loads of pollutants carried by the stream. The pollutant load is the total amount of pollutant that the stream carries past a point, such as a stream gage, over some time period. It is a function of both the concentration of the pollutant and the amount of streamflow. At a given concentration, higher streamflows result in higher pollutant loads. Similarly, at a given magnitude of flow, higher concentrations result in higher pollutant loads. The interaction between discharge and concentration can have complex effects on the magnitude of pollutant loads.

Flooding Evaluation

Flooding in the Oak Creek watershed may occur either via stream water levels rising above the banks, or by runoff from rainfall or snow melting events exceeding the capacity of the stormwater conveyance system to the stream. The discussion on flooding for the Oak Creek watershed has been subdivided accordingly into stream or stormwater flooding. Considerable work has been done regarding mitigating the impacts of stream flooding in the Oak Creek watershed, thus the discussion in this plan will be a brief summary of those efforts and documentation of extreme flooding impacts to roadway crossings. The stormwater flooding discussion will be targeted to areas of interest suggested by watershed stakeholders.

Stream Flooding

There have been numerous studies for mitigation of stream flooding on the Oak Creek mainstem and its tributaries. For reference the current regulatory FEMA floodplains are included in Map 3.4. A brief summary of each study is outlined below in chronological order.

1967 – A report was prepared for MMSD that recommended major channel modifications for much of the Oak Creek watershed stream system.[169] Many of the bridges, channel improvements, and storm drainage networks in the Oak Creek watershed today have been built based on the channel modifications recommended in this report. This has led to some storm sewer outfalls in the watershed that do not properly tie into the current stream bottom.

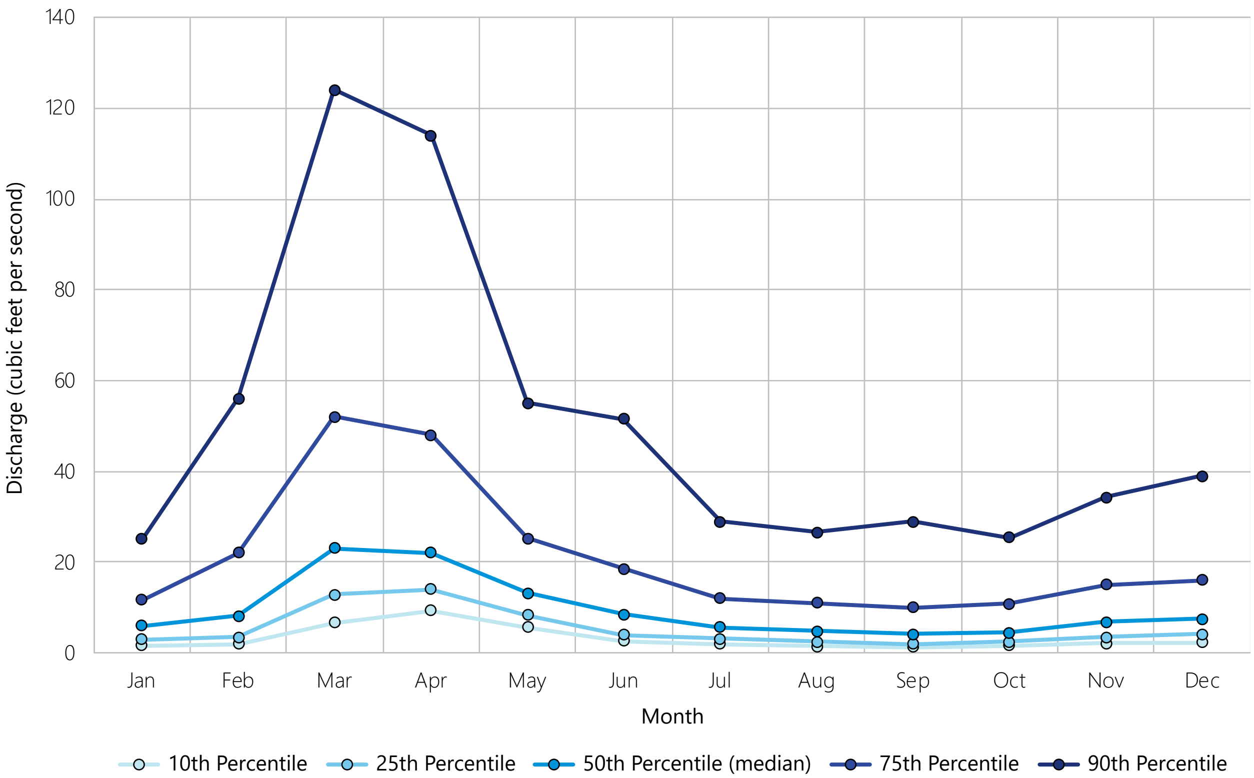
1986 – Commission staff completed a comprehensive plan for the Oak Creek watershed.[170] That plan included three main elements: a detailed land use and park and open space plan, a floodland management plan, and a water quality management plan. Recognizing the somewhat limited and scattered nature of structure flooding within the watershed, the floodland management plan had a general recommendation of addressing flooding through a combination of structure floodproofing, elevation, and acquisition and demolition. This report documented 22 structures in the Oak Creek regulatory floodplain.

In addition, the 1986 plan included a recommendation for limited channel deepening and shaping along two reaches, one along a 1.4-mile-long reach of the Oak Creek mainstem downstream of S. 27th Street, and the other for a one-mile-long reach of the North Branch of Oak Creek downstream from S. 13th Street. The purpose of this deepening was to accommodate existing storm sewer outfalls that had been built based on the future channel modification included in the 1967 study. A secondary benefit of the proposed channel deepening would be the establishment of a positive streambed gradient along these two channel reaches.

[169] Klug & Smith Company, *Report on Oak Creek Flood Survey on Entire Basin for the Metropolitan Sewerage Commission of the County of Milwaukee*, 1967.

[170] *SEWRPC Planning Report No. 36*, A Comprehensive Plan for the Oak Creek Watershed, *August 1986*.

Figure 4.41
Seasonal Percentiles of Stream Flow in Oak Creek at the USGS Gage at 15th Avenue (RM 2.8): 1963-2017



Source: U.S. Geological Survey and SEWRPC

1990 – The recommendations from the 1986 Oak Creek watershed plan were reiterated in this stormwater drainage and flood control system plan that SEWRPC prepared for MMSD.[171] This plan also included an explicit recommendation that any loss of floodwater storage resulting from the recommended channel deepening along the two stream reaches be compensated for so as to cause no increase to downstream flood flows and stages for the regulatory, or 1-percent-annual-probability, event.

The 1990 plan noted that the limited channel deepening and shaping along the recommended reaches of Oak Creek and the North Branch of Oak Creek would require significant compensatory storage volumes to offset the loss of floodplain storage and minimize an increase in peak flood flows downstream.

Subsequent to the 1990 plan the City of Oak Creek investigated the storm sewers discharging to the 1.4-mile-long reach of the Oak Creek mainstem downstream of S. 27th Street. That survey determined channel deepening and shaping would not be required for proper function of the storm sewers along that reach.

2000 – The MMSD completed a watercourse system management plan that addressed flood management within the Oak Creek watershed.[172] This work was also discussed in Section 2.3 of this plan. The 2000 plan, which was intended to serve as an update to the plan prepared by SEWRPC in 1990, considered three approaches for addressing flooding within the watershed. These included: 1) constructing facilities to reduce the height of peak flood elevations either by providing storage to

[171] *SEWRPC Community Assistance Planning Report No. 152,* A Stormwater Drainage and Flood Control System Plan for the Milwaukee Metropolitan Sewerage District*, December 1990.*

[172] Camp Dresser & McKee, *Oak Creek Phase 1 Watercourse System Management Plan, Prepared for the Milwaukee Metropolitan Sewerage District*, August 2000.

reduce flood discharges or through increasing the conveyance capacity of the waterway; 2) providing a protective barrier to prevent floods from damaging structures either through structure floodproofing or construction of levees and floodwalls; and 3) removing structures from the flood hazard area. The recommendation given in the report for flood risk reduction within the watershed was a combination of structure acquisition and demolition and floodproofing.

2019 – SEWRPC was authorized by MMSD to update the 2000 Phase 1 Oak Creek report and work began in 2010.[173] This effort was also discussed in Section 2.3 of this plan. The purpose of the study was to identify and categorize flooded structures located within the floodplain resulting from the 1-percent-annual-probability (100-year recurrence interval) storm event, update structural damage estimates, and develop costs related to structure floodproofing or acquisition based on floodplain mapping developed by SEWRPC in 2002. The study draft report was completed in 2011, and then put on hold pending MMSD contact with identified floodplain property owners as well as a District policy revision regarding floodproofing. The report initially documented 23 structures in the Oak Creek regulatory floodplain. In 2018 Short Elliot Hendrickson, Inc. (SEH) prepared a technical memorandum at the request of MMSD to address conceptual floodproofing designs for structures within the Oak Creek Watershed.[174] Three flooded structures remain in the regulatory Oak Creek floodplain as of 2019; one single family residential structure, one multi-family residential structure, and one commercial structure. Voluntary floodproofing or voluntary acquisition in collaboration with the local municipality and consistent with the MMSD Flood Risk Reduction policy is recommended for these three remaining structures.

As indicated by the studies summarized above, stream flooding impacts to insurable structures were scattered throughout the Oak Creek watershed. Thus, large flood mitigation projects were not warranted. Nevertheless, stream flooding does impact roadways, properties, and infrastructure in the watershed. Included on Map 4.16 are the locations where the regulatory FEMA flood profiles overtop roadways on Oak Creek, the North Branch of Oak Creek, and the Mitchell Field Drainage Ditch. Also indicated on this map is the frequency with which the roadway would be overtopped. The higher the flood event frequency, the more often this roadway would be overtopped by flood waters. Flood overtopping of roads is a concern for structure and roadway maintenance, safety, and emergency access.

For the three stream reaches included in Map 4.16, there are 11 roadway locations on the Oak Creek mainstem overtopped for the regulatory FEMA flood profile. The majority of these locations are located at the upstream end in the City of Franklin where the top of the roadway is lower relative to the stream. The North Branch of Oak Creek has four roadway locations that indicate impacts for roadway flooding. There is one location of roadway flooding on the Mitchell Field Drainage Ditch on a service road on MMIA property. This map is not comprehensive, as there may be additional locations where flood waters will overtop road crossings on tributaries to Oak Creek, the North Branch of Oak Creek, and Mitchell Field Drainage Ditch.

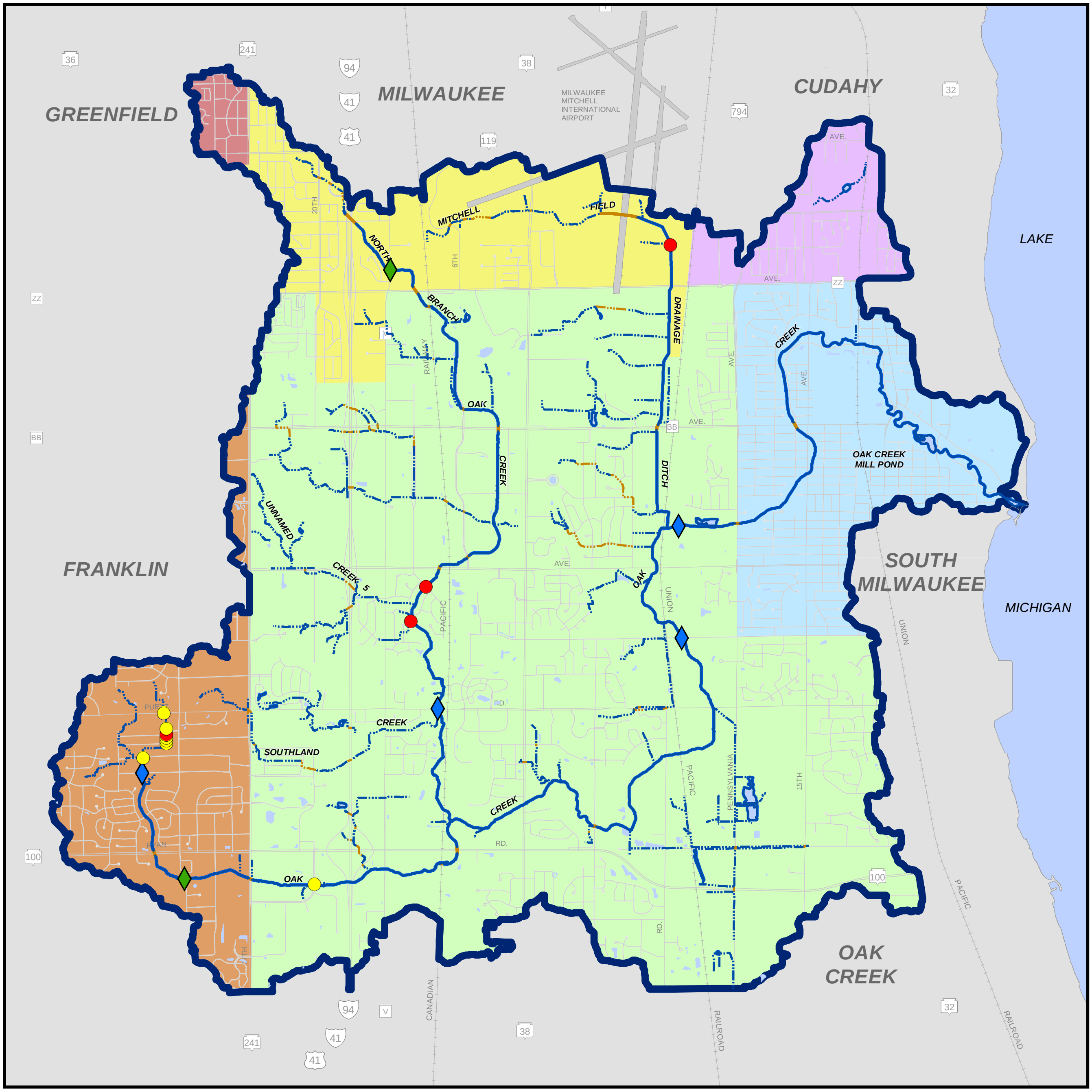
Locations of observed stream flooding were also provided by stakeholders through a project online survey, a stakeholder meeting in August 2016, and the Milwaukee County Hazard Mitigation Plan.[175] These creek related flood locations are summarized in Map 4.17 and Table 4.14. Nine additional creek related potential flooding locations are included. Major areas of stream flooding include the middle and lower Oak Creek subbasins in the Cities of Oak Creek and South Milwaukee. The stakeholder documentation of potential creek flooding locations is not all-inclusive, as there may be additional creek flooding locations within the Oak Creek watershed.

[173] *SEWRPC Memorandum Report No. 198,* Oak Creek Updated Phase 1 Watercourse Management Plan*, December 2011, Revised May 2019 (draft).*

[174] *Short Elliot Hendrickson Inc.,* Oak Creek Watershed Conceptual Floodproofing Designs*, Technical Memorandum to MMSD, June 22, 2018.*

[175] *Milwaukee County Office of Emergency Management*, Hazard Mitigation Plan, *2016-2021*.

Map 4.16
Riverine Flood Road Overtopping Locations



10-TO 500-YEAR EVENT OVERTOPPING
50-TO 500-YEAR EVENT OVERTOPPING
100-TO 500-YEAR EVENT OVERTOPPING
500-YEAR EVENT OVERTOPPING

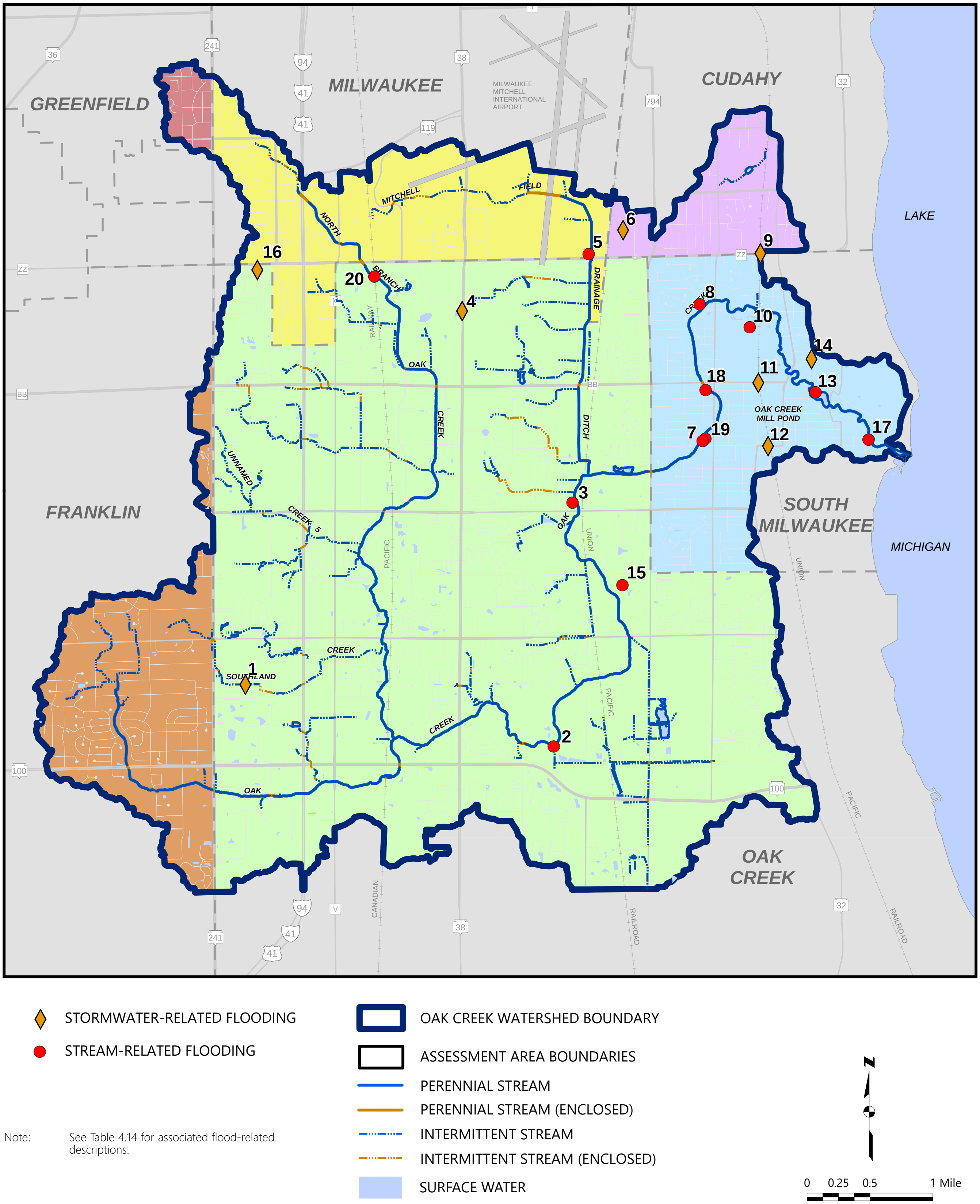
OAK CREEK WATERSHED BOUNDARY
PERENNIAL STREAM
PERENNIAL STREAM (ENCLOSED)
INTERMITTENT STREAM
INTERMITTENT STREAM (ENCLOSED)
SURFACE WATER

N

0 0.25 0.5 1 Miles

Source: Milwaukee County 2008 Flood Insurance Study and SEWRPC

Map 4.17
Areas of Flood Concern from Stakeholder Input



Note: See Table 4.14 for associated flood-related descriptions.

Source: Municipal Staff, Stakeholders, and SEWRPC

Table 4.14
Areas of Flood Concern from Stakeholder Input

Map ID[a]	Community	Subbasin	Description	Comment Made By
1	City of Oak Creek	North Branch	Stormwater flooding issues in this neighborhood along Southland Creek.	City Staff
2	City of Oak Creek	Middle Oak Creek	Culvert for drainage ditch is damaged and causes overflow in upstream reaches.	Stakeholder
3	City of Oak Creek	Middle Oak Creek	Stream flooding impacts adjacent properties at Drexel Avenue.	Stakeholder
4	City of Oak Creek	MFDD	Stormwater pond adjacent to Howell Avenue (west side of road) floods during high rain events.	Stakeholder
5	City of Milwaukee	MFDD	Stream flooding issues due to under-sized culvert under College Avenue.	City Staff
6	City of Cudahy	MFDD	Stormwater flooding issues in Industrial Park parking lots due to local issues and downstream railroad culverts.[b]	City Staff
7	City of South Milwaukee	Lower Oak Creek	Stream flooding in floodplain area adjacent to creek during extreme events.	Stakeholder
8	City of South Milwaukee	Lower Oak Creek	Stream flooding at High School baseball field during extreme events.	City Staff
9	City of South Milwaukee	Lower Oak Creek	Stormwater flooding under railroad tracks at College Avenue due to inadequate inlet capacity at street level.	Stakeholder
10	City of South Milwaukee	Lower Oak Creek	Stream and stormwater flooding issues at High School football field during extreme events.	City Staff
11	City of South Milwaukee	Lower Oak Creek	Stormwater flooding along Rawson Avenue at the railroad tracks during extreme events.	Stakeholder
12	City of South Milwaukee	Lower Oak Creek	Stormwater flooding occurs at Marquette Avenue and UP railroad overpass during heavy rain events.	City staff
13	City of South Milwaukee	Lower Oak Creek	Stream flooding at Parkway crossing floods adjacent bike path during extreme events.	Stakeholder
14	City of South Milwaukee	Lower Oak Creek	Stormwater ponding issues at the school fields on Pine Street due to site drainage issues.	Milwaukee County Staff
15	City of Oak Creek	Middle Oak Creek	Stream flooding impacts adjacent properties and East Forest Hill Avenue.	Stakeholder
16	City of Oak Creek	North Branch	Stormwater flooding issues at Oak Creek Estates south of College Avenue (mobile home park).	City Staff
17	City of South Milwaukee	Lower Oak Creek	Sanitary lift station along Oak Creek Parkway is vulnerable to stream flooding.	City Staff
18	City of South Milwaukee	Lower Oak Creek	Sanitary lift station along Oak Creek Parkway is vulnerable to stream flooding.	City Staff
19	City of South Milwaukee	Lower Oak Creek	Emergency sanitary relief station along Oak Creek Parkway is vulnerable to stream flooding.	City Staff
20	City of Oak Creek	North Branch	Stream water backups at railroad culvert causing flooding concerns during extreme events.	Milwaukee County Staff

[a] *See Map 4.17*

[b] *In 2020 two new 48-inch diameter metal culverts were installed under the railroad to the west of the Industrial Park to remove the stormwater flooding concern.*

Source: SEWRPC

Stormwater Flooding

Stormwater flooding in the Oak Creek watershed typically occurs when runoff from rainfall or snow melting events exceeds the capacity of the stormwater conveyance system to the stream. Stormwater management plans have been completed by the Cities of Franklin and Oak Creek.[176] These plans typically include an analysis of the existing stormwater sewer system for each community, and where there are maintenance concerns or capacity issues. Storm sewer systems are designed to convey the smaller rainfall events, typically the 20-percent-annual-probability (5-year recurrence) to the 10-percent-annual-probability (10-year recurrence) storms. Storm events that are larger than what the system has been designed for will cause flooding as the runoff cannot fit in the storm sewer.

The locations of observed stormwater flooding were also provided by stakeholders through the project online survey, a stakeholder meeting in August 2016, and the Milwaukee County Hazard Mitigation Plan. These stormwater related flood locations are summarized in Map 4.17 and Table 4.14. Eight stormwater related potential flooding locations are documented. The locations of stormwater flooding are somewhat clustered in the more highly urbanized areas of the Cities of Cudahy and South Milwaukee, although there are additional potential stormwater flooding locations in the watershed outside of these communities. This documentation is not all-encompassing, as there may be additional stormwater flooding locations within the watershed.

Oak Creek Mill Pond and Dam

Introduction

The Mill Pond dam is located on the Oak Creek mainstem within the Milwaukee County park system in the City of South Milwaukee. The dam is approximately 0.8 miles upstream of the Creek outlet to Lake Michigan (see Map 4.18). The current dam configuration and upstream impoundment, known as the Mill Pond, were constructed in the mid-1930s by the Works Progress Administration (WPA). As of 2015, the Mill Pond had a water surface area of about five acres, a water depth of one to two feet, and a water storage volume below the top of the dam of approximately 3.5 acre-feet.

History

There is a long history of dam construction in the Oak Creek mainstem near its confluence with Lake Michigan. A dam was built by an early settler of the area named John Fowle approximately 0.1 mile upstream from the stream mouth in 1840 to power a sawmill and a gristmill to grind corn, wheat, and barley.[177] Elihu Higgens also built a sawmill on Oak Creek around this same time, approximately one mile west (upstream) of Mr. Fowle's location. In the spring of 1852 both mills were flooded out and abandoned. Shortly after the 1852 floods, a new grist mill was erected at Mr. Higgens' site and a new sawmill was constructed at Mr. Fowle's location further downstream. This sawmill was operated by the family of Mr. Fowle until 1867, when it was sold to Charles Ahrens. No additional records could be found regarding dams in the lower Oak Creek mainstem for the period 1867 to 1930.

In the mid-1930s a limestone spillway dam was built by the WPA in its current form and location, approximately 0.8 miles upstream from Lake Michigan. The original 1840 granite millstones created by Mr. Fowle and William Sivyer can still be seen on either side of the dam and are labeled with a commemorative plaque.[178] On November 10, 2003, the Oak Creek (Mill Pond) dam was declared a Milwaukee County Landmark by the Milwaukee County Landmarks Committee.

The Mill Pond has provided many forms of recreation for the surrounding community. It was used for rowboat activities until the early 1960s and for ice skating, as seen in Figure 4.42. There is also a historic warming house on the southeastern shore of the Mill Pond. Currently the accumulated sediment in the pond, to

[176] *While there are no known plans for the Cities of Cudahy, Greenfield, Milwaukee, or South Milwaukee to prepare systemwide stormwater management plans, the development of localized plans can be expected as the need arises. The cities do require that a stormwater management plan be prepared for all new development or redevelopment per MMSD's Chapter 13 Rules.*

[177] *J. A. Watrous (editor),* Memoirs of Milwaukee County, Volume 1, *Western Historical Association, Madison, Wisconsin, 1909.*

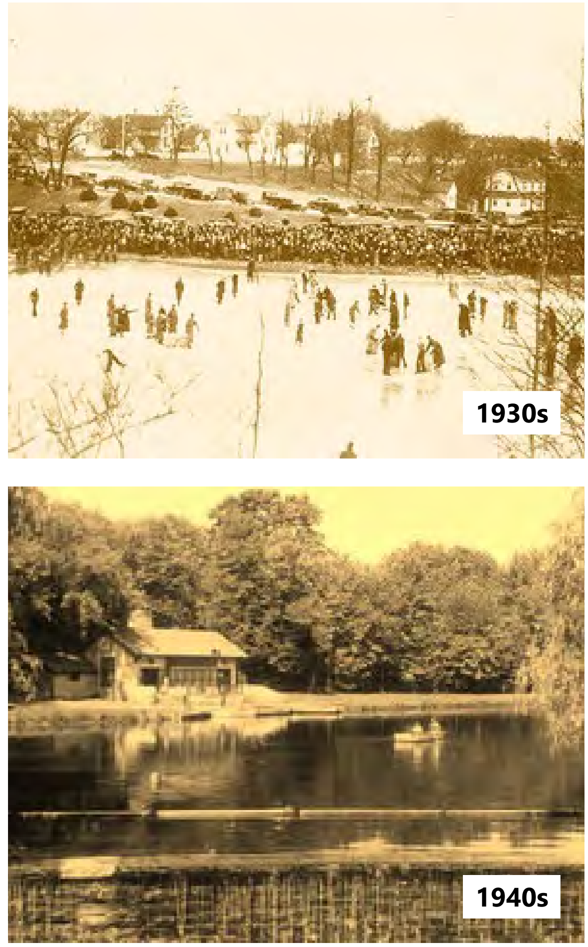
[178] "History," *Friends of the Mill Pond and Oak Creek Watercourse, Inc., smfomp.org.*

Map 4.18
Oak Creek Mill Pond and Dam: Spring 2015

Source: SEWRPC

be discussed in greater detail in a subsequent section, inhibits activities enjoyed by the community in the past, but community groups have expressed interest in seeing the pond restored so that these recreational activities can resume. Today, due to sediment accumulations, a long peninsula has formed in the pond's northwest corner near the inlet. This peninsula extends to the center of the pond. An island has also formed in the southeast corner near the dam (see Map 4.18).

Figure 4.42
Historic Photos of the Oak Creek Mill Pond



Source: Friends of the Mill Pond & Oak Creek Watercourse, Inc.

Dam Design Details

The Mill Pond dam abutment walls and arch spillway are made of concrete and are covered with dolomite stone masonry. The dam has a hydraulic height (water fall) of 14 feet and is 62 feet wide, with a 42 foot wide main spillway. The original 1932 plans for the Mill Pond dam are included in Figure I.1 in Appendix I, and photos of the dam taken after construction and today are shown in Figure 4.43. On the southeast bank, the dam structure contains a 36-inch drain pipe with a sluice gate that was intended to lower water levels in the impoundment when necessary for maintenance. The sluice gate is currently inoperable due to clogging from years of sediment accumulation. A 1938 plan for the sluice gate and a proposed 1989 design for an intake grate are included as Figures I.2 and I.3 respectively in Appendix I. Records could not be found to determine if the sluice gate intake grate was installed in the Mill Pond dam inlet.

Past Dam Inspections and Repairs

The dam was inspected by WDNR staff in 2012. Staff noted that it would be necessary to remove trees and brush from the sides of the spillway as well as immediately downstream, and to repair the inoperable sluice gate. It was also recommended that an engineer be hired to investigate the deteriorating masonry on the dam. These factors earned the dam an inspection Sufficiency Rating of "Conditionally Fair." The inspection report and follow up correspondence between the WDNR and Milwaukee County are included in Figure I.4 in Appendix I.

On December 4, 2013, AECOM staff performed an inspection of the dam masonry. The consultant noted that there was some deterioration and missing stones, but that the stone masonry was a non-structural component of the dam and that overall the dam is in good structural condition. AECOM recommended that the missing and weathered stones be replaced within the next ten years (Figure I.5 in Appendix I).

In 2015 preliminary plans were developed by AECOM for Milwaukee County to repair the Mill Dam sluice gate (Figure I.6 in Appendix I). The proposed repairs include dredging around the inlet of the intake pipe, clearing the intake pipe of all sediment and debris, and dewatering around this pipe so work can be done on the control structure. The major repairs would involve installing a new 4-foot by 6-foot control structure and lift gate just downstream of the existing control structure. A section of the existing 36-inch diameter corrugated metal pipe between the existing and new control structure would be removed and replaced with a 30-inch diameter reinforced concrete pipe. The existing inlet pipe, dam control structure (with the exception of the existing control gate), and outlet pipe would all remain. The 2015 engineer's estimate of construction cost for the sluice gate repair was approximately $200,000. An operations and maintenance plan would be developed in the future to maintain the functionality of the gate. The WDNR has extended the deadline for submittal of the final plans for the sluice gate repair to September 15, 2021.

Dam Hazard Rating

The Mill Pond dam has been classified as a small dam by the WDNR. As a small dam, the Mill Pond dam does not need to meet the spillway and inspection requirements of Wisconsin Administrative Code NR 333.[179] Upon review, there is no development other than open space use downstream of the Mill Pond dam and a failure of the dam should not cause loss of life.

Mill Pond Design Details

The Mill Pond was created in the mid-1930s, and a photo during construction is included as Figure 4.44. Plans for the proposed pond contours along with the original 1930 topography of the area are shown in Figure 4.45. At that time, considerable excavation was proposed in the southeast lobe of the pond to access the dam spillway. The Mill Pond was designed to be approximately six feet deep, with a maximum depth of 10 feet in the area near the dam. The original alignment of the stream centerline for Oak Creek at the pond location is shown in blue on Figure 4.45. This alignment matches well with portions of the current stream centerline included on Map 4.18.

Past Mill Pond Maintenance

A review of Milwaukee County Parks records found that the Mill Pond has been at least partially dredged in the late 1970s and then again in 1990. The work in 1990 included as much as four to five feet of depth of sediment removal from portions of the Mill Pond. Approximately 24,000 cubic yards (CY) were included in the engineer's planned estimate for the 1990 dredging effort, but it is unclear how much sediment volume was actually removed from the Mill Pond at that time.

Figure 4.43
Photos of the Oak Creek Mill Pond Dam

Source: Friends of the Mill Pond & Oak Creek Watercourse, Inc. and SEWRPC

The Mill Pond warming house has also recently been renovated by the Friends of the Mill Pond and Oak Creek Watercourse, Inc. in collaboration with Milwaukee County Parks. The improvements occurred between 2007 and 2014 and included a new roof and gutters, new exterior doors, chimney tuckpointing, electrical upgrades, and aesthetic improvements (see Figure 4.46).

Sediment in the Pond

Sediment accumulation in the Mill Pond has occurred due to suspended solids in the flow of Oak Creek dropping out with slower flow conditions at the pond. Sources for the suspended solids may include stormwater runoff, streambank and streambed erosion, and sediment deposited in floodplain areas adjacent to streams in the Oak Creek watershed. Sediment accumulation in the Mill Pond has decreased its storage capacity over time, which has reduced the recreational opportunities such as boating and ice skating (see Figure 4.42).

The WDNR collected bathymetric data of the Mill Pond in May 1970 in order to measure sedimentation; a map summarizing that investigation is included in Figure 4.47. At that time the Mill Pond was three feet to five feet deep, with a lone spot eight feet deep in the northeast corner of the pond.

[179] Wisconsin Administrative Code, *Chapter Natural Resources 333, Dam Design and Construction, April 2005*.

As part of its assessment of the Mill Pond, the City of Racine Public Health Department estimated the sedimentation rate in the pond over the period 1970 to 2015.[180] New bathymetric data was collected in order to calculate an approximate water volume of the pond in 2015. In 2015 the Mill Pond was approximately one to two feet deep. The study concluded that the pond's water volume decreased from roughly 23.5 ac-ft in 1970 to 3 ac-ft in 2015. This translates to approximately 32,900 CY of sediment accumulation over the 45-year period. The report calculated a sedimentation rate of about 730 CY per year between 2015 and 1970. However, it should be noted that, this analysis did not take into account the pond dredging that occurred in the late 1970s or 1990.

Figure 4.44
Construction of the Oak Creek Mill Pond Facing West Just North of the Dam (1930s)

Source: Friends of the Mill Pond & Oak Creek Watercourse, Inc.

Commission staff calculated the sediment accumulation in the Mill Pond volume between 1930 and 2015 based on bathymetry contours from the 1930 construction plans (see Figure 4.45), the 2015 bathymetry data gathered by the City of Racine Public Health Department,[181] and the Milwaukee County 2015 one foot contours. The sediment calculation below the pond water surface was based on 16 cross sections across the pond, while the sediment accumulation above the pond water surface was based on 11 cross sections (see Figure 4.48). The change in sediment volume between 1930 and 2015 was calculated using the average end-area method for the appropriate cross sections. Commission staff estimate that the Mill Pond accumulated sediment volume was approximately 37,700 CY between 1930 and 2015. When taking into account a typical sediment swell factor of 25 percent, it can be expected that approximately 47,100 CY of sediment would need to be dredged and hauled away to restore the pond to its original 1930 configuration. This volume is equivalent to approximately 4,000 dump truck loads of dredged material.

Figure 4.49 shows a comparison of historical aerial photographs of the Mill Pond area for 1980, 1990, 2005, and 2010. All of the aerial photos appear to have been taken in spring, which may have coincided with high water conditions at the Mill Pond. The year 1980 photo was taken after the late 1970s dredging and shows the absence of a peninsula near the inlet to the pond and island in the southeastern portion of the Mill Pond. The year 1990 photo indicates sediment starting to accumulate in the pond at the inlet and near the pond island (this island was part of the original plans for the pond). It is unclear if this photo was taken before or after the 1990 dredging effort. Sediment continued to drop out in the pond by the year 2005 photo, with the peninsula at the inlet connecting to the eastern portion of the pond island. The year 2010 aerial photo is starting to show the formation of the southeastern island near the Mill Pond dam. The 2015 aerial photo, which is the most recent, shows a larger sediment island by the dam (see Map 4.18).

4.4 SURFACE WATER QUALITY

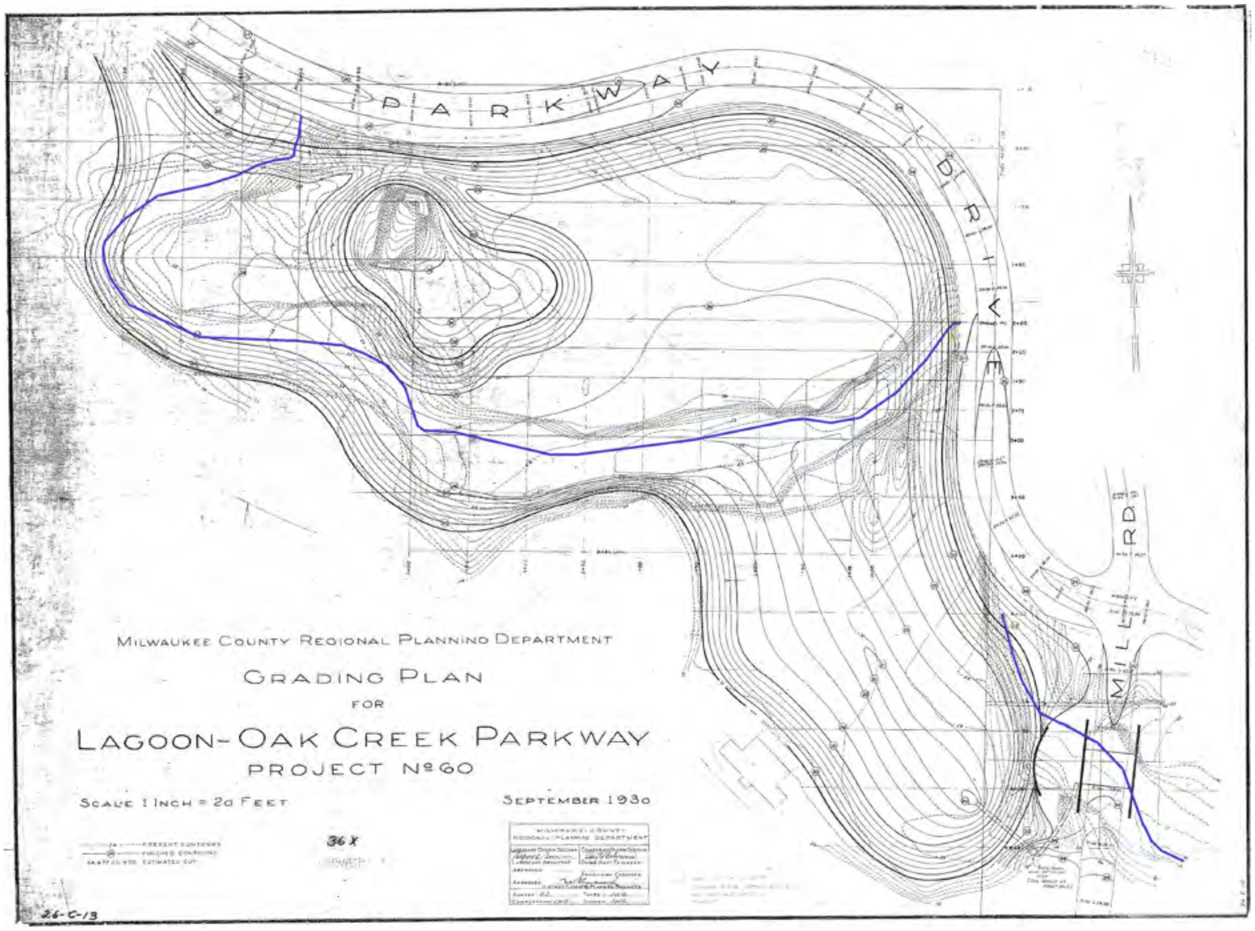
The term surface water quality refers to the physical, chemical, and biological characteristics of surface water. Water quality is determined both by the natural environment and by human activities. The uses that can be made of surface water resources are significantly affected by its quality and each potential use requires a certain level of water quality. Similarly, whether water quality in a waterbody is "good" or "bad" depends in part upon the uses or activities that the community desires the waterbody to support.

Clean water is vital to the health of individuals, the welfare of communities, and the strength of the economy. At any point within a watershed, having clean water upstream is essential to having healthy communities downstream. The health of waterbodies depends upon the tributaries and wetlands in which they begin. These waterbodies provide many benefits to communities including conveying and storing floodwaters, assimilating and filtering pollutants, and providing habitat for fish and wildlife.

[180] *L. Turner, A. Koski, and J. Kinzelman*, An Assessment of the Mill Pond Dam Impoundment – Oak Creek Watershed, *City of Racine Public Health Department Laboratory, January 2017.*

[181] *Ibid.*

Figure 4.45
1930 Grading Plan Showing the Original and Proposed Contours for the Oak Creek Mill Pond



Source: Milwaukee County and SEWRPC

This section examines the existing state of water quality in the Oak Creek watershed relative to those water quality constituents that impact the focus areas of this watershed restoration plan. Because the condition of the biota and sediment within waterbodies reflects, affects, and is affected by water quality conditions, this section also examines the condition of sediment and aquatic biota within the Oak Creek watershed.

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 (CWA) 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 prevent 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," NR 105, "Surface Water Quality Criteria and Secondary Values for Toxic Substances," and NR 207, "Water Quality Antidegradation and Antibacksliding," of the *Wisconsin Administrative Code*.

Designated Uses and Impairments

The designated uses of a waterbody are a statement of the types of activities the waterbody should support—regardless of whether they are currently being attained. These uses establish water quality goals for the waterbody and determine the water quality criteria needed to protect the uses. In Wisconsin, waterbodies are assigned four uses: fish and aquatic life, recreation, public health and welfare, and wildlife. The fish and aquatic life use is divided into several categories:

- Coldwater community
- Warmwater sportfish community
- Warmwater forage fish community
- Limited forage fish community
- Limited aquatic life community

Figure 4.46
Oak Creek Mill Pond Warming House

Source: SEWRPC

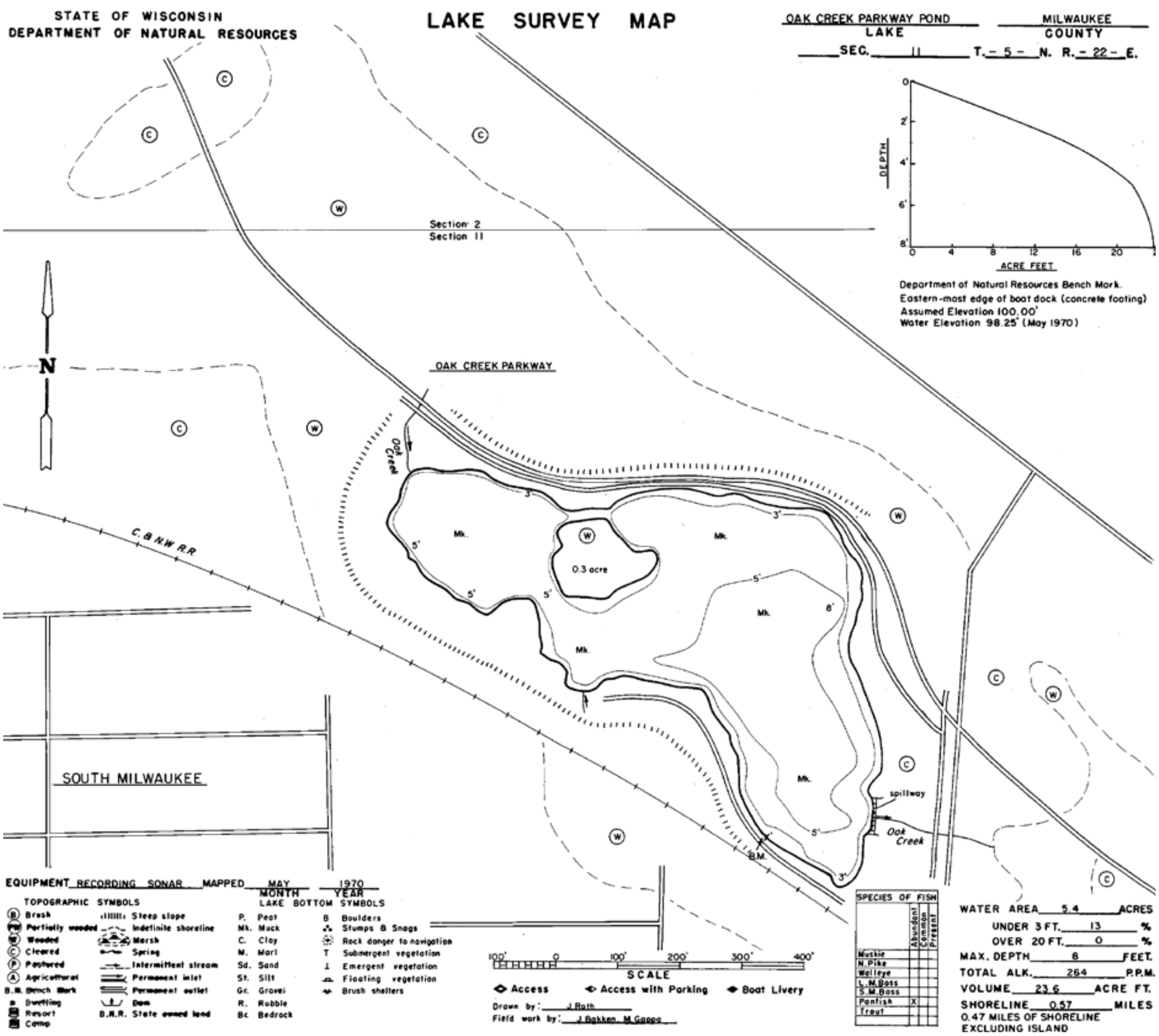
Coldwater communities include surface waters capable of supporting a community of coldwater fish and other aquatic organisms or serving as a spawning area for coldwater fish species. Warmwater sportfish waters include surface waters capable of supporting a community of warmwater sport fish or serving as a spawning area for warmwater sport fish. Warmwater forage fish waters include those capable of supporting an abundant diverse community of forage fish and other aquatic organisms. Because identical water quality criteria apply to them, the warmwater sportfish and warmwater forage fish categories are sometimes referred to as "warmwater fish and aquatic life (FAL)." Limited forage fish waters include surface waters of limited capacity and naturally poor water quality or habitat. These waters are capable of supporting only a limited community of forage fish and other aquatic organisms. Limited aquatic life waters include surface waters of severely limited capacity and naturally poor water quality or habitat. These waters are capable of supporting only a limited community of aquatic organisms. It is important to note that establishment of a stream water use objective other than coldwater or warmwater fish and aquatic life is not necessarily an indication of reduced water quality, since such streams may be limited by flow or size, but may still be performing well relative to other functions.

As part of an anti-degradation policy to prevent the lowering of existing water quality, the WDNR has classified some waters of the State as outstanding or exceptional resource waters. These waters, listed in Sections NR 102.10 and NR 102.11 of the *Wisconsin Administrative Code*, are deemed to have significant value as fisheries, hydrologically or geographically unique features, outstanding recreational opportunities, and unique environmental settings.

The water use objectives for fish and aquatic life for streams in the Oak Creek watershed are shown on Map 4.19. All of the stream reaches within the watershed are classified as warmwater fish and aquatic life communities and full recreational use. There are no designated coldwater communities, or outstanding or exceptional resource waters within the watershed.

The designated uses shown on Map 4.19 are regulatory designations. They serve to define the water quality criteria that apply to these waters and as the basis for determining whether the level of water quality in them meets the requirements set forth under the CWA and Wisconsin law. For management purposes, agencies such as the WDNR may also use other classification systems. These systems may be based on factors such as water temperature, stream discharge, stream depth, or stream width, and may provide useful information about water quality and biological conditions within waterbodies. While they may serve as a basis for evaluating such conditions for management purposes, until they are reflected in the water quality standards promulgated by the State, they lack the regulatory significance of the designated uses shown on Map 4.19.

Figure 4.47
1970 Lake Survey Map of the Oak Creek Mill Pond



Source: Wisconsin Department of Natural Resources

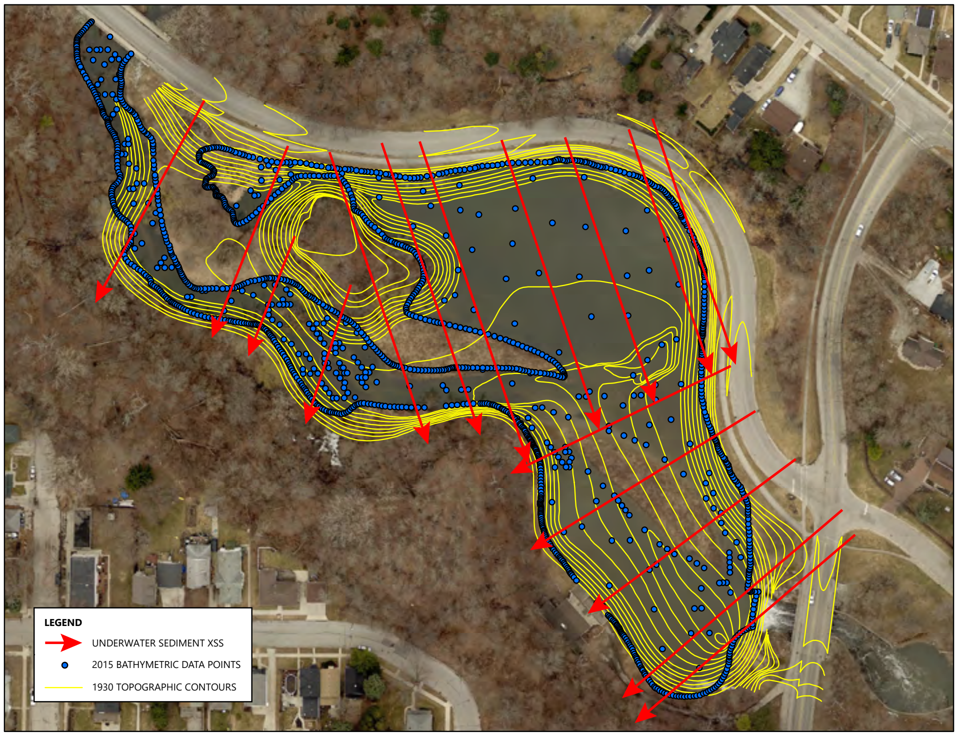
Under the CWA, waterbodies that are not achieving their designated uses are considered impaired waters. Section 303(d) of the CWA requires that states periodically submit a list of impaired waters to the U.S. Environmental Protection Agency (USEPA) for approval. The State of Wisconsin most recently submitted this list in 2020 and the USEPA approved it in 2020. Table 4.15 and Map 4.20 indicate the stream reaches in the Oak Creek watershed that were listed as impaired as of 2020.[182]

The entire mainstem of Oak Creek is currently listed as impaired with three impairments. The Creek is listed as impaired due to chronic aquatic toxicity related to an unknown pollutant. It is also listed as impaired due to the presence of a degraded biological community related to high concentrations of total phosphorus. Finally, the Creek is listed as impaired due to chronic and acute aquatic toxicity related to high concentrations of chloride. Each of these impairments apply to the entire length of the mainstem of Oak Creek.

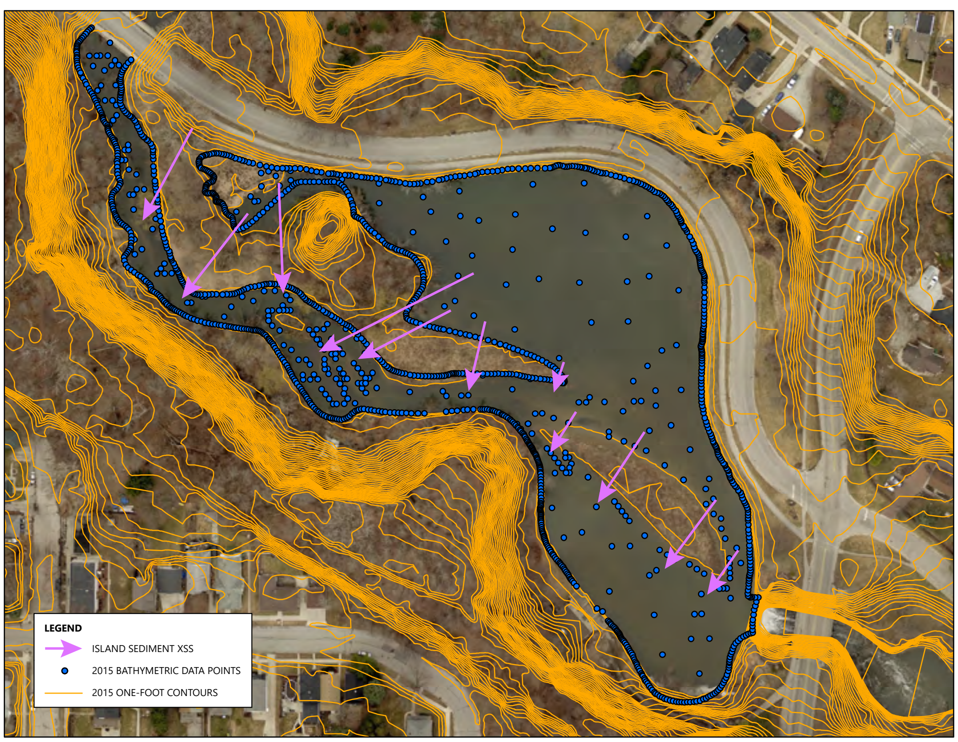
[182] *It should be noted that the absence of a stream or a particular impairment for a stream from the impaired waters list does not necessarily mean that conditions in the stream meet all applicable water quality standards. In some instances, this absence reflects a lack of adequate or sufficient data to determine whether impairments are present.*

Figure 4.48
Sediment Analysis for the Oak Creek Mill Pond

Below Water Cross Sections

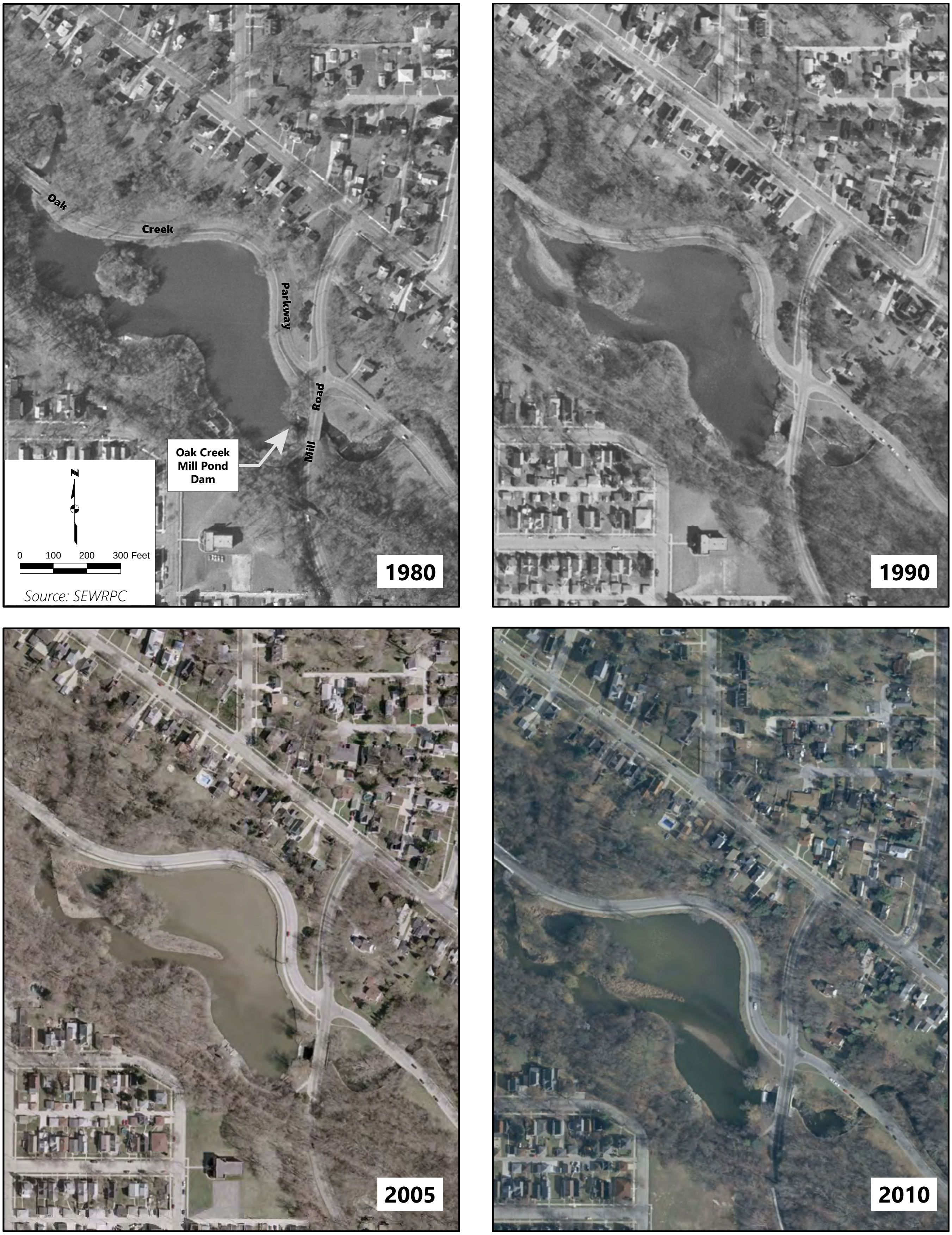


Above Water Cross Sections

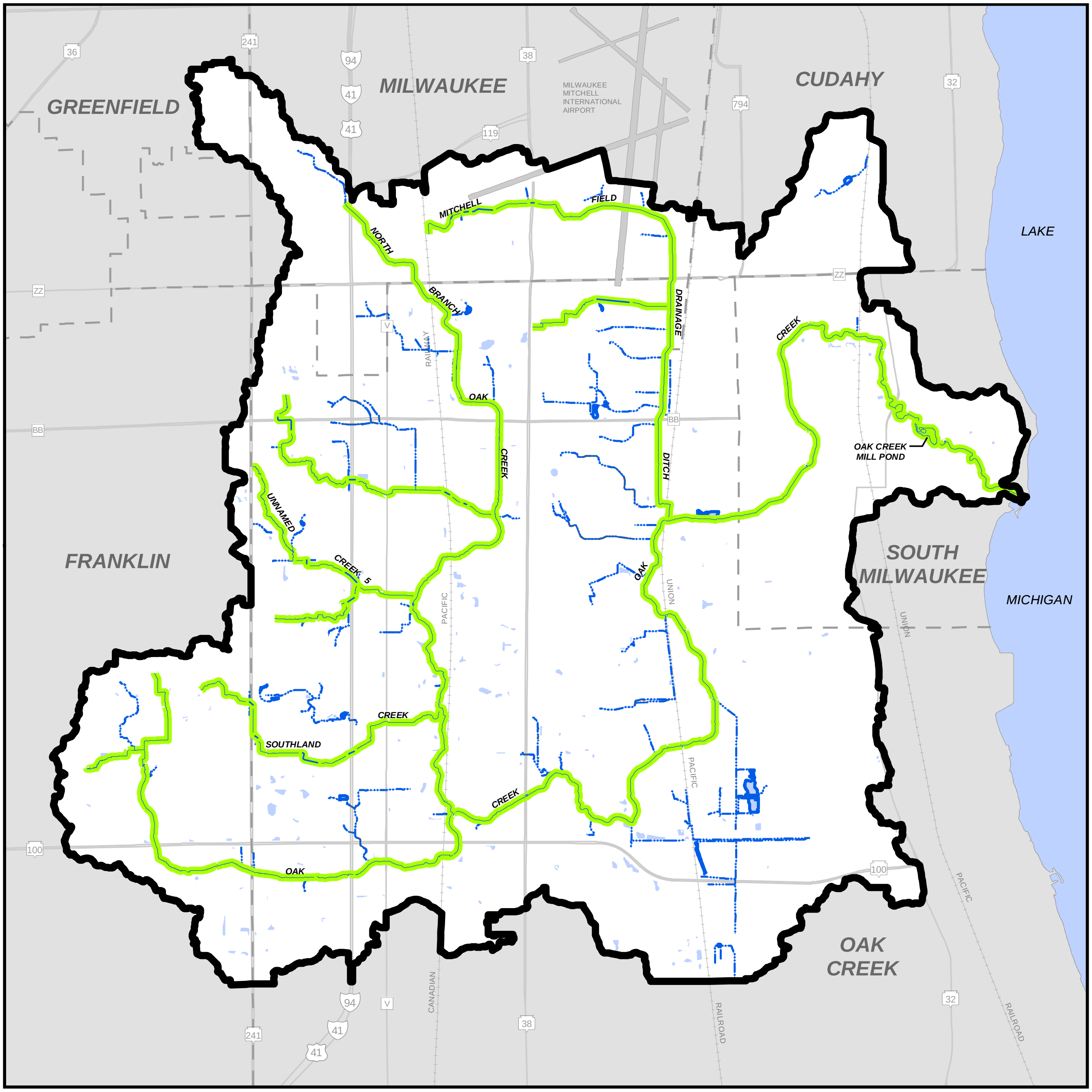


Source: City of Racine Health Department, Milwaukee County, and SEWRPC

Figure 4.49
Oak Creek Mill Pond Comparison: 1980, 1990, 2005, and 2010



Map 4.19
Water Use Objectives for Streams Within the Oak Creek Watershed: 2017



OAK CREEK WATERSHED BOUNDARY

OAK CREEK SUBWATERSHED BOUNDARIES

PERENNIAL STREAM

INTERMITTENT STREAM

WARMWATER FISH AND AQUATIC LIFE (FAL)

SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: SEWRPC

Table 4.15
Impaired Waters Within the Oak Creek Watershed: 2020[a]

Stream	Extent (river mile)[b]	Impairment	Contributing Pollutants	Listing Date
Oak Creek	0.00-13.32	Chronic aquatic toxicity	Unknown pollutant	1998
		Degraded biological community	Total phosphorus	2012
		Chronic aquatic toxicity/acute aquatic toxicity	Chloride	2014
North Branch of Oak Creek	0.0-5.7	Chronic aquatic toxicity/acute aquatic toxicity	Chloride	2018
Mitchell Field Drainage Ditch	0.0-2.3	Chronic aquatic toxicity/acute aquatic toxicity	Chloride	2020

[a] *As listed on the State of Wisconsin's impaired waters list pursuant to Section 303(d) of the Federal Clean Water Act.*

[b] *For Oak Creek, river mile is the distance upstream from the confluence with Lake Michigan. For tributary streams, river mile is the distance upstream from the confluence with the waterbody into which the tributary flows.*

Source: Wisconsin Department of Natural Resources

One tributary stream is listed as impaired on the 2018 list and another is proposed for listing as impaired on the 2020 list. The North Branch of Oak Creek is listed as impaired due to the presence of chronic and acute aquatic toxicity related to high concentrations of chloride. The WDNR has proposed adding a 2.3-mile section of the Mitchell Field Drainage Ditch to the 2020 impaired waters list due to the presence of chronic and acute aquatic toxicity related to high concentrations of chloride.

Surface Water Quality Criteria

Water quality standards also specify certain criteria that must be met to ensure that the designated uses of waterbodies are supported. These water quality criteria are statements of the physical, chemical, and biological characteristics of the water that must be maintained if the water is to be suitable for the designated uses. Some criteria are limits or ranges of chemical concentrations that are not to be exceeded. Others are narrative standards that apply to all waters.

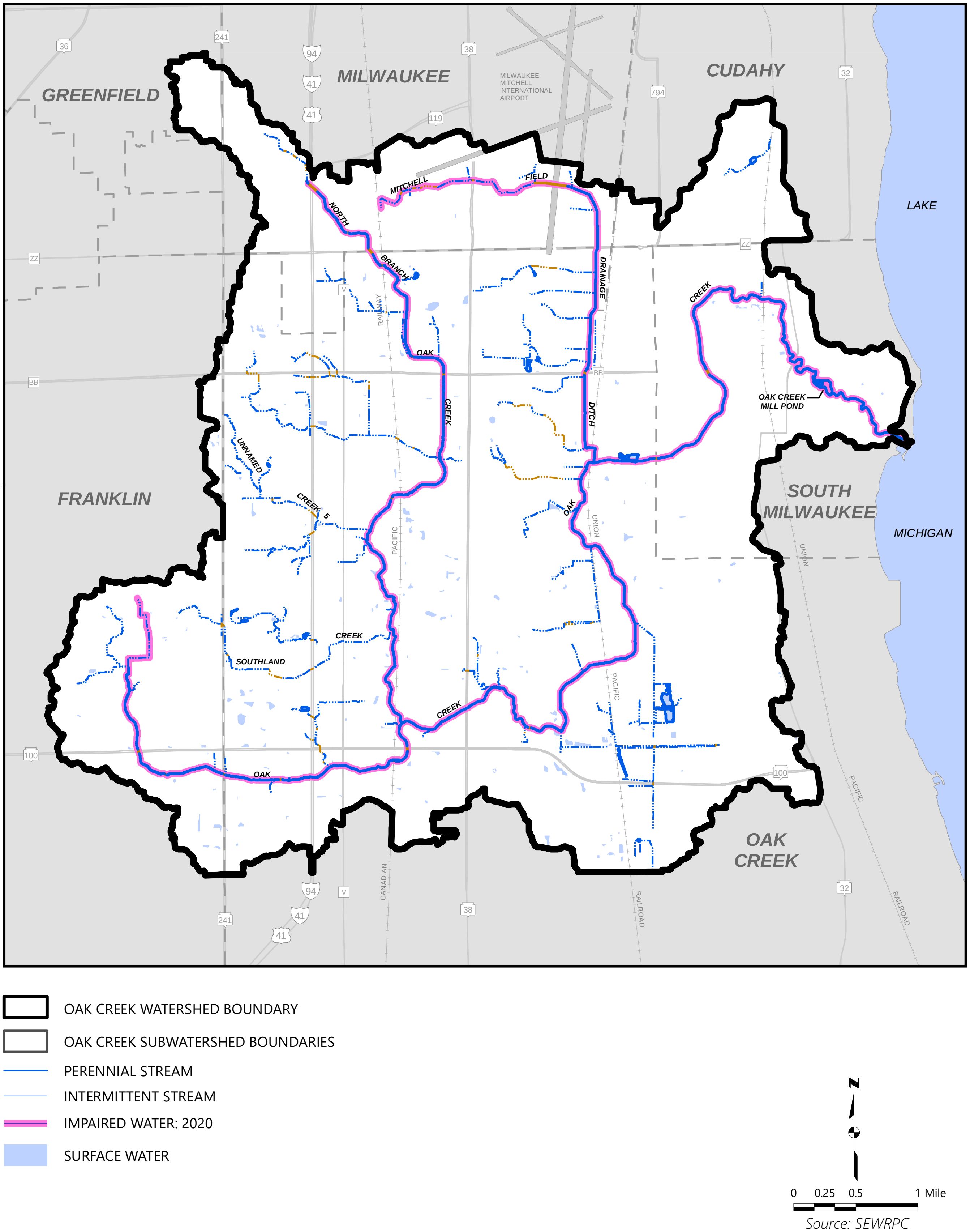
The applicable water quality criteria for all water uses designated in Southeastern Wisconsin are set forth in Tables 4.16 and 4.17. Table 4.16 shows the applicable water quality criteria for all designated uses for five water quality parameters—dissolved oxygen concentration, pH, *Escherchia coli* (*E. coli*) bacteria concentration, total phosphorus concentration, and chloride concentration. Table 4.17 shows the water quality criteria for each of the aquatic life categories. The warmwater communities are further categorized based on their seven-day, 10-percent probability low flow (7Q10).[183] The 7Q10s of all of the streams in the Oak Creek watershed are less than 200 cfs, thus they are designated as small warmwater communities.

In addition to the numerical criteria presented in the tables, there are narrative standards that apply to all waters. All surface waters must meet certain conditions at all times and under all flow conditions. Section NR 102.04(1) 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 meet the following conditions at all times and under all flow conditions:

> "(a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in the waters of the State.
>
> "(b) Floating or submerged debris, oil, scum or other material shall not be present in such amounts as to interfere with public rights in the waters of the State.
>
> "(c) Materials producing color, odor, taste, or unsightliness shall not be present in such amounts as to interfere with public rights in the waters of the State.
>
> "(d) Substances 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 such substances be present in amounts which are acutely harmful to animal, plant or aquatic life."

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

Map 4.20
Impaired Waters Within the Oak Creek Watershed: 2020



Source: SEWRPC

Table 4.16
Applicable Water Quality Standards for Streams and Lakes in Southeastern Wisconsin

Water Quality Parameter	Designated Use Category[a] 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 Community (Variance Category)	Source
Temperature (°F)	See Table 4.17						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 102.04(3) NR 102.06(2)
pH Range (Standard Units)	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]
E. coli Bacteria (cfu per 100 ml)[e]							NR 102.04(5) NR 104.06(2)
Geometric Mean	126	126	126	--	--	126	
Statistical Test Value	410	410	410	--	--	410	
Total Phosphorus (mg/l)							NR 102.06(3) NR 102.06(4) NR 102.06(5) NR 102.06(6)
Designated Streams[f]	0.100	0.100	0.100	0.100	0.100	0.100	
Other Streams	0.075	0.075	0.075	0.075	0.075	--	
Stratified Reservoirs	0.030	0.030	0.030	0.030	0.030	--	
Unstratified Reservoirs	0.040	0.040	0.040	0.040	0.040	--	
Stratified Two-story Fishery Lakes	0.015	0.015	0.015	0.015	0.015	--	
Stratified Drainage Lakes	0.030	0.030	0.030	0.030	0.030	--	
Unstratified Drainage Lakes	0.040	0.040	0.040	0.040	0.040	--	
Stratified Seepage Lakes	0.020	0.020	0.020	0.020	0.020	--	
Unstratified Seepage Lakes	0.040	0.040	0.040	0.040	0.040	--	
Chloride (mg/l)							NR 105.05(2) NR 105.06(5)
Acute Toxicity[g]	757	757	757	757	757	757	
Chronic Toxicity[h]	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: (a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water, shall not be present in such amounts as to interfere with public rights in waters of the state. (b) Floating or submerged debris, oil, scum, or other material, shall not be present in amounts as to interfere with public rights in waters of the state. (c) 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. (d) Substances in concentrations 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 natural seasonal maximum and minimum.*

[e] *Under the criteria, the geometric mean of* E. coli *in samples collected over any 90-day period between May 1 and September 30 shall not exceed 126 colony forming units (cfu) per 100 ml. In addition, the concentrations of* E. coli *shall not exceed 410 cfu per 100 ml in more than 10 percent of the samples collected over any 90-day period between May 1 and September 30.*

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

[g] *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.*

[h] *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

Table 4.17

Ambient Temperatures and Water Quality Criteria for Temperarture for Nonspecific Streams and Lakes in Southern Wisconsin[a]

	Cold Water Communities (°F)			Large Warmwater Communities[b] (°F)			Small Warmwater Communities[c] (°F)			Limited Forage Fish Communities[d] (°F)			Inland Lakes and Impoundments[e] (°F)		
Month	Ta	SL	A	Ta	SL	A	Ta	SL	A	Ta	SL	A	Ta	SL	A
January	35	47	68	33	49	76	33	49	76	37	54	78	35	49	77
February	36	47	68	33	50	76	34	50	76	39	54	79	39	52	78
March	39	51	69	36	52	76	38	52	77	43	57	80	41	55	78
April	47	57	70	46	55	79	48	55	79	50	63	81	49	60	80
May	56	63	72	60	65	82	58	65	82	59	70	84	58	68	82
June	62	67	72	71	75	85	66	76	84	64	77	85	70	75	86
July	64	67	73	75	80	86	69	81	85	69	81	86	77	80	87
August	63	65	73	74	79	86	67	81	84	68	79	86	76	80	87
September	57	60	72	65	72	84	60	73	82	63	73	85	67	73	85
October	49	53	70	52	61	80	50	61	80	55	63	83	54	61	81
November	41	48	69	39	50	77	40	49	77	46	54	80	42	50	78
December	37	47	69	33	49	76	35	49	76	40	54	79	35	49	77

Note: Acronyms for temperature criteria categories include: Ta-ambient temperature, SL-sublethal temperature, and A-acute temperature. The ambient temperature, sublethal temperature water quality criterion, and acute temperature water quality 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 of the daily maximum water temperatures over a calendar week. The acute criteria are to be applied as the daily maximum temperature. 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.

[a] *As set forth in Section NR 102.25 of the* Wisconsin Administrative Code.

[b] *Waters with a fish and aquatic life use designation of "warmwater sportfish community" or "warmwater forage fish community" and unidirectional 7Q10 flows greater than or equal to 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).*

[c] *Waters with a fish and aquatic life use designation of "warmwater sportfish community" or "warmwater forage fish community" and 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).*

[d] *Waters with a fish and aquatic life use designation of "limited forage fish community."*

[e] *Values are applicable for those lakes and impoundments south of STH 10.*

Source: Wisconsin Department of Natural Resources

Other Water Quality Guidelines

There are several water quality constituents for which the State of Wisconsin has not developed water quality criteria. For many of these constituents, it would be useful to have guidelines that could be used to evaluate what particular values of these constituents indicate regarding the quality of surface waters. Table 4.18 sets forth guidelines for several water quality constituents. The guidelines are drawn from a variety of sources including the Milwaukee River Basin Total Maximum Daily Load (TMDL) study,[184] studies conducted in support of developing water quality criteria for the State of Wisconsin,[185] and studies presenting recommendations to states and tribes for water quality criteria development.[186] These sources consist of work completed by the USEPA and WDNR or studies conducted by the USGS or the MMSD on behalf of the WDNR. Table 4.18 combines information from all these sources to provide preferred guidelines for evaluating several additional water quality constituents. These guidelines were developed specifically for Wisconsin and, in some cases, Southeastern Wisconsin.

Three different types of guidelines are presented in Table 4.18: TMDL target concentrations, recommended water quality criteria, and reference values. A TMDL target concentration represents a goal set by a TMDL study. It is a concentration or value of a constituent that defines acceptable water quality. A recommended water quality criterion is a scientific assessment of the effects of a water quality constituent on human health or aquatic organisms. Only when a water quality criterion is adopted by a state, tribe, or territory or promulgated by USEPA does it become the relevant standard for developing permit limits, assessing waters, and developing TMDLs. Finally, a reference value is a scientific assessment of the potential level of water quality that could be achieved in the absence of human activities. Unless they are adopted by the State or promulgated by USEPA as water quality criteria, these guidelines have no regulatory impact. Instead they serve as indicators of where the division between good and poor water quality lies and can serve as proxies in lieu of adopted water quality criteria to better understand water quality conditions within the Oak Creek watershed.

Monitoring Data

Sources of Monitoring Data

Systematic water quality sampling in the Oak Creek watershed has been conducted since the early 1950s. Much of this sampling was conducted in conjunction with several planning and management efforts. The earliest watershed-wide systematic sampling effort was conducted in 1952 and 1953 by the Wisconsin Conservation Department, the predecessor agency to the WDNR as part of an investigation of pollution of surface waters in Milwaukee County.[187] Regular sampling began in the Oak Creek watershed in the mid-1960s and continued into the mid-1970s.[188] This effort was conducted in conjunction with the preparation of an areawide water quality plan pursuant to Section 208 of the CWA.[189] Data collected since these initial efforts

---

[184] *Milwaukee Metropolitan Sewerage District,* Total Maximum Daily Loads for Total Phosphorus, Total Suspended Solids, and Fecal Coliform: Milwaukee River Basin, Wisconsin, Report, *March 19, 2019.*

[185] *D.M. Robinson, D.J. Graczyk, L. Wang, G. LaLiberte, and R. Bannerman,* Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin, *U.S. Geological Survey Professional Paper No. 1722, 2006; D.M. Robinson, B.M Weigel, and D.J. Graczyk,* Nutrient Concentrations and Their Relations to the Biotic Integrity of Nonwadeable Rivers in Wisconsin, *U.S. Geological Survey Professional Paper No. 1754, 2008.*

[186] *U.S. Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Rivers and Streams in Nutrient Ecoregion VII, *EPA 822-B-00-018, December 2000; U.S. Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Lakes and Reservoirs in Nutrient Ecoregion VII, *EPA 822-B-00-009, December 2000.*

[187] *Wisconsin Conservation Department,* Report on Investigations of Pollution of Surface Waters in Milwaukee County and that Portion of the Root River System Draining from Waukesha through Milwaukee County Conducted during 1952 and 1953, *March 1954, cited in SEWRPC Planning Report No. 36,* A Comprehensive Plan for the Oak Creek Watershed, *August 1986.*

[188] *SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin, *April 1967; SEWRPC Technical Report No 17,* Water Quality of Streams and Lakes in Southeastern Wisconsin: 1964-1975, *June 1978.*

[189] *SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; Volume Three,* Recommended Plan, *June 1979.*

Table 4.18
Guidelines for Water Quality Constituents in Southeastern Wisconsin for Which Water Quality Criteria Have Not Been Promulgated

Title	Stream Guidance	Lake and Reservoir Guidance	Category	Source
Total Suspended Solids (mg/l)	12	--	TMDL target concentration	Milwaukee Basin TMDL[a] USGS/WDNR[b]
Nitrogen				
Total Nitrogen (mg/l)	0.65[c]	0.66	Streams: reference value Lakes: Recommended criterion	USGS/WDNR[d] USEPA[e]
Nitrate plus Nitrite (mg/l)	0.94	0.04	Reference value	USEPA[e,f]
Total Kjeldahl Nitrogen (mg/l)	0.65	0.54	Reference value	USEPA[e,f]
Chlorophyll-*a* (μg/l)	1.50[g]	2.63[h]	Recommended criteria	USEPA[e,f]
Transparency tube (cm)[i]	> 115	--	Reference value	USGS/WDNR[d]
Secchi depth (m)	--	3.33[j]	Recommended criteria	USEPA[e]
Turbidity (ntu)	1.70[k]		Recommended criteria	USEPA[f]
Fecal coliform bacteria				
Geometric mean (MFFCC/100 ml)	200	200	Previous Wisconsin criteria	WDNR
Single sample maximum (MFFCC/100 ml)	400	400		

[a] *Milwaukee Metropolitan Sewerage District,* Total Maximum Daily Loads for Total Phosphorus, Total Suspended Solids, and Fecal Coliform: Milwaukee River Basin, Wisconsin, *March 19, 2018.*

[b] *D.M Robinson, B.M. Weigel, and D.J. Graczyk,* Nutrient Concentrations and Their Relations to the Biotic Integrity of Nonwadeable Rivers in Wisconsin, *U.S. Geological Survey Professional Paper No. 1754, 2008.*

[c] *This is a reference value developed by USGS and WDNR for this portion of Wisconsin. It should be noted that USEPA has developed a similar reference value for the southern Wisconsin till plains area of 1.30 mg/l and a recommended criterion for Nutrient Ecoregion VII (mostly glaciated dairy region) of 0.54 mg/l.*

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

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

[f] *U.S. Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Rivers and Streams in Nutrient Ecoregion VII, *EPA 822-B-00-018, December 2000.*

[g] *This is consistent with the finding by USGS and WDNR of reference values for chlorophyll-*a *in wadeable streams in Wisconsin between 1.20 and 1.70 μg/l. It should be noted that the guidance and reference values are based upon fluorometric analysis of chlorophyll-*a *concentrations. Other values may apply for chlorophyll-*a *concentrations that were determined using other techniques.*

[h] *The WDNR has proposed recreational use criteria for chlorophyll-*a *for lakes. As of October 2017, the proposal states that during the summer swimming season, concentrations of chlorophyll-*a *in shallow lakes are not to exceed 20 μg/l on more than 25 percent of days. For deep lakes, the proposal states that concentrations of chlorophyll-*a *are not to exceed 20 μg/l on more than 5 percent of days.*

[i] *This is based on the use of a minimum transparency tube length of 120 cm.*

[j] *For lakes in the southern Wisconsin till plains area, USEPA found a reference value for secchi depth of 3.19 m.*

[k] *It should be noted that the guideline and recommended criterion are based upon nephelometric analysis of turbidity. Other values may apply for turbidity determined using other techniques.*

[l] *U.S. Environmental Protection Agency,* Recreational Water Quality Criteria, *EPA 820-F-12-058, November 2012.*

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC were compiled and analyzed as part of the regional water quality management plan update (RWQMPU) completed in 2007.[190] Most of these data were collected by a diverse set of agencies for a variety of purposes.

The data set for the Oak Creek watershed that was used in the RWQMPU was drawn from several sources.[191] These sources included data from the MMSD Corridor Study Database.[192] In addition to data from MMSD's sampling program, this database contains data collected by the USGS and the WDNR. Fish and macroinvertebrate data used for evaluating water quality came from WDNR databases.

Data have also been collected since the end of the period examined in the RWQMPU. MMSD has continued collecting water chemistry samples at sites along the mainstem of Oak Creek. MMSD's data are available from the USEPA STORET Modern database.[193] Data collected by the USGS are available from the National Water Information System (NWIS) database. These include stream stage and discharge data that were collected at the USGS stream gage on Oak Creek at 15th Avenue, water quality data collected at the stream gage and from the Mitchell Field Drainage Ditch at College Avenue, and data from studies conducted by the USGS. Data collected by the WDNR are available from the STORET Modern databases and the WDNR Surface Water Information System (SWIMS) database. The WDNR also collected fish and macroinvertebrate samples in 2015 both as part of their water quality planning efforts and in support of developing this plan.[194] The City of Racine Public Health Department (RHD) collected data at sites within the watershed.[195] The Health Department's data collection in 2015 and 2016 was conducted in support of this planning effort under a project funded by the Fund for Lake Michigan. It included collecting macroinvertebrate samples by the University of Wisconsin-Parkside. SEWRPC collected continuous water temperature data at 21 sites within the watershed between 2016 and 2017 and at eight sites in the watershed in 2019. Finally, some data are available from volunteer monitoring programs, mostly through the WDNR/University of Wisconsin-Extension's Water Action Volunteers Program. These data are available from the SWIMS database.

Sampling sites for surface water quality are shown on Map 4.21 and listed in Table 4.19. There are 27 sample sites along the mainstem of Oak Creek, including the sample sites within the Oak Creek Mill Pond. There are 18 sample sites along six tributary streams. Most of these sites are located on either the North Branch of Oak Creek or the Mitchell Field Drainage Ditch. Because of the large number of sampling stations, not all stations are depicted on graphs; however, data from all stations are included in statistical summaries.

Several things should be kept in mind regarding the data available for evaluating water quality in the Oak Creek watershed. The data were collected by several agencies and organizations for a variety of purposes as part of a number of different studies. Each of these studies assessed a different group of water quality constituents. For some constituents, this means that data are only available for some portions of the watershed. Each study also sampled for a different time period. These periods range from studies that collected a single sample at a site, through studies that collected over a season, to long-term sampling programs that collected data for over 20 years. Some sampling stations have been used by multiple agencies or in multiple studies (see Table 4.19). While the use of multiple data sources has extended the period of record at these stations, it should be kept in mind that differences among studies in the constituents sampled may allow for fewer time-based comparisons than would be expected based purely on the length of the period of record. Relatively few samples were collected during the winter months of December through February. Samples collected during the winter represent about 8 percent of the samples collected from streams.

---

[190] *SEWRPC Technical Report No. 39,* op. cit.

[191] *Ibid*.

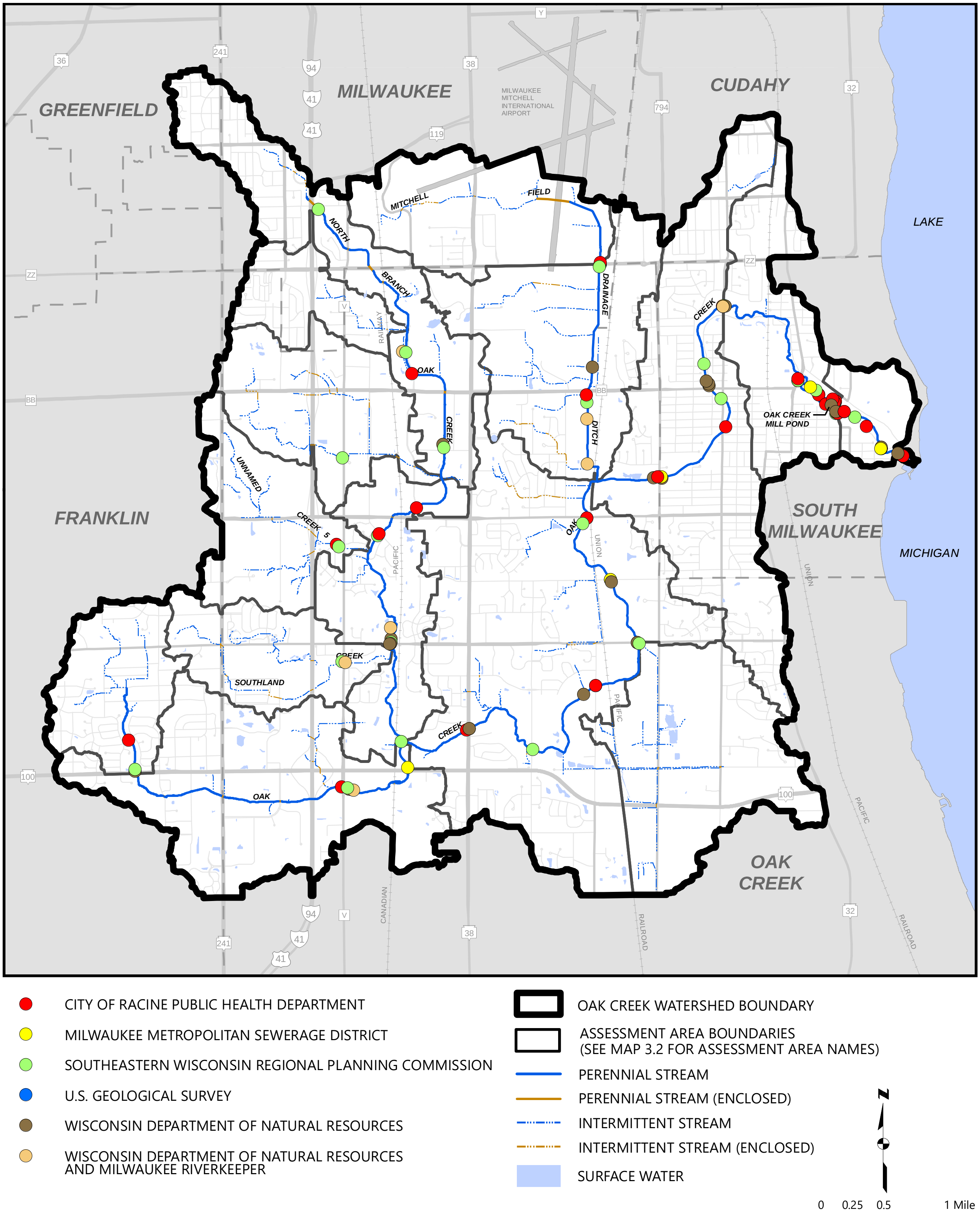
[192] *U.S. Geological Survey,* Water-Resources-Related Information for the Milwaukee Metropolitan Sewerage District Planning Area, 1970-2002, *U.S. Geological Survey Water-Resources Investigations Report 03-4240, 2004.*

[193] *It should be noted that as of July 2019 MMSD was considering archiving its water quality data in the WDNR SWIMS database.*

[194] *Wisconsin Department of Natural Resources,* Oak Creek Frontal Lake Michigan TWA WQM Plan 2017, *EGAD # 3200-2017-11, September 1, 2017.*

[195] *Jacob Jozefowski, Kwabena Boateng, Adrian Koski, and Julie Kinzelman,* Baseline Assessment of Water Quality in Support of the Oak Creek Watershed Restoration Plan, *City of Racine Public Health Department, 2017.*

Map 4.21
Water Quality Sampling Sites in the Oak Creek Watershed: 1952-2016



Source: SEWRPC

Table 4.19
Sample Sites Used for the Analysis of Surface Water Quality Conditions and Trends in the Oak Creek Watershed: 1952-2017

Location	River Mile[a]	Assessment Area	Period of Record	Data Sources[b]
Mainstem of Oak Creek				
Oak Creek at Southwood Drive	12.8	Oak Creek Headwaters	2013-2016	RHD
Oak Creek at Ryan Road	12.5	Oak Creek Headwaters	2005-2006, 2015-2017	SEWRPC, WDNR
Oak Creek at CTH V	10.7	Upper Oak Creek	2012-2016	RHD, SEWRPC
Oak Creek east of 13th Street and South of Ryan Road	10.6	Upper Oak Creek	2008-2016	MKER, WDNR
Oak Creek at Ryan Road	10.1	Upper Oak Creek	1985-2016	MMSD
Oak Creek at STH 38	9.2	Middle Oak Creek	1953, 1968, 1985-2016	MMSD, RHD, SEWRPC
Oak Creek at Shepard Avenue	8.4	Middle Oak Creek	1964-1975	SEWRPC
Oak Creek upstream of Nicholson Road	7.5	Middle Oak Creek	2011	WDNR
Oak Creek at S. Nicholson Road	7.4	Middle Oak Creek	2011-2016	RHD, USGS
Oak Creek at Puetz Road and Former Railroad Tracks	6.8	Middle Oak Creek	1953, 1968, 1975-1976, 2015-2016	SEWRPC, WDNR
Oak Creek at E. Forest Hill Avenue	6.3	Middle Oak Creek	1968, 1985-2016	MMSD, WDNR
Oak Creek at Drexel Avenue	5.6	Middle Oak Creek	1952-1953, 1968, 2012-2016	RHD, SEWRPC, WDNR
Oak Creek at Pennsylvania Avenue	4.7	Lower Oak Creek	1952-1953, 1968, 1975-1976, 2016-2017	MMSD, RHD, SEWRPC, WDNR
Oak Creek at 15th Avenue and Milwaukee Avenue	4.0	Lower Oak Creek	2007	RHD
Oak Creek Below 15th Avenue Bridge	3.8	Lower Oak Creek	1976	SEWRPC
Oak Creek at Rawson Avenue	3.6	Lower Oak Creek	1952-1953, 1968	WDNR
Oak Creek at Chestnut Street	3.5	Lower Oak Creek	2016-2017	SEWRPC, WDNR
Oak Creek at 15th Avenue	2.8	Lower Oak Creek	1968, 1972-2016	MKER, MMSD, RHD, USGS, WDNR
Oak Creek at Chicago Avenue	1.6	Lower Oak Creek – Mill Pond	1952-1953, 1964-1975, 2007, 2012-2014	RHD, SEWRPC, WDNR
Oak Creek at First Parkway Bridge upstream of Dam	1.2	Lower Oak Creek – Mill Pond	1952-1953, 2015-2016	RHD, SEWRPC, WDNR
Oak Creek at Mill Pond	1.1	Lower Oak Creek – Mill Pond	2015-2016	RHD, SEWRPC
Oak Creek at Parkway east of STH 32	1.0	Lower Oak Creek – Mill Pond	1985-2016	RHD, MMSD,SEWRPC, WDNR
Oak Creek at Second Parkway Bridge upstream of Creek Mouth	0.9	Lower Oak Creek – Mill Pond	1952, 2007	RHD, WDNR
Oak Creek 900 feet downstream of Dam	0.8	Grant Park Ravine	2016-2017	SEWRPC
Oak Creek 600 yards below Dam	0.6	Lower Oak Creek – Mill Pond	1975-1976	RHD, WDNR
Oak Creek Parkway Bridge upstream of Mouth	0.4	Lower Oak Creek – Mill Pond	1952-1953, 2007	WDNR
Oak Creek Parkway East of Lake Drive	0.3	Grant Park Ravine	1985-2016	RHD, MMSD
Oak Creek Mouth	0.1	Grant Park Ravine	1952-1953, 1968, 2006-2007, 2012-2016	RHD, SEWRPC, WDNR
North Branch Oak Creek				
Oak Creek at Maitland Park	5.6	Upper North Branch Oak Creek	2016-2017	SEWRPC
North Branch Oak Creek along S. 6th Street	4.1	Upper North Branch Oak Creek	2015	MKER, SEWRPC, WDNR
North Branch Oak Creek at S. 6th Street	3.9	Upper North Branch Oak Creek	2013-2016	RHD, SEWRPC
North Branch Oak Creek upstream of W. Marquette Avenue	3.0	Upper North Branch Oak Creek	1975-1976, 2016-2017	SEWRPC, WDNR
North Branch Oak Creek at S. 6th Street	2.4	Lower North Branch Oak Creek	2012-2014	RHD

Table continued on next page.

Table 4.19 (Continued)

Location	River Mile[a]	Assessment Area	Period of Record	Data Sources[b]
North Branch Oak Creek (continued)				
North Branch Oak Creek at Wildwood Drive	2.0	Lower North Branch Oak Creek	2016-2017	SEWRPC
North Branch Oak Creek at Weatherly Drive	1.8	Lower North Branch Oak Creek	2015-2016	RHD
North Branch Oak Creek 200 Feet upstream of Puetz Road	1.0	Lower North Branch Oak Creek	1990, 1996, 2008-2016	MKER, WDNR
North Branch Oak Creek at Puetz Road	0.9	Lower North Branch Oak Creek	1975-1976, 1990, 1996, 2015-2016	SEWRPC, WDNR
North Branch Oak Creek upstream of Confluence with Oak Creek	0.1	Lower North Branch Oak Creek	2016-2017	SEWRPC
Mitchell Field Drainage Ditch				
Mitchell Field Drainage Ditch at College Avenue	1.8	Mitchell Field Drainage Ditch – Airport	1998-2000, 2007-2016	RHD, SEWRPC, USGS, WDNR
Mitchell Field Drainage Ditch between College Avenue and Rawson Avenue	1.0	Lower Mitchell Field Drainage Ditch	2015	WDNR
Mitchell Field Drainage Ditch at Rawson Avenue	0.8	Lower Mitchell Field Drainage Ditch	2015-2016	RHD, SEWRPC, WDNR
Mitchell Field Drainage Ditch south of Rawson Avenue	0.6	Lower Mitchell Field Drainage Ditch	2008-2013	MKER, WDNR
Mitchell Field Drainage Ditch at railroad tracks	0.2	Lower Mitchell Field Drainage Ditch	1985, 2004	MKER, WDNR
Southland Creek				
Southland Creek at S. 13th Street	0.5	Southland Creek	2016-2017	MKER, SEWRPC
Unnamed Creek 5				
Unnamed Creek 5 at Willow Drive	0.3	Drexel Avenue Tributary	2015-2016	RHD, SEWRPC
Unnamed Tributary to North Branch Oak Creek				
Unnamed Tributary to North Branch Oak Creek at S. 13th Street	0.8	Rawson Avenue Tributary	2016-2017	SEWRPC
Unnamed Tributary to Oak Creek				
Unnamed Tributary to North Branch Oak Creek near Puetz Road	0.1	Oak Creek Drainage Ditches	2016-2017	SEWRPC

[a] *River mile is the distance upstream from the confluence of the steam in question with the waterbody it flows into.*

[b] *Agency codes are:*

MMSD Milwaukee Metropolitan Sewerage District
MKER Milwaukee Riverkeeper through the WNDR/UWEX Water Action Volunteers program
RHD City of Racine Public Health Department
SEWRPC Southeastern Wisconsin Regional Planning Commission
USGS U.S. Geological Survey
WDNR Wisconsin Department of Natural Resources, including data from the Water Action Volunteers program

Source: SEWRPC

For analytical purposes, data from five time periods were examined: 1952-1974, 1975-1986, 1987-1996, 1997-2006, and 2007-2016. These analytical periods are slightly different from those that were used in the initial regional water quality management plan and the RWQMPU. The initial regional water quality management plan was based upon data collected over the period beginning in 1964 and continuing through 1974. The analytical periods used for the RWQMPU reflected changes in MMSD surface water quality sampling procedures and the fact that MMSD's Inline Storage System (ISS or Deep Tunnel) came on line in 1994. Because operating the ISS would not be expected to have as direct an effect on instream water quality in the Oak Creek watershed as it does in the Kinnickinnic River, Menomonee River, and Milwaukee River watersheds, the analytical periods for the Oak Creek watershed restoration plan were chosen to represent about the same lengths of time, at least for more recent periods.

Water Quality Conditions

Bacteria and Biological Conditions

Bacterial Indicators of Safety for Human Contact

The suitability of surface water for human contact and recreational uses is assessed by examining water samples for the presence and concentrations of organisms indicating fecal contamination. A variety of disease-causing organisms can be transmitted through water contaminated with fecal material. These organisms include bacteria, such as those that cause cholera and typhoid fever; viruses, such as those that cause poliomyelitis and infectious hepatitis; and protozoa, such as *Giardia* and *Cryptosporidium*. The concentrations of two groups of bacteria are commonly examined in surface waters of the Oak Creek watershed as indicators of fecal contamination: *Escherichia coli* (*E. coli*) and fecal coliform bacteria. Under Wisconsin's water quality criteria, the suitability of surface waters for recreational uses is assessed using *E. coli*. Until recently, the State's water quality standards were based upon fecal coliform bacteria, a group of bacteria that includes *E. coli*. All warm-blooded animals have these bacteria in their feces. Because of this, the presence of high concentrations of *E. coli* or fecal coliform bacteria in water indicates a high probability of fecal contamination. Most strains of these bacterial groups have a low probability of causing illness. Instead, they act as indicators of the potential presence of other pathogenic agents in water. While the presence of high concentrations of these indicator bacteria does not necessarily indicate the presence of pathogenic agents, they are generally found when the pathogenic agents are found, thus these bacteria are not themselves pollutants of concern. Instead, they act as surrogate measures indicating the likelihood that surface waters are contaminated with fecal wastes and may contain disease-causing agents.

Fecal wastes can originate from several sources, including sanitary sewage, agricultural and barnyard wastes, and wastes from domestic pets and wild animals. Fecal pollution from different sources will carry different pathogens; however, fecal pollution from sanitary sewage generally constitutes a more serious public health risk because multiple human pathogens including bacteria, viruses, and protozoa can be present in high concentrations. Because of this, assessments of the source of waste—specifically microbial source tracking assessments that can determine whether stormwater contains fecal wastes of human origin—can provide important information for prioritizing action when high concentrations of *E. coli* or fecal coliform bacteria are detected in stormwater discharges.[196]

The State of Wisconsin has promulgated two recreational use water quality criteria for *E. coli*, a geometric mean criterion under which the geometric mean of sample concentrations is not to exceed 126 cells per 100 milliliters (cells per 100 ml) over any 90-day period between May 1 and September 30 and a statistical test value criterion under which concentrations in no more than 10 percent of samples collected are to exceed 410 cells per 100 ml over any 90-day period between May 1 and September 30. The State's recreational use criteria were formerly based upon fecal coliform bacteria. Under the previous rule, the geometric mean of concentrations of fecal coliform bacteria was not to exceed 200 cells per 100 ml and the concentrations in individual samples were not to exceed 400 cells per 100 ml.

Figure 4.50 shows concentrations of *E. coli* at sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, concentrations of *E. coli* in Oak Creek ranged from below the limit of detection[197] to over 241,960 cells per 100 ml, with a median value of 480 cells per 100 ml and a mean value of 3,755 cells per 100 ml. The *E. coli* concentrations observed at any site showed considerable variability.

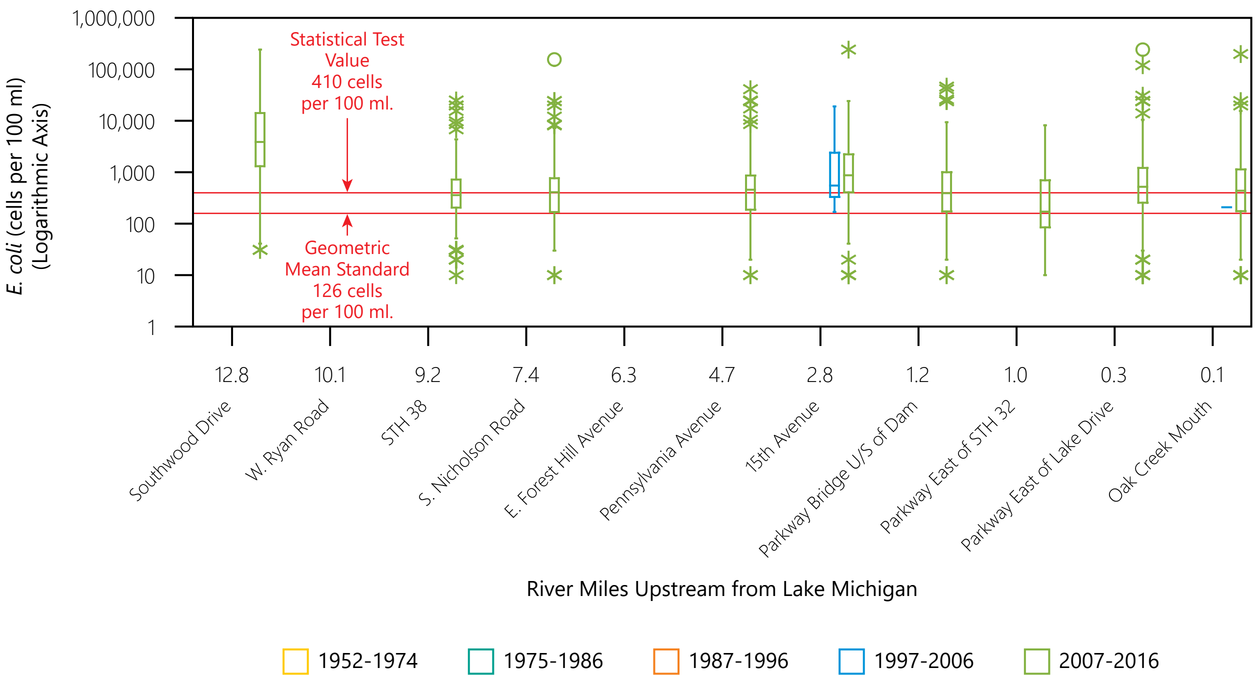
Concentrations of *E. coli* showed a complicated pattern from upstream to downstream along the Creek. The highest concentrations occurred at the sampling station farthest upstream, Southwood Drive (RM 12.8). Concentrations decreased markedly between there and the sampling station at STH 38 (RM 9.2). Concentrations then gradually increased from upstream to downstream, reaching a second peak at STH 32 (RM 1.6, not shown in Figure 4.50). Concentrations decreased between STH 32 and the Mill Pond and increased slightly downstream of the Mill Pond. Lower concentrations were observed near the mouth of Oak Creek (RM 0.1).

---

[196] *Sandra L. McLellan and Elizabeth P. Sauer*, Greater Milwaukee Watersheds Pathogen Source Identification Report: March 1, 2006 to July 28, 2009, *MMSD contract No. M03016902, November 2, 2009*.

[197] *For most samples, the limit of detection for* E. coli *was 10 cells per 100 ml. In some samples, the limit of detection was 100 cells per 100 ml.*

Figure 4.50
Concentrations of *E. coli* Bacteria at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

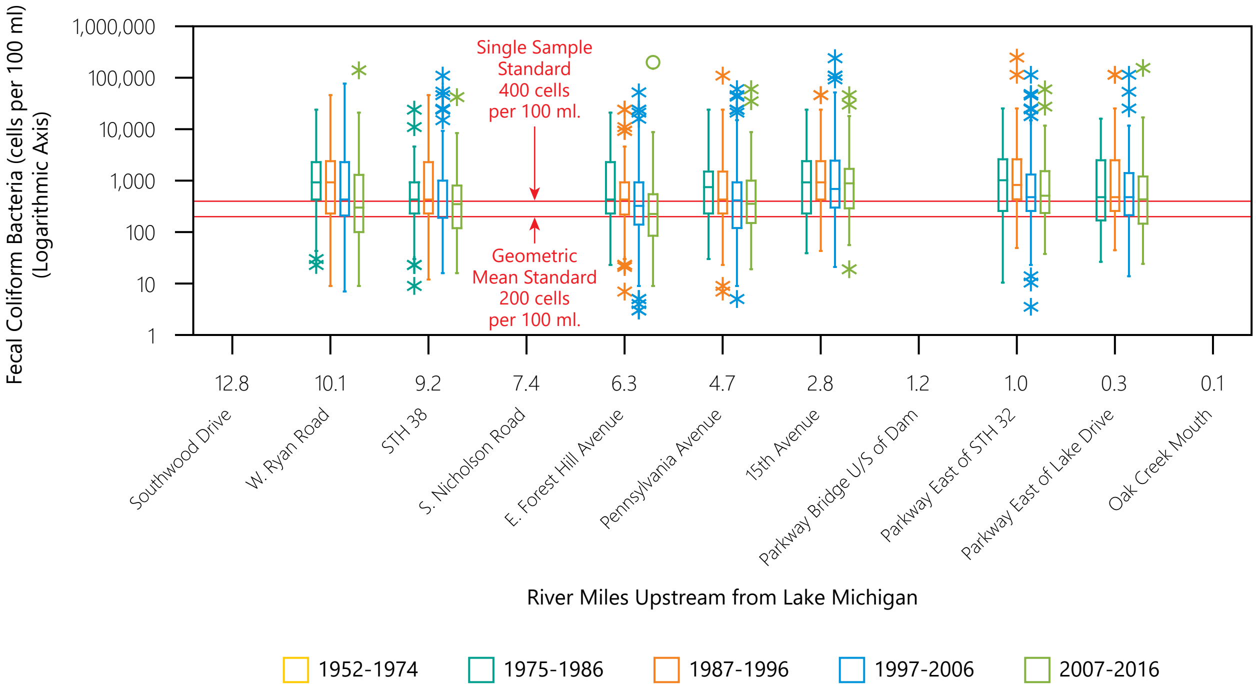
At all stations along the mainstem of Oak Creek where *E. coli* were sampled, a substantial fraction of the samples had concentrations higher than the State's recreational use water quality criteria (see Figure 4.50). Concentrations of *E. coli* in 55 percent of samples collected were higher than the statistical test value (STV) of 410 cells per 100 ml. The percentage of samples at individual sampling stations with concentrations higher than the STV ranged between 23 and 89 percent. Concentrations of *E. coli* in 80 percent of samples collected were higher than the geometric mean criterion of 126 cells per 100 ml. The percentage of samples at individual sampling stations with concentrations higher than the geometric mean criterion ranged between 61 and 100 percent. A formal comparison of *E. coli* concentrations to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

Few historical *E. coli* data are available for the mainstem of Oak Creek. Only 13 samples were collected prior to 2007 in the entire watershed. Almost all of the historical fecal indicator bacteria data collected in the watershed consists of samples of fecal coliform bacteria. Under Wisconsin's previous recreational use water quality criteria, the geometric mean of the concentrations of fecal coliform bacteria was not to exceed 200 cells per 100 ml and concentrations of fecal coliform bacteria in single samples were not to exceed 400 cells per 100 ml. Because historical *E. coli* data are lacking and samples in the Oak Creek watershed were collected and analyzed for fecal coliform bacteria through 2016, the examination of historical trends in fecal indicator bacteria in Oak Creek will be based on fecal coliform bacteria.

Figure 4.51 shows historical and recent concentrations of fecal coliform bacteria at sampling stations along the mainstem of Oak Creek. During the period of record, concentrations ranged from below the limit of detection to more than 240,000 cells per 100 ml, with a median value of 430 cells per 100 ml and mean value of 3,014 cells per 100 ml. Concentrations during the period 2007-2016 were lower, ranging from a minimum of three cells per 100 ml to a maximum of 200,000 cells per 100 ml, with a median value of 390 cells per 100 ml and a mean value of 2,478 cell per 100 ml. The concentrations of fecal coliform bacteria observed at any site during any time period showed considerable variability.

Figure 4.51

Concentrations of Fecal Coliform Bacteria at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC

During the period 2007 through 2016, median concentrations of fecal coliform bacteria at individual sampling stations were between 230 and 460 cells per 100 ml. There was one exception to this generalization—the median concentration of fecal coliform bacteria at 15th Avenue (RM 2.8) was 900 cells per 100 ml. The median concentrations of fecal coliform bacteria at this site were higher than those at any other site during all analysis periods for which data were available. As previously discussed, this site also had a relatively high median concentration of *E. coli*, one of the bacteria making up the fecal coliform group.

At most sampling stations, concentrations of fecal coliform bacteria decreased over time (see Figure 4.51). For example, median concentrations of fecal coliform bacteria at W. Ryan Road (RM 10.1) decreased from 930 cells per 100 ml during the period 1975 through 1986 to 310 cells per 100 ml during the period 2007 through 2016. This trend toward decreasing concentrations did not occur at 15th Avenue (RM 2.8). During most analysis periods, median concentrations of fecal coliform bacteria were equal to or greater than 900 cells per 100 ml at this sampling station.

At all stations along the mainstem of Oak Creek where fecal coliform bacteria were sampled during the period 2007 through 2016, a substantial fraction of the samples had concentrations higher than the State's previous recreational use water quality criteria (see Figure 4.51). Concentrations of fecal coliform bacteria in 48 percent of samples collected were higher than the single sample criterion of 400 cells per 100 ml. The percentage of samples at individual sampling stations with concentrations higher than the single sample criterion ranged between 33 and 69 percent. Concentrations of fecal coliform bacteria in 65 percent of samples collected were higher than the geometric mean criterion of 200 cells per 100 ml. The percentage of samples at individual sampling stations with concentrations higher than the geometric mean criterion ranged between 53 and 81 percent. The highest percentages of samples with concentrations exceeding both criteria occurred at the station at 15th Avenue (RM 2.8). It should be noted that this site also had high percentages of samples exceeding the recreational use criteria for *E. coli* during the same period.

Figure 4.52 shows concentrations of *E. coli* at sampling stations along the North Branch of Oak Creek. During the period 2007 through 2016, concentrations in this Creek ranged between 10 cells per 100 ml and 241,960 cells per 100 ml, with a median value of 135 cells per 100 ml and a mean value of 2,949 cells per 100 ml. Concentrations of *E. coli* increased between the middle and southern sampling stations along S. 6th Street (RM 3.9 and RM 2.4) and then decreased between the southern sampling station along S. 6th Street and the station at Weatherly Drive (RM 1.8). Median concentrations at individual stations ranged between 110 cells per 100 ml and 187 cells per 100 ml, with the highest value occurring at the southern sampling station along S. 6th Street (RM 2.4). At all stations along the North Branch of Oak Creek where *E. coli* were sampled, a substantial fraction of the samples had concentrations higher than the State's recreational use water quality criteria. Concentrations in 27 percent of the samples collected from this stream were higher than the STV. Concentrations in 52 percent of the samples were higher than the geometric mean criterion. Higher fractions of exceedances were seen at the southern sampling station along S. 6th Street. A formal comparison of *E. coli* concentrations to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

No recent fecal coliform bacteria data are available for the North Branch of Oak Creek. Historical data from selected sampling stations for 1975 through 1986 are shown in Figure 4.53. Historically, concentrations of fecal coliform bacteria in the North Branch of Oak Creek ranged from below the limit of detection to 59,000 cells per 100 ml, with a median value of 225 cells per 100 ml and a mean value of 4,184 cells per 100 ml.

Figure 4.54 shows concentrations of *E. coli* from sampling stations along the Mitchell Field Drainage Ditch. During the period 2007 through 2016, concentrations in this Creek ranged from below the limit of detection to 24,196 cells per 100 ml, with a median value of 245 cells per 100 ml and a mean value of 1,264 cells per 100 ml. Concentrations at the sampling station at Rawson Avenue (RM 0.8) were lower than those at College Avenue (RM 1.8), with median values of 172 cells per 100 ml and 300 cells per 100 ml, respectively. At both stations along the Mitchell Field Drainage Ditch where *E. coli* were sampled, a substantial fraction of the samples had concentrations higher than the State's recreational use water quality criteria. Concentrations in 34 percent of the samples collected from this stream were higher than the STV. Concentrations in 73 percent of the samples were higher than geometric mean criterion. Higher fractions of exceedances were seen at the upstream sampling station at College Avenue. A formal comparison of *E. coli* concentrations to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

No fecal coliform bacteria data are available for the Mitchell Field Drainage Ditch.

Concentrations of *E. coli* were also provided from one sampling station along Unnamed Creek No. 5. During the period 2007 through 2016, concentrations in this Creek ranged from below the limit of detection to 72,700 cells per 100 ml, with a median value of 213 cells per 100 ml and a mean value of 2,539 cells per 100 ml. A substantial fraction of the samples collected from Unnamed Creek 5 had concentrations higher than the State's recreational use water quality criteria. Concentrations in 36 percent of the samples collected from this stream were higher than the STV. Concentrations in 60 percent of the samples were higher than geometric mean criterion. Since *E. coli* was sampled at only one location along this stream, no comparison of upstream concentrations to downstream concentrations could be made. A formal comparison of *E. coli* concentrations to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

No fecal coliform bacteria data are available for Unnamed Creek No. 5.

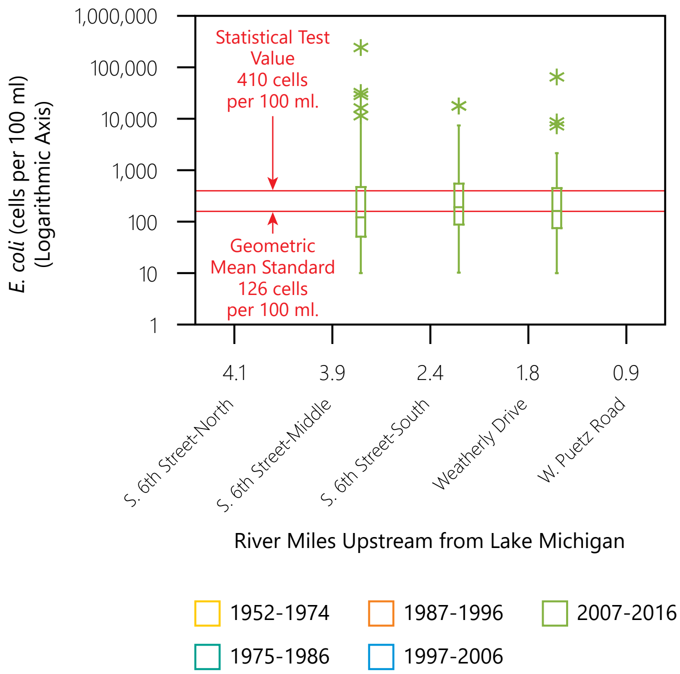
Sources of Fecal Bacteria in Surface Waters of the Oak Creek Watershed

Identifying the sources of fecal indicator bacteria present in surface waterbodies is useful in evaluating the risks posed by high concentrations of fecal indicator bacteria to recreational users. In addition, it enables municipal staff to prioritize the most important areas for further investigation, implement remedial measures such as illicit discharge detection and elimination, and install best management practices intended to reduce bacteria levels. Because the presence of fecal indicator bacteria is not a sufficient indication of a significant threat to human health, which would actually result from the presence of pathogens that are generally not directly measured, determining sources makes it possible for such a prioritization to be conducted on a basis of actions that reduce the likelihood of threats to human health. In particular, such identification allows higher priority to be given to sites where fecal indicator bacteria originate from human sources, which are more likely to indicate the possible presence of pathogens harmful to human health, than to bacteria originating from sources such as domestic and/or wild animals.

Stormwater runoff is known to carry human pathogens, and stormwater management systems can convey these pathogens into waterbodies.[198] Although human-sourced pathogens in stormwater management systems might be found in stormwater runoff, it is more likely that they enter storm sewers through "illicit" connections from the sanitary sewer systems such as infiltration from leaking sanitary sewers or cross connections between sanitary and storm sewers.[199] A preliminary step in detecting the presence of such illicit connections is to examine stormwater outfalls for the presence of flow during periods of dry weather.

Two recent efforts noted the presence of stormwater outfalls with dry-weather flow in the Oak Creek watershed: an assessment of instream and habitat conditions conducted by Commission staff and field surveys conducted by the RHD.

Figure 4.52
Concentrations of *E. coli* at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: City of Racine Public Health Department and SEWRPC

Commission staff conducted an assessment of instream and habitat conditions in streams of the Oak Creek watershed during 2016 and 2017. This survey examined conditions along 13 miles of the mainstem of Oak Creek, 5.5 miles of the North Branch of Oak Creek, and 1.8 miles of the Mitchell Field Drainage Ditch. As part of this survey, Commission staff geolocated stormwater outfall locations, assessed their condition, and noted whether water was flowing from the outfalls at the time of assessment.[200] The assessment dates for those outfalls with flowing water were compared to National Weather Service meteorological records for precipitation at MMIA to determine whether the flow was occurring during dry-weather conditions. Outfalls where flow was observed after at least 24 hours without precipitation are shown on Map 4.22. Outfalls where flow was observed after at least 72 hours without precipitation are shown on Map 4.23. A more complete description of and additional findings from the instream surveys was presented earlier in this chapter.

In order to identify sources of fecal contamination to streams in the Oak Creek watershed, the RHD conducted field surveys and collected samples from stormwater outfalls that discharge into Oak Creek and its tributaries in 2016.[201] Because of the large number of outfalls in the watershed, the RHD surveys were conducted at outfalls that were located within stream segments where there were large increases in average concentration of *E. coli* between sampling stations. All known stormwater outfalls in these segments were selected for further investigation. Additional outfalls located outside of these segments were selected for investigation based upon their size and proximity to a surface water site.

[198] *Stephen J. Gaffield, Robert L. Goo, Lynn A. Richards, and Richard J. Jackson, "Public Health Effects of Inadequately Managed Stormwater Runoff,"* American Journal of Public Health, *Volume 9, pages 1,527-1,533; Russell D. Arnone and Joyce P. Walling, "Waterborne Pathogens in Urban Watersheds,"* Journal of Water and Health, *Volume 5, pages 149-162, 2007.*

[199] *Elizabeth P. Sauer, Jessica L. VandeWalle, Melinda J. Bootsma, and Sandra L. McLellan, "Detection of the Human Specific* Bacteroides *Genetic Marker Provides Evidence of Widespread Sewage Contamination of Stormwater in the Urban Environment,"* Water Research, *Volume 45, pages 4,081-4,091, 2011.*

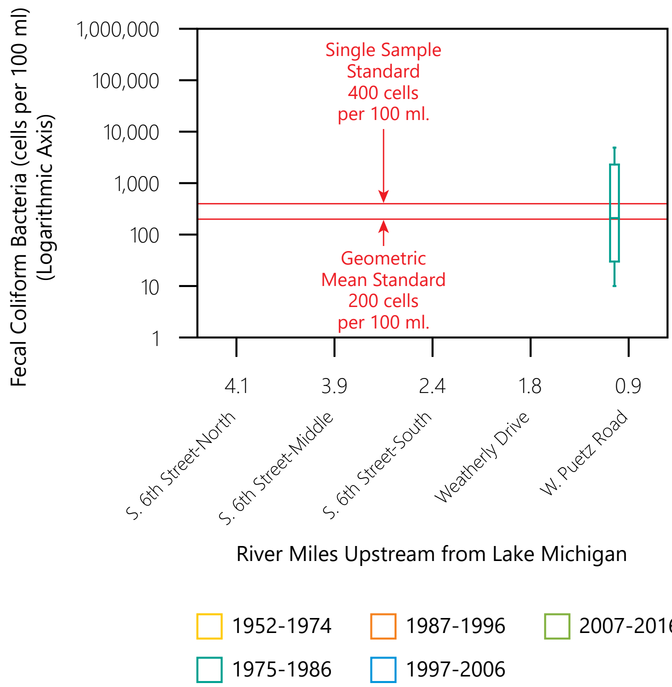
[200] *Appendix E presents an integration of the outfalls mapped during this survey with information provided by Milwaukee County, the municipalities of the watershed, and the City of Racine Public Health Department.*

[201] *Jacob Jozefowski et al., 2017,* op. cit.

The RHD prioritization identified 111 outfalls as candidates for investigation. A total of 106 of these were selected for field surveys. Most of these outfalls were located within four portions of the watershed:

- The mainstem of Oak Creek between S. Pennsylvania Avenue and the confluence with Lake Michigan
- A 0.35-mile section of a tributary to the Rawson Avenue tributary to the North Branch of Oak Creek, immediately upstream from its confluence with the North Branch of Oak Creek
- The North Branch of Oak Creek upstream from Rawson Avenue
- A portion of the upper reaches of the mainstem of Oak Creek near W. Southwood Drive

Figure 4.53
Concentrations of Fecal Coliform Bacteria at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources and SEWRPC

Field surveys were conducted by the RHD at the outfalls during dry-weather conditions in which no precipitation had occurred within the 24-hour period prior to visiting the outfall. During the surveys, the outfalls were examined to determine whether any flow was present. Surveys were conducted between July 7, 2016 and August 11, 2016. Of the 106 outfalls surveyed, a total of 31 outfalls were found to have dry-weather flow. Flow samples were collected from 24 of these outfalls under both wet- and dry-weather conditions (see Map 4.24). These samples were analyzed for a number of water quality constituents, including water temperature, turbidity, pH, specific conductance, total chlorine, detergents, copper, phenols, and *E. coli*, in order to determine the sources of dry-weather flow. Depending on the results, this combination of water quality constituents can provide clues as to whether the source of the discharge consists of sewage, septage, washwater, liquid wastes, tap water, landscape irrigation water, or groundwater. Samples were not collected from the remaining seven outfalls either due to a lack of flow during sampling or because conditions in the stream at or near the mouth of the outfall were judged by the field staff to be unsafe.

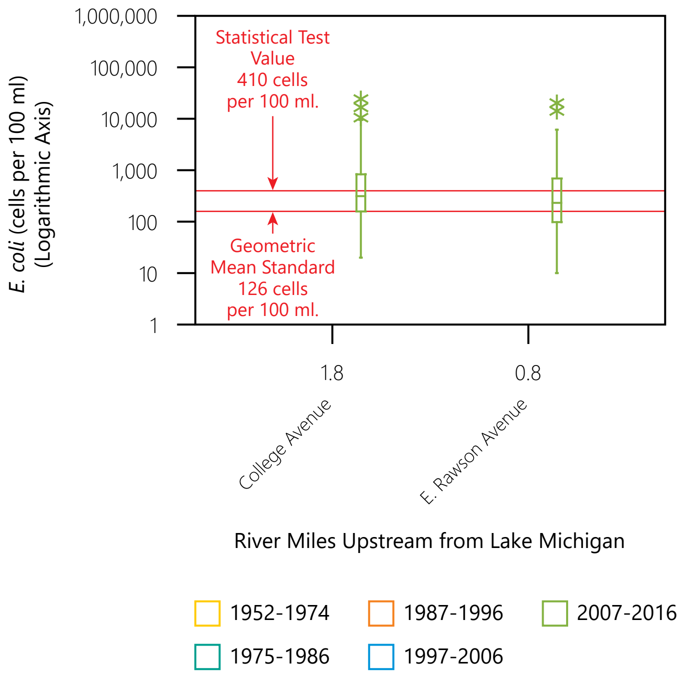
Based on the results of the outfall sampling, the RHD applied microbial source tracking techniques to 20 outfalls showing dry-weather flow. Microbial source tracking is a set of methods that attempt to determine whether fecal indicator bacteria such as *E. coli* originate from a human, domestic animal, or wildlife source. It relies upon the idea that fecal bacteria from a particular host have certain unique characteristics and that these characteristics can be used to identify the source of the contamination. Examples of these characteristics include bacterial genes that are associated with a particular host such as humans or individual animal species. RHD's microbial source tracking used two bacterial indicators: human-associated *Bacteroides* and human-associated *Lachnospiraceae*. Two indicators were used because the human-associated genes in these organisms can sometimes be associated with bacteria originating from animal hosts. The use of two bacterial groups gives greater assurance that detection of human-associated genes indicates sewage contamination and not contamination by an animal source. Based on this, RHD attributed the source of fecal contamination to human sources when high concentrations of both human-associated *Bacteroides* and human-associated *Lachnospiraceae* were present in a sample.[202] When high concentrations of human-associated *Lachnospiraceae* and low concentrations of human-associated *Bacteroides* were found, RHD

[202] *Kwabeba A. Boateng,* Assessment of the Impact of Storm Water Outfalls on The Oak Creek, *Masters Thesis, University of Surrey, Guildford, Surrey, United Kingdom, August 2016.*

attributed the fecal contamination to a canine source.[203] Similarly, when low concentrations of human-associated *Lachnospiraceae* and high concentrations of human-associated *Bacteroides* were found, RHD attributed the fecal contamination to raccoons.

Concentrations of human-associated *Bacterioides* and human-associated *Lachnospiraceae* were measured in 58 samples collected from 20 stormwater outfalls. Samples were collected under both dry-weather and wet-weather conditions, with 41 samples collected during dry-weather periods and 17 samples collected during wet weather periods.[204] The tests found seven outfalls that showed evidence of contamination with human sewage.[205] The locations of these outfalls are shown on Map 4.24. Four of these outfalls discharge into the mainstem of Oak Creek in the City of South Milwaukee. The other three discharge into a tributary to the Rawson Avenue tributary to the North Branch of Oak Creek in the City of Oak Creek. The tests also found five outfalls that showed evidence of contamination with canine fecal material. The locations of these outfalls are also shown on Map 4.24. Four of these outfalls discharge into the mainstem of Oak Creek in the City of South Milwaukee. The fifth discharges into the mainstem of Oak Creek in the City of Franklin. The twelve outfalls shown on Map 4.24 should be investigated further to determine and eliminate the sources of fecal contamination.

Figure 4.54
Concentrations of *E. coli* at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: City of Racine Public Health Department and SEWRPC

The results of the SEWRPC and RHD surveys may help explain the previously described complicated patterns of fecal indicator bacteria along streams in the Oak Creek watershed. For example, dry weather flow from three outfalls upstream of Southwood Drive (see Map 4.22) may be contributing to the high concentrations of *E. coli* observed in the mainstem of Oak Creek at the sampling station at Southwood Drive (RM 12.8, see Figure 4.50). Microbial source tracking provides evidence that canine fecal material is likely being discharged from at least one of these outfalls (see Map 4.24). Further investigations should be conducted at these outfalls with a goal of finding and remediating the source of this contamination. Similarly, dry-weather flow from about eight outfalls located between Pennsylvania Avenue and 15th Avenue (see Map 4.22) may be contributing to the high concentrations of both *E. coli* and fecal coliform bacteria observed in the mainstem of Oak Creek at the sampling station at 15th Avenue (RM 2.8, see Figures 4.50 and 4.51). Microbial source tracking provides evidence that canine fecal material is likely being discharged from at least three of these outfalls and human fecal material is likely being discharged from at least one of them (see Map 4.24). Again, further investigations should be conducted at these outfalls with a goal of finding and remediating the source of this contamination, with a high priority being given to investigating outfall 72 due to evidence of the presence of human fecal material at this site.

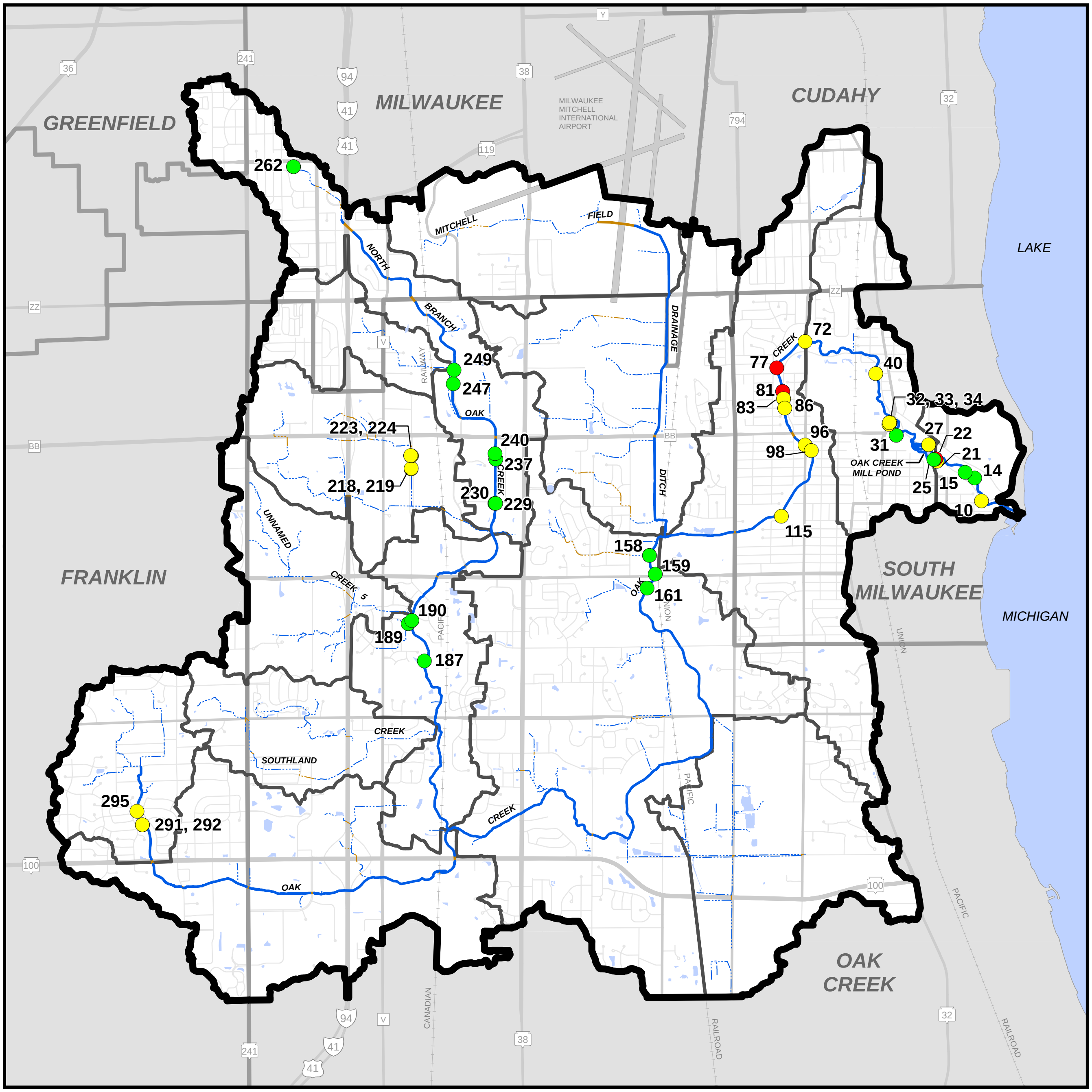
Dry weather flow from outfalls may also account for the increase in *E. coli* concentrations observed at the southernmost sampling station at S. 6th Street (RM 2.4) along the North Branch of Oak Creek (see Figure 4.52). Dry-weather flow was observed at three outfalls that discharge into the North Branch of Oak

[203] *It should be noted that this test is not sensitive enough to distinguish between wild canine species, such as coyotes and foxes, and domestic dogs.*

[204] *Jozefowsik et al. 2017,* op. cit.

[205] *Boateng 2016,* op. cit.

Map 4.22
Outfalls Where Flow Was Observed After at Least 24 Hours Without Rainfall: 2016-2017



● OUTFALL WITH FLOW OBSERVED DURING BOTH SEWRPC AND CITY OF RACINE PUBLIC HEALTH DEPARTMENT SURVEYS

● OUTFALL WITH FLOW OBSERVED DURING SEWRPC SURVEY

● OUTFALL WITH FLOW OBSERVED DURING CITY OF RACINE PUBLIC HEALTH DEPARTMENT SURVEY

52 OUTFALL SEQUENCE ID (SEE APPENDIX TABLE E.1)

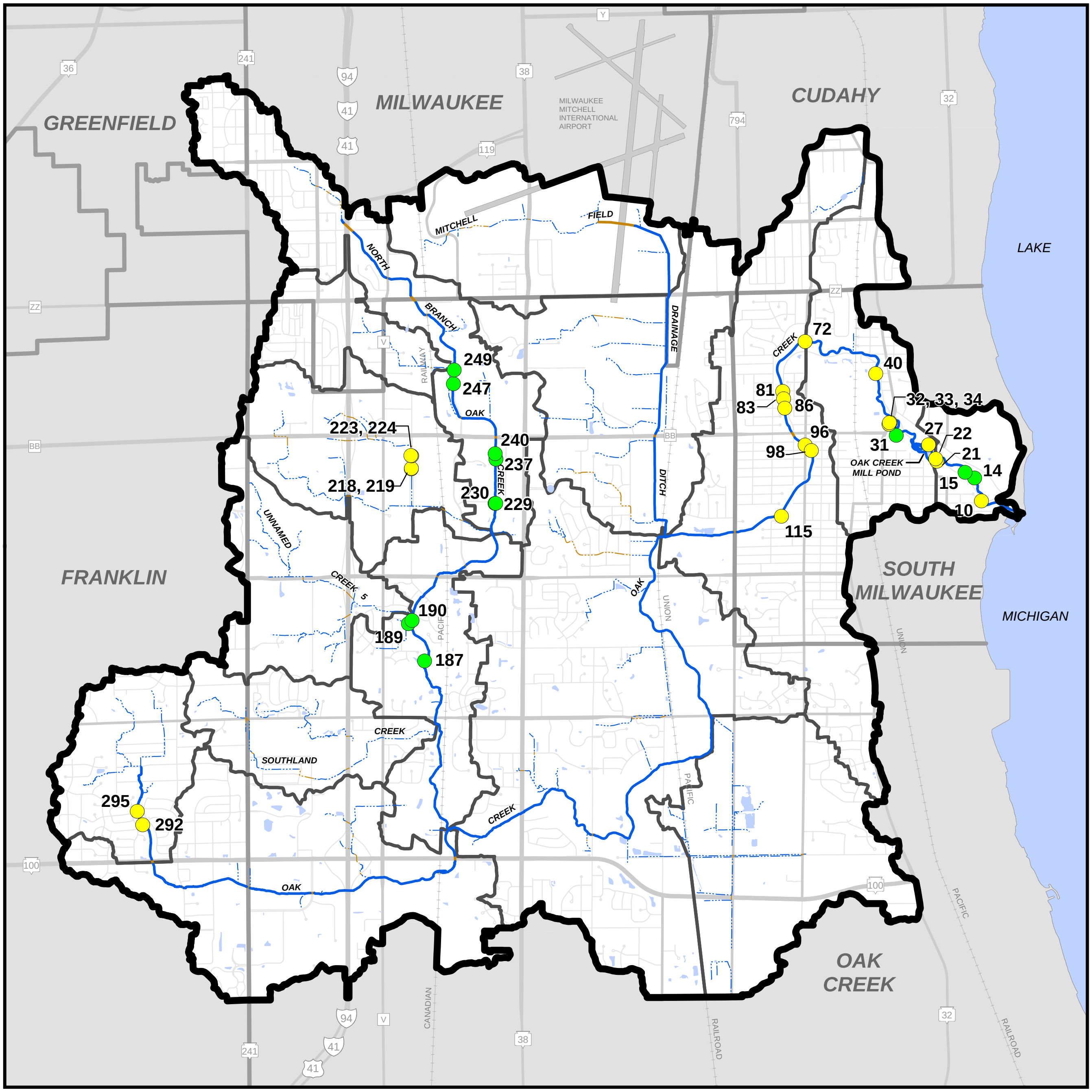
Note: The City of Racine Public Health Department also reported dry weather flow at outfalls with sequence identification numbers of 74, 93, 100, 102, 104, 106, and 222; however, the date of observation could not be determined, thus the number of hours without rainfall could not be determined. See Appendix Table E.1 for more information on these outfalls.

N

0 0.25 0.5 1 Mile

Source: City of Racine Public Health Department and SEWRPC

Map 4.23
Outfalls Where Flow Was Observed After at Least 72 Hours Without Rainfall: 2016-2017



OUTFALL WITH FLOW OBSERVED DURING BOTH SEWRPC AND CITY OF RACINE PUBLIC HEALTH DEPARTMENT SURVEYS (NONE)

OUTFALL WITH FLOW OBSERVED DURING SEWRPC SURVEY

OUTFALL WITH FLOW OBSERVED DURING CITY OF RACINE PUBLIC HEALTH DEPARTMENT SURVEY

33 OUTFALL SEQUENCE ID (SEE APPENDIX TABLE E.1)

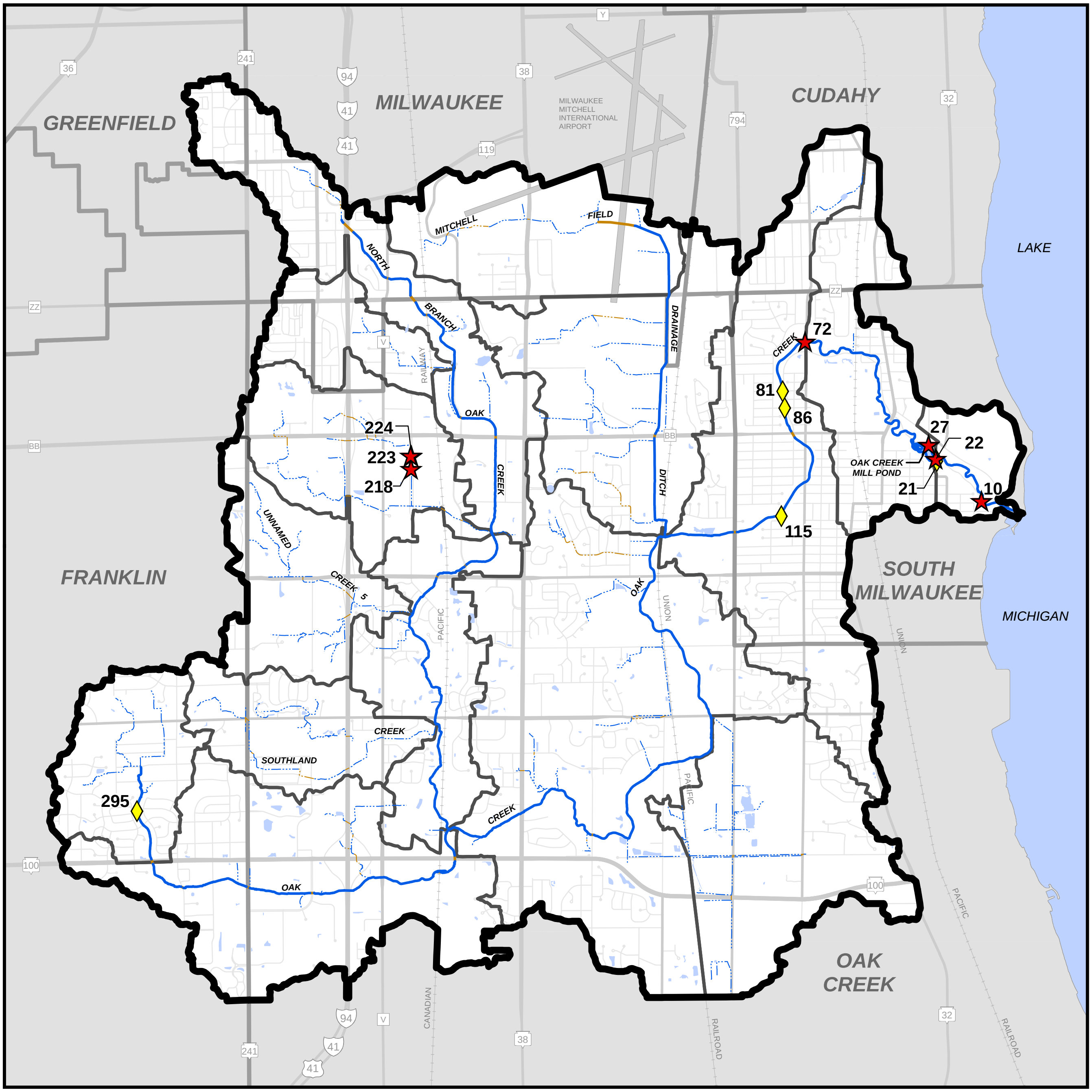
Note: The City of Racine Public Health Department also reported dry weather flow at outfalls with sequence identification numbers of 74, 93, 100, 102, 104, 106, and 222; however, the date of observation could not be determined, thus the number of hours without rainfall could not be determined. See Appendix Table E.1 for more information on these outfalls.

N

0 0.25 0.5 1 Mile

Source: City of Racine Public Health Department and SEWRPC

Map 4.24
Outfalls with Human or Canine Sources of Fecal Contamination: 2016-2017



★ OUTFALLS WITH HUMAN FECAL CONTAMINATION

◊ OUTFALLS WITH CANINE FECAL CONTAMINATION

11 OUTFALL SEQUENCE ID (SEE APPENDIX TABLE E.1)

N

0 0.25 0.5 1 Mile

Source: City of Racine Public Health Department and SEWRPC

Creek upstream of this sampling station and at four outfalls that discharge into a tributary to the Rawson Avenue Tributary that discharges into the North Branch of Oak Creek upstream of this sampling station (see Map 4.22). Microbial source tracking provides evidence that human fecal material is likely being discharged from at least three of the outfalls that discharge into the tributary stream (see Map 4.24). Further investigations should be conducted at these outfalls with a goal of finding and remediating the source of this contamination, with a high priority being given to investigating outfalls 218, 223, and 224 due to evidence of the presence of human fecal material at these sites.

Giardia *and* Cryptosporidium

Samples have been collected in the Oak Creek watershed for two disease-causing organisms. *Giardia* and *Cryptosporidum* are protozoan parasites that can infect humans and other vertebrate animals. Both of these organisms can infect the small intestine, causing gastrointestinal illness, including abdominal cramps and diarrhea. *Cryptosporidium* can also sometimes infect the respiratory tract, causing respiratory illness. Cysts of both of these parasites are excreted in the feces of infected individuals. Infection can occur as a result of ingestion of water contaminated with cysts, which can occur inadvertently through contact with contaminated water during recreational activities. Clinical studies have shown that ingestion of as few as 10 *Giardia* cysts can result in infection.[206] Similarly, clinical studies have shown that low doses of *Cryptosporidium* cysts can result in infection.[207]

During 2004 and 2005, water samples were collected at the USGS stream gage and sampling station at 15th Avenue and analyzed for the presence of *Giardia* and *Cryptosporidium* cysts. Concentrations of cysts of both parasites were below the limit of detection in about two-thirds of the samples collected. The maximum concentration of *Giardia* cysts detected during this time period was 100 cysts per 100 liters. The maximum concentration of *Cryptosporidium* cysts detected was 242 cysts per 100 liters.

*Chlorophyll-*a

Chlorophyll-*a* is a pigment found in all photosynthetic organisms, including plants, algae, and photosynthetic bacteria. Measurements of chlorophyll-*a* are used to estimate the biomass of phytoplankton suspended in the water column. It is important to keep in mind that this is an estimate of the entire phytoplankton community. Chlorophyll-*a* concentration can vary depending on several factors other than the total biomass of phytoplankton present, including which species are present, the amount of light available, the ambient temperature, and nutrient availability. High concentrations of chlorophyll-*a* are indicative of poor water quality and are often associated with high turbidity, poor light penetration, and nutrient enrichment. In addition, chlorophyll-*a* concentrations will be high during blooms of harmful algae, such as toxic cyanobacteria.

Figure 4.55 shows chlorophyll-*a* concentrations at sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, chlorophyll-*a* concentrations in Oak Creek ranged between 0.08 micrograms per liter (μg/l) and 87.4 μg/l, with a median value of 3.78 μg/l and a mean value of 5.71 μg/l. During the period 2007 through 2016, concentrations generally increased from upstream to downstream, with median concentrations ranging from 2.1 μg/l at the W. Ryan Road sampling station (RM 10.1) to 5.8 μg/l at the sampling station along the Oak Creek Parkway east of Lake Drive (RM 0.3). Concentrations of chlorophyll-*a* showed considerable variability, with concentrations in excess of 100 μg/l being occasionally reported. The maximum concentration reported in the watershed was 179 μg/l.

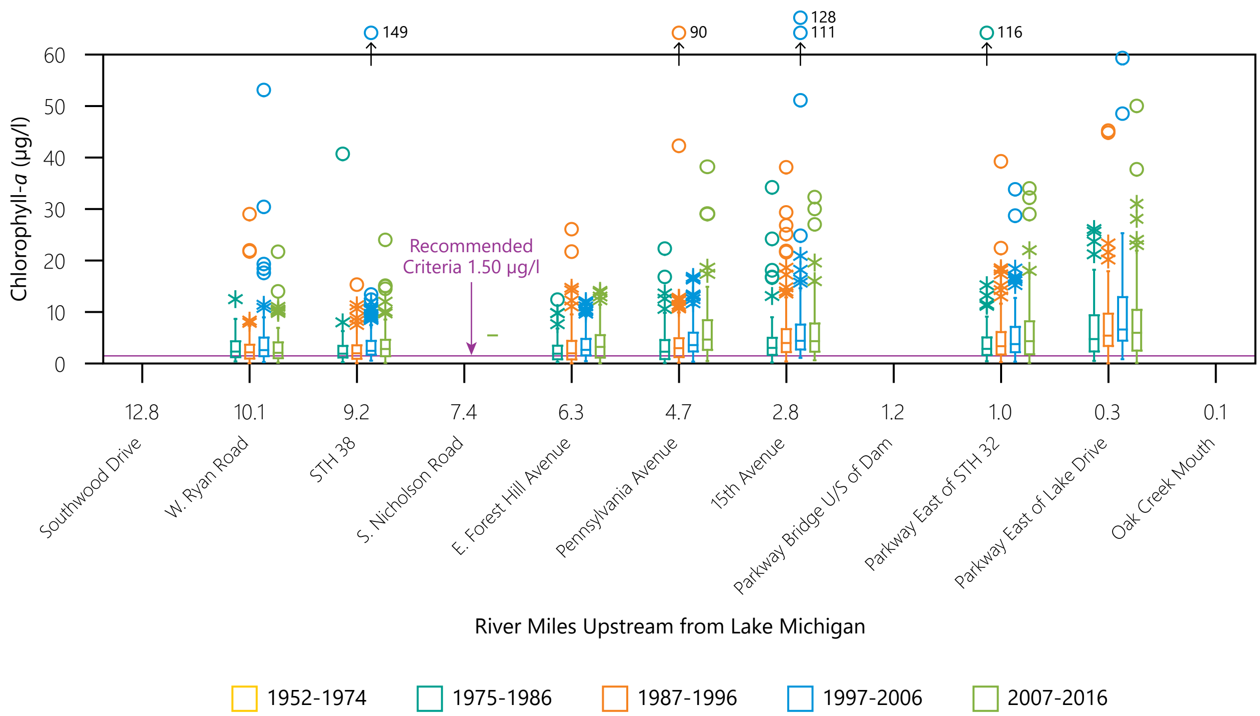
At most sampling stations, concentrations of chlorophyll-*a* increased over time (see Figure 4.55). For example, median concentrations of chlorophyll-*a* at the sampling station at E. Forest Hills Avenue (RM 6.3) increased from 1.89 μg/l during the period 1975 through 1986 to 3.31 μg/l during the period 2007 through 2016. There

---

[206] *R.C. Rendtorff, "The Experimental Transmission of Human Intestinal Protozoan Parasites. II.* Giardia lamblia *cysts given in capsules,"* American Journal of Hygiene, *volume 59, pages 209-220, 1954; R.C. Rendtorff, "The Experimental Transmission of* Giardia lamblia *among Volunteer Subjects," In: W. Jakubowski and J.C. Hoff (eds.),* Waterborne Transmission of Giardiasis, *U.S. Environmental Protection Agency, EPA-600/9-79-001, 1979.*

[207] *H. DuPont, C. Chappell, C. Sterling, P. Okhuysen, J. Rose, and W. Jakubowski, "The Infectivity of* Cryptosporidium parvum *in Healthy Volunteers,"* New England Journal of Medicine, *volume 332, pages 855-859, 1995; P. Okhuysen, C. Chappell, J.H. Crabb, C.R. Sterling, and H.L. DuPont, "Virulence of Three Distinct* Cryptosporidium parvum *Isolates for Healthy Adults,"* Journal of Infectious Diseases, *Volume 180, pages 1275-1281, 1999.*

Figure 4.55
Concentrations of Chorophyll-*a* at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC

were three exceptions to this generalization. While overall increasing trends in the median concentrations of chlorophyll-*a* were observed at the sampling stations at STH 38 (RM 9.2), 15th Avenue (RM 2.8), and the Oak Creek Parkway east of Lake Drive (RM 0.3), the median concentrations during the period 2007 through 2016 at these stations were lower than those observed during the period 1997 through 2006.

It is not clear what accounts for the increase over time in chlorophyll-*a* concentration in the Oak Creek mainstem. As previously discussed, chlorophyll-*a* concentrations give a rough estimate of the biomass of phytoplankton suspended in the water column. Because phytoplankton growth responds to nutrient concentrations, typically differences in the amount of phytoplankton can be attributed to changes in nutrient concentrations among the sampling sites. This does not seem to be the case. While there have been changes in nutrient concentration over time at each of the sampling sites, the pattern of the changes does not correspond well to the pattern of changes in chlorophyll-*a* concentration. This lack of correspondence is seen when chlorophyll-*a* concentrations are compared to total phosphorus, dissolved phosphorus, or total nitrogen. During most analysis periods, few correlations were found between concentrations of chlorophyll-*a* and concentrations of any of these three nutrients. The exception to this generalization occurred during the period 2007 through 2016 when statistically significant correlations were found between total phosphorus concentration and chlorophyll-*a* concentration at five of the seven sampling stations monitored by MMSD. These correlations were weak, accounting for less than 15 percent of the variation in chlorophyll-a concentrations.

The increase in chlorophyll-*a* concentration over time might reflect changes in the composition of the phytoplankton community in the Creek. Chlorophyll-*a* concentration represents a combined measure of all the phytoplankton species suspended in the water. Each of these species has its own characteristic combination of pigments, with cells from different species containing different amounts of chlorophyll-*a*. The physiological requirements of phytoplankton species and their responses to changes in environmental conditions differ from one another. Because of this, changes in chlorophyll-*a* could reflect changes in the composition of the phytoplankton community, with some species becoming more abundant while other become less abundant. Numerous factors can drive such changes in community composition. These factors include changes in nutrient concentrations, changes in water temperature, changes in the availability of light, and changes in grazing pressure by zooplankton. Because no phytoplankton community composition data are available for Oak Creek, it is not known whether the trend toward increasing chlorophyll-*a* concentrations in the Creek reflect changes in phytoplankton community composition.

It should be noted that the data shown in Figure 4.55 may not reflect conditions within much of the Mill Pond. The data shown in the figure probably give a reasonable representation of chlorophyll-*a* concentrations in the portions of the pond through which water is actively flowing, because the residence time of water in that portion of the pond is quite short. Limited data collected during the summer suggest that chlorophyll-*a* concentrations in portions of the pond containing stagnant water may be higher. The median concentrations of samples collected during summer over the period 2007 through 2016 in the northeast basin of the pond was 9.12 μg/l. Median chlorophyll-*a* concentrations during summer over the same period at the sampling stations above and below the pond were 4.05 μg/l and 3.72 μg/l, respectively.

Figure 4.56 shows seasonal concentrations of chlorophyll-*a* at the Oak Creek mainstem sampling station at Pennsylvania Avenue during the period 2007 through 2016. The concentrations that were observed during spring months tended to be higher than those observed during summer months. Similarly, concentrations during summer tended to be higher than those observed during the fall. Few winter data were available at any station. This pattern occurred at all seven sampling stations along the mainstem of Oak Creek at which chlorophyll-*a* data are available.

No recent data for chlorophyll-*a* were available from sampling stations along any tributary stream in the Oak Creek watershed.

<u>Chemical and Physical</u>

Water Temperature

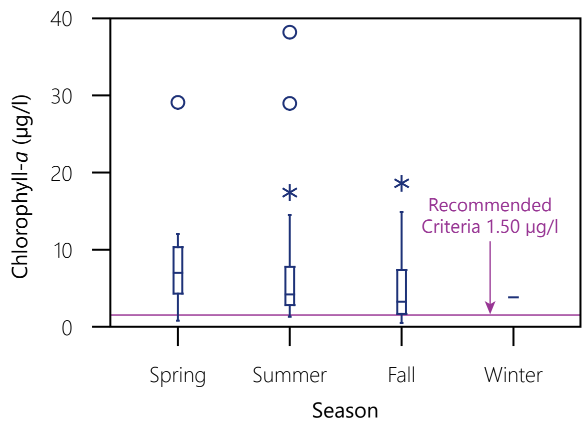
The temperature of a waterbody is a measure of the heat energy it contains. Water temperature drives numerous physical, chemical, and biological processes in aquatic systems. Processes affected by temperature include the solubility of substances in water, the rates at which chemical reactions progress, metabolic rates of organisms, the settling rates of small particles, and the toxicity of some substances. For example, the solubility of many gases in water decreases as water temperature increases. The solubility of oxygen in water is an example of this—colder water can hold more dissolved oxygen. By contrast, the solubility of many solids in water increases as water temperature increases. Temperature is a major determinant of the suitability of waterbodies as habitat for fish and other aquatic organisms. Each species has a range of temperatures that it can tolerate and a smaller range of temperatures that is optimal for its growth and reproduction. These ranges vary for different species. As a result, very different biological communities may be found in otherwise similar waterbodies experiencing dissimilar temperature regimes. In Wisconsin for example, high-quality warmwater systems are characterized by many native species. Cyprinids, darters, suckers, sunfish, and percids typically dominate the fish assemblages in these streams. In contrast to warmwater streams, coldwater systems are characterized by few native species, with salmonids such as trout and cottids such as sculpin dominating the community. These streams lack many of the taxonomic groups that are important in high-quality warmwater streams.

Air temperatures affect water temperatures, especially in smaller waterbodies. Solar heating strongly influences water temperature and factors that affect the incidence of light on waterbodies or light penetration through waterbodies can affect temperature. The presence of suspended material or colored dissolved material in the water column can increase the absorption of light by the waterbody, leading to heating. Water temperature follows a seasonal cycle, with lowest temperatures occurring during winter and highest temperatures occurring during summer. Water temperature can also be affected by discharges of groundwater, stormwater runoff, and discharges from point sources.

Wisconsin has promulgated two water quality criteria for water temperature: an acute criterion based upon the daily maximum temperature and a sublethal criterion based upon the average of the daily maximum temperature over the calendar week. The values of these criteria vary with the stream's size and natural community type and the month of the year. These criteria are given in Table 4.17.

Two methods were used to monitor water temperature: grab sampling and continuous monitoring. Individual temperature readings were taken as part of collecting samples for chemical and biological water quality monitoring. This "grab sampling" typically occurred at the same frequency as the associated chemical and biological monitoring. Commission staff also deployed continuous temperature monitoring devices (temperature loggers) at 21 locations in the mainstem of Oak Creek and several tributary streams to measure water temperatures and at one site to monitor air temperatures. At most sites this monitoring was conducted between May 17, 2016, and October 10, 2017. These temperature loggers were programmed to record temperature in hourly increments. Additional temperature loggers were deployed during the summer and fall of 2019 to examine the effect of the Mill Pond on downstream waters. Table 4.19 and Map 4.21 describe the locations, river miles, and collection dates for those continuous monitoring devices.

Figure 4.56
Seasonal Concentrations of Chlorophyll-*a* in Oak Creek at Pennsylvania Avenue (RM 4.7): 2007-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC

Figure 4.57 shows continuously collected water temperatures from 10 sampling stations along the mainstem of Oak Creek upstream of the Mill Pond and in the Mill Pond. During the 528-day period over which these data were collected, water temperatures in the section of the mainstem of Oak Creek upstream from the Mill Pond ranged between about -0.3°C and 29.3°C, with a mean value of 13.6°C and a median value of 16.1°C. Water temperatures within the Mill Pond were often warmer during this period, ranging between about -2.0°C and 36.4°C, with a mean value of 14.9°C and a median value of 17.0°C.

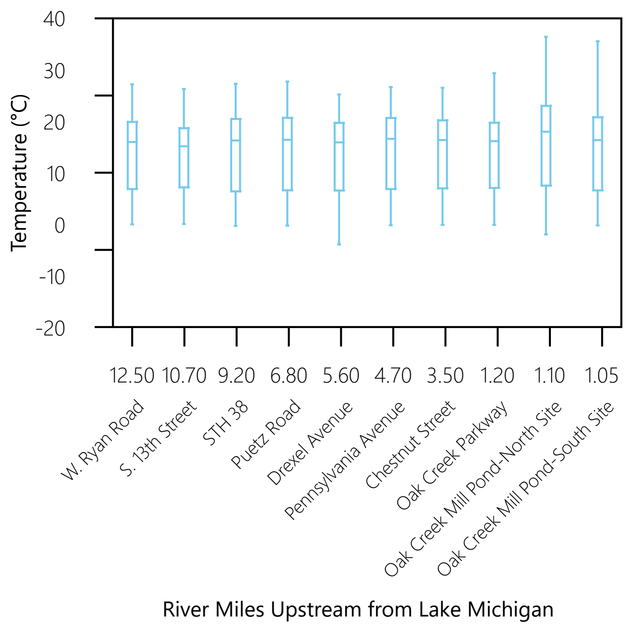
Water temperatures in the section of the mainstem of Oak Creek below the Mill Pond ranged between -11.9°C and 27.7°C; with a mean value of 14.1°C and a median value of 16.6°C. The extremely low minimum value was recorded by only one temperature logger. This minimum temperature indicates that the temperature logger was probably enclosed in ice for a portion of the winter. During the period over which water temperature was collected continuously, air temperature near the Drexel Avenue crossing of the mainstem (RM 5.6) ranged between 24.7°C and 31.9°C, with a mean value of 12.7°C and a median value of 15.3°C.

As indicated in Figure 4.57, water temperatures showed a complicated pattern along the length of the Creek. Median water temperatures at individual sampling stations ranged from 15.1°C at S. 13th Street to 16.6°C at Pennsylvania Avenue. Median water temperatures in the Mill Pond were higher, ranging between 16.3°C in the south lobe to 18.0°C in the north lobe. Median temperatures rose and fell along the length of the Creek, reaching local maxima at Puetz Road, Pennsylvania Avenue, and in the Mill Pond. Maximum water temperatures along Oak Creek followed the same general pattern as median water temperatures. It is likely that the differences among sites reflect a number of influences including the volume of discharge at that point in the Creek; the rate of flow; the presence of obstructions such as dams, drop structures, or debris jams; inputs of stormwater runoff through outfalls or overland flow; shading by riparian vegetation; and groundwater discharge.

An example of a portion of a continuous water temperature record is shown in Figure 4.58. This graph shows hourly water temperatures collected from the mainstem of Oak Creek at STH 38 (RM 9.2) from May 17, 2016, to October 31, 2016. It also shows the air temperature collected adjacent to the mainstem of Oak Creek near the Drexel Avenue crossing (RM 5.6) over the same time period. The continuously collected data show that air temperatures are major determinants of water temperatures. Air temperature affects water temperature on at least three different time scales. On a short time scale, daily fluctuations in water temperature at all sites tend to mirror those in air temperature. On average, the magnitudes of these daily fluctuations in water temperature are much less those in air temperature. During the period over which continuous temperature data were collected, the average difference between the daily maximum air temperature and the daily minimum air temperature was 9.6ºC. At sites along the mainstem of Oak

Creek upstream of the Mill Pond, the average differences between daily maximum and daily minimum water temperatures ranged between 1.8ºC and 3.3ºC, with higher average differences occurring at the furthest upstream site. The average differences between daily maximum and minimum water temperatures in the Mill Pond were higher, ranging between 3.2°C and 6.3°C. This higher daily variability reflects the fact that that portions of the Mill Pond resemble and behave more like a shallow lake system than a stream system. The average differences between daily maximum and daily minimum water temperatures at sites along the mainstem of Oak Creek downstream of the Pond were on the high end of those at sites upstream of the Pond, ranging between 2.7°C and 2.9°C. It should be noted that the averages at the sites downstream from the Pond are not strictly comparable to those from sites in or upstream of the Pond because the temperature sensor downstream of the Pond was relocated midway through the period over which data were collected.

Figure 4.57
Continuously Collected Water Temperature at Sites Along the Mainstem of Oak Creek: May 2016-October 2017



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: SEWRPC

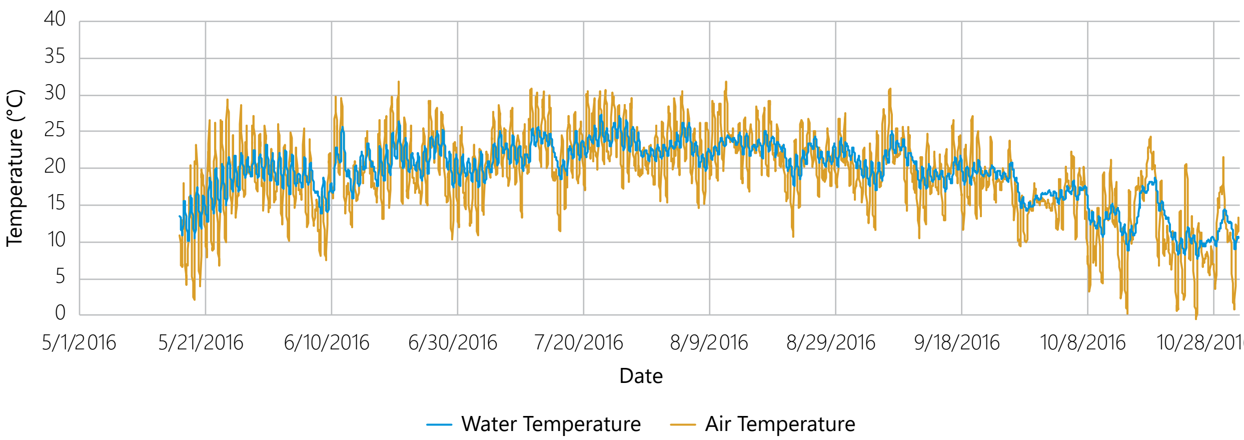
There are a couple reasons why daily fluctuations in water temperature are smaller than those in air temperature. First, water has a higher heat capacity than air. Because of this, a given amount of water must absorb more heat than the same amount of air to increase its temperature by a given amount. Similarly, a given amount of water must lose more heat than the same amount of air to decrease its temperature by a given amount. Second, discharges of groundwater into the stream will tend to reduce the magnitude of daily water temperature fluctuations. This is especially the case during low flow periods when groundwater discharge can constitute a substantial portion of streamflow.

Water temperatures also reflect air temperatures on longer time scales. Two of these time scales are apparent in the data shown in Figure 4.58. On time scales of a few days to a couple weeks, water temperatures increase and decrease in response to changes in air temperature accompanying synoptic weather events. For example, Figure 4.58 shows several decreases in water temperature that reflect decreases in air temperature that followed the passage of a cold front through the watershed. One such example occurred on October 8, 2016. Typically, on this time scale, there is a short time lag between changes in air temperature and water temperature. On an even longer time scale, the seasonal decrease in average air temperature during September and October was mirrored in decreases in water temperature at all of the sites. At these time scales, water temperatures at a particular site are dependent upon both the current and preceding daily air temperature conditions. So, as daily temperatures decrease over time, water temperatures within the streams tend to get cooler. Warming temperature patterns work the same way.

Figures 4.59 and 4.60 show the seasonal pattern of change in water temperatures at 10 sampling stations along the mainstem of Oak Creek. Water temperatures in the Creek are generally at their lowest during the months of December and January. They rise through the first half of the year, usually reaching maximum values in July or August. Following this, they decrease until they reach minimum values during the winter. As previously noted, this pattern is largely driven by changes in air temperature.

Figure 4.61 shows water temperatures from grab samples collected from the mainstem of Oak Creek over the period 1952 through 2016. At several stations, the data suggest that there may be a long-term trend toward increasing water temperatures in the Creek. This apparent effect should be interpreted with caution as it is not consistent among the seven sites with long-term data. In addition, the frequency of sampling and the months during which sampling was conducted has changed over the period depicted in the figure. Sampling also differed somewhat from site to site.

Figure 4.58
Hourly Water Temperature from the Mainstem of Oak Creek at STH 38 (RM 9.2): May-October, 2016



Source: SEWRPC

Water temperatures within the mainstem of Oak Creek usually complied with applicable water quality standards. With the exception of the Mill Pond, daily maximum water temperatures in the mainstem were less than the acute temperature criteria on more than 99 percent of the days assessed. Maximum daily water temperatures in the Mill Pond were below the acute criterion on about 82 percent of the days assessed. A more complicated pattern was observed when water temperatures in the mainstem of Oak Creek were compared to the sublethal temperature criterion. In the reaches of the Creek upstream from the Mill Pond, compliance with the weekly averages of daily maximum water temperatures were below the sublethal temperature criterion in 84 to 91 percent of the weeks assessed, with an average level of compliance of 87 percent. This level of compliance dropped to about 56 percent in the Mill Pond and was about 81 percent in the reach of Oak Creek downstream of the Mill Pond. A formal comparison of water temperature to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

As previously discussed, continuous monitoring of water temperature showed that the mean water temperature within the Mill Pond was higher than that in the section of the mainstem of Oak Creek upstream from the Mill Pond. In addition, this monitoring found that the mean water temperature in the section of Oak Creek downstream of the Mill Pond was higher than that in the upstream section but lower than that in the Mill Pond. This poses a question as to whether the presence of the Mill Pond is warming downstream reaches of the mainstem of Oak Creek.

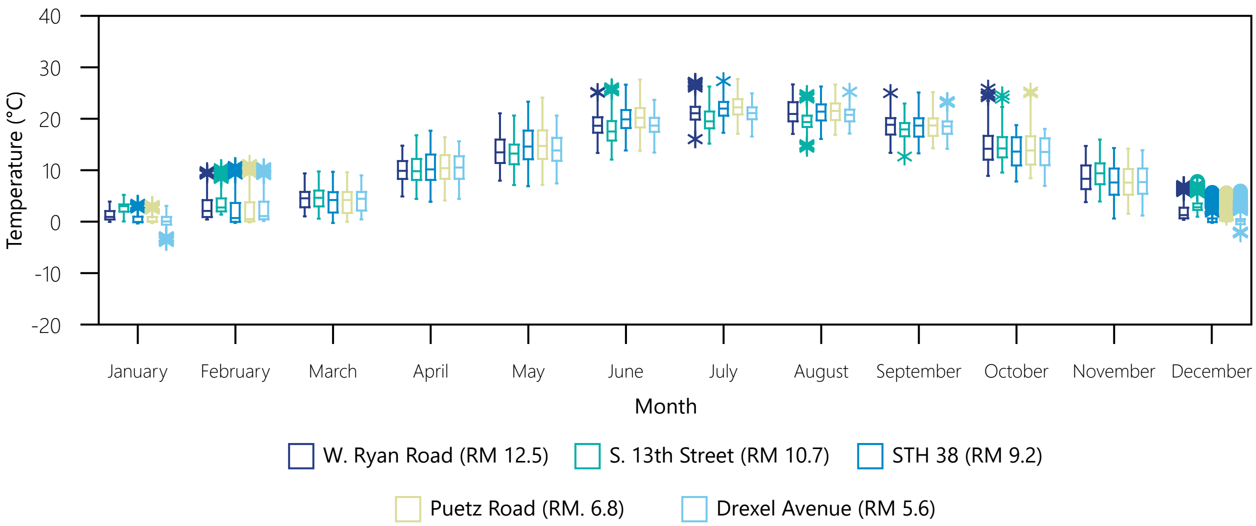
Small impoundments created by small, surface-release dams[208] are generally thought to warm downstream waters due to warming of water within the impoundment by solar heating and the mass of water within the impoundment diluting cooler subsurface flows.[209] The results of studies examining this effect vary. Some studies have found that small-surface release dams have a warming effect on downstream waters.[210] Those studies that found an effect and examined longitudinal effects found that this warming can persist

[208] *The inoperability of the gate in the Mill Pond dam effectively makes this dam a surface release dam.*

[209] *A. Bednarek, "Undamming Rivers: A Review of the Ecological Impacts of Dam Removal," Environmental Management, volume 27, pages 803-814, 2001.*

[210] *J. Lessard and D. Hayes, "Effects of Elevated Water Temperature on Fish and Macroinvertebrate Communities below Small Dams," River Research and Applications, volume 19, pages 721-732, 2003; S. Saila, D. Poyer, and D. Aube, Small Dams and Habitat Quality in Low Order Streams, Report to the Wood-Pawcatuck Watershed Association, Hope Valley, Rhode Island, 2005, wpwa.org/reports/Small_Dam_Study_2005.pdf (accessed 1/23/2020); P.A. Zaidel, Impacts of Small, Surface-release Dams on Stream Temperature and Dissolved Oxygen in Massachusetts, Master's Thesis, University of Massachusetts-Amherst, Amherst, Massachusetts, 2018.*

Figure 4.59
Monthly Continuously Collected Water Temperature at Upstream Sites Along the Mainstem of Oak Creek: May 2016-October 2017



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: SEWRPC

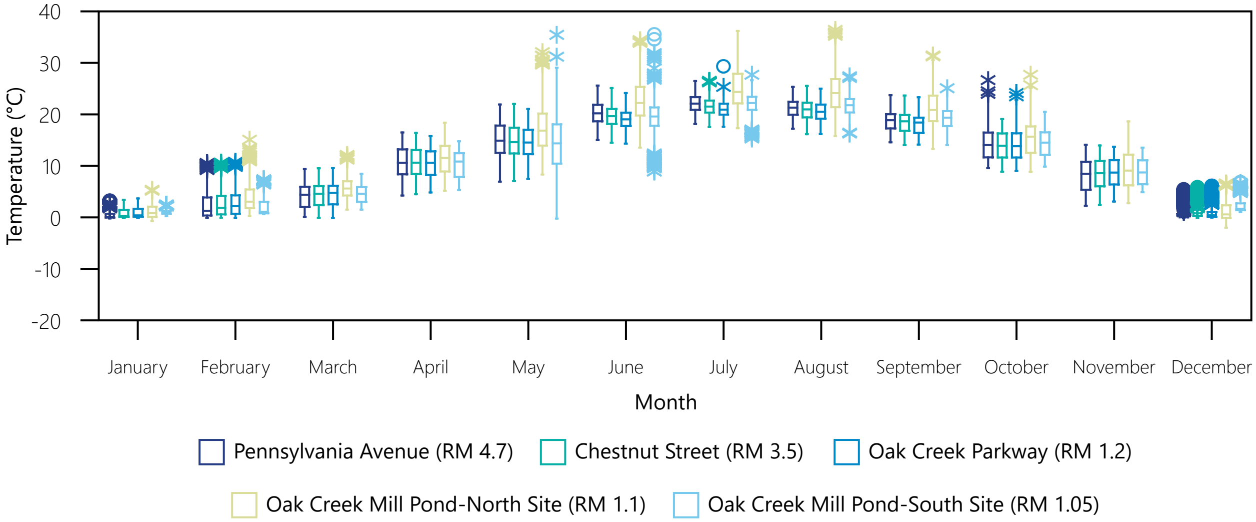
for a long distance downstream of a dam.[211] Other studies have found little to no impact of these dams on downstream water temperatures.[212]

During the summer of 2019, Commission staff deployed eight temperature loggers in Oak Creek upstream of, within, and downstream of the Mill Pond to examine whether the presence of the Mill Pond acts to warm downstream reaches of Oak Creek. These temperature loggers were programmed to record temperature in hourly increments. The locations where the temperature loggers were placed are shown on Map 4.25. This map also shows the path water takes as it flows through the pond. The temperature loggers recorded water temperatures between June 7 and October 10, 2019. Two problems were discovered with the temperature loggers that required adjustments to the data. First, while visiting the site on July 24, Commission staff discovered that the temperature logger located in the downstream channel within the pond (Logger F) had been removed from the water and was recording air temperature. Examination of the temperature records from this and the other loggers indicated that Logger F was exposed to air between June 26 and July 24, 2019. To account for this, data from all of the temperature loggers from the period during which Logger F was outside of the water were excluded from the analysis. Second, during the final recovery and downloading of data from the temperature loggers, staff found that the most downstream temperature logger (Logger I) had disappeared. Data from this logger were only available to August 20, 2019, the date of an interim download. Comparisons involving this logger reflect the period June 7-25, July 25-August 20, 2019.

[211] *J.J. Fraley, "Effects of Elevated Stream Temperatures below a Shallow Reservoir on Cold-water Macroinvertebrate Fauna, pages 257-272 in J. V. Ward and J. A. Stanford, editors, The Ecology of Regulated Streams, Plenum Press, New York,1979; Lessard and Hayes, op. cit.; C.J. Bellucci, M. Becker, and M. and Beauchene. "Effects of Small Dams on Aquatic Biota in Two Connecticut Streams." Connecticut Department of Energy and Environmental Protection, 2011; W. Dripps, and S.R. Granger, "The Impact of Artificially Impounded, Residential Headwater Lakes on Downstream Water Temperature," Environmental Earth Sciences, volume 68, pages 2,399-2,407, 2013.*

[212] *K. Bushaw-Newton, D. Hart, J. Pizzuto, J. Thomson, J. Egan, J. Ashley, T. Johnson, R. Horwitz, M. Keeley, J. Lawrence, D. Charles, C. Gatenby, D. Kreeger, T. Nightengale, R. Thomas, and D. Velinsky, "An Integrative Approach towards Understanding Ecological Responses to Dam Removal: The Manatawny Creek Study," Journal of the American Water Resources Association, volume 38, pages 1,581-1,599, 2002; E. Stanley., M. Luebke, M. Doyle, and D. Marshall, "Short-term Changes in Channel, Form and Macroinvertebrate Communities Following Low-head Dam Removal," Journal of the North American Benthological Society, volume 21, pages 172-187, 2002; S.C.F. Smith, S.J. Meiners, R.P. Hastings, T. Thomas, and R.E. Colombo, "Low-head Dam Impacts on Habitat and the Functional Composition of Fish Communities," River Research and Applications, volume 33, pages 680-689, 2017.*

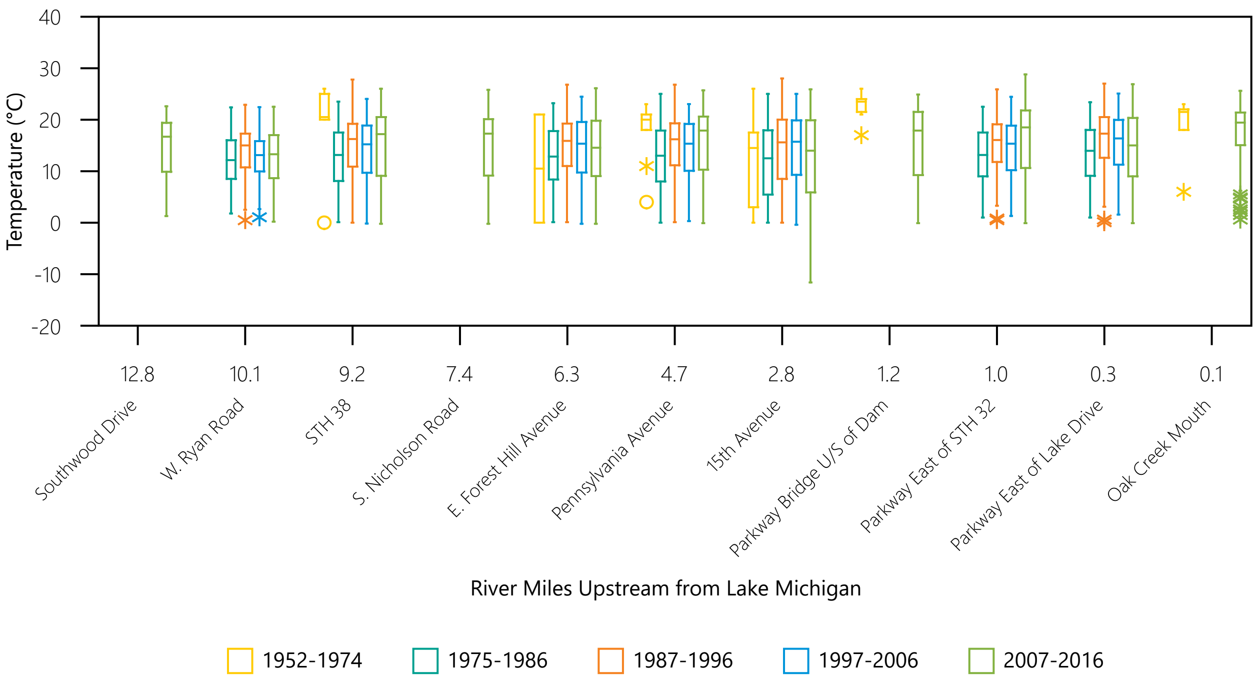
Figure 4.60
Monthly Continuously Collected Water Temperature at Downstream Sites Along the Mainstem of Oak Creek: May 2016-October 2017



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: SEWRPC

Figure 4.61
Water Temperature at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

Map 4.25
Continuous Temperature Monitoring Sites in Oak Creek Upstream, Within, and Downstream of the Mill Pond: June 7 through October 10, 2019

Source: SEWRPC

Figure 4.62 shows six comparisons of water temperatures simultaneously collected from pairs of temperature loggers. In each graph, the x-axis shows the water temperature at the site of the logger that was located farther upstream. The y-axis shows the water temperature at the site of the logger that was located farther downstream. When the water temperature was the same at both locations, the point lies along the red line on the graph. Points above the red line indicate that the temperature was higher at the downstream location. Points below the red line indicate that the temperature was lower at the downstream location.

Panel A in Figure 4.62 compares water temperatures upstream of the Mill Pond to those in the channel immediately downstream of the Pond. Upstream temperatures were taken in the new channel that developed following obstruction of the main channel by debris jams (Logger B on Map 4.25). Downstream temperatures were taken in the channel where the Parkway crosses the Creek below the Pond (Logger H). Water temperatures were higher in the channel downstream of the Pond, indicating that heating of water is occurring in the Mill Pond and/or the sections of the Creek between the two temperature logger sites.

Panel B in Figure 4.62 compares water temperatures in the upstream channel within the Mill Pond (Logger D) to those in the stream channel immediately downstream of the Pond (Logger H). The pattern shown in this panel is almost identical to that shown in Panel A. This indicates that little of the heating is occurring in the channel upstream of the Pond or within the upper portion of the upstream channel within the Pond. This largely reflects shading of this section of the channel by trees in the riparian area.

Panel C in Figure 4.62 compares water temperatures in the upstream channel within the Mill Pond (Logger D) to those in the downstream channel within the Pond (Logger F). As shown on Map 4.25, both temperature loggers were placed in the main path of water flow through the Mill Pond. The panel shows that water temperatures within the Pond were higher in the downstream channel than in the upstream channel. This indicates that heating is occurring within the Pond.

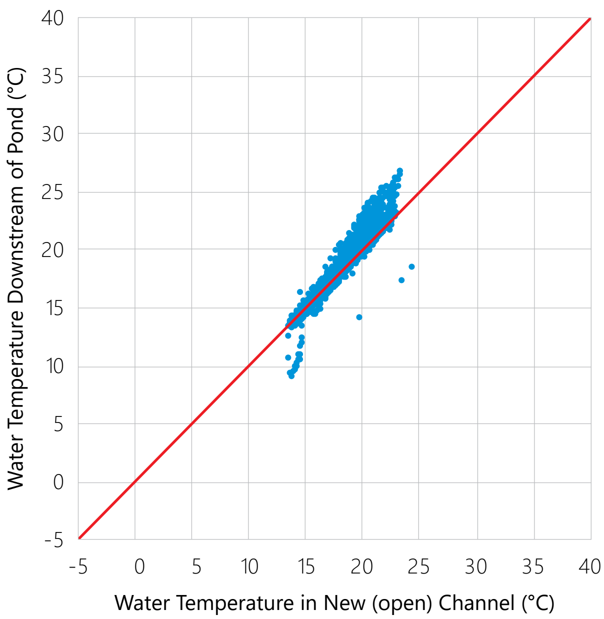
Considerable heating is occurring in the north lobe of the Mill Pond. Panel D in Figure 4.62 compares water temperatures in the upstream channel within the Mill Pond (Logger D) to those in the north lobe of the Pond (Logger E). Temperatures in the north lobe can be as much as 8°C warmer than those in the upstream channel. Much of the heat captured in the north lobe does not appear to be flowing out of the Pond into downstream sections of Oak Creek. First, comparison of Panel B with Panel D shows that the temperature difference between the upstream channel in the Pond and the north lobe is considerably greater than the temperature difference between the upstream channel in the Pond and the channel downstream of the Pond. In addition, the comparison of water temperatures between the north lobe of the Pond (Logger E) to those in downstream channel within the Pond (Logger F) shown in Panel E indicates that water temperatures in the downstream channel within the Pond are consistently lower than those in the north lobe. During low flows there appears to be little mixing between water flowing through the Mill Pond and water in the north lobe of the Pond. This was indicated by dye testing that showed most flow from upstream did not enter the north lobe of the Pond and that water flowing through the Pond did not disperse into the north lobe.[213] While the north lobe may contribute some heat to downstream areas throughout the summer, it is likely that the largest contribution of heat from north lobe occurs during high water periods, such as during storm events, when the normal pattern of flow through the Pond is altered.

Similar heating is also occurring in the south lobe of the Mill Pond. Temperatures in this portion of the Pond (Logger G) can be as much as 7°C warmer than those in the upstream channel (Logger D). They were also warmer than those in the downstream channel in the Pond (Logger F) and at the Parkway below the Mill Pond (Logger H). Water temperatures in the south lobe were slightly cooler than those in the north lobe. The difference between the mean and maximum temperatures at these sites were about 1.9°C and 2.6°C, respectively. Much of the heat captured in the south lobe of the Pond does not appear to be flowing out of the Pond into downstream sections of Oak Creek. The temperature difference between the upstream channel in the Pond and the south lobe is considerably greater than the temperature difference between the upstream channel in the Pond and the channel downstream of the Pond. The comparison of water temperatures in the south lobe of the Pond (Logger G) to those in downstream channel within the Pond (Logger F) indicates that water temperatures in the downstream channel within the Pond are consistently lower than those in the south lobe. During low flows there appears to be little mixing between water flowing through the Mill Pond and

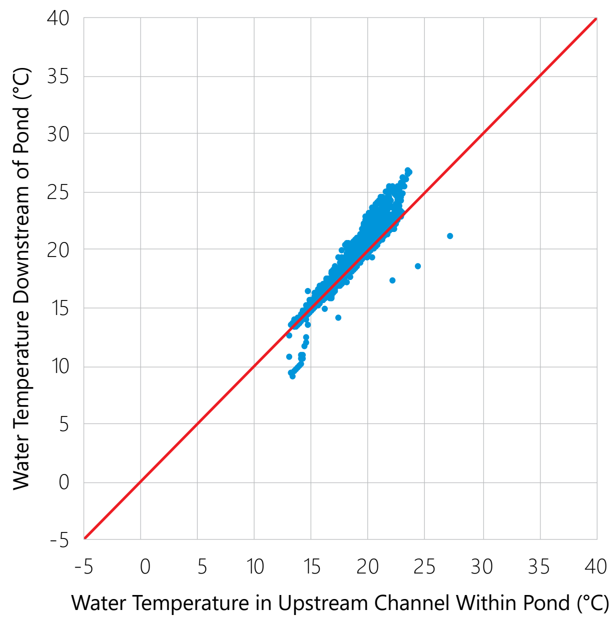
[213] *Turner, Koski, and Kinzelman, 2017,* op. cit.

Figure 4.62
Continuously Collected Water Temperature at Sites Upstream, Within, and Downstream of the Oak Creek Mill Pond; June 7-25, July 25-October 10, 2019

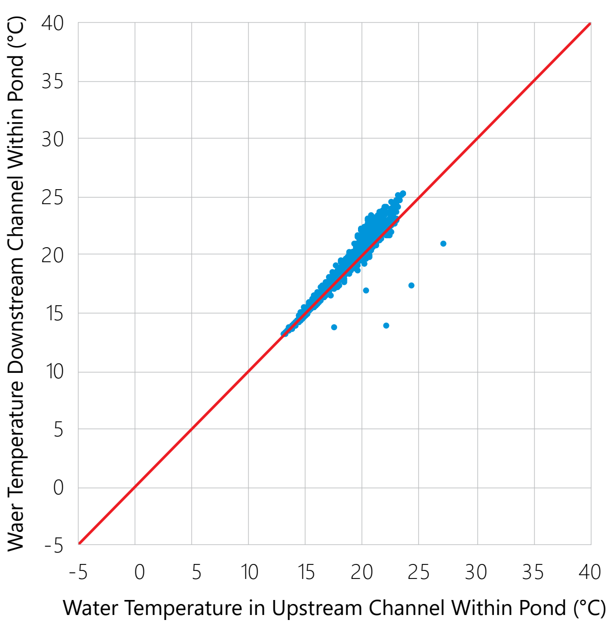
A **Comparison of New Channel Above Pond (Logger B) to Parkway Below Pond (Logger H)**



B **Comparison of Upstream Channel Within Pond (Logger D) to Parkway below Pond (Logger H)**



C **Comparison of Upstream Channel Within Pond (Logger D) to Downstream Channel Within Pond (Logger F)**



D **Comparison of Upstream Channel Within Pond (Logger D) to North Lobe of Pond (Logger E)**

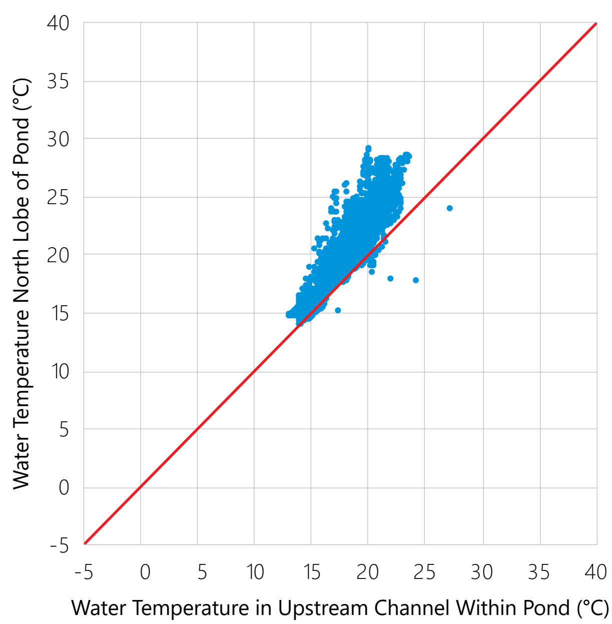
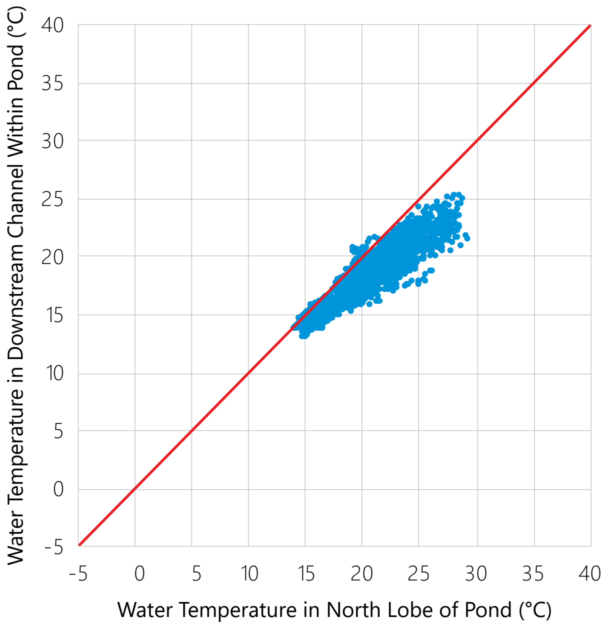


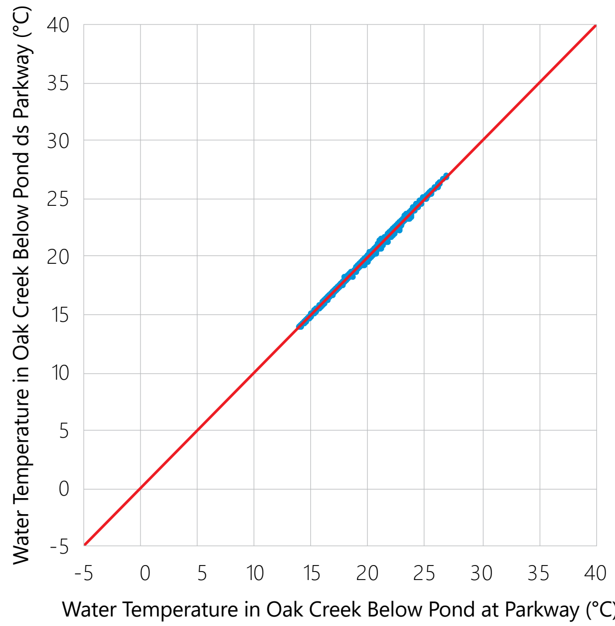
Figure continued on next page.

Figure 4.62 (Continued)

E **Comparison of North Lobe of Pond (Logger E) to Downstream Channel Within Pond (Logger F)**



F **Comparison of Parkway Below Pond (Logger H) to Parkway Farther Downstream (Logger I)[a]**



Note: Logger locations are shown on Map 4.24

[a] *Logger I was not recovered during final recovery and downloading of the temperature loggers. The period on shown on graph F is June 7-25, July 25-August 20, 2019.*

Source: SEWRPC

water in the south lobe of the Pond. This was indicated by dye testing that showed most flow from upstream did not enter the south lobe of the Pond and that water flowing through the Pond did not disperse into the south lobe.[214] While the south lobe may contribute some heat to downstream areas throughout the summer, it is likely that the largest contribution of heat from south lobe occurs during high water periods, such as during storm events, when the normal pattern of flow through the Pond is altered.

Panel F in Figure 4.62 compares water temperatures in Oak Creek at the Parkway below the Mill Pond (Logger H) to those further downstream (Logger I). Water temperatures at the two locations are almost identical. This indicates that little heating is going on in this reach of the stream. This largely reflects shading of this section of the channel by trees in the riparian area.

It is important to note that the temperature difference shown in Panel C of Figure 4.62 does not appear to fully account for the increase shown in Panel B between the upstream channel in the Pond and channel immediately downstream of the Pond. In many instances when water temperatures in the upstream channel within the Pond (Logger D) are above about 17°C, the temperature increase in the channel downstream from the Pond (Logger H) is greater than that in the downstream channel within the Pond (Logger F). It is unlikely that this additional increase comes from heat contributed in the north lobe of the Pond because such heat would be reflected in the water temperature recorded by Logger F in the downstream channel within the Pond. There are two possible sources for the heat that is responsible for this additional temperature increase. Heating in the south lobe of the pond could be contributing to the temperature increase. This is unlikely because the dye testing conducted by RHD showed a lack of flow to the dam from the south lobe of the pond.[215] In addition, both Commission staff and RHD staff noted the presence of a sandbar at the northwestern tip of the island that separates the south lobe from main path of flow through the Mill

[214] *Ibid.*

[215] *Ibid.*

Pond. Under normal summer conditions, this sandbar prevents flow from the main flow path through the pond from entering the south lobe. Thus, it is likely that heat from this lobe is contributed to the stream downstream of the Mill Pond mostly during high water periods such as storm events. The most likely source of the additional heat needed to account for the temperature increase shown in Panel B is the large pool in Oak Creek immediately downstream of the dam (see Map 4.25). The depth of this pool is greater than four feet and the pool is large enough that it is not shaded during much of the day. In addition, a large stormwater outfall discharges into this pool. The combination of solar heating in this pool and discharge of stormwater into this pool may account for the additional temperature increase between the downstream channel in the Pond and the Creek near the crossing of the Parkway.

The temperature comparisons shown in Figure 4.62 indicate that the Mill Pond acted to warm downstream waters during summer and fall. Other data suggest that this warming is likely to occur throughout much of the year. As part of its study of Oak Creek's water quality, RHD collected 57 paired grab samples of water temperature between June 2015 and August 2016. These pairs bracketed the Pond and consisted of one sample collected immediately upstream of the Mill Pond and another collected near the Pond's outlet. Water temperature increased between these two sites in 82.5 percent of the paired samples and decreased in only 7.0 percent of the paired samples. There was no difference in the water temperatures between the two sites in 10.5 percent of the paired samples. RHD staff found that the median change in water temperature between the two sites was an increase of 1.1°C.

A similar analysis can be performed to examine the effects upon the temperature regime within the mainstem of Oak Creek of water flowing into the mainstem from the two major tributaries.

The records from three temperature loggers were examined to evaluate the effects of water from the North Branch of Oak Creek on the thermal regime in the mainstem of Oak Creek. Two were deployed upstream from the confluence of these two streams, one at S. 13th Street (RM 10.7) in the mainstem of Oak Creek and another at the railroad crossing just upstream from the confluence with Oak Creek (RM 0.1) in the North Branch of Oak Creek. A third logger was placed in the mainstem of Oak Creek downstream of the confluence at STH 38 (RM 9.2). As previously noted, these loggers recorded instream temperatures between May 17, 2016, and October 10, 2017.

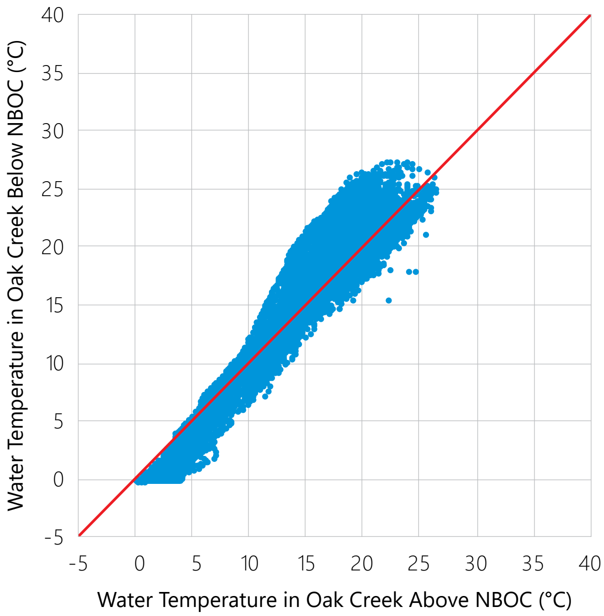
Figure 4.63 shows comparisons of water temperatures simultaneously collected from pairs of temperature loggers that bracket the confluence of the North Branch of Oak Creek with the mainstem of Oak Creek. These comparisons reveal that the effect of the North Branch of Oak Creek on the thermal regime in the mainstem is complex and dependent on the season of the year.

During warm weather, the North Branch of Oak Creek appears to be acting to warm the mainstem of Oak Creek downstream from the confluence of the two streams. Panel A of Figure 4.63 compares water temperatures in Oak Creek upstream from the confluence with the North Branch to those in the mainstem downstream from the confluence. During warm periods when water temperatures in Oak Creek at S. 13th Street (RM 10.7) were above about 13°C, water temperatures in the mainstem of Oak Creek usually increased from upstream to downstream between these two sampling stations. In some instances, temperature increased by as much as 7°C. Panel B compares water temperatures in the mainstem of Oak Creek upstream from the confluence with those in the North Branch of Oak Creek. It shows that during those periods when water temperatures in Oak Creek at S. 13th Street (RM 10.7) were above about 13°C, water temperatures in the North Branch of Oak Creek were warmer than those in the mainstem of Oak Creek upstream from the confluence. In some instances, this difference was almost 6°C. Panel C compares water temperatures in the North Branch of Oak Creek to those in the mainstem of Oak Creek below the confluence. During warmer periods, waters in the mainstem of Oak Creek below the confluence were slightly warmer than those in the North Branch of Oak Creek. This suggests that during warmer weather water from the North Branch of Oak Creek contributes to the temperature increase in the mainstem of Oak Creek between S. 13th Street (RM 10.7) and STH 38 (RM 9.2). The relationship shown in Panel C also suggests that additional heating is occurring due to solar insolation in the mainstem between the two stations. Much of this 1.5-mile section of channel is poorly buffered and poorly shaded.

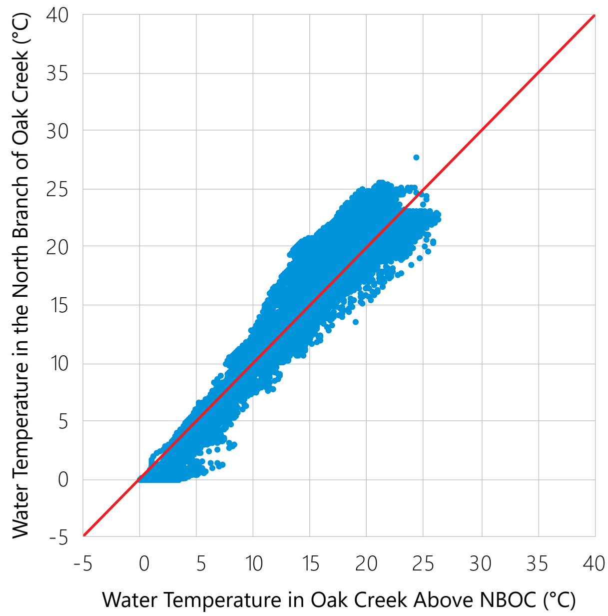
During colder weather, the North Branch of Oak Creek appears to be acting to cool the mainstem of Oak Creek downstream from the confluence of the two streams. Panel A of Figure 4.63 shows that during

Figure 4.63
Continuously Collected Water Temperature at Sites Upstream and Downstream of the Confluence of the North Branch of Oak Creek with the Mainstem of Oak Creek: May 2016-October 2017

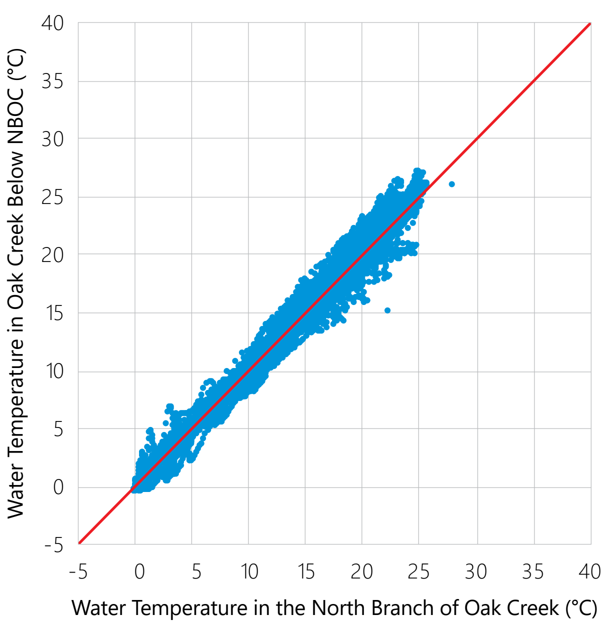
A **Comparison of Mainstem Oak Creek Above the Confluence (RM 10.7) with the North Branch of Oak Creek (NBOC) to Mainstem Oak Creek Below the Confluence (RM 9.2)**



B **Comparison of Mainstem Oak Creek Above the Confluence (RM 10.7) with the North Branch of Oak Creek the North Branch of Oak Creek (RM 0.1)**



C **North Branch of Oak Creek (RM 0.1) to Mainstem Oak Creek Below the Confluence (RM 9.2)**



Source: SEWRPC

periods when water temperatures in Oak Creek at S. 13th Street (RM 10.7) were below about 10°C, water temperatures in the mainstem of Oak Creek below the confluence with the North Branch of Oak Creek were usually cooler than those in the mainstem of Oak Creek upstream from the confluence. The difference in temperature was as much as 4°C. Panel B shows that during the same periods water temperatures in the North Branch of Oak Creek were usually cooler than those in the mainstem of Oak Creek upstream from the confluence. This difference was also as much as 4°C. Panel C shows that during cool periods, water temperatures in the mainstem of Oak Creek below the confluence were similar to or slightly warmer than those in the North Branch of Oak Creek. This suggests that cold water from the North Branch of Oak Creek is contributing to cooling of the mainstem between the two sampling stations.

The records from three temperature loggers were examined to evaluate the effects of water from the Mitchell Field Drainage Ditch on the thermal regime in the mainstem of Oak Creek. Two were deployed upstream from the confluence of these two streams, one at Drexel Avenue (RM 5.6) in the mainstem of Oak Creek and another at Rawson Avenue (RM 0.8) in the Mitchell Field Drainage Ditch. A third logger was placed in the mainstem of Oak Creek downstream of the confluence at Pennsylvania Avenue (RM 4.7). As previously noted, these loggers recorded instream temperatures between May 17, 2016, and October 10, 2017.

Figure 4.64 shows comparisons of water temperatures simultaneously collected from pairs of temperature loggers that bracket the confluence of the Mitchell Field Drainage Ditch with the mainstem of Oak Creek. These comparisons reveal that contributions from the Mitchell Field Drainage Ditch have less effect on the thermal regime in the mainstem than those from the Mill Pond or the North Branch of Oak Creek. Panel A compares water temperatures in the mainstem of Oak Creek upstream of the confluence with the Mitchell Field Drainage Ditch to those in the mainstem below the confluence. Water temperatures usually increased from upstream to downstream between these two stations. This increase was as much as 4°C. Panel B shows that water temperatures in the Mitchell Field Drainage Ditch were generally similar to those in mainstem of Oak Creek upstream of the confluence. Panel C shows that water temperatures in the mainstem of Oak Creek downstream of the confluence with the Mitchell Field Drainage Ditch were usually warmer than those in the Mitchell Field Drainage Ditch. The similarity of water temperatures between the Mitchell Field Drainage Ditch and the mainstem of Oak Creek upstream of the confluence with the Mitchell Field Drainage Ditch indicate that contributions of water from the Mitchell Field Drainage Ditch did not account for the temperature increase in the mainstem between the Drexel Avenue (RM 5.6) and Pennsylvania Avenue (RM 4.7) sampling stations.

There are three likely sources for the heat that is warming water in the mainstem of Oak Creek between Drexel Avenue (RM 5.6) and Pennsylvania Avenue (RM. 4.7). These sources are not mutually exclusive and may be acting in combination.

First, there is a pond located adjacent to Oak Creek between the Creek and E. Montana Avenue. This pond is located in an old gravel quarry and has a surface area of about three acres. During surveys of Oak Creek, Commission staff observed that this pond has developed an outlet and discharges into the mainstem of the Creek. Discharge of water warmed by solar heating from this pond into Oak Creek may contribute to the warming of the Creek.

Second, the temperature increase may result from contributions of stormwater runoff to Oak Creek and the Mitchell Field Drainage Ditch. Stormwater runoff can warm receiving waterbodies. The higher temperature of runoff reflects the presence of impervious cover which absorbs and emits heat. This can create air and surface temperatures that are higher than those found in rural areas.[216] For example, one study found that under solar heating, the temperature of impervious asphalt was 17°C higher than air temperature.[217] The heat absorbed by impervious surfaces can be transferred to stormwater as it flows over the surface. This warms the stormwater. In some instances, a second warming may occur in unshaded stormwater ponds.[218] The presence of impervious cover also results in additional runoff. The combination of these two effects creates a larger volume of runoff with higher temperatures.

---

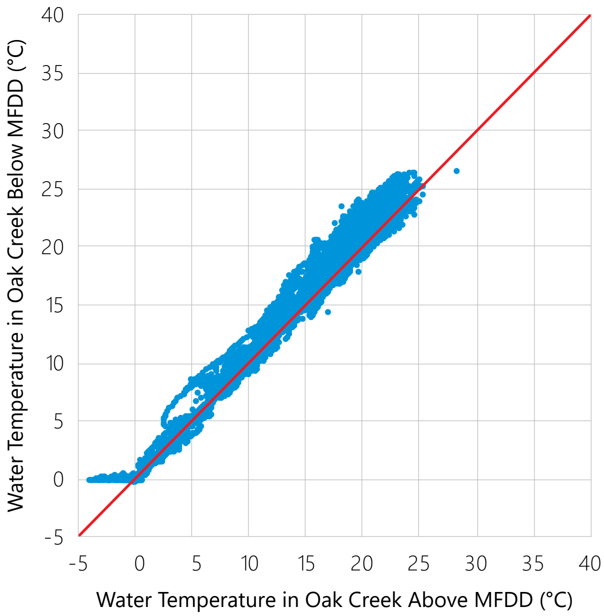
[216] *S.P. Arya,* Introduction to Micrometeorology, *Academic Press, New York, 2001.*

[217] *M.A. Eusuf, and T. Asaeda, "Heating Effects of Pavement on Urban Thermal Environment,"* Journal of Civil Engineering, The Institution of Engineers, Bangladesh, *volume 26, pages 173-190, 1998.*

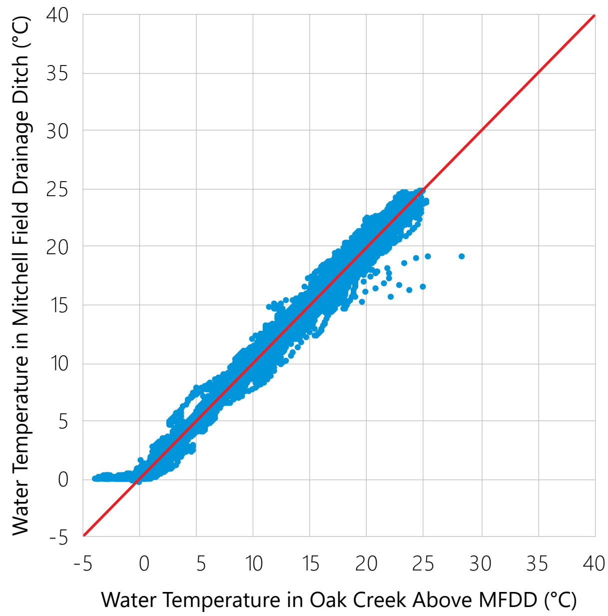
[218] *M.S. Kieser, A. Fang, and J.A. Spoelstra, "Role of Urban Stormwater Best Management Practices in Temperature TMDLs." Proceedings of the Water Environment Federation, volume 2003, pages 1,716-1,739, 2003.*

Figure 4.64
Continuously Collected Water Temperature at Sites Upstream and Downstream of the Confluence of the Mitchell Field Drainage Ditch with the Mainstem of Oak Creek: May 2016-October 2017

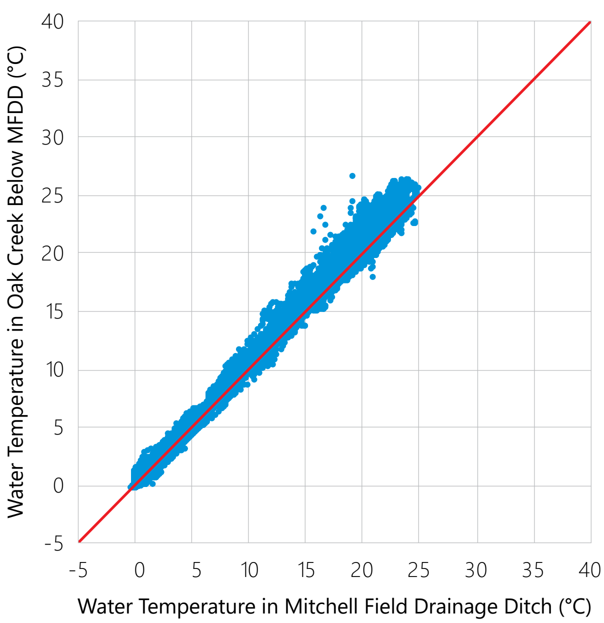
A **Comparison of Mainstem Oak Creek Above the Confluence (RM 5.6) with the Mitchell Field Drainage Ditch (MFDD) to Mainstem Oak Creek Below the Confluence (RM 4.7)**



B **Comparison of Mainstem Oak Creek Above the Confluence (RM 5.6) with the Mitchell Field Drainage Ditch (RM 0.8)**



C **Mitchell Field Drainage Ditch (RM 0.8) to Mainstem Oak Creek Below the Confluence (RM 4.7)**



Source: SEWRPC

It is likely that considerable stormwater is entering Oak Creek and the Mitchell Field Drainage Ditch in the reaches between the sites of two temperature loggers upstream from the confluence of these streams and the site of the temperature logger downstream of the confluence. At least seven outfalls discharge into these reaches (see Map E.1 in Appendix E). Three of these outfalls discharge into the mainstem of Oak Creek, one discharges into a small, unnamed tributary to Oak Creek, one discharges into the Mitchell Field Drainage Ditch, and two discharge into an unnamed tributary to the Mitchell Field Drainage Ditch. Five of these outfalls are part of the City of Oak Creek's storm sewer system and drain about 365 acres within the City (see Table E.1 in Appendix E). The functions and owners of the remaining two outfalls have not been identified. The presence of these outfalls indicate that discharge of stormwater may be contributing to the temperature increases in this section of Oak Creek.

Third, warming may be occurring in the stream channel in the sections of Oak Creek and the Mitchell Field Drainage Ditch downstream of the sites of the temperature loggers. The combined length of these stream reaches is about 1.7 miles. While some portions of these reaches have riparian vegetation that can shade the channel, other portions are exposed to sunlight and consequently to solar heating. Though highly variable, turbidity in the mainstem of Oak Creek at the two stations bracketing the confluence with the Mitchell Field Drainage Ditch is higher than average for the mainstem (medians of about 12.0 – 12.6 ntu versus 10.6 ntu). Absorption of heat by this turbid water may also be contributing to the in-channel warming between Drexel Avenue and Pennsylvania Avenue. Note that turbidity in the Mitchell Field Drainage Ditch is lower, with a median of about 9.0 ntu at Rawson Avenue.

Temperature data were also collected from several tributary streams including the North Branch of Oak Creek, the Mitchell Field Drainage Ditch, an unnamed tributary that enters Oak Creek near Puetz Road, Southland Creek, Unnamed Creek 5, and the Rawson Avenue tributary. The Puetz Road tributary to Oak Creek is the outlet of the Oak Creek drainage ditches into the mainstem of Oak Creek in the Middle Oak Creek assessment area. Southland Creek, Unnamed Creek 5, and the Rawson Avenue tributary are tributaries of the North Branch of Oak Creek.

Figure 4.65 shows continuously collected water temperatures from six sampling stations along the North Branch of Oak Creek. Water temperatures in this stream ranged between about -0.3°C and 29.0°C, with a mean value of 13.8°C and a median value of 16.5°C. As previously noted, air temperature near the Drexel Avenue crossing of Oak Creek (RM 5.6) ranged between -24.7°C and 31.9°C, with a mean value of 12.7°C and a median value of 15.3°C. Water temperatures showed a complicated pattern along the length of this Creek. Median water temperatures at individual sampling stations ranged from 16.2°C at the northern station at S. 6th Street to 17.2°C at Wildwood Drive. Median temperatures rose and fell along the length of the Creek, reaching a maximum at Wildwood Drive. Maximum water temperatures along the North Branch of Oak Creek followed a slightly different pattern, increasing from upstream to downstream to peak at Marquette Avenue, decreasing slightly at Wildwood Drive, increasing at Puetz Road, and decreasing near the confluence with Oak Creek. It is likely that the differences among sites reflect a number of influences including the volume of discharge at that point of Creek; the rate of flow; the presence of obstructions such as dams, drop structures, or debris jams; inputs of stormwater runoff through outfalls or overland flow; shading by riparian vegetation; and groundwater discharge.

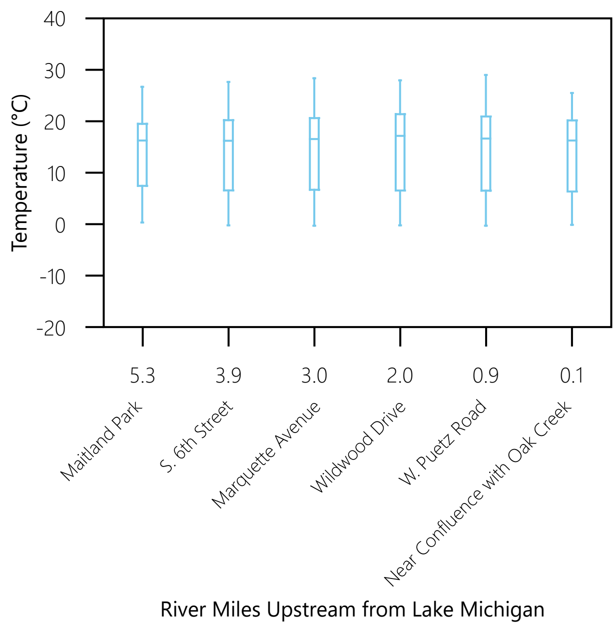
Water temperatures in the North Branch of Oak Creek showed variations on the same time scales as were seen in the mainstem of Oak Creek. During the period over which continuous temperature data were collected, the average difference between the daily maximum air temperature and the daily minimum air temperature was 9.6°C. At sites along the North Branch of Oak Creek, the average differences between daily maximum and daily minimum water temperatures ranged between 1.8°C and 3.7°C. The lowest average difference occurred at the site near the confluence with Oak Creek (RM 0.1). This may reflect backwater effects in which water from the mainstem mixes into water from the North Branch. Temperature variations were also seen on longer time scales. These were similar to those observed in the mainstem of Oak Creek. Like the daily variations, they reflect the variations in air temperature over multiple time scales.

Figure 4.66 shows water temperatures from grab samples collected from the North Branch of Oak Creek over the period 1952 through 2016. The temperatures shown are within the ranges detected through continuous temperature monitoring in this Creek during the period 2016-2017 (see Figure 4.65). The low temperatures shown at the northern site at S. 6th Street (RM 4.1) probably reflect the small number of samples collected at this site and not any differences between the thermal regime at this site and the rest of the Creek. The data from the W. Puetz Road station (RM 0.1) suggest that there might be a long-term trend toward increasing water temperatures in the Creek; however, this should be interpreted with caution. The sample sizes at this site for each of the available periods are small. In addition, the frequency of sampling and the months during which sampling was conducted has changed over the periods depicted in the figure.

Water temperatures within the North Branch of Oak Creek usually complied with applicable water quality standards. Daily maximum water temperatures in this Creek were less than the acute temperature criteria on more than 98 percent of the days assessed. Weekly averages of daily maximum water temperatures were below the sublethal temperature criterion in 81 percent of the weeks assessed. A formal comparison of water temperature to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

Figure 4.67 shows continuously collected water temperatures from two sampling stations along the Mitchell Field Drainage Ditch. Water temperatures in this stream ranged between about -0.3°C and 26.2°C, with a mean value of 13.1°C and a median value of 15.6°C. Water temperatures showed some differences between the two stations along this Creek. Median water temperatures were slightly higher at the sampling station at Rawson Avenue (RM 0.8) than at the sampling station at College Avenue (RM 1.8). Maximum water temperatures showed the opposite pattern, being slightly higher at the College Avenue station. It is likely that the differences among the sites reflect a number of influences including the volume of discharge at that point of Creek; the rate of flow; the presence of obstructions such as dams, drop structures, or debris jams; inputs of stormwater runoff through outfalls or overland flow; shading by riparian vegetation; and groundwater discharge.

Figure 4.65
Continuously Collected Water Temperature at Sites Along the North Branch of Oak Creek: May 2016-October 2017



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: SEWRPC

Water temperatures in the Mitchell Field Drainage Ditch showed variations on the same time scales as were seen in the mainstem of Oak Creek. During the period over which continuous temperature data were collected, the average difference between the daily maximum air temperature and the daily minimum air temperature was 9.6ºC. At sites along the Mitchell Field Drainage Ditch, the average differences between daily maximum and daily minimum water temperatures ranged between 1.9ºC and 3.1ºC. The lowest average difference occurred at the Rawson Avenue station (RM 0.8). Temperature variations were also seen on longer time scales. These were similar to those observed in the mainstem of Oak Creek. Like the daily variations, they reflect the variations in air temperature over multiple time scales.

Figure 4.68 shows water temperatures from grab samples collected from the Mitchell Field Drainage Ditch over the period 1952 through 2016. The two sampling sites show different temperature distributions. The temperature distribution shown at the Rawson Avenue site (RM 0.8) is similar to that detected through continuous temperature monitoring in this creek during the period 2016-2017 (see Figure 4.67). While the overall range of temperatures at the College Avenue station (RM 1.8) is similar to that observed at Rawson Avenue, most of the readings at College Avenue are near the high end of the range. About three-quarters of the samples at College Avenue are higher than the median at Rawson Avenue. This is an artifact of differences in sampling between the two sites. About two-thirds of the samples collected at College Avenue were collected during summer months. Though fewer samples were collected at Rawson Avenue, they were more evenly spread over the four seasons of the year. When this is accounted for, the grab samples give a similar picture regarding the temperature regime in the Mitchell Field Drainage Ditch during the period

2007 through 2016 as the continuous temperature monitoring. Sufficient older data are not available to assess long-term temperature trends in this stream.

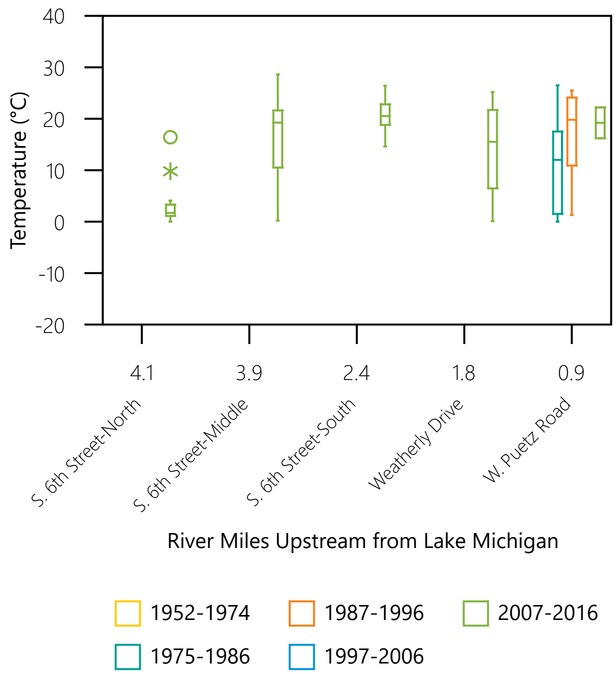
Water temperatures within the Mitchell Field Drainage Ditch usually complied with applicable water quality standards. Daily maximum water temperatures in this Creek were less than the acute temperature criteria on more than 99 percent of the days assessed. Weekly averages of daily maximum water temperatures were below the sublethal temperature criterion in about 89 percent of the weeks assessed. Higher levels of compliance with the sublethal criterion occurred at the downstream sampling station. A formal comparison of water temperature to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

Figure 4.69 shows continuously collected water temperature data from four tributary streams in the Oak Creek watershed. Southland Creek, Unnamed Creek No. 5, and the Rawson Avenue Tributary are tributaries to the North Branch of Oak Creek. The Puetz Road tributary to Oak Creek is the outlet of the Oak Creek drainage ditches into the mainstem of Oak Creek in the Middle Oak Creek assessment area.

Between May 17, 2016, and October 10, 2017, temperatures in Southland Creek ranged between -0.5°C and 24.8°C, with a mean value of 13.1°C and a median value of 15.8°C (see Figure 4.69). The average difference between daily minimum and daily maximum temperature in this stream was 2.3°C. Examining the continuous temperature record from this stream indicated two things. First, the stream was frozen at the monitored site from early December 2016 through late February 2017. The temperature record showed no evidence of thaws during this period. Second, although this stream is classified as an intermittent stream, the continuous temperature record from the period was consistent with flow being present during the entire period over which the stream was monitored. It should be noted that flow was present in the stream on each occasion when Commission staff visited the monitoring site. In addition, Commission staff observed evidence that this stream receives inputs from groundwater discharge.

Temperatures in Unnamed Creek 5 ranged between -0.4°C and 24.1°C, with a mean value of 12.8°C and a median value of 15.4°C (see Figure 4.69). The average difference between daily minimum and daily maximum temperature in this stream was 2.2°C. The continuous temperature record from this stream indicated two things. First, the stream was

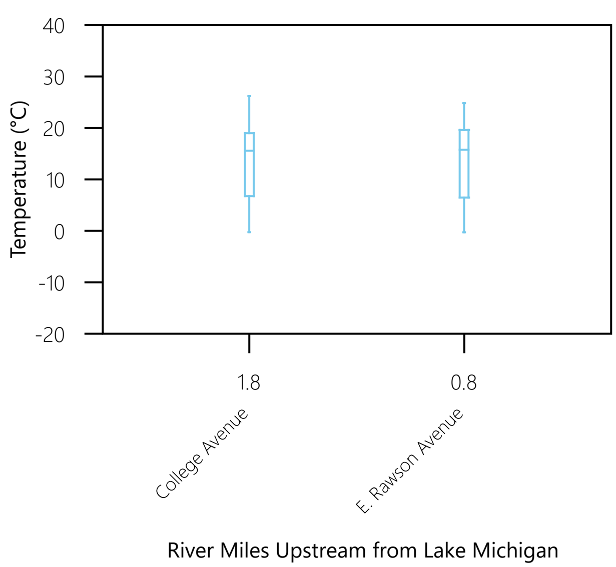
Figure 4.66
Water Temperature at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, City of Racine

Figure 4.67
Continuously Collected Water Temperature at Sites Along the Mitchell Field Drainage Ditch: May 2016-October 2017



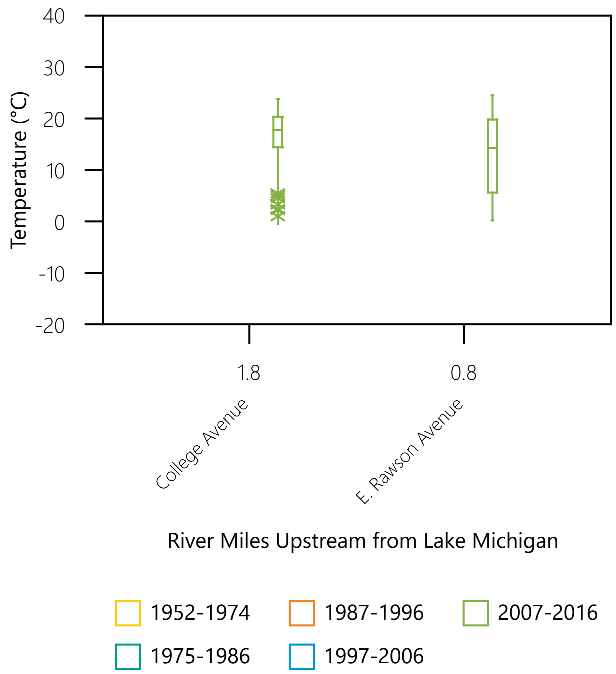
Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: SEWRPC

frozen at the monitored site from early December 2016 through late February 2017. This period was interrupted by two approximately weeklong thaws: one that began in late December and lasted into early January and another that occurred during late January. Second, although this stream is classified as an intermittent stream, the continuous temperature record from the period was consistent with flow being present during the entire period over which the stream was monitored. It should be noted that flow was present in the stream on each occasion when Commission staff visited the monitoring site.

Temperatures in the Rawson Avenue tributary to the North Branch of Oak Creek ranged between -0.1°C and 30.0°C, with a mean value of 13.1°C and a median value of 15.6°C (see Figure 4.69). The average difference between daily minimum and daily maximum temperature in this stream was 3.6°C. Review of the continuous temperature record from this stream indicated two things. First, the stream was frozen at the monitored site from early December 2016 through late February 2017. This period was interrupted by three short thaws of a few days length during January and early February. Second, the continuous temperature record from the period was consistent with flow being intermittently absent at the monitoring site. During some periods, the temperature pattern recorded by the logger placed in this stream's channel was similar to the corresponding air temperature pattern. This is consistent with observations by Commission staff, who noted that the channel was dry at the monitoring site during some site visits.

Figure 4.68
Water Temperature at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

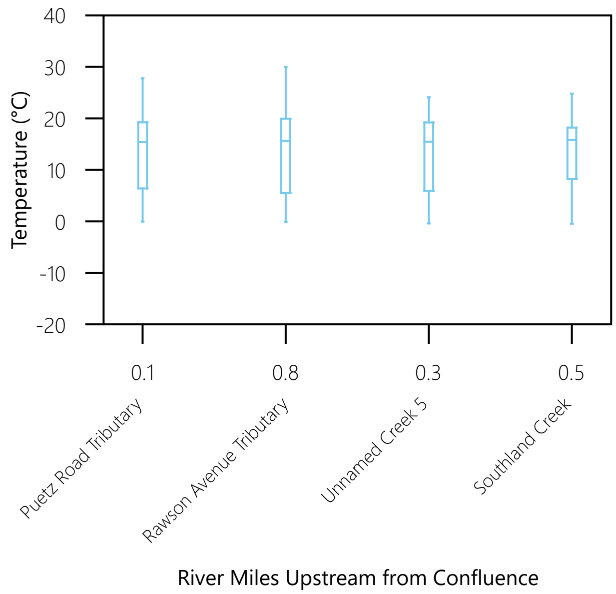
Temperatures in the unnamed tributary that enters Oak Creek near the Puetz Road crossing of the mainstem ranged between 0.0°C and 27.8°C, with a mean value of 13.1°C and a median value of 15.4°C (see Figure 4.69). The average difference between daily minimum and daily maximum temperature in this stream was 3.6°C. Examining the continuous temperature record from this stream indicated two things. First, the stream was frozen at the monitored site from early December 2016 through mid-February 2017. This period was interrupted by a short thaw of a few days length during late January. Second, the continuous temperature record from the period was consistent with flow being intermittently absent at the monitoring site. During some periods, the temperature pattern recorded by the logger placed in this stream's channel was similar to the corresponding air temperature pattern. This is consistent with observations by Commission staff, who noted that the channel was dry at the monitoring site during some site visits.

Water temperatures in the four minor tributaries usually complied with applicable water quality standards. Daily maximum water temperatures in these Creeks were less than the acute temperature criteria on all of the days assessed. The level of compliance with the sublethal criterion varied among these streams. Weekly averages of daily maximum water temperatures were below the sublethal temperature criterion in over 94 percent of the weeks assessed in Southland Creek and the unnamed tributary that enters Oak Creek near the Puetz Road crossing of the mainstem. Weekly averages of daily maximum water temperatures were below the sublethal temperature criterion in about 84 percent of the weeks assessed in Rawson Avenue tributary to the North Branch of Oak Creek and Unnamed Creek 5. A formal comparison of water temperature to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

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. For example, common carp (*Cyprinus carpio*) are very tolerant of concentrations of dissolved oxygen below 2.0 milligrams per liter (mg/l) and can survive at concentrations above 1.0 mg/l.[219] Bluegill (*Lepomis macrochirus*), on the other hand, depend on water with dissolved oxygen concentrations above 5.0 mg/l.[220] Trout and salmon may require even higher dissolved oxygen concentrations. This is reflected in the fact that dissolved oxygen criteria for the coldwater habitats in which trout and salmon are found are higher than those for warmwater habitats (see Table 4.16).

Figure 4.69
Continuously Collected Water Temperature in Tributary Streams of the Oak Creek Watershed: May 2016-October 2017



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: SEWRPC

Sources of dissolved oxygen in 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 on dissolved oxygen concentrations for two reasons. First, as noted in the previous temperature 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.

Concentrations of dissolved oxygen in surface waters typically show a strong seasonal pattern. Highest concentrations usually occur during the winter. Concentrations decrease through the spring to reach a minimum during summer. Concentrations rise through the fall to reach maximum values in winter. This cycle is driven by seasonal changes in water temperature. Dissolved oxygen concentrations in some waterbodies may also show daily fluctuations in which high concentrations occur during daylight due to photosynthesis and lower concentrations occur during periods of darkness when photosynthesis ceases and respiration increases.

Supersaturation of water with dissolved oxygen occurs when the water contains a higher concentration of dissolved oxygen than is normally soluble at ambient conditions of temperature and pressure. Dissolved oxygen supersaturation can result from several causes, including the presence of waterfalls; discharge of water through dams; water temperature increases related to solar heating or discharge of industrial or power generation cooling water effluent; sudden decreases in air or water pressure; and high levels of photosynthesis in waterbodies with high densities of aquatic plants, phytoplankton, or benthic algae. Dissolved oxygen supersaturation can cause a number of physiological conditions that are harmful or fatal to fish and other aquatic organisms.

As previously discussed, the minimum dissolved oxygen criterion for warmwater fish and aquatic life in streams such as Oak Creek and its tributaries is 5.0 mg/l (see Table 4.16).

[219] *U.S. Fish and Wildlife Service,* Habitat Suitability Index Models: Common Carp, *1982.*

[220] *U.S. Fish and Wildlife Service,* Habitat Suitability Index Models: Bluegill, *1982.*

During the period 2007 through 2016, the concentration of dissolved oxygen at sampling stations along the mainstem of Oak Creek ranged between 0.10 milligrams per liter (mg/l) and 35.28 mg/l, with a median value of 8.96 mg/l and a mean value of 9.57 mg/l. Figure 4.70 shows dissolved oxygen concentrations at selected sampling stations along the mainstem of Oak Creek. The hatching on the graph shows dissolved oxygen concentration levels that are either below the State's dissolved oxygen criterion for fish and aquatic life for warmwater streams or sufficiently high to indicate supersaturation which can cause severe physiological stress to aquatic organisms.

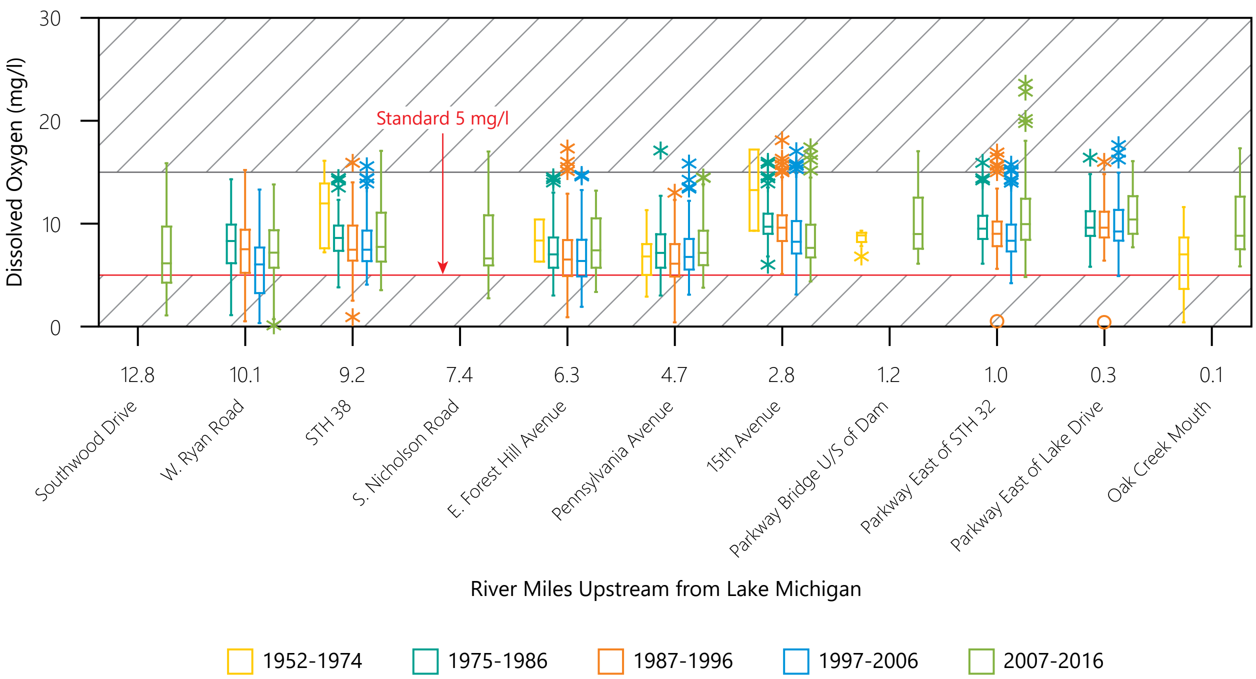
The two sampling stations that are farthest upstream reflect water quality conditions in the mainstem of the Creek in the Oak Creek-Headwaters and Upper Oak Creek assessment areas. Median concentrations of dissolved oxygen during the period 2007 through 2016 at the stations at Southwood Drive (RM 12.8) and W. Ryan Road (RM 10.1) were 6.85 mg/l and 7.20 mg/l, respectively. At both of these stations, low concentrations of dissolved oxygen were detected in samples collected during this period (see Figure 4.70), with concentrations in a substantial fraction of samples being below the State's water quality criterion of 5.0 mg/l. During this period, dissolved oxygen concentration in about 21 percent of the samples collected from this section of the mainstem of the Creek were below this standard. Concentrations at the station at W. Ryan Road during the period 2007 through 2016 were higher than those observed during the period 1997 through 2006, suggesting some improvement in dissolved oxygen conditions in this section of the Creek. It is not clear whether dissolved oxygen conditions have improved in the most upstream sections of the Creek, because historical data are not available for the sampling station at Southwood Drive. Examining historical dissolved oxygen concentrations at the station at W. Ryan Road suggests that low dissolved oxygen concentrations are a long-standing problem in this section of the Creek.

Several factors might account for the relatively low dissolved oxygen concentrations observed in this upstream section of the Oak Creek mainstem. The relatively low concentrations may reflect low flows in the Creek through these two assessment areas. During surveys of the Creek, Commission staff found that flows were generally low in this section of the mainstem. Field staff also reported finding evidence of erosion along streambanks in this section, suggesting that the flows are flashy (see Map 4.3). They found several areas of stagnant water in these reaches, most notably near and upstream of the sampling station at W. Ryan Road (RM 10.1). In addition, there is a series of three drop structures near Southwood Drive. Field staff reported that these drop structures are probably impounding water. This combination of conditions suggests that this section of the Creek may be experiencing decreases in dissolved oxygen during dry periods followed by rapid increases in concentration as flows increase during and after storm events. This pattern has been previously observed in other streams with low flows.[221] In addition, RHD field staff observed dry-weather flow at a stormwater outfall discharging into the mainstem of Oak Creek south of W. Thorncrest Drive. This outfall is shown as number 295 on Map 4.24. Commission staff observed considerable growth of attached algae and plants on the flared end section of this outfall (see Figure 4.71). The density of algae growing on this outfall was far greater than what was seen growing on the stream channel bed at this location. This suggests that flow from this outfall may be contributing nutrients to the stream. As described in the section on bacteria, sampling conducted by the RHD indicated that flow from this outfall was contaminated with fecal material, probably of canine origin. This suggests that stormwater discharged from this outfall may contain organic materials. Degradation of such materials by bacteria would require oxygen, potentially lowering dissolved oxygen concentrations in sections of the stream immediately downstream of this outfall.

The next three sampling stations (RM 9.2, RM 7.4, and RM 6.3) reflect water quality conditions in the mainstem of the Creek in the Middle Oak Creek assessment area. Median concentrations of dissolved oxygen at the sampling stations at STH 38 (RM. 9.2), S. Nicholson Road (RM 7.4), and E. Forest Hill Avenue (RM 6.3) during the period 2007 through 2016 were 8.07 mg/l, 7.45 mg/l, and 7.50 mg/l. During this period, dissolved oxygen concentrations at these stations were higher than those upstream, but lower than those at stations further downstream (see Figure 4.70). At all three stations, dissolved oxygen concentrations in occasional samples were below the State's water quality criterion of 5.0 mg/l. During this period, dissolved oxygen concentration in about 11 percent of the samples collected from this section of the mainstem of the Creek were below this standard. Concentrations at the stations at STH 38 and E. Forest Hill Avenue during the period 2007 through 2016 were higher than those from samples collected during the period 1997 through 2006, suggesting that dissolved oxygen conditions in this section of the Creek improved between these two periods.

[221] *SEWRPC Community Assistance Planning Report No. 316,* A Restoration Plan for the Root River Watershed, *July 2014.*

Figure 4.70
Concentrations of Dissolved Oxygen at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Saturation levels of dissolved oxygen of 140 percent and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration translates to a saturation of approximately 150 percent at an average water temperature of 14° C.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

Several factors might account for the relatively low dissolved oxygen concentrations observed in the mainstem of Oak Creek in the Middle Oak Creek assessment area. The stream gradient through much of this section of the Creek is lower than what is found through most of the length of the mainstem (see Figure 4.4). As a result, flow through this assessment area may be slow. This slower flow can be accompanied by less turbulence, which can reduce the rate at which oxygen diffuses into the water from the atmosphere. Slower flow can also be accompanied by sediment deposition on the streambed. Many of the thickest deposits of sediment in the channel of the mainstem of Oak Creek are located in the lower portions of this reach between Puetz Road and Drexel Avenue (See Figure 4.17). If this sediment contains organic material, bacterial degradation of this material could reduce dissolved oxygen concentrations in the water above. The decrease in median dissolved oxygen concentration from upstream to downstream along the length of this reach of the Creek is consistent with the distribution of sediment deposits in the channel and suggests that oxygen demand from degradation of organic material in the sediment may partially account for both the relatively low concentrations of dissolved oxygen detected in this reach and the pattern of dissolved oxygen concentrations observed along the length of this reach.

Water flowing into the mainstem from the Oak Creek Drainage Ditches assessment area might also affect dissolved oxygen concentrations in the lower portions of the Middle Oak Creek reach. This assessment area is drained by a ditch that joins the mainstem of Oak Creek just upstream of E. Puetz Road. Water quality samples have not been collected from this ditch or any other ditch in the Drainage Ditches assessment area, so the concentration of dissolved oxygen in the water flowing into the mainstem of the Creek from this assessment area is unknown. If it is lower than that in the mainstem, it could account for the relatively low concentrations of dissolved oxygen in reaches of Oak Creek located in the lower portions of the Middle Oak Creek assessment area. It should also be noted that during stream surveys, Commission staff observed that water flowing into the mainstem from the Drainage Ditch assessment area had a red-brown color on at least one occasion. This coloration was observed in ditches that drain ponds located upstream of Puetz Road and east of Pennsylvania Avenue. These ponds are associated with a salvage yard. The observed coloration could indicate the presence of organic chemicals. Degradation of such chemicals by bacteria could lower dissolved oxygen concentrations in the Creek.

The next two sampling stations (RM 4.7 and RM 2.8) reflect water quality conditions in mainstem of the Creek in the Lower Oak Creek assessment area. Median concentrations of dissolved oxygen during the period 2007 through 2016 at the sampling stations at Pennsylvania Avenue (RM 4.7) and 15th Avenue (RM 2.8) were 7.39 mg/l and 8.10 mg/l, respectively. Dissolved oxygen concentrations at Pennsylvania Avenue, the upstream station of this reach, tended to be lower than those at stations in the Middle Oak Creek assessment area (see Figure 4.70). Over the length of this reach, dissolved oxygen concentrations tend to increase. At both stations, dissolved oxygen concentrations were rarely below the State's water quality criterion of 5.0 mg/l. During the period 2007 through 2016 dissolved oxygen concentrations in 3 percent of the samples collected from this reach were below this standard.

Figure 4.71
Algal and Plant Growth on Stormwater Outfall Discharging into Oak Creek near W. Thorncrest Drive: July 25, 2017

Source: SEWRPC

Different patterns of change in dissolved oxygen concentrations occurred at the two sampling stations along the mainstem of the Creek in the Lower Oak Creek assessment area. Dissolved oxygen concentrations increased over time at the station at Pennsylvania Avenue (RM 4.7). At the station at 15th Avenue (RM 2.8), they decreased over time. The difference in the temporal trends occurring at these two sampling stations in the Lower Oak Creek reach may reflect the differences in land use near and upstream of the stations. Much of the area upstream of the sampling station at Pennsylvania Avenue consists of wetlands, woodlands, and agricultural lands. The area upstream from and around the 15th Avenue station is highly urbanized. In addition, field staff found more storm sewer outfalls in the reach of the Creek upstream of the 15th Avenue station than in the reach upstream from Pennsylvania Avenue (see Map E.1 in Appendix E). As previously discussed in the section on bacteria, this includes an especially large outfall immediately upstream of 15th Avenue. The detection of high numbers of fecal indicator bacteria in samples collected from this outfall suggest that this outfall may be discharging untreated sewage originating from an illicit connection or cross-connection. If this is the case, bacterial decomposition of organic material associated with this sewage could be reducing dissolved oxygen concentrations at this station.

The next two sampling stations (RM 1.2 and RM 1.0) reflect water quality conditions in the mainstem of the Creek in the Oak Creek-Mill Pond assessment area. These two stations bracket the Mill Pond, with the data from the station at the Parkway Bridge upstream of the dam (RM 1.2) reflecting the state of water flowing into the pond and the data from the station at the Parkway east of STH 32 (RM 1.0) reflecting the state of water flowing out of the pond. Median concentrations of dissolved oxygen during the period 2007 through 2016 at the sampling stations at the Parkway Bridge upstream of the dam and the Parkway east of STH 32 were 10.35 mg/l and 10.66 mg/l, respectively. Dissolved oxygen concentrations at the station at the Parkway Bridge upstream of the dam during the period 2007 through 2016 were higher than they were at the station immediately upstream (see Figure 4.70). Dissolved oxygen concentrations in all of the samples collected from this reach of the mainstem during the period 2007 through 2016 were above the State's water quality criterion of 5.0 mg/l.

It should be noted that there is complicated flow of water in this reach of the Creek that could affect concentrations of dissolved oxygen. Between the two parkway bridges immediately upstream of the Mill Pond, debris jams have obstructed flow in the original channel (see Figure 4.34). As a result, streamflow has been diverted to a new channel that is located south of the old channel and runs roughly parallel to the parkway. The gradient in the new channel is relatively steep and contains several riffles. This aerates water running through the channel, adding oxygen from the air to water in the Creek. These contributions of oxygen to the stream may be lessened somewhat by contributions from the original channel. During field surveys, Commission staff noted that the original channel contained stagnant water. They also noted that a small amount of flow was passing through the debris jams in the original channel and entering the mainstem of the Creek.

The presence of the Mill Pond also affects dissolved oxygen concentrations in this reach of the mainstem of Oak Creek. Figure 4.72 shows dissolved oxygen concentrations at four locations in the Mill Pond during 2015 and 2016. The Mill Pond-1 site was located within the path of water flow through the pond. The Mill Pond-3 and Mill Pond-4 sites were located in the northeast basin of the pond. Dye testing indicated that most flow from upstream does not enter this section of the pond.[222] The RHD-14 site is located near and slightly to the northeast of the tip of the peninsula that extends from the inlet to the center of the pond. While this site is within the northeast basin, it is near the path of flow through the pond. Dye testing in the pond, though, indicated that flow through the pond did not extend to this site. Concentrations of dissolved oxygen at the three sites in the northeast basin were considerably higher than those at the Mill Pond-1 site. In addition, concentrations at the three northeast basin sites were sufficiently high to indicate supersaturation of dissolved oxygen. In some samples collected from this area of the Pond, concentrations exceeded 23.0 mg/l and levels of oxygen saturation were over 200 percent. Supersaturation can be caused by photosynthesis by submerged plants and algae during clear, sunny conditions. RHD staff noted the presence of both aquatic plants and suspended algae in the northeast basin.[223] The presence of suspended algae in this basin was also noted by Commission staff. Supersaturation of dissolved oxygen can indicate that a site is experiencing wide swings in dissolved oxygen over the course of the day, especially in water that overlays sediments containing organic material. During the night when photosynthesis does not occur due to the lack of light, bacterial decomposition of organic material in the sediment can remove oxygen from the water column, lowering dissolved oxygen concentrations. Both RHD and Commission staffs noted anoxic sediment containing organic material in the Mill Pond. It should be noted that dissolved oxygen swings associated with supersaturation have been reported in reaches of other streams in Southeastern Wisconsin, including the Kinnickinnic River[224] and the Root River.[225]

Several samples collected at the sampling station at the Parkway east of STH 32 (RM 1.0) show evidence of supersaturated dissolved oxygen concentrations (see Figure 4.70). The maximum concentration observed at this site was 35.28 mg/l. The most likely cause of supersaturation at this site is aeration of water flowing over the dam as it leaves the pond. It is less likely that supersaturation at this site represents discharge of supersaturated water from the northeast basin. The main reason why this second possible explanation is less likely is that flow through the pond does not appear to enter the northeast basin.

While dissolved oxygen concentrations at the station at the Parkway east of STH 32 (RM 1.0) generally decreased over time, concentrations in samples collected during the period 2007 through 2016 were higher than those from samples collected during the period 1997 through 2006, suggesting that dissolved oxygen conditions in this section of the Creek improved between these two periods (see Figure 4.70). There were not sufficient historical dissolved oxygen data from the sampling station at the Parkway Bridge upstream of the dam (RM 1.2) or from within the Mill Pond to assess temporal trends in dissolved oxygen.

The last two sampling stations (RM 0.3 and RM 0.1) reflect water quality conditions in the mainstem of the Creek in the Grant Park Ravine assessment area. Median concentrations of dissolved oxygen during the period 2007 through 2016 at the sampling stations at the Parkway east of Lake Drive (RM 0.3) and the Oak Creek Mouth (RM 0.1) were 10.66 mg/l and 9.19 mg/l, respectively. Over the length of this reach, dissolved oxygen concentrations tended to decrease slightly. This decrease from upstream to downstream was accompanied by greater dissolved oxygen variability at the station at the Creek's mouth. Both the slightly lower dissolved oxygen concentrations and higher variability may reflect the influence of Lake Michigan on water quality at this site. The backwater effects from the Lake extend upstream to about the first parkway bridge upstream of the South Milwaukee Yacht Club. During the period 2007 through 2016, dissolved oxygen concentrations at both stations were always above the State's water quality criterion of 5.0 mg/l. For most of the period over which data are available, there was no temporal trend in dissolved oxygen concentration at the sampling station at the Parkway east of Lake Drive; however, concentrations in samples collected at this site during the period 2007 through 2016 were higher than those from samples collected during the period 1997 through 2006, suggesting that dissolved oxygen conditions in this section of the

[222] *Turner, Koski, and Kinzelman, 2017,* op. cit.

[223] *Ibid*.

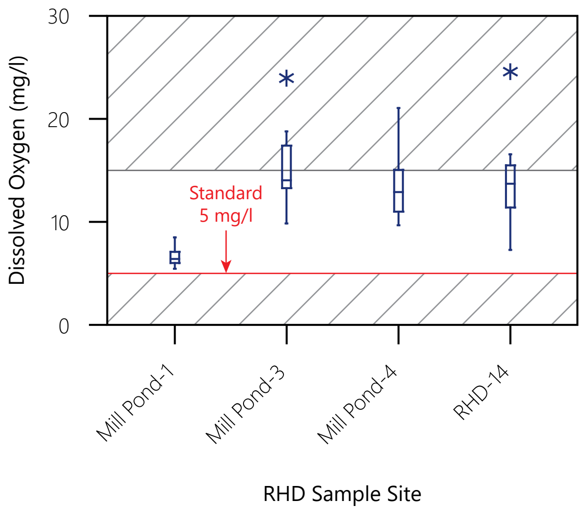
[224] *SEWRPC Technical Report No. 39,* op. cit.

[225] *SEWRPC Community Assistance Planning Report No. 316,* op. cit.

Creek improved between these two periods. There were not sufficient historical data from the station at the mouth of the Creek to assess temporal trends.

As discussed above, supersaturation of dissolved oxygen has occasionally occurred at sampling stations located within and immediately downstream of the Mill Pond. Figure 4.70 shows other locations at which some samples have dissolved oxygen concentrations that are sufficiently high to suggest that supersaturation may be occurring. During the period 2007-2016, most of these samples were collected in downstream reaches of the Creek, between 15th Avenue and the confluence with Lake Michigan. Some of these samples were collected during the winter and early spring months of December through March. Because water temperatures are low during these months and solubility of oxygen in water is consequently high, it is likely that some of these concentrations are below saturation levels.[226] It is also important to note that because water chemistry samples are usually collected during the day, the dissolved oxygen concentration shown in the graph may be less representative of average concentrations and more typical of maximum concentrations achieved during the daytime.

Figure 4.72
Concentrations of Dissolved Oxygen at Sites in the Oak Creek Mill Pond: 2015-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Saturation levels of dissolved oxygen of 140 percent and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration translates to a saturation of approximately 150 percent at an average water temperature of 14° C.

Source: City of Racine Public Health Department and SEWRPC

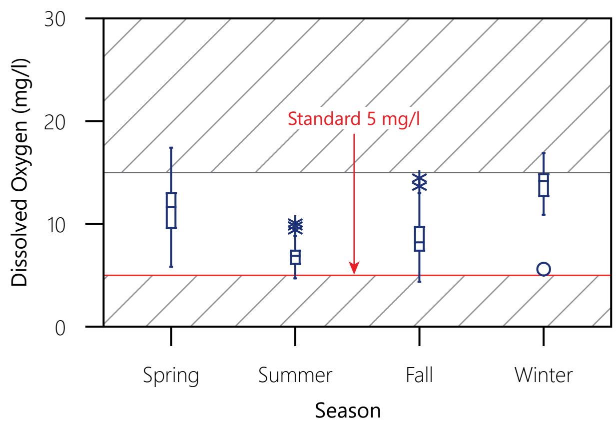
Dissolved oxygen concentrations in Oak Creek show a distinct pattern of season variation. Figure 4.73 shows seasonal concentrations of dissolved oxygen at the sampling station at the Parkway east of STH 32 (RM 1.0) over the period 2007 through 2016. Dissolved oxygen concentrations were highest during the winter. They decreased during spring and reached their lowest levels in summer. This was followed by an increase through the fall. This pattern was seen at most sampling stations at which data were available throughout the year. It is driven by the effects of water temperature on the solubility of gasses, with solubility increasing with decreasing temperature.

Figure 4.74 shows dissolved oxygen concentrations in the North Branch of Oak Creek. During the period 2007 through 2016, the concentration of dissolved oxygen at sampling stations along this stream ranged between 2.00 milligrams per liter (mg/l) and 30.02 mg/l, with a median value of 10.18 mg/l and a mean value of 10.63 mg/l. Concentrations of dissolved oxygen in the North Branch of Oak Creek decreased from upstream to downstream. During the period 2007 through 2016, median concentrations at the middle sampling station at S. 6th Street (RM 3.9) and at the sampling station at Weatherly Drive (RM 1.8) were 13.10 mg/l and 9.72 mg/l, respectively. The median concentration at the station at W. Puetz Road (RM 0.9) was higher than the median concentration at Weatherly Road; however, this was based on only two samples. The overall trend continued at the sampling station just upstream of W. Puetz Road (RM 1.0) where a median concentration of 8.31 mg/l was observed. Dissolved oxygen concentrations in samples collected from the North Branch of Oak Creek were rarely below the State's water quality criterion of 5.0 mg/l. During the period 2007 through 2016, dissolved oxygen concentrations in less than 5 percent of the samples collected from this stream were below this standard. Samples collected at W. Puetz Road suggest that concentrations of dissolved oxygen in the North Branch of Oak Creek have increased over time. This result should be interpreted with caution because it is based on limited data—21 samples that were collected over a period of more than 40 years. Thus, this apparent trend may represent statistical variation. There are not sufficient historical data at any other sampling stations along the North Branch of Oak Creek to assess temporal trends in dissolved oxygen concentration.

[226] *For the purposes of this analysis the supersaturation concentration is defined based on a water temperature of 14°C. At lower water temperatures saturation concentrations for dissolved oxygen would be higher than the concentration at a water temperature of 14°C.*

Figure 4.74 also shows samples from the North Branch of Oak Creek that have dissolved oxygen concentrations that are sufficiently high to suggest that supersaturation may be occurring. While this occurs occasionally at downstream stations such as the one at Weatherly Drive (RM 1.8), it happens frequently at the middle S. 6th Street station (RM 3.9). During the period 2007 through 2016, dissolved oxygen concentrations in 41 percent of the samples collected at this station were greater than 15 mg/l. Some features of the stream channel upstream of this site may contribute to the high incidence of samples with supersaturated dissolved oxygen concentrations. The North Branch channel at and immediately upstream from this sampling station is lined with concrete (see Map 4.1). This section contains deposits of sediment that overlay the concrete lining. The channel upstream from the concrete-lined portion is lined with rock. Field staff observed low flows, some standing water, and algal and plant growth in these sections of the North Branch of Oak Creek.

Figure 4.73
Seasonal Concentrations of Dissolved Oxygen in Oak Creek at Oak Creek Parkway East of STH 32 (RM 1.0): 2007-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Saturation levels of dissolved oxygen of 140 percent and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration translates to a saturation of approximately 150 percent at an average water temperature of 14° C.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

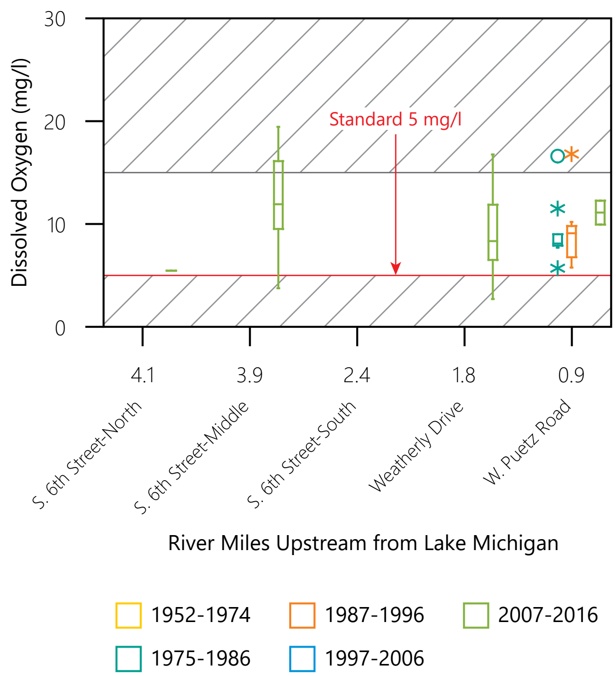
Figure 4.75 shows dissolved oxygen concentrations in the Mitchell Field Drainage Ditch. During the period 2007 through 2016, the concentration of dissolved oxygen at sampling stations along this stream ranged between 0.14 milligrams per liter (mg/l) and 13.30 mg/l, with a median value of 4.70 mg/l and a mean value of 4.99 mg/l. Concentrations of dissolved oxygen in the Mitchell Field Drainage Ditch decreased from upstream to downstream. During the period 2007 through 2016, median concentrations at the sampling stations at College Avenue (RM 1.8) and E. Rawson Avenue (RM 0.8) were 4.30 mg/l and 3.78 mg/l, respectively. Median concentrations of dissolved oxygen increased to 6.95 mg/l at a sampling station south of E. Rawson Avenue (RM 0.6); however, the data were mostly collected in years when data were not available from the other stations along this Creek. Because of this, the longitudinal trend in dissolved oxygen concentrations in the Mitchell Field Drainage Ditch should be interpreted with caution. Dissolved oxygen concentrations in a substantial fraction of the samples collected from the Mitchell Field Drainage Ditch were below the State's water quality criterion of 5.0 mg/l. During the period 2007 through 2016, dissolved oxygen concentrations in about 54 percent of the samples collected from this stream were below this standard. There are not sufficient historical data from the Mitchell Field Drainage Ditch to assess temporal trends in dissolved oxygen concentration.

The low concentrations of dissolved oxygen in the Mitchell Field Drainage Ditch were associated with elevated levels of biochemical oxygen demand (BOD). During the period 2007 through 2016, concentrations of 5-day BOD (BOD_5) ranged from below the limit of detection to 380 mg/l, with a median value of 4.5 mg/l. The two sampling stations along the Mitchell Field Drainage Ditch were the only sampling stations in the watershed at which BOD_5 was sampled where the median concentrations were above the limit of detection. Based on limited data, median concentrations of BOD_5 decreased between upstream sampling station at College Avenue (RM 1.8) and the downstream station at E. Rawson Avenue (RM 0.8), suggesting that some of this material is being metabolized in the stream. This would act to lower ambient concentrations of dissolved oxygen.

Concentrations of dissolved oxygen tend to be lower in the Mitchell Field Drainage Ditch than in other streams of the Oak Creek watershed for which data are available. This is probably not due to temperature differences between the streams. During the period 2007 through 2016, the North Branch of Oak Creek had both higher median, mean, and maximum water temperatures and higher concentrations of dissolved oxygen than the Mitchell Field Drainage Ditch. It is more likely that the low dissolved oxygen concentrations in this stream are related to other causes such as runoff containing aircraft deicing and anti-icing fluids entering the stream from Milwaukee Mitchell International Airport (MMIA), discharges of unknown substances into the stream, or degradation of organic matter in sediment located in impoundments behind beaver dams on the stream. These possible causes are not mutually exclusive. They are discussed in the following paragraphs.

Runoff of aircraft deicing and anti-icing fluids from MMIA into the Mitchell Field Drainage Ditch may be contributing BOD. While formulations of these fluids are usually proprietary and differ from one another depending on the brand and type of fluid, they typically contain either ethylene glycol or propylene glycol as a major constituent. These two compounds have very high BODs associated with them. Estimates of BOD_5 for ethylene glycol and propylene glycol are on the order of 526,000 mg/l and 1,105,000 mg/l, respectively.[227] Values this high indicate that small amounts of these compounds can potentially have large effects on dissolved oxygen concentrations in receiving waters. Mass balance estimates made as part of a study of deicing and anti-icing fluids at MMIA found that the fate of a substantial fraction of the fluids that were applied could not be accounted for.[228] This study found that, on average, about 7 percent of applied glycol deicers and anti-icers ended up in snowbanks on airport grounds, about 13 percent was contained in direct runoff from airport grounds, and about 27 percent was captured by the airport's recovery system. The study was unable to account for the fate of about 53 percent of the applied glycol deicers and anti-icers. The authors of the study noted that possible fates of the unaccounted for deicers include dripping off aircraft onto pavement while the aircraft were taxiing, being sheared off aircraft on takeoff followed by being deposited on the airfield and nearby areas, flowing through cracks in the pavement and entering groundwater, and degrading in the environment. While the results of this study reflect conditions in the early to mid-2000s, it should be noted that MMIA's stormwater discharge permit requires the airport to have the capacity to capture or recover 34 percent of the total deicing and anti-icing fluids applied during the winter season.[229] Between 2007 and 2016, sampling was conducted at the College Avenue station (RM 1.8) along the Mitchell Field Drainage Ditch for ethylene glycol and propylene glycol. This station is located immediately downstream of the airport, and water quality at this station reflects conditions in the stream as it flows out of the airport. Ethylene glycol was detected in about 8 percent of the samples. Propylene glycol was detected in about 32 percent of samples. While most of the detections of these compounds occurred during the months of December through April, each compound was detected once during September. Concentrations of ethylene glycol detected in the Mitchell Field Drainage Ditch ranged from below the limit of detection to 54 mg/l. Concentrations of propylene glycol detected in the Mitchell Field Drainage Ditch ranged from below the limit of detection to 190 mg/l.

Figure 4.74
Concentrations of Dissolved Oxygen at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Saturation levels of dissolved oxygen of 140 percent and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration translates to a saturation of approximately 150 percent at an average water temperature of 14° C.

Source: *Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC*

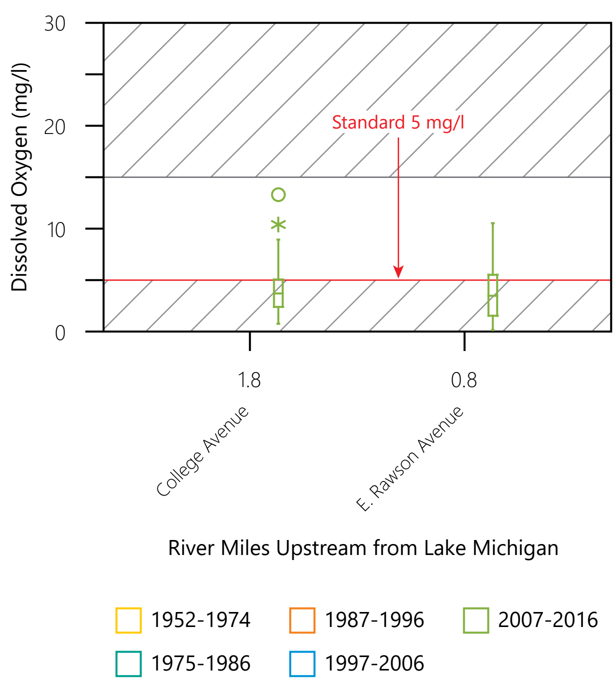
[227] *S. R. Corsi, D. Mericas, and G. T. Bowman, "Oxygen Demand of Aircraft and Airfield Pavement Deicers and Alternative Freezing Point Depressants,"* Water, Air and Soil Pollution, *volume 223, pages 2447-2461, 2012.*

[228] *S. R. Corsi, S. W. Geis, J. E. Loyo-Rosales, C. P. Rice, R. J. Sheesley, G. G. Failey, and D. A. Cancilla, "Characterization of Aircraft Deicer and Anti-Icer Components and Toxicity in Airport Snowbanks and Snowmelt Runoff,"* Environmental Science and Technology, *volume 40, pages 3195-3202, 2006.*

[229] *General Mitchell International Airport,* Winter Operations Plan: 2015-2016, *October 2015.*

Discharges of unknown substances into the Mitchell Field Drainage Ditch may contribute to the low concentrations of dissolved oxygen in this stream. During field surveys, Commission staff observed evidence that could indicate the presence of such substances. Staff noted that water flowing out of the culvert under College Avenue (RM 1.8) was cloudy, was tinted blue, and had an oily residue on its surface (see Figure 4.76). Staff also noticed an unusual, chemical odor at this location in the stream. This odor was not typical of that associated with anoxic sediment. While water flowing through this culvert originates from the MMIA grounds, the observed coloration suggests that the substance may not have consisted of aircraft deicing or anti-icing fluids. Depending on the type of fluid, these substances are typically red-orange, straw, yellow-green, or emerald-green. Staff also observed cloudy, blue tinted water in the stream about 625 feet downstream from College Avenue (see Figure 4.77) and oily residues on the water's surface at locations about 925 feet downstream and 3,390 feet downstream from College Avenue (see Figures 4.78 and 4.79). The identity and composition of the substance or substances responsible for these observations are unknown; however, should it consist of organic material, it could contribute BOD to the stream and its decomposition could result in lower dissolved oxygen concentrations.

Figure 4.75
Concentrations of Dissolved Oxygen at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Saturation levels of dissolved oxygen of 140 percent and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration translates to a saturation of approximately 150 percent at an average water temperature of 14° C.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

Finally, degradation of organic matter in sediment located in impoundments behind beaver dams on the stream might also contribute to the low concentrations of dissolved oxygen in the Mitchell Field Drainage Ditch. During field surveys, Commission staff observed the presence of three beaver dams along this stream near Rawson Avenue (see Figure 4.35). The largest and most upstream of these was about 680 feet upstream from Rawson Avenue. Water levels behind this dam may have been raised by as much as a couple of feet. Two other dams were found about 250 feet upstream from Rawson Avenue and about 125 feet downstream from Rawson Avenue. Staff noted that these impoundments contained large deposits of sediment. As previously noted, if this sediment contains organic material, bacterial degradation of this material could reduce dissolved oxygen concentrations in the water above. The presence of impoundments increases the amount of time that water is in contact with this sediment, increasing the potential for bacterial action to lower oxygen concentration. On a subsequent visit to this stream, staff observed that the three beaver dams had been removed.

During the period 2007 through 2016, concentrations of dissolved oxygen in Unnamed Creek 5 ranged between 0.28 mg/l and 16.22 mg/l, with a median concentration of 6.44 mg/l. Dissolved oxygen concentration in about 38 percent of the samples collected from this stream were below the State's water quality criterion of 5.0 mg/l. Because of the lack of historical data for this stream, temporal trends in dissolved oxygen concentration could not be assessed.

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 unit (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 concentration 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. For example, carp, suckers, and catfish generally prefer a pH range between 6.0 and 9.0 stu, although carp have been reported to tolerate water with pH values as low as 5.4 stu.[230] Sunfish, such as bass and crappies, prefer a narrower pH range between about 6.5 and 8.5 stu. Snails, clams, and mussels that incorporate calcium carbonate into their shells require higher pH values. Typically, they tolerate a range between about 7.5 and 9.0 stu. Some aquatic macroinvertebrates prefer water with relatively narrow pH ranges. For example, many mayfly, stonefly, and caddisfly nymphs prefer pH values between 6.5 and 7.5 stu. Other aquatic macroinvertebrates are able to tolerate much wider pH ranges. Mosquito larvae, for example, have been reported living in natural waters with pH values as low as 2.4 stu.[231]

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. This is the result of chemical reactions in the atmosphere that convert these oxides into strong acids. For example, in the presence of water or water vapor sulfur dioxide (SO_2) emitted into the atmosphere from sources like coal-burning power plants undergoes a series of chemical reactions that convert it into sulfuric acid (H_2SO_4). Similarly, nitrogen oxides (NO_x) emitted by the same types of sources are converted to nitric acid (HNO_3). Both of these acids are strong acids and will lower the pH of waterbodies that they enter through rainfall or other deposition. The mineral content of the soil and bedrock underlying a waterbody also has a strong influence on the waterbody's pH. Because much of the Oak Creek 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 benthic algae will tend to raise pH and can cause pH variations both on a daily and seasonal basis.

Figure 4.76
Oily Blue Water Flowing Out of College Avenue Culvert into the Mitchell Field Drainage Ditch: September 29, 2017

Source: SEWRPC

Figure 4.77
Turbid Blue Water in the Mitchell Field Drainage Ditch About 640 Feet Downstream from College Avenue Culvert: September 29, 2017

Source: SEWRPC

[230] *J.E. McKee and H.W. Wolf,* Water Quality Criteria (second edition)*, California State Water Quality Control Board, Publication No. 3-A, 1963.*

[231] *J.B. Lackey, "The Flora and Fauna of Surface Waters Polluted by Acid Mine Drainage,"* Public Health Reports, Washington, *Volume 53, pages 1499-4507, 1938.*

As previously discussed, Wisconsin's water quality criterion for pH for warmwater fish and aquatic life streams such as Oak Creek requires that pH remain within the range of 6.0 to 9.0 stu, with no change greater than 0.5 stu outside the estimated natural seasonal maximum and minimum.

Figure 4.80 shows the values of pH at selected sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, pH in the mainstem of Oak Creek ranged between 6.36 stu and 10.00 stu with a median value of 7.80 stu. Values of pH at these stations were only rarely outside the range of 6.0 stu to 9.0 stu specified in Wisconsin's water quality criteria, with over 99.9 percent of samples complying with the criteria. The few measurements that were outside this range were between 9.0 stu and 10.0 stu. In addition, at most sampling stations pH varied by less than ±1.0 stu from the station's mean value.

Figure 4.80 shows two trends in the data. First, at those sampling stations for which sufficient data are available to assess temporal trends, pH in the Creek decreased between the periods 1975 through 1986 and 1997 through 2006 and then increased during the period 2007 through 2016. Depending on the sampling station, the decrease in median pH ranged between 0.2 stu and 0.5 stu, with the median at most stations decreasing by about 0.3 stu. The subsequent increase in median pH ranged between 0.1 stu and 0.3 stu, with the median at most stations increasing by about 0.2 stu.

Figure 4.78
Oily Residue in the Mitchell Field Drainage Ditch About 925 Feet Downstream from College Avenue Culvert: September 29, 2017

Source: SEWRPC

Figure 4.79
Oily Residue in the Mitchell Field Drainage Ditch about 3,400 Feet Downstream from College Avenue Culvert: September 27, 2017

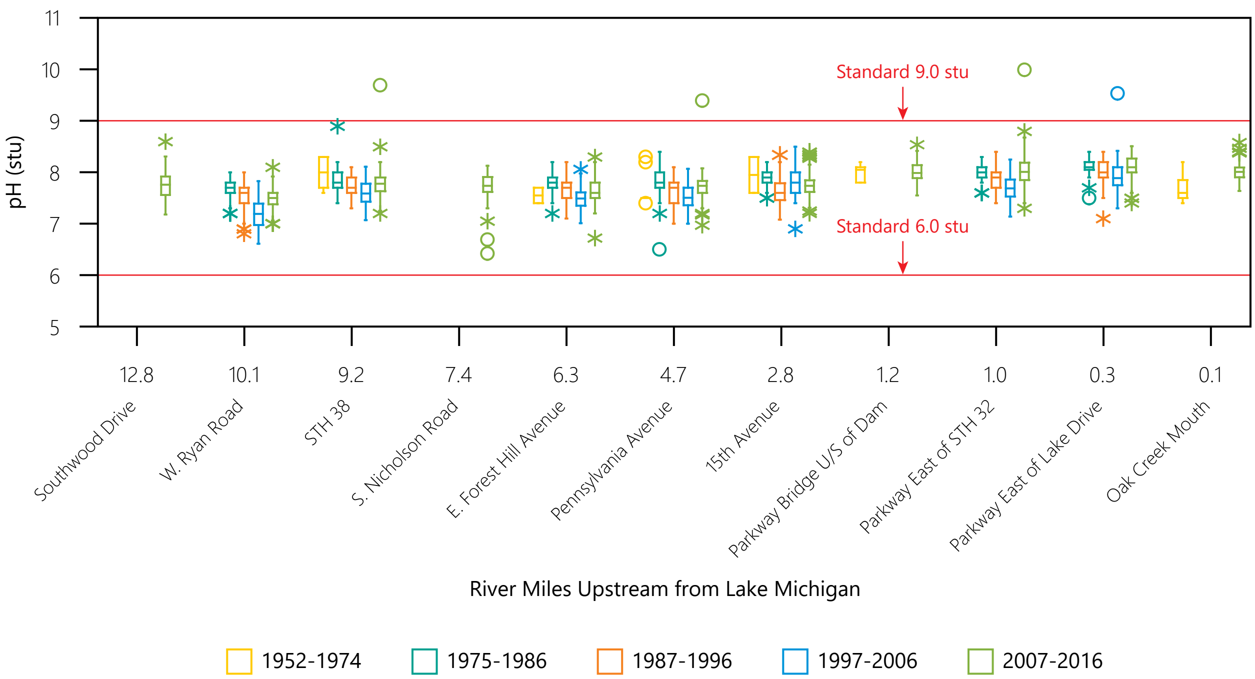
Source: SEWRPC

The causes of the temporal trend in pH in Oak Creek are not completely clear. Some of the increase in pH during the period 2007 through 2016 may reflect changes in the chemistry of emissions from nearby electric power generating plants. We Energies' Oak Creek power plant uses coal to generate electricity. Weather data collected at Milwaukee Mitchell International Airport indicate that winds over the Oak Creek watershed come from the southeast quadrant about 15 to 20 percent of the time.[232] Winds from these directions tend to carry emissions from the We Energies Oak Creek power plant over the Oak Creek watershed. In 2012, We Energies installed advanced air quality control systems at the Oak Creek power plant. These systems included wet flue gas desulfurization to address SO_2 and selective catalytic reduction to address NO_x. According to We Energies, these modifications to the power plant have reduced emissions of SO_2 by over 90 percent and emissions of NO_x by 50 to 60 percent.[233] Figure 4.81 shows annual distributions of pH in the mainstem of Oak Creek at the Oak Creek Parkway east of Lake Drive (RM 0.3). Beginning in 2012, pH at this sampling station increased, with the median pH during the period 2012-2016 being about 0.2 stu higher than the median pH during the period 2007-2011. This pattern occurred at all of the downstream stations for which sufficient data were available, with the median pH being 0.1 to 0.2 stu higher during 2012 through 2016 than in 2007 through 2011. At the two upstream stations, W. Ryan Road

[232] *See the wind rose available from the Iowa Environmental Mesonet at Iowa State University, mesonet.agron.iastate.edu/sites/windrose.phtml?station=MKE&network=WI_ASOS.*

[233] *www.we-energies.com/home/oak-creek-power-plant.htm.*

Figure 4.80
pH at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

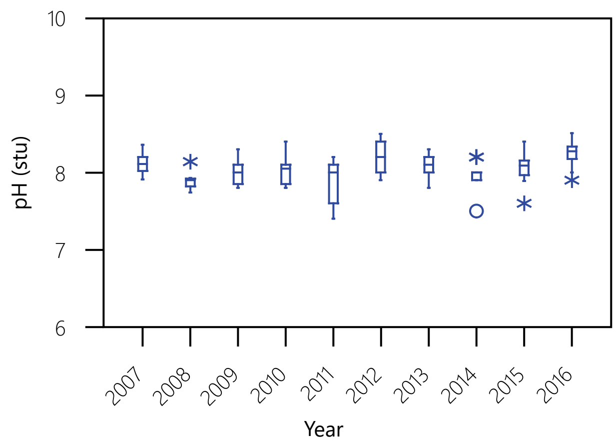
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

(RM 10.1) and STH 38 (RM 9.2), median pH was about the same during 2012 through 2016 as it was during 2007 through 2011 Figure 4.82 shows this for the station at W. Ryan Road. The timing of the increase in pH and the greater increase in downstream portions of the Creek, suggest that the reductions in SO_2 and NO_x emissions effected by the modifications to the Oak Creek power plant may have contributed to the increase in pH seen in the Creek in recent years. If this is the case, it would also partially account for the increase in pH that occurred throughout the watershed between the periods 1997 through 2006 and 2007 through 2016. During 2014 and 2015, We Energies converted its Valley power plant, which is located about eight miles to the north-northeast of the Oak Creek watershed, from burning coal to burning natural gas. If changes in the chemistry of power plant emissions are a factor in the increase in pH seen in Oak Creek over time, the modifications to the Valley power plant could result in additional pH increases in stream flows.

The second trend observed in Figure 4.80 is that pH in Oak Creek tended to increase from upstream to downstream. This increase was not continuous along the length of the Creek. Rather, most of the increase appeared to occur at two locations. One increase occurred between the sampling stations at W. Ryan Road (RM 10.1) and STH 38 (RM 9.2). During the period 2007 through 2016, the increase in the median value of pH between these two stations was about 0.30 stu. Given that the confluence of the North Branch of Oak Creek with the mainstem of Oak Creek is located between these two stations, some of the increase in median pH between these two stations may be attributable to water flowing into Oak Creek from the North Branch of Oak Creek. During the period 2007 through 2016, median pH in the North Branch of Oak Creek at the sampling station upstream of Puetz Road (RM 0.9) was 7.70 stu, slightly higher than the median value of 7.50 stu at the station at W. Ryan Road on Oak Creek (see Figure 4.83). Since the median pH at the STH 38 station along Oak Creek was 7.79 stu, it is unlikely that contributions from the North Branch fully account for this increase. The second increase occurred between the sampling stations at 15th Avenue (RM 2.8) and the Oak Creek Parkway east of STH 32 (RM 1.0).

The increases in pH along the length of the mainstem may reflect process occurring in the stream channel or Mill Pond. It may reflect the effects of photosynthesis by algae and aquatic plants. When carbon dioxide diffuses into water, it undergoes a chemical reaction with water to produce carbonic acid. This adds acidity to the water, lowering pH. Removal of carbon dioxide from water by plants and algae during photosynthesis will reduce the amount of carbonic acid in the water, resulting in an increase in pH. The increases in the median concentration of dissolved oxygen between 15th Avenue (RM 2.8) and the Oak Creek Parkway east of STH 32 (RM 1.0) and between W. Ryan Road (RM 10.1) and STH 38 (RM 9.2) are consistent with this explanation (see Figure 4.70). During field surveys of the mainstem, Commission staff found a few beds of the aquatic plants *Elodea* and *Myriophyllum* in the channel downstream of the sampling station at 15th Avenue (RM 2.8). They found few macrophytes in the section of the channel between the stations at W. Ryan Road (RM 10.1) and STH 38 (RM 9.2). They also found few macrophytes in the Mill Pond but did report the presence of suspended algae in the Pond's water column. While the amount of plant growth present during the field surveys seems insufficient for photosynthetic activity to fully account for the two increases in pH that occur along the length of the mainstem, it is likely that photosynthesis is a contributing factor.

Figure 4.81
Annual Distribution of pH Values in Oak Creek at Oak Creek Parkway East of Lake Drive (RM 0.3): 2007-2016

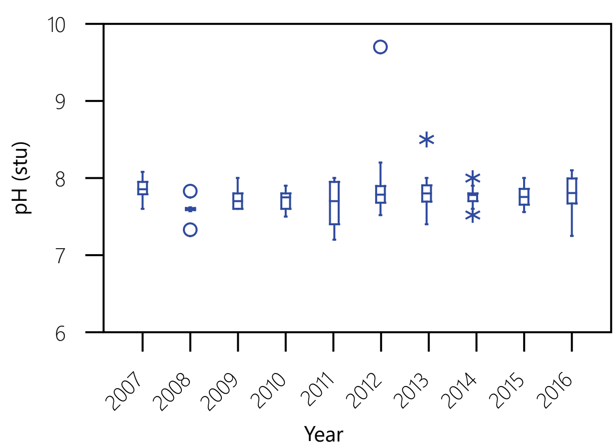


Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

The pH increases may also reflect inputs of groundwater into the mainstem of Oak Creek. Shallow groundwater in the Oak Creek watershed consists of hard water, with hardness in excess of 120 mg/l as calcium carbonate ($CaCO_3$).[234] Water this hard is generally alkaline and usually has a high pH. As part of field surveys, Commission staff identified two suspected sites of groundwater seepage into the mainstem of Oak Creek between stations at W. Ryan Road (RM 10.1) and STH 38 (RM 9.2) (see Map 4.26). Two other suspected sites of seepage were identified just upstream of the Mill Pond. While the amount of seepage observed at these sites during the field survey was not great, it may be contributing to the increases in pH shown in Figure 4.80.

Figure 4.82
Annual Distribution of pH Values in Oak Creek at STH 38 (RM 9.2): 2007-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

The increases in pH in the mainstem of Oak Creek between the sampling stations at 15th Avenue (RM 2.8) and the Oak Creek Parkway east of STH 32 (RM 1.0) might also be related to illicit connections into storm sewers that discharge into the stream between these two locations. As previously described in the section on fecal indicator bacteria, Commission staff and RHD staff conducted separate surveys of stormwater outfalls discharging into Oak Creek and some of its tributaries. These surveys identified eight outfalls between 15th Avenue (RM 2.8) and the Oak Creek Parkway east of STH 32 (RM 1.0) sampling stations at which staff observed dry weather flow at least 72 hours after the last precipitation event. The locations of these outfalls are shown on Map 4.23. During July and August 2016, RHD staff collected water samples from six of these outfalls and analyzed them for pH. The results of this sampling are given in Table 4.20. Mean and median pH in the discharges from each these outfalls is higher than median pH in the Creek at the sampling station at 15th Avenue. In addition, median and mean pH at three of these outfalls is higher than median pH in the Creek at the sampling station at the Oak Creek Parkway east of STH 32. The dry-weather discharge

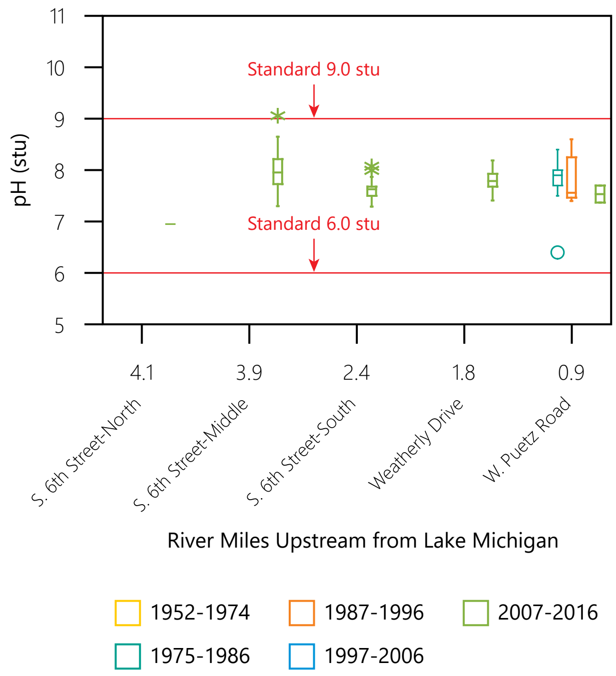
[234] *SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin, *June 2002.*

from these outfalls could partially account for the increase in pH between these two sampling stations. These outfalls should be investigated to determine and remediate the sources of dry weather flow.

Figure 4.83 shows the values of pH at selected sampling stations along the North Branch of Oak Creek. During the period 2007 through 2016 pH in the North Branch of Oak Creek ranged between 6.86 stu and 9.06 stu with a median value of 7.77 stu. Values of pH in this stream were only rarely outside the range of 6.0 stu to 9.0 stu specified in Wisconsin's water quality criteria, with over 99.6 percent of samples complying with the criteria. In addition, at most sampling stations pH varied by less than ± 1.0 stu from the station's mean value. The available pH data for this stream were not sufficient to assess longitudinal or temporal trends.

Figure 4.84 shows the values of pH at selected sampling stations along the Mitchell Field Drainage Ditch. During the period 2007 through 2016 pH in this stream ranged between 6.23 stu and 8.10 stu with a median value of 7.63 stu. Values of pH in all samples collected from this stream were within the range of 6.0 stu to 9.0 stu specified in Wisconsin's water quality criteria, with all of samples complying with the criteria. In addition, at most sampling stations pH varied by less than ± 1.0 stu from the station's mean value. The available pH data for this stream were not sufficient to assess longitudinal or temporal trends.

Figure 4.83
pH at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

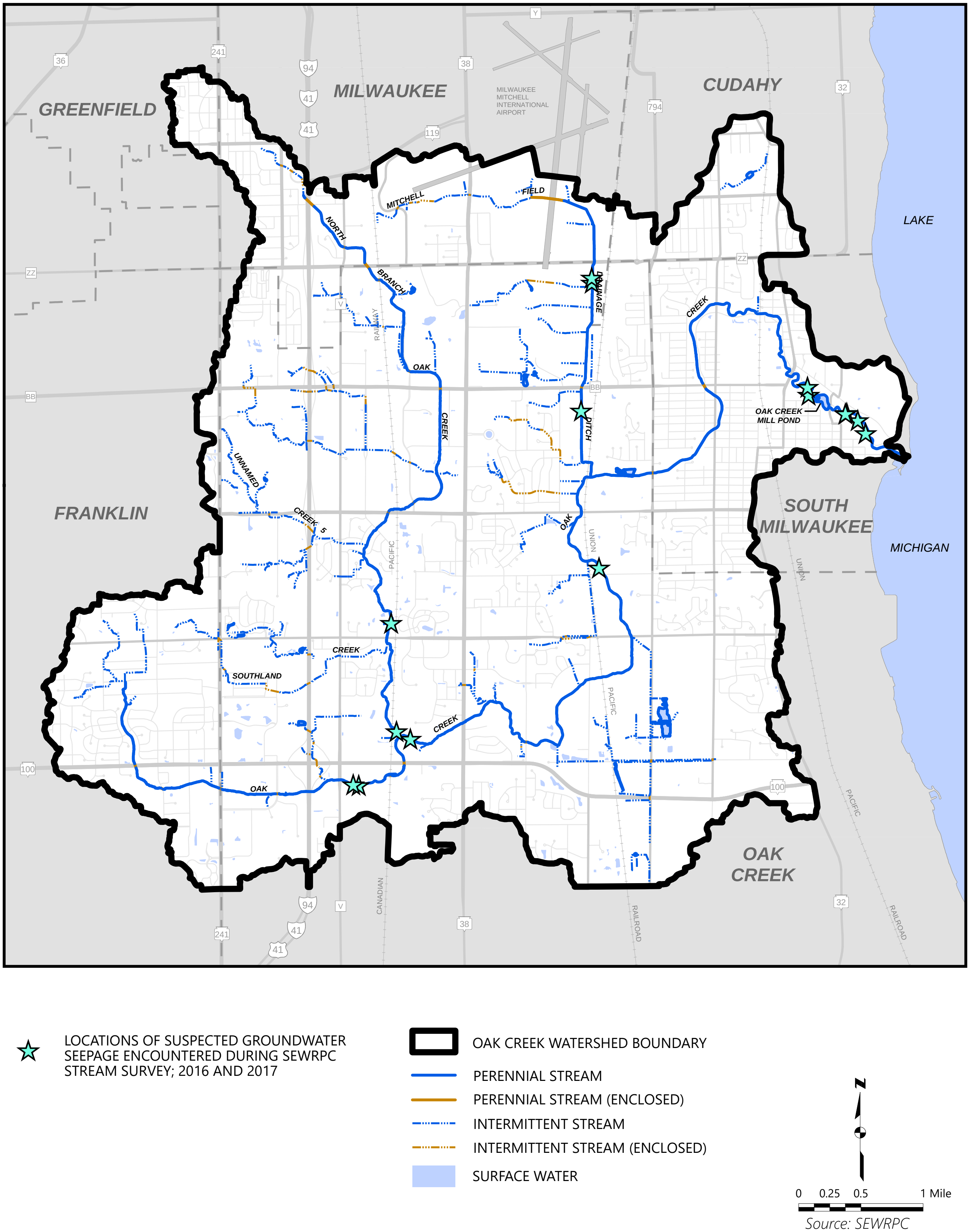
Unnamed Creek 5 has also been monitored for pH. During the period 2007 through 2016 pH in this stream ranged between 7.28 stu and 8.13 stu with a median value of 7.66 stu. Values of pH in all samples collected from this stream were within the range of 6.0 stu to 9.0 stu specified in Wisconsin's water quality criteria, with all of samples complying with the criteria. In addition, at most sampling stations pH varied by less than ± 1.0 stu from the station's mean value. The available pH data for this stream were not sufficient to assess longitudinal or temporal trends.

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 Oak Creek 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; salts applied to the land in chemical fertilizers; and salts from sewage and animal wastes. Because of the high solubility of chloride in water, if chloride is present on the land surface or in topsoil, 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.[235]

[235] *Frits van der Leeden, Fred L. Troise, and David Keith Todd,* The Water Encyclopedia (second edition), *Lewis Publishers, Inc., 1990.*

Map 4.26
Locations of Suspected Groundwater Seepage Encountered Within the Oak Creek Watershed: 2016-2017



Source: SEWRPC

Table 4.20
pH Reported from Stormwater Outfalls Discharging into the Mainstem of Oak Creek Between 15th Avenue and the Oak Creek Parkway East of STH 32: July-August 2016

Outfall Sequence ID (See Map O.1)	RHD Outfall Designation	Number of Samples	Mean pH (stu)	Median pH (stu)	pH Range (stu)
22	OF 50	5	8.07	8.07	7.94-8.22
27	OF 52	6	7.79	7.80	7.65-7.93
32	OF 99	5	8.23	8.25	8.14-8.44
33	OF 100	4	7.89	7.93	7.89-8.08
34	OF 101	4	7.92	7.91	7.72-8.14
40	OF 95	1	8.22	8.22	--

Source: City of Racine Public Health Department and SEWRPC

The State of Wisconsin has promulgated two water quality criteria for chloride, an acute toxicity criterion and a chronic toxicity criterion (see Table 4.16). Under the acute toxicity criterion, the maximum daily concentration of chloride is not to exceed 757 mg/l more than once every three years. Under the chronic toxicity criterion, the maximum four-day concentration of chloride is not to exceed 395 mg/l more than once every three years.

Figure 4.85 shows chloride concentrations at sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, chloride concentrations in Oak Creek ranged between 44 mg/l and 1,480 mg/l, with a median value of 250 mg/l and a mean value of 293 mg/l. Concentrations of chloride showed considerable variability, with concentrations in excess of 500 mg/l being reported on numerous occasions.

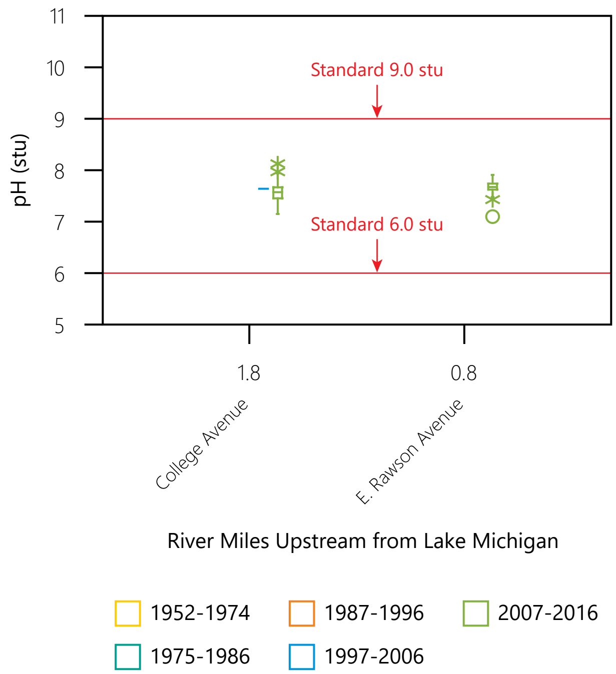
Figure 4.86 shows seasonal concentrations of chloride in Oak Creek at the sampling station at 15th Avenue (RM 2.8). The highest chloride concentrations and highest variability in chloride concentrations were observed during the winter. Concentrations and variability decreased through subsequent seasons, reaching their lowest values during the fall. These seasonal differences can be large. Seasonal median concentrations at this station during the period 2007 through 2016 ranged between 210 mg/l in the fall to 872 mg/l in the winter. There were not a sufficient number of samples of chloride collected at other sampling stations during winter months to determine whether this seasonal pattern occurred at other sampling stations along the Creek. At several stations, the seasonal pattern of values of specific conductance, which is often used as a surrogate measure for chloride concentration, was similar to the pattern of chloride shown in Figure 4.86. This suggests that the seasonal pattern of chloride concentrations shown in the figure probably occurs throughout the Creek.

The seasonal pattern shown in Figure 4.86 corresponds well with the temporal pattern of the use of salt for snow and ice control. High concentrations of chloride during the winter reflect the use of deicing salts, with the high variability in chloride concentration during this season reflecting both the fact that deicers are only applied during winter weather events and that loading of deicing compounds to waterbodies occurs both during periods of application and periods when temperatures rise above freezing resulting in runoff due to either the melting of accumulated snow and ice or rainfall. The relatively high values and variability in chloride concentration observed during spring reflect the variability of weather during spring. While this season is associated with snowmelt, winter storms may still occur leading to deicer application. Spring rains also act to flush accumulated chloride from ground surfaces and soils. This flushing leads to the lower chloride concentrations and lower degrees of variability observed during summer and fall.

Concentrations of chloride along the mainstem of Oak Creek generally decreased from upstream to downstream, with median concentrations during the period of record ranging from 190 mg/l at the W. Ryan Road sampling station (RM 10.1) to 160 mg/l at the sampling station along the Oak Creek Parkway east of Lake Drive (RM 0.3). There was one major exception to this generalization: chloride concentrations often increased between the sampling stations at W. Ryan Road (RM 10.1) and STH 38 (RM 9.2). Figure 4.87 shows the pattern of chloride concentrations along the stream on two dates in March 2003. The increase in chloride concentration between the W. Ryan Road and STH 38 stations was observed on 69 percent of the dates on which samples were collected at both stations.[236] The tendency of chloride to increase between these two sampling stations suggests that the reach of the Creek between W. Ryan Road and STH 38 constitutes a "hotspot" for chloride loading in the watershed.

The fraction of samples from 1985 to 2016 in which chloride concentrations were higher at the STH 38 (RM 9.2) station than at the W. Ryan Road (RM 10.1) station was strongly influenced by season (see Figure 4.88). During the month of March, concentrations were higher at the STH 38 station than at the W. Ryan Road station in about 93 percent of sample pairs. This percentage decreased slightly during the spring, reaching about 85 percent in May. It then dropped markedly in early summer, reaching about 65 percent in June. The decrease in this percentage continued through the summer reaching a minimum of 57 percent in August. The percentage of sample pairs in which the concentration of chloride is greater at the STH 38 sampling station than at the W. Ryan Road station increased through the fall, reaching a maximum of 100 percent in December.[237] This seasonal pattern in the increase in chloride concentrations between the sampling stations at W. Ryan Road (RM 10.1) and STH 38 (RM 9.2) shown in Figure 4.88 suggests that the use of chloride-based deicers for snow and ice control is a major factor driving the increase in concentration between these two stations.

Figure 4.84
pH at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

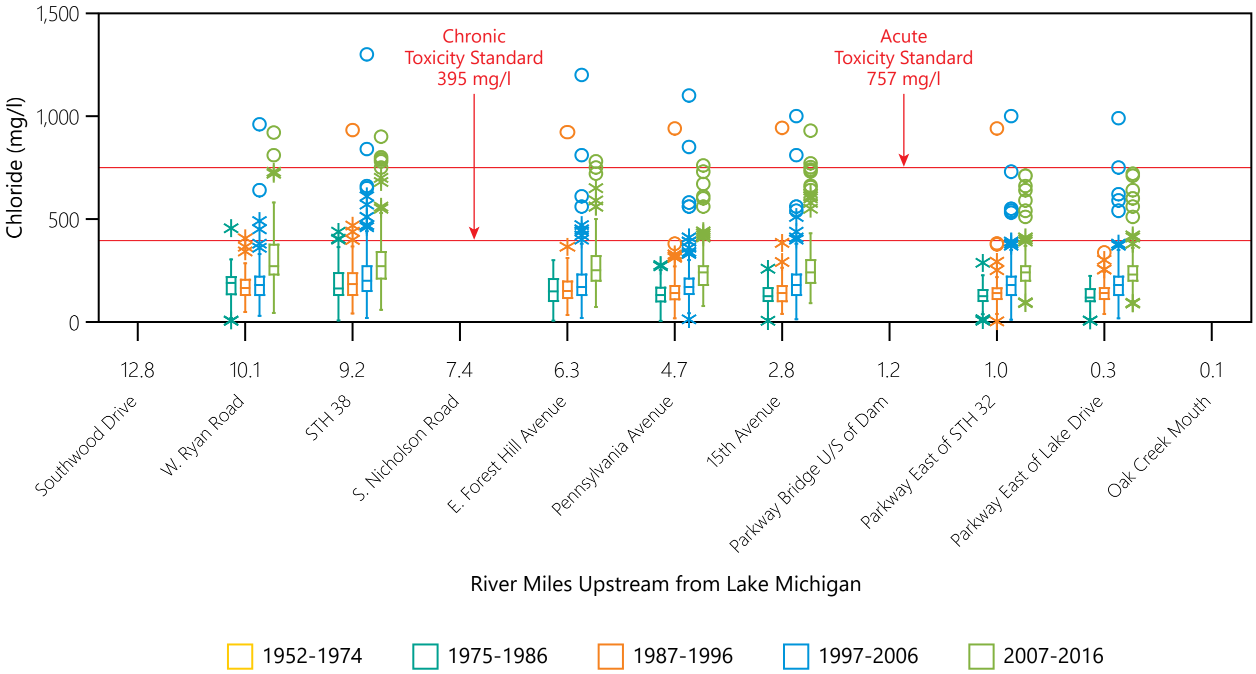
There are two likely sources of chloride to the "hotspot" between the W. Ryan Road (RM 10.1) and STH 38 (RM 9.2) sampling stations. First, given that the confluence of the North Branch of Oak Creek with the mainstem of Oak Creek is located between these two stations, the increase in chloride concentration may be attributable to runoff from lands in the assessment areas drained by the North Branch of Oak Creek. This possibility is supported by the high percentage of urban land uses and land uses likely to be treated with deicers within the North Branch of Oak Creek subwatershed. Urban land uses comprise about 78 percent of the area in this subbasin, with about 25 percent being devoted to roads, off-street parking uses, and other motor vehicle-related land uses (see Table 3.10 in Chapter 3). There may be additional sources of chloride in this subbasin. For example, there is a salt storage structure located about 60 feet from the North Branch of Oak Creek on Milwaukee Area Technical College's property near the end of S. 6th Street north of W. Rawson Avenue. Second, the increase in chloride concentration may be due to runoff from STH 38, which is a major arterial road. It should be noted that both of these possible causes could be contributing to the increase in chloride concentration that occurs between these two sampling stations. These changes could also be related to the presence of additional lane miles from recent highway and interchange projects, or operational changes to deicing and anti-icing practices on private property in the watershed.

It should be noted that chloride concentrations in Oak Creek during 2012 were higher than in both previous years and 2013. Figure 4.89 shows this for the sampling station along the Creek at W. Ryan Road (RM 10.1). A similar increase was observed in 2012 at other sampling stations along the mainstem of Oak Creek. This is probably a result of the drought conditions that affected the watershed during late spring and summer of 2012. The watershed experienced abnormally dry conditions beginning in late May. These conditions progressed to moderate drought by late June and extreme drought by mid-July. Extreme drought conditions

[236] *In most instances, samples at the two stations were collected within two hours of one another.*

[237] *Water samples were not collected at these two stations during the months of January and February.*

Figure 4.85
Concentrations of Chloride at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC

persisted through early August.[238] Because of the low levels of precipitation during much of 2012, baseflow from groundwater most likely made up a larger fraction of the flow in the upper portions of the mainstem of Oak Creek than it would during years with normal or wet conditions.

As previously discussed, chloride is highly soluble in water. When it is present in groundwater, it moves at the rate at which groundwater moves. These rates are considerably lower than the rates at which surface water flows. For example, the rates of horizontal hydraulic conductivity in the sand and gravel aquifer estimated for the areas in and around the Oak Creek watershed as part of the aquifer simulation modeling that was conducted as part of the regional water supply plan were on the order of 0.2 to 1.0 feet per day.[239] The estimated rates of vertical hydraulic conductivity for these same areas were about 0.03 feet per day. A consequence of this is that there may be a considerable time lag between chloride entering groundwater through infiltration and the same chloride being discharged as baseflow into a surface waterbody. This also suggests that, with continued releases of chloride into the environment, a reservoir of chloride may accumulate in groundwater. Over time this will lead to an increase in the chloride concentration in groundwater and in water discharged from groundwater to surface waterbodies as baseflow. This is the likely explanation as to why chloride concentrations were high in Oak Creek during 2012—because of drought conditions the concentrations in the Creek were more reflective of groundwater concentrations than they would be during a normal year. Another consequence is that in the absence of additional inputs of chloride, it could take considerable time for this reservoir of chloride to move through the aquifer and into the surface water system.

There have been similar reports of evidence of chloride contamination of shallow aquifers in the Southeastern Wisconsin Region.[240] In addition, increases in chloride concentrations in shallow aquifers

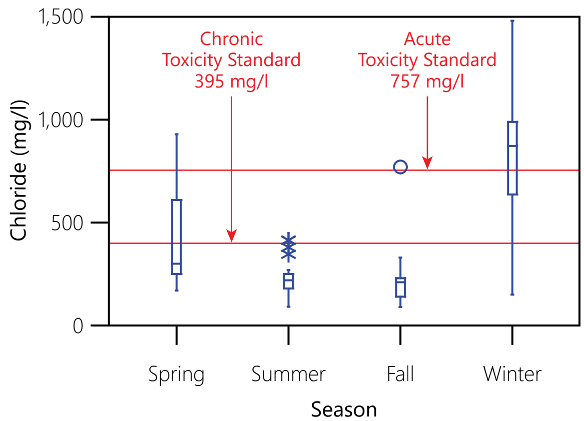
[238] *Maps showing the time course of the drought can be accessed at the National Drought Monitor at droughtmonitor.unl.edu. This monitor is a collaboration of the National Drought Mitigation Center at the University of Nebraska-Lincoln, the U.S. Department of Agriculture, and the National Oceanic and Atmospheric Administration.*

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

[240] *SEWRPC Community Assistance Planning Report No. 316,* op. cit.

have been reported in other regions. For example, a study of water quality in public water supply wells drawing from shallow aquifers in six counties in the Chicago metropolitan area found that median concentrations of chlorides in the water withdrawn from these wells had increased between the 1950s and 2005, with about 43 percent of the wells showing rates of increase in chloride concentrations greater than 1 mg/l per year and about 15 percent of wells showing rates of increase greater than 4 mg/l per year.[241] These increases may reflect accumulation of chlorides from deicing salt application in shallow groundwater. A mass balance study of a catchment in Toronto, Canada found that only 45 percent of the salt applied in the catchment was removed annually through flow of surface waters out of the catchment. The remaining chlorides entered storage in the shallow aquifer.[242]

Figure 4.86
Seasonal Concentrations of Chloride in Oak Creek at 15th Avenue (RM 2.8): 2007-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC

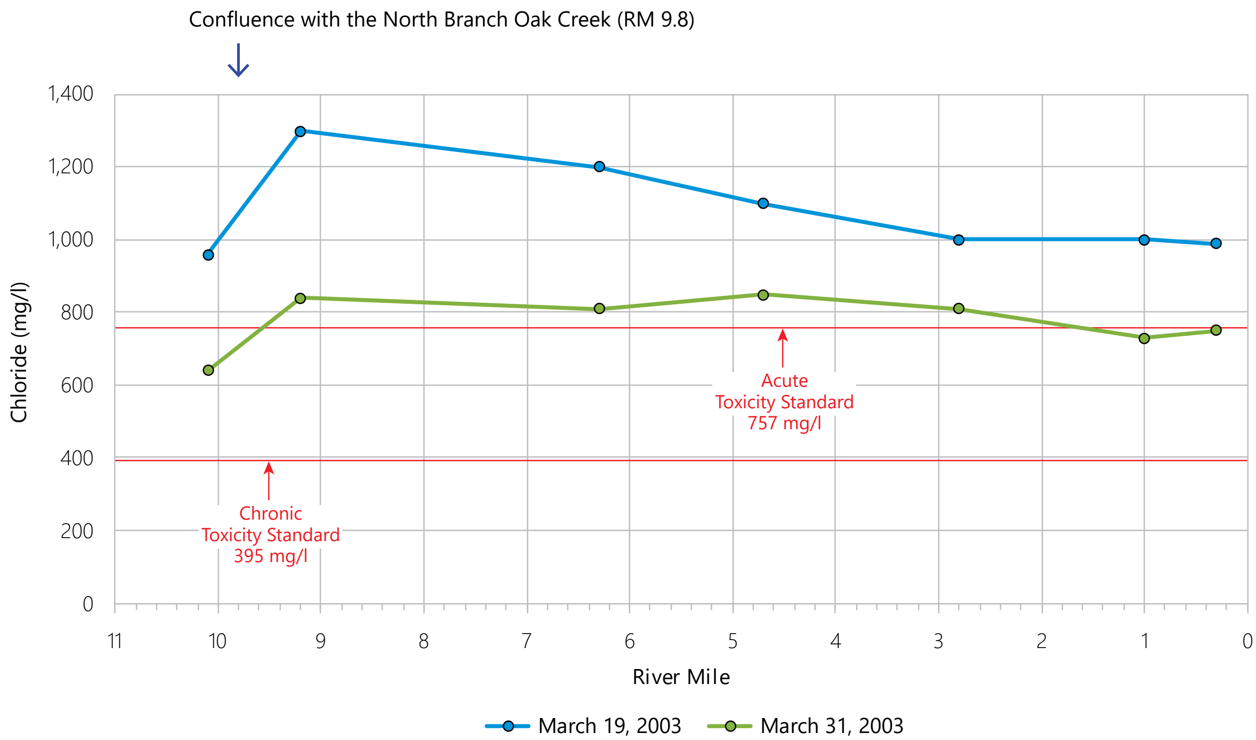
Figure 4.85 shows the presence of a long-term trend in chloride concentrations in Oak Creek. At the sampling stations at which sufficient chloride data are present to assess long-term trends, chloride concentrations have increased. In the mainstem of the Creek, median concentrations increased from 100 mg/l during the period 1952 through 1974 to 250 mg/l over the period 2007 through 2016. The increase between the periods 1997 through 2006, when the median concentration was 184 mg/l, and 2007 through 2016 was especially large. Much of the increase between the two periods occurred during the years 2014 through 2016. Figure 4.89 shows annual chloride concentrations at the sampling station at W. Ryan Road (RM 10.1) over the period 2007 through 2016. Chloride concentrations in the Creek at this station increased gradually between 2006 and 2013. Concentrations in 2012 were higher than would be expected based on the trend, but this most likely reflects the effects of the drought that occurred in that year. In 2014 chloride concentrations in the Creek at this station increased markedly and remained high in subsequent years. The fact that this pattern was observed at every sampling station along the mainstem of Oak Creek for which sufficient chloride data are available to assess trends suggests that this increase was a system-wide event.

Figure 4.90 shows the changes in chloride concentration at the sampling station at W. Ryan Road (RM 10.1) over each year shown in Figure 4.89 except 2012, with the upper graph showing the changes during the years prior to 2014 and the lower graph showing the changes during the years 2014 through 2016. The x-axis in Figure 4.90 shows the day of the year, with Day 1 being January 1 and Day 350 being December 16 in normal years and December 15 in leap years. The pattern of change in chloride concentration in the years 2014 through 2016 was different from that seen in the years prior to 2014. During the years prior to 2014, chloride concentrations during early spring (days 80 through 120) were generally between about 200 mg/l and 400 mg/l. While there was variability during any year, the concentration of chloride decreased gradually over spring through fall. By mid-to-late fall (days 275 through 335), concentrations had generally declined to a range of about 150 mg/l to 300 mg/l. Early spring concentrations during the years 2014 through 2016 were higher than in previous years, ranging between about 500 mg/l and 800 mg/l. Concentrations decreased over the course of the years, ranging between about 200 mg/l and 550 mg/l by mid-to-late fall. In the later years, chloride concentrations were higher at the beginning of the sampling season, decreased more rapidly, and remained higher at the end of the sampling season than in the earlier years. Similar differences between the pre-2014 and post-2013 patterns were observed at every sampling station along the mainstem of Oak Creek for which sufficient chloride data are available to assess trends.

[241] *V. R. Kelly, "Long-Term Trends in Chloride Concentrations in Shallow Aquifers near Chicago,"* Ground Water, *Volume 45, pages 772-781, 2008.*

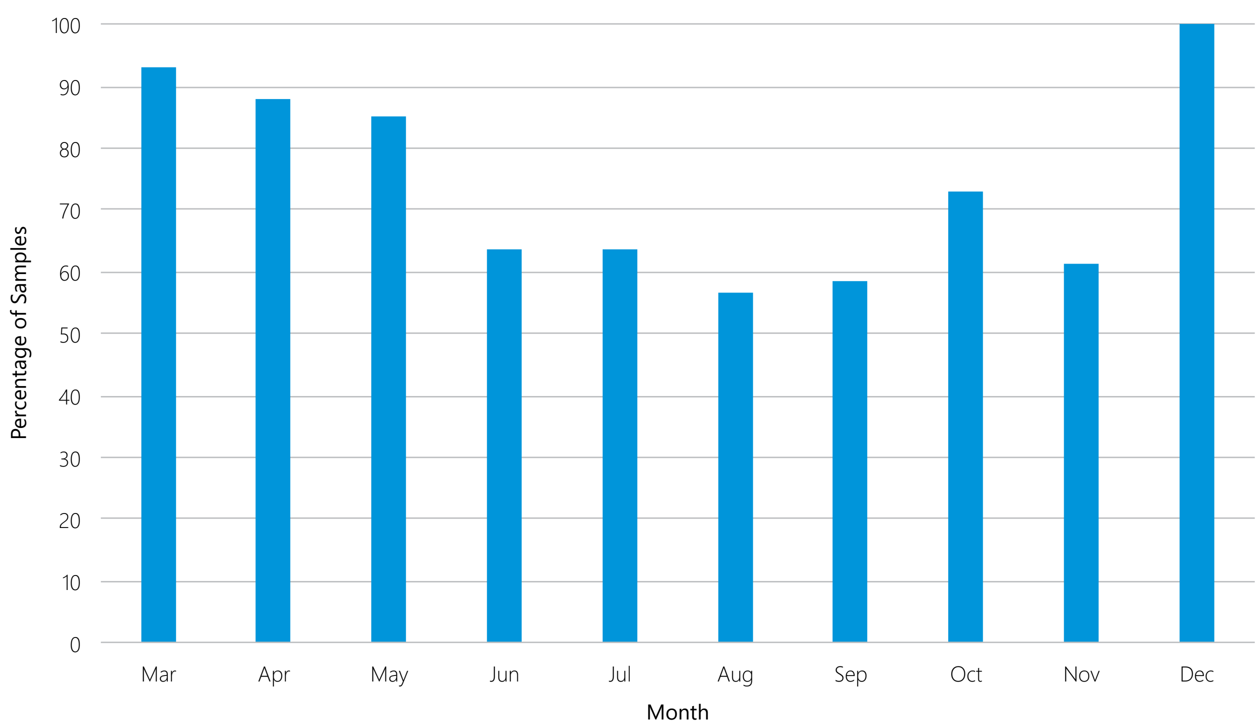
[242] *K.W.F. Howard, and J. Haynes, "Groundwater Contamination Due to Road Deicing Chemicals—Salt Balance Implications,"* Geoscience Canada, *Volume 20, pages 1-8, 1993.*

Figure 4.87
Chloride Concentrations Along the Mainstem of Oak Creek: March 2003



Source: U.S. Geological Survey and SEWRPC

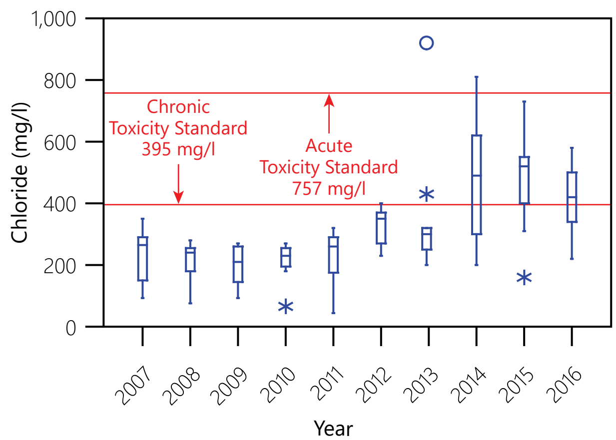
Figure 4.88
Percentages of Samples from Oak Creek in Which Chloride Concentrations at STH 38 (RM 9.2) were Higher than that at W. Ryan Road (RM 10.1): 1985-2016



Source: Milwaukee Metropolitan Sewerage District and SEWRPC

It is not clear what caused the relatively large increase in chloride concentrations in Oak Creek that occurred in 2014 and subsequent years. Most of the chloride data available for the years 2007 through 2016 was collected and analyzed by MMSD. Water quality monitoring staff from the District indicated that they made no changes in their collection and chemical analysis procedures related to chloride in 2014. The fact that concentrations during the early spring were so much higher during the years 2014 through 2016 suggest that the increase in concentration and change in the annual pattern of concentration may be related to application of deicing salts; however, just how the change is related is not apparent. While the frequency of deicer application and the amount of deicers applied during any winter depend on that winter's weather, examining meteorological records from the National Weather Service station at Milwaukee Mitchell International Airport revealed no obvious differences between the periods 2007 through 2013 and 2014 through 2016 in such variables as average daily temperature, number or timing of thaws, numbers of precipitation and snowfall events, amounts of winter and spring precipitation and snow, and depth of snow on the ground that could result in differences in deicer applications that would account for the increase of chloride shown in Figure 4.89. These changes could also be related to the presence of additional lane miles from recent highway and interchange projects, or operational changes to deicing and anti-icing practices on private property in the watershed.

Figure 4.89
Annual Distributions of Chloride Concentrations in Oak Creek at W. Ryan Road (RM 10.1): 2007-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

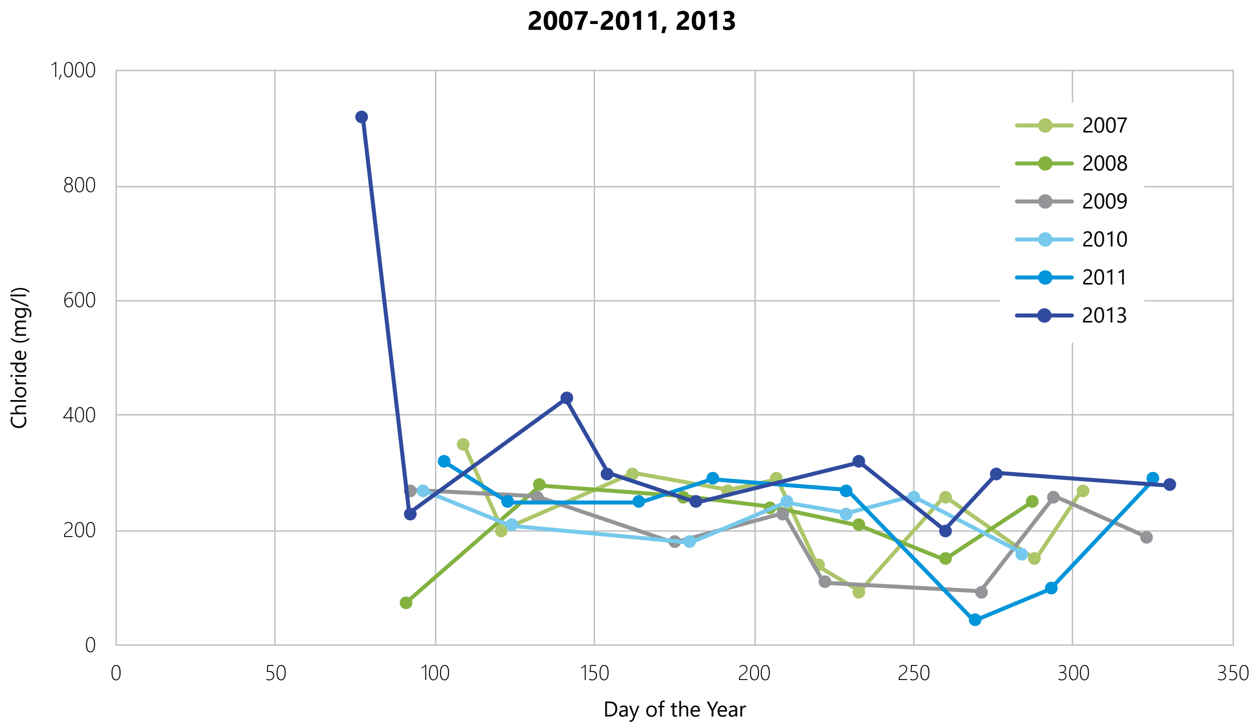
Source: Milwaukee Metropolitan Sewerage District, and SEWRPC

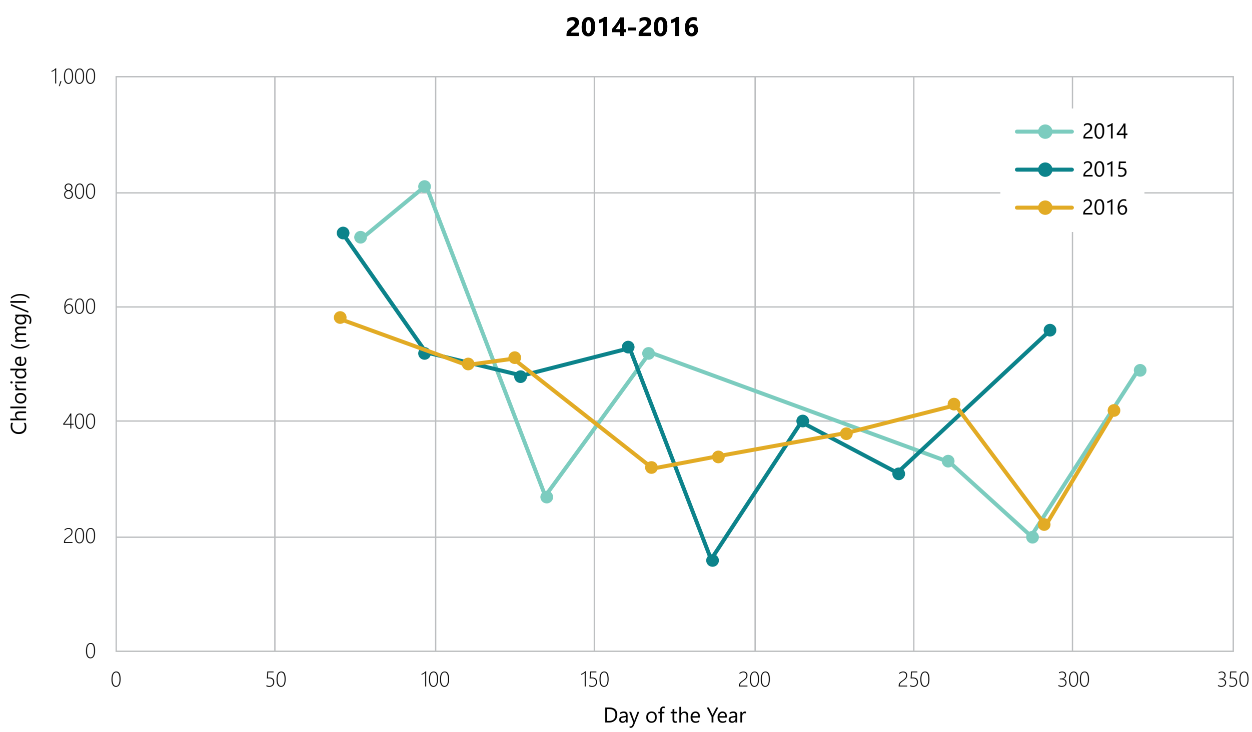
The conclusions regarding trends should be interpreted with caution. Deicing operations are conducted mostly during winter months. Very few data are available for chloride in this watershed from winter months, especially from the period 2007 through 2016. This is due to the fact that most of the chloride data available for the Oak Creek watershed were collected by MMSD and the District does not conduct much sampling during winter months. Because few data are available from the months during which deicing operations are conducted, the data presented here probably underestimate the maximum and average concentrations that actually occur in the Creek. In addition, the lack of winter data means that the assessment of trends cannot take winter concentrations into account. It should be noted, though, that increasing trends in chloride concentration have been observed in many waterbodies in Southeastern Wisconsin and have been reported in other parts of the nation where snow and ice control operations are conducted during the winter.[243]

At all stations along the mainstem of Oak Creek where chloride was investigated, samples were collected that had concentrations higher than one or both the State's toxicity criteria for aquatic life (see Figure 4.85). Concentrations of chloride in 3 percent of samples collected during the period 2007 through 2016 were higher than the acute toxicity criterion of 757 mg/l. The percentage of samples at individual sampling stations with concentrations higher than the acute criterion ranged between 0 and 9 percent. Concentrations of chloride in 17 percent of samples collected during the same period were higher than the chronic toxicity criterion of 395 mg/l. The percentage of samples at individual sampling stations with concentrations higher than the chronic toxicity criterion ranged between 10 and 26 percent. A formal comparison of chloride concentrations to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

[243] *See, for example, SEWRPC Technical Report No. 39,* op. cit.*; SEWRPC Community Assistance Planning Report No. 315,* A Water Resources Management Plan for the Village of Chenequa, Waukesha County, Wisconsin, *June 2014; SEWRPC Community Assistance Planning Report No. 316,* op. cit*; Steven R. Corsi, Laura A. DeCicco, Michelle A. Lutz, and Robert M. Hirsch, "River Chloride Trends in Snow-Affected Urban Watersheds: Increasing Concentrations Outpace Urban Growth Rate and Are Common Among All Seasons,* Science of the Total Environment, *Volume 508, pages 488-497, 2015.*

Figure 4.90
Chloride Concentrations in Oak Creek at W. Ryan Road (RM 10.1): 2007-2016





Note: Time course of chloride for 2012 is not shown because the year was atypical due to the occurrence of a severe drought.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC

During the period 2007 through 2016, two chloride samples were collected from the North Branch of Oak Creek. These samples were collected during the winter. The concentrations reported in these samples were 833 mg/l and 1,610 mg/l. These concentrations exceeded both the State's chronic and acute toxicity criteria for aquatic life. A few chloride samples were collected from this stream between 1975 and 2006. The concentrations in these samples ranged between 52 mg/l and 625 mg/l with a median concentration of 91 mg/l.

Figure 4.91 shows chloride concentrations at sampling stations along the Mitchell Field Drainage Ditch. During the period 2007 through 2016, chloride concentrations in this stream ranged between 71 mg/l and 2,100 mg/l with a median concentration of 476 mg/l. Data were not available to examine spatial or temporal trends in chloride concentrations in this stream. Concentrations in 36 percent of the samples were higher than the State's acute toxicity criterion for fish and aquatic life. Concentrations in 55 percent of the samples were higher than the State's chronic toxicity criterion for fish and aquatic life. A formal comparison of chloride concentrations to the State's water quality standards is given in the section on achievement of water use objectives later in this chapter.

No recent or historical chloride data are available for other tributary streams in the Oak Creek watershed.

Specific Conductance

Specific conductance measures the ability of water to conduct an electric current. Because this ability is affected by water temperature, conductance values are corrected to a standard temperature of 25ºC (77 degrees Fahrenheit). This corrected value is referred to as specific conductance. Pure water is a poor conductor of electrical currents and exhibits low values of specific conductance. For example, distilled water produced in a laboratory has a specific conductance in the range of 0.5 to 3.0 microSiemens per centimeter (μS/cm), a very low value. The ability of water to carry a current depends upon the presence of ions in the water, and on their chemical identities, total concentration, mobility, and electrical charge. Solutions of many inorganic compounds, such as salts, are relatively good conductors. As a result, specific conductance gives a measure of the concentration of dissolved solids in water, with higher values of specific conductance indicating higher concentrations of dissolved solids.

Under certain circumstances, measurements of specific conductance may act as a useful surrogate for measurements of the concentrations of particular dissolved materials. For example, measurements of specific conductance may be able to give indications of chloride concentrations in receiving waters. Analysis of data collected by the USGS suggests that there is a linear relationship between specific conductance and chloride concentration at higher values of conductance and chloride concentration.[244] This suggests that during periods when chloride is being carried into receiving waters by discharges of stormwater or snowmelt, ambient chloride concentrations could be estimated using specific conductance. The advantage to this is that specific conductance can be measured inexpensively in the field using a hand-held meter, while measurements of chloride concentrations may require chemical analysis.

Estimates of chloride concentrations from this sort of regression model should be interpreted with caution. A comparison of the chloride concentrations predicted by the USGS regression model to actual chloride concentrations in samples collected from the Root River found that the regression model usually predicted higher chloride concentrations based on specific conductance than were observed in the River.[245] Simultaneous collection of both specific conductance and chloride data could be helpful in refining the regression relationship. Such refinement could potentially allow the substitution of specific conductance monitoring for some chloride monitoring with a potential cost savings.

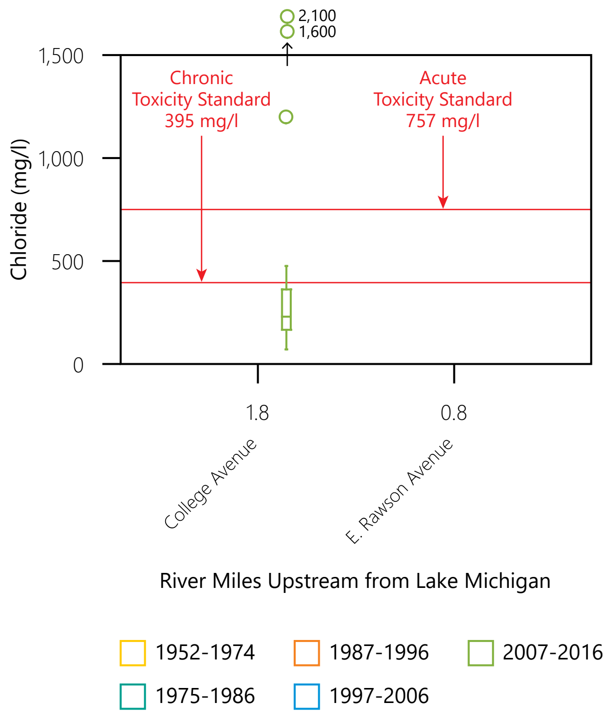
Figure 4.92 shows values of specific conductance at sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, chloride concentrations in Oak Creek ranged between 2.4 µS/cm and 6,200 µS/cm, with a median value of 1,438 µS/cm and a mean value of 1,489 µS/cm. Values of specific conductance showed considerable variability, with values in excess of 2,500 µS/cm being reported on numerous occasions.

[244] *Steven R. Corsi, David J. Graczyk, Steven W. Geis, Nathaniel L. Booth, and Kevin D. Richards, "A Fresh Look at Road Salt: Aquatic Toxicity and Water Quality Impacts on Local, Regional, and National Scales,"* Environmental Science and Technology, *Volume 44, 2010.*

[245] *SEWRPC Community Assistance Planning Report No. 316*, op. cit.

Figure 4.92 shows the presence of a long-term trend in values of specific conductance in Oak Creek. At the sampling stations at which sufficient data are present to assess long-term trends, values of specific conductance have increased. In the mainstem of the Creek, median concentrations increased from about 1,000 µS/cm during the period 1952 through 1974 to over 1,400 µS/cm during the period 2007 through 2016. The increase between the periods 1997 through 2006, when the median concentration was about 1,200 µS/cm, and 2007 through 2016 was especially large. Much of the increase between the two periods occurred during the years 2014 through 2016. Figure 4.93 shows annual distributions of values of specific conductance at the sampling station at W. Ryan Road (RM 10.1) over the period 2007 through 2016. Values of specific conductance in the Creek at this station increased gradually between 2006 and 2013. Values in 2012 were higher than would be expected based on the trend, but this most likely reflects the effects of the drought that occurred in that year. In 2014 values of specific conductance in the Creek at this station increased markedly and remained high in subsequent years. The fact that this pattern was observed at every sampling station along the mainstem of Oak Creek for which sufficient data are available to assess trends suggests that this increase was a system-wide event. This pattern is very similar to the changes observed in chloride concentrations during the same period (see Figure 4.89). This suggests that the marked increase in specific conductance that began in 2014 probably reflects changes in chloride concentrations in the Creek.

Figure 4.91
Concentrations of Chloride at Sites Along the Mitchell Field Drainage Ditch: 1952-2016

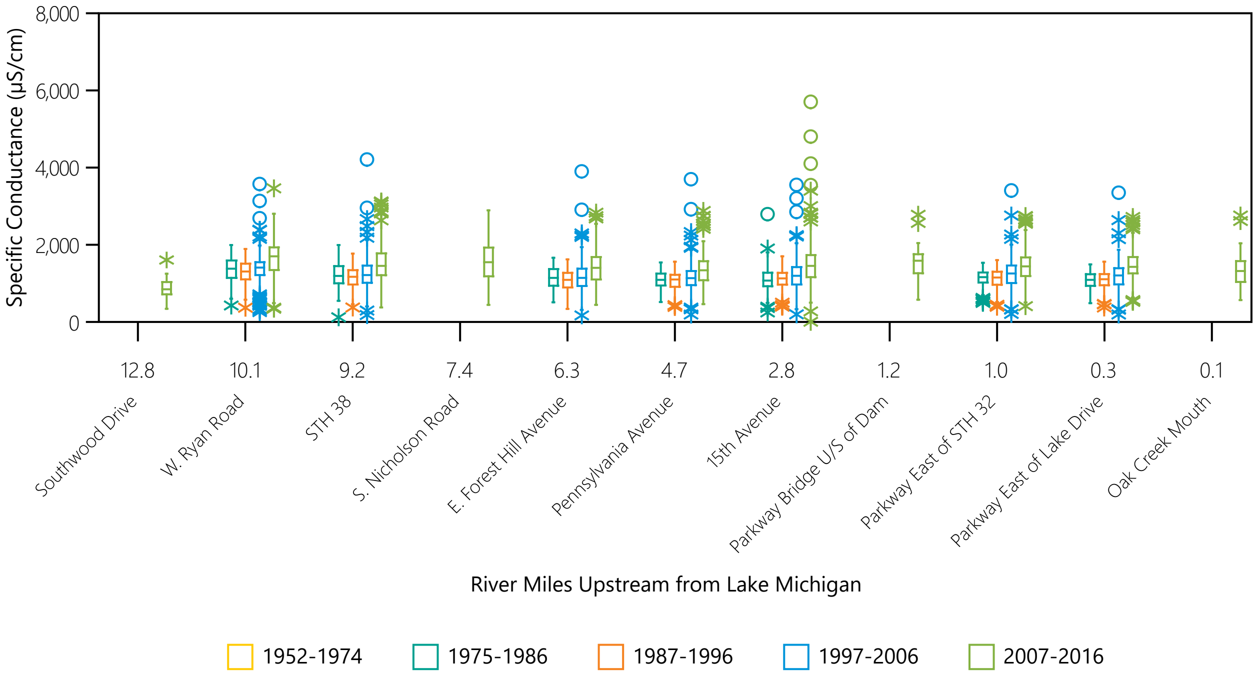


Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, and SEWRPC

During the period 2007 through 2016, the values of specific conductance from upstream to downstream along the mainstem of Oak Creek show a complicated pattern (see Figure 4.92). This pattern shows more variation from upstream to downstream than the decreasing trend in chloride concentrations and may reflect the fact that other ions in addition to chloride contribute to the conductivity of the water. While the overall trend appears to be decreasing specific conductance from upstream to downstream, this trend is punctuated by increases some points. Median values of specific conductance doubled between the sampling stations at Southwood Drive (RM 12.8) and W. Ryan Road (RM 10.1). This increase may reflect the highly urbanized nature of the Oak Creek Headwaters assessment area and the portion of the Upper Oak Creek assessment area upstream of IH 94. In addition, this reach of the mainstem of Oak Creek receives runoff from several major roadways including IH 94, STH 241, CTH V, and two crossings of STH 100. Median values of specific conductance decreased between W. Ryan Road and STH 38 (RM 9.2). It is not clear whether this decrease is the result of inputs from the North Branch of Oak Creek. Median values of specific conductance at Weatherly Drive, the downstream station along the North Branch, were higher than those in the mainstem at either W. Ryan Road or STH 38, but this station is 1.8 miles upstream from the confluence with the mainstem (see Figure 4.94). Because of this, the values of specific conductance detected at Weatherly Drive may not give a good indication of specific conductance in the North Branch of Oak Creek where it joins the mainstem of Oak Creek. Between STH 38 and S. Nicholson Road (RM 7.4), the median value of specific conductance increased. Between S. Nicholson Road and Pennsylvania Avenue (RM 4.7), median values of specific conductance decreased. This decrease happens despite the fact that median values of conductance at E. Rawson Avenue (RM 0.8), the downstream station along the Mitchell Field Drainage Ditch, were considerably higher than those in the mainstem (see Figure 4.93). Median values of specific conductance increased between the stations at Pennsylvania Avenue and the parkway bridge upstream of the dam (RM 1.2). This increase may reflect the highly urbanized nature of the Lower Oak Creek and Oak Creek-Mill Pond assessment areas. Finally, there was a decreasing trend in median specific

Figure 4.92
Specific Conductance at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Specific conductance consists of conductance corrected to a standard temperature of 25° C.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

conductance from upstream to downstream between the parkway bridge station and the confluence with Lake Michigan. The decrease between the sampling stations at the parkway east of STH 32 (RM 0.3) and the Oak Creek mouth (RM 0.1) was particularly marked and may reflect dilution with water from Lake Michigan.

Figure 4.95 shows seasonal values of specific conductance in Oak Creek at the sampling station at 15th Avenue (RM 2.8). The highest values of and variability in specific conductance were observed during the winter. Values and variability decreased through subsequent seasons, reaching their lowest values during the fall. These seasonal differences can be large. Seasonal median concentrations at this station during the period 2007 through 2016 ranged between 1,250 µS/cm in the fall to 2,100 µS/cm in the winter. This seasonal pattern in specific conductance occurred at several other stations. The seasonal pattern of values of specific conductance is similar to the seasonal pattern of chloride shown in Figure 4.86. This suggests that the values of specific conductance in Oak Creek are strongly influenced by the concentrations of chloride in the stream.

The seasonal pattern shown in Figure 4.95 corresponds well with the temporal pattern of the use of salt for snow and ice control. High values of specific conductance during the winter reflect the use of deicing salts, with the high variability observed during this season reflecting both the fact that deicers are only applied in the event of winter weather events and that loading of deicing compounds to waterbodies occurs both during periods of application and periods when temperatures rise above freezing resulting in runoff due to either the melting of accumulated snow and ice or rainfall. The relatively high values and variability in specific conductance observed during spring reflect the variability of weather during spring. While this season is associated with snowmelt, winter storms may still occur leading to deicer application. Spring rains also act to flush accumulated chloride from ground surfaces and soils. This flushing leads to the lower values and reduced variability in specific conductance observed during summer and fall.

Figure 4.94 shows values of specific conductance at sampling stations along the North Branch of Oak Creek. During the period 2007 through 2016, values of specific conductance in this stream ranged between 196 µS/

cm and 6,300 μS/cm with a median concentration of 1,668 μS/cm. Data were not available to examine temporal trends in specific conductance in this stream. From upstream to downstream, values of conductance appear to first decrease then increase. This trend should be interpreted with caution. The values shown in Figure 4.94 for the stations at S. 6th Street North (RM 4.1) and W. Puetz Road (RM 0.9) are each based on a small number of samples.

Figure 4.96 shows values of specific conductance at sampling stations along the Mitchell Field Drainage Ditch. During the period 2007 through 2016, values of specific conductance in this stream ranged between 301 μS/cm and 14,100 μS/cm with a median concentration of 1,967 μS/cm. Data were not available to examine temporal trends in values of specific conductance in this stream. The median value of specific conductance at College Avenue (RM 1.8) was slightly higher than that at E. Rawson Avenue (RM 0.8). Higher variability was also observed at the station at College Avenue than at E. Rawson Avenue; however, this may reflect the greater number of samples that were collected at College Avenue.

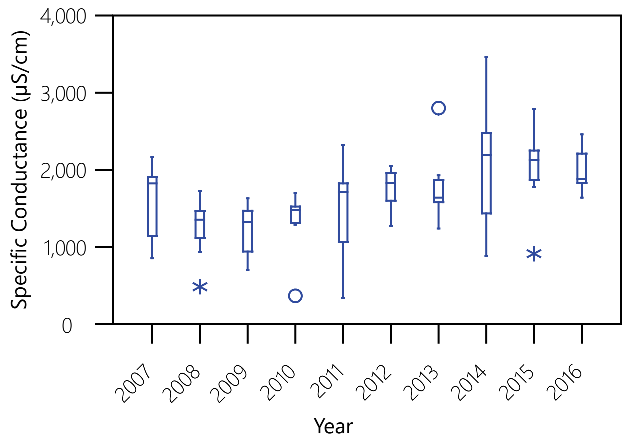
During the period 2007 through 2016, specific conductance in Unnamed Creek No. 5 ranged between 707 μS/cm and 3,113 μS/cm, with a median value of 1,813 μS/cm and a mean value of 1,938 μS/cm. Since data were collected at only one sampling station, no information is available regarding how specific conductance varies along the length of this Creek. Due to the lack of historical data, temporal trends in specific conductance cannot be assessed in this stream.

Suspended Material

Suspended material in surface waters consists of particles of sand, silt, and clay; planktonic organisms; and fine organic and inorganic debris. The composition of suspended material varies with characteristics of the watershed and pollution sources.

Energy in water motion keeps particulate material suspended. Because the density of these particles is greater than the density of water, they will settle out of the water in the absence of water movement such as flow or turbulence. The rate at which a particle settles is a function of its size, density, and shape. In general, larger and denser particles will settle more quickly than smaller and less dense particles. Flow and mixing will keep particles suspended, with stronger flow or mixing being required to keep larger or denser particles suspended. This relationship has implications for suspended material in waterbodies. In streams, for

Figure 4.93
Specific Conductance in Oak Creek at W. Ryan Road (RM 10.1): 2007-2016

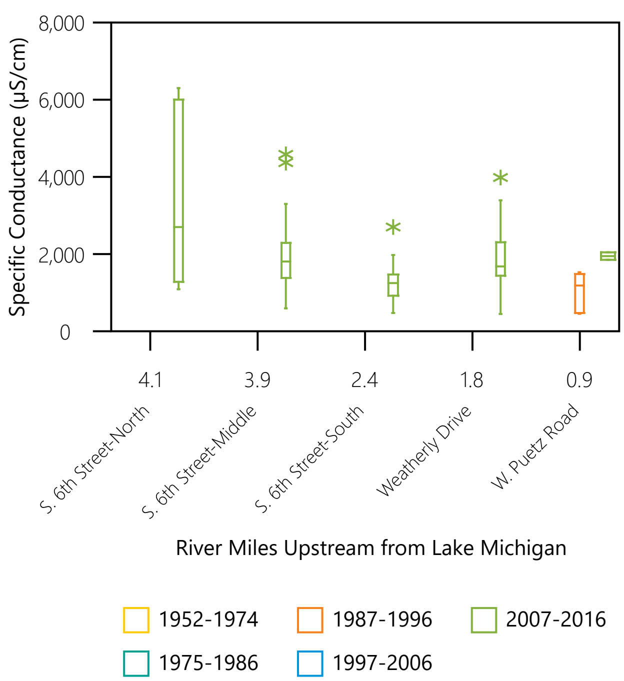


Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Specific conductance consists of conductance corrected to a standard temperature of 25°C.

Source: Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

Figure 4.94
Specific Conductance at Sites Along the North Branch of Oak Creek: 1952-2016

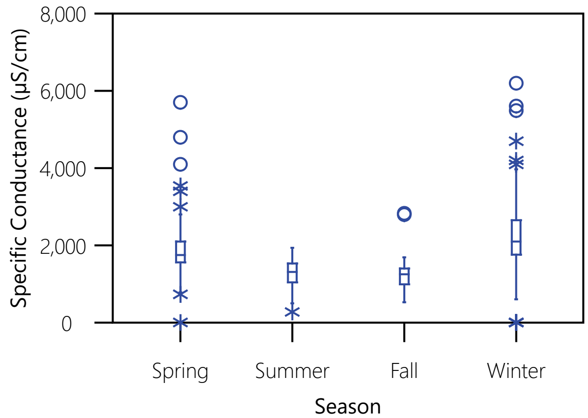


Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Specific conductance consists of conductance corrected to a standard temperature of 25°C.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC example, higher concentrations and larger and denser suspended particles are associated with higher water velocities—both in fast-moving sections of streams and during high flow periods. If water velocities are great enough, they may cause resuspension of sediment from the bed or erosion from the bed and banks of the stream. By contrast, deposition of suspended material may occur in slow-moving streams or during periods of low flow, with progressively smaller and lighter particles being deposited with decreasing flow. The result of this is that concentrations of suspended material and the nature of the suspended particles in a waterbody vary, both spatially and over time.

Figure 4.95
Seasonal Specific Conductance in Oak Creek at 15th Avenue (RM 2.8): 2007-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Specific conductance consists of conductance corrected to a standard temperature of 25°C.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

Some best management practices (BMPs) that are designed to reduce sediment contributions to waterbodies take advantage of this relationship between flow and suspension of particulate material. Part of the way that sedimentation ponds work is through slowing water velocity down. This causes suspended particles to settle out of the water column and can reduce the amount of sediment released to receiving waters. This mechanism will also act to reduce contributions of any material that is associated with the particles through incorporation into the particles or adsorption onto the particle surfaces. For example, because phosphorus is often a constituent of sediment particles or adsorbed to the surface of such particles, settling of suspended particles in these ponds will act to reduce the amount of phosphorus released from the ponds. When the pond water depth is reduced due to the accumulation of sediment, water moving through a pond can also act to resuspend sediment. Under these conditions, such ponds can act as a source of sediment and associated pollutants to receiving waters.

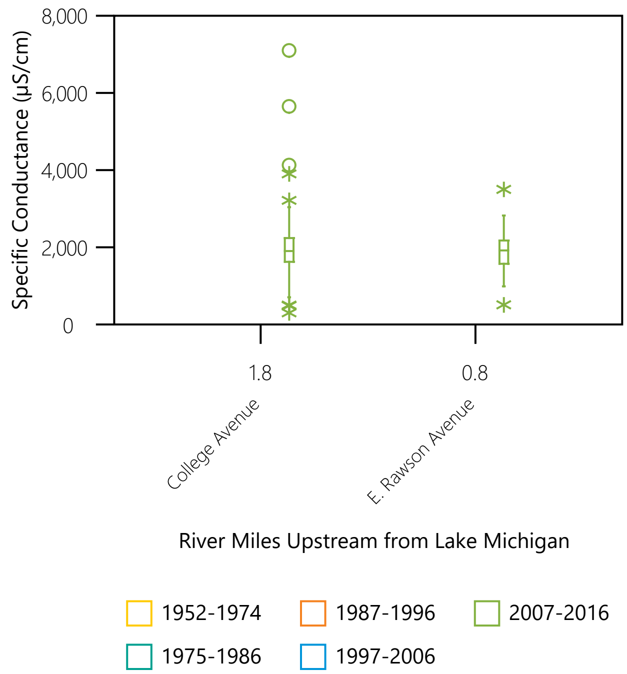
Sources that contribute suspended material to waterbodies include those within the waterbody as well as those in the contributing watershed. Within a waterbody, natural weathering of rocks and soil; decomposition of dead plant material; growth of plankton; resuspension of sediment in the beds of waterbodies; and erosion of beds and banks can contribute suspended materials. Suspended materials can also be contributed by point and nonpoint pollution sources within the watershed. Concentrations of suspended materials in most discharges from point sources are subject to effluent limitations through the Wisconsin Pollutant Discharge Elimination System (WPDES) permit program. A variety of nonpoint sources can also contribute suspended materials to waterbodies. Many BMPs for urban and rural nonpoint source pollution are geared toward reducing discharges of suspended materials.

Several different measures can be used to examine the amount of suspended materials in water. These methods differ both in the approach taken and the characteristics actually being measured. Two measures are commonly used to assess the bulk concentration of suspended materials in water: total suspended solids (TSS) and suspended sediment concentration (SSC). Both of these are based upon weighing the amount of material retained when a sample is passed through a filter. They differ in the details of sample handling and subsampling. It is important to note that these two measures are not comparable to one another.[246] Turbidity is another measure of the amount of suspended materials in water. Turbidity measures how much light is scattered as it passes through water. Higher concentrations of suspended materials in water are generally associated with greater scattering of light. A final measure is the concentration of chlorophyll-*a*, which estimates the biomass of phytoplankton suspended in the water. Chlorophyll-*a* concentrations in waters of the Oak Creek watershed were discussed in a previous subsection of this chapter. The majority of suspended material samples available for Oak Creek and its tributaries consist of samples analyzed for TSS.

[246] *J.R. Gray, G.D. Glysson, L.M. Turcios, and G.E. Schwartz,* Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data, *U.S. Geological Survey Water-Resources Investigation Report No. 00-4191, 2000.*

High concentrations of suspended solids can cause several impacts in waterbodies. High turbidity is a result of high concentrations of suspended solids. High concentrations of suspended solids reduce the penetration of light into the water, reducing the amount of photosynthesis. In addition, as suspended particles absorb light, they also absorb heat. As a result, this can lead to an increase in water temperature in streams. Both of these effects can lead to lower concentrations of dissolved oxygen. High concentrations of suspended solids can clog the gills of fish and other aquatic organisms, stressing them physiologically—in some cases fatally. Deposition of sediments may alter the substrate, making it unsuitable as habitat for aquatic organisms, or changing channel characteristics. In addition, as a result of physical and chemical interactions, other materials may adsorb to particles suspended in water. Examples include poorly soluble organic molecules, such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and pesticides; nutrients, such as phosphate and nitrate ions; metals, such as copper and zinc ions; and microorganisms, such as bacteria and viruses. As a result, some pollutants may be carried into or transported within waterbodies in association with suspended material. In areas where sediment is deposited, reservoirs of these pollutants may accumulate in the sediment. The State of Wisconsin has not promulgated water quality criteria for suspended solids. The TMDL for the Milwaukee River Basin, which is adjacent to the Oak Creek watershed, set a target concentration of 12 mg/l TSS.[247] This concentration can serve as a guideline for assessing water quality related to suspended material in streams of the Oak Creek watershed.

Figure 4.96
Specific Conductance at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Specific conductance consists of conductance corrected to a standard temperature of 25°C.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

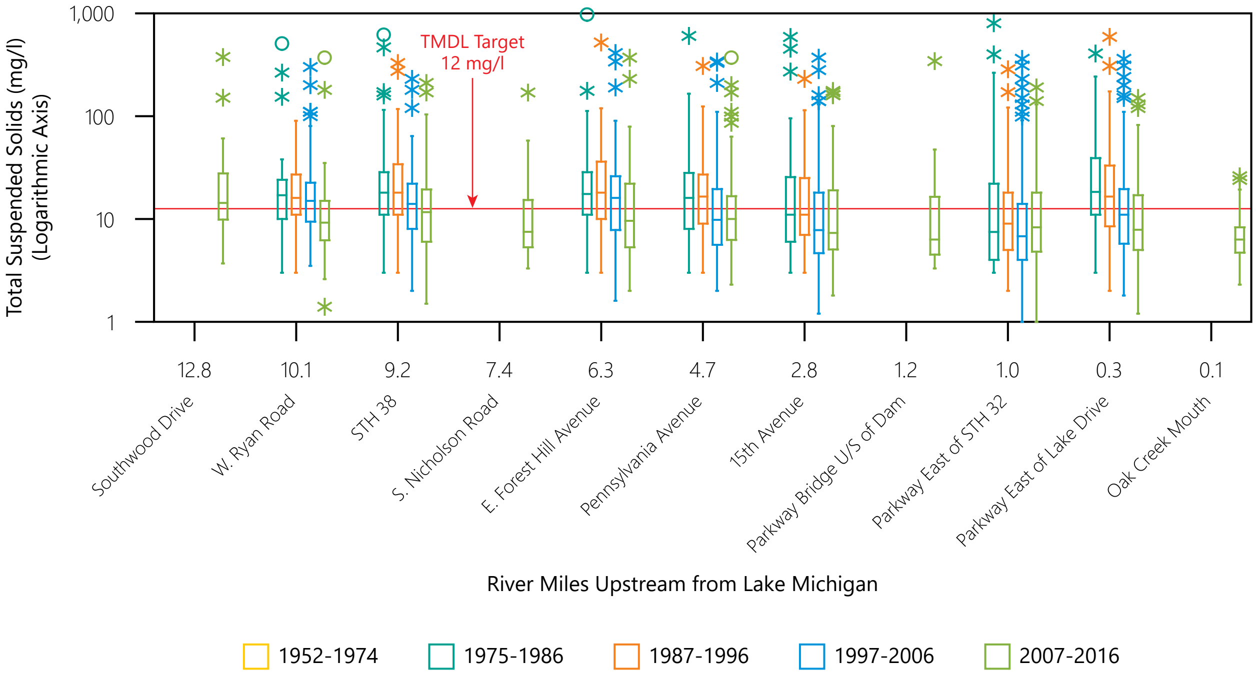
Total Suspended Solids

Figure 4.97 shows TSS concentrations from sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, TSS concentrations in Oak Creek ranged between 1.0 mg/l and 375.5 mg/l, with a median value of 8.7 mg/l and a mean value of 18.4 mg/l. Concentrations at all sampling stations showed considerable variability, with ranges at some stations exceeding two orders of magnitude. This variability is likely related to stream discharge, with higher flows being able to carry larger, heavier particles and more solids.

As shown in Figure 4.97, there is a trend toward TSS concentrations in Oak Creek decreasing over time. Median concentrations over the length of the Creek decreased from 15.0 mg/l during the period 1975 through 1986 to 8.7 mg/l during the period 2007 through 2016. This decrease occurred at most of the sampling stations for which there are sufficient data to assess temporal trends, with medians at individual sampling stations ranging between about 11.0 mg/l and 18.0 mg/l during the period 1975 through 1986 and between 7.3 mg/l and 11.9 mg/l during the period 2007 through 2016. Different patterns of decrease occurred at different sampling stations. At some stations, such as the Parkway east of Lake Drive (RM 0.3), TSS concentrations decreased through all of these four periods. At others such as STH 38 (RM 9.2), TSS concentrations during the period 1987 through 1996 were similar to those during the period 1975 through 1986, while concentrations decreased through subsequent periods. At still other stations such as

[247] *Milwaukee Metropolitan Sewerage District, 2018* op. cit.

Figure 4.97
Concentrations of Total Suspended Solids (TSS) at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

Pennsylvania Avenue (RM 4.7), TSS concentrations during the period 1987 through 1996 were similar to those during the period 1975 through 1986. While TSS concentrations decreased after the period 1987 through 1996, similar concentrations were observed at Pennsylvania Avenue (RM 4.7) during the periods 1997 through 2006 and 2007 through 2016.

Two factors may account for the decrease in TSS concentrations over time in Oak Creek. The implementation of stormwater management practices in the watershed over the last 45 years may be responsible for some of the decrease. Many of these practices are designed to reduce the amount of suspended material discharged to waterbodies. Changes in land use in the watershed may also have contributed to the decrease in TSS concentrations. Between 1970 and 2015, the percentage of land in the watershed devoted to urban land uses increased from about 40 percent to 65 percent. Over the same period, the percentage of land devoted to agricultural land uses decreased from about 39 percent to 9 percent. These sorts of changes in land use can affect the concentration and character of solids suspended in a stream and the amount and type deposited on stream beds. Activities related to early stages of urban development such as clearing of land and construction can mobilize large amounts of solids into streams. The amounts entering streams from construction sites can be much greater than the amounts entering from agricultural areas.[248] Contributions of sediments from soil erosion in older, established urban areas that have few areas of bare soil can be much less than those in either newly developed areas or agricultural areas.[249]

[248] *D.W. Owens, P. Jopke, D.W. Hall, J. Balousek, and A. Rou,* Soil Erosion from Two Small Construction Sites, Dane County, Wisconsin, *U.S. Geological Survey Fact Sheet No. FS-109-00, 2000; C.J. Lee and A.C. Ziegler,* Effects of Urbanization, Construction Activity, Management Practices, and Impoundments on Suspended-Sediment Transport in Johnson County, Northeast Kansas, February 2006 through November 2008, *U.S. Geological Survey Scientific Investigations Report No. 2010-5218, 2010.*

[249] *L.B. Leopold, R. Huppman, and A. Miller, "Geomorphic Effects of Urbanization in Forty-one Years of Observation,"* Proceedings of the American Philosophical Society, *volume 149, pages 349-371, 2005.*

Figure 4.98 shows median concentrations of TSS along the length of Oak Creek over the period 2007 through 2016. Median TSS concentrations generally decreased from upstream to downstream, although there was some variation to this. Some aspects in the longitudinal pattern of TSS concentration correspond to differences in elevation gradient along the stream. A steeper stream gradient leads to higher water velocities, which will keep material suspended in the water column.

For example, the highest median concentration of TSS was observed at the sampling station at Southwood Drive (RM 12.8) (see Figure 4.98). This sampling station is located in a reach of the Creek that has a steep gradient (see Figure 4.4). Lower median concentrations were observed at the sampling stations at CTH V (RM 10.7) and W. Ryan Road (RM 10.1). The station at CTH V is located within a section of the Creek that has a shallow gradient. Similarly, the station at W. Ryan Road is located immediately downstream from this section. During field survey, Commission staff found considerable deposits of sediment on the stream bed between STH 241 (RM 11.7) and CTH V (see Figure 4.17). In some places, the depth of these sediments exceeded 1.5 feet. The deposition of sediment in this section of the Creek is likely a major factor contributing to concentrations being lower at the sampling stations at CTH V and W. Ryan Road than at the station at Southwood Drive.

A steeper gradient is present both immediately upstream and downstream of the sampling station at STH 38 (RM 9.2) (see Figure 4.4).[250] Median concentrations of TSS at this site were higher than those at the two stations immediately upstream (see Figure 4.98). In addition, Commission staff found that deposits of sediment that were present on the stream bed in the sections of the Creek immediately upstream and downstream of this station were less than 0.3 foot thick (see Figure 4.19). This suggests that water velocity in this section of the Creek is fast enough to keep solids suspended in the water.

TSS concentrations in and downstream of the Mill Pond constitute a departure from the overall upstream to downstream trend toward decreasing concentrations. The median concentration of TSS in the pond during the period 2007 through 2016 was higher than those at the two sampling stations immediately upstream from the pond (see Figure 4.98). While median TSS concentrations at sampling stations downstream of the dam were lower than that in the Mill Pond, they were higher than those at the two sampling stations immediately upstream from the pond.

The higher TSS concentrations downstream from the Mill Pond suggest that the Pond is acting as a net source of sediment to the downstream reach of Oak Creek. This is supported by several observations. As previously discussed, Commission staff estimated that about 47,100 CY of sediment has accumulated in the pond over its 1930 configuration and the pond is very shallow. A 2015 survey of the pond's bathymetry by RHD staff found that water in the pond has an average depth of 0.7 foot and a maximum depth of 4.3 feet.[251] The RHD study found that substantial portions of the pond, including potions in the main path of water flow through the pond, had water depths of less than 0.8 foot. RHD staff also conducted sampling in 2015 and 2016 in which paired samples were collected immediately upstream and downstream of the Mill Pond.[252] This study found that in about 88 percent of paired samples, the concentration of TSS was higher at the sampling station immediately downstream of the pond than it was at the station immediately upstream. The median change in TSS concentration from upstream to downstream in these samples was 3.85 mg/l. The study noted that this impact was spatially limited and that the increase in TSS concentration was not observed about 0.3 miles downstream of the dam. It concluded that the reduced storage capacity of the Mill Pond prevents it from acting as a sink for sediments originating upstream.

During the period 2007 through 2016, concentrations of TSS at sampling stations along the mainstem of Oak Creek often exceeded the target level set in the Milwaukee Basin TMDL (see Figure 4.97). About 63 percent of samples collected from the Creek during this period had concentrations equal to or less than 12 mg/l. There were considerable differences among sampling stations in the percentage of samples that were equal to or less than this guideline. The lowest percentage was observed at the station at Southwood

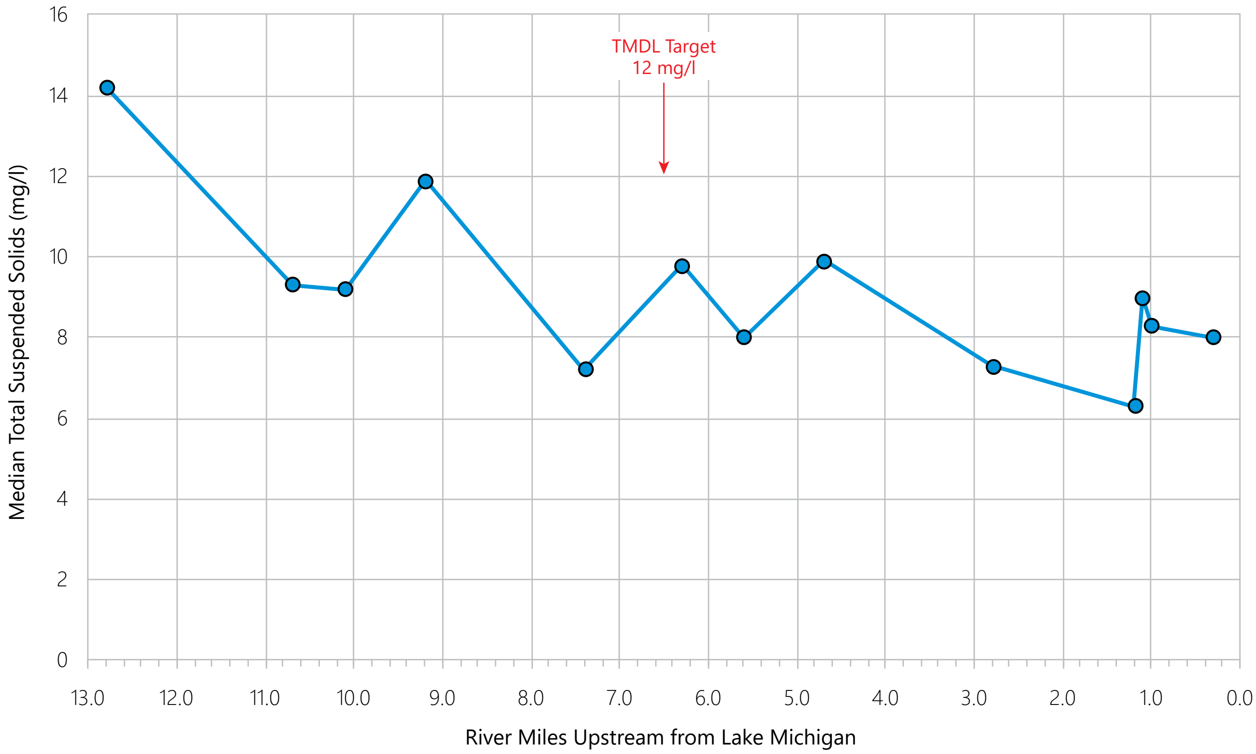
---

[250] *Shown on Figure 4.4 as S. Howell Avenue.*

[251] *Turner, Koski, and Kinzelman, 2017,* op. cit.

[252] *J. L. Jozefowski,* The Unintended Benefits of Dams Should Be Considered Prior to Removal, *Masters Thesis, University of Wisconsin Milwaukee, May 2018.*

Figure 4.98
Median Concentrations of Total Suspended Solids (TSS) at Sites Along Oak Creek: 2007-2016



Source: Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

Drive (RM 12.8), where about 38 percent of samples had concentrations that conformed to this guideline. Higher percentages were observed at stations such as Drexel Avenue (RM 5.6) and the Oak Creek mouth, where 75 and 84 percent of samples, respectively, conformed to this guideline.

Figure 4.99 shows TSS concentrations in the North Branch of Oak Creek. During the period 2007 through 2016, TSS concentrations in the North Branch of Oak Creek ranged between 1.0 mg/l and 130 mg/l with a median value of 5.7 mg/l and a mean value of 10.6 mg/l. While some historical TSS samples are available for this stream, they were not collected at the same locations as the samples collected during the period 2007 through 2016. As a result, historical trends in TSS concentrations in this stream cannot be assessed. TSS concentrations in this stream decreased slightly from upstream to downstream. Median concentrations at the middle station at S. 6th Street (RM 3.9) and at the station at Weatherly Drive (RM 1.8) were 6.7 mg/l and 5.0 mg/l, respectively. Concentrations of TSS in the North Branch of Oak Creek were usually below the 12 mg/l guideline set in the Milwaukee Basin TMDL. During the period 2007 through 2016, concentrations in about 81 percent of samples were under this guideline. Exceedances of this guideline were more common at the middle station at S. 6th Street than at the station at Weatherly Drive.

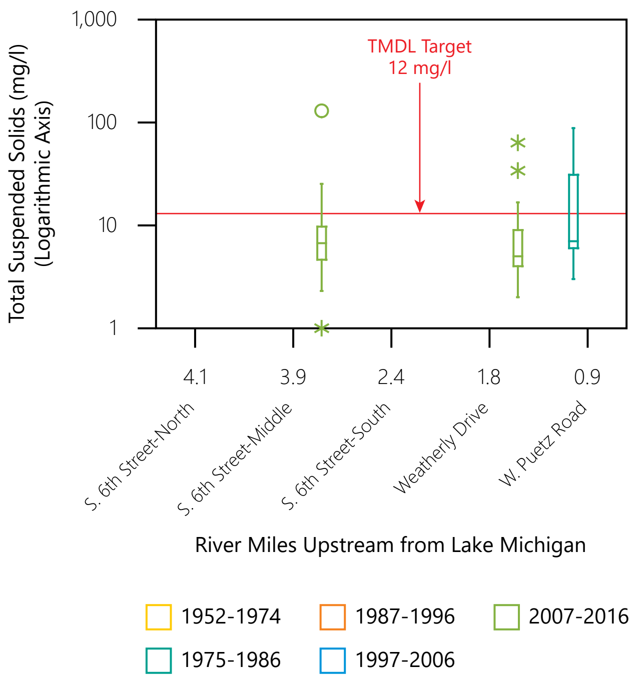
Figure 4.100 shows TSS concentrations in the Mitchell Field Drainage Ditch. During the period 2007 through 2016, TSS concentrations in the Mitchell Field Drainage Ditch ranged between 3.0 mg/l and 96.7 mg/l with a median value of 7.0 mg/l and a mean value of 12.5 mg/l. No historical TSS samples are available for this stream, so historical trends in TSS concentrations in this stream cannot be assessed. TSS concentrations in this stream decreased slightly from upstream to downstream. Median concentrations at the sampling station at College Avenue (RM 1.8) and at the sampling station at Rawson Avenue (RM 0.8) were 7.3 mg/l and 6.0 mg/l, respectively. Concentrations of TSS in the Mitchell Field Drainage Ditch were usually below the 12 mg/l guideline set in the Milwaukee Basin TMDL. During the period 2007 through 2016, concentrations in about 74 percent of samples were under this guideline. Exceedances of this guideline were more common at the station at College Avenue than at the station at Rawson Avenue

During the period 2007 through 2016, TSS concentrations in Unnamed Creek No. 5 ranged between 3.3 mg/l and 44.7 mg/l, with a median value of 10.0 mg/l and a mean value of 12.2 mg/l. Since data were collected at only one sampling station, no information is available regarding how TSS concentrations vary along the length of this Creek. Due to the lack of historical data, temporal trends in TSS concentration cannot be assessed in this stream.

Suspended Sediment Concentration

A limited number of samples have been collected from the mainstem of Oak Creek at the sampling station at 15th Avenue (RM 2.8) for suspended sediment concentration (SSC). SSC concentrations at this site ranged between 2 mg/l and 1,150 mg/l, with a median value of 92.5 mg/l and a mean value of 148 mg/l. No samples were collected during the period 2007 through 2016. The available SSC data are not sufficient to assess temporal trends or trends along the Creek.

Figure 4.99
Concentrations of Total Suspended Solids (TSS) at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

Turbidity

Turbidity is a measure of the clarity of water. It results from light being scattered and absorbed by particles and molecules rather than being transmitted through the water. Turbid water appears cloudy. Turbidity is caused by fine material that is suspended in the water, such as particles of silt, clay, finely divided organic and inorganic material, and planktonic organisms. Colored substances that are dissolved in the water can also contribute to turbidity. There are several ways of measuring turbidity. It is often measured using a nephelometer, which is a specialized optical device that measures the amount of light scattered when a beam of light is passed through a sample. The unit of measurement for this method is called a nephelometric turbidity unit (ntu), with low values indicating high water clarity and high values indicating low water clarity. Other methods involve measuring the depth of water through which a black and white disk remains visible. For lakes and ponds, this is often done using a Secchi disk. For streams this is done using a transparency tube. High turbidity can significantly reduce the aesthetic quality of lakes and streams, having a harmful impact on recreation. It reduces the penetration of light into the water, reducing the amount of photosynthesis. In addition, suspended particles absorb more heat than water does. As a result, high turbidity can lead to an increase in the water temperature in streams. Both of these effects can lead to lower concentrations of dissolved oxygen.

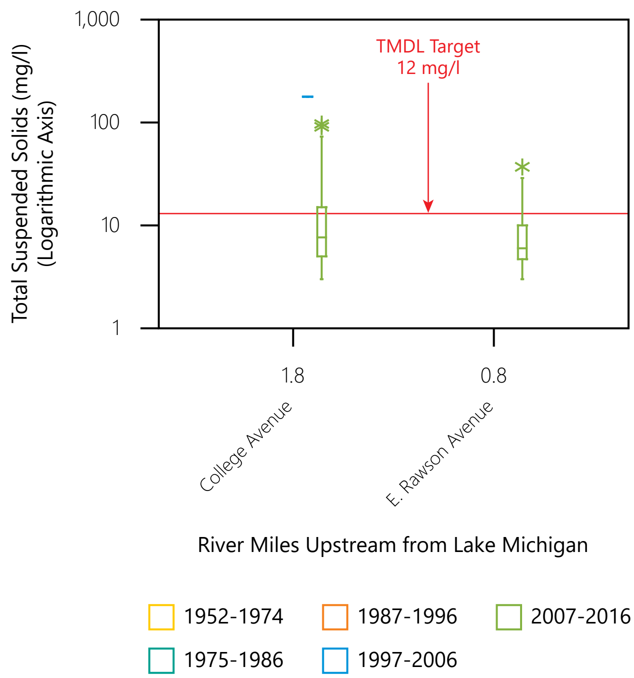
Turbidity can be strongly influenced by streamflow. During periods of low flow, turbidities are low, usually less than 10 ntu. During periods of high flow, water velocities are faster and water volumes are greater. This can stir up and suspend material from the stream bed, causing higher turbidities. If high flows are the result of precipitation or snowmelt, particles from the surrounding land are washed into the stream. This can make the water a muddy brown color, indicating water that has higher turbidity values.

Turbidity can harm fish and other aquatic life by reducing food supplies, degrading spawning beds, and affecting gill function. It can also reduce the growth of aquatic plants. The State of Wisconsin has not promulgated water quality criteria for turbidity.

Figure 4.101 shows turbidity values from sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, turbidity values in Oak Creek ranged between 1.0 ntu and 276.0 ntu, with a median value of 10.6 ntu and a mean value of 19.1 ntu. Values at all sampling stations showed considerable variability, with ranges at some stations exceeding two orders of magnitude. This variability is likely related to stream discharge, with higher flows being able to carry larger, heavier particles and more solids.

Figure 4.101 also shows that different patterns of change in turbidity values have occurred over time at different sampling stations. At some, such as the Parkway East of Lake Drive (RM 0.3) and 15th Avenue (RM 2.8), there are trends toward turbidity values decreasing over time. The decrease in turbidity values at these stations do not correspond exactly with the pattern of decrease in TSS concentration (see Figure 4.97). At the Parkway East of Lake Drive, for example, TSS concentrations decreased through all four periods, while the decrease in turbidity values at this station appears to have ended after 2006, with values during the period 2007 through 2016 being similar to those observed during the period 1997 through 2006. At other sampling stations, values of turbidity have increased in recent years. There are differences among these stations as to when the increase began. At the Parkway East of STH 32 (RM 1.0), the increase consists of turbidity values during the period 2007 through 2016 being higher than those in previous periods. At E. Forest Hill Avenue (RM 6.3), the increase appears to be earlier. The temporal patterns in turbidity values at these stations do not correspond well with the temporal patterns in TSS concentration.

Figure 4.100
Concentrations of Total Suspended Solids at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

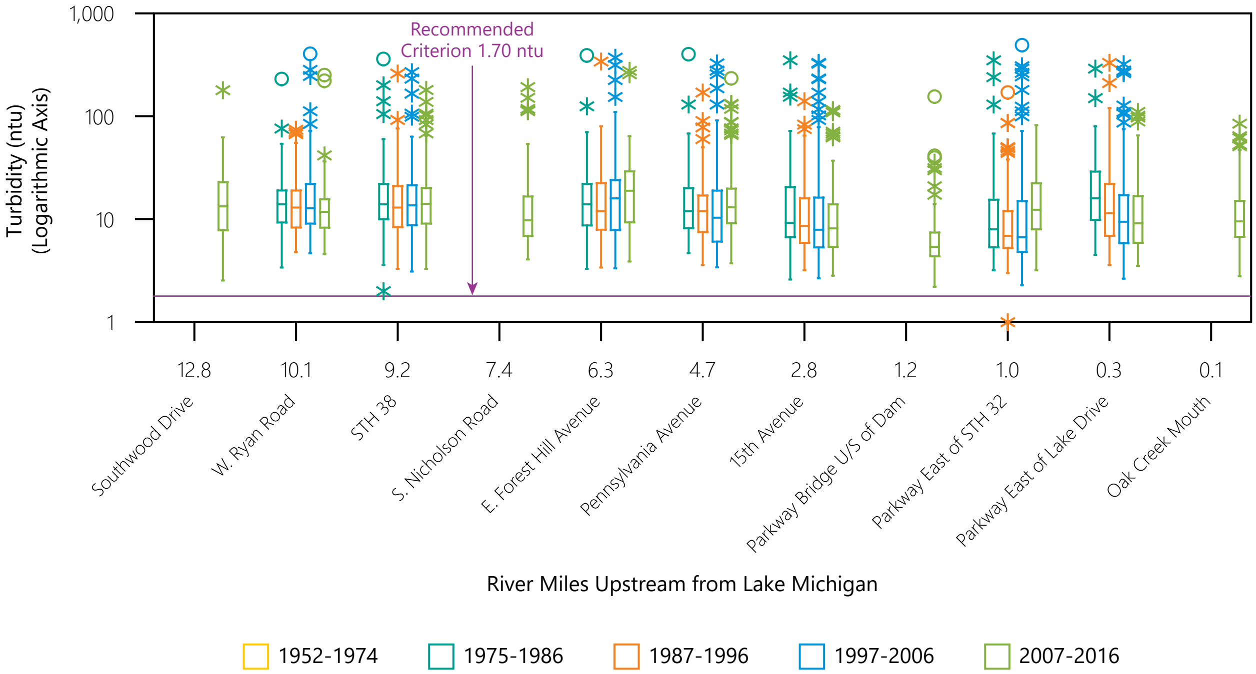
The poor correspondence between temporal trends in turbidity values and TSS concentrations may reflect the differences between these two water quality constituents. While there is considerable overlap in what each constituent measures, there are also differences. Both of them give an indication of the combined amounts of algae, bacteria, clay, silt, sediment, and nonsettleable solids in the water column. TSS also includes all settleable solids in the water column, even those that are too large to affect turbidity. Turbidity also reflects the influence of dyes, humic acids, colloids, and colored dissolved organic matter in the water. The relationship between turbidity and suspended solids is not straightforward. In particular, it can be confounded by aspects such as the sizes, shapes, and compositions of particles in the water.[253]

The USEPA has issued a recommended water quality criterion for turbidity of 1.70 ntu for rivers and streams in nutrient region VII (see Table 4.18). During the period 2007 through 2016, values of turbidity at sampling stations along the mainstem of Oak Creek almost always exceeded this guideline. (see Figure 4.101).

Figure 4.102 shows turbidity values in the North Branch of Oak Creek. During the period 2007 through 2016, turbidity values in the North Branch of Oak Creek ranged between 2.4 ntu and 145 ntu with a median value of 7.5 ntu and a mean value of 12.8 mg/. While a few historical turbidity samples are available for this stream, they were not collected at the same locations as the samples collected during the period 2007 through 2016. As a result, historical trends in turbidity in this stream cannot be assessed. From upstream to downstream, median turbidity values increased and then decreased. Median values at the middle station at S. 6th Street (RM 3.9), the south station at S. 6th Street (RM 2.4), and at the station at Weatherly Drive (RM 1.8) were 7.4 ntu, 9.5 ntu, and 6.7 ntu, respectively. Values of turbidity in all samples collected from the North Branch of Oak Creek were above the 1.70 ntu guideline recommended by USEPA.

[253] *C.J. Gippel, "Potential of Turbidity Monitoring for Measuring the Transport of Suspended Solids in Streams,"* Hydrological Processes, *volume 9, pages 83-97, 1995.*

Figure 4.101
Nephelometric Turbidity at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

Figure 4.103 shows turbidity values in the Mitchell Field Drainage Ditch. During the period 2007 through 2016, turbidity values in the Mitchell Field Drainage Ditch ranged between 3.98 ntu and 92.8 ntu with a median value of 10.3 ntu and a mean value of 14.1 ntu. No historical turbidity samples are available for this stream, so historical trends in turbidity in this stream cannot be assessed. Turbidity values in this stream decreased slightly from upstream to downstream. Median values at the sampling station at College Avenue (RM 1.8) and at the sampling station at Rawson Avenue (RM 0.8) were 11.1 ntu and 8.9 ntu, respectively. Values of turbidity in all samples collected from the Mitchell Field Drainage Ditch were above the 1.70 ntu guideline recommended by USEPA.

During the period 2007 through 2016, turbidity values in Unnamed Creek No. 5 ranged between 1.19 ntu and 66.1 ntu, with a median value of 4.8 ntu and a mean value of 9.6 ntu. Since data were collected at only one sampling station, no information is available regarding how turbidity values vary along the length of this Creek. Due to the lack of historical data, temporal trends in turbidity cannot be assessed in this stream.

Nutrients

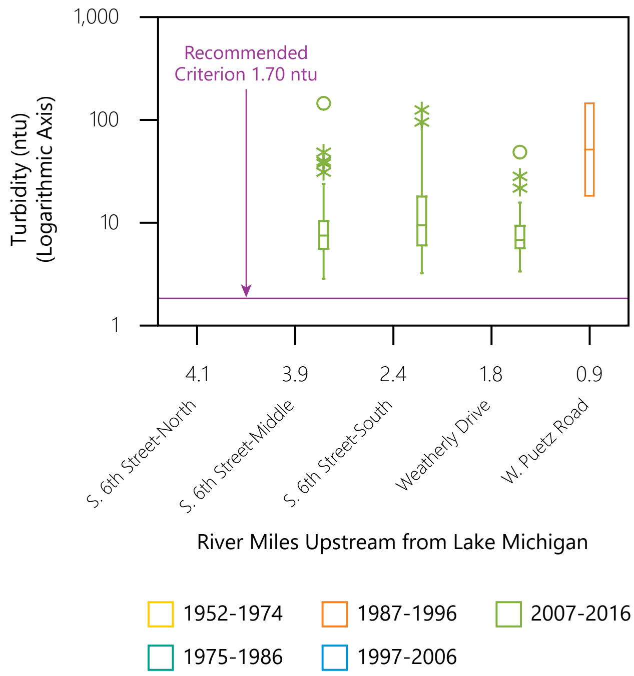
Nutrients are elements and compounds needed for plant and algal growth. They are often found in a variety of chemical forms, both inorganic and organic, which may vary in their availability to plants and algae. Typically, plant and algal growth and biomass in a waterbody are limited by the availability 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 those within the waterbody and those in the contributing watershed. Within a waterbody, mineralization of nutrients from sediment, resuspension of sediment in the bed, erosion of bed 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 nutrient point sources include industrial discharges. Concentrations of some chemical forms of nutrients in discharges from points sources are subject to effluent limitations through the WPDES permit program. A variety of nonpoint sources can 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. Three forms are commonly sampled in surface waters: total phosphorus, dissolved phosphorus, and orthophosphate. Total phosphorus consists of all the phosphorus contained in material dissolved or suspended in water. It includes dissolved forms of phosphorus and forms that are incorporated in or bound to particulate matter. 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. Orthophosphate consists of a single chemical form, phosphate groups (PO_4^{3-}) dissolved in water. This is the form of phosphorus that is most readily available to aquatic plants and algae. Particulate phosphorus is a fourth form of phosphorus that can be present in surface waters. This consist of phosphorus that is either incorporated into or adsorbed onto the surfaces of particulate matter such as sediment, algal cells, and detritus. It is usually quantified as the difference between total phosphorus and dissolved phosphorus.

Figure 4.102
Nephelometric Turbidity at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

Because the degree of eutrophication in freshwater systems generally correlates more strongly with total phosphorus concentration than with dissolved phosphorus or orthophosphate concentration, the State's water quality criteria are expressed in terms of total phosphorus and water quality sampling tends to focus most strongly on assessing total phosphorus concentrations. In areas where water utilities add phosphates to municipal water for corrosion control, discharges by industrial facilities that use municipal water as noncontact cooling water may contribute phosphorus to receiving waterbodies. In rural settings, phosphorus from agricultural fertilizers or animal manure may be contributed through discharges from drain tiles or direct runoff into waterbodies. Phosphorus may also 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.[254] 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.[255]

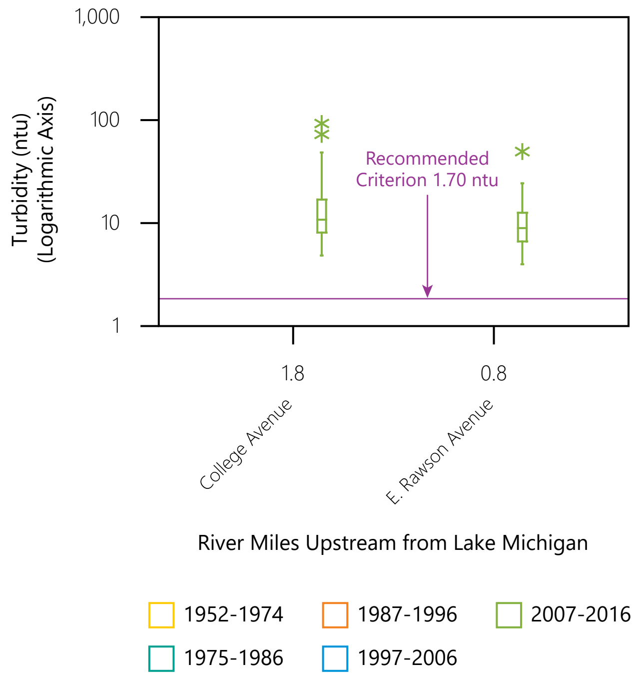
Under Wisconsin's water quality criterion for phosphorus, total phosphorus concentrations are not to exceed 0.075 mg/l.

[254] *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.*

[255] *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.*

Figure 4.104 shows total phosphorus concentrations at sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, concentrations of total phosphorus in the mainstem of Oak Creek ranged from below the limit of detection to 0.860 mg/l, with a mean concentration of 0.076 mg/l and a median concentration of 0.059 mg/l. Several things are evident in this figure. First, concentrations of total phosphorus vary along the length of the Creek. Median concentrations observed at individual sampling stations range between 0.042 mg/l at station at the Oak Creek mouth (RM 0.1) and 0.075 mg/l at the station at E. Forest Hill Avenue (RM 6.3). Second, at those sampling stations with longer periods of records, total phosphorus concentrations appear to have decreased between the periods 1997 through 2006 and 2007 through 2016. At each station with sufficient data from each of the periods 1975 through 1986, 1987 through 1996, 1997 through 2006, and 2007 through 2016, mean total phosphorus concentrations detected during the periods were compared to one another using analysis of variance (ANOVA).[256] With one exception, no statistically significant differences were detected among the mean concentrations of total phosphorus during the four periods at any station. A significant difference among mean total phosphorus concentrations was found at the sampling station at W. Ryan Road (RM 10.1). Post-hoc comparisons found that the mean concentrations of total phosphorus during the periods 1997 through 2006 and 2007 through 2016 were different from one another. This suggests that mean total phosphorus concentrations at this station decreased between these two periods. These results should be interpreted with caution. Total phosphorus concentrations in streams are highly variable. The combination of this variability and the relatively small number of samples collected over the four periods may indicate that the statistical test lacks sufficient power to detect a slight difference in total phosphorus concentrations.

Figure 4.103
Nephelometric Turbidity at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



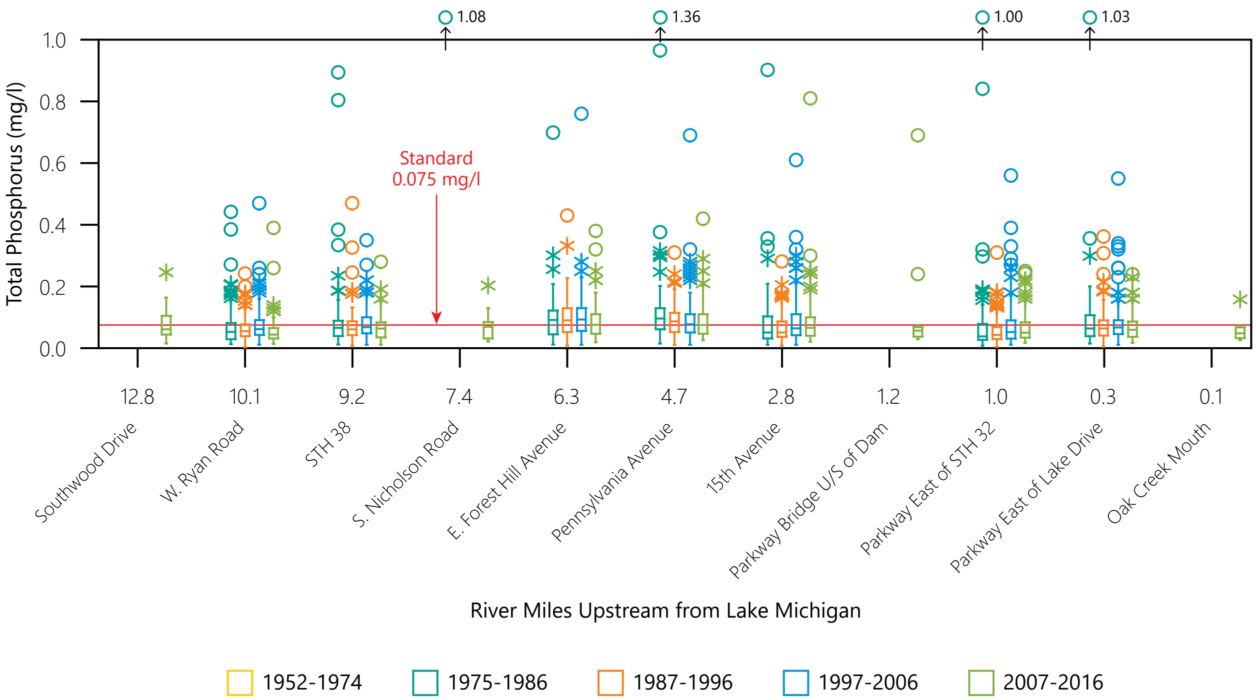
Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

Figure 4.104 also shows differences in total phosphorus concentrations along the length of the mainstem of Oak Creek. During the period 2007 through 2016, median concentrations of total phosphorus increased from upstream to downstream from the sampling station at Southwood Drive (RM 12.8) to the sampling station at E. Forest Hill Avenue (RM 6.3). Beyond E. Forest Hill Avenue, median concentrations of total phosphorus decreased from upstream to downstream, reaching their lowest value at the mouth of the Creek (RM. 0.1). There were three exceptions to this pattern. First, median total phosphorus decreased markedly between CTH V (RM 10.7) and W. Ryan Road (RM 10.1). It then increased at STH 38 (RM 9.2). Second, median total phosphorus decreased slightly from E. Forest Hill Avenue (RM 6.3) to Drexel Avenue (RM 5.6) and increased slightly at Pennsylvania Avenue (RM 4.7). This decrease may reflect a statistical anomaly, as the number of samples collected at the Drexel Avenue station was considerably smaller the numbers collected at the other two stations. Third, median total phosphorus increased markedly between the sampling station at the Parkway east of STH 32 (RM 1.0) and the station at the Parkway east of Lake Drive (RM 0.3). This increase may reflect the higher gradient within the stream reach below the Mill Pond dam (see Figure 4.4). In addition, during instream surveys, Commission staff found that this reach contains several areas of streambank erosion, including three sites with severe erosion and one site with very severe erosion (see Map 4.3). Phosphorus associated with suspended solids resulting from erosion from these sites may be contributing to higher total phosphorus concentrations at the sampling station at the Parkway east of Lake Drive.

[256] *In order to meet the assumptions of ANOVA, total phosphorus concentrations were log-transformed.*

Figure 4.104
Concentrations of Total Phosphorus at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

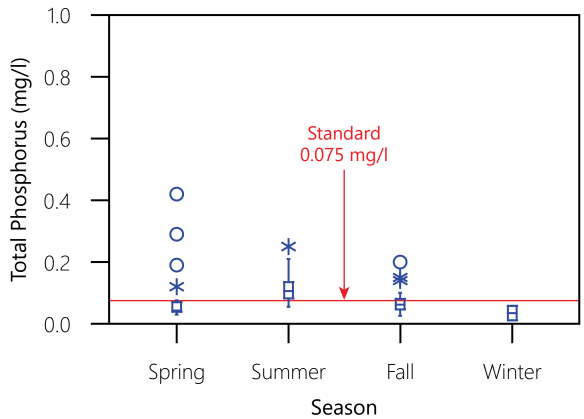
Figure 4.104 also shows that total phosphorus concentrations in a high proportion of samples exceeded the State's applicable water quality criterion of 0.075 mg/l. Over the period 2007 through 2016, total phosphorus concentrations in about 64 percent of samples collected from the mainstem of Oak Creek met this criterion. At individual sampling stations along the mainstem of the Creek, the percentage of samples in which the concentration of total phosphorus was equal to or less than 0.075 mg/l ranged between 50 percent and 92 percent. In general, the concentrations of total phosphorus are high along the entire length of the mainstem of the Oak Creek. Additional discussion of how concentrations of total phosphorus in the Oak Creek watershed compare to water quality criteria is given in the section on achievement of water use objectives later in this chapter.

Figure 4.105 shows seasonal concentrations of total phosphorus in the mainstem of Oak Creek at the sampling station at Pennsylvania Avenue (RM 4.7) during the period 2007 through 2016. Total phosphorus concentrations tended to be highest during the summer. They decreased during the fall, reaching their lowest levels during the winter. Following winter, concentrations increase during spring. This pattern occurred at every sampling station that had sufficient data for assessing seasonal trends.

Total phosphorus consists of two components: dissolved phosphorus and particulate phosphorus. Figure 4.106 shows the percentage of total phosphorus that consists of dissolved phosphorus at sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, the percentage total phosphorus consisting of dissolved phosphorus ranged between 0 percent and 100 percent, with a median value of 44.5 percent. The percentage of total phosphorus that consists of dissolved phosphorus varied in a complex pattern along the length of the Creek. During the period 2007 through 2016, the median percentage of dissolved phosphorus along the length of the Creek increased from 43.5 percent at W. Ryan Road (RM 10.1) to 50.5 percent at E. Forest Hill Avenue (RM. 6.3). After this, it decreased to 41.3 percent at 15th Avenue (RM. 2.8) and then increased to 43.9 percent at the Oak Creek Parkway east of STH 32 (RM 1.0). Finally, it decreased to 40.9 percent at the Oak Creek Parkway east of Lake Drive (RM 0.3). This longitudinal pattern appears to be consistent across the analytical periods. While the actual median percentages at individual stations differed from period to period, the same pattern of increasing and decreasing percentages of dissolved phosphorus along the length of the Creek occurred during the periods 1987 through 1996 and 1997 through 2006.

Several factors may contribute to the longitudinal pattern of the percentage of total phosphorus that consists of dissolved phosphorus along the mainstem of Oak Creek. Settling of particles in areas of slower flow would tend to remove particulate phosphorus from the water column, increasing the relative amount of dissolved phosphorus. This may be contributing to the pattern in at least two sections of Oak Creek. Deposition of sediment may be a factor in the increase in the percentage of dissolved phosphorus between the sampling stations at W. Ryan Road (RM 10.1) and E. Forest Hill Avenue (RM. 6.3). Commission staff observed thick deposits of sediment in the stream channel in the vicinities of both the W. Ryan Road station and the confluence with the North Branch of Oak Creek (see Figure 4.17 and Map 4.27). In addition, much of the land immediately adjacent to the stream in these reaches was in agricultural land uses in 2015 (see Map 3.7 in Chapter 3). Runoff of fertilizer from these lands would tend to increase the percentage of dissolved phosphorus in the water. Deposition of sediment may also contribute to the increase in the percentage of dissolved phosphorus between the sampling stations at 15th Avenue (RM. 2.8) and the Oak Creek Parkway east of STH 32 (RM 1.0). It is likely that much of this deposition is occurring within the Mill Pond. Release of phosphorus from accumulated sediment in the Mill Pond may also contribute to the increased percentage of dissolved phosphorus in and downstream of the Mill Pond. Depletion of dissolved oxygen levels in the sediment and overlying water would change the chemical environment in the sediment in a way that would allow for such release. If this depletion is occurring, the sediment in the pond may be contributing dissolved phosphorus to the water column.

Figure 4.105
Seasonal Concentrations of Total Phosphorus in Oak Creek at Pennsylvania Avenue (RM 4.7): 2007-2016



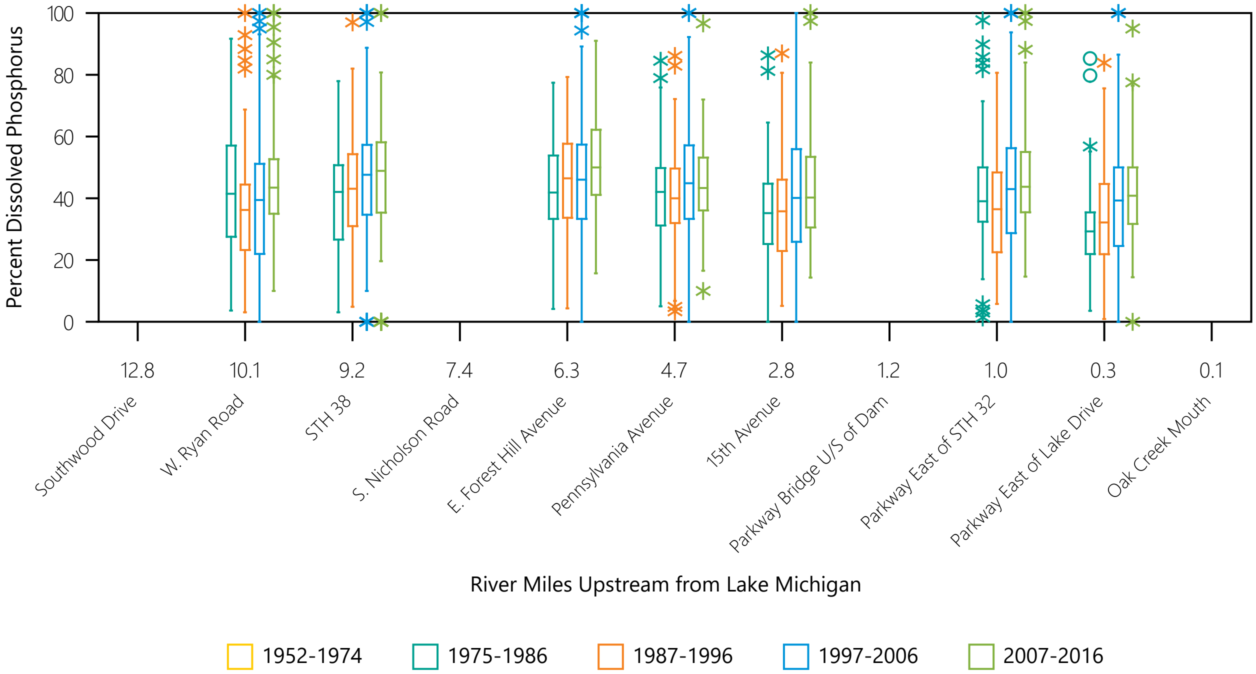
Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

Streambank erosion may be acting to decrease the percentage of total phosphorus that consists of dissolved phosphorus along the mainstem of Oak Creek. In particular, this may be a factor that accounts for the decrease in the percentage of dissolved phosphorus between the sampling stations at E. Forest Avenue Road (RM 6.3) and Pennsylvania Avenue (RM 4.7). During field surveys, Commission staff identified numerous areas of streambank erosion upstream from Pennsylvania Avenue (see Map 4.3). The reach containing these areas extended about 0.5 mile upstream to the confluence with the Mitchell Field Drainage Ditch. Commission staff also identified areas of erosion along this tributary, immediately upstream from its confluence with Oak Creek. Erosion in these areas would tend to contribute sediment to the mainstem of Oak Creek. To the extent that the contributed sediment contains phosphorus, it would tend to reduce the percentage of dissolved phosphorus in the stream.

Figure 4.106 also shows that the percentage of total phosphorus in samples from the mainstem Oak Creek that consists of dissolved phosphorus has increased over time. The median percentage of dissolved phosphorus increased from 38.7 percent during the period 1975 through 1986 to 44.5 percent during the period 2007 through 2016. While somewhat different patterns of increase were seen at different sampling stations, an increase occurred at all stations at which the data were sufficient to assess this question. This increase in the percentage of total phosphorus consisting of dissolved phosphorus corresponds with the decrease over time in TSS concentrations in the Creek. This decrease in TSS concentration is probably a factor in the increase in the percentage of dissolved phosphorus as such a decrease could result in a reduction in the concentration of particulate phosphorus. If the decrease in TSS concentration is a factor in the increase in the percentage of dissolved phosphorus in Oak Creek, then the percentage increase also probably reflects the factors causing the decrease in TSS concentrations—long-term changes in land use and implementing stormwater management practices in the watershed.

Figure 4.106
Percentage of Total Phosphorus Consisting of Dissolved Phosphorus at Sites Along the Mainstem of Oak Creek: 2007-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC

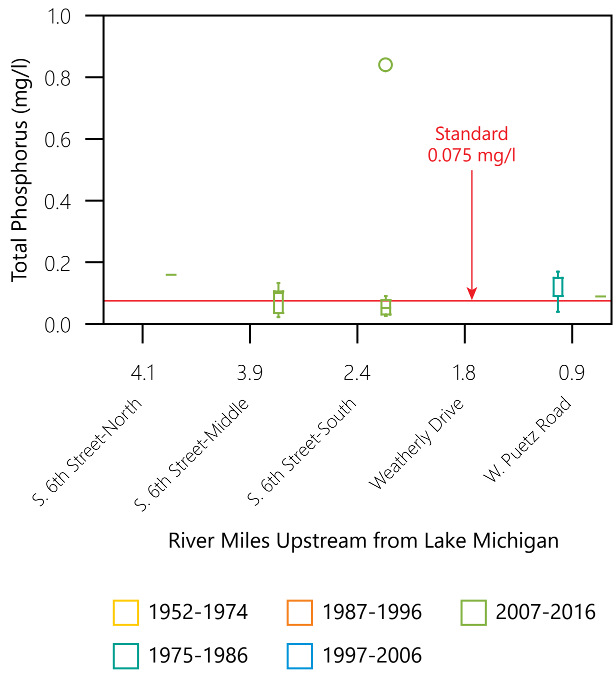
Figure 4.107 shows total phosphorus at sampling stations along the North Branch of Oak Creek. During the period 2007 through 2016, concentrations of total phosphorus in the North Branch of Oak Creek ranged between 0.003 mg/l and 0.840 mg/l, with a median concentration of 0.055 mg/l and a mean concentration of 0.093 mg/l. Concentrations of total phosphorus in this stream tended to decrease from upstream to downstream. This may reflect deposition of suspended material in the channel between the middle and southern sampling stations along S. 6th Street. Commission staff observed sediment deposits on the streambed within this reach. The maximum thickness of these deposits was greater than 2.4 feet (see Figure 4.19 and Map 4.27). Deposition of suspended material would remove phosphorus that is either incorporated in or adsorbed to particulate material from the water column, lowering the concentration of total phosphorus. While some historical total phosphorus samples are available for this stream, they were not collected at the same locations as the samples collected during the period 2007 through 2016. As a result, historical trends in total phosphorus concentrations in this stream cannot be assessed. Concentrations of total phosphorus in this stream often exceeded the State's water quality criterion of 0.075 mg/l. Concentrations in about 41 percent of samples collected during the period 2007 through 2016 were higher than this criterion.

Figure 4.108 shows total phosphorus at sampling stations along the Mitchell Field Drainage Ditch. During the period 2007 through 2016, concentrations of total phosphorus in the Mitchell Field Drainage Ditch ranged between 0.001 mg/l and 0.338 mg/l, with a median concentration of 0.103 mg/l and a mean concentration of 0.113 mg/l. Concentrations of total phosphorus in this stream tended to increase from upstream to downstream. During the period 2007 through 2016, median concentrations at the sampling stations at College Avenue (RM 1.8) and Rawson Avenue (RM 0.8) were 0.093 mg/l and 0.116 mg/l, respectively. Few historical data are available for the Mitchell Field Drainage Ditch. Because of this, historical trends in total phosphorus concentrations in this stream cannot be assessed. Concentrations of total phosphorus in this stream usually exceeded the State's water quality criterion of 0.075 mg/l. Concentrations in about 62 percent of samples collected during the period 2007 through 2016 were higher than this criterion.

During the period 2007 through 2016, total phosphorus concentrations in Unnamed Creek No. 5 ranged between 0.007 mg/l and 0.191 mg/l, with a median concentration of 0.049 mg/l and a mean concentration of 0.077 mg/l. Since data were collected at only one sampling station, no information is available regarding how total phosphorus concentrations vary along the length of this Creek. Due to the lack of historical data, temporal trends in total phosphorus concentrations cannot be assessed in this stream. Concentrations of total phosphorus in this stream often exceeded the State's water quality criterion of 0.075 mg/l. Concentrations in about 42 percent of samples were higher than this criterion.

Efforts to address phosphorus concentrations in waterbodies of the Oak Creek watershed may be complicated by the presence of legacy phosphorus. Legacy phosphorus consists of phosphorus that is retained within a system such as a watershed. Such phosphorus may be retained in a number of ways including as particulate phosphorus deposited in sediments on the beds of waterbodies, dissolved phosphorus adsorbed to sediments on the beds of waterbodies, phosphorus contained within the bodies of plants and algae growing within waterbodies, particulate and dissolved phosphorus stored in sediments that are deposited on seasonally inundated floodplains, and phosphorus that has accumulated in soils and groundwater. A major source of legacy phosphorus consists of phosphorus from nutrient or fertilizer applications that is not taken up or used by plants.

Figure 4.107
Concentrations of Total Phosphorus at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

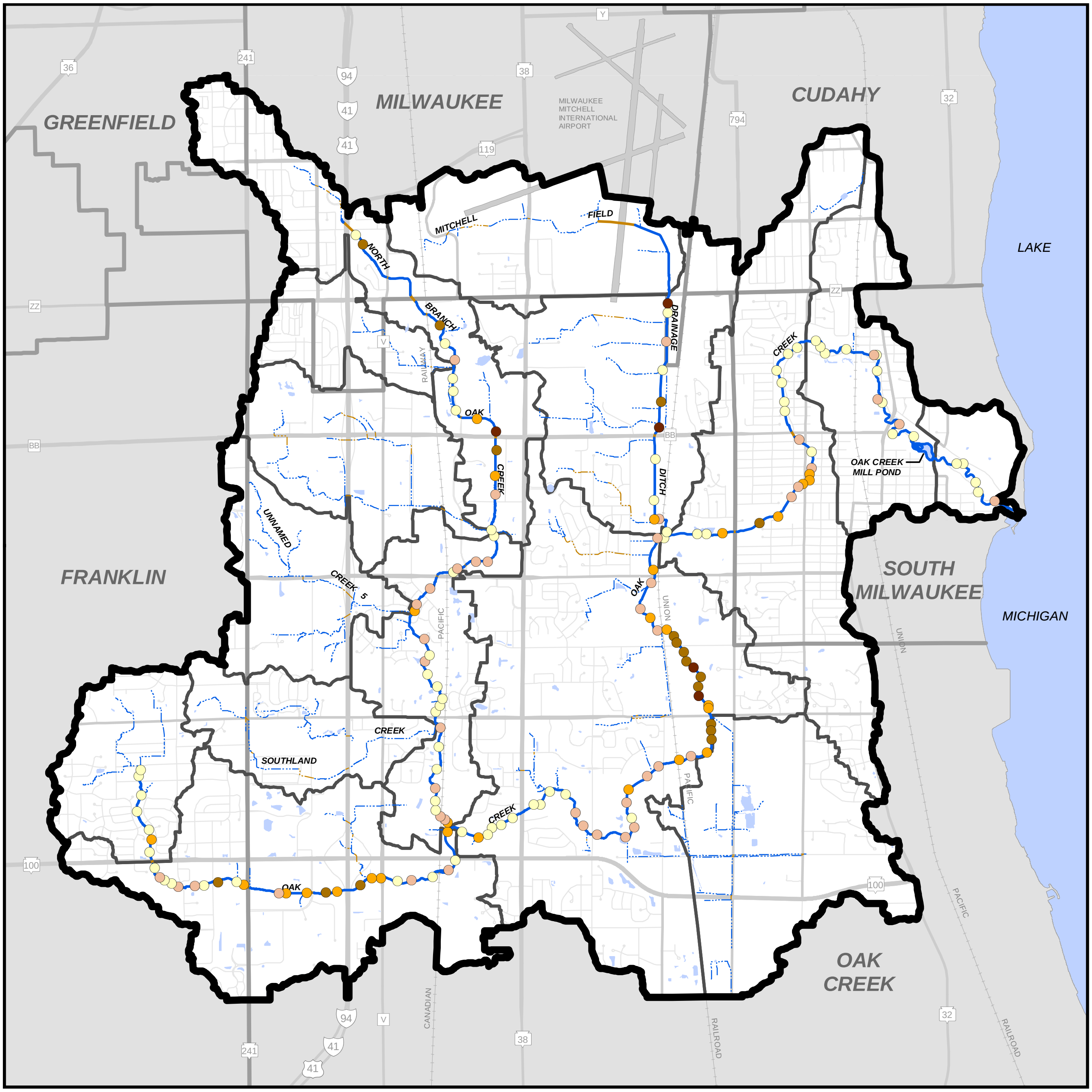
Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

Accumulation of enough sediment and legacy phosphorus can reduce a system's capacity to store phosphorus. The accumulation of sufficient phosphorus can turn areas where phosphorus is stored from sinks to internal sources. This can often happen with lakes and ponds, especially shallow ones. It is likely that this has happened in the Oak Creek Mill Pond. As previously discussed, there is evidence that the Mill Pond is acting as a net source of suspended solids and sediment to downstream areas of Oak Creek. This suggests that the Pond may also be contributing phosphorus associated with the sediment being released.

An additional consequence of the presence of legacy phosphorus is that this phosphorus can be released back into the water at a later time. There are a number of ways that such release can take place. Examples of these mechanisms include high instream flows returning stored particulate phosphorus to the water column through resuspension of sediment, degradation of organic material in sediment or water releasing stored phosphorus, or changes in chemical conditions in the water column or sediment allowing chemically-bound phosphorus in sediment to enter solution and diffuse into the water. Some release mechanisms may take place over a very long time. For example, it has been found that it may take years to decades for concentrations of excess phosphorus stored in agricultural soils to decrease to minimum levels needed to support crops.[257] Because groundwater tends to move slowly, dissolved phosphorus stored or transported in groundwater may take a long time to enter waterbodies in baseflow. Similarly, phosphorus stored in sediments deposited in floodplains might not be remobilized until streambank erosion and channel migration occurs. These processes could potentially occur over time scales of decades to centuries.

[257] *A. Sharpley, H.P. Jarvey, A. Buda, L. May, B. Spears, and P. Kleinman, "Phosphorus Legacy: Overcoming the Effects of Past Management Practices to Mitigate Future Water Quality Impairment,"* Journal of Environmental Quality, *volume 42, pages 1,308-1,326, 2013.*

Map 4.27
Maximum Sediment Depths Measured Within the Oak Creek Watershed



MAXIMUM SEDIMENT DEPTH (FEET)

- 0.0 - 0.2
- 0.3 - 0.7
- 0.8 - 1.4
- 1.5 - 2.3
- 2.4 - 3.8

OAK CREEK WATERSHED BOUNDARY

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

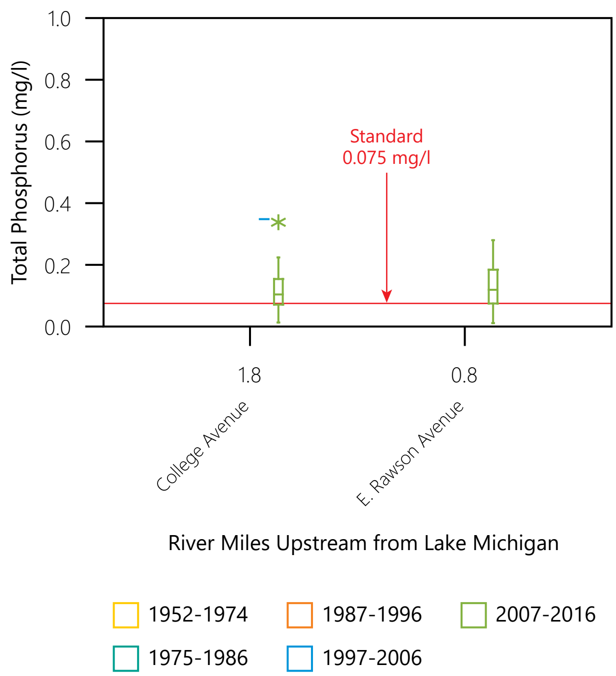
SURFACE WATER

0 0.25 0.5 1 Mile

Source: SEWRPC

A major consequence of the presence of legacy phosphorus is that it may obscure the effects of reduced phosphorus loadings in the watershed. When inputs of phosphorus to a waterbody are reduced, release of legacy phosphorus from storage can continue to supply high amounts of phosphorus to the waterbody. This creates time lags between the implementation of actions to reduce phosphorus loading in the watershed and the response of the stream. Such time lags may occur as delays in instream phosphorus concentrations decreasing following reduction of phosphorus loading to the waterbody. This may also result in time lags between reductions in phosphorus loading and biological responses to such reductions. The lengths of time lags associated with the presence of legacy phosphorus are likely to depend on a number of factors including the amount of phosphorus stored in the watersheds, the locations in which it is stored, the forms in which it is stored, and the mechanisms through which it is released back into waterbodies.

Figure 4.108
Concentrations of Total Phosphorus at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

An example of the impacts of legacy phosphorus can be seen in the Yahara watershed of southern Wisconsin. This watershed includes the Yahara River and a chain of four lakes, including Lake Mendota, along the River. Several studies show evidence that phosphorus inputs to this watershed are greater than outputs and that the levels of phosphorus in soils are greater than those required by plants and needed to sustain crop yields.[258] One study in the late 1990s estimated it could take decades to centuries for crops to draw soil phosphorus concentrations down to 1974 levels.[259] A more recent phosphorus budget for the Lake Mendota watershed indicates that inputs of phosphorus to the watershed have likely declined since the mid-1990s, but still exceed outputs.[260] Despite considerable nutrient reduction efforts over the past three decades, phosphorus loads to Lake Mendota have not changed.[261] The persistence of loads has been attributed, in part, to the presence of legacy phosphorus.[262]

The phosphorus content of sediment in the streambed and banks of the Oak Creek watershed has rarely been assessed. A few data are available from three locations in the Oak Creek watershed. Between 2006 and 2010, six surface sediment samples collected from the mainstem of Oak Creek at 15th Avenue (RM. 2.8) were analyzed for phosphorus content. Dry weight concentrations of phosphorus in these samples ranged between 253

---

[258] *E.M. Bennett, T. Reed-Anderson, J.N. Houser, J.R. Gabriel, and S.R. Carpenter, "A Phosphorus Budget for the Lake Mendota Watershed,"* Ecosystems, *volume 2, pages 69-75, 1999; T. Reed-Anderson, S.R. Carpenter, and R.C. Lathrop, "Phosphorus Flow in a Watershed-Lake Ecosystem,"* Ecosystems, *volume 3, pages 561-573, 2000; E.L. Kara, C. Heimerl, T. Killpack, M.C. Van de Bogert, H. Yoshida, and S.R. Carpenter,"* Aquatic Sciences, *volume 74, pages 241-253, 2011.*

[259] *Bennett and others, 1999,* op. cit.

[260] *Kara and others, 2011,* op. cit.

[261] *R.C. Lathrop and S.R. Carpenter, "Water Quality Implications from Three Decades of Phosphorus Loads and Trophic Dynamics in the Yahara Chain of Lakes,"* Inland Waters, *volume 4, pages 1-14, 2013.*

[262] *A.R. Rissman and S.R. Carpenter, "Progress on Nonpoint Pollution: Barriers & Opportunities,"* Daedalus, *volume 144, pages 34-47, 2015; S. Gillon, E.B. Booth, and A.R. Rissman, "Shifting Drivers and Static Baseline in Environmental Governance: Challenges for Improving and Proving Water Quality Outcomes,"* Regional Environmental Change, *volume 16, pages 759-775, 2016.*

milligrams per kilogram (mg/kg) and 740 mg/kg, with a mean concentration of 466 mg/kg. In 2001, samples at three depths in a sediment core taken from the Mill Pond just upstream of the dam were analyzed for phosphorus. Concentrations of phosphorus in sediment at this location increased with depth. Concentrations were 562 mg/kg, 625 mg/kg, and 866 mg/kg at depths of 3.5 feet, 4.4 feet, and 5.6 feet, respectively. In 2001, a surface sediment sample collected from the North Branch of Oak Creek at Ramsay Avenue (RM 5.6) was analyzed for phosphorus. The concentration of phosphorus in this sample was 200 ng/kg.

The substantial amount of sediment stored in the channels of streams of the Oak Creek watershed and bed of the Mill Pond suggest that a considerable amount of legacy phosphorus may have accumulated in waterbodies. If this is the case, it is likely that there will be a delay between reductions of phosphorus loading to waterbodies of the watershed and responses including reductions of instream total phosphorus concentrations and biological responses such as chlorophyll-*a* concentrations and fish and macroinvertebrate indices. While the lengths of these time lags are not certain, it is possible that they may be on the order of several years to decades.

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 that 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.

The biogeochemistry of inorganic nitrogen in aquatic systems involves several processes. While molecular nitrogen (nitrogen gas) is not highly soluble in water, it is usually found at saturation concentrations in streams. For nitrogen to become available to most organism, it must be fixed. The process of biological nitrogen fixation converts molecular nitrogen to ammonia or amino form. In aquatic systems, this is done by bacteria, especially cyanobacteria (blue-green algae).[263] Biological nitrogen fixation requires anoxic conditions, either within the environment or within specialized bacterial cells. Ammonia in the environment can be taken up by plants or algae, volatilized into the atmosphere, or oxidized to nitrite or nitrate through the process of nitrification. Nitrification is conducted by nitrifying bacteria and requires the presence of oxygen. The nitrite and nitrate produced can be taken up by plants or algae or converted to molecular nitrogen through the process of denitrification. Denitrification is conducted by bacteria and requires anoxic conditions. Thus, it does not normally occur in the water column of streams but may occur in anoxic sediments in stream beds.

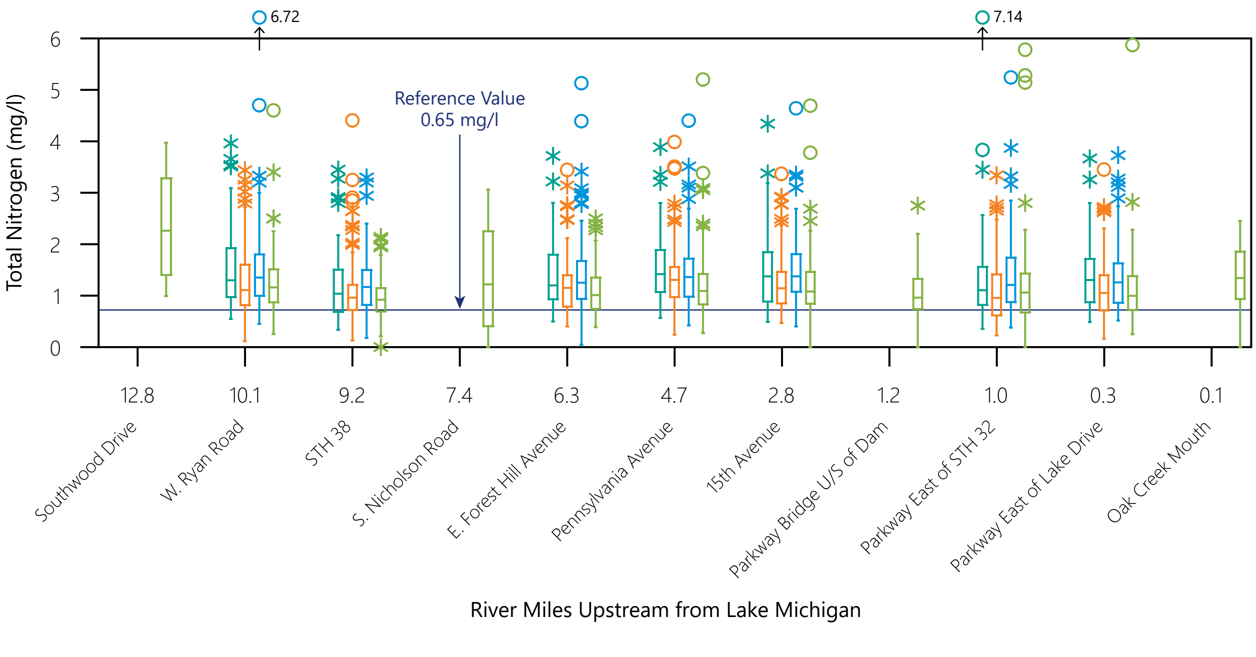
Nitrogen compounds can be contributed to waterbodies from a variety of point and nonpoint sources. In urban settings, nitrogen compounds from lawn fertilizers and other sources may be discharged through storm sewer systems and direct runoff into streams. Cross-connections between sanitary and storm sewer 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.

Figure 4.109 shows concentrations of total nitrogen at sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016 total nitrogen concentrations in the Creek ranged from below the limit of detection to 5.87 mg/l, with a median value of 1.09 mg/l and a mean value of 1.21 mg/l.

[263] *In the presence of oxygen, molecular nitrogen in the atmosphere can also be fixed into nitrite or nitrate through the action of lightning. This process represents a small fraction of nitrogen fixation.*

Figure 4.109
Concentrations of Total Nitrogen at Sites Along the Mainstem of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

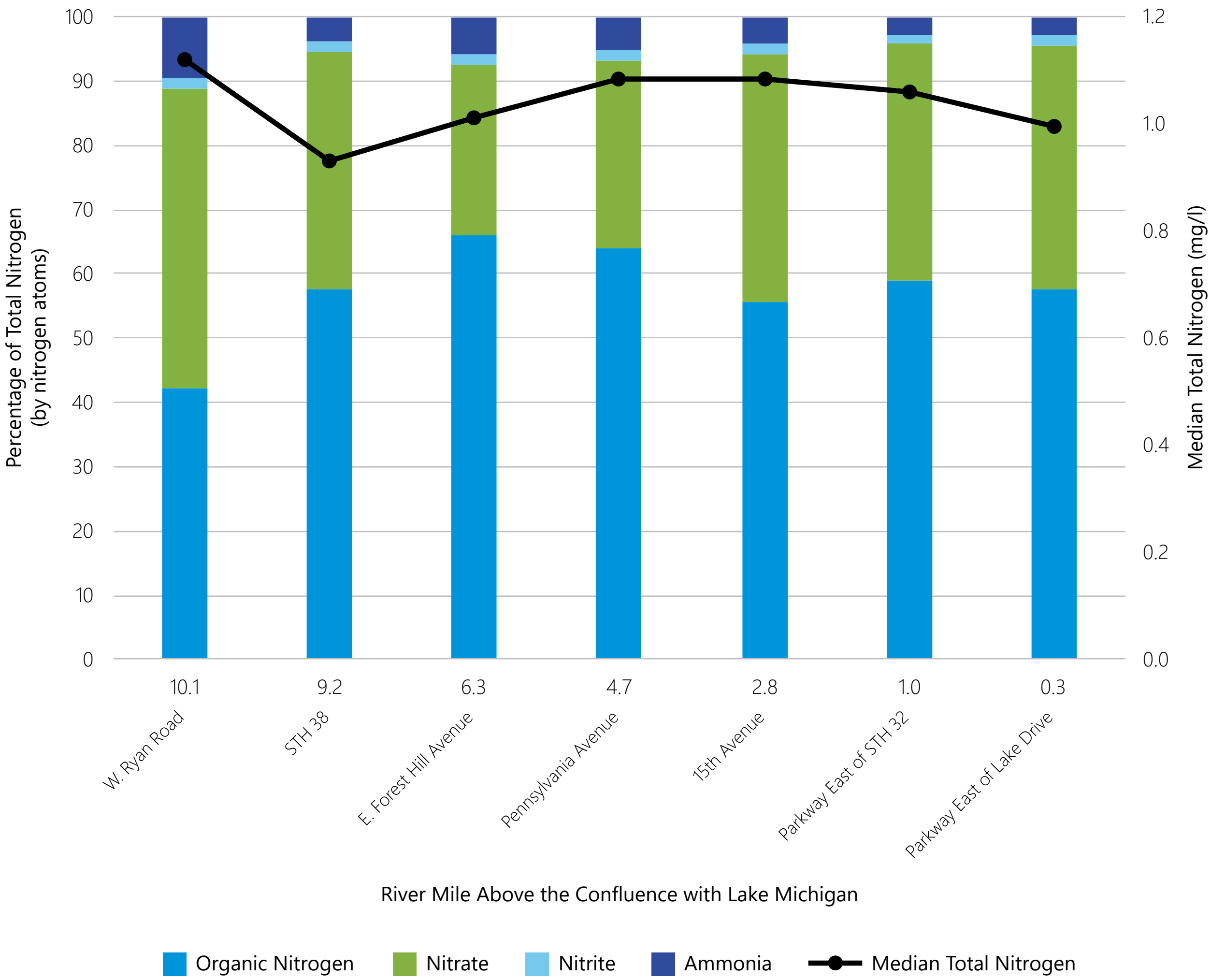
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

With the exception of toxicity criteria for ammonia, the State of Wisconsin has not promulgated water quality criteria for nitrogen compounds. Figure 4.109 shows that the concentration of total nitrogen in most samples collected from the mainstem of Oak Creek was greater than the 0.65 mg/l reference concentration developed by the WDNR and USGS for Wisconsin (see Table 4.18). It is important to recognize that this reference value is not a water quality criterion. Instead, it represents a potential level of water quality that could be achieved in the absence of human activity. Only about 16 percent of samples collected during the period 2007 through 2016 had concentrations less than or equal to this value. There was variation among sampling stations in the fraction of samples that conformed with this guideline, with the percentage of samples conforming ranging from 0 to 33 percent.

Concentrations of total nitrogen in the mainstem of Oak Creek show a complicated pattern of changes over time (see Figure 4.109). At each sampling station for which sufficient data are available to assess temporal trends, the median concentration during the period 1987 through 1996 was lower than that observed during the period 1975 through 1986. With one exception, the median concentration at each station during the period 1997 through 2006 was higher than that observed during the period 1987 through 1996. The only exception to this change occurred at the sampling station at Pennsylvania Avenue (RM 4.7), where median total nitrogen concentration was the same during these two periods. Median concentrations of total nitrogen at each sampling station during the period 2007 through 2016 was lower than that observed during the period 1997 through 2006. At each station, the median concentration during the period 2007 through 2016 was lower than that observed during the period 1975-1986.

As previously described, total nitrogen consists of a variety of nitrogen-containing compounds, including ammonia, nitrates, nitrites, and organic nitrogen compounds. While the proportions of these compounds that are present in samples at any sampling station vary greatly from sample to sample, there are some trends in the composition of total nitrogen along the length of the mainstem of Oak Creek. Figure 4.110 shows the median concentrations and average proportions of constituents of total nitrogen at sampling stations along Oak Creek during the period 2007 through 2016. Median concentrations of total nitrogen at the sampling

Figure 4.110
Median Concentrations and Compostion of Total Nitrogen at Sampling Stations Along the Mainstem of Oak Creek: 2007-2016



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Public Health Department, and SEWRPC

station at W. Ryan Road (RM 10.1) were 1.14 mg/l. This was the highest median concentration seen at the seven stations along the mainstem of the Creek for which data were available. The median concentration decreased to 0.93 mg/l at STH 38 (RM 9.2). This was the lowest median concentration reported along the length of the mainstem of the Creek. Median concentration of total nitrogen increased at the next two stations, reaching a second peak of 1.09 mg/l at Pennsylvania Avenue (RM 4.7). Median concentration of total nitrogen decreased along the remaining length of the Creek, reaching a second low point of 1.00 mg/l at the station located along the Oak Creek Parkway east of Lake Drive (RM 0.3).

The mixture of nitrogen compounds present changed along the length of the mainstem of Oak Creek (see Figure 4.110). In general, the proportion of total nitrogen consisting of ammonia decreased from upstream to downstream. On average, ammonia accounted for about 10 percent of total nitrogen at the station farthest upstream (RM 10.1). At the station farthest downstream (RM 0.3), it accounted for about 3 percent of total nitrogen. The proportions of total nitrogen consisting of nitrate and organic nitrogen compounds show more complicated patterns of change along the length of the Creek. The highest proportion of nitrate was detected at the sampling station farthest upstream. At this station, W. Ryan Road (RM 10.1), nitrate represented about 42 percent of total nitrogen. This proportion decreased to about 26 percent at E. Forest Hill Avenue (RM 6.8). It increased downstream from this site, reaching a second peak of about 38 percent near the Mill Pond dam (RM 1.0). Below the Mill Pond the proportion of total nitrogen consisting of nitrate decreased slightly, reaching about 35 percent at the Oak Creek Parkway (RM 0.3).

The proportion of total nitrogen consisting of organic nitrogen compounds showed the opposite pattern as the proportion consisting of nitrate (see Figure 4.110). The lowest proportion of organic nitrogen was detected at the sampling station farthest upstream (RM 10.1). At this site, organic nitrogen represented about 42 percent of total nitrogen. The proportion of total nitrogen consisting of organic nitrogen increased downstream from this station, reaching a peak of 66 percent at E. Forest Hill Avenue (RM 6.8). The organic nitrogen proportion then decreased downstream from this site, reaching a second minimum of about 57 percent at 15th Avenue. This proportion increased slightly through and below the Mill Pond, reaching a second peak of about 60 percent at the Oak Creek Parkway (RM 1.0).

At all of the sampling stations shown in Figure 4.110, nitrite accounted for less than 2 percent of total nitrogen.

These upstream to downstream changes in the proportions of the components of total nitrogen mask some changes in the concentrations of the components. From upstream to downstream median concentration of ammonia generally decreased along the mainstem of Oak Creek, from about 0.008 mg/l at the sampling station at W. Ryan Road (RM 10.1) to about 0.04 mg/l at STH 38 (RM 9.2). It then increased to 0.07 mg/l at E. Forest Hill Avenue (RM 6.3) before decreasing along the remaining length of the Creek to 0.04 mg/l at the station along the Oak Creek Parkway (RM 0.3). Simultaneously, median concentrations of organic nitrogen increased from 0.510 mg/l at W. Ryan Road (RM 10.1) to 0.650 mg/l at Pennsylvania Avenue (RM 4.7). Downstream of Pennsylvania Avenue, median concentrations of organic nitrogen decreased to 0.58 mg/l at the station along the Oak Creek Parkway (RM 0.3). Median concentration of nitrate decreased from 0.500 mg/l at W. Ryan Road (RM10.1) to 0.265 mg/l at E. Forest Hill Avenue (RM 6.3). It then increased to a second peak of 0.400 mg/l at 15th Avenue (RM 2.8) and decreased to 0.340 mg/l at the station along the Oak Creek Parkway (RM 0.3).

Several processes may be driving these changes in the chemical composition of total nitrogen along the length of Oak Creek. A combination of three processes probably accounts for the decrease in ammonia concentrations from upstream to downstream. First, ammonia in water will volatilize and enter the atmosphere. Second, plants and algae can assimilate ammonia, removing it from the water. Because this process requires less energy than assimilation of nitrate or nitrite, many of these organisms will preferentially assimilate ammonia over nitrate or nitrite if it is available. Third, ammonia may be oxidized through bacterial action to nitrite or nitrate. This process occurs in oxygenated waters with neutral or alkaline pH. It is likely that all three of these processes are occurring in Oak Creek.

Two processes may account for the increasing concentrations of nitrate and nitrite. First, some of the increase in nitrate and nitrite may result from the oxidation of ammonia to nitrite and nitrate through bacterial action. Second, the increase in nitrate and nitrite concentration along the length of the River may reflect excess nitrate originating from fertilizer applications that wash into the River and its tributaries either through surface runoff or agricultural drainage tiles.

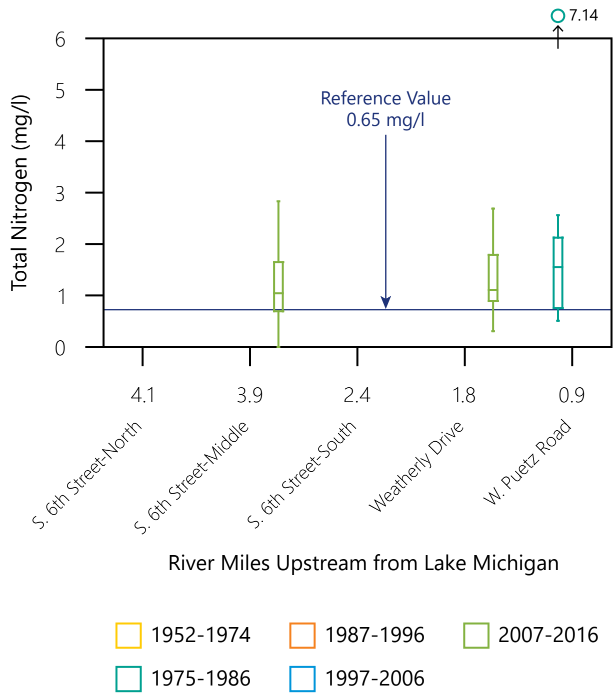
Most of the increase in organic nitrogen along the length of the River probably reflects decomposition of organic matter in the water column and sediment. A portion of this increase may also be due to the uptake and assimilation of inorganic forms of nitrogen by organisms in the water column. These processes result in the conversion of inorganic forms of nitrogen into organic compounds.

Figure 4.111 shows concentrations of total nitrogen at sampling stations along the North Branch of Oak Creek. During the period 2007 through 2016, concentrations of total nitrogen in this stream ranged from below the limit of detection to 2.83 mg/l, with a median of 1.11 mg/l and a mean of 1.25 mg/l. Median concentrations were slightly higher at the sampling station at Weatherly Drive (RM 1.8); however, concentrations were more variable at the middle sampling station along S. 6th Street (RM 3.9). Concentrations in most samples were higher than the reference value of 0.65 mg/l recommended by the WDNR and USGS. During the period 2007 through 2016 concentrations in only 16 percent of samples conformed to this guideline. The level of conformance was the same at the two sampling stations for which data were available. While some historical total nitrogen data are available for this stream, they were not collected at the same sampling stations as the data from 2007 through 2016. As a result, historical trends in total nitrogen concentrations cannot be assessed in this stream.

Figure 4.112 shows concentrations of total nitrogen at sampling stations along the Mitchell Field Drainage Ditch. During the period 2007 through 2016, concentrations of total nitrogen in this stream ranged from below the limit of detection to 5.76 mg/l, with a median of 1.058 mg/l and a mean of 1.658 mg/l. Higher median concentrations and greater variability were observed sampling station at College Avenue (RM 1.8) than at the station a Rawson Avenue. Concentrations in most samples were higher than the reference value of 0.65 mg/l recommended by the WDNR and USGS. During the period 2007 through 2016 concentrations in only 20 percent of samples conformed to this guideline. Slightly greater conformance occurred at the sampling station at Rawson Avenue than at station at College Avenue. Due to the lack of historical data, historical trends in total nitrogen concentrations cannot be assessed in this stream.

During the period 2007 through 2016, total nitrogen concentrations in Unnamed Creek 5 ranged from below the limit of detection to 3.64 mg/l with a median of 1.02 mg/l and a mean of 1.18 mg/l. Concentrations in most samples were higher than the reference value of 0.65 mg/l recommended by the WDNR and USGS. During the period 2007 through 2016 concentrations in only 25 percent of samples conformed to this guideline. Since data were collected at only one sampling station, no information is available regarding how total nitrogen concentrations vary along the length of this Creek. Due to the lack of historical data, temporal trends in total nitrogen concentrations cannot be assessed in this stream.

Figure 4.111
Concentrations of Total Nitrogen at Sites Along the North Branch of Oak Creek: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

Metals and Metalloids

Concentrations of several heavy metals have also been monitored in the Oak Creek watershed. These metals can produce a variety of toxic effects in humans, wildlife, fish, and aquatic organisms with the effects depending upon the type of metal, its chemical form, its biological role, the type of organism exposed to the metal, and the conditions of exposure. In addition to direct toxicity, these metals can bioaccumulate in the tissues of organisms with tissue concentrations being considerably higher than ambient concentrations in the environment. Tissue concentrations of some of these metals may also be magnified as they are passed up the food web through trophic interactions.

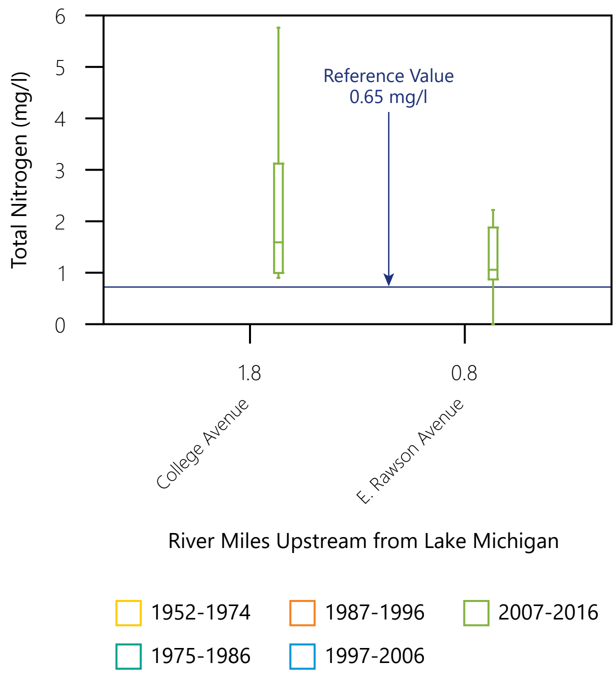
A number of sources can contribute heavy metals to surface waters. Natural sources include release of minerals from bedrock and soil during weathering and deposition from the atmosphere of metals released during volcanic activity. Sources related to human activities include atmospheric deposition of metals contributed to the atmosphere by vehicles and stationary combustion sources, discharges from point sources of water pollution, and urban and rural stormwater runoff. Particular sources vary among the metals.

Arsenic

Arsenic is a metalloid that occurs in Earth's crust, mostly as inorganic arsenic compounds. The industrial uses of arsenic include manufacturing metal alloys and semiconductors. In addition, arsenic compounds have been used as pesticides and wood preservatives. Exposure to arsenic can cause mortality in aquatic organisms. Chronic exposure to low concentrations can inhibit the growth and reproduction of organisms and can inhibit photosynthesis by plants and algae. In addition, chronic exposure to arsenic has been linked to several cancers. The State of Wisconsin has promulgated acute and chronic toxicity criteria for aquatic life for arsenic. Under the acute criterion, arsenic concentrations in warm water systems are not to exceed 339.8 µg/l. Under the chronic criterion, arsenic concentrations in warm water systems are not to exceed 152.2 µg/l.

Water samples from seven stations along the mainstem of Oak Creek have been analyzed for arsenic since 1991. In most of the samples, the concentration of arsenic was below the limit of detection. Depending upon the sampling station and period examined, arsenic concentrations were below the limit of detection in between 55 percent and 70 percent of samples. Median concentrations of arsenic in samples from all stations were below the limit of detection. During the period 2007 through 2016, maximum concentrations of arsenic detected at individual sampling stations ranged between 14 µg/l and 29 µg/l. Historically, the maximum concentration detected in Oak Creek was 89 µg/l. During the period 2007 through 2016, arsenic concentrations in all samples were below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

Figure 4.112
Concentrations of Total Nitrogen at Sites Along the Mitchell Field Drainage Ditch: 1952-2016



Note: See Figure 4.10 for description of symbols and Table 4.19 for location of sample sites.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, City of Racine Public Health Department, and SEWRPC

Cadmium

Cadmium is a metal with no known biological function in aquatic organisms. The industrial uses of cadmium include manufacturing batteries, pigments, metal coatings, metal alloys, electronics, and stabilizers for plastics. It is also used in the manufacture of nanoparticles for use in solar cells and color displays. Natural sources of cadmium to surface waters include weathering and erosion of rocks and soils. Anthropogenic sources include mining and smelting of non-ferrous metals, combustion of fossil fuels, and metal plating. Exposure to cadmium can cause mortality in aquatic organisms. Chronic exposure to lower concentrations can affect growth, reproduction, development, immune system function, and behavior in aquatic organisms. The toxicity of cadmium is affected by water hardness, with softer water resulting in more severe toxic effects. The State of Wisconsin has promulgated acute and chronic toxicity criteria for aquatic life for cadmium. The values of these criteria vary depending upon water hardness levels.

The earliest assessment of cadmium in surface water of the Oak Creek watershed occurred during 1975 and 1976 when water samples from three sampling stations along the mainstem of Oak Creek and one station along the North Branch of Oak Creek were sampled for cadmium. Since 1985, water samples have been regularly sampled for cadmium at seven sampling stations along the mainstem of Oak Creek. Cadmium was commonly detected at these stations in samples collected prior to 1997. Since then, cadmium concentrations were below the limit of detection in between 84 and 99 percent of samples, depending on the station and period. Median concentrations of cadmium in samples collected during the periods 1997 through 2006 and 2007 through 2016 were below the limit of detection at all sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, maximum concentrations of cadmium detected at individual sampling stations were 4.1 µg/l. Over the period of record, the maximum concentration detected in Oak Creek was 14 µg/l. During the period 2007 through 2016, cadmium concentrations in all samples were below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

A small number of samples from tributary streams in the Oak Creek watershed have been analyzed for cadmium. Three samples collected from the North Branch of Oak Creek in 1996 constitute the most recent sampling of this stream. The maximum concentration detected in these samples was 0.18 µg/l. Cadmium concentrations in two of these samples were below the limit of detection. Concentrations of cadmium in these samples were below both the acute and chronic toxicity water quality criteria for fish and aquatic life. Five samples were collected from the Mitchell Field Drainage Ditch between 1998 and 2010. The maximum concentration detected in these samples was 0.5 µg/l. Cadmium concentrations in two of these samples were below the limit of detection. Cadmium concentrations in the samples from the Mitchell Field Drainage Ditch were below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

Chromium

Chromium (Cr) is a metal that occurs in Earth's crust, mostly as chromium compounds. While it is regarded as an essential nutrient for animals in trace amounts, higher amounts are toxic. Chromium is used in electroplating metals, tanning of leather, and in the production of metal alloys, dyes and pigments, wood preservatives, chemical catalysts, and textiles. Natural sources of chromium to surface waters include erosion of chromium-containing rocks and soils and deposition of chromium compounds released to the atmosphere through volcanic activity. Anthropogenic sources include industrial discharges and deposition of chromium compounds released to the atmosphere from metal refining and combustion of fossil fuels. High concentrations of chromium can cause mortality in aquatic organisms. Chronic exposure to lower concentrations can lead to adverse effects on survival, growth, and reproduction. In addition, chromium is known to be carcinogenic and cause mutations and birth defects. The toxicity of chromium is affected by its chemical form, with Cr^{6+} ions being considerably more toxic than Cr^{3+} ions. The toxicity of Cr^{3+} is affected by water hardness, with softer water resulting in more severe toxic effects. The State of Wisconsin has promulgated acute and chronic toxicity criteria for aquatic life for two forms of chromium: Cr^{6+} and Cr^{3+}. For acute toxicity, concentrations of Cr^{6+} are not to exceed 16.02 µg/l. For chronic toxicity, concentrations of Cr^{6+} are not to exceed 10.98 µg/l. The values of the acute and chronic criteria for Cr^{3+} vary depending upon water hardness levels.

The earliest assessment of chromium in surface water of the Oak Creek watershed occurred during 1975 and 1976 when water samples from three sampling stations along the mainstem of Oak Creek and one station along the North Branch of Oak Creek were sampled for chromium. Since 1985, water samples have been regularly analyzed for chromium at seven sampling stations along the mainstem of Oak Creek. Chromium was commonly detected at these stations in samples collected prior to 1997. Since then, chromium concentrations were below the limit of detection in between 34 and 61 percent of samples, depending on the station and period. Median concentrations of chromium in samples collected during the period 2007 through 2016 at sampling stations along the mainstem of Oak Creek ranged between 4.85 µg/l and 5.00 µg/l. During the period 2007 through 2016, maximum concentrations of chromium detected at individual sampling stations ranged between 10.0 µg/l and 37.0 µg/l. Historically, the maximum concentration of chromium detected in Oak Creek was 420 µg/l. During the period 2007 through 2016, chromium concentrations in all samples collected from the mainstem of Oak Creek were below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

A small number of samples from tributary streams in the Oak Creek watershed have been analyzed for chromium. Three samples collected from the North Branch of Oak Creek between 1990 and 1996 constitute the most recent sampling of this stream. The maximum concentration detected in these samples was 3.0 µg/l. Chromium concentrations in two of these samples were below the limit of detection. Concentrations in these samples were below both the acute and chronic toxicity water quality criteria for fish and aquatic life. One sample was collected from the Mitchell Field Drainage Ditch in 2010. The chromium concentration detected in this sample was 2.0 µg/l and was below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

Copper

Copper is a metal that occurs in Earth's crust, both as a pure metal and in copper compounds. While it is an essential nutrient for plants and animals in trace amounts, higher amounts are toxic. Copper is widely used in electric wire, roofing and plumbing supplies, and industrial machinery. Other uses include electronics components, metal alloys, fungicides, and algaecides. Natural sources of copper to surface waters include geological deposits, volcanic activity, and weathering and erosion of rocks and soils. Anthropogenic sources include mining activities, metal and electrical manufacturing, sludge from wastewater treatment plants, and pesticide use. High concentrations of copper can cause mortality in aquatic organisms. Chronic exposure to lower concentrations can lead to adverse effects on survival, growth, and reproduction, as well as alterations of brain function, enzyme activity, blood chemistry, and metabolism. The toxicity of copper is affected by water hardness, with softer water resulting in more severe toxic effects. The State of Wisconsin has promulgated acute and chronic toxicity criteria for aquatic life for copper. The values of these criteria vary depending upon water hardness levels.

The earliest assessment of copper in surface water of the Oak Creek watershed occurred during 1975 and 1976 when water samples from three sampling stations along the mainstem of Oak Creek and one station along the North Branch of Oak Creek were sampled for copper. Since 1985, water samples have been regularly analyzed for copper at seven sampling stations along the mainstem of Oak Creek. During the periods 1997 through 2006 and 2007 through 2016, copper concentrations were below the limit of detection in between 21 and 37 percent of samples, depending on the station and period. Median concentrations of copper in samples collected during the period 2007 through 2016 at sampling stations along the mainstem of Oak Creek ranged between 6.8 µg/l and 7.2 µg/l. During the period 2007 through 2016, maximum concentrations of copper detected at individual sampling stations ranged between 23.0 µg/l and 42.0 µg/l. Over the period of record, the maximum concentration of copper detected in Oak Creek was 111 µg/l. During the period 2007 through 2016, copper concentrations in more than 97 percent of the samples collected from the mainstem of Oak Creek were below the acute toxicity water quality criterion for fish and aquatic life. Copper concentrations in more than 96 percent of these samples were below chronic toxicity water quality criterion for fish and aquatic life.

A small number of samples from tributary streams in the Oak Creek watershed have been analyzed for copper. Three samples collected from the North Branch of Oak Creek between 1990 and 1996 constitute the most recent sampling of this stream. The maximum concentration detected in these samples was 10.0 µg/l. Copper concentrations in one of these samples was below the limit of detection. Copper concentrations in these samples were below both the acute and chronic toxicity water quality criteria for fish and aquatic life. One sample was collected from the Mitchell Field Drainage Ditch in 2010. The copper concentration detected in this sample was 7.0 µg/l and was below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

Lead

Lead is a metal that occurs in Earth's crust, mostly as lead compounds. It has no known biological function in organisms. Major current uses include the production of lead-acid batteries, metal alloys, and semiconductors. Historically, lead was also used in the production of plumbing material, solders, bullets and shot, dyes, and pigments; as a pesticide; and as a gasoline additive. Natural sources of lead include volcanic activity and weathering and erosion of rocks and soil. Anthropogenic sources of lead include the mining and smelting of ore, manufacture of lead-containing products, combustion of fossil fuels, and waste incineration. Many anthropogenic sources of lead, most notably leaded gasoline, lead-based paint, lead solder in food cans, lead-arsenate pesticides, and shot and sinkers, have been eliminated or strictly regulated. Because lead does not degrade, these former uses leave their legacy as higher concentrations of lead in the environment. High concentrations of lead can cause mortality in aquatic organisms. Chronic exposure to lower concentrations can lead to adverse effects on survival, growth, reproduction, development, and metabolism. Lead is a potent neurotoxin and chronic toxicity can result in permanent damage to the central nervous system. The State of Wisconsin has promulgated acute and chronic toxicity criteria for aquatic life for lead. The values of these criteria vary depending upon water hardness levels.

The earliest assessment of lead in surface water of the Oak Creek watershed occurred during 1975 and 1976 when water samples from three sampling stations along the mainstem of Oak Creek and one station along the North Branch of Oak Creek were sampled for lead. Since 1985, water samples have been regularly analyzed for lead at seven sampling stations along the mainstem of Oak Creek. During the period 1997 through 2006, lead concentrations were below the limit of detection in between 47 and 60 percent of water samples collected from Oak Creek, depending upon sampling station. During the period 2007 through 2016, lead concentrations were below the limit of detection in between 71 and 79 percent of samples, depending on the station. Median concentrations of lead in samples collected during the period 2007 through 2016 at all sampling stations along the mainstem of Oak Creek were below the limit of detection. During the period 2007 through 2016, maximum concentrations of lead detected at individual sampling stations ranged between 18.0 µg/l and 41.0 µg/l. Over the period of record, the maximum concentration of lead detected in Oak Creek was 464 µg/l. Maximum concentrations detected in recent years have been much lower. During the period 2007 through 2016, lead concentrations in all samples collected from the mainstem of Oak Creek were below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

A small number of samples from tributary streams in the Oak Creek watershed have been analyzed for lead. Three samples collected from the North Branch of Oak Creek between 1990 and 1996 constitute the most recent sampling of this stream. The maximum lead concentration detected in these samples was 9.7 μg/l. The lead concentration in one of these samples was below the limit of detection. Concentrations in these samples were below both the acute and chronic toxicity water quality criteria for fish and aquatic life. One sample was collected from the Mitchell Field Drainage Ditch in 2010. The concentration detected in this sample was 1.0 μg/l and was below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

Mercury

Mercury is a metal that occurs in Earth's crust, mostly as mercury compounds. It has no known biological function in aquatic organisms. It has been used for thousands of applications, including dental fillings, electrical switches, batteries, lamps, thermometers, and pigments. Deposition from the atmosphere is a major source of mercury to waterbodies. Sources to the atmosphere include combustion of fossil fuels, production of lime, and industrial uses of mercury. High concentrations of mercury can produce mortality in aquatic organisms. Chronic exposure to lower concentrations can lead to adverse effects on survival, growth, and reproduction. In humans, chronic exposures to mercury can cause neurological damage, kidney damage, respiratory problems, and miscarriages. Mercury bioaccumulates in organism tissue and tissue concentrations are magnified as mercury passes through the food web. The State of Wisconsin has promulgated acute and chronic toxicity criteria for aquatic life for mercury. For acute toxicity, concentrations of mercury are not to exceed 0.83 μg/l. For chronic toxicity, concentrations of mercury are not to exceed 0.44 μg/l.

The most recent assessment of mercury in surface water of the Oak Creek watershed occurred during the years 2000 through 2003 when water samples from seven sampling stations along the mainstem of Oak Creek were sampled for mercury. During this time period, mercury concentrations were below the limit of detection in a substantial number of samples. At individual sampling stations, the fraction of samples in which mercury was not detected ranges between 34 and 55 percent. Median concentrations of mercury in samples collected during this period at sampling stations along the mainstem of Oak Creek ranged from below the limit of detection to 0.056 μg/l, depending on the station. The maximum concentrations of mercury detected at individual sampling stations ranged between 0.34 μg/l and 0.74 μg/l. Over the period of record, the maximum concentration of mercury detected in Oak Creek was 0.74 μg/l. During the period 2000 through 2003, mercury concentrations in all samples collected from the mainstem of Oak Creek were below the acute toxicity water quality criterion for fish and aquatic life. The percentage of samples in which mercury concentrations were below the chronic toxicity water quality criterion for fish and aquatic life differed among sampling stations, ranging between 91 percent to 100 percent.

One sample collected from the North Branch of Oak Creek in 1996 was analyzed for mercury. The mercury concentration detected in this sample was below the limit of detection and below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

Nickel

Nickel is a metal that occurs in Earth's crust, mostly as nickel compounds. Major uses of nickel include plating of metals and the manufacture of metal alloys, batteries, magnets, and electronics. Natural sources of nickel to surface waters include weathering and erosion of rocks and soils. Anthropogenic sources include mining, refining, and smelting of metals and combustion of fossil fuels. In trace amounts, nickel is an essential nutrient for some plants, fungi, and bacteria. High concentrations of nickel can cause mortality in aquatic organisms. Chronic exposure to lower concentrations can lead to adverse effects on survival, growth, and reproduction. The toxicity of nickel is affected by water hardness, with softer water resulting in more severe toxic effects. The State of Wisconsin has promulgated acute and chronic toxicity criteria for aquatic life for nickel. The values of these criteria vary depending upon water hardness levels.

The earliest assessment of nickel in surface water of the Oak Creek watershed occurred during 1975 and 1976 when water samples from three sampling stations along the mainstem of Oak Creek and one station along the North Branch of Oak Creek were sampled for nickel. Since 1990, water samples have been regularly analyzed for nickel at seven sampling stations along the mainstem of Oak Creek. During the period 2007 through 2016, nickel concentrations were below the limit of detection in between 7 and 17 percent of samples, depending on the station. Median concentrations of nickel in samples collected during the period 2007 through 2016 at sampling stations along the mainstem of Oak Creek ranged between

3.10 µg/l and 3.45 µg/l. During the period 2007 through 2016, maximum concentrations of nickel detected at individual sampling stations ranged between 10.0 µg/l and 54.0 µg/l. Over the period of record, the maximum concentration of nickel detected in Oak Creek was 81.0 µg/l. During the period 2007 through 2016, nickel concentrations in all of the samples collected from the mainstem of Oak Creek were below the acute and chronic toxicity water quality criteria for fish and aquatic life.

Few samples from tributary streams in the Oak Creek watershed have been analyzed for nickel. Several samples were collected at one station along the North Branch of Oak Creek in 1975 and 1976. The concentration of nickel in these samples was below the limit of detection. One sample was collected from the Mitchell Field Drainage Ditch in 2010. The concentration detected in this sample was 3.0 µg/l and was below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

Silver

Silver is a metal that occurs in Earth's crust, both as a pure metal and in silver compounds. It has no known biological function. Major uses of silver include the manufacture of jewelry, tableware, electronics, metal alloys, and films for traditional photography. Natural sources of silver to surface waters include geological deposits, volcanic activity, and weathering and erosion of rocks and soils. Anthropogenic sources include mining operations, metal production, and manufacture of silver-containing materials. Silver is highly toxic to freshwater microorganisms, strongly inhibiting their growth and reproduction. High concentrations of silver can cause mortality in aquatic organisms. Chronic exposure to lower concentrations can lead to adverse effects on survival, growth, and reproduction. The toxicity of silver is affected by water hardness, with softer water resulting in more severe toxic effects. The State of Wisconsin has promulgated a human threshold water quality criterion for silver of 28,000 µg/l for those waters not used for public water supply.

Water samples from seven sampling stations along the mainstem of Oak Creek have been sampled for silver since 1996. In most of the samples analyzed, the concentration of silver was below the limit of detection. Depending upon the sampling station and period examined, silver concentrations were below the limit of detection in between 64 percent and 79 percent of samples. Median concentrations of silver in samples from all stations were below the limit of detection. Maximum concentrations detected at individual stations ranged between 9.0 µg/l and 18.0 µg/l. Silver concentrations were below the human threshold water quality criterion in all samples analyzed.

Zinc

Zinc is a metal that is found in Earth's crust, mostly as zinc compounds. While it is an essential nutrient for plants and animals in trace amounts, higher amounts are toxic. Zinc is one of the most widely used metals in the world. Major uses of zinc include galvanizing iron and steel; preparation of metal alloys; production of roofing materials, gutters, rubber, paints, and batteries. Natural sources of zinc to surface waters include windborne soil particles, volcanic emissions, forest fires, and weathering and erosion of rocks and soils. Anthropogenic sources include industrial activities, coal and waste combustion, wastewater treatment plants, industrial effluents, and urban runoff. Zinc loadings from buildings and automobiles make a major contribution to zinc concentrations in urban stormwater runoff. High concentrations of zinc can cause mortality in aquatic organisms. Algae, crustaceans, salmon, mollusks, and some aquatic insects are particularly sensitive to zinc toxicity. The State of Wisconsin has promulgated acute and chronic toxicity criteria for aquatic life for zinc. The values of these criteria vary depending upon water hardness levels.

The earliest assessment of zinc in surface water of the Oak Creek watershed occurred during 1975 and 1976 when water samples from three sampling stations along the mainstem of Oak Creek and one station along the North Branch of Oak Creek were sampled for zinc. Since 1985, water samples have been regularly analyzed for zinc at seven sampling stations along the mainstem of Oak Creek. During the period 1997 through 2006, zinc concentrations were below the limit of detection in between 2 and 14 percent of water samples collected from Oak Creek, depending upon sampling station. During the period 2007 through 2016, zinc concentrations were below the limit of detection in between 5 and 9 percent of samples, depending on the station. Median concentrations of zinc in samples collected at stations along the mainstem of Oak Creek during the period 2007 through 2016 were between 11.5 µg/l and 15.0 µg/l, depending on sampling station. During the period 2007 through 2016, maximum concentrations of zinc detected at individual sampling stations ranged between 55 µg/l and 120 µg/l. Over the period of record, the maximum concentration of zinc detected in Oak Creek was 212 µg/l. During the period 2007 through 2016, zinc concentrations in all samples collected from the mainstem of Oak Creek were below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

A small number of samples from tributary streams in the Oak Creek watershed have been analyzed for zinc. Three samples collected from the North Branch of Oak Creek between 1990 and 1996 constitute the most recent sampling of this stream. The maximum concentration detected in these samples was 43 µg/l. Concentrations of zinc in these samples were below both the acute and chronic toxicity water quality criteria for fish and aquatic life. One sample was collected from the Mitchell Field Drainage Ditch in 2010. The zinc concentration detected in this sample was 30 µg/l. Because this sample was not analyzed for water hardness, it cannot be used to evaluate compliance with water quality standards; however, at the levels of hardness typically found in this stream the zinc concentration in this sample would be below both the acute and chronic toxicity water quality criteria for fish and aquatic life.

<u>Other Compounds</u>

Selenium

Selenium is a nonmetallic element present in sedimentary rocks, shales, coal, phosphate deposits, and soils. While it is an essential nutrient for animals in trace amounts, higher amounts are toxic. Selenium is used in the production of glass, batteries, metal alloys, electronics, and solar cells and in the vulcanization of rubber. Selenium bioaccumulates in the tissues of aquatic organisms. Tissue concentrations can be magnified at higher levels in aquatic food chains. Exposure to selenium can cause mortality in aquatic organisms and wildlife. Chronic exposure to lower concentrations can cause reproductive impairments such as deformities in early life stages and can adversely affect juvenile growth. The State of Wisconsin has a chronic toxicity criterion for fish and aquatic life for selenium. Under this criterion the maximum four-day concentration of selenium is not to exceed 5.0 µg/l more than once every three years.

Water samples from seven sampling stations along the mainstem of Oak Creek have been sampled for selenium since 1991. In most of the samples analyzed, the concentration of selenium was below the limit of detection. Depending upon the sampling station and period examined, selenium concentrations were below the limit of detection in between 86 percent and 99 percent of samples. Median concentrations of selenium in samples from all stations were below the limit of detection. Maximum concentrations detected at individual stations ranged between 9.0 µg/l and 18 µg/l. During the period 2007 through 2016, the percentage of samples in which selenium concentrations were above the chronic toxicity water quality criterion ranged between 8 percent and 12 percent, depending on sampling station.

Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) make up a group of over 5,000 chemicals used in numerous industrial and consumer applications. PFAS are or have been used for or in the manufacture of water repellant and stain resistant fabrics and leather; grease and oil resistant coatings for paper; nonstick coatings for cookware; wire coatings and insulation; hydraulic fluids; industrial surfactants, resins, molds, and plastics; plated and etched metals; paints and polishes; semiconductors; photolithography; flame retardants; and fire-fighting foams. PFAS compounds are of concern because many are highly persistent in the environment, they bioaccumulate in the tissue of organisms, and some have been linked to adverse health effects in humans and animals.

Structurally, PFAS molecules consist of two parts: a tail consisting of a chain of two or more carbon atoms and a head consisting of a charged functional group. In the tails of perfluoroalkyl substances, fluorine atoms are attached to all of the bonding sites on the carbon chain except for one site on the last carbon atom where the head is attached. The complete coverage of the tail by fluorine atoms make perfluoroalkyl substances highly resistant to degradation. In the tails of polyfluoroalkyl substances, at least one non-fluorine atom is attached to at least one carbon atom in the chain. The non-fluorine atom is typically, but not always, an oxygen or hydrogen atom. The presence of a non-fluorine atom along the tail creates a “weak point” in the carbon chain that is susceptible to degradation. The head of a PFAS molecule consists of a functional group that may contain one or more carbon atoms or sulfur atoms. While commonly-occurring functional groups include carboxylic acids (carboxylate), sulfonic acids (sulfonate), and sulfonamides, a wide range of functional groups may be found in different PFAS chemicals. The functional groups that serve as the head are typically acidic. Depending on chemical conditions, PFAS molecules can exist in either anionic form in which a hydrogen atom has dissociated from the molecule's head or acidic form in which dissociation has not occurred. The physical properties of a PFAS molecule are highly dependent on which of these forms the molecule is in.

Reliable information on physical and chemical properties of PFAS compounds is scarce. This is a very large group of chemicals and only a few have been characterized. Some of the available information consists of modeling results rather than measured properties. In addition, much of the available information consists of characterization of the undissociated acid form. In general, PFAS compounds occur in this form only under environmental conditions in which the pH is less than 3.0 stu. This pH is much lower than what usually occurs under ambient environmental conditions. For these reasons, the following general discussion of the properties of PFAS compounds should be interpreted with caution. Not all of the properties discussed below are universal to all PFAS compounds.

While each PFAS chemical has its own set of properties, some generalizations can be made. While many PFAS are solids at room temperature, some are liquids, and a few are gasses. PFAS chemicals with longer chain sizes tend to be solid.[264] While there are exceptions, PFAS are generally less volatile than many other groundwater contaminants. PFAS chemicals also show high thermal stability. While some decomposition occurs at temperatures above 400°C, complete degradation of perfluoroalkyl substances requires temperatures above 1,000°C. Perfluoroalkyl substances are highly chemically stable and show low chemical reactivity. As a result of the strength of the carbon-fluorine chemical bond and the shielding of the carbon chain by fluorine atoms, perfluoroalkyl substances are resistant to hydrolytic, oxidative, and reductive processes. Polyfluoralkyl substances tend to be less stable; however, they tend to degrade into perfluoroalkyl substances. Many PFAS chemicals are strong acids and will dissociate completely at neutral pH. The tails of PFAS molecules are hydrophobic. The heads are often hydrophilic, especially in the dissociated anionic form. As a result, PFAS molecules may sometimes straddle interfaces between aqueous and non-aqueous media. In addition, the tails may adsorb to soil or sediment particles containing organic carbon, with longer tail lengths being associated with a greater tendency to adsorb. Many PFAS compounds bind to proteins. Because their gross structure is similar to that of phospholipids, some may insert themselves into cell membranes of organisms. PFAS compounds can bioaccumulate in organisms; however, the mechanisms through which this occurs are different from those that drive the bioaccumulation of other hydrophobic contaminants such as PCBs or legacy pesticides.

Some PFAS chemicals have been linked to adverse health conditions in humans. Studies conducted during and since the 1970s reported the presence of some PFAS in the blood of occupationally exposed workers.[265] Similarly, studies conducted during and since the 1990s reported detections of PFAS chemicals in blood of the general human population.[266] Some long-chain PFAS chemicals have been shown to have relatively long half-lives in humans.[267] Examples include half-lives of 5.4 years for perfluorooctane sulfonic acid (PFOS), 8.0 years for perfluorooctanoic acid (PFOA), and 8.4 years for perfluorohexane sulfonic acid (PFHxS). A major study on the effects of exposure to a single PFAS chemical was conducted by the C8 Science Panel.[268] This panel consisted of three epidemiologists and was created by the West Virginia Circuit Court as part of the settlement to a class action lawsuit related to releases of PFOA, an eight-carbon PFAS, from a DuPont

---

[264] *Much of the literature on PFAS makes a distinction between long-chain and short-chain PFAS. Long-chain PFAS consist of perfluoroalkyl carboxylic acids containing eight or more carbon atoms and perfluoroalkyl sulfonic acids containing six or more carbon atoms. Forms with fewer carbon atoms are considered short-chained.*

[265] *G.W. Olsen, "PFAS Biomonitoring in Higher Exposed Populations," Chapter 4 in J.C. DeWitt (editor),* Toxicological Effects of Perfluoroalkyl and Polyfluoroalkyl Substances, *pages 77-126, Humana Press, 2015.*

[266] *G.W. Olsen, D.C. Mair, C.C. Lange, L.M. Harrington, T.R. Church, C.L. Goldberg, R.M. Herron, H. Hanna, J.B. Nobiletti, and J.A. Rios, "Per- and polyfluoroalkyl substances (PFAS) in American Red Cross adult blood donors, 2000-2015,"* Environmental Research, *volume 157, pages 87-95, 2017.*

[267] *G.W. Olsen, J.M Burris, D.J. Ehresman, J.W. Froehlich, A.M. Seacat, J.L. Butenhoff, and L.R. Zobel, "Half-life of Serum Elimination of Perfluorooctanesulfonate, Perfluorohexanesulfonate, and Perfluorooctonate in Retired Fluorochemical Production Workers,"* Environmental Health Perspectives, *volume 115, pages 1,298-1,305, 2007.*

[268] *See S.J. Frisbee, A.P. Brooks, Jr., A. Maher, P. Flensborg, S. Arnold, T. Fletcher, K. Steenland, A. Shankar, S.S. Knox, C. Pollard, J.A. Halverson, V.M. Vieira, C. Jin, K.M. Leyden, and A.M. Ducatman, "The C8 Health Project: Design, Methods, and Participants,"* Environmental Health Perspectives, *volume 117, pages 1,873-1,882, 2009; K. Steenland, T. Fletcher, and D.A. Savitz, "Epidemiological Evidence on the Health Effects of Perfluorooctanoic Acid (PFOA),"* Environmental Health Perspectives, *volume 118, pages 1,100-1,108, 2010; and references given at www.c8sciencepanel.org/publications.html.*

facility. The Science Panel collected and analyzed epidemiological data from exposed workers at the facility and members of the affected communities and reviewed the relevant scientific and medical literature to examine linkages between exposure to PFOA and human diseases. The Panel examined potential linkages of 72 diseases in 17 classes to PFOA exposure. They concluded that the data showed evidence of probable links for six diseases: high cholesterol, ulcerative colitis, thyroid disease, testicular cancer, kidney cancer, and pregnancy-induced hypertension. Additional studies suggest that some PFAS may suppress the immune system. The National Toxicology Program (NTP) of the U.S. Department of Health and Human Services conducted a systematic review of studies related to the effects of PFOA and PFOS on the immune system.[269] Based on this review, the NTP concluded that PFOA is presumed to be an immune hazard to humans based on suppression of antibody response, reduction of disease resistance, increased hypersensitivity-related outcomes, and increased autoimmune disease incidence. The NTP also concluded that PFOS is presumed to be an immune hazard to humans based on suppression of antibody response, reduction of disease resistance, and suppression of natural killer cell activity.

There are four major sources of PFAS releases to the environment: fire-fighting training and response sites, industrial facilities, wastewater treatment plants (WWTPs), and landfills. Other sources of PFAS exist and may be important locally in particular situations, but these are generally thought to make small contributions relative to the main four. The major sources are described in the following paragraphs.

PFAS are often released at fire-fighting training and response sites through the use of aqueous film-forming foams (AFFF) in fire fighting. AFFFs have been used to extinguish hydrocarbon fires at U.S. military installations, civilian airports, and other facilities since the 1960s. The exact composition of any specific AFFF product is highly variable and consists of a diverse mixture of PFAS chemicals, including both perfluorinated and polyfluorinated forms. This variable composition reflects the fact that they are typically formulated to fire-fighting specifications and not to chemical composition. AFFF applied during either fire fighting, testing of equipment, or training may:

- Volatilize into the atmosphere and subsequently be deposited at locations away from the site of application

- Runoff to surface waterbodies leading to infiltration into groundwater or uptake by organisms

- Infiltrate into soils and subsequently into groundwater

Any of these processes may lead to dispersal of the PFAS contained in AFFF through the environment. In addition, these processes may lead to conversion of polyfluorinated PFAS chemicals into more persistent perfluorinated forms.

PFAS may also be released from industrial sites. This includes sites engaged in primary manufacturing of PFAS in which PFAS-containing materials are synthesized and made into products and chemical feed stocks and secondary manufacturing in which PFAS products and feed stocks are used as part of industrial processes. Releases of PFAS into the environment from industrial sites may occur through wastewater discharges, stormwater discharges, stack emissions, onsite and offsite disposal of wastes, and leaks or spills.

WWTPs may also release PFAS to the environment. Conventional primary and secondary wastewater treatment is not designed to degrade these chemicals. Concentrations of individual PFAS compounds may change during treatment as a result of conversion of polyfluorinated forms to perfluorinated forms. The composition of PFAS chemicals released by WWTPs depends on the types and composition of PFAS received by the WWTP, conversion of polyfluorinated forms to perfluorinated forms or intermediate compounds during treatment, and physical and chemical partitioning of compounds between media that occurs during treatment. PFAS may be released to the environment from WWTPs through point source discharge of effluent into receiving waters, leakage or unintended releases from surface impoundments, emission into the air, or disposal of biosolids. In particular, biosolid application on agricultural lands can constitute a significant pathway into the environments as it can lead to PFAS ultimately entering surface waters, groundwater, and the food chain.

[269] *National Toxicology Program,* NTP Monograph on Immunotoxicity Associated with Exposure to Perfluorooctanoic Acid (PFOA) or Perfluorooctane sulfonate (PFOS)," *U.S. Department of Health and Human Services, September 2016.*

Landfills are a fourth source that can release PFAS to the environment. They constitute the ultimate repository for industrial waste, site-mitigation waste, sewage sludge, and consumer goods containing, treated with, or contaminated with PFAS. PFAS were manufactured, used, and disposed of for decades prior to the enactment of Federal and state waste disposal regulations.[270] Consumer products containing PFAS have been landfilled since at least the 1950s. Landfills constructed since the 1990s are required to have linings and leachate collections systems. Leachate from these newer landfills typically goes either to WWTPs or collection ponds. PFAS contained in leachate may enter the environment through these facilities. Failure of these leachate collection systems may also allow PFAS to enter the environment. Older landfills were not required to have linings or leachate collection systems. Wastes in these landfills are often in direct contact with soil and groundwater which can allow PFAS to enter and disperse into the environment. Typically, landfills containing PFAS will release them at slow but relatively steady rates for decades following initial placement of PFAS-containing wastes.

Neither the State of Wisconsin nor USEPA have promulgated surface water quality or groundwater quality criteria for PFAS chemicals. Under provisions of the Federal Safe Drinking Water Act (SDWA), USEPA issued a lifetime health advisory for PFOA and PFOS in drinking water in 2016. Such an advisory provides information on concentration thresholds intended to protect sensitive populations from health impacts and constitute nonenforceable levels to help drinking water suppliers address contaminants that lack drinking water standards. Under this advisory it is recommended that separate or combined concentrations of PFOS and PFOA in drinking water not exceed 70 nanograms per liter (ng/l). The SDWA also requires that every five years USEPA issue a list of no more than 30 unregulated contaminants to be monitored by public water systems. The monitoring required under this provision of the SDWA can serve as a basis for developing drinking water regulations. In 2012, USEPA issued the third Unregulated Contaminant Monitoring Rule, which included monitoring of six PFAS compounds in drinking water systems: PFOA, PFOS, PFHxS, perfluorononanoic acid (PFNA), perfluoroheptanoic acid (PFHpA), and perfluorobutane sulfonic acid (PFBS). It has also been proposed that these chemicals be monitored under the fifth Unregulated Contaminant Monitoring Rule. It is expected that the final draft list of chemicals to be monitored will be issued in summer 2020 and the rule specifying the list of chemicals to be monitored will be issued in late 2021. The WDNR is currently developing both surface water quality standards and drinking water standards for PFAS, including PFOA and PFOS. Based on a review of the scientific literature, the Wisconsin Department of Health Services has recommended that the WDNR set a groundwater enforcement standard of 20 ng/l for separate or combined concentrations of PFOS and PFOA.

Evidence of PFAS contamination has been found within the Oak Creek watershed. In 2015, a preliminary assessment was conducted at the Wisconsin Air National Guard (WIANG) base at MMIA to identify potential sites of historical releases of PFAS from AFFF usage and storage.[271] This assessment also conducted research on fire training areas in operation on the base since 1970. Based on evidence of AFFF storage or use, this study recommended further evaluation of 13 sites on the base, including two that are located wholly or partially within the Oak Creek watershed. Additional evaluations were conducted at these sites in 2017.[272] These evaluations included collection and analysis of samples from soil, groundwater, surface water, and sediment for six PFAS compounds: PFOA, PFOS, PFHxS, PFNA, PFHpA, and PFBS. Concentrations of some compounds were compared to screening criteria from a variety of sources.[273] Sites at which concentrations of PFAS exceeded screening criteria were identified and recommended for further investigation. The report recommended that further investigations be conducted at eleven of the evaluated sites. It also recommended no further action be taken at the two sites located within the Oak Creek watershed.

---

[270] *For example, the Federal Resource Conservation and Recovery Act of 1976.*

[271] *BB&E, Inc.,* Perfluorinated Compounds Preliminary Assessment Site Visit Report: Wisconsin Air National Guard Base, General Mitchell International Airport, Milwaukee, Wisconsin, *December 2016.*

[272] *Amec Foster Wheeler Environment & Infrastructure, Inc.,* Final Report FY16 Phase 1 Regional Site Inspections for Perfluorinated Compounds: General Mitchell Air National Guard Base, Milwaukee, Wisconsin, *Report to National Guard Bureau, February 2019.*

[273] *Concentrations of PFOA and PFOS in soil and sediment were compared to U.S. Air Force guidance levels of 1,260 micrograms per kilogram (µg/kg), concentrations of PFOA and PFOS in surface water and groundwater were compared to the USEPA drinking water health advisory level of 0.070 µg/l, concentrations of PFBS in soil were compared to a USEPA screening criterion for residential soil of 1,300,000 µg/kg, and concentrations of PFBS in water were compared to a USEPA screening criterion for tap water of 400 µg/l.*

Table 4.21 shows concentrations of six PFAS chemicals in groundwater samples collected from the two sites on the WIANG base at MMIA that are wholly or partially located within the Oak Creek watershed. Five PFAS compounds were detected at one site and four compounds were detected at the other site. The concentrations of PFOA, PFOS, and PFBS at these two sites were below the screening criteria used in the assessment. In addition, the concentrations detected at these sites were lower than those detected at many of the other sites that were sampled on the WIANG base. For example, concentrations of PFOS in groundwater samples collected at other sites on the WIANG base ranged from below the limit of detection to 32.6 µg/l, with a mean value of 3.43 µg/l. The concentration detected at the one of the two sites in the Oak Creek watershed was 0.0151 µg/l, while at the other it was below the limit of detection.

Table 4.22 shows concentrations of six PFAS chemicals in soil samples collected from the two sites on the WIANG base at MMIA that are wholly or partially located within the Oak Creek watershed. Five PFAS compounds were detected at one site and four compounds were detected at the other site. The concentrations of PFOA, PFOS, and PFBS at these two sites were below the screening criteria used in the assessment. In addition, the concentrations of these chemicals were within the range of the concentrations detected in soil samples at other sites on the WIANG base.

Since no surface waterbodies are present at the two sites on the WIANG base that are located in the Oak Creek watershed, surface water and sediment samples were not collected at these sites.

PFAS have also been reported in groundwater samples collected from the site of the former 440th Air Force Reserve Tactical Airlift Wing station at MMIA. This base is located within the Oak Creek watershed. Combined concentrations of PFOA and PFOS in groundwater samples ranged between 0.088 µg/l and 10.83 µg/l.[274] Concentrations in most samples exceeded the USEPA drinking water advisory level used as a screening criterion. The PFAS contamination was attributed to known or suspected releases of AFFF.[275]

Evidence of PFAS contamination of surface water has also been found at MMIA where the use of AFFF was historically required by the Federal Aviation Administration for emergency response and fire suppression. MMIA was required by the WDNR to conduct an initial survey of PFAS compounds in surface waters at MMIA a part of the WPDES permit process. This initial characterization was conducted by MMIA and the USGS. The findings of this investigation indicate the presence of PFAS compounds at all sampling points and surface water discharge locations. As a result of this initial survey, the WDNR issued a Responsible Party Letter to MMIA and the two military installations requiring a site investigation to define the nature, degree, and extent of PFAS compound at MMIA. Milwaukee County submitted a workplan for this site investigation to the WDNR which was subsequently approved on June 12, 2020. The site investigation focuses on property owned by MMIA and will be completed in 2020.

The Cudahy Woods natural area in the City of Oak Creek is a third site within the Oak Creek watershed where soils or groundwater might be contaminated with PFAS chemicals (see Map 2.3 in Chapter 2). On September 5, 1985, Midwest Express Flight 105 crashed at this site shortly after taking off from MMIA. This DC-9 aircraft exploded following impact and was largely consumed by the post-crash fire. According to the accident report, several fire-fighting departments responded to the crash, including departments from the City of Oak Creek, MMIA, the 440th Air Force Reserve, and the 128th Air National Guard.[276] The report also noted that the responding units discharged "fire extinguishing agent," but did not identify the type or composition of the agent. Given that some of the fire departments responding to this fire are known to have been equipped with AFFF and news reports refer to the presence of canisters of fire-fighting foam at the wreckage,[277] it is possible that soils or groundwater in or around this natural area may contain PFAS chemicals.

---

[274] *Maureen Sullivan,* Addressing Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA), *U.S. Department of Defense Presentation, March 2018.*

[275] *U.S. Department of Defense,* Aqueous Film Forming Foam Report to Congress, *October 2017.*

[276] *National Transportation Safety Board,* Aircraft Accident Report: Midwest Express Airlines Inc., DC-9-14, N100ME, General Billy Mitchell Field, Milwaukee, Wisconsin, September 6, 1985, *NTSB/AAR-87/01, February 3, 1987.*

[277] *D.B. Feaver, "Plane Engine Failed Before DC9 Hit Ground,"* The Washington Post, *September 8, 1985.*

Table 4.21
Concentrations of Perfluorinated Alkyl Substances in Groundwater at Sites Located on Portions of the Wisconsin Air National Guard Base Within the Oak Creek Watershed: November 2017

Compound	Site 3: Fire Department Equipment Testing Site (Guard Central) (μg/l)	Site 4: Fire Department Equipment Testing Site (Guard South) (μg/l)
Perfluorooctane Sulfonic Acid (PFOS)	0.0151	<LOD
Perfluorooctanoic Acid (PFOA)	0.0247	0.0142
Perfluorobutane Sulfonic Acid (PFBS)	0.1700	0.0707
Perfluoroheptanoic Acid (PFHpA)	0.0286	0.0242
Perfluorohexane Sulfonic Acid (PFHxS)	0.6810	0.1470
Perfluorononanoic Acid (PFNA)	<LOD	<LOD

Note: <LOD indicates that the concentration was less than the limit of detection.

Source: Amec Foster Wheeler Environment and Infrastructure, Inc.

Table 4.22
Concentrations of Perfluorinated Alkyl Substances in Soil at Sites Located on Portions of the Wisconsin Air National Guard Base Within the Oak Creek Watershed: November 2017

Site	Soil Depth (feet)	PFOS[a] (μg/kg)	PFOA[a] (μg/kg)	PFBS[a] (μg/kg)	PFHpA[a] (μg/kg)	PFHxS[a] (μg/kg)	PFNA[a] (μg/kg)
Site 3: Fire Department Equipment Testing Site (Guard Central)	0.5-1.0	3.86[b]-45.2	<LOD-1.72[b]	<LOD-2.44	0.345[b]-1.04[b]	0.522[b]-36	<LOD
	1.0-2.0	20.7[b]-39.8b	12.2[b]-20.5[b]	13.5[b]-21.8	4.13-6.14	362[b]-698[b]	<LOD
	4.0-4.5	<LOD	<LOD	<LOD	<LOD	1.09[b]	<LOD
	5.0-5.5	1.38[b]-56.2	<LOD-4.69	<LOD-7.19	<LOD-6.14	0.64[b]-112	<LOD
Site 4: Fire Department Equipment Testing Site (Guard South)	0.5-1.0	6.18-7.69	<LOD-0.351[b]	<LOD	<LOD-0.29[b]	0.454[b]-4.14	<LOD
	5.0-10.0	1.61[b]	<LOD	<LOD	<LOD	1.35[b]	<LOD
	11.0-11.5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
	12.0-12.5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Note: <LOD indicates that the concentration was below the limit of detection.

[a] *Abbreviations indicate:*
PFOS Perfluorooctane Sulfonic Acid
PFOA Perfluorooctanoic Acid
PFBS Perfluorobutane Sulfonic Acid
PFHpA Perfluoroheptanoic Acid
PFHxS Perfluorohexane Sulfonic Acid
PFNA Perfluorononanoic Acid

[b] *Compound was detected but concentration was estimated.*

Source: Amec Foster Wheeler Environment & Infrastructure, Inc.

Emerging Water Pollutants

Emerging water pollutants are synthetic or naturally occurring substances that are not commonly monitored, but which have either been detected in waterbodies or have the potential to enter waterbodies and which are known or suspected to cause adverse ecological and/or human health effects. Most of these substances are not regulated under current environmental laws and for most of them water quality criteria have not been promulgated and water quality guidelines have not been developed. The class of emerging pollutants consists of hundreds to thousands of compounds, each potentially having its own chemistry, biological activity, and toxicology. Despite this, they can be classified into a number of broad groups. These groups include antimicrobial agents, aromatic organic compounds, corrosion inhibitors, dyes, flame retardants, flavors and fragrances, food preservatives, hormones and their precursors and derivatives, nanomaterials, polycyclic aromatic hydrocarbons (PAHs), pharmaceuticals and other pharmaceutically active compounds, plasticizers, solvents, and surfactants. It should be noted that the toxicology and ecological effects of many of these compounds have not been examined and are poorly understood. In addition, many of these substances may be altered through chemical degradation in the environment or metabolic activity in organisms. The toxicology and ecological effects of many of their degradation and metabolic products have not been examined and are poorly understood.

Between 2002 and 2009, the USGS collected water samples at the sampling station at 15th Avenue (RM 2.8) and analyzed them for 58 emerging water pollutants. The results of this sampling are summarized in Appendix J. For most of the substances sampled, concentrations in the majority of samples were below the limit of detection. There were 10 substances that were detected in more than half of the samples collected. These include the aromatic organic compound 3,4-dichlorophenyl isocyanate; the dye 9,10-Anthraquinone; the flame retardant Tris (2-chloroethyl) phosphate; the hormone precursor chlolesterol; the PAHs fluoranthene, phenanthrene, and pyrene; the pharmaceutically active compound caffeine; the plasticizer tributyl phosphate; and the solvent isophorone.

Toxicity Conditions

Toxic substances are substances that can poison or cause other health effects in organisms. These substances damage living tissue by interfering with processes within cells, tissues, or organs. The toxicity or potential to cause damage of a toxic substance is related to dosage of, route of exposure to, and length of exposure to the substance. Substances vary in the dose needed to produce an effect with some substances causing toxic effects at very low doses. Other chemicals require relatively high doses to produce effects. For many substances, higher doses result in stronger or more serious toxic effects. The route of exposure can also affect a substance's toxicity. The effects of a substance may differ depending on whether it is ingested, inhaled, or absorbed through skin or gills. The length of exposure can also affect a substance's toxicity and the types of effects it produces. Short-term exposures are referred to as acute, and long-term or repeated exposures are referred to as chronic.

A toxic substance may also have acute and chronic effects. Acute effects typically occur within a short time following exposure. Chronic effects may begin subtly and may last over a lifetime.

It should be noted that some toxic compounds may accumulate in the tissue of organisms. This is known as bioaccumulation. Over time, this accumulation can result in a substance reaching toxic dosages. This can also result in biomagnification of the toxin through the food chain.

This section discusses four classes of toxic substances—metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) in surface water, sediment, and aquatic organisms in the Oak Creek watershed. It should be noted that the toxicity of other water quality constituents has been discussed in previous sections of this chapter.

Classes of Toxic Substances

Toxic effects of individual heavy metals were discussed in previous sections of this chapter which reviewed concentrations of these substances in surface water.

Pesticides are chemical and biological substances intended to control pest organisms. Specific pesticides have been developed and used for many types of organisms including insects, rodents, plants, fungi, and algae. These compounds are designed to be toxic to the target pests but can also have impacts on other organisms. Examples of unintended impacts attributed to exposure to pesticides include fish kills, reproductive failure in birds and amphibians, and acute or chronic illness in humans.

Pesticides represent a large group of chemicals consisting of many classes of compounds. These classes of compounds all have their own modes of actions, chemical properties, and biological effects. Some pesticides break down over time as a result of chemical and microbiological reactions in the environments. Others are resistant to breakdown and persist in the environment. Some, such as chlorinated hydrocarbon insecticides, can bioaccumulate in the tissue of organisms with tissue concentrations being considerably higher than ambient concentrations in the environment. Tissue concentrations of some of these compounds may be magnified as they are passed up the food web through trophic interactions, with higher tissue concentrations being found at higher trophic levels.

Pesticides are registered for use in the United States by the USEPA. In Wisconsin, they are registered by the Department of Agriculture, Trade and Consumer Protection. Some pesticides that have been banned are still found in environmental samples and tissue samples of aquatic organisms. Examples of this include DDT and its metabolites. While Wisconsin has promulgated water quality criteria for some pesticides, criteria have not been promulgated for most.

PAHs are members of a large class of organic compounds containing two or more fused aromatic rings of carbon. Some of these compounds occur naturally in peat, lignite, coal, and crude oil. A few of these compounds are manufactured as intermediates in the production of materials such as dyes, pigments, pesticides, and plasticizers. Mixtures of some are manufactured to treat wood used for railroad ties and marine timbers or to seal asphalt. Most PAHs are produced as byproducts due to incomplete combustion of organic materials during industrial processes and other human activities.

PAHs exhibit a wide range of physical and chemical properties. In general, they tend to be solid at ambient temperatures. They tend to have low volatilities, high melting points, and high boiling points. Similarly, their solubilities in water are low. In general, the volatilities and water solubilities of these compounds tend to decrease with increasing molecular weight. They are soluble in lipids and polar organic solvents, and they tend to adsorb to particles. While PAHs can undergo photodecomposition in the atmosphere and react with strong oxidizing agents such as ozone and oxides of nitrogen and sulfur, they are fairly stable compounds. Individual PAH compounds that contain more aromatic rings and have higher molecular weights tend to exhibit greater chemical stability. PAHs are usually found in the environment as mixtures of compounds and are often associated with other contaminants such as heavy metals, pesticides, and PCBs.

PAHs enter the environment through several routes. Often, they are released to the atmosphere by combustion sources, usually sorbed to particulates. They can travel long distances through the air and be deposited at sites far away from where they were released. They enter surface waters through atmospheric deposition, urban runoff, abrasion of asphalt, accidental spills, and release from creosote-treated wood. The use of coal-tar-based pavement sealants is a major source of PAHs.[278] PAHs entering surface waters tend to accumulate in sediment. It should be noted that four municipalities in the Oak Creek watershed have recently prohibited the use of coal-tar sealants within their jurisdictions.

PAHs can be taken up by small organisms and fish in water through contact with contaminated water or sediment or through ingestion of organisms carrying PAHs. Once assimilated, PAHs are widely distributed throughout organism tissue. They can be found in most organs but accumulate most in lipid-rich tissue. The metabolism of PAHs within organisms is complex. Some are converted to nontoxic forms while others are converted to forms that bind to DNA or RNA. Organisms can excrete PAHs in feces and urine. While turnover of some PAHs in organisms can be rapid, others persist in fatty tissue or remain bound to cellular DNA or RNA.

PAHs have been shown to produce health effects in humans and other organisms. The acute toxicity of PAHs to humans tends to be fairly low. Fish, algae, and some invertebrates show acute toxicity to PAHs. Some PAHs can damage DNA and are mutagenic and some of these compounds are highly carcinogenic. Some PAHs are known or suspected to be endocrine disruptors that can interfere with hormonal regulation of biological activities. In addition, the metabolic products of some PAHs are compounds that are toxic, mutagenic, or carcinogenic.

The USEPA has classified several PAHs as priority pollutants. These are listed in Table 4.23.

Polychlorinated biphenyls (PCBs) are members of a family of 209 separate chemical compounds, referred to as congeners, formed by the substitution of chlorine atoms for hydrogen atoms on a biphenyl molecule. A particular PCB congener may have from one to ten chlorine atoms. These chemicals were used for numerous applications in industry and households. Common uses included insulators in electrical equipment and heating coils, lubricating oils, printing inks, adhesives, synthetic rubbers, and carbonless copy paper. While their manufacture in the United States ended in 1977, many PCBs may still be in use today.

All PCB congeners share certain physical and chemical properties. PCBs are highly stable compounds and tend to persist in the environment. They have high boiling points. While they are highly soluble in lipids and organic solvents, they have low solubility in water. They can also adsorb to sediment and other particles. The

[278] *B.J. Mahler, P.C. Van Metre, T.J. Bashara, J.T. Wilson, and D.A. Johns, "Parking Lot Sealcoat: An Unrecognized Source of Urban Polycyclic Aromatic Hydrocarbons,"* Environmental Science and Technology, *Volume 39, pages 5,560-5,566, 2005; A.K. Baldwin, S.R. Corsi, M.A Lutz, C.G. Ingersoll, R. Dorman, C. Magruder, and M. Magruder, "Primary Sources and Toxicity of PAHs in Milwaukee-area Streambed Sediment,"* Environmental Toxicology and Chemistry, *Volume 36, pages 1,622-1,635, 2017.*

properties of any particular PCB compound are strongly influenced by the number of chlorine atoms in its molecule. Congeners containing fewer chlorine atoms are lighter, more volatile, more soluble in water, and more mobile in the environment than congeners containing more chlorine atoms. PCBs were commercially produced in mixtures referred to as arochlors. An individual arochlor consists of a mixture of many PCB compounds.

PCBs enter the environment through several routes. Some were released to air, water, or soil during their manufacture, use, and disposal. Others were released through accidental spills, leaks, or fires. Currently, PCBs enter the environment through hazardous waste sites, illegal or improper disposal of industrial wastes and consumer products, leaks from old electrical transformers, and burning of some wastes in incinerators. PCBs do not readily break down in the environment. They can travel long distances in the air and can be deposited at sites far away from where they were released.

PCBs can be taken up by small organisms and fish in water, as well as by amphibians, reptiles, birds, and mammals through contact with contaminated water or sediment or through ingestion of an organism carrying PCBs. The chemicals will build up in the fatty tissue of the ingesting organisms. Larger and older organisms will tend to have higher body burdens of PCBs than smaller and younger organisms of the same species. Tissue concentrations can be magnified as PCBs move through the food chain, reaching levels that may be many thousands of times higher than the concentration in water. Higher levels of PCBs will be found in the tissue of species at the top of the food chain, such as piscivorous fish. In addition, species such as carp that have high exposure to contaminated sediments will tend to have high body burdens of PCBs.

Table 4.23
Polycyclic Aromatic Hydrocarbon (PAH) Compounds Classified as Priority Pollutants

PAH Compound
Acenaphthene
Acenaphthylene
Antracene
Benz(a)anthracene[a]
Benzo(a)pyrene[a]
Benzo(b)fluoranthene[a]
Benzo(e)pyrene[a]
Benzo(g,h,i)perylene[a]
Benzo(k)fluoranthene[a]
Chrysene[a]
Dibenz(a,h)anthracene[a]
Fluoranthene
Fluorene
Indeno(1,2,3-c,d)pyrene[a]
Perylene
Phenanthrene
Pyrene

[a] *Considered a class 2 carcinogen by the U.S. Environmental Protection Agency.*

Source: SEWRPC

PCBs have been shown to produce a number of health effects. Acute toxic effects have been seen only at high doses. PCBs have been shown to induce tumors in laboratory animals. Animal studies and epidemiological studies have shown liver cancers and liver damage to be associated with PCB exposure. Developmental problems especially related to learning and memory, have been seen in the children of women exposed to PCBs during pregnancy. Chloracne and rashes have also been associated with high levels of exposure to PCBs.

The most common way that humans are exposed to PCBs is by consuming contaminated fish. Repeated ingestion is needed to produce toxic effects. The WDNR has issued a general fish consumption advisory for fish caught from most of the surface waters of the State. PCBs can also be absorbed through the skin, if contaminated material is touched.

Surface Water

Since the 1970s, the Oak Creek watershed has been sampled for the presence of pesticides in surface waters on several occasions. Sampling was conducted in 1975, 1982, 1993, 2002 through 2009, and 2016. Most of the sampling was conducted at the USGS gage at 15th Avenue (RM 2.8). Sampling during 1975 focused heavily on the organochloride insecticides dieldrin, lindane, and DDT and on the metabolites of DDT. The concentrations of these substances were below the limits of detection in all samples collected in 1975. Single samples from sites on the mainstem of Oak Creek were taken in 1982 and 1993 and tested for toxaphene. In both cases, the concentration of this insecticide was below the limit of detection. Between 2002 and 2009, samples collected from the mainstem of Oak Creek at the sampling station at 15th Avenue were analyzed for 81 pesticides and pesticide breakdown products. Twenty-four of these substances were detected in one or more sample. Substances that were detected in at least half of the samples include the amide herbicide trifluralin; 4-chlor-2-methylphenol, a breakdown product of the phenoxy herbicide 2-methyl-4-chlorophenoxyacetic acid (MCPA); the triazine herbicide atrazine and its breakdown product deethylatrazine; 3,4-dichloroaniline, a breakdown product of the urea herbicide diuron; and the insect repellant N,N-diethyl-meta-toluamide (DEET). In 2016, samples collected from the mainstem of Oak

Creek at the sampling station at 15th Avenue were analyzed for 105 pesticides and pesticide breakdown products. These substances included 37 that were sampled during the period 2002 through 2009. Only eight substances were detected. These included the phenoxy herbicides 2,4-dichlorophenoxyacetic acid (2,4-D) and mecoprop; the pyradine herbicides imazapyr and triclopyr; the triazine herbicide atrazine and its breakdown products deethylatrazine and deisopropyl atrazine; and the urea herbicide diuron. Atrazine and deethylatrazine were the only substances detected in both the 2002 through 2009 and 2016 samplings. The State of Wisconsin has not promulgated water quality criteria for most of the pesticides that have been detected in Oak Creek. The results of the 2002 through 2009 and 2016 sampling are summarized in Appendix K.

On three dates in 2002, unfiltered samples were collected and analyzed for 18 PAH compounds at the sampling station at 15th Avenue (RM 2.8). This sampling examined the total concentration of the PAH compounds in water, including both PAHs dissolved in water and PAHs incorporated into or adsorbed to suspended particles. The concentrations of all 18 compounds in all three samples were below the limit of detections. On 12 dates during 2004 and 2005, filtered samples were collected and analyzed for nine PAH compounds at the sampling station at 15th Avenue (RM 2.8). This sampling examined the concentrations of PAH compounds dissolved in water. Ten PAH compounds were detected in at least one sample. Three compounds, fluoranthene, phenanthrene, and pyrene were detected in at least half of the samples. On 20 dates in 2007 through 2009, unfiltered samples were collected and analyzed for nine PAH compounds at the sampling station at 15th Avenue (RM 2.8). This sampling examined the total concentration of the PAH compounds in water, including both PAHs dissolved in water and PAHs incorporated into or adsorbed to suspended particles. All nine substances were detected in at least one sample. Seven compounds, 1-methylnaphthalene, 2-methylnaphthalene, anthracene, benzo[a]pyrene, fluoranthene, phenanthrene, and pyrene were detected in at least half of the samples. It should be noted that because of differences in sample preparation, the results of the 2007 through 2009 sampling are not directly comparable to those of the 2004 through 2005 sampling. The results of the 2004 through 2005 and 2007 through 2009 samplings are summarized in Table 4.24.

In 1975, three sites in the Oak Creek watershed were sampled for the presence and concentrations of PCBs in the water column, two sites on three dates and one site on one date. The concentrations of PCBs in all of these samples were below the limit of detection. Since then streams of the Oak Creek watershed have not been sampled for the presence of PCBs in water.

Groundwater

Contamination of wells with molybdenum has been reported in the vicinity of the Oak Creek watershed. Molybdenum is a metallic element that is naturally present at low levels in the Earth's crust. Trace amounts of molybdenum are necessary for human health and are obtained from common foods in the diet such as leafy vegetables, legumes, grains, and organ meats. Naturally occurring levels of molybdenum in groundwater are usually low; the USGS found a median concentration of one microgram per liter (μg/l) nationwide. Higher concentrations have been found in soil or groundwater, typically in conjunction with spills or some historical waste disposal practices. In 2009, the WDNR reported that 18 private wells in the City of Oak Creek and the Village of Caledonia had exceeded Wisconsin's groundwater enforcement standard for molybdenum of 40 μg/l during routine water sample testing at least once since 1993. In 2010, the WDNR in collaboration with the Wisconsin Department of Health Services (WDHS) tested private wells from 120 homes in the area. Additional testing was conducted over the period 2011 through 2013.

At the request of the WDNR, the WDHS reviewed the published information on molybdenum toxicity in light of the requirements for establishing groundwater quality enforcement standards under Chapter 160, "Groundwater Protection Standards," of the *Wisconsin Statutes*. Based upon their review of the toxicological literature and the fact that Wisconsin's molybdenum standard was developed using a value recommended by USEPA that in 2013 was under active review by USEPA, WDHS recommended that the WDNR use an interim health advisory level of 90 μg/l when advising about the safety of private drinking water supplies.[279] This interim health advisory level was developed using methods consistent with Wisconsin law.

[279] *Charles J. Warzecha, Wisconsin Department of Health Services, "Response to Request for Review of Molybdenum Toxicity Information," Letter to Jill D. Jonas, Wisconsin Department of Natural Resources, August 2, 2013.*

Table 4.24
Surface Water Quality Monitoring Results for Polycyclic Aromatic Hydrocarbons (PAHs) in the Mainstem of Oak Creek at 15th Avenue: 2004-2009

	2004-2005 (filtered samples)[a]				2007-2009 (unfiltered samples)[a]			
Compound	Samples Collected	Samples with Detections	Percent Samples with Detections	Range of Concentrations (μg/l)[b]	Samples Collected	Samples with Detections	Percent Samples with Detections	Range of Concentrations (μg/l)[b]
1-Methylnaphthalene	12	3	25	<LOD-0.013[c]	20	10	50	<LOD-0.04[c]
2,6-Dimethylnaphthalene	12	0	0	<LOD	20	8	40	<LOD-0.03[c]
2-Methylnaphthalene	12	5	42	<LOD-0.025[c]	20	10	50	<LOD-0.07[c]
Anthracene	12	2	17	<LOD-0.027[c]	20	11	55	<LOD-0.18[c]
Benzo[a]pyrene	12	0	0	<LOD	20	13	65	<LOD-0.61
Fluoranthene	12	10	83	<LOD-0.11[c]	20	16	80	<LOD-1.47
Naphthalene	12	5	42	<LOD-0.037[c]	20	9	45	<LOD-0.17[c]
Phenanthrene	12	8	67	<LOD-0.077[c]	20	16	80	<LOD-1.32
Pyrene	12	9	75	<LOD-0.079[c]	20	15	75	<LOD-1.15

[a] *Concentrations in filtered and unfiltered samples are not directly comparable to one another.*

[b] *Footnote <LOD indicates that concentrations were less than the limit of detection.*

[c] *Maximum concentration was estimated.*

Source: U.S. Geological Survey and SEWRPC

Map 4.28 shows results from testing of wells in and around the Oak Creek watershed through August 2013. The data are presented by U.S. Public Land Survey sections. Samples were collected from wells in 15 sections that are wholly or partially located in the Oak Creek watershed. In one of these sections, at least one sample was collected that had a concentration of molybdenum equal to or greater than 90 μg/l. In all of the samples collected from wells in the other sections in the watershed, concentrations of molybdenum were below 90 μg/l.

The source of the molybdenum in well water has not been definitively determined. Based upon relationships between concentrations of molybdenum measured in wells and the distances to sites where coal ash has been disposed of in reuse projects such as structural fill, embankments, and road base, one study attributes the source of the molybdenum to the reuse of unencapsulated coal ash.[280]

Another study analyzed samples collected from private water supply wells and from groundwater monitoring wells located near ash fill areas and near the Hunts Disposal Landfill, a remediated Superfund site located in the Village of Caledonia in Racine County.[281] In this study, samples of water, ash, and leachate were collected and tested in an attempt to determine the source or sources of the elevated molybdenum concentrations. Samples were analyzed for a suite of organic and inorganic parameters, as well as for tritium, an isotope of hydrogen, and for isotopes of boron, strontium, and molybdenum. These isotopes have been used in other studies to identify contaminant sources. The investigation did not succeed in identifying the source of the molybdenum. It was able to rule out the Hunt Landfill as a likely source based on the fact that the concentration of molybdenum in leachate from the landfill was lower than that in the groundwater of the surrounding area. The study also found that the tritium data suggested that most of the water in the private water supply wells may be older than 1953. This could indicate that molybdenum may have entered the water before ash from the Oak Creek power plant was disposed of on the We Energies property; however, mixing of older and younger water may complicate the interpretation of the tritium results.

A third study examined several diagnostic geochemical tracers in samples from private wells with a range of molybdenum concentrations.[282] The sampled wells were chosen to encompass differences in molybdenum concentrations and proximity to known coal ash deposit sites. This study found that the relationships between molybdenum concentration and isotopic ratios of boron and strontium mimicked the composition of local lithologies and were not consistent with expected isotopic fingerprints from coal combustion residues. Based on tritium analysis and ratios of helium isotopes, it found that the mean residence time of groundwater with high molybdenum concentrations was greater than 300 years. The study concluded that the evidence supports the idea that the source of the high molybdenum concentrations is geological rather than the result of coal ash contamination.

Sediments

In addition to being present in water, many contaminants can accumulate in stream, pond, and lake sediments. Based upon the potential for contaminants present in the sediment at particular sites to create biological impacts, the WDNR has developed consensus-based sediment quality guidelines.[283] The consensus-based guidelines apply average effect-level concentrations from several guidelines of similar intent and are used to predict the presence or absence of toxicity. Three criteria based on likely effects to benthic-dwelling organisms are proposed in the guidelines: threshold effect concentration (TEC), probable effect concentration (PEC), and midpoint effect concentration (MEC). TECs indicate contaminant concentrations below which adverse effects to benthic organisms are considered to be unlikely. PECs indicate contaminant concentrations at which adverse effects to the benthic organisms are highly probable or will frequently be seen. MECs are derived from TEC and PEC values for the purpose of interpreting the

---

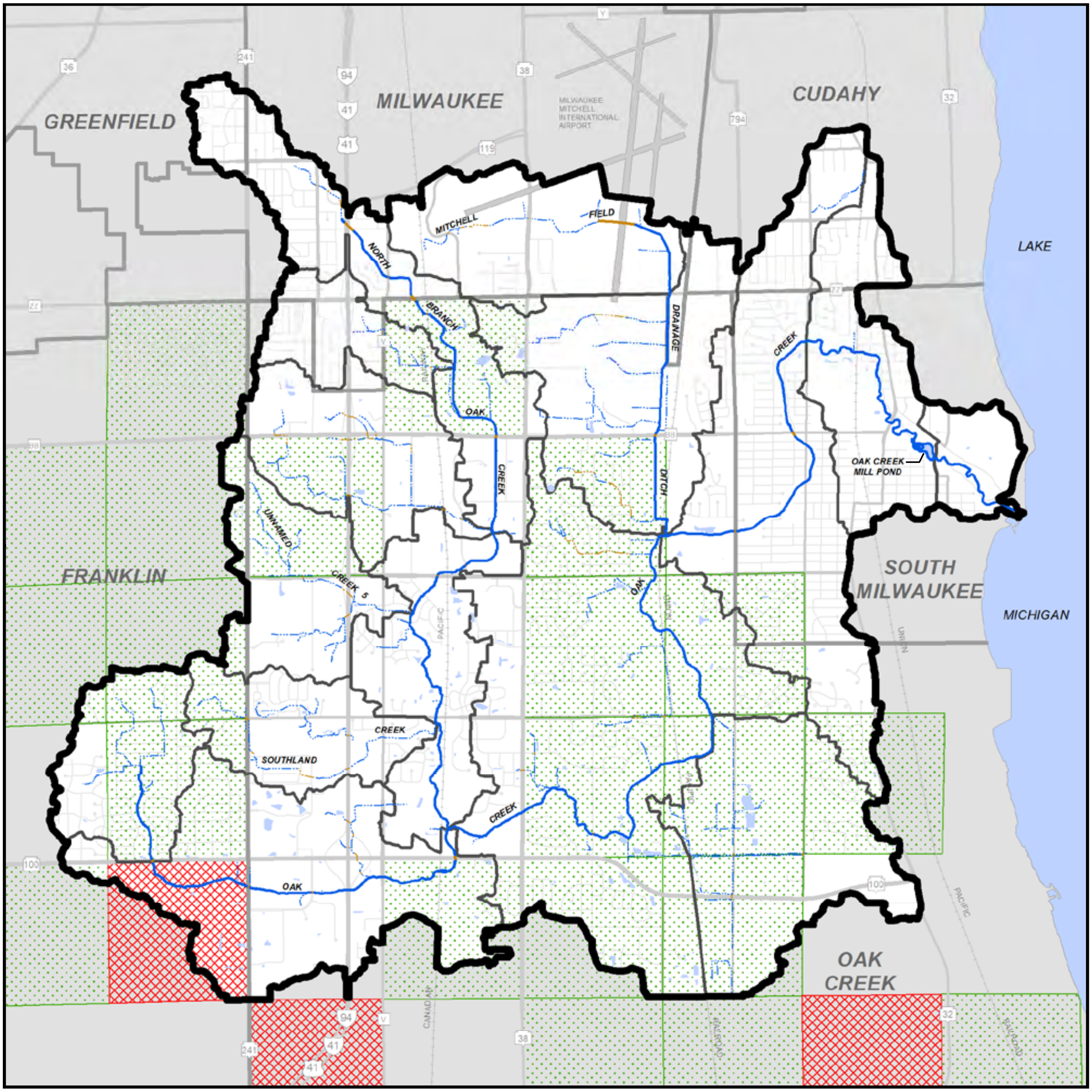
[280] *Tyson Cook, Paul Mathewson, and Katie Nekola,* Don't Drink the Water: Groundwater Contamination and the "Beneficial Reuse" of Coal Ash in Southeast Wisconsin, *Clean Wisconsin, November 2014.*

[281] *Joe Lourigan and William Phelps,* Caledonia Groundwater Molybdenum Investigations, Southeast Wisconsin, *Wisconsin Department of Natural Resources, PUB-WA 1625, January 2013.*

[282] *J.S. Harkness, T.H. Darrah, M.T. Moore, C.J. Whyte, P.D. Mathewson, T. Cook, and A. Vengosh, "Naturally Occurring versus Anthropogenic Sources of Elevated Molybdenum in Groundwater: Evidence of Geogenic Contamination from Southeast Wisconsin, United States,"* Environmental Science and Technology, *volume 51, pages 12,190- 12,199, 2017.*

[283] *Wisconsin Department of Natural Resources,* Consensus-Based Sediment Quality Guidelines: Recommendations for Use & Application—Interim Guidance, *WT-732-2003, December 2003.*

Map 4.28
Test Results for Molybdenum in Private Wells in and Around the Oak Creek Watershed: 2010-2013



SECTION WITH AT LEAST ONE MOLYBDENUM SAMPLE HAVING A CONCENTRATION GREATER THAN OR EQUAL TO 90 MICRO GRAMS PER LITER

SECTION WITH ALL MOLYBDENUM SAMPLES HAVING A CONCENTRATIONS LESS THAN 90 MICRO GRAMS PER LITER

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

0 0.25 0.5 1 Mile

Source: Wisconsin Department of Natural Resources and SEWRPC

effects of contaminant concentrations that fall between the TEC and the PEC. The WDNR recommends these criteria be used to establish levels of concern for prioritizing sites for additional study. It is important to note that these guidelines estimate only the effects of contaminants on benthic macroinvertebrate species. Where noncarcinogenic and nonbioaccumulative compounds are concerned, these guidelines should be protective of human health and wildlife concerns. For bioaccumulative compounds, considerations of the protection of human health or wildlife may necessitate the use of more restrictive concentration levels.

The PECs can be used to derive mean PEC quotients (PEC-Q) for evaluating the toxicity of mixtures of contaminants in sediment to benthic organisms. A PEC-Q is calculated for each contaminant in each sample by dividing the concentration of the contaminant in the sediment by the PEC concentration for that chemical. The mean PEC quotient is then calculated by summing the individual quotients and dividing the sum by the number of PECs evaluated. This normalizes the value to provide comparable indices of contamination among samples for which different numbers of contaminants were analyzed. Results of the evaluation of this method show that mean PEC-Qs that represent mixtures of contaminants are highly correlated with incidences of toxicity to benthic organisms in the same sediments and can be used to estimate the likely incidence of toxic effects experienced by benthic organisms.[284]

The amount of organic carbon in sediment can exert considerable influence on the toxicity to benthic organisms of nonpolar organic compounds such as PAHs, PCBs, and certain pesticides. While the biological responses of benthic organisms to nonionic organic compounds has been found to differ across sediments when the concentrations are expressed on a dry weight basis, they have been found to be similar when the concentrations have been normalized to a standard percentage of organic carbon.[285] Because of this, the concentrations of PAHs, PCBs, and pesticides are generally normalized to 1 percent organic carbon prior to analysis. In some instances, data from measurements of organic carbon were not available for sediment samples from the Oak Creek watershed. Where organic carbon data were unavailable, the organic contaminants in sediment were not normalized and consensus-based sediment toxicity values were not calculated.

Sediment samples have been collected from waterbodies in the Oak Creek watershed and analyzed for toxic substances since 1975. Samples collected after 2000 were collected from either the mainstem of Oak Creek at 15th Avenue (RM 2.8) or the Mill Pond immediately upstream from the dam (RM 1.0). Samples collected prior to 2000 were collected at a number of locations including the mainstem of Oak Creek downstream of IH 94 (RM 11.0), upstream from the confluence with the North Branch of Oak Creek (RM 9.8), at Pennsylvania Avenue (RM 4.7), the Mill Pond upstream from the dam (RM 1.0), and below the Dam (RM 0.6); the North Branch of Oak Creek downstream from Rawson Avenue (RM 3.5), at W. Marquette Avenue (RM 3.0), and upstream from Drexel Avenue; and the Mitchell Field Drainage Ditch at College Avenue.

Results of sediment sampling in waterbodies of the Oak Creek watershed between 1975 and 2012 are summarized in Table 4.25. A number of toxic compounds have been detected, including metals, pesticides, PAHs, and PCBs.

Since 2000, concentrations of metals in sediment have been examined at two locations along the mainstem of Oak Creek: the sampling station at 15th Avenue (RM 2.8) and the Mill Pond immediately upstream from the dam. Results from these samples are summarized in Table 4.26. Sediment samples taken from the station at 15th Avenue contained detectable concentrations of 15 metals. Concentrations of some metals in individual samples were higher than sediment quality guidelines. The maximum concentrations of arsenic, copper, manganese and zinc were higher than the TECs for these metals. The mean and maximum concentrations of lead were higher than the TEC and MEC, respectively. Sediment samples taken from the Mill Pond contained detectable concentrations of eight metals and some concentrations of some metals were higher than sediment quality guidelines. The maximum concentration of chromium was higher than the TEC. Concentrations of copper, lead, nickel, and zinc in all three samples were higher than their respective TECs. The maximum concentration of lead was higher than the MEC. The fact that concentrations of some metals are higher than the TEC suggests that they may be producing some toxic effects in benthic organisms.

---

[284] *D.D. MacDonald, C.G. Ingersoll, and T.A. Berger, "Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems,"* Archives of Environmental Contamination and Toxicology," *volume 39, pages 20-31, 2000.*

[285] *U.S. Environmental Protection Agency,* Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (SEGs) for the Protection of Benthic Organisms: Nonionic Organics, *USEPA Office of Science and Technology, 2000.*

Table 4.25
Sediment Sampling in Streams of the Oak Creek Watershed: 1975-2012[a]

Compound	Concentration Units	Sites Sampled	Samples Collected	Year of Most Recent Sample	Samples with Detections	Percent of Samples with Detections	Range of Concentrations[b]
Dyes							
2,6-Dichloroaniline	µg/kg	1	1	2007	0	0	<LOD
Metals							
Aluminum	mg/kg	1	8	2010	8	100	3,270-12,300
Arsenic	mg/kg	7	18	2010	13	72	<LOD-20
Barium	mg/kg	1	5	2010	5	100	17.9-72.1
Cadmium	mg/kg	9	17	2010	13	76	<LOD-1.5
Calcium	mg/kg	1	8	2010	8	100	51,200-73,900
Chromium	mg/kg	10	19	2012	19	100	9.1-48
Copper	mg/kg	10	22	2010	22	100	10.7-9,100
Iron	mg/kg	1	10	2011	10	100	7,240-20,500
Lead	mg/kg	10	21	2010	21	100	10-460
Magnesium	mg/kg	1	8	2010	8	100	23,400-35,700
Manganese	mg/kg	1	8	2010	8	100	262-564
Mercury	mg/kg	5	9	2012	8	89	<LOD-0.095
Molybdenum	mg/kg	1	5	2010	1	20	<LOD-1.4
Nickel	mg/kg	9	17	2010	17	100	7-30
Potassium	mg/kg	1	2	2007	2	100	1,000-2,300
Selenium	mg/kg	2	6	2010	0	0	<LOD
Sodium	mg/kg	1	3	2007	3	100	257-470
Strontium	mg/kg	1	5	2010	5	100	25-52
Vanadium	mg/kg	1	5	2010	5	100	14.4-32.7
Zinc	mg/kg	10	21	2010	21	100	52-500
Nutrients							
Ammonia nitrogen	mg/kg	6	9	2001	9	100	2-100
Phosphorus	mg/kg	3	12	2010	12	100	200-866
Sulfur	mg/kg	1	1	2006	1	100	1470
Polycyclic Aromatic Hydrocarbons (PAHs)							
1,2-Dimethylnaphthalene	µg/kg	1	1	2007	1	100	<LOQ
1,6-Dimethylnaphthalene	µg/kg	1	1	2007	1	100	20[c]
1-Methyl-9H-Fluorene	µg/kg	1	1	2007	1	100	20[c]
1-Methylnaphthalene	µg/kg	1	8	2010	1	13	<LOD-80
1-Methylpyrene	µg/kg	1	1	2007	1	100	70

Table continued on next page.

Table 4.25 (Continued)

Compound	Concentration Units	Sites Sampled	Samples Collected	Year of Most Recent Sample	Samples with Detections	Percent of Samples with Detections	Range of Concentrations[b]
Polycyclic Aromatic Hydrocarbons (PAHs) (continued)							
2,3,6-Trimethylnaphthalene	µg/kg	1	1	2007	1	100	20[c]
2,6-Dimethylnaphthalene	µg/kg	1	1	2007	1	100	20[c]
2,7-Dimethylnaphthalene	µg/kg	1	8	2010	1	13	<LOD-15
2-Ethylnaphthalene	µg/kg	1	1	2007	1	100	10[c]
2-Methylanthracene	µg/kg	1	1	2007	1	100	40
2-Methylnaphthalene	µg/kg	1	11	2012	7	64	<LOD-37
4H-Cyclopenta[def]phenanthrene	µg/kg	1	1	2007	1	100	190
9H-Fluorene	µg/kg	1	2	2012	2	100	90-100
Acenaphthene	µg/kg	8	16	2012	7	44	<LOD-1,100
Acenaphthylene	µg/kg	8	14	2010	2	14	<LOD-120
Anthracene	µg/kg	8	24	2012	20	83	<LOD-3,000
Benzo[a]anthracene	µg/kg	8	24	2012	24	100	240-8,500
Benzo[a]pyrene	µg/kg	8	24	2012	24	100	290-8,100
Benzo[b]fluoranthene	µg/kg	8	26	2012	26	100	540-12,000
Benzo[e]pyrene	µg/kg	8	14	2012	12	86	<LOD-6,000
Benzo[g,h,i]perylene	µg/kg	8	16	2012	16	100	220-4,600
Benzo[k]fluoranthene	µg/kg	8	26	2012	26	100	200-4,500
Chrysene	µg/kg	7	25	2012	25	100	380-6,500
Coronene	µg/kg	1	1	2012	1	100	170
Dibenzo[a,h]anthracene	µg/kg	8	22	2012	17	77	<LOD-1,200
Fluoranthene	µg/kg	8	27	2012	26	96	<LOD-21,000
Fluorene	µg/kg	8	22	2010	13	59	<LOD-1,300
Indeno[1,2,3-cd]pyrene	µg/kg	8	16	2012	16	100	240-5,900
Naphthalene	µg/kg	1	8	2010	1	13	<LOD-10[c]
Perylene	µg/kg	8	11	2007	8	73	400-2,400
Phenanthrene	µg/kg	8	26	2012	26	100	280-13,000
Pyrene	µg/kg	8	26	2012	26	100	540-15,000
Polychlorinated Biphenyls (PCBs)							
PCB 1016/1242	mg/kg	1	1	2007	1	100	3.4[c]
PCB 1242	mg/kg	1	1	1976	1	100	34,000
PCB 1248	mg/kg	1	1	1976	1	100	34,000
PCB 1248/1254	mg/kg	1	2	2001	2	100	0.2-0.23
PCB 1254	mg/kg	4	4	2007	4	100	0.042-250

Table continued on next page.

Table 4.25 (Continued)

Compound	Concentration Units	Sites Sampled	Samples Collected	Year of Most Recent Sample	Samples with Detections	Percent of Samples with Detections	Range of Concentrations[b]
Polychlorinated Biphenyls (PCBs) (continued)							
PCB 1260	mg/kg	2	2	2007	2	100	2.9[d]-250
Total PCBs	mg/kg	1	1	1992	0	0	<LOD
Pesticides							
Amides/Anilides/Anilines							
Alachor	µg/kg	1	1	2007	0	0	<LOD
Metolachlor	µg/kg	1	1	2007	0	0	<LOD
Napropamide	µg/kg	1	1	2007	0	0	<LOD
Pendimethalin	µg/kg	1	1	2007	0	0	<LOD
Carbimates							
Carbaryl	µg/kg	1	1	2007	0	0	<LOD
Carbofuran	µg/kg	1	1	2007	0	0	<LOD
Ethalfluralin	µg/kg	1	1	2007	0	0	<LOD
Dipheyl ethers							
Oxyflurofen	µg/kg	1	1	2007	0	0	<LOD
Organochlorides							
Aldrin	µg/kg	1	1	2007	0	0	<LOD
BHC							
BHC-alpha	mg/kg	1	1	1993	1	100	0.01
BHC-gamma (Lindane)	mg/kg	3	3	2007	1	33	<LOD-0.01
Chlordane							
alpha-Chlordane	mg/kg	1	1	1992	0	0	<LOD
cis-Chlordane	µg/kg	1	1	2007	1	100	0.8[c]
trans-Chlordane	µg/kg	3	4	2007	1	25	<LOD-0.64
cis-Nonachlor	mg/kg	1	1	1992	0	0	<LOD
trans-Nonachlor	mg/kg	2	2	2007	0	0	<LOD
alpha-Endosulfan	µg/kg	1	1	2007	0	0	<LOD
alpha-HCH	µg/kg	1	1	2007	0	0	<LOD
beta-HCH	µg/kg	1	1	2007	0	0	<LOD
DDT							
o,p′-DDD	mg/kg	2	2	1993	2	100	0.05-8
p,p′-DDD	mg/kg	3	3	2007	2	67	<LOD-3.5
o,p′-DDE	mg/kg	2	2	1993	1	50	<LOD-0.05
p,p′-DDE	mg/kg	3	3	2007	2	67	<LOD-3.43

Table continued on next page.

Table 4.25 (Continued)

Compound	Concentration Units	Sites Sampled	Samples Collected	Year of Most Recent Sample	Samples with Detections	Percent of Samples with Detections	Range of Concentrations[b]
Pesticides (continued)							
Organochlorides (continued)							
DDT (continued)							
o,p′-DDT	mg/kg	2	2	1993	1	50	<LOD-0.05
p,p′-DDT	mg/kg	3	3	2007	2	67	<LOD-3.7
Dieldrin	mg/kg	3	3	2007	1	33	<LOD-0.02
Endrin	µg/kg	1	1	2007	0	0	<LOD
Heptachlor							
Heptachlor epoxide	µg/kg	1	1	2007	0	0	<LOD
Hexachlorobenzene	µg/kg	1	1	2007	0	0	<LOD
p,p′-Methoxychlor	µg/kg	1	1	2007	0	0	<LOD
Mirex	µg/kg	1	1	2007	0	0	<LOD
Toxaphene-like compounds	mg/kg	2	2	2007	0	0	<LOD
Organphosphates							
Diazinon	µg/kg	1	1	2007	0	0	<LOD
Malathion	µg/kg	1	1	2007	0	0	<LOD
Methidation	µg/kg	1	1	2007	0	0	<LOD
Methyl parathion	µg/kg	1	1	2007	0	0	<LOD
Phosmet	µg/kg	1	1	2007	0	0	<LOD
Phenylpyrazoles							
Fipronil	µg/kg	1	1	2007	0	0	<LOD
Desulfinylfipronil	µg/kg	1	1	2007	0	0	<LOD
Fipronil sulfide	µg/kg	1	1	2007	0	0	<LOD
Fipronil sulfone	µg/kg	1	1	2007	0	0	<LOD
Pyrethroids							
Allethrin	µg/kg	1	1	2007	0	0	<LOD
Bifenthrin	µg/kg	1	4	2007	0	0	<LOD
Cyfluthrin	µg/kg	1	2	2007	0	0	<LOD
lambda-Cyhalothrin	µg/kg	1	2	2007	0	0	<LOD
Cypermethrin	µg/kg	1	2	2007	0	0	<LOD
Deltamethrin	µg/kg	1	3	2007	0	0	<LOD
Esfenvalerate	µg/kg	1	4	2007	0	0	<LOD
Fenpropathrin	µg/kg	1	4	2007	0	0	<LOD
tau-Fluvalinate	µg/kg	1	1	2007	0	0	<LOD

Table continued on next page.

Table 4.25 (Continued)

Compound	Concentration Units	Sites Sampled	Samples Collected	Year of Most Recent Sample	Samples with Detections	Percent of Samples with Detections	Range of Concentrations[b]
Pesticides (continued)							
Pyrethroids (continued)							
Permethrin	µg/kg	1	2	2007	0	0	<LOD
Phenothrin	µg/kg	1	1	2007	0	0	<LOD
Resmethrin	µg/kg	1	1	2007	0	0	<LOD
Tefluthrin	µg/kg	1	1	2007	0	0	<LOD
Tetramethrin	µg/kg	1	1	2007	0	0	<LOD
Terpenes							
Methoprine	µg/kg	1	1	2007	0	0	<LOD
Thiocarbimates							
Butylate	µg/kg	1	1	2007	0	0	<LOD
Cycloate	µg/kg	1	1	2007	0	0	<LOD
S-Ethyl dipropylthiocarbimate (EPTC)	µg/kg	1	1	2007	0	0	<LOD
Molinate	µg/kg	1	1	2007	0	0	<LOD
Pebulate	µg/kg	1	1	2007	0	0	<LOD
Thiobencarb	µg/kg	1	1	2007	0	0	<LOD
Triazines							
Atrazine	µg/kg	1	1	2007	0	0	<LOD
Hexazinone	µg/kg	1	1	2007	0	0	<LOD
Simazine	µg/kg	1	1	2007	0	0	<LOD
Pesticide Enhancers							
Piperonyl butoxide	µg/kg	1	1	2007	0	0	<LOD

[a] *Samples collected after 2000 were collected from either the mainstem of Oak Creek at 15th Avenue (RM 2.8) or the Mill Pond immediately upstream from the dam (RM 1.0). Samples collected prior to 2000 were collected at a number of locations including the mainstem of Oak Creek downstream of IH-94 (RM 11.0), upstream from the confluence with the North Branch of Oak Creek (RM 9.8), at Pennsylvania Avenue (RM 4.7), the Mill Pond upstream from the dam (RM 1.0), and below the Dam (RM 0.6); the North Branch of Oak Creek downstream from Rawson Avenue (RM 3.5), at W. Marquette Avenue (RM 3.0), and upstream from Drexel Avenue; and the Mitchell Field Drainage Ditch at College Avenue.*

[b] *<LOD indicates less than the limit of detection. < LOQ means detected, but less than the limit of quantification.*

[c] *Maximum concentration was estimated.*

[d] *Minimum concentration was estimated.*

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

Table 4.26
Concentrations of Toxic Metals in Sediment Samples from the Mainstem of Oak Creek: 2001-2010

	15th Avenue (RM 2.8) 2006-2010				Mill Pond Above Dam 2001			
Substance	Samples	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Samples	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)
Aluminum	6	3,270	12,300	6,670	--	--	--	--
Arsenic	6	<LOD	13	4	3	<LOD	6	2
Barium	5	18	72	43	--	--	--	--
Cadmium	5	<LOD	0.3	0.2	3	<LOD	0.8	0.3
Cobalt	5	12	32	24	--	--	--	--
Chromium	5	3	8	6	3	36	48	40
Copper	6	11	34	21	3	42	50	47
Iron	6	7,240	18,400	12,545	--	--	--	--
Lead	6	10	123	56	3	52	96	77
Manganese	6	262	564	400	--	--	--	--
Mercury	--	--	--	--	3	0.07	0.08	0.07
Molybdenum	5	<LOD	1.4	0.3	--	--	--	--
Nickel	5	7	21	14	3	24	30	28
Selenium	--	--	--	--	3	<LOD	<LOD	<LOD
Silver	5	<LOD	<LOD	<LOD	--	--	--	--
Strontium	5	25	52	40	--	--	--	--
Vanadium	5	14	33	23	--	--	--	--
Zinc	6	52	175	109	3	170	210	190

Note: <LOD indicates that the concentration was less than the limit of detection.

Source: Wisconsin Department of Natural Resources and SEWRPC

In 2007, two surface sediment samples were collected from the mainstem of Oak Creek at the sampling station at 15th Avenue (RM 2.8) and analyzed for pesticides in several classes, including amides, anilides, anilines, carbimates, organochlorides, organophosphates, phenylpyrazoles, pyrethroids, terpenes, thiocarbimates, and triazines. Concentrations of all of the pesticides sampled were below the limit of detection.

In 1997, sediment samples were collected from several locations in the Oak Creek watershed and analyzed for PAHs. Sampling locations included the mainstem of Oak Creek downstream of IH 94 (RM 11.0), upstream from the confluence with the North Branch of Oak Creek (RM 9.8), and at the Mill Pond upstream from the dam (RM 1.0); the North Branch of Oak Creek downstream from Rawson Avenue (RM 3.5) and upstream from Drexel Avenue (RM 1.0); and the Mitchell Field Drainage Ditch at College Avenue (RM 1.8). Concentrations of PAHs in six sediment samples collected in 1997 ranged between about 5,050 micrograms PAH per kilogram sediment (μg PAH/kg) and 89,090 μg PAH/kg, with a mean value of 27,100 μg PAH/kg. Total organic carbon data were not available for these samples.

Since 2000, concentrations of PAHs in sediment have been examined at two locations along the mainstem of Oak Creek: the sampling station at 15th Avenue (RM 2.8) and in the Mill Pond immediately upstream from the dam. Sampling at both of these examined concentrations of 17 PAH compounds. These are listed in Table 4.23.

Between 2006 and 2010, seven surface sediment samples were collected at 15th Avenue and analyzed for PAHs. Total PAH concentrations in these samples ranged from 8,667 μg PAH/kg to 29,438 μg PAH/kg, with a mean value of 17,640. When the concentrations of PAHs in these samples were normalized to 1 percent total organic carbon and the normalized values compared to the sediment quality guideline, it was found that total PAH concentrations in all of the samples were higher than the TEC and that concentrations in four samples were higher than the MEC. This suggests that sediment PAH concentrations at this site may be high enough to produce toxic effects in benthic organisms. These samples were also analyzed for three additional PAH compounds: 1-methylnaphthalene, 2-methylnaphthalene, and 2,7-dimethylnaphthalene. The compound 2-methylnaphthalene was detected in three samples at concentrations ranging between 13 μg/kg and 37 μg/kg and 2,7-dimethylnaphthalene was detected in one sample at a concentration of 15 μg/kg.

In 2001, three sediment samples were collected from the Mill Pond immediately upstream from the dam and analyzed for PAHs. Total PAH concentrations in these samples ranged between 18,150 µg PAH/kg and 22,730 µg PAH/kg, with a mean value of 19,993 µg PAH/kg. When the concentrations of PAHs in these samples were normalized to 1 percent total organic carbon and the normalized values compared to the sediment quality guideline, it was found that total PAHs in each of these samples was higher than the TEC, suggesting that sediment PAH concentrations at this site may be high enough to produce toxic effects in benthic organisms.

Coal-tar pavement sealant may be a major source of PAHs to sediment in waterbodies of the Oak Creek watershed. A recent study examined PAHs in streambed sediment samples from 40 sites in Milwaukee-area streams.[286] While the study did not include sampling sites in the Oak Creek watershed, it did evaluate sites in adjacent watersheds such as the Kinnickinnic River, Menomonee River, and Root River watersheds. Based on multiple lines of evidence, it concluded that coal-tar pavement sealant was the primary source of PAHs in a majority of streambed sediment samples and accounted for an average of about 77 percent of total PAHs in the samples.

Between 2001 and 2018, sediment samples from waterbodies in the Oak Creek watershed were examined for concentrations of PCBs.

In June 2001, concentrations of PCBs were examined in three surface sediment samples collected from the Oak Creek Mill Pond. Concentrations of total PCBs in these samples ranged between 42 micrograms of PCB per kilogram of sediment (µg PCB/kg sediment) and 230 µg PCB/kg sediment, with a mean value of 118 µg PCB/kg sediment. Total organic carbon data were available for these samples. When PCB concentrations in the sediment were normalized to 1 percent organic carbon and compared to the consensus-based sediment quality guidelines, it was found that the mean sediment concentration of PCBs in these samples was between the TEC and MEC. This suggests that it is likely that benthic-dwelling aquatic organisms are experiencing adverse effects from PCBs in the sediment.

In October 2016, the USGS examined surface sediment samples from two sites in the Oak Creek watershed for PCBs.[287] One site was located in the Oak Creek Mill Pond. The second was in the Oak Creek Parkway at the first bridge upstream from the mouth of the Creek. The concentration of PCBs in sediment in the Mill Pond was low, about 40 µg PCB/kg sediment. When compared to consensus-based sediment quality guidelines, this concentration was found to be below the TEC. A high concentration of PCBs was found at the site near the mouth of Oak Creek. The concentration of PCBs in sediment at this location was about 2,200 µg PCB/kg sediment. This concentration in more than twice the concentration found at sites in the Milwaukee Harbor Estuary Area of Concern.[288] Comparison of this concentration to consensus-based sediment quality guidelines indicate that these concentrations are high enough to cause adverse effects to benthic-dwelling aquatic organisms.

In November 2018, concentrations of PCBs were examined in surface sediment samples collected from six sites in the downstream reach of the Oak Creek watershed Map 4.29. From upstream to downstream, these sites included a location within the Mill Pond, a site slightly upstream from Milwaukee Avenue (extended), a site at Michigan Avenue (extended), a site in the Oak Creek Parkway at the first bridge upstream from the mouth of the Creek, at the sandbar at the mouth of the Creek, and along the Lake Michigan beach north of the mouth of the Creek. PCBs were detected in three samples, those collected at Milwaukee Avenue, Michigan Avenue, and Parkway bridge sites. Concentrations ranged from 120 µg PCB/kg sediment at the Milwaukee Avenue site to 980 µg PCB/kg sediment at the Parkway bridge site. PCBs were not detected in the surface sample from the Mill Pond. Total organic carbon data were not available for these samples.

On September 4, 2019, the WDNR's Remediation and Redevelopment program issued a "No Action Required" determination for the PCB contamination found in sediment in the reach of the mainstem of

---

[286] *A.K. Baldwin and other 2017,* op. cit.

[287] *B.C. Scudder Eikenberry, J.M. Besser. R.A. Dorman, and H.T. Olds, "Sediment Toxicity Assessment in Two Wisconsin Areas of Concern and Selected Lake Michigan Tributaries," Poster Presentation, 2018.*

[288] *Ibid*.

Map 4.29
Sediment Sampling for Polychlorinated Biphenyls (PCBs) in the Lower Reaches of Oak Creek: November 2018

Source: Wisconsin Department of Natural Resources

Oak Creek downstream from the Mill Pond.[289] The determination noted that the concentrations found were below the Department's current "interest threshold" and that investigation determined that the source of the contamination is more likely closer to the sampling locations, than from an upstream source. It concluded that a larger-scale investigation using State funds does not seem practicable at this time. Local WDNR staff indicated that they would discuss the posting of a general notice sign, based on WDNR fish consumption advisories for Lake Michigan with the Milwaukee County Health Department and the Milwaukee County Parks.

The findings from sediment sampling indicate that further evaluation of sediment quality is warranted in the lower reaches of Oak Creek, especially within and downstream of the Mill Pond. Such evaluation should include collection and examination of sediment cores to characterize the extent, types, and amounts of contaminants within the sediment through its entire depth.

The combined effects of several toxicants in sediment on benthic organisms were estimated using mean PEC-Q methodology.[290] The mean PEC-Q values were used to estimate the likely incidence of toxic effects to benthic organisms.[291] This analysis indicates that the estimated incidence toxic effects to benthic organisms at the sampling station at 15th Avenue due to the sampled sediment contaminants ranged between 22 and 45 percent. Similarly, the estimated incidence of toxic effects in the Mill Pond upstream from the dam ranged between 15 and 31 percent. Based upon this analysis, it is likely that benthic organisms at these locations in Oak Creek are experiencing some degree of toxic effects due to sediment contaminants.

Organisms

The WDNR periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Surveys were conducted at sites within the Oak Creek watershed between 1987 and 1993. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. Because of potential risks posed to humans by consuming fish containing high levels of contaminants, the WDNR has issued fish consumption advisories for several species of fish taken from the Oak Creek watershed. The statewide fish consumption advisory for mercury applies to fish in the Oak Creek watershed. Under this advisory it is recommended that women of child-bearing age and children under 15 not eat muskies; eat no more than one serving per month of walleye, pike, bass, and catfish and eat no more than one serving per week of bluegill, crappies, yellow perch, sunfish, bullheads, and inland trout. The advisory also recommends that men and women beyond childbearing age eat no more than one serving per month of muskies and one serving per week of walleye, pike, bass, and catfish. The advisory does not recommend men and women beyond child-bearing age restrict consumption of bluegill, crappies, yellow perch, sunfish, bullheads, and inland trout. In addition, a special consumption advisory has been issued for several species of fish taken from Lake Michigan and its tributaries, including Oak Creek, due to tissue concentrations of PCBs (see Table 4.27).

It is important to note that some fish samples collected from the Oak Creek watershed consisted of whole organism homogenates and others consisted of fillets of skin and muscle tissue. These types of samples are not directly comparable. Consumption advisories are based on contaminant concentrations in fillet samples. In both types of samples, a single sample may represent tissue from several fish of the same species.

Between 1987 and 1993 the WDNR examined fillet samples of green sunfish and whole organism samples of carp and crayfish from Oak Creek for mercury contamination. Contamination was found in these tissue samples.

Between 1987 and 1993 the WDNR examined fillet samples of green sunfish and whole organism samples of carp and crayfish from Oak Creek for contamination by historically used, bioaccumulative pesticides and their breakdown products. Measurable concentrations of o,p'-DDT, p,p'-DDT, 2,4,5-trichlorophenol, 2,4,6-trichlorophenol, aldrin, dieldrin, endrin, α-BHC, γ-BHC (lindane), hexachlorobenzene, pentachlorophenol,

---

[289] *Wisconsin Department of Natural Resources, "Rationale for No Action Required, BRRTS No. 09-41-584292, September 4, 2019.*

[290] *Wisconsin Department of Natural Resources WT-732-2003,* op. cit.

[291] *MacDonald and others, 2000,* op. cit.

Table 4.27
PCB-Related Fish Consumption Advisories for Lake Michigan and Its Tributaries Including Oak Creek[a]

	Consumption Advisory Level				
Species[b]	Unrestricted	Up to one meal per week	Up to one meal per month	Up to six meals per year	Do not eat
Brown trout	--	--	All sizes	--	--
Chinook salmon	--	--	All sizes	--	--
Chubs	--	--	All sizes	--	--
Coho salmon	--	Under 24 inches	Over 24 inches	--	--
Lake trout	--	--	Under 30 inches	--	Over 30 inches
Lake whitefish	--	--	All sizes	--	--
Rainbow trout	--	Under 28 inches	Over 28 inches	--	--
Smelt	--	All sizes	--	--	--
Yellow perch	--	Under 11 inches	Over 11 inches	--	--

[a] *In Southeastern Wisconsin, separate advisories have been issued for the Milwaukee, Pike, and Root Rivers.*

[b] *The Statewide general fish consumption advisory applies to other fish species not listed in this table.*

Source: Wisconsin Department of Natural Resources

chlordane isomers, and toxaphene-like compounds were not detected in tissue of fish or crayfish. Measurable concentrations of the DDT breakdown products o,p'-DDD, p,p'-DDD, o,p'-DDE, and p,p'-DDE were detected in whole organism samples of carp.

Between 1987 and 1993 the WDNR examined fillet samples of green sunfish and carp and whole organism samples of carp and crayfish from Oak Creek for contamination with PCBs. Contamination was also found in these samples.

It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of mercury, pesticide, and PCB contamination are quite small. In addition, the sampling was conducted over 25 years ago. Because of this, these tissue data may not be completely representative of the body burdens of these contaminants currently carried by aquatic organisms in Oak Creek and its tributaries.

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.[292]

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 use and water management in a watershed 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.[293]

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 Oak Creek watershed.

[292] *D.M. Carlisle et al., 2013,* op. cit.

[293] *Ibid.*

Fisheries

Wisconsin is comprised of coldwater, warmwater, and coolwater streams that are distinguished by summer maximum water temperatures, which is an important environmental determinant influencing the occurrence and abundance of fishes.[294] Streams with relatively cold summer maximum water temperatures are usually dominated by a small number of ''coldwater'' species in the salmonid (i.e., trout) and cottid (e.g., sculpin) families that are not able to tolerate warmer temperatures while streams with relatively warm temperatures contain a greater richness of ''warmwater'' species in the minnow and carp, sucker, bullhead, sunfish, and perch families. These species, while able to survive as individuals at colder temperatures, require warmer temperatures to complete their life cycle and persist as populations.[295,296] However, it is now also recognized that coolwater streams, which are generally intermediate in species richness and fish abundance between coldwater versus warmwater streams, are the most widespread and abundant thermal class comprising as much as 65 percent of the total stream lengths in the State.[297]

It is important to recognize these distinctions, because they help inform fisheries management goals and development of appropriate environmental protections or strategies. For example, many coolwater streams, although warmer than coldwater streams, are still potentially thermally suitable to support trout.[298] However, if coolwater streams are lumped with warmwater streams in management classifications (which is precisely how Oak Creek was previously classified in the Commission's Technical Report 39), coolwater streams may not receive adequate thermal protection, and/or opportunities to expand trout or other coldwater fisheries may be missed.[299] Since the publication of Technical Report 39, which included a summary of the fishery quality in the Oak Creek watershed from 1902 through 2004, there has been significant updated research related to both fishery thermal tolerances and tools to assess fishery quality that include the stream natural community classification, the coolwater index of biological integrity (IBI), and the small-stream (intermittent) IBI. Therefore, the following summary can be considered an update of the fisheries IBI classification summary set forth in Technical Report 39 as these tools were not available at the time that report was completed.

Based on a combination of detailed temperature data,[300] fish species occurrence and abundance observations, and the WDNR's stream natural community classification, reaches of mainstem Oak Creek as well as its tributaries were classified into their appropriate biotic community and ecological conditions (i.e., streamflow and water temperature).[301] These natural community designations were used to assign the appropriate IBI to assess fishery health (see Table 4.28). Due to the fundamental differences among warmwater, coolwater, and coldwater headwater and mainstem streams, separate fish IBIs have been developed to assess the health of each of these types of streams.[302] However, these IBIs do share some common elements, such as the number and/or percent of native species, the number and/or percent of intolerant species, numbers of species by thermal tolerance, and number of species in specific functional feeding groups. Generally, higher numbers and/or percentages of native and intolerant species are associated with higher IBI scores

---

294 *John J. Magnuson, "Temperature as an Ecological Resource,"* American Zoologist *19(1): 331-343, 1979.*

295 *John Lyons, "Patterns in the Species Composition of Fish Assemblages among Wisconsin Streams,"* Environmental Biology of Fishes *45, 329-341, 1996.*

296 *John Lyons, "Influence of Winter Starvation on the Distribution of Smallmouth Bass among Wisconsin Streams: a Bioenergetics Modeling Assessment,"* American Fisheries Society *126(1), 157-162, 1997.*

297 *John Lyons et al., "Defining and Characterizing Coolwater Streams and Their Fish Assemblages in Michigan and Wisconsin, USA,"* North American Journal of Fisheries Management *29, 1130–1151, 2009.*

298 *K.E. Wehrly, M.J. Wiley, and P.W. Seelbach, "Classifying Regional Variation in Thermal Regime Based on Stream Fish Community Patterns,"* Transactions of the American Fisheries Society *132, 18-38, 2003.*

299 *SEWRPC Technical Report No. 39,* op. cit.

300 *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 *139, 365-374, 2007.*

301 *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*; *John Lyons,* Proposed Temperature and Flow Criteria for Natural Communities for Flowing Waters, *February 2008, updated October 2012; and, John Lyons, Wisconsin Department of Natural Resources,* An Overview of the Wisconsin Stream Model, *January 2007.*

302 *John Lyons, 1996,* op. cit.

Table 4.28
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 Exceedance Flow (cfs)	Primary Index of Biotic Integrity
Ephemeral	Any	0.0	N/A
Macroinvertebrate	Any	0.0-0.03	Macroinvertebrate
Coldwater	<69.3	0.03-150	Coldwater Fish
Cool (Cold-Transition) Headwater	69.3-72.5	0.03-3.0	Small-Stream (Intermittent) Fish
Cool (Cold-Transition) Mainstem	69.3-72.5	3.0-150	Cool-Cold Transition Fish
Cool (Warm-Transition) Headwater	72.6-76.3	0.03-3.0	Small-Stream (Intermittent) Fish
Cool (Warm-Transition) Mainstem	72.6-76.3	3.0-150	Cool-Warm Transition Fish
Warm Headwater	>76.3	0.03-3.0	Small-Stream (Intermittent) Fish
Warm Mainstem	>76.3	3.0-110.0	Warmwater Fish
Nonwadeable Warm River	>76.3	>110.0	Large River Fish

Source: Wisconsin 2020 Consolidated Assessment and Listing Methodology (WisCALM) for CWA Section 303(d) and 305(b) Integrated Reporting, *Guidance # 3200-2019-04, Wisconsin Department of Natural Resources, April 2019*

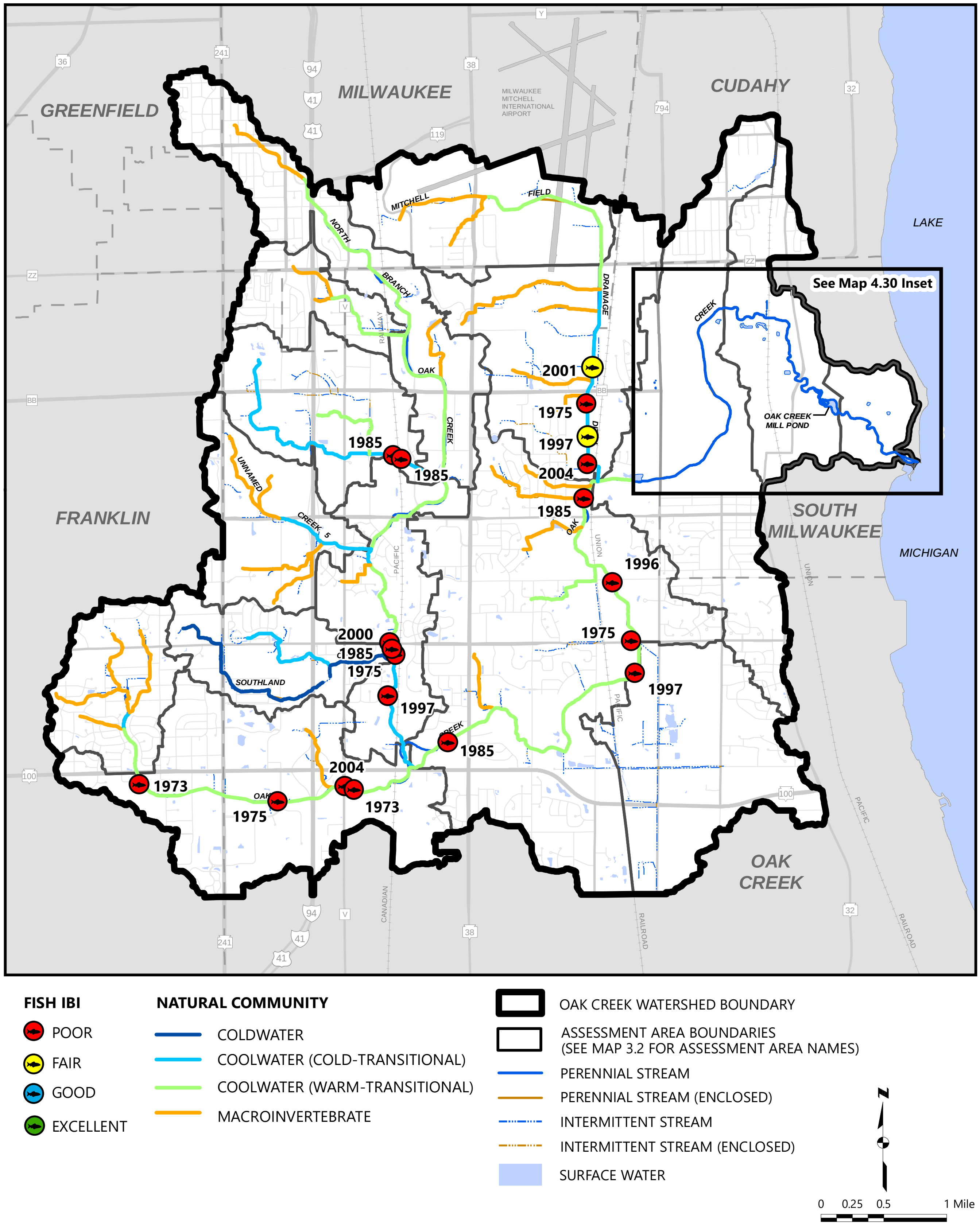
while surveys with more intolerant and non-native species attain lower IBI scores. Through calculation of the IBI, fish population data can provide insight into the overall health of the stream ecosystem. The Oak Creek watershed contains a variety of stream natural communities, with cool-warm headwaters, cool-cold headwaters, coldwater, and macroinvertebrate reaches all featured (see Map 4.30). Commission staff evaluated the WDNR natural community classifications with respect to the temperature data and streamflow information collected for this study (see "Water Quality" section) and found that the majority of the WDNR designations were consistent with the Commission's findings. The sole exception, Southland Creek, is described later in this section.

The Oak Creek fishery is dominated by the coolwater designation for the majority of its total stream length including the mainstem and tributaries (see Map 4.30). More specifically, the majority of the coolwater designated waterways are considered ''warm-transition'' headwater streams compared to "cold-transition" headwater streams and the observed July mean and maximum daily water temperatures support these designations. Hence, it is expected that Oak Creek fish assemblage be comprised of warmwater and coolwater transitional species and coldwater species to be uncommon, which is consistent with the observed species present as shown in Table 4.29. Since 1973, the system upstream of the Mill Pond Dam has been dominated by coolwater species that include creek chub (*Semotilus atromaculatus*), white sucker (*Catostomus commersonii*), brook stickleback (*Culea inconstans*), and johnny darter (*Etheostoma nigrum*) and common warmwater species that include green sunfish (*Lepomis cyanellus*), fathead minnow (*Pimephalus promelas*), and black bullhead (*Ameiurus melas*) (see Figure 4.113).

The Southland Creek tributary is the only portion of the stream network classified as a coldwater stream as shown on Map 4.30, and its observed July maximum daily mean water temperatures generally support such a designation with occasional exceedances of the coldwater temperature standard of 69.3°F (see Section 4.4, "Surface Water Quality"). However, there has never been a survey conducted in this tributary to verify if a coldwater fish assemblage exists.

In addition to temperature, streamflow is also an important determinant for fish species occurrence and abundance. The majority of the Oak Creek watershed reaches are classified as headwater streams, which range in annual 90 percent exceedance flows between 0.03 to 3.0 cfs (see Table 4.28 and Map 4.30). As described in Section 4.3, "Water Quantity Conditions," the measured annual 90 percent exceedance flow at the USGS 15th Avenue gage is 2.0 cfs; thus, the Oak Creek mainstem is correctly classified as a headwater stream according to the natural community designation. While headwater streams are usually perennial (i.e., maintain water flow the entire year), they can exhibit large variations in temperature, streamflow, and dissolved oxygen concentrations that limit fish size and reproduction and thus generally have a reduced

Map 4.30
Historical Natural Community and Fish Biotic Indices Within the Oak Creek Watershed: 1902-2004



Source: SEWRPC

Inset to Map 4.30

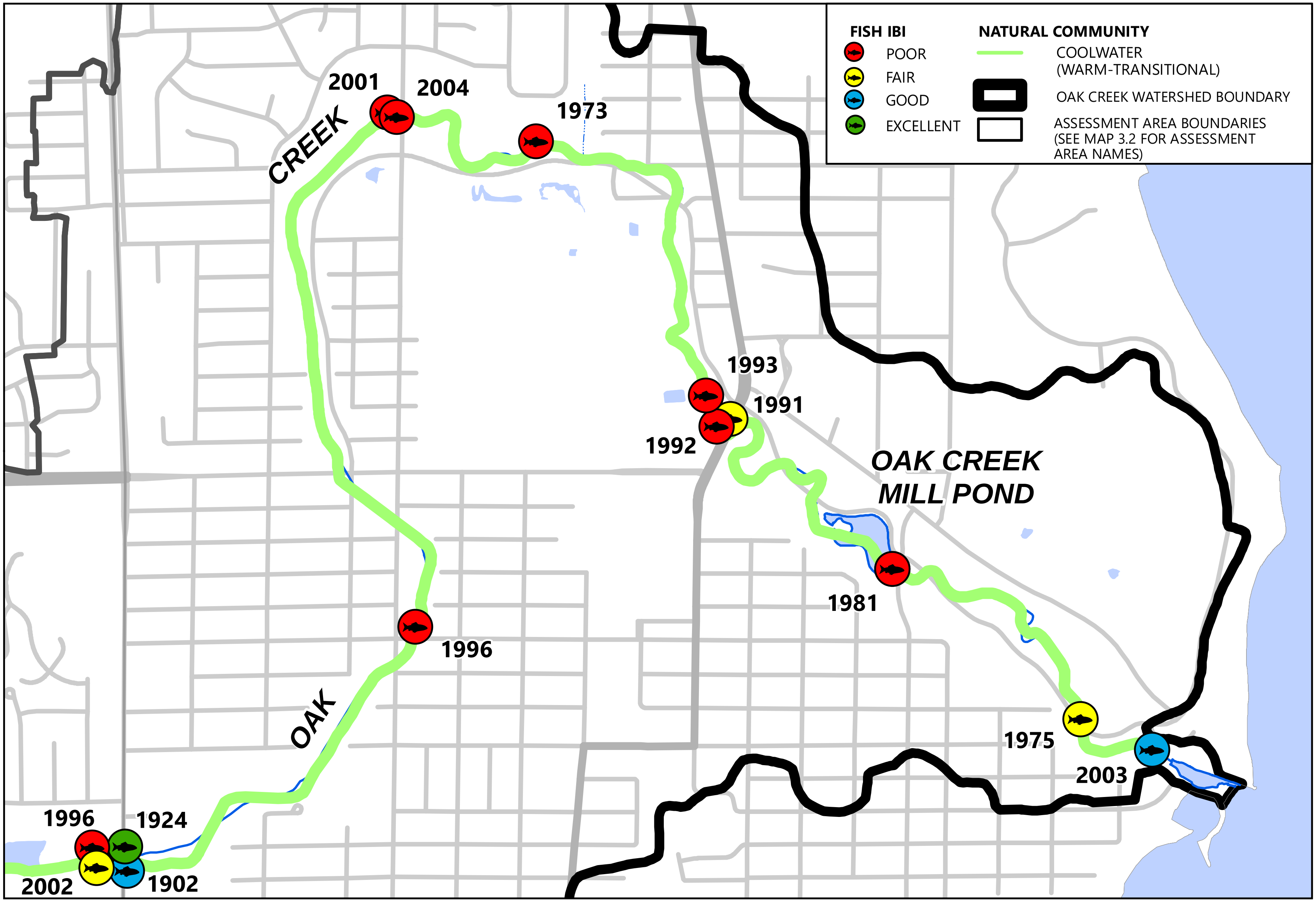


Table 4.29
Fish Species Percent, Composition, and Temperature Preference in the Oak Creek Watershed: 1902-2016

Fish Species According to Their Relative Tolerance to Temperature	Date and Location of Fish Survey in Oak Creek Watershed						
	1902 – 1924	1973 – 2004			2005 – 2016		
	Mainstem: Above Dam	Mainstem: Below Dam	Mainstem: Above Dam	North Branch	Mainstem: Below Dam	Mainstem: Above Dam	North Branch
Coldwater							
Intolerant							
Brook Trout[a,b]	--	X	--	--	--	--	--
Intermediate							
Brown Trout[a,b]	--	X	--	--	--	--	--
Chinook Salmon[a,b]	--	X	--	--	--	--	--
Coho Salmon[a,b]	--	X	--	--	--	--	--
Rainbow Trout[a,b]	--	X	X	--	3.2	X	--
Coolwater (Cold- and Warm-Transitional)							
Intolerant							
Blacknose Shiner	19.3	--	--	--	--	--	--
Intermediate							
Brassy Minnow	0.8	--	--	--	--	--	--
Lake Chub	--	2.5	--	--	--	--	--
Johnny Darter	27.0	1.9	--	0.1	--	3.9	--
Yellow Perch[b]	--	--	<0.1	--	--	--	--
Tolerant							
Brook stickleback	--	--	6.7	10.7	--	5.6	16.1
Central Mudminnow	0.8	0.1	11.0	1.4	--	31.4	--
Creek Chub	8.7	16.7	27.6	74.1	16.9	21.8	74.5
Eastern Blacknose Dace	1.4	0.1	--	--	--	--	--
White Sucker	4.9	14.2	25.8	2.3	12.9	22.9	--
Warmwater							
Intolerant							
Iowa darter	0.3	--	--	--	--	5.0	--
Least darter	27.0	--	--	--	--	--	--
Rock Bass	--	0.7	--	--	--	--	--
Intermediate							
Bluegill	--	0.1	1.3	--	--	0.3	--
Channel Catfish	--	0.1	--	--	--	--	--
Common Shiner	1.6	--	--	--	--	--	--
Emerald Shiner	--	0.1	--	--	--	--	--

Table continued on next page.

Table 4.29 (Continued)

Fish Species According to Their Relative Tolerance to Temperature	Date and Location of Fish Survey in Oak Creek Watershed						
	1902 – 1924	1973 – 2004			2005 – 2016		
	Mainstem: Above Dam	Mainstem: Below Dam	Mainstem: Above Dam	North Branch	Mainstem: Below Dam	Mainstem: Above Dam	North Branch
Warmwater (continued)							
Intermediate (continued)							
Gizzard Shad	--	0.4	--	--	--	--	--
Largemouth Bass[b]	--	0.1	0.7	--	--	--	--
Pumpkinseed	--	--	4.6	0.1	--	--	--
Round Goby	--	--	--	--	50.0	--	--
Sand Shiner	--	0.1	--	--	--	--	--
White Crappie	--	--	--	--	3.2	--	--
Tolerant							
Black bullhead	0.3	--	2.8	--	1.6	0.2	--
Bluntnose minnow	6.8	33.8	--	--	--	--	--
Common carp	--	--	0.4	--	--	0.2	--
Fathead minnow	--	2.5	8.0	8.2	2.4	2.2	8.3
Golden shiner	1.1	--	<0.1	--	--	--	--
Goldfish	--	0.1	0.4	--	--	0.2	--
Green sunfish	0.3	9.1	10.2	2.3	9.7	5.9	1.1
Not Rated							
Green Sunfish X Bluegill	--	0.1	0.3	--	--	0.1	--
Grass carp	--	--	<0.1	--	--	--	--
Natural Communities	Cool-Cold	Cool-Warm	Cool-Cold to Cool-Warm	Cool-Cold to Cool-Warm	Cool-Warm	Cool-Cold to Cool-Warm	Cool-Cold to Cool-Warm
Small-Stream (Intermittent) IBI Ratings[c]	Good	Fair	Poor to Fair	Poor to Fair	Fair to Good	Poor to Good	Fair
Cool-Cold Transition IBI Ratings	Excellent	Poor to Excellent	Poor to Fair	Poor to Good	Fair	Poor to Excellent	Poor
Cool-Warm Transition IBI Ratings	Excellent	Fair to Good	Poor to Fair	Poor	Good	Poor to Good	Poor
Species Richness	14	23	17	8	8	14	4

Note: 'X' denotes an observation of species presence from stocking records but no fish survey count data was available for this species. Surveys prior to 1925 did not record exact numbers for large counts of individual species, so these percentages are approximations. No fish surveys were collected in the Oak Creek watershed between 1925 and 1972, so these years are not included in the ranges.

[a] *Not a resident species; only migrates seasonally to reproduce.*

[b] *This species is stocked in Oak Creek by the Wisconsin Department of Natural Resources.*

[c] *The Small-Stream (Intermittent) IBI ratings are Poor, Fair, and Good; there is no Excellent rating for this IBI.*

Source: Wisconsin Department of Natural Resources and SEWRPC

Figure 4.113
Most Commonly Observed Fish Species in the Oak Creek Watershed

BROOK STICKLEBACK
Culea inconstans

WHITE SUCKER
Catostomus commersonii

CENTRAL MUDMINNOW
Umbra limi

FATHEAD MINNOW
Pimephales promelas

CREEK CHUB
Semotilus atromaculatus

GREEN SUNFISH
Lepomis cyanellus

The coolwater Brook Stickleback, Central Mudminnow, Creek Chub, and White Sucker as well as the warmwater Fathead Minnow and Green Sunfish are the most commonly observed species in the Oak Creek watershed. Many of these species are generalist feeders and thus can survive disruptions to any specific part of the food web. These species are generally tolerant of high turbidity and low dissolved oxygen concentrations. Their dominance within the Oak Creek watershed are indicators of the watershed's historical poor water quality conditions. Climate-induced higher water temperatures may decrease abundance of the coolwater species.

Source: SEWRPC

number of fish species.[303,304,305] The small-stream (intermittent) IBI was developed to assess fishery health under these conditions (see Table 4.28).[306] While the small-stream IBI is similar to other fish IBIs in its consideration of native and intolerant species, it is unique in that it also explicitly considers the number of headwater species, which are fish species adapted for small streams with permanent habitat.[307] The majority of headwater fish are minnows and darters, but this designation also includes northern pike (*Esox lucius*), which spawns in small headwater streams.[308] Since the majority of reaches in the Oak Creek watershed are classified as headwater streams, the small-stream IBI is recommended as the primary IBI to assess the fishery health for most of the watershed.[309] However, following consultation with a WDNR biologist, this report will also utilize the cool-warm and cool-cold transition IBIs to better compare the fisheries among sites within the Oak Creek watershed, as the small-stream IBI may be less suitable for the Grant Park Ravine reach with its higher, perennial streamflow and connection to Lake Michigan.[310] Considering both the small-stream IBI as well as the coolwater transition IBIs can provide perspectives on how the Oak Creek fisheries are faring for headwater and coolwater species.

Additionally, Oak Creek is fed by numerous intermittent tributaries that likely contain few or no fish but may harbor macroinvertebrate communities, as shown on Map 4.30. The WDNR stream natural community classifies these tributaries, such as the College Avenue Tributary, Unnamed Creek 5, Rawson Avenue Tributary, and those found in the Oak Creek Headwaters as macroinvertebrate streams, with anticipated annual 90 percent exceedance flows of 0.0 to 0.03 cubic feet per second.[311] Macroinvertebrate streams tend to be very small, are almost always intermittent streams (i.e., cease flow for part of the year, although water may remain in the channel), and often contain very warm summer temperatures. Due to their limited water depths and volume conditions such streams tend to contain no or few resident fish; however, seasonally (i.e., high spring flow events) these streams may be important spawning habitats for other migrating fish species and aquatic invertebrates may also be common. Due to lack of resident fish, macroinvertebrate IBIs and other metrics are more appropriate for assessing the biological conditions within these reaches, as discussed later in this section.[312,313]

Fisheries Assemblages and Biotic Indices

Data from historical fish surveys of the Oak Creek watershed are useful in assessing the overall change in the fish populations, and therefore in water quality conditions. In most cases where intolerant fish species have been significantly reduced or eliminated, significant alteration of stream habitat or surrounding land use may be the cause, such as channelization; draining of connected wetlands; runoff of sediment, fertilizer, pesticides, and/or toxic substances; and the discharge of municipal and/or industrial wastes. The earliest survey in the watershed was in 1910, with the collection site only identified as "Oak Creek." Only three fish species were identified in this survey: fathead minnow, eastern blacknose dace (*Rhinichthys atratulus*), and johnny darter. The most comprehensive historical survey of the Oak Creek fish community was conducted in 1924 in the mainstem of Lower Oak Creek. At that time, 14 fish species were collected, of which four are

---

[303] *R.J. Horowitz, "Temporal variability patterns and the distributional patterns of stream fishes,"* Ecological Monographs *48, 307-321, 1978.*

[304] *A.V. Zale et al.,* "The Physiochemistry, Flora, and Fauna of Intermittent Prairie Streams: a Review of the Literature," *Biological Report 89(5), U.S. Fish and Wildlife Service, 1989.*

[305] *K.G. Ostrand and G.R. Wilde, "Changes in Prairie Stream Fish Assemblages Restricted to Isolated Streambed Pools,"* Transactions of the American Fisheries Society *133, 1329-1338, 2004.*

[306] *John Lyons, "A Fish-Based Index of Biotic Integrity to Assess Intermittent Headwater Streams in Wisconsin, USA,"* Environmental Monitoring and Assessment *122, 239-258, 2006.*

[307] *Ibid*.

[308] *G.C. Becker,* Fishes of Wisconsin*, University of Wisconsin Press, Madison, Wisconsin, 1983.*

[309] *Wisconsin Department of Natural Resources*, Wisconsin 2020 Consolidated Assessment and Listing Methodology (WisCALM) Clean Water Act Section 303(d) and 305(b) Integrated Reporting*, April 2019.*

[310] *Personal communication, Craig Helker, WDNR Water Resources Biologist – East District, 2020.*

[311] *WDNR, 2019,* op. cit.

[312] *Lyons, 2006,* op. cit.

[313] *WDNR, 2019,* op. cit.

considered intolerant (blacknose shiner (*Notropis heterolepis*), brassy minnow (*Hybognathus hanksoni*), Iowa darter (*Etheostoma exile*), and least darter (*Etheostoma microperca*). The presence of these intolerant species indicates that a healthy cool headwater fishery existed at that time, with this survey attaining an Excellent coolwater IBI rating and a Good small-stream IBI rating (see Table 4.29). These fish generally require clear water and high dissolved oxygen concentrations, so their presence indicates good water quality conditions within Oak Creek in 1924.

No documented fish surveys were conducted in Oak Creek for nearly fifty years, until three 1973 surveys along the Oak Creek mainstem found a combined six species, with no intolerant species recorded. The loss of these intolerant species indicates the deteriorating water quality conditions in the Oak Creek watershed throughout this period, associated with increasing urban development (see Map 3.6). Nearly every reach within the watershed upstream of the Mill Pond Dam has undergone significant channelization, removal of instream shelter and shading from overhanging vegetation, and alteration of the natural riffle, run, and pool structure that sustain diverse habitats for fish and their macroinvertebrate prey (see Tables 4.10 and 4.11). Partially as a consequence of this channelization, many reaches within the watershed have high turbidity (see "Water Quality Conditions" above in this section), which can harm fish directly by clogging their gills as well as indirectly by hiding their macroinvertebrate prey and burying their eggs on the stream bottom. Additionally, reaches within Upper Oak Creek, Lower North Branch Oak Creek, the Mitchell Field Drainage Ditch, and the Lower Oak Creek – Mill Pond have historically experienced bouts of low dissolved oxygen as well as dissolved oxygen supersaturation; both of these conditions can cause physiological stress to fish.

From 1973 to 2004, fish communities throughout the watershed upstream of the Mill Pond had high proportions of low dissolved oxygen tolerant fishes and low numbers of native fish species, with fish surveys most frequently attaining Poor or Fair coolwater and small-stream IBI ratings (see Table 4.29). These surveys show high dominance by central mudminnow (*Umbra limi*), creek chub, fathead minnow, white sucker, and green sunfish, which constitute a typical "urban" tolerant fishery assemblage (see Figure 4.113).[314] These fish are generally tolerant of turbid waters, low dissolved oxygen concentrations, and high water temperatures and are largely generalist feeders that are not reliant on any specific food source.[315] These adaptations enhance their survival in what constitutes poor conditions for more sensitive species. In addition to these native tolerant species, common carp (*Cyprinus carpio*), an exotic, invasive, tolerant species, were first observed in the South Milwaukee Mill Pond in 1981. Since then, common carp have been observed at four locations in the Middle and Lower Oak Creek mainstem as well as one location in the Lower Mitchell Field Drainage Ditch and dominate within the Mill Pond. Carp populations can generally persist in a wider range of water quality conditions than native fish species. For example, carp are tolerant of dissolved oxygen concentrations below 2.0 mg/l and can survive at concentrations below 1.0 mg/l[316] while bluegill require dissolved oxygen concentrations above 5.0 mg/l.[317] Additionally, carp can tolerate a wide range of water pH, from 6.0 to 9.0 stu while native sunfish can only tolerate a more narrow range of 7.0 to 8.5.[318] Carp are likely having a negative effect on the fishery by destroying habitat, reducing water quality by stirring up sediment, competing for food with native fish species, and disrupting spawning areas by dislodging aquatic plants.[319] Studies have suggested that these detrimental effects are the cause of lower sport fish abundance in lakes with high common carp density.[320]

Surveys within the last two decades by the WDNR and the USGS indicate slight improvement in the Oak Creek fishery, with increasing species diversity in the mainstem above the Mill Pond Dam. Bluegill (*Lepomis macrochirus*) was first observed in the watershed in 2001 while the reemergence of johnny darter in 2000

---

[314] *Personal communication, William Wawrzyn, Wisconsin Department of Natural Resources, 2004.*

[315] *Becker, 1983,* op. cit.

[316] *U.S. Fish and Wildlife Service,* Habitat Suitability Index Models: Common Carp, *1982.*

[317] *U.S. Fish and Wildlife Service,* Habitat Suitability Index Models: Bluegill, *1982.*

[318] *J.E. McKee and H.W. Wolf,* Water Quality Criteria (second edition), *California State Water Quality Control Board, Publication No. 3-A, 1963.*

[319] *Joe Pfeiffer and Bonnie Duncan,* A Review of the Impacts, Effects of Common Carp on Freshwater Lake Systems through Nutrient Contributions and Ecological Thresholds, *KCI Associates of Ohio, PA, 2016.*

[320] *Ibid.*

was the first observation upstream of the Mill Pond dam since 1924. More notably, Iowa darter was observed in 2015 in the Upper Oak Creek, Middle Oak Creek, and Lower Oak Creek assessment areas, marking its first observations in the watershed since 1924. Iowa darter is a coolwater and headwater species that is intolerant of turbid waters, as turbidity limits its predominantly macroinvertebrate food supply (see Figure 4.114).[321] Its reemergence within the Oak Creek mainstem may be an indication of improving water quality conditions, which is consistent with decreasing turbidity in some mainstem reaches (see Figure 4.101). Reaches of the mainstem with Iowa darter attained Fair or Good IBI coolwater ratings and Good small-stream IBI ratings in 2015, an improvement from previous Poor to Fair coolwater and small-stream IBI ratings in the mainstem (see Map 4.31).

However, other reaches within the watershed have not improved; only four species, all tolerant, were observed in the North Branch in 2015, earning it Poor coolwater and Fair small-stream IBI ratings (see Map 4.31). Furthermore, Upper Oak Creek and the Mitchell Field Drainage Ditch are still only attaining Poor or Fair coolwater and Fair small-stream IBI ratings. Low dissolved oxygen concentrations (see Figure 4.75) and high turbidity (see Figures 4.102 and 4.103) have likely contributed to the decline of these communities, while fish passage barriers between the North Branch and the Oak Creek mainstem, as described later in this section, limit species reintroduction and maintain these species-poor communities. Efforts to improve water quality and instream habitat as well as to remove fish passage barriers are necessary to enhance the health of the Oak Creek fishery.

In contrast with the fishery upstream of the Mill Pond Dam, the health of the downstream Oak Creek fishery in Grant Park Ravine has not substantially changed over time. From 1973 to 2004, this reach attained Fair and Good coolwater IBI ratings, with observations of western blacknose dace (*Rhinichtys obtusus*), johnny darter, rock bass (*Ambloplites rupestris*), and sand shiner (*Notropis stramineus*) in addition to several of the "urban" tolerant species present upstream of the dam. Some of these species were not observed in the 2015 survey, but their absence may reflect transient populations from Lake Michigan rather than an indication of species loss within the reach. The 2015 survey attained a Good coolwater IBI rating (see Map 4.31), consistent with its Good to Excellent stream habitat ratings (see Table 4.11) and generally healthy range of dissolved oxygen concentrations (see Figure 4.71). While the Grant Park Ravine has largely attained Fair small-stream IBI ratings, the perennial and higher streamflow of this reach supports few headwater species, which may reflect more on the application of the small-stream IBI for this reach rather than its fishery quality. The species present within this reach also indicate its close connection with Lake Michigan. Observations of round goby (*Neogobius melanostomus*) and white crappie (*Pomoxis annularis*) just upstream of the confluence with Lake Michigan in 2015 are the only records of these species within the Oak Creek watershed. However, neither of these species have been observed upstream of the dam. The Grant Park Ravine reach of Oak Creek also serves as an important spawning area for native sucker species, such as longnose sucker (*Catostomus catostomus*) and white sucker, migrating into Oak Creek from Lake Michigan, as summarized later in this section.[322]

In addition to the naturally-reproducing fish populations described above, the WDNR has maintained a stocking program for the Oak Creek Parkway as part of its Southeast region urban fishing program. Rainbow trout (*Oncorhynchus mykiss*) have been annually stocked within the Mill Pond for a total of 23,559 since 1989, while 2,000 yellow perch (*Perca flavescens*) and 600 largemouth bass (*Micropterus salmoides*) were stocked in 1975 and 1991, respectively.[323] Within the Grant Park Ravine, 23,712 brook trout (*Salvelinus fontinalis*), 73,564 brown trout (*Salmo trutta*), 265,000 chinook salmon (*Oncorhynchus tshawytscha*), 65,464 coho salmon (*Oncorhynchus kisutch*), and 54,889 rainbow trout were stocked in total from 1991 to 1998, while 128,178 rainbow trout have been stocked since 1999. All stocked fish have been of the yearling or fingerling age classes.

---

[321] *Becker, 1983,* op. cit.

[322] *SEWRPC Planning Report No. 36, 1986,* op. cit.

[323] *Fish stocking data provided by the WDNR Bureau of Fisheries Management Fish Stocking Summaries tool: infotrek.er.usgs.gov/doc/wdnr_biology/Public_Stocking/StateMapHotspotsAllYears.htm*

Fish Migration and Passage Barriers

The Oak Creek watershed is also one of the sites for an ongoing fish migration study by researchers from the Daniel P. Haerther Center for Conservation and Research at the Shedd Aquarium in Chicago, IL.[324] During spring, many species of Great Lakes fish migrate into tributaries for their spawning runs, including white suckers and steelhead trout (*Oncorhynchus mykiss*) from Lake Michigan into Oak Creek. This study is monitoring the number of white sucker and steelhead entering Oak Creek from Lake Michigan to better understand fish migratory patterns, barriers, and impacts of their migration on stream ecosystems. So far, this study has recorded 296 white suckers migrating upstream in 2017, 986 in 2018, and 350 in 2019, as well as 122 steelhead in 2018 and 139 steelhead in 2019.[325] While white suckers are a common species throughout the majority of the Oak Creek watershed, steelhead trout have only been found below the dam. Steelhead, rainbow, brown, and brook trout, as well as chinook and coho salmon have been observed migrating from Lake Michigan upstream to the Mill Pond dam and this reach is a known and valuable recreational fishery managed by WDNR.[326] Thus, Grant Park Ravine has become a local hotspot for salmon and trout fishing, particularly during spring and fall runs (see information on fishing access in Section 4.7, "Recreational Access and Use").

Figure 4.114
Iowa Darter, Indicator of Improving Water Quality

IOWA DARTER
Etheostoma exile

The brightly colored Iowa darter is uncommon to common locally within Wisconsin and is one of the few darters more often observed in lakes than streams. Iowa darters prefer small streams with aquatic vegetation as well as sand and gravel bottoms. While Iowa darters are tolerant of low dissolved oxygen, they are intolerant of turbid waters as turbidity disrupts its macroinvertebrate food supply. First observed in Oak Creek in 1924, the Iowa darter was not observed in fish surveys for 91 years until it reemerged at three locations within the Oak Creek mainstem in 2015. As this species in intolerant of turbidity, its reemergence is an indicator of improving water quality conditions within the mainstem where it has been found.

Source: SEWRPC

Passage barriers strongly influence the distribution of species within a watershed. As discussed more thoroughly in the "Habitat Quality Conditions" section, the Oak Creek watershed has several bridges, culverts, dams, weirs, and/or drop structures that are likely impediments to fish passage. As several of these structures have existed for over a century and a half, these barriers have shaped the watershed fish community observed today. The most prominent example is the passage impediment posed by the Mill Pond dam that divides the Oak Creek mainstem fish community into the reach below the dam, which maintains connection with Lake Michigan, and the reaches upstream of the dam, where that connection has been severed. Preventing fish passage between Oak Creek and Lake Michigan limits access of Lake Michigan fishes to feeding areas, spawning areas, juvenile rearing habitat, and/or overwintering sites; and increases the vulnerability of fishes to predation, especially immediately downstream of the dam spillway. In addition, this barrier limits the reintroduction of the diverse Lake Michigan fish community into the Oak Creek watershed upstream of the Mill Pond dam. For example, reconnection of all of the reaches of Oak Creek with Lake Michigan may enable the introduction of northern pike into the watershed. If introduced, the greater connection of the mainstem with its floodplain would provide larger areas of flooded emergent vegetation that are the pike's preferred spawning habitat.[327] Preventing fish migration into Oak Creek also limits the potential for recreational salmon and trout fishing, as is popular in the Grant Park Ravine, within the rest of the watershed. Thus, the Mill Pond dam likely contributes to the poor abundance and diversity of the Oak Creek fishery overall.

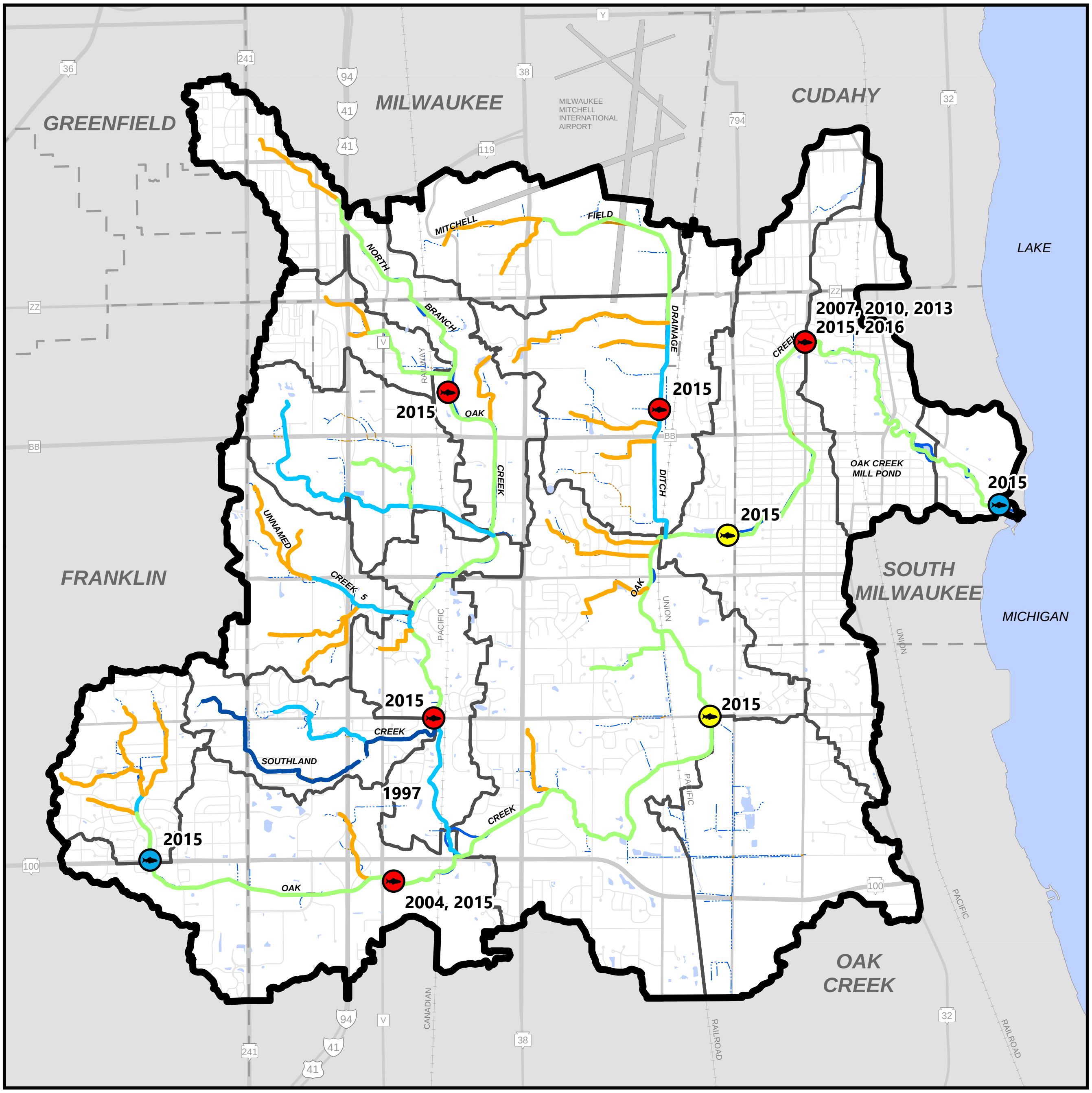
[324] *For more information on this study, see www.sheddaquarium.org/care-and-conservation/shedd-research/investigating-great-lakes-sucker-migrations.*

[325] *Karen Murchie, John G. Shedd Aquarium, unpublished data, 2019.*

[326] *For more information, see dnr.wi.gov/topic/fishing/lakemichigan/fallfishing.html.*

[327] *Becker, 1983,* op. cit.

Map 4.31
Current Stream Natural Community and Fish Biotic Indicies Within the Oak Creek Watershed: 2005-2016



FISH IBI
- POOR
- FAIR
- GOOD
- EXCELLENT (NONE)

NATURAL COMMUNITY
- COLDWATER
- COOLWATER (COLD-TRANSITIONAL)
- COOLWATER (WARM-TRANSITIONAL)
- MACROINVERTEBRATE

- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

0 0.25 0.5 1 Mile

Source: SEWRPC

Passage barriers may also be influencing fish communities upstream of the Mill Pond dam by separating the North Branch from the Oak Creek mainstem. As discussed previously in this section, the North Branch has lower species diversity and a greater proportion of pollutant tolerant species than the Oak Creek mainstem. Additionally, the fishery quality appears to be decreasing in the North Branch while it is slightly improving within the mainstem. As described in Section 4.2, under "Habitat Quality Conditions," a concrete drop structure at the Canadian Pacific Railroad crossing (see structure 65 in Map 4.14 as well as in Appendix H, Figure H.1 and Table H.1) likely impedes fish passage between the North Branch and the Middle Oak Creek mainstem. Large stretches of the North Branch have little or no riparian buffer and highly developed storm sewer system and thus little capacity to mitigate pollutant runoff. Subsequently, declining water quality in the North Branch may have caused the loss of more pollution intolerant species. The passage barrier between the North Branch and mainstem may be exacerbating poor fishery conditions in the North Branch, as it prevents species reintroduction from the mainstem and inhibits travel to the mainstem for habitat, spawning, feeding, or refugia from lethal water quality conditions. Reducing fragmentation or reconnecting stream reaches within Oak Creek to Lake Michigan as well as reconnecting tributary streams to the Oak Creek mainstem are critical aspects to consider for developing a sustainable fishery within the watershed.

Projected Effects of Climate Change

The USGS has developed the "FishVis" decision support tool to display model projections of changes in stream temperature, streamflow, and fish species occurrence throughout the 21st century for watersheds within the Great Lakes Region, including the Oak Creek watershed.[328,329] The model was developed using historical information on stream temperatures and flow, as well as projections from thirteen downscaled climate models, to model stream temperatures and streamflow for the present day, mid (2046 – 2065), and late (2081 – 2100) 21st century. With this modeled temperature and streamflow information, as well as a suite of environmental variables, the model then predicts the occurrence of four coldwater, five coolwater, and four warmwater species across these time periods (present day, mid, and late 21st century) within individual reaches of each watershed. Of these thirteen modeled species, five species (brook stickleback, common carp, green sunfish, rainbow trout, and white sucker) have been observed within Oak Creek. The model correctly predicts that brook stickleback, green sunfish, and white suckers are found throughout the majority of the watershed at the present time. The model does not predict that rainbow trout are present in Oak Creek and the model under predicts the present extent of common carp within the watershed. However, these discrepancies may be due to a difference in data collection periods; the fish presence model was generated using 1995 to 2011 survey data while the presence of rainbow trout and the larger extent of common carp in the watershed were identified in the 2015 survey.

The FishVis model predicts that stream temperatures will increase by up to 3.6°F (2°C) by the late 21st century with concurrent average daily streamflow increases in all modeled reaches of the Oak Creek watershed. Modeled temperature increases may be further exacerbated by shading loss along the Oak Creek Parkway, due to the ongoing decline of the ash tree canopy and subsequent spread of invasive buckthorn and reed canary grass, as described in Section 4.2, under "Habitat Quality Conditions" (see Map 4.13). Increased stream temperatures are not expected to drastically change the fish communities in the Oak Creek mainstem but could still decrease the quality of these communities. However, the majority of the Oak Creek North Branch, as well as the watershed headwater and tributaries streams, are modeled as presentday cold transition communities. A 3.6°F temperature increase is expected to shift these reaches to warm transition or warmwater communities by the late 21st century. Similarly, average daily streamflow is projected to increase in all reaches of the watershed as the model incorporated the projections of increased precipitation in southeastern Wisconsin with climate change. This increase is projected to shift the Oak Creek mainstem from its current headwater natural community classification (0.03 to 3.0 cfs) into the mainstem classification (3.0 to 150 cfs).[330]

---

[328] *J.S. Stewart et al., "FishVis, A Regional Decision Support Tool for Identifying Vulnerabilities of Riverine Habitat and Fishes to Climate Change in the Great Lakes Region,"* U.S. Geological Survey Scientific Investigations Report 20165124, *15 p., with appendixes pubs.er.usgs.gov/publication/sir20165124, 2006.*

[329] *ccviewer.wim.usgs.gov/FishVis/#app=d936&912-selectedIndex=0&3eb4-selectedIndex=0.*

[330] *WDNR, 2019,* op. cit.

FishVis projected changes to the fish community from predicted climate change scenarios are more apparent at the individual species level (see projected fish species distributions in the Oak Creek watershed on Maps 4.32 and 4.33), with significant declines in the extent of cool water species. Brook stickleback, a cool water species present throughout most of the watershed, is projected to dramatically decline with only the Mitchell Field Drainage Ditch – Airport reach capable of supporting this species by the mid-21st century. However, as this reach is largely enclosed under the airport (a fact unknown to the FishVis model), it is likely incapable of supporting any fish community. White sucker, another cool water species that is currently found in the Oak Creek mainstem and the North Branch, is projected to largely disappear from the mainstem by the late 21st century. If white sucker populations are present in the mainstem, as projected in the model, then the North Branch population would be unlikely to survive as well. Fish surveys from 2015 indicate that common carp, a warm water species, is already present in the reaches that the model projects it would expand to by the late 21st century. Improving canopy cover, increasing stormwater infiltration volumes via green infrastructure and other improvements, and protecting groundwater supply to the streams are important aspects to consider to mitigate the effects of warmer air temperatures on cool water species within the Oak Creek watershed.

Macroinvertebrates

Benthic macroinvertebrates are organisms without backbones that inhabit stream substrate, such as sediment, debris, logs, and plant vegetation, for at least part of their life cycle. Macroinvertebrates are visible to the naked eye, are abundant in freshwater systems, and include insect larvae and some adult insects as well as leeches, worms, crayfish, shrimp, clams, mussels, and snails. In streams, many macroinvertebrate species utilize particulate organic matter such as leaves and twigs that enter the stream from the adjacent terrestrial environment as a source of energy and nutrients. This acts to pass much of the energy and nutrients in this material into the stream community's food web. Many macroinvertebrate species serve as food for other organisms, including fish.

The majority of macroinvertebrates tend to be found within the shallow, fast flowing riffle habitats of streams as compared to deeper and slower flowing pool or run habitats. Riffles can range from uneven bedrock or large boulders to sand substrates. However, the optimum riffle substrates for macroinvertebrates are characterized by particle diameters ranging from gravels (one inch) to cobbles (ten inches). Water flowing through these areas provides plentiful oxygen and food particles. Riffle-dwelling communities are made up of macroinvertebrates that generally require high dissolved oxygen levels and clean water, and most are intolerant of pollution. For example, mayflies (Ephemeroptera), stonefly larvae (Plecoptera), and caddisfly larvae (Trichoptera) tend to be found in cold, clear flowing water with a gravel or stone bottom and with high dissolved oxygen concentrations. Experimental sensitivity studies have indicated that mayflies in particular are sensitive to low water pH and oxygen depletion.[331]

Macroinvertebrate Metrics

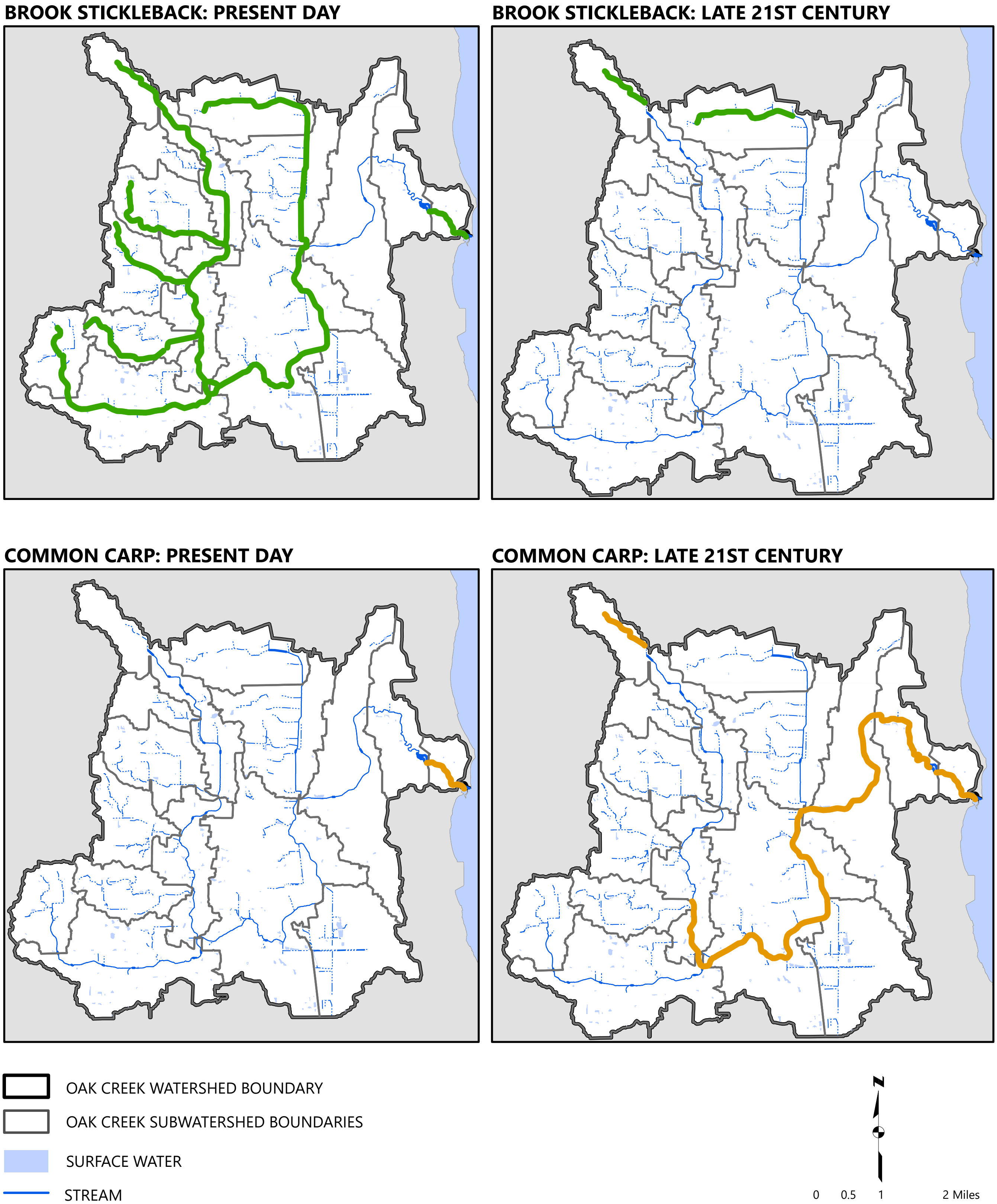
Macroinvertebrates are useful indicators of water quality because they spend much of their life in the waterbody, they are not highly mobile, they are easily sampled, and the references needed to identify them to a useful degree of taxonomic resolution are readily available. In addition, the differences among macroinvertebrate species in habitat preferences, feeding ecology, and environmental tolerances allow the quality of water and habitat in a waterbody to be evaluated based upon the identity of the groups that are present and their relative abundances. The differences among macroinvertebrate species in feeding ecology are often represented through the classification of species into functional feeding groups based upon the organisms' principal feeding mechanisms.[332] Functional feeding groups include scrapers, shredders, and collectors. Scrapers include herbivores and detritivores that graze microflora, microfauna, and detritus attached to mineral, organic, or plant surfaces. Shredders include detritivores and herbivores that feed primarily on coarse particulate organic matter. Collectors, which feed on fine particulate organic matter, include filterers that remove suspended material from the water column and gatherers that utilize material deposited on the substrate.

---

[331] *Arden R. Gaufin,* Water Quality Requirements of Aquatic Insects*, US Environmental Protection Agency, 1973; Arden R. Gaufin, Robert Clubb, and Robert Newell, "Studies on the Tolerance of Aquatic Insects to Low Oxygen Concentrations",* Great Basin Naturalist*, Volume 34, Number 1, pages 45-59, 1974.*

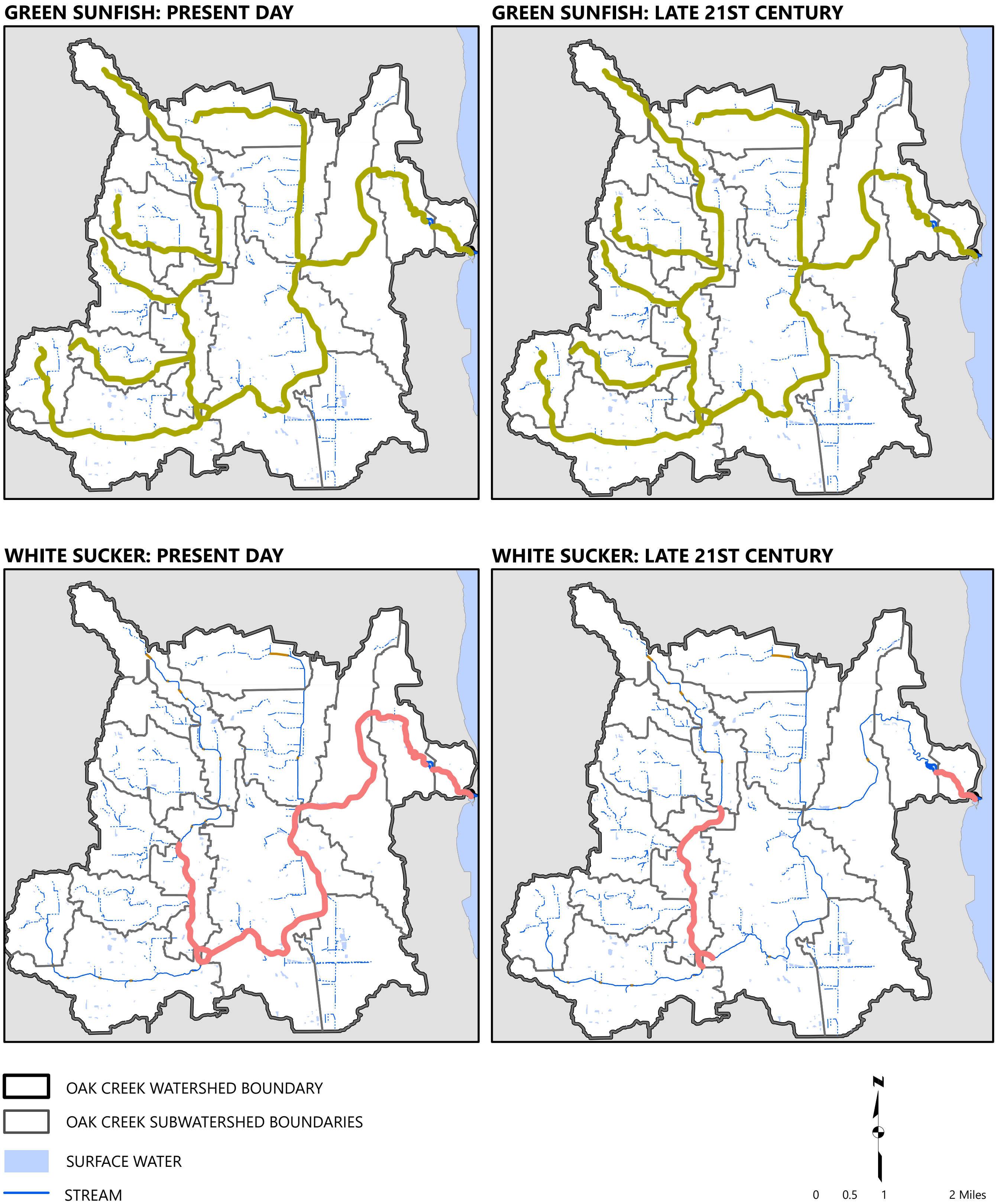
[332] *Kenneth W. Cummins, "Trophic Relations of Aquatic Insects,"* Annual Review of Entomology, *Volume 18, pages 183-206, 1973*; *Kenneth W. Cummins and Michael J. Klug, "Feeding Ecology of Stream Invertebrates,"* Annual Review of Ecology and Systematics, *Volume 10, pages 147-172, 1979*.

Map 4.32
Projected Changes in Fish Species Occurrence Between Present Day and Late 21st Century



Source: SEWRPC

Map 4.33
Projected Changes in Fish Species Occurrence Between Present Day and Late 21st Century



Source: SEWRPC

A variety of metrics have been developed and used for evaluating water quality based upon macroinvertebrate assemblages.[333] These include metrics based on taxa richness, trophic function, relative abundance of the dominant taxa, and diversity, as well as more complicated metrics. Most of these metrics have been developed for stream systems, though some macroinvertebrate metrics are being developed for other aquatic environments, such as wetlands.[334] The Hilsenhoff Biotic Index (HBI), and the percent of individuals detected consisting of members of the insect orders Ephemeroptera, Plecoptera, and Trichoptera (percent EPT) were used to classify the historical and existing macroinvertebrate data and to evaluate the environmental quality of the stream system using survey data from various sampling locations in the Oak Creek watershed.[335] Other metrics examined include the percentages of macroinvertebrates in a sample belonging to each functional feeding group, the number of species detected in a sample (species richness), and the percentage of macroinvertebrates detected that belong to particular taxa.

The HBI represents the average weighted pollution tolerance values of all arthropods, i.e. animals with an exoskeleton, paired jointed appendages, and a segmented body such as insects and crustaceans, present in a sample. It is based upon the macroinvertebrate community's response to high loading of organic pollutants and reductions in the concentration of dissolved oxygen. Lower values of the HBI indicate better water quality conditions while higher values indicate worse water quality conditions. Table 4.30 show the values of the HBI associated with different ratings of water quality and degrees of organic pollution. The HBI is designed for use with samples collected from riffles and runs and may not be reliable for interpreting data collected from other stream environments. For example, macroinvertebrate data from samples collected from snags (clusters of logs, branches, and/or leaves) tend to be more variable and give higher HBI values than data from samples collected in riffles.[336]

Percent EPT-I and percent EPT-G consists of the percentage of individuals and genera, respectively, detected in a sample that are members of the insect orders Ephemeroptera, Plecoptera, and Trichoptera. These taxa are separated out from other aquatic taxa because they generally represent the organisms in streams and rivers that are more intolerant of organic pollution. Higher percent EPT indicates better water quality while lower indicates worse water quality. Low percent EPT may result from a variety of stressors including high loadings of organic pollution, low concentrations of dissolved oxygen, biologically active concentrations of toxic substances, disruption of stream flow regime, and increases in water temperature.

Dominance 3 Percent-I is a metric of what percent of the total individuals are in the three most common taxa. This metric is useful for understanding the biodiversity of a stream macroinvertebrate community, as low dominance is associated with high diversity. Percent-G Depositional indicates the percent of genera detected in a sample that can tolerate depositional stream substrate. Increased percentages of depositional genera are expected in areas with high stream sedimentation.

Multiple macroinvertebrate indices, including species richness, genera richness, the HBI, percent EPT-I, percent EPT-G, the percent of each forage feeding group, dominance 3 percent-I, and the percent-G depositional, have been calculated from the WDNR surveys that can be useful indicators of macroinvertebrate community health and water quality in Oak Creek and its tributaries (see Table 4.31). In addition, the WDNR utilizes the macroinvertebrate index of biotic integrity,[337] an index that incorporates several of the aforementioned metrics including species richness, a modified form of the HBI, percent EPT, and feeding morphology, to evaluate macroinvertebrate community health and water quality in streams.[338]

---

[333] *Richard A. Lillie, Stanley W. Szczytko, and Michael A. Miller*, Macroinvertebrate Data Interpretation Manual, *Wisconsin Department of Natural Resources, PUB-SS-965 2003, Madison, Wisconsin, 2003*.

[334] *Richard A. Lillie, "Macroinvertebrate Community Structure as a Predictor of Water Duration in Wisconsin Wetlands,"* Journal of the American Water Resources Association, *Volume 39, pages 389-400, 2003.*

[335] *William L. Hilsenhoff,* op. cit.

[336] *Lillie, Szcytko, and Miller, 2003,* op. cit

[337] *B.M. Weigel, "Development of Stream Macroinvertebrate Models that Predict Watershed and Local Stressors in Wisconsin,"* Journal of the North American Benthological Society*, 22(1): 123-142, 2003.*

[338] *Use of the M-IBI was excluded from this analysis as reported values in the WDNR Surface Water Integrated Monitoring System (SWIMS) were outside of the defined 0 to 10 range.*

Community Conditions

Between 1979 and 2015, the WDNR conducted 51 macroinvertebrate surveys in the Oak Creek watershed (see Table 4.31). The USGS conducted macroinvertebrate sampling at the 15th Avenue crossing in South Milwaukee in 2004, 2007, 2010, and 2013. Researchers from the University of Wisconsin-Parkside also conducted surveys along the mainstem at the Mill Pond, 15th Avenue, Drexel Avenue, Nicholson Road, and CTH V as well as in the North Branch at Weatherly Drive and S. 6th Street, all in 2015. Some Plan assessment areas have never had a macroinvertebrate survey conducted within their boundaries; these include the College Avenue Tributary, Oak Creek Drainage Ditches, and Southland Creek. Thus, the following discussion will not address the macroinvertebrate community conditions present within these assessment areas.

Table 4.30
Water Quality Ratings for Hilsenhoff Biotic Index (HBI) Values

HBI Value	Water Quality Rating	Degree of Organic Pollution
< 3.50	Excellent	None apparent
3.51 - 4.50	Very Good	Possible slight
4.51 - 5.50	Good	Some
5.51 - 6.50	Fair	Fairly significant
6.51 - 7.50	Fairly Poor	Significant
7.51 - 8.50	Poor	Very significant
8.51 - 10.00	Very Poor	Severe

Source: W.L. Hilsenhoff, "An Improved Biotic Index of Organic Stream Pollution," The Great Lakes Entomologist, *Volume 20, pages 31-39, 1987*

A total of 241 macroinvertebrate taxa were identified in these samples. It should be noted that these organisms were identified to varying degrees of taxonomic resolution. In many cases, the particular species of organism was identified. In other cases, the organisms were identified to genus, subfamily, or family levels. In some instances, the organisms were identified only to order or class level. The majority of taxa identified, 186 taxa, were insects. These include true flies, beetles, caddisflies, mayflies, true bugs, dragonflies, and damselflies. Other groups present in samples included crustaceans, such as amphipods, crayfish, and isopods; annelid worms; nematode worms; turbellarian worms; and mollusks. While most taxa were found in five or fewer samples and at two or fewer sites, some were very common. The five most commonly identified taxa were the isopod *Caecidotea intermedia*, caddisflies of the genus *Cheumatopsyche*, beetles of the genus *Stenelmis*, the caddisfly *Hydropsyche betteni*, and midges of the genus *Stictochironomus*. Each of these taxa was detected at 12 or more sites and in 30 or more samples. The macroinvertebrate taxa found in samples collected from the Oak Creek watershed are listed in Appendix L.

HBI ratings, a water quality metric based on macroinvertebrate tolerance to organic pollution, have generally ranged from Very Poor to Fair across the entire watershed (see Maps 4.34 and 4.35 as well as Figure 4.115). The North Branch Oak Creek and Mitchell Field Drainage Ditch assessment areas appear to be in the most impoverished conditions, as indicated by HBI ratings that have remained Poor or have actively declined from better conditions. These assessment areas generally have lower percentages of EPT-I (see Figure 4.116) and EPT-G as well as a greater percentage of genera that can tolerate depositional substrate (see Table 4.31); all of these are associated with increasing environmental stress.[339,340] Conditions have severely declined in the Mitchell Field Drainage Ditch, where the 1985 survey garnered a Good HBI rating and had high percent EPT-I, but the 2015 survey earned a Fairly Poor rating and had low percent EPT-I. In addition, the 2015 survey indicated a substantial decrease in species richness and greater dominance by the top three taxa, indicating a poorer and less diverse macroinvertebrate community. As described in Section 4.4, "Surface Water Quality," Mitchell Field Drainage Ditch has very low dissolved oxygen concentrations, potentially due to organic matter decomposition and/or high biochemical oxygen demand from contaminants in airport runoff. In addition, 2007 through 2016 measurements in both the North Branch and Mitchell Field Drainage Ditch had higher turbidity than USEPA guidance and higher total phosphorus concentrations than the WDNR water quality criterion. Thus, poor water quality is likely contributing to the poor macroinvertebrate community conditions within these assessment areas.

Despite the historical poor conditions, macroinvertebrate community conditions may be slightly improving in the Oak Creek mainstem. The majority of HBI ratings from the 2015 macroinvertebrate surveys attained Fair to Good ratings, indicating a potential decline in the degree of organic pollution within the watershed. Species richness has increased throughout the majority of the watershed, with an average of 7.6 species identified per survey in 1979 to an average of 17.6 species per survey in 2015. Increases in richness were

[339] *William L. Hilsenhoff,* op. cit.

[340] *Weigel, B.M., 2003,* op. cit.

Table 4.31
Summary Metrics for WDNR Macroinvertebrate Surveys in the Oak Creek Watershed: 1979-2015

Survey Date	Species Richness	Genera Richness	HBI	Percent EPT-I	Percent EPT-G	Percent Filterers	Percent Gatherers	Percent Scrapers	Percent Shredders	Dominance 3 Percent-I	Percent-G Depositional
Lower Oak Creek Subwatershed											
5/17/1979	8	8	6.5	30	38	27	61	2	0	83	13
11/1/1979	6	6	6.8	58	67	53	46	0	1	93	50
11/25/1985	5	4	7.3	18	50	8	85	7	0	98	20
11/25/1985	4	4	5.4	5	25	0	37	55	0	89	25
11/25/1985	18	18	7.6	5	11	4	88	0	4	63	67
11/25/1985	11	11	7.8	0	0	0	92	1	0	72	73
10/8/1996	7	7	6.3	74	43	69	31	0	0	86	40
10/8/1996	14	13	6.9	40	31	8	80	12	0	71	55
10/8/1996	20	20	5.8	48	20	54	29	11	3	57	43
10/8/1996	24	23	6.3	10	17	11	69	15	2	65	50
11/13/2000	24	24	6.5	9	8	3	60	10	22	44	64
10/30/2002	14	14	5.6	81	21	82	5	5	3	82	42
10/6/2003	10	10	5.5	67	30	66	8	18	1	77	50
10/31/2008	16	16	5.8	62	31	65	27	4	4	58	36
4/9/2009	22	21	6.8	4	10	8	58	10	18	44	19
10/19/2012	17	16	5.4	82	31	77	13	5	5	77	40
10/22/2015	15	15	5.3	66	13	67	26	1	4	79	43
10/22/2015	28	26	5.5	67	19	59	33	1	4	61	36
10/22/2015	26	22	5.4	67	32	68	14	2	11	64	42
Middle Oak Creek Subwatershed											
5/17/1979	11	11	7.7	23	27	5	48	0	0	71	64
11/1/1979	8	8	9.0	7	13	0	72	0	0	72	75
11/25/1985	11	10	6.3	49	40	22	66	11	0	66	27
11/25/1985	24	23	5.7	44	22	37	46	3	1	56	63
11/25/1985	15	14	6.5	35	29	15	73	8	3	59	40
11/25/1985	7	7	7.9	5	29	3	96	1	0	96	57
10/8/1996	18	15	6.0	67	27	32	63	3	0	43	27
10/8/1996	17	16	5.4	50	25	44	26	29	0	67	62
10/9/1997	27	25	6.9	71	4	0	85	11	3	79	55
11/5/2015	28	28	6.6	18	21	29	41	6	2	42	50

Table continued on next page.

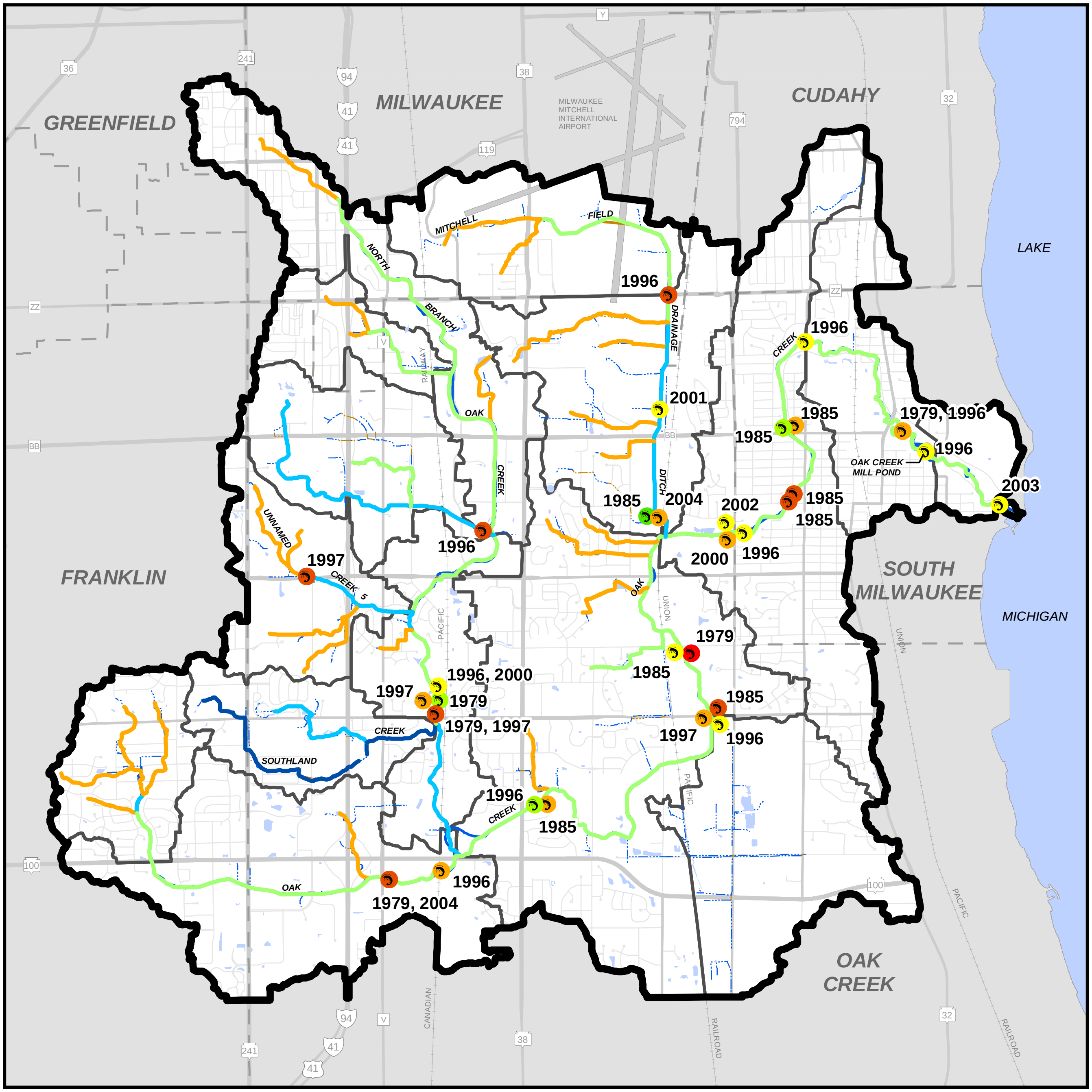
Table 4.31 (Continued)

Survey Date	Species Richness	Genera Richness	HBI	Percent EPT-I	Percent EPT-G	Percent Filterers	Percent Gatherers	Percent Scrapers	Percent Shredders	Dominance 3 Percent-I	Percent-G Depositional
Mitchell Field Drainage Ditch Subwatershed											
11/25/1985	17	15	4.4	51	20	43	43	4	3	48	35
10/8/1996	23	21	8.1	0	0	1	80	0	3	66	65
11/16/2001	20	20	6.2	1	5	1	65	5	5	76	67
10/7/2004	28	27	7.1	2	7	4	70	3	19	50	60
10/22/2015	9	8	7.1	26	38	17	79	0	0	87	63
North Branch Oak Creek Subwatershed											
11/5/2004	6	6	7.7	0	0	6	94	0	0	88	14
11/5/2004	28	28	7.9	0	4	19	63	0	0	74	100
5/17/1979	7	7	5.3	1	14	2	34	29	0	66	73
11/1/1979	8	8	8.2	0	0	0	35	0	0	89	67
10/8/1996	15	15	6.2	36	20	38	51	9	2	80	50
10/8/1996	16	16	8.1	1	13	2	94	0	1	79	80
10/9/1997	14	14	7.2	21	21	25	69	4	1	83	88
10/9/1997	13	13	7.9	0	0	1	95	1	1	76	50
10/9/1997	9	9	8.1	3	11	0	89	11	0	57	57
10/9/1997	12	12	7.8	35	17	1	90	9	0	97	83
11/13/2000	27	26	5.5	36	12	38	24	28	3	58	41
11/5/2015	7	7	8.0	0	0	0	98	0	1	88	14
11/5/2015	19	19	5.7	18	16	16	58	18	3	74	100
Upper Oak Creek Subwatershed											
5/17/1979	8	8	7.9	2	25	2	84	0	0	93	50
11/1/1979	5	5	7.9	1	20	1	95	0	0	98	80
10/8/1996	11	11	6.6	7	27	24	74	0	0	83	60
10/7/2004	27	26	7.8	2	15	2	70	0	9	70	52
10/22/2015	16	16	5.5	0	0	1	95	0	2	88	69
10/22/2015	10	10	6.3	25	20	25	67	0	6	81	56

Note: These summary metric values were calculated by the WDNR Surface Water Integrated Monitoring System (SWIMS) and not by Commission staff.

Source: Wisconsin Department of Natural Resources and SEWRPC

Map 4.34
Historical Hilsenhoff's Biotic Index Ratings Within the Oak Creek Watershed: 1979-2004



NATURAL COMMUNITY

- COLDWATER
- COOLWATER (COLD-TRANSITIONAL)
- COOLWATER (WARM-TRANSITIONAL)
- MACROINVERTEBRATE

HILSENHOFF'S BIOTIC INDEX

- VERY GOOD
- GOOD
- FAIR
- FAIRLY POOR
- POOR
- VERY POOR

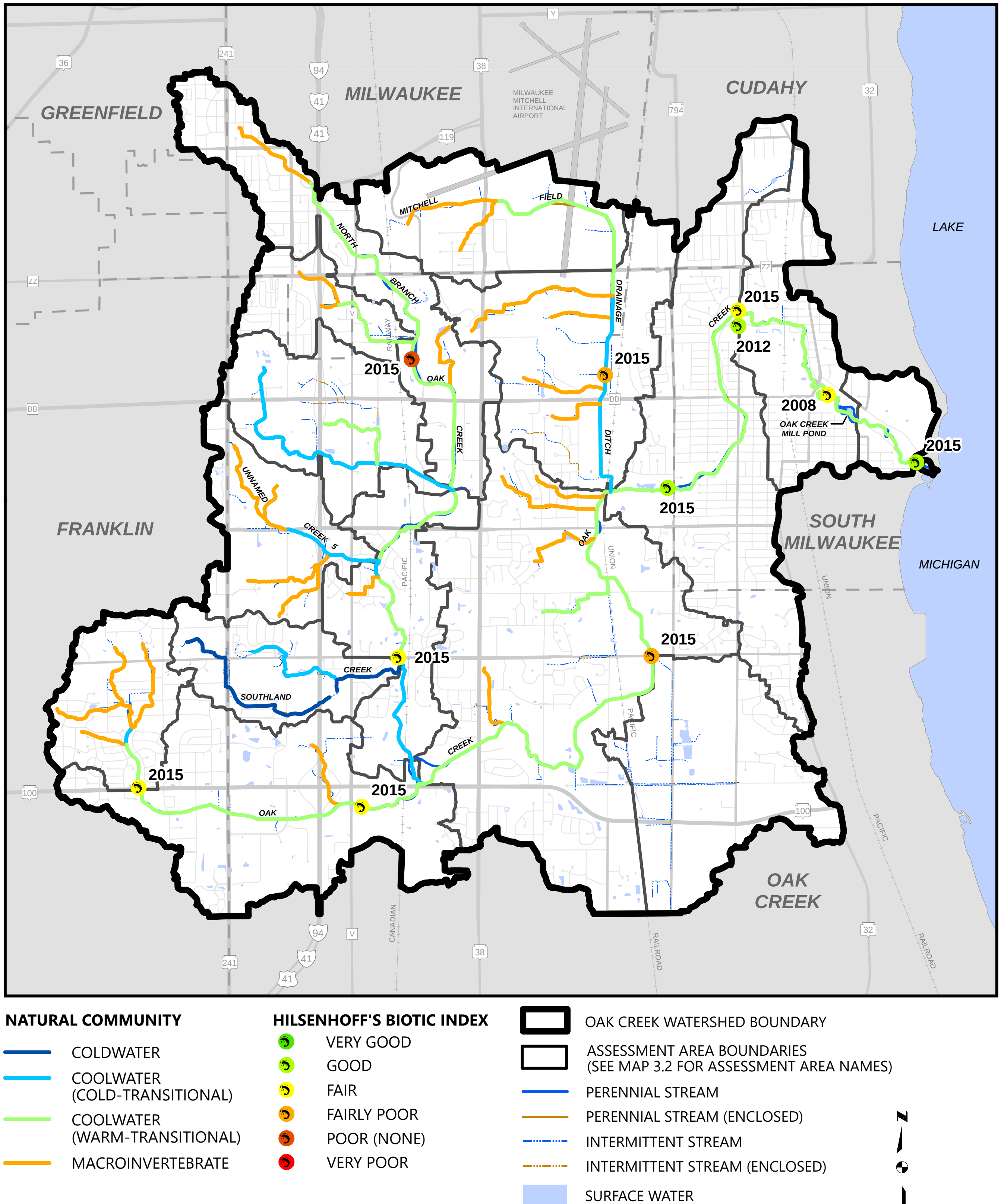
- OAK CREEK WATERSHED BOUNDARY
- ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)
- PERENNIAL STREAM
- PERENNIAL STREAM (ENCLOSED)
- INTERMITTENT STREAM
- INTERMITTENT STREAM (ENCLOSED)
- SURFACE WATER

Note: Survey locations were slightly adjusted for greater visiblity when multiple surveys occurred at the same location.

0 0.25 0.5 1 Mile

Source: SEWRPC

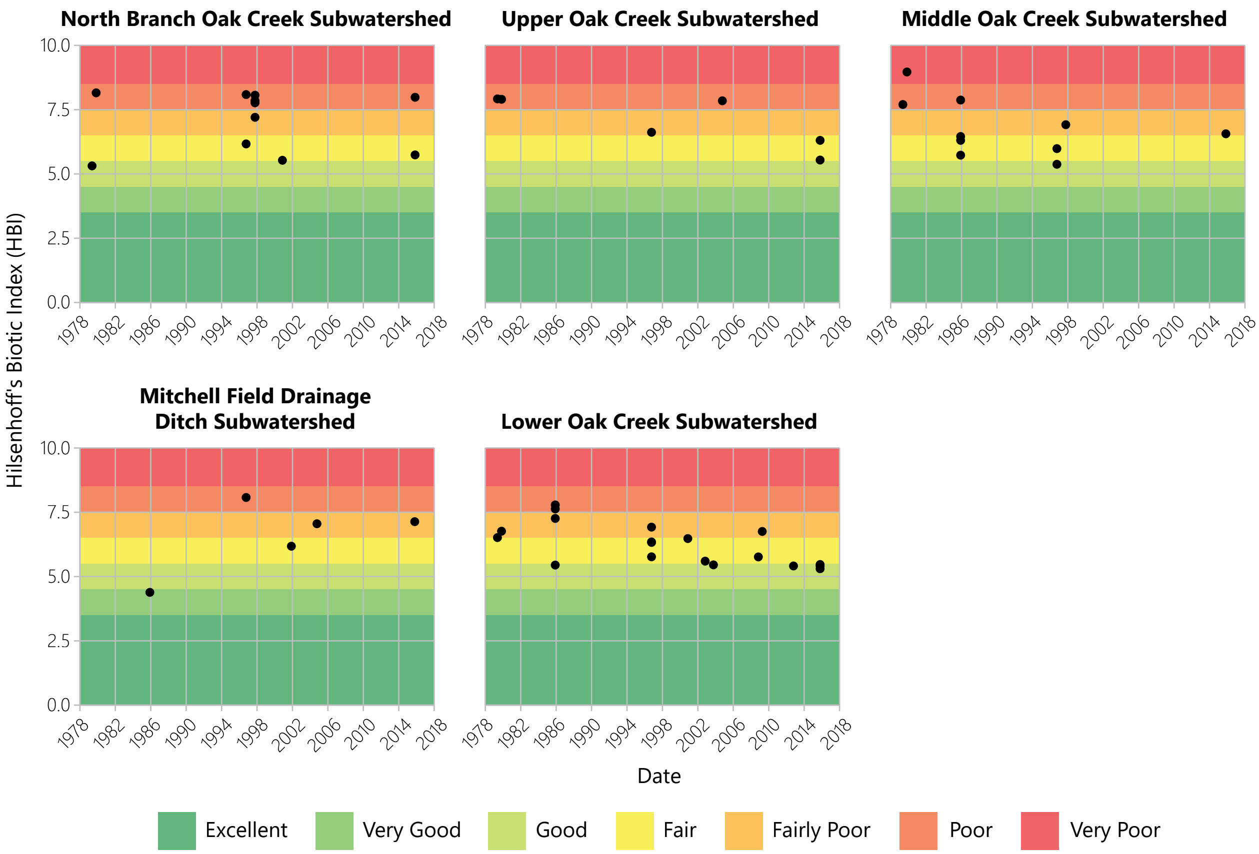
Map 4.35
Current Hilsenhoff's Biotic Index Ratings Within the Oak Creek Watershed: 2005-2015



Note: Survey locations were slightly adjusted for greater visiblity when multiple surveys occurred at the same location.

Source: SEWRPC

Figure 4.115
Hilsenhoff's Biotic Index for Macroinvertebrate Surveys in the Oak Creek Watershed: 1976-2015



Note: Macroinvertebrate data was grouped by subwatershed as several assessment areas have rarely or never been surveyed.

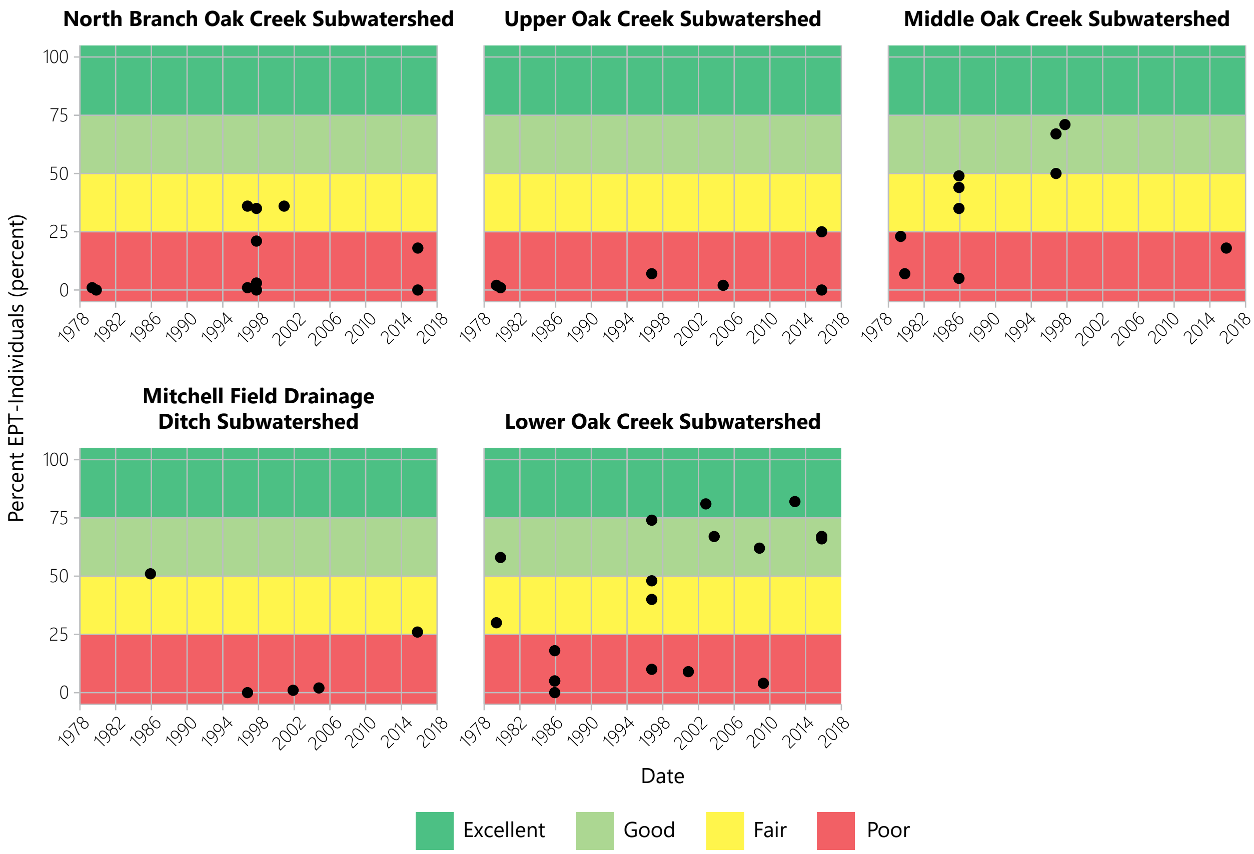
Source: Wisconsin Department of Natural Resources and SEWRPC

accompanied by decreasing dominance by the top three taxa in the Lower Oak Creek, Lower North Branch Oak Creek, Middle Oak Creek, and Upper Oak Creek assessment areas (see Figure 4.117). Lower and Middle Oak Creek have lower percentages of macroinvertebrate genera that can tolerate depositional substrate and higher EPT-I than the other assessment areas. As with HBI, increasing species richness and decreasing dominance by the top three taxa indicates that macroinvertebrate communities are healthier and more diverse. These are positive trends for water quality along the Oak Creek mainstem, indicating healthier macroinvertebrate communities and decreasing stress from organic pollutants. As much of the watershed still exceeds USEPA guidance for turbidity and does not meet WDNR water quality standards for dissolved oxygen, improving water quality could greatly promote healthy macroinvertebrate communities.

Gatherers were the most dominant functional feeding group found throughout the watershed in the 2015 sampling, particularly in the North Branch, Upper Oak Creek, and along the mainstem in Lower Oak Creek (see Table 4.31). Filterers, the second most dominant feeding group throughout the watershed, often made up the majority of the observed taxa in surveys within Lower Oak Creek, Lower Oak Creek – Mill Pond, and Grant Park Ravine assessment areas. Species in the gatherer and filterer feeding groups tend to be generalist in their feeding and are thought to be more tolerant of certain forms of water pollution.[341] Scrapers and shredders were the least dominant feeding groups, with several surveys observing no members of either feeding group. Shredders only attained greater than 10 percent of the macroinvertebrate community in four surveys, all of which were located near the confluence of the Mitchell Field Drainage Ditch and the Oak Creek mainstem.

[341] *M.T. Barbour, J. Gerritsen, G.E. Griffith, E. Frydenborg, E. McCarron, J.S. White, and M.L. Bastian, "A Framework for Biological Criteria for Florida Streams Using Benthic Macroinvertebrates,"* Journal of the North American Benthological Society, *Volume 15, pages 185-211, 1996.*

Figure 4.116
Percent EPT-Individuals for Macroinvertebrate Surveys in the Oak Creek Watershed: 1979-2015



Note: Macroinvertebrate data was grouped by subwatershed as several assessment areas have rarely or never been surveyed.

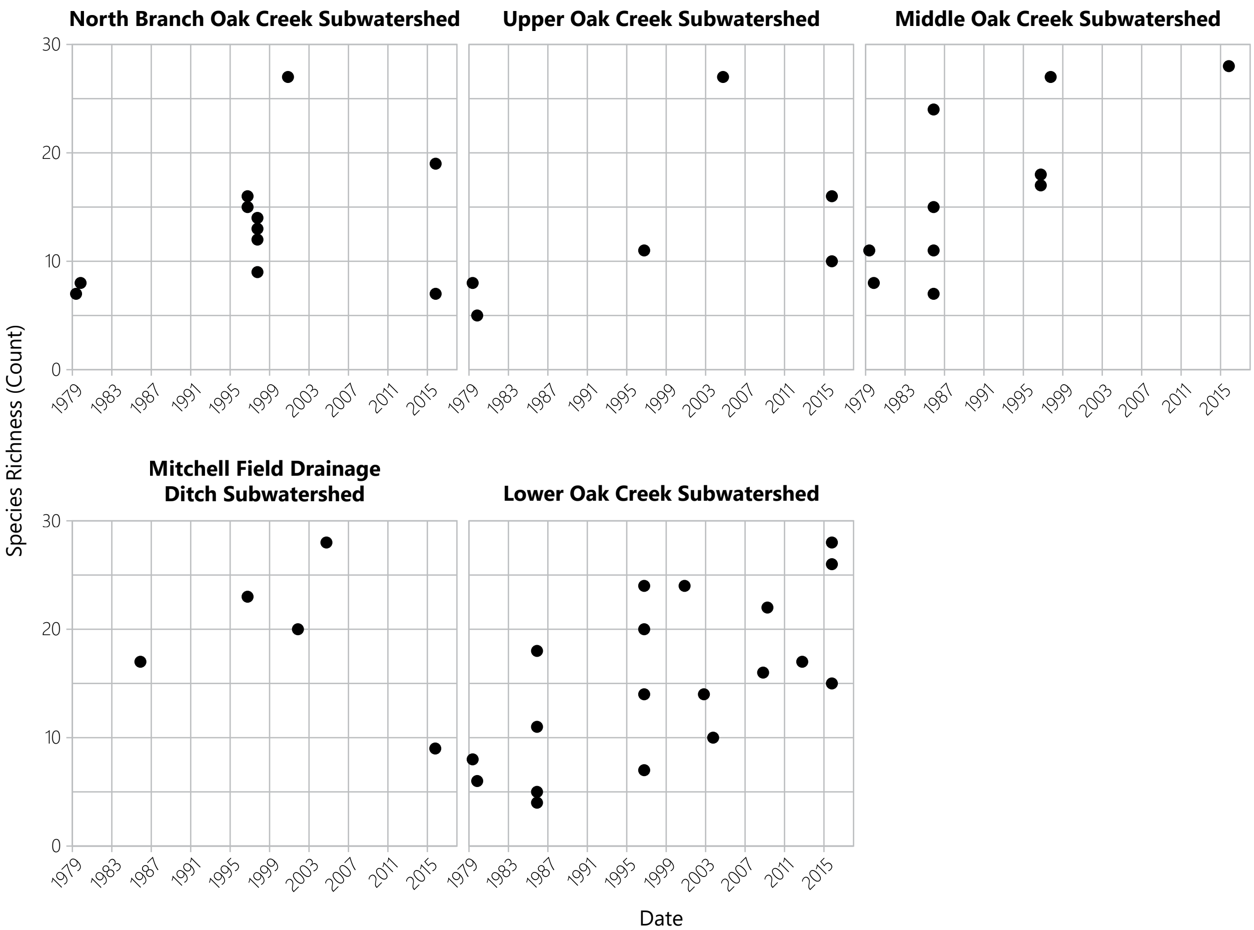
Source: Wisconsin Department of Natural Resources and SEWRPC

The poor to fair macroinvertebrate community quality within the Oak Creek watershed is likely indicative of historical poor water quality conditions and loss of instream macroinvertebrate habitat. Land conversion from natural woodlands, prairies, and wetlands to agricultural and urban land use is typically associated with declines in macroinvertebrate abundance and diversity. Elevated temperatures and declining dissolved oxygen concentrations, as well as elevated concentrations of organic contaminants, may all have contributed to declines in pollution intolerant species within the watershed. Additionally, channelization has altered the naturally meandering channel and associated riffle habitats within the Upper and Lower Oak Creek reaches. Riffle habitats produce the highest abundance and diversity of macroinvertebrate prey, such as Ephemeroptera, Trichoptera, and Diptera, for insectivorous fish species compared to other instream habitats. However, as with the fisheries, there does appear to be slightly improving macroinvertebrate community conditions in the Oak Creek mainstem, with increasing species richness, higher percentages of EPT, and better HBI ratings. Continued monitoring of the macroinvertebrate community will be an important and effective tool to assess changes in water quality in the future, particularly as the recommendations in this plan to improve water quality are implemented.

Mussels

Freshwater mussels are bivalve (two-shelled) mollusks that live in sediments of rivers, streams, lakes, and ponds. These soft-bodied animals are enclosed by two shells made mostly of calcium carbonate that are 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 part in aquatic communities by helping stabilize river bottoms; serving as natural water filters; and serving as food for fish, birds, and some mammals. Live mussels and relict shells provide a relatively stable substrate in dynamic riverine environments for a variety of other macroinvertebrates, such as caddisflies and mayflies and for algae.

Figure 4.117
Species Richness for Macroinvertebrate Surveys in the Oak Creek Watershed: 1979-2015



Note: Macroinvertebrate data was grouped by subwatershed as several assessment areas have rarely or never been surveyed.

Source: Wisconsin Department of Natural Resources and SEWRPC

Mussels are 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 are wholly dependent on fishes to complete their life history, particularly for early larval stages. Hence, loss of fish species from an environment results in the eventual decline and loss of the mussel species as well. Many mussel species grow slowly and have long life spans, with some individuals in some species able to survive for up to 100 years. For this reason, mussels can be used to document changes in water quality over long periods of time. Shells accumulate metals from both water and sediment, so testing heavy metal concentrations in shells can provide information on contamination history. 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.

Freshwater mussels have a unique life cycle that includes a parasitic stage. Fish act as the host for this stage. Reproduction occurs when a male mussel releases sperm into the water column. This is siphoned into the female mussel to fertilize the eggs. Reproduction may be triggered by increasing water temperature and/or day length. Larvae are brooded through early development in the female's gills and development and retention of larvae within the female may last from one to 10 months. Immature mussels, known as glochidia, are generally released from the female in spring and early summer. The glochidia must attach to the gills of a fish to obtain nutrients from blood serum. Mussel species show a variety of adaptations that increase the success of glochidia in attaching to their fish hosts. As parasites, glochidia are dependent on fish for their nutrition at this stage in their life. Some mussels may depend on only a single fish species, whereas others are able to parasitize many different fishes. The attachment of glochidia causes no problems for the host fish. Immature mussels spend at least two to three weeks attached to fish. Following this they drop off the host and settle 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. The characteristics and potential host fish species of those mussel species that have been found in the Oak Creek watershed are shown in Table 4.32.

The dispersal of mussel species depends upon the transport of glochidia by host fish. The habitat preferences of freshwater mussel species and their hosts generally coincide closely.[342] Studies of peripheral populations of freshwater mussels in Nova Scotia indicate that the invasion of new habitats by mussels occurs primarily through dispersal of the host fish.[343] This dependence upon host fish for dispersal means that barriers to fish movement are also barriers to mussel dispersal and may act to restrict mussels from otherwise suitable habitats.

Mussels are considered one of the most endangered groups of animals in North America. 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. Prior to 2006, harvesting of freshwater mussels was allowed in Wisconsin, and rules were in place that allowed each individual to harvest up to 50 pounds of mussels per day. Under those rules threatened and endangered species could not be harvested. This was problematic because even experts had difficulty identifying individual mussel species. Since 2006, it is illegal to harvest mussels from inland waters in the State. The law does allow dead shells from species that are not threatened or endangered to be collected.

Currently, the WDNR Bureau of Natural Heritage Conservation[344] is working with citizen scientists on a mussel monitoring program that aims to update information on statewide mussel distributions. 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 Wisconsin Mussel Monitoring Program. 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.[345]

Mussels have never been thoroughly sampled in the Oak Creek watershed, so their abundance and diversity within this system is unknown. However, a few live specimens and relict shells were incidentally observed and documented during the Commission's 2016 stream surveys, with the most observations occurring in the Middle Oak Creek Assessment Area (see Map 4.36). Photos were taken for each specimen and relict shell (see Figure 4.118 for examples); these photos were sent to the Wisconsin Mussel Monitoring Program for taxonomic identification by WDNR conservation biologists. White heelsplitters (*Lasmigona complanata*) were the most commonly observed species, but a fatmucket (*Lampsilis siliqoidea*) and a fingernail clam (family Sphaeriidae) were observed as well. Fatmuckets have a wide range of available fish hosts, including basses, minnows, perches, and sunfishes, while white heelsplitters' host fish include common carp, crappies, green sunfish, and largemouth bass (see Table 4.32). These fish species are common throughout the watershed, so lack of hosts does not seem to limit the range of these mussels. It should be noted that the presence of passage barriers in streams of the watershed may limit access of fish hosting glochidia to areas suitable

[342] *P.W. Kat, "Parasitism and Unionaceae (Bivalvia),"* Biological Review, *Volume 59, pages 189-207, 1984.*

[343] *P.W. Kat and G.M. Davis, "Molecular Genetics of Peripheral Populations of Nova Scotian Unionidae (Mollusca: Bivalvia),"* Biological Journal of the Linnean Society, *Volume 22, pages 157-185, 1984.*

[344] *This was formerly the Bureau of Endangered Resources.*

[345] *For more information, visit the Wisconsin Mussel Monitoring Program website at wiatri.net/inventory/mussels as well as their iNaturalist project at www.inaturalist.org/projects/wisconsin-mussel-monitoring-program.*

Table 4.32
Characterisitics of Mussel Species Observed in the Oak Creek Watershed

Species	Maximum Size	Habitat	Potential Host Fish Species	
			Occur in Oak Creek	Not Found in Oak Creek
Fatmucket	5 inches	Small streams to large rivers, lakes, and ponds in silt, sand and gravel	Bluegill, bluntnose minnow,[a] green sunfish, largemouth bass, pumpkin seed, rock bass,[a] sand shiner,[a] smallmouth bass, white crappie, white sucker, yellow perch	Black crappie, common shiner, tadpole madtom, warmouth, silver shiner
White Heelsplitter	8 inches	Small streams to large rivers, ponds, and lakes in mud, sand, and gravel	Common carp, gizzard shad,[a] green sunfish, largemouth bass, white crappie	Banded killifish, longnose gar, orange spotted sunfish, river redhorse, walleye

[a] *These fish species have only been found in the Oak Creek mainstem below the dam and thus cannot currently act as host fish for mussels in the upstream portion of the watershed.*

Source: D.C. Allen, B.E. Sietman, D.E. Kelner, M.C, Hove, J.E. Kurth, J.M. Davis, and D.J. Hornbach, "Early Life-History and Conservation Status of Venustaconcha ellipsiformis (Bivalia, Unionidae), in Minnesota," American Midland Naturalist, Volume 157, pages 74-91, 2007; K. Hillegass and M. Hove, "Suitable Fish Hosts for Glochidia of Three Freshwater Mussels: Strange Floater, Ellipse, and Snuffbox," Triannual Unionie Report, Volume 13, page 25, 1997; M. Hove, "Suitable Fish Hosts of the Lilliput, Toxolasma parvus," Triannual Unionid Report, Volume 8, page 9, 1995; M. Hove, R. Engelking, M. Peteler, E.M. Peterson, A.R. Kapuscinski, L.A. Sovell, and E.R. Evers, "Suitable Fish Hosts for Glochidia of Four Freshwater Mussels," Conservation and Management of Freshwater Mussels II: Proceedings of a UMRCC Symposium, 1997; M. Hove and A.R. Kapuscinski, "Ecological Relationships Between Six Rare Minnesota Mussels and Their Host Fishes," Final Report to the Minnesota Department of Natural Resources, 1998; R. Howells, "New Fish Hosts for Nine Freshwater Mussels (Bivalvia: Unionidae) in Texas," Texas Journal of Science, Volume 49, pages 255-258, 1997; R. Klocek, J. Bland, and L. Barghusen, A Field Guide to the Freshwater Mussels of Chicago Wilderness, Chicago Wilderness, 2008; R. Mulcrone, Incorporating Habitat Characteristics and Fish Hosts to Predict Freshwater Mussel (Bivalvia: Unionidae) Distributions in the Lake Erie Drainage, Southeastern Michigan, Ph.D. Dissertation, University of Michigan, 2004; S. O'Dee and G. Watters, "New or Confirmed Host Identifications for Ten Freshwater Mussels," Proceedings of the Conservation, Captive Care ,and Propagation of Freshwater Mussels Symposium, pages 77-82, 2000; F.A. Riusech and M.C. Barnhart, "Host Suitability and Utilization in Venustaconcha ellipsiformis and Venustaconcha pleasii (Bivalvia: Unionidae) from the Ozark Plateaus, Proceedings of the Conservation, Captive Care ,and Propagation of Freshwater Mussels Symposium, pages 83-91, 2000; R. Trdan, "Reproductive Biology of Lampsilis radiate siliquoidea (Pelecypoda: Unionidae)," American Midland Naturalist, Volume 106, pages 243-248, 1982; R. Trdan and W. Hoeh, "Eurytopic Host Use by Two Congeneric Species of Freshwater Mussel (Pelecypoda: Unionidae: Anodonta)," American Midland Naturalist, Volume 108, pages 381-388, 1982; E. van Snik Gray, W. Lellis, J. Cole, and C. Johnson, "Hosts of Pyganodon cataracta (Easter Floater) and Strophitus undulates (Squawfoot) from the Upper Susquehanna River Basin, Pennsylvania," Triannual Unionid Report, Volume 18, page 6, 1999; G. T. Watters, "An Annotated Bibliography of the Reproduction and Propagation of the Unionoidea (Primarily of North America)." Ohio Biological Survey Miscellaneous Contributions No. 1, 1994; G.T. Watters, A Guide to the Freshwater Mussels of Ohio, Ohio Department of Natural Resources, 1995; G.T. Watters, S. O'Dee, and S. Chordas, "New Potential hosts for: Strophitus undulatus-Ohio River Drainage; Strophitus undulates-Susquehanna River Drainage; Alasimidonta undulate- Susquehanna River Drainage; Actinonaias ligamentina-Ohio River Drainage; and Lasmigona costata-Ohio River Drainage," Triannual Unionid Report, Volume 15, pages 27-29, 1998; and J.L. Weiss and J.B. Layzer, "Infestations of Glochidia on Fishes in the Barren River, Kentucky," American Malacological Bulletin, Volume 11, pages 153-159, 1995.

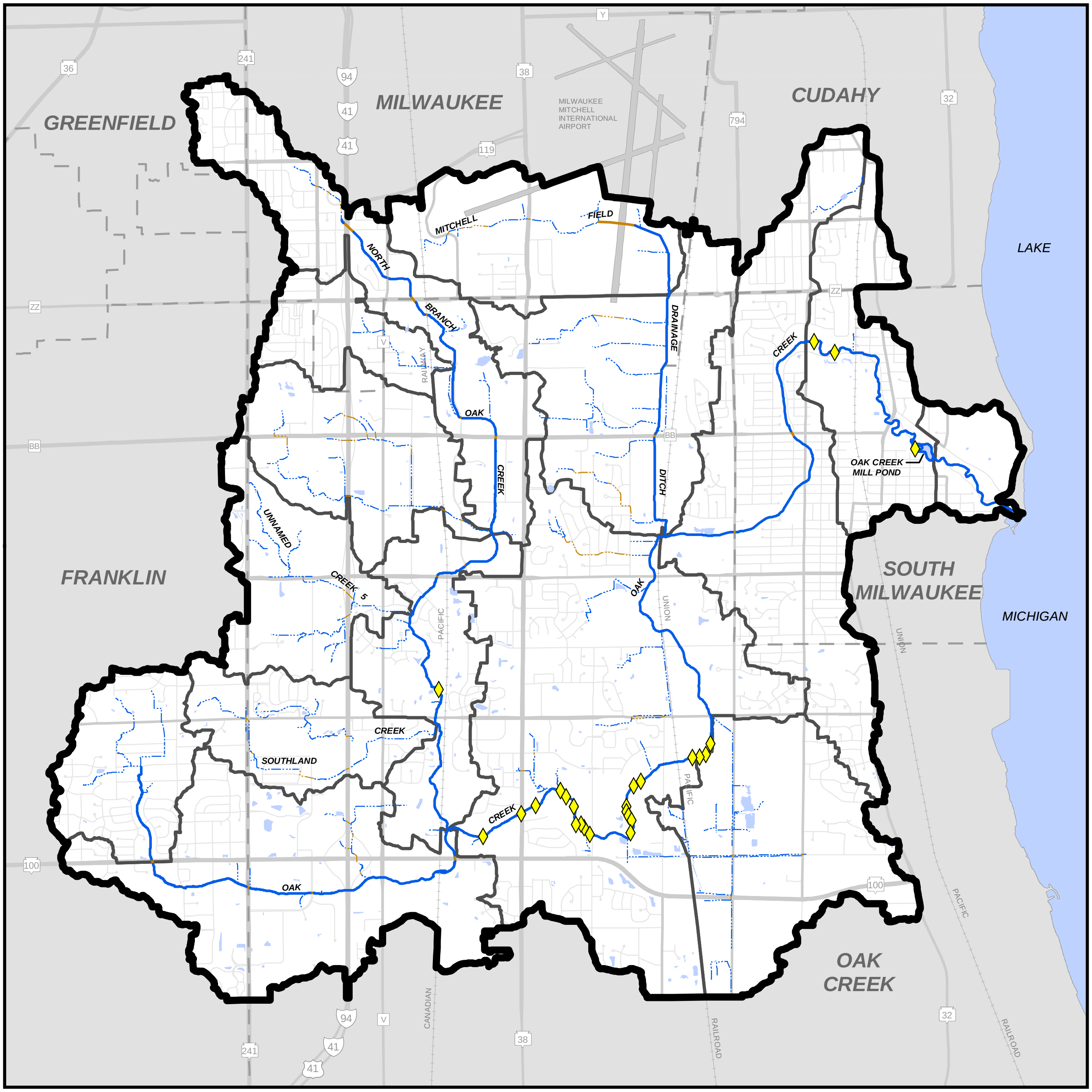
for mussel colonization, potentially limiting the range of these mussels. Although mussels are generally intolerant of environmental degradation, these species are among the mussels that are more tolerant of pollutants and poor water quality. However, the presence of mussels in the watershed is a positive indicator for water quality. Improving water quality and increasing host fish diversity can help enhance the native mussel community within Oak Creek.

<u>Other Wildlife</u>

Given the variety of habitat types within the watershed, it is no surprise that it contains a diversity of breeding and migratory wildlife species. Within the last 10 years, Milwaukee County Parks Natural Areas staff has conducted numerous wildlife surveys within the watershed including snake cover board surveys, breeding and migratory bird surveys (transects, point counts, nocturnal, and constrained area searches), ephemeral wetland surveys (funnel traps and visual encounter surveys), nest box surveys, turtle trapping and basking surveys, camera trapping surveys, and deer browse surveys.

Results from the aforementioned surveys can tell a great deal about the wildlife within the Oak Creek watershed and has allowed Milwaukee County Parks staff to make well informed land management decisions. Survey results indicate that there are 80 confirmed breeding bird species within the watershed. A number of these species, such as the sedge wren (*Cistothorus stellaris*), marsh wren (*Cistothorus palustris*), Virginia

Map 4.36
Mussels Observed During Stream Surveys Within the Oak Creek Watershed: 2016-2017



MUSSEL LOCATION

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

0 0.25 0.5 1 Mile

Note: Map includes locations where live and relic mussels were found.

Source: SEWRPC

Figure 4.118
Examples of Mussels Observed During 2015-2016 Stream Surveys in the Oak Creek Watershed

WHITE HEELSPLITTER *Lasmigona complanata*	FATMUCKET *Lampsilis powellii*
	

Note: Wisconsin Department of Natural Resource conservation biologists taxonomically identified these mussel specimens.

Source: SEWRPC

rail (*Rallus limicola*), veery (*Catharus fuscescens*), grasshopper sparrow (*Ammodramus savannarum*), red-headed woodpecker (*Melanerpes erythrocephalus*), and wood thrush (*Hylocichla mustelina*) are uncommon breeders across the greater Milwaukee County area, and some are unique only to the Oak Creek watershed. In addition, there have been 172 bird species documented within the watershed to date,[346] of which 34 can be considered year-round resident species and 138 are considered migratory species that only seasonally inhabit the watershed.

The watershed's grassland plant communities are known to contain populations of Butler's gartersnake (*Thamnophis butleri*), a state listed species of special concern, and common gartersnake (*Thamnophis sirtalis*) a species considered of local concern by Milwaukee County Parks. Habitat also exists for several species of snakes such as the northern brown snake (*Storeria dekayi*) and the northern red-bellied snake (*Storeria occipitomaculata*), both of which are also considered of local concern by Milwaukee County Parks. Though these species have not been documented in the watershed, they have been documented in Milwaukee County Parks natural areas adjacent to the Oak Creek watershed.

Recent Milwaukee County Parks ephemeral wetland surveys have confirmed the presence of breeding blue-spotted salamanders (*Ambystoma laterale*), and tiger salamanders (*Ambystoma tigrinum*), as well as boreal chorus frogs (*Pseudacris maculate*), northern leopard frogs (*Lithobates pipiens*), American bullfrogs (*Lithobates catesbeianus*), northern green frogs (*Rana clamitans melanota*), wood frogs (*Lithobates sylvaticus*), white river crayfish (*Procambarus acutus*), calico crayfish (*Orconectes immunis*), digger crayfish (*Fallicambarus fodiens*), and prairie crayfish (*Procambarus gracilis*), all of which are either considered of local or State-wide concern. Wetland surveys have also documented the presence of central mudminnows (*Umbra limi*), snapping turtles (*Chelydra serpentina*), and painted turtles (*Chrysemys picta*), as well as red-eared sliders (*Trachemys scripta elegans*), and introduced species.

Limited data is available for mammals within the Oak Creek watershed. Milwaukee County Parks Natural Areas staff have observed 18 species of mammals during their land management activities, but no formal surveys have been conducted. Potential habitat does exist for an additional 19 mammal species within the watershed.

Further surveys would be necessary for birds, herptiles, and especially mammals and invertebrates to determine the full extent of breeding and migratory wildlife populations utilizing the watershed.

Additional information on the occurrence and habitat of critical species is described Section 4.2 under "Habitat Quality Conditions."

[346] *Cornell Lab of Ornithology eBird Project.*

Exotic and Invasive Species

A noticeable feature of the upland areas, waterbodies, and riparian areas on the post-European-settlement landscape of Southeastern Wisconsin is the large number of nonnative species of plants and animals that have become established and capable of reproducing in local habitats. Where their introduction has caused, or is likely to cause, economic or environmental harm or harm to human health, exotic species may be considered invasive. Typically, populations of exotic invasive species can grow rapidly, due to both the high reproductive capacities of these organisms and the absence of predators, parasites, pathogens, and competitors in their new habitat. Once established, these species can rarely be eliminated. In addition, many of these species are capable of readily dispersing to other nearby areas. In many cases, this dispersal is aided by direct or indirect human intervention.

The presence of invasive species is an important issue in the Oak Creek watershed and management practices intended to prevent further establishment and spread of invasive species, particularly when trying to restore or preserve native wetland and upland community types will be presented later in this report. Invasive plants 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. There are 97 known invasive plant species found in waterbodies, wetlands, riparian areas, and uplands of the Oak Creek watershed (see Table 4.33).[347]

Aquatic invasive species pose threats to the integrity of watersheds in Wisconsin. Several aquatic invasive species are present in the Oak Creek watershed including plant species such as curly-leaf pondweed (*Potamogeton crispus*), Eurasian water milfoil (*Myriophyllum spicatum*), and flowering rush (*Butomus umbellatus)* (see Table 4.33 for full list); and animal species such as common carp (*Cyprinus carpio*), round goby (*Neogobius melanostomus)*, rusty crayfish (*Orconectes rusticus)*, and Chinese mystery snail (*Cipangopaludina chinensis)*. Eurasian water milfoil was observed by Commission field staff growing in thick beds at one location within Oak Creek's mainstem. Rusty crayfish were also commonly observed by field staff throughout the mainstem of Oak Creek. Common carp were observed assembling in large numbers within the Mill Pond during their spawning season in late spring and early summer, greatly increasing the turbidity of the water within the Mill Pond and flowing over the Mill Pond dam.

Invasive plant and animal species pose threats to the integrity of terrestrial, semi-aquatic, and aquatic components of riparian areas, wetlands, and upland communities in the Oak Creek watershed as well. Invasive plants that are commonly observed in wetland and/or riparian areas within the watershed include common burdock (*Arctium minus),* common and glossy buckthorn (*Rhamnus cathartica and Franula alnus*), garlic mustard (*Alliaria officinalis*), reed canary grass (*Phalaris arundinacea)*, purple loosestrife (*Lythrum salicaria*), narrow-leaf cattail (*Typha angustifolia*), and common reed (*Phragmites australis*). Invasive species like purple loosestrife and phragmites tend to colonize disturbed areas such as roadside and highway ditches and then expand into nearby areas. The emerald ash borer, an invasive insect species, is present throughout the Oak Creek watershed and has devastated the ash tree population within the riparian lands and throughout the watershed (see riparian buffers section above for more details).

Milwaukee County Parks Department Invasive Plant Surveys

The only systematic surveys for invasive plant species conducted within the Oak Creek watershed in recent years have been conducted by Milwaukee County Park's Natural Areas staff. Since 2009, Milwaukee County Park's staff has conducted surveys of invasive plant species in County parks and County-owned open space lands. These surveys mapped locations of invasive plant species populations. The plant species mapped in these surveys include species considered prohibited or restricted under the classification established pursuant to Chapter NR 40, "Invasive Species Identification, Classification, and Control," of the *Wisconsin Administrative Code*, as well as species that are regarded as invasive, but not currently classified as prohibited or restricted.

[347] *Milwaukee County Parks surveys.*

Table 4.33
Invasive Plant Species Found in the Oak Creek Watershed

Common Name	Scientific Name	Classification
Amur Cork Tree	*Plellodendron amurense*	NR 40-Restricted
Amur Maple	*Acer ginnala*	NR 40-Restricted
Amur Honeysuckle	*Lonicera maackii*	NR 40-Restricted
Autumn Olive	*Elaeagnus umbellata*	NR 40-Restricted
Bird's-Foot Trefoil	*Lotus corniculatus*	Non-restricted
Bishop's Goutweed	*Aegopodium podagraria*	NR 40-Restricted
Black Locust	*Robinia pseudoacacia*	NR 40-Restricted
Bouncing Bet	*Saponaria officinalis*	NA
Bull Thistle	*Cirsium vulgare*	NA
Callery Pear	*Pyrus calleryana*	Non-restricted
Canada Thistle	*Cirsium arvense*	NR 40-Restricted
Cattail Hybrid	*Typha x glauca*	NR 40-Restricted
Cheat Grass	*Bromus tectorum*	Caution
Colt's Foot	*Tussilago farfara*	NR 40-Prohibited
Common Barberry	*Berberis vulgaris*	NR 40-Prohibited
Common Buckthorn	*Rhamnus cathartica*	NR 40-Restricted
Common Burdock	*Arctium minus*	NA
Common Hound's Tongue	*Cynoglossum officinale*	NR 40-Restricted
Common Reed	*Phragmites australis*	NR 40-Restricted
Common St. John's-Wort	*Hypericum perforatum*	Non-restricted
Common Teasel	*Dipsacus fullonum*	NR 40-Restricted
Creeping Bellflower	*Campanula rapunculoides*	NR 40-Restricted
Creeping Charlie	*Glechoma hederacea*	Caution
Crown Vetch	*Securigera varia*	NR 40-Restricted
Curly-Leaf Pondweed	*Potamogeton crispus*	NR 40-Restricted
Cut-Leaved Teasel	*Dipsacus laciniatus*	NR 40-Restricted
Cypress Spurge	*Euphorbia cyparissias*	NR 40-Restricted
Dame's Rocket	*Hesperis matronalis*	NR 40-Restricted
Devil's Walking Stick	*Aralia spinosa*	NA
English Hawthorn	*Crataegus monogyna*	NA
European Privet	*Ligustrum vulgare*	Caution
Eurasian Water-Milfoil	*Myriophyllum spicatum*	NR 40-Restricted
European Spindle Tree	*Euonymus europeaus*	NA
European Black Alder	*Alnus glutinosa*	NR 40-Restricted
Everlasting Pea	*Lathyrus latifolius*	NA
Field Bindweed	*Convolvulus arvensis*	Non-restricted
Field Thistle	*Cirsium discolor*	NA
Flowering Rush	*Butomus umbellatus*	NR 40-Restricted
Flower-of-an-Hour	*Hibiscus trionum*	NA
Forget-Me-Not	*Myosotis scorpioides*	NR 40-Restricted
Garden Valerian	*Valeriana officinalis*	NR 40-Restricted
Garden Yellow Loosestrife	*Lysimachia vulgaris*	NR 40-Restricted
Garlic Mustard	*Alliaria officinalis*	NR 40-Restricted
Glossy Buckthorn	*Franula alnus*	NR 40-Restricted
Greater Celandine	*Cheliodonium majus*	NR 40-Restricted
Grecian Foxglove	*Digitalis lanata*	NR 40-Prohibited
Helleborine Orchid	*Epipactis helleborine*	NR 40-Restricted
Hybrid Honeysuckle	*Lonicera x bella*	NR 40-Restricted
Japanese Barberry	*Berberis thunbergii*	NR 40-Restricted
Japanese Hedge Parsley	*Torilis japonica*	NR 40-Restricted
Japanese Honeysuckle	*Lonicera japonica*	NR 40-Prohibited
Japanese Knotweed	*Fallopia japonica*	NR 40-Restricted
Japanese Plume Grass	*Miscanthus sacchariflorus*	NA
Japanese Spiraea	*Spiraea bumalda*	NA

Table continued on next page.

Table 4.33 (Continued)

Common Name	Scientific Name	Classification
Japanese Tree Lilac	*Syringa reticulata*	NA
Leafy Spurge	*Euphorbia esula*	NR 40-Restricted
Lesser Celandine	*Rannunculus ficaria*	NR 40-Prohibited
Lily-of-The-Valley	*Convallaria majalis*	Non-restricted
Little Leaved Linden	*Tilia cordata*	NA
Lyme Grass	*Leymus arenarius*	NR 40-Restricted
Moneywort	*Lysimachia nuummularia*	NR 40-Restricted
Morrow's Honeysuckle	*Lonicera morrowii*	NR 40-Restricted
Multiflora Rosa	*Rosa multiflora*	NR 40-Restricted
Narrow-Leaf Cattail	*Typha angustifolia*	NR 40-Restricted
Nodding Thistle	*Carduus nutans*	NR 40-Restricted
Norway Maple	*Acer platanoides*	Caution
Orange Daylily	*Hemerocallis fulva*	Caution
Oriental Bittersweet	*Celastrus orbiculatus*	NR 40-Restricted
Poison Hemlock	*Conium maculatum*	NR 40-Restricted
Porcelain Berry	*Ampelopsis brevipedunula*	NR 40-Prohibited
Purple Loosestrife	*Lythrum salicaria*	NR 40-Restricted
Queen Anne's Lace	*Daucus carota*	Non-restricted
Reed Canary Grass	*Phalaris arundinacea*	Non-restricted
Running Strawberry	*Euonymus obovatus*	NA
Russian Olive	*Elaeagnus angustifolia*	NR 40-Restricted
Scarlet Pimpernel	*Anagallis arvensis*	NR 40-Restricted
Scotch Pine	*Pinus sylverstris*	Non-restricted
Siberian Elm	*Ulmus pumila*	NR 40-Restricted
Siberian Squill	*Scilla sibirica*	NA
Smooth Brome	*Bromus inermis*	Non-restricted
Spotted Knapweed	*Centaurea stoebe*	NR 40-Restricted
Tall Coreopsis	*Coreopsis tripterus*	NA
Tall Manna Grass	*Glyceria maxima*	NR 40-Restricted
Tansy	*Tanacetum vulgare*	NR 40-Restricted
Tartarian Honeysuckle	*Lonicera tatarica*	NR 40-Restricted
Tree of Heaven	*Ailanthus altissima*	NR 40-Restricted
Tuberous Pea	*Lathyrus tuberosus*	NA
Wayfaring Tree	*Viburnum lantana*	NA
White Mulberry	*Morus alba*	NR 40-Restricted
White Poplar	*Populus alba*	NR 40-Restricted
White Sweetclover	*Melilotus albus*	Non-restricted
Wild Chervil	*Anthriscus sylvestris*	NR 40-Prohibited
Wild Parsnip	*Pastinaca sativa*	NR 40-Restricted
Winged Burning-Bush	*Euonymus alatus*	NR 40-Restricted
Wormwood	*Artemesia absinthium*	NR 40-Restricted
Yellow Iris	*Iris pseudacorus*	NR 40-Restricted
Yellow Sweet-Clover	*Melilotus officinalis*	Non-restricted

Note: Caution indicates that the species cannot be categorized as prohibited, restricted, or non-restricted because it is not currently found in the state, it appears to be invasive only regionally, or its potential for invasiveness in Wisconsin is unknown.

Non-restricted indicates that the species may have some beneficial uses as well as negative impacts on the environment, but is already integrated into Wisconsin's ecosystems so that control or eradication is not practical or feasible.

NR 40-Prohibited indicates a species that, with the exception of small pioneer stands of terrestrial plants and aquatic species that are isolated to a specific watershed in the State, is not currently found in Wisconsin, but which, if introduced into the State, is likely to survive and spread, potentially causing significant environmental or economic harm or harm to human health.

NR 40-Restricted indicates a species that is already established in the State and causes or has the potential to cause significant environmental or economic harm or harm to human health.

NA indicates that the species is not classified by the WDNR as invasive, but is showing invasive tendencies in the Milwaukee County park system.

Source: Milwaukee County Department of Parks, Recreation and Culture

The most recent surveys that were conducted by Milwaukee County Parks Natural Areas staff from 2016 through 2019 in the Oak Creek watershed occurred in the following County-owned parks and open space lands: Barloga Woods, Copernicus Park, Cudahy Nature Preserve, Cudahy Park, Falk Park, Grant Park, Maitland Park, Oak Creek Parkway, Rawson Park, and Riverton Meadows. A total of 1,629 infestations of invasive plant species have been located and mapped within the Oak Creek watershed as shown on Maps 4.37 through 4.42.

Map 4.37 and Map 4.38 shows locations of observed infestations of herbaceous (i.e., non-woody plants) invasive species. There was a total of 255 observed infestations of 24 herbaceous invasive species as shown on Map 4.37. Because they were so numerous, infestations of two additional herbaceous invasive species—common burdock and garlic mustard, totaling 178 and 193 observed infestations, respectively—are shown separately on Map 4.38 (the number of observed infestations is shown in parentheses next to each species on each map). Other commonly observed infestations included Canada thistle, Dame's rocket, purple loosestrife, and reed canary grass (see Figure 4.119).

Maps 4.39 through 4.42 show observed infestations of the 20 woody invasive plant species found in the Oak Creek watershed. Map 4.39 shows 337 infestations of 16 woody species were found distributed among 11 park locations. Because they were so abundant, infestations of common buckthorn and European privet are shown separately on Map 4.40; infestations of honeysuckle are shown on Map 4.41,[348] and infestations of Japanese barberry are shown on Map 4.42. There was a total of 249 observed infestations of common buckthorn, 94 of European privet, 216 of honeysuckle species, and 91 of Japanese barberry. Other commonly observed woody invasive species infestations in Milwaukee County-owned lands within the Oak Creek watershed included European spindle tree, multiflora rose, and wayfaring tree (see Figure 4.120).

Table 4.34 indicates the Milwaukee County-owned parks and open spaces where each of the 26 species of invasive herbaceous plants and 20 species of invasive woody plants were observed. Most parks were observed to contain infestations of several invasive plant species. Falk Park and Oak Creek Parkway had the most individual invasive species observed with 24 and 38 observed species, respectively. In addition, Copernicus Park, Cudahy Nature Preserve, and Rawson Park all had more than 10 individual invasive species observed. Honeysuckle was found at nine of the 11 parks surveyed; while common burdock, garlic mustard, and common buckthorn were found at eight of the 11 parks surveyed.

Milwaukee County Parks Department Natural Areas staff have developed ecological restoration and management plans for many of the County-owned parks and open space lands within the Oak Creek watershed. These management plans aim to maintain and increase native plant and wildlife diversity and implemented actions have helped reduce the impact of invasive species within County-owned lands. The management plans are the focus of invasive species management strategies and recommendations and are discussed in greater detail in Chapter 6 of this Report.

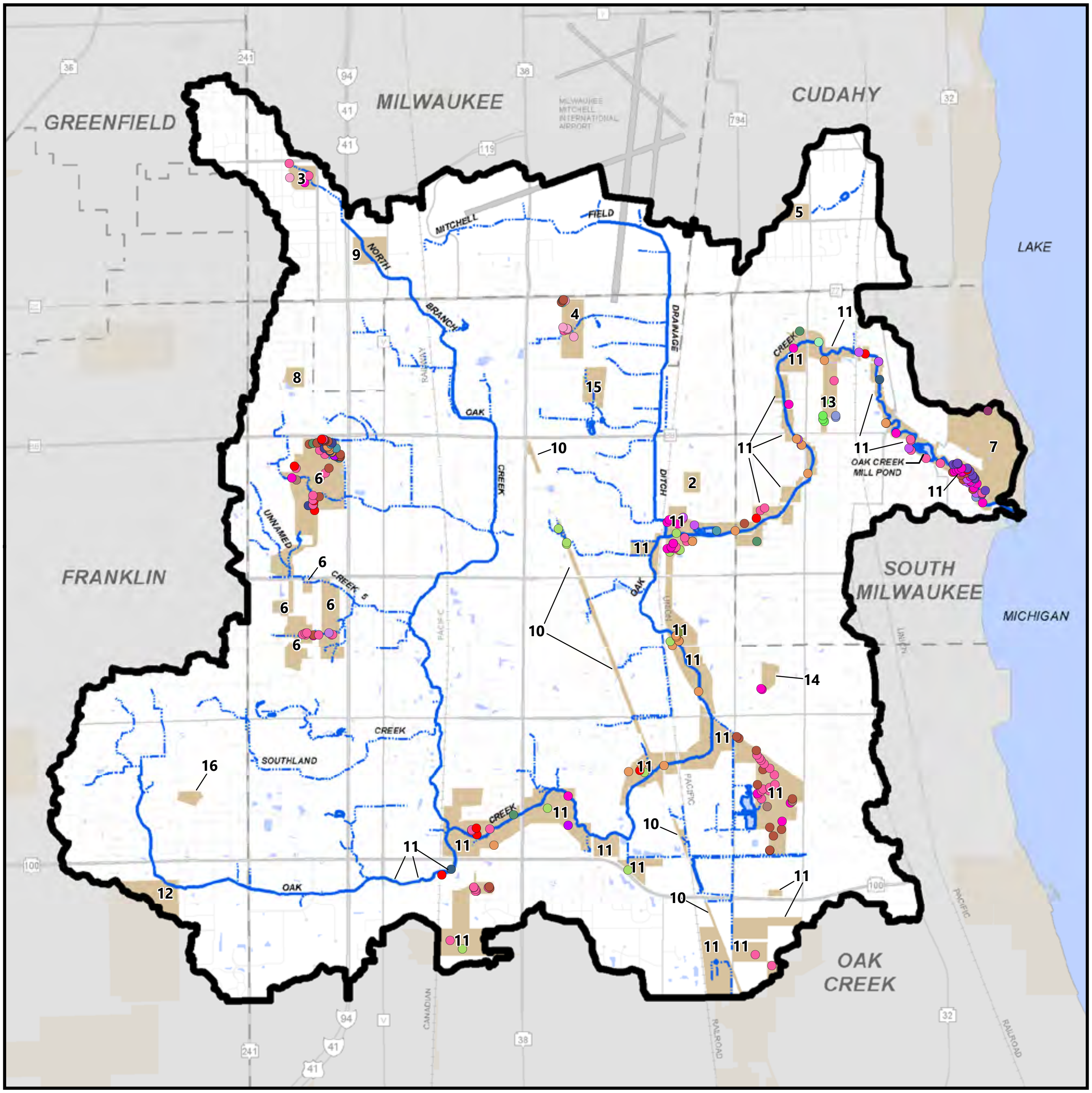
Although there are no systematic invasive species surveys that have been conducted within the Oak Creek watershed outside of County-owned parks and open space lands, the prevalence of invasive species observed within these surveyed areas combined with a lack of management suggest that many of these species are likely present in other areas of the watershed.

Biological Conditions Synthesis

The Oak Creek watershed currently contains a poor to fair fishery and poor to fair macroinvertebrate communities, the quality of which are limited by poor water quality, habitat alteration through stream channelization, and fragmentation by passage barriers. The fish community above the Mill Pond dam contains relatively few species, with few or no top carnivores, and is largely dominated by tolerant fishes. The North Branch will likely continue to be a poor-quality fishery as re-introduction of fish species from the mainstem is limited by a major passage barrier. In addition, the passage barrier posed by the Mill Pond Dam limits the quality of the entire watershed fishery by inhibiting fish migration from Lake Michigan into the watershed. Temperature increases from climate change will further threaten coolwater species within

[348] *It should be noted that four species invasive honeysuckle, including Amur honeysuckle, Hybrid honeysuckle, Morrow's honeysuckle, and Tartarian honeysuckle are all represented under the invasive honeysuckle symbology on Map 4.41 and* Table 4.34*.*

Map 4.37
Observed Locations of Herbaceous Invasive Plant Species Within Milwaukee County Owned Lands Located in the Oak Creek Watershed: 2016-2019



OBSERVED LOCATIONS OF HERBACEOUS INVASIVE PLANTS

- BIRDSFOOT TREFOIL (6)
- CREEPING BELLFLOWER (12)
- CYPRESS SPURGE (1)
- CANADA THISTLE (38)
- CATTAIL SP. (1)
- CROWN VETCH (8)
- DEADLY NIGHTSHADE (6)
- DAMES ROCKET (33)
- POISON HEMLOCK (1)
- HELLEBORINE ORCHID (1)
- JAPANESE HEDGE PARSLEY (1)
- JAPANESE KNOTWEED (5)
- LESSER CELANDINE (1)
- LILY OF THE VALLEY (4)
- ORIENTAL DAY LILY (4)
- PHRAGMITES (3)
- PURPLE LOOSESTRIFE (25)
- QUEEN ANNE'S LACE (2)
- REED CANARY GRASS (62)
- TEASEL (12)
- WILD CHERVIL (12)
- WILD PARSNIP (2)
- WHITE SWEET CLOVER (13)
- YELLOW SWEET CLOVER (2)

11 COUNTY-OWNED SITE
OAK CREEK WATERSHED BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
SURFACE WATER

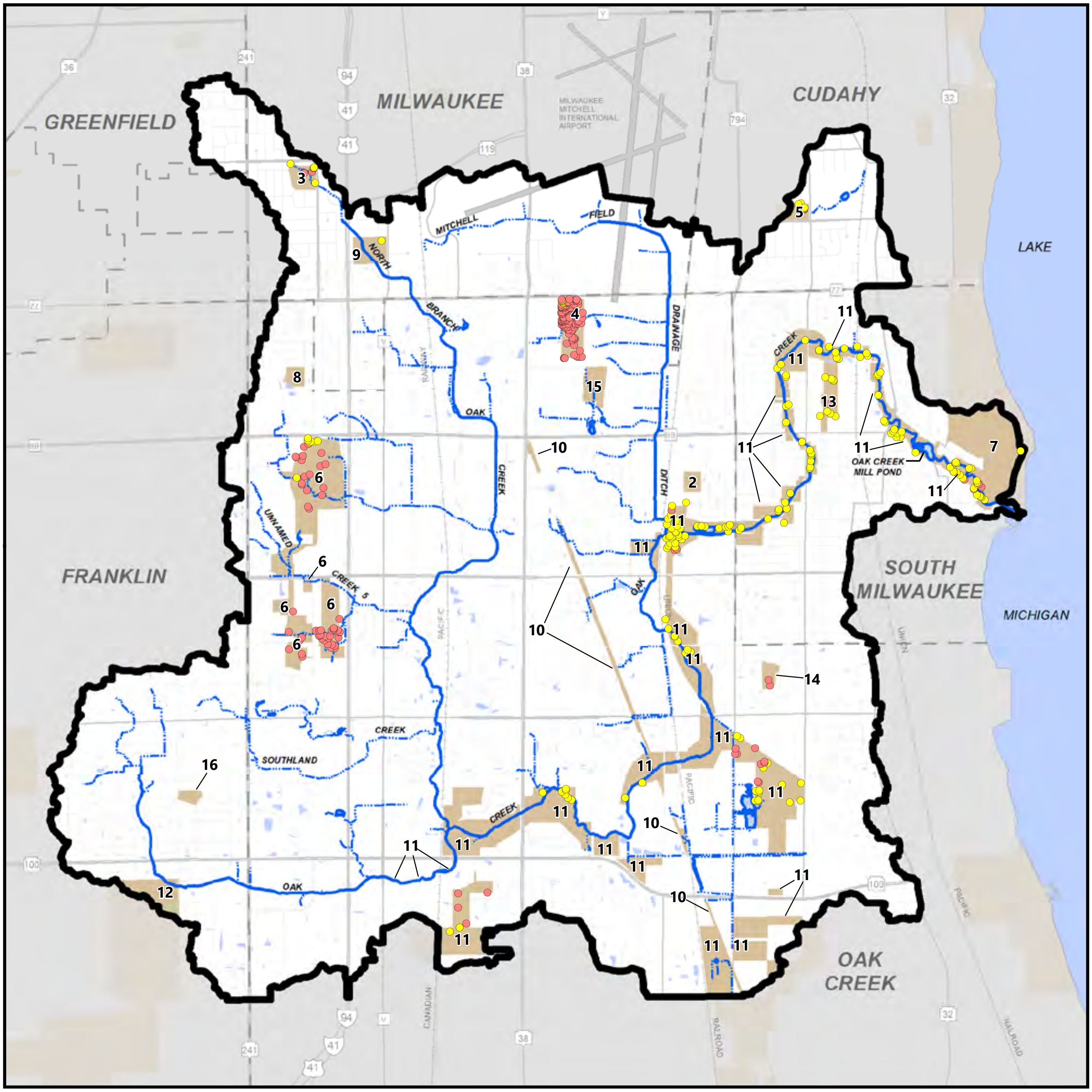
Note: See Table 4.42 for site names and details.

N

0 0.25 0.5 1 Mile

Source: Milwaukee County Parks Department and SEWRPC

Map 4.38
Observed Locations of Common Burdock and Garlic Mustard Within Milwaukee County Owned Lands Located in the Oak Creek Watershed: 2016-2019



OBSERVED LOCATIONS OF COMMON BURDOCK (178)

OBSERVED LOCATIONS OF GARLIC MUSTARD (193)

11 COUNTY-OWNED SITE

OAK CREEK WATERSHED BOUNDARY

PERENNIAL STREAM

INTERMITTENT STREAM

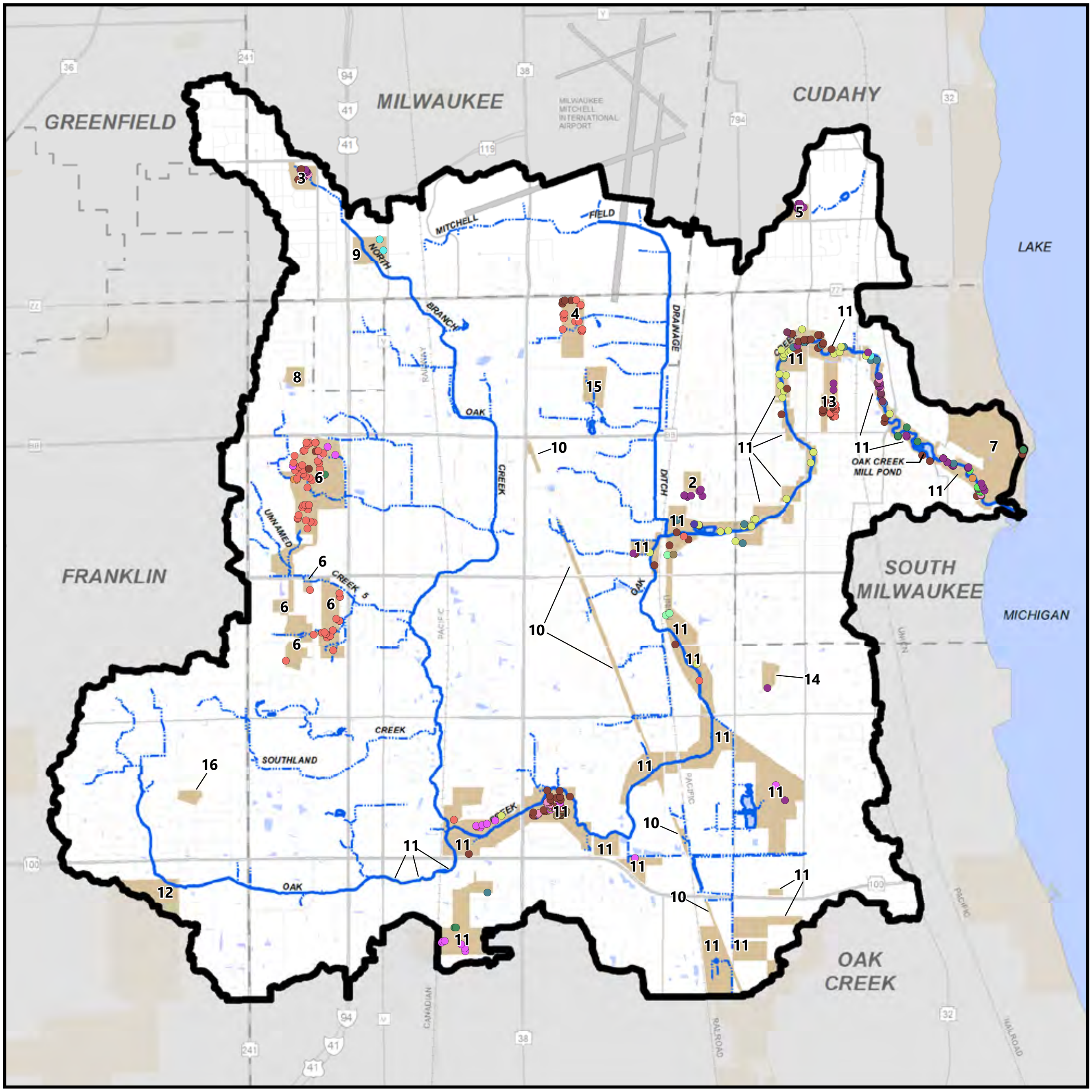
SURFACE WATER

Note: See Table 4.42 for site names and details.

0 0.25 0.5 1 Mile

Source: Milwaukee County Parks Department and SEWRPC

Map 4.39
Observed Locations of Woody Invasive Plant Species Within Milwaukee County Owned Lands Located in the Oak Creek Watershed: 2016-2019



OBSERVED LOCATIONS OF WOODY INVASIVE PLANTS

- AMUR MAPLE (7)
- AUTUMN OLIVE (22)
- BLACK ALDER (5)
- BLACK LOCUST (1)
- CALLERY PEAR (3)
- EUROPEAN MOUNTAIN ASH (5)
- EUROPEAN SPINDLE TREE (31)
- GLOSSY BUCKTHORN (9)
- LITTLE LEAF LINDEN (5)
- MULTIFLORA ROSE (78)
- NORWAY MAPLE (16)
- ORIENTAL BITTERSWEET (12)
- PORCELAIN BERRY (3)
- WINGED EUONYMUS (56)
- WHITE POPLAR (4)
- WAYFARING TREE (80)

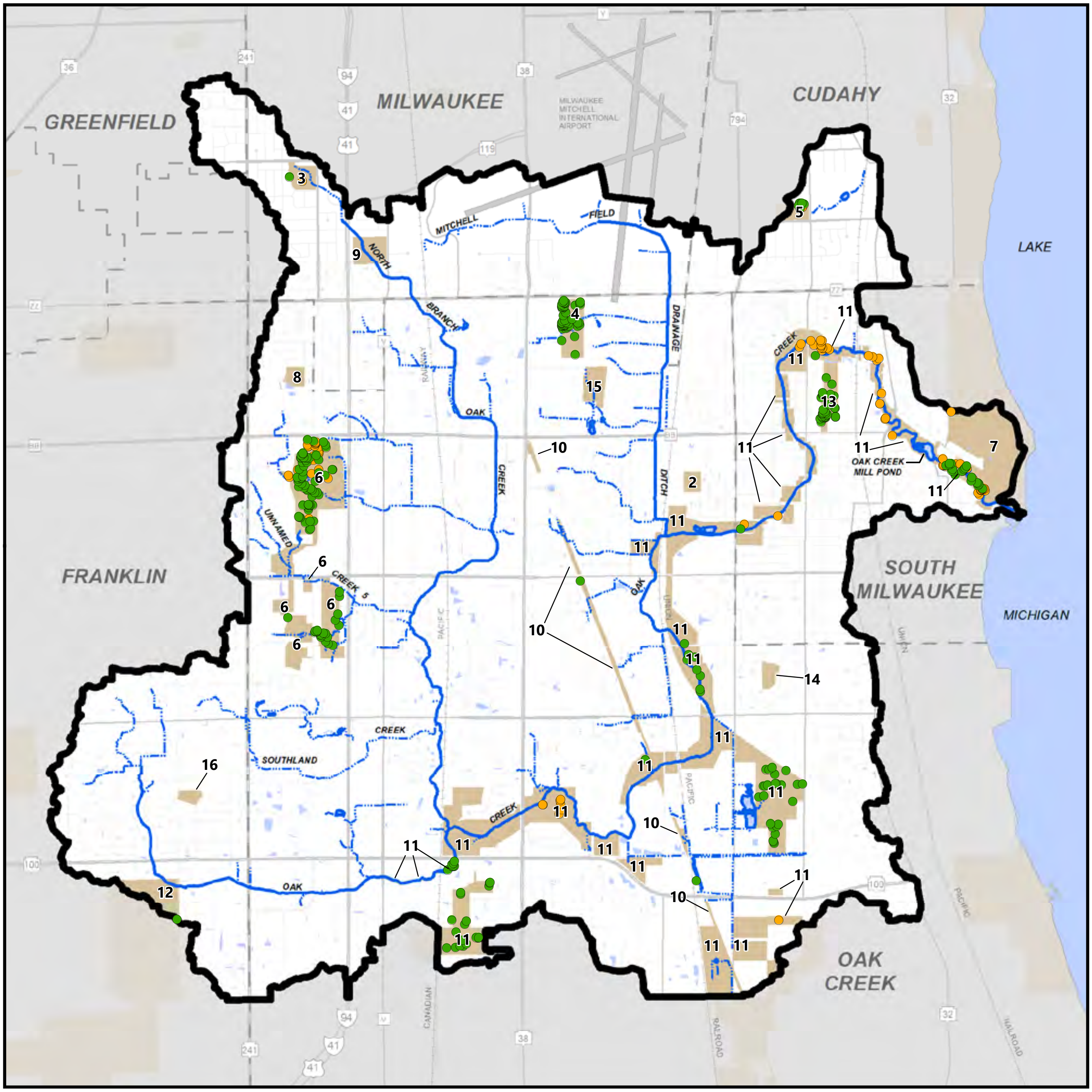
11 COUNTY-OWNED SITE
OAK CREEK WATERSHED BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
SURFACE WATER

Note: See Table 4.42 for site names and details.

0 0.25 0.5 1 Mile

Source: Milwaukee County Parks Department and SEWRPC

Map 4.40
Observed Locations of Common Buckthorn and European Privet Within Milwaukee County Owned Lands Located in the Oak Creek Watershed: 2016-2019



- OBSERVED LOCATIONS OF COMMON BUCKTHORN (249)
- OBSERVED LOCATIONS OF EUROPEAN PRIVET (94)

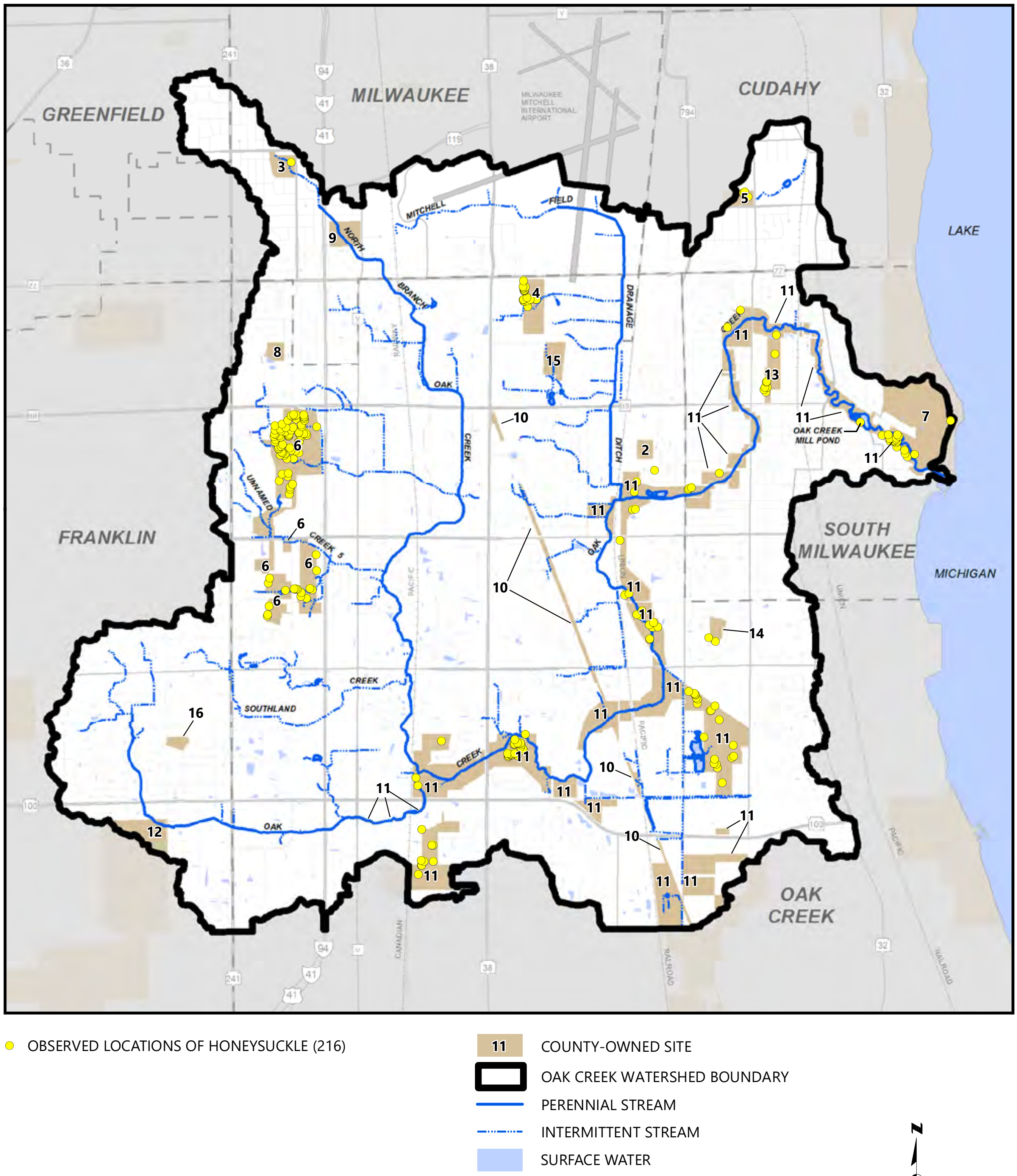
11 COUNTY-OWNED SITE
OAK CREEK WATERSHED BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
SURFACE WATER

Note: See Table 4.42 for site names and details.

0 0.25 0.5 1 Mile

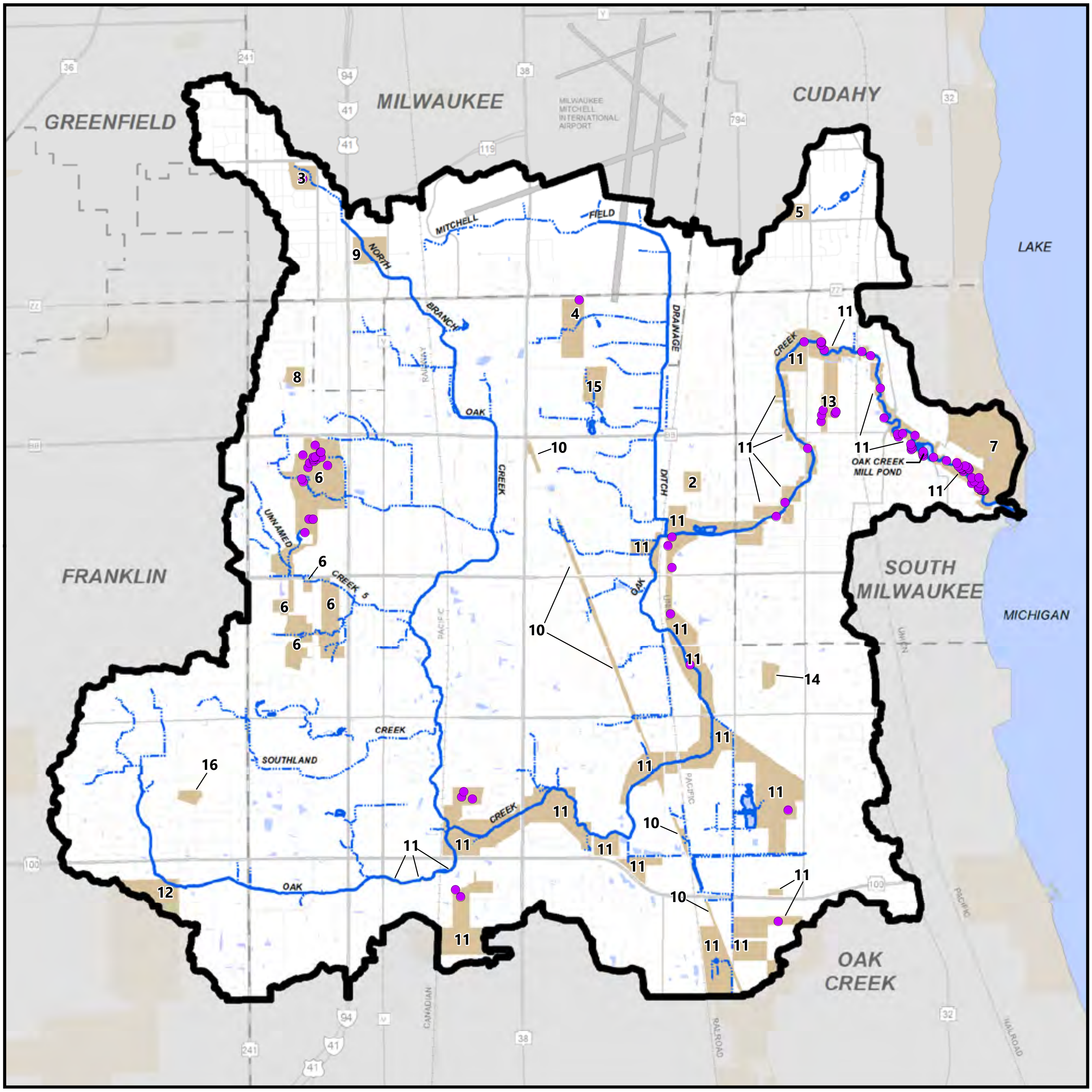
Source: Milwaukee County Parks Department and SEWRPC

Map 4.41
Observed Locations of Honeysuckle Within Milwaukee County Owned Lands Located in the Oak Creek Watershed: 2016-2019



Source: Milwaukee County Parks Department and SEWRPC

Map 4.42
Observed Locations of Japanese Barberry Within Milwaukee County Owned Lands Located in the Oak Creek Watershed: 2016-2019



● OBSERVED LOCATIONS OF JAPANESE BARBERRY (91)

11 COUNTY-OWNED SITE

OAK CREEK WATERSHED BOUNDARY

PERENNIAL STREAM

INTERMITTENT STREAM

SURFACE WATER

Note: See Table 4.42 for site names and details.

Source: Milwaukee County Parks Department and SEWRPC

Figure 4.119
Common Invasive Herbaceous Plant Species Found Within Milwaukee County Owned Lands in the Oak Creek Watershed

CANADA THISTLE
Cirsium arvense

COMMON BURDOCK
Arctium minus

DAME'S ROCKET
Hesperis matronalis

GARLIC MUSTARD
Alliaria officinalis

PURPLE LOOSESTRIFE
Lythrum salicaria

REED CANARY GRASS
Phalaris arundinacea

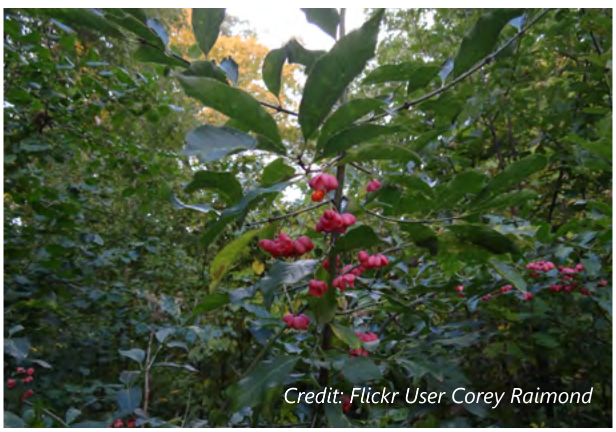
Source: Individual cited photographers, Milwaukee County Parks Department, WDNR, and SEWRPC

Figure 4.120
Common Invasive Woody Plant Species Found Within Milwaukee County Owned Lands in the Oak Creek Watershed

COMMON BUCKTHORN
Rhamnus cathartica

EUROPEAN PRIVET
Ligustrum vulgare

EUROPEAN SPINDLE TREE
Euonymus europeaus



JAPANESE BARBERRY
Berberis thunbergii

MULTIFLORA ROSA
Rosa multiflora

WAYFARING TREE
Viburnum lantana

Figure continued on next page.

Figure 4.120 (Continued)

AMUR HONEYSUCKLE
Lonicera maackii

HYBRID HONEYSUCKLE
Lonicera x bella

MORROW'S HONEYSUCKLE
Lonicera morrowii

TARTARIAN HONEYSUCKLE
Lonicera tatarica

Source: Individual cited photographers, Milwaukee County Parks Department, WDNR, and SEWRPC

the watershed, particularly with the potential decline in shading through loss of ash tree canopy cover. The macroinvertebrate community has largely been species-poor and dominated by tolerant taxa, particularly in the North Branch and Mitchell Field Drainage Ditch. However, the reemergence of the intolerant Iowa darter, higher species richness and HBI ratings of macroinvertebrate communities, and the observation of living mussels indicates that conditions have recently improved at least within a portion of the Oak Creek mainstem. Efforts to improve water quality, restore instream habitat (including reduction of instream flashiness), remove or reduce passage barriers, control and eradicate invasive species, and enhance riparian buffers can greatly improve biological conditions within waterbodies of the watershed.

Terrestrial and wetland areas in the watershed provide habitat that supports a variety of plant and animal species. Animals that have been reported include invertebrates, amphibians, reptiles, breeding and migratory birds, and mammals. These include six endangered and five threatened species and 22 species of special concern. Plants reported as being present in the watershed include three endangered and one threatened species and five species of special concern. The diversity of terrestrial and wetland organisms that is present is threatened by loss of habitat due to development and other causes and degradation of habitat caused by the presence and proliferation of invasive species. Efforts to protect, preserve, and restore terrestrial and wetland habitat can improve biological conditions within the terrestrial and wetland areas of the watershed.

Table 4.34
Infestations of Invasive Plant Species in Milwaukee County Owned Lands Located within the Oak Creek Watershed: 2016-2019

Species	Barloga Woods	Copernicus Park	Cudahy Nature Preserve	Cudahy Park	Falk Park	Grant Park[a]	Maitland Park	Oakwood Park[a]	Oak Creek Parkway	Rawson Park	Riverton Meadows	Count
Herbaceous Plants												
Birdsfoot Trefoil					X				X			2
Common Burdock		X	X	X	X	X	X		X	X		8
Creeping Bellflower									X			1
Cypress Spurge					X							1
Canada Thistle	X		X		X				X			4
Cattail Spp.					X							1
Crown Vetch					X							1
Deadly Nightshade		X	X									2
Dames Rocket		X			X				X		X	4
Garlic Mustard	X	X	X	X	X				X	X	X	8
Poison Hemlock						X						1
Helleborine Orchid									X			1
Japanese Hedge Parsley									X			1
Japanese Knotweed									X	X		2
Lesser Celandine	X											1
Lily of the Valley										X		1
Oriental Day Lily					X				X			2
Phragmites					X				X			2
Purple Loosestrife					X				X			2
Queen Anne's Lace			X									1
Reed Canary Grass	X	X	X		X				X	X		6
Teasel									X			1
Wild Chervil									X			1
Wild Parsnip									X			1
White Sweet Clover					X				X			2
Yellow Sweet Clover					X				X			2
Woody Plants												
Amur Maple									X			1
Autumn Olive					X				X			2
Black Alder									X			1
Black Locust									X			1
Common Buckthorn	X	X	X	X	X			X	X	X		8
Callery Pear							X		X			2
European Mountain Ash									X			1
European Privet		X		X	X	X			X			5
European Spindle Tree									X			1
Glossy Buckthorn					X	X			X			3
Honeysuckle	X	X	X	X	X	X			X	X	X	9
Japanese Barberry		X	X		X				X	X		5
Little Leaf Linden									X			1
Multiflora Rose	X		X	X	X				X	X		6
Norway Maple		X			X				X			3
Oriental Bittersweet									X			1
Porcelain Berry									X			1
Winged Euonymus		X		X					X	X		4
White Poplar					X				X			2
Wayfaring Tree		X	X		X	X			X	X	X	7
Total Number of Invasive Species Found	7	12	11	7	24	6	2	1	38	11	4	--

[a] *This table only includes data for the portion of the County-owned land within the Oak Creek watershed.*

Source: Milwaukee County Parks Department and SEWRPC

Comparison to Water Use Objectives and Impairment Designation

The water use objectives and supporting water quality criteria for the Oak Creek watershed were previously described in this chapter. Streams and ponds of this watershed are recommended for warmwater fish and aquatic life and full recreational uses.

Previous Assessments of Achievement of Water Use Objectives

Based upon the available data for sampling stations in the watershed, the mainstem of Oak Creek and its major tributaries did not fully meet the water quality criteria supporting its designated uses during and prior to 1975, the base year of the regional water quality management plan.[349] Review of subsequent data indicated that as of 1995, the recommended water use objectives were only being partially achieved in the majority of streams in the watershed.[350]

During the 1998-2001 baseline period examined in the regional water quality management plan update (RWQMPU) for the greater Milwaukee watersheds, which included Oak Creek, the recommended water use objectives were only being partially achieved in much of the Oak Creek watershed.[351] Based upon data from 1998-2001, the RWQMPU drew the following conclusions:

- Ammonia concentrations in all samples taken along the mainstem of Oak Creek and along the Mitchell Field Drainage Ditch were under the acute toxicity criterion for fish and aquatic life for ammonia, indicating compliance with the standard.

- Water temperatures in all samples taken from the mainstem were at or below the relevant standard, indicating compliance with the standard.

- Dissolved oxygen concentrations at most stations along the mainstem were at or above the standard for fish and aquatic life in the vast majority of samples, indicating substantial compliance with the standard. The major exception to this generalization occurred in the portion of the mainstem upstream from the confluence with the North Branch of Oak Creek. In this reach, dissolved oxygen concentrations were below the standard in a substantial portion of the samples, indicating substantial noncompliance with the standard.

- Concentrations of fecal coliform bacteria generally exceeded the standard in samples collected at stations along the mainstem, indicating general noncompliance with the standard.

- Concentrations of total phosphorus in samples collected from the mainstem of Oak Creek and the Mitchell Field Drainage Ditch commonly exceeded the recommended levels in the regional water quality management plan.[352]

Achievement of Water Use Objectives during the Period 2007-2016

Table 4.35 presents a comparison of water quality constituents in the streams Oak Creek watershed to applicable water quality criteria for the period beginning in 2007 and continuing through the end of 2016. This comparison examines ambient levels of five water quality constituents: water temperature and concentrations of dissolved oxygen, chloride, total phosphorus, and fecal coliform bacteria. In the case of water temperature and chloride concentration, ambient levels were compared to two applicable criteria—one that applies to acute effects to aquatic organisms and another that applies to chronic conditions. Because data regarding concentrations of fecal coliform bacteria are not available for much of the watershed, Table 4.35 also compares concentrations of *E. coli* to Wisconsin's newly adopted recreational water quality criteria.

---

[349] *SEWRPC Technical Report No. 17,* Water Quality of Lakes and Streams in Southeastern Wisconsin: 1964-1975, *June 1978.*

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

[351] *SEWRPC Technical Report No. 39*, op. cit.

[352] *This evaluation was conducted prior to the enactment of Wisconsin's phosphorus rule. In this evaluation, total phosphorus concentrations were compared to a planning standard of 0.10 mg/l that was recommended in the initial regional water quality management plan.*

Table 4.35
Water Quality Characteristics of Streams in the Oak Creek Watershed: 2007-2016

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Criteria (total number of samples indicated in parentheses)									
								Bacteria			
			Chloride		Temperature			Fecal Coliform Bacteria		*Escherichia coli (E. coli)*	
		Dissolved Oxygen	Chronic	Acute	Sublethal	Acute	Total Phosphorus	Single Sample Value	Geometric Mean	Statistical Test Value	Geometric Mean
Oak Creek Headwaters Assessment Area											
Oak Creek above W. Ryan Road-west crossing	1.5	72.1 (61)	--	--	84.4 (32)	100.0 (229)	71.4 (14)	--	--	26.5 (83)	13.3 (83)
Upper Oak Creek Assessment Area											
Oak Creek between W. Ryan Road-west crossing and the confluence with North Branch Oak Creek	2.7	81.8 (187)	77.4 (84)	97.6 (84)	86.0 (136)	99.4 (990)	76.5 (102)	59.0 (83)	43.4 (83)	53.7 (95)	20.0 (95)
Middle Oak Creek Assessment Area											
Oak Creek between confluence with North Branch Oak Creek and E. Forest Hills Road	3.5	89.2 (288)	83.1 (172)	97.1 (172)	85.5 (83)	100.0 (603)	58.4 (197)	60.0 (170)	43.5 (170)	56.1 (173)	24.6 (173)
Lower Oak Creek Assessment Area											
Oak Creek between E. Forest Hills Road and S. Pennsylvania Avenue	1.6	92.5 (201)	84.9 (86)	98.8 (86)	87.5 (64)	100.0 (458)	52.3 (111)	56.5 (85)	35.3 (85)	48.7 (197)	18.7 (197)
Oak Creek between S. Pennsylvania Avenue and 15th Avenue	1.9	98.5 (200)	74.1 (108)	90.7 (108)	91.4 (116)	100.0 (845)	62.0 (100)	31.3 (83)	19.3 (83)	29.9 (97)	15.5 (97)
Lower Oak Creek – Millpond Assessment Area											
Oak Creek between 15th Avenue and Oak Creek Parkway	1.6	100.0 (64)	--	--	84.4 (32)	100.0 (229)	83.3 (12)	--	--	35.8 (120)	13.3 (120)
Oak Creek between Oak Creek Parkway to Oak Creek Millpond	0.2	99.6 (274)	88.4 (86)	100.0 (86)	56.3 (64)	81.9 (458)	70.4 (115)	43.5 (85)	22.4 (85)	44.9 (243)	23.5 (243)
Grant Park Ravine Assessment Area											
Oak Creek between Oak Creek Millpond and confluence with Lake Michigan	1.0	100.0 (178)	89.5 (86)	100.0 (86)	80.6 (31)	100.0 (225)	68.9 (106)	51.8 (85)	37.6 (85)	52.1 (169)	21.3 (169)
Mitchell Field Drainage Ditch – Airport Assessment Area											
Mitchell Field Drainage Ditch between S. Howell Avenue and College Avenue	1.5	35.6 (87)	45.5 (33)	63.6 (33)	81.3 (32)	100.0 (229)	41.7 (24)	--	--	63.0 (100)	19.0 (100)
Lower Mitchell Field Drainage Ditch Assessment Area											
Mitchell Field Drainage Ditch between College Avenue and Rawson Avenue	1.0	41.7 (60)	--	--	91.2 (114)	99.7 (933)	30.8 (13)	--	--	72.4 (58)	39.7 (58)
Mitchell Field Drainage Ditch between E. Rawson Avenue and confluence with Oak Creek	0.8	84.4 (32)	--	--	--	--	--	--	--	--	--
Oak Creek Drainage Ditches Assessment Area											
Unnamed Tributary to Oak Creek (near E. Puetz Road)	1.0	--	--	--	93.3 (30)	100.0 (222)	--	--	--	--	--
Upper North Branch Oak Creek Assessment Area											
North Branch Oak Creek above S. 6th Street-north crossing	1.9	96.6 (59)	--	--	79.7 (64)	100.0 (458)	46.2 (13)	--	--	74.4 (82)	53.7 (82)

Table continued on next page.

Table 4.35 (Continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Criteria (total number of samples indicated in parentheses)										
								Bacteria			
			Chloride		Temperature			Fecal Coliform Bacteria		*Escherichia coli (E. coli)*	
		Dissolved Oxygen	Chronic	Acute	Sublethal	Acute	Total Phosphorus	Single Sample Value	Geometric Mean	Statistical Test Value	Geometric Mean
Lower North Branch Oak Creek Assessment Area											
North Branch Oak Creek between S. 6th Street-north crossing and Weatherly Drive	2.1	93.2 (59)	--	--	79.7 (64)	100.0 (458)	76.9 (13)	--	--	72.0 (100)	43.0 (100)
North Branch Oak Creek between Weatherly Drive and confluence with Oak Creek	1.8	96.3 (54)	--	--	81.9 (171)	98.3 (1,235)	0.0 (1)	--	--	--	--
Southland Creek Assessment Area											
Southland Creek	2.3	--	--	--	93.8 (32)	100.0 (229)	--	--	--	--	--
Drexel Avenue Tributary Assessment Area											
Unnamed Creek 5	1.3	62.1 (58)	--	--	84.4 (32)	100.0 (229)	58.3 (12)	--	--	63.8 (58)	37.9 (58)
Rawson Avenue Tributary Assessment Area											
Unnamed Creek	2.0	--	--	--	84.4 (32)	100.0 (229)	--	--	--	--	--
College Avenue Tributary Assessment Area											
Unnamed Creek	--	--	--	--	--	--	--	--	--	--	--

Source: SEWRPC

During the period 2007-2016, the recommended water use objectives were only being partially achieved in the Oak Creek watershed. Review of the data from this period shows the following:

- Dissolved oxygen concentrations at sampling stations along the mainstem of Oak Creek upstream from the confluence with the North Branch of Oak Creek were occasionally below the applicable water quality criterion, indicating occasional noncompliance with the standard. At stations downstream from the confluence with the North Branch, dissolved oxygen concentrations were usually in compliance with the applicable water quality criterion. Dissolved oxygen concentrations at sampling stations along the North Branch of Oak Creek were usually above the criterion, indicating compliance with the standard. At sampling stations along the Mitchell Field Drainage Ditch upstream from Rawson Avenue, dissolved oxygen concentrations were usually below the applicable water quality criterion, indicating substantial noncompliance with the standard. Downstream from Rawson Avenue, dissolved oxygen concentrations were occasionally below the applicable water quality criterion, indicating occasional noncompliance with the standard. Dissolved oxygen concentrations at the sampling station along Unnamed Creek 5, a tributary to the North Branch of Oak Creek, were often below the applicable water quality criterion, indicating substantial noncompliance with the standard.

- Chloride concentrations at sampling stations along the mainstem of Oak Creek were almost always below the acute toxicity criterion, indicating compliance with this standard. Chloride concentrations at several stations along the mainstem of Oak Creek were occasionally above the chronic toxicity criterion, indicating occasional noncompliance with this standard. At the one station along the Mitchell Field Drainage Ditch where water samples were examined for chloride, concentrations were often above the acute toxicity criterion and usually above the chronic toxicity criterion, indicating substantial noncompliance with these standards. It should be noted that few chloride samples were collected anywhere in the watershed during the winter deicing season. Because of this, the level of compliance with the water quality criteria for chloride during the winter deicing season is unknown.

- At all but one site examined along the mainstem of Oak Creek and at all sites examined along tributary streams, daily maximum water temperatures rarely exceeded the applicable acute criterion for temperature. Similarly, at most sites along the mainstem and tributary streams, the weekly means of maximum daily water temperatures were usually less than the applicable sublethal criterion for water temperature. The major exception to these generalizations occurred at a site within the Mill Pond that had shallow water, was off the main channel of the stream, and was exposed to the sun. With the exception of this site, water temperatures at sampling stations along streams in the watershed complied with the applicable water quality criteria for temperature.

- Concentrations of total phosphorus at sampling stations along the mainstem of Oak Creek, the North Branch of Oak Creek, the Mitchell Field Drainage Ditch, and Unnamed Creek 5 were often above the applicable water quality criterion, indicating substantial noncompliance with the standard.

- At sampling stations along the mainstem of Oak Creek, concentrations of fecal coliform bacteria were often higher than the single sample criterion and usually above the geometric mean criterion, indicating general noncompliance with the standard. In addition, at those locations along the mainstem of Oak Creek and along tributary streams for which data are available, concentrations of *E. coli* were often higher than the statistical test value and usually higher than the geometric mean criterion. At several stations, concentrations were usually above both of these criteria. This suggests that these stream reaches would also not comply with the State's former water quality criteria for fecal coliform bacteria.[353]

Table 4.36 presents a more rigorous comparison of *E. coli* concentrations in streams of the Oak Creek watershed during the period 2007 through 2016 to Wisconsin's recreational use water quality criteria. Under these criteria, the geometric mean of *E. coli* concentrations is not to exceed 126 cells per 100 ml during any 90-day period and no more than 10 percent of samples collected during any 90-day period may exceed the statistical test value of 410 cells per 100 ml. These criteria are applied during the swimming seasons

[353] E. coli *is one of the species of bacteria included in the fecal coliform bacteria group.*

Table 4.36
Percent of 90-Day Periods During May 1 Through September 30 with *E. coli* Concentrations in Compliance with Wisconsin's Recreational Water Quality Criteria: 2007-2016

Stream Reach	Stream Length (miles)	Periods	Samples	Geometric Mean[a]	Statistical Test Value[b]
Oak Creek Headwaters Assessment Area					
Oak Creek above W. Ryan Road-west crossing	1.5	256	54	0.0	0.0
Upper Oak Creek Assessment Area					
Oak Creek between W. Ryan Road-west crossing and the confluence with North Branch Oak Creek	2.7	320	71	0.0	0.0
Middle Oak Creek Assessment Area					
Oak Creek between confluence with North Branch Oak Creek and E. Forest Hills Road	3.5	320	121	0.0	0.0
Lower Oak Creek Assessment Area					
Oak Creek between E. Forest Hills Road and S. Pennsylvania Avenue	1.6	320	146	0.0	0.0
Oak Creek between S. Pennsylvania Avenue and 15th Avenue	1.9	320	68	0.0	0.0
Lower Oak Creek – Millpond Assessment Area					
Oak Creek between 15th Avenue and Oak Creek Parkway	1.6	384	94	0.0	0.0
Oak Creek between Oak Creek Parkway and Oak Creek Millpond	0.2	384	178	0.0	0.0
Grant Park Ravine Assessment Area					
Oak Creek between Oak Creek Millpond and confluence with Lake Michigan	1.0	384	126	0.0	0.0
Mitchell Field Drainage Ditch – Airport Assessment Area					
Mitchell Field Drainage Ditch between S. Howell Avenue and College Avenue	1.5	320	74	0.0	2.2
Lower Mitchell Field Drainage Ditch Assessment Area					
Mitchell Field Drainage Ditch between College Avenue and E. Rawson Avenue	1.0	128	32	0.0	0.0
Mitchell Field Drainage Ditch between E. Rawson Avenue and confluence with Oak Creek	0.8	--	--	--	--
Oak Creek Drainage Ditches Assessment Area					
Unnamed Tributary to Oak Creek (near E. Puetz Road)	1.0	--	--	--	--
Upper North Branch Oak Creek Assessment Area					
North Branch Oak Creek above S. 6th Street-north crossing	1.9	256	56	9.8	0.0
Lower North Branch Oak Creek Assessment Area					
North Branch Oak Creek between S. 6th Street-north crossing and Weatherly Drive	2.1	320	73	5.6	0.0
North Branch Oak Creek between Weatherly Drive and confluence with Oak Creek	1.8	--	--	--	--
Southland Creek Assessment Area					
Southland Creek	2.3	--	--	--	--
Drexel Avenue Tributary Assessment Area					
Unnamed Creek 5	1.3	128	32	0.0	0.0
Rawson Avenue Tributary Assessment Area					
Unnamed Creek	2.0	--	--	--	--
College Avenue Tributary Assessment Area					
Unnamed Creek	--	--	--	--	--

[a] *The geometric mean of samples collected over any 90-day period between May 1 and September 30 shall not exceed 126 colony forming units per 100 milliliters.*

[b] *The concentration of* E. coli *shall exceed 410 colony forming units per 100 milliliters in no more than 10 percent of the samples collected over any 90-day period between May 1 and September 30.*

Source: SEWRPC

between May 1 and September 30. Under this more rigorous test, conditions in streams of the Oak Creek watershed were rarely in compliance with the recreational use criteria. Review of the data from this period shows the following:

- No reach of the mainstem of Oak Creek for which data are available met either the geometric mean or the statistical test value criteria during any assessed 90-day period.

- No assessed reach of the Mitchell Field Drainage Ditch met the geometric mean criterion during any assessed 90-day period. The reach of the Mitchell Field Drainage Ditch upstream from College Avenue met the statistical test value criterion during about 2 percent of the periods assessed. The reach between College Avenue and Rawson Avenue did not meet the statistical test value criterion during any assessed period.

- No assessed reach of the North Branch of Oak Creek met the statistical test value criterion during any assessed 90-day period. The reach of the North Branch of Oak Creek upstream from the northern-most sampling station along S. 6th Street met the geometric mean criterion in about 10 percent of the periods assessed. The reach between the northern-most sampling station along S. 6th Street and Weatherly Drive met the geometric mean criterion in about 6 percent of the periods assessed.

- Unnamed Creek 5 did not meet either the geometric mean or the statistical test value criteria during any assessed period.

- Data were not available for assessing compliance with the proposed recreational use criteria for Southland Creek or any streams within the Oak Creek Drainage Ditches, Rawson Avenue Tributary, or College Avenue Tributary assessment areas.

There are several water quality constituents for which water quality criteria have not been promulgated. Guidelines are available for several of these constituents for the purpose of evaluating whether ambient concentrations and values reflect good water quality (see Table 4.18). While these guidelines have no regulatory impact, they can serve as indicators of where the division between good and poor water quality lies and serve as proxies in lieu of adopted water quality criteria to better understand water quality conditions within the Oak Creek watershed.

Concentrations and values of several water quality constituents in streams of the Oak Creek watershed during the period 2007 through 2016 were compared to water quality guidelines (see Table 4.37). The water quality constituents evaluated fall into three broad categories: suspended materials, chlorophyll-*a*, and forms of nitrogen. Suspended material data were evaluated through three comparisons. Total suspended solids (TSS) concentrations were compared to the target concentration set forth in the Milwaukee Basin TMDL. Turbidity values measured through nephelometry were compared to a reference value recommended by USEPA. Transparency tube depths were compared to a reference value developed by the USGS and WDNR. Concentrations of chlorophyll-*a* were compared to a water quality criterion recommended by the USEPA and a recreational use criterion proposed for Wisconsin by the WDNR. Three forms of nitrogen were evaluated. Concentrations of total nitrogen were compared to a reference value developed by the USGS and WDNR. The sum of the concentrations of nitrate and nitrite were compared to a reference value developed by the USEPA. The concentrations of total Kjeldahl nitrogen, which consists of the sum of the concentrations of ammonia and organic nitrogen, was compared to a reference value developed by the USEPA. Review of the evaluation shows the following:

- TSS concentrations were below the target concentrations set in the Milwaukee Basin TMDL in more than 60 percent of samples in most stream reaches for which data were available

- Nephelometric turbidity values were almost always higher than the reference value recommended by USEPA

- Transparency of water in transparency tubes was almost always less than the reference value developed by the USGS and WDNR

Table 4.37
Comparison of Water Chemistry in Streams of the Oak Creek Watershed to Water Quality Guidelines: 2007-2016

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Guidelines (total number of samples indicated in parentheses)							
					Chlorophyll-*a*		Nitrogen		
		Total Suspended Solids	Turbidity	Transparency Tube	Reference Value	Proposed Recreational Criterion	Total Nitrogen	Nitrate plus Nitrite	Total Kjeldahl Nitrogen
Oak Creek Headwaters Assessment Area									
Oak Creek above W. Ryan Road-west crossing	1.5	39.5 (43)	1.2 (83)	0.0 (1)	--	--	0.0 (13)	38.5 (13)	23.1 (13)
Upper Oak Creek Assessment Area									
Oak Creek between W. Ryan Road-west crossing and the confluence with North Branch Oak Creek	2.7	64.3 (135)	0.7 (136)	24.4 (45)	37.3 (83)	98.8 (83)	7.4 (94)	86.5 (96)	58.9 (95)
Middle Oak Creek Assessment Area									
Oak Creek between confluence with North Branch Oak Creek and E. Forest Hills Road	3.5	56.8 (266)	0.0 (255)	0.0 (1)	27.7 (173)	99.4 (173)	20.6 (194)	96.6 (207)	55.7 (194)
Lower Oak Creek Assessment Area									
Oak Creek between E. Forest Hills Road and S. Pennsylvania Avenue	1.6	67.4 (181)	0.0 (238)	100.0 (1)	10.6 (85)	96.5 (85)	14.8 (106)	93.6 (110)	42.2 (109)
Oak Creek between S. Pennsylvania Avenue and 15th Avenue	1.9	65.3 (121)	0.0 (102)	9.5 (63)	11.5 (87)	96.6 (87)	8.3 (96)	96.3 (109)	53.1 (98)
Lower Oak Creek – Millpond Assessment Area									
Oak Creek between 15th Avenue and Oak Creek Parkway	1.6	71.4 (35)	0.0 (108)	--	--	--	23.0 (12)	83.3 (12)	58.3 (12)
Oak Creek between Oak Creek Parkway to Oak Creek Millpond	0.2	63.3 (237)	0.0 (273)	--	19.4 (93)	93.5 (93)	21.9 (114)	93.9 (115)	45.6 (114)
Grant Park Ravine Assessment Area									
Oak Creek between Oak Creek Millpond and confluence with Lake Michigan	1.0	73.2 (153)	0.0 (178)	--	7.1 (85)	90.6 (85)	18.3 (104)	95.3 (106)	55.2 (105)
Mitchell Field Drainage Ditch – Airport Assessment Area									
Mitchell Field Drainage Ditch between S. Howell Avenue and College Avenue	1.5	68.4 (95)	0.0 (100)	--	--	--	53.8 (13)	100.0 (13)	8.9 (56)
Lower Mitchell Field Drainage Ditch Assessment Area									
Mitchell Field Drainage Ditch between College Avenue and Rawson Avenue	1.0	84.3 (51)	0.0 (58)	100.0 (2)	--	--	25.0 (12)	100.0 (12)	33.3 (12)
Mitchell Field Drainage Ditch between E. Rawson Avenue and confluence with Oak Creek	0.8	--	--	12.9 (31)	--	--	--	--	--
Oak Creek Drainage Ditches Assessment Area									
Unnamed Tributary to Oak Creek (near E. Puetz Road)	1.0	--	--	--	--	--	--	--	--
Upper North Branch Oak Creek Assessment Area									
North Branch Oak Creek above S. 6th Street-north crossing	1.9	75.0 (32)	0.0 (82)	100.0 (1)	--	--	16.7 (12)	83.3 (12)	58.3 (12)

Table continued on next page.

Table 4.37 (Continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Guidelines (total number of samples indicated in parentheses)							
					Chlorophyll-*a*		Nitrogen		
		Total Suspended Solids	Turbidity	Transparency Tube	Reference Value	Proposed Recreational Criterion	Total Nitrogen	Nitrate plus Nitrite	Total Kjeldahl Nitrogen
Lower North Branch Oak Creek Assessment Area									
North Branch Oak Creek between S. 6th Street-north crossing and Weatherly Drive	2.1	85.7 (49)	0.0 (100)	--	--	--	15.4 (13)	84.6 (13)	38.5 (13)
North Branch Oak Creek between Weatherly Drive and confluence with Oak Creek	1.8	--	--	52.9 (51)	--	--	--	--	--
Southland Creek Assessment Area									
Southland Creek	2.3	--	--	--	--	--	--	--	--
Drexel Avenue Tributary Assessment Area									
Unnamed Creek 5	1.3	70.6 (34)	5.2 (58)	--	--	--	25.0 (12)	100.0 (12)	41.7 (12)
Rawson Avenue Tributary Assessment Area									
Unnamed Creek	2.0	--	--	--	--	--	--	--	--
College Avenue Tributary Assessment Area									
Unnamed Creek	--	--	--	--	--	--	--	--	--

Source: SEWRPC

- Chlorophyll-*a* concentrations in most samples were above the reference value recommended by the USEPA, but below the WDNR's proposed recreational use criterion

- Total nitrogen concentrations in the vast majority of samples were higher than the reference value developed by the USGS and WDNR

- In all but one stream reach for which data were available, combined concentrations of nitrate and nitrite were usually to almost always below the reference value recommended by USEPA

- Concentrations of total Kjeldahl nitrogen were often to usually higher than the reference value recommended by USEPA

It should be noted that the guidelines that were applied in this assessment are not regulatory criteria and are used only to give an indication of what may distinguish good water quality from bad water quality.

As previously discussed, waterbodies that are not meeting applicable water quality criteria are considered impaired. Section 303(d) of the CWA requires that states periodically submit a list of impaired waters to USEPA for approval. The most recently approved list for the State of Wisconsin was submitted in 2018. In addition, the State has developed a list that it submitted in 2020. Table 4.15 and Map 4.20 indicate the stream reaches in the Oak Creek watershed that were listed as impaired as of 2018 and are proposed to be listed as of 2020. Currently, impairments present in the mainstem of Oak Creek include one for total phosphorus, one for chloride, and one for an unknown pollutant. The North Branch of Oak Creek is considered impaired for chloride. Under the proposed 2020 list, the Mitchell Field Drainage Ditch is also considered impaired for chloride. The analyses described in this section suggest that the impairments are warranted.

Summary and Synthesis

Summary

The analysis of water quality given in this section identified several improvements in water quality conditions in the Oak Creek watershed. These improvements include:

- Concentrations of fecal coliform bacteria have decreased over time at most sampling stations along the mainstem of Oak Creek

- Recent increases in instream pH appear to represent a reversal of a long-term trend toward decreasing pH

- Instream concentrations of TSS have decreased over time

- Some heavy metals, such as cadmium, chromium, and lead, are detected in water samples less frequently and at lower concentrations than in the past

- The quality of the biological community has improved in some reaches of the mainstem of Oak Creek

The analysis also identified several current and potential future water quality and water quality-related problems in the Oak Creek watershed:

- High concentrations of fecal indicator bacteria throughout the watershed indicate that water in Oak Creek, its tributaries, and the Mill Pond is not safe for human contact, limiting the recreational potential of these waterbodies.

- Instream concentrations of chlorophyll-*a* have increased over time.

- Projections of future conditions indicate that average water temperatures in Oak Creek are likely to increase by about 2°C by the end of the 21st Century due to climate change, resulting in changes to the biological communities that the Creek and its tributaries are able to support.

- Concentrations of dissolved oxygen are low in the Mitchell Field Drainage Ditch, Unnamed Creek 5, and upstream reaches of the mainstem of Oak Creek. Supersaturation of dissolved oxygen also occurs in the Mill Pond and some reaches of the mainstem of Oak Creek.

- Instream concentrations of chloride occasionally exceed water quality criteria for toxicity to fish and aquatic life. There is a long-term trend toward chloride concentrations increasing.

- Instream concentrations of phosphorus are high and often exceed water quality standards. The percentage of phosphorus that is present as dissolved phosphorus has increased over the period of record. The watershed may also contain considerable stores of legacy phosphorus.

- Instream concentrations of total nitrogen are high and usually exceed guideline values, suggesting that they are contributing to water quality problems in surface waters of the watershed.

- The watershed contains a poor to fair quality fishery and poor to fair quality aquatic macroinvertebrate communities, reflecting the combined effects of poor water quality, habitat alteration, and habitat fragmentation.

- The presence and proliferation of exotic and invasive species is degrading the quality and threatening the integrity of aquatic, wetland, riparian, and upland areas within the watershed.

- Several toxic substances and emerging pollutants have been detected in the watershed. These substances include heavy metals, pesticides, PCBs, and PAHs, as well as emerging pollutants such as PFAS. Depending on the substance, they have been found in surface water, groundwater, sediment, organism tissue, and soils. At some instream locations, concentrations present in sediment are high enough to produce toxic effects in benthic organisms.

Synthesis

The analysis of water quality conditions also illustrates the numerous interrelationships that determine the state of water quality in a watershed. These include interrelationships among causes, interrelationships among effects, and interrelationships in the pathways leading from causes to effects.

Several water quality problems may be interrelated through a single cause. For example, the microbial source tracking study described earlier in this chapter found that human wastes are entering surface waters of the Oak Creek watershed at several locations. These wastes contribute to several water quality problems. They are a source of suspended solids and sediment. More importantly, they constitute a major source of fecal indicator bacteria and pathogens to the stream system, making the water unsuitable for contact recreational activities. Human wastes also constitute a source of organic material to the Creek and its tributaries. Degradation of this material by naturally occurring bacteria in the water column and sediment reduces concentrations of dissolved oxygen in the water. Human wastes are also a source of nutrients, such as phosphorus and nitrogen, which spur the growth of algae and plants within the stream system. This growth can increase turbidity in the water column and if it is heavy enough, it can cause large swings in concentrations of dissolved oxygen in the water. In addition, degradation of the subsequent algal and plant material after it dies can reduce instream concentrations of dissolved oxygen. The increases in turbidity and the reduction in dissolved oxygen concentration reduce the watershed's suitability as habitat for aquatic species, especially those that are intolerant of pollution and low dissolved oxygen concentrations, leading to low quality fish and macroinvertebrate communities.

Similarly, many water quality problems are the result of multiple causes. The numerous factors affecting instream dissolved oxygen concentrations provide an example of this. As noted in the previous paragraph, the introduction of human wastes into surface waters can lead to reductions of dissolved oxygen concentrations through contributions of organic material and nutrients. The microbial source tracking study that found that human wastes are entering surface waters of the Oak Creek watershed also found that canine wastes are entering surface waters at several locations. The same mechanisms act upon these wastes to potentially reduce dissolved oxygen concentrations. Inputs of organic material from sources other than fecal wastes may also act to reduce instream dissolved oxygen concentrations through degradation by bacteria. These inputs originate from several sources, including material such as leaves and leachate from leaves in stormwater runoff, aircraft deicing and anti-icing compounds in runoff from MMIA, and unidentified substances observed entering through the Mitchell Field Drainage Ditch and from the Middle Oak Creek drainage ditch assessment area during field surveys.

Other factors influencing instream dissolved oxygen concentrations include nutrients, sediment organic material, water temperature, and water flow. Nutrient contributions from runoff and other sources can increase the growth of algae and aquatic plants, resulting under some circumstances in reductions in dissolved oxygen concentration and in others supersaturation of dissolved oxygen or large swings in dissolved oxygen over the course of the day. Accumulation of organic material and nutrients in streambed sediments and the Mill Pond can result in persistent problems related to dissolved oxygen. Water temperature has a strong effect because it determines the amount of oxygen that the water can hold. While it is not clear whether temperatures within Oak Creek have increased over the last five or six decades, given the high levels of urban development, loss of groundwater recharge areas due to buildings and other structures, and loss of riparian buffers in some areas of this watershed, it is highly likely that they have increased. In addition, projections indicate that instream water temperatures will be warmer by the end of this century, so this combined with planned increases in urban development, in the absence of mitigation, will likely contribute to this increase in water temperatures throughout this watershed. This will lead to lower instream concentrations of dissolved oxygen. Water flow can have pronounced effects on dissolved oxygen concentrations. Turbulent flow in which air mixes with water enhances the diffusion of oxygen from the atmosphere into the water. This occurs especially at riffles, which is one of the reasons that such habitat areas contain greater concentrations and diversity of aquatic life (e.g., macroinvertebrates and fishes). However, a large proportion of the network of streams within the Oak Creek watershed have been channelized and riffle habitats have been greatly reduced and/or eliminated. Low flows and intermittent flows can allow water to stagnate, lowering dissolved oxygen concentrations. This can be a problem in some channelized reaches, in the lobes of the Mill Pond, and behind instream barriers such as drop structures, beaver dams, and debris jams—especially if large deposits of sediment containing organic material are present. As mentioned above, low flows could also be related to one or more factors that include: loss of groundwater recharge due to urban development (i.e., increased impervious surface), channel relocation or channelization, loss of riparian buffers, and stormwater infrastructure network. Clearly, many different factors affect dissolved oxygen concentrations in Oak Creek, its tributaries, and the Mill Pond. This suggests that multiple strategies may be available to ameliorate the identified problems related to instream concentrations.

The examples of the various problems caused by the introduction of human waste into surface waters and the various causes leading to dissolved oxygen problems illustrate the interrelationships among causes and problems that affect the state of water quality in the Oak Creek watershed. The same types of patterns of interrelatedness can be described for many of the problems affecting water quality in the watershed. While these patterns of causes producing multiple impacts and individual problems deriving from multiple causes can complicate management efforts, they also provide opportunities. Many of these opportunities are related to the pathways through which the causes of problems produce impacts within the stream system.

Municipal separate storm sewer systems (MS4s) serve as an example of one such pathway for opportunities for improvement in the watershed. MS4s collect and convey water from rainfall and snow melt from developed areas to receiving waterbodies for the purposes of drainage and preventing and relieving stormwater-related flooding. These storm drainage systems act as a pathway linking several sources to instream water quality impacts. Runoff entering these systems contains many substances washed off the landscape such as sediment and other solids; larger debris such as trash; nutrients from fertilizers, decaying plant material, and wastes from pets and wildlife; salt from road deicing and anti-icing activities; metals from wear and tear on automobile engines and brakes; oil and grease from industrial areas and leaking automobiles; pesticides used on lawns and gardens; and a variety of other substances. This pathway also transports heat picked up by stormwater flowing over impervious surfaces into receiving waters. Finally, cross-connections between sanitary and storm sewers, illicit discharges into storm sewers, and degrading sanitary and storm sewer infrastructure can introduce a variety of materials into this pathway, often bypassing elements of the stormwater management system that are intended to provide treatment. The presence of this pathway provides opportunities for addressing some water quality problems though design and implementation of BMPs that are designed to reduce the volume of water entering storm sewers or treat this water, either prior to entering the storm sewer or prior to discharge into receiving waters. Thoughtful design and placement of these BMP practices may allow them to at least partially address multiple causes of water quality problems.

It is important to recognize, however, that some causes of water quality problems may be more easily addressed through a particular pathway than others. Again, MS4 systems serve as an example. Many conventional treatment practices commonly used in MS4 systems provide treatment through settling or filtration of solids and sediment. While practices that rely on these mechanisms can provide reductions in concentrations and loads of particulate and particulate-associated pollutants, they are likely to be less effective or ineffective at treating dissolved materials such as dissolved phosphorus or chloride. It may be necessary to look for other means to address the problems caused by these substances. In the instance of chloride, its extreme solubility in water makes it incredibly resistant to treatment. Source reduction may be the only viable approach to address the problems cause by increasing instream chloride concentrations.

Finally, the analysis of water quality conditions given in this section shows how intimately water quality in Oak Creek, its tributaries, and the Mill Pond is connected to its watershed. The linkage between emissions from the Oak Creek power plant and pH within Oak Creek is a particularly subtle example of this connection. The preceding discussion of causes, problems, and pathways give several other illustrations. A major implication of these connections is that addressing water quality problems within surface waters of the Oak Creek watershed will require addressing conditions and activities taking place on the landscape within the watershed.

4.5 SOURCES OF WATER POLLUTION

An evaluation of water quality in a watershed should include an identification, characterization, and where feasible, quantification of known pollution sources. This identification, characterization, and quantification can aid in determining the causes of the water quality problems discussed earlier in this chapter.

Pollutants can reach surface waterbodies by several pathways. First, pollutants may be discharged from discrete outfall points into surface waters. Second, pollutants associated with the land may be transported to waterbodies either in surface runoff associated with wet weather events such as precipitation and snow melt or through dry weather pathways. Third, pollutants may be transported from their point of origin through the atmosphere to the watershed and then be carried into waterbodies through precipitation or dry deposition processes. Fourth, pollutants may be carried into surface waters through groundwater flow. Finally, pollutants stored within sediments within the waterbody may be released to the overlying surface water.

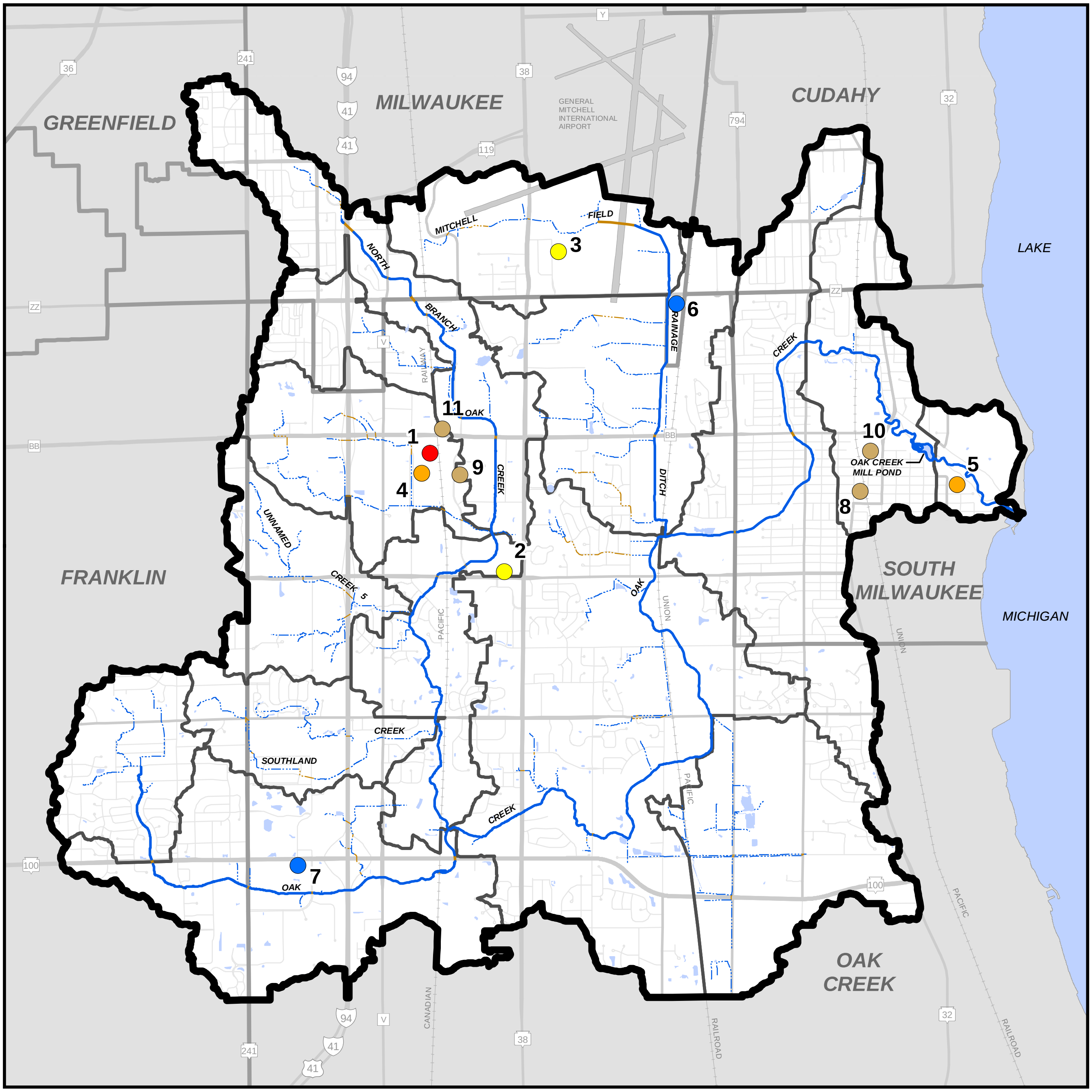
Point Sources

Point sources of pollution are discharges that come from a pipe or point of discharge and can be attributed to a specific source. In Wisconsin, discharges from point sources are regulated through the WPDES program. Facilities discharging into surface waters are required to obtain a WPDES permit. These permits are issued by the WDNR with oversight by the USEPA. The WDNR issues four types of WPDES permits: individual, general, storm water, and agricultural. In addition, permitted facilities are required to comply with conditions set forth in their permit. While permit conditions vary among the types of permits, they are drafted to be protective of water quality in and downstream of the receiving waters.

Individual permits are issued to municipal and private wastewater treatment and private industrial facilities that discharge to surface and/or groundwater. WPDES individual permits include limits upon the discharge of individual pollutants. These limits reflect either technology-based categorical (or base level) limits for industries or the levels necessary to achieve water quality standards, whichever is more stringent. As of 2018 there were four facilities in the Oak Creek watershed permitted to discharge wastewater under WPDES individual permits. These facilities are shown on Map 4.43 and listed in Table 4.38.

The WDNR also issues WPDES general permits for specific categories of industrial, municipal, and other wastewater discharges that are not significant contributors of pollution. These permits cover multiple facilities under a single permit when circumstances do not warrant site-specific permit requirements or limitations. There are currently 24 categories of WPDES general permits. Examples of the types of discharges that may be covered under a WPDES general permit include non-contact cooling water, hydrostatic test and water supply system water, discharges from pit or trench dewatering, and discharges from swimming pool facilities. As of 2018 there were seven facilities in the Oak Creek watershed permitted to discharge wastewater under WPDES general permits. One of these was for concrete products operations and two each were for municipal bypasses and overflows, noncontact cooling waters, and petroleum contaminated water. These facilities are also shown on Map 4.43 and listed in Table 4.38.

Map 4.43
Permitted Wastewater Discharges Under the WPDES Program in the Oak Creek Watershed: 2018



CONCRETE PRODUCTS OPERATIONS

MUNICIPAL BYPASSES AND OVERFLOWS

NONCONTACT COOLING WATER

PETROLEUM CONTAMINATED WATER

INDIVIDUAL PERMITS

11 WASTEWATER DISCHARGER REFERENCE NUMBER (SEE TABLE 4.38)

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: Wisconsin Department of Natural Resources and SEWRPC

Table 4.38
Permitted Wastewater Dischargers Under the WPDES Program in the Oak Creek Watershed: 2018

Permit Type	Number on Map 4.43	Facility	Address	Municipality	WPDES Permit Number	Facility Identification Number
Concrete Products Operations	1	Ozinga Ready Mix Concrete, Inc.	7300 S. Tenth Street	Oak Creek	0046507	19254
Municipal Bypasses and Overflows	2	City of Oak Creek	170 W. Drexel Avenue	Oak Creek	0047341	18600
	3	U.S. Air Force 440th	300 W. College Avenue	Milwaukee	0047341	9497
Noncontact Cooling Water	4	DIC Imaging Products, USA, Inc.	7300 S. Tenth Street	Oak Creek	0044938	1805
	5	EGS Electrical Group – Appleton	2105 5th Avenue	South Milwaukee	0044938	922
Petroleum Contaminated Water	6	MKE Fuel Company, LLC	1701 E. College Avenue	South Milwaukee	0046531	13348
	7	Pilot Travel Centers, LLC	2031 W. Ryan Road	Oak Creek	0046531	16484
Individual Permits	8	Appleton Electric Company – Lighting Products Division	2201 12th Avenue	South Milwaukee	0028312	6228
	9	Applied Plastics Company, Inc.	7320 S. 6th Street	Oak Creek	0041700	6703
	10	Caterpillar Global Mining, LLC	1100 Milwaukee Avenue	South Milwaukee	0001058	5617
	11	Industrial Fuel, Inc.	610 W. Rawson Avenue	Oak Creek	0040428	6668

Source: Wisconsin Department of Natural Resources

To meet the requirements of the CWA, the WDNR developed a stormwater discharge permit program under Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code*. A municipal separate storm sewer system (MS4) permit is required for a municipality that is either located within a Federally designated urbanized area, has a population of 10,000 or more, or is designated for permit coverage by the WDNR. Municipal permits require that the municipalities develop, maintain, and implement stormwater management programs to prevent pollutants from the MS4 from entering State waters. Such programs include implementing BMPs such as detention basins, street sweeping, filter strips, bioretention facilities, and rain gardens. Chapter NR 216 also requires certain types of industrial facilities in the State to obtain stormwater discharge permits. Permitted industrial facilities are required to develop a site-specific stormwater pollution prevention plan. The goal of this plan is to encourage source-area control by designating a stormwater pollution prevention individual, implementing site-specific best management practices, and developing an implementation schedule to help decrease the amount of contaminated stormwater runoff from a facility.

All six municipalities that are wholly or partially located in the Oak Creek watershed are designated MS4 communities. Each of these communities is covered under an MS4 permit. In addition, Milwaukee County is designated as an MS4 and has been issued an MS4 permit. There are several County facilities covered under this permit that are located in the Oak Creek watershed. These are mostly related to County parks, parkway roads, and County Trunk Highways.[354] In addition, the air operations area of Milwaukee Mitchell International Airport is covered under an individual WPDES MS4 permit. A preliminary delineation of the portions of the watershed that are known to be served by MS4s are shown on Map 4.44. This includes areas served by storm sewers and storm ditches, Interstate, U.S., State Trunk, and County Trunk highways, and MMIA. This map should be refined by the MS4 communities in the watershed.

Certain types of industries are required to obtain stormwater discharge permits from the WDNR. These permits are issued under a tiered system that groups industries by type and by how likely they are to discharge contaminated stormwater. Tier 1 permits cover a variety of heavy manufacturers. Examples of these include paper manufacturing, petroleum refining, and bulk storage of coal. Tier 2 permits cover a variety of light industries, including food processing, furniture manufacturing, and transportation facilities with vehicle maintenance areas. The WDNR also issues stormwater discharge permits that are customized to address potential stormwater contamination issues that are common to particular types of industries. Three industry-specific stormwater discharge permits have been developed and are issued by the Department. These cover automobile parts recycling and salvage facilities, scrap and waste material recycling facilities, and nonmetallic mining operations. The WDNR may also exclude some industrial facilities from the requirement of having a permit due to having no exposure to contaminated stormwater. Facilities may be eligible for this exclusion when all industrial materials and activities are protected by a storm-resistant shelter to prevent exposure to rain, snow, snowmelt, and or runoff.

Facilities covered under Tier 1 and 2 industrial stormwater discharge permits are required to identify and eliminate non-stormwater discharges, develop a stormwater pollution prevention plan, implement best management practices per the stormwater pollution protection plan, and complete periodic facility inspections. Facilities covered under Tier 1 permits are also required perform annual chemical monitoring.

In 2018, the Oak Creek watershed contained four facilities with Tier 1 industrial stormwater discharge permits, 24 facilities with Tier 2 industrial stormwater discharge permits, and two facilities with automobile parts recycling stormwater discharge permits. In addition, 15 facilities in the watershed had been issued exclusions for no exposure. The facilities in the Oak Creek watershed that are covered under the State's industrial stormwater discharge permit program are shown on Map 4.45 and listed in Table 4.39.

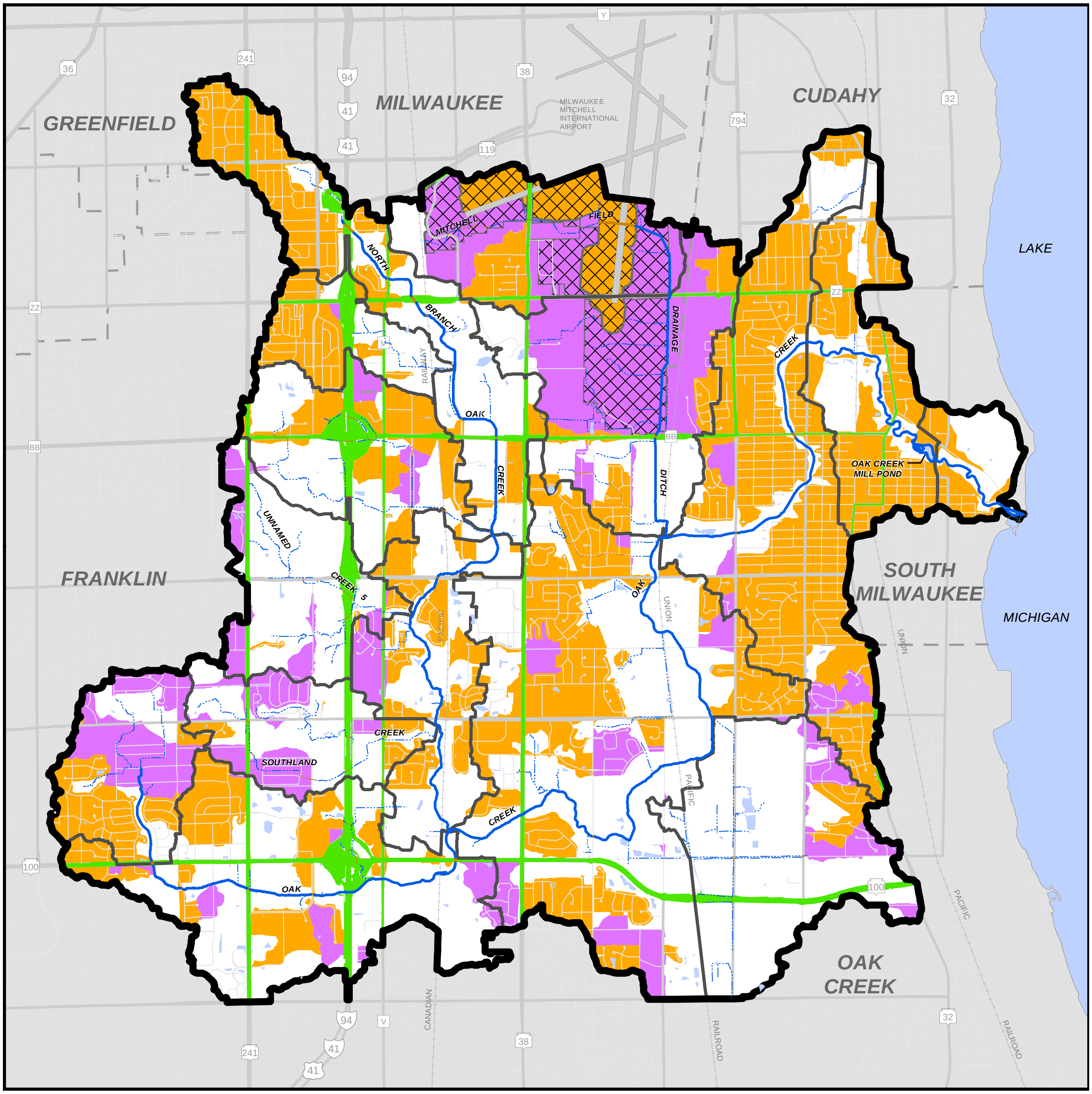
State and Federal laws also require that Concentrated Animal Feeding Operations (CAFOs) have WPDES permits. An animal feeding operation is considered a CAFO if it has 1,000 animal units or more.[355] A smaller

---

[354] *It should be noted that municipal storm sewers and storm sewers from private landowners may outfall into or pass through the County's County Trunk Highway storm sewers.*

[355] *Methods for calculating animal units are set forth in Section NR 243.05 of the* Wisconsin Administrative Code. *They are based on the type of animal, live weight of animal, and characteristics of the animal's manure. An animal unit is roughly equivalent to 1,000 pounds of live weight.*

Map 4.44
Preliminary MS4 Drainage Area Map Within the Oak Creek Watershed



MS4 DRAINAGE AREA UNDER INTERSTATE, STATE, AND COUNTY HIGHWAY SYSTEM

MS4 DRAINAGE AREA SERVED BY STORM SEWERS

MS4 DRAINAGE AREA SERVED BY STORM DITCHES

LAND UNDER MILWAUKEE MITCHELL INTERNATIONAL AIRPORT OWNERSHIP

Note: Areas shown outside of the categories indicated above are likely not served as part of a municipal separate storm sewer system (MS4).

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

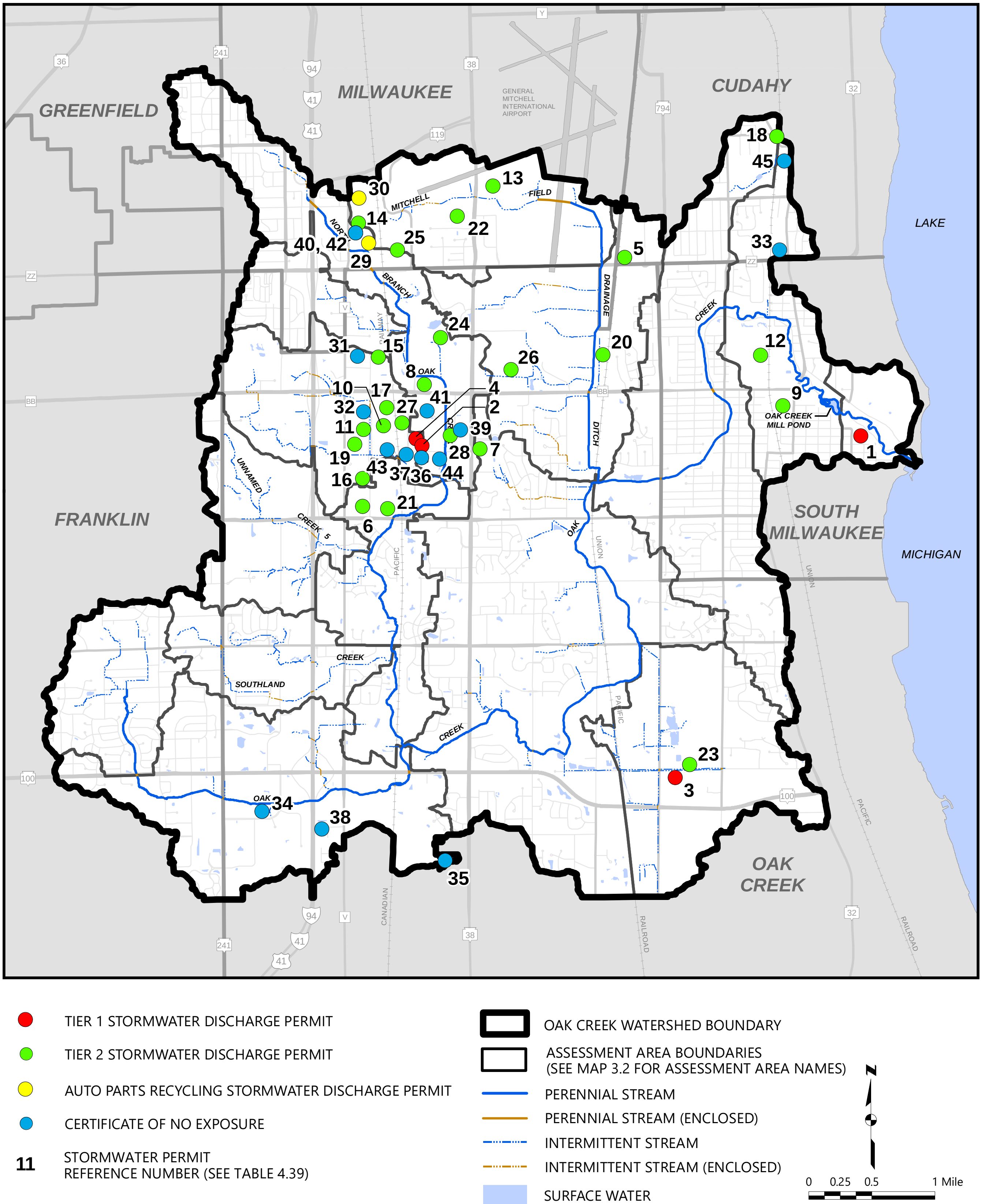
SURFACE WATER

N

0 0.25 0.5 1 Mile

Source: SEWRPC

Map 4.45
Facilities with WPDES Stormwater Discharge Permits in the Oak Creek Watershed: 2018



Source: Wisconsin Department of Natural Resources and SEWRPC

Table 4.39
Facilities Permitted for the Discharge of Stormwater Under the WPDES Program in the Oak Creek Watershed: 2018

Permit Type	Number on Map 4.44	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Stormwater Industrial Tier 1	1	EGS Electrical Group-Appleton	2105 5th Avenue	South Milwaukee	S067849	241015390	922
	2	Henkel Corporation	420 W. Marquette Avenue	Oak Creek	S067849	241165210	6917
	3	Le Pine Enterprises, Inc.	9540 S. Pennsylvania Avenue	Oak Creek	S067849	341130460	36801
	4	WPC Technologies	7350 S. 6th Street	Oak Creek	S067849	341224620	58928
Stormwater Industrial Tier 2	5	Ace World Wide & Storage Co., Inc.	1900 E. College Avenue	Cudahy	S067857	241308210	1935
	6	Bay View Industries	7821. S. 10th Street	Oak Creek	S067857	241736990	358
	7	Bay View Industries, Inc.	7420 S. Howell Avenue	Oak Creek	S067857	341301510	64813
	8	Behrens Moving Company	500 W. Rawson Avenue	Oak Creek	S067857	241815750	2075
	9	Caterpillar Global Mining, LLC	1100 Milwaukee Avenue	South Milwaukee	S067857	241008130	5617
	10	DIC Imaging Products, USA, Inc.	7300 S. Tenth Street	Oak Creek	S067857	241332080	1805
	11	DIC Imaging Products, USA, Inc	7335 S. 10th Street	Oak Creek	S067857	341018810	57796
	12	Falk Corporation Foundry Landfill	13th Avenue and Rawson Avenue	South Milwaukee	S067857	241514790	6953
	13	Johnson Controls, Inc.-Milwaukee Aviation	300 E. Citation Way	Milwaukee	S067857	341232650	49227
	14	Lamers Bus Lines, Inc.-Boden Court	1122 W. Boden Court	Milwaukee	S067857	241975690	9174
	15	Miltec, Inc.	6870 S. 10th Street	Oak Creek	S067857	241331640	684
	16	National Technologies, Inc.	7641 S. 10th Street	Oak Creek	S067857	241447470	58412
	17	Ozinga Ready Mix Concrete, Inc.	841 W. Rawson Avenue	Oak Creek	S067857	241323500	19254
	18	Pelman Iron & Metal Company	5510 S. Whitnall Avenue	Cudahy	S067857	241989440	13300
	19	Riteway Bus Service, Inc.	7743 S. 10th Street	Oak Creek	S067857	341075020	22628
	20	Sievert Trucking Inc.	1610 E. Rawson Avenue	Oak Creek	S067857	341173580	62818
	21	Superior Die Set Corporation	900 W. Drexel Avenue	Oak Creek	S067857	241051800	860
	22	Tax Airfreight, Inc.	5975 S. Howell Avenue	Milwaukee	S067857	241366510	11968
	23	Timber Creek Resource	2730 E. Ryan Road	Oak Creek	S067857	241775490	8302
	24	United Parcel Service-Oak Creek	6800 S. 6th Street	Oak Creek	S067857	241304910	9291
	25	USF Holland	6361 S. 6th Street	Milwaukee	S067857	341058740	22226
	26	YRC, Inc.	6880 S. Howell Avenue	Oak Creek	S067857	241902870	10917
	27	Zenar Crane Corporation	7310 S. Sixth Street	Oak Creek	S067857	241197990	419
	28	Zierden Company	7355 S. 1st Street	Oak Creek	S067857	241198100	177
Stormwater Auto Parts Recycling	29	LKQ Self Service Auto Parts	6102 S. 13th Street	Milwaukee	S059145	241472880	44932
	30	Roz Auto Salvage	5848 S. 13th Street	Milwaukee	S059145	241784070	10767
Certification of No Exposure	31	Ashland, Inc.	7721 S. 10th Street	Oak Creek	S066666	--	40931
	32	Ashland, Inc.	6870 S. 13th Street	Oak Creek	S066666	--	40932
	33	Breier Trucking, Inc.	6227 S. Packard Avenue	Cudahy	S066666	241596410	237
	34	Creation Technologies	2250 Southbranch Boulevard	Oak Creek	S066666	--	40912

Table continued on next page.

Table 4.39 (Continued)

Permit Type	Number on Map 4.44	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Certification of No Exposure (continued)	35	GE Healthcare-Opus	120 W. Opus Drive	Oak Creek	S066666	--	54513
	36	Henkel Corporation	525 W. Marquette Avenue	Oak Creek	S066666	--	1384
	37	Independence Corrugated, LLC	7475 S. Sixth Street	Oak Creek	S066666	--	41025
	38	MGS Group North America, Inc.	9875 Stern Street	Oak Creek	S066666	--	57802
	39	Milwaukee Composites	7330 S. 1st Street	Oak Creek	S066666	--	18302
	40	Milwaukee Metropolitan Sewerage District	6060 S. 13th Street	Milwaukee	S066666	--	48175
	42	Milwaukee Metropolitan Sewerage District – South Service Facility	6060 S. 13th Street	Milwaukee	S066666	241588600	62933
	41	Nucor Cold Finish Wisconsin, Inc.	7700 S. 6th Street	Oak Creek	S066666	241279280	40991
	43	UPS Cartage Services, Inc.	7434 S. 10th Street	Oak Creek	S066666	--	40943
	44	Victory Graphics, Inc.	303 W. Marquette Avenue	Oak Creek	S066666	--	11387
	45	Vilter Manufacturing Corporations	5555 S. Packard	Cudahy	S066666	241832360	9202

Source: Wisconsin Department of Natural Resources

animal feeding operation may be designated as a CAFO by the WDNR, if it discharges pollutants to navigable waters or groundwater. A CAFO permit requires that the production area have zero discharge. There are currently no permitted CAFOs in the Oak Creek watershed.

Nonpoint Sources

Nonpoint source pollution consists of various discharges of pollutants to surface waters which cannot be readily identified as point sources. Nonpoint source pollution comes from diffuse sources and is transported from land areas of a watershed to surface waters by means of direct runoff from the land via overland routes, via storm sewers and channels, and via interflow following rainfall or snowmelt events. Nonpoint source pollution also includes pollutants conveyed to surface waters via groundwater discharge and deposition from the atmosphere. The distinction between point and nonpoint sources of pollution is somewhat arbitrary since a nonpoint source pollutant, such as sediment being transported in overland runoff, can be collected in open channels or storm sewers and conveyed to points of discharge, such as a storm sewer outfall.

Nonpoint source pollution differs from point source pollution in one important respect: nonpoint source pollution is transported to surface waters at irregular rates because large portions of overall transport occur during rainfall or snowmelt events. During the dry period following such a washoff event, potential pollutants gradually accumulate on the land surface as a result of human activities and other processes, becoming available for transport to surface waters during a subsequent runoff event.

The following activities or effects of human activities can result in nonpoint source pollution:

- Dry fallout and washout of pollutants from the atmosphere
- Vehicle exhaust and leakage of fuel and lubricating oil from vehicles
- Gradual wear and disintegration of vehicle components such as tires, engines, brakes, and bodies
- Gradual wear and disintegration of pavement, structures, and infrastructure
- Improper disposal of yard waste such as grass clippings and leaves
- Improperly sited and maintained onsite wastewater treatment systems
- Poor soil and water conservation practices
- Improper management of livestock wastes
- Excessive application of pesticides, fertilizers, and manure
- Improper storage and handling of materials
- Poor property maintenance
- Construction and demolition activity
- Application of sand and deicers for winter snow and ice control
- Poor management of domestic and wild animal litter
- Streambank erosion

The RWQMPU concluded that almost all of the pollutant loads of six pollutants to surface waters in the Oak Creek watershed—biochemical oxygen demand, total phosphorus, total suspended solids, fecal indicator bacteria, total nitrogen, and total copper—originated as nonpoint source pollution.[356]

---

[356] *SEWRPC Technical Report No. 39,* op. cit.

Solid Waste Disposal Sites

Solid waste disposal sites are a potential source of surface water and groundwater pollution. It is important to recognize the distinction between a properly designed and constructed solid waste landfill and the variety of operations that are referred to as refuse dumps, especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A solid waste landfill may be defined as a solid waste disposal site that is carefully located, designed, and operated to avoid hazards to public health or safety, or contamination of groundwater or surface waters. The proper design of solid waste landfills requires careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest practicable volume, to avoid surface water runoff, to minimize leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day's operation or at more frequent intervals as necessary.

In order for a landfill to produce leachate, there must be some source of water moving through the fill material. Possible sources included precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the solid waste landfill, the production of leachates in a well-designed and managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evaporation or evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 35 inches, which is typical of the Oak Creek watershed, could produce from 190,000 to 480,000 gallons of leachates per year per acre of landfill if the facility is not properly located, designed, and operated.

Table 4.40 and Map 4.46 show active, inactive, and legacy solid waste disposal sites in the Oak Creek watershed. As of 2019, there was one active solid waste landfill within the watershed, the South College Avenue Landfill. The site is an unlicensed solid waste disposal facility presently under long-term monitoring. In the summer of 2014, the site was re-opened and operated by the City of Milwaukee's Department of Public Works for its exclusive use for the placement of uncontaminated soils generated as a result of its water distribution system maintenance projects, as well as other approved clean fill. WDNR records indicate that there are also seven inactive sites in the watershed. Finally, an inventory of solid waste management facilities conducted in 1980 identified five pre-regulation landfills that were known to exist in the watershed.[357] These legacy sites had been found during the mid-1960s as a result of the preparation of detailed soil survey maps by the U.S. Soil Conservation Service and SEWRPC. They range in size from about two to eleven acres and consist of sites where waste materials had been deposited prior to the enactment of licensing requirements. It is unknown how many additional sites of this sort may be present in the Oak Creek watershed.

4.6 CURRENT MANAGEMENT PRACTICES

Urban Areas

As discussed in Chapter 3, urban land uses within the Oak Creek watershed have been increasing since the first SEWRPC land use inventory was conducted in 1963, and under planned land use conditions are expected to continue to increase. With urban development comes increased impervious surface and the negative impacts this can present to adjacent waterways. As of 2015, the watershed had about 65 percent of its land in urban uses, corresponding to an estimated 18 percent of the watershed's land considered to be directly connected impervious surface. These levels of connected imperviousness are expected to increase to about 25 percent of the watershed under planned land use conditions (see Figure 3.3 and Table 3.12). Impervious surface impacts can be mitigated to some degree through good land use planning, implementing traditional stormwater best management practices, creative site design, and emerging green infrastructure technologies. Local stormwater management practices affecting runoff volume and water quality, such as those promoting detention, infiltration, green infrastructure projects, and preservation and expansion of riparian buffers will be crucial to mitigate the consequences of continued urban development within the watershed.

---

[357] *R.P. Biebel and J.E. Stuber, "Inventory of Solid Waste Management Facilities in Southeastern Wisconsin: 1980,"* SEWRPC Technical Record, *volume 4, number 3, pages 15-53, February 1982.*

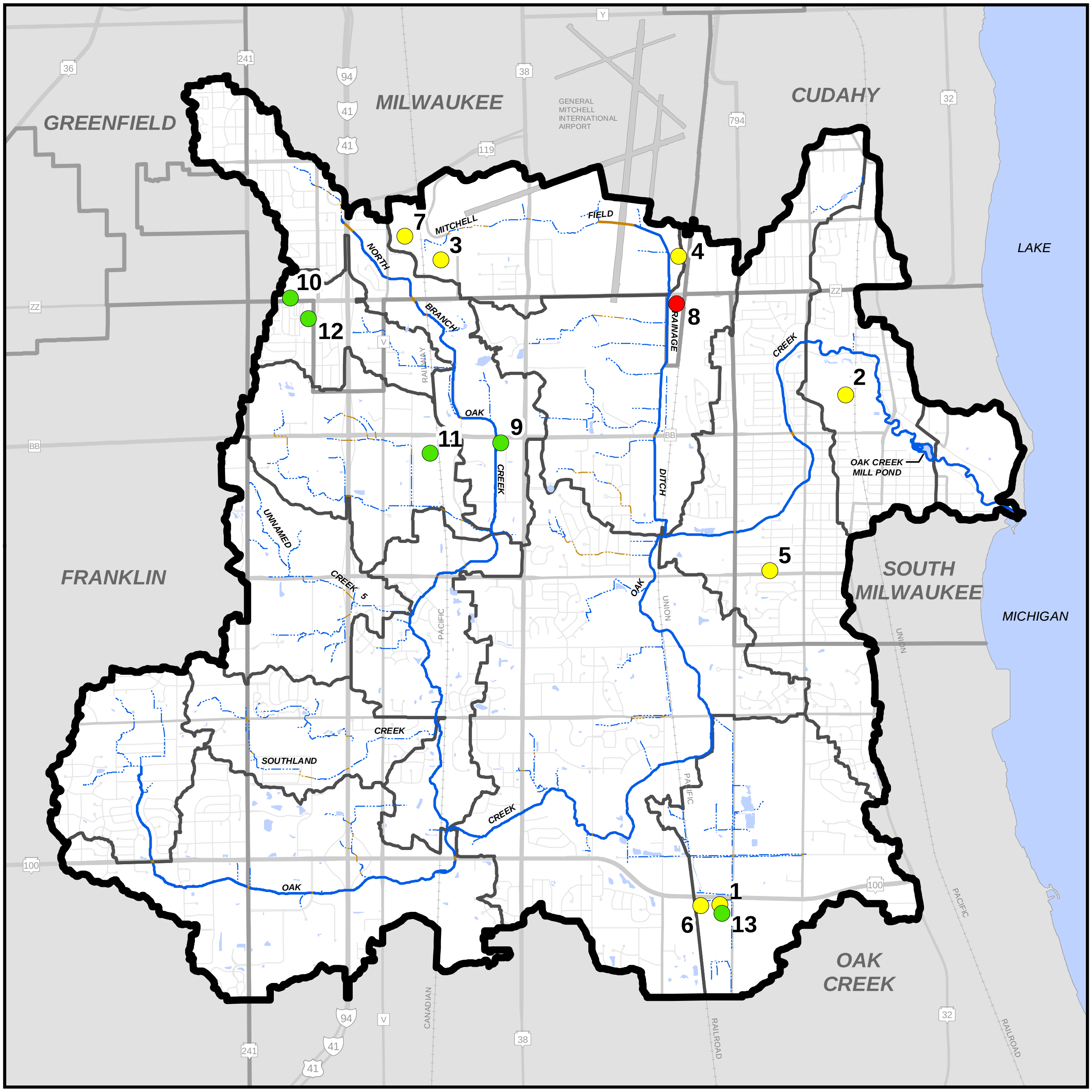
Table 4.40
Active, Inactive, and Legacy Solid Waste Disposal Sites in the Oak Creek Watershed: 2019

Number on Map 4.45	Facility Name	Address	Municipality	Classification	Facility ID	Status
1	Derosso Landfill Co., Inc.	9631 S. Pennsylvania Avenue	Oak Creek	Landfill, > 500,000 cubic yards	241210090	Inactive
2	Falk Corporation Landfill	13th Avenue north of Rawson Avenue	South Milwaukee	Landfill, > 500,000 cubic yards	241514790	Inactive
3	Linder Terminal	6055 S. 6th Street	Milwaukee	Landfill, unclassified	241262340	Inactive
4	Milwaukee County-College Avenue Landfill	1800 E. College Avenue	Milwaukee	Landfill, > 500,000 cubic yards	241207780	Inactive
5	Oak Creek City	1700 E. Drexel Avenue	Oak Creek	Landfill, 50,000-500,000 cubic yards	241208550	Inactive
6	Oak Creek Disposal	9781 S. Pennsylvania Avenue	Oak Creek	Landfill, unclassified	241378610	Inactive
7	WEPCo EMBK Airport Spur/WisDOT	Airport Spur Freeway	Milwaukee	Landfill, Unclassified	241219220	Inactive
8	South College Avenue Landfill	1701 E. College Avenue	Milwaukee	Landfill, 50,000-500,000 cubic yards	241687050	Active
9	Fun Services	185 W. Rawson Avenue	Oak Creek	Legacy disposal site[a]	241843690	Inactive
10	--	College Avenue between 19th Street and 23rd Street	Oak Creek	Legacy disposal site	--	Inactive
11	--	Rawson Avenue between 6th Street and 10th Street	Oak Creek	Legacy disposal site	--	Inactive
12	--	--	Oak Creek	Legacy disposal site	--	Inactive
13	--	--	Oak Creek	Legacy disposal site	--	Inactive

[a] *This site consists of a building on an abandoned landfill.*

Source: Wisconsin Department of Natural Resources and SEWRPC Technical Record, volume 43, number 3, pages 15-53, 1982

Map 4.46
Active, Inactive, and Legacy Solid Waste Disposal Sites in the Oak Creek Watershed: 2019



ACTIVE LANDFILL SITE

INACTIVE LANDFILL SITE

LEGACY DISPOSAL SITE

11 LANDFILL REFERENCE NUMBER (SEE TABLE 4.40)

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES (SEE MAP 3.2 FOR ASSESSMENT AREA NAMES)

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

0 0.25 0.5 1 Mile

Source: Wisconsin Department of Natural Resources and SEWRPC

NR 151 requires counties and local units of government in urbanized areas, which are identified based on population density, to obtain a WPDES stormwater discharge permit as required under Chapter NR 216.02. As a result of these requirements, Milwaukee County and all of the municipalities that make up the Oak Creek watershed have applied for and been issued municipal separate storm sewer (MS4) discharge permits from the WDNR. These designated MS4 communities are required to reduce 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
- Improving municipal “good housekeeping” practices, including winter road management programs, public works yard inspections, and inventorying and maintaining existing stormwater facilities. This includes mapping certain elements of their stormwater systems
- 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 addition to the standards given in NR 151, units of government within the MMSD service area (which includes all municipalities within the Oak Creek watershed except South Milwaukee) are required to comply with Chapter 13, “Surface Water and Storm Water Rules,” of the MMSD rules. Communities also must have stormwater management ordinances that are consistent with Chapter 13 and must update the ordinances to include amendments to the Chapter. The requirements of the WPDES permits and MMSD’s stormwater rules are further discussed in Chapter 2 of this Report.

Generally speaking, stormwater BMPs installed in areas developed prior to 1990 consisted of storm sewers, curb and gutter, catch basins, and grass swales. Catch basins are underground structures typically fitted with a slotted grate flush with the curbside gutter system on a roadway. Catch basins collect stormwater runoff and allow sediment and debris to settle out prior to routing it thorough underground pipes to the streams and rivers of the watershed. Municipalities in the Oak Creek watershed perform regular maintenance on catch basins to keep them clear of debris and functioning properly. Grass swales are installed in areas of the Oak Creek watershed that do not have a curb and gutter system. Grass swales are typically trapezoidal or parabolic in shape and are lined with turf grass. They are commonly maintained as part of a residential lawn. Grass swales can trap particulate pollutants through settling and filtration and can allow for absorption and vegetative uptake of dissolved pollutants. Grass swales are best suited to transport and treat stormwater runoff generated from impervious surfaces with small drainage basins.

Development and redevelopment since 1990 continue to utilize the aforementioned practices along with the addition of wet and dry stormwater detention basins. These detention basins are designed to capture stormwater runoff and release it to nearby streams over time at a flow rate closer to predevelopment conditions. Wet basins allow the total suspended solids and associated nutrients and 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. Both wet and dry stormwater detention basins have the ability to attract wildlife and could be managed to improve or expand habitat for wildlife within the watershed. Restoring mowed areas within or adjacent to detention basins with native prairie and wetland plants can improve water quality while providing important habitat for pollinators, amphibians, and other wildlife. In addition, these plantings discourage congregating of geese and their associated feces that can often litter the edges of stormwater detention basins. Stormwater detention basins located directly adjacent to or within the riparian corridor have great potential for increasing access or use by organisms such as frogs, turtles, and salamanders that need to migrate between the river and other habitat types.

In cooperation with the WDNR, inventories of stormwater infrastructure and strormwater best management practices were obtained for each of the MS4 municipalities within the watershed. The stormwater BMPs that have been reported to WDNR for water quality improvement are summarized by assessment area and community in Table 4.41. In total there were about 320 miles of grass swales, 73 wet retention basins, 475 catch basins, 3 acres of porous pavement, and 3 biofilter units reported by communities within the Oak Creek watershed.[358] All communities also perform street cleaning operations at varying time increments to remove pollutants before they can enter storm sewers. Additionally, all communities provide information and education programs about stormwater that are targeted to the general public, developers, and internal staff. The estimated pollutant removal achieved by each of these reported stormwater BMPs will be discussed in more detail in Chapter 5 of this Report. Map 4.47 shows locations of stormwater management BMPs as of 2018.[359]

The State nonpoint source pollution control program that began in 2000 led to the adoption of new buffer standards in 2011 with the revision of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* and establishes a requirement of a five- to 20-foot tillage setback in agricultural settings and a 10- to 75-foot impervious surface setback in urban settings. Nonagricultural performance standards set forth in Section NR 151.125 laid out specific setback requirements for designated "protective areas" that are defined as areas of land that commence 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:

- 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 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

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

- 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. For current riparian buffer conditions and potential areas for riparian buffer expansion, see the "Riparian Buffers" section above.

Because urban lands located adjacent to streams have a great impact on the biological community, an assumption might be made that riparian buffer strips located along the stream could ameliorate the negative effects caused by runoff from urbanization. While riparian buffers do have a mitigating effect, streambank buffers may not always treat this runoff since most urban stormwater is delivered directly to the stream via storm sewer or engineered channels. As a result, this runoff bypasses the potential filtering that buffers adjacent to the stream may offer. While a natural buffer between urban development and waterbodies are extremely important for the many water quality and wildlife habitat benefits they provide, the adequate mitigation of the impacts of urban stormwater runoff requires that they be used in combination with other management practices such as detention basins, grass swales, and infiltration facilities. Where conditions allow, retrofitting stormwater outfalls to discharge to buffer areas before they enter the stream may be beneficial. Combining practices into a "treatment train" can provide a much higher level of reduction in the volume of runoff and pollutant removal than can single, stand-alone practices. It is important to note that stormwater treatment practices vary in their function and level of effectiveness. The location on the landscape, as well as proper construction and continued maintenance, greatly influence their level of pollutant removal and runoff volume management.

---

[358] *Information reported in Table 4.41 reflects year 2013 conditions for the City of Oak Creek, 2011 conditions for the City of Franklin, and 2008 conditions for the Cities of Cudahy, Greenfield, Milwaukee, and South Milwaukee.*

[359] *Note that Map 4.47 contains digital information received from communities and may be more current than reported in Table 4.41. As such, this map does not show every element of the stormwater infrastructure in each community as recorded in Table 4.41. Information on stormwater outfalls is described in detail earlier in Chapter 4 and in Appendix E. Information on specific characteristics of municipal stormwater management systems can be found in individual reports for each community as reported in Table 2.6 in Chapter 2 of this Report.*

Table 4.41
Summary of Stormwater Best Management Practices Modeled by MS4 Permitted Communities Within the Oak Creek Watershed

	Grass Swale		Wet Retention		Catch Basins		Porous Pavement		Biofilter		Other BMP
Assessment Areas	Length (miles)	Area Treated (acres)	Number of Practices	Area Treated (acres)	Number of Practices	Area Treated (acres)	Area of Porous Pavement (acres)	Area Treated (acres)	Number of Practices	Area Treated (acres)	Area Treated (acres)
Oak Creek Mainstem											
Grant Park Ravine											
City of South Milwaukee	--	--	--	--	--	--	--	--	--	--	--
Lower Oak Creek – Mill Pond											
City of South Milwaukee	--	--	2	32.0	--	--	--	--	--	--	--
City of Cudahy	--	--	1	10.8	--	--	--	--	--	--	--
Lower Oak Creek											
City of Oak Creek	24.0	378.4	5	21.0	14	8.6	--	--	--	--	--
City of South Milwaukee	--	--	--	--	--	--	--	--	--	--	--
City of Cudahy	--	--	1	116.5	--	--	--	--	--	--	--
Middle Oak Creek											
City of Oak Creek	87.5	1,437.2	24	415.0	191	93.4	2.6	12.4	3	3.6	21.8
City of South Milwaukee	--	--	--	--	--	--	--	--	--	--	--
Middle Oak Creek – Drainage Ditches											
City of Oak Creek	36.6	561.0	1	66.6	18	1.0	--	--	--	--	18.1
Upper Oak Creek											
City of Oak Creek	23.2	441.4	9	102.5	--	--	--	--	--	--	8.6
City of Franklin	5.1	230.8	5	39.7	--	--	--	--	--	--	--
Oak Creek Headwaters											
City of Franklin	6.3	277.0	3	91.4	--	--	--	--	--	--	--
Mitchell Field Drainage Ditch											
Lower Mitchell Field Drainage Ditch											
City of Oak Creek	29.8	544.0	1	79.3	128	2.4	0.5	8.2	--	--	8.6
City of Milwaukee	--	--	--	--	--	--	--	--	--	--	--
City of Greenfield	--	--	1	6.3	--	--	--	--	--	--	--
Mitchell Field Drainage Ditch – Airport											
City of Oak Creek	0.8	12.1	--	--	--	--	--	--	--	--	--
City of Milwaukee	--	--	--	--	5	12.4	--	--	--	--	1.4

Table continued on next page.

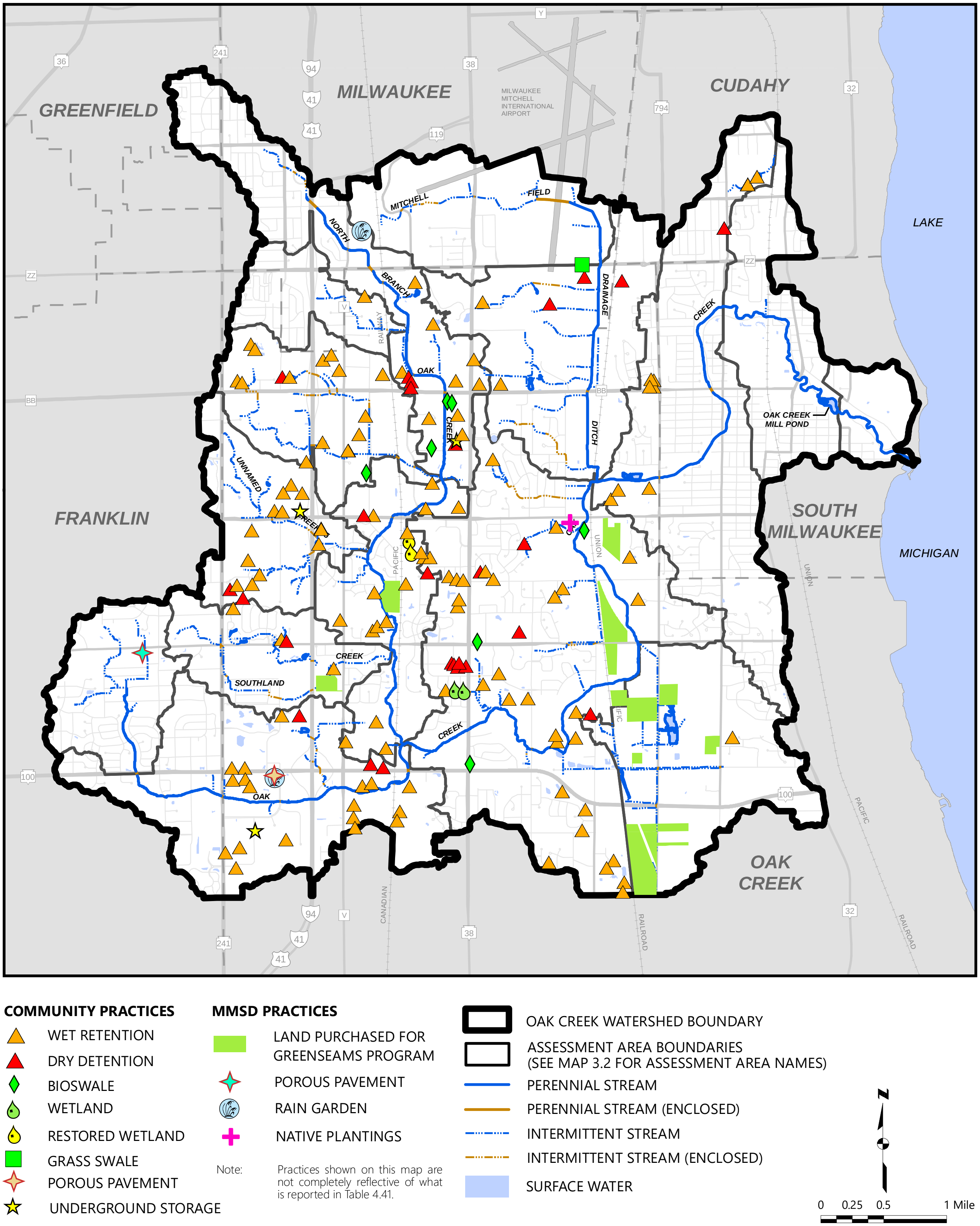
Table 4.41 (Continued)

Assessment Areas	Grass Swale		Wet Retention		Catch Basins		Porous Pavement		Biofilter		Other BMP
	Length (miles)	Area Treated (acres)	Number of Practices	Area Treated (acres)	Number of Practices	Area Treated (acres)	Area of Porous Pavement (acres)	Area Treated (acres)	Number of Practices	Area Treated (acres)	Area Treated (acres)
North Branch Oak Creek											
Lower North Branch Oak Creek											
City of Oak Creek	22.8	393.2	6	101.3	42	17.0	--	--	--	--	2.1
Upper North Branch Oak Creek											
City of Oak Creek	6.7	192.1	2	11.9	28	17.7	--	--	--	--	1.6
City of Milwaukee	4.2	63.4	--	--	2	2.0	--	--	--	--	--
City of Greenfield	4.7	79.7	--	--	--	--	--	--	--	--	--
Southland Creek											
City of Oak Creek	20.8	317.4	5	131.3	28	28.7	--	--	--	--	--
City of Franklin	2.9	130.0	2	25.5	--	--	--	--	--	--	--
Drexel Avenue Tributary											
City of Oak Creek	9.1	158.0	1	8.0	--	--	--	--	--	--	--
City of Franklin	1.5	88.2	2	38.4	--	--	--	--	--	--	--
Rawson Avenue Tributary											
City of Oak Creek	24.1	401.8	1	3.1	--	--	--	--	--	--	--
City of Milwaukee	--	--	--	--	--	--	--	--	--	--	--
City of Franklin	--	--	--	--	--	--	--	--	--	--	--
College Avenue Tributary											
City of Oak Creek	4.3	143.1	--	--	16	10.0	--	--	--	--	--
City of Milwaukee	3.5	53.1	1	2.5	3	4.1	--	--	--	--	2.5
Watershed Total	320.2	5,960.9	73	1,302.9	475	197.1	3.1	20.6	3	3.6	64.7

Note: Information reported in this table reflects year 2013 conditions for the City of Oak Creek; 2011 conditions for the City of Franklin, and 2008 conditions for the Cities of Cudahy, Greenfield, Milwaukee, and South Milwaukee. Practices within this table are not completely reflective of what is shown on Map 4.45.

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee, Wisconsin Department of Natural Resources, and SEWRPC

Map 4.47
Stormwater Management Practices and Green Infrastructure Reported by Communities and MMSD: 2018



Note: Practices shown on this map are not completely reflective of what is reported in Table 4.41.

Source: Cities of: Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee, MMSD, and SEWRPC

Emerging stormwater management technologies differ from traditional 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 technologies have been implemented throughout the Southeastern Wisconsin Region and within the Oak Creek watershed. The largest and most visible installations of these green technologies within the watershed were installed as part of the Drexel Town Square development. This development project included the installation of wet detention ponds, a dry detention pond, stormwater trees, biofiltration basins, rain gardens, porous pavement, and floating treatment wetlands (see Figure 4.121). The practices on this site redirect and provide storage for all stormwater up to a 100-year storm event and reduce total suspended solids from site runoff by 80 percent.[360] Several other green infrastructure projects have been installed within the Oak Creek watershed. These include two permeable pavement projects, several rain gardens, and a constructed wetland. Residential rain gardens have also been installed throughout the watershed. In addition, actions as simple as disconnecting residential downspouts can go a long way to control the impacts of increased urban runoff.

Agricultural Areas

In addition to the urban impacts discussed above, agricultural land uses can also have detrimental impacts to surface and groundwater. As of 2015 about nine percent, or 1,664 acres of the Oak Creek watershed was in agricultural land uses (see Tables 3.4 through 3.7 and Map 3.8). It is anticipated that over 1,000 acres of current agricultural land will be converted to urban land under planned conditions. Map 3.11 in Chapter 3 of this Report identifies agricultural land, woodlands, and other open lands in 2015 that are expected to be converted to urban uses under planned land use conditions. Knowing which areas are projected to be developed for urban uses allows for proper planning and incorporation of best management practices into the development plans to lessen the impacts on water quality and habitat that urban development can present. In addition, this information allows communities to develop strategies to protect some of the most ecologically and hydrologically vital areas prior to development. To that end, MMSD has created a program that aims to make voluntary purchases of undeveloped, privately owned properties in areas that are expected to have major urban development in the next 20 years. The Greenseams program has a flood management focus and targets key lands that contain water-absorbing soils to permanently protect them from development. In addition to flood management, protecting these vital lands helps maintain groundwater recharge and protects water quality and wildlife habitat. Through the Greenseams program, MMSD has purchased 14 properties within the Oak Creek watershed totaling 259 acres (see Map 4.47). Ownership for several of these properties has been transferred to Milwaukee County and the City of Oak Creek, with MMSD maintaining easement rights.

As of 2018, the Milwaukee County Department of Parks, Recreation, and Culture (DPRC) owned 134 acres within the Oak Creek watershed that were leased for agricultural operations. The administration and management of these leases is directed by DPRC's Agricultural Land Lease Policy. This policy sets forth the terms and conditions for the leased lands including requirements for conservation plans and other land management related conditions. Another element of the policy is a requirement that no annual crops be planted within 75 feet of any river or stream or within 30 feet of any field ditch on leased lands. DPRC intends to convert all County owned leased agricultural land to either forest, wetland, or native grassland conditions through restoration projects as funding opportunities become available. In 2019 DPRC reforested a former leased agricultural field at Barloga Woods/Falk Park and is currently planning to reforest a second former agricultural field in the same area in 2020. Both reforestation projects were funded by a grant from the Fund for Lake Michigan.[361]

Milwaukee County Environmental Services plans to perform an analysis to identify priority farms for compliance determinations, track progress on implementing performance standards, and determine whether these farms are meeting reporting requirements.[362] The analysis will be focused on Water Quality Management Areas (WQMA) that include areas 300 feet from a stream or 1,000 feet from a lake or areas susceptible to

[360] *J. Hansen and B. Henk, "Eyesore to Amenity, Storm Water Management System Controls Pollution at a Former Milwaukee Brownfield Site,"* Storm Water Solutions, *pages 22-24, June 2016.*

[361] *Personal communication, Brian Russart, Milwaukee County Parks Natural Areas Coordinator, December 2019.*

[362] *SEWRPC Community Assistance Planning Report No. 312,* A Land and Water Resource Management Plan for Milwaukee County: 2012-2021, *August 2011.*

groundwater contamination. Information from the U.S. Department of Agriculture Farm Service Agency, NRCS soil surveys, and digital orthophotography taken in spring 2015 will be used to identify potential locations of runoff or groundwater problems within the WQMA. Landowners within these areas will be contacted for a compliance evaluation based on the initial screening and additional onsite review may also be identified through complaints or staff observations. This analysis is planned to be completed by the end of 2020.

4.7 RECREATIONAL ACCESS AND USE

The state of recreational use of and access to surface waters and riparian areas is one of the focus areas of this watershed restoration plan. While the Oak Creek watershed is located in a heavily urbanized portion of the Region, it contains many high-quality natural resource amenities, including ponds, streams, attractive woodlands and wetlands, good wildlife habitat, and scenic landscapes. These resource amenities provide outdoor recreation opportunities for residents of the Southeastern Wisconsin Region. Preserving and protecting these resource amenities and finding ways to accommodate outdoor recreational activities that depend upon the natural resource base are important public policy objectives.

This section reviews the state of recreational facilities and access within the Oak Creek watershed. It presents inventories related to four recreational features: parks and parkways, trails, access to surface waters, and nature centers.

Parks and Parkways

Park and Open Space Sites Owned by Milwaukee County and the State of Wisconsin

The practice of the first Milwaukee County park commissioners of setting aside land for park purposes, dedicating land along principal routes of travel to allow for highway beautification, and developing parkways following the routes of rivers and streams led to an ambitious program to acquire open space land. This has resulted in a park and parkway system within the County that has long been recognized as one of the finest such systems in the Nation.[363]

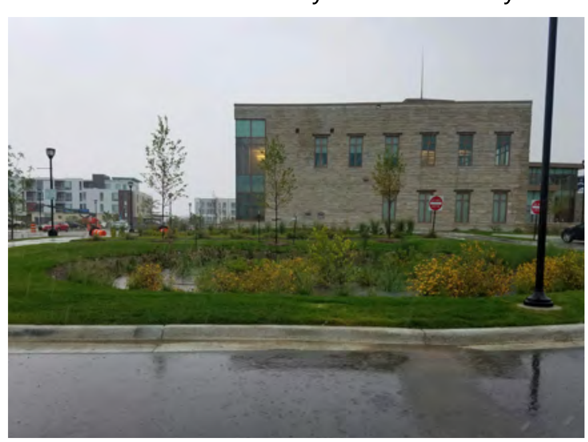
In 2020, there were 15 Milwaukee County-owned park and open space sites located wholly or partially within the Oak Creek watershed, encompassing a total of 2,363 acres, with 1,742 acres located within the watershed. These County-owned sites are shown on Map 4.48 and listed in Table 4.42, along with the amenities that they offer. There were four existing major County-owned

Figure 4.121
Examples of Green Infrastructure Within the Oak Creek Watershed: August 2016

Bioswale Capturing Runoff from Parking Lots at Drexel Town Square

Porous Pavement Infiltrating Runoff from Parking Lot at Drexel Town Square

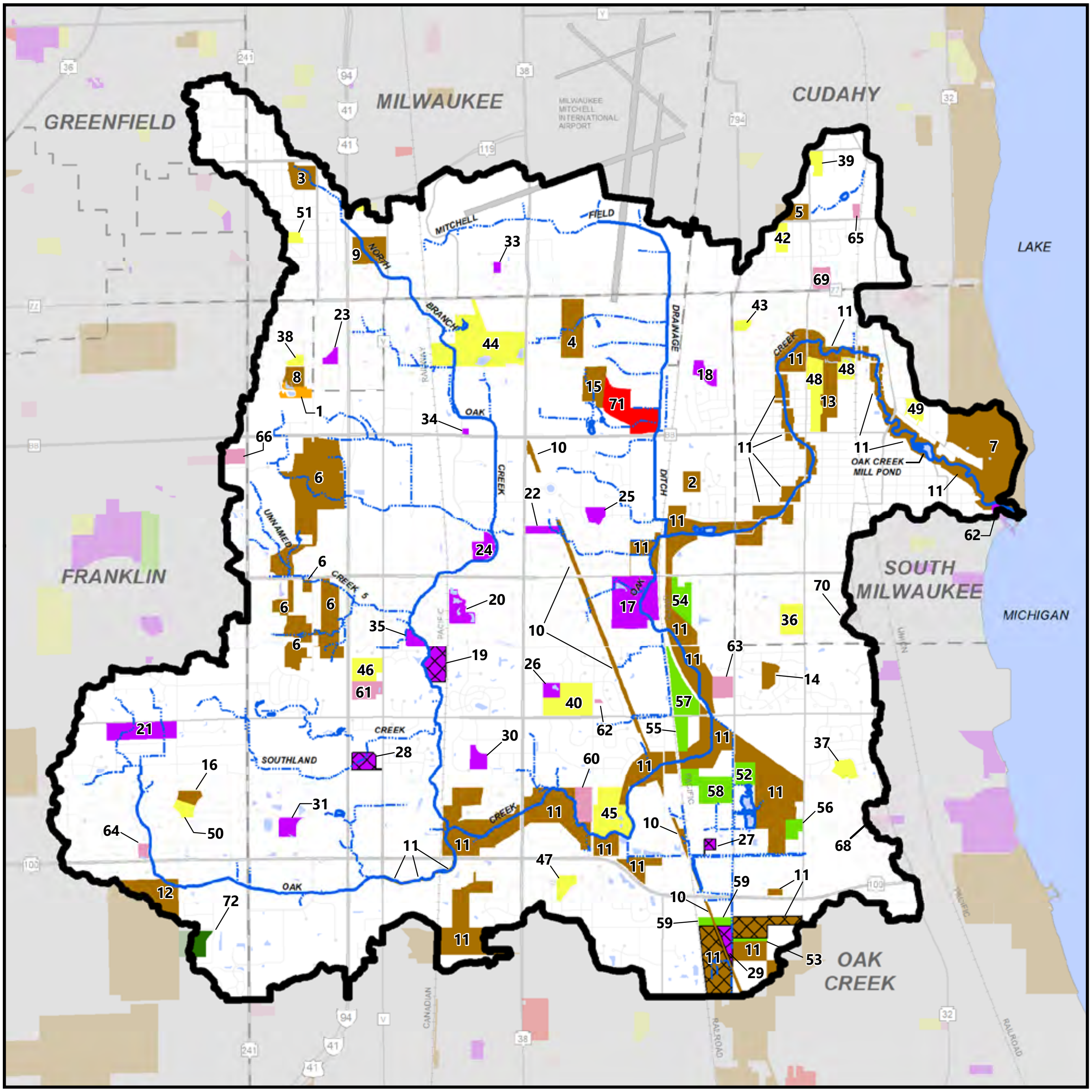
Rain Garden Capturing Runoff at the Oak Creek City Hall and Library



Source: SEWRPC

[363] *Preliminary Draft of SEWRPC Community Assistance Planning Report No. 132 (2nd Edition)*, A Park and Open Space Plan for Milwaukee County, *which was being updated as this plan was under preparation.*

Map 4.48
State, County, Municipal, MMSD, and Private Organization Owned Park and Open Space Land Within the Oak Creek Watershed: 2020



STATE-OWNED SITE
COUNTY-OWNED SITE
MUNICIPAL-OWNED SITE
SCHOOL DISTRICT-OWNED SITE
MMSD-OWNED SITE (GREENSEAMS)
OWNERSHIP TRANSFERRED BUT MMSD RETAINS EASEMENT RIGHTS (GREENSEAMS)
PRIVATE ORGANIZATION-OWNED SITE
COMMERCIAL SITE (LEASED FROM COUNTY)
CONSERVATION ORGANIZATION-OWNED SITE

OAK CREEK WATERSHED BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
SURFACE WATER

Note: See Table 4.42 for site names and details. Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

0 0.25 0.5 1 Mile

Source: SEWRPC

Table 4.42
Park and Open Space Sites and Selected Recreational Amenities Within the Oak Creek Watershed: 2020

Number on Map 4.47	Site Name	Size (acres)[a]	Playfield						Basketball	Play Area	Picnic Area[b]	Outdoor Swimming[c]	Tennis	Other Facilities
			Baseball	Softball	Sandlot	Soccer	Football	Volleyball						
	State-Owned Sites													
1	WDNR Wetland Mitigation Site	9	--	--	--	--	--	--	--	--	--	--	--	--
	County-Owned Sites													
2	Camelot Park (Leased to City of Oak Creek)	10	--	--	X	--	--	--	X	X	--	--	--	Shelter
3	Copernicus Park	20	--	--	--	--	--	--	X	X	--	--	--	Forked Aster Hiking Trail
4	Cudahy Nature Preserve	42	--	--	--	--	--	--	--	--	--	--	--	Forked Aster Hiking Trail, State Natural Area
5	Cudahy Park	18	--	--	--	X	--	--	X	X	X	--	--	Forked Aster Hiking Trail
6	Falk Park	258	--	--	--	--	--	--	--	--	--	--	--	Building rental, Forked Aster Hiking Trail, Oak Leaf Trail
7	Grant Park	381	--	--	X	X	--	X	X	X	X	B	X	Building rental, cross-country skiing, disc golf practice, Forked Aster Hiking Trail, golf, Oak Leaf Trail, overnight lodge, Seven Bridges Trail, Wil-O-Way Grant
8	Johnstone Park	13	--	X	--	--	--	X	--	X	--	--	--	Leased to the City of Oak Creek
9	Maitland Park	33	--	--	--	--	--	--	--	X	--	--	--	--
10	North Shore Right of Way	70	--	--	--	--	--	--	--	--	--	--	--	Oak Leaf Trail
11	Oak Creek Parkway	1,165	X	--	X	--	--	--	--	X	--	P	X	Grobschmidt pool, Oak Leaf Trail
12	Oakwood Park	276	--	--	--	--	--	--	--	--	--	--	--	Golf
13	Rawson Park	30	--	--	--	--	--	--	--	--	--	--	--	Forked Aster Hiking Trail, leased by the South Milwaukee School District
14	Riverton Meadows	12	--	X	--	--	--	X	X	X	--	--	X	Leased by the City of Oak Creek
15	Runway Dog Exercise Area	26	--	--	--	--	--	--	--	--	--	--	--	Dog exercise area
16	Southwood Glen	9	--	--	X	--	--	X	--	--	--	--	--	Leased by Franklin Public Schools
	Municipal-Owned Sites													
17	Abendschein Park	76	X	--	--	X	--	--	--	X	X	--	--	Disc golf, paved trails, skateboarding and bicycle park
18	Chapel Hills Park	12	--	X	--	--	--	X	X	X	X	--	X	Exercise stations, ice skating[d]
19	City of Oak Creek Open Space (MMSD Conservation Plan Worthington Property Easement)	22	--	--	--	--	--	--	--	--	--	--	--	--

Table continued on next page.

Table 4.42 (Continued)

Number on Map 4.47	Site Name	Size (acres)[a]	Playfield						Basketball	Play Area	Picnic Area[b]	Outdoor Swimming[c]	Tennis	Other Facilities
			Baseball	Softball	Sandlot	Soccer	Football	Volleyball						
	Municipal-Owned Sites (continued)													
20	Emerald Preserve Park	20	--	--	--	--	--	--	--	--	--	--	--	--
21	Franklin Woods Nature Center	39	--	--	--	--	--	--	--	X	X	--	--	Marked nature trails
22	Greenlawn Park	9	--	--	--	--	--	--	--	--	X	--	--	--
23	Jewel Playfield	6	--	X	--	--	--	X	X	X	X	--	X	Hiking and paved trails
24	Little League Complex	19	X	X	--	--	--	--	--	--	--	--	--	--
25	Manor Marquette Park	9	--	X	--	--	--	--	X	X	X	--	X	Paved trails
26	Miller Park	8	--	--	--	--	--	--	--	--	X	--	--	Paved trails, fishing pond, ice skating[d]
27	Oak Creek MMSD Conservation Plan Finke Property	5	--	--	--	--	--	--	--	--	--	--	--	--
28	Oak Creek MMSD Conservation Plan Lesch Property	14	--	--	--	--	--	--	--	--	--	--	--	--
29	Oak Creek MMSD Conservation Plan Vanslow Property	9	--	--	--	--	--	--	--	--	--	--	--	--
30	Oak Leaf Park	11	--	X	--	--	--	X	X	X	--	--	X	--
31	South Hills Park	12	--	X	--	--	--	X	X	X	--	--	X	Paved trails
32	South Milwaukee Yacht Club	12	--	--	--	--	--	--	--	--	--	--	--	Boat launch, fishing
33	Uncas Playground	3	--	X	--	--	--	--	X	X	--	--	X	--
34	Veteran's Memorial Park	1	--	--	--	--	--	--	--	--	--	--	--	--
35	Willow Heights Park	8	--	X	--	--	--	--	X	X	X	--	X	Exercise stations, paved trails
	School District-Owned Sites													
36	Blakewood School	15	--	X	--	--	--	--	X	X	--	--	--	--
37	Carollton School and Park	9	--	X	--	--	--	--	X	X	--	--	X	--
38	Cedar Hills School	3	--	--	--	--	--	--	X	X	--	--	--	Funnel ball
39	Cudahy Middle School	3	--	--	X	X	X	X	X	--	--	--	--	--
40	Edgewood Elementary School/Oak Creek High School	36	--	X	X	X	X	--	X	X	--	--	X	Track
41	Garland School	3	--	--	--	X	--	--	X	X	--	--	--	Track
42	General Mitchell School	4	--	--	X	X	--	--	X	X	--	--	--	Funnel ball, track
43	Hickory Park	5	--	--	--	--	X	--	X	X	--	--	X	--
44	MATC South Campus	53	X	--	--	--	--	--	--	--	--	--	--	--

Table continued on next page.

Table 4.42 (Continued)

Number on Map 4.47	Site Name	Size (acres)[a]	Playfield						Basketball	Play Area	Picnic Area[b]	Outdoor Swimming[c]	Tennis	Other Facilities
			Baseball	Softball	Sandlot	Soccer	Football	Volleyball						
	School District-Owned Sites (continued)													
45	Oak Creek East Middle School	41	--	X	--	X	X	--	--	--	--	--	--	--
46	Oak Creek West Middle School	13	--	--	--	X	--	--	--	--	--	--	--	--
47	Shepard Hills School and Park	8	--	X	--	--	--	--	X	X	--	--	--	--
48	South Milwaukee High School	22	--	X	--	X	X	--	X	X	--	--	--	Track
49	South Milwaukee Middle School	5	--	--	--	X	--	--	X	X	--	--	--	--
50	Southwood Glen Elementary	3	--	--	--	--	--	--	X	X	--	--	--	--
51	Victory School and Playfield	3	--	X	--	X	--	--	X	X	--	--	--	--
	MMSD-Owned Sites													
52	Cannon Greenseams Property	15	--	--	--	--	--	--	--	--	--	--	--	--
53	Domoe Greenseams Property	4	--	--	--	--	--	--	--	--	--	--	--	--
54	Grall Greenseams Property	22	--	--	--	--	--	--	--	--	--	--	--	--
55	Ludwig Greenseams Property	13	--	--	--	--	--	--	--	--	--	--	--	--
56	Oak Creek Investment Greenseams Property	10	--	--	--	--	--	--	--	--	--	--	--	--
57	Rowan Greenseams Property	33	--	--	--	--	--	--	--	--	--	--	--	--
58	Watson Greenseams Property	39	--	--	--	--	--	--	--	--	--	--	--	--
59	Weiss Greenseams Property	9	--	--	--	--	--	--	--	--	--	--	--	--
	Private Organization-Owned Sites													
60	American Legion Park	20	--	X	--	--	--	--	--	--	X	--	--	--
61	Badger State Baptist School	2	--	--	X	--	--	--	X	X	--	--	--	--
62	Creative Explorers Learning Center	1	--	--	--	--	--	--	--	X	--	--	--	--
63	Grace Lutheran Church	11	--	--	X	X	--	--	X	X	--	--	--	--
64	House of Prayer Lutheran Church and Academy of Integrity	3	--	--	--	--	--	X	--	X	--	--	--	--

Table continued on next page.

Table 4.42 (Continued)

Number on Map 4.47	Site Name	Size (acres)[a]	Playfield						Basketball	Play Area	Picnic Area[b]	Outdoor Swimming[c]	Tennis	Other Facilities
			Baseball	Softball	Sandlot	Soccer	Football	Volleyball						
	Private Organization-Owned Sites (continued)													
65	Ladish Little League Park	3	--	X	--	--	--	--	--	--	--	--	--	--
66	St. James Catholic Church and Preschool	19	--	--	--	--	--	--	--	--	--	--	--	--
67	St. John's Lutheran School	6	--	--	--	--	--	--	X	--	--	--	--	--
68	St. Matthews School	5	--	--	--	X	--	--	X	X	--	--	--	--
69	YMCA	13	--	--	--	X	--	X	--	X	--	--	--	Track
70	Zion School	3	--	--	X	--	--	--	X	X	--	--	--	--
	Commercial Site													
71	Gastrau's Golf Center	50	--	--	--	--	--	--	--	--	--	--	--	Leased from County, driving range, Mini golf, Foot golf
	Conservancy-Owned Site													
72	Fitzsimmons Woods	25	--	--	--	--	--	--	--	--	--	--	--	--
	Total	3,199	4	19	10	15	5	11	30	36	11	2	13	--

Note: The availability of outdoor recreation amenities within parks and open space sites may vary from year to year, more frequently within certain parks than in others, depending on a variety of factors including demand, field conditions, and staffing resources.

[a] *Includes area of park or open space outside of the Oak Creek watershed where applicable.*

[b] *Picnic areas include both informal areas as well as designated picnic facilities available for reservation.*

[c] *Swimming facilities are annotated as follows:*
B – Beach
P – Pool

[d] *Ice skating available in season on community-supported land rink or lagoon as weather permits.*

Source: Cities of Cudahy, Franklin, Greenfield, Milwaukee, Oak Creek, and South Milwaukee, Milwaukee County Parks, MMSD, and SEWRPC parks of 100 acres or more in size located wholly or partially within the Oak Creek watershed, encompassing a total of 2,080 acres (1,475 acres located within the watershed). These major parks include Falk Park, Grant Park, the Oak Creek Parkway, and Oakwood Park.[364]

The State of Wisconsin owns one open space site within the Oak Creek watershed, a nine-acre WDNR wetland mitigation site. This site is contiguous with Milwaukee County-owned Johnstone Park (see Map 4.48).

Park and Open Space Sites Owned by Municipalities, School Districts, and the Milwaukee Metropolitan Sewerage District

In addition to County-owned park and open space sites located wholly or partially within the Oak Creek watershed, there were 19 sites owned by local units of government (totaling 295 acres, all within the Oak Creek watershed) and 16 sites owned by school districts or colleges (totaling 376 acres). MMSD owns eight open space sites in the Oak Creek watershed (totaling about 145 acres) as part of their Greenseams Program. In addition to these eight sites, MMSD retains easement rights to four sites purchased through its Greenseams program for which ownership was transferred to the City of Oak Creek, and two sites for which ownership was transferred to Milwaukee County (see Table 4.42 and Map 4.48). All properties purchased through the Greenseams program are publicly accessible and, where applicable, can be used for hiking, bird watching, and other passive recreation. They are intended to remain largely undeveloped and to be restored to natural conditions.

Park and Open Space Sites Owned by Private and Non-Profit Organizations

There are 11 open space sites partially or completely within the Oak Creek watershed that are owned by private organizations (totaling about 86 acres). There is also one 50-acre commercial open space site that is leased from the County and offers mini golf and a golfing range, and one open space site owned by a land conservancy (25 total acres, 14 of which are within the Oak Creek watershed).

Trails

Milwaukee County Parks has been constructing paved off-road trails since 1967. In 1976, the multi-use trail system was 76 miles in length and was named the "76 Trail" to commemorate the U.S. bicentennial. The year 2000 park and open space plan for Milwaukee County, completed in 1991, recommended that a total of 89 miles of trails be provided. In 1996 the trail system was renamed the "Oak Leaf Trail." As of 2015, there were 125 miles of trail, including 72 miles of paved off-road trails, 27 miles along parkway drives, and 26 miles of bicycle ways on municipal streets in Milwaukee County.[365] There are over 12 miles of the Oak Leaf Trail located within the Oak Creek watershed. In addition, the adopted regional land use and transportation plan proposes adding almost 75 miles of additional multi-use trail within Milwaukee County, almost six miles of which would be within the Oak Creek watershed (see Map 4.49).[366] Bicycle use can and does legally occur on many public roadways in the County that are not specifically designated for such use. State law permits bicycle use on all public roadways, except expressways and freeways and those roadways where the local unit of government has acted to prohibit bicycle use by ordinance.

In addition to paved trails, Milwaukee County Parks operates the Forked Aster Hiking Trail System, a series of soft trails within County-owned parks. Trails within the Forked Aster Hiking Trail System pass through grasslands, wetlands, and woodlands and offer the opportunity to observe a diverse array of native flora and fauna. There are over nine miles of the Forked Aster Hiking Trail in County-owned parks that are wholly or partially located within the Oak Creek watershed. These parks include Copernicus Park, Cudahy Nature Preserve, Cudahy Park, Falk Park, Grant Park, and Rawson Park (see Map 4.49).[367] There are additional paved and unpaved trail opportunities at municipal-owned park and open space sites, as noted in Table 4.42.

---

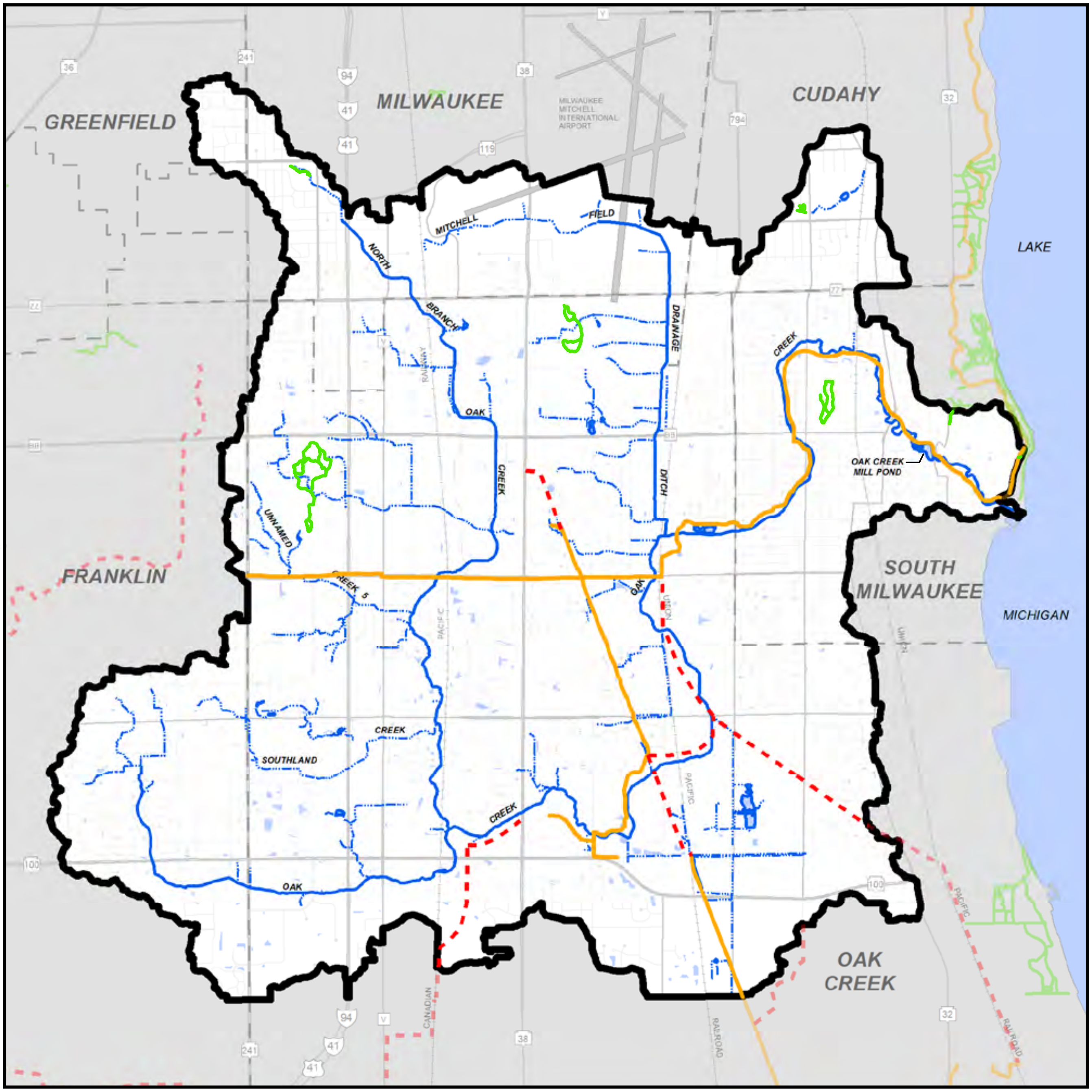
[364] *Portions of Grant Park, Oakwood Park, and the Oak Creek Parkway are located outside of the Oak Creek watershed.*

[365] *Draft SEWRPC Community Assistance Planning Report No. 132 (2nd Edition),* op. cit.

[366] *SEWRPC Planning Report No. 55,* VISION 2050: A Regional Land Use and Transportation Plan for Southeastern Wisconsin, *July 2017.*

[367] *Most of the 5.25 miles of the Forked Aster Hiking Trails in Grant Park are outside of the Oak Creek watershed.*

Map 4.49
Existing and Proposed Off-Street Multi-Use Trails Within the Oak Creek Watershed: 2019



OAK LEAF TRAIL (EXISTING OFF-STREET PATH 2019)
PROPOSED OFF-STREET PATH
FORKED ASTER HIKING TRAIL (EXISTING SOFT TRAIL 2020)
OAK CREEK WATERSHED BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
SURFACE WATER

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

0 0.25 0.5 1 Mile

Source: SEWRPC

Access to Surface Waters

Due to insufficient water depths, most of Oak Creek and its tributaries are not suitable for recreational canoeing, kayaking, or swimming. Access to surface waters in the Oak Creek watershed focuses on fishing, hiking and biking trails adjacent to streams, and passive recreation.

Fishing Access

Access from Banks

Fishing access to the surface waters of the Oak Creek watershed is available from the shoreline within public land adjacent to the Creek and Mill Pond, specifically in the Milwaukee County Parks and Parkway system. For the most part, Oak Creek and its tributaries can be accessed from any adjacent public lands that the angler can legally access where local ordinances do not prohibit fishing. The most popular fishing locations in the watershed are just below the Mill Pond dam, where a large pool offers refuge for larger fish species, and the reach of Oak Creek downstream of this pool extending to the Creek's confluence with Lake Michigan. An unpaved trail on Oak Creek Parkway land offers public access to the Creek along this reach. These areas are especially popular for anglers during the salmon and brown trout runs for several weeks in the fall and the run of Steelhead (or rainbow trout) in mid- to late-February. A trail and a pier within Grant Park at the confluence of Oak Creek and Lake Michigan also offers opportunities for larger water fishing.

Urban Fishing Waters Program

Under the State's urban fishing program, the Oak Creek Mill Pond is managed to provide fishing opportunities in an urban area. This pond is posted with signs and has a shoreline that is accessible to the public. In addition, special fishing regulations apply to this pond. These regulations include:

- A year-round fishing season
- No length limits on fish caught
- A special season for children 15 years of age and younger and for certain anglers with disabilities

This pond also has a daily bag limit of:

- Three trout
- One game fish (largemouth or smallmouth bass, walleye, sauger, and northern pike)
- Ten panfish (bluegill, crappie, pumpkinseed, yellow perch, and bullhead)

Management of Oak Creek Parkway Pond includes fish stocking. In 2017, the WDNR stocked about 500 catchable-size rainbow trout into this pond.

Nature Centers and Other Facilities

As described in Chapter 2 of this report, there are no nature centers located within the Oak Creek watershed. Wehr Nature Center is located near the Oak Creek watershed in Whitnall Park in the City of Franklin. This center offers programming that includes field trip opportunities for school groups, nature and environmental education programs for visitors, natural history and environmental education programs for adults and families, citizen-based science, and training and educational resources for educators. Wehr Nature Center also provides support for outdoor recreation programs. As part of Whitnall Park, the center is connected to the park's hiking trail system. These trails are connected to Milwaukee County's Oak Leaf Trail.

Oak Creek Recreational Use Surveys

In order to better understand the patterns of outdoor recreation in the Oak Creek watershed, several surveys were conducted to collect information on the use of parks and open space sites and the outdoor activities that occur. These surveys are summarized below.

On April 12, 2016, SEWRPC staff held a stakeholder meeting to introduce background information and the scope of the Oak Creek Watershed Restoration Plan. At the meeting, participants were asked to complete a survey about their opinions regarding the Oak Creek watershed. Out of 34 responders, more than half (18) said that they enjoy the Oak Creek watershed for outdoor recreation. When asked about outdoor recreational issues in the watershed, responders most commonly listed the quality and location of the trails as a key issue for outdoor recreation. Responders also noted that having adequate recreational safety and a variety of recreational activities available and supported by the parks was important to outdoor recreation in the Oak Creek watershed.

An online survey was conducted in late 2017 to collect additional perspectives on the Oak Creek watershed. A total of 108 wholly or partially completed surveys were submitted. About 70 percent of responders said they enjoy the outdoor recreation that is offered within Oak Creek watershed. The most commonly reported recreational activities in the watershed were walking (57 percent of responders), hiking (46 percent), fishing (38 percent), and biking (21 percent). Thirty people who completed the survey expressed interest in dredging the Mill Pond to restore it to its original depth so that recreational activities such as ice skating and boating could resume. Responders also suggested improving the recreational experience by cleaning up trash and pollution, possibly via organized groups of volunteers. Some recommended restoring and maintaining existing paths and trails, adding additional paths, and installing signage for educational purposes.

In the winter of 2017 and fall of 2018, a passive infrared counter was used to quantify the number of bicyclists and pedestrians traveling along the Oak Leaf Trail at its intersection with E. Drexel Avenue in the Oak Creek watershed. This count was done as part of an effort for the Federal Highway Administration Bicycle-Pedestrian Technology Pilot Project. A count conducted from January 21 to February 2, 2017, (13 days) observed a total of 349 pedestrians and cyclists using the trail, with an average of 27 passersby per day. Between September 20 and October 3, 2018, (14 days), a total of 610 passersby were counted, with an average of 44 people using the trail per day. The weather conditions were noted every day of these studies, and greater numbers of cyclists and pedestrians were strongly associated with favorable weather. Summaries of the count data are shown in Table 4.43.

In the summer and fall of 2019, SEWRPC staff visited nine parks and natural areas in the Oak Creek watershed on eight different occasions to observe the number of people using the areas, and how they were using them (see Map 4.50 for locations). This study included counting the numbers of vehicles parked at five recreational sites in the watershed and counting individuals at three sites. The findings showed that walking and running were the most common activities for the eight sites observed. Fishing was also a popular activity just downstream of the Mill Pond dam during the salmon and brown trout run, with as many as 13 anglers seen here during a visit in the fall. The survey also showed that Franklin Woods Nature Center had consistently high usage, with an average of 25 cars in the parking lot per visit. Many of the visitors at this site appeared to be using Kayla's Playground, a large play area designed to be accessible to children with special needs. Runway Dog Park in Oak Creek was also heavily used, with an average of 13 cars parked in the parking lot per survey visit. The high visitor traffic and proximity of this park to a tributary to the Mitchell Field Drainage Ditch highlights the importance of dog owners cleaning up after their pets. The counts for each location per visit are given in Tables 4.44 and 4.45, and each site is shown on Map 4.50. It should be noted that the counts in Table 4.45 were conducted over a period of half an hour, while the counts in Table 4.44 were based on a single point in time.

4.8 ARCHEOLOGICAL INVENTORY

The State Historic Preservation Office of the Wisconsin Historical Society maintains the Wisconsin Historic Preservation Database (WHPD), which includes an archeological sites inventory (ASI) for Wisconsin. The ASI includes information about archeological and burial sites, unmarked cemeteries, marked cemeteries, and cultural sites.[368] Commission staff reviewed the ASI for documented sites within the Oak Creek watershed as of August 2019. As of that date there were 56 total archeological sites included in the ASI for the Oak Creek watershed. The 56 documented sites were categorized as follows: 28 village/campsite/cabin/workshop sites, 14 cemetery sites, 10 isolated finds or lithic scatter sites, three native American burial mound sites, and one schoolhouse site. It should be noted that sites are added and revised on the ASI on a daily basis.

---

[368] *WHPD webpage at www.wisconsinhistory.org/Records/Article/CS4091.*

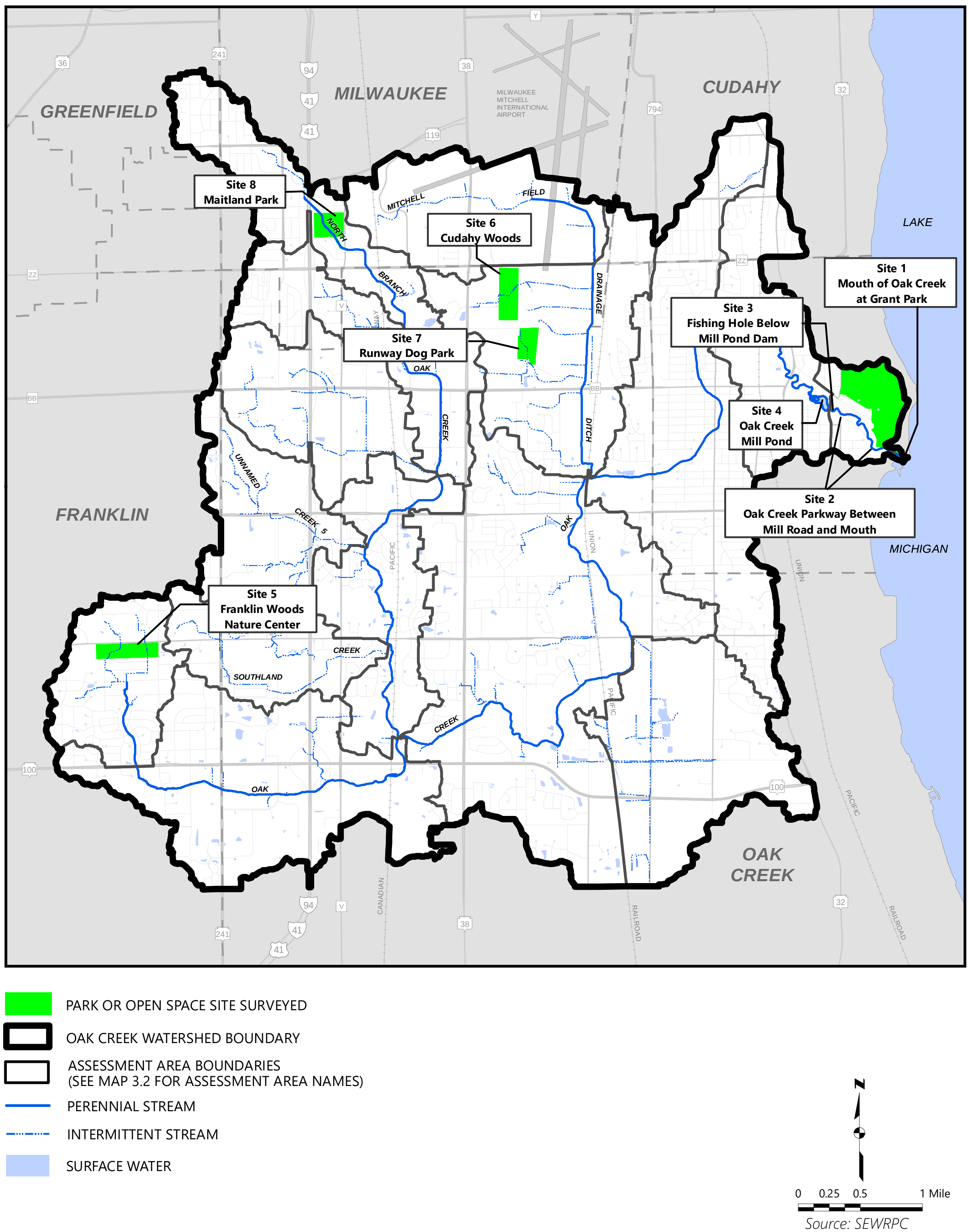
Table 4.43
Volume Summary for Infrared Counter on Oak Leaf Trail at E. Drexel Avenue

Statistic	Total	Northbound	Southbound
All Volume January 21 – February 2, 2017	349	160	189
January 21-27 Total	260	116	144
Monday – Friday Total	118	52	66
Saturday – Sunday Total	142	64	78
January 28 – February 2 Total	89	44	45
Monday – Friday Total	45	20	25
Saturday – Sunday Total	44	24	20
Percent Volume Split	--	45.8	54.2
All Volume September 20 – October 3, 2018	610	328	282
September 20-26 Total	326	181	145
Monday – Friday Total	233	126	107
Saturday – Sunday Total	93	55	38
September 27 – October 3 Total	284	147	137
Monday – Friday Total	223	117	106
Saturday – Sunday Total	61	30	31
Percent Volume Split	--	53.8	46.2

Source: U.S. Federal Highway Administration and SEWRPC

The exact locations of the documented ASI sites will not be included in this plan, but will be used to refine the recommended projects for watershed restoration. A review by the State Historic Preservation Officer (SHPO) may be required during watershed restoration project design. The SHPO review will depend on the level of Federal, State, or local government involvement and if the project site is listed on the WHPD at that time.

Map 4.50
Recreational Use Survey Sites: 2019



Source: SEWRPC

Table 4.44
Parked Vehicle Counts Within the Oak Creek Watershed

Site Name and Number on Map 4.49	Weekdays		Weekends	
	Date and Time of Day	Site Users[a]	Date and Time of Day	Site Users[a]
Site Number 2 *Oak Creek Parkway – Mouth to Mill Road*	August 28, 2019, Evening	2	August 24, 2019, Afternoon	1
	August 29, 2019, Morning	3	August 25, 2019, Afternoon	1
	September 26, 2019, Morning	7	September 28, 2019, Afternoon.	4
	October 23, 2019, Morning	4	October 26, 2019, Morning	11
Site Number 3 *Just Below Mill Pond Dam*	August 28, 2019, Evening	0	August 24, 2019, Evening	4
	August 29, 2019, Morning	1	August 25, 2019, Afternoon.	0
	September 26, 2019, Morning	7	September 28, 2019, Afternoon	4
	October 23, 2019, Morning	6	October 26, 2019, Morning	3
Site Number 5 *Franklin Woods*	August 28, 2019, Evening	13	August 24, 2019, Evening	42
	August 29, 2019, Morning	28	August 25, 2019, Morning	37
	September 26, 2019, Afternoon	29	September 28, 2019, Evening	41
	October 23, 2019, Morning	3	October 26, 2019, Morning	3
Site Number 6 *Cudahy Woods*	August 28, 2019, Evening	1	August 24, 2019, Afternoon	0
	August 29, 2019, Morning	0	August 25, 2019, Afternoon	3
	September 26, 2019, Morning	0	September 28, 2019, Afternoon	4
	October 23, 2019, Morning	0	October 26, 2019, Morning	2
Site Number 7 *Runway Dog Park*	August 28, 2019, Evening	11	August 24, 2019, Afternoon	25
	August 29, 2019, Morning	12	August 25, 2019, Afternoon	11
	September 26, 2019, Morning	10	September 28, 2019, Afternoon	13
	October 23, 2019, Morning	7	October 26, 2019, Morning	16

[a] *"Site Users" represent the number of vehicles parked at a point in time except for Site 3 where the "Site Users" represent individuals visiting the site.*

Source: SEWRPC

Table 4.45
Activity Counts Within the Oak Creek Watershed

Site Name and Number on Map 4.49	Date and Time of Day[a]	Activity							Total
		Walking/ Running	Biking	Fishing	Sitting	Using Playground	Taking Photos	Mobile Game Players	
Site Number 1 *Mouth of Oak Creek in Grant Park*	Weekdays								
	August 28, 2019, Evening	8	0	0	3	N/A	0	0	11
	August 29, 2019, Morning	3	0	0	0	N/A	0	0	3
	September 26, 2019, Morning.	4	0	0	0	N/A	1	0	5
	October 23, 2019, Morning	2	0	0	0	N/A	0	0	2
	Weekends								
	August 24, 2019, Afternoon	50	4	3	4	N/A	0	0	61
	August 25, 2019, Afternoon	44	1	7	0	N/A	0	0	52
	September 28, 2019, Afternoon	10	0	2	0	N/A	0	0	12
	October 26, 2019, Morning	32	0	4	1	N/A	0	0	37
Site Number 4 *Mill Pond at Mill Road*	Weekdays								
	August 28, 2019, Evening	14	7	2	0	N/A	2	15	40
	August 29, 2019, Morning	3	3	0	0	N/A	0	0	6
	September 26, 2019, Morning	4	0	0	0	N/A	2	0	6
	October 23, 2019, Morning	6	0	0	0	N/A	0	0	6
	Weekends								
	August 24, 2019, Afternoon	7	5	0	0	N/A	0	0	12
	August 25, 2019, Afternoon	6	19	0	0	N/A	0	0	25
	September 28, 2019, Afternoon	6	1	0	6	N/A	0	0	13
	October 26, 2019, Morning	10	0	0	0	N/A	2	0	12
Site Number 8 *Maitland Park*	Weekdays								
	August 28, 2019, Evening	2	2	0	0	9	0	0	13
	August 29, 2019, Morning	1	0	0	0	0	0	0	1
	September 26, 2019, Morning	3	0	0	0	0	0	0	3
	October 23, 2019, Morning	0	0	0	0	0	0	0	0
	Weekends								
	August 24, 2019, Afternoon	1	0	0	0	2	0	0	3
	August 25, 2019, Morning	2	1	0	0	0	0	0	3
	September 28, 2019, Afternoon	2	0	0	0	2	0	0	4
	October 26, 2019, Morning	1	0	0	0	0	0	0	1

[a] *Sites were visited for a one half-hour time period, counting the number of users and the activities during that time period.*

Source: SEWRPC

WATERSHED GOALS AND MANAGEMENT OBJECTIVES 5

Credit: SEWRPC Staff

5.1 INTRODUCTION

As noted in Chapter I, the purpose of this plan is to provide a set of specific, targeted, and implementable recommendations to improve conditions in the watershed. The recommendations address four focus areas: water quality, recreational access and use, habitat conditions, and targeted stormwater drainage and flooding issues. In addition, this plan addresses the status of the Oak Creek Mill Pond and the associated dam, considering their relationship to multiple focus areas. This plan is designed to serve as a practical guide for managing water quality within the Oak Creek watershed and for managing the land surfaces that drain directly and indirectly to the streams of the watershed and to the Mill Pond. The improvements that would result from implementing the recommendations represent steps toward achieving the overall goal of restoring and improving the water resources of the Oak Creek watershed.

This chapter describes the goals of the plan and the management objectives to be achieved through the plan's implementation. The management objectives related to each goal consist of broad approaches or general types of actions required to meet the goal. Specifying these objectives breaks the goals down into manageable pieces, helps determine the specific steps necessary to achieve a goal, and facilitates developing measures to track progress. In some instances, specific targets are associated with a management objective. These targets estimate the level of effort that will be required to achieve a defined amount of improvement. The management objectives and targets also provide direction for developing specific policies and projects to address problems related to the focus areas of this plan in the Oak Creek watershed. Chapter 6 of this report identifies specific actions to achieve the management objectives, in the form of policies, activities, or projects.

The goals of this plan are:

1. To improve water quality in surface waters of the watershed
2. To improve instream, riparian, wetland, and upland habitat conditions in the watershed
3. To reduce the impacts of flooding and stormwater runoff problems at targeted locations in the watershed
4. To improve recreational access to and use of surface waters and riparian areas in the watershed

5.2 WATER QUALITY

Description of Problems Related to Water Quality

The existing state of surface water quality in the Oak Creek watershed is described in Chapter 4 of this report. That description documents several water quality problems that currently exist in the watershed and are briefly summarized below:

- Chronically high concentrations of fecal indicator bacteria are present in all monitored surface waters of the watershed, indicating that the water is not safe for human contact due to the potential presence of pathogens.

- Chronically low concentrations of dissolved oxygen are present in some stream reaches of the watershed. In addition, there is evidence that supersaturation of dissolved oxygen occurs in the Mill Pond and some stream reaches. Both of these conditions reduce the ability of surface waters to support fish and other aquatic organisms.

- Chronically high concentrations of nutrients that can stimulate excessive growth of plants and algae are present in surface waters.

  - Instream concentrations of total phosphorus often exceed the State's water quality criterion. An increasing percentage of this phosphorus is present as dissolved phosphorus, which is the form most readily used by algae and aquatic plants.

  - High instream concentrations of total nitrogen are present. These concentrations usually exceed guidelines for good water quality.

- Instream concentrations of total suspended solids (TSS) are often high and contribute to sedimentation in stream channels and the Mill Pond.

- Instream concentrations of chloride are often high and have increased over time.

As described in Chapter 4, many of these and other problems are interrelated through their causes, their effects, and the pathways leading from causes to effects.

Management Objectives for Water Quality

Based on the statement of water quality problems above and the analyses in Chapter 4, there are 11 management objectives for the Oak Creek watershed related to water quality improvements:

1. Locate and eliminate sources that contribute sanitary wastewater and other human wastes to surface waters

2. Locate and eliminate anthropogenic sources that contribute fecal contamination of nonhuman origin such as pet wastes, fertilizers, trash, and leaking dumpsters

3. Locate and eliminate non-anthropogenic sources that contribute fecal contamination of nonhuman origin such as urban wildlife, soils, and decaying organic material

4. Reduce contributions of TSS and sediment to surface waters

5. Address eroding stream banks along streams of the watershed

6. Reduce contributions of organic materials to surface waters

7. Reduce contributions of total phosphorus to surface waters

8. Reduce contributions of dissolved phosphorus to surface waters

9. Reduce contributions of nitrogen compounds including ammonia, nitrate, nitrite, and organic nitrogen compounds to surface waters

10. Reduce contributions of chlorides to surface waters and groundwater

11. Continue collecting and distributing monitoring data that are adequate to evaluate the state of water quality conditions and the efficacy of management measures on a watershed scale

For the most part, these objectives are not prioritized and should be pursued simultaneously. With respect to addressing fecal contamination, highest priority should be given to finding and eliminating sources of human wastes followed by finding and eliminating anthropogenic and nonanthropogenic sources of non-human fecal contamination. This reflects the fact that the health risks associated with fecal contamination originating from human sources are considered to be higher than those originating from nonhuman sources.

Table 5.1 shows the problems that each of the water quality management objectives for the Oak Creek watershed addresses. Most of the objectives address more than one water quality problem because of the interrelations among multiple problems.

Co-Benefits from Addressing Water Quality Management Objectives

Achieving individual water quality management objectives would provide additional benefits beyond the problems the objectives are intended to address. These co-benefits fall into three broad classes: co-benefits that address other issues within the water quality focus area of this plan, co-benefits that address issues within other focus areas of this plan, and co-benefits that address other desirable outcomes that are not encompassed in the immediate goals of this plan. To some extent these co-benefits emerge through the interrelationships among causes and effects related to water quality problems and pathways leading from causes to effects that were discussed in Chapter 4 of this report.

Achieving one water quality management objective may contribute to achieving others. Actions taken to reduce contributions of an individual pollutant may also result in reductions of other pollutants because pollutants are often introduced into waterbodies together. For example, the management objectives related to reducing contributions of human wastes and fecal contamination are intended to reduce the introduction of fecal indicator bacteria and pathogens into surface waters. Because fecal wastes also contain nutrients, organic materials, and solids, achieving these objectives will also contribute to achieving several other water quality management objectives. Similarly, achieving the objective related to addressing streambank erosion will also contribute to the objectives calling for reductions in nutrient loading because soils and sediments along streambanks contain appreciable amounts of phosphorus and nitrogen compounds.

Achieving water quality management objectives may also contribute to achieving management objectives related to other goals of this plan. For instance, achieving management objectives related to reducing contributions of human wastes and fecal contamination would increase the suitability of surface waters in the watershed for human contact, helping to improve recreational access and use. Similarly, achieving objectives related to reducing contributions of nutrients, organic material, chloride, and suspended solids would help to improve the habitat quality of streams within the watershed for aquatic organisms. In addition to its importance in directing water quality management efforts, continued collection and distribution of monitoring data would also inform decisions related to the management of aquatic habitat.

Finally, achieving water quality management objectives may also contribute to achieving other desirable outcomes that are not encompassed in the immediate goals of this plan. For example, by reducing the likely exposure to waterborne pathogens, achieving management objectives related to reducing contributions of human wastes and fecal contamination would also improve human health and reduce health-related costs. Achieving these and other water quality management objectives would also contribute to:

- Improving water quality in Lake Michigan and at nearby Lake Michigan beaches

- Maintaining the suitability of Lake Michigan as a source of public water supply

Table 5.1
Water Quality Problems Addressed by Management Objectives for the Oak Creek Watershed

Management Objective	Fecal Bacteria	Dissolved Oxygen	Nutrients	Suspended Solids	Chloride
Locate and eliminate sources that contribute sanitary wastewater and other human wastes to surface waters	X	X	X	--	--
Locate and eliminate anthropogenic sources of fecal contamination of nonhuman origin to surface waters	X	X	X	--	--
Locate and eliminate non-anthropogenic sources of fecal contamination of nonhuman origin to surface waters	X	X	X	--	--
Reduce contributions of total suspended solids and sediment to surface waters	--	X	X	X	--
Address eroding streambanks along streams of the watershed	--	X	X	X	--
Reduce contributions of other organic material to surface waters	--	X	X	--	--
Reduce contributions of total phosphorus to surface waters	--	X	X	--	--
Reduce contributions of dissolved phosphorus to surface waters	--	X	X	--	--
Reduce contributions of nitrogen compounds to surface waters	--	X	X	--	--
Reduce contributions of chloride to surface waters and groundwater	--	--	--	--	X
Continue collecting and distributing monitoring data that are adequate to evaluate the state of water quality conditions and the efficacy of management measures on a watershed scale	X	X	X	X	X

Source: SEWRPC

- Improving water quality in downstream areas such as the other Great Lakes, the St. Lawrence River, and the Gulf of St. Lawrence

- Improving the aesthetics of streams and riparian areas, which may help maintain or increase property values

Targeted Load Reduction Goals

Several of the management objectives for the Oak Creek watershed call for reducing contribution of several pollutants to surface waters. These pollutants include phosphorus compounds, nitrogen compounds, suspended solids, and chlorides. In addition, progress on three other management objectives can be assessed by measuring loads of fecal indicator bacteria, such as fecal coliform bacteria or *Escherichia coli* (*E. coli*). For four of these pollutants, total phosphorus, TSS, total nitrogen, and fecal coliform bacteria, numerical targets for load reductions can be derived from pollutant load estimates developed as part of the regional water quality management plan update for the greater Milwaukee watersheds (RWQMPU).[369]

The RWQMPU estimated pollutant loads for total phosphorus, TSS, total nitrogen, and fecal coliform bacteria for existing 2000 conditions and several alternative and planned conditions through the use of a calibrated water quality simulation model. The planned condition that this model estimated pollutant loads for was based on planned 2020 land use. A description of the water quality simulation model is given in Appendix L.

It should be noted that much of the urban development that was anticipated to occur by 2020 in the RWQMPU has not yet occurred. A comparison of the planned 2020 land use upon which the RWQMPU was based to the planned land use shown in Chapter 3 used to develop this plan show that they anticipate that

[369] *SEWRPC Planning Report No. 50,* A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds, *December 2007.*

a similar percentage of land in the Oak Creek watershed will be devoted to urban land uses. Because of this, pollutant load reduction targets derived from the water quality model used in the RWQMPU are still relevant and are used as estimates of needed reductions in this plan.

The urban nonpoint pollutant load reduction targets were adjusted to account for changes in the application of NR 151 that were required by 2011 Wisconsin Act 32. These changes prohibited the WDNR from enforcing the requirement that municipal separate storm sewer systems (MS4s) reduce contributions of TSS from area of existing development by 40 percent by October 1, 2013.[370] Appendix L gives a description of the adjustments. The requirements of NR 151 are described in Chapter 2 of this report.

In addition to presenting estimates of pollutant loads, the RWQMPU provided estimates of water quality conditions under the Existing (2000) and Recommended Plan conditions. These estimates were calculated using the calibrated water quality model. Comparison of the modeled water quality conditions under the Recommended Plan (2020) condition to those under the Existing (2000) condition provides an estimate of the degree of improvement in water quality conditions in the Oak Creek watershed that would be achieved by meeting the load reduction targets discussed below. It is important to emphasize that the goal of the RWQMPU was to develop cost-effective measures to improve water quality; it was not specifically designed to assure full compliance with water quality standards. As part of the RWQMPU planning process, an "extreme measures" alternative was developed, modeled, and analyzed.[371] This alternative examined the effects of several potential measures that went beyond what was included in the recommended plan. The model results indicated that implementation of these additional measures would have resulted in little additional improvement in water quality. Thus, it is important to note that even if the pollutant load reductions called for in the load reduction targets derived from the RWQMPU are achieved, it will probably not be sufficient to bring streams in the Oak Creek watershed into full compliance with water quality standards. It will be necessary to continue monitoring water quality and periodically reassess achievement of water quality standards and make adjustments in future plan updates as necessary to ultimately bring these waterbodies into compliance.

Targeted Reductions for Total Phosphorus

Table 5.2 shows the adjusted annual nonpoint source load reductions for total phosphorus for the Oak Creek watershed. On a watershed basis, this sets a target of reducing nonpoint source loads of phosphorus to the stream system by 2,030 pounds. This represents a reduction of about 19 percent from existing 2000 loads of 10,630 pounds. Of this reduction, 1,740 pounds would come from urban nonpoint sources, with 508 pounds of this reduction being attributable to implementation of NR 151 and 1,232 pounds of this reduction being attributable to implementation of other measures in addition to those implemented to comply with the requirements of NR 151. The remaining 290 pounds would come from rural nonpoint sources, with 50 pounds of this reduction being attributable to implementation of NR 151 and 240 pounds of this reduction being attributable to implementation of other measures.

Table 5.2 also shows adjusted nonpoint source load reductions for total phosphorus for individual subwatersheds. The reduction targets range from an annual reduction of 160 pounds in the Middle Oak Creek subwatershed to an annual reduction of 750 pounds in the North Branch Oak Creek subwatershed.

Table 5.3 shows a comparison of modeled total phosphorus summary statistics under the Existing (2000) and Recommended Plan conditions. These summary statistics are estimated for 10 assessment points located within the watershed. The locations of these assessment points are shown on Map 5.1. Estimated mean concentrations of total phosphorus at these assessment points under the Existing (2000) condition ranged between 0.075 mg/l and 0.092 mg/l, with an average value of 0.084 mg/l. Under the Recommended Plan condition, estimated mean concentrations of total phosphorus ranged between 0.064 mg/l and 0.088 mg/l, with an average value of 0.076 mg/l. Estimated median concentrations of total phosphorus at these assessment points under the Existing (2000) condition ranged between 0.031 mg/l and 0.062 mg/l, with an average value of 0.043 mg/l. Under the Recommended Plan condition, estimated median concentrations of total phosphorus ranged between 0.025 mg/l and 0.064 mg/l, with an average value of 0.042 mg/l. The highest estimated mean and median concentrations under Existing (2000) conditions are present in the

[370] *2011 Act 39 also required that any existing reductions of TSS over the required 20 percent that had already been achieved be maintained.*

[371] *SEWRPC Planning Report No. 50* op. cit.

Table 5.2
Annual Reductions in Nonpoint Source Loads of Total Phosphorus Required by the RWQMPU Adjusted for Changes in NR 151

		Annual Reduction in Loads of Phosphorus (pounds)						
		Urban Sources			Rural Sources			
Subwatershed	**Assessment Areas**	NR 151-Related	Other Reductions	Subtotal	NR 151-Related	Other Reductions	Subtotal	**Total**
Upper Oak Creek	Oak Creek Headwaters, Upper Oak Creek	58	112	170	50	10	60	230
Middle Oak Creek	Middle Oak Creek, Oak Creek Drainage Ditches	52	98	150	-70[a]	80	10	160
Lower Oak Creek	Lower Oak Creek, Lower Oak Creek-Millpond, Grant Park Ravine	199	271	470	20	0	20	490
North Branch Oak Creek	Upper North Branch Oak Creek, Lower North Branch Oak Creek, College Avenue Tributary, Rawson Avenue Tributary, Drexel Avenue Tributary, Southland Creek	180	520	700	-10[a]	60	50	750
Mitchell Field Drainage Ditch	Lower Mitchell Field Drainage Ditch, Mitchell Field Drainage Ditch-Airport	19	231	250	60	90	150	400
	Total	508	1,232	1,740	50	240	290	2,030

[a] *In certain limited cases, relatively minor anomalies in loads may occur among the modeled conditions upon which the load reductions presented in this table are based. Those anomalies might indicate a slight increase in loads under the recommended plan, relative to the revised 2020 baseline. In those cases, it may be assumed that no significant change in loads occurs among those various conditions. Since it was not always possible to explicitly represent certain components of the recommended plan in the water quality model, adjustments were made to model parameters that served as surrogates for the actual water pollution control measure being represented. In the sense that those modifications sometimes alter parameters in the revised 2020 baseline model, in limited cases, representation of a measure in the recommended plan model may have a side effect of introducing small, relatively insignificant anomalies in the comparative results.*

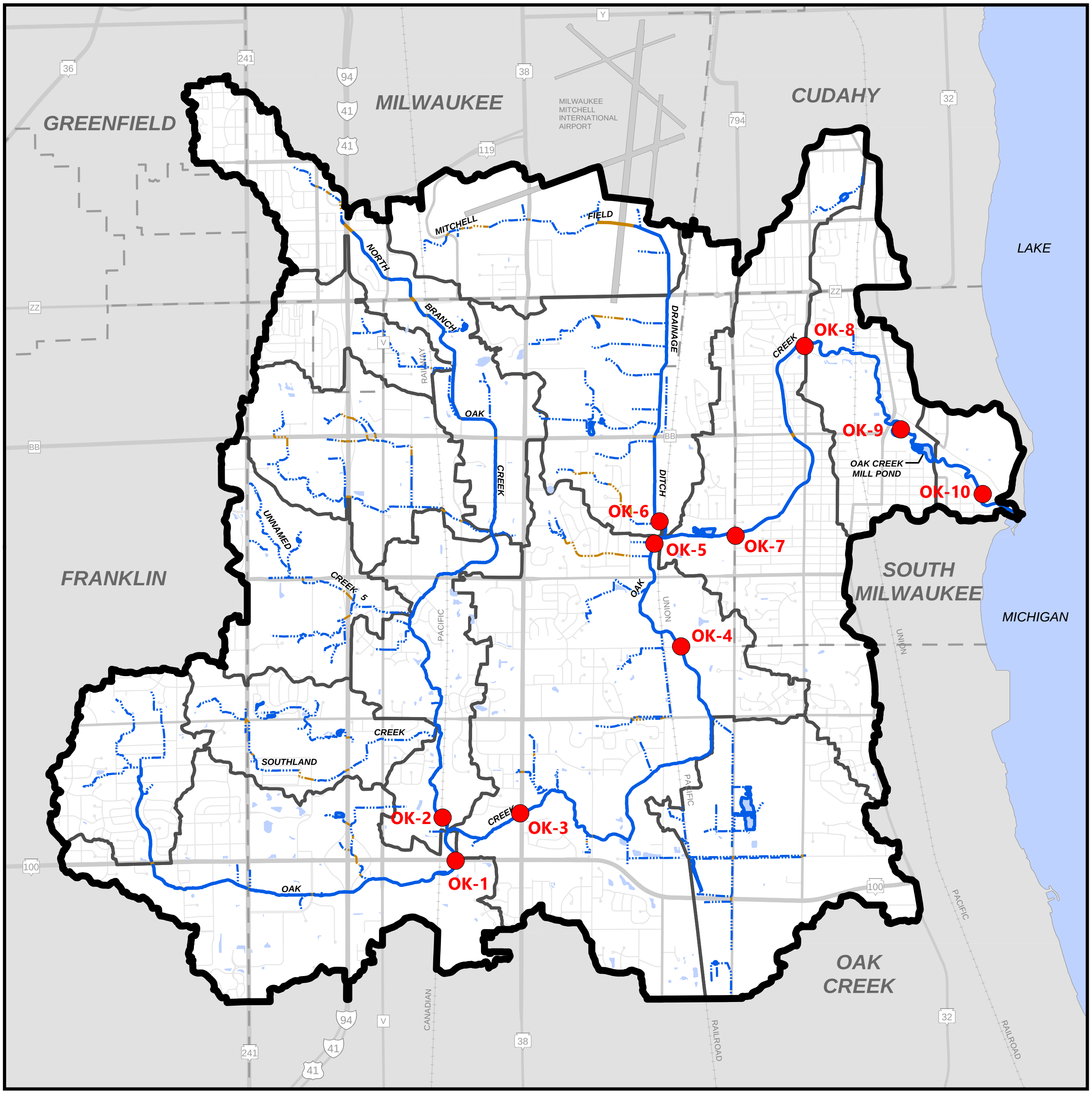
Source: SEWRPC

Table 5.3
Modeled Total Phosphorus Summary Statistics from the RWQMPU for the Oak Creek Watershed

Assessment Point	Assessment Area	Mean Concentration (mg/l)		Median Concentration (mg/l)		Percent Compliance with Recommended Planning Standard for Phosphorus (0.1 mg/l)	
		Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan
OK-1: Oak Creek at W. Ryan Road (east crossing)	Upper Oak Creek	0.075	0.064	0.031	0.025	83	83
OK-2: North Branch Oak Creek Above Confluence with Oak Creek	Lower North Branch Oak Creek	0.084	0.072	0.032	0.030	78	80
OK-3: Oak Creek at S. Howell Avenue	Middle Oak Creek	0.086	0.074	0.032	0.029	79	80
OK-4: Oak Creek at E. Forest Hills Avenue	Middle Oak Creek	0.081	0.071	0.032	0.029	79	81
OK-5: Oak Creek Above Confluence with Mitchell Field Drainage Ditch	Middle Oak Creek	0.083	0.076	0.033	0.032	79	78
OK-6: Mitchell Field Drainage Ditch Above Confluence with Oak Creek	Lower Mitchell Field Drainage Ditch	0.076	0.070	0.046	0.046	84	82
OK-7: Oak Creek at S. Pennsylvania Avenue	Lower Oak Creek	0.091	0.088	0.056	0.058	76	75
OK-8: Oak Creek at 15th Avenue	Lower Oak Creek	0.091	0.088	0.058	0.060	76	74
OK-9: Oak Creek at Parkway	Lower Oak Creek-Millpond	0.092	0.085	0.062	0.063	75	76
OK-10: Oak Creek at Parkway	Grant Park Ravine	0.078	0.070	0.046	0.044	78	80

Source: SEWRPC

Map 5.1
Locations Used to Evaluate Water Quality in the Modeling of Oak Creek for the Regional Water Quality Management Plan Update



OK-10 ASSESSMENT POINTS

OAK CREEK WATERSHED BOUNDARY

ASSESSMENT AREA BOUNDARIES

PERENNIAL STREAM

PERENNIAL STREAM (ENCLOSED)

INTERMITTENT STREAM

INTERMITTENT STREAM (ENCLOSED)

SURFACE WATER

0 0.25 0.5 1 Mile

Source: SEWRPC

Oak Creek-Mill Pond assessment area. The highest mean concentrations under the Recommended Plan condition are present in the Lower Oak Creek assessment area. The highest median concentration under the Recommended Plan condition is present in the Oak Creek-Mill Pond assessment area.

Table 5.3 also shows the amount of time the model estimated that total phosphorus concentrations at each assessment point would be at or below a concentration of 0.100 mg/l. This comparison was made because the RWQMPU was developed prior to the promulgation of the State of Wisconsin's water quality criteria for total phosphorus. The value of 0.100 is a planning standard that was recommended in the initial regional water quality management plan. The estimated level of compliance with this planning standard under the Existing (2000) condition ranged between 75 percent and 83 percent, with an average level of compliance of 78.7 percent. The estimated level of compliance with this planning standard under the Recommended Plan condition ranged between 74 percent and 83 percent, with an average level of compliance of 78.9 percent. While the level of compliance with the planning standard under the recommended plan condition is similar to that under the Existing (2020) condition, the reduction in mean concentration by about 0.008 mg/l indicates a substantial reduction in phosphorus concentrations would occur under Recommended Plan condition.

At the time that the RWQMPU was prepared, the State of Wisconsin had not promulgated instream water quality criteria for total phosphorus. In the absence of a regulatory criterion, a planning standard of 0.100 mg/l was applied. Following completion of the RWQMPU, the State adopted phosphorus criteria as set forth in Chapter NR 102, "Water Quality Standards for Wisconsin Surface Waters," of the *Wisconsin Administrative Code*. Chapter NR 102 establishes the applicable total phosphorus criterion for Oak Creek and its tributaries as a concentration of 0.075 milligrams per liter (mg/l) (see Table 4.16 in Chapter 4 of this report). The degree to which the recommended RWQMPU would meet the new regulatory 0.075 mg/l water quality criterion was assessed during a subsequent effort.[372] Implementing the recommended RWQMPU components that relate to the Oak Creek watershed is anticipated to result in the following levels of compliance with water quality criteria:

- Along the mainstem Oak Creek (assessment points OK-1, 2, 4, 5, 7, 8, 9, and 10) the total phosphorus water quality criterion of 0.075 mg/l would be expected to be met from about 64 to 88 percent of the time during an average year, with the degree of compliance decreasing from upstream to downstream. The expected percentage of compliance during the average year would increase slightly downstream from the Mill Pond Dam.

- For the North Branch of Oak Creek (assessment point OK-3), the total phosphorus water quality criterion would be expected to be met about 76 percent of the time during an average year.

- For the Mitchell Field Drainage Ditch (assessment point OK-5), the total phosphorus water quality criterion would be expected to be met about 75 percent of the time during an average year.

Targeted Reductions for Total Suspended Solids

Table 5.4 shows the adjusted annual nonpoint source load reductions for TSS for the Oak Creek watershed. On a watershed basis, this sets a target of reducing nonpoint source loads of TSS to the stream system by 1,968,530 pounds. This represents a reduction of about 37 percent from existing 2000 loads of 5,305,010 pounds. Of this reduction, 1,267,540 pounds would come from urban nonpoint sources, with 659,489 pounds of this reduction being attributable to implementing NR 151 and 608,051 pounds of this reduction being attributable to implementing other measures. The remaining 700,990 pounds would come from rural nonpoint sources, with 691,070 pounds of this reduction being attributable to implementing NR 151 and 9,920 pounds of this reduction being attributable to implementing other measures.

Table 5.4 also shows adjusted nonpoint source load reductions for TSS for individual subwatersheds. The reduction targets range from an annual reduction of 276,100 pounds in the Upper Oak Creek subwatershed to an annual reduction of 711,300 pounds in the North Branch Oak Creek subwatershed.

---

[372] *S. McLellan, H. Bravo, M.G. Hahn, with contributions from K. Kratt and J. Butcher,* Climate Change Risks and Impacts on Urban Coastal Water Resources in the Great Lakes, *Final Report to the National Oceanic and Atmospheric Administration Sectoral Applications Research Program, October 29, 2013.*

Table 5.4
Annual Reductions in Nonpoint Source Loads of Total Suspended Solids Required by the RWQMPU Adjusted for Changes in NR 151

		Annual Reduction in Loads of Total Suspended Solids (pounds)						
		Urban Sources			Rural Sources			
Subwatershed	**Assessment Areas**	NR 151-Related	Other Reductions	Subtotal	NR 151-Related	Other Reductions	Subtotal	**Total**
Upper Oak Creek	Oak Creek Headwaters, Upper Oak Creek	96,866	33,354	130,220	145,530	350	145,880	276,100
Middle Oak Creek	Middle Oak Creek, Oak Creek Drainage Ditches	102,033	38,727	140,760	284,940	670	285,610	426,370
Lower Oak Creek	Lower Oak Creek, Lower Oak Creek-Millpond, Grant Park Ravine	151,009	130,481	281,490	19,590	0	19,590	301,080
North Branch Oak Creek	Upper North Branch Oak Creek, Lower North Branch Oak Creek, College Avenue Tributary, Rawson Avenue Tributary, Drexel Avenue Tributary, Southland Creek	250,056	296,484	546,540	162,020	2,740	164,760	711,300
Mitchell Field Drainage Ditch	Lower Mitchell Field Drainage Ditch, Mitchell Field Drainage Ditch-Airport	59,525	109,005	168,530	78,990	6,160	85,150	253,680
	Total	659,489	608,051	1,267,540	691,070	9,920	700,990	1,968,530

Source: SEWRPC

Table 5.5 shows a comparison of modeled TSS summary statistics under the Existing (2000) and Recommended Plan conditions at 10 assessment points throughout the watershed. The locations of these assessment points are shown on Map 5.1. Estimated mean concentrations of TSS at these assessment points under the Existing (2000) condition ranged between 11.0 mg/l and 22.9 mg/l, with an average value of 16.4 mg/l. Under the Recommended Plan condition, estimated mean concentrations of TSS ranged between 7.1 mg/l and 15.7 mg/l, with an average value of 10.8 mg/l. Estimated median concentrations of TSS at these assessment points under the Existing (2000) condition ranged between 6.7 mg/l and 9.0 mg/l, with an average value of 7.6 mg/l. Under the Recommended Plan condition, estimated median concentrations of TSS ranged between 4.2 mg/l and 6.4 mg/l, with an average value of 5.0 mg/l.

Targeted Reductions for Fecal Coliform Bacteria

Table 5.6 shows the adjusted annual nonpoint source load reductions for fecal coliform bacteria for the Oak Creek watershed. On a watershed basis, this sets a target of reducing nonpoint source loads of fecal coliform bacteria to the stream system by 1,292 trillion cells annually. This represents a reduction of about 46 percent from existing 2000 loads of 2,792 trillion cells. Of this reduction, 1,229 trillion cells would come from urban nonpoint sources, with 162 trillion cells of this reduction being attributable to implementing NR 151 and 1,067 trillion cells of this reduction being attributable to implementing other measures. The remaining 63 trillion cells would come from rural nonpoint sources, with an increase of 4 trillion cells being attributable to implementing of NR 151 and a reduction of 67 trillion cells being attributable to implementing other measures.

Table 5.6 also shows adjusted nonpoint source load reductions for fecal coliform bacteria for individual subwatersheds. The reduction targets range from an annual reduction of 157 trillion cells in the Upper Oak Creek subwatershed to an annual reduction of 385 trillion cells in the North Branch Oak Creek subwatershed.

Table 5.7 shows a comparison of modeled fecal coliform bacteria summary statistics under the Existing (2000) and Recommended Plan conditions calculated over the entire year. These summary statistics are estimated for 10 assessment points located throughout the watershed. The locations of these assessment points are shown on Map 5.1. Estimated mean concentrations of fecal coliform bacteria at these assessment points under the Existing (2000) condition ranged between 4,905 cells per 100 ml and 15,506 cells per 100 ml, with an average value of 7,994 cells per 100 ml. Under the Recommended Plan condition, estimated mean concentrations of fecal coliform bacteria ranged between 2,603 cells per 100 ml and 8,662 cells per 100 ml, with an average value of 4,427 cells per 100 ml. Estimated geometric mean concentrations of fecal coliform bacteria at these assessment points under the Existing (2000) condition ranged between 541 cells per 100 ml and 2,700 cells per 100 ml. Under the Recommended Plan condition, estimated geometric mean concentrations of fecal coliform bacteria ranged between 346 cells per 100 ml and 1,550 cells per 100 ml. The highest estimated mean and geometric mean concentrations under both conditions were present in the Lower Oak Creek assessment area.

Table 5.7 also shows estimates of the degree of compliance with the State's former water quality criteria for fecal coliform bacteria at each assessment point under both conditions. Two estimates are given: the percent of time that concentrations of fecal coliform bacteria would be at or below the single-sample criterion of 400 cells per 100 ml and the number of days per year that the geometric mean of fecal coliform bacteria concentrations would be at or below the geometric mean criterion of 200 cells per 100 ml. The estimated level of compliance with the single-sample criterion under the Existing (2000) condition ranged between 17 percent and 66 percent, with an average level of compliance of 47 percent. The estimated level of compliance with the single-sample criterion under the Recommended Plan condition ranged between 39 percent and 67 percent, with an average level of compliance of 56 percent. The estimated level of compliance with the geometric mean criterion under the Existing (2000) condition ranged between zero days per year and 70 days per year, with an average level of compliance of 30 days per year. The estimated level of compliance with the geometric mean criterion under the Recommended Plan condition ranged between 13 days per year and 123 days per year, with an average level of compliance of 60 days per year.

Table 5.8 shows a comparison of modeled fecal coliform bacteria summary statistics under the Existing (2000) and Recommended Plan conditions calculated over the 153-day May through September swimming season. These summary statistics are estimated for 10 assessment points located throughout the watershed. The locations of these assessment points are shown on Map 5.1. Estimated mean concentrations of fecal coliform bacteria at these assessment points under the Existing (2000) condition ranged between 2,101

Table 5.5
Modeled Total Suspended Solids Summary Statistics from the RWQMPU for the Oak Creek Watershed

Assessment Point	Assessment Area	Mean Concentration (mg/l)		Median Concentration (mg/l)	
		Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan
OK-1: Oak Creek at W. Ryan Road (east crossing)	Upper Oak Creek	13.7	7.9	7.8	4.6
OK-2: North Branch Oak Creek Above Confluence with Oak Creek	Lower North Branch Oak Creek	22.9	15.7	9.0	6.4
OK-3: Oak Creek at S. Howell Avenue	Middle Oak Creek	20.9	13.7	8.5	5.9
OK-4: Oak Creek at E. Forest Hills Avenue	Middle Oak Creek	14.9	9.9	7.9	5.3
OK-5: Oak Creek Above Confluence with Mitchell Field Drainage Ditch	Middle Oak Creek	14.1	9.4	7.2	4.7
OK-6: Mitchell Field Drainage Ditch Above Confluence with Oak Creek	Lower Mitchell Field Drainage Ditch	11.0	7.1	7.0	4.2
OK-7: Oak Creek at S. Pennsylvania Avenue	Lower Oak Creek	14.9	9.9	7.3	4.8
OK-8: Oak Creek at 15th Avenue	Lower Oak Creek	15.9	10.7	7.3	4.8
OK-9: Oak Creek at Parkway	Lower Oak Creek-Millpond	16.0	10.4	6.7	4.3
OK-10: Oak Creek at Parkway	Grant Park Ravine	19.6	13.2	7.4	5.1

Source: SEWRPC

Table 5.6
Annual Reductions in Nonpoint Source Loads of Fecal Coliform Bacteria Required by the RWQMPU Adjusted for Changes in NR 151

		Annual Reduction in Loads of Fecal Coliform Bacteria (trillion cells)[a]						
		Urban Sources			Rural Sources			
Subwatershed	**Assessment Areas**	NR 151-Related	Other Reductions	Subtotal	NR 151-Related	Other Reductions	Subtotal	**Total**
Upper Oak Creek	Oak Creek Headwaters, Upper Oak Creek	29	125	154	1	2	3	157
Middle Oak Creek	Middle Oak Creek, Oak Creek Drainage Ditches	24	143	167	-5[b]	34	29	197
Lower Oak Creek	Lower Oak Creek, Lower Oak Creek-Millpond, Grant Park Ravine	64	233	297	0	0	0	297
North Branch Oak Creek	Upper North Branch Oak Creek, Lower North Branch Oak Creek, College Avenue Tributary, Rawson Avenue Tributary, Drexel Avenue Tributary, Southland Creek	57	318	376	-8[b]	17	9	385
Mitchell Field Drainage Ditch	Lower Mitchell Field Drainage Ditch, Mitchell Field Drainage Ditch-Airport	-12[a]	248	235	8	14	21	256
	Total	162	1,067	1,229	-4[a]	67	63	1,292

[a] *Effective May 1, 2020 Wisconsin's recreational use water quality criteria changed from using fecal coliform bacteria to* E. coli*. Load reduction targets for* E. coli *can be estimated from the targets for fecal coliform bacteria given in this table using the translator ratios developed for the Milwaukee River Basin TMDL.*

[b] *In certain limited cases, relatively minor anomalies in loads may occur among the modeled conditions upon which the load reductions presented in this table are based. Those anomalies might indicate a slight increase in loads under the recommended plan, relative to the revised 2020 baseline. In those cases, it may be assumed that no significant change in loads occurs among those various conditions. Since it was not always possible to explicitly represent certain components of the recommended plan in the water quality model, adjustments were made to model parameters that served as surrogates for the actual water pollution control measure being represented. In the sense that those modifications sometimes alter parameters in the revised 2020 baseline model, in limited cases, representation of a measure in the recommended plan model may have a side effect of introducing small, relatively insignificant anomalies in the comparative results.*

Source: SEWRPC

Table 5.7
Modeled Fecal Coliform Bacteria Annual Summary Statistics from the RWQMPU for the Oak Creek Watershed[a]

		Mean Concentration (cells per 100 ml)		Percent Compliance with Single Sample Standard (<400 cells per 100 ml)		Geometric Mean Concentration (cells per 100 ml)		Days of Compliance with Geometric Mean Standard (<200 cells per 100 ml)[b]	
Assessment Point	Assessment Area	Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan
OK-1: Oak Creek at W. Ryan Road (east crossing)	Upper Oak Creek	4,905	2,603	66	67	541	346	65	123
OK-2: North Branch Oak Creek Above Confluence with Oak Creek	Lower North Branch Oak Creek	4,987	2,722	57	60	611	385	60	108
OK-3: Oak Creek at S. Howell Avenue	Middle Oak Creek	10,233	5,436	55	58	1,191	729	17	36
OK-4: Oak Creek at E. Forest Hills Avenue	Middle Oak Creek	7,953	4,447	51	56	1,041	648	20	46
OK-5: Oak Creek Above Confluence with Mitchell Field Drainage Ditch	Middle Oak Creek	7,666	4,289	49	55	1,105	664	18	40
OK-6: Mitchell Field Drainage Ditch Above Confluence with Oak Creek	Lower Mitchell Field Drainage Ditch	6,917	3,966	31	62	1,442	775	0	13
OK-7: Oak Creek at S. Pennsylvania Avenue	Lower Oak Creek	7,729	4,358	49	56	1,190	696	13	35
OK-8: Oak Creek at 15th Avenue	Lower Oak Creek	15,506	8,662	17	39	2,700	1,550	6	13
OK-9: Oak Creek at Parkway	Lower Oak Creek-Millpond	7,401	4,091	51	57	993	526	26	68
OK-10: Oak Creek at Parkway	Grant Park Ravine	6,643	3,696	48	52	752	404	70	118

[a] *Within the water quality models for the recommended plan condition, the detection and elimination of illicit discharges to storm sewer systems and control of urban source pathogens, including those in stormwater runoff, are represented using stormwater disinfection units. Such units were initially considered as a recommended approach to the treatment of runoff, but were eliminated from further consideration based on comments from the RWQMPU Technical Advisory Committee. However, the use of such units is considered to be appropriate as a surrogate representation of the varied and as yet undetermined means that would be applied to detect and eliminate illicit discharges and to control pathogens in urban stormwater runoff. Those units explicitly address the control of bacteria in stormwater runoff, and, based on the way that bacteria loads are represented in the calibrated model, they also implicitly provide some control of bacteria that may reach streams through illicit connections that contribute to baseflow.*

[b] *Out of 365 days.*

Source: SEWRPC

Table 5.8
Modeled Fecal Coliform Bacteria Swimming Season Summary Statistics from the RWQMPU for the Oak Creek Watershed[a,b]

		Mean Concentration (cells per 100 ml)		Percent Compliance with Single Sample Standard (<400 cells per 100 ml)		Geometric Mean Concentration (cells per 100 ml)		Days of Compliance with Geometric Mean Standard (<200 cells per 100 ml)[c]	
Assessment Point	**Assessment Area**	Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan
OK-1: Oak Creek at W. Ryan Road (east crossing)	Upper Oak Creek	2,102	1,079	84	84	256	181	47	82
OK-2: North Branch Oak Creek Above Confluence with Oak Creek	Lower North Branch Oak Creek	2,561	1,289	74	76	289	192	44	71
OK-3: Oak Creek at S. Howell Avenue	Middle Oak Creek	4,750	2,382	72	76	555	355	15	30
OK-4: Oak Creek at E. Forest Hills Avenue	Middle Oak Creek	3,103	1,672	69	75	463	308	17	35
OK-5: Oak Creek Above Confluence with Mitchell Field Drainage Ditch	Middle Oak Creek	3,019	1,595	66	73	497	309	15	32
OK-6: Mitchell Field Drainage Ditch Above Confluence with Oak Creek	Lower Mitchell Field Drainage Ditch	2,906	1,590	27	80	806	411	0	5
OK-7: Oak Creek at S. Pennsylvania Avenue	Lower Oak Creek	3,136	1,657	66	74	543	320	11	28
OK-8: Oak Creek at 15th Avenue	Lower Oak Creek	6,370	3,218	31	61	1,079	593	6	12
OK-9: Oak Creek at Parkway	Lower Oak Creek-Millpond	3,061	1,502	71	76	388	189	21	50
OK-10: Oak Creek at Parkway	Grant Park Ravine	2,504	1,262	71	74	179	89	59	93

[a] *Within the water quality models for the recommended plan condition, the detection and elimination of illicit discharges to storm sewer systems and control of urban source pathogens, including those in stormwater runoff, are represented using stormwater disinfection units. Such units were initially considered as a recommended approach to the treatment of runoff but were eliminated from further consideration based on comments from the RWQMPU Technical Advisory Committee. However, the use of such units is considered to be appropriate as a surrogate representation of the varied and as yet undetermined means that would be applied to detect and eliminate illicit discharges and to control pathogens in urban stormwater runoff. Those units explicitly address the control of bacteria in stormwater runoff, and, based on the way that bacteria loads are represented in the calibrated model, they also implicitly provide some control of bacteria that may reach streams through illicit connections that contribute to baseflow.*

[b] *The swimming season is taken as May 1 through September 30.*

[c] *Out of 153 days.*

Source: SEWRPC

cells per 100 ml and 6,370 cells per 100 ml, with an average value of 3,351 cells per 100 ml. Under the Recommended Plan condition, estimated mean concentrations of fecal coliform bacteria ranged between 1,079 cells per 100 ml and 3,218 cells per 100 ml, with an average value of 1,725 cells per 100 ml. Estimated geometric mean concentrations of fecal coliform bacteria at these assessment points under the Existing (2000) condition ranged between 179 cells per 100 ml and 1,079 cells per 100 ml. Under the Recommended Plan condition, estimated geometric mean concentrations of fecal coliform bacteria ranged between 89 cells per 100 ml and 593 cells per 100 ml. The highest estimated mean concentrations under both the Existing (2000) and Recommended Plan conditions were present in the Lower Oak Creek assessment area. The highest estimated geometric mean concentrations under both conditions were also present in the Lower Oak Creek assessment area.

Table 5.8 also shows estimates of the degree of compliance with the State's water quality criteria for fecal coliform bacteria during the swimming season at each assessment point under both conditions. Two estimates are given: the percent of time that concentrations of fecal coliform bacteria would be at or below the single-sample criterion of 400 cells per 100 ml and the number of days out of 153 that the geometric mean of fecal coliform bacteria concentrations would be at or below the geometric mean criterion of 200 cells per 100 ml. The estimated level of compliance with the single-sample criterion during the swimming season under the Existing (2000) condition ranged between 27 percent and 84 percent, with an average level of compliance of 63 percent. The estimated level of compliance with the single-sample criterion during the swimming season under the Recommended Plan condition ranged between 61 percent and 84 percent, with an average level of compliance of 75 percent. The estimated level of compliance with the geometric mean criterion during the swimming season under the Existing (2000) condition ranged between zero out of 153 days and 59 out of 153 days, with an average level of compliance of 24 out of 153 days. The estimated level of compliance with the geometric mean criterion during the swimming season under the Recommended Plan condition ranged between five out of 153 days and 93 out of 153 days, with an average level of compliance of 44 out of 153 days.

Effective May 1, 2020, the basis of Wisconsin's recreational use water quality criteria was changed from concentrations of fecal coliform bacteria to concentrations of the bacterium *Escherichia coli* (*E. coli*). The modeling for the RWQMPU did not include estimation of *E. coli* concentrations. It is anticipated that future monitoring for fecal indicator bacteria will focus on *E. coli*. Because *E. coli* is one species in the fecal coliform bacteria group, it should still be possible to use the load reduction targets derived from the RWQMPU modeling to guide restoration efforts in the Oak Creek watershed. As part of the development of the Milwaukee River Basin total maximum daily load (TMDL), researchers at the University of Wisconsin-Milwaukee developed translator ratios based on concentrations in the Kinnickinnic, Menomonee, and Milwaukee Rivers and the Milwaukee Harbor Estuary to estimate concentrations of *E. coli* from those of fecal coliform bacteria.[373] This work found that a range of translator ratios between 0.5875 and 0.65 *E.coli* to 1.0 fecal coliform bacteria encompassed the majority of *E. coli* to fecal coliform bacteria ratios observed under different conditions. As an example, applying this translator to a reduction target for a fecal coliform bacteria load of 50 trillion cells per year indicates that the load of *E. coli* should be reduced by between about 29.4 trillion and 32.5 trillion cells per year.

Targeted Reductions for Total Nitrogen

Table 5.9 shows the adjusted annual nonpoint source load reductions for total nitrogen for the Oak Creek watershed. On a watershed basis, this sets a target of reducing nonpoint source loads of nitrogen to the stream system by 26,110 pounds annually between 2000 and 2050. This represents a reduction of about 27 percent from existing 2000 loads of 97,110 pounds. Of this reduction, 7,830 pounds would come from urban nonpoint sources, with 2,247 pounds of this reduction being attributable to implementing NR 151 and 5,583 pounds of this reduction being attributable to implementing other measures. The remaining 18,280 pounds would come from rural nonpoint sources, with 17,180 pounds of this reduction being attributable to implementing NR 151 and 1,100 pounds of this reduction being attributable to implementing other measures.

---

[373] *D.K. Dila and S.L. McLellan, "Translator Development for Bacterial Indicator TMDLs, revised July 2016," Appendix E in: Milwaukee Metropolitan Sewerage District,* Total Maximum Daily Loads for Total Phosphorus, Total Suspended Solids, and Fecal Coliform: Milwaukee River Basin, Wisconsin, Report, *March 19, 2018.*

Table 5.9
Annual Reductions in Nonpoint Source Loads of Total Nitrogen Required by the RWQMPU Adjusted for Changes in NR 151

		Annual Reduction in Loads of Total Nitrogen (pounds)						
		Urban Sources			Rural Sources			
Subwatershed	**Assessment Areas**	NR 151-Related	Other Reductions	Subtotal	NR 151-Related	Other Reductions	Subtotal	**Total**
Upper Oak Creek	Oak Creek Headwaters, Upper Oak Creek	117	143	260	3,770	10	3,780	4,040
Middle Oak Creek	Middle Oak Creek, Oak Creek Drainage Ditches	188	132	320	5,530	-10	5,520	5,840
Lower Oak Creek	Lower Oak Creek, Lower Oak Creek-Millpond, Grant Park Ravine	1,052	878	1,930	630	0	630	2,560
North Branch Oak Creek	Upper North Branch Oak Creek, Lower North Branch Oak Creek, College Avenue Tributary, Rawson Avenue Tributary, Drexel Avenue Tributary, Southland Creek	701	2,599	3,300	4,300	210	4,510	7,810
Mitchell Field Drainage Ditch	Lower Mitchell Field Drainage Ditch, Mitchell Field Drainage Ditch-Airport	191	1,830	2,020	2,950	890	3,840	5,860
	Total	2,247	5,583	7,830	17,180	1,100	18,280	26,110

Source: SEWRPC

Table 5.9 also shows adjusted annual nonpoint source load reductions for total nitrogen for individual subwatersheds. The reduction targets range from an annual reduction of 2,560 pounds in the Middle Oak Creek subwatershed to an annual reduction of 7,810 pounds in the North Branch Oak Creek subwatershed.

Table 5.10 shows a comparison of modeled total nitrogen summary statistics under the Existing (2000) and Recommended Plan conditions. These summary statistics are estimated for 10 assessment points located within the watershed. The locations of these assessment points are shown on Map 5.1. Estimated mean concentrations of total nitrogen at these assessment points under the Existing (2000) condition ranged between 1.07 mg/l and 1.57 mg/l, with an average value of 1.23 mg/l. Under the Recommended Plan condition, estimated mean concentrations of total nitrogen ranged between 0.81 mg/l and 1.00 mg/l, with an average value of 0.82 mg/l. Estimated median concentrations of total nitrogen at these assessment points under the Existing (2000) condition ranged between 0.98 mg/l and 1.41 mg/l, with an average value of 1.20 mg/l. Under the Recommended Plan condition, estimated median concentrations of total nitrogen ranged between 0.71 mg/l and 0.94 mg/l, with an average value of 0.833 mg/l. The highest estimated mean and median concentrations under both Existing (2000) and Recommended Plan conditions are present in the Lower Mitchell Field Drainage Ditch assessment area.

Impacts of TMDLs on Load Reduction Targets

As discussed in Chapter 4 of this report, three streams in the Oak Creek watershed are considered impaired waters pursuant to the Federal Clean Water Act (CWA). The mainstem of Oak Creek has impairments related to contributions of total phosphorus, chloride, and an unknown pollutant, while both the North Branch of Oak Creek and the Mitchell Field Drainage Ditch have impairments related to contribution of chloride. When a waterbody is listed as impaired, the CWA requires that a TMDL be developed for the waterbody for those pollutants causing or contributing to the impairments. A TMDL consists of a scientific determination of the maximum amount of a pollutant waterbody can assimilate while still meeting water quality standards. It also includes allocations of portions of that assimilative capacity to various sources that contribute the pollutant to the waterbody. In practical terms, this can include requirements for load reductions for sources such as wastewater treatment plants, industrial dischargers, municipal separate storm sewer systems, and nonpoint source pollution from urban and rural areas. When a TMDL is completed for the Oak Creek watershed, the pollutant load reductions presented in this plan shall be superseded by the load reductions included in the TMDL for those pollutants addressed by the TMDL.

5.3 HABITAT

Description of Problems Related to Habitat Conditions

The existing state of instream and terrestrial habitat in the Oak Creek watershed is described in detail in Chapter 4 of this report. That description documents several problems that currently lead to reduced quality of aquatic and terrestrial habitat in the watershed and are briefly summarized below:

- Urbanization and prior agricultural development have significantly altered surface and groundwater hydrology contributing to many of the problems summarized below.

- Stream channels throughout the watershed have been highly modified contributing to many of the problems summarized below.

- Many stream reaches in the watershed have been disconnected from their floodplains. This disconnection confines flow and increases peak flow velocities and volumes, streambank erosion, and the accumulation of sediment.

- The flashiness of streamflow in the watershed increases erosion of stream beds and banks and reduces the suitability of instream habitat for aquatic organisms.

- Excessive streambank erosion is present in some areas the watershed. This degrades habitat for aquatic organisms and has potential to threaten vital infrastructure.

- Poor diversity of instream habitat in some stream reaches in the watershed limits the quality of aquatic communities.

Table 5.10
Modeled Total Nitrogen Summary Statistics from the RWQMPU for the Oak Creek Watershed

		Mean Concentration (mg/l)		Median Concentration (mg/l)	
Assessment Point	Assessment Area	Existing (2000)	Recommended Plan	Existing (2000)	Recommended Plan
OK-1: Oak Creek at W. Ryan Road (east crossing)	Upper Oak Creek	1.52	0.88	1.38	0.82
OK-2: North Branch Oak Creek Above Confluence with Oak Creek	Lower North Branch Oak Creek	1.32	0.91	1.18	0.80
OK-3: Oak Creek at S. Howell Avenue	Middle Oak Creek	1.37	0.88	1.24	0.80
OK-4: Oak Creek at E. Forest Hills Avenue	Middle Oak Creek	1.34	0.86	1.17	0.76
OK-5: Oak Creek Above Confluence with Mitchell Field Drainage Ditch	Middle Oak Creek	1.32	0.89	1.15	0.78
OK-6: Mitchell Field Drainage Ditch Above Confluence with Oak Creek	Lower Mitchell Field Drainage Ditch	1.57	1.00	1.41	0.94
OK-7: Oak Creek at S. Pennsylvania Avenue	Lower Oak Creek	1.38	0.98	1.25	0.92
OK-8: Oak Creek at 15th Avenue	Lower Oak Creek	1.30	0.96	1.18	0.90
OK-9: Oak Creek at Parkway	Lower Oak Creek-Millpond	1.26	0.95	1.14	0.91
OK-10: Oak Creek at Parkway	Grant Park Ravine	1.07	0.81	0.98	0.71

Source: SEWRPC

- The coverage, connectivity, and widths of riparian buffers in the watershed is insufficient to provide good habitat for aquatic and terrestrial organisms and protect water quality.

- Invasive plant and insect species have degraded the quality of waterways, riparian areas, wetlands, and uplands in the watershed.

- Passage impediments such as road crossings, drop structures, large debris jams, and the Mill Pond dam restrict migration of fish and other aquatic organisms throughout the watershed, limiting their access to refuge areas (e.g., summer heating can lead to thermal stress), feeding, and/or breeding habitat and contributing to poor abundance and diversity.

- Projections of future conditions indicate that average water temperatures in Oak Creek are likely to increase by about 2°C by the end of the 21st century due to climate change, resulting in changes to the biological communities that Oak Creek and its tributaries are able to support.

- Accumulation of trash and debris has degraded the aesthetics of streams and riparian areas and can harm wildlife and aquatic organisms.

Management Objectives for Habitat Quality

Based on the statements of habitat quality problems given above and the analyses given in Chapter 4, there are 12 management objectives for this plan related to habitat improvements:

1. Re-establish and maintain natural surface water hydrology to the extent practicable

2. Re-connect stream channels, floodplains, and adjacent wetlands

3. Protect and preserve environmentally sensitive areas such as designated Natural Areas, wetlands, and environmental corridors

4. Protect, expand, restore, and connect riparian buffer areas

5. Protect areas with high groundwater recharge potential and prevent groundwater contamination

6. Remove or modify instream passage impediments that restrict aquatic organism access to a variety of habitats

7. Protect and restore the diversity and quality of instream habitat

8. Protect, restore, and expand terrestrial wildlife habitat, and increase connections among various habitats

9. Control, manage, and/or remove non-native and invasive species in waterbodies, riparian areas, wetlands, and uplands

10. Reduce or mitigate the negative physical, chemical, and biological impacts on aquatic and terrestrial ecosystems caused by climate change

11. Address excessive erosion of streambanks

12. Remove trash and debris within stream channels and riparian areas

Co-Benefits from Addressing Habitat Management Objectives

Achieving individual habitat management objectives would provide additional benefits beyond the problems the objectives are intended to address. These co-benefits fall into three broad classes: co-benefits that address other issues within the habitat focus area of this plan, co-benefits that address issues within other focus areas of this plan, and co-benefits that address other desirable outcomes that are not encompassed in the immediate goals of this plan.

Achieving one habitat management objective may contribute to achieving others. Habitat consists of a complex association of physical, chemical, geographic, and biotic factors that allow for the survival and reproduction of organisms. Thus, actions taken to improve one factor making up habitat may also contribute to improvement in other factors. For example, achieving the management objective related to re-connecting stream channels, floodplains, and adjacent wetlands also contributes to achieving objectives related to re-establishing natural surface water hydrology, preserving and improving groundwater recharge, reducing stream bed and bank erosion, and reducing negative impacts of climate change on ecosystems. Similarly, achieving the management objective to protect and preserve environmentally sensitive areas also contributes to achieving management objectives related to protecting riparian buffer areas, protecting the diversity and quality of instream habitat, and protecting terrestrial wildlife habitat.

Achieving habitat management objectives may also contribute to achieving management objectives related to other goals of this plan. For instance, achieving the management objective related to re-connecting stream channels, floodplains, and adjacent wetlands also contributes to achieving objectives related to reducing inputs of nutrients, sediment, and other pollutants into surface waters and preserving and increasing recreational and educational opportunities. Achieving the objective related to removing passage impediments to aquatic organisms contributes to improving recreational opportunities by improving the quality of the fishery. It may also contribute to reducing flooding by addressing structures that lack the capacity to pass high flows.

Finally, achieving habitat management objectives may also contribute to achieving other desirable outcomes that are not encompassed in the immediate goals of this plan. For example, achieving the objective to protect, expand, restore, and connect riparian buffers would also contribute to reducing urban heat island effects, sequestering carbon which helps to mitigate climate change, and maintain and increase biodiversity. Similarly, addressing excessive erosion of streambanks would also protect vital public infrastructure. Removing trash and debris from stream channels and riparian areas would also improve the aesthetics of the watershed, improve the public's valuation of the waterways, and increase the value of nearby property.

5.4 WATER QUANTITY

Description of Problems Related to Targeted Stream and Stormwater Flooding

The existing state of flooding problems in the Oak Creek watershed, including specific areas of concern regarding stream and stormwater is described in Chapter 4 of this report and briefly summarized below:

- There are several remaining insurable structures impacted by the regulatory FEMA flood elevations, and they are scattered throughout the Oak Creek watershed.

- Additional stream flooding locations were provided by stakeholders, and these predominantly occur in the lower portion of the Oak Creek mainstem. Impacts included public and private property flooding, flooding at the South Milwaukee High School grounds, and potential impacts to sanitary sewer lift stations in South Milwaukee.

- There are numerous road crossings impacted by the regulatory FEMA flood elevations for Oak Creek, located predominantly on the mainstem of Oak Creek. Some of these road crossings are overtopped for events as small as the 10-percent-annual-probability (10-year recurrence interval) event.

- Stormwater flooding areas were also provided by stakeholders. These areas were spread throughout the watershed and include streets, public property, and private property.

- Storm event flows in streams of the Oak Creek watershed are flashy due to large amounts of impervious surfaces and the dominance of direct connections from the local storm sewer systems.

Management Objectives for Targeted Stream and Stormwater Flooding

Based on the statements of flooding problems given above and the analyses given in Chapter 4, there are seven management objectives related to the reduction of flooding impacts:

1. Acquire and remove or floodproof (through a voluntary process) the remaining insurable structures in the regulatory Oak Creek floodplain as opportunities arise

2. Protect public infrastructure and private property from stream and stormwater flooding

3. Elevate or modify road crossings impacted by the regulatory floodplain

4. Reconnect streams in the Oak Creek watershed to their floodplains

5. Protect and expand riparian buffers to allow stream floodwaters to spread out and slow down

6. Retain rainfall runoff onsite to mitigate stream and stormwater flooding

7. Maintain sufficient undeveloped land in the watershed for infiltration and flood storage

For the most part, these objectives are not prioritized and should be pursued simultaneously; however, achievement of some of the objectives may reduce the need to pursue others.

Co-Benefits from Addressing Targeted Stream and Stormwater Flooding Management Objectives

Achieving individual targeted stream and stormwater flooding management objectives would provide additional benefits beyond the problems the objectives are intended to address. These co-benefits fall into three broad classes: co-benefits that address other issues within the targeted stream and stormwater flooding focus area of this plan, co-benefits that address issues within other focus areas of this plan, and co-benefits that address other desirable outcomes that are not encompassed in the immediate goals of this plan.

Achieving individual targeted stream and stormwater flooding management objectives may contribute to achieving others. For example, achieving the management objective related to re-connecting stream channels to their floodplains would increase the retention of floodwater.

Achieving targeted stream and stormwater flooding management objectives may also contribute to achieving management objectives related to other goals of this plan. For instance, achieving the management objective related to voluntarily acquire and remove the remaining insurable structures from the floodplain would also make additional land available for riparian habitat and recreational use, contributing to achieving objectives related to achieving habitat and recreational access and use goals. Similarly, achieving the management objective related to retaining rainfall runoff onsite would contribute to protecting groundwater recharge. It would also reduce inputs of pollutants into surface waters, contributing to meeting management objectives related to improving water quality.

Finally, achieving targeted stream and stormwater flooding management objectives may also contribute to achieving other desirable outcomes that are not encompassed in the immediate goals of this plan. For example, achieving the objective to protect public infrastructure and private property from stream and stormwater flooding will improve safety, lower insurance costs, reduce the tax burden, and improve property values.

Descriptions of Problems at the Mill Pond and Dam

The historical and existing conditions for the Oak Creek Mill Pond and dam are described in Chapter 4 of this report. That description documents specific areas of concern related to the condition of the Mill Pond and dam as it relates to flooding, water quality, habitat, and recreational access and use and are briefly summarized below:

- The sluice gate that is required to dewater the pond for dam maintenance is inoperable due to sediment accumulation and lack of regular operation of the gate.

- The Mill Pond was not designed to provide flood storage but for recreational and aesthetic purposes. Under the current configuration of the dam, the regulatory FEMA floodplain indicates that the adjacent Oak Creek Parkway would be flooded during the 1-percent-annual-probability event.

- Sediment accumulation in the Mill Pond has become excessive, creating islands in the pond and very shallow water depths that have adversely impacted water quality, habitat, aquatic species, and recreation.

- The dam is a full barrier to fish and aquatic organism passage between Lake Michigan and the upstream Oak Creek watershed.

- The Mill Pond warming house has not been utilized to its full potential due to the diminished recreational opportunities at the pond.

Management Objectives for the Mill Pond and Dam

Based on the descriptions of problems given above and the evaluation given in Chapter 4, there are six management objectives related to the Mill Pond and dam for this plan:

1. If the dam is not removed, provide a way to dewater the pond for dam maintenance

2. If the dam is not removed, evaluate an emergency spillway design to improve safety at and downstream of the dam structure and lower flood elevations in the pond area

3. Manage sediment more effectively in the Mill Pond area

4. Enhance recreational opportunities in the Mill Pond area

5. Improve habitat quality for aquatic and terrestrial wildlife in the Mill Pond area

6. Evaluate aquatic organism passage through the Mill Pond and dam area as a part of potential improvements

These objectives are not prioritized, but their implementation depends on what alternatives are considered for the Mill Pond and dam. Chapter 6 will include a discussion of alternatives for the Mill Pond and dam area.

Co-Benefits from Addressing Mill Pond and Dam Objectives

Achieving individual Mill Pond and dam management objectives would provide additional benefits beyond the problems the objectives are intended to address. These co-benefits fall into three broad classes: co-benefits that address other Mill Pond and dam objectives, co-benefits that address issues within other focus areas of this plan, and co-benefits that address other desirable outcomes that are not encompassed in the immediate goals of this plan.

Achieving individual Mill Pond and Dam objectives may contribute to achieving others. For example, achieving the management objectives related to improving habitat quality in the Mill Pond area and providing aquatic organism passage would also enhance recreational opportunities in the Mill Pond area.

Achieving Mill Pond and dam objectives may also contribute to achieving management objectives related to other goals of this plan. For instance, achieving the management objectives related to providing a way to dewater the pond for dam maintenance and managing sediment more effectively in the Mill Pond area would contribute to improving water quality as well as improving aquatic habitat in the mainstem of Oak Creek downstream of the dam.

Finally, achieving Mill Pond and dam objectives may also contribute to achieving other desirable outcomes that are not encompassed in the immediate goals of this plan. For example, by enabling more frequent maintenance of the dam, achieving the objective to provide a way to dewater the pond will enhance public safety. In addition, providing aquatic organism passage would contribute to maintaining or improving the quality of the fishery in Lake Michigan by providing additional spawning and rearing habitat for fish such as walleye, smallmouth bass, largemouth bass, northern pike, white sucker, and rock bass that spawn in tributary streams.

5.5 RECREATIONAL ACCESS AND USE

Description of Findings and Issues Related to Recreational Use and Access

The existing state of recreational facilities and access as well as the results of public and observational surveys of recreational uses that the public currently practices in the Oak Creek watershed are described in Chapter 4 of this report. Several findings and issues related to recreational use and access that currently exist in the watershed are briefly summarized below:

- Major recreational uses of the watershed include walking, hiking, biking, and fishing
- The public has expressed a desire for improved quality and increased extent of trails within the watershed
- The Milwaukee County Parks has proposed adding about six miles of trails to the Oak Leaf Trail system within the watershed
- The public has expressed a desire for educational signage
- The recreational fishery upstream from the Mill Pond Dam is of poor quality

It should be noted that much of the riparian area adjacent to the mainstem of Oak Creek and some of its tributaries is publicly owned. This presents a unique opportunity to provide the public with close access to these streams and the associated riparian areas.

Management Objectives for Recreational Use and Access

Based on the statement of issues related to recreational use and access and the analyses given in Chapter 4, there are three management objectives for the Oak Creek watershed related to recreational use and access:

1. Continue development of trails and recreational corridors within the Oak Creek watershed to provide an interconnected trail system within the watershed that provides access to the streams of the watershed and to local, County, and regional trail systems within adjacent watersheds
2. Improve fishing access along the mainstem of Oak Creek
3. Provide educational signage along trails within the watershed

Co-Benefits from Addressing Recreational Use and Access Management Objectives

Achieving individual recreational use and access management objectives would provide additional benefits beyond the problems the objectives are intended to address. These co-benefits fall into three broad classes: co-benefits that address other issues within the recreational use and access focus area of this plan, co-benefits that address issues within other focus areas of this plan, and co-benefits that address other desirable outcomes that are not encompassed in the immediate goals of this plan.

Achieving individual recreational use and access management objectives may contribute to achieving others. For example, achieving the management objective related to continued development of trails and recreational corridors within the watershed would also serve to improve fishing access along the mainstem of Oak Creek and its major tributaries.

Achieving recreational use and access management objectives may also contribute to achieving management objectives related to other goals of this plan. For instance, achieving the management objective related to providing educational signage along trails within the watershed would help to make the public more aware of issues and efforts related to water quality, flooding, and habitat. This would promote behaviors that can contribute to improvements in conditions related to these focus areas.

Finally, achieving recreational use and access management objectives may also contribute to achieving other desirable outcomes that are not encompassed in the immediate goals of this plan. For example, achieving the management objective related to continued development of trails and recreational corridors within the watershed will increase the public's opportunities for exercise and outdoor recreation, leading to improvements in human health and reductions in health-related costs. In addition, achieving recreational use and access management objectives helps turn community attention toward the surface waters of the watershed. This helps to create a sense of place, which can help promote economic development. The surface waters of the watershed can be a destination and attract multiple uses such as housing, retail businesses, restaurants, performing arts facilities, and recreation. All of these activities benefit from an attractive setting. Achieving this can lead to the watershed having more visitors who tend to spend money on things like food and lodging without adding stress to larger infrastructure.