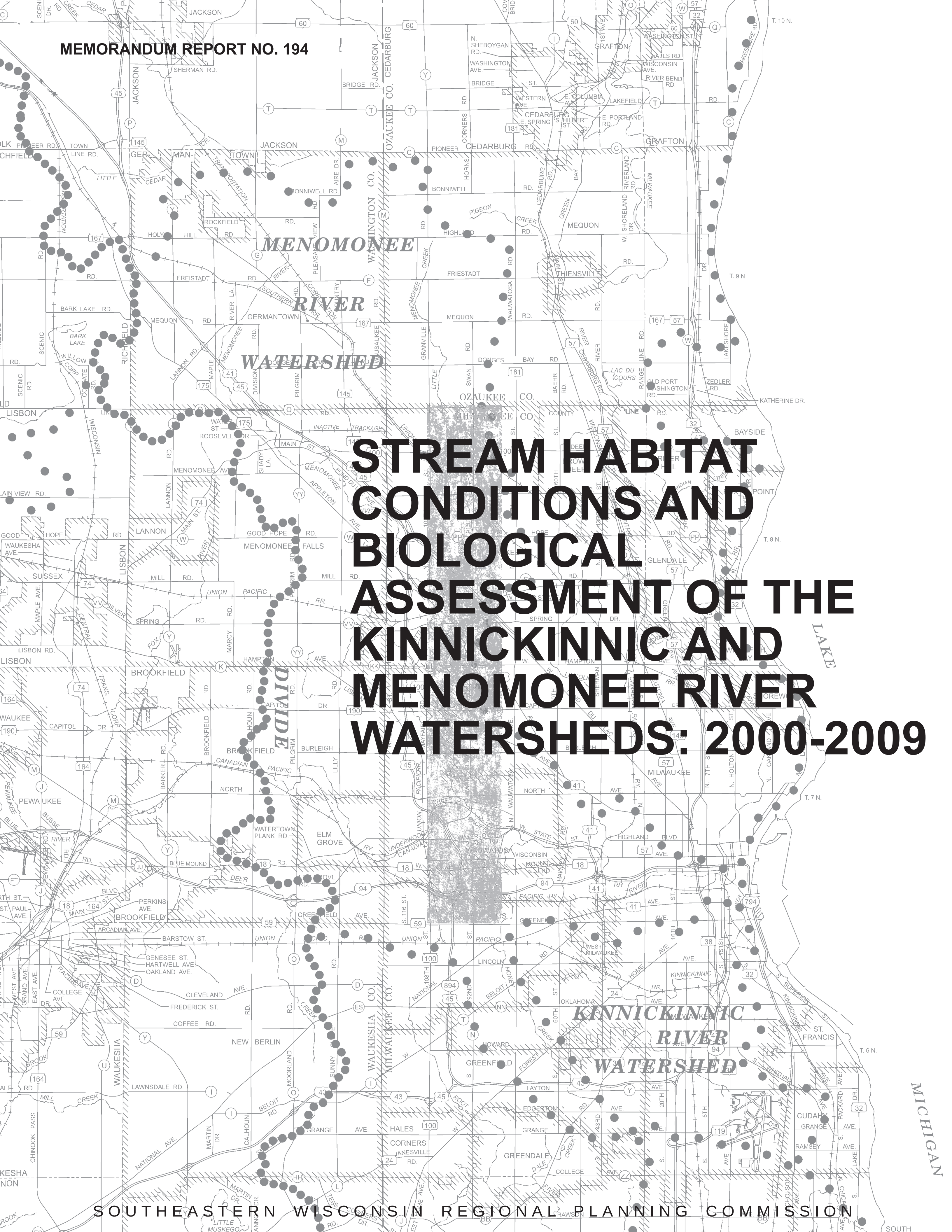
MEMORANDUM REPORT NO. 194

STREAM HABITAT CONDITIONS AND BIOLOGICAL ASSESSMENT OF THE KINNICKINNIC AND MENOMONEE RIVER WATERSHEDS: 2000-2009



SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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Chapter I

INTRODUCTION

BACKGROUND

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) is the State-designated and Federally recognized areawide water quality planning agency with responsibility for preparation of a regional water quality management plan for the seven-county Southeastern Wisconsin Region. In this capacity, the Commission prepared and adopted the first areawide water quality management plan for the Southeastern Wisconsin Region in 1979.[1] This plan has been amended, refined, and updated since 1979 with the most recent major plan amendment being documented in SEWRPC Planning Report No. 50 (PR No. 50), *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*, which was completed in 2007.[2] From the outset, SEWRPC has approached the process of developing a regional water quality management plan, and all subsidiary plans, within a watershed framework, incorporating regional land use planning, public involvement, and application of sound science. This plan, based upon a five year data gathering, analysis, and interpretation effort that is summarized in SEWRPC Technical Report No. 39 (TR No. 39), *Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds*, continues this long-standing tradition.[3]

Key elements in the PR No. 50 planning process included:

- Application of updated land use, demographic, and economic data through the year 2000, and updated planned land use, demographic, and economic data through the plan year 2035;

- Coordination with, and incorporation of, the Milwaukee Metropolitan Sewerage District (MMSD) 2020 facilities plan;

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

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

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

- Consideration of historical and existing surface water and groundwater conditions as the basis for formulating and refining recommendations for actions to continue to improve fishery and water-based recreational conditions—including extensive consideration of riparian buffers (Appendix O), and criteria and guidelines for stream crossings to allow fish passage and allow stream stability (Appendix P), as well as consideration of sediment remediation as part of dam removal, stream corridor management as an element of aquatic and terrestrial fish and wildlife management, restoration of connectivity along streams, and re-naturalization of stream hydrology;

- Identification of sources of water pollution under existing and future land use conditions;

- Utilization of simulation models;

- Review of the existing legal structure governing the management and mitigation of the sources of pollution;

- Review of technological options and management for management and mitigation;

- Refinement of planning objectives, principles, and standards;

- Participation of multiple stakeholder groups, including both governmental and nongovernmental organizations.

The Southeastern Wisconsin Watersheds Trust, Inc. (SWWT),[4] is a new umbrella organization that was formed in response to the recommendations set forth in PR No. 50. The SWWT is a nongovernmental, voluntary organization dedicated to promoting and encouraging the protection and improvement of water quality in the Greater Milwaukee Watersheds. The SWWT operates through a committee structure that includes: Executive Steering Council, Science Committee, Policy Committee, Watershed Action Teams, and *Ad Hoc* Committees.

The Science Committee of the SWWT formed the Habitat Subcommittee (hereinafter, the Subcommittee) at their meeting on May 14, 2009. It was requested that the SEWRPC staff serve as the Chair of the Subcommittee, which was formed to address habitat issues related to the preparation by MMSD and SWWT of watershed restoration plans (WRPs) for the Menomonee River and Kinnickinnic River watersheds. The Subcommittee was tasked with developing recommendations for conserving and restoring fisheries and wildlife habitat within the Menomonee and Kinnickinnic River watersheds. Specific tasks assigned to the Subcommittee included:

- Characterizing existing instream and riparian physical and biological conditions based on SEWRPC TR No. 39;

- Defining habitat, including consideration of factors that influence habitat quality;

- Identifying data gaps and information needs;

- Identifying potential habitat restoration projects that would be expected to positively influence the overall aquatic ecosystem based on existing information; and

- Recommending future habitat data collection and analysis, and possible additional planning requirements, after the WRPs are completed.

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[4]*Southeastern Wisconsin Watersheds Trust, Inc. (SWWT),* http://www.swwtwater.org/home/.

This report expands on habitat-related information set forth in PR No. 50 and includes fishery, invertebrate, and habitat data gathered since completion of that plan up to the year 2009. Specifically, this report is intended to provide the Science Committee members with a basis to understand the quality and extent of habitat, limitations to habitat, and project prioritization strategies to improve habitat and the resultant fisheries within the Menomonee and Kinnickinnic River watersheds. This report provides the basis for integration of habitat-related recommendations in the WRPs. This document summarizes data, research, and information gathered among numerous formal and informal meetings with the Science Committee, SWWT Menomonee and Kinnickinnic River Watershed Action Teams, MMSD, Wisconsin Department of Natural Resources (WDNR), U.S. Geological Survey (USGS), nongovernmental agencies, and various university faculties held between May through November 2009.

Project Identification, Development, and Prioritization

This report presents the results of an inventory and analysis of the surface waters and related features of the Menomonee and Kinnickinnic River watersheds. It includes descriptive information pertaining to the historical trends and current status of habitat (physical, chemical, and biological) quality and ecological integrity, bank stability, and potential limitations to water quality and fishery resources. To the extent that instream biological conditions are a reflection of channel conditions and structures, and to the extent that channel conditions are a reflection of riparian corridor conditions, either existing or historical, this report is based on the instream surveys completed during the process of data gathering associated with the regional water quality management plan update. This monitoring data was provided by WDNR, USGS, MMSD, and Wisconsin Lutheran College. This report is intended to provide a strategic framework for decision-making for the purpose of protecting and improving recreation, water quality, and fisheries. Specifically, it summarizes the biological and habitat quality within each watershed; identifies factors potentially limiting the aquatic community and habitat quality; identifies information needs; provides recommended goals, objectives, and actions to address the impairments; recommends a prioritization strategy to maximize project cost effectiveness; and recommends post-project monitoring to assess project success.

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Chapter II

INVENTORY FINDINGS

INTRODUCTION AND BACKGROUND

The water-resource and water-resource-related problems of a watershed, as well as the ultimate solutions to those problems, are a function of the human activities within the watershed and of the ability of the underlying natural resource base to sustain those activities. Regional water quality management planning seeks to rationally direct the future course of human actions within the watershed so as to promote the conservation and wise use of the natural resource base. Accordingly, two recently completed and separate regional planning documents, SEWRPC Technical Report No. 39 (TR No. 39), *Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds*, November 2007, and SEWRPC Planning Report No. 50 (PR No. 50), *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*, December 2007, have thoroughly described both the natural resource base and the man-made features of the Menomonee and Kinnickinnic River watersheds, thereby establishing a factual base upon which the refined local watershed restoration planning process undertaken by the Southeastern Wisconsin Watersheds Trust, Inc., with funding from the Milwaukee Metropolitan Sewerage District could proceed. A more thorough description of the natural and human-made features of the Menomonee and Kinnickinnic River watersheds can be found on the Southeastern Wisconsin Regional Planning Commission (SEWRPC) website (*www.sewrpc.org*).

The following sections present a summary of important stream characteristics and their relationship to agricultural and urban development, as well as an inventory and analysis of the surface waters and related features of the Menomonee and Kinnickinnic River watersheds. Included is descriptive information pertaining to the historical trends and current status of habitat (physical and biological) quality and ecological integrity within the Menomonee and Kinnickinnic River watersheds, bank and bed stability evaluation, riparian buffer analysis, and potential limitations to water quality and fishery resources.

Stream System Characteristics

Water from rainfall and snowmelt flows into streams by one of two pathways: 1) either directly flowing overland as surface water runoff or 2) infiltrating into the soil surface, 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 drainage systems within the Menomonee and Kinnickinnic River watersheds contain totals of about 142 and 31 miles of both perennial and ephemeral streams, respectively, as shown on Maps 1 and 2. Maps 1 and 2 show the modeling assessment points and reaches for the Menomonee River and Kinnickinnic River watersheds. The reaches for the Menomonee River watershed range from MN-1 through MN-19 and from KK-1 through KK-11 for the Kinnickinnic River watershed (see Tables 1 and 2). These reaches form the basis for the summary statistics and recommendations in this report.

Table 1

PHYSICAL AND BIOLOGICAL CONDITIONS ALONG REACHES WITHIN THE MENOMONEE RIVER WATERSHED: 2000-2009

Parameters	Physical, Biological, or Programmatic Component	Tributary Reaches and Subwatersheds														Mainstem Reaches and Subwatersheds							Watershed Total
		MN-1	MN-2	MN-3	MN-4	MN-6	MN-10	MN-11	MN-7	MN-8	MN-13A	MN-13	MN-14A	MN-14	MN-16	MN-5	MN-9	MN-12	MN-17	MN-17A	MN-18	MN-19	
		North Branch Menomonee River	Menomonee River–Upper[a]	West Branch Menomonee River	Willow Creek	Nor-X-Way Channel	Little Menomonee Creek	Little Menomonee River	Lilly Creek	Butler Ditch	Dousman Ditch	Underwood Creek–Upper	South Branch Underwood Creek	Underwood Creek–Lower	Honey Creek	Menomonee River–Upper[b]	Menomonee River–Upper[c]	Menomonee River–Upper[d]	Menomonee River–Lower[a]	Menomonee River–Lower[b]	Menomonee River–Lower[c]	Menomonee River–Lower[d]	
Stream Channel Conditions	Area (square miles)	3.75	8.32	4.64	6.22	5.13	3.31	18.48	5.69	5.66	3.48	4.86	5.43	6.13	10.87	7.78	11.89	1.20	8.99	2.04	8.24	3.59	43.74
	Total Stream Length (miles)	6.16	14.63	7.33	8.20	5.71	5.70	18.86	3.44	4.16	4.88	7.45	3.46	6.68	8.70	10.10	11.95	2.53	4.02	2.18	4.22	2.10	37.10
Streambed Conditions	Degrading (miles)	NA	0	NA	NA	0	0	0.52	0	0	0	0	0	0	0	0	0.12	0	0	0.07	0	0	0.71
	Degrading (percent)	NA	0	NA	NA	0	0	5.11	0	0	0	0	0	0	0	0	1.39	0	0	3.10	0	0	<1
	Aggrading (miles)	NA	0	NA	NA	0	0	1.21	0	0.66	0	0	0	0.18	0.27	0.96	0.69	0	0	0	0	0	3.97
	Aggrading (percent)	NA	0	NA	NA	0	0	11.90	0	15.63	0	0	0	4.47	3.1	21.38	8.00	0	0	0	0	0	<1
	Bedrock (miles)	NA	0	NA	NA	0	0	0	0	0.26	0	0	0	0	0.12	0	0.31	0	0.06	0.08	0.42	0	1.25
	Bedrock (percent)	NA	0	NA	NA	0	0	0	0	6.16	0	0	0	0	1.38	0	3.60	0	0.98	3.55	8.11	0	<1
	Concrete Lining (miles)	NA	0	NA	NA	0	0	0	0	0	0	0	1.07	2.63	4.41	0	0	0	0	0	0.85	0	8.96
	Concrete Lining (percent)	NA	0	NA	NA	0	0	0	0	0	0	0	91.06	65.34	50.81	0	0	0	0	0	16.42	0	<1
	Enclosed Channel (miles)	NA	0	NA	NA	0	0	0.76	0	0	0	0	0	0.14	2.44	0	0	0	0	0	0	0	3.34
	Enclosed Channel (percent)	NA	0	NA	NA	0	0	7.52	0	0	0	0	0	3.48	28.11	0	0	0	0	0	0	0	<1
Streambank Conditions	Proportion of Total Stream Length Assessed (percent)	NA	2	NA	NA	2	0.1	54	100	100	28	62	34	60	100	45	72	77	100	100	100	100	17
	Total Length of Eroding bank (miles)	NA	0	NA	NA	0	0	0.85	2.45	0.05	0	0.25	0	0.19	0.23	0.43	0.92	0.41	0.25	0.26	0.17	0.00	6.45
	Proportion Eroding (percent)	NA	0	NA	NA	0	0	8	71	1	0	5	0	5	3	10	11	21	4	12	3	0.00	45
Obstructions	Dam and Drop Structures (number)	0	0	0	0	1	0	0	0	0	1	3	0	6	15	0	3	0	1	5	1	0	36
	Road Crossings – Culverts and Bridges (number)	8	5	14	3	15	8	31	16	9	8	21	5	20	21	10	21	5	10	8	21	10	269
	Total Obstructions (number)	8	5	14	3	16	8	31	16	9	9	24	5	26	36	10	24	5	11	13	22	10	305
	Total Obstructions – Road/Rail Crossings, Culverts, Bridges, Dams, Drop Structures (number/mile)	1.8	2.2	3.9	1.1	4.9	3.5	3.0	4.7	2.3	3.7	6.1	2.9	6.9	4.8	2.3	3.0	2.3	2.7	6.0	5.2	4.8	8.2
Point Source Outfall Locations	Noncontact Cooling Water Permits (number)	0	1	1	1	7	0	12	0	0	0	0	2	2	2	1	3	2	8	1	11	8	62
	Individual Permits (number)	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	0	3	1	8
	SSO (number)	0	0	0	0	0	0	1	0	4	3	2	3	8	9	2	3	0	8	4	7	0	54
	CSO (number)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	21	29
	Stormwater Outfalls (number)	0	0	3	6	10	0	27	8	13	9	5	12	4	38	50	20	5	7	0	14	5	236
	Point Source Outlet Totals (number)	0	1	4	7	17	0	41	8	17	12	7	17	15	50	53	27	7	23	5	43	35	389
	Stormwater Outfalls (number/mile)	0	0	0.8	2.1	3.1	0	2.6	2.3	3.3	3.7	1.3	6.9	1.1	5.0	11.3	2.5	2.3	1.7	0.0	3.3	2.4	1.2
	Point Source Outlets (number/mile)	0	0.4	1.1	2.5	5.2	0	3.9	2.3	4.3	4.9	1.8	9.8	4.0	6.6	12.0	3.4	3.3	5.7	2.3	10.2	16.7	2.7
Riparian Buffers[a]	Proportion of Total Stream Length that Riparian Buffers were Assessed (percent)	91	93	85	95	98	95	92	96	94	28	54	40	57	70	84	94	71	100	93	91	100	85
	Riparian Buffers <75 Feet wide (percent)	50	27	33	43	36	71	52	72	54	100	52	50	77	72	59	59	26	47	34	94	100	45
	Riparian Buffers >75 Feet wide (percent)	50	73	67	57	64	29	48	28	46	0	48	50	23	28	41	41	74	53	66	6	0	40
Plant Community Assessment[b]	FQI – Very Poor (number sites)	0	1	3	1	0	0	2	0	0	0	1	1	0	0	0	0	1	0	0	1	0	11
	FQI – Poor (number sites)	0	0	1	1	0	0	3	1	0	1	1	2	2	1	1	5	0	1	1	1	0	22
	FQI – Fair (number sites)	0	0	1	0	0	0	3	1	0	0	1	1	1	1	2	0	0	1	0	2	0	14
	FQI – Fairly Good (number sites)	1	1	0	0	1	0	5	0	0	1	2	0	1	0	0	2	0	2	1	0	0	17
	FQI – Good (number sites)	0	1	0	2	0	0	0	0	1		0	0	1	1	0	2	1	0	0	1	0	10
	Total (number)	1	3	5	4	1	0	13	2	1	2	5	4	5	3	3	9	2	4	2	5	0	74
Monitoring Stations	Milwaukee River Keepers – Level 1[c]	0	0	0	1	0	0	0	0	0	0	2	1	2	3	0	0	0	1	1	2	0	13
	Milwaukee River Keepers – Level 2[c]	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	7	0	1	0	2	0	12
	Milwaukee River Keepers – Thermal	0	0	0	0	2	0	2	0	1	0	0	0	0	0	0	0	0	0	0	2	0	7
	MMSD Surface Water Quality Monitoring Sites		1	0	0	0	0	2	1	0	0	2	2	3	5	1	1	0	1	1	2	2	24
	MMSD Continuous Water Quality Monitoring Sites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	USGS Level Gauge Stations	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	USGS Continuous Water Quality Monitoring Sites	0	0	0	0	0	0	1	0	0	0	0	0	1	1	5	0	0	1	0	0	1	10
	Precipitation Gauges	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	1	0	1	0	0	1	7

[a] *Riparian buffer segments includes separate buffer widths for the right bank and left bank.*

[b] *The following qualities were assigned to the Floristic Quality Index (10-19 = Very Poor, 20-29 = Poor, 30-39 = Fair, 40-49 = Fairly Good, 50-59 = Good).*

[c] *Level-1 volunteers conduct periodic stream assessments and measure dissolved oxygen, temperature, turbidity, flow, and qualitative aquatic invertebrate assessments. Level-2 volunteers are advanced monitors that assess water quality using WDNR equipment and protocols for pH, dissolved oxygen, turbidity, and temperature (using automated programmable temperature data loggers).*

Source: SEWRPC.

Table 2

PHYSICAL AND BIOLOGICAL CONDITIONS ALONG REACHES WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000-2009

Parameters	Physical, Biological, or Programmatic Component	Tributary Reaches and Subwatersheds							Mainstem Reaches and Subwatersheds			Watershed Total
		KK-4	KK-8	KK-5	KK-6	KK-7	KK-1	KK-2	KK-3	KK-10 (includes KK-9)	KK-11	
		Wilson Park Creek–Upper	Wilson Park Creek–Lower	Holmes Avenue Creek	Villa Mann Creek	Cherokee Park Creek	Lyons Park Creek	South 43rd Street Ditch	Kinnickinnic River–Upper	Kinnickinnic River–Middle	Kinnickinnic River–Lower	
Stream Channel Conditions	Area (square miles)	3.47	3.56	1.72	1.32	0.96	1.33	1.71	2.62	4.33	3.63	25
	Total Stream Length (miles)	6.95	5.17	2.64	1.66	2.23	1.46	1.50	2.90	2.82	3.20	31
Streambed Conditions	Concrete Lined Channel (miles)	1.13	1.94	1.15	0.56	0	0.46	0	1.03	2.39	0	9
	Concrete Lined Channel (percent)	16	37	44	34	0	32	0	32	85	0	28
	Enclosed Channel (miles)	3.31	1.14	1.31	0.41	0.73	0.38	0.61	0.20	0.01	0.00	8
	Enclosed Channel (percent)	48	22	50	25	33	26	40	7	1	0	27
Streambank Conditions	Proportion of Total Stream Length Assessed (percent)	0	25	0	11	63	48	29	63	11	0	20
	Proportion Eroding (percent)	NA	36.3	NA	25.4	62.8	53.4	39.1	62.8	0	0	20
Obstructions	Dam and Drop Structures (number)	0	0	0	3	1	10	0	1	0	0	15
	Road Crossings – Culverts and Bridges (number)	8	11	3	8	5	9	3	9	14	8	78
	Total Obstructions – Road/Rail Crossings, Culverts, Bridges, Dams, Drop Structures (number/mile)	3	3	1	16	3	15	3	3	5	3	55
Point Source Outfall Locations	Noncontact Cooling Water Permits (number)	2	0	3	0	0	0	5	0	4	0	14
	Individual Permits (number)	1	0	0	0	0	0	2	0	1	2	6
	SSO (number)	2	1	0	0	0	1	7	3	2	0	16
	CSO (number)	0	0	0	0	0	0	0	0	6	19	25
	Stormwater Outfalls (number)	4	13	4	2	1	4	6	9	7	3	53
	Point Source Outlet Totals (number)	9	14	7	2	1	5	20	12	20	24	114
	Stormwater Outfalls (number/mile)	1.5	3.7	1.5	2.8	0.4	3.1	5.5	3.1	2.6	1.3	1.7
	Point Source Outlets (number/mile)	3.5	4.0	2.7	2.8	0.4	3.8	18.2	4.1	7.4	10.0	3.7
Riparian Buffers[a]	Proportion of Total Stream Length that Riparian Buffers were Assessed (percent)	41	73	47	75	70	79	31	83	88	56	62
	Riparian Buffers <75 Feet wide (percent)	100	90	100	100	81	90	100	73	77	84	88
Riparian Buffers continued[a]	Riparian Buffers >75 Feet wide (percent)	0	10	0	0	19	10	0	27	23	16	12
Plant Community Assessment[b]	FQI – Poor (number sites)	0	2	0	0	0	0	0	0	0	0	2
	FQI – Fair (number sites)	0	0	1	0	0	1	0	1	0	0	3
	FQI – Fairly Good (number sites)	0	0	0	0	0	0	0	1	0	0	1
	Total (number)	0	2	1	0	0	1	0	2	0	0	6
Monitoring Stations	Milwaukee River Keepers – Level 1[c]	1	1	0	0	0	0	0	1	0	0	3
	Milwaukee River Keepers – Level 2[c]	0	1	0	0	0	0	0	0	2	0	3
	Milwaukee River Keepers – Thermal	1	0	0	0	0	0	0	2	0	0	3
	MMSD Surface Water Quality Monitoring Sites	0	1	0	0	0	0	1	1	3	2	8
	MMSD Continuous Water Quality Monitoring Sites	0	0	0	0	0	0	0	0	1	0	1
	USGS Level Gauge Stations	3	1	0	0	0	0	0	0	1	0	5
	USGS Continuous Water Quality Monitoring Sites	0	0	0	0	0	0	0	0	0	0	0
	Precipitation Gauges	0	0	0	0	0	0	1	0	1	1	3

[a]Riparian buffer segments includes separate buffer widths for the right bank and left bank.

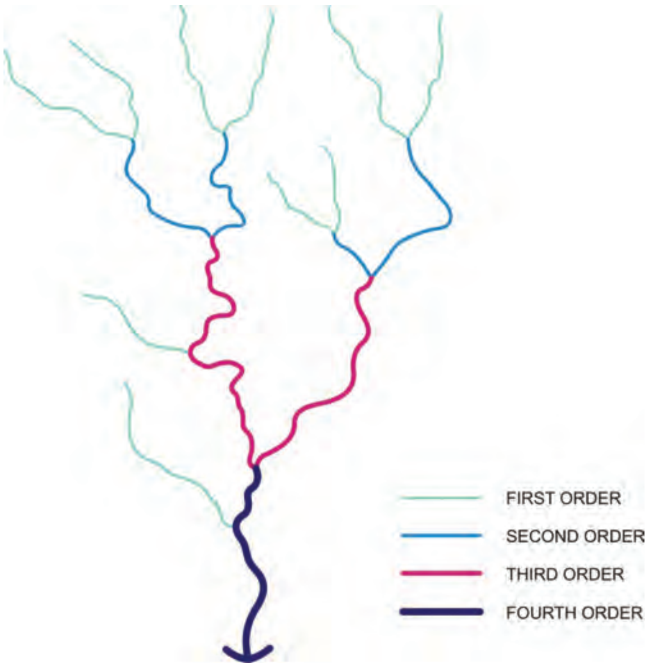
[b]The following qualities were assigned to the Floristic Quality Index (10-19 = Very Poor, 20-29 = Poor, 30-39 = Fair, 40-49 = Fairly Good, 50-59 = Good).

[c]Level-1 volunteers conduct periodic stream assessments and measure dissolved oxygen, temperature, turbidity, flow, and qualitative aquatic invertebrate assessments. Level-2 volunteers are advanced monitors that assess water quality using WDNR equipment and protocols for pH, dissolved oxygen, turbidity, and temperature (using automated programmable temperature data loggers).

Source: SEWRPC.

Figure 1

TYPICAL STREAM NETWORK PATTERNS BASED ON HORTON'S CLASSIFICATION SYSTEM



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

Viewed from above, the network of water channels that form a river system typically displays a branch-like pattern as shown in Figure 1. A stream channel that flows into a larger channel is called a tributary of that channel. The entire area drained by a single river system is termed a drainage basin, or watershed. Stream size increases in the downstream direction as more and more tributary segments enter the main channel. A classification system based on the position of a stream within the network of tributaries, called stream order, was developed by Robert E. Horton and later modified by Arthur Strahler. In general, the lower stream order numbers correspond to the smallest headwater tributaries and are shown as the Order 1 or first-order streams in Figure 1. Second-order streams (Order 2) are those that have only first-order streams as tributaries, and so on (see Figure 1). As water travels from headwater streams toward the mouth of larger rivers, streams gradually increase their width and depth and the amount of water they discharge also increases. It is important to note that over 80 percent of the total length of Earth's rivers and streams are a headwater stream (first- and second-order), which is also generally characteristic of the Menomonee and Kinnickinnic River watersheds.

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 2.[1] Microhabitats, such as a handful-sized patch of gravel, are most susceptible to disturbance and river systems and watersheds, or drainage basins, are least susceptible. Furthermore, events that affect smaller-scale habitat characteristics may not affect larger-scale system characteristics, whereas large disturbances can directly influence smaller-scale features of streams. For example, on a small spatial scale, deposition at one habitat site may be accompanied by scouring at another site nearby, and the reach or segment does not appear to change significantly. In contrast, a large-scale disturbance, such as a debris flood, is initiated at the segment level and reflected in all lower levels of the hierarchy (reach, habitat, microhabitat). Similarly, on a temporal scale, siltation of microhabitats may disturb the biotic community over the short term. However, if the disturbance is of limited scope and intensity, the system may recover quickly to pre-disturbance levels.[2] In contrast, extensive or prolonged disturbances, such as stream channelization due to ditching and agricultural drainage practices, have resulted in longer term impacts throughout the study area.

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

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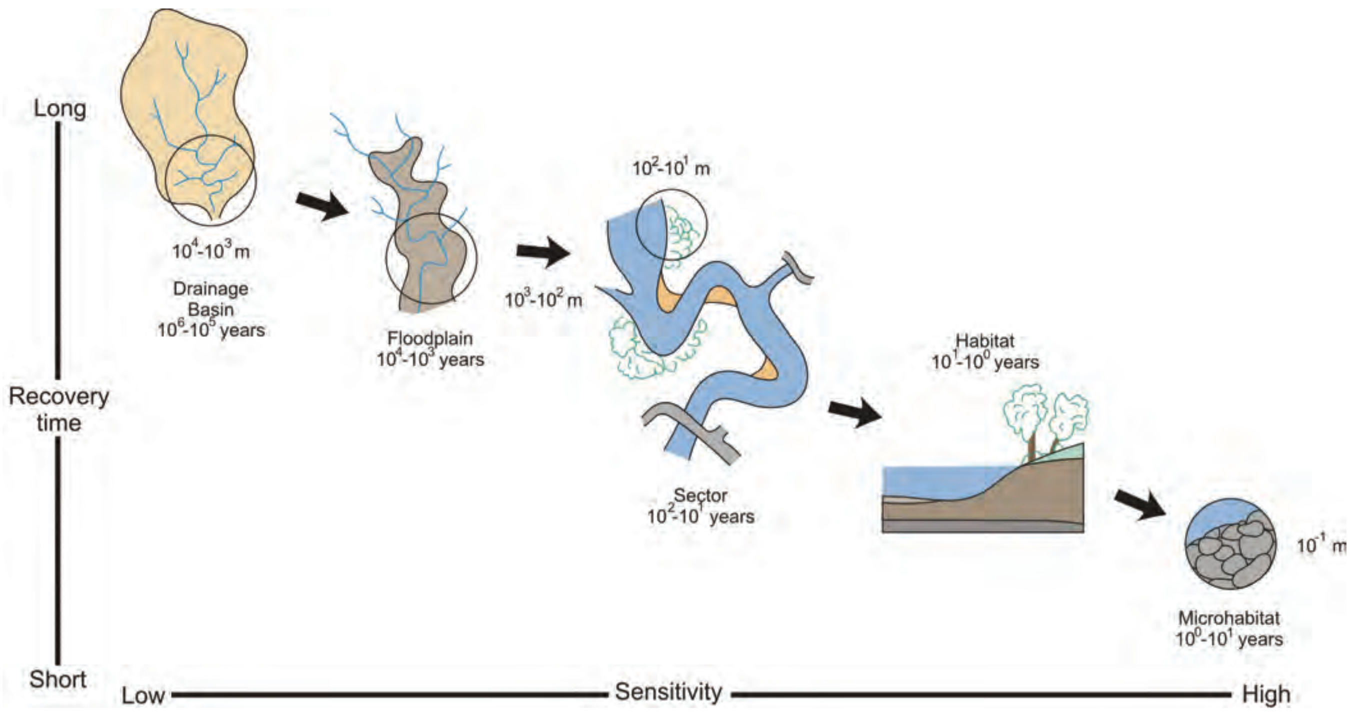
[1]*C.A. Frissell and others, "A Hierarchical Framework for Stream Classification: Viewing Streams in a Watershed Context,"* Journal of Environmental Management*, Volume 10, pages 199-214, 1986.*

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

Figure 2

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



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

upon the upstream areas; and 2) that streams are intimately connected to their adjacent terrestrial setting, that is, the land-stream interaction is crucial to the functioning of stream ecosystem processes and this connectivity does not diminish in importance with stream size. In this regard, land uses have a significant impact on stream channel conditions and associated biological responses.[3]

Urban Development, Imperviousness, and Hydrology

The Kinnickinnic River watershed is nearly entirely built out and contained about 93 percent urban land in year 2000 (TR No. 39). Urban land use in the Menomonee River watershed is expected to increase from about 64 percent in year 2000 to approximately 76 percent in 2035 (TR No. 39 and PR No. 50). In the absence of planning, such urbanization can create negative impacts on streams. Urbanization itself is not the main factor driving the degradation of the local waterbodies. Streams can survive and flourish in urban settings. The main factors leading to the degradation of urban waterbodies are the creation of large areas of connected impervious surfaces, the lack of adequate stormwater management facilities to control the quantity and quality of runoff,

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[3]*Lizhu Wang and others, "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams," Fisheries, Volume 22, No. 6, June 1997; Jana S. Stewart and others, "Influences of Watershed, Riparian-Corridor, and Reach-Scale Characteristics on Aquatic Biota in Agricultural Watersheds," Journal of the American Water Resources Association, Volume 37, No. 6, December 2001; Faith A. Fitzpatrick and others, "Effects of Multi-Scale Environmental Characteristics on Agricultural Stream Biota in Eastern Wisconsin,"* Journal of the American Water Resources Association, *Volume 37, No. 6, December 2001.*

Table 3

APPROXIMATE PERCENTAGE OF CONNECTED IMPERVIOUS SURFACES CREATED BY URBAN DEVELOPMENT

Type of Urban Development	Impervious Surface (percent)
Two-Acre Residential	10-15
One-Acre Residential	15-25
One-Half-Acre Residential	20-30
One-Third-Acre Residential	25-35
One-Fourth-Acre Residential	35-45
One-Eighth-Acre Residential	60-70
Industrial	70-80
Commercial	85-90

Source: B.K. Ferguson, Introduction to Stormwater: Concept, Purpose, Design*, New York, John Wiley & Sons, 1998.*

proximity of development to waterbodies, loss of natural areas, and inadequate construction erosion controls. These factors increase the potential for the occurrence of the negative water quality/quantity effects associated with urbanization. Good land use planning, creative site design, and the application of best management practices for construction site erosion control and post-construction stormwater management can greatly reduce the potential for urban development to negatively affect the surrounding environment.

Industrial and commercial land uses have significantly more impervious area than most residential land uses. Furthermore, smaller residential lots create more impervious surfaces than larger residential lots. Table 3 lists the approximate amount of impervious surfaces created by residential, industrial, commercial, and governmental and institutional development.

Although commercial and industrial developments create a larger percentage of impervious surfaces, residential developments, where lawns are the single largest use of land area, present different concerns. Lawns are considered pervious, but they do show some similarities to impervious surfaces. When lawns are compared to woodlands and cropland, they are found to contain less soil pore space (up to 15 percent less than cropland and 24 percent less than woodland) available for the infiltration of water. In many instances, considerable soil compaction occurs during grading activities, significantly reducing the perviousness of lawns. Native grasses, forbs, and sedges have significantly deeper root systems than turf grass, which loosen the soil and create flow channels that increase infiltration capacity. Also, owing to excessive application of fertilizers and pesticides on urban lawns, they typically produce higher unit loads of nutrients and pesticide than does cropland.[4]

When a new commercial or residential development is built near a stream, the area in driveways, rooftops, sidewalks, and lawns increases; while native plants and undisturbed soils decrease; and the ability of the shoreland area to perform its natural functions (flood control, pollutant removal, wildlife habitat, and aesthetic beauty) is decreased. In the absence of mitigating measures, urbanization impacts the watershed, not only by altering the ratio between stormwater runoff and groundwater recharge, but also through the changing of stream hydrology (i.e., increasing stormwater runoff volumes and peak flows and altering the baseflow regime) and through divergence of the seasonal thermal regimes away from their historical patterns (see Figure 3). These changes further influence other characteristics of the stream, such as channel morphology, water quality/quantity, and biological diversity. More specifically, recent research has shown that average flow magnitude, high flow magnitude, high flow event frequency, high flow duration, and rate of change of stream cross-sectional area were the hydrological variables most consistently associated with changes in algal, invertebrate, and fish communities.[5] When urban development increases, the area of impervious surfaces increases proportionately to the decrease in the amount of pervious surfaces. For this reason alone, many researchers throughout the United States, including those at the Wisconsin Department of Natural Resources (WDNR), report that the amount of connected

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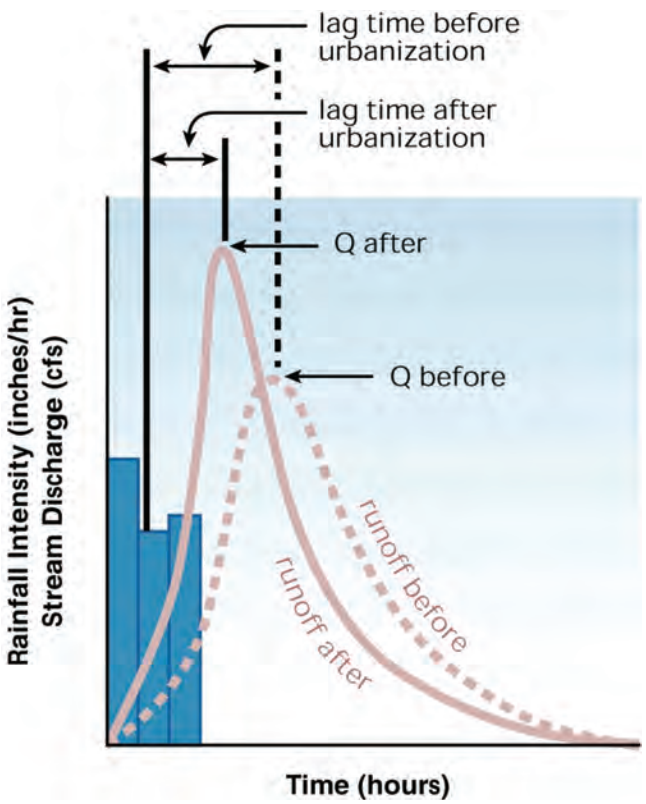
[4]*Center for Watershed Protection, "Impacts of Impervious Cover on Aquatic Systems,"* Watershed Protection Research Monograph No. 1, *March 2003, p. 7.*

[5]*Personal Communication, Dr. Jeffrey J. Steuer, US Geological Survey.*

Figure 3

A COMPARISON OF HYDROGRAPHS BEFORE AND AFTER URBANIZATION



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

impervious surfaces is the best indicator of the level of urbanization in a watershed.[6] Connected impervious surfaces have a direct hydraulic connection to a stormwater drainage system, and ultimately, to a stream. The studies mentioned above have found that relatively low levels of urbanization, 8 to 12 percent connected impervious surface, can cause subtle changes in physical (increased temperature and turbidity) and chemical (reduced dissolved oxygen and increased pollutant levels) properties of a stream that may lead to a decline in the biological components of the stream. For example, each 1 percent increase in watershed imperviousness can lead to an increase in water temperature of about 0.25 degrees Celsius.[7] This temperature increase is small in magnitude, but even this small increase can have significant impacts to fish and other members of the biological community.

To some degree, impervious surface impacts can be mitigated through implementation of traditional stormwater management practices and emerging green infrastructure technologies such as pervious pavement, green roofs, rain gardens, bioretention, and infiltration facilities. Traditional stormwater management practices seek to manage runoff using a variety of measures, including detention, retention, conveyance, and infiltration. Emerging technologies, in contrast, differ from traditional stormwater practices in that they seek to better mimic the disposition of precipitation on an undisturbed landscape by retaining and infiltrating stormwater onsite. There are a number of nontraditional emerging technologies that have been implemented throughout the greater Milwaukee watersheds that include disconnection of downspouts, installation of rain barrels, green roofs, and rain gardens, as well as constructing biofiltration swales in parking lots and along roadways and application of low impact development (LID) measures. Recent experience has shown that these emerging technologies can be effective. For example, recent research has demonstrated that bioretention systems can work in clayey soils with proper sizing, remain effective in the winter, and contribute significantly to groundwater recharge, especially when such facilities utilize native prairie plants (see Figure 4).[8]

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[6]*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.*

[7]*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.*

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

Figure 4

WHAT HAS BEEN LEARNED FROM BIORETENTION AND RAIN GARDEN STUDIES?

Source: Roger Bannerman, Wisconsin Department of Natural Resources, and SEWRPC.

In the absence of mitigating measures, one of the consequences of urban development is the increase in the amount of stormwater, which runs off the land, instead of infiltrating into the groundwater. A parking lot or driveway produces much more runoff than an undisturbed meadow or agricultural hay field. Depending on the degree of watershed impervious cover, the annual volume of storm water runoff can increase by up to 16 times that for natural areas.[9] In addition, since impervious cover prevents rainfall from infiltrating into the soil, less flow is available to recharge groundwater. Therefore, during extended periods without rainfall, baseflow levels are often reduced in urban streams.[10] This has been observed to occur in both the Menomonee and Kinnickinnic River watersheds. Furthermore, runoff traveling over a parking lot or driveway will pick up more heavy metals, hydrocarbons, chlorides, bacteria, pathogens, and other stream pollutants than runoff traveling over surfaces that allow some of the stormwater to be filtered or to infiltrate. Runoff traveling over impervious surfaces bypasses the filtering action of the soil particles, soil microbes, and vegetation present above (stems and leaves) and below (roots) the soil surface. For example, as shown in Figures 5 and 6, MMSD staff observed that total phosphorus and total suspended solids concentrations downstream of stormwater outfalls in the greater Milwaukee River watersheds were significantly higher during the initial first flush of a rainfall event compared to later samples.

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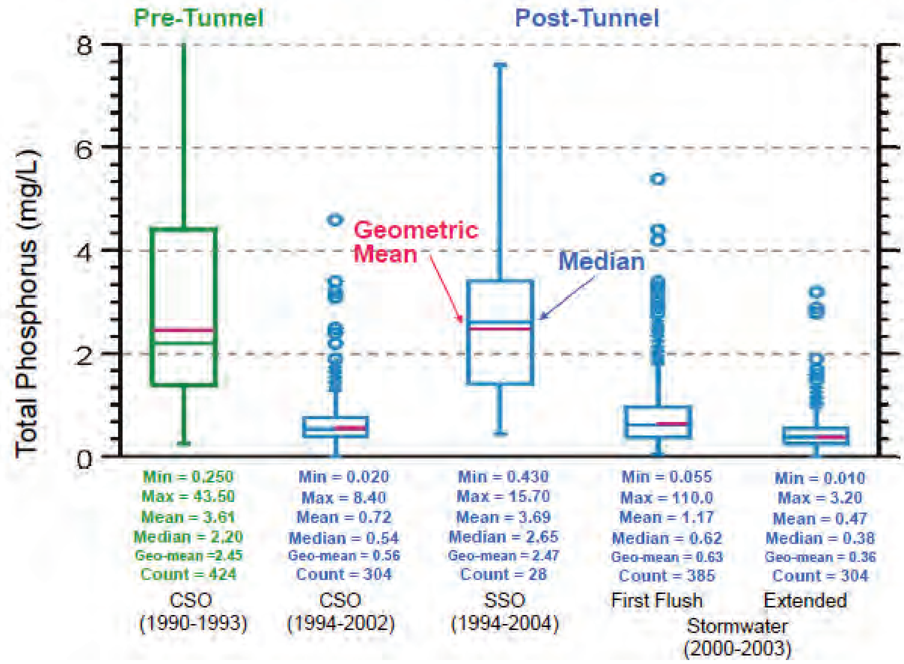
[9]*T. Schueler, "The importance of imperviousness,"* Watershed Protection Techniques, *Volume 1(3): 100-111, 1995.*

[10]*D. Simmons and R. Reynolds, "Effects of urbanization on baseflow of selected south shore streams, Long Island, NY,"* Water Resources Bulletin, *Volume 18(5): 797-805, 1982.*

Figure 5

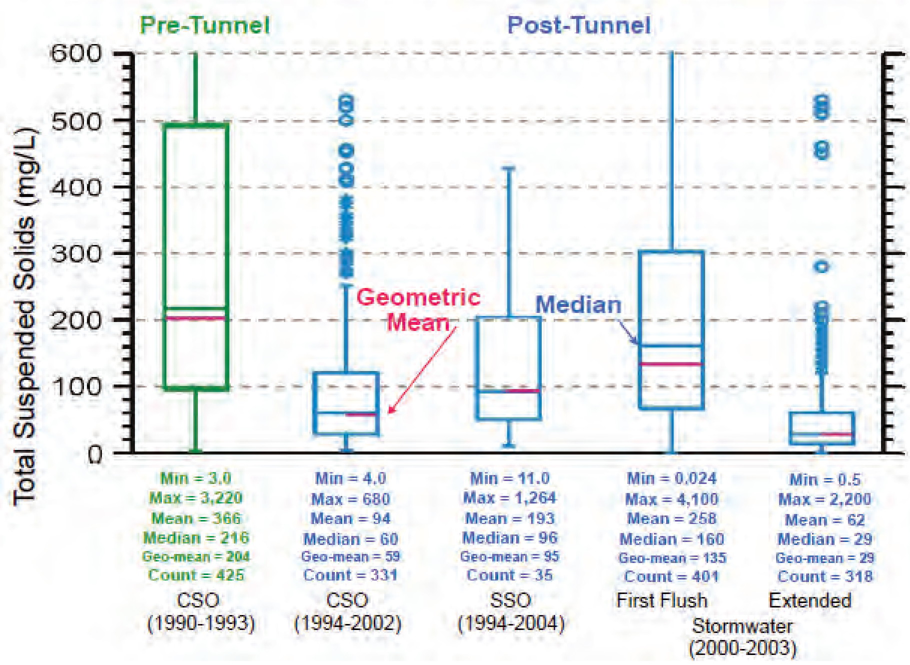
COMPARISON OF TOTAL PHOSPHORUS CONCENTRATIONS AMONG COMBINED SEWER OVERFLOWS (CSOs), SANITARY SEWER OVERFLOWS (SSOs), AND STORMWATER OUTFALL DISCHARGES WITHIN THE GREATER MILWAUKEE WATERSHEDS



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 6

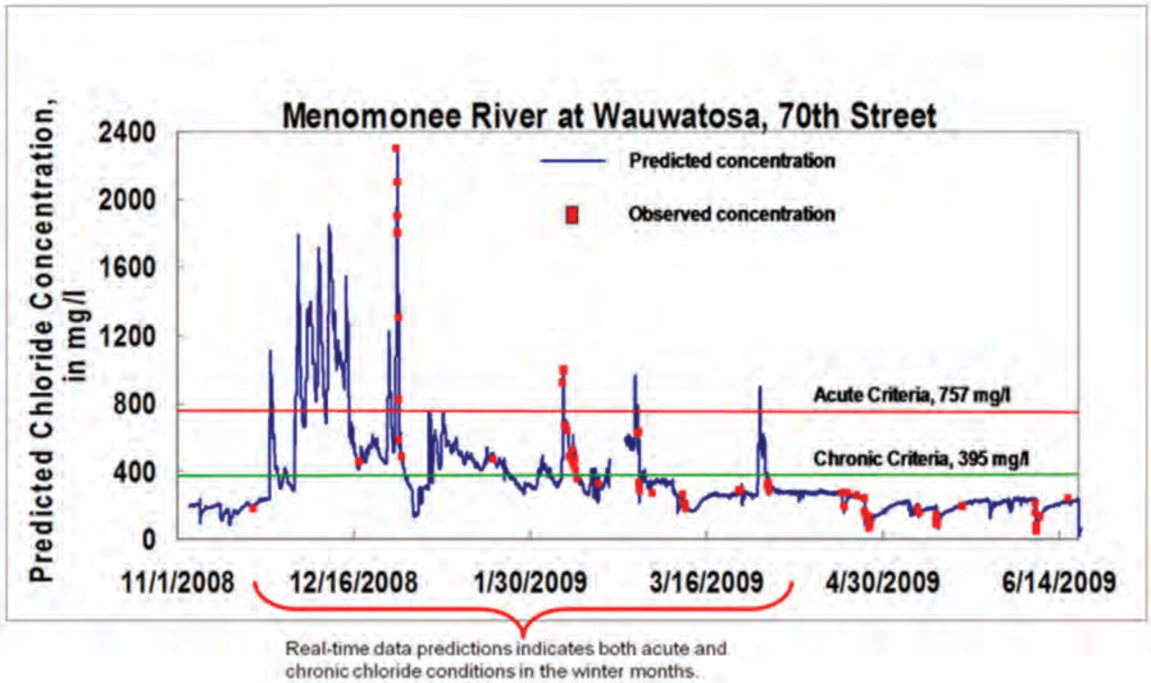
COMPARISON OF TOTAL SUSPENDED SOLIDS CONCENTRATIONS AMONG COMBINED SEWER OVERFLOWS (CSOs), SANITARY SEWER OVERFLOWS (SSOs), AND STORMWATER OUTFALL DISCHARGES WITHIN THE GREATER MILWAUKEE WATERSHEDS



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 7

PREDICTED AND OBSERVED CHLORIDE CONCENTRATIONS AT 70TH STREET WITHIN THE MENOMONEE RIVER WATERSHED: 2008-2009



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figures 5 and 6 also illustrate important points relative to the Inline Storage System, or deep tunnel, that was constructed by MMSD to reduce the number of sewer overflows: 1) post deep tunnel pollutant concentrations for combined sewer overflows (CSOs) have improved significantly compared to pre-tunnel conditions, 2) stormwater pollutant concentrations of total suspended solids associated with the initial first flush during a storm are equivalent or exceed pollutant concentrations in both CSOs and sanitary sewer overflows (SSOs), and 3) stormwater pollutant concentrations of total phosphorus associated with the first flush are similar, or slightly greater, than pollutant concentrations in CSOs, but less than SSOs.

Figure 7 illustrate the connection or synergistic relationship between stream flashiness (water quantity) and pollutant loadings (water quality) associated with urban stormwater runoff. This figure shows how observed chloride concentrations and predicted concentrations based on associated total conductivity measurements in the Menomonee River at N. 70th Street fluctuate in response to rainfall events and seasons. It is clear that this location on the River is impacted by chlorides for extended periods during the winter (December through March). There are both episodic periods of acute toxicity and extended periods of chronic toxicity at this location during the winter. Additionally the fish index of biotic integrity score at this location is very poor. A variety of factors are likely contributing to this result, with chloride concentrations being one of them. Based on this relatively new real-time information, it is becoming clear that chloride impacts are not short lived; rather chronic toxicity impacts can last most of the winter depending on snowfall and weather. This same relationship is also likely to be the case for the Kinnickinnic River.[11] In addition, researchers found that the high levels of imperviousness within

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[11]*Personal communication, Chris Magruder, MMSD.*

the Honey Creek and Kinnickinnic River watersheds were strongly associated with higher amounts of nonpoint source pollutants that significantly affect fathead minnow reproductive behavior.[12] The most striking results in this study showed decreased sexual development in males, reduced average egg count by females, and reduced number of breeding pairs.

Location of impervious surfaces also determines the degree of direct impact they will have upon a stream. There is a greater impact from impervious surfaces located closer to a stream, due to the fact that there is less time and distance for the polluted runoff to be naturally treated before entering the stream. A study of 47 watersheds in southeastern Wisconsin found that one acre of impervious surface located near a stream could have the same negative effect on aquatic communities as 10 acres of impervious surface located further away from the stream.[13] Because urban lands located adjacent to streams have a greater impact on the biological community, an assumption might be made that riparian buffer strips located along the stream could absorb the negative runoff effects attributed to urbanization. Yet, riparian buffers may not be the complete answer since most urban stormwater is delivered directly to the stream via a storm sewer or engineered channel and, therefore, enters the stream without first being filtered by the buffer. Riparian buffers need to be combined with other management practices, such as infiltration facilities, detention basins, and grass swales, in order to adequately mitigate the effects of urban stormwater runoff. Combining practices into such a "treatment train" can provide a much higher level of pollutant removal, than single, stand-alone practices could ever achieve. Stormwater and erosion treatment practices vary in their function, which in turn influences their level of effectiveness. Location of a practice on the landscape, as well as proper construction and continued maintenance, greatly influences the level of pollutant removal.

An additional artifact of urbanization is the intentional and unintentional accumulation of trash and debris in waterways and associated riparian lands, including those within the Menomonee River and Kinnickinnic River watersheds (see Figure 8). These accumulations of trash are unsightly, as well as posing potential human health concerns. Trash and debris can cause physical and/or chemical (i.e. toxic) damage to aquatic and terrestrial wildlife. In some cases, historical fill, ranging from abandoned vehicles to gasoline pumps can be found within the riparian corridors adjacent to the waterways within the Menomonee River watershed.[14] Sometimes debris can accumulate to such an extent that it may limit recreation and the passage of aquatic organisms and/or cause streambank erosion. Although there has not been a comprehensive survey of trash and debris conditions within riparian areas of the Menomonee and Kinnickinnic River watersheds, continued efforts to remove trash and debris within these watersheds by the River Skimmer project, Keep Greater Milwaukee Beautiful, and Milwaukee Riverkeeper cleanup projects (see Appendix A for list of cleanup sites) indicates that this is an important issue to consider for the protection of these watersheds.[15]

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[12]*D. Weber and R. Bannerman, "Relationships between impervious surfaces within a watershed and measures of reproduction in fathead minnows (Pimephales promelas),"* Hydrobiologia, *Volume 525:215-228, 2004.*

[13]*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.*

[14]*Eddee Daniels,* Urban Wilderness: Exploring a Metropolitan Watershed, *University of Chicago Press, September, 2008.*

[15]*Note: The City of Milwaukee Department of Public Works owns and operates the River Skimmer boat in partnership with MMSD, the Milwaukee Water Works, the Milwaukee Community Service Corps, and the Port of Milwaukee. Keep Greater Milwaukee Beautiful and Milwaukee Riverkeeper organize annual river cleanups in the greater Milwaukee River watersheds. In 2009, volunteers removed hundreds of thousands of pounds of garbage out of waterways and surrounding land within the Menomonee River and Kinnickinnic River watersheds.*

Figure 8

EXAMPLES OF TRASH AND DEBRIS WITHIN THE MENOMONEE RIVER AND KINNICKINNIC RIVER WATERSHEDS

MENOMONEE RIVER (WITHIN REACH MN-19)

HONEY CREEK (WITHIN REACH MN-2)

S. 43RD STREET DITCH (WITHIN REACH KK-2)

EDGERTON CHANNEL (WITHIN REACH KK-4)

Source: Milwaukee Metropolitan Sewerage District.

What is Habitat?

Habitat is comprised of a complicated mixture of biological, physical, chemical, and hydrological variables. Biotic interactions such as predation and competition can affect species abundance and distributions within aquatic systems, however, such interactions are beyond the scope of this report and are not considered further in this document. Abiotic factors such as stream flow, channelization, fragmentation of stream reaches, temperature, dissolved oxygen concentrations, substrates, among others are strong determinants of aquatic communities (fishes, invertebrates, algae). Therefore, biological community quality is a surrogate for habitat quality. For example, high abundance and diversity of fishes is strongly associated with high-quality habitat. It is important to note that habitat quality is intimately related to land use within a watershed, as well as to land use directly adjacent to the streambank. Consequently, watershed size and associated land use characterization as well as riparian buffer width are critical elements necessary in defining habitat quality.

As noted previously, urbanization increases impervious surface, which can lead to an increase in "flashiness" (or the rate at which flow responds to a precipitation event). Such increases in streamflow subsequently affect streambank stability, streambed stability, pollutant loading, and sediment dynamics, which, in turn, affect habitat availability and quality. As detailed in TR No. 39, the Menomonee River watershed contains approximately 20 percent imperviousness and the Kinnickinnic River watershed contains about 30 to 40 percent imperviousness based upon the amount of urban land development in year 2000. Therefore, the hydrology of the urban stream systems within both watersheds is a major determinant of stream dynamics and is a vital component of habitat for fishes and other organisms (see Figure 9).

Based upon this information and for purposes of this report, habitat has been divided into two separate elements that distinguish "Land Based" versus "Instream" dimensions of habitat. The land based elements include a number of features that include existing and planned land use, historical urban growth, stormwater runoff, riparian buffers, and civil divisions, among others. However, the land based elements addressed specifically in this report are focused on riparian buffer width and continuity, plant community quality, recreational opportunities, and groundwater recharge potential within the Menomonee and Kinnickinnic River watersheds. Instream measures addressed in this report include channelization, streambank and streambed stability, channel obstructions, recreational opportunities, habitat quality, fishery quality, and invertebrate quality.

INVENTORY FINDINGS

Based upon the analysis of physical and biological conditions from data obtained for years 2000 through 2009, this section summarizes information by stream reaches for the Menomonee and Kinnickinnic River watersheds as shown in Tables 1 and 2. This assessment was based upon a total of 94 fish samples, 39 invertebrate samples, and 55 habitat samples collected for a variety of purposes by WDNR staff, U.S. Geological Survey (USGS) staff, and Dr. Robert Anderson of the Wisconsin Lutheran College. These samples were collected for a variety of purposes and programs that include baseline monitoring by the WDNR, the MMSD Corridor Study Database Project, the USGS National Water Quality Assessment (NAWQA) and Effects of Urbanization on Stream Ecosystems (EUSE) projects, and other research projects. It is important to note that the collection methods used were similar and comparable for purposes of this report. The only samples not used in direct comparison were fisheries samples collected with mini-boom shocking gear within the downstream reaches of the Menomonee River and associated shipping canals. These data were used for species presence or absence information only.

Historical Conditions

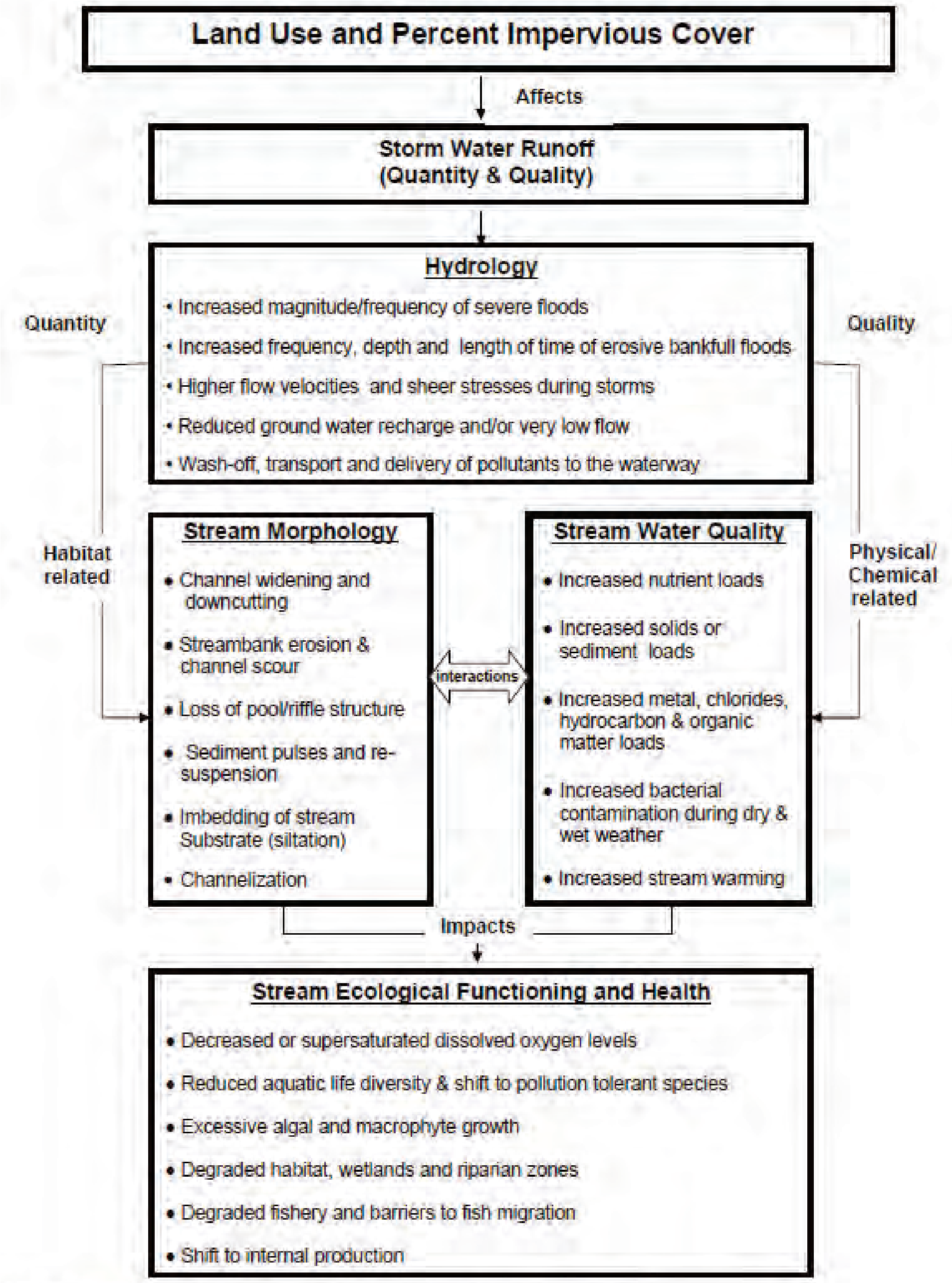
Early records reveal that the Milwaukee Estuary Area including the Milwaukee, Menomonee, and Kinnickinnic Rivers has been substantially channelized, relocated, dredged, filled, and dammed to convert the significant wetland complex into the highly constructed navigable port that currently exists.[16] This conversion allowed for the development and growth of the greater Milwaukee metropolitan area that currently exists, but this conversion has lead to significant environmental degradation in water quality, fisheries, and wildlife habitat.[17] Further comparison of the earliest known survey of the entire Menomonee River and Kinnickinnic River systems completed in 1836 to the present channel conditions in 2005 also shows evidence of significant channelization and diversion of stream channels over this time period (see Maps 3 and 4).

[16]*R. Poff and C. Threinen,* Surface Water Resources of Milwaukee County*, Wisconsin Conservation Department, Madison, Wisconsin, 1964.*

[17]*Milwaukee River Estuary Area of Concern (AOC),* http://www.epa.gov/glnpo/aoc/milwaukee.html#pagetop

Figure 9

SCHEMATIC DIAGRAM DEPICTING THE RELATIONSHIP BETWEEN LAND USE, HYDROLOGY, WATER QUALITY, HABITAT QUALITY, AND ECOLOGICAL HEALTH



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Straightening of meandering stream channels or "channelization" was once a widely used and accepted technique in agricultural management. The National Resources Conservation Service (NRCS) (formerly Soil Conservation Service) cost shared such activities up to the early 1970s within southeastern Wisconsin.[18] The objectives of channelization were to reduce floods by conveying stormwater runoff more rapidly, to facilitate drainage of low-

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

Figure 10

EXAMPLES OF A COMBINATION OF CHANNEL ENCLOSURE, CONCRETE CHANNEL LINING, AND DROP STRUCTURES ENGINEERED FOR FLOODWATER CONTROL WITHIN THE MENOMONEE RIVER AND KINNICKINNIC RIVER WATERSHEDS

UNDERWOOD CREEK (WITHIN REACH MN-14)

LYONS PARK CREEK (WITHIN REACH KK-1)

Source: Milwaukee Metropolitan Sewerage District.

lying agricultural land, and to allow more efficient farming in rectangular fields. Through channelization, farmers attempted to protect their crops by increasing the velocity of water moving downstream and the rate at which water drained away from their land. However, channelization rarely succeeds in increasing the speed of water moving downstream for two main reasons; 1) waterways throughout the Southeastern Wisconsin Region often have low slopes (i.e. slopes less than 1 percent), and 2) the effective slope within a reach that is channelized is generally not changed, because slope within the channelized section is limited by the streambed elevation of flatter, downstream reaches. These two factors combined with the fact that channelized reaches are often dredged too deep and too wide, produce areas that are characterized by slow moving, stagnant waterways. Many channelized reaches become long straight pools or areas of sediment deposition. Because the velocities within these reaches are too low to carry suspended materials, sediment particles settle out and accumulate. This is why many channelized reaches contain uniformly deep flocculent organic sediments. Channelization can also lead to instream hydraulic changes that can decrease or interfere with surface water contact to overbank areas during floods. This may result in reduced filtering of nonpoint source pollutants by riparian area vegetation and soils, as well as increased erosion of the banks. Channelization can lead to increased water temperature, due to the loss of riparian vegetation, and it can alter instream sedimentation rates and paths of sediment erosion, transport, and deposition. Therefore, channelization activities, as traditionally accomplished without mitigating features, generally lead to a diminished suitability of instream and riparian habitat for fish and wildlife.

Historically, prevention of flooding problems has been the major focus of stormwater and floodland management efforts in urban areas. This has led to channelization (both ditching and straightening), placement of concrete (to promote conveyance of flood flows and to control flows as in the case of dams, drop structures, and enclosed channels) as shown in Figure 10, without consideration of habitat impacts in portions of both the Menomonee and Kinnickinnic River watersheds. Concrete-lined stream segments are particularly damaging, due to the creation of conditions that 1) fragment and limit linear and lateral connectivity with the stream and their corridor habitat and ecosystem; 2) limit or prevent fish and wildlife movement; 3) increase water temperature; 4) destroy fish, aquatic life and wildlife habitat; 5) limit recreational uses, including those attendant to navigation, fishing, and aesthetics; and 6) may actually increase flooding and decrease public safety if not designed as part of an overall system plan. Today, recognition of the value of lotic water resources and their multi-faceted contributions to quality of life has

Figure 11

UNDERWOOD CREEK FLOOD MITIGATION AND STREAM RESTORATION PRE- AND POST-CONSTRUCTION

PRE-CONSTRUCTION SHOWING CONCRETE LINED STREAMBED AND STREAMBANKS

POST-CONSTRUCTION SHOWING RESTORED FLOODPLAIN CONNECTIVITY AND STREAM CHANNEL: 2009

Source: Thomas R. Sear, Short Elliott Hendrickson, Inc. (SEH) and SEWRPC.

lead to programs to restore and recreate naturalized river systems that not only meet flood mitigation requirements, but also incorporate features related to habitat and maintenance of aquatic life.

MMSD has completed a number of concrete and drop structure removal projects throughout the greater Milwaukee watersheds over the last decade. The most recent project is located along Underwood Creek as shown in Figure 11. That project involved removal of both concrete lining and drop structures.[19] Stream stabilization and flooding are important issues that must be addressed when removing concrete lining. Figure 12 shows how increased stream velocities within a concrete lined section of channel on Lyons Park Creek within the Kinnickinnic River watershed can impact downstream "natural" channels and cause excessive streambed and streambank erosion. This is an example of why streambed and streambanks must be protected after concrete lining is removed. Protecting the streambed and streambanks with some type of material increases stream channel roughness relative to a smooth surface like concrete, which slows water down, increasing flood elevations and the potential risk to nearby structures. To mitigate or offset the potential for increased flood risk, concrete removal needs to be associated with mitigative measures such as expanding the floodplain to the lands adjacent to the channel and lowering the ground elevation in the overbanks outside the low- and moderate-flow channel to allow more room for attenuation and/or conveyance of flood flows. Such measures have the added benefit of decreasing instream velocities for multiple flood stages and reducing streambed and streambank erosion. Expansion of the floodplain also allows for the opportunity to restore connectivity with the stream channel, restore native riparian vegetation, and allow space for a more naturally functioning stream channel, as well as providing stable instream habitat.

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[19]*Milwaukee Metropolitan Sewerage District,* Underwood Creek Rehabilitation and Flood Management Project, *Preliminary Design Report, prepared by Tetra Tech, August 2006.*

Figure 12

EXAMPLE OF CHANNEL EROSION DOWNSTREAM OF CONCRETE LINING ON LYONS PARK CREEK (WITHIN REACH KK-1) WITHIN THE KINNICKINNIC RIVER WATERSHED

Note placement of large stone on the streambed and streambank to mitigate excessive erosion due to high velocities.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Current Conditions

Kinnickinnic River

The Kinnickinnic River system is comprised of about 30 percent concrete lining and 30 percent enclosed channel, with most of the remaining open stream channel unstable and eroding (see Table 2 and Map 5). A 2004 stream assessment report indicated that the upper unchannelized sections of the Kinnickinnic River are severely incised (downcut or eroded streambed) and laterally unstable (see Figure 13).[20] Comparison of historic longitudinal profiles indicates that up to four to five feet of incision has occurred since the 1970s. This channel instability is due to a combination of elements that include: a large amount of urban development and associated impervious area, a stormwater management system designed to move runoff quickly and efficiently off the land surface and into the stream; significant encroachment of urban development near the stream, which confines flows within a narrow area and exposes the streambank and streambed to extremely high velocities and shear stresses; and steep slopes. The eroding streambed and streambank areas as shown on Map 5 should be addressed. A high degree of bank instability is associated with extensive areas within the Kinnickinnic River watershed with riparian buffers less than 75 feet in width (see Table 2 and Map 6). Table 2 shows that more than 70 percent of the river corridors within the Kinnickinnic River watershed contain buffers that are less than 75 feet in width. The Upper and Middle subwatersheds of the Kinnickinnic River (KK-3, KK-10) contain the most highly buffered stream reaches with about 27 and 23 percent, respectively, of the River having buffers greater than 75 feet in width. These areas are located within Milwaukee County park land, and the Upper Kinnickinnic River also contains two of the six total highest-quality vegetation communities in the entire watershed based upon their Floristic Quality Index (FQI),[21] The Lower Wilson Park Creek (KK-8), Holmes Avenue Creek (KK-5), and Lyons Park Creek (KK-1) subwatersheds also contain important plant community areas with fair to good-quality, which serve as important wildlife refuge areas within the highly urbanized landscape (see Table 2 and Map 6). These park lands, natural areas, and remaining environmental corridors also include areas with the best groundwater recharge potential within the Kinnickinnic River watershed (see Map 7). Map 7 shows that developed areas are associated with the lowest groundwater recharge potential; therefore, preservation and, where practical, expansion of open space would protect, and perhaps enhance, the groundwater recharge potential within the watershed.

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[20]*Milwaukee County,* Milwaukee County Stream Assessment, *Final Report, completed by Inter-Fluve, Inc., September, 2004.*

[21]*Note that these ratings are approximate indications of plant community quality due to the following potential limitations: 1)inventories in some cases date back 20 years and may not reflect current conditions and 2) data collection methods may be different among sites, due to inventories being conducted for multiple purposes or only partial inventories being conducted. For more information see T. Bernthal, Development of a Floristic Quality Assessment Methodology for Wisconsin, Final report to the U.S. Environmental Protection Agency Region V, June 2003.*

Figure 13

EXAMPLES OF EXCESSIVE STREAMBED AND STREAMBANK EROSION CONDITIONS WITHIN THE KINNICKINNIC RIVER WATERSHED

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Stream widths in the Kinnickinnic River were noted as being 42 and 74 feet at the only two cross-sections obtained by Inter-Fluve, Inc., under a study conducted for Milwaukee County. Stream widths in the remaining subwatersheds generally ranged from about 10 to 30 feet in width.[22] Substrates throughout the Kinnickinnic River watershed were dominated by gravels and course sands. These large substrate sizes are consistent with high velocity flows that occur throughout this watershed. However, not much instream physical information exists within this watershed.

As previously summarized within TR No. 39 there are a total of 61 point sources identified within the Kinnickinnic River watershed that include permitted noncontact cooling water discharges, permitted individual discharges, CSO outfalls, and SSO outfalls. As shown in Table 2 these are predominantly located within the mainstem of the Kinnickinnic River reaches KK-3, KK-10, and KK-11 of the watershed. There are an estimated 53 stormwater outfalls within this watershed, which comprise about 50 percent of the total outfalls observed. The stormwater outfalls are not concentrated in any particular area, but are widely distributed throughout the watershed. These outfalls are far more numerous than any other type of outfall in the watershed. In addition, since these stormwater outfalls discharge during most rainfall events and during periods of snowmelt, as opposed to only a few events a year when CSOs may occur, their potential for water quality impacts is significant. The physical outfall pipes themselves can potentially create significant localized erosion to streambed and/or banks, especially if they are constructed at poor angles in relationship to the flow of the river or stream. These outfalls can be retrofitted by changing pipe angles, installing deflectors, or shortening pipes, among other strategies. It is also important to note that these outfalls may provide opportunities for innovative infiltration practices, as well as protecting streambed and streambanks from erosion. For example, Figure 14 shows two outfalls where infiltration and streambank protection treatments were constructed as part of the Underwood Creek stream restoration project in the Menomonee River watershed.

Menomonee River

The Menomonee River system, including tributaries, has about 6 percent concrete-lined channel and 2 percent enclosed channel (see Table 1). The highest amounts of concrete lined channel are located within the Honey

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[22]Ibid.

Figure 14

OUTFALL TREATMENTS CONSTRUCTED AS PART OF THE UNDERWOOD CREEK FLOOD MITIGATION AND STREAM RESTORATION PROJECT: 2009

NOTE: This project has not yet been completed and more native tree, shrub, and wetland plantings will be implemented in the year 2010.

Source: SEWRPC.

Creek (MN-16) and Underwood Creek (MN-14) subwatersheds. With the exception of the Lilly Creek subwatershed, the majority of the stream system is in open channel and largely stable, with limited localized areas of erosion, as shown on Map 8. The streambanks along Lilly Creek and two tributaries (MN-7) are unstable, with more than 70 percent of the assessed streambanks being classified as eroded, whereas assessed streambanks in the remaining subwatersheds are generally less than 20 percent eroded. Research has indicated that high-quality streams have less than 20 percent of their total stream bank lengths severely eroded. Streams with less than 20 percent severe streambank erosion have been found to maintain a high-quality fishery.[23] However, all of the eroding streambed and streambank areas as shown on Map 8 should be addressed, since such erosion may still cause significant habitat degradation. The relatively small amount of streambed and streambank erosion is consistent with a high amount of protection from riparian buffers greater than 75 feet in width throughout the Menomonee River watershed (see Table 1 and Map 9). Table 1 shows that at least 50 percent or more of the river corridors among the subwatersheds within the Menomonee River watershed are protected by riparian buffers that are greater than 75 feet in width. However, in the Lilly Creek (MN-7), Little Menomonee Creek (MN-10), Dousman Ditch (MN-13A), Underwood Creek (MN-14), Honey Creek (MN-16) and

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[23]*T. D. Simonson and others,* Guidelines for evaluating fish habitat in Wisconsin Streams, *U.S. Department of Agriculture," General Technical Report NC-164, 1994.*

the Lower Menomonee River (MN-18, MN-19) subwatersheds, generally less than 30 percent of riparian buffers are greater than 75 feet in width and many areas of these streams have no buffers with widths greater than 75 feet. Like the Kinnickinnic River watershed, these riparian areas are coupled with park systems and are often associated with high-quality vegetation communities. As shown on Map 9 and Table 1 there are a total of 74 significant vegetation plant communities distributed throughout the Menomonee River watershed that are components of primary environmental corridors (PEC), natural areas, and critical species habitat areas as summarized in TR No. 39. These vegetation communities range in quality from poor to excellent based upon their Floristic Quality Index (FQI),[24] which is a measure of plant species diversity and native community composition. In general, the highest FQI ratings in the good to excellent range are associated with the largest stands of plant species, but it is important to note that all of these vegetation communities provide necessary habitat for a variety of wildlife. These park lands, natural areas, environmental corridors, and remaining agricultural lands are associated with the best groundwater recharge area lands within the Menomonee River watershed (see Map 10). Since the highest amount of agricultural and open lands are located in the northern portion of the watershed, these areas are currently providing the greatest amount of groundwater infiltration, helping to sustain stream baseflows. Map 10 also shows that the developed areas within the watershed are associated with the lowest groundwater recharge potential. Therefore, preservation and, where feasible, expansion of the open space lands including agricultural lands would protect, and perhaps enhance, the groundwater recharge potential within the watershed.

Stream widths in the Menomonee River were observed to range from about 20 to 30 feet in the headwaters to about 70 to 100 feet in the downstream reaches.[25] The Menomonee River is generally dominated by gravel and sand substrates. The Little Menomonee River is dominated by sand substrates and ranges from about 20 to 30 feet in width. Honey Creek and Underwood Creek are both dominated by gravel substrates and range from about 10 to 40 feet in width. Butler Ditch ranges from about 10 to 25 feet in width and is dominated by sand substrates in the headwaters and gravel substrates in the lower reaches.

As previously summarized in TR No. 39, there are a total of 153 point sources identified within the Menomonee River watershed that include permitted noncontact cooling water discharges, permitted individual discharges, CSO outfalls, and SSO outfalls. As shown in Table 1 these are predominantly located within the lower areas of the Menomonee River watershed. There are an estimated 236 stormwater outfalls within this watershed, which comprise about 60 percent of the total outfalls observed. These stormwater outfalls are found throughout the watershed and, much like in the Kinnickinnic River watershed, there are likely to be more outfalls than identified.

Biological Conditions

The most recent biological assessment of the Menomonee and Kinnickinnic River watersheds identified a strong relationship between water and aquatic community quality and amount of urban land use.[26] For example, median chloride concentrations among several watersheds throughout the greater Milwaukee metropolitan area tend to increase with increasing urban development. More specifically, the less developed upper areas of the Menomonee River watershed (Willow Creek, Upper Menomonee River, Little Menomonee River) contain better water quality than areas within the more highly urbanized, lower reaches of the Menomonee River watershed (Honey Creek, Lower Menomonee River) and the entire Kinnickinnic River watershed. However, it is important to note that not

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[24]*T. Bernthal,* Development of a Floristic Quality Assessment Methodology for Wisconsin, *Final report to the U.S. Environmental Protection Agency Region V, June 2003.*

[25]Ibid.

[26]*J.C. Thomas, M.A. Lutz, and others,* Water Quality Characteristics for Selected Sites Within the Milwaukee Metropolitan Sewerage District Planning Area, February 2004-September 2005, *U.S. Geological Survey Scientific Investigations Report 2007-5084, 2007.*

all water quality constituents showed the same pattern in relationship with urban lands. Some showed opposite responses and some showed no patterns at all, which is similar to what SEWRPC documented in TR No. 39. Figures 15 and 16 also show the strong negative relationship between fisheries Index of Biotic Integrity (IBI) and Hilsenhoff Biotic Integrity (HBI) quality with increased levels of urbanization among the greater Milwaukee River watersheds.[27]

Table 4 shows that the highest-quality fish, invertebrate, and algal communities are located in less developed watersheds of the greater Milwaukee area including the Upper Menomonee River.[28] The poorest biological communities were associated with the highest urbanized watersheds and include Honey Creek, Underwood Creek, and the Kinnickinnic River. This is also consistent with observations detailed in the SEWRPC TR No. 39 report. More specifically, TR No. 39 summarized that the biological community in both the Menomonee River and Kinnickinnic River watersheds is limited primarily due to 1) periodic stormwater pollutant loads (associated with increased flashiness); 2) decreased base flows and increased water temperatures due to urbanization; and 3) habitat loss and continued fragmentation due to culverts, concrete lined channels, enclosed conduits, drop structures, and past channelization (see Channel Obstructions Section below).

Fish and invertebrate community data from 2000-2009 as shown in Table 5 and Map 8 generally supports the conclusions summarized above that higher-quality areas are located within less developed areas compared to the more developed areas of the Menomonee River watershed. However, these recent data also show that where multiple samples were taken there is a range in both warmwater IBI and intermittent IBI quality throughout the entire watershed. Although the intermittent IBI is not applicable for larger perennial streams within the watershed, it was used to provide an assessment for the smaller tributaries and headwater reaches of the larger tributaries to the Menomonee River. Basically, intermittent headwater streams are associated with less diverse fish assemblage than perennial larger warmwater stream systems. Therefore, an intermittent IBI assessment will generally provide a better score when compared to the warmwater IBI assessment. However, although these tributaries may not necessarily be intermittent streams, an intermittent IBI was used to assess whether or not these urbanized tributaries were at least functioning as good-quality intermittent systems; the idea being that, given the high potential for fragmentation of fish passage and species extirpations, it is possible that these tributaries cannot currently function better than an intermittent stream system. Therefore, comparison of the intermittent IBI versus the warmwater IBI quality potentially indicates that the majority of the tributaries sampled are functioning as fair and good intermittent fisheries. It is also important to note that Map 8 shows the maximum quality achieved within each subwatershed reach throughout the time period from 2000 to 2009, as well as the highest quality ranking achieved by either the warmwater IBI or intermittent IBI, whichever indicated better quality. Hence, Map 8 shows the best possible fish community quality achievable within a particular reach, as well as the highest functional stream assemblage achievable.

In contrast, invertebrate quality throughout the Menomonee River watershed shows that this community is consistently ranked as good. Since invertebrates tend to colonize or re-establish sooner after a reach has been disturbed and begins to stabilize, the high proportion of good HBI scores is a potential sign the Menomonee River watershed may be recovering/improving. Invertebrates as a biotic indicator also tend to show a clearer relationship to habitat as compared to Fish Indices.[29] This also seems to be the case given that the invertebrate quality ratings are more closely associated with the habitat quality ratings than are the fish ratings. This may also be a good indication that habitat and food-based organisms are improving and that the fishery may need more time to recover.

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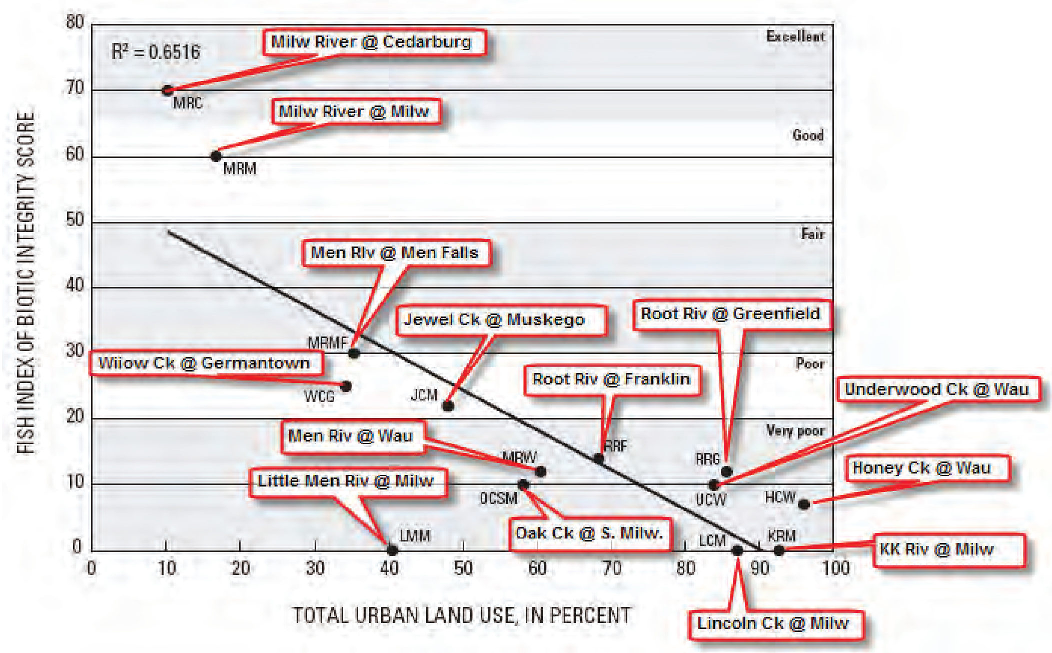
[27]Ibid.

[28]Ibid.

[29]*Personal communications, USGS staff.*

Figure 15

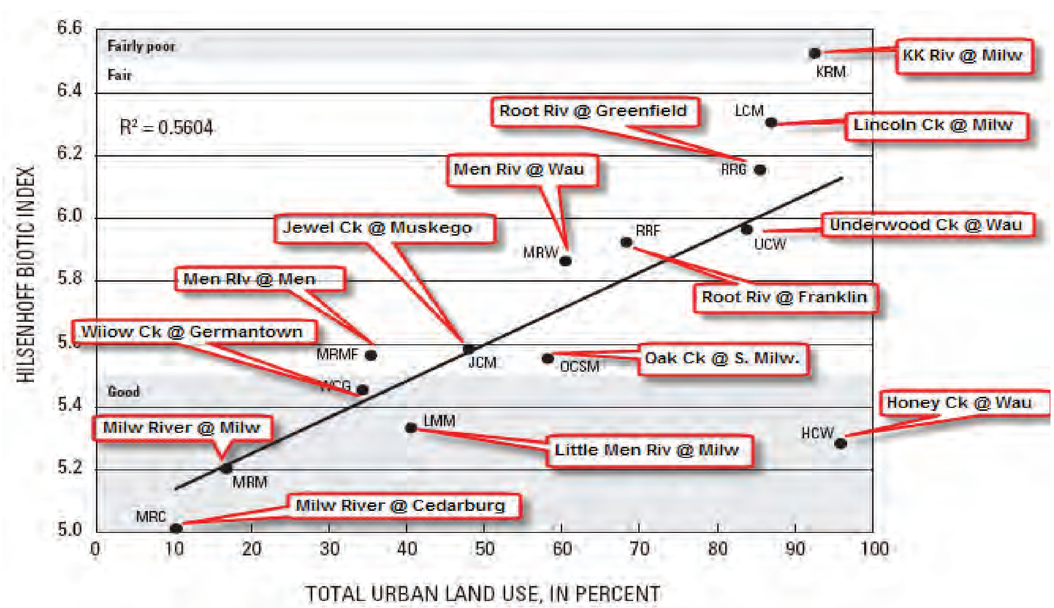
FISH INDEX OF BIOTIC INTEGRITY (IBI) SCORES COMPARED TO PERCENT URBAN LAND USE AMONG SITES IN THE GREATER MILWAUKEE WATERSHEDS



Source: *U.S. Geological Survey,* Water Quality Characteristics for Selected Sites Within the Milwaukee Metropolitan Sewerage District Planning Area, Wisconsin, February 2004-September 2005*, Scientific Investigations Report 2007-5084, 2007.*

Figure 16

A MODIFIED HILSENHOFF BIOTIC INDEX (HBI-10) COMPARED TO PERCENT URBAN LAND USE AMONG SITES IN THE GREATER MILWAUKEE WATERSHEDS



Source: *U.S. Geological Survey,* Water Quality Characteristics for Selected Sites Within the Milwaukee Metropolitan Sewerage District Planning Area, Wisconsin, February 2004-September 2005*, Scientific Investigations Report 2007-5084, 2007.*

Table 4

AVERAGE TROPHIC-LEVEL RANKINGS AND AGGREGATE BIOASSESSMENT RANKING AMONG STREAM SITES WITHIN THE GREATER MILWAUKEE WATERSHEDS: 2004-2005

Site	Average Trophic-Level Ranking: Fish[a]	Invertebrates[b]	Algae[c]	Aggregate Bioassessment Ranking
				Quartile 1
Milwaukee River near Cedarburg	1.00	1.33	2.00	1.44
Milwaukee River at Milwaukee	2.00	2.67	6.00	3.56
Jewel Creek at Muskego	5.00	6.00	1.50	4.17
Menomonee River at Menomonee Falls	3.00	7.33	4.00	4.78
				Quartile 2
Willow Creek at Maple Road near Germantown	4.00	6.17	7.00	5.72
Root River near Franklin	6.00	6.67	8.50	7.06
Root River at Grange Avenue at Greenfield	7.50	11.00	7.00	8.50
				Quartile 3
Menomonee River at Wauwatosa	7.50	8.33	10.00	8.61
Oak Creek at South Milwaukee	9.50	7.33	9.50	8.78
Little Menomonee River at Milwaukee	13.00	8.33	6.50	9.28
				Quartile 4
Honey Creek at Wauwatosa	11.00	8.17	9.00	9.39
Underwood Creek at Wauwatosa	9.50	10.33	8.50	9.44
Lincoln Creek at N. 47th Street at Milwaukee	13.00	9.67	12.00	11.56
Kinnickinnic River at S. 11th Street at Milwaukee	13.00	11.67	13.50	12.72

NOTE: IBI = Index of Biotic Integrity; EPT = Ephemeroptera, Plecoptera, and Trichoptera; HBI = Hilsenhoff Biotic Index. Fill color indicates quartile of ranking (quartile 1, blue; quartile 2, light blue; quartile 3, light orange; quartile 4, orange; each column is considered independently).

[a] *Averaged trophic-level rankings included only fish IBI scores.*

[b] *Averaged trophic-level rankings included Shannon index of diversity scores, percent of EPT taxa, and HBI-10 scores.*

[c] *Averaged trophic-level rankings included percent of most-sensitive diatoms and percent of sensitive diatoms.*

Source: U.S. Geological Survey, Water-Quality Characteristics for Selected Sites within the Milwaukee Metropolitan Sewerage District Planning Area, Wisconsin, February 2004-September 2005*, Scientific Investigations Report 2007-5084, 2007.*

Table 5 also shows that habitat quality conditions are generally good to excellent within the Menomonee River watershed. However, there are a few tributaries where habitat was only rated as fair and in one case very poor (Lower Underwood Creek subwatershed). It is important to note that the habitat ratings within the Lower subwatershed of Underwood Creek were conducted prior to completion of the concrete removal and floodplain/channel restoration project (see Figure 11).[30] Riparian buffer and instream habitat has been substantially improved in this portion of Underwood Creek and associated habitat and fisheries quality within this area are expected to improve, especially after concrete and drop structures downstream of this project are

[30] *Milwaukee Metropolitan Sewerage District,* Underwood Creek Rehabilitation and Flood Management Project, *Preliminary Design Report, prepared by Tetra Tech, August 2006.*

Table 5

FISH, INVERTEBRATE, AND HABITAT QUALITY AMONG REACHES WITHIN THE MENOMONEE RIVER WATERSHED: 2000-2009

Subwatershed	Reach ID	Biological Conditions			
		Fisheries Warmwater IBI	Fisheries Intermittent IBI	Invertebrates HBI	Habitat Rating
Tributary Reaches and Subwatersheds					
North Branch Menomonee	MN-1	- -	- -	- -	- -
Upper Menomonee River	MN-2	Very poor	Fair	Fair	- -
West Branch Menomonee River	MN-3	- -	- -	Good	Fair
Willow Creek	MN-4	Poor-fair	Good	Fair-good	Fair
Nor-X-Way Channel	MN-6	- -	- -	- -	- -
Little Menomonee Creek	MN-10	Poor-fair	Good	Good	Good
Little Menomonee River	MN-11	Very poor-fair	Poor-fair	Fairly poor-good	Fair-excellent
Lilly Creek	MN-7	Good	Good	Good	Fair
Butler Ditch	MN-8	Very poor	Fair-good	- -	Fair-good
Dousman Ditch	MN-13A	- -	- -	- -	- -
Underwood Creek-Upper	MN-13	Very poor-fair	Poor-fair	Fair-good	Fair-good
South Branch Underwood Creek	MN-14A	- -	- -	- -	- -
Underwood Creek-Lower	MN-14	No fish-fair	No fish-good	Fairly poor-fair	Very poor-fair
Honey Creek	MN-16	Very poor-fair	Fair-good	Fair	Good
Mainstem Reaches and Subwatersheds					
Upper Menomonee River	MN-5	Poor-fair	Fair-good	- -	- -
Upper Menomonee River	MN-9	Very poor-good	Poor-good	Fairly poor-good	Poor-excellent
Upper Menomonee River	MN-12	Fair	N/A	Good	Good
Lower Menomonee River	MN-17	Very poor	N/A	Fair	Fair-good
Lower Menomonee River	MN-17A	Very poor-fair	N/A	Fair	- -
Lower Menomonee River	MN-18	Very poor-fair	N/A	Fair-good	Fair-good
Lower Menomonee River	MN-19	N/A	N/A	N/A	N/A

NOTE: The tributary reaches and mainstem reaches are generally ordered from upstream to downstream.

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

removed. However, it is important to note that a significant amount of concrete channel will remain in upstream areas, which will continue to limit the potential overall fishery within the Underwood Creek subwatershed. For example, the very poor habitat rating within the lower subwatershed of Underwood Creek was associated with the worst invertebrate rating, as well as the worst fish rating where several samples yielded no fish at all. This demonstrates that although urban development may be associated with biological degradation, stream channel conditions such as concrete lining can cause further collapse of the biological quality and severely limit its ultimate potential for restoration.

Channel Obstructions or Fragmentation

There are nearly 100 potential channel obstructions in the Kinnickinnic River watershed and more than 300 in the Menomonee River watershed. These structures are primarily associated with road and railway crossings in the form of culverts and bridges, but obstructions can also include concrete lined channels, drop structures, debris jams, and beaver dams. These obstructions can form physical and/or hydrological barriers to fisheries movements, which can severely limit the abundance and diversity of fishes within stream systems.[31] Not all road or railway crossings are limiting fish passage in the Menomonee and Kinnickinnic River watersheds, but many of these

[31]*T.M. Slawski, and others, "Effects of low-head dams, urbanization, and tributary spatial position on fish assemblage structure within a Midwest stream,"* North American Journal of Fisheries Management, *2008.*

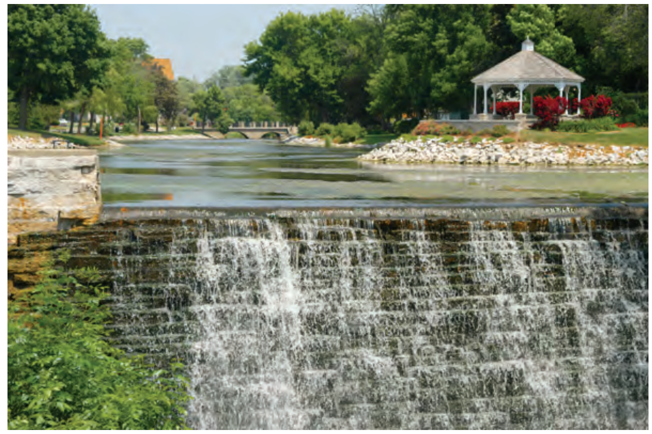
Figure 17

CONCRETE LINING IN THE MENOMONEE RIVER WATERSHED NEAR THE CANADIAN PACIFIC RAILWAY BRIDGE FROM RIVER MILE 3.62 TO 4.24 (SEE TABLE 6)

Source: SEWRPC.

Figure 18

MENOMONEE FALLS DAM IN THE MENOMONEE RIVER WATERSHED AT RIVER MILE 21.93 (SEE TABLE 6)



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

structures have not been assessed for fish passage and it is not known which of these structures are limiting the fishery. However, the section of concrete lining near Miller Park (River Mile 3.62 to 4.24), as shown in Figure 17, and the Menomonee Falls dam (River Mile 21.9), as shown in Figure 18, are two of the most significant fish passage obstructions on the Menomonee River (see Table 6). The Menomonee Falls dam is a complete barrier to upstream fish passage. This particular reach also contains bedrock outcrops resulting in natural falls (see Map 8). These outcrops have probably limited fish passage upstream both historically and currently, so the upper reach of the Menomonee River may have always been rather isolated from the downstream areas, even before construction of the dam. The upper approximately 1,000 feet of the concrete lining from River Mile 3.62 to 4.24 along the lower reach of the main stem limits fish passage due to the occurrence of supercritical flows at high velocities in combination with no resting areas (see Figure 19). Similarly, the concrete lining within the lower reach of the Kinnickinnic River (KK-10) also limits fish passage due to its length, lack of habitat, lack of adequate water depths, high velocities, and flashiness.

As summarized in TR No. 39, there has been an apparent loss of multiple fish species throughout the Menomonee River and Kinnickinnic River watersheds over the last 100 years. However, it is important to note that this loss of species has been disproportionately greater among reaches that are further away from a connection with Lake Michigan. For example, comparison of historic (pre-2000) versus current (post-2000) fish species abundance within the Kinnickinnic River indicates that species abundance has been and continues to be much greater in the most downstream reach (KK-11) connected to the Milwaukee River estuary and Lake Michigan compared to any other areas in the watershed (see Table 7). This indicates that the poor habitat, hydrology, and water quality conditions primarily associated with concrete lining as shown in Figure 20 continue to severely limit fisheries within this watershed. Table 4 confirms that the Kinnickinnic River contains the poorest fish, invertebrate, and algal communities among the greater Milwaukee watersheds. In fact, only two native fish species have been found to occur within this watershed since the year 2000 (see Table 7). However, due to its connection with the Estuary and Great Lakes system, the lower reach of the Kinnickinnic has the greatest potential for fishery improvement. That factor, combined with the completion of the removal of 167,000 cubic yards of contaminated

Table 6

FISH SPECIES COMPOSITION AMONG REACHES IN THE MENOMONEE RIVER WATERSHED: 1902-1999 VS 2000-2009

Species According to Their Relative Tolerance to Pollution	Reaches						Entire Watershed	
	MN-1, 2, 3, 4, 5		MN-6, 7, 8, 9, 10, 11, 12, 13, 13A, 14, 14A, 16, 17, 17A, Portion of 18		Portion of MN-18, MN-19			
	Reach above Menomonee Falls Dam at River Mile 21.93		Reach from Menomonee Falls Dam at River Mile 21.93 to Concrete Lining at River Mile 4.24		Reach from Concrete Lining at River Mile 4.24 to Confluence with the Milwaukee River			
	Years Sampled		Years Sampled		Years Sampled		Years Sampled	
	1902-1999	2000-2009	1902-1999	2000-2009	1902-1999	2000-2009	1902-1999	2000-2009
Intolerant								
Blackchin Shiner	- -	X	- -	- -	- -	- -	- -	X
Blacknose Shiner	- -	X	X	- -	- -	- -	X	X
Brook Trout	- -	- -	- -	- -	- -	X	- -	X
Greater Redhorse[a]	- -	- -	- -	- -	X	X	X	X
Least Darter[b]	X	- -	X	- -	- -	- -	X	- -
Redside Dace[b]	- -	- -	X	- -	- -	- -	X	- -
Rock Bass	- -	- -	- -	- -	- -	X	- -	X
Smallmouth Bass	- -	- -	- -	- -	- -	X	- -	X
Spottail Shiner	- -	- -	- -	X	- -	- -	X	X
Intermediate								
Black Bullhead	X	X	X	X	X	X	X	X
Black Crappie	- -	- -	- -	X	- -	X	- -	X
Bluegill	X	X	X	X	X	X	X	X
Brassy Minnow	X	- -	X	- -	- -	- -	X	- -
Brook Stickleback	X	X	X	X	- -	- -	X	X
Brown Bullhead	- -	X	X	- -	- -	- -	X	X
Brown Trout	- -	- -	X	- -	- -	X	X	X
Central Stoneroller	X	X	X	X	- -	X	X	X
Channel Catfish	- -	- -	- -	X	- -	X	- -	X
Chinook Salmon	- -	- -	- -	- -	- -	X	- -	X
Coho Salmon	- -	- -	- -	- -	- -	X	- -	X
Common Shiner	X	X	X	X	- -	X	X	X
Emerald Shiner	- -	- -	- -	X	- -	X	- -	X
Fantail Darter	X	- -	X	X	- -	- -	X	X
Gizzard Shad	- -	- -	- -	- -	X	X	X	X
Golden Redhorse	- -	- -	- -	- -	X	X	X	X
Grass Pickerel	- -	- -	X	X	- -	- -	X	X
Hornyhead Chub	X	- -	X	X	- -	X	X	X
Johnny Darter	X	X	X	X	- -	X	X	X
Lake Sturgeon[b]	- -	- -	- -	- -	- -	X	- -	X
Largemouth Bass	X	X	X	X	X	X	X	X
Largescale Stoneroller	- -	- -	X	- -	- -	X	X	X
Longnose Dace	- -	- -	- -	X	- -	- -	- -	X
Northern Pike	- -	X	X	X	- -	X	X	X
Northern Redbelly Dace	X	- -	X	- -	- -	- -	X	- -
Pearl Dace	X	X	X	X	- -	- -	X	X
Pumpkinseed	X	X	X	X	X	X	X	X
Rainbow Trout	- -	- -	- -	- -	- -	X	- -	X
River Carpsucker	- -	- -	X	- -	- -	- -	X	- -
Round Goby	- -	- -	- -	- -	- -	X	- -	X
Sand Shiner	- -	- -	X	X	- -	- -	X	X
Shorthead Redhorse	- -	- -	- -	- -	- -	X	- -	X
Silver Redhorse	- -	- -	- -	- -	- -	X	- -	X
Southern Redbelly Dace	X	- -	X	- -	- -	- -	X	- -
Spotfin Shiner	- -	- -	- -	- -	- -	X	- -	X
Stonecat	- -	X	- -	- -	- -	- -	- -	X
Threespine Stickleback	- -	X	- -	- -	- -	- -	- -	X
Walleye	- -	- -	- -	- -	- -	X	- -	X
Yellow Perch	- -	- -	X	X	X	X	X	X
Tolerant								
Blacknose Dace	X	- -	X	X	- -	X	X	X
Bluntnose Minnow	X	X	X	X	- -	X	X	X
Central Mudminnow	X	X	X	X	- -	X	X	X

Table 6 (continued)

Species According to Their Relative Tolerance to Pollution	Reaches: MN-1, 2, 3, 4, 5 — Reach above Menomonee Falls Dam at River Mile 21.93 — Years Sampled		MN-6, 7, 8, 9, 10, 11, 12, 13, 13A, 14, 14A, 16, 17, 17A, Portion of 18 — Reach from Menomonee Falls Dam at River Mile 21.93 to Concrete Lining at River Mile 4.24 — Years Sampled		Portion of MN-18, MN-19 — Reach from Concrete Lining at River Mile 4.24 to Confluence with the Milwaukee River — Years Sampled		Entire Watershed — Years Sampled	
	1902-1999	2000-2009	1902-1999	2000-2009	1902-1999	2000-2009	1902-1999	2000-2009
Tolerant (continued)								
Common Carp	X	X	X	X	X	X	X	X
Creek Chub	X	X	X	X	- -	X	X	X
Fathead Minnow	X	X	X	X	- -	X	X	X
Golden Shiner	X	X	X	X	- -	X	X	X
Goldfish	- -	- -	X	X	- -	X	X	X
Grass Carp	- -	- -	- -	- -	- -	X	- -	X
Green Sunfish	X	X	X	X	X	X	X	X
White Sucker	X	X	X	X	X	X	X	X
Yellow Bullhead	- -	X	- -	- -	- -	X	- -	X
Total Number of Species	24	24	35	30	12	42	39	54
Total Native and Gamefish Species	23	22	33	28	11	38	37	50
Total Nonnative Species	1	2	2	2	1	4	2	5
Total Intolerants	1	2	3	1	2	4	5	7
Total Intermediate	14	13	22	19	7	26	24	35
Total Tolerant	9	9	10	10	3	12	10	12

[a]*Designated threatened species.*

[b]*Designated Species of special concern.*

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

sediment from the Kinnickinnic River between Becher Street and Kinnickinnic Avenue in 2009 under the U.S. Environmental Protection Agency (USEPA)/WDNR Kinnickinnic River Environmental Restoration Project, makes it much more likely that fish species utilization will increase within this lower part of the system.[32]

In contrast, historic fish assemblages within the lowest reach of the Menomonee River (4.24 miles) contained the fewest number of species (12) as compared to the upstream areas that were comprised of more than twice as many fish species. However, the lower reach of the Menomonee River was only recently reconnected with the Milwaukee River estuary and Lake Michigan when the Falk dam was completely removed in 2001. In addition, removal of the North Avenue dam on the Milwaukee River at the upstream end of the Milwaukee Harbor estuary and major habitat improvements near the dam site that were completed in 1996 has also contributed to a significant increase in abundance and diversity of fishes in the Milwaukee River, Menomonee River, and estuary areas. These efforts combined with several instream restoration enhancements, as well as fish stocking programs have also contributed to the highest ever recorded number of total species (42) found within the Menomonee River in over 100 years of fishery surveys.

[32]*USEPA, "Kinnickinnic River cleanup means a revitalized Milwaukee neighborhood," News Release 09-OPA221,* http://epa.gov/greatlakes/sediment/legacy/kk/index.html, *November 2, 2009.*

Figure 19

ADULT SALMON MIGRATING FROM LAKE MICHIGAN TRYING TO SWIM THROUGH THE EXCESSIVE VELOCITIES WITHIN THE CONCRETE LINING OF THE MENOMONEE RIVER WATERSHED DOWNSTREAM OF RIVER MILE 4.24 (SEE MAP 8 AND TABLE 6)

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

MMSD has completed a number of stream restoration and enhancement projects over the last several decades that have lead to significant improvements in water quality and instream habitat, as well as improved fish passage.[33] For example, a restoration project along the Menomonee River in Hoyt Park stabilized the streambed and streambank, as well as lowered (excavated) the adjacent lands to reconnect the riparian lands with the stream system as shown in Figure 21. This reconnection with the floodplain protects the streambanks from erosion by allowing water to flow outside the banks and into the riparian areas, reducing velocities by distributing flow over a greater area. Instream fisheries habitat and fish passage were improved as part of the removal of concrete lining and the drop structure within the Menomonee River near N. 43rd Street and W. State Street as shown in Figure 22. These and other projects, such as restoration by the USEPA of the reach of the Little Menomonee River associated with the Moss-American Superfund Site in Milwaukee County or restoration of the Dretzka Park Tributary associated with Wisconsin Department of Transportation (WisDOT) roadway improvements from N. 124th Street to W. Brown Deer Road (STH 100) in the Village of Menomonee Falls have contributed to improvements in water, habitat, and fishery quality within the Menomonee River watershed.[34] More specifically, the WisDOT project led to restoration of more than 1,200 linear stream feet of stream channel and an associated eight-acre wetland mitigation/restoration project, which resulted in a significant improvement in fish species diversity (two to three times increase in species richness) and abundance (three to 13 times increase in fish abundance). This restored area currently accounts for the highest-quality of fish assemblages, based upon samples taken, within the MN-9 subwatershed area (see Map 8). Construction of this roadway improvement project was completed in 2001 and the fishery and habitat assessment was completed in 2008,[35] which demonstrates that the stream system can respond positively to improvements in stream hydrology, habitat, and associated riparian corridors and those improvements can lead to a sustained improvement in the fishery.

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[33]*Milwaukee Metropolitan Sewerage District,* Menomonee River Phase 2 Watercourse Management Plan, *prepared by Tetra Tech, August 2002.*

[34]*USEPA, Cleanup Nears Completion in Little Menomonee River, Moss-American Superfund Site, Milwaukee, Wisconsin,* http://www.epa.gov/region5/sites/mossamerican/, *December 2007; and SEWRPC Staff Memorandum, "Village of Menomonee Falls, Waukesha County—Survey Data, Analysis, and Recommendations Relating to the Proposed Relocation of Dretzka Park Tributary to the Menomonee River Under the Jobs Corridor Project," August 1999.*

[35]*The N. 124th Street and W. Brown Deer Road WisDOT roadway improvement project won the national 2001 Globe Award for excellence in environmental protection and mitigation for exceeding regulatory compliance by incorporating principles of stream ecology into a stream relocation design.*

Table 7

FISH SPECIES COMPOSITION AMONG REACHES IN THE KINNICKINNIC RIVER WATERSHED: 1902-1999 VS 2000-2009

Species According to Their Relative Tolerance to Pollution	Reaches						Entire Watershed	
	KK-4, KK-5, KK-6, KK-7, KK-8		KK-1, KK-2, KK-3, KK-10		KK-11			
	Upstream Confluence of Wilson Park Creek with the Kinnickinnic River		Upper Kinnickinnic River to River Mile 2.81		Lower Kinnickinnic River Downstream of Concrete Lining (approximately River Mile 2.81 at 6th Street) to confluence with Milwaukee Harbor Estuary			
	Years Sampled		Years Sampled		Years Sampled		Years Sampled	
	1902-1999	2000-2009	1902-1999	2000-2009	1902-1999	2000-2009	1902-1999	2000-2009
Intolerant								
Greater Redhorse[a]	- -	- -	- -	- -	X	- -	X	- -
Redhorse Species	- -	- -	- -	- -	X	- -	X	- -
Smallmouth Bass	- -	- -	- -	- -	- -	X[b]	- -	X[b]
Intermediate								
Alewife	- -	- -	- -	- -	X	- -	X	- -
Black Bullhead	- -	- -	- -	- -	X	- -	X	- -
Brassy Minnow	- -	- -	X	- -	- -	- -	X	- -
Brook Trout	- -	- -	- -	- -	- -	X[b]	- -	X[b]
Brown Trout	- -	- -	- -	- -	- -	X[b]	- -	X[b]
Brook Stickleback	X	- -	- -	- -	- -	- -	X	- -
Chinook Salmon	- -	- -	- -	- -	X	X[b]	X	X[b]
Coho Salmon	- -	- -	- -	- -	X	- -	X	- -
Common Shiner	- -	- -	- -	X	- -	- -	- -	X
Gizzard Shad	- -	- -	- -	- -	X	- -	X	- -
Johnny Darter	X	- -	- -	- -	- -	- -	X	- -
Northern Pike	- -	- -	- -	- -	X	X[b]	X	X[b]
Orangespotted Sunfish	X	- -	- -	- -	- -	- -	X	- -
Pumpkinseed	- -	- -	- -	- -	X	- -	X	- -
Rainbow Trout	- -	- -	- -	- -	X	X[b]	X	X[b]
Striped Shiner[c]	- -	- -	X	- -	- -	- -	X	- -
Threespine Stickleback	- -	- -	- -	- -	X	- -	X	- -
Yellow Perch	- -	- -	- -	- -	- -	X[b]	- -	X[b]
Walleye	- -	- -	- -	- -	- -	X[b]	- -	X[b]
Tolerant								
Banded Killifish[d]	- -	- -	X	- -	- -	- -	X	- -
Common Carp	- -	- -	- -	- -	X	- -	X	- -
Creek Chub	X	- -	- -	- -	X	- -	X	- -
Fathead Minnow	X	- -	- -	X	X	- -	X	X
Golden Shiner	- -	- -	- -	- -	X	- -	X	- -
Goldfish	- -	- -	X	X	X	- -	X	X
Green Sunfish	- -	- -	- -	- -	X	- -	X	- -
White Sucker	- -	- -	- -	- -	X	- -	X	- -
Total Number of Species	5	0	4	3	18	8[b]	24	11
Total Native and Gamefish Species	5	0	3	2	14	8[b]	20	10
Total Nonnative Species	0	0	1	1	4	0	4	1
Total Intolerants	0	0	0	0	2	1[b]	2	1
Total Intermediate	3	0	2	1	9	7[b]	14	8
Total Tolerant	2	0	2	2	7	0	8	2

[a]*Designated threatened species.*

[b]*These species were estimated to be potentially present based upon a recent creek survey of the Lower Milwaukee River and Estuary adjacent to the Lower Kinnickinnic River as summarized in the WDNR, Milwaukee and Menomonee River Creek Survey Report, PUB-FH-514-2008, January 2006.*

[c]*Designated endangered species.*

[d]*Designated species of special concern.*

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

Figure 20

CONCRETE LINING IN THE KINNICKINNIC RIVER WATERSHED WITHIN REACH KK-10

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Comparison of current fish assemblages among reaches within the Menomonee River shows that the middle reach (River Mile 4.24 to 21.9) and upper reach (upstream of River Mile 21.9) contained 35 and 24 total fish species, respectively. Although the concrete-lined channel between River Miles 3.62 and 4.24 and the Menomonee Falls dam are significant factors affecting fish species diversity as discussed above, the fisheries data indicate that fish assemblages are less diverse in stream reaches that are farther away from Lake Michigan. Therefore, reduction of fragmentation or reconnection of stream reaches within the Menomonee River is a critical aspect to address for consideration in development of a sustainable fishery with this watershed.

Existing Water Quality Monitoring Information

There is considerable ongoing surface water monitoring within the Menomonee and Kinnickinnic River watersheds as shown on Maps 11 and 12, respectively. The current distribution and location of monitoring sites includes a variety of continuous water quality monitoring stations, instantaneous water quality sites, water level gauges, water temperature sites, and precipitation gauges (see also Tables 1 and 2). The Menomonee River watershed currently has a total of 34 total monitoring stations and the Kinnickinnic River watershed has a total of 26 stations. The majority of the water quality data is being collected by MMSD, the U.S. Geological Survey (USGS), WDNR, and volunteers affiliated with the Milwaukee Riverkeeper's Citizen Based Monitoring program. These data are managed by each of the agencies and are publicly accessible through the USGS, the MMSD Corridor Database and the WDNR SWIMS and Fish and Habitat databases.

MMSD continues to collect and analyze physical and chemical samples bi-monthly at 11 mainstem and 14 tributary sites on the Menomonee River, as well as six mainstem and two tributary sites on the Kinnickinnic River. Measurements are taken for inorganic, organic, bacteriological, and instantaneous water quality parameters. The MMSD contributes funds for the operation of flow gaging stations by the USGS on the Menomonee River and Kinnickinnic River and some of their associated tributaries.

The MMSD and USGS have also established six real-time water quality monitoring stations throughout the Menomonee River watershed and one site on the mainstem of the Kinnickinnic River (see Maps 11 and 12). Using remote sensor technology, MMSD and USGS are measuring real-time specific conductance, water temperature, dissolved oxygen and turbidity along with stream flow and stage, and applying regression models to estimate concentrations of suspended solids, suspended sediment, chloride, fecal coliform and *E. coli* under a variety of seasonal, temporal, and flow conditions. The real-time sensors are connected to data-collection platforms which transmit data in parallel to MMSD and USGS public websites. Access to this information on a real-time basis allows for water resources management decisions and provides information for citizens to see water quality conditions throughout the Menomonee River watershed.

Figure 21

RESTORATION OF EXCESSIVE STREAMBANK AND STREAMBED EROSION AND RECONNECTION OF FLOODPLAIN WITHIN THE MENOMONEE RIVER AT HOYT PARK

BEFORE

AFTER

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

The Milwaukee Riverkeeper staff trains and manages numerous volunteers who conduct Citizen Based Monitoring efforts in the watershed. They currently have seven Level-1 sites, 13 Level-2 sites, and 15 temperature monitoring locations throughout the mainstem and tributary areas of the Menomonee River and Kinnickinnic River watersheds.

Their monitoring program was launched in 2006 and they currently have 58 volunteers monitoring sites throughout the greater Milwaukee River watersheds. Volunteers are trained at two levels. Level-1 volunteers conduct periodic stream assessments and measure dissolved oxygen, temperature, turbidity, flow, and qualitative aquatic invertebrate assessments. Level-2 volunteers are advanced monitors that assess water quality using WDNR equipment and protocols for pH, dissolved oxygen, turbidity, and temperature (using automated programmable temperature data loggers). Volunteers generally monitor on at least a monthly basis, and data is entered into either the WDNR “SWIMS” or Water Action Volunteer (WAV) databases.

These ongoing data collection efforts have and will continue to provide a sound basis for the assessment of current and future water quality conditions and high-quality data to evaluate the effectiveness of water pollution control measures, to detect new and emerging water quality problems, and to help decision makers manage these systems.

Figure 22

PRE- VERSUS POST- CONCRETE CHANNEL AND DROP STRUCTURE REMOVAL/STREAM RESTORATION NEAR N. 43RD STREET AND W. STATE STREET ALONG THE MENOMONEE RIVER

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Chapter III

WATERSHED TARGETS, OBJECTIVES, AND RECOMMENDED ACTIONS

INTRODUCTION

This chapter provides a strategic framework for decision-making and project prioritization for the purposes of 1) protecting and improving recreation, water quality, and fisheries and 2) cost-effectively and efficiently implementing projects to meet those improvement goals. Although not mutually exclusive, the recommended prioritization strategies are different for Land-Based versus Instream-Based Measures as summarized below. The differences in prioritization strategies are related to the fundamental differences potentially limiting the aquatic versus terrestrial community and habitat quality within the Menomonee and Kinnickinnic River watersheds. However, each of these prioritization strategies is based upon the main premise of protecting the existing quality areas—either within water or on land—and expanding those areas through reconnection of stream-miles and/or acres of land to reduce fragmentation.

Land-Based Measures

This prioritization is similar to the Three-Tier Instream fisheries approach, and is designed to focus on protecting the existing highest-quality terrestrial wildlife habitat areas as well as expanding riparian corridors to preserve instream quality for the short- and long-term. Prioritization for improving riparian corridors should be based upon improvement in ecosystem structure and function where possible. Such improvements include protection of groundwater recharge areas, expansion of existing corridor widths and/or connection to high-quality wildlife and critical species habitat areas (see Maps 6, 7, 9, and 10). It is also recommended that this prioritization build upon considerable prior open space planning efforts that include: environmental corridors delineated by the Regional Planning Commission; the open space preservation elements of adopted County park and open space plans; the MMSD Green Seams Conservation Plan, Greenway Connection Plan; and, the recently completed River Revitalization Foundation Menomonee River Mainstem Land Protection Plan.[1] It is important to note that a key consideration in the identification of priority areas includes consideration of maintaining or expanding stormwater management and flood control benefits, which is consistent with the goals of this report. In addition,

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[1]*SEWRPC Planning Report No. 42 (PR No. 42),* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997; SEWRPC Planning Report No. 48 (PR No. 48),* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006; SEWRPC Memorandum Report No. 152 (MR No. 152),* A Greenway Connection Plan for the Milwaukee Metropolitan Sewerage District, *December 2002; and Kristen Wilhelm and Jason Schroeder,* River Revitalization Foundation's Menomonee River Mainstem Land Protection Plan 2008-2009, *2009.*

lands currently held in public ownership by the State, counties, cities, villages, towns, and nongovernmental organizations form the structural framework for prioritization of the land-based measures from which to expand protections. The high-priority lands for the Menomonee River and Kinnickinnic River watersheds are shown on Maps 13 and 14, respectively. The high-priority lands identified to be protected represent a synthesis of recommendations from multiple planning efforts and they include open lands in public or public interest ownership identified in the regional land use plan (SEWRPC PR No. 48) and in the River Revitalization Foundation Menomonee River Land Protection Plan, MMSD conservation areas identified in SEWRPC MR No. 152, open space areas identified to be protected through public land use regulation (MR No. 152), groundwater recharge areas,[2] high-quality plant community areas (SEWRPC PR No. 42), and riparian buffers adjacent to streams with less than 75 feet of buffer width (SEWRPC PR No. 50 and TR No. 39) (see Maps 6, 7, 9, 10, 13, and 14).

Instream-Based Measures

This framework is based upon a three-tiered approach, focused on the reconnection of waterways that have been historically isolated from the Lake Michigan stream system through construction of dams, roadways, and flow control structures, or modified through construction of single-purpose systems, such as stormwater conveyances. As indicated in Figures 23 and 24, the three components of this strategy are:

- Tier 1–Restoring connectivity and habitat quality between the mainstem waterways and the Lake Michigan endpoint,

- Tier 2–Restoring connectivity and habitat quality between the tributary streams and the mainstems of the Menomonee and Kinnickinnic Rivers, and

- Tier 3–Expanding connection of highest-quality fish, invertebrate, and habitat sites within each of the watersheds as shown on Maps 5 and 8.

The third tier is a “catch-all” that enables stakeholders to link the goals of habitat restoration and improvement of recreational options with ongoing activities throughout each watershed. This strategic element provides the flexibility for communities and stakeholders to take advantage of opportunities throughout each watershed that may arise independently of the primary strategy of restoring linkages with Lake Michigan and tributary streams. An example of this latter strategic approach would be using the opportunity provided by scheduled reconstruction of area roadways to remove obstructions or modify channelized stream segments that might not fully conform to the first two strategic priorities. To this end, it is further noted that provision of fish passage will provide passage for other aquatic organisms such as invertebrates.[3] By providing restored connectivity, and associated habitat, it is envisioned that implementation of this plan will not only further the purpose of establishing a sustainable fishery but also enhance human economic opportunities and recreational and aesthetic values associated with the waterways of the greater Milwaukee watersheds.

It is fully recognized that within this framework opportunities will arise that should be acted upon. For example, even though it is a general principle of this strategy that activities progress from downstream to upstream, the completion of an action in headwaters areas or on a tributary stream should not be passed up or ignored simply because it does not conform to the downstream to upstream strategy. Rather, all opportunities should be seized as they become available. However, where multiple opportunities exist, and where limited funds are available, this strategic framework is intended to assist decision-makers in allocating resources where they would be most appropriate and effective in achieving the goals of the regional water quality management plan update.

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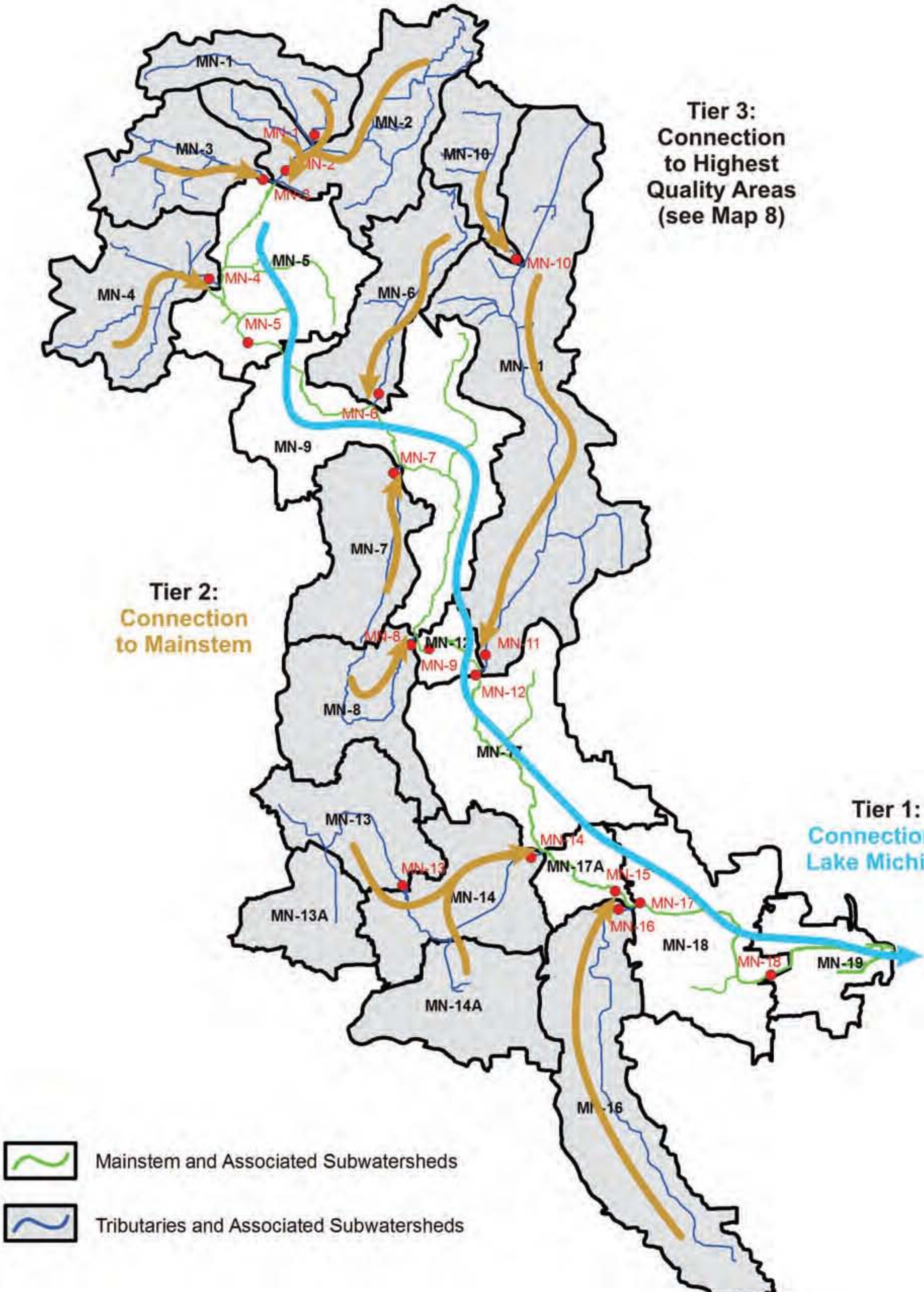
[2]*SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin, *in progress.*

[3]*D.M. Vaughan,* Potential Impact of Road-Stream Crossings (Culverts) on the Upstream Passage of Aquatic Macroinvertebrates, *U.S. Forest Service Report, March 21, 2002.*

Figure 23

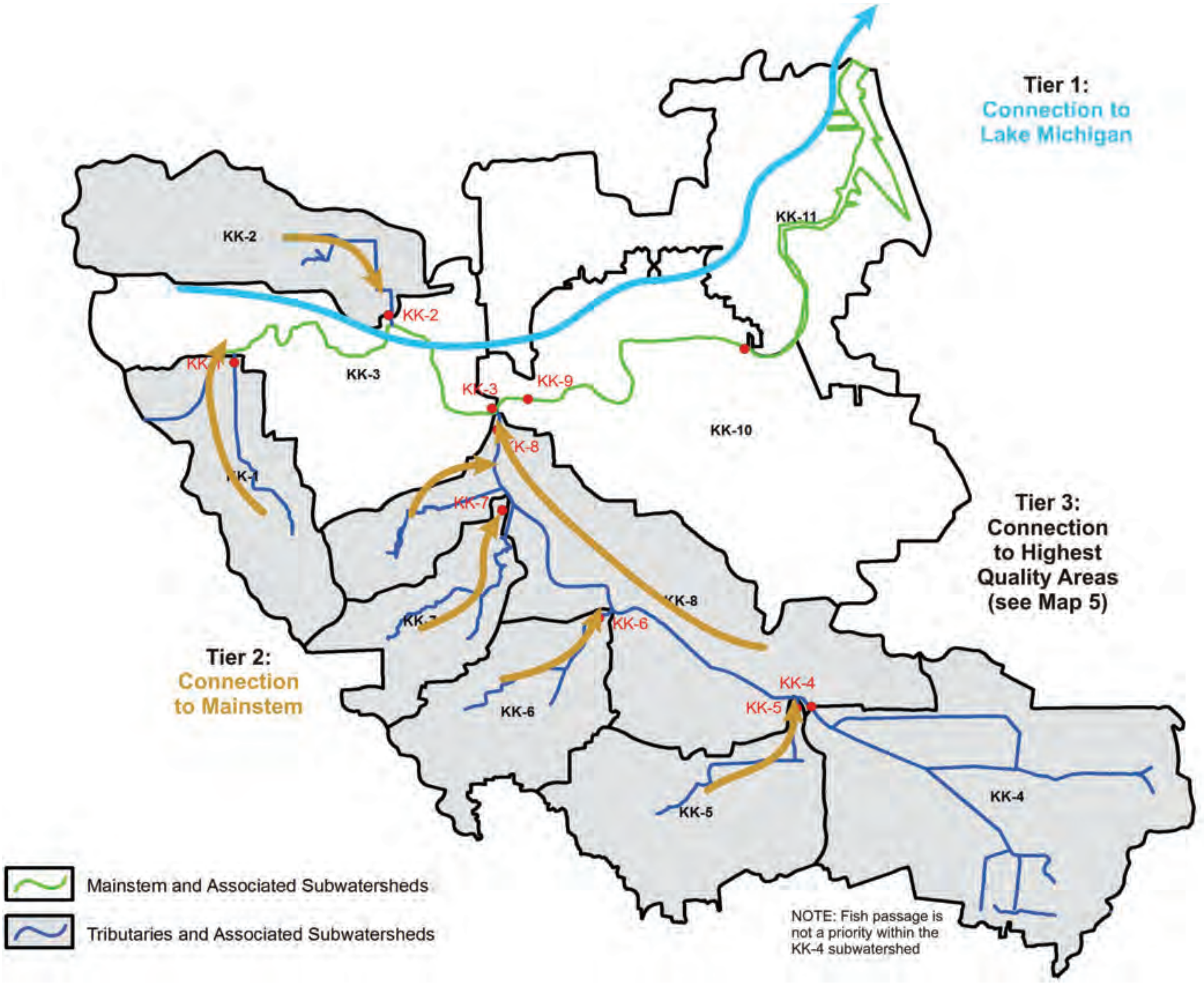
INSTREAM THREE-TIER PRIORITIZATION STRATEGY WITHIN THE MENOMONEE RIVER WATERSHED



Source: SEWRPC.

Figure 24

INSTREAM THREE-TIER PRIORITIZATION STRATEGY WITHIN THE KINNICKINNIC RIVER WATERSHED



Source: SEWRPC.

The Tier 1 prioritization is based upon the understanding that Lake Michigan is the most diverse resource and greatest asset that both the Menomonee and Kinnickinnic River systems have for the potential to restore and maintain a sustainable fishery. This prioritization is also based upon the understanding that within River systems the widest and deepest downstream areas are generally associated with a greater abundance and diversity of fishes compared to narrower and shallower upstream areas.[4] For example, as shown in Tables 6 and 7 in Chapter II of this report, those portions of the Menomonee and Kinnickinnic Rivers connected with Lake Michigan through the Milwaukee Harbor estuary contain the most diverse fish assemblages. This observation is also consistent with the most diverse fish assemblages being found within the downstream reaches of the Milwaukee River that were

[4]*I.J. Schlosser, "A conceptual framework for fish communities in small warmwater streams," pages 17-24 in W.J. Matthews and D.C. Heins (editors),* Community and Evolutionary Ecology of North American Stream Fishes, *University of Oklahoma Press, 1987.*

connected with Lake Michigan through removal of the North Avenue dam as described in TR No. 39. Position within a stream network also is an important determinant of fish species assemblage structure with greater abundance and diversity generally associated with tributary streams located in lower portions of the stream network.[5] Therefore, the highest priority, or Tier 1, approach focuses on restoring continuity of passage and habitat restoration for native fishes on the mainstems of the Menomonee River (MN-19 through MN-5) and Kinnickinnic River (KK-11 through KK-3) from downstream at Lake Michigan to their headwaters upstream as shown in Figures 23 and 24, respectively. This approach is designed to redevelop the fishery through reconnection and restoration of the strongest determinants of overall fish species diversity and assemblage structure, namely Lake Michigan and the tributary networks and their associated habitats from downstream to upstream.

The Tier 2 prioritization is based upon the understanding that through their connection with Lake Michigan the mainstems of the Menomonee and Kinnickinnic Rivers are the most diverse resources and greatest assets that their tributaries have for the potential to restore and maintain a sustainable fishery. Tributary streams that are connected to, as opposed to being not fragmented from, the associated mainstem of stream systems have a greater potential for increased fish abundance and diversity via access to feeding, rearing, and spawning, as well as refuge from thermal stress or low-water periods.[6] Hence, the second tier approach is focused on addressing fish passage continuity and habitat quality from the tributary streams to the mainstems of the Menomonee River and Kinnickinnic Rivers. The Tier 2 prioritization component is illustrated graphically in Figures 23 and 24.

The Tier 3 approach is designed to focus on improving fish passage and habitat quality throughout the entire watershed. Prioritization of projects to improve the fishery quality should be based upon where fish passage obstructions have been identified to be a problem and where improvement in ecosystem structure and function can be attained. Factors to be considered include connection to one or more tributaries, length of stream between structures, and/or connection to high-quality fish and habitat areas as indicated in Table 8 for the Menomonee River watershed. A similar table was not developed for the Kinnickinnic River watershed because fish passage and habitat quality improvements cannot begin until substantial removal of concrete channel segments and drop structures is accomplished and the channels are rehabilitated within this system. It is recommended that these structures and crossings be examined at the time of replacement or major modification with the intent of minimizing the numbers of crossings, and improving crossings to eliminate barriers to fish migration. Further, it is anticipated that new development or redevelopment may provide opportunities for interventions that do not conform to the first and second tier approaches. These opportunities should not be ignored; rather, where there are opportunities to enhance passage of fish and aquatic organism and/or to improve instream habitat, and where funds can be obtained, it is recommended that actions be taken to enhance fish and aquatic organism passage and habitat quality throughout the river systems.

RECOMMENDED LAND-BASED HABITAT PROTECTION ACTIONS

The following subsections are structured to indicate a habitat protection feature, such as riparian buffers; to identify a target to achieve relative to that feature; and to discuss issues, key questions, objectives, recommended actions needed to meet the target, and potential quantifiable measures related to the target.

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[5]*L.L. Osborne and M.J. Wiley, "Influence of tributary spatial position on the structure of warmwater fish communities,"* Canadian Journal of Fisheries and Aquatic Sciences, *Volume 49: 671-681, 1992.*

[6]*T.M. Slawski and others, "Effects of tributary spatial position, urbanization, and multiple low-head dams on warmwater fish community structure in a Midwestern stream,"* North American Journal of Fisheries Management, *Volume 28: 1020-1035, 2008.*

Table 8

FISH PASSAGE ASSESSMENT AT ROAD CROSSING STRUCTURES, CALCULATED STREAM LENGTH BETWEEN STRUCTURES, AND BIOLOGICAL (FISH, INVERTEBRATE) AND HABITAT QUALITY DETERMINATIONS AMONG MAINSTEM AND TRIBUTARY REACHES WITHIN THE MENOMONEE RIVER WATERSHED: 2000-2009

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Mainstem									
Menomonee River-Lower	MN-19W				0.0250	- -	- -	- -	- -
		0.025	No	C.M. St. P.&P. Railroad					
					0.0300	- -	- -	- -	- -
		0.055	No	N. Plankinton Avenue					
		0.15			0.3000	- -	- -[a]	- -	- -
		0.23				- -	- -[a]	- -	- -
		0.355	No	N. 6th Street					
					0.2150	- -	- -	- -	- -
		0.57	No	IH 94					
					0.3525	- -	- -	- -	- -
		0.9225	No	Emmber Lane/Muskego Avenue					
					0.1875	- -	- -	- -	- -
		1.11	No	N. 16th Street					
					0.7650	- -	- -	- -	- -
		1.875	No	C.M. St. P.&P. Railroad					
					0.0375	- -	- -	- -	- -
		1.9125	No	Canal Street					
					0.0400	- -	- -	- -	- -
		1.9525	No	Canadian Pacific Railway					
					0.0200	- -	- -	- -	- -
		1.9725	No	Canadian Pacific Railway					
					0.1300	- -	- -	- -	- -
		2.1025	No	N. 27th Street					
	MN-18				0.5385	- -	- -	- -	- -
		2.641	No	S. 35th Street					
		2.71			0.1390	- -	very poor	good	- -
		2.78	No	Pedestrian bridge					
		2.91			0.3850	- -	fair	fair	fair
		3.11				- -	fair	fair	good
		3.165	No	South access road					
					0.0800	- -	- -	- -	- -
		3.245	No	Pedestrian bridge					
					0.1800	- -	- -	- -	- -
		3.425		North access road					
		3.615	Yes	Begin concrete lining	0.2230	- -	- -	- -	- -
		3.648	Yes	IH 94					
			Yes		0.0620	- -	- -	- -	- -
		3.71	Yes	Canadian Pacific Railway					
			Yes		0.3600	- -	- -	- -	- -
		4.07	Yes	W. Bluemound Road					
			Yes		0.1700	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
				Menomonee River Mainstem (continued)					
Menomonee River-Lower (continued)	MN-18 (continued)	4.24	Yes	Canadian Pacific Railway-end concrete lining					
					0.1980	- -	- -	- -	- -
		4.438	No	Pedestrian bridge					
					0.0120	- -	- -	- -	- -
		4.45	Unknown	N. 45th Street					
					0.1100	- -	- -	- -	- -
		4.56	Unknown	Canadian Pacific Railway					
					0.0630	- -	- -	- -	- -
		4.623	Unknown	USH 41 (northbound)					
					0.0160	- -	- -	- -	- -
		4.639	Unknown	USH 41 (southbound)					
					0.1920	- -	- -	- -	- -
		4.831	No	Pedestrian bridge					
					0.3240	- -	- -	- -	- -
		5.155	Unknown	Hawley Road					
					0.5350	- -	- -	- -	- -
		5.69	No	Pedestrian bridge					
					0.2700	- -	- -	- -	- -
		5.9625	Unknown	N. 68th Street					
		6.06			0.1400	- -	fair	fair	good
		6.09				- -	very poor	good	good
		6.1025	Unknown	N. 70th Street					
		6.24		Confluence with Honey Creek	0.2100	- -	- -	- -	- -
		6.3135	Unknown	Bike trail bridge					
	MN-17A				0.3900	- -	very poor	fair	- -
		6.7025	Unknown	Canadian Pacific Railway					
					0.0200	- -	- -	- -	- -
		6.7215	Unknown	Harwood Avenue pedestrian bridge					
					0.0600	- -	- -	- -	- -
		6.78	Unknown	Harmonee Avenue					
					0.1100	- -	- -	- -	- -
		6.8895	No	Bike trail bridge					
					0.3400	- -	- -	- -	- -
		7.23	Yes	Ford-#5					
					0.1100	- -	- -	- -	- -
		7.34	Yes	Obstruction-#4					
					0.3300	- -	- -	- -	- -
		7.67	Yes	Obstruction-#3					
					0.0100	- -	- -	- -	- -
		7.6805	No	Footbridge					
					0.1400	- -	- -	- -	- -
		7.82	Yes	Paved ford-#2					
					0.0500	- -	- -	- -	- -
		7.87	Yes	Obstruction-#1					
					0.1300	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Mainstem (continued)									
Menomonee River-Lower (continued)	MN-17A (continued)	8.0025	Unknown	Swan Boulevard					
					0.3100	- -	- -	- -	- -
		8.314	No	Golf course bridge					
					0.0100	- -	- -	- -	- -
		8.325	Yes	Paved ford					
		8.37		Confluence with Underwood Creek	0.1800	Underwood Creek	- -	- -	- -
		8.5015	Unknown	W. North Avenue					
	MN-17	8.62			1.1800	- -	very poor	fair	good
		9.6805	Unknown	W. Burleigh Street (eastbound)					
					0.0030	- -	- -	- -	- -
		9.6835	Unknown	W. Burleigh Street (westbound)					
					0.6000	- -	- -	- -	- -
		10.28	Yes	Limestone ford					
					0.3900	- -	- -	- -	- -
		10.671	Unknown	N. Mayfair Road (northbound)					
					0.0000	- -	- -	- -	- -
		10.674	Unknown	N. Mayfair Road (southbound)					
					0.2300	- -	- -	- -	- -
		10.9	Unknown	Pedestrian bridge					
					0.0400	- -	- -	- -	- -
		10.94	Unknown	Private drive					
					0.1000	- -	- -	- -	- -
		11.041	Unknown	Golf course bridge					
					0.1600	- -	- -	- -	- -
		11.202	Unknown	W. Capitol Drive					
		11.22			1.3200	- -	poor	- -	fair
		12.05				- -	- -	fair	- -
		12.41				- -	- -	fair	- -
		12.521	Unknown	W. Hampton Avenue (eastbound)					
					0.0030	- -	- -	- -	- -
		12.524	Unknown	W. Hampton Avenue (westbound)					
Menomonee River-Upper	MN-12	12.57		Confluence with Little Menomonee River	0.3600	Little Menomonee River	- -	- -	- -
		12.883	Unknown	USH 45					
					0.5400	- -	- -	- -	- -
		13.423	Unknown	Railroad					
					0.1000	- -	- -	- -	- -
		13.523	Unknown	N. 124th Street					
					0.2800	- -	- -	- -	- -
		13.8	Unknown	Pedestrian bridge					
		13.89			0.8400	- -	fair	good	fair
		14.41		Confluence with Butler Ditch		Butler Ditch			
		14.643	Unknown	W. Silver Spring Drive					

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Mainstem (continued)									
Menomonee River-Upper (continued)	MN-9	14.72			0.3200	- -	fair	Good	- -
		14.963	Unknown	Railroad					
					1.0200	- -	- -	- -	- -
		15.983	Unknown	W. Mill Road					
		15.99			0.5700	- -	- -	- -	good
		16.55	Unknown	W. Appleton Avenue					
					0.7500	- -	- -	- -	- -
		17.303	Unknown	W. Good Hope Road					
					0.9200	- -	- -	- -	- -
		18.22	Unknown	Private bridge					
					0.1900	- -	- -	- -	- -
		18.41	Unknown	Private bridge					
					0.2400	- -	- -	- -	- -
		18.65	Unknown	Private bridge					
					0.0800	- -	- -	- -	- -
		18.73	Unknown	Private bridge					
					0.0300	- -	- -	- -	- -
		18.76	Unknown	Private bridge					
					0.0500	- -	- -	- -	- -
		18.81	Unknown	Private bridge					
					0.0400	- -	- -	- -	- -
		18.85	Unknown	Private bridge					
					0.1000	- -	- -	- -	- -
		18.95	Unknown	Private bridge					
		18.98		Confluence with Lilly Creek	0.7500	Lilly Creek	- -	- -	- -
		19.703	Unknown	Lilly Road					
		19.78			0.5100	- -	poor	- -	good
		20.21	Unknown	Pedestrian bridge					
		20.3		Confluence with Nor-X-Way Channel	0.6000	Nor-X-Way	- -	- -	- -
		20.81	No	Pedestrian bridge					
					0.2800	- -	- -	- -	- -
		21.093	Unknown	Pilgrim Road					
		21.17			0.3500	- -	poor	good	excellent
		21.443	Unknown	Arthur Avenue					
					0.3100	- -	- -	- -	- -
		21.75	Yes	Limestone drop					
					0.0700	- -	- -	- -	- -
		21.82	No	Pedestrian bridge					
					0.0900	- -	- -	- -	- -
		21.907	Yes	Main Street-Menomonee Falls dam					
					0.1700	- -	- -	- -	- -
		22.073	Unknown	Roosevelt Drive					
					0.1000	- -	- -	- -	- -
		22.17	Unknown	Private bridge					
		22.44			0.5100	- -	very poor	- -	fair
		22.68				- -	- -	fairly poor	- -
		22.683	Unknown	Private Drive					

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Mainstem (continued)									
Menomonee River-Upper (continued)	MN-5				0.5000	- -	- -	- -	- -
		23.179	Unknown	River Crest Road					
					0.2500	- -	- -	- -	- -
		23.433	Unknown	County Line Road (CTH Q)					
					0.8500	- -	- -	- -	- -
		24.282	Unknown	Private drive					
		24.7		Confluence with Willow Creek	0.5200	Willow Creek	- -	- -	- -
		24.803	Unknown	USH 41/45					
					0.4300	- -	- -	- -	- -
		25.233	Unknown	Lilac Avenue					
		25.34			0.6600	- -	fair	- -	- -
		25.893	Unknown	Mequon Road					
					0.0500	- -	- -	- -	- -
		25.943	Unknown	River Drive					
					0.5900	- -	- -	- -	- -
		26.536	Unknown	Private drive					
					0.3500	- -	- -	- -	- -
		26.883	Unknown	Railroad					
		27.12		Confluence with West Branch		West Branch	- -	- -	- -
	MN-1				0.2500	- -	- -	- -	- -
		27.133	Unknown	Freistadt Road					
		27.135			0.1200	- -	fair	fair	- -
		27.253	Unknown	STH 145					
		27.87			0.6200	- -	- -	- -	- -
		27.873	Unknown	Railroad/Confluence with North Branch					
					0.7900	- -	- -	- -	- -
		28.663	Unknown	Pleasant View Drive					
					0.2500	- -	- -	- -	- -
		28.913	Unknown	Lovers Lane Road					
					0.4600	- -	- -	- -	- -
Menomonee River Tributary Subwatersheds									
Honey Creek	MN-16				0.0300	- -	- -	- -	- -
		0.032	Unknown	Bike trail bridge					
					0.1200	- -	- -	- -	- -
		0.15	Unknown	Honey Creek Parkway Drive					
					0.3400	- -	- -	- -	- -
		0.49	Unknown	W. Portland Avenue					
		0.577			0.1000	- -	good	fair	good
		0.59	Unknown	Honey Creek Parkway Drive					
					0.3000	- -	- -	- -	- -
		0.89	Unknown	W. Wisconsin Avenue					
					0.1900	- -	- -	- -	- -
		1.08	Unknown	Honey Creek Parkway Drive					
					0.2900	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
Honey Creek (continued)	MN-16 (continued)	1.37	Unknown	Honey Creek Parkway Drive					
					0.4200	- -	- -	- -	- -
		1.79	Unknown	S. 84th Street					
					0.1600	- -	- -	- -	- -
		1.9491	Yes	IH 894 tunnel outlet					
					2.3300	- -	- -	- -	- -
		4.2767	Yes	W. Arthur Avenue tunnel inlet					
					0.2400	- -	- -	- -	- -
		4.515	Unknown	McCarty Park footbridge					
					0.1100	- -	- -	- -	- -
		4.62	Unknown	W. Beloit Road					
					0.4200	- -	- -	- -	- -
		5.04	Unknown	S. 76th Street					
					0.1600	- -	- -	- -	- -
		5.2	Unknown	W. Oklahoma Avenue					
					0.2400	- -	- -	- -	- -
		5.436	Unknown	S. 72nd Street					
					0.1800	- -	- -	- -	- -
		5.6144	Yes	Channel drop structure					
					0.2600	- -	- -	- -	- -
		5.878	Unknown	W. Morgan Avenue					
					0.2200	- -	- -	- -	- -
		6.1	Unknown	S. 68th Street					
					0.3700	- -	- -	- -	- -
		6.4722	Yes	W. Howard Avenue (downstream)					
					0.0500	- -	- -	- -	- -
		6.524	Yes	W. Forest Home Avenue (upstream)					
					0.3900	- -	- -	- -	- -
		6.9121	Yes	S. 60th Street (downstream)					
					0.1000	- -	- -	- -	- -
		7.012	Yes	S. 60th Street (upstream)					
					0.1300	- -	- -	- -	- -
		7.14	Unknown	W. Cold Spring Road					
					0.3300	- -	- -	- -	- -
		7.47	Unknown	IH 43/894					
					0.0900	- -	- -	- -	- -
Underwood Creek	MN-14 and MN-13				0.2250	- -	- -	- -	- -
		0.225	Yes	Channel drop structure					
					0.5800	- -	- -	- -	- -
		0.805	Yes	Channel drop structure					
					0.0100	- -	- -	- -	- -
		0.8125	Unknown	Canadian Pacific Railway					
					0.4600	- -	good	fair	excellent
		1.27	Unknown	N. Mayfair Road					
					0.1900	- -	poor	- -	fair

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
Underwood Creek (continued)	MN-14 and MN-13 (continued)	1.46	Yes	Channel drop structure					
					0.0000	- -	- -	- -	- -
		1.462	Unknown	Union Pacific Railroad					
					0.0400	- -	- -	- -	- -
		1.5	Unknown	Watertown Plank Road					
					0.0300	- -	- -	- -	- -
		1.535	Yes	Channel drop structure					
					0.1000	- -	- -	- -	- -
		1.635	Yes	Channel drop structure					
					0.0600	- -	- -	- -	- -
		1.695	Yes	Channel drop structure					
					0.1800	- -	- -	- -	- -
		1.8725	Unknown	N. 115th Street					
					0.7000		fair	fairly poor	fair
		2.56		Confluence with South Branch Underwood Creek		South Branch Underwood Creek			
		2.5725	Unknown	UPS Driveway					
					0.0100	- -	- -	- -	- -
		2.5805	Unknown	Pedestrian bridge					
					0.0900	- -	- -	- -	- -
		2.6725	Unknown	Private drive					
					0.0200	- -	- -	- -	- -
		2.6925	Unknown	Private drive					
					0.0400	- -	- -	- -	- -
		2.7325	Unknown	Private drive					
					0.1000	- -	- -	- -	- -
		2.8325	Unknown	Private drive					
					0.2700	- -	- -	- -	- -
		3.1025	Unknown	Canadian Pacific Railway					
					0.0200	- -	- -	- -	- -
		3.1225	Unknown	Private drive					
					0.1300	- -	- -	- -	- -
		3.2525	Unknown	Wall Street					
					0.0600	- -	- -	- -	- -
		3.311	Yes	Parking Lot tunnel outlet					
					0.1000	- -	- -	- -	- -
		3.41	Yes	Parking Lot tunnel inlet					
					0.0200	- -	- -	- -	- -
		3.4325	Unknown	Watertown Plank Road					
					0.0700	- -	- -	- -	- -
		3.505	Unknown	Private drive					
					0.0400	- -	- -	- -	- -
		3.54	Unknown	Private bridge					
					0.0100	- -	- -	- -	- -
		3.5525	Unknown	Canadian Pacific Railway					
					0.1200	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
Underwood Creek (continued)	MN-14 and MN-13 (continued)	3.6725	Unknown	Juneau Boulevard					
					0.0900	- -	- -	- -	- -
		3.7625	Unknown	Elm Grove Village Hall bridge					
					0.7200	- -	- -	- -	- -
		4.4825	Unknown	Marcela Drive					
		4.67			0.3400	- -	poor	fair	fair
		4.74				- -	fair	good	good
		4.8225	Unknown	North Avenue					
					0.6600	- -	- -	- -	- -
		5.4825	Unknown	Private drive					
					0.1100	- -	- -	- -	- -
		5.5925	Unknown	Clearwater Road					
					0.2900	- -	- -	- -	- -
		5.881	Unknown	Private bridge					
					0.1100	- -	- -	- -	- -
		5.9925	Unknown	Santa Maria Court					
					0.0900	- -	- -	- -	- -
		6.0825	Unknown	Woodbridge Road					
					0.1200	- -	- -	- -	- -
		6.2025	Unknown	Indian Creek Parkway					
					0.1200	- -	- -	- -	- -
		6.3215	Unknown	Canadian Pacific Railway					
					0.0500	- -	- -	- -	- -
		6.37	Unknown	Private bridge					
					0.0400	- -	- -	- -	- -
		6.41	Unknown	Private bridge					
					0.0700	- -	- -	- -	- -
		6.48	Unknown	Private bridge					
					0.0200	- -	- -	- -	- -
		6.5	Unknown	Private bridge					
					0.0100	- -	- -	- -	- -
		6.5125	Unknown	Private drive					
					0.0800	- -	- -	- -	- -
		6.59	Unknown	Private bridge					
					0.0500	- -	- -	- -	- -
		6.6425	Unknown	Private drive					
					0.0400	- -	- -	- -	- -
		6.6825	Unknown	Pilgrim Parkway					
					0.0020	- -	- -	- -	- -
		6.685	Unknown	Pedestrian bridge					
		6.95		Confluence with Dousman Ditch	0.5500	Dousman Ditch	- -	- -	- -
		7.2385	Unknown	Wirth Park bridge					
					0.4500	- -	- -	- -	- -
		7.685	Unknown	Canadian Pacific Railway					
					0.0200	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
South Branch Underwood Creek	MN-14A				0.0525	- -	- -	- -	- -
		0.0525	Unknown	W. Bluemound Road					
					0.1000	- -	- -	- -	- -
		0.1525	Unknown	Canadian Pacific Railway					
					0.4200	- -	- -	- -	- -
		0.5725	Unknown	IH 94					
					0.5100	- -	- -	- -	- -
		1.081	Yes	W. Schlinger Avenue tunnel outlet					
		1.662			0.6500	- -	- -	- -	- -
		1.726	Yes	W. Greenfield Avenue tunnel inlet					
		1.73			0.0040	- -	- -	- -	- -
Dousman Ditch	MN-13A				0.2800	- -	- -	- -	- -
		0.028	Unknown	Union Pacific Railroad					
					0.0300	- -	- -	- -	- -
		0.06	Unknown	North Avenue					
					0.1400	- -	- -	- -	- -
		0.2	No	Pedestrian bridge					
					0.4300	- -	- -	- -	- -
		0.625	Unknown	Gebhardt Road					
					0.6300	- -	- -	- -	- -
		1.258	Unknown	Private drive					
					0.3600	- -	- -	- -	- -
		1.62	Unknown	Private drive					
					0.2300	- -	- -	- -	- -
		1.847	Unknown	Private drive					
					0.5200	- -	- -	- -	- -
		2.369	Unknown	Lake Road					
					0.0700	- -	- -	- -	- -
Little Menomonee River	MN-11				0.0880	- -	- -	- -	- -
		0.088	Unknown	N. Lovers Lane Road (STH 100)					
					0.4200	- -	- -	- -	- -
		0.51	Unknown	Pedestrian bridge					
					0.6200	- -	- -	- -	- -
		1.126	Unknown	W. Silver Spring Drive					
					0.3300	- -	- -	- -	- -
		1.46	Unknown	Union Pacific Railroad					
		1.47			0.0300	- -	poor	fairly poor	excellent
		1.485	Unknown	Bike trail bridge					
					0.1000	- -	- -	- -	- -
		1.589	Unknown	W. Appleton Avenue					
					0.8100	- -	- -	- -	- -
		2.402	Unknown	W. Mill Road					
					0.1700	- -	- -	- -	- -
		2.567	Unknown	W. Fond du Lac Avenue (STH 145)					
					0.0400	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
Little Menomonee River (continued)	MN-11 (continued)	2.603	Unknown	W. Leon Terrace					
					0.7300	- -	- -	- -	- -
		3.33	Unknown	Park bridge					
					0.0500	- -	- -	- -	- -
		3.3835	Unknown	Bike trail bridge					
					0.3000	- -	- -	- -	- -
		3.685	Unknown	W. Good Hope Road (CTH PP)					
					0.0700	- -	- -	- -	- -
		3.76	Unknown	N. Granville Road (CTH F)					
					0.4600	- -	- -	- -	- -
		4.215	Unknown	W. Calumet Road					
					0.6200	- -	- -	- -	- -
		4.835	Unknown	W. Bradley Road					
					0.0900	- -	- -	- -	- -
		4.92	Unknown	Wisconsin & Southern Railroad					
					1.1600	- -	- -	- -	- -
		6.075	Unknown	Union Pacific Railroad					
					0.0500	- -	- -	- -	- -
		6.125	Unknown	W. Brown Deer Road (STH 100)					
					0.3800	- -	- -	- -	- -
		6.5	Unknown	Park bridge					
					0.2600	- -	- -	- -	- -
		6.76	Unknown	Footbridge					
					0.3900	- -	- -	- -	- -
		7.15	Unknown	W. County Line Road					
					0.1900	- -	- -	- -	- -
		7.34	Unknown	Private bridge					
					0.1100	- -	- -	- -	- -
		7.45	Unknown	Private bridge					
					0.2600	- -	- -	- -	- -
		7.71	Unknown	Farm bridge					
					0.1200	- -	- -	- -	- -
		7.83	Unknown	Private bridge					
		7.92			0.3900	- -	fair	good	fair
		8.21				- -	fair	fair	fair
		8.22	Unknown	Donges Bay Road					
		8.31		Confluence with Little Menomonee Creek	0.8500	Little Menomonee Creek	- -	- -	- -
		9.07	Unknown	Private bridge					
					0.3000	- -	- -	- -	- -
		9.365	Unknown	Mequon Road					

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
Little Menomonee River (continued)	MN-11 (continued)				0.0200	- -	- -	- -	- -
		9.38	Unknown	Private bridge					
					0.0400	- -	- -	- -	- -
		9.425	Unknown	Farm bridge					
					1.0200	- -	- -	- -	- -
		10.44	Unknown	Freistadt Road					
					0.2900	- -	- -	- -	- -
Little Menomonee Creek	MN-10	0.29	Unknown	Private bridge (0.29)					
					0.2900	- -	- -	- -	- -
		0.58	Unknown	Private bridge (0.58)					
					0.2400	- -	- -	- -	- -
		0.8225	Unknown	Granville Road					
					0.0200	- -	- -	- -	- -
		0.84	Unknown	Private bridge (0.84)					
					0.0700	- -	- -	- -	- -
		0.91	Unknown	Private bridge (0.91)					
		1.03			0.1200	- -	- -	- -	- -
		1.0325	Unknown	Mequon Road					
		1.16			0.8600	- -	good	good	good
		1.47				- -	good	good	good
		1.89	Unknown	Private bridge (1.89)					
					0.3600	- -	- -	- -	- -
		2.2525	Unknown	Freistadt Road					
					0.0100	- -	- -	- -	- -
Willow Creek	MN-4				0.0625	- -	- -	- -	- -
		0.0625	Unknown	Maple Road					
					0.5900	- -	good	fair	fair
		0.6525	Unknown	Lannon Road					
					0.5000	- -	good	good	fair
		1.1525	Unknown	Appleton Avenue (STH 175)					
					1.7000	- -	- -	- -	- -
North Branch Menomonee River	MN-1				0.6315	- -	- -	- -	- -
		0.6315	Unknown	Holy Hill Road					
					0.4200	- -	- -	- -	- -
		1.05	Unknown	Private bridge (1.05)					
					0.2200	- -	- -	- -	- -
		1.2725	Unknown	Rockfield Road					
					0.3300	- -	- -	- -	- -
		1.6015	Unknown	Division Road					
					0.2300	- -	- -	- -	- -
		1.8315	Unknown	Railroad					
					1.0600	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
North Branch Menomonee River (continued)	MN-1 (continued)	2.895	Unknown	Maple Road					
					0.4700	- -	- -	- -	- -
		3.365	Unknown	STH 145					
					0.7200	- -	- -	- -	- -
		4.085	Unknown	Goldendale Road					
					0.4400	- -	- -	- -	- -
West Branch Menomonee River	MN-3				0.3315	- -	fair	good	fair
		0.3315	Unknown	Freistadt Road					
					0.0600	- -	- -	- -	- -
		0.3915	Unknown	Private drive					
					0.1200	- -	- -	- -	- -
		0.51	Unknown	Private bridge (0.51)					
					0.6500	- -	- -	- -	- -
		1.1625	Unknown	Maple Road					
					0.0900	- -	- -	- -	- -
		1.2525	Unknown	Railroad					
					0.3800	- -	- -	- -	- -
		1.6325	Unknown	Private drive-bridge					
					0.4200	- -	- -	- -	- -
		2.0525	Unknown	Private drive-bridge					
					0.1700	- -	- -	- -	- -
		2.225	Unknown	Dalebrook Road					
					0.1100	- -	- -	- -	- -
		2.335	Unknown	Goldendale Road					
					0.1900	- -	- -	- -	- -
		2.525	Unknown	Freistadt Road					
					0.2200	- -	- -	- -	- -
		2.745	Unknown	Goldendale Road					
					0.2700	- -	- -	- -	- -
		3.015	Unknown	Goldendale Road					
					0.2700	- -	- -	- -	- -
		3.285	Unknown	USH 41/45					
					0.0200	- -	- -	- -	- -
		3.305	Unknown	Hilltop Drive					
					0.3000	- -	- -	- -	- -
Lilly Creek	MN-7		Unknown		0.4015	- -	- -	- -	- -
		0.4015		Appleton Avenue					
			Unknown		0.4400	- -	- -	- -	- -
		0.8425		Good Hope Road					
		0.85	Unknown		0.2200	- -	- -	- -	fair
		1.0625		Brentwood Drive					
		1.07	Unknown		0.4100	- -	good	good	fair
		1.469		Daylily Drive					
			Unknown		0.3300	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
Lilly Creek (continued)	MN-7 (continued)	1.8025		Lilly Road					
			Unknown		0.0800	- -	- -	- -	- -
		1.8825		Mill Road					
			Unknown		0.1100	- -	- -	- -	- -
		1.99		Private bridge (1.99)					
			Unknown		0.0600	- -	- -	- -	- -
		2.05		Private bridge (2.05)					
			Unknown		0.0600	- -	- -	- -	- -
		2.1125		Private drive					
			Unknown		0.0900	- -	- -	- -	- -
		2.2025		Private drive					
			Unknown		0.0600	- -	- -	- -	- -
		2.2625		Private drive					
			Unknown		0.1700	- -	- -	- -	- -
		2.43		Kaul Avenue					
			Unknown		0.0500	- -	- -	- -	- -
		2.48		Bobolink Avenue					
			Unknown		0.0700	- -	- -	- -	- -
		2.5525		Private drive					
			Unknown		0.0400	- -	- -	- -	- -
		2.5925		Railroad					
			Unknown		0.3800	- -	- -	- -	- -
		2.9725		Silver Spring Road					
			Unknown		0.4700	- -	- -	- -	- -
Nor-X-Way Channel	MN-6				0.0725	- -	- -	- -	- -
		0.0725	Unknown	Fond du Lac Avenue					
					0.0600	- -	- -	- -	- -
		0.1325	Unknown	USH 45 entrance ramp					
					0.0400	- -	- -	- -	- -
		0.1725	Unknown	USH 45					
					0.1000	- -	- -	- -	- -
		0.2725	Unknown	Stanley Drive					
					0.0400	- -	- -	- -	- -
		0.3125	Unknown	Main Street					
					0.1400	- -	- -	- -	- -
		0.4525	Unknown	Patrita Drive/Fountain Boulevard					
					0.2800	- -	- -	- -	- -
		0.7325	Unknown	Private drive					
					0.0900	- -	- -	- -	- -
		0.8225	Unknown	Wisconsin & Southern Railroad					
					0.4900	- -	- -	- -	- -
		1.3125	Unknown	STH 145					
					0.0600	- -	- -	- -	- -
		1.3725	Unknown	County Line Road (CTH Q)					
					0.7500	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
Nor-X-Way Channel (continued)	MN-6 (continued)	2.12	Unknown	Railroad					
					0.0800	- -	- -	- -	- -
		2.2	Unknown	Railroad					
					0.3000	- -	- -	- -	- -
		2.495	Unknown	Culvert at upstream end of pond					
					0.1500	- -	- -	- -	- -
		2.645	Unknown	Donges Bay Road					
					0.5600	- -	- -	- -	- -
		3.205	Unknown	Wasaukee Road					
					0.0600	- -	- -	- -	- -
Butler Ditch	MN-8	0.23			0.2400	- -	fair	- -	good
		0.24	Unknown	Campbell Road					
					0.4100	- -	- -	- -	- -
		0.645	Unknown	Overview Drive					
					0.2600	- -	- -	- -	- -
		0.9	Unknown	Private bridge					
					0.1200	- -	- -	- -	- -
		1.0225	Unknown	Hampton Road					
		1.03			0.3300	- -	fair	- -	- -
		1.3525	Unknown	Lisbon Road					
		1.36			0.4100	- -	good	- -	fair
		1.49				- -	poor	- -	- -
		1.7625	Unknown	Lilly Road					
					0.0500	- -	- -	- -	- -
		1.81	Unknown	Lilly Heights dam					
		2.5		Confluence with South Branch Butler Ditch	0.9100	South Branch Butler Ditch	- -	- -	- -
		2.715	Unknown	Shamrock Lane					
					0.6900	- -	- -	- -	- -
		3.405	Unknown	Lisbon Road					
					0.5900	- -	- -	- -	- -
Dretzka Park Creek	MN-9				0.0530	- -	- -	- -	- -
		0.0531	Unknown	Fond du Lac Avenue					
					0.0770	- -	- -	- -	- -
		0.13	Unknown	USH 41/45 downstream					
					0.1800	- -	- -	- -	- -
		0.31	Unknown	USH 41/45 upstream					
					0.1820	- -	- -	- -	- -
		0.492	Unknown	W. Bradley Road					
					0.1700	- -	- -	- -	- -
		0.662	Unknown	Golf course bridge #1					
					0.1260	- -	- -	- -	- -
		0.788	Unknown	Golf course bridge #2					
					0.1300	- -	- -	- -	- -

Table 8 (continued)

Subwatershed	Reach	River Mile	Fish Passage Obstruction	Structure Identification	Distance between Structures (river miles)	Major Tributaries	Fish Sites (2000-2009)	Invertebrate Sites (2000-2009)	Habitat Sites (2000-2009)
Menomonee River Tributary Subwatersheds (continued)									
Dretzka Park Creek (continued)	MN-9 (continued)	0.918	Unknown	Golf course bridge #3					
					0.0670	- -	- -	- -	- -
		0.985	Unknown	Golf course bridge #4					
					0.1640	- -	- -	- -	- -
		1.149	Unknown	Golf course bridge #5					
					0.0325	- -	- -	- -	- -
		1.1815	Unknown	Golf course bridge #7					
					0.0610	- -	- -	- -	- -
		1.242	Unknown	Golf course bridge #8					
					0.0930	- -	- -	- -	- -
		1.335	Unknown	Golf course bridge #9					
					0.0350	- -	- -	- -	- -
		1.3695	Unknown	Golf course bridge #10					
					0.1100	- -	- -	- -	- -
		1.475	Unknown	Golf course bridge #11					
					0.0730	- -	- -	- -	- -
		1.5475	Unknown	Golf course bridge #12					
		1.66			0.3000	- -	poor	- -	poor
		1.845	No	N. 124th Street					
		1.89			0.1800	- -	good	- -	excellent
		2.02	No	W. Brown Deer Road					
		2.04			0.1500	- -	fair	- -	good
		2.17	Unknown	N. 124th Street					
					0.3700	- -	- -	- -	- -
		2.54	Unknown	Private drive					
					0.0500	- -	- -	- -	- -
		2.585	Unknown	Abandoned railroad					
					0.1700	- -	- -	- -	- -
		2.755	Unknown	Wisconsin & Southern Railroad					
					0.0400	- -	- -	- -	- -
		2.795	Unknown	Railroad					
					0.4800	- -	- -	- -	- -
		3.275	Unknown	W. County Line Road					
					0.0750	- -	- -	- -	- -

NOTE: The tributary reaches and mainstem reaches are generally ordered from upstream to downstream.

[a]*No quality could be assigned to this site due to the sampling methods.*

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

Quality Rating		
Fish Sites	Invert Sites	Habitat Sites
very poor	fairly poor	very poor
poor	fair	poor
fair	good	fair
good		good
		excellent

Riparian Corridors

Healthy riparian corridors help to protect water quality, groundwater, fisheries and wildlife, and ecological resilience to invasive species, as well as reducing potential flooding of structures and harmful effects of climate change.[7] In turn, the health of riparian corridors is largely dependent upon width (size) and continuity. Therefore, efforts to protect and expand the remaining riparian corridor width and continuity are the foundation for protecting and improving the fishery and recreation within the Menomonee and Kinnickinnic River watersheds.

Corridor Target 1

Expand riparian buffer width to a minimum of 75 feet.

Issue

All riparian buffers provide some level of protection that is greater than if there were no buffer at all. In addition, wider buffers provide a greater number of functions (infiltration, temperature moderation, species diversity) than narrower buffers. Therefore, it is important that existing buffers be protected and expanded where possible and not be converted to urban land uses, which could lead to increased degradation to the fishery, water quality, wildlife, and recreational opportunities of the Menomonee and Kinnickinnic River watersheds.

Key Questions

- What are the major human uses in the area?
- Where do they generally occur in the watershed (map the location of important uses such as recreational facilities, public access points, and trails)?
- What impacts are the uses having, and what opportunities are there to reduce those impacts?
- What needs or opportunities are there related to human uses or facilities in terms of meeting management objectives and moving toward desired conditions in the watersheds?

Objective

The objective is to protect, preserve, and expand riparian buffer width to a minimum of 75 feet where possible among mainstem and tributary waterways throughout the Menomonee and Kinnickinnic River systems.

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities for establishment or expansion of riparian buffers:

- Encourage the establishment of setback requirements to accommodate shoreland buffers, use of appropriate and environmentally friendly landscaping practices, and inclusion of stormwater management measures that provide water quality and water quantity benefits.
- Use public lands or purchase lands identified on Maps 13 and 14 through donation, grants, fee simple purchase, or acquisition of conservation easements.
- Implement management activities to promote restoration.

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[7]*N.E. Seavy and others, "Why Climate Change Make Riparian Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration, *Volume 27(3): pages 330-338, September, 2009; "Association of State Floodplain Managers, Natural and Beneficial Floodplain Functions: Floodplain Management—More Than Flood Loss Reduction, 2008,"* www.floods.org/NewUrgent/Other.asp.

- Conduct additional surveys to determine riparian buffer widths along streams for which inventories have not yet been conducted.

- Effect changes in zoning ordinances to minimize the adverse effects of urban development by providing specific provisions and incentives for the clustering of development on smaller lots within conservation subdivisions, thus preserving significant portions of the open space within each property or group of properties considered for development, and minimizing the "footprint" of the developed area relative to the open space on and around a development site.

Potential Measures

- Stream-miles inventoried and area of potential buffer identified.

- Stream-miles with buffer width of 75 feet or greater preserved or established.

- Volume of historic fill and/or tons of trash removed from riparian areas.

- Area of native wetland or upland reconstructed.

- Number of native species restored.

- Area of exotic invasive species removed.

Corridor Target 2
Expand riparian buffer continuity (connectedness).

Issue
Fragmentation of riparian buffers by roads, railways, and utilities combined with encroachment by development impacts the structure and function of riparian corridors and their ability to adequately protect waterways and wildlife habitat. Stream crossings tend to have a cumulative impact on the stream and associated lands and on the quality of water and the fishery.

Objective
The objective is to reduce the linear fragmentation of the existing riparian buffers by either removing crossings where possible or at least not increasing the number of crossings of waterways within the Menomonee and Kinnickinnic River systems, where practical. The human safety need to preserve access by police, fire protection, and emergency medical services is an overriding consideration that must be applied in determining whether the objective of removing a crossing is feasible. This objective is only meant to apply to situations where more road crossings exist than are necessary to ensure adequate access for emergency services.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to expand riparian buffer continuity:

- Use of public lands or purchase lands identified on Maps 13 and 14 through donation, grants, fee simple purchase, or acquisition of conservation easement.

- Implement management activities to promote restoration.

- Implement management activities to promote recreation.

- Removal of nonessential roads where appropriate.

Potential Measures

- Stream-miles of continuous buffer widths of 75 feet or greater preserved or established.

- Number of stream channel crossings and/or impediments to flow removed and/or retrofitted to restore continuity of riparian buffers.

- Increase in number of locations of safe public access for recreational use of streams.

Corridor Target 3
Protection of high-quality areas or environmentally sensitive lands.

Issue
The existing plant communities, natural areas, and critical species habitat areas are the most vital wildlife areas remaining within the Menomonee and Kinnickinnic River watersheds, and those areas need to be protected. Such areas help provide local and regional ecological resilience within these largely urbanized watersheds. In addition, protection of primary and secondary environmental corridors, isolated natural resource areas, and groundwater recharge areas throughout the two watersheds should also be a priority.

Key Questions

- What plant/animal communities or species are in decline or are considered rare on the landscape?

- How do the current conditions compare with reference or desired conditions, and how do these relate to human activities in the watershed?

- How might the current conditions affect future land management objectives and strategies, and what can be done to bridge the gap between current and desired conditions?

- What is the relative abundance and distribution of species of concern that are important in the watershed (Threatened or Endangered Species, Management Indicator Species, Species of Special Concern, Birds of Conservation Concern)?

- What is the distribution and character of the plant and animal habitats?

- What activities could occur to improve riparian habitat conditions and improve wildlife habitat conditions?

- What needs and opportunities are there for habitat protection, maintenance, or enhancement?

Objective
Protect and manage environmentally sensitive lands to maximize native plant and animal biodiversity as well as groundwater recharge.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to protect high-quality areas or environmentally sensitive lands:

- Protect wetlands, woodlands, and groundwater recharge areas through land use regulation, public land acquisition via donation or purchase, establishment of conservation easements on critical lands, and/or possible expansion of environmental corridors. These protections are recommended for the priority lands indentified on Maps 13 and 14 within the Menomonee River and Kinnickinnic River watersheds, respectively.

- Wetland areas, many of which have been historically modified or filled, are currently largely protected through the existing regulatory framework provided by the U.S. Army Corps of Engineers permit program, State wetland zoning requirements, and local zoning ordinances. Many wetland areas in the watersheds are included in the environmental corridors delineated by the Regional Planning Commission and protected under one or more of the existing Federal, State, county, and local regulations. Consistent and effective application of the provisions of these regulations is recommended.

- Certain wetland and woodland areas have been identified for acquisition in the adopted regional natural areas and critical species habitat protection and management plan.[8] Implementation of these recommendations, in addition to those set forth in the adopted park and open space plan for Milwaukee County,[9] would complement the protection and preservation of environmentally sensitive lands.

- Consider adopting and enforcing municipal shoreland setback requirements and should actively enforce construction site erosion control and stormwater management ordinances.

- Provide informational materials to shoreland property owners.

- Enforce local zoning regulations to discourage development within the one-percent-annual-probability floodplain.

- As a refinement of the recommendations of the regional water quality management plan update, specific candidate sites for restoration of native wetland and/or upland prairie communities have been identified as shown on Maps 13 and 14. Those lands should be purchased or easements should be obtained, and the lands should ultimately be restored through modification of agricultural drainage systems, removal of nonnative exotic invasive species, removal of historical fill, and/or establishment of native vegetation, among other best management practices.

- Conduct additional surveys to inventory environmentally sensitive lands.

- Purchase lands to expand buffers within the SEWRPC-delineated primary and secondary environmental corridors, especially along the river mainstems and tributary streams.

Potential Measures

- Stream-miles inventoried and area of potential buffer identified.

- Stream-miles or area of land protected.

- Continued enforcement of local shoreland and floodplain zoning ordinances.

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

[9]*SEWRPC Community Assistance Planning Report No. 137,* A Park and Open Space Plan for Waukesha County, *December 1989; SEWRPC Community Assistance Planning Report No. 132,* A Park and Open Space Plan for Milwaukee County, *November 1991.*

Information Needs
Conduct wildlife species surveys to identify high-quality riparian buffer and/or environmental corridor lands throughout the Menomonee and Kinnickinnic River watersheds. These areas would then become the focus of protection and reconnection with possible additional corridor lands.

Maintain current inventories on riparian buffer conditions and widths throughout the watersheds and expand riparian buffer inventories within tributaries not assessed.

Hydrology
Urban development brings with it significant changes in the landscape. These changes historically have included modification of the drainage pattern, hardening of surfaces, and alteration of infiltration, all of which can affect water quality and quantity. All of these changes generally increase the volume and rate of runoff from precipitation events. Historically, managing these increases in rates and volumes of runoff would often involve construction of storm sewer and/or open channel systems to convey stormwater as quickly and efficiently as possible to the streams of the watersheds, and ultimately to Lake Michigan. In recent years, however, flooding, water quality impairment, and environmental degradation have demonstrated the need for an alternative approach to stormwater management. Consequently, current stormwater management practices seek to manage runoff using a variety of measures, including detention, retention, infiltration, and filtration, better mimicking the disposition of precipitation on an undisturbed landscape.

Hydrology Target 1
Moderate flow regimes to decrease flashiness.

Issue
Urbanization increases the area of impervious surfaces, which can lead to an increase in "flashiness" (or the rate at which flow responds to a precipitation event) and can subsequently affect streambank and streambed stability, pollutant loading, and sediment dynamics, which, in turn, affect habitat availability and quality. Therefore, increased flashiness has been determined to be a cause of degradation of aquatic communities.

Key Questions
- What beneficial water resource uses occur in the watershed, and how are these affected by stormwater management practices?
- Which water quality parameters are critical to a healthy aquatic ecosystem?
- What are current water quality conditions, and are there any problem areas?
- How is water quality being affected by types of land use?

Objective
The objective is to emulate stream discharges in response to rainfall to levels observed prior to urbanization or agricultural development to the extent practical. More specifically, decreases in average flow magnitude, high flow magnitude, high flow event frequency, and/or high flow duration are sought to provide potential improvements to the algal, invertebrate, and fish communities within the Menomonee River and Kinnickinnic River watersheds. Significant reductions in streamflow rates and volumes would be difficult to achieve in either of these extensively developed watersheds; however, opportunities for reductions may exist in the headwaters areas of the Menomonee River watershed.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to moderate flow regimes and decrease flashiness:

- Manage stormwater runoff to meet, to the maximum extent practicable, the agricultural performance standards and the nonagricultural standards for existing development, new development, and redevelopment as established under Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*. The objectives of the first tier and second tier approaches would be to ensure that new development and redevelopment conform to the water quantity and quality control requirements of Chapter NR 151 and the MMSD Chapter 13 rule, "Surface Water and Storm Water." The objective of the third tier approach would be to address runoff from existing development as opportunities arise, so that the quality of stormwater runoff meets the requirements of Chapter NR 151.

- Municipalities should take an active role in promoting urban nonpoint source pollution abatement through meeting the conditions of their municipal separate storm sewer system (MS4) discharge permits under the Wisconsin Pollutant Discharge Elimination System. Stormwater management planning could be undertaken by municipalities to promote cost-effective urban nonpoint source pollution abatement.

- In addition to the adoption and enforcement of stormwater management ordinances, the most viable measures to control urban nonpoint sources of pollution appear to be good urban land management and urban housekeeping practices (see Appendix B). [10] Such practices consist of fertilizer and pesticide use management, litter and pet waste controls, lawn watering, and management of leaf litter and yard waste. These measures should be promoted under the public informational programs being conducted under the conditions of the municipal MS4 discharge permits.

- Implement and maintain stormwater management practices at the subwatershed and neighborhood levels.

- Restore floodplain connectivity with the stream system, where feasible.

- Improve infiltration through innovative best management practices (BMP) that associated with low-impact development, including bioretention and rain garden projects (see Appendix C),[11] installation of rain barrels, disconnection of downspouts, and installation of green roofs and porous pavement projects.

Potential Measures

- Numbers of detention and infiltration basins installed, drainage area controlled by regenerative stormwater practices that achieve quality and quantity control, area of permeable paving materials installed, acres of wetland and upland restored, area of low-impact development.

- Number of rain gardens or rain barrels installed and downspouts disconnected, green roofs installed.

- Drainage area controlled by regenerative stormwater practices that achieve quality and quantity control and numbers of basins inspected and maintained.

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[10]*UW-Extension, Water Resources Education Publications,* http://clean-water.uwex.edu/pubs/index.htm.

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

- Miles of stream connected with the floodplain.

- Decreases in average flow magnitude, high flow magnitude, high flow event frequency, and/or high flow duration.

- Improvement in flashiness index.

- Improvement in instream water quality.[12]

Water Quality and Quantity

Water Quality and Quantity Target 1

Reduce water quality and quantity impacts from stormwater outfalls, nonpoint runoff, and sewer overflows including reduction of localized erosion at pipe outfalls.

Issue

There are hundreds of outfalls, primarily storm sewer outfalls, distributed throughout the Menomonee River and Kinnickinnic River watersheds that have the potential to cause significant degradation to water quality and streambed and streambank stability.

Objective

Reduce water quality and quantity impacts to improve instream habitat and aquatic communities within the Menomonee River and Kinnickinnic River watersheds.

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities to reduce impacts from storm sewer outfalls, nonpoint runoff, and sewer overflows:

- Provide adequate stormwater management through traditional (e.g., detention and infiltration basins) and innovative techniques (e.g., bio-infiltration and green infrastructure).

- Identify stream reaches with high salt concentrations and target them for pilot programs.

- Evaluate existing road deicing and anti-icing programs with an emphasis on salt reduction;[13] establish new road deicing and anti-icing programs in communities that do not have programs; and promote optimal application of deicing agents on commercial, industrial, governmental and institutional, airport, and residential properties.

- Implement measures to reduce localized erosion and physically modify the most-active outfalls (i.e., those with the greatest effect on instream physical conditions).

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[12]*Improvements in instream water quality would be expected as a result of implementing many of the recommendations set forth herein. Because of the complex nature of the stream systems in the Menomonee and Kinnickinnic River watersheds and because of the existence of pollutants from stormwater runoff and other sources within the drainage network and streams, a long-term time frame may be needed to identify measurable improvements in instream water quality. Thus, maintenance of a long-term network of streamflow and water quality monitoring gauges is recommended (see the Monitoring and Information section below).*

[13]*Calcium chloride application could be reduced through implementing practices such as applying salt only at intersections, mixing salt with sand, and calibrating spreaders and also through substitution of less environmentally damaging anti-icing and deicing agents.*

Potential Measures

- Improvement in flashiness index.
- Improvement in instream water quality through obtaining water quality and biological data on stream reaches where salt application has been reduced in tributary areas.
- Number of commercial owners, contractors, operators, municipalities, and the public contacted through information programs on use of salt on driveways and other areas.
- Number of flow deflectors installed, pipes cut back from streambank, linear feet of riprap installed, or land area treated by infiltration practices.
- Number of communities implementing new road salt reduction programs.
- Reduction in amount of road salt applied by municipalities.

Land-Based Monitoring and Information

It is important that steps be taken to ensure the existence of a sound program of water quality monitoring to determine the extent to which physical, chemical, and biological conditions are improving over time, to measure temporal and spatial trends, to provide data to evaluate the effectiveness of water pollution control measures, and to detect new and emerging water quality problems specifically linked to land use and land management issues in the watersheds. Therefore, monitoring of land-based activities should be coordinated and linked with the instream monitoring program (see Instream-Based Monitoring and Information section below) in order to optimize the use of the scarce monitoring resources of multiple agencies and groups, generate monitoring data that are scientifically defensible and relevant to the decision-making process, and manage and report water quality data in ways that are meaningful and understandable to decision makers and other affected parties.

Monitoring and Information Target 1

Continue and expand monitoring and informational programming.

Issue

It is critical to establish improvements or degradation to water quality and biological communities, as well as physical conditions of the stream and associated corridor lands, in response to land use changes throughout the watersheds.

Key Questions

- Where are land use changes occurring in the area?
- What are the current mitigation practices such as rain gardens, downspout disconnection, wet and dry stormwater basins, infiltration facilities, green roofs, winter road salt reduction, among others?
- What mitigation practices are required by ordinance?
- Are these mitigation practices effective and maintained?
- What are the opportunities for citizen monitoring and participation by schools?

Objective

Continue existing monitoring efforts and expand monitoring and informational programming when possible.

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities to continue and expand monitoring and informational programming:

- Continue and expand coordination of terrestrial monitoring, sampling schedules, and sharing of data and results among government agencies, nongovernment agencies, citizen monitoring, and research institutions. Specifically, such monitoring would include periodic bird counts, transect sampling of upland habitat, and species counts of vegetation, invertebrates (butterflies, beetles, etc.), mammals, amphibians, and reptiles.

- Implement storm drain stenciling and related informational programming to encourage residents to dispose of waste products safely, avoiding discharge directly to surface waters.

- Promote and encourage use of green infrastructure, and monitor implementation and effectiveness of such practices. Maintain practices as required.

- Continue awareness programming and implement monitoring and management of nonnative invasive species such as buckthorn, gypsy moth, emerald ash borer, and purple loosestrife, among other species identified or may be identified in Chapter NR 40 of the *Wisconsin Administrative Code*.

Potential Measures

- Number of monitoring stations established, expansion of the biological database, and number of data analysis and interpretation efforts continued or increased.

- Number of stormwater management and green infrastructure practices installed and/or maintained.

- Number of citizen monitoring stations established.

- Amounts of invasive species removed and/or treated within an area.

- Number of informational programs developed or workshops held.

INSTREAM HABITAT PROTECTION MEASURES

Aquatic Organism Passage

Aquatic Organism Passage Target 1

Restore fish and aquatic organism passage from Lake Michigan to the headwaters and tributaries (i.e., follow three-tiered prioritization strategy as outlined in Figures 23 and 24).

Issue

Fishing, both recreational angling and commercial harvesting of fishes, is an important economic activity in the greater Milwaukee watersheds and Lake Michigan. The maintenance and continuity of both the species of economic importance and those species on which they depend is associated to a large degree with the protection and restoration of appropriate habitat. To this end, efforts to remove obstructions to fish migration along the mainstems and tributaries of the Menomonee and Kinnickinnic Rivers are a key element to the long-term restoration of the fishery. These obstructions include dams, drop structures, roadways, and channelized river reaches, among others. Removal of these obstructions should be accompanied by the restoration or re-creation of habitat within the stream and riparian corridor that is essential for resting, rearing, feeding, and spawning of fishes and other organisms.

Key Questions

- What are the characteristics of the physical instream habitat (e.g., aquatic habitat composition, pool quality, structural complexity) and what factors are influencing this condition?

- What is the condition of aquatic communities and what factors (e.g., habitat suitability, habitat fragmentation, nonnative species) are influencing the distribution or population viability of native and desired aquatic species?

Objective
The objective is to restore the biotic integrity of the Menomonee and Kinnickinnic River systems by reducing the fragmentation within these stream systems and reconnecting them with Lake Michigan. This objective is based upon a three-tiered approach (see Figures 23 and 24), focused on the reconnection of waterways that have been historically isolated from the Lake Michigan stream system (e.g., through construction of dams, roadways, stream enclosures, concrete lining, and flow control structures) or modified through single-focus structural means (e.g., stormwater conveyances). The strategy is predicated upon a tiered approach: Tier 1–restoring connectivity between the mainstem waterways and the Lake Michigan endpoint, Tier 2–restoring connectivity between the tributary streams and the mainstems of the Menomonee and Kinnickinnic Rivers, and Tier 3–expanding connection of highest-quality fish, invertebrate, and habitat sites within each of the watersheds, as shown on Maps 5 and 8. As structures are removed or retrofitted, to promote fish passage over time, there will be improved access to the highest-quality habitat areas for feeding, rearing, and spawning, leading to restoration of a more sustainable fishery within both of these watersheds.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to restore fish and aquatic organism passage from Lake Michigan to the headwaters and tributaries of the Menomonee and Kinnickinnic Rivers:

- Develop plans for improving fish passage in the 0.6-mile-long reach of the Menomonee River from IH 94 to the upstream side of the Canadian Pacific Railway bridge in reach MN-18, subject to preserving the integrity of the Valley Park flood management facilities as shown in Figure 17 in Chapter II of this report.

- Develop plans for improving fish passage in the currently concrete-lined reaches of the Kinnickinnic River (reaches KK-3 and KK-10) as shown in Figure 20 in Chapter II of this report, subject to meeting flood management objectives.

- Develop plans for removal and/or retrofitting of five low-head structures in the Menomonee River between Swan Boulevard and Harmonee Avenue and implement those plans (see Figure 25).

- Concrete removal identified above is recommended to be undertaken simultaneously with restoring connectivity with the floodplain and recreating a more natural meandering stream. For example, the first phase of the Underwood Creek rehabilitation and flood management project was able to successfully accomplish flood management goals, reconnection with the floodplain, re-creation of riparian buffers, and instream restoration goals simultaneously with removal of concrete (see Figure 11 in Chapter II of this report).

- Develop plans for removal and/or retrofitting of additional obstructions such as road crossings, enclosed pipe (daylighting streams subject to satisfaction of floodplain management requirements), debris jams, among others on the mainstem and tributaries and implement the plans throughout the Menomonee and Kinnickinnic River watersheds. However, it is not recommended that projects to improve fish passage be implemented at General Mitchell International Airport (GMIA) within the KK-4 subwatershed. The airport is currently served by an extensive series of floodwater and stormwater conveyances, including stream channel enclosures.[14] These facilities are designed to minimize flooding on the airport grounds and upstream of the airport. It is not feasible or desirable to

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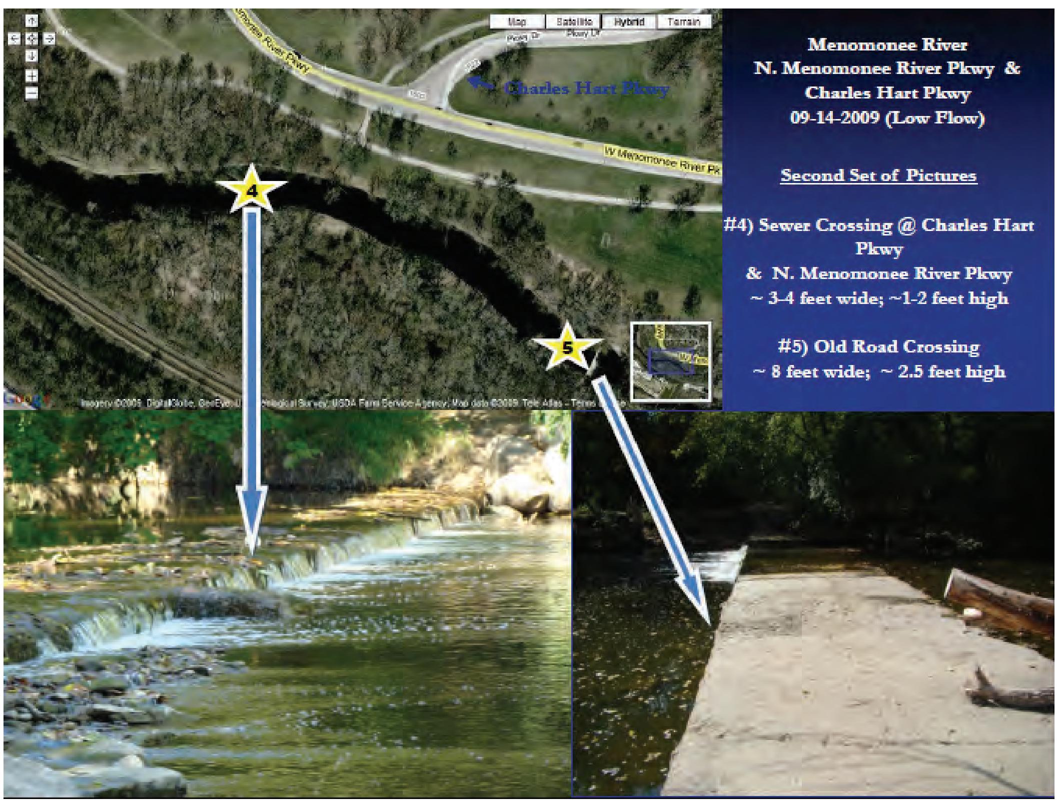
[14]*The airport area was historically comprised of a complex wetland system as shown in the 1836 channel condition, as shown on Map 4.*

Figure 25

FISH PASSAGE OBSTRUCTIONS WITHIN THE MENOMONEE RIVER WATERSHED BETWEEN SWAN BOULEVARD AND HARMONEE AVENUE WITHIN THE MENOMONEE RIVER: 2009

River Crossing – Fish Passage Obstructions ☆

Figure 25 (continued)



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

modify these systems; however, there are continued opportunities for actions to improve water quality within the KK-4 subwatershed from pollutant runoff from deicing agents or other constituents.

- Develop detailed assessments to expand restoration efforts to promote aquatic organism passage beyond the mainstem to the tributaries, develop priorities, and implement restoration projects. See Table 8 for a list of the number of road crossings or obstructions for each subwatershed within the Menomonee River watershed and their relationship to fish passage, stream length, habitat quality, and biological quality sample sites.

Potential Measures

- Stream-miles of concrete removed.
- Number of native species present or some equivalent biological indicator (see "Biological Assessment" section above).
- Number of structures removed or retrofitted (e.g., bridge crossings or drop structures).
- Stream-miles of enclosed channel daylighted or retrofitted, number of tributary miles connected to mainstem, or miles of stream channel restored.

Information Needs

Refine assessment of fish passage obstructions throughout the Menomonee River and Kinnickinnic River watersheds (see Appendix D).

Aquatic Habitat

Aquatic Habitat Target 1

Restore fish and aquatic organism habitat from Lake Michigan to the headwaters and tributaries (i.e., follow three-tiered prioritization strategy as outlined in Figures 23 and 24).

Issue

Since the early 1800s both the Menomonee and Kinnickinnic River systems have been substantially altered through channelization, development (agricultural and urban) impacts, road construction, stormwater conveyance systems, historical fill, and other historical and present day actions that have physically, chemically, and hydrologically degraded habitat.

Key Questions

- What are the basic morphological characteristics of streams in the watershed?
- What are the causes of current instabilities in the hydrologic processes within the watershed?
- What aquatic resources are they affecting?
- How do current riparian conditions contribute to existing channel conditions?
- How much area within the watershed has severe erosion and where does it occur?
- What are the dominant hydrologic characteristics (e.g., baseflow, peak flows, minimum flows) and other notable hydrologic features and processes in the watershed (e.g., groundwater recharge areas)?
- What is needed in terms of aquatic and riparian resource restoration within the watershed?

Figure 26

DOWNSTREAM REACHES WITHIN THE MENOMONEE RIVER AND KINNICKINNIC RIVER WATERSHEDS

MENOMONEE RIVER (WITHIN REACH MN-19) KINNICKINNIC RIVER (WITHIN REACH KK-11)

Source: Milwaukee Metropolitan Sewerage District.

Objective

The objective is to preserve and improve, to the extent practical, physical, chemical, and hydrological characteristics related to habitat conditions throughout both the Menomonee and Kinnickinnic River watersheds. The prioritization strategy is based upon the three-tiered approach as previously described and is focused on restoring habitat in a number of ways primarily including removal of concrete, remeandering streams to rehabilitate channelized reaches, and protecting excessively eroding streambanks and streambeds (Figures 23 and 24). These actions would be designed to improve several dimensions of habitat that include but are not limited to elements such as adequate water depth, pool-riffle structure, stream hydrology, variable substrate composition, and instream cover such as overhanging vegetation or large woody debris. As habitat among reaches and the connectedness of the stream system are improved over time, there will be improved access to the highest-quality habitat areas for feeding, rearing, and spawning, leading to restoration of a more sustainable fishery within both of these watersheds.

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities to restore fish and aquatic organism habitat from Lake Michigan to the headwaters and tributaries of the Menomonee and Kinnickinnic River systems:

- Protect and expand existing highest-quality remaining fishery and aquatic habitat (see Maps 5 and 8 and Table 8).

- Enhance fisheries within reach KK-11 (see Figure 26) of the Kinnickinnic River and within reach MN-19 (see Figure 26) of the Menomonee River by providing areas for fish spawning, juvenile rearing, and refuge and feeding. Habitat restoration methods could include provision of spawning reefs that have been successfully established by WDNR staff within and adjacent to the Milwaukee Harbor estuary as well as potential use of emerging technologies such as the Cuyahoga Habitat Underwater Baskets (CHUBs) pioneered by the Cuyahoga River Community Planning Organization with financial support from the U.S. Army Corps of Engineers (*http://www.cuyahogariverrap.org/index.html*).

- Provide instream habitat treatments including pool and riffle structure, substrates, and vegetation.

- Protect excessively eroding streambanks or streambeds, especially where structures such as bridge abutments and buildings are threatened.

- Restore connectivity with the floodplain and recreate a more natural meandering stream. This is also recommended to be undertaken simultaneously with restoring habitat areas, where possible, in order to provide for the diverse habitat life history needs of fish and aquatic organisms (rearing, feeding, spawning, and refuge areas).

- Maintain water quality conditions conducive to a successful and sustainable fishery.

- Remove trash and other debris from the stream channel and adjacent riparian areas.

- Expand operation of the River skimmer boat and other clean-up programs within the Menomonee and Kinnickinnic River systems.

Potential Measures

- Stream-miles of habitat protected.

- Stream-miles of habitat created.

- Number of miles connected and functional as fish and aquatic organism habitat.

- Number of native species present or some equivalent biological indicator (see biological assessment section above).

- Tons of trash and debris removed.

- Improvements in water quality, especially as related to thermal regime, oxygen concentrations and/or fluctuations, turbidity, and chlorides.

Information Needs

Complete periodic streambank and streambed erosion assessments to identify areas for protection.

Aquatic Organisms

Aquatic Organism Target 1

Restore a sustainable fishery.

Issue

Since the early 1800s both the Menomonee River and Kinnickinnic River systems have been substantially altered through channelization, development (agricultural and urban) impacts, road construction, stormwater conveyance systems, historical fill, and other historical and present day actions that have lead to aquatic and semi-aquatic community degradation to fishes, amphibians, invertebrates, and algae.

Key Questions

- What aquatic or semi-aquatic (amphibian) communities or species are in decline or are considered rare within and adjacent to streams?

- How do the current conditions compare with reference or desired conditions, and how do these relate to human activities in the watershed?

- How might the current conditions affect future land management objectives and strategies, and what can be done to bridge the gap between current and desired conditions?

- What is the relative abundance and distribution of species of concern that are important in the watershed (Threatened or Endangered Species, Management Indicator Species, Species of Special Concern, Birds of Conservation Concern)?

- What is the distribution and character of their habitats?

- What activities could occur to improve riparian habitat conditions and improve wildlife habitat conditions?

- What needs and opportunities are there for habitat protection, maintenance, or enhancement?

Objective

The objective is to restore a sustainable fishery through the improvement of multiple aquatic and semi-aquatic communities that include fishes, invertebrates, algae, mussels, and amphibians. Although there is limited information on amphibians, mussels, or algae, these are important dimensions necessary to achieve the sustainable fishery target. The prioritization strategy is based upon the three-tiered approach as previously described and is focused on expanding the most diverse and highest-quality aquatic communities within the Menomonee and Kinnickinnic River watersheds (see Maps 5 and 8 and Table 8).

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities to restore a sustainable fishery in the Menomonee and Kinnickinnic River systems:

- Protect and expand the remaining or existing highest-quality aquatic communities (see Maps 5 and 8 and Table 8).

- Develop and implement plans for control and removal of nonnative species.

- Reintroduce native species.

Potential Measures

- Number, type, and life stages of native species observed (see "Biological Assessment" section above).

- Area cleared or tons removed of nonnative species.

Instream Monitoring and Informational Programming

Target

Continue and expand monitoring and informational programming.

Issue

Knowledge of land use and instream conditions is essential for good planning and implementation of management measures that will be both acceptable to communities and sustainable from an ecological and economic perspective. In addition, creation of awareness of the multiple values of the waterways of the greater Milwaukee watersheds is an important element of any restoration or protection effort. Without such awareness and "buy in" from communities, efforts to affect land use decisions and improve instream conditions are limited to very little, if any, success. Consequently, integration of public awareness building into the framework of interventions planned in the Menomonee and Kinnickinnic River watersheds will be a key element of the success of the ecosystem restoration projects proposed herein. Toward these ends, the following section summarizes the recommended constituents (physical, chemical, and biological) and methods to conduct existing and future monitoring efforts within both of these watersheds.

Key Questions

- Where are the existing physical, chemical, and biological monitoring points in the area?
- What are the current monitoring protocols—site locations, frequency of sampling, parameters analyzed?
- What are the opportunities for citizen monitoring and participation by schools?

Objective

The objective of the environmental monitoring activities is to document scientifically sound data and related information on the physical, chemical, and biological conditions of the Kinnickinnic and Menomonee River watersheds to guide management actions in the River systems. Scientifically sound data and related information provides the basis not only for completing the detailed engineering and technical designs of specific projects, but also provides a basis for assessing success or failure of those projects. These data form an element of the process of public knowledge-building associated with increasing public awareness of the issues facing the Kinnickinnic and Menomonee River watersheds, and provide an avenue for direct civic involvement in the design and implementation of priority projects. The goal of the monitoring projects would be to fully document the before-and-after conditions extent in the vicinity of each activity, in both the upstream and downstream flow directions and cross-river transects. While river depth and flow conditions are important considerations in determining the types and nature of the monitoring to be conducted—citizen-based or classroom-based monitoring may be appropriate in some situations where samples and data can be safely accessed without risk to volunteers or students—professional monitoring may be more appropriate for certain parameters and in situations where specialized knowledge or equipment may be required. It is envisioned that a combination of citizen monitoring and monitoring by professional staff (e.g., USGS, WDNR, MMSD, and others) would be required to document the outcomes of implementing recommended projects.

The objective of the informational programming is to enhance awareness of the values of the River systems and their tributaries as elements of the natural resource base, as vital arteries of the local neighborhoods, and as important economic resources for the communities through which the Rivers and the tributaries flow.

Restoration of naturalized systems and the reconnection of linkages between stream reaches that had been segmented by structures is not without risk. The introduction and spread of exotic invasive species, for example, continues to be a problem in the greater Milwaukee watersheds and Lake Michigan. However, to some degree, this risk remains regardless of the connectivity of stream segments and streams to Lake Michigan. Nonnative species have been, and will continue to be, introduced into inland waters of the State in the absence of direct linkages between the Great Lakes and the tributary streams. Consequently, the presence of nonnative species should not be viewed as a reason to maintain the status quo regarding connectivity of streams and lakes. For example, the removal of impediments to the movement of fish and aquatic life as in the case of the former North Avenue dam has benefited desirable species including smallmouth bass and lake sturgeon and has not resulted in the proportion of nonnative species in the Milwaukee River.

Nevertheless, the presence of nonnative species in a habitat can produce alterations in the physical and biological characteristics of the habitat. Since the early 19th century, at least 145 nonnative species, preferentially introduced into the Great Lakes through ballast water discharges from ships, have become established in the Great Lakes. Other nonnative species, such as common carp, Eurasian water milfoil, zebra mussels and purple loosestrife, have been introduced into the greater Milwaukee watersheds from other sources, and have become established in lakes and streams throughout the region. Typically, these populations can grow rapidly due to both their high reproductive capacities and the absence of predators, parasites, pathogens, and competitors in their new habitat. Once established in a waterbody, these species can rarely be eliminated, but, rather, are capable of being readily dispersed to other waterbodies. In many cases, this dispersal is aided by direct or indirect human actions; therefore, incorporation of invasive species monitoring and informational programming is an important element to be included in a monitoring program for the Menomonee and Kinnickinnic River watersheds.

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities to continue and expand monitoring and informational programming in the Menomonee and Kinnickinnic River watersheds:

- As the Menomonee River and Kinnickinnic River Watershed Restoration Plans are implemented by the Southeastern Wisconsin Watersheds Trust, Inc. (SWWT), Watershed Actions Teams (WATs), liaison with the ongoing WDNR, MMSD, and USGS monitoring programs is recommended, and modification of these programs is suggested so they can provide site-specific information on potential priority project areas within the Kinnickinnic and Menomonee River watersheds. Where appropriate, these programs should include collection, dissemination, and analysis of data on a range of parameters, including physical (stream morphological and hydrological data), chemical, and biological (fisheries and invertebrate population data) parameters. The selection of specific parameters should be guided not only by existing data collection programs, to ensure consistency and continuity of data collection, but also by the likely interventions to be considered at specific sites. Again, these data should be collected both before and after the interventions are designed and implemented. Such data will provide the basis for evaluating the effectiveness of the specific interventions and support future implementation of similar, successful actions elsewhere in the watersheds.

- Continue and expand citizen- and student-supported monitoring efforts and maintenance of inventories for fish passage, habitat, aquatic organisms, and water quality. Such efforts should be supported and integrated into the data collection and analysis process associated with the professional programs noted above. These programs form a vehicle for ongoing data collection that frequently extend beyond the specific project period, and can contribute both to enhanced civic awareness and to the education of youth.

- Identify and develop new monitoring sites in cooperation with citizen and other monitoring programs and share the knowledge with stakeholders.

- Because prevention remains the first line of defense in the protection of the ecological integrity of the waters of the Menomonee and Kinnickinnic Rivers, it is recommended that programs to reduce the spread of nonnative and invasive species as well as programs to inform and educate the public on these issues be continued and supported.

- Incorporate information from MMSD infrastructure reports (detailed information on concrete-lined channels, storm sewer outfalls, drop structures, road crossings, sanitary sewer overflow and combined sewer overflow outfalls, among others) in future inventory updates to provide the most up-to-date structure inventories.

Potential Measures

- Number of monitoring stations continued and/or established and conditions documented and shared with stakeholders.

- Amounts of invasive species removed and/or treated within a reach.

- Number of informational programs delivered.

Recreation

Recreation Target 1

Improve recreational opportunities.

Issue

The Kinnickinnic and Menomonee Rivers and their tributary streams form an important element of the natural resource base of the metropolitan Milwaukee area. The location of the Rivers within environmental corridors and open space areas provides an opportunity for people to utilize and enjoy these resources for recreational and aesthetic viewing purposes. Consequently, these resources can provide an essential avenue for relief of urban stressors among the population and improve quality of life in local neighborhoods and the entire Milwaukee area, such as identified in the Vision for the Kinnickinnic River Trail Corridor project.[15] Such uses also sustain industries associated with outfitting and support recreational and other uses of the natural environment, and, therefore, provide economic opportunities for the local communities.

Key Questions

- Where are the major human concentrations in the area?
- What are the current recreational opportunities within the watersheds?
- What are the limitations to outdoor recreation?
- What are some of the other opportunities that could be captured, such as linking trail systems, creating water trails, and connecting with businesses and attractions?
- What negative impacts may be associated with the recreational activities, and what opportunities are there to reduce those impacts?

Objectives

As embodied in the regional park and open space plan and county and local open space plans, the objective of this element is to ensure continuity of access to the water resources of the Menomonee and Kinnickinnic River watersheds, and to restore access opportunities in the Kinnickinnic River watershed as may be appropriate. Making these urban waterways an attractive and welcoming part of the open space system will enhance public awareness and commitment to these resources.

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities to improve recreational opportunities in the Menomonee and Kinnickinnic River watersheds:

- With respect to the regulation and management of fishing, boating and related land-based recreational opportunities offered in the Kinnickinnic and Menomonee River watersheds, it is recommended that current levels of enforcement be maintained and that ordinances be reviewed to determine whether canoe and kayak access is unnecessarily restricted under certain conditions.
- Promote and implement the ideas and recommendations identified within the Kinnickinnic River Corridor Neighborhood Plan such as expanding views and safe use/access to the river corridor, improving water quality and habitat for fishes and wildlife, establish riverfront activities that engage

[15] *Sixteenth Street Community Health Center*, A Vision for the Kinnickinnic River Trail Corridor, *prepared in partnership with City of Milwaukee, WDNR, National Park Service, Groundwork Milwaukee, and the University of Wisconsin-Milwaukee's Community Design Solutions program, November 2007.*

users and create a lively environment such as community gardens, enhance local neighborhood business districts, among others.[16]

- In addition, recreational boating access users should be made aware of the presence of the exotic invasive species Eurasian water milfoil, zebra mussel, and rusty crayfish among others. Appropriate signage should be placed at the public and private recreational boating sites, and supplemental materials on the control of invasive species should be made available to the public. These materials could be provided to riparian householders by means of mail drops or distribution of informational materials at public buildings, such as municipal buildings and public libraries, and to nonriparian users by means of informational materials provided at the entrance to all municipal public recreational boating access sites.

- Make disposal bins available at the public recreational boating access sites for disposal of plant materials and other refuse removed from watercraft using the public recreational boating access sites.

- Additionally, the rivers, their associated parkways, and proximity to other economic and cultural resources of the metropolitan Milwaukee area provide further opportunities for linking watersheds through both land-based and water-based trails (see Maps 15 and 16). Connecting these landscape features through an integrated system of roads, trails, paths, and waterways will further bolster the need for services, including services such as hostelries, restaurants, and entertainment, as well as outlets for supplies and maintenance. All of these services, in turn, provide outlets for informational programming materials that will build awareness of the value of the natural environment to the region, and create a base for citizen and stakeholder action to underpin the needed investments in ecosystem management. Therefore, it is recommended that opportunities to form a continuous riverfront trail system be pursued.[17]

- Build landowner relationships and seek conservation easements, land donation, or land purchase within the recommend priority lands indentified on Maps 13 and 14 within the Menomonee River and Kinnickinnic River watersheds, respectively.

- Where feasible, and subject to land access considerations related to the efficient movement of vehicles and trains and the provision of emergency services, consider removal of bridges or other navigational hazards to reduce the risk of injury and/or fatalities due to recreation.

- Consider removal of low-clearance bridges or dangerous abutments and other navigational hazards to improve recreational opportunities and safety within the Rivers.

- Consider signage to advise boaters of obstructions and/or other safety hazards.

- Design and install trail connections and interpretive signs to identify habitat types, trials, canoeing, and fishing access areas.

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[16]*The Milwaukee Metropolitan Sewerage District with Sixteenth Street Community Health Center,* Kinnickinnic River Corridor Neighborhood Plan, *prepared by JJR, PDI/Graef, Beth Foy and Associates, and Gladys Gonzalez of ¡Pa'lante! Creative, LLC., final draft October 2009.*

[17]*SEWRPC Memorandum Report No. 152,* A Greenway Connection Plan for the Milwaukee Metropolitan Sewerage District, *December 2002; and Kristen Wilhelm and Jason Schroeder,* River Revitalization Foundation's Menomonee River Mainstem Land Protection Plan 2008-2009, *2009.*

Potential Measures

- Number of facilities maintained or added for public access to streams
- Miles of trials established or managed
- Numbers of signs installed to identify unsafe navigational hazards, number of navigational hazards removed or retrofitted, number of new public access sites or facilities created, number of informational signs installed
- Number of safe recreation days, number of areas identified as safe for recreation, number of safe exits constructed in confined channels
- Number of trash and debris accumulation locations identified, improvement of trash and debris accumulation points in the watershed, and tons of trash and debris collected and disposed of

SAMPLING PARAMETERS AND METHODOLOGIES

The land use, surface water quality, and auxiliary elements of the recommended plan set forth in PR No. 50 contain proposed actions which, when combined with the refined targets and actions described in this report, should enhance and/or help preserve the surface water quality and biological quality of the streams in both the Menomonee and Kinnickinnic River watersheds. It is also important that steps be taken to ensure the existence of a sound program of water quality monitoring to determine the extent to which physical, chemical, and biological conditions are improving over time, to measure temporal and spatial trends, to provide data to evaluate the effectiveness of water pollution control measures, and to detect new and emerging water quality problems. It is important that such a monitoring program integrate and coordinate the use of scarce monitoring resources of multiple agencies and groups, generate monitoring data that are scientifically defensible and relevant to the decision-making process, and manage and report water quality data in ways that are meaningful and understandable to decision makers and other affected parties. As summarized in the "Existing Water Quality Monitoring Information" section in Chapter II of this report, water quality monitoring is well-established within both the Menomonee River and Kinnickinnic River watersheds. Therefore, the following section summarizes the recommendations related to habitat and biological monitoring parameters and methods to conduct existing and future monitoring efforts within both of these watersheds.

Habitat Assessment

It is essential to the proper evaluation of potential habitat improvements or impacts that physical, chemical, and biological monitoring data be collected. The habitat methodologies should include consideration of both key chemical and physical parameters and biological response parameters within the streams of the Menomonee and Kinnickinnic River watersheds. Assessments should be consistent with protocols for characterizing habitat conditions used by both the WDNR and USGS.[18] In addition to these quantitative habitat methods, there are qualitative fish habitat rating methods developed by the WDNR for small (less than 10 meters, or about 30 feet, in width) and large (greater than 10 meters in width) wadable streams (see data sheets in Appendix E). Although these qualitative methods do not provide as much information as the quantitative methods, they do provide very useful supplemental information, are much less time consuming to complete, and may provide an easy methodology for volunteer monitoring.

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[18]*U.S. Geological Survey, "Protocol for Characterizing Habitat," Water Resources Investigations Report 98-4052; Wisconsin Department of Natural Resources, "Guidelines for Evaluating Habitat in Wadable Streams," June 2000; L. Wang and others, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management, *Volume 18:775–785, 1998; and T.D. Simonson and others, "Guidelines for evaluating fish habitat in Wisconsin Streams," U.S. Department of Agriculture, General Technical Report NC-164, 1994.*

In addition to the more traditional methodologies summarized above, there are newly emerging monitoring procedures such as the Center for Watershed Protection's Unified Stream Assessment methodology for urban river systems.[19] These methodologies go beyond the traditional methods and incorporate important elements such as stormwater outfalls, severe erosion, impacted buffers, utilities, trash and debris, and stream crossings. These methodologies, or some equivalent, should be a part of the long-term monitoring strategies for the Menomonee and Kinnickinnic River watersheds. Fish passage assessment at roadway crossings is becoming recognized as one of the most fundamental potential limiting factors in urban watersheds, which is why it is vital to include assessment protocols that address passage at road crossings into monitoring programs for these watersheds (see proposed draft fish passage assessment protocols developed by The Nature Conservancy in Appendix D). The U.S. Environmental Protection Agency (USEPA) Causal Analysis/Diagnosis Decision Information System (CADDIS) is a tool for identifying stressors causing biological impairments in aquatic ecosystems. CADDIS is an online application that helps scientists and engineers find, access, organize, use and share information to conduct causal evaluations in aquatic systems. It is based on the USEPA Stressor Identification process, which is a formal method for identifying causes of impairments in aquatic systems.

The amount of impervious surface and tributary area land uses are extremely important to consider in a long-term monitoring program. These estimates form the basis for pollutant modeling, tracking trends in land use changes, and identifying opportunities. SEWRPC staff is scheduled to initiate a revised land use update for the entire seven county Southeastern Wisconsin Region in 2010. When completed, the updated existing land use information should be incorporated into the monitoring program assessment for both the Menomonee and Kinnickinnic River watersheds. For example, this could involve comparison of existing and historical land use over time and the effect on habitat of changes over time and prioritization of open lands for acquisition, and it could relate to the selection of sites to monitor.

Biological Assessment

Biological assessments using existing WDNR protocols or some equivalent are recommended to be conducted for fishes and invertebrates to characterize the aquatic community. [20] Where possible these biological assessments should be conducted at the same monitoring stations where habitat data are collected. Consistent with the recommendations of PR No. 50, the initial habitat and biological monitoring stations should be established at existing long-term USGS streamflow and water quality gages. Fisheries surveys should target collection of the entire fish assemblage. Diatoms (microscopic algae) also are good indicators for habitat evaluations, but limited data exists within the Menomonee and Kinnickinnic River systems.

There are a large number of potential parameters and/or indices that could be used to measure biological community quality, however, some of the key recommended constituents are listed below.

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[19]*Center for Watershed Protection, Urban Subwatershed Restoration Manual No. 11,* Unified Subwatershed and Site Reconnaissance: A User's Manual Version 1.0*, March 2004.*

[20]*Wisconsin Department of Natural Resources, "Guidelines for Assessing Fish Communities of Wadable Streams in Wisconsin," June 2000; W.L. Hilsenhoff, "An improved index of organic stream pollution,"* Great Lakes Entomology*, Volume 20, pages 31-39, 1987; and W.L. Hilsenhoff, "A modification of the biotic index of organic stream pollution to remedy problems and to permit its use throughout the year,"* The Great Lakes Entomologist*, Volume 31, pages 1-12, 1998.*

Fisheries
Species richness
Total abundance
Shannon's diversity index[21]
Warmwater Index of Biological Integrity (IBI)[22]
Number and proportion of native species
Number and proportion of nonnative species
Number and proportion of species intolerant to pollution
Number and proportion of species tolerant to pollution
Number of species and individuals, native species, predator fish; and number of fish in certain groups, such as sunfishes, suckers, darters, and other groups
Intermittent Index of Biological Integrity (IBI)[23]
Cool and warmwater transitional fish species[24]

Invertebrates
Counts by genera
Counts by family
Ephemeroptera-Plecoptera-Trichoptera (EPT) Index
Hilsenhoff Biotic Index (HBI)
Invertebrate Index of Biotic Integrity (IBI)[25]
Number and proportion of EPT genera
Shannon's diversity index

Algae
Algal metrics including tolerance indices and relative-abundance[26]

In addition to the selected indices listed above, there are numerous other physical, chemical, water quality, toxicity, and biological parameters that have been identified to be important indicators within urbanizing watersheds in Wisconsin based upon recent USGS research under the National Water Quality Assessment

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[21] *J.E. Brower, Jerrold H. Zar, and Carl N. von Ende,* Field and Laboratory Methods for General Ecology, *Third Edition, Wm. C. Brown Publishers, Dubuque, Iowa, 1989; Robert E. Ricklefs,* Ecology, *Second Edition, University of Pennsylvania, Chiron Press, New York, New York, 1979.*

[22] *J. Lyons,* Using the Index of Biotic Integrity to measure environmental quality in warmwater streams of Wisconsin, *U.S. Forest Service General Technical Report NC-149, 1992.*

[23] *J. Lyons, "A fish based Index of biotic integrity to assess intermittent headwater streams in Wisconsin, USA,"* Environmental Monitoring and Assessment, *Volume 122: 239-258, 2006.*

[24] *J. Lyons, "Defining and characterizing coolwater streams and their fish assemblages in Michigan and Wisconsin, USA,"* North American Journal of Fisheries Management, *Volume 29: 1130-1151, 2009.*

[25] *Brian Weigel, "Development of stream invertebrate models that predict watershed and local stressors in Wisconsin",* Journal of the North American Benthological Society, *Volume 22(1):123–142, 2003.*

[26] *Herman Van Dam, Adrienne Mertens, and Jos Sinkeldam, "A coded checklist and ecological indicator values of freshwater diatoms from The Netherlands,"* Journal of Aquatic Ecology, *Volume 28(1), pages 117-133, 1994.*

Program.[27] These parameters also should be considered as part of the ongoing and future monitoring programs within the Menomonee and Kinnickinnic River watersheds.

Hydrological Assessment

Several important hydrological constituents summarized below have been identified by USGS staff, [28] based upon recent research related to the effects of urbanization on stream ecosystems among 30 sites in nine metropolitan areas around the country, including one location in the Milwaukee metropolitan area. In general, the Flashiness Index, which reflects the frequency and rapidity of short terms changes in streamflow in response to rainfall events,[29] correlates well to the Fish IBI metric. For example, a Flashiness Index above a certain threshold may cause the IBI (fish) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) (invertebrate) metrics to decrease (degrading stream condition). In addition, average flow magnitude, high flow magnitude, high flow event frequency, high flow duration, and rate of change of stream cross-sectional area are the hydrological variables most consistently associated with changes in algal, invertebrate, and fish communities. Wet weather sampling protocols have also been identified as important to incorporate into a monitoring program for these watersheds (see SEWRPC PR No. 50 and Appendix F).[30] Finally, hydraulic shear stress in a stream reach is an important factor to evaluate. If the reach is in an area that is prone to more scouring effects, suspended solids increase and more filter feeding invertebrates would usually be found in this location. If the reach is in an area that has less scraping effects, the suspended solids are reduced and more gathering type invertebrates would be expected in the reach.[31]

Additional Monitoring and Evaluation Parameters to Consider

There are many important water quality constituents, including metals and nutrients, that are currently monitored and/or recommended to be monitored in the Menomonee and Kinnickinnic River watersheds (see SEWRPC TR No. 39 and PR No. 50). However, there are a number of potential nontraditional measures besides improvements in dissolved oxygen, total phosphorus, or temperature that are equally important and should be incorporated into a monitoring and evaluation program. These measures are a mixture of direct physical improvements to the channel and land- and water-based recreation. Since it may be very difficult to actually demonstrate a direct improvement in water quality from an activity such as the purchase of lands to enhance a riparian buffer at one site, it remains important to identify some type of measure of achieving the goal of improved water quality. In this case, the amount of land purchased could be a good indicator of implementation for the protection and improvement of water quality. To this end, several measures are recommended to be considered in evaluating progress toward watershedwide habitat improvement. A monitoring and evaluation program should consider: improvements in wet weather and dry weather water quality; increase in number of safe recreational days; volume of contaminated

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[27]*Kevin D. Richards, Barbara C. Scudder, Faith A. Fitzpatrick, Jeffery J. Steuer, Amanda H. Bell, Marie C. Peppler, Jana S. Stewart, and Mitchell A. Harris,* Effects of Urbanization on Stream Ecosystems Along an Agriculture-to-Urban Land-use Gradient, Milwaukee to Green Bay, Wisconsin, 2003-2004, *Scientific Investigations Report 2006-5101-C, U.S. Geological Survey, Reston, Virginia, 2008.*

[28]*Personal Communication with U.S. Geological Survey staff, including Barb Scudder, Dave Graczyk , Jeff Steuer, Peter Hughes, and Morgan Schneider.*

[29]*D.B. Bake, and others, "A new flashiness index: characteristics and applications to Midwestern rivers and streams",* Journal of the American Water Resources Association*, Volume 40(2): Pages 503-522, April 2004.*

[30]*Water Environment Research Foundation (WERF) Publication: Protocols for Studying Wet Weather Impacts and Urbanization Patterns by L. A. Roesner, and others (WERF Stock # 03WSM3)*

[31]*Personal Communication with U.S. Geological Survey staff including Barb Scudder, Dave Graczyk , Jeff Steuer, Peter Hughes, and Morgan Schneider.*

sediment removed; ordinances developed or setbacks established to promote riparian buffers; length of concrete channel lining removed and stream restored; length of channel enclosure removed; length of streambank stabilized; amount of riparian buffer expanded, purchased, donated, protected, or established; length of trash-free stream reaches; area of historical fill removed; stream length with safe fishing and canoeing conditions; number of fish passage obstructions removed or retrofitted; length of channel connected to Lake Michigan, mainstem, or high-quality area; and improvement of habitat quality ratings.

ANCILLARY RECOMMENDATIONS

In addition to the numerous recommended actions and potential projects identified in the sections above, there are an unlimited number of additional potential actions that SWWT WAT members could undertake, but that do not necessarily fit within the confines of the targets identified. To that end, the following list of ideas or examples are intended to help share ideas from past projects or experiences that have been successful in protecting the environment.

- Provide input to municipal plan commissions on land use decisions affecting the Rivers.

- Maintain a geographic information system database of existing projects to monitor and improve water quality. For example, riparian buffer width changes through purchase or easements or other types of agreements.

- Maintain contact with State, county and local elected officials and inform them of concerns regarding protection of the Rivers and associated tributaries. Consider introduction of a program such as the Rock River Coalition "Send your Legislator Down the River" awareness program.

- Encourage inclusion of river-oriented curricula in local schools. Promote river monitoring and storm drain stenciling in cooperation with community organizations such as the Urban Ecology Center.

- Share inventory information with MMSD, WDNR, and SEWRPC to incorporate into planning documents.

- Consider establishment of demonstration projects on WAT members' properties. Encourage implementation of demonstration projects or sustainable landscaping in public parks.

- Create and erect signage identifying watershed boundaries or stream crossings on local roadways with appropriate permission.

- Develop and distribute newsletters at municipal buildings and public libraries. Also consider distributing recycled paper placemats containing river access points and activities of interest, to local restaurants.

- Create a recreational opportunity map showing locations such as access points, parks, viewing areas for bird watching and watching salmon runs (seek sponsorship of publication cost from businesses or agencies).

- Sponsor a poster, photograph, essay, or video contest to promote awareness and protections of the Rivers and their watersheds. Solicit prizes and support from community businesses and/or service organizations.

- Identify activities appropriate to community youth and service organizations and share these with the leadership of these groups (e.g., Eagle Scout projects, community garden projects)

- Promote synergies with existing community activities and organizations such as recycling, public health, project clean sweep, among others. Develop partnerships with the Wisconsin Department of Tourism and local tourism outlets and offices to promote river-oriented outdoor recreation. Partner with local businesses (e.g., bike shops, canoe liveries, ice cream parlors).

- Develop a “River Day” annual event to promote awareness of the ongoing efforts to protect and enhance fisheries and recreation. Encourage public access television stations to develop, obtain, and screen programs related to the natural history of the specific rivers.

- Compile an oral and/or photographic history of the rivers in partnership with County historical societies. Sponsor a river oriented display in community centers and libraries focused on local neighborhoods.

- Develop a revolving grant program to support various activities to protect and enhance water quality throughout the watersheds similar to the program created by the Root-Pike Water Initiative Network (WIN).

SUMMARY AND SYNTHESIS

This report represents a refinement of the habitat-related data and recommendations of the SEWRPC regional water quality management plan update for the greater Milwaukee watersheds (PR No. 50), specifically including fishery, invertebrate, and habitat data gathered from completion of that plan up to the year 2009. Therefore, the recommendations summarized in this memorandum assume that progressing toward achievement of designated and recommended water use objectives and criteria as recommended in PR No. 50 is a high priority action. The preservation and maintenance of well-functioning habitat within the Menomonee and Kinnickinnic River watersheds are closely associated with the continued improvement of water quality.

Maintenance and improvement of habitat for fish and aquatic organisms in the Kinnickinnic and Menomonee River watersheds is important to the quality of life of the residents of the greater Milwaukee area. The provision of fish and aquatic life passage is closely linked with the restoration and re-creation of instream and riparian habitat. This habitat provides not only refuges for fishes and aquatic life, but also forms feeding and breeding areas necessary for the survival of these organisms. Shoreland habitat, in the form of vegetated buffers, contributes to the natural ambience of the river systems and their tributaries, and provides important ecosystem functions related to flood mitigation, groundwater recharge, water quality enhancement, and terrestrial wildlife. Reconnection of the rivers and streams to their floodplains provides ecological benefits and helps to protect and promote human activities in the watersheds, limiting flood damage and promoting good public health, while at the same time enhancing the visual landscape and providing the human inhabitants with recreational opportunities, including angling, boating, and scenic viewing opportunities. Protection of the lands indicated on Maps 13 and 14 through appropriate zoning provisions, purchase, and/or acquisition of easements as opportunities arise is an important aspect of the land-based and instream-based prioritization strategies developed to protect the Kinnickinnic and Menomonee River watersheds. These prioritization strategies are based upon the main premise of protecting the existing quality areas—either within water or on land—and expanding those areas through reconnection of streams and land to reduce fragmentation. Ultimately, these actions will not only ensure progress toward achievement of the fishable and swimmable goals of the Federal Clean Water Act, but also enhance the quality of life of the resident populations of these watersheds and their visitors.

Continued monitoring of aquatic (physical, chemical, biological) and terrestrial conditions is an essential component of both the land-based and instream-based priority actions in order to document achievement of objectives set forth in PR No. 50 and to refine the objectives as necessary as remedial measures are implemented.

Priority Actions to Improve Habitat
Within the context described above, the following groups of management measures represent critical priorities for action to protect and enhance land-based and instream-based habitat within the Menomonee and Kinnickinnic River watersheds.

Land-based habitat recommendations:

1. Protect and expand riparian buffers with a priority on reducing fragmentation through linking public, private, and other protected lands.

2. Control stormwater quantity to reduce flashiness and improvement of stormwater runoff quality to moderate contaminant loads including nutrients, metals, salts (chloride), among others.

3. Manage terrestrial diversity through control of exotic invasive species and introduction of native plantings.

Instream-based habitat recommendations:

1. Restore fish and aquatic organism passage to enhance connectivity with Lake Michigan.

2. Protect and enhance instream habitat through stabilization of areas with excessive bank and bed erosion; removal of concrete and restoration of stream hydrology dynamics, subject to satisfying floodland management objectives; and reconnection with floodplain.

3. Management of aquatic diversity through supplemental stocking, control of exotic invasive species, and continued habitat improvement (e.g., floodplain or reef spawning areas, juvenile rearing areas, native and/or critical species reintroduction).

In addition, based upon the analysis and the critical priority actions set forth above, specific management actions within each of the watersheds are described below.

Kinnickinnic River Watershed

- Fisheries enhancement projects within KK-11 should consider habitat re-creation to provide for fish spawning, juvenile rearing, and refuge and feeding areas. Habitat restoration methods could include provision of spawning reefs that have been successfully established by WDNR staff within and adjacent to the Milwaukee Harbor estuary as well as potential use of emerging technologies, such as the Cuyahoga Habitat Underwater Baskets (CHUBs) pioneered by the Cuyahoga River Community Planning Organization with financial support from the U.S. Army Corps of Engineers (*http://www.cuyahogariverrap.org/index.html*).

- Removal of concrete within the downstream reaches of the mainstem (beginning in KK-10 and continuing through KK-3 from downstream to upstream) should precede any other habitat improvement projects within this watershed. This concrete removal should utilize the experience and lessons learned from the MMSD Underwood Creek project which integrated floodplain mitigation and fisheries habitat improvements (see photo).

- Rehabilitation of instream and riparian habitat within the eroding portions of the mainstem within KK-3. Actions required could include land acquisition for buffer expansion, bed and streambank protection measures, and fisheries habitat improvements.

Menomonee River Watershed

- Removal of approximately 3,800 linear feet of concrete (within reach MN-18) in the vicinity of W. Wisconsin Avenue and IH 94 to reestablish fish passage to upstream reaches from Lake Michigan while continuing to provide protection of development from floods. This rehabilitation should include provisions for low-flow fish passage through a series of pools and riffles. In addition, the side slopes and retaining walls should be removed and regraded, where possible. This project should utilize the experience and lessons learned from the Underwood Creek rehabilitation project, which integrated floodplain mitigation and fisheries habitat improvements.

- Removal and/or retrofitting of five low-head structures along the Menomonee River between Swan Boulevard and Harmonee Avenue (within Reach MN-17A). These structures consist of three sewer crossings, one abandoned road, and one grade control structure. Rehabilitation of riparian and instream habitat should also be undertaken as part of this removal. It is recommended that concrete associated with these structures be removed from the stream channel or floodplain where possible.

Kinnickinnic and Menomonee River Watersheds

- Continued expansion of recreational trails and creation of linkages between these recreational trails and regional recreational trails.

- Continued expansion of trash and debris cleanup efforts and programs within waterways and associated riparian lands.

- Development of demonstration projects to promote newly emerging technologies such as green roofs, bio-retention, and porous pavement to promote both water quality improvement and peak flow improvements (reduction in flashiness) throughout the watershed.

MAPS

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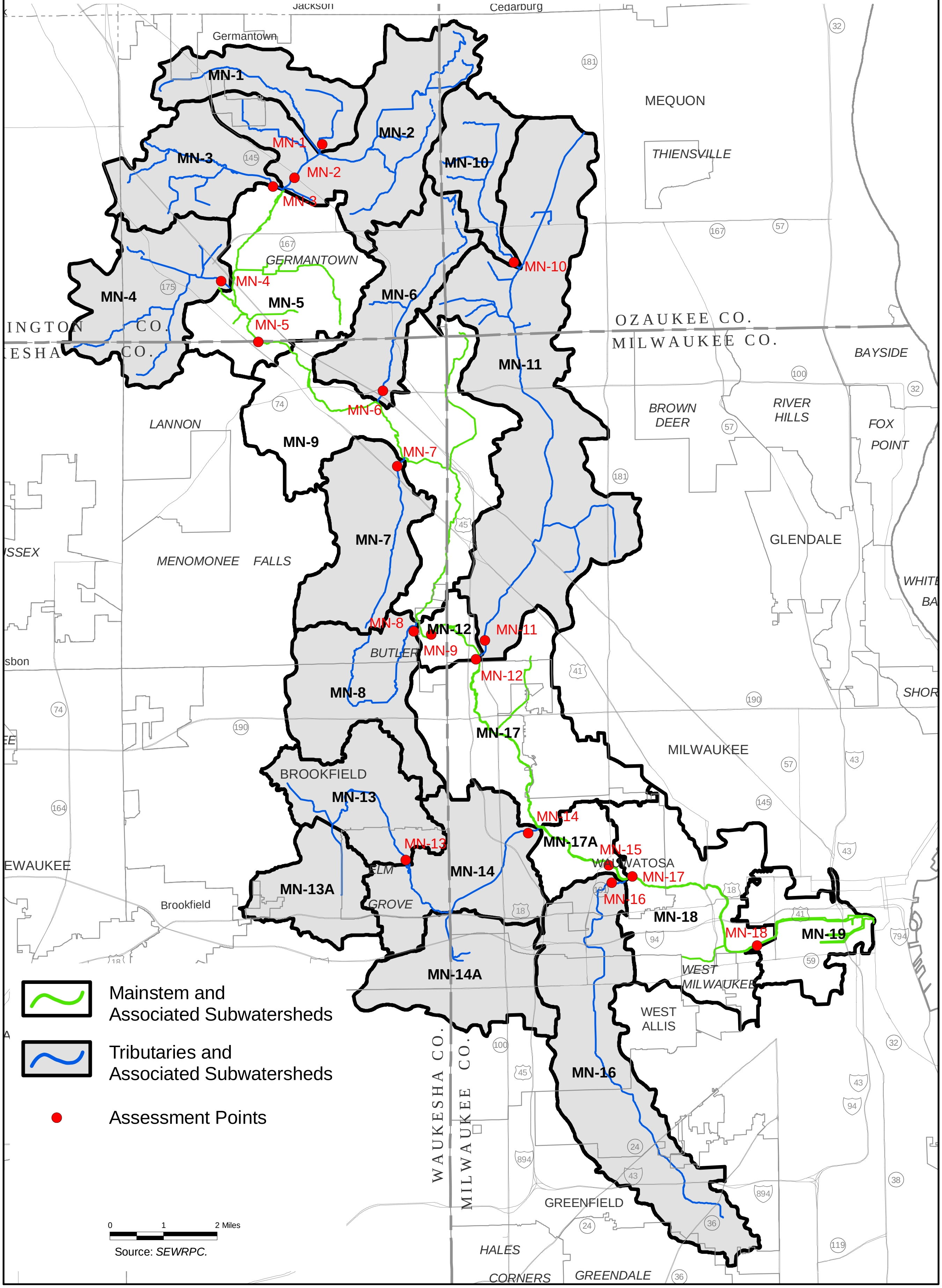
Map 1

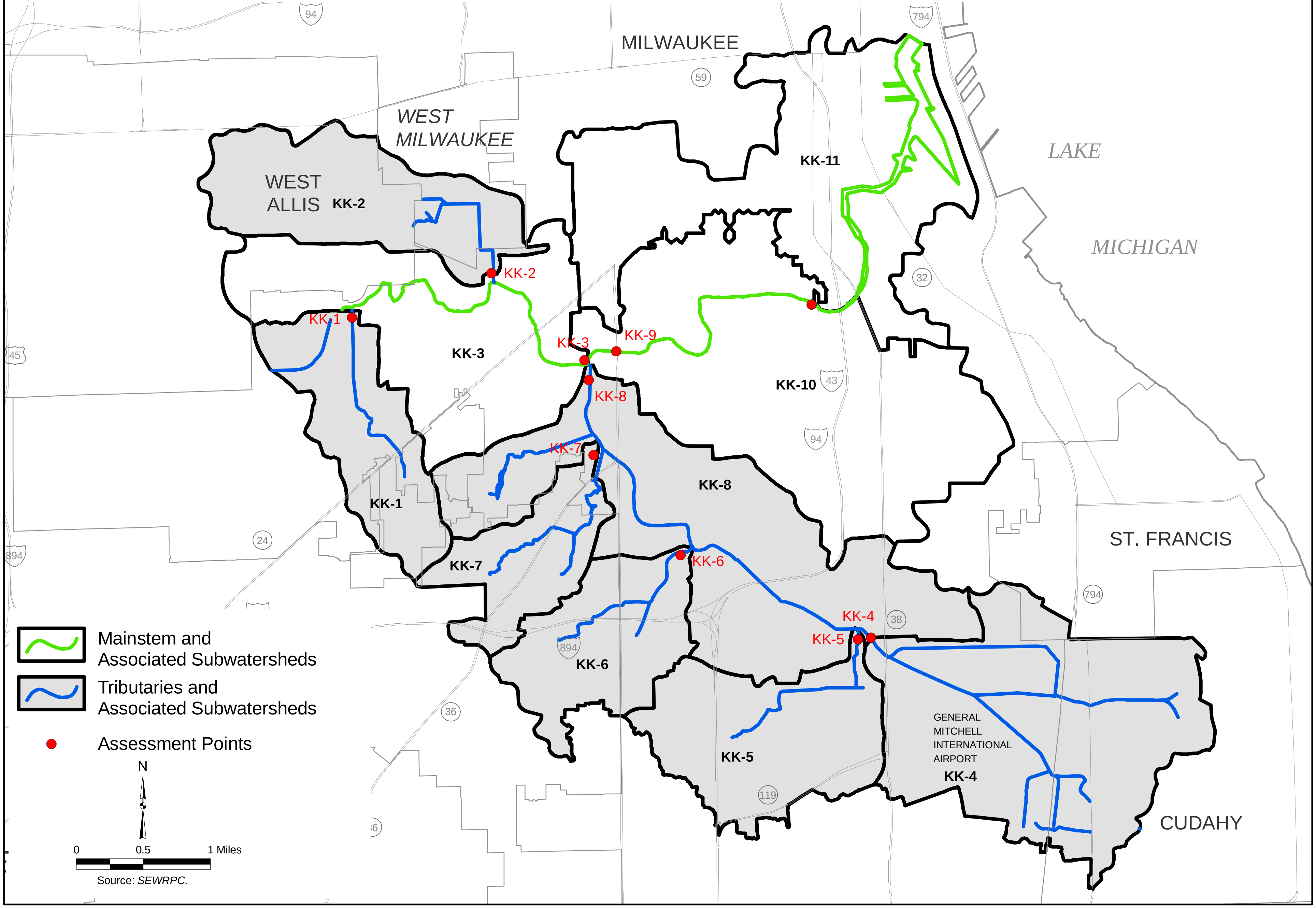
MAINSTEM REACHES, TRIBUTARY REACHES,
AND ASSESSMENT POINTS WITHIN THE MENOMONEE RIVER WATERSHED: 2009



Source: *SEWRPC.*

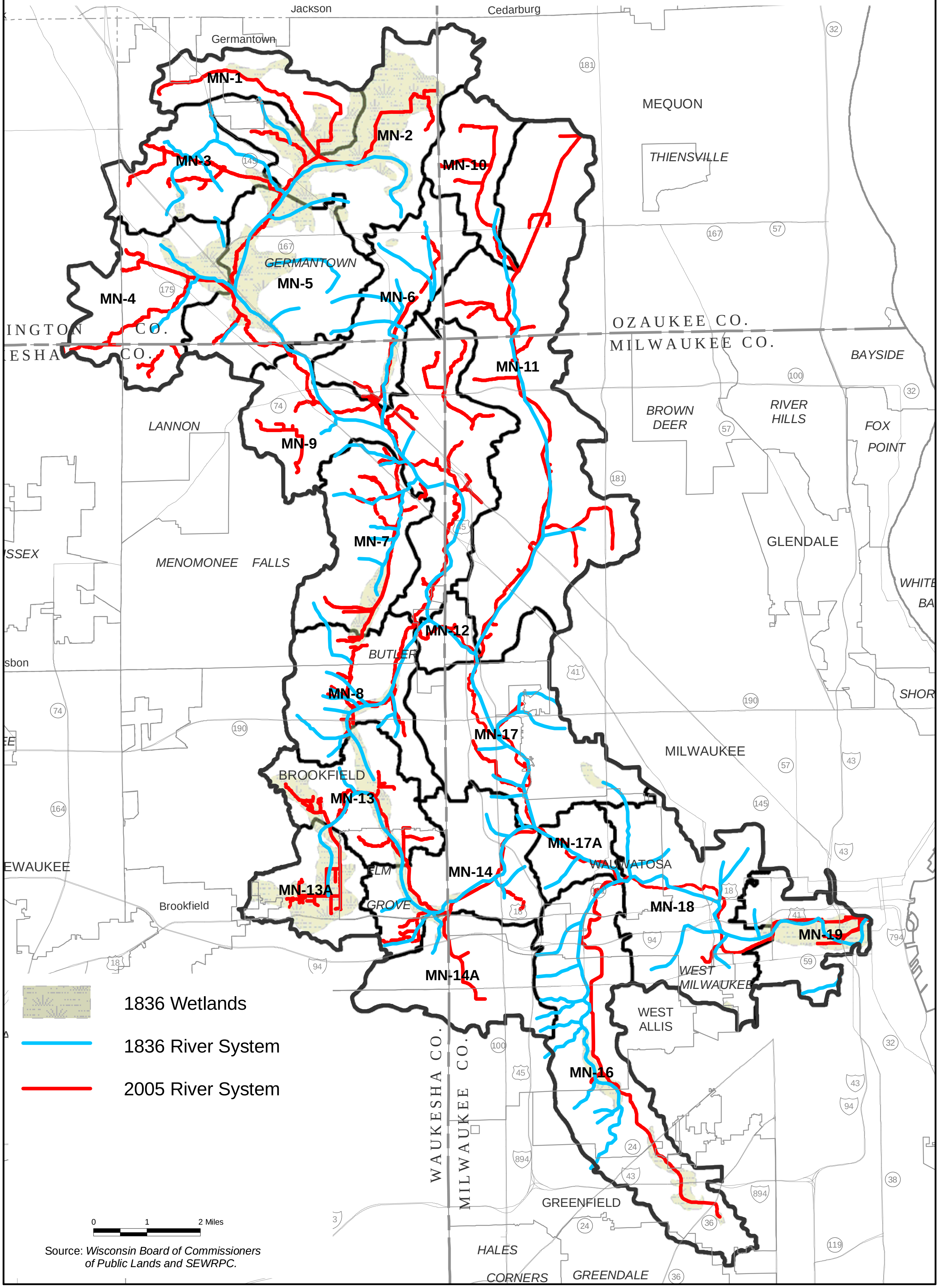
Map 2

MAINSTEM REACHES, TRIBUTARY REACHES, AND ASSESSMENT POINTS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2009



Map 3

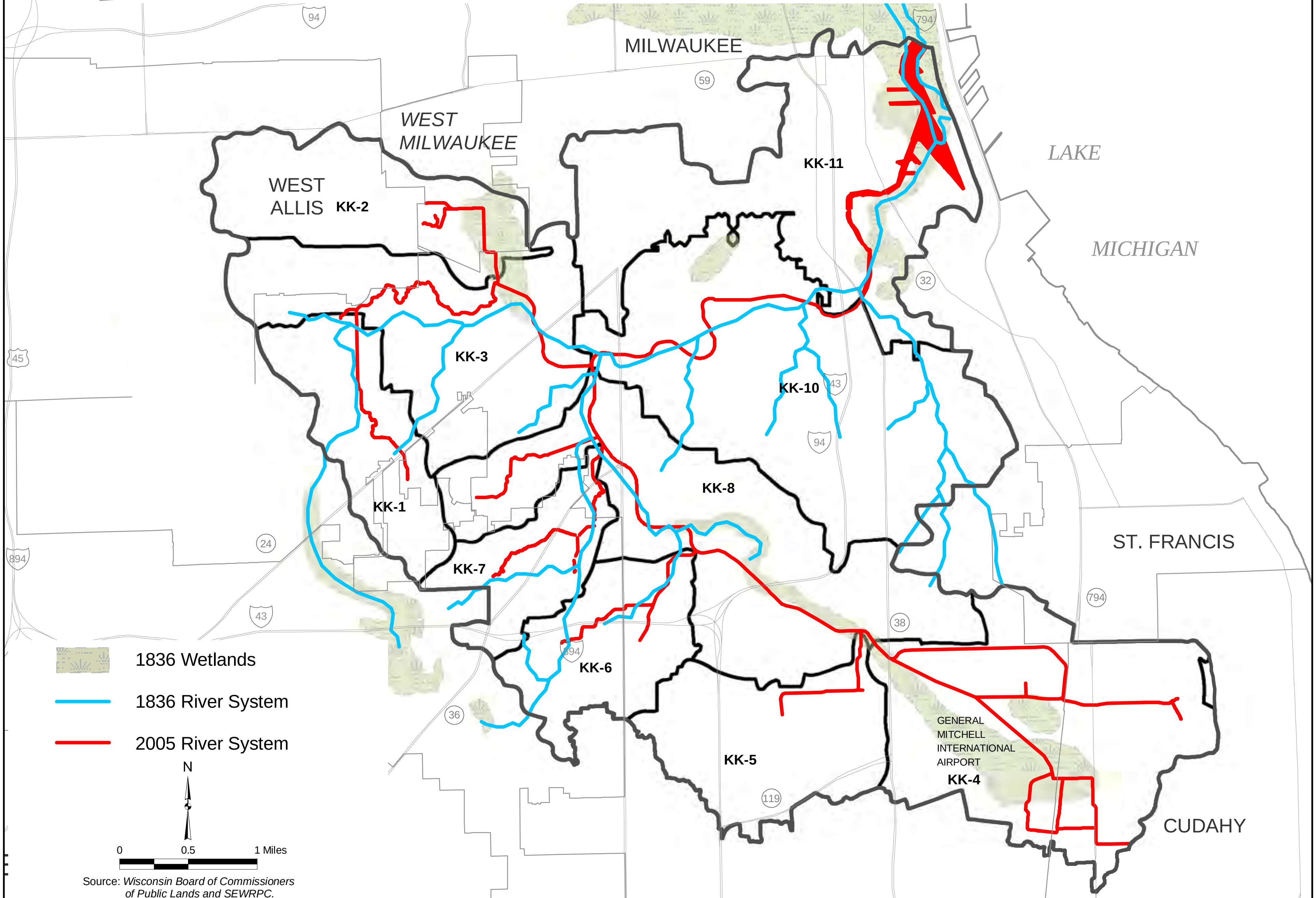
HISTORICAL VERSUS CURRENT STREAM CHANNEL ALIGNMENTS WITHIN THE MENOMONEE RIVER WATERSHED: 1836 AND 2005



Source: *Wisconsin Board of Commissioners of Public Lands and SEWRPC.*

Map 4

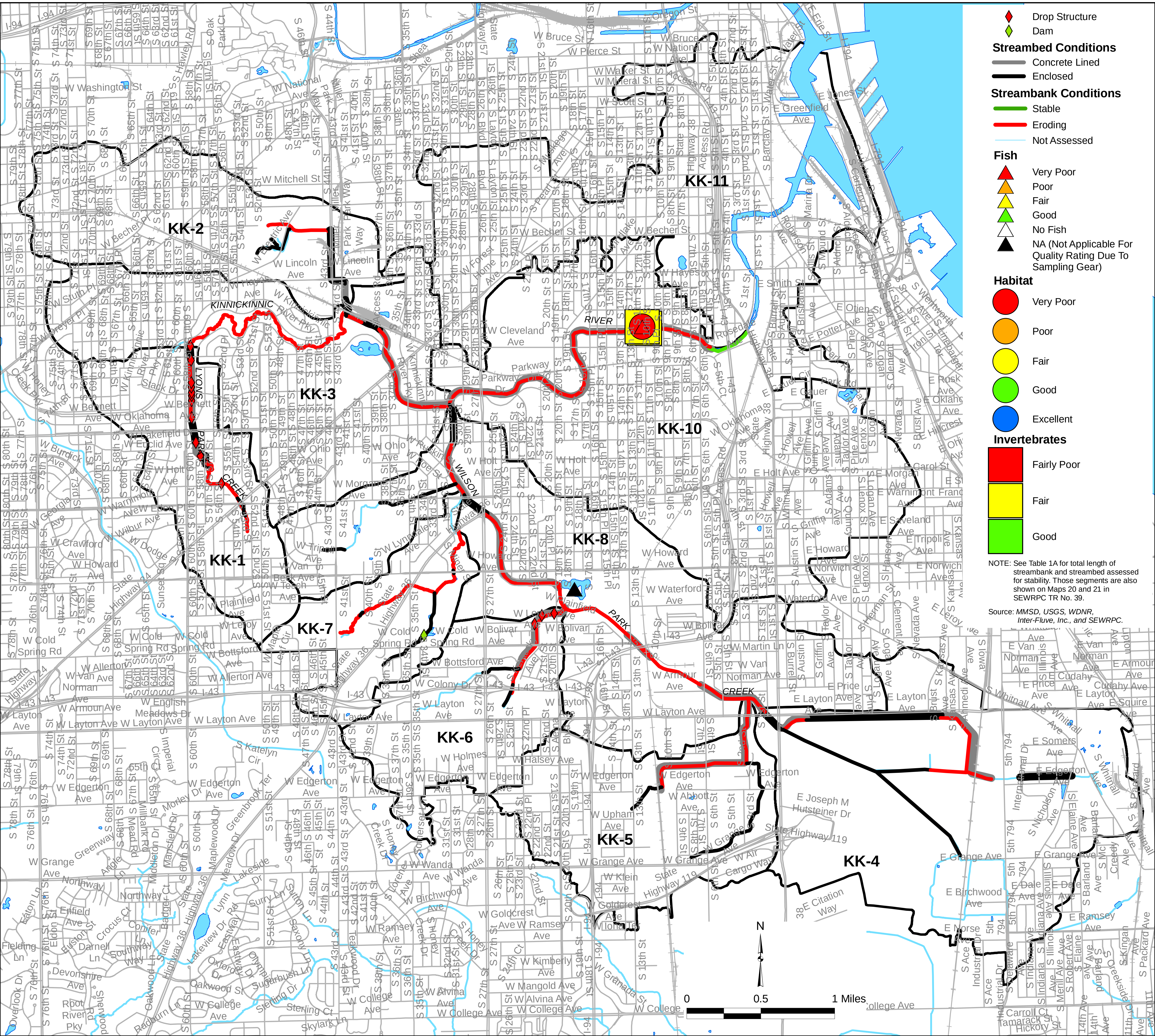
HISTORICAL VERSUS CURRENT STREAM CHANNEL ALIGNMENTS WITHIN THE KINNICKINNIC RIVER WATERSHED: 1836 AND 2005



Source: *Wisconsin Board of Commissioners of Public Lands and SEWRPC.*

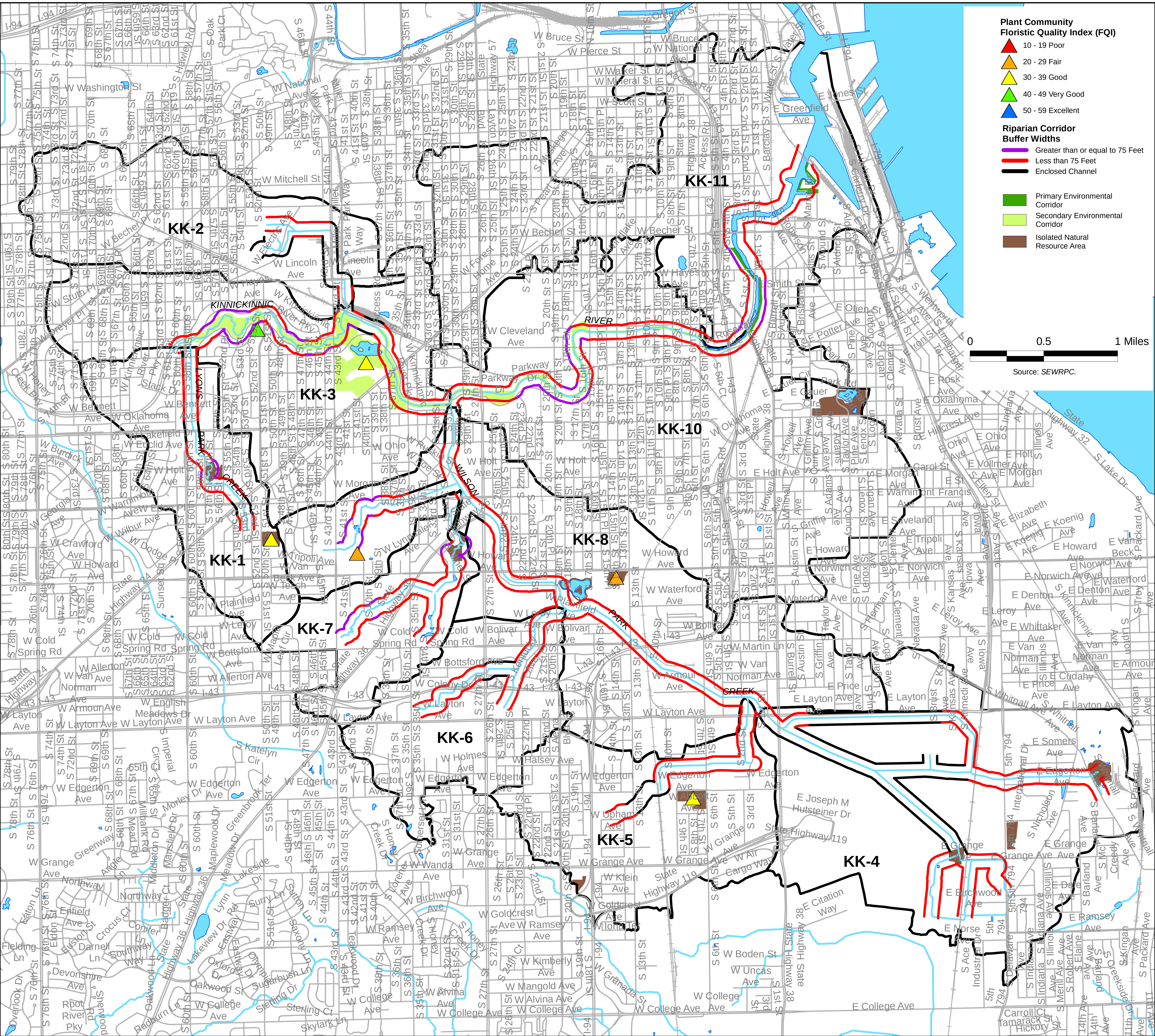
Map 5

STREAM CHANNEL AND BIOLOGICAL QUALITY CONDITIONS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000-2009



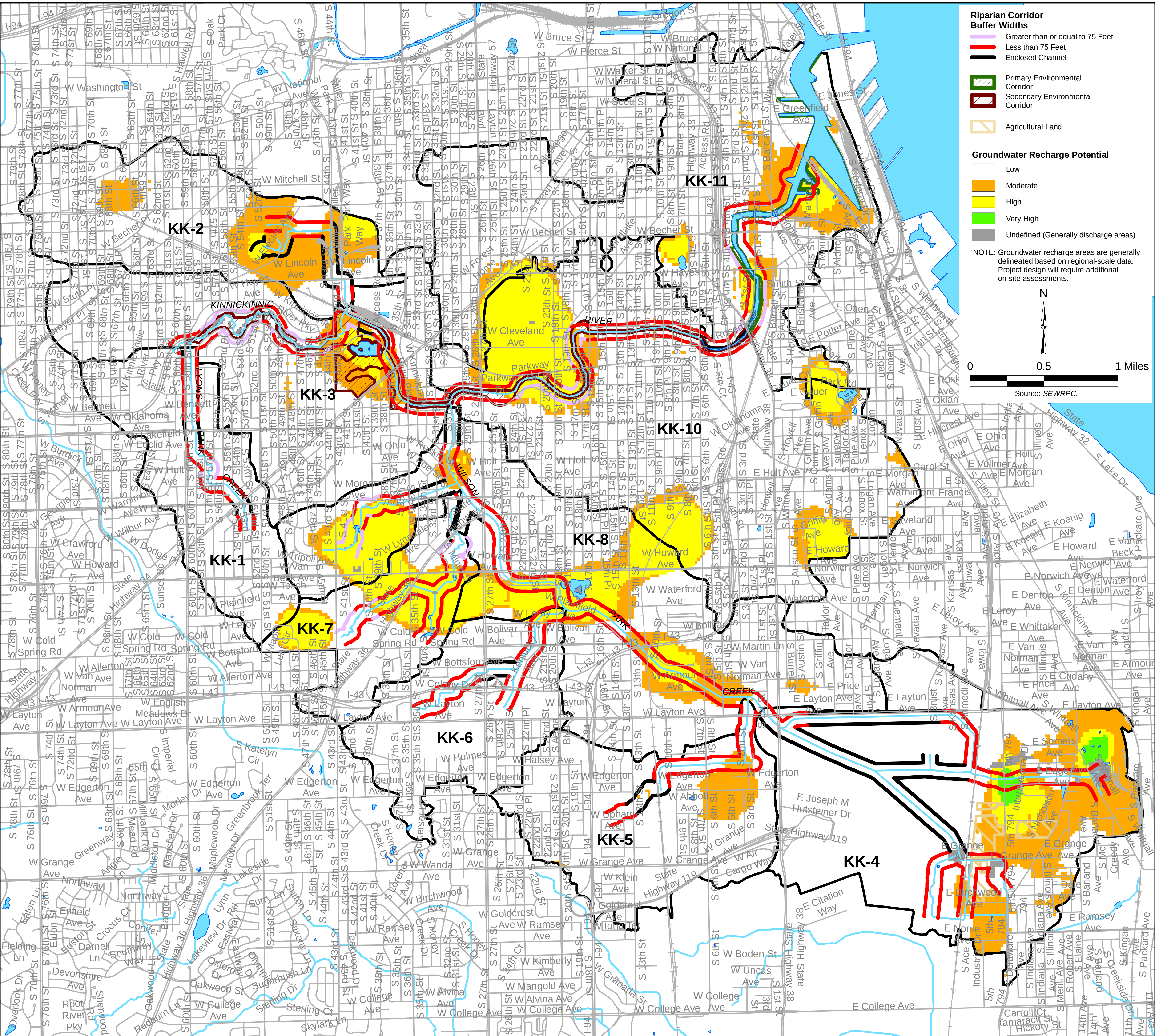
Map 6

RIPARIAN CORRIDOR AND PLANT COMMUNITY CONDITIONS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2009



Map 7

RIPARIAN CORRIDOR CONDITIONS AND GROUNDWATER RECHARGE POTENTIAL WITHIN THE KINNICKINNIC RIVER WATERSHED: 2009



Map 8

STREAM CHANNEL AND BIOLOGICAL QUALITY CONDITIONS WITHIN THE MENOMONEE RIVER WATERSHED: 2000-2009

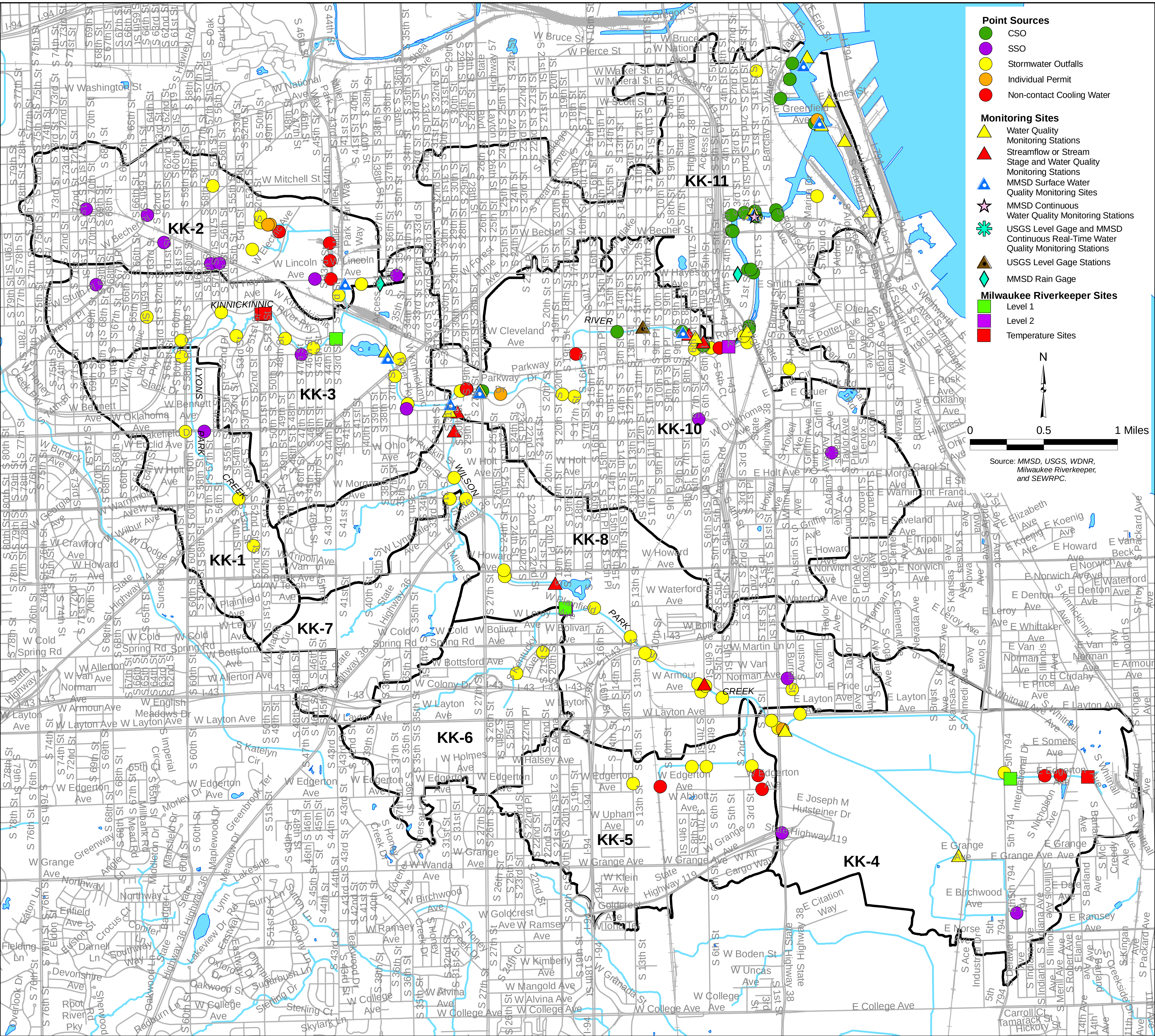

Map 9
RIPARIAN CORRIDOR AND PLANT COMMUNITY CONDITIONS
WITHIN THE MENOMONEE RIVER WATERSHED: 2009
Plant Community
Floristic Quality Index (FQI)
10 - 19 Poor
20 - 29 Fair
30 - 39 Good
40 - 49 Very Good
50 - 59 Excellent
Riparian Corridor
Buffer Widths
Greater than or equal to 75 Feet
Less than 75 Feet
Enclosed Channel
Primary Environmental Corridor
Secondary Environmental Corridor
Isolated Natural Resource Area
0
0.5
1 Miles
Source: SEWRPC.
NORTH BRANCH MENOMONEE RIVER
GOLDENTHAL CREEK
WILLOW CREEK
MENOMONEE RIVER
NOR-X-WAY CHANNEL
LITTLE MENOMONEE RIVER
DRETZKA PARK CREEK
PARK NOYES CREEK
LILLY CREEK
BUTLER DITCH
GRANTOSA CREEK
UNDERWOOD CREEK
DOUSMAN DITCH
SOUTH BRANCH UNDERWOOD CREEK
HONEY CREEK
WOODS CREEK
SOUTH MENOMONEE CANAL
BURNHAM CANAL
MN-1
MN-2
MN-3
MN-4
MN-5
MN-6
MN-7
MN-8
MN-9
MN-10
MN-11
MN-12
MN-13
MN-13A
MN-14
MN-14A
MN-15
MN-16
MN-17A
MN-18
MN-19

Map 10
RIPARIAN CORRIDOR CONDITIONS AND GROUNDWATER RECHARGE POTENTIAL WITHIN THE MENOMONEE RIVER WATERSHED: 2009
Riparian Corridor Buffer Widths
Greater than or equal to 75 Feet
Less than 75 Feet
Enclosed Channel
Primary Environmental Corridor
Secondary Environmental Corridor
Agricultural Land
Groundwater Recharge Potential
Low
Moderate
High
Very High
Undefined (Generally discharge areas)
NOTE: Groundwater recharge areas are generally delineated based on regional-scale data. Project design will require additional on-site assessments.
0
0.5
1 Miles
Source: SEWRPC.
NORTH BRANCH MENOMONEE RIVER
MENOMONEE RIVER
GOLDENTHAL CREEK
WILLOW CREEK
NOR-X-WAY CHANNEL
LITTLE MENOMONEE RIVER
LITTLE MENOMONEE CREEK
PARK CREEK
NOYES CREEK
LILLY CREEK
BUTLER DITCH
GRANTOSA CREEK
UNDERWOOD CREEK
DOUSMAN DITCH
SOUTH BRANCH UNDERWOOD CREEK
WOODS CREEK
HONEY CREEK
SOUTH MENOMONEE CANAL
BURNHAM CANAL
MN-1
MN-2
MN-3
MN-4
MN-5
MN-6
MN-7
MN-8
MN-9
MN-10
MN-11
MN-12
MN-13
MN-13A
MN-14
MN-14A
MN-16
MN-17
MN-17A
MN-18
MN-19

Map 11

POINT SOURCE OUTFALL LOCATIONS AND WATER QUALITY MONITORING STATION LOCATIONS WITHIN THE MENOMONEE RIVER WATERSHED: 2009

POINT SOURCE OUTFALL LOCATIONS AND WATER QUALITY MONITORING STATION LOCATIONS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2009

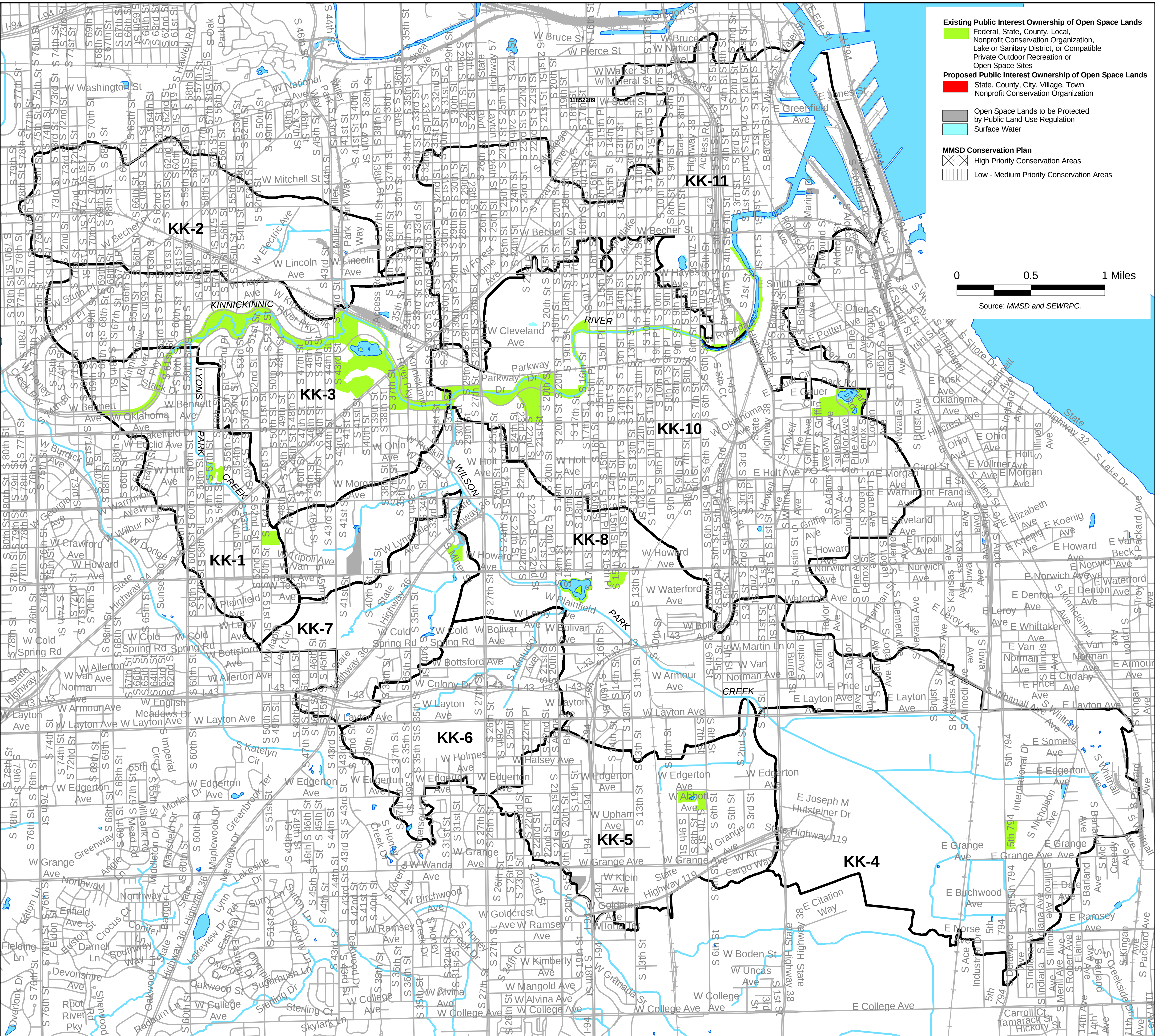


Map 13

PROPOSED PRIORITY PROTECTION AREAS WITHIN THE MENOMONEE RIVER WATERSHED: 2009

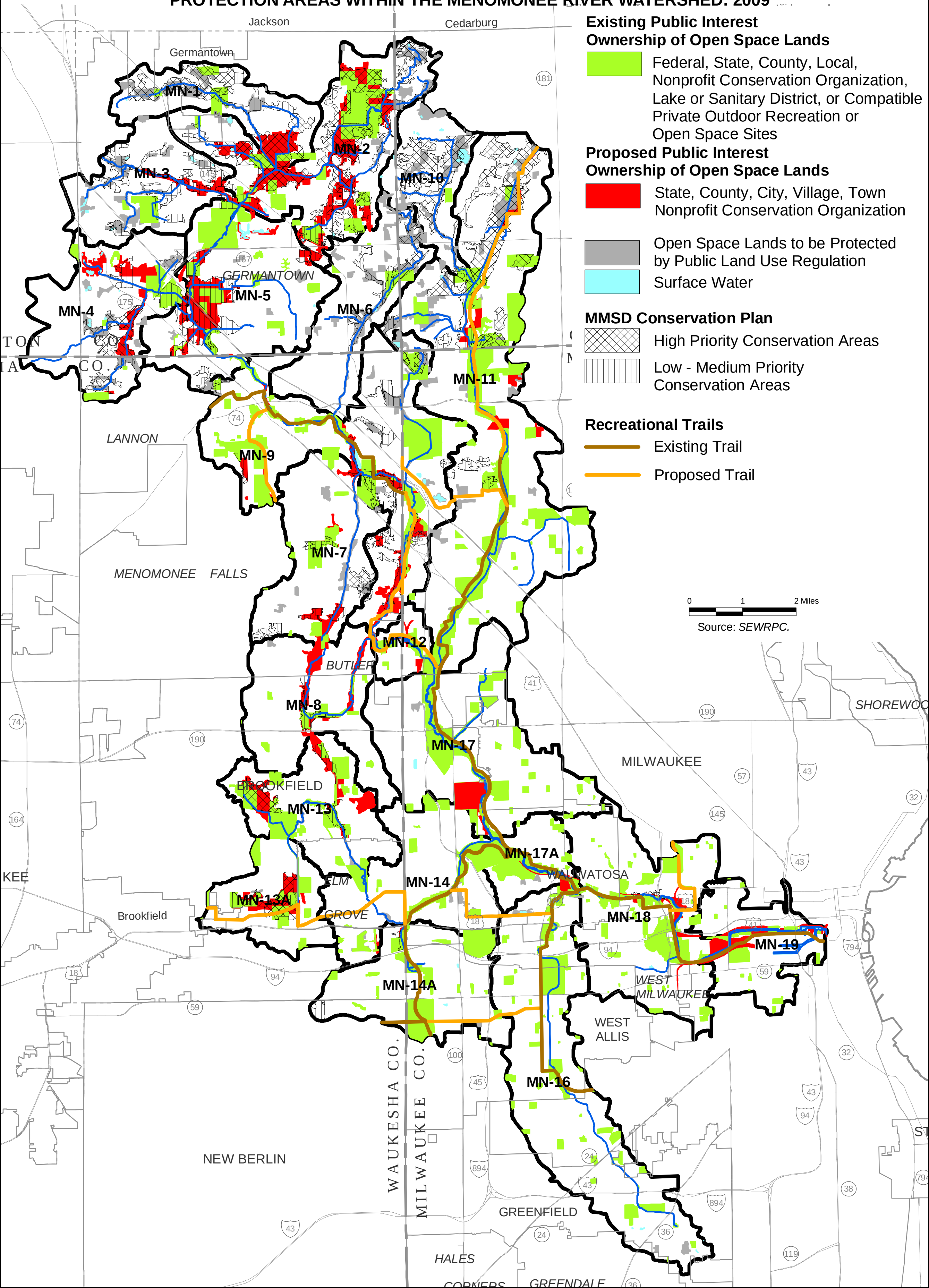
Map 14

PROPOSED PRIORITY PROTECTION AREAS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2009



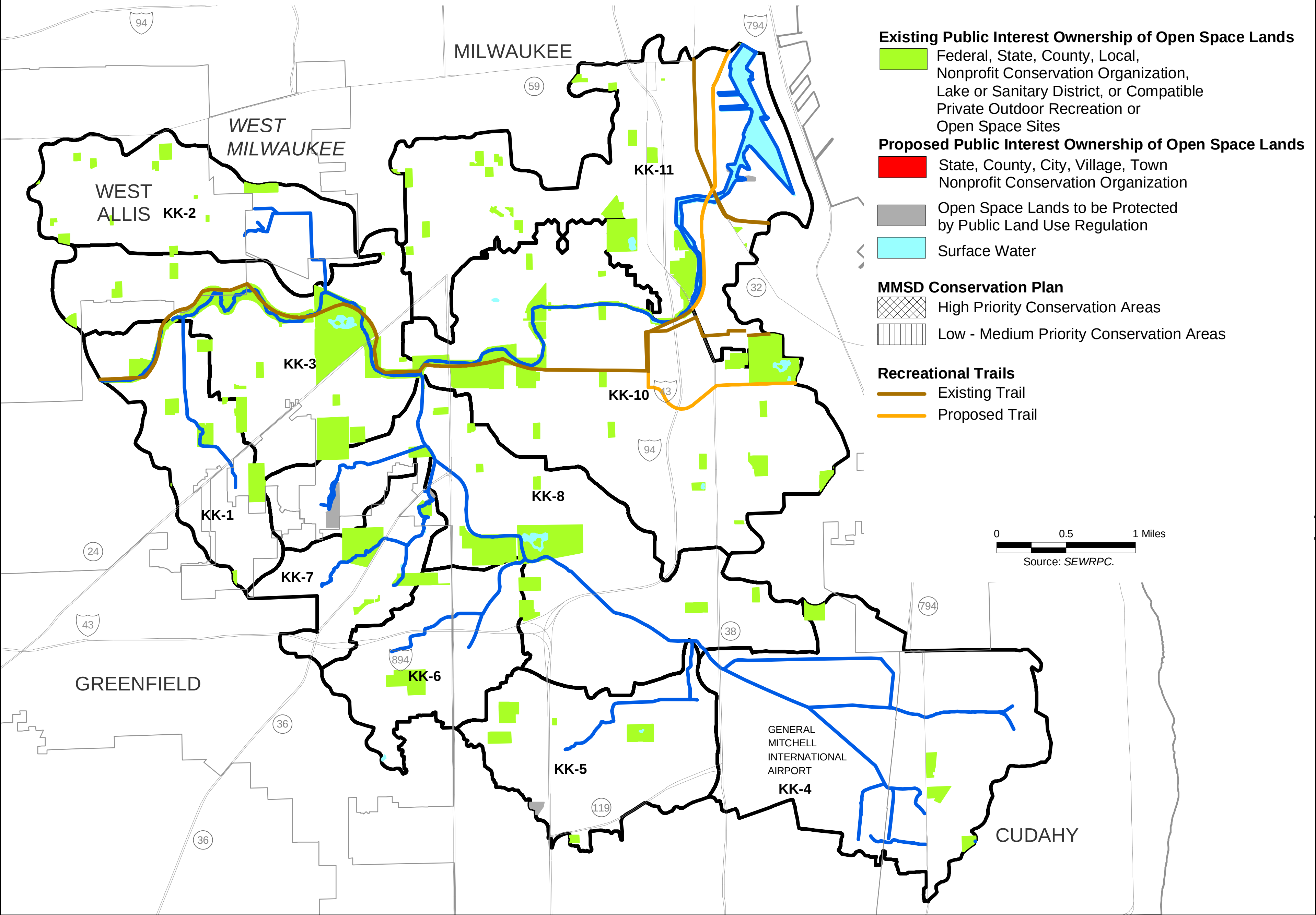
Map 15

RECREATIONAL CORRIDOR TRAILS AND PRIORITY PROTECTION AREAS WITHIN THE MENOMONEE RIVER WATERSHED: 2009



Map 16

RECREATIONAL CORRIDOR TRAILS AND PRIORITY PROTECTION AREAS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2009



Source: *SEWRPC.*

APPENDICES

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Appendix A

LIST OF RIVER CLEANUP SITES WITHIN THE MILWAUKEE, MENOMONEE, AND KINNICKINNIC RIVER WATERSHEDS: SPRING 2009

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2009 Spring River Cleanup Sites (thus far)

Saukville (takes place week after 4/25/09): Location TBD

NORTHERN WATERSHED

Cedarburg Village- Meet at Groth Design Group; N58w6181 Columbia Rd., Cedarburg

Fredonia/Newburg– Meet at Fireman's Park in Newburg. *450 Main St, West Bend, WI 53090*

Lime Kiln Park (Grafton)- 2020 N. Green Bay Rd., Grafton. Meet in the top parking lot

Menomonee Falls - Rotary Park- Meet by park pavilion off Fond du Lac Ave near parking Lot. *N85w14199 Fond Du Lac Ave, Menomonee Falls, WI 53051.*

Mequon-Thiensville (Village Park)- 250 Elm St., Thiensville. Meet at the parking lot near the boat launch

West Bend- 400 University Dr., West Bend. Meet at the Washington County student parking lot

Kewaskum – *Meet at River Hill Park by the Pavilion*

Town of Jackson - Location TBA

MILWAUKEE RIVER

Brown Deer Road- *8800 N Upper River Rd. & Brown Dr. Road.* Paddle from Brown Deer Rd. to Kletzsch Park while picking up trash. Canoe needed, must preregister for this site

Estabrook Park- 4400 N. Estabrook Dr. Meet at the parking lot of picnic area 6

Gaenslen School- Meet at the back parking lot of Gaenslen School on the Auer St. side

Gordon Park- 1321 E. Locust St. Meet at the parking lot next to maintenance building

Hubbard Park- 3565 N. Morris Blvd. *Meet in the circle by the flagpole.*

Kern Park- 3614 N. Humboldt Blvd. *Park along the street. Meet at the pavilion.*

Kletzsch Park- 6560 N. Milwaukee River Pkwy. Glendale, WI 53209. Meet at the pavilion on the east side of the Parkway

Lincoln Creek- 5385 N. Green Bay Ave. Milwaukee, WI 53209. Meet at the Eastbrook Church West parking lot

Lincoln Park- 1301 W. Hampton Ave. Milwaukee, WI 53209. Meet in main parking lot off Hampton.

North Avenue East- Meet on the north side of North Ave. next to the Hometown Gas station

Riverside Park- 1400 E. Riverside Place. *Meet at playground by Riverside Park sign off Oakland Ave.*

RiverView Dorm-Intersection of North & Humboldt

Rowing Club- Meet at the Rowing Club boathouse on Commerce St.

UWM Park & Ride Lot- *4300 N. Humboldt. O*ff Capitol Dr. behind WTMJ building

MENOMONEE RIVER

Krueger Park- 100 N. Columbia Blvd., Brookfield. Meet in the parking lot

Harley Woods- Meet at the intersection of Capitol Dr. and Menomonee River Pkwy. (off Hwy 45) – *on the north-west portion of the intersection on the grass.*

Hart Park - 7300 W. Chestnut St., Wauwatosa. Meet at the Park Administrative Building

Honey Creek - *135 S. 84th St. Meet at the CH2M Hill Parking Lot at northeast corner of 1-94/84th St.*

Hoyt/Hansen Park - 1800 Swan Blvd. Meet at Hoyt Park Swimming Pool lot at 8:00a m

Jacobus Park- 6501 W. Hillside Lane. Meet behind the pavilion near the flag pole

Menomonee/Burleigh- Meet at Burleigh St. and Menomonee River Pkwy.

***REI* - Menomonee/Hampton**- Meet across the street from Unity Church (4750 N. Mayfair Rd.)

Menomonee/North Ave. – Meet at the intersection of North Ave. and Menomonee River Pkwy.

Underwood Creek Parkway- *SE Parking Lot at* Intersection of 115th and Watertown Plank Rd.

MENOMONEE VALLEY & HANK AARON STATE TRAIL

Hank Aaron State Trail Loop- Meet at the DPW parking lot east of the 25th St. traffic circle

Hank Aaron Trail Extension - 65th & Schlisinger Ave (between Hawley & 70th St)

Lakeshore State Park- Meet at Discovery World

Menomonee Valley Community Park - Canal St. under the 35th St. viaduct. Meet at the chimneys.

Miller Park- Meet at Picnic shelter #2

Sigma – 13th & Canal St.

KINNICKINNIC RIVER

Jackson Park- Meet at the boathouse, *3500 W. Forest Home Ave.*

Wilson Park- Meet on the east side of S. 20th St. at the pedestrian bridge

St Luke's Medical Center - *2900 W. Oklahoma Ave.* Meet at picnic tables.

Other Kinnickinnic location/s needed please e-mail if you're interested in organizing a site.

Not on the main list:
Caesar's Park: exclusive Miller site
A Corps Site-Men River Parkway-91st & Appleton to Dean & 91st

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Appendix B

WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND UNIVERSITY OF WISCONSIN-EXTENSION RESIDENTIAL YARD CARE FACT SHEET TO IMPROVE WATER QUALITY AND THE ENVIRONMENT

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Yard Care and the Environment

Rethinking Yard Care

A SERIES OF WATER QUALITY FACT SHEETS FOR RESIDENTIAL AREAS

A wooden rain barrel was a familiar sight in many backyard gardens at the turn of the century. Its purpose was simple – collect rainfall running off a roof and store it for future use. Often, that use would have been watering flowers and garden plants when the weather turned dry.

Turn-of-the-century gardeners knew by experience what chemistry teaches us today: rain water can be better for plants than water pumped from the ground or piped through a city water main. It's not chlorinated, fluoridated or loaded with dissolved salts. And, rain water is mildly acidic, which helps plants take up important minerals from the soil.

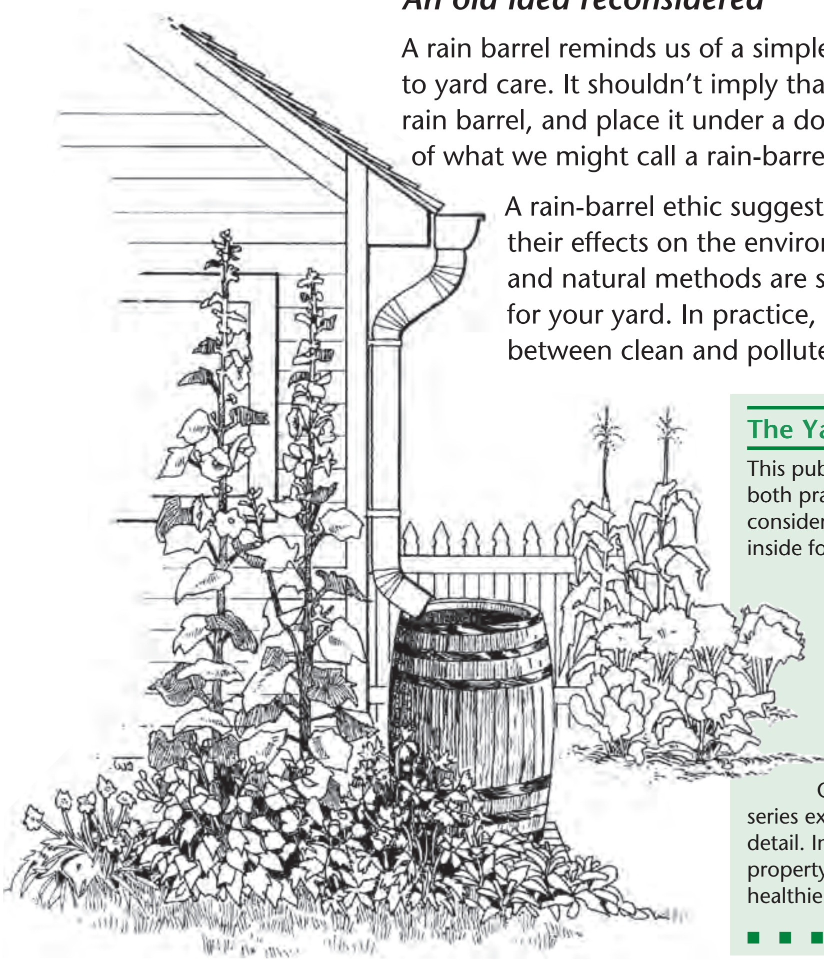
The old-fashioned rain barrel can symbolize a simpler, more sensible approach to yard care.

Today, electric well pumps and city water pressure make storing water in rain barrels seem like more work than it's worth. Nevertheless, we might reflect upon the past and consider what the rain barrel can symbolize.

An old idea reconsidered

A rain barrel reminds us of a simpler, in some ways more sensible, approach to yard care. It shouldn't imply that conscientious people must go out, buy a rain barrel, and place it under a downspout. But there are applications today of what we might call a rain-barrel ethic.

A rain-barrel ethic suggests an awareness of personal actions and their effects on the environment, with the knowledge that simple and natural methods are sometimes the most effective ways to care for your yard. In practice, such an ethic could mean the difference between clean and polluted lakes and streams.



The Yard Care Series

This publication describes an approach to yard care that is both practical and environmentally sound. It offers ideas to consider around your home and in your community. Look inside for information on:

- ✔ water quality problems originating at home
- ✔ the environmental consequences of lawn and garden chemicals
- ✔ ways to reintroduce natural processes
- ✔ practical tips for protecting water quality around the home

Other fact sheets in the *Yard Care and the Environment* series explain environmentally sound actions in greater detail. In some cases, the suggestions can actually make your property easier to manage or more inviting. All promote a healthier environment and better water quality.

THE CONSEQUENCES OF MODERN LIFE

Modern-day activities, especially in urban areas, have greatly disrupted the cycle of water movement and polluted much of our water. It may be a surprise to learn that many of the things we do in our communities and around our homes can create environmental problems.

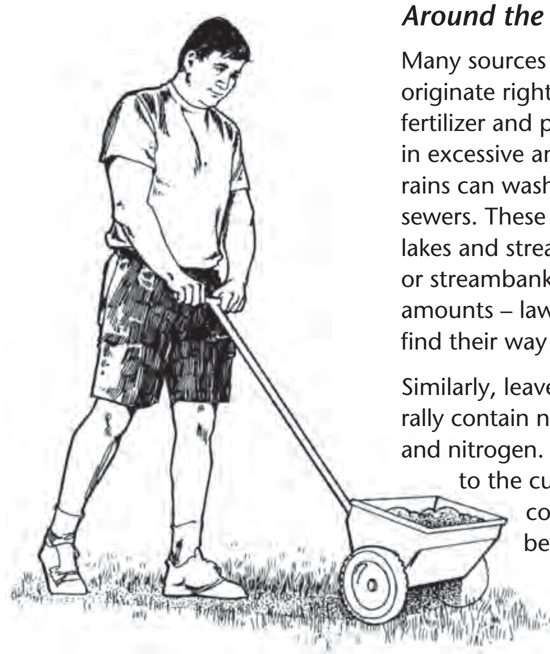
Many sources of water pollution originate right at home. Fertilizers and pesticides can wash into storm sewers, which carry the chemicals to lakes and streams.

In the community

Removal of vegetation during development and its replacement with streets, rooftops, and driveways has significantly decreased the amount of rainfall absorbed by the soil. As a consequence, the amount of water running off toward nearby lakes and streams has increased dramatically.

In addition, stormwater drainage systems are typically designed to remove water from developed areas as quickly as possible during a storm. While these systems are convenient for urban residents, they also carry pollutants to surface waters at a "rapid transit" pace. Contrary to popular belief, pet wastes, oil and other materials dumped into storm sewer grates do not go to the sewage treatment plant, but flow directly to streams and lakes.

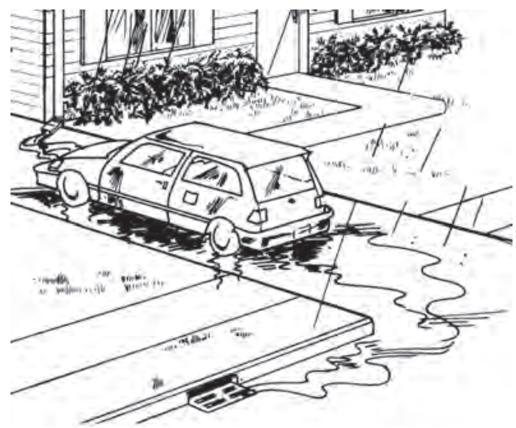
Around the home



Many sources of urban water pollution originate right at home. For example, fertilizer and pesticides applied to lawns in excessive amounts or before heavy rains can wash into ditches and storm sewers. These chemicals then travel to lakes and streams. If used near lakeshores or streambanks – even in modest amounts – lawn chemicals may quickly find their way into the water.

Similarly, leaves and grass clippings naturally contain nutrients such as phosphorus and nitrogen. If leaves and grass are raked to the curb, the nutrients they contain can be washed away before collection and end up in our waters. Leaves and grass can also clog storm sewers and contribute to localized flooding. On the other hand, the practice of burning these yard "wastes" not only releases air pollutants, but the ashes can pollute lakes and streams if carried away by runoff waters.

The connection between auto maintenance and water quality can be very serious and direct. Anything that drips from a motor vehicle onto pavement – oil, gasoline, brake fluid, antifreeze – can quickly be flushed into lakes with a rainstorm. These materials



are toxic to downstream aquatic life. Downspouts positioned to empty directly onto driveways compound the problem.

Dumping oil into a storm sewer grate has almost unthinkable consequences. Five quarts of oil can create a slick as large as two football fields and persist on mud or plants for six months or more.

Time to rethink

Clearly, there is a need to rethink what we're doing at home if urban waters are to be clean and usable. Nowhere is this truer than in our use of lawn and garden chemicals. To understand some of the problems caused by our "chemical dependence" and the advantages of introducing natural processes into lawn and garden care, read on . . .

For some, yard care can be a very rewarding pastime; for others, it is merely a chore necessary to protect the investment in a property's appearance. Regardless of motivation, most homeowners rely, at one time or another, on lawn and garden pesticides and fertilizers. Unfortunately, routine use of these chemicals threatens to open a Pandora's Box of unintended environmental consequences. Following some common-sense guidelines, however, will bring about healthy lawns and gardens and minimize environmental problems.

Be wary of the "chemical fix"

When the seasons change, you can almost feel it in the air – that urge to get out and do something in the yard. Unfortunately, what many people end up doing sometimes leads to more harm than good. Fertilizing without a soil test when the lawn really doesn't need it, using weed killers at the wrong time of year, spraying with insecticides "just to be on the safe side," even watering a little bit every day . . . are all wasteful and environmentally damaging practices.

Without thinking about it, some home-owners reach first for the "solution" that should be a last resort. The serious warning labels on many pesticide products clearly indicate the hazards to songbirds, aquatic life, and humans. In a sense, using such chemicals without proper diagnosis of the problem and careful application procedures is no different than a doctor prescribing medicine with potentially serious side effects for a condition that proper diet and moderate exercise could cure. Resist the urge for a quick chemical solution.

Develop a healthy respect

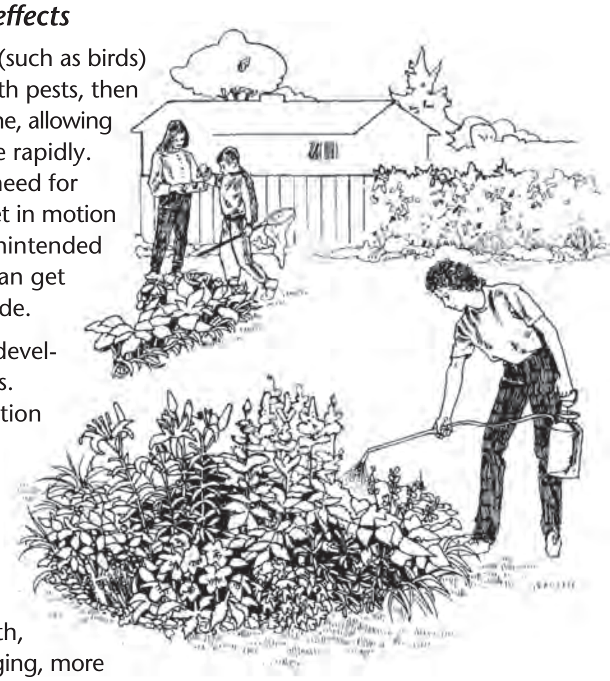
Because yard care chemicals have come into widespread and routine use for many homeowners, there is some danger that a "healthy respect" for them has faded. Homeowners may have used yard care chemicals before without incident. When pressed for time and confronted by profuse label directions and warnings in fine print, it's tempting to skip the instructions and just "get the job done." But pesticide application is not the time to overlook something important. The suffix "icide" means "to kill." Insecticides kill insects, herbicides kill plants and fungicides kill fungus species. While greater success is realized every year in developing chemical and application methods that are more target-specific, the fact remains that pesticides sometimes kill living things other than their targets.

Consider the side-effects

If beneficial predators (such as birds) are poisoned along with pests, then natural controls are gone, allowing pests to multiply more rapidly. This may further the need for more chemicals and set in motion an unfortunate and unintended cycle. Thus the yard can get "hooked" on a pesticide.

A similar pattern can develop with lawn fertilizers. When careless fertilization is followed by routine removal of grass clippings (a natural source of nitrogen) further fertilization is required. The cycle of fertilizing, rapid growth, more cutting and bagging, more fertilizing, etc. gets to be time consuming and costly. It also increases the chance that fertilizer will be washed off to lakes and streams.

On an individual lawn or garden the problem may not seem like much, but area-wide it adds up.



Because yard care chemicals have come into widespread and routine use for many homeowners, there is some danger that a "healthy respect" for them has faded.

Do it in moderation

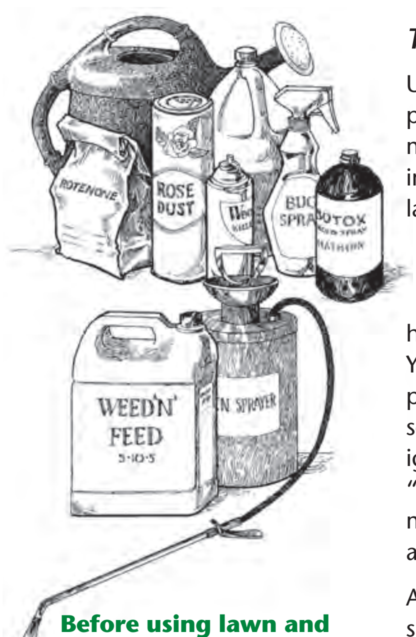
When used in heavier-than-recommended concentrations, nearly all yard care chemicals can pose an environmental problem. This not only wastes money, but puts the applicator, family, neighbors, beneficial plants and animals, and downstream waters at risk. Many recommended label rates are already liberal, designed so that products still work under less than optimal conditions.

Even under-application can create problems. If label directions are misread or pesticides are being "sprayed about" in diluted amounts just to use up existing supplies, then chemicals will not be effective and needlessly enter the environment. Also, pest populations subjected to non-lethal doses may begin to genetically develop resistance to the chemicals designed to kill them.

Timing is everything

Using the wrong product, or the right product at the wrong time, again wastes money and needlessly releases chemicals into the environment. If an insecticide label does not indicate effectiveness against a specific pest – or is effective only during a certain stage in the pest's life cycle – then application can end up harming the wrong thing (like honeybees). Yet the temptation may exist when product "X" is in hand now and worked so well against another pest. However, ignoring basic label directions such as "do not apply if rain is forecast" will, at minimum, result in a chemical application that doesn't do the job.

Another temptation exists during early spring. A dose of nitrogen fertilizer at that time can "green up" a lawn fast. Peer pressure among neighbors to do likewise may set in. Unfortunately, the green top growth takes place at the expense of the root system. An early appearance of health can later give way to a lawn susceptible to drought. The response may then be more watering (more time, expense and possible problems).



Before using lawn and garden pesticides, know the plants, their pests and the chemicals you plan to use.

Handle with care

An irony of urban society is that some people are squeamish at the idea of picking bugs off plants by hand, yet find it perfectly acceptable to employ chemicals, some of which are hazardous enough that professionals must be certified to use larger quantities. History has shown that some chemicals initially believed safe have had to be removed from the market after damaging effects were later discovered.

Chemicals spilled on pavement during chemical mixing and loading can quickly be washed away with the next rain to pollute lakes and streams. If not cleaned up, a sometimes-severe health threat may also persist. Fortunately, an impermeable surface can contain some spills and allow time for clean-up.

Buy only what you need

Most people want to solve a perceived yard care problem as easily and economically as possible. But buying ahead is definitely not a good idea. Freezing temperatures, for example, can render surplus volumes of some products useless, although they will remain hazardous. Also, if chemicals pile up in a garage, a temptation may develop to throw out the accumulated mess. Proper pesticide storage and disposal – often overlooked or the last thing considered – can be difficult to do right. Meanwhile, curious children and pets may be at risk.

When in doubt, ask for help

Safe and reliable chemical treatment of some yard care problems is definitely possible for the informed homeowner. The key is to know plants, their pests and the chemicals you plan to use. Rather than attempting to tackle a problem you are not prepared for, it is always better to seek professional assistance and consider more natural alternatives whenever possible.

AN ALTERNATIVE: HARNESSING NATURAL PROCESSES

The natural amenities that originally drew residents to some areas – clean waters and quality woodlands – were often compromised as people sought to embrace them. However, these qualities can be restored by reintroducing natural processes into lawn and garden care.

The natural cycle

Consider what happens in the forest environment. A layer of fallen leaves helps reduce erosion by protecting soil from the impact of falling raindrops.

That's why, even after a heavy rain, clear water is found in undisturbed woodland streams. Natural grasslands protect water quality in much the same way.

Leaves and grassy vegetation are naturally decomposed by soil organisms, which return nutrients to the soil. The nutrients needed by plants are then taken up by roots to produce new growth year after year in a very efficient recycling process. Under these conditions, plants grow without the need for additional fertilizers. Decaying vegetation also forms an insulating layer of mulch and adds organic matter which reduces daily temperature fluctuations and increases the soil's capacity to hold moisture.

Imitate nature through planning and action

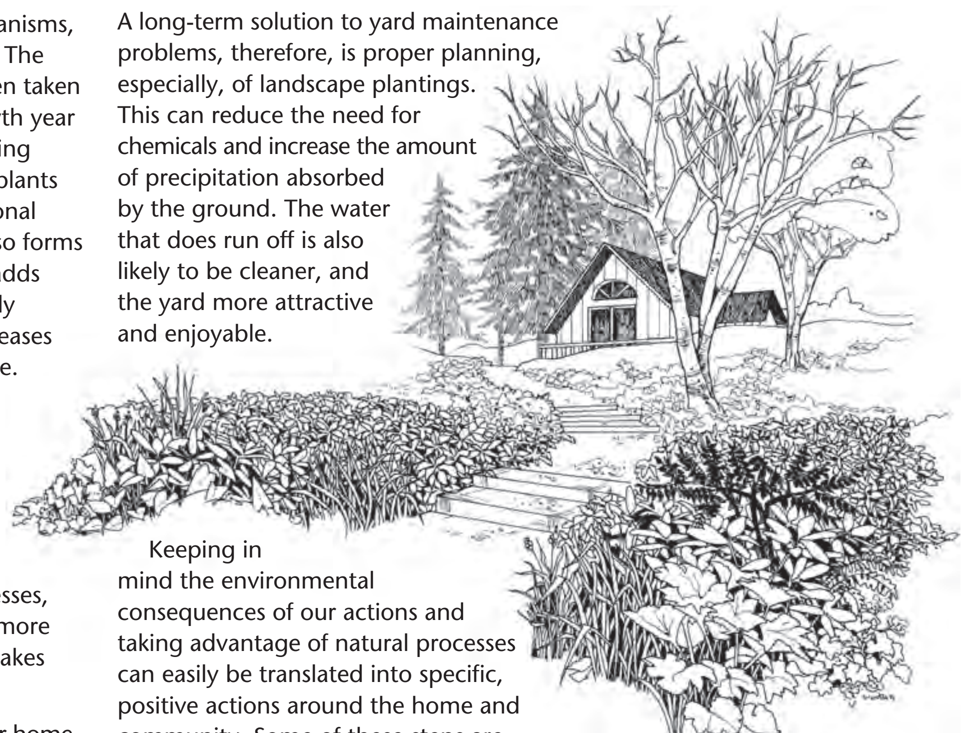
We can't expect that a natural ecosystem can be duplicated in the urban environment; but by taking advantage of natural processes, yard care can generally be made more efficient and less problematic for lakes and streams.

What works for nature can work for home-owners. By properly mowing, mulching, and composting leaves and grass clippings, the normal amount of fertilizing, watering, and weeding can often be reduced. If grass clippings are allowed to remain on lawns instead of being raked or bagged, they will produce benefits from natural recycling. Even pests become less of a problem if more "natural diversity" in plantings is used – as opposed to typical urban uniformity – so that susceptible plants are grown farther apart.

If you have natural or "wild" areas on your property, think twice before deciding to convert them to more formal landscaped areas. Natural landscapes often require less time and money to maintain than formal landscapes, and are usually the best at preventing water pollution from runoff. This is especially important for waterfront property.

Areas of natural landscaping can be a long-term solution to yard maintenance chores, and reduce the need for fertilizers and pesticides.

A long-term solution to yard maintenance problems, therefore, is proper planning, especially, of landscape plantings. This can reduce the need for chemicals and increase the amount of precipitation absorbed by the ground. The water that does run off is also likely to be cleaner, and the yard more attractive and enjoyable.

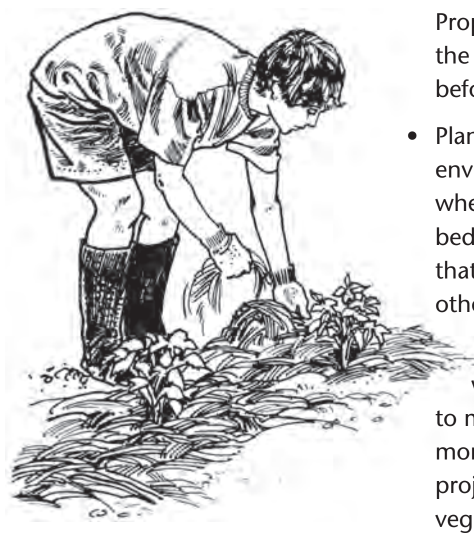


Keeping in mind the environmental consequences of our actions and taking advantage of natural processes can easily be translated into specific, positive actions around the home and community. Some of these steps are highlighted on the following pages.

PRACTICAL TIPS FOR CLEAN WATER

Whether you live in the city or the country . . . whether your home is large or small . . . whether you have a lot of time and money to invest in your yard or just a little, there is something you can do to improve water quality. The following suggestions are ways that you can make a contribution to clean water and a healthy environment.

Around your home



If you have excess grass clippings, use the clippings as a mulch or compost them along with leaves that might otherwise "fertilize" local waters.

- Mow often enough to leave grass clippings on the lawn.
- Keep fallen leaves out of the streetside gutter or ditch, using them around the yard as practical. Properly place the remainder near the curb (not in the street) just before municipal collection.
- Plant an extra tree for multiple environmental benefits, especially where it becomes part of a planting bed or "naturalized" landscape area that recycles leaves, twigs, and other yard "wastes."
- Seed bare soil and cover it with a mulch as soon as possible to minimize erosion. Disturb no more ground than necessary for a project, while preserving existing vegetation.
- Direct roof downspouts away from foundations and driveways to planting beds and lawns where the water can safely soak into the ground. Use a rain barrel where practical.
- Use lawn and garden chemicals carefully and sparingly. Pesticides, including weed killers, should be considered a last resort – other controls come first.
- Limit the use of toxic or hazardous products in general. Keep them away from storm sewers, lakes, and streams.
- Collect oil and other automotive products preferably for recycling, or tightly seal and wrap them for proper disposal.
- Wash cars on the lawn, where soapy water can't quickly run toward the nearest storm sewer, picking up other pollutants as it goes.
- Keep cars tuned up and in good operating condition. Check for drips and repair leaks immediately to keep nuisance oils off pavement. Better yet, walk, bike or take the bus.
- For waterfront property, grow a "buffer strip" of dense, natural vegetation along the water's edge to filter pollutants and stabilize the shoreline.
- If using a septic tank system, maintain it properly through regular inspections and licensed pumping every two to three years.
- Monitor fuel use from any underground gas and oil tanks to make sure they are not leaking.
- Plan your landscape with environmental health in mind, reducing the area that is heavily maintained.
- Clean up pet wastes, from which nutrients and bacteria could be washed toward lakes and streams.
- Conservatively use salt in winter. Substitute sand or old-fashioned "chipping" when possible.

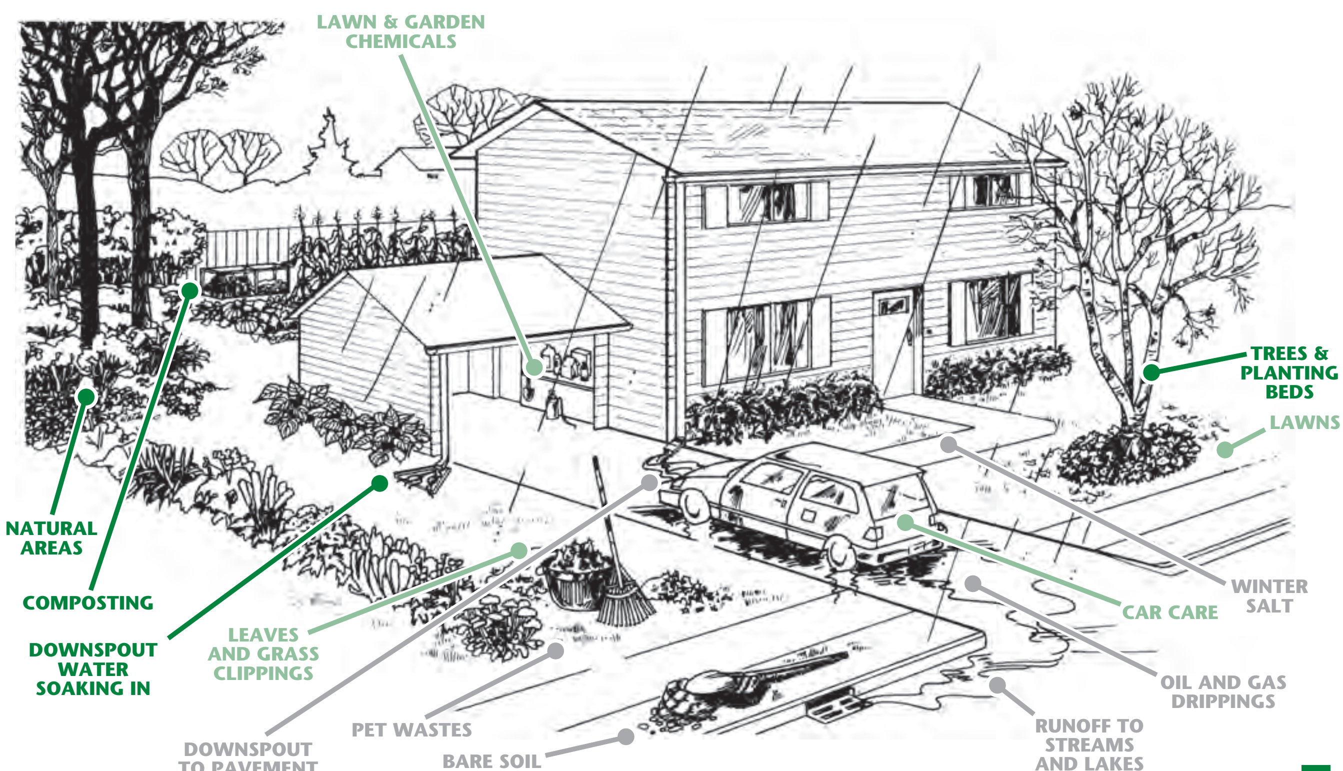
In your community

- Support and follow ordinances that limit soil erosion from construction sites.
- Encourage detention ponds and other stormwater management practices that reduce runoff pollution by temporarily holding water or letting it soak into the ground.
- Encourage the safe but conservative use of salt on roads and limit application to critical areas.
- Tell public officials about your interest in cleaning up local waters and about their value to recreation and the economy.
- Support the preservation of wetlands as natural filters that protect water quality, prevent flooding, and provide vital open space.
- Promote "environmental or parkway corridors" adjacent to streams and waterways for water quality, wildlife, and multiple-use benefits.
- Participate in groups, projects and events that promote conservation, waterfront recreation, or shoreline clean-ups.

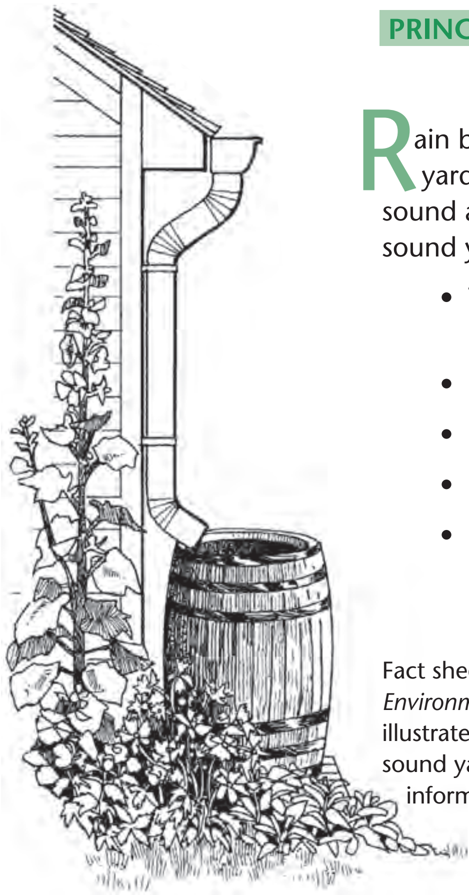
Home hot spots for water quality

Around every yard are spots where your activities affect water quality. The illustration shows a few of them. Take a look around your own home with an eye toward water quality.

● Good for water quality ● Bad for water quality ● Could be good or bad, depending on your actions



PRINCIPLES OF ENVIRONMENTALLY SOUND YARD CARE



Rain barrels were used in the past to collect water for use around the yard. Today, they symbolize a bygone era of sensible, environmentally sound approaches to growing healthy lawns and gardens. Environmentally sound yard care stresses:

- Thinking of environmental consequences in addition to conveniences.
- Planning for greater harmony with natural surroundings.
- Being conservative and resourceful, rather than wasteful.
- Believing that little changes collectively make a big difference.
- Capitalizing on the time and cost-savings that rethinking yard care can bring.

Fact sheets in the *Yard Care and the Environment* series are designed to illustrate the principles of environmentally sound yard care. They provide specific information about pesticides, fertilizers, landscaping, watering, and related topics. These and other publications can be obtained from your county UW-Extension office. Help is also available there regarding soil testing, pest identification, plant selection, and other important items related to yard care and water quality.

This publication is available from county UW-Extension offices, Cooperative Extension Publications – 1-877-947-7827, and from DNR Service Centers.

A publication of the University of Wisconsin–Extension in cooperation with the Wisconsin Department of Natural Resources.

Author: Gary Korb, UW-Extension

Illustrations: Carol Watkins

Editing and design by the Environmental Resources Center, University of Wisconsin–Extension.

UW Extension

WISCONSIN DEPT. OF NATURAL RESOURCES

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DNR WT-526-99

R-09-99-10M-30-S

Appendix C

WISCONSIN DEPARTMENT OF NATURAL RESOURCES AND UNIVERSITY OF WISCONSIN-EXTENSION RAIN GARDEN DESIGN AND CONSTRUCTION MANUAL FOR RESIDENTIAL HOMEOWNERS

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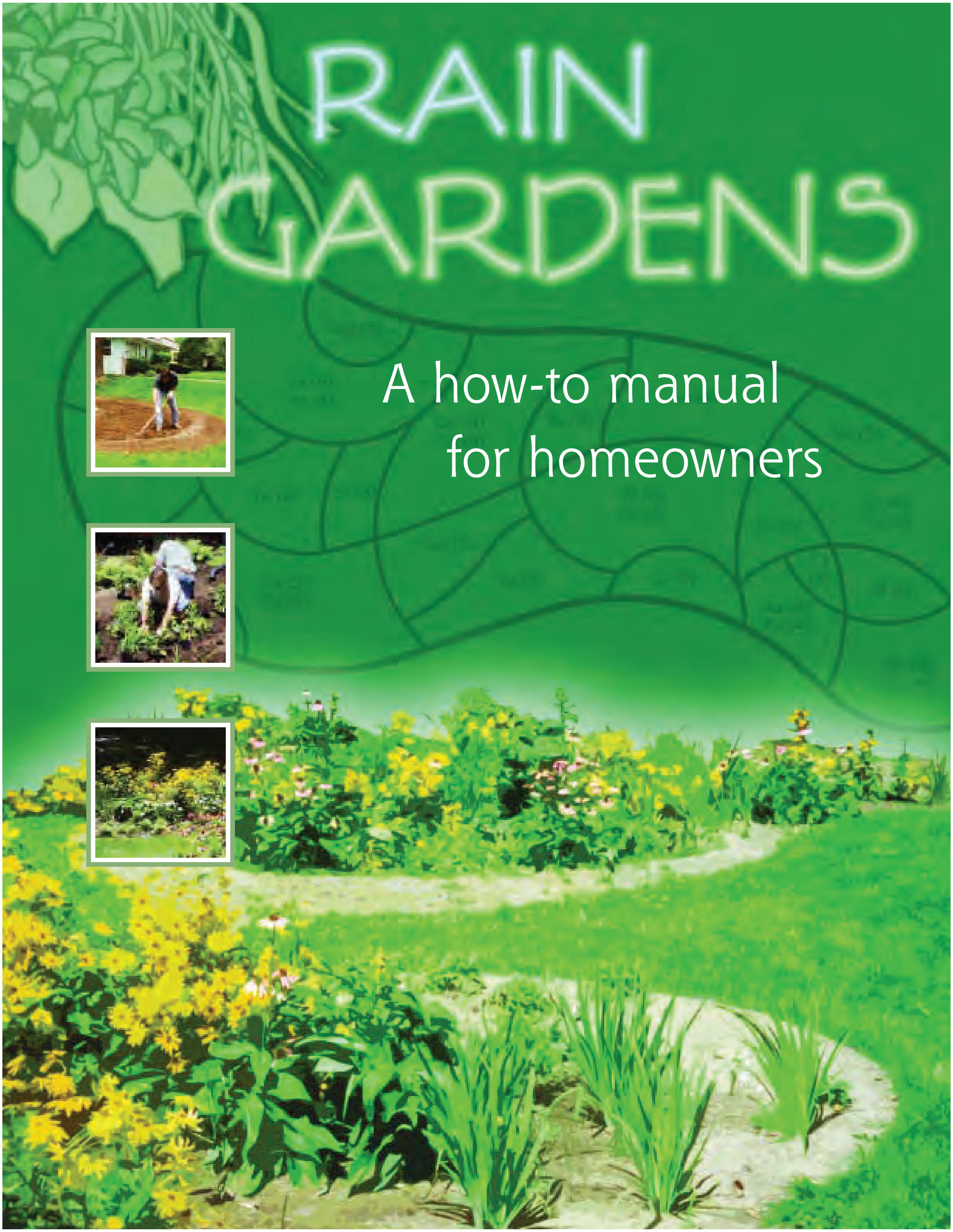

RAIN
GARDENS
A how-to manual
for homeowners

RAIN GARDENS

Your personal contribution to cleaner water

Homeowners in many parts of the country are catching on to rain gardens – landscaped areas planted to wild flowers and other native vegetation that soak up rain water, mainly from the roof of a house or other building. The rain garden fills with a few inches of water after a storm and the water slowly filters into the ground rather than running off to a storm drain. Compared to a conventional patch of lawn, a rain garden allows about 30% more water to soak into the ground.

Why are rain gardens important? As cities and suburbs grow and replace forests and agricultural land, increased stormwater runoff from impervious surfaces becomes a problem. Stormwater runoff from developed areas increases flooding; carries pollutants from streets, parking lots and even lawns into local streams and lakes; and leads to costly municipal improvements in stormwater treatment structures.

By reducing stormwater runoff, rain gardens can be a valuable part of changing these trends. While an individual rain garden may seem like a small thing, collectively they produce substantial neighborhood and community environmental benefits. Rain gardens work for us in several ways:

- Increasing the amount of water that filters into the ground, which recharges local and regional aquifers;
- Helping protect communities from flooding and drainage problems;
- Helping protect streams and lakes from pollutants carried by urban stormwater – lawn fertilizers and pesticides, oil and other fluids that leak from cars, and numerous harmful substances that wash off roofs and paved areas;
- Enhancing the beauty of yards and neighborhoods;
- Providing valuable habitat for birds, butterflies and many beneficial insects.

Who should use this manual?

This manual provides homeowners and landscape professionals with the information needed to design and build rain gardens on residential lots. Guidelines presented in this manual can also be used to treat roof runoff at commercial and institutional sites. However, the manual should not be used to design rain gardens for parking lots, busy streets and other heavily used paved areas where stormwater would require pretreatment before entering a rain garden.

Frequently asked questions

Does a rain garden form a pond?

No. The rain water will soak in so the rain garden is dry between rainfalls. (Note: some rain gardens can be designed to include a permanent pond, but that type of rain garden is not addressed in this publication).

Are they a breeding ground for mosquitoes?

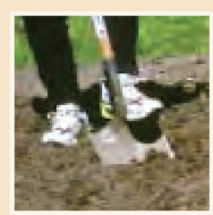
No. Mosquitoes need 7 to 12 days to lay and hatch eggs, and standing water in the rain garden will last for a few hours after most storms. Mosquitoes are more likely to lay eggs in bird baths, storm sewers, and lawns than in a sunny rain garden. Also rain gardens attract dragonflies, which eat mosquitoes!

Do they require a lot of maintenance?

Rain gardens can be maintained with little effort after the plants are established. Some weeding and watering will be needed in the first two years, and perhaps some thinning in later years as the plants mature.

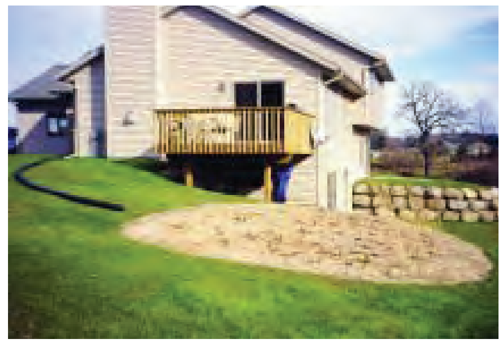
Is a rain garden expensive?

It doesn't have to be. A family and a few friends can provide the labor. The main cost will be purchasing the plants, and even this cost can be minimized by using some native plants that might already exist in the yard or in a neighbor's yard.



Step 1 Sizing and Siting the Rain Garden

This section of the manual covers rain garden basics – where to put the rain garden, how big to make it, how deep to dig it, and what kind of soils and slope are best. Following the instructions in this section is the best way to ensure a successful rain garden project.



An extension of PVC pipe helps direct downspout water to this rain garden.

If you already know the size you want your rain garden to be, then skip ahead to the section about building the rain garden. However, take time read the pointers about location, and do find the slope of the lawn. If the location has a slope more than about 12%, it's best to pick a different location because of the effort it will take to create a level rain garden.

Where should the rain garden go?

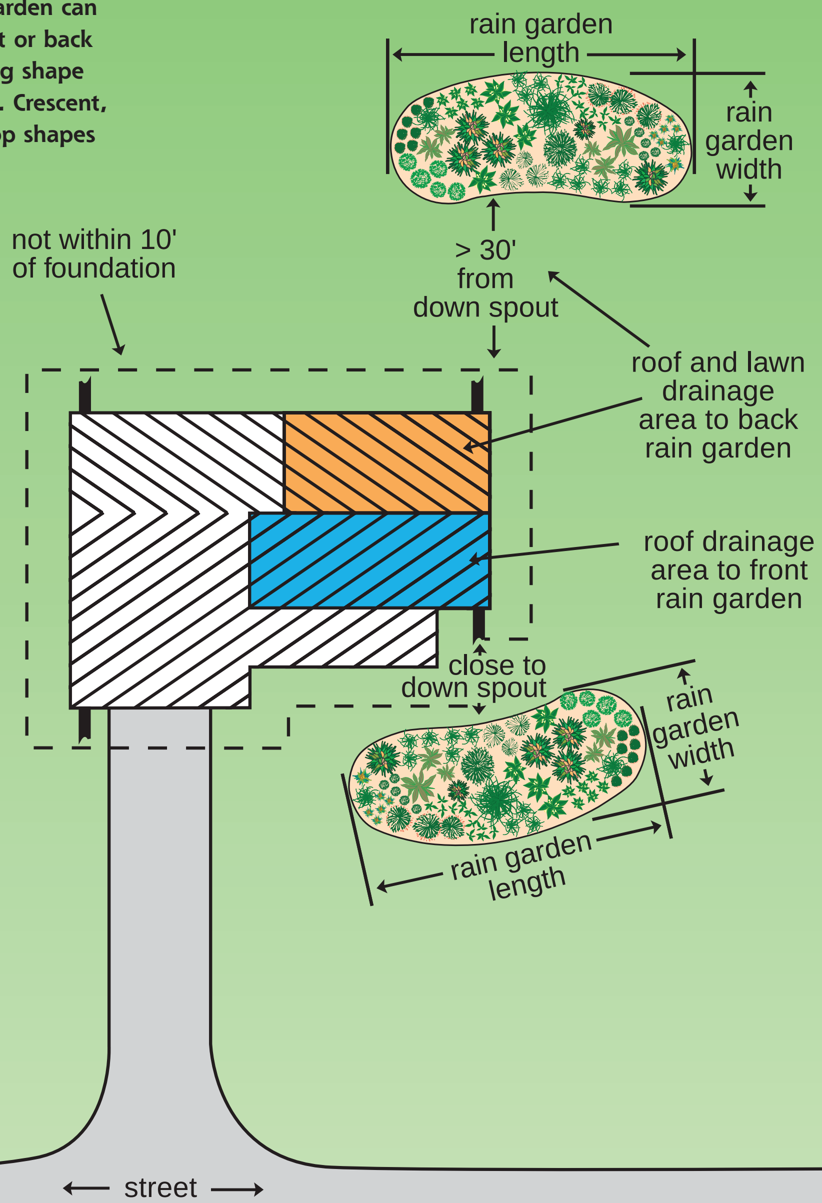
Home rain gardens can be in one of two places – near the house to catch only roof runoff or farther out on the lawn to collect water from the lawn and roof. (Figure 1 shows the possible locations on a residential lot.) To help decide where to put a rain garden, consider these points:

- The rain garden should be at least 10 feet from the house so infiltrating water doesn't seep into the foundation.
- Do not place the rain garden directly over a septic system.
- It may be tempting to put the rain garden in a part of the yard where water already ponds. Don't! The goal of a rain garden is to encourage infiltration, and your yard's wet patches show where infiltration is slow.
- It is better to build the rain garden in full or partial sun, not directly under a big tree.
- Putting the rain garden in a flatter part of the yard will make digging much easier. For example, a rain garden 10 feet wide on a 10% slope must be 12 inches deep to be level, unless you import topsoil or use cut and fill.

Consider your overall landscape

When considering placement of your rain garden, design with the end in mind. Carefully consider how the rain garden can be integrated into existing and future landscaping. Also, pay attention to views from inside the house as well as those throughout the landscape. Determine how far or how close you want your rain garden to outdoor gathering spaces or other play areas. Why not locate it near a patio where you can take advantage of the colors and fragrances for hours on end!

Figure 1 A rain garden can be built in the front or back yard. Pick a pleasing shape for the rain garden. Crescent, kidney, and teardrop shapes seem to work well.



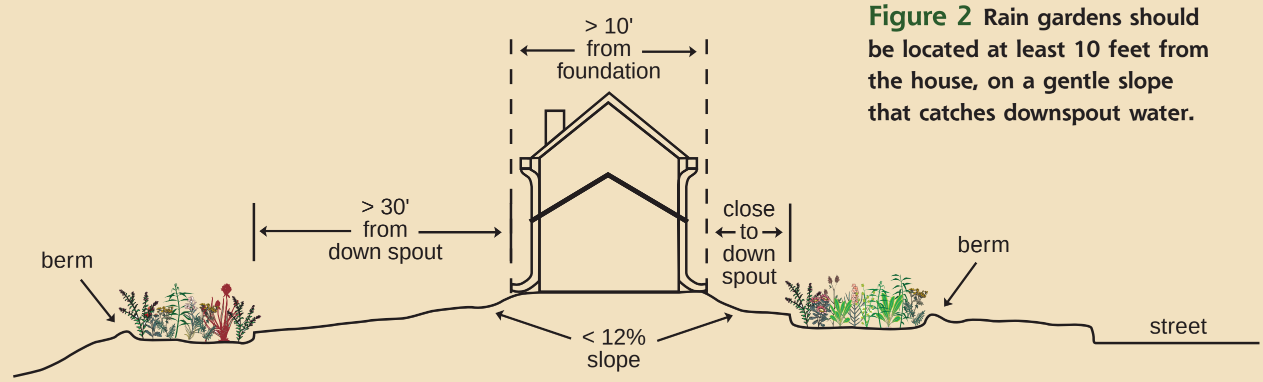


Figure 2 **Rain gardens should be located at least 10 feet from the house, on a gentle slope that catches downspout water.**

How big should the rain garden be?

The surface area of the rain garden can be almost any size, but time and cost will always be important considerations in sizing decisions. Any reasonably sized rain garden will provide some stormwater runoff control. A typical residential rain garden ranges from 100 to 300 square feet. Rain gardens can be smaller than 100 square feet, but very small gardens have little plant variety. If a rain garden is larger than 300 square feet it takes a lot more time to dig, is more difficult to make level, and could be hard on your budget.

The size of the rain garden will depend on

- how deep the garden will be,
- what type of soils the garden will be planted in, and
- how much roof and/or lawn will drain to the garden.

This information, along with the sizing factor from the tables on page 9, will determine the surface area of the rain garden.

Digging with a rented backhoe.

Guidelines are not rules...

The sizing guidelines described in this manual are based on a goal of controlling 100% of the runoff for the average rainfall year while keeping the size of the rain garden reasonable. Establishing a 100% runoff goal helps compensate for some of the errors that creep into the design and construction of any rain garden.

If you follow the guidelines in the manual and decide the calculated surface area is just too large for your goals, it is perfectly acceptable to make the rain garden smaller. The rain garden can be up to 30% smaller and still control almost 90% of the annual runoff. On the other hand, it is fine to make the rain garden bigger than the guidelines indicate.

How Deep Should the Rain Garden Be?

A typical rain garden is between four and eight inches deep. A rain garden more than eight inches deep might pond water too long, look like a hole in the ground, and present a tripping hazard for somebody stepping into it. A rain garden much less than four inches deep will need an excessive amount of surface area to provide enough water storage to infiltrate the larger storms.

No matter what the depth of the rain garden, the goal is to keep the garden level. Digging a very shallow rain garden on a steep lawn will require bringing in extra topsoil to bring the downslope part of the garden up to the same height as the up-slope part of the garden. As the slope gets steeper, it is easier to dig the rain garden a little deeper to make it level.

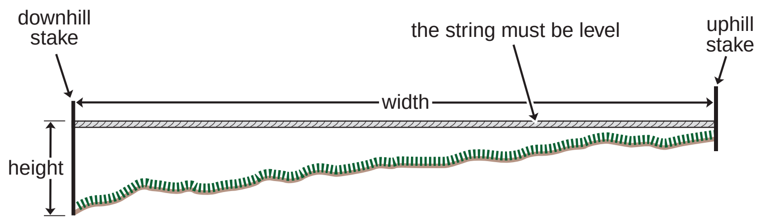


Figure 3 The string should be tied to the base of the uphill stake, then tied to the downhill stake at the same level.

The slope of the lawn should determine the depth of the rain garden. Find the slope of your lawn by following these steps. (Figure 3 shows how the stakes and string should look.)

1. Pound one stake in at the uphill end of your rain garden site and pound the other stake in at the downhill end. The stakes should be about 15 feet apart.
2. Tie a string to the bottom of the uphill stake and run the string to the downhill stake.
3. Using a string level or the carpenter's level, make the string horizontal and tie the string to the downhill stake at that height.
4. Measure the width (in inches) between the two stakes.
5. Now measure the height (in inches) on the downhill stake between the ground and string.
6. Divide the height by the width and multiply the result by 100 to find the lawn's percent slope. If the slope is more than 12%, it's best to find another site or talk to a professional landscaper.

Using the slope of the lawn, select the depth of the rain garden from the following options:

- If the slope is less than 4%, it is easiest to build a 3 to 5-inch deep rain garden.
- If the slope is between 5 and 7%, it is easiest to build one 6 to 7 inches deep.
- If the slope is between 8 and 12%, it is easiest to build one about 8 inches deep.

EXAMPLE

Todd measures the length of the string between the stakes; it is 180 inches long. The height is 9 inches. He divides the height by the width to find his lawn's percent slope.

$$\frac{\text{height}}{\text{width}} \times 100 = \%\ \text{slope} \qquad \frac{9\ \text{inches}}{180\ \text{inches}} \times 100 = 5\%\ \text{slope}$$

With a 5% slope, Todd should build a 6 inch deep rain garden.

What type of soils are on the rain garden site?

After choosing a rain garden depth, identify the lawn's soil type as sandy, silty, or clayey. Sandy soils have the fastest infiltration; clayey soils have the slowest. Since clayey soils take longer to absorb water, rain gardens in clayey soil must be bigger than rain gardens in sandy or silty soil. If the soil feels very gritty and coarse, you probably have sandy soil. If your soil is smooth but not sticky, you have silty soil. If it is very sticky and clumpy, you probably have clayey soil.

How big is the area draining to the rain garden?

The next step in choosing your rain garden size is to find the area that will drain to the rain garden. As the size of the drainage area increases so should the size of the rain garden. There is some guesswork in determining the size of a drainage area, especially if a large part of the lawn is up-slope from the proposed garden site. Use the suggestions below to estimate the drainage area without spending a lot of time.

Rain gardens less than 30 feet from the downspout

1. In this case, where the rain garden is close to the house, almost all water will come from the roof downspout. Walk around the house and estimate what percent of the roof feeds to that downspout. Many houses have four downspouts, each taking about 25% of the roof's runoff.
2. Next find your home's footprint, the area of the first floor. If you don't already know it, use a tape measure to find your house's length and width. Multiply the two together to find the approximate area of your roof.
3. Finally, multiply the roof area by the percent of the roof that feeds to the rain garden downspout. This is the roof drainage area.

Rain gardens more than 30 feet from the downspout

1. If there is a significant area of lawn uphill that will also drain to the rain garden, add this lawn area to the roof drainage area. First find the roof drainage area using the steps above for a rain garden less than 30' from the downspout.
2. Next find the area of the lawn that will drain to the rain garden. Stand where your rain garden will be and look up toward the house. Identify the part of the lawn sloping into the rain garden.
3. Measure the length and width of the uphill lawn, and multiply them to find the lawn area.
4. Add the lawn area to the roof drainage area to find the total drainage area.

▸ **If the rain garden is far from the house, and you don't want a swale or downspout cutting across the lawn, run a PVC pipe underground from the downspout to the rain garden. In this case do calculations as for a rain garden less than 30 feet from the house.**

EXAMPLE

Todd's house is 60 feet by 40 feet, so the roof area is 2400 square feet. He estimates that the downspout collects water from 25% of the roof, so he multiplies 2400 by 0.25 to get a downspout drainage area of 600 square feet.

Roof Area: 60 ft by 40 ft = 2400 square ft.

Drainage Area: 2400 square ft. x 0.25 = 600 square ft.

Simple soil tests

Two small tests can ensure your soil can handle a rain garden:

- Dig a hole about 6 inches deep where the rain garden is to go and fill the hole with water. If the water takes more than 24 hours to soak in, the soil is not suitable for a rain garden.
- Take a handful of soil and dampen it with a few drops of water. After kneading the soil in your fingers, squeeze the soil into a ball. If it remains in a ball, then work the soil between your forefinger and thumb, squeezing it upward into a ribbon of uniform thickness. Allow the ribbon to emerge and extend over the forefinger until it breaks from its own weight. If the soil forms a ribbon more than an inch long before it breaks, and it also feels more smooth than gritty, the soil is not suitable for a rain garden.

The map is a starting point for assessing what type of soils you might find in your yard. However, the soil on a small plot of a yard can be very different from the soils indicated on the map. Use the simple soil test described here for a more accurate representation of the soils in the possible rain garden location. More information about sampling and testing lawn and garden soils can be obtained at county UW-Extension offices.

Using the Rain Garden Size Factors

Having estimated the drainage area, soil type, and depth for your rain garden, use Table 1 or Table 2 to determine the rain garden's surface area. Use Table 1 if the rain garden is less than 30 feet from the downspout, and use Table 2 if it is more than 30 feet from the downspout.

Table 1 Rain gardens less than 30 feet from downspout.

	3-5 in. deep	6-7 in. deep	8 in. deep
Sandy soil	0.19	0.15	0.08
Silty soil	0.34	0.25	0.16
Clayey soil	0.43	0.32	0.20

Table 2 Rain gardens more than 30 feet from downspout.

	Size Factor, for all depths
Sandy soil	0.03
Silty soil	0.06
Clayey soil	0.10

1. Find the size factor for the soil type and rain garden depth.
2. Multiply the size factor by the drainage area. This number is the recommended rain garden area.
3. If the recommended rain garden area is much more than 300 square feet, divide it into smaller rain gardens.

EXAMPLE

Todd's rain garden is less than 30 feet from the downspout, and his lawn has a 5% slope, so he will have a 6-inch deep rain garden. His lawn is silty, so Table 1 recommends a size factor of 0.25. He multiplies the downspout drainage area, 600 square feet, by 0.25 to find the recommended rain garden area, 150 square feet.

600 square ft. by 0.25 = 150 square ft.

Runoff flows into a new rain garden (shown before plants are fully grown).

How long and how wide should the rain garden be?

Before building the rain garden, think about how it will catch water. Runoff will flow out of a downspout and should spread evenly across the entire length of the rain garden. The rain garden must be as level as possible so water doesn't pool at one end and spill over before it has a chance to infiltrate.

Choose a size that is best for your yard

Remember that these are only guidelines. The size of the rain garden also depends on how much money you want to spend, how much room you have in your yard, and how much runoff you want to control. Again, you can reduce the size of your rain garden by as much as 30% and still control almost 90% of the runoff. If the sizing table suggests that the rain garden be 200 square feet, but there is only enough room for a 140-square-foot rain garden, that's fine. A smaller rain garden will usually work to control most stormwater runoff, although some bigger storms might over-top the berm.

The longer side of the rain garden should face upslope; that is, the length of the rain garden should be perpendicular to the slope and the downspout. This way the garden catches as much water as possible. However, the rain garden should still be wide enough for the water to spread evenly over the whole bottom and to provide the space to plant a variety of plants. A good rule of thumb is that the rain garden should be about twice as long (perpendicular to the slope) as it is wide.

When choosing the width of the garden, think about the slope of the lawn. Wide rain gardens and rain gardens on steep slopes will need to be dug very deep at one end in order to be level. If the rain garden is too wide, it may be necessary to bring in additional soil to fill up the downhill half. Experience shows that making a rain garden about 10 feet wide is a good compromise between the effect of slope and how deep the rain garden should be. A rain garden should have a maximum width of about 15 feet, especially for lawns with more than about an 8 percent slope.

To determine the length of the rain garden:

1. Pick the best rain garden width for your lawn and landscaping.
2. Divide the size of your rain garden by the width to find your rain garden's length.

EXAMPLE

Todd wants a 10-foot wide rain garden, so he divides 150 by 10 to find the rain garden length, 15 feet.

$$\frac{\text{rain garden area}}{\text{width}} = \text{length} \qquad \frac{150\ \text{ft}^2}{10\ \text{ft}} = 15\ \text{ft}$$

Step 2 Building the Rain Garden

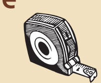
Now that the size and place for the rain garden are set, it's time to get a shovel and start digging. Working alone, it will take about six hours to dig an average-size rain garden. If friends help it will go much faster, possibly only an hour or two.

Before you start digging, call Digger's Hotline at 1-800-242-8511.

▸If you are building the rain garden into an existing lawn, digging time can be reduced by killing the grass first. A chemical such as Round-Up can be used, but a more environmentally friendly approach is to place black plastic over the lawn until the grass dies. Also, the best time to build the rain garden is in the spring. It will be easier to dig, and the plants are more likely to thrive.

A note on tools

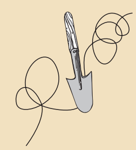
The following tools will help in building the rain garden. Some of the tools are optional.



- **Tape measure**
- **Shovels**

- **Rakes**
- **Trowels**
- **Carpenter's level**

- **Wood stakes, at least 2 ft long**



- **String**
- **2x4 board, at least 6 ft long (optional)**
- **Small backhoe with cater-pillar treads (optional)**

Leveling the rain garden

One way to check the level of the rain garden is to just "eyeball" it. To do it more accurately follow these steps:

- **When the whole area has been dug out to about the right depth, lay the 2x4 board in the rain garden with the carpenter's level sitting on it. Find the spots that aren't flat. Fill in the low places and dig out the high places.**
- **Move the board to different places and different directions, filling and digging as necessary to make the surface level.**
- **When the rain garden is as level as you can get it, rake the soil smooth.**

The perimeter of a rain garden is defined with string before digging.

Digging the rain garden

While digging the rain garden to the correct depth, heap the soil around the edge where the berm will be. (The berm is a low "wall" around three sides of the rain garden that holds the water in during a storm.) On a steeper lawn the lower part of the rain garden can be filled in with soil from the uphill half, and extra soil might need to be brought in for the berm.

Start by laying string around the perimeter of your rain garden. Remember that the berm will go outside the string. Next, put stakes along the uphill and downhill sides, lining them up so that each uphill stake has a stake directly downhill. Place one stake every 5 feet along the length of the rain garden.

Start at one end of the rain garden and tie a string to the uphill stake at ground level. Tie it to the stake directly downhill so that the string is level. Work in 5-foot-wide sections, with only one string at a time. Otherwise the strings will become an obstacle.

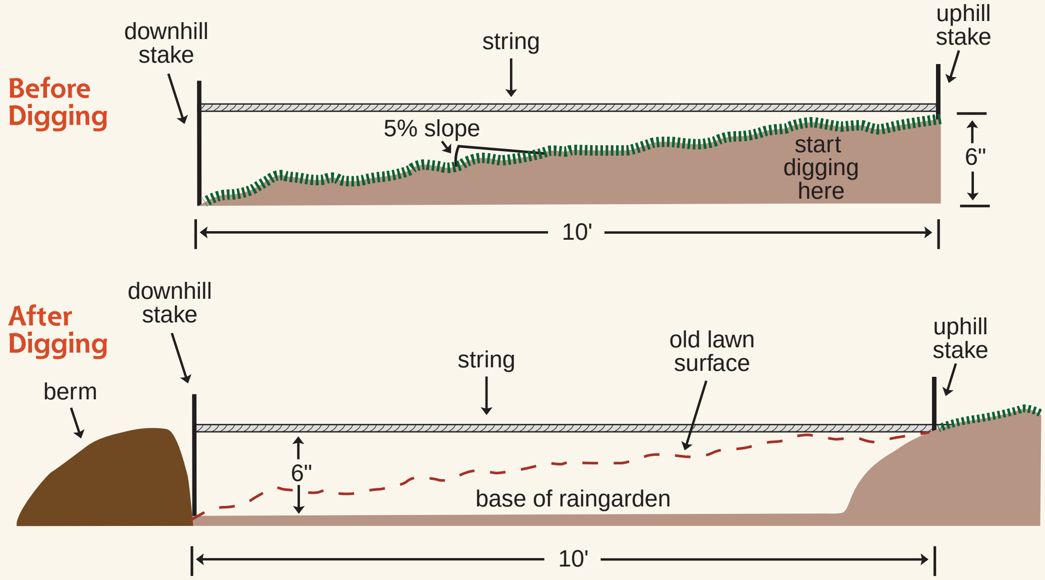
Start digging at the uphill side of the string. Measure down from the string and dig until you reach the depth you want the rain garden to be. If the rain garden will be four inches deep, then dig four inches down from the string. Figure 4 shows how.

If the lawn is almost flat, you will be digging at the same depth throughout the rain garden and using the soil for the berm. If the lawn is steeper, the high end of the rain garden will need to be dug out noticeably more than the low end, and some of the soil from the upper end can be used in the lower end to make the rain garden level. Continue digging and filling one section at a time across the length of your rain garden until it is as level as possible.

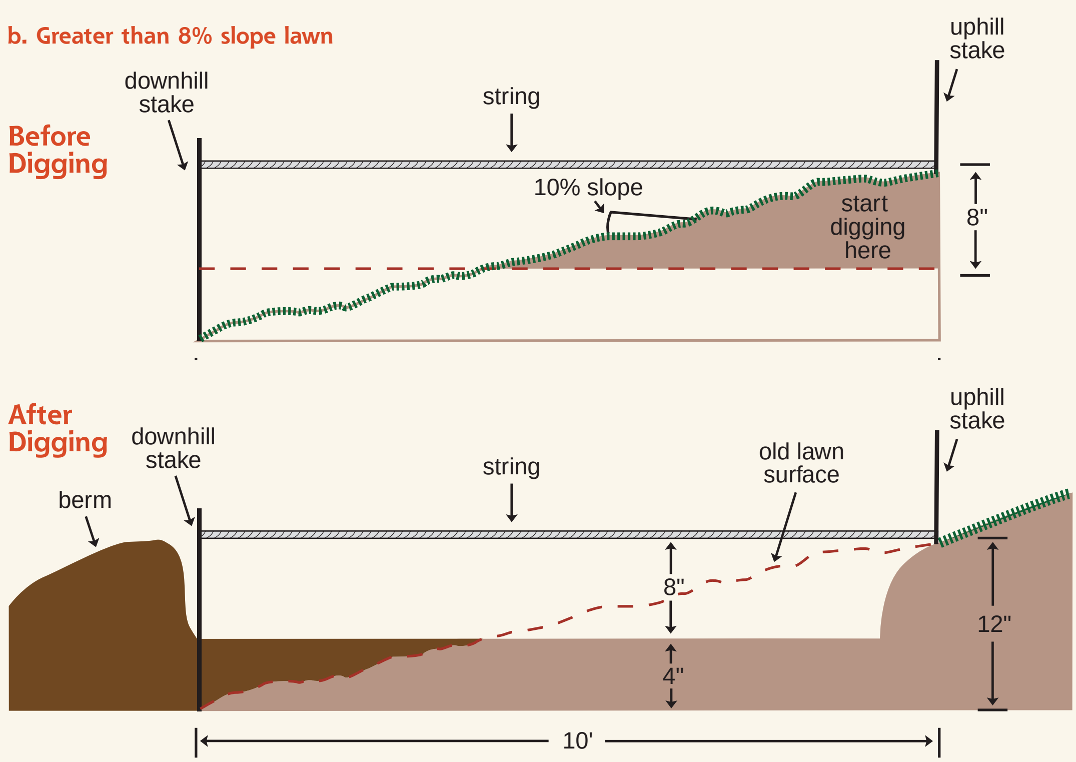
In any garden, compost will help the plants become established and now is the time to mix in compost if needed. Using a roto-tiller can make mixing much easier, but isn't necessary. If you do add compost, dig the rain garden a bit deeper. To add two inches of compost, dig the rain garden one to two inches deeper than planned.

Figure 4 Where to dig and where to put the soil you've dug.

a. Between 3% and 8% slope lawn



b. Greater than 8% slope lawn



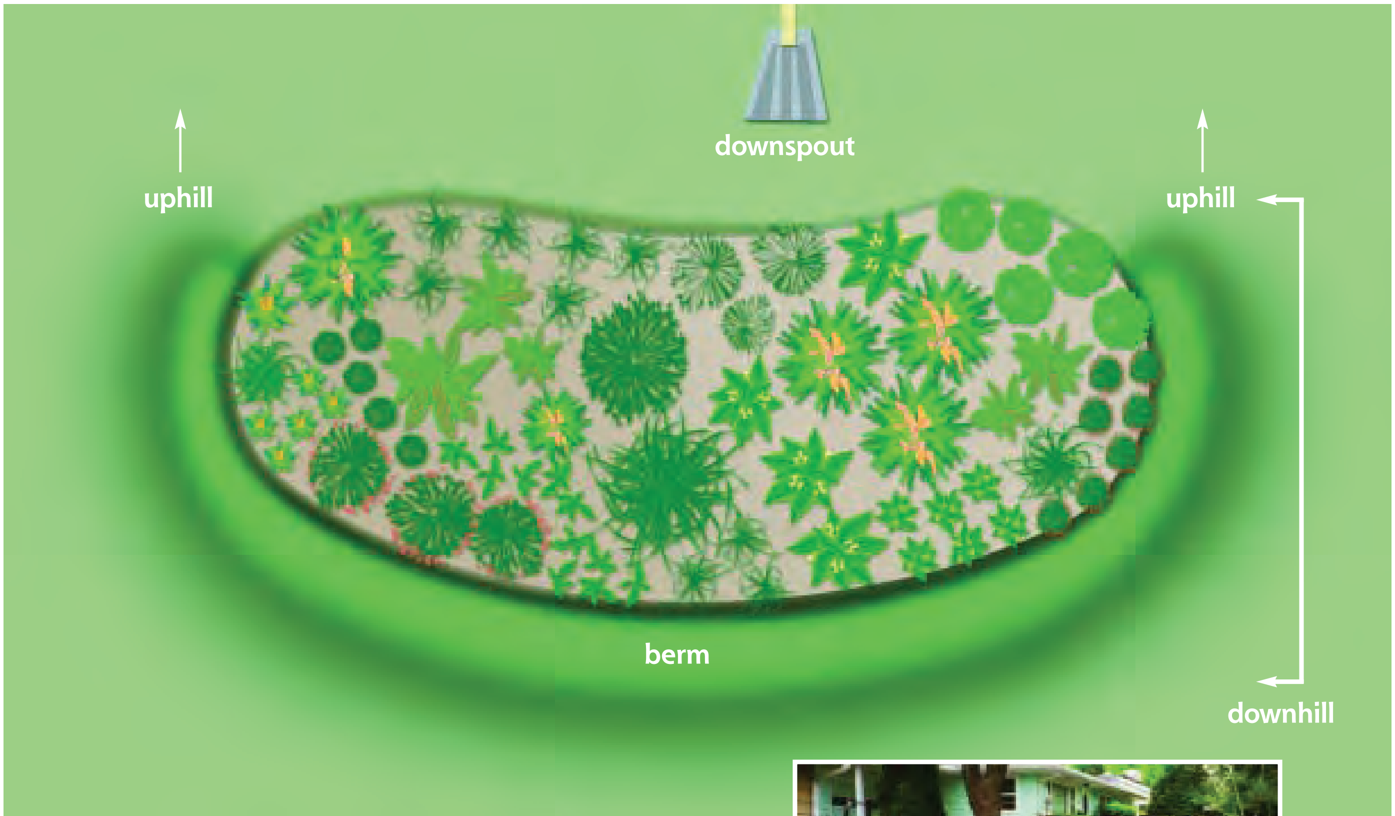


Figure 5 The top of the downhill part of the berm should come up to the same elevation as the entry to the rain garden at the uphill end.

On a gentle slope, soil from digging out the garden can be used to create the berm. This rain garden is 4 inches deep.

Making the Berm

Water flowing intro the rain garden will naturally try to run off the downhill edge. A berm is needed to keep the water in the garden, The berm is a "wall" across the bottom and up the sides of the rain garden. The berm will need to be highest at the downhill side. Up the sides of the rain garden, the berm will become lower and gradually taper off by the time it reaches the top of the rain garden. Figure 5 shows how the berm should look.

On a flat slope there should be plenty of soil from digging out the rain garden to use for a berm. On a steeper slope, most of the soil from the uphill part of the rain garden was probably used to fill in the downhill half, and soil will have to be brought in from somewhere else. After shaping the berm into a smooth ridge about a foot across, stomp on it. It is very important to have a well-compacted berm, so stomp hard. The berm should have very gently sloping sides; this helps smoothly integrate the rain garden with the surrounding lawn and also makes the berm less susceptible to erosion.

To prevent erosion, cover the berm with mulch or plant grass. Use straw or erosion-control mat to protect the berm from erosion while the grass is taking root.

If you don't want to plant grass or mulch over the outside of the berm, you can also plant dry-tolerant prairie species. Some potential berm species are prairie dropseed, little bluestem, prairie smoke, blue-eyed grass, prairie phlox, and shooting star.

Note: If the downspout is a few feet from the entry to the rain garden, make sure the water runs into the garden by either digging a shallow grass swale or attaching an extension to the downspout.

Tips for designing an attractive rain garden

While rain gardens are a highly functional way to help protect water quality, they are also gardens and should be an attractive part of your yard and neighborhood. Think of the rain garden in the context of your home's overall landscape design. Here are a few tips:

When choosing native plants for the garden, it is important to consider the height of each plant, bloom time and color, and its overall texture. Use plants that bloom at different times to create a long flowering season. Mix heights, shapes, and textures to give the garden depth and dimension. This will keep the rain garden looking interesting even when few wildflowers are in bloom.

When laying plants out, randomly clump individual species in groups of 3 to 7 plants to provide a bolder statement of color. Make sure to repeat these individual groupings to create repetition and cohesion in a planting. This will provide a more traditional formal look to the planting.

Try incorporating a diverse mixture of sedges, rushes, and grasses with your flowering species (forbs). This creates necessary root competition that will allow plants to follow their normal growth patterns and not outgrow or out-compete other species. In natural areas, a diversity of plant types not only adds beauty but also create a thick underground root matrix that keeps the entire plant community in balance. In fact, 80% of the plant mass in native prairie communities is underground. Once the rain garden has matured and your sedges, rushes and grasses have established a deep, thick root system, there will be less change in species location from year to year, and weeds will naturally decline.

Finally, consider enhancing the rain garden by using local or existing stone, ornamental fences, trails, garden benches, or additional wildflower plantings. This will help give the new garden an intentional and cohesive look and provide a feeling of neatness that the neighbors will appreciate.

Step 3 Planting and Maintaining the Rain Garden

Planting the rain garden is the fun part! A number of planting designs and lists of suggested plants are included at the end of this publication. Use these for ideas, but don't be afraid to be creative – there's no single best way to plant a rain garden. Anyone who has ever done any gardening will have no problem planting a rain garden, but a few basic reminders are listed below.

Planting the rain garden

Select plants that have a well established root system. Usually one or two-year-old plants will have root systems that are beginning to circle or get matted. (Note: use only nursery-propagated plants; do not collect plants from the wild).

Make sure to have at least a rough plan for which plants will be planted where. Lay out the plants as planned one foot apart in a grid pattern, keeping them in containers if possible until they are actually planted to prevent drying out before they get in the ground.

Dig each hole twice as wide as the plant plug and deep enough to keep the crown of the young plant level with the existing grade (just as it was growing in the cell pack or container). Make sure the crown is level and then fill the hole and firmly tamp around the roots to avoid air pockets.

Apply double-shredded mulch evenly over the bed approximately two inches thick, but avoid burying the crowns of the new transplants. Mulching is usually not necessary after the second growing season unless the "mulched look" is desired.

Stick plant labels next to each individual grouping. This will help identify the young native plants from non-desirable species (weeds) as you weed the garden.

As a general rule plants need one inch of water per week. Water immediately after planting and continue to water twice a week (unless rain does the job) until the plugs are established. You should not have to water your rain garden once the plants are established. Plugs can be planted anytime during the growing season as long as they get adequate water.

Fire safety

Make sure burning is allowed in your locale. If so, be sure to notify the local fire department and obtain a burn permit if needed. It's also wise – not to mention neighborly – to make sure the neighbors know that you're burning and that all safety precautions are being taken. Basic fire precautions include:

- **Make sure there is a fire-break (non-burnable area, such as turfgrass) at least 10-feet wide surrounding the area to be burned.**
- **Never burn on windy days.**
- **Never leave an actively burning fire unattended.**
- **Keep a garden hose handy in case fire strays where it is not wanted. Also have a metal leaf rake in hand to beat out flames that creep beyond the burn zone.**

Maintaining the rain garden

Weeding will be needed the first couple of years. Remove by hand only those plants you are certain are weeds. Try to get out all the roots of the weedy plants. Weeds may not be a problem in the second season, depending on the variety and tenacity of weeds present. In the third year and beyond, the native grasses, sedges, rushes, and wildflowers will begin to mature and will out-compete the weeds. Weeding isolated patches might still be needed on occasion.

After each growing season, the stems and seedheads can be left for winter interest, wildlife cover and bird food. Once spring arrives and new growth is 4-6-inches tall, cut all tattered plants back. If the growth is really thick, hand-cut the largest plants and then use a string trimmer to mow the planting back to a height of six to eight inches. Dead plant material can also be removed with a string trimmer or weed whacker (scythe) and composted or disposed of as appropriate.

The best way to knock back weeds and stimulate native plant growth is to burn off the dead plant material in the rain garden. However, burning is banned in most municipalities. Another option is to mow the dead plant material. If the mowing deck of your lawn mower can be raised to a height of six inches or so, go ahead and simply mow your rain garden. Then, rake up and compost or properly dispose of the dead plant material.

If the mower deck won't raise that high, use a string trimmer or weed-eater to cut the stems at a height of 6-8 inches. On thicker stems, such as cup plant, goldenrods and some asters, a string trimmer may not be strong enough. For these, use hand clippers or pruning shears to cut the individual stems.

What does a rain garden cost?

The cost of a rain garden will vary depending on who does the work and where the plants come from. If you grow your own plants or borrow plants from neighbors there can be very little or no cost at all. If you do all the work but use purchased prairie plants, a rain garden will cost approximately $3 to $5 per square foot. If a landscaper does everything, it will cost approximately $10 to $12 per square foot.

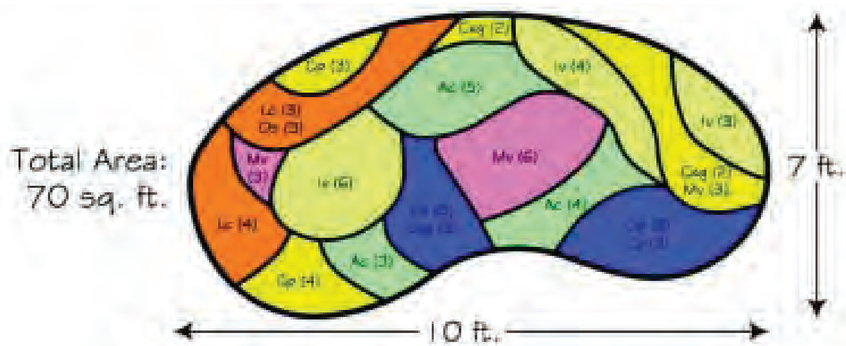
It might seem easiest to sow native wildflower seed over the garden, but experience shows that seeding a rain garden has its problems. Protecting the seeds from wind, flooding, weeds, and garden pests is very difficult, and the rain garden will be mostly weeds for the first two years. Growing plugs from seed indoors or dividing a friend's plants is much better. If you grow plugs, start them about four months before moving them to the rain garden. When the roots have filled the pot and the plants are healthy, they may be planted in the rain garden

Rain Garden Designs and Plant Lists

The following pages contain conceptual planting designs and plant lists for rain gardens with varying sun and soil conditions. Keep in mind that design possibilities for rain gardens are almost limitless. Many landscape nurseries, particularly those specializing in native plants and landscaping, can provide other ideas, designs and suggested plants.

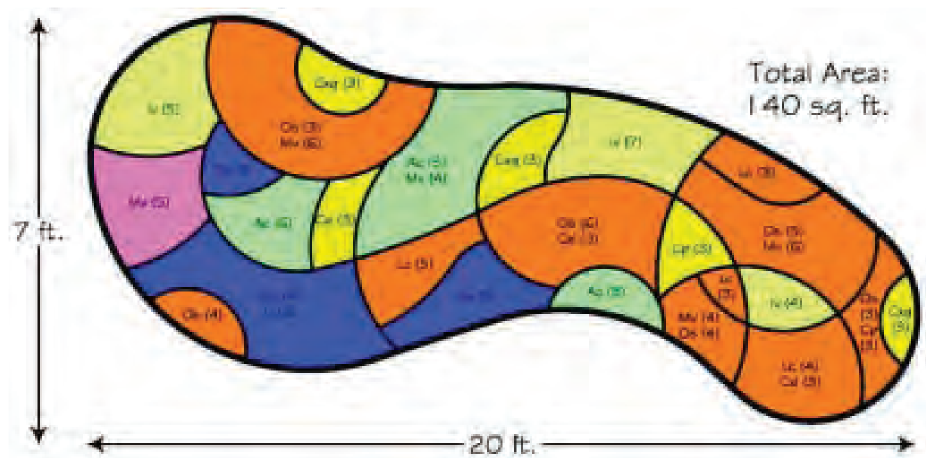
The following eight designs and plant lists have been provided by Applied Ecological Services, Inc., Brodhead, WI.

10 feet wide; full to partial shade with clay soils



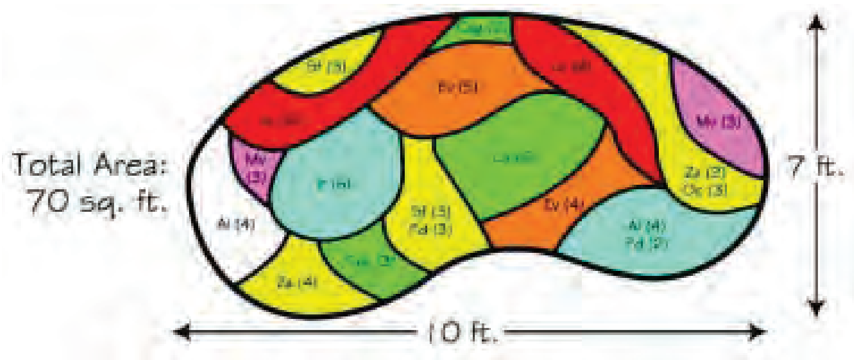
Symbol	Species Name	Common Name	No. of Plants
Ac	Acorus calamus	Sweet flag	12
Ca	Campanula americana	Tall bellflower	6
Cp	Caltha palustris	Marsh marigold	7
Cxg	Carex Grayii	Bur sedge	7
Cxl	Carex lupulina	Hop sedge	3
Iv	Iris virginica-shrevei	Wild blue flag iris	13
Lc	Lobelia cardinalis	Cardinal flower	7
Mv	Mertensia virginica	Virginia bluebells	12
Os	Onoclea sensibilis	Sensitive fern	3
		Total Plants Needed	70

20 feet wide; full to partial shade with clay soils



Symbol	Species Name	Common Name	No. of Plants
Ac	Acorus calamus	Sweet flag	16
Cp	Caltha palustris	Marsh marigold	9
Ca	Campanula americana	Tall bellflower	5
Cxg	Carex Grayii	Bur sedge	9
Cxl	Carex lupulina	Hop sedge	15
Iv	Iris virginica-shrevei	Wild blue flag iris	21
Lc	Lobelia cardinalis	Cardinal flower	15
Mv	Mertensia virginica	Virginia bluebells	25
Os	Onoclea sensibilis	Sensitive fern	25
		Total Plants Needed	140

10 feet wide; full to partial shade with silty & sandy soils

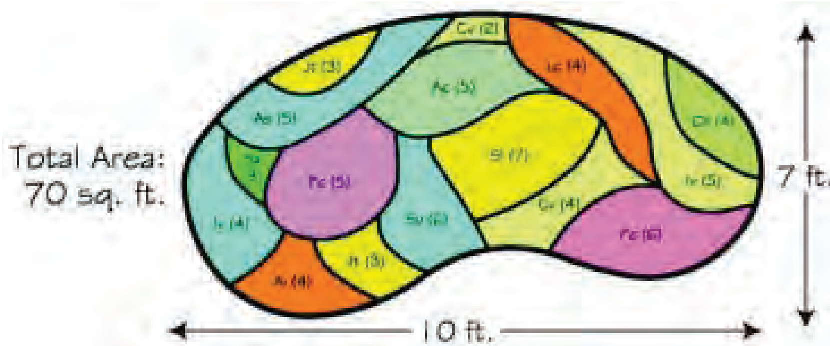


Symbol	Species Name	Common Name	No. of Plants
Al	Aster lateriflorus	Side-flowering aster	8
Ca	Campanula americana	Tall bellflower	6
Cxg	Carex Grayii	Bur sedge	5
Ev	Elymus virginicus	Virginia wild rye	9
Iv	Iris virginica-shrevei	Wild blue flag iris	6
Lc	Lobelia cardinalis	Cardinal flower	10
Mv	Mertensia virginica	Virginia bluebells	6
Oc	Osmunda claytoniana	Interupted fern	3
Pd	Phlox divaricata	Woodland phlox	5
Sf	Solidago flexicaulis	Zig zag goldenrod	6
Za	Zizia aurea	Golden Alexander	6
		Total Plants Needed	70

20 feet wide; full to partial shade with silty & sandy soils

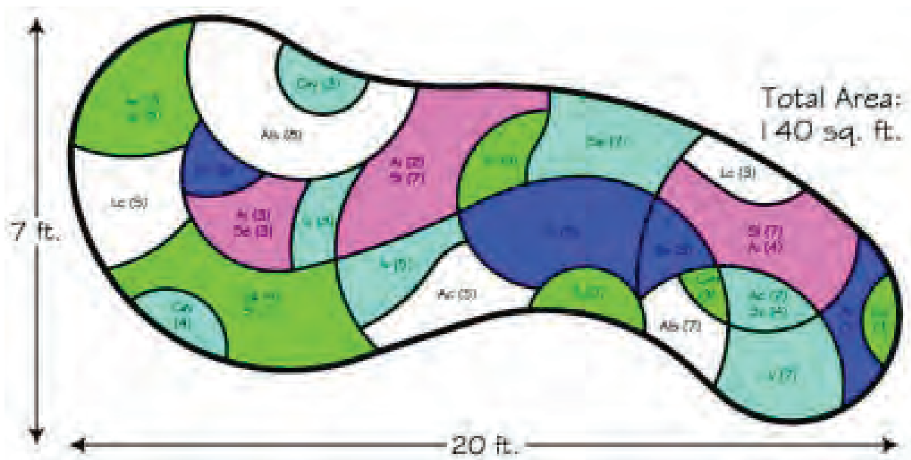
Symbol	Species Name	Common Name	No. of Plants
Aa	Arisaema atrorubens	Jack-in-the-pulpit	7
Al	Aster lateriflorus	Side-flowering aster	17
Ca	Campanula americana	Tall bellflower	9
Cxg	Carex Grayi	Bur sedge	8
Cxl	Carex lupulina	Hop sedge	7
Ev	Elymus virginicus	Virginia wild rye	11
Ep	Eupatorium purpureum	Purple Joe-Pye weed	3
Iv	Iris virginica-shrevei	Wild blue flag iris	6
Lc	Lobelia cardinalis	Cardinal flower	15
Mv	Mertensia virginica	Virginia bluebells	11
Oc	Osmunda claytoniana	Interupted fern	12
Pd	Phlox divaricata	Woodland phlox	15
SF	Solidago flexicaulis	Zig zag goldenrod	9
Za	Zizia aurea	Golden Alexander	14
		Total Plants Needed	143

10 feet wide;
full to partial sun with clay soils



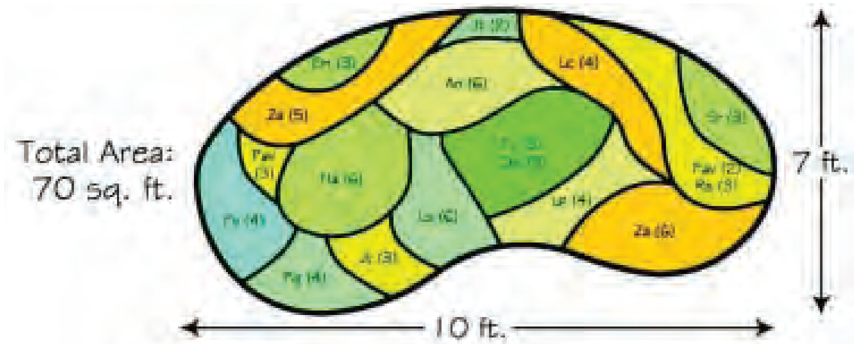
Symbol	Species Name	Common Name	No. of Plants
Ac	Acorus calamus	Sweet flag	5
As	Asclepias incarnata	Swamp milkweed	4
Als	Alisma subcordatum	Water plantain	5
Ch	Carex hystricina	Bottle brush sedge	4
Cv	Carex vulpinoidea	Fox sedge	6
Iv	Iris virginica-shrevei	Wild blue flag iris	9
Jt	Juncus torreyi	Torrey's rush	6
Lc	Lobelia cardinalis	Cardinal flower	4
Pc	Pontedaria cordata	Pickerel weed	11
Sl	Sagittaria latifolia	Arrowhead	7
Sa	Scirpus atrovirens	Green bulrush	3
Sv	Scirpus validus creber	Soft stemmed bulrush	6
		Total Plants needed	70

20 feet wide;
full to partial sun with clay soils



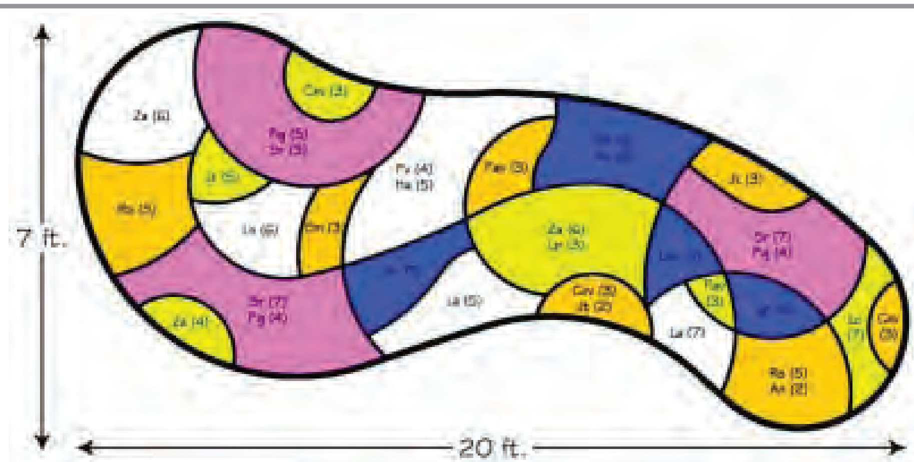
Symbol	Species Name	Common Name	No. of Plants
Ac	Acorus calamus	Sweet flag	10
Ai	Asclepias incarnata	Swamp milkweed	9
Als	Alisma subcordatum	Water plantain	15
Ch	Carex hystricina	Bottle brush sedge	6
Cv	Carex vulpinoidea	Fox sedge	7
Iv	Iris virginica-shrevei	Wild blue flag iris	15
Jt	Juncus torreyi	Torrey's rush	8
Lc	Lobelia cardinalis	Cardinal flower	8
Pc	Pontedaria cordata	Pickerel weed	21
Sl	Sagittaria latifolia	Arrowhead	21
Sa	Scirpus atrovirens	Green bulrush	7
Sv	Scirpus validus creber	Soft stemmed bulrush	7
Se	Sparganium eurycarpum	Common bur-reed	10
		Total Plants needed	144

10 feet wide; full to partial sun with silt and sandy soils



Symbol	Species Name	Common Name	No. of Plants
An	Aster novae-angliae	New England Aster	6
Cac	Carex comosa	Bottlebrush sedge	3
Ep	Eupatorium maculatum	Spotted Joe-Pye weed	3
Ha	Helenium autumnale	Sneezeweed	6
Jt	Juncus torreyi	Torrey's rush	5
Lp	Liatris pycnostachya	Gayfeather	4
Lc	Lobelia cardinalis	Cardinal flower	4
Ls	Lobelia siphilitica	Great blue lobelia	6
Pav	Panicum virgatum	Switch grass	5
Pg	Phlox glaberrima	Marsh phlox	4
Pv	Pycnanthemum virginianum	Mountain mint	7
Rs	Rudbeckia subtomentosa	Sweet coneflower	5
Sr	Solidago Riddellii	Riddell's goldenrod	3
Za	Zizia aurea	Golden Alexander	11
		Total Plants needed	72

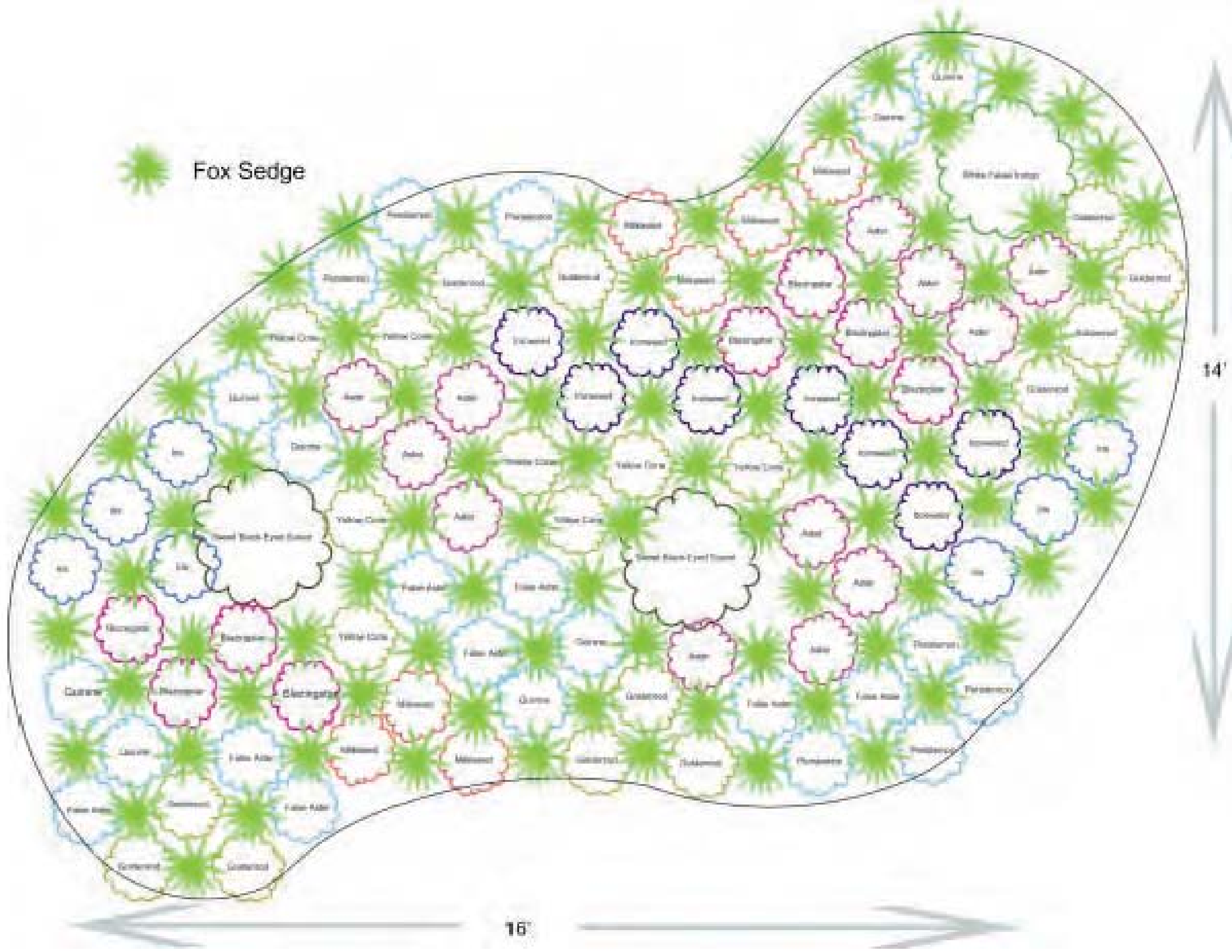
20 feet wide; full to partial sun with silt and sandy soils



Symbol	Species Name	Common Name	No. of Plants
An	Aster novae-angliae	New England Aster	9
Cvu	Carex vulpinoidea	Fox sedge	8
Ep	Eupatorium maculatum	Spotted Joe-Pye weed	3
Ha	Helenium autumnale	Sneezeweed	5
Jt	Juncus torreyi	Torrey's rush	10
Lp	Liatris pycnostachya	Gayfeather	9
Lc	Lobelia cardinalis	Cardinal flower	7
Ls	Lobelia siphilitica	Great blue lobelia	8
La	Lythrum alatum	Winged loosestrife	12
Mf	Monarda fistulosa	Wild Bergamot	5
Pav	Panicum virgatum	Switch grass	6
Pg	Phlox glaberrima	Marsh phlox	13
Pv	Pycnanthemum virginianum	Mountain mint	4
Rs	Rudbeckia subtomentosa	Sweet coneflower	10
Sr	Solidago Riddellii	Riddell's goldenrod	17
Za	Zizia aurea	Golden Alexander	16
		Total Plants needed	144

22

The following three designs and plant lists have been provided by Prairie Nursery, Inc., Westfield, WI

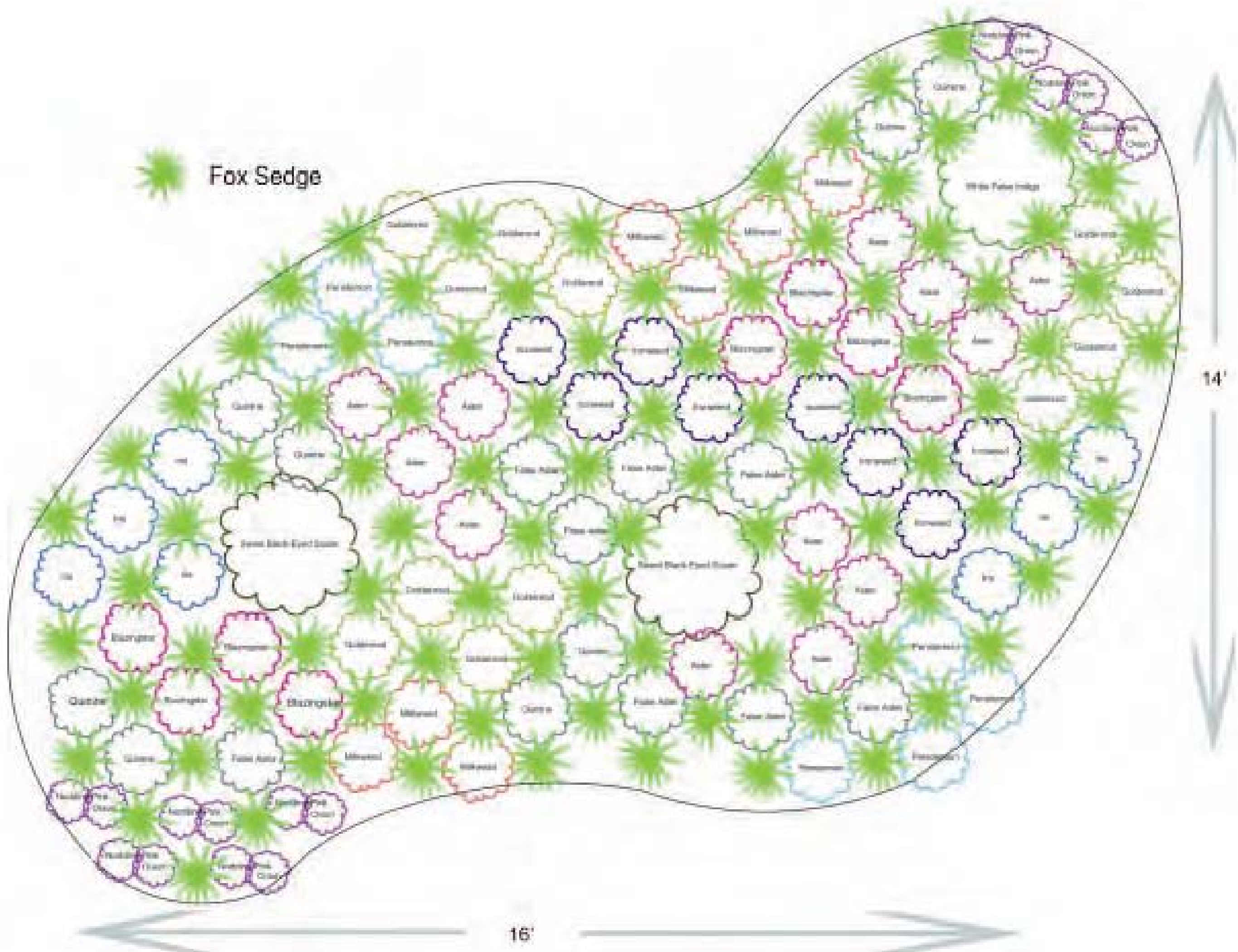

Fox Sedge
14'
16'

RAIN GARDEN FOR CLAY SOILS AND FULL SUN

AREA: 192 Square Feet

Designed to thrive through conditions of periodic water infiltrations as well as dry periods
Designed to control 45% of annual runoff from an average sized rooftop (500 to 700 square feet)
Install at least 10′ from your foundation, in-line with a down-spout and/or downslope to intercept the rooftop water
Depth of the garden designed to be 3.5″ to 4″ deep to hold about 200 gallons of water during periods of heavy rainfall

LATIN NAME	COMMON NAME	AMT	BLOOM TIME	BLOOM COLOR	HEIGHT	SPACING
Asclepias incarnata	Red Milkweed	7	early summer	red	3′-5′	1′
Baptisia lactea	White False Indigo	1	early summer	white	3′-5′	2′
Iris versicolor	Blue Flag Iris	7	early summer	blue	2′-3′	1′
Penstemon digitalis	Smooth Penstemon	7	early summer	white	2′-3′	1′
Liatris pycnostachya	Prairie Blazingstar	8	summer	pink	3′-5′	1′
Parthenium integrifolium	Wild Quinine	8	summer	white	3′-5′	1′
Ratibida pinnata	Yellow Coneflower	8	summer	yellow	3′-6′	1′
Boltonia asteroides	False Aster	8	late summer	white/pink	2′-4′	1′
Rudbeckia subtomentosa	Sweet Black-Eyed Susan	2	late summer	yellow	4′-6′	2′
Vernonia fasciculata	Ironweed	8	late summer	magenta	4′-6′	1′
Aster novae-angliae	New England Aster	12	fall	pink/purple	3′-6′	1′
Solidago rigida	Stiff Goldenrod	12	fall	yellow	3′-5′	1′
Carex vulpinoidea	Fox Sedge	96			1′-3′	1′
		184 plants				

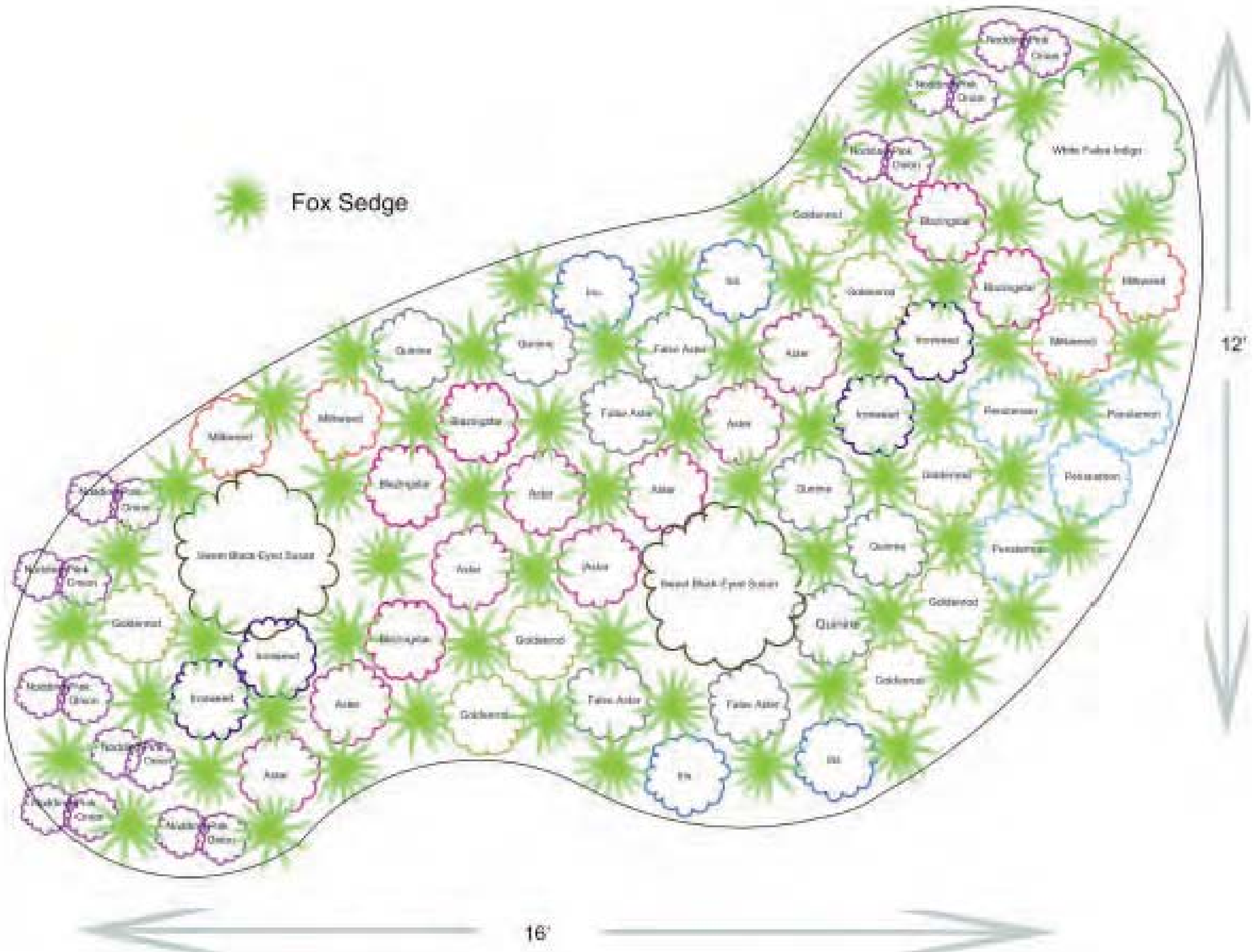

Fox Sedge
14'
16'

RAIN GARDEN FOR LOAM TO SANDY/LOAM SOILS AND FULL SUN

AREA: 192 Square Feet

Designed to thrive through conditions of periodic water infiltrations as well as dry periods
Designed to control 90% of annual runoff from an average sized rooftop (500 to 700 square feet)
Install at least 10' from your foundation, in-line with a down-spout and/or downslope to intercept the rooftop water
Depth of the garden designed to be 3.5" to 4" deep to hold about 400 gallons of water during periods of heavy rainfall

LATIN NAME	COMMON NAME	AMT	BLOOM TIME	BLOOM COLOR	HEIGHT	SPACING
Asclepias incarnata	Red Milkweed	7	early summer	red	3'-5'	1'
Baptisia lactea	White False Indigo	1	early summer	white	3'-5'	2'
Iris versicolor	Blue Flag Iris	7	early summer	blue	2'-3'	1'
Penstemon digitalis	Smooth Penstemon	7	early summer	white	2'-3'	1'
Allium cernuum	Nodding Pink Onion	16	summer	pink	1'-2'	6"
Liatris pycnostachya	Prairie Blazingstar	8	summer	pink	3'-5'	1'
Parthenium integrifolium	Wild Quinine	8	summer	white	3'-5'	1'
Boltonia asteroides	False Aster	8	late summer	white/pink	2'-4'	1'
Rudbeckia subtomentosa	Sweet Black-Eyed Susan	2	late summer	yellow	4'-6'	2'
Vernonia fasciculata	Ironweed	8	late summer	magenta	4'-6'	1'
Aster novae-angliae	New England Aster	12	fall	pink/purple	3'-6'	1'
Solidago ohioensis	Ohio Goldenrod	12	fall	yellow	3'-4'	1'
Carex vulpinoidea	Fox Sedge	96			1'-3'	1'
		192 plants				


Fox Sedge
12'
16'
Quinine
Goldenrod
Aster
False Aster
Milkweed
Ironweed

RAIN GARDEN FOR SANDY SOILS AND FULL SUN

AREA: 128 Square Feet

Designed to thrive through conditions of periodic water infiltrations as well as dry periods
Designed to control 90% of annual runoff from an average sized rooftop (500 to 700 square feet)
Install at least 10' from your foundation, in-line with a down-spout and/or downslope to intercept the rooftop water
Depth of the garden designed to be 3.5" to 4" deep to hold about 400 gallons of water during periods of heavy rainfall

LATIN NAME	COMMON NAME	AMT	BLOOM TIME	BLOOM COLOR	HEIGHT	SPACING
Asclepias incarnata	Red Milkweed	4	early summer	red	3'-5'	1'
Baptisia lactea	White False Indigo	1	early summer	white	3'-5'	2'
Iris versicolor	Blue Flag Iris	4	early summer	blue	2'-3'	1'
Penstemon digitalis	Smooth Penstemon	4	early summer	white	2'-3'	1'
Allium cernuum	Nodding Pink Onion	18	summer	pink	1'-2'	6"
Liatris pycnostachya	Prairie Blazingstar	5	summer	pink	3'-5'	1'
Parthenium integrifolium	Wild Quinine	5	summer	white	3'-5'	1'
Boltonia asteroides	False Aster	4	late summer	white/pink	2'-4'	1'
Rudbeckia subtomentosa	Sweet Black-Eyed Susan	2	late summer	yellow	4'-6'	2'
Vernonia fasciculata	Ironweed	4	late summer	magenta	4'-6'	1'
Aster novae-angliae	New England Aster	8	fall	pink/purple	3'-6'	1'
Solidago ohioensis	Ohio Goldenrod	8	fall	yellow	3'-4'	1'
Carex vulpinoidea	Fox Sedge (sedge)	64			1'-3'	1'
		128 plants				

Special Rain Garden Locations

In addition to conventional lawns, there are other locations where rain gardens can be created. A rectangular-shaped rain garden (above) was located in a narrow sideyard between two homes. A new rain garden (below), now helps control runoff that would flow into a parking lot.

Rain garden designs and plant lists provided by John Gishnock, Applied Ecological Services, Inc. (pages 19-22) and Jennifer Baker, Prairie Nursery Inc. (pages 24-29).

RAIN GARDENS

A how-to manual for homeowners

A frosted rain garden in autumn.

This publication developed by Roger Bannerman, Wisconsin Department of Natural Resources and Ellen Considine, U.S. Geological Survey. Special thanks to John Gishnock, Applied Ecological Services, Inc., Jennifer Baker, Prairie Nursery Inc. and Joyce Powers, CRM Ecosystems Inc.

Photos by Roger Bannerman, Wisconsin Department of Natural Resources.

Layout design/production by Jeffrey Strobel, and editorial assistance by Bruce Webendorfer, University of Wisconsin–Extension Environmental Resources Center.

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The publication can also be viewed and printed from pdf format on the web at clean-water.uwex.edu/pubs/raingarden

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UWEX Publication GWQ037

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Appendix D

ROAD/STREAM CROSSING INSPECTION PROTOCOL DATA SHEET

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Road/Stream Crossing Inspection Data Sheet

Site ID: ___________

Name of Observer(s)______________________________ **Date**_____________

GPS coordinates (lat/long.) ________________________________ OR **T/R**____________ **Sec**____ ¼____

Road Name_____________________________ **Road Number** _________ **Structure ID** _________

Stream Name___________________________________ **Road type** State County Town Private Federal Other

Land Use In Surrounding Area: (circle all that apply)
Forest Wetland Open/Field Pasture Cultivated Urban Other

Additional comments about location (milepost, etc.)**:**

Road Surface (circle all that apply) Paved Gravel Native **Road Width** _______ft. **with shoulders** _______ft.

Erosion of road near crossing? Y N
(if YES, also fill out Section F)

Is there a trash rack or beaver prevention structure? Y N

Evidence of crossing blow-out? Y N **Evidence of beaver activity? Y N**

Structure Type (circle one) Culvert Bridge Ford No Structure

A. Crossing Characteristics:

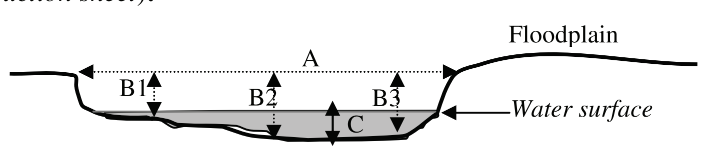
		Inlet/Upstream	Outlet/Downstream	Comments/Notes
Embankment or Side Slopes (not applicable to Fords)	Protection	vegetation armor other	vegetation armor other	
	Erosion *(if Y, fill out Section F)*	Y N	Y N	
Channel	Aligned	Y N	Y N	
	Pool present	Y N	Y N	
	Pool scour width	ft.	ft.	
	Pool water depth (max.)	ft.	ft.	
	Protection	armor other none	armor other none	
Ditch	Present	Y N	Y N	
	Protection	vegetation armor other	vegetation armor other	
	Connected to stream	Y N	Y N	
	Erosion *(if Y, fill out Section F)*	Y N	Y N	

B. Stream Measurements (*See standard procedure in instruction sheet*)**:**

A: Bankfull Width __________feet

B: Bankfull Depth (left to right facing downstream)
B1:______feet B2:______feet B3:______feet

C: Water depth _______ feet



Cross-section of stream channel

Flow conditions: overbank at bankfull below bankfull very low none

Fish present? Y N

C. Photos: (At a minimum take photos of the structure inlet and outlet and upstream and downstream conditions). Record photo number and camera number if applicable (example: Photo 6 or Camera 1 Photo 6).

Inlet __________ Upstream __________

Outlet _________ Downstream ________

Additional Photos (as needed to identify issues). Provide location and/or description of issue:

Location ___________________________ Photo Number (and camera number if applicable) ____________

Location ___________________________ Photo Number (and camera number if applicable) ____________

D. Culvert Characteristics (For multiple culverts fill out table below.)

Culvert Shape (circle one)
- ○ Round
- □ Square/Rectangle
- ⊓ Open Bottom Square/Rectangle
- Open Bottom Arch
- Pipe Arch
- Ellipse

Culvert Material
- Metal
- Concrete
- Plastic
- Wood

Condition of Structure (check all that apply)
- General condition: new good fair poor
- Plugged ____% where? inlet outlet in pipe
- Crushed ____% where? inlet outlet in pipe
- Rusted through □
- Condition comments: _____________________________

Culvert Measurements:

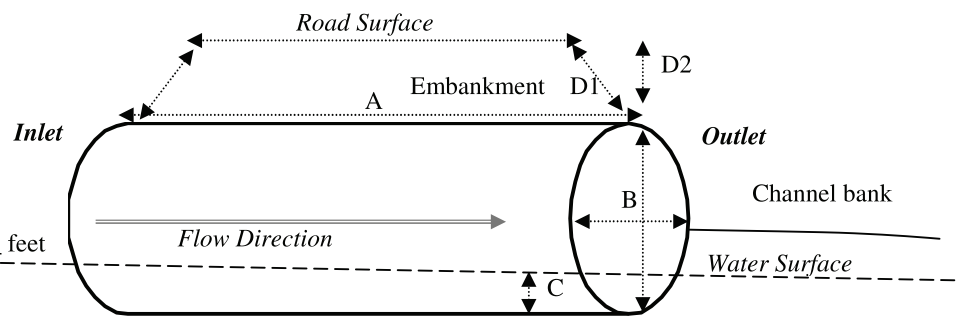
A: Culvert Length ________ feet

B: Culvert Height ________ feet

Culvert Width ________ feet

C: Depth of water in structure: _______ feet

D: Embankment:



Inlet: D1_____feet D2______feet **Outlet:** D1______feet D2______feet

Culvert Rise (top of culvert to stream bed): **Inlet Rise**: ____ft **Outlet Rise**: ______ft

Inlet/Outlet Characteristics: **Inlet Drop**: ____ft **Outlet Perch**: _____ft

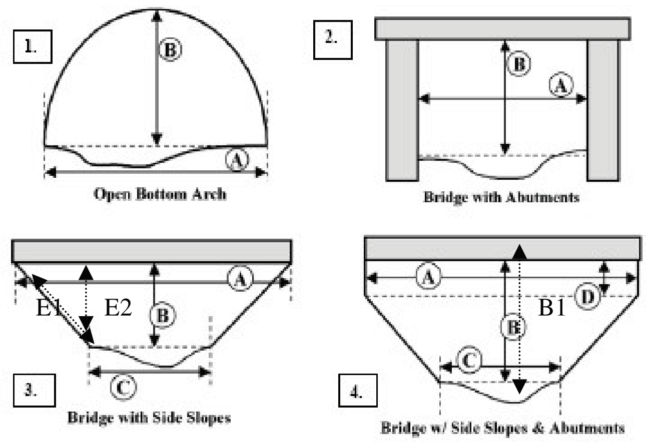
Inlet Type: Projecting Headwall Wingwalls Mitered Apron Other
Outlet Type: Projecting Headwall Wingwalls Mitered Apron Other

Substrate: Y N Match Stream? Y N

Multiple Culverts: NOTE: (*number multiple culverts from left to right facing downstream. Fill in sections above for culvert # 1 and use this table for remaining culverts)*

Culvert #	Shape/ Material	Length	Height	Width	Rise inlet/outlet	Depth of water in structure	Inlet drop	Outlet perch	Condition
2									
3									
4									

E. Bridge Characteristics (For multiple cells see below):



Bridge Type (# from diagram) _______

Bridge Surface Material:

Wood	Open decking? Y N
Concrete	Asphalt
Metal	other __________

Bridge Measurements:

A: Span ______feet Width (parallel to stream) ______feet

B: Bottom of beam to water surface _______feet

B1: Bridge Rise (bottom of beam to stream bed) _______feet

C: Stream width _______feet

D: Bottom of beam to top of embankment _______feet

E: Side Slopes (facing downstream):

Left bank: E1_______feet E2______feet **Right Bank**: E1______feet E2______feet

Present at inlet (circle all that apply):	Wingwalls	Apron	Other _______________
Present at outlet (circle all that apply):	Wingwalls	Apron	Other _______________

Condition of Structure: Deteriorating **Y or N**

If yes, where (check all that apply)? ☐ Abutments ☐ Decking ☐ Wingwalls ☐ Other___________________

Multiple Bridge Cells

NOTE: *(number multiple bridge cells (usually separated by abutments) from left to right facing downstream. Fill in sections above for bridge cell # 1 and use this section for remaining cells)*

Bridge Cell #	A (ft.)	B (ft.)	B1 (ft.)
2			
3			
4			

F. Erosion Properties – *(fill out all that apply, add other locations in blank rows. Other locations to note may include prominent erosion along stream banks within 50' of crossing.)*

Location of Erosion	Erosion Dimensions (feet)			Material Eroded (clay, silt, sand, gravel, loam, sandy loam, OR gravelly loam)	Erosion Reaching Stream? (Y/N)	Comments
	Length	Width	Depth			
Road approach *(left, facing downstream)*						
Road approach *(right, facing down stream)*						
Ditch(s) *(upstream side of road)*						
Ditch(s) *(downstream side of road)*						
Road over crossing (or bridge deck)						
Culvert inlet embankment						
Culvert outlet embankment						
Bridge Side slopes *(left, facing downstream)*						
Bridge Side slopes *(right, facing down stream)*						

If erosion occurs on the approaches or in the ditches, is there opportunity (room) to install road drainage measures?
Y **N**

G. Site Sketches (Identify road crossing, stream, flow direction, issues, and location and direction of photos):

↑ **N**

Comments: *(Provide additional information such as invasive plants present, spillways present, etc)*

Appendix E

QUALITATIVE FISH HABITAT RATING PROTOCOLS FOR SMALL AND LARGE WADABLE STREAMS

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State of Wisconsin
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Wadable Stream Qualitative Fish Habitat Rating for Streams < 10 m wide

Form 3600-532A (R 6/07)

Instructions: **Bold** fields must be completed. Record all measurements in metric units.

Station Summary

Stream Name		**Waterbody ID Code**	**SWIMS Station ID**	FH Database ID
Date (MMDDYYYY)	**Station Name**			
Latitude - Longitude Determination Method Used				**Datum Used**
Start Latitude	**Start Longitude**	End Latitude	End Longitude	**County**

Water Characteristics

Time (24-hr clock)	Air Temperature (C)	Water Temperature (C)	Conductivity (µs/cm)	Transparency (cm)
Dissolved Oxygen (mg/l)	Dissolved Oxygen % Saturation	pH		

Flow (m^3/sec)

Water Level (check one - measure distance if Above or Below Normal): ☐ Normal ☐ Below: ________(m) ☐ Above: ________(m)

Water Clarity: ☐ Clear ☐ Turbid ☐ Stained

Channel and Basin Characteristics

Mean Stream Width (m)	**Station Length (m)**

Channel Condition: (check one) ☐ Natural ☐ > 20-year-old Channelization ☐ 10- to 20-year-old Channelization ☐ < 10-year-old Channelization ☐ Concrete Channel

Percent Channelization	Sinuosity	Gradient (m/km)	Stream Order	Basin Area (km^2)

Comments / Notes

Wadable Stream Qualitative Fish Habitat Rating for Streams < 10 m wide

Form 3600-532A (R 6/07)

Rating Item	Excellent	Good	Fair	Poor	Score
Riparian Buffer Width (m) Width of contiguous undisturbed land uses; meadow, shrubs, woodland, wetland, exposed rock	Riparian zone well protected; buffer wide (> 10.0 m) 15	Riparian zone protected, but buffer width moderate (5.0 - 10.0 m) 10	Riparian zone moderately disturbed, buffer narrow (1.0 - 4.9 m) 5	Most of the riparian zone disturbed, buffer very narrow or absent (< 1.0 m) 0	
Bank Erosion Width of bare soil on bank, along transects	No significant bank erosion; < 0.20 m of bank is bare soil 15	Limited erosion; 0.20 - 0.50 m of bank is bare soil 10	Moderate erosion; 0.51 - 1.0 m of bank is bare soil 5	Extensive erosion; > 1.0 m of bank is bare soil 0	
Pool Area % of stream length in pools	Pools common; wide, deep, slow velocity habitat, balanced by other habitats; 40 to 60% of station 10	Pools present; not frequent or over-abundant; 30 to 39% or 61 to 70% of station 7	Pools present, but either rare or overly dominant, few other habitats present; 10 to 29% or 71 to 90% of station 3	Pools either absent or dominant, not balanced by other habitats; < 10% or > 90% of station 0	
Width:Depth Ratio Average stream width divided by average thalweg depth in runs and pools	Streams very deep and narrow; width/depth ≤ 7 15	Stream relatively deep and narrow; width/depth 8-15 10	Stream moderately deep and narrow; width/depth 16-25 5	Stream relatively wide and shallow; width/depth > 25 0	
Riffle:Riffle or Bend:Bend Ratio Average distance between riffles or bends divided by average stream width	Diverse habitats; meandering stream with deep bends and riffles common; ratio < 10 15	Diverse habitats; bends and riffles present, but not abundant; ratio 10 to 14 10	Habitat diversity low; occasional riffles or bends, ratio 15 to 25 5	Habitat monotonous; riffles or bends rare; generally continuous run habitat; ratio > 25 0	
Fine Sediments % of the substrate that is < 2 mm (sand, silt, or clay)	Fines rare or absent, < 10% of the stream bed 15	Fines present but limited, generally in stream margins or pools; 10 to 20% of stream bed 10	Fines common in mid-channel areas, present in riffles and extensive in pools; 21 to 60% 5	Fines extensive in all habitats; > 60% of stream bed covered 0	
Cover for Fish % of the stream area with cover	Cover/shelter for fish abundant; > 15% of stream 15	Cover common, but not extensive; 10 - 15% of stream 10	Occasional cover, limited to one or two areas; 5 - 9% of stream 5	Cover rare or absent; limited to < 5% of stream 0	
				Total Score	

State of Wisconsin
Department of Natural Resources
dnr.wi.gov

Wadable Stream Qualitative Fish Habitat Rating for Streams > 10 m wide

Form 3600-532B (R 6/07)

Instructions: **Bold** fields must be completed. Record all measurements in metric units.

Station Summary

Stream Name	**Waterbody ID Code**	**SWIMS Station ID**	FH Database ID

Date (MMDDYYYY)	**Station Name**

Latitude - Longitude Determination Method Used	**Datum Used**

Start Latitude	**Start Longitude**	End Latitude	End Longitude	**County**

Water Characteristics

Time (24-hr clock)	Air Temperature (C)	Water Temperature (C)	Conductivity (µs/cm)	Transparency (cm)

Dissolved Oxygen (mg/l)	Dissolved Oxygen % Saturation	pH

Flow (m^3/sec)	**Water Level** (check one - measure distance if Above or Below Normal):	**Water Clarity:**
	☐ Normal ☐ Below: ________(m) ☐ Above: ________(m)	☐ Clear ☐ Turbid ☐ Stained

Channel and Basin Characteristics

Mean Stream Width (m)	**Station Length (m)**

Channel Condition: (check one) ☐ Natural ☐ > 20-year-old Channelization ☐ 10- to 20-year-old Channelization ☐ < 10-year-old Channelization ☐ Concrete Channel

Percent Channelization	Sinuosity	Gradient (m/km)	Stream Order	Basin Area (km^2)

Comments / Notes

Wadable Stream Qualitative Fish Habitat Rating for Streams > 10 m wide

Form 3600-532B (R 6/07)

Rating Item	Excellent	Good	Fair	Poor	Score
Bank Stability % of bank protected by rock or vegetation	No significant bank erosion; ≥ 90% of bank protected; < 10% bare soil 12	Limited erosion; 70 to 90% of bank protected; 10 - 30% bare soil 8	Moderate erosion; 50 to 69% of bank protected; 31 - 50% bare soil 4	Extensive erosion; < 50% of bank protected; > 50% bare soil 0	
Maximum Thalweg Depth Average of the four deepest depths recorded	Stream very deep; ≥ 1.5 m 25	Stream relatively deep; 1 - 1.5 m 16	Stream moderately deep; 0.6 - 0.9 m 8	Stream relatively shallow; < 0.6 m 0	
Riffle:Riffle or Bend:Bend Ratio Average distance between riffles or bends divided by average stream width	Diverse habitats; meandering stream with deep bends and riffles common; ratio < 10 12	Diverse habitats; bends and riffles present, but not abundant; ratio 10 to 14 8	Habitat diversity low; occasional riffles or bends, ratio 15 to 25 4	Habitat monotonous; riffles or bends rare; generally continuous run habitat; ratio > 25 0	
Rocky Substrate % of substrate, by area, that is bedrock, boulder, rubble/ cobble, or gravel	Extensive rocky substrate; ≥ 65% of the stream bed 25	Moderate rocky substrate; 45 - 65% of stream bed 16	Limited rocky substrate; 15 - 44% of stream bed 8	Rocky substrate uncommon; < 15% of stream bed 0	
Cover for Fish % of the stream area with cover	Cover/shelter for fish abundant; ≥ 12% of stream 25	Cover common, but not extensive; 7 - 12% of stream 16	Occasional cover, limited to one or two areas; 2 - 6% of stream 8	Cover rare or absent; limited to < 2% of stream 0	
				Total Score	

Appendix F

PROTOCOLS FOR STUDYING WET WEATHER IMPACTS AND URBANIZATION PATTERNS

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Protocols for Studying Wet Weather Impacts and Urbanization Patterns

The research team conducted a pilot study of eight watersheds with a gradient of urban development in the North Carolina Piedmont and demonstrated that the hydrologic metric $T_{0.5}$ responds to changes in land use and to alternative runoff control scenarios. (The $T_{0.5}$ is defined as the percent of time that the flow is greater than the peak flow of the 0.5-year storm.)

This research explored the relationship of urbanization to ecology in the wadeable streams of developing watersheds.

The study also found that the ecological health of streams in the North Carolina Piedmont, as measured by macroinvertebrate indices, is responsive to the $T_{0.5}$ metric.

Furthermore, limited flow monitoring and macroinvertebrate data can be used in conjunction with hydrologic and hydraulic modeling to estimate how changes in land use patterns and runoff control scenarios affect the biotic integrity of streams in a developing watershed.

The team developed a protocol based on two key findings from the literature review:

- The biotic integrity of an urban stream, as measured by the benthic index of biological integrity (B-IBI), can be related directly to the hydrologic metrics, $T_{0.5}$ and TQmean, and these two metrics are in turn related to the intensity of urbanization on a watershed.
- The hydrologic metric $T_{0.5}$ can be computed using mathematical storm water models, and $T_{0.5}$ is sensitive to alternative land use and runoff control scenarios.

This implies that land use planning and runoff control strategies can be related to biotic integrity in streams.

Overview of the Protocol

The protocol is illustrated on the next page. The black boxes portray the identification and collection of necessary biologic data. The white boxes are data analysis activities comprising hydrologic, geomorphic, and biotic analyses that define the baseline for stormwater management planning. They also form a basis for evaluating the relative impact of alternative storm water management plans (land use patterns and/or runoff control strategies) on stream biota for developing watersheds.

The protocol focuses on the relationship of storm water management practices in urbanizing watersheds to biologic health in the receiving streams, as represented by measures of the fish and aquatic macroinvertebrate communities. Water quality is not explicitly included in the protocol; however, it is included implicitly because the protocol requires storm water treatment practices be employed as part of the hydrologic stability analysis.

Research Recommendations

A carefully conducted experiment should be conducted on an urbanizing watershed of 1–3 square miles, using runoff controls and BMPs designed according to the criteria recommended in this study (see conclusions in report) to relate macroinvertebrate health to $T_{0.5}$ as the watershed develops. This data needs to be compared to watersheds that are

BENEFITS

- Develops a protocol to evaluate the impacts of land use patterns and alternative stormwater management strategies on the biotic integrity of streams in urbanizing watersheds.
- Applies the protocol to urbanization questions in a pilot study area.

RELATED PRODUCTS

Research Needs: Physical Effects of Wet Weather Flows on Aquatic Habitats (00WSM4)

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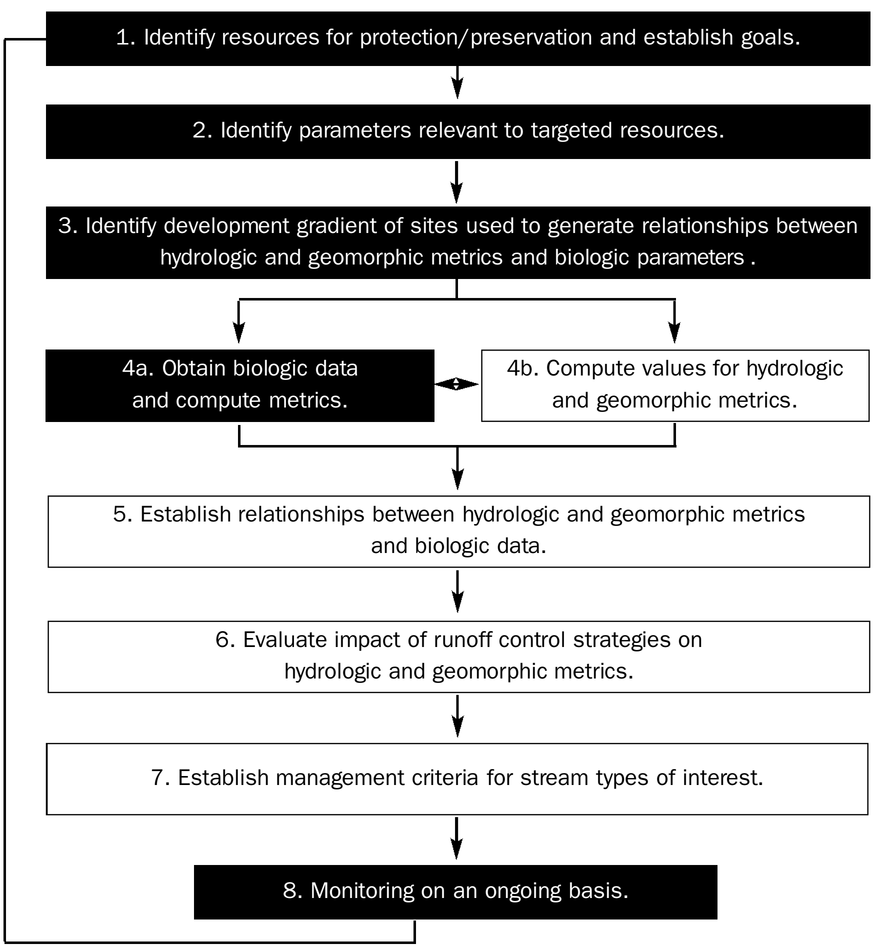
in various states of urbanization but that have no significant runoff controls. Care must be taken in this experiment to control runoff during the construction phase or the macroinvertebrate indices will reflect the construction impacts rather than the built environment impacts.

Water quality was not addressed in this work. From the standpoint of protecting the biotic integrity of receiving streams in urbanizing watersheds, the researchers in this study believe that the main issues are the runoff controls required to achieve hydrologic and geomorphic stability. (The controls must include BMPs.) If properly designed, the controls will remove pollutants from storm water runoff. Nevertheless, the federal Clean Water Act is based on water quality criteria in receiving streams, and stormwater regulations now require that TMDL calculations include storm water runoff. Therefore, it is recommended that future research build on this protocol, by adding water quality sampling of constituents identified in the water quality criteria applicable to the receiving stream, adding water quality to storm water models as a runoff parameter, and simulating the removal of pollutants by runoff control practices.

The researchers believe that implementation of storm water management practices that reduce the overall volume of runoff through infiltration or evapotranspiration will also aid in moving towards a more natural hydrologic flow regime that will allow for ecologically healthy receiving waters. The impact of such practices depends upon the extent to which they are implemented. Future research could quantify the biotic impacts of volume reduction through practices such as low impact development.

The Evaluation Protocol



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