TECHNICAL REPORT NO. 61

FIELD MONITORING AND DATA COLLECTION FOR THE CHLORIDE IMPACT STUDY

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INTRODUCTION 1

Credit: SEWRPC Staff

1.1 PURPOSE OF THIS REPORT

Past Southeastern Wisconsin Regional Planning Commission (Commission) studies indicate that there are insufficient data available to assess overall chloride conditions of surface waters within the Southeastern Wisconsin Region (Region). The frequency at which chloride or specific conductance levels were collected within streams and lakes are inadequate to characterize the dynamics of chloride concentrations and loads and potential impacts on the waterways of the Region. Deficiencies in available data are particularly apparent during critical winter months when the potential impacts of chloride on the surface waters are likely to be greatest. In order to conduct a comprehensive assessment of current chloride conditions and trends in the surface water resources of the Region for the Chloride Impact Study,[1] it was necessary for Commission staff to supplement existing water quality data collected by other agencies.[2]

For this Study, Commission staff established a set of water quality monitoring sites in streams and lakes that are representative of the Region. Water quality monitoring at selected stream locations included continuous collection of specific conductance using automated monitoring equipment. In addition, grab samples which capture water quality conditions at one point in time were regularly collected for chemical analysis. Where possible, stream monitoring sites were located near existing U.S. Geological Survey (USGS) stream gage stations to provide reliable streamflow data. Commission staff also collected flow data at several ungaged stream monitoring sites to support the interpretation of water quality data. Water quality monitoring at lake locations included collecting grab samples at several selected lake depths for chemical analysis. Lake monitoring also included collecting specific conductance levels and temperatures along a vertical profile at the deepest point of the lake.

One objective of this comprehensive monitoring strategy was to assemble a dataset consisting of simultaneously collected specific conductance and chloride samples. Datasets collected at stream monitoring sites were used to develop regression models to estimate chloride concentrations from specific

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[1] *SEWRPC Planning Report No. 57,* A Chloride Impact Study for Southeastern Wisconsin, *in preparation*.

[2] *For a description of all sources of water quality data used to assess current chloride conditions within the Region, see SEWRPC Technical Report No. 63,* Chloride Conditions and Trends in Southeastern Wisconsin, *in preparation.*

conductance.[3] These regression models were then used to develop estimates of chloride concentrations at stream monitoring sites that were used for subsequent analyses conducted as part of the Study.

This Technical Report describes the field monitoring and data collection methods used in the Study, including:

- The approach used to select stream and lake water quality monitoring sites throughout the Region
- Characterization of the areas draining to the water quality monitoring sites
- A description of the equipment used for continuous water quality monitoring and the process for installing the equipment
- How the continuous monitoring equipment was maintained
- A summary of the water quality parameters collected at continuous stream monitoring sites
- A description of the equipment and methodology used for collecting water quality grab samples at stream and lake monitoring sites
- Water quality parameters measured from grab samples that were sent to the Wisconsin State Laboratory of Hygiene for chemical analysis
- Methodology used for winter weather event sampling at stream monitoring sites
- Quality assurance and quality control procedures for water quality monitoring and data collection
- Data management, documentation, and post-processing procedures

1.2 RELATIONSHIP OF THIS REPORT TO THE CHLORIDE IMPACT STUDY

This Technical Report documents the procedures and methodology used by Commission staff to collect water quality data at selected stream and lake locations within the Region for the Chloride Impact Study. The Chloride Impact Study was initiated due to heightened public concern over the effects of the growing use of road salt and evidence of increasing chloride concentrations in the surface and groundwater within the Region. The findings of this Study are being presented in a series of reports.

Major objectives of the Chloride Impact Study include:

1. Documenting historical and existing conditions and trends in chloride concentrations in surface and groundwater in the Region
2. Evaluating the potential for increased amounts of chloride in the environment to cause impacts to surface water, groundwater, and the natural and built environment in the Region
3. Identifying the major sources of chloride to the environment in the Region
4. Investigating and defining the relationship between the introduction of chloride into the environment and the chloride content of surface and groundwater
5. Developing estimates of chloride loads introduced into the environment under existing conditions and forecasts of such loads under planned land use conditions
6. Evaluating the potential effects of climate change on the major sources of chloride under planned land use conditions

[3] *SEWRPC Technical Report No. 64,* Regression Analysis of Specific Conductance and Chloride Concentrations*, in preparation.*

7. Reviewing the state-of-the-art of technologies and best management practices affecting chloride inputs to the environment and developing performance and cost information for such practices and technologies

8. Exploring legal and policy options for addressing chloride contributions to the environment

9. Developing and evaluating alternative chloride management scenarios for minimizing impacts to the environment from chloride use while meeting public safety objectives

10. Presenting recommendations for the management of chloride and mitigation of impacts of chloride on the natural and built environment

1.3 REPORT FORMAT AND ORGANIZATION

This Report is organized into four chapters. Following this introductory chapter, Chapter 2 describes the selection process for stream and lake monitoring sites. The Chapter also includes a characterization of the selected monitoring sites and their drainage areas.

Chapter 3 summarizes the methods and procedures used for the collection of water quality data at stream and lake monitoring sites. This Chapter describes the equipment used for continuous stream monitoring and how it was deployed and maintained. It also describes the methods used for collecting water quality samples for chemical analysis at stream and lake monitoring sites.

Chapter 4 describes the data management processes and quality assurance and quality control protocols for the datasets that were collected and maintained by Commission staff for this Study. The Chapter also describes the post-processing methodology for the continuous specific conductance datasets collected at the stream monitoring sites.

WATER QUALITY MONITORING SITE SELECTION AND CHARACTERIZATION 2

Credit: SEWRPC Staff

2.1 INTRODUCTION

The Southeastern Wisconsin Region (Region) encompasses (from north to south) Washington, Ozaukee, Waukesha, Milwaukee, Walworth, Racine, and Kenosha Counties. The Region includes 29 cities, 66 villages, and 52 townships and covers about 2,690 square miles, or roughly 5 percent of the total area of Wisconsin (see Map 2.1). These seven counties are home to approximately 2.05 million people, accounting for about 35 percent of the population of the State. The Region is an economic hub of the State, spanning heavily urbanized metropolitan areas, highly productive agricultural lands, and high-quality natural lands.

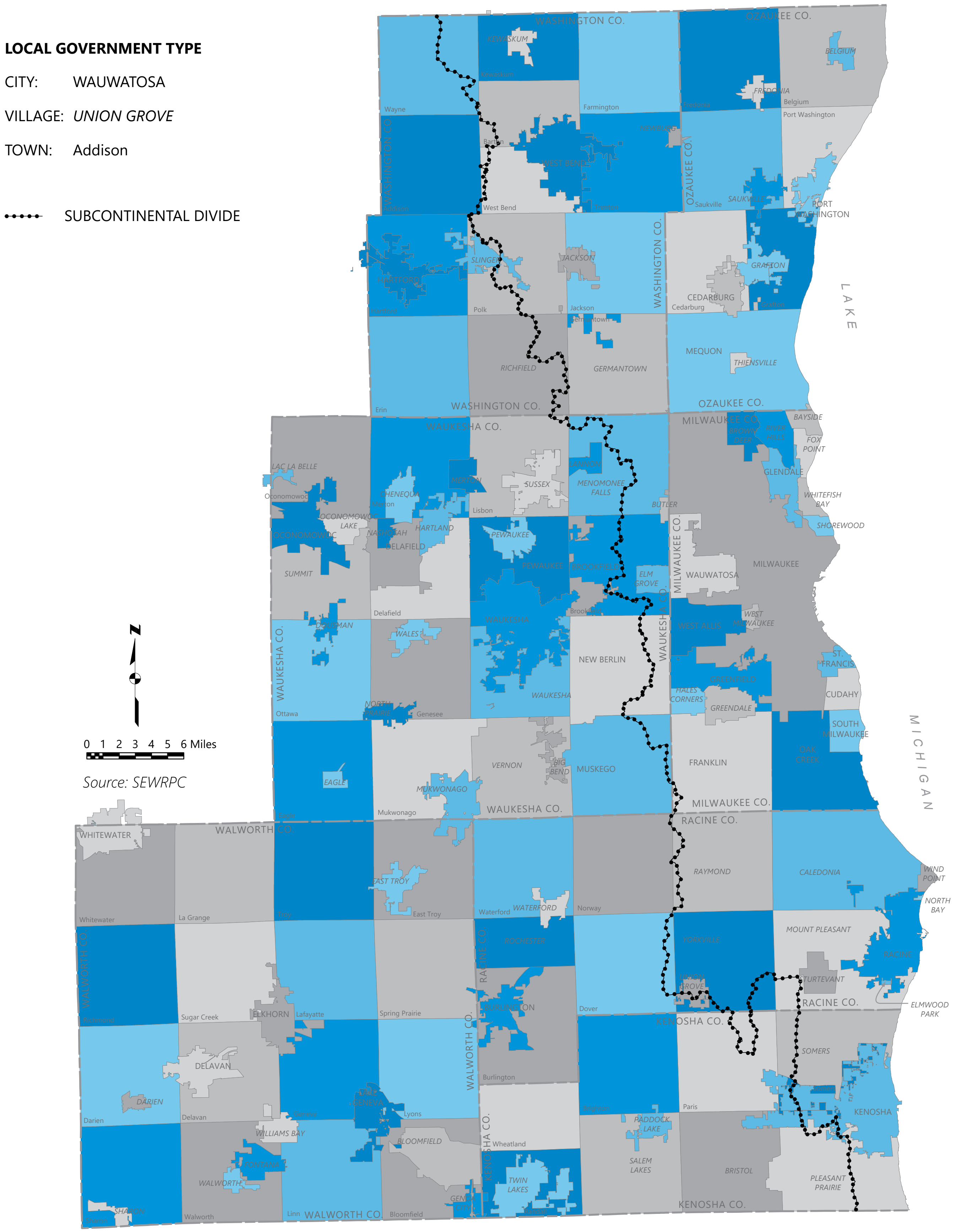
Surface water resources, consisting of streams, lakes, and wetlands form a critical element of the natural resource base of the Region. The groundwater resources of the Region are closely interrelated with the surface water resources because they sustain lake levels and provide the baseflow for streams. The contribution of these natural resources to the economic development, recreational activity, and aesthetic quality of the Region is immeasurable. The residents of the Region also rely on the surface and groundwater resources to provide a reliable source of domestic, municipal, and industrial water supply. The impacts of chloride to the environment affect all of the Counties and local communities of the Region to some extent. Growing public concern regarding the environmental impacts of chloride salts, particularly to the surface and groundwater resources of the Region, was the catalyst for developing the Regional Chloride Impact Study.

This Chapter defines the study area for the Chloride Impact Study and provides a summary of the considerations and strategies for selecting waterbodies to monitor for water quality conditions throughout the Region. The Chapter also presents a description of the selected stream and lake monitoring locations and a characterization of the lands draining to those waterbodies.

2.2 DEFINING THE STUDY AREA

Addressing water quality problems in surface and groundwater resources often requires assessing conditions that go beyond regional and municipal boundaries. Areas upstream of a waterbody can have large impacts on downstream water quality conditions, regardless of political boundaries. Therefore, assessing water quality conditions on a watershed basis is a more comprehensive approach that allows for a more complete understanding of the factors that contribute to the health of a waterbody. A watershed approach also helps

Map 2.1
Civil Divisions Within the Region: 2020



guide more effective management strategies to improve the health of a waterbody. Therefore, the study area for the Chloride Impact Study includes the seven counties of the Region as well as significant areas outside the Region that drain into it, including about 292 square miles of Dodge, Fond du Lac, Jefferson, and Sheboygan Counties (see Table 2.1).

The full study area for the Chloride Impact Study encompasses approximately 2,982 square miles and is shown on Map 2.2. The study area covers all or portions of 11 counties, 29 cities, 75 villages, and 73 townships (see Map 2.3). The study area also encompasses all or portions of 12 major watersheds including the Des Plaines River, Fox River, Kinnickinnic River, Menomonee River, Milwaukee River, Oak Creek, Pike River, Rock River, Root River, Sauk Creek, and Sheboygan River watersheds, as well as the areas draining directly to Lake Michigan (see Map 2.4 and Table 2.2).

2.3 WATER QUALITY MONITORING SITE SELECTION

The collection of new water quality data for this Study was envisioned to establish an existing baseline condition of the chloride content within streams and lakes that is representative of the diverse characteristics of the Region. The amount of chloride that enters the waterways and the primary sources of that chloride may differ greatly throughout the Region. Therefore, when determining which waterbodies throughout the Region should be monitored, it was critical to consider many factors for where and how chloride may enter the waterways.

This Study examined several potential ways that chloride enters the environment including the application and storage of road salt and other deicing materials used by both public and private entities, domestic wastewater and water softener discharge to wastewater treatment facilities and private septic systems, industrial wastewater, and agricultural fertilizers. Monitoring sites were targeted for streams and lakes that were expected to be most directly affected by chloride from these potential sources. Monitoring sites were also targeted to include waterbodies judged to be less susceptible to chloride pollution. In total, the sites would establish a baseline condition that is representative of a range of chloride impacts on the surface water resources of the Region.

Stream Monitoring Site Selection

Southeastern Wisconsin Regional Planning Commission (Commission) staff gathered data and inventories for the study area to assist in selecting a preliminary list of potential stream locations to be monitored for water quality. Further site-specific considerations and field reconnaissance were then conducted to narrow the preliminary list to a final set of selected locations to establish stream monitoring sites. The preliminary considerations and site-specific considerations for monitoring site selection are described in the following sections.

Preliminary Site Selection Considerations

The selection of potential streams to be monitored was informed by compiling previous water quality monitoring and analyses, inventories of various features within the study area, and assessments of geographic considerations. Factors that were considered for selecting water quality monitoring sites included geographic distribution, availability of current and historical water quality data, and various characteristics of the watersheds and drainage basins. These factors were assessed based on professional experience and local knowledge of the Region, previous Commission and other agency studies, and geographic information systems (GIS) analyses. Inventories used to inform the decisions for locating stream monitoring sites were collected for the entire study area, when available. In some instances, inventories and analyses were only available for the seven-county Southeastern Wisconsin Region. The preliminary site selection considerations and sources of inventories are summarized in the following sections.

<u>Geographic Distribution</u>

The study area consists of portions of 12 major watersheds (see Map 2.4). Selection of proposed monitoring locations included considerations to ensure a balanced coverage among these watersheds. As a component of this, Commission staff reviewed the proportion of the study area encompassed by each of the major watersheds (see Table 2.2).

Balanced coverage throughout the seven-county Region was also a consideration when determining streams to be monitored. As described previously, political boundaries are not the best determinants when it comes to assessing water quality. However, Commission staff wanted to include stream monitoring sites

Table 2.1
Counties Within the Study Area

County[a]	Area (sq mi)	Percent of Region	Percent of Study Area
Waukesha	581	21.6	19.5
Walworth	576	21.4	19.3
Washington	436	16.2	14.6
Racine	341	12.7	11.4
Kenosha	278	10.3	9.3
Milwaukee	243	9.0	8.2
Ozaukee	235	8.8	7.9
Fond du Lac[b]	139	--	4.7
Sheboygan[b]	123	--	4.1
Dodge[b]	26	--	0.9
Jefferson[b]	4	--	0.1
Total	2,982	100.0	100.0

[a] *Counties within the study area are shown on Map 2.1.*

[b] *Only a portion of the county is within the study area.*

Source: SEWRPC

within each county of the Region and a balanced coverage based on the areal size of the counties. As described earlier in this Chapter, the study area consisted of the seven counties in southeastern Wisconsin and portions of four adjacent counties with areas that drain into the Region. The counties that make up the study area and the proportion of the study area that each county represents is provided in Table 2.1.

Land Use

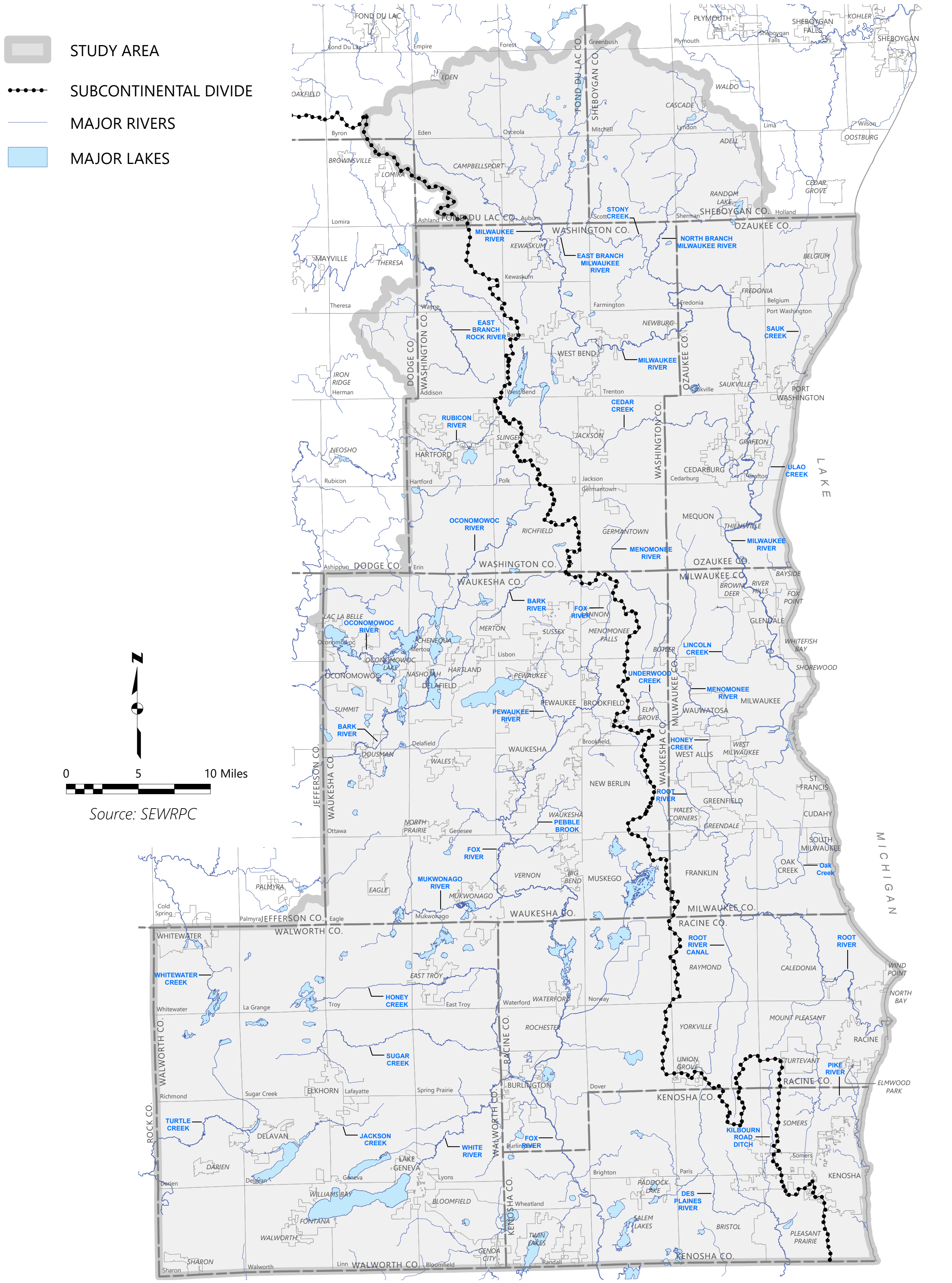
The type, intensity, and spatial distribution of different land uses within a watershed is critical in determining where, how, and the extent to which a particular pollutant may impact the waterways of the Region. Often water quality conditions can be correlated with the extent and type of land use. The land use near a stream as well as the land use throughout a contributing drainage area were important factors when considering potential stream sites to monitor for this Study. Certain land use types and distributions are more likely to introduce different sources of chloride to the environment. It was critical to select stream monitoring sites that were geographically distributed to represent locations where runoff to streams comes from areas of low-, medium-, and high-density development.

The Commission has regularly, since 1963, conducted definitive inventories of existing land use patterns within the seven-county Region. The Commission land use inventory is intended to serve as a precise record of land use for the entire Regional area at selected points in time. The land use classification system used in the inventory consists of 62 discrete, detailed land use codes, and an additional eight supplemental land use suffix codes. The supplemental land use codes allow a finer scale of characterization for a particular parcel of land.[4] These discrete land use codes and supplemental land use suffix codes combined to form 103 unique classifications of land uses within the Region. This inventory provides the basis for a variety of planning efforts that analyze the impacts of specific urban and nonurban land uses throughout the Region. Aerial photographs serve as the primary basis for identifying existing land use and are augmented by field surveys as appropriate. The most recent Regional land use inventory at the time of the stream monitoring site selection for this Study was based upon aerial photography taken in the spring of 2015.

Areas considered "urban" under the Commission land use inventory include areas identified as residential; commercial; industrial; transportation, communication, and utility; governmental and institutional; intensive recreational uses; and unused urban lands. Areas considered "nonurban" under the land use inventory include agricultural lands, wetlands, woodlands, surface water, extractive and landfill sites, and unused rural lands.

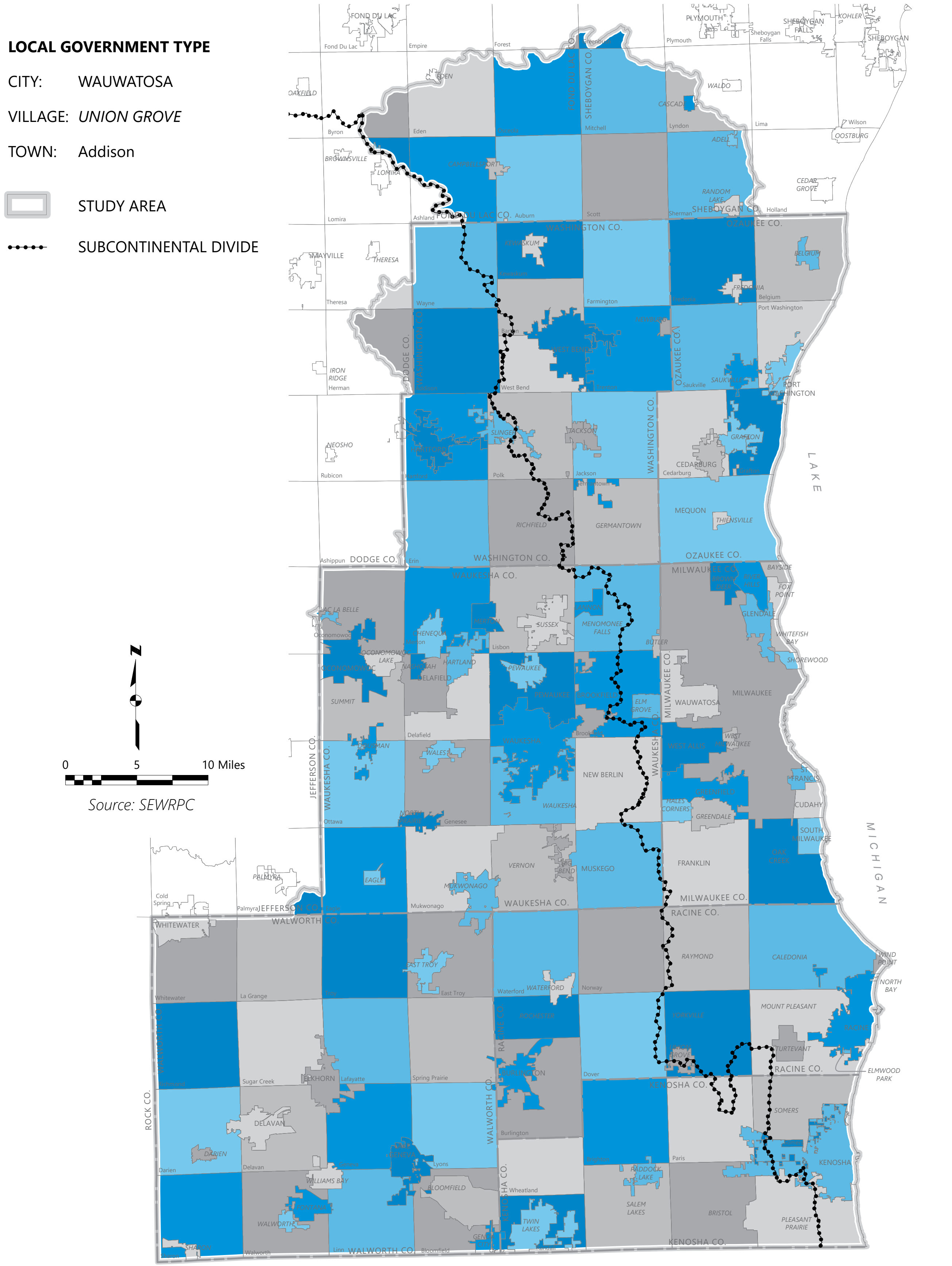
[4] *For instance, the discrete land use code used for single-family residential can be augmented with a supplemental land use suffix code to further describe the single-family residential parcels as "high-density," "medium-density," or "low-density" residential developments.*

Map 2.2
Study Area for the Regional Chloride Impact Study



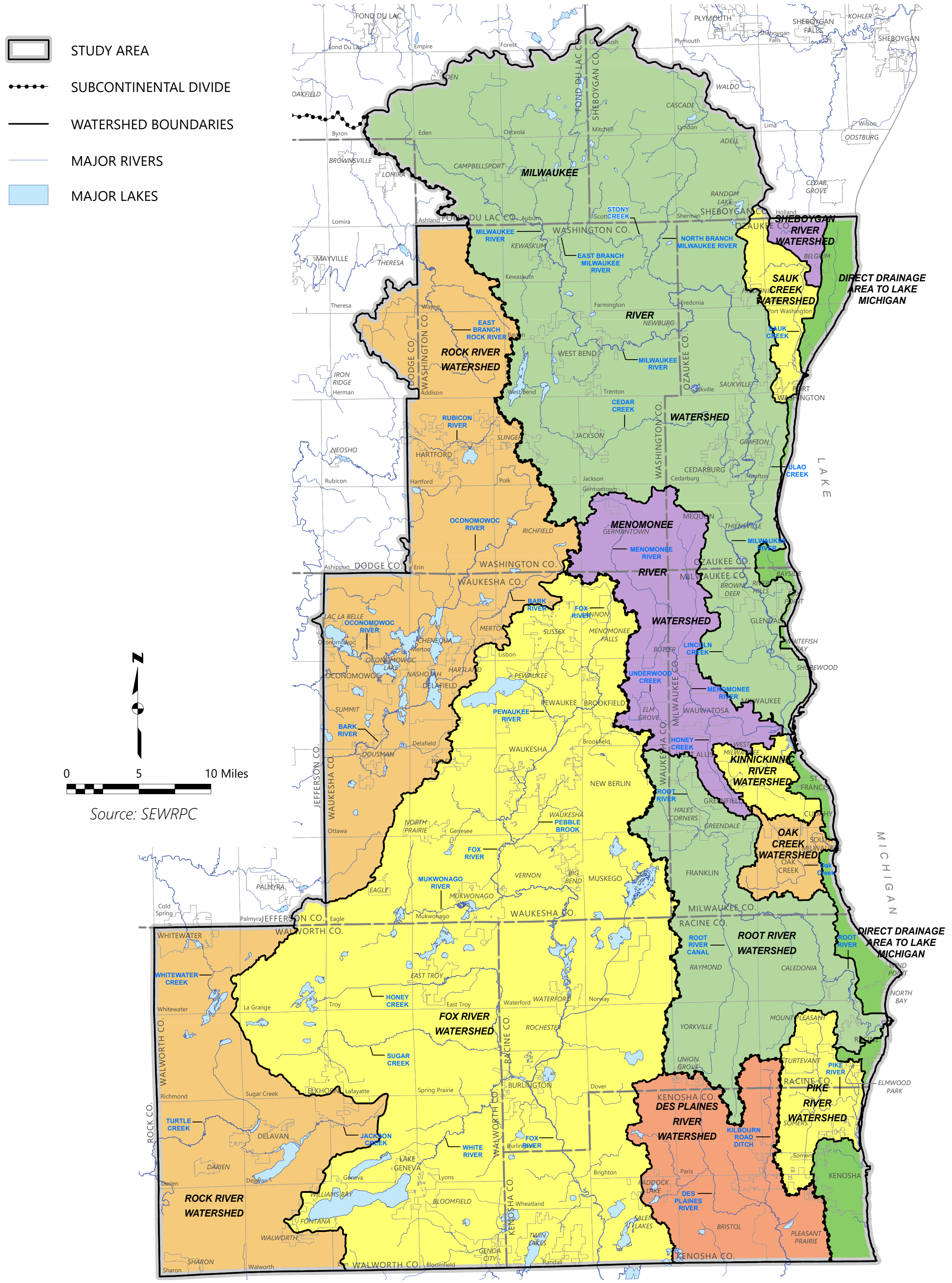
Source: SEWRPC

Map 2.3
Civil Divisions Within the Study Area



Source: SEWRPC

Map 2.4
Major Watersheds and Surface Waters Within the Study Area



Source: SEWRPC

Table 2.2
Major Watersheds Within the Study Area

Watershed[a]	In-Region Area (square miles)	Out-of-Region Area (square miles)	Total Study Area (square miles)	Percent of Study Area
Fox River[b]	934	4	938	31.5
Rock River[b]	611	21	632	21.2
Milwaukee River	435	266	701	23.5
Root River	198	--	198	6.6
Menomonee River	136	--	136	4.6
Des Plaines River[b]	133	--	133	4.5
Direct Drainage to Lake Michigan	94	--	94	3.1
Pike River	51	--	51	1.7
Sauk Creek	34	1	35	1.2
Oak Creek	28	--	28	0.9
Kinnickinnic	25	--	25	0.8
Sheboygan[b]	11	--	11	0.4
Total	2,690	292	2,982	100.0

[a] *Major watersheds within the study area are shown on Map 2.4.*

[b] *Only a portion of the watershed is within the study area of the Chloride Impact Study.*

Source: SEWRPC

For the purpose of this Study, the 103 unique land use categories found within the Region were combined to form 16 major Chloride Impact Study land use groups consisting of ten urban groups and six nonurban groups. These land use groupings were developed specifically for the analysis of chloride impacts to the environment within the Region. The land use groups developed for the Study were similar to the generalized land use groupings typically used in Commission work with some chloride-focused changes, such as creating a land use group for roads and parking lots separate from the other transportation-related land use types. The Chloride Impact Study land use groups and the detailed land use categories that comprise them are provided in Table 2.3. The composition of existing land use organized by Chloride Impact Study land use groups is provided for the Region in Table 2.4.

As discussed previously in this Chapter, the study area for the Chloride Impact Study includes the seven counties of the Region as well as portions of watersheds outside of the Region that drain into it. These out-of-Region areas include about 292 square miles spread across the Milwaukee River, Rock River, Fox River, and Sauk Creek watersheds. Because these areas are outside of the Commission planning area, they are not covered by the 2015 Regional land use inventory and Commission staff needed to acquire datasets to characterize and assess land use for these areas.

The portion of the Milwaukee River watershed that is within Fond du Lac and Sheboygan Counties is the largest portion of the study area that is not included in the Commission 2015 land use inventory. For this portion of the study area, a land use inventory that was developed as part of the Commission's Regional Water Quality Management Plan Update for the Greater Milwaukee watersheds (RWQMPU) was used.[5] The land use inventory developed for the RWQMPU used datasets provided by Fond du Lac and Sheboygan Counties that reflected year 2000 conditions.[6] For the RWQMPU, the land use classifications given in the County datasets were reassigned land use codes to align with the Commission land use inventory, to form a uniform dataset for areas within and outside of the Region.

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

[6] *While this dataset reflected conditions 15 years prior to the Commission land use inventory for the Region, comparison of census data from 2000 to 2015 indicated there was not significant population changes in these areas of Fond du Lac and Sheboygan Counties. In addition, a visual comparison of year 2000 and year 2015 aerial photographs indicated insignificant change in land development in the area. Based on these analyses, year 2000 land use data developed for the RWQMPU for this portion of the study area was considered sufficient for use in this Study.*

Table 2.3
Land Use Groups for the Chloride Impact Study

Chloride Study Land Use Group	SEWRPC Land Use Code	SEWRPC Land Use Description
Lower-Density Residential	111R	Rural-Density Single-Family Residential
	111S	Suburban-Density Single-Family Residential
	111L	Low-Density Single-Family Residential
	199	Residential Land Under Development
Medium-Density Residential	111M	Medium-Density Single-Family Residential
	150	Mobile Homes
High-Density Residential	111X	High-Density Single-Family Residential
	120	Two-Family Residential
	141	Multi-Family Low Rise
	142	Multi-Family High Rise
Commercial	210	Retail Sales and Service--Intensive
	220	Retail Sales and Service--Nonintensive
	299	Retail Sales and Service Land Under Development
Industrial	310	Manufacturing
	340	Wholesaling and Storage
	399	Industrial Land Under Development
Government and Institutional	611	Administrative, Safety, and Assembly - Local
	612	Administrative, Safety, and Assembly - Regional
	641	Educational - Local
	642	Educational - Regional
	661	Group Quarters - Local
	662	Group Quarters - Regional
	681	G&I Local - Cemeteries
	682	G&I Regional - Cemeteries
	699	Government and Institutional Land Under Development
Roads and Parking Lots	411	Freeway
	414	Standard Arterial Street and Expressway
	418	Local and Collector Streets
	425	Bus Terminal
	426	Truck Terminal
	430	Off-Street Parking - Multiple Land Use-Related
	431	Off-Street Parking - Residential-Related
	432	Off-Street Parking - Retail Sales and Service-Related
	433	Off-Street Parking - Industrial-Related
	434	Off-Street Parking - Transportation-Related
	435	Off-Street Parking - Communication and Utilities-Related
	436	Off-Street Parking - Government and Institution-Related
	437	Off-Street Parking - Recreation-Related
	499	Transportation Land Under Development
Transportation, Communication, and Utilities	441	Railroad Track Right-of-Way
	443	Railroad Switching Yards
	445	Railroad Stations and Depots
	463	Air Fields
	465	Air Terminals and Hangars
	485	Ship Terminal
	510	Communication and Utilities
	599	Communication and Utility Land Under Development
Recreational	711	Recreation - Public Cultural/Special Recreation Areas
	712	Recreation - Nonpublic Cultural/Special Recreation Areas
	731	Public - Land-Related Recreation Areas
	732	Nonpublic - Land-Related Recreation Areas
	781	Public - Water-Related Recreation Areas
	782	Nonpublic - Water-Related Recreation Areas
	799	Recreation Land Under Development

Table continued on next page.

Table 2.3 (Continued)

Chloride Study Land Use Group	SEWRPC Land Use Code	SEWRPC Land Use Description
Urban Unused Lands	210H	Unused Lands - Retail Sales and Service--Intensive
	220H	Unused Lands - Retail Sales and Service--Nonintensive
	310H	Unused Lands - Manufacturing
	340H	Unused Lands - Wholesaling and Storage
	425H	Unused Lands - Bus Terminal
	426H	Unused Lands - Truck Terminal
	463H	Unused Lands - Air Fields
	510H	Unused Lands - Communication and Utilities
	611H	Unused Lands - G&I Local - Administrative, Safety, and Assembly
	612H	Unused Lands - G&I Regional - Administrative, Safety, and Assembly
	641H	Unused Lands - G&I Local - Educational
	642H	Unused Lands - G&I Regional - Educational
	661H	Unused Lands - G&I Local - Group Quarters
	662H	Unused Lands - G&I Regional - Group Quarters
	681H	Unused Lands - G&I Local - Cemeteries
	682H	Unused Lands - G&I Regional - Cemeteries
	921	Urban - Unused Lands
Agricultural	811	Cropland
	811G	Wetlands - Cropland
	815	Pasture & Other Agriculture
	815G	Wetlands - Pasture & Other Agriculture
	820	Orchards and Nursery
	820G	Wetlands - Orchards and Nursery
	841	Special Agriculture
	841G	Wetlands - Special Agriculture
	871	Farm Building
Wetlands	411G	Wetlands - Freeway
	414G	Wetlands - Standard Arterial Street and Expressway
	418G	Wetlands - Local and Collector Streets
	441G	Wetlands - Track Right-of-Way
	463G	Wetlands - Air Fields
	499G	Wetlands - Transportation Land Under Development
	510G	Wetlands - Communication and Utilities
	731G	Wetlands - Public - Land-Related Recreation Areas
	910	Wetlands - Open Lands
Woodlands	411F	Woodlands - Freeway
	414F	Woodlands - Standard Arterial Street and Expressway
	611F	Woodlands - G&I Local - Administrative, Safety, and Assembly
	612F	Woodlands - G&I Regional - Administrative, Safety, and Assembly
	641F	Woodlands - G&I Local - Educational
	642F	Woodlands - G&I Regional - Educational
	662F	Woodlands - G&I Regional - Group Quarters
	681F	Woodlands - G&I Local - Cemeteries
	682F	Woodlands - G&I Regional - Cemeteries
	940	Woodlands - Unused Lands
Rural Unused Lands	922	Rural - Unused Lands
Extractive and Landfills	360	Extractive
	930	Land Fills and Dumps
Surface Water	950	Surface Water

Note: Colors in the left column of this table correspond to colors assigned to Chloride Impact Study land use groups shown on Map 2.5 and on land use maps in Appendix B and Appendix C.

Source: SEWRPC

Table 2.4
Existing Land Use Within the Region: 2015

Land Use Group[a]	Acres	Percent of Region
Urban		
Lower-Density Residential	161,658	9.4
Medium-Density Residential	58,380	3.4
High-Density Residential	38,603	2.3
Commercial	11,744	0.7
Industrial	15,881	0.9
Government and Institutional	17,844	1.0
Roads and Parking Lots	147,814	8.6
Transportation, Communication, and Utilities	12,196	0.7
Recreational	34,443	2.0
Urban Unused Lands	34,778	2.0
Urban Subtotal	533,341	31.0
Nonurban		
Agricultural	672,672	39.1
Rural Unused Lands	112,581	6.5
Extractive and Landfills	11,691	0.7
Natural Lands		
Wetlands	203,181	11.8
Woodlands	133,772	7.8
Surface Water	54,179	3.1
Natural Lands Subtotal	391,132	22.7
Nonurban Subtotal	1,188,076	69.0
Total	1,721,417	--

[a] *See Table 2.3 for detailed land use categories that comprise each land use group.*

Source: SEWRPC

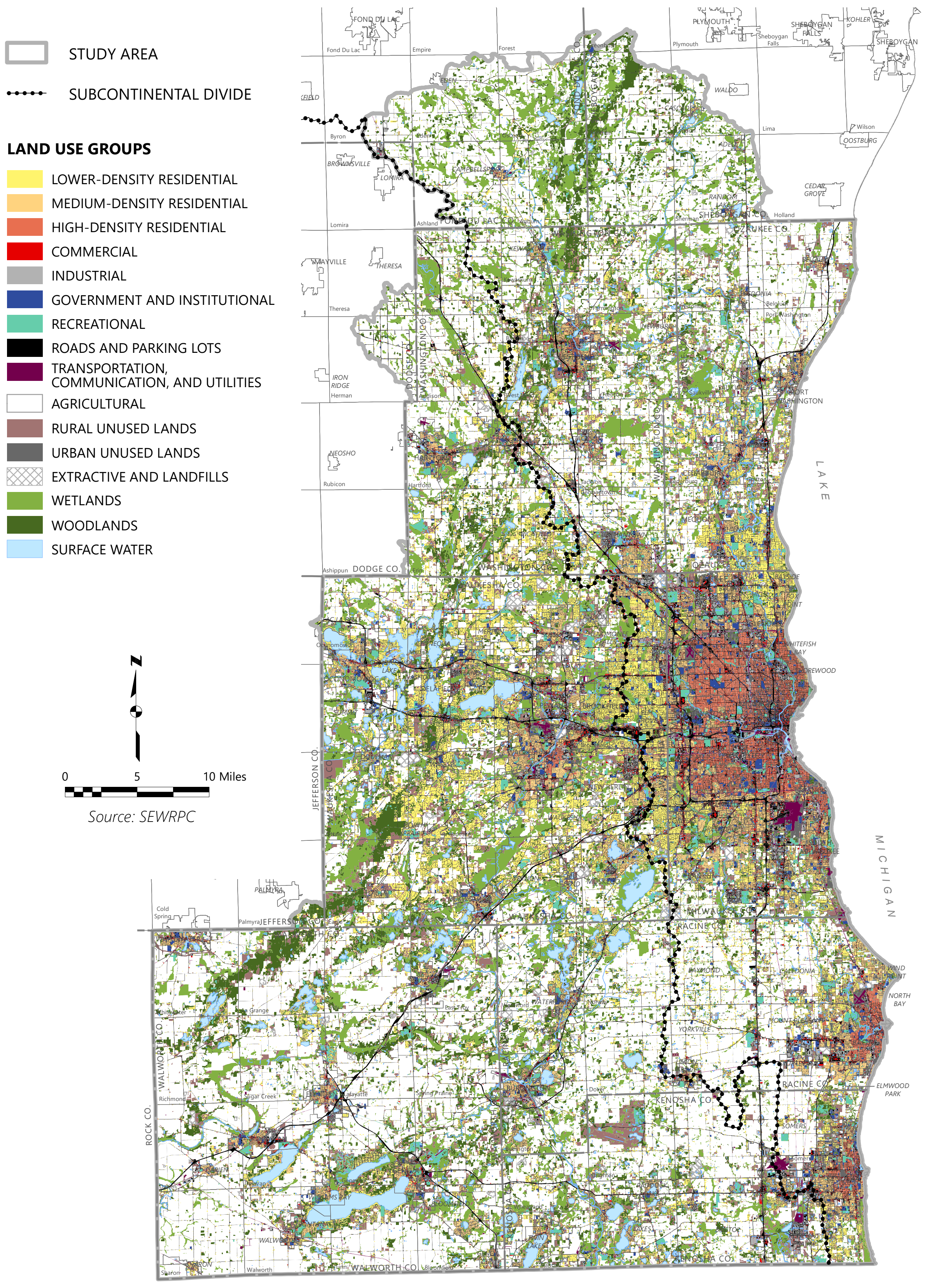
It was also necessary to obtain land use data for the out-of-Region portions of the study area in the Rock River, Fox River, and Sauk Creek watersheds. Commission staff reached out to the county officials that govern these out-of-Region areas to request shapefiles for their most recent land use inventories. The inventories provided by each county represented land use conditions based on various dates.[7]

Land use inventories that were received from the out-of-Region counties each were developed using different land use classifications. To assemble a uniform assessment of land use throughout the entire study area, it was necessary for Commission staff to systematically assign the Chloride Impact Study land use groups to comparable land use classifications for the out-of-Region areas. A majority of the land use classifications used in the out-of-Region county inventories readily aligned with an equivalent land use group used for this Study. For those land use classifications that did not have an obvious equivalent category, Commission staff used best professional judgement to assign Chloride Impact Study land use groups based on examination of aerial photography from a year corresponding to the respective county land use inventory.

Through the analysis described, Commission staff assembled a uniform land use inventory for the entire study area. The geographic distribution of Chloride Impact Study land use groups within the study area is shown on Map 2.5. The total acreage and percentage of the study area for each land use group is provided in Table 2.5. Descriptions of the land use composition and distribution for each of the drainage areas for monitoring sites are provided later in this Chapter.

[7] *The land use data for Dodge County was based on conditions in 2014, for Jefferson County was based on conditions in 2018, and for the Sauk Creek watershed portion of Sheboygan County was based on conditions in 2002.*

Map 2.5
Existing Land Use Within the Study Area



Source: SEWRPC

Table 2.5
Existing Land Use Within the Study Area

Land Use Group[a]	Acres	Percent of Study Area
Urban		
Lower-Density Residential	166,812	8.7
Medium-Density Residential	58,798	3.1
High-Density Residential	38,656	2.0
Commercial	11,897	0.6
Industrial	16,210	0.9
Government and Institutional	18,159	1.0
Roads and Parking Lots	153,929	8.1
Transportation, Communication, and Utilities	12,509	0.7
Recreational	35,135	1.8
Urban Unused Lands	35,104	1.8
Urban Subtotal	547,209	28.7
Nonurban		
Agricultural	784,063	41.1
Rural Unused Lands	114,237	6.0
Extractive and Landfills	12,151	0.6
Natural Lands		
Wetlands	236,918	12.4
Woodlands	157,083	8.2
Surface Water	56,451	3.0
Natural Lands Subtotal	450,452	23.6
Nonurban Subtotal	1,360,903	71.3
Total	1,908,112	--

[a] *See Table 2.3 for detailed land use categories that comprise each land use group.*

Source: SEWRPC

Wastewater Treatment Facilities and Sanitary Sewer Service Areas

Chlorides are contributed to wastewater via a variety of sources including residential, commercial, food processing, wastewater treatment processes, and industrial wastes.[8] Residential sources include water softening salts, chlorine-based cleaning agents, detergents, personal care products, food waste, and human excretion. Wastewater treatment plants (WWTPs) in the Region are not designed to remove chloride ions from wastewater. Thus, any chloride ions in wastewater that arrive at a treatment facility will remain in the water, even after treatment. Effluent from a WWTP is typically discharged into a nearby local waterway or more rarely to infiltration ponds that allow the effluent to infiltrate into soils and eventually reach groundwater.

Map 2.6 indicates the locations of public WWTPs and the planned sanitary sewer service areas (SSSAs) that these treatment facilities serve. In 2016, there were 49 public WWTPs in operation within the study area. Table 2.6 provides additional information for these public WWTPs, including the SSSAs from which each facility receives wastewater, the estimated population served, the annual average design flow for the facility, the major watershed where the facility is located, and the waterbody that receives effluent from the facility after treatment. Treated wastewater effluent is typically discharged to waterways in close vicinity to the WWTPs shown on Map 2.6.[9] Map 2.6 also indicates areas that are within planned SSSAs. Planned SSSAs can include a combination of areas that are currently served by sanitary sewer as well as areas where sanitary sewers are planned to be extended to serve future development. In 2020, approximately 35 percent of the study area for the Chloride Impact Study was within a planned sanitary sewer service area.

[8] *Sources and pathways of chlorides in wastewater are discussed in further detail in SEWRPC Technical Report No. 62,* Impacts of Chloride on the Natural and Built Environment, *in development, and SEWRPC Technical Report No. 65,* Mass Balance Analysis for Chloride in Southeastern Wisconsin, *in development.*

[9] *The one exception within the study area is the Delafield-Hartland Water Pollution Control Commission wastewater treatment facility that pumps effluent via force main and discharges into the Bark River at a point approximately four miles southwest of the facility.*

Map 2.6
Planned Sanitary Sewer Service Areas Grouped by Existing Public Wastewater Treatment Facility Operator Within the Study Area

- EXISTING WASTEWATER TREATMENT FACILITY (DISCHARGE TO SURFACE WATER)
- EXISTING WASTEWATER TREATMENT FACILITY (DISCHARGE TO SOIL)
- STUDY AREA
- SUBCONTINENTAL DIVIDE

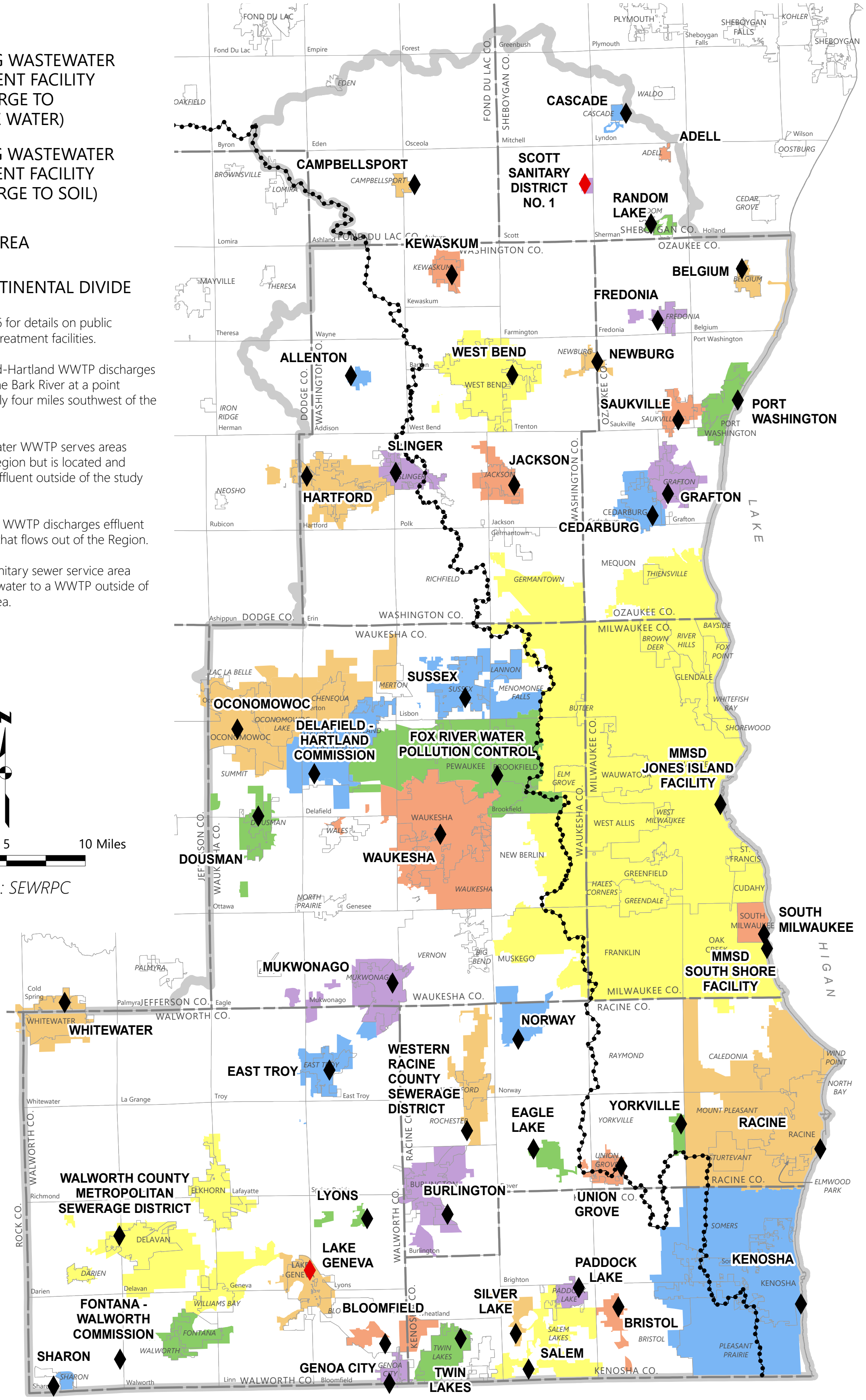
Notes: See Table 2.6 for details on public wastewater treatment facilities.

The Delafield-Hartland WWTP discharges effluent to the Bark River at a point approximately four miles southwest of the facility.

The Whitewater WWTP serves areas within the Region but is located and discharges effluent outside of the study area.

The Belgium WWTP discharges effluent to a stream that flows out of the Region.

The Adell sanitary sewer service area sends wastewater to a WWTP outside of the study area.



Source: SEWRPC

Table 2.6
Public Wastewater Treatment Facilities Within the Study Area

Facility Name	Sewer Service Areas[a]	Population Served[b]	Annual Average Design Flow (MGD)	Major Watershed	Receiving Water
Fond du Lac County[c]					
Campbellsport Wastewater Treatment Facility	Campbellsport	--[d]	0.47	Milwaukee River	Milwaukee River
Kenosha County					
Bristol Utility District No.1	Bristol	1,780	0.87	Des Plaines	Tributary to Des Plaines River
Kenosha Wastewater Treatment Facility	Greater Kenosha	124,870	28.6	Lake Michigan	Lake Michigan
Paddock Lake Wastewater Treatment Facility	Paddock Lake	3,000	0.80	Des Plaines	Tributary to Brighton Creek
Salem Lakes – Salem Wastewater Treatment Plant[e]	Salem	11,130	2.13	Fox River	Fox River
Salem Lakes – Silver Lake Wastewater Treatment Plant[e]	Silver Lake	2,380	0.47	Fox River	Fox River
Twin Lakes Wastewater Treatment Facility	Twin Lakes	5,980	1.30	Fox River	Tributary to Bassett Creek (to Fox River)
Milwaukee County					
Milwaukee Metropolitan Sewerage District – Jones Island Facility and South Shore Facility	Bayside, Brown Deer, Cudahy, Fox Point, Franklin, Greendale, Greenfield, Glendale, Hales Corners, Milwaukee, Oak Creek, Shorewood, St. Francis, River Hills, Whitefish Bay, Wauwatosa, West Allis, West Milwaukee, *Mequon/Thiensville, Caddy Vista, Caledonia (part), Germantown, Brookfield East, Butler, Elm Grove, Menomonee Falls East, Muskego (part), New Berlin*	1,072,150[f]	310	Lake Michigan	Milwaukee River Outer Harbor and Lake Michigan[g]
South Milwaukee Wastewater Treatment Facility	South Milwaukee	21,130	6.00	Lake Michigan	Lake Michigan
Ozaukee County					
Belgium Wastewater Treatment Facility	Belgium, Lake Church	2,260	0.63	Sheboygan River	Belgian-Holland Ditch[h]
Cedarburg Wastewater Treatment Facility	Cedarburg	11,610	2.75	Milwaukee River	Cedar Creek
Fredonia Municipal Sewer and Water Utility	Fredonia, Waubeka	2,260	0.60	Milwaukee River	Milwaukee River
Grafton Water and Wastewater Utility	Grafton	11,950	2.50	Milwaukee River	Milwaukee River
Port Washington Wastewater Treatment Plant	Port Washington	11,470	3.10	Lake Michigan	Lake Michigan
Saukville Sewer Utility	Saukville	4,460	1.61	Milwaukee River	Milwaukee River
Racine County					
Burlington Water Pollution Control	Burlington, Bohner Lake, Browns Lake	15,040	3.50	Fox River	Fox River
Eagle Lake Sewer Utility District	Eagle Lake	1,640	0.40	Fox River	Eagle Creek
Town of Norway Sanitary District No. 1 Wastewater Treatment Facility	Norway/Wind Lake	6,660	1.60	Fox River	Tributary to Wind Lake Drainage Canal

Table continued on next page.

Table 2.6 (Continued)

Facility Name	Sewer Service Areas[a]	Population Served[b]	Annual Average Design Flow (MGD)	Major Watershed	Receiving Water
Racine Wastewater Utility	Greater Racine	134,930	36.0	Lake Michigan	Lake Michigan
Union Grove Wastewater Treatment Plant	Southern Wisconsin Center, Union Grove	5,730	2.00	Root River	West Branch Root River Canal
Western Racine County Sewerage District	Waterford/Rochester	12,370	2.50	Fox River	Fox River
Yorkville Sewer Utility District No. 1	Yorkville	250	0.15	Root River	Ives Grove Ditch (to Hoods Creek)
Sheboygan County[c]					
Cascade Wastewater Treatment Facility	Cascade, Lake Ellen	--[d]	0.13	Milwaukee River	North Branch Milwaukee River
Random Lake Sewage Treatment Plant	Random Lake	--[d]	0.45	Milwaukee River	Silver Creek
Town of Scott Sanitary District No.1	Batavia (Town of Scott)	--[d]	0.03	Milwaukee River	Discharge to Soil
Walworth County					
Village of Bloomfield Utility Department	Bloomfield, Powers–Benedict-Tombeau Lakes	3,670	0.46	Fox River	Tributary to East Branch Nippersink Creek
East Troy Wastewater Treatment Facility	East Troy	5,690	0.81	Fox River	Honey Creek
Fontana – Walworth Water Pollution Control Commission	Fontana/Walworth	4,700	1.77	Rock River	Picasaw Creek
Genoa City Water Treatment Plant	Genoa City	3,070	0.58	Fox River	North Branch Nippersink Creek
Lake Geneva Wastewater Treatment Plant	Lake Geneva	8,600	2.50	Fox River	Discharge to Soil
Lyons Sanitary District No. 2	Lyons, Country Estates	1,390	0.21	Fox River	White River
Sharon Wastewater Treatment Facility	Sharon	1,640	0.26	Rock River	Little Turtle Creek
Walworth County Metropolitan Sewerage District	Darien, Delavan/Delavan Lake, Elkhorn, Mallard Ridge Landfill, Williams Bay/Geneva National/Lake Como	30,530	7.00	Rock River	Turtle Creek
Whitewater Wastewater Treatment Facility	Whitewater	11,110	3.65	Rock River	Whitewater Creek[h]
Washington County					
Allenton Sanitary District Wastewater Treatment Plant	Allenton	740	0.35	Rock River	East Branch Rock River
Hartford Water Pollution Control Facility	Hartford[i]	15,190	3.60	Rock River	Rubicon River
Jackson Wastewater Treatment Plant	Jackson	7,350	1.69	Milwaukee River	Cedar Creek
Kewaskum Wastewater Treatment Plant	Kewaskum	4,030	0.75	Milwaukee River	Milwaukee River
Village of Newburg Sanitary Sewer Treatment Facility	Newburg[j]	1,170	0.12	Milwaukee River	Milwaukee River
Slinger Wastewater Treatment Facility	Slinger	5,530	1.50	Rock River	Tributary to the Rubicon River
City of West Bend Sewage Treatment Facility	West Bend	33,630	9.00	Milwaukee River	Milwaukee River

Table continued on next page.

Table 2.6 (Continued)

Facility Name	Sewer Service Areas[a]	Population Served[b]	Annual Average Design Flow (MGD)	Major Watershed	Receiving Water
		Waukesha County			
Delafield – Hartland Water Pollution Control Commission	Delafield-Nashotah, Delafield South, Hartland	18,210	3.23	Rock River	Bark River[k]
Fox River Water Pollution Control Center	Brookfield West, Menomonee Falls South, New Berlin (part), Pewaukee	53,070	12.5	Fox River	Fox River
Dousman Wastewater Treatment Facility	Dousman, Genesee Lake, Golden Lake	2,710	0.57	Rock River	Bark River
Mukwonago Wastewater Treatment Plant	Eagle Spring Lake/Mukwonago County Park/Rainbow Springs, Mukwonago	7,380	1.50	Fox River	Mukwonago River
Oconomowoc Wastewater Treatment Plant	Ashippun Lake, Beaver Lake, Lake Keesus, Merton, North Lake, Oconomowoc, Oconomowoc Lake, Okauchee Lake, Pine Lake	20,440	4.02	Rock River	Oconomowoc River
Sussex Wastewater Treatment Facility	Lannon, Menomonee Falls South, Sussex	16,740	5.10	Fox River	Spring Creek
Waukesha Wastewater Treatment Facility	Delafield-Fox River, Genesee East, Wales, Waukesha	73,580	14.0	Fox River	Fox River

Note: See sanitary sewer service areas and the wastewater treatment facilities that serve them on Map 2.6

[a] *Communities shown in italics are located outside of the county in which they are listed.*

[b] *Represents population sewered as of 2010. Does not include unsewered population as of 2010.*

[c] *Only wastewater treatment facilities within watersheds that drain into the Southeastern Wisconsin Region are included in this table.*

[d] *Populations located within sewer service areas outside of the Southeastern Wisconsin Region are not reported.*

[e] *The Town of Salem and Village of Silver Lake merged to create the Village of Salem Lakes in 2017. At the time of water quality monitoring site selection and throughout a portion of the water quality data collection period for the Chloride Impact Study, the Village of Salem Lakes was served by two wastewater treatment facilities that originally served the two separate municipalities. In 2021 a project was completed that converted the Silver Lake Wastewater Treatment Plant to a lift station that now pumps wastewater to a sanitary sewer where it then flows by gravity to the Salem Wastewater Treatment Plant for treatment. The latter plant was expanded and currently operates as the only wastewater treatment facility for the Village of Salem Lakes.*

[f] *This total includes the combined populations served by both the Jones Island and the South Shore treatment facilities.*

[g] *The Jones Island Facility discharges to the Milwaukee Outer Harbor. The South Shore Facility discharges to Lake Michigan.*

[h] *Flows out of the Southeastern Wisconsin Region.*

[i] *Includes portions of Dodge County.*

[j] *The Village of Newburg is in both Washington and Ozaukee Counties.*

[k] *Effluent from the Delafield-Hartland Water Pollution Control Commission treatment facility is pumped via force main and discharged into the Bark River at a point approximately four miles southwest of the facility.*

Source: Wisconsin Department of Natural Resources and SEWRPC

The location of WWTPs, and more specifically the locations of effluent discharged from these facilities, were critical considerations for Commission staff when determining potential locations of stream monitoring sites. In order to examine the influence that treated wastewater effluent has on chloride levels in streams, Commission staff needed to select water quality monitoring sites on streams with flows that included effluent from WWTPs as well as streams with flows that did not include effluent. In addition, staff proposed monitoring sites that bracketed a WWTP, both upstream and downstream of the discharge location, in order to examine the potential impacts of the wastewater effluent on an individual stream.

It was also important for Commission staff to consider the potential impacts of urban development that is not served by public sanitary sewerage systems. These areas are likely to be served by private onsite wastewater treatment systems, such as septic tanks or mound systems. Private onsite wastewater treatment systems can contribute pollutants such as chloride to surface water and groundwater through infiltration.[10] Areas identified in blue on Map 2.7 indicate areas of urban development in the Region with known established connections to public sanitary sewer and wastewater treatment facilities as of 2010, accounting for about 19.5 percent of the Region.[11] These areas are different than the planned sanitary sewer service areas indicated on Map 2.6 which include both areas currently served by public sanitary sewer treatment facilities as well the extent of areas that could be served in the future. Areas identified in orange on Map 2.7 indicate clusters of urban development that were not served by public sewer as of 2010, accounting for 6.1 percent of the Region. These areas are assumed to be served by private onsite wastewater treatment systems.

Stormwater Management and Storm Sewer Systems

A municipal separate storm sewer system (MS4) permit is required for a municipality that is either located within a Federally designated urbanized area, has a population of 10,000 or more, or is designated for permit coverage by the Wisconsin Department of Natural Resources (WDNR). MS4 permits require communities and entities to reduce the urban pollutants entering local waterways via any stormwater conveyance system. Requirements include implementing such programs as construction site and long-term stormwater control; illicit discharge screenings; information and education programs about stormwater that are targeted to the general public, developers, and internal staff; and improving municipal "good housekeeping" practices, including winter road management programs, public works yard inspections, and inventorying and maintaining existing stormwater facilities, including mapping their systems. Each MS4-permitted municipality is required to submit an annual report for each calendar year summarizing and evaluating the programs being implemented and stating where improvements and cost-effective changes should be made. Although there are no specific mapping standards (i.e., formatting, labeling, coordinate system, etc.), each permitted entity is required to provide detailed and accurate inventories for the elements included in the following summary.

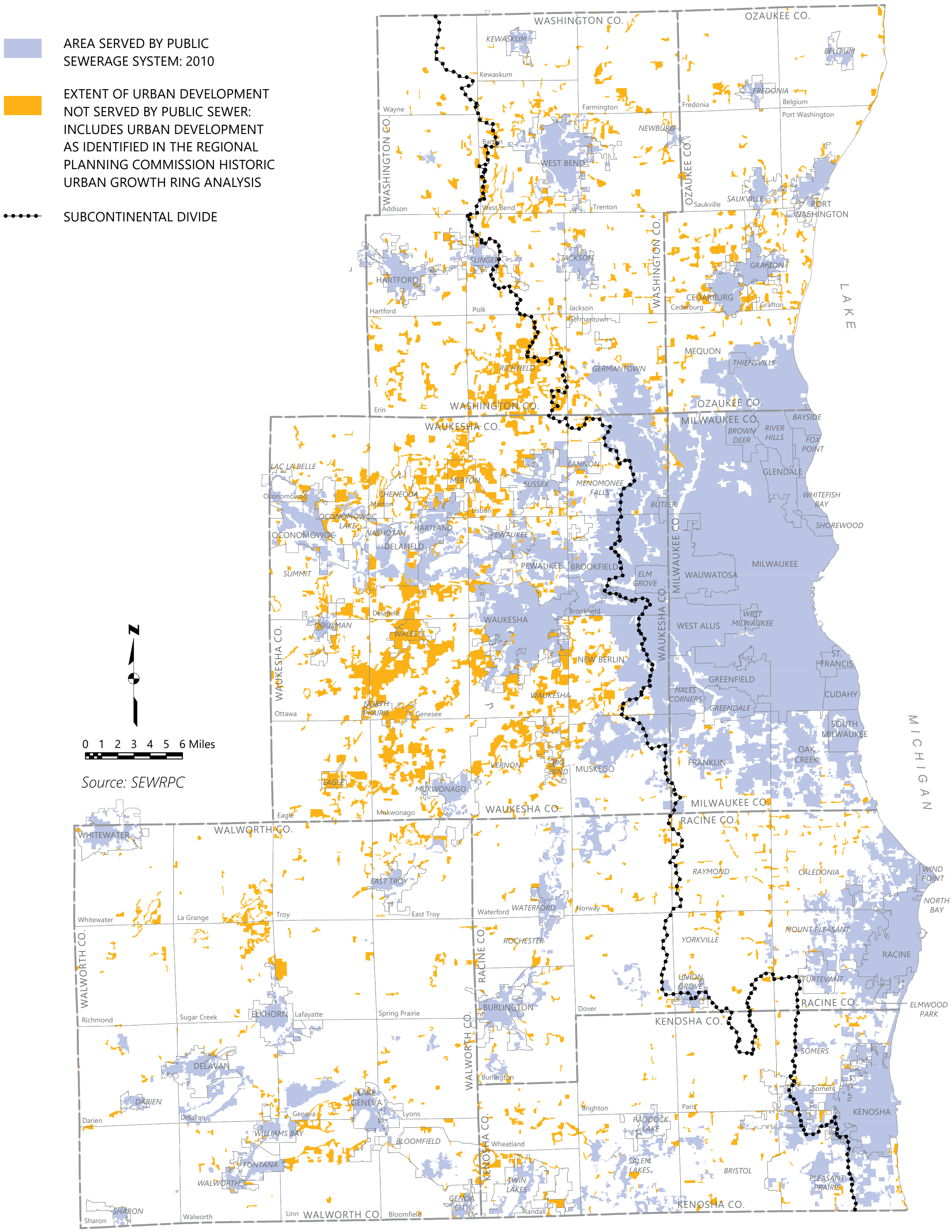
- Track and report usage of road salt and other deicing agents
- Identification of all known municipal storm sewer system outfalls discharging to waters of the State or to another MS4 system, including minor and major outfalls
- Location and permit number of any known discharge to the MS4 system that has been issued a Wisconsin Pollutant Discharge Elimination System (WPDES) permit coverage by the WDNR
- Location of structural stormwater facilities including detention basins, infiltration basins, and other treatment practices
- Location of municipal garages, storage areas, and other public works facilities
- Identification of streets

Within the study area for the Chloride Impact Study, a total of 95 municipalities, 8 counties, 3 universities, the Wisconsin State Fair Park, and the Southeast Wisconsin Professional Baseball Park District are required to have an MS4 permit under the WPDES program. These municipalities, counties, and other entities are shown on Map 2.8.

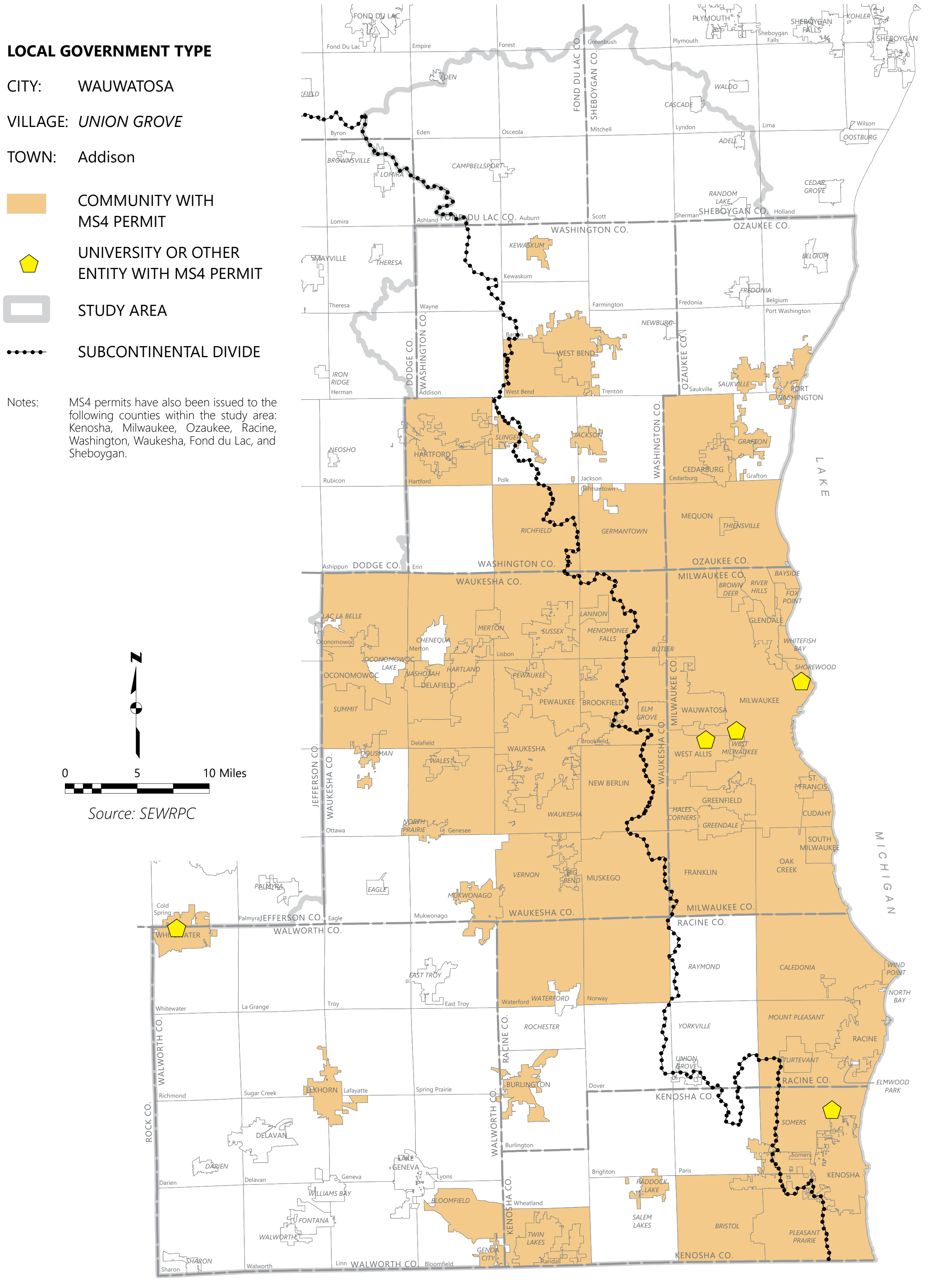
[10] *In some cases, private onsite wastewater is stored in holding tanks that are periodically emptied and the waste is transported to a WWTP.*

[11] *This analysis was not available for the portions of the study area outside of the seven county Region.*

Map 2.7
Areas Served by Public Sanitary Sewerage Systems in the Region: 2010



Map 2.8
MS4 Permitted Communities and Other Entities Within the Study Area



Notes: MS4 permits have also been issued to the following counties within the study area: Kenosha, Milwaukee, Ozaukee, Racine, Washington, Waukesha, Fond du Lac, and Sheboygan.

Source: SEWRPC

Through the collection and conveyance of stormwater to receiving waters, many of these systems likely deliver large contributions of chloride to the streams of the Region. Due to the extent of the study area, inventories of stormwater infrastructure for these permitted communities were not assembled for this Technical Report. However, knowledge of which communities are required to keep such inventories may be used in other analyses for the Chloride Impact Study. To help assess the impacts that these systems might have upon water quality of streams in the study area, it may be helpful to differentiate the locations and areas that are served by MS4 systems and those areas located outside of MS4s.

USGS Stream Gage Stations

In 2018 there were 34 continuous recording streamflow gaging stations within the study area that were maintained and operated by the U.S. Geological Survey (USGS) in partnership with local cooperators, including the Commission.[12] These stream gages within and in the immediate vicinity of the study area for the Chloride Impact Study are shown on Map 2.9.

Commission staff prioritized establishing stream monitoring sites for this Study at stream locations that were near USGS stream gage stations. Selecting stream locations at or near continuously recording streamflow gages may provide several advantages.

- Streamflow data are required for analyses such as in-stream chloride loading calculations
- Continuous streamflow data could be used in combination with data collected by Commission sensors and surface water quality grab samples to identify correlations between water quality parameters and streamflow, and may help provide valuable information on the sources and transport of chloride within the waterways of the Region
- USGS stream gages are typically located at stream and river sites that have reliable and relatively safe access for Commission field staff
- USGS stream gages may be located at stream and river locations that have historical water quality data
- Continuous streamflow data provides insight into the hydrologic conditions of a stream or river location that can help interpret data that may be collected by Commission sensors and surface water quality grab samples

Stream Size

Water quality monitoring sites established for this Study were selected to represent a range of stream and river sizes. Commission staff also aimed to select streams with a range of drainage area sizes. Consideration of stream size at potential monitoring locations were assessed in four ways including stream channel width; stream order; streamflow based on USGS stream gaging stations, where available; and modeled streamflow based on the WDNR natural community model for those streams without USGS streamflow gages. Stream channel widths were based on simple measurements from streambank to streambank using GIS and aerial photography.

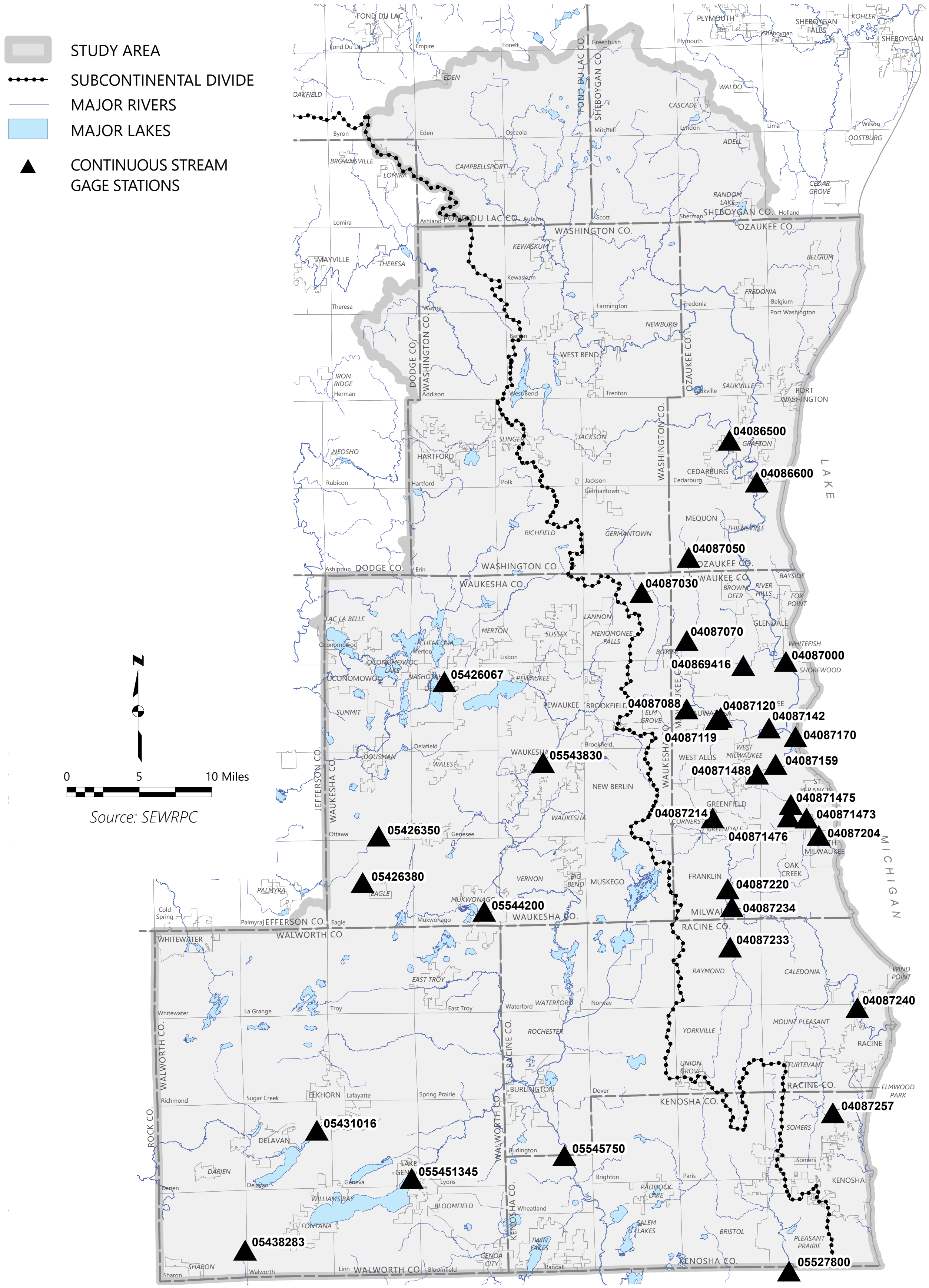
Stream order considerations were based on Strahler stream order designations. These designations are included as an attribute in the WDNR 24k Hydrography database.[13] The Strahler stream order designation is a simple method of classifying stream and river segments based on the number of tributaries upstream.[14] A stream with no tributaries is considered a headwater, or first-order stream. A segment downstream of the confluence of two first order streams is considered a second-order stream. A third-order stream is formed when two second-order streams join. Higher order streams are formed in a similar way with the joining of streams of lower order. This stream order designation can help characterize the size of a stream because higher order streams are generally larger and convey more water than streams of a lower order.

[12] *This total includes the Des Plaines River at Russell, Il USGS stream gage that is located just outside of the study area.*

[13] *Wisconsin Department of Natural Resources Bureau of Enterprise Information Technology & Applications,* Wisconsin DNR 24K Hydrography User's Guide, Version 6, *July 2007.*

[14] *A.N. Strahler, "Hyposomertic Area-Altitude Analysis of Erosional Topography,"* Geological Society of American Bulletin, 63: 1117-1142, 1952.

Map 2.9
Locations of U.S. Geological Survey Continuous Stream Gage Stations: 2018



Detailed streamflow statistics are available for streams where USGS continuous recording streamflow gaging stations are established (see Map 2.9). These statistics can be used as a measurement of stream size based on the volume of water the stream conveys. For potential stream monitoring locations that were near USGS stream gages, the annual 90 percent exceedance flow from both the latest available water year and for the full period of record was used as one factor for stream size when comparing to other candidate monitoring sites.

A stream model has been developed by the WDNR to classify stream reaches into their biotic community by fish occurrence and abundance, as well as ecological conditions that largely determine the biotic community. These ecological conditions include parameters such as water temperature and streamflow.[15] Although this model has some limitations, it does provide an objective, standardized, and ecologically meaningful framework to classify stream reaches and estimate certain stream characteristics.[16] The proposed natural community classification has eleven natural community classes. In the case of this Technical Report, the model was used to provide a general characterization of stream size based on the modeled annual 90 percent exceedance flow given in cubic feet per second (cfs).[17] This estimate was used for potential stream monitoring sites that are not located near USGS stream gages and was only used as a general estimate of stream size when comparing to other candidate monitoring sites. The natural community classifications and estimated flow criteria are summarized in Table 2.7.

Table 2.7
Flow Criteria for Defining Natural Stream Community Type Based on the Wisconsin Stream Model

Natural Community	Annual 90 Percent Exceedance Flow (cfs)
Ephemeral	0.0
Macroinvertebrate	0.0-0.03
Cold Headwater	0.03 -1.0
Cold Mainstem	>1.0
Cool (Cold-Transition) Headwater	0.03-3.0
Cool (Cold-Transition) Mainstem	>3.0
Cool (Warm-Transition) Headwater	0.03-3.0
Cool (Warm-Transition) Mainstem	>3.0
Warm Headwater	0.03-3.0
Warm Mainstem	3.0-110.0
Warm River	>110.0

Note: For further information on stream natural community types, see the WDNR webpage explaining stream natural communities: dnr.wisconsin.gov/topic/Rivers/NaturalCommunities.html.

Source: Wisconsin Department of Natural Resources

Availability of Historical Surface Water Quality Monitoring

The availability of past and ongoing surface water quality monitoring was an important factor considered in selecting locations for establishing monitoring sites for this Study for several reasons. First, awareness of existing monitoring sites can avoid duplication of monitoring efforts. Second, knowing which streams in the study area have never been sampled may increase the priority to assess the water quality of that stream. Lastly, conducting water quality monitoring at a location which is not currently being monitored, but where sampling has been conducted in the past, may provide insight into changing chloride conditions over time at a specific location.

As a component of the stream monitoring site selection process for this Study, Commission staff assembled an inventory of locations where surface water quality monitoring data has been collected within the Region. Commission staff gathered publicly available water quality inventories including from the WDNR's Surface Water Integrated Monitoring System (SWIMS) database, the USGS National Water Information Systems (NWIS) database, and the U.S. Environmental Protection Agency (USEPA) STORET database.[18] Commission staff also reviewed stream sites where water quality data was collected as part of Commission studies in

[15] *J. Lyons, "Patterns in the Species Composition of Fish Assemblages Among Wisconsin Streams,"* Environmental Biology of Fishes, *45: 329-341, 1996.*

[16] *J. Lyons,* An Overview of the Wisconsin Stream Model, *Wisconsin Department of Natural Resources, 2007.*

[17] *The modeled annual 90 percent exceedance flow represents the daily average flow measurement of a stream that is exceeded 90 percent of the year (QAnn90). This measurement will be referred to as "modeled low flow" for the application in this Technical Report to assist in characterizing the stream size based on flow.*

[18] *In addition to water quality data collected as part of the WDNR water quality monitoring programs, the SWIMS database houses water quality data collected through the joint WDNR/University of Wisconsin-Extension (UWEX) Water Action Volunteers (WAV) program including data collected through volunteers with Milwaukee Riverkeeper.*

the 1960s and 1970s.[19] In addition, relevant datasets were also requested from other entities that have conducted surface water quality monitoring within the Region, including the Milwaukee Metropolitan Sewerage District (MMSD), the counties, and municipalities.

The monitoring site selection process for this Study considered only the locations of the aforementioned water quality datasets. The water quality data itself was not analyzed for this assessment. Compilation and analysis of these available datasets is included in Technical Report No. 63.[20]

MMSD Surface Water Quality Monitoring Sites

MMSD employs a comprehensive water quality monitoring program to track the health of the rivers and the watersheds within the MMSD service area as well as Lake Michigan. Early in the Study, during the water quality monitoring site selection phase, MMSD operated 16 continuous stream water quality monitoring stations.[21] These monitoring stations collected various water quality parameters including hourly measurements of specific conductance, water temperature, dissolved oxygen, and turbidity. Several of the continuous stream monitoring stations collected data year-round. In addition to the continuous monitoring data, monthly grab samples were collected near some of these monitoring stations to measure chloride concentrations, among other water quality constituents. Many of the MMSD continuous monitoring stations were also located near a USGS stream gage station.

During the initial stages of assessing where to establish water quality monitoring sites for this Study, Commission staff determined that several of the MMSD continuous stream monitoring stations could help adequately cover the continuous water quality monitoring needs for a substantial portion of Milwaukee County. However, during the data collection phase of this Study it was necessary for MMSD staff to remove continuous monitoring equipment during the winter months at many of the Milwaukee County stream sites due to several factors. Extensive ice cover contributed to difficulties in maintaining monitoring equipment, and subsequent ice dams and ice jams created conditions that could damage equipment and disrupt data collection. Extended periods of elevated Lake Michigan water levels at near-record levels exacerbated ice issues for stations located near the Milwaukee River Estuary, where the Milwaukee, Menomonee, and Kinnickinnic Rivers meet and flow into Lake Michigan. Later in the Study, MMSD was forced to remove equipment from additional continuous monitoring stations, as field work was hindered by COVID-19-related restrictions and issues. To account for the loss of continuous monitoring data coverage within this portion of the study area, Commission staff deployed additional monitoring equipment at selected stream locations to establish supplementary continuous water quality monitoring sites within Milwaukee County. These additional monitoring sites were installed later in the Study data collection period than the rest of the stream monitoring sites established in 2018.

<u>Sources of Water Supply</u>

Aquifers composed of soluble rock types that contain calcium- and magnesium-bearing minerals can produce hard or very hard water. These types of aquifers include those found in glacial deposits, sandstone, and carbonate rock, and are commonly used as sources of water supply in southeastern Wisconsin.[22] Hard water is often treated using water softeners that are recharged with chloride salts. After use in water softeners, the chlorides flushed during regeneration are typically discharged to wastewater treatment plants or to private onsite wastewater treatment systems.

In the Southeastern Wisconsin Region, water softening is most common in areas that rely on groundwater as a source of water supply. As discussed previously in the site selection considerations related to WWTPs, chlorides from water softeners are not removed during the wastewater treatment process and are included in effluent discharged directly to surface water, or less frequently to groundwater through infiltration.

[19] *SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin, *November 1966 and SEWRPC Technical Report No. 17,* Water Quality of Lakes and Streams in Southeastern Wisconsin: 1964-1975, *June 1978.*

[20] *SEWRPC Technical Report No. 63,* Chloride Conditions and Trends in Southeastern Wisconsin, *in development.*

[21] *Of the 16 continuous water quality monitoring stations, 12 stations were located within Milwaukee County, three stations were in Ozaukee County, and one station was in Waukesha County.*

[22] *L.A. DeSimone,* Quality of Water from Domestic Wells in Principal Aquifers of the United States: 1991-2004, *U.S. Geological Survey Scientific Investigations Report No. 2008-5227, 2009.*

Chlorides from water softeners in areas served by private onsite wastewater treatment systems are not removed by the onsite systems and are discharged to the surrounding subsurface soils. Those chlorides may eventually reach shallow groundwater aquifers or surface waters as interflow or baseflow.

Sources of water supply within the Region are shown on Map 2.10. To examine the influence that softening practices may have on chloride levels in the streams of the Region, it was necessary to establish monitoring sites representing streams that received treated wastewater effluent from areas that are primarily served by groundwater supply as well as streams in areas that are primarily served by Lake Michigan supply. Monitoring sites were also considered for streams with contributing areas that are served by both groundwater and Lake Michigan water.

Impaired Streams

Under the Federal Clean Water Act, waterbodies that do not meet the applicable water quality standards are considered impaired. Section 303(d) of the Federal Clean Water Act requires states to periodically submit a list of impaired waters to the USEPA for approval. At the time of the monitoring site selection process for this Study, the most recent approved list of impaired streams for Wisconsin was from 2016. As of that year, 10 streams in the Region were listed as impaired due to chronic and acute aquatic toxicity caused by high chloride concentrations. These include all or portions of the Kinnickinnic River, Lilly Creek, Lincoln Creek, Little Menomonee River, Oak Creek, Pike Creek, Pike River, an unnamed tributary to the North Branch Pike River, Root River, and Ulao Creek.[23] Commission staff considered these impaired waters when selecting stream monitoring sites for this Study.

Other Preliminary Stream Site Selection Considerations

In addition to the considerations described in the previous sections, several peripheral considerations were assessed including salt storage locations, large agricultural feed lots, landfills, and certain food processing activities. Any known locations of these types of facilities were considered prior to preliminary site selection.

Potential Stream Monitoring Sites

Based on the considerations and inventories described in the previous sections, Commission staff assembled a preliminary list of 55 potential stream monitoring locations for this Study. This preliminary list of potential sites was broadly representative of varying characteristics across the Region. The list included 19 sites in the Fox River watershed; 12 in the Rock River watershed; 10 in the Milwaukee River watershed; four in the Root River watershed; two each in the Menomonee River and Des Plaines River watersheds and the areas draining directly to Lake Michigan; and one each in the Pike River, Oak Creek, Kinnickinnic River, and Sauk Creek watersheds. The potential sites also provided widespread Regional coverage with 13 sites located in Walworth County; 12 in Waukesha County; nine in Washington County; six in Racine County; and five in each of Kenosha, Milwaukee, and Ozaukee Counties.

Site-Specific Considerations

After developing a preliminary list of 55 potential stream monitoring sites, Commission staff investigated site-specific characteristics and in-stream conditions to further narrow and finalize a list of sites to be installed. Commission staff anticipated installing approximately 30 to 40 stream monitoring sites for the Study.[24] Onsite and in-stream reconnaissance was conducted to assess site characteristics and suitability for installation of monitoring equipment. Site specific characteristics that were assessed are described in the following sections.

Stream Access and Safety

Commission staff planned to have the new stream monitoring sites collect water quality data year-round, during all seasons for two full years. Stream monitoring sites would be visited at least once per month during the two-year data collection period of the Study. Additional site visits would be required for weather event sampling and for maintaining and troubleshooting the continuous monitoring equipment (site visits

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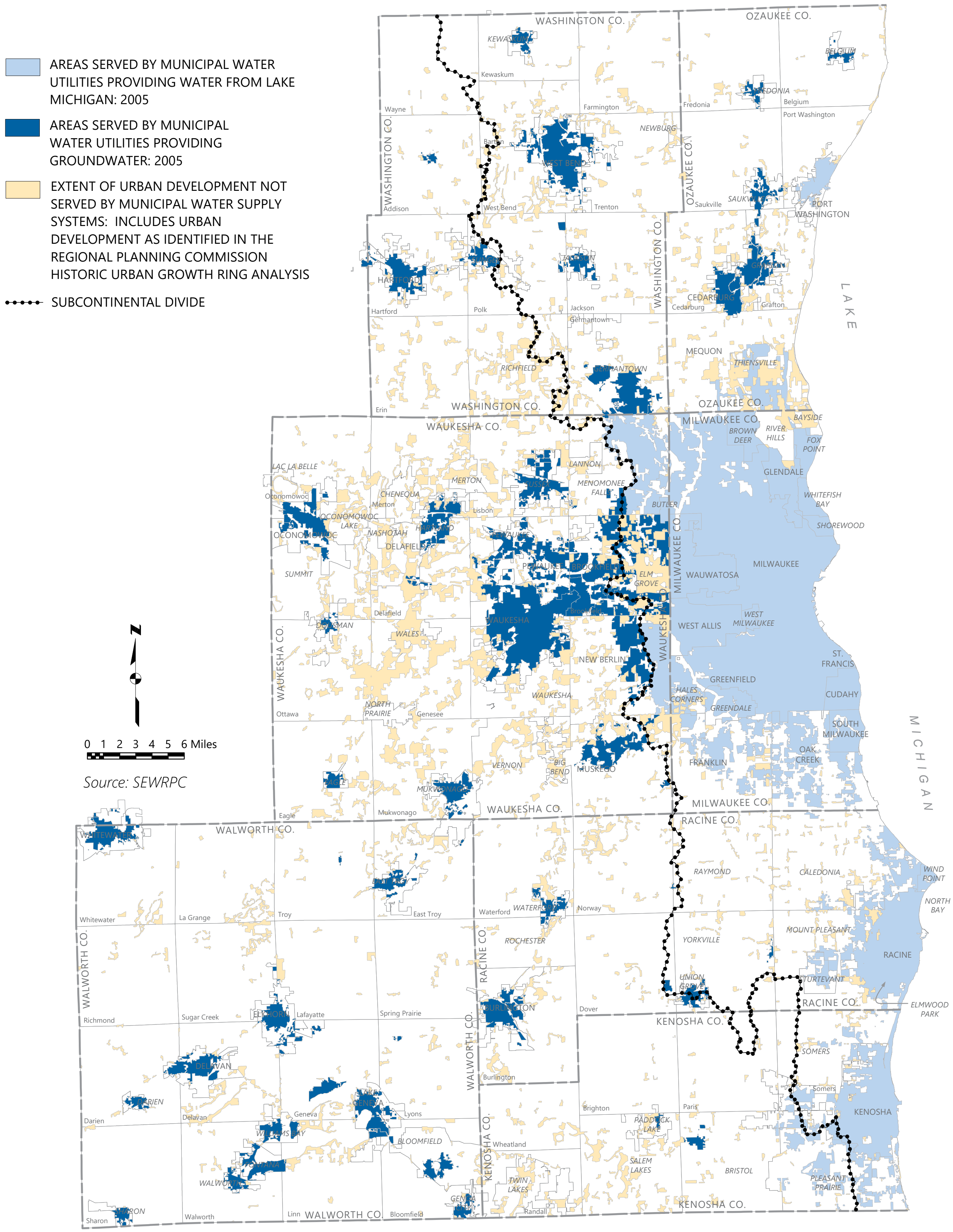
[23] *The reach of the Pewaukee River that was listed as impaired on the 303(d) list in 2016 for chronic and acute chloride toxicity was later delisted in 2020.*

[24] *Southeastern Wisconsin Regional Planning Commission,* Prospectus for A Chloride Impact Study for the Southeastern Wisconsin Region, *March 2016.*

Map 2.10
Municipal Water Supply Service Areas and Sources of Supply in the Region: 2005



Source: SEWRPC

and equipment maintenance are described in detail in Chapter 3). Therefore, monitoring sites needed to be relatively easy to access. Commission staff prioritized stream locations with publicly owned land adjacent to the stream that would allow for easy access whenever necessary. Stream locations near public parks, parkways, and other public facilities were identified prior to field reconnaissance through available GIS datasets. Commission staff confirmed public lands and public accessibility during field reconnaissance visits.

Occasionally, public land was not available adjacent to desired stream monitoring locations. In these instances, Commission staff obtained landowner information from publicly available GIS tax parcel shapefiles. Formal letters of request for access were mailed to the landowners of candidate monitoring site locations (see a sample letter in Appendix A). Landowners willing to grant access to their property signed and returned the letter to Commission offices. Commission staff answered any additional questions and met with landowners onsite upon request.

Safety is always a top priority for Commission staff while conducting fieldwork. Commission field staff needed to have safe parking for vehicles for up to an hour or more. Often, site visits required carrying heavy equipment between the vehicle and the monitoring site. To ensure safe and readily-accessible stream locations, potential monitoring sites were visited and evaluated for the following characteristics.

- Proximity to road crossings
- Availability of off-street parking or sufficient roadside shoulder to safely park a vehicle for an extended period of time
- Safe and nearby access from the parking location to the stream site
- Safe access into the stream from adjacent streambanks

<u>Stream and Riparian Characteristics</u>

Commission field staff also conducted site reconnaissance to assess the physical characteristics of the stream and adjacent riparian areas. This assessment required field staff to get into the streams and assess in-stream conditions to identify specific locations that would be suitable for potential equipment deployment.

A desired characteristic for potential monitoring sites were opportunities to install the equipment at inconspicuous locations that would be out of public view as much as possible. This was often a delicate balance between the desire for public land access and the desire to be out of public view. Wooded riparian corridors, bridges, and areas off the beaten path often offered some opportunities to conceal the equipment. Stickers with the Southeastern Wisconsin Regional Planning Commission logo and contact information were placed onto the equipment that would be installed on the streambank to discourage the public from tampering with the devices.

Potential installation sites were also assessed for suitable water depths within the stream channel. Commission staff walked stream segments with measuring equipment to gauge water depths. This assessment was conducted during periods of relatively normal- to low-flow conditions. It was critical to select sites that had sufficient water depths during low-flow periods to prevent the water quality monitoring sensor from freezing in the winter. However, it was just as important that the installation locations had depths that were safely wadable during most flow conditions so that field staff could access the equipment when necessary for cleaning and maintenance. Commission field staff targeted water depths of approximately three feet to satisfy these requirements.

Commission field staff also evaluated flow conditions and streambed substrates concurrently while measuring water depths. Stagnant water conditions were undesirable because sediments and other fouling debris could clog the sensors. Conversely, rapidly moving water can create unsafe conditions and make for difficult installation, cleaning, and troubleshooting of the equipment. Steady and moderate flows were ideal for safe equipment access while still flushing debris from the sensors and allowing for accurate measurements of water quality parameters.

Streambed substrates needed to be stable enough to support the weight of the concrete block upon which the in-stream sensor was mounted. Silty or mucky substrates were avoided because sensors placed on such substrates would be more likely to get buried or clogged with sediment, which could cause inaccurate sensor measurements. Stream locations with silty and mucky substrates would also be difficult for field staff to access. Ideal substrates were a mixture of firm sand and/or gravel. Other substrates considered advantageous near the potential installation locations were cobble or small boulders. These substrates could be used to stabilize the sensor and housing assembly and prevent the concrete block from tipping during periods of high streamflow. Cobble substrates were also helpful in anchoring the cable conduit to the stream channel. More discussion of the use of these substrates is described in the Continuous Stream Monitoring Site Installation section in Chapter 3.

Finally, Commission staff assessed riparian conditions along the streambanks for suitable options to install the out-of-water equipment components that were necessary for each water quality monitoring station. Each monitoring station included an in-stream sensor connected by stereo cable to an external data logger and telemetry unit that was to be installed on streambanks (see Continuous Stream Monitoring Site Installation section in Chapter 3 for a detailed description of monitoring equipment and installation). Commission field staff assessed several site characteristics that would be helpful for equipment installation on streambanks. First, while the data logger and telemetry units are weather resistant, they cannot be submerged in water and therefore needed to be secured to a stable vertical post or tree at an elevation high enough to be kept dry during major flooding events. For several potential monitoring sites, evaluation of the necessary mounting heights included examination of floodplain maps and related data. Second, the sensor cable must be able to reach from the potential in-stream sensor location at the bottom of the stream channel to a data logger and telemetry unit mounting location on the streambank. Cables for the sensor used in this Study were available in lengths ranging from 10 meters to 23 meters. Lastly, it was critical to locate and position the data logger and telemetry unit with the solar panel facing south for maximum exposure to the sun in order to recharge the batteries and to assist in melting any snow that would accumulate on the solar panel in the winter.

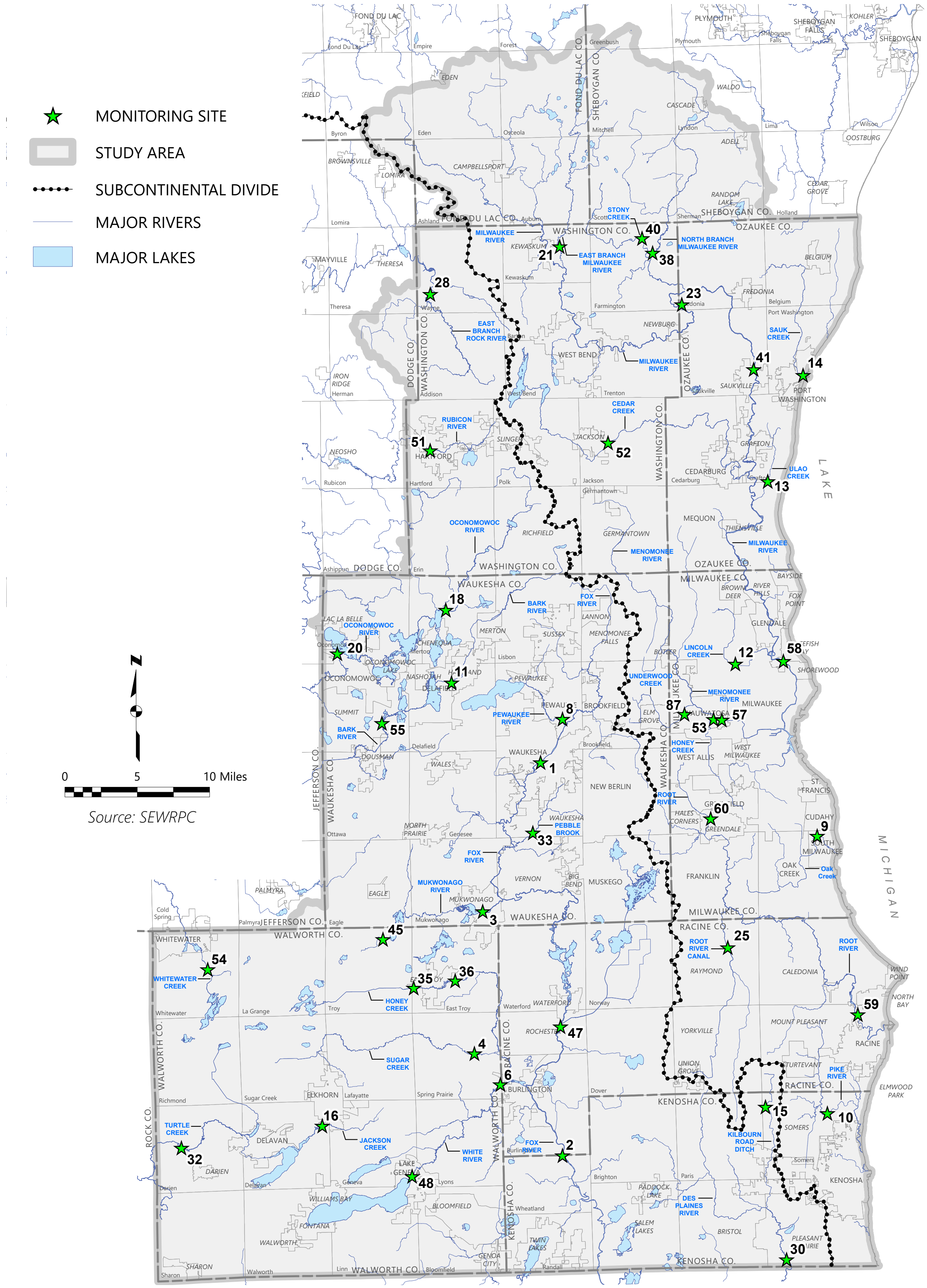
Stream Monitoring Sites

After onsite reconnaissance and assessment of site-specific characteristics, Commission staff narrowed the list of 55 potential stream locations to 37 selected locations for installation of stream monitoring equipment. Commission staff selected an additional four monitoring sites during the course of water quality data collection period. These additional monitoring sites were deemed necessary after MMSD determined that their continuous water quality monitoring equipment at several locations would need to be removed during the winter season. Thus, a total of 41 stream monitoring sites were installed for the Chloride Impact Study. The locations of the installed stream monitoring sites are shown on Map 2.11. Basic details for each monitoring site are provided in Table 2.8. A detailed characterization of each selected stream monitoring site and its upstream contributing drainage area are provided later in this Chapter.

The chosen monitoring sites provide water quality data for an array of streams and rivers that are representative of the diverse characteristics of the Region. The stream monitoring sites established for this Study include 12 sites in the Fox River watershed; 9 sites each in the Rock River and Milwaukee River watersheds; three sites each in the Root River and Menomonee River watersheds; two sites in the Des Plaines River watershed; and one site each in the Pike River, Oak Creek, and Sauk Creek watersheds. The final 41 sites also provide a balanced Regional coverage with nine sites located in Walworth County, eight in Waukesha County, seven in Milwaukee County, six in Washington County, four in both Kenosha and Ozaukee Counties, and three sites in Racine County. There were 15 stream monitoring sites with drainage areas containing other stream monitoring sites selected for the Study. These 15 monitoring sites and the monitoring sites nested within their drainage areas are provided in Table 2.9.

The stream sites selected to be monitored included 17 locations that were near or in the vicinity of USGS continuous streamflow gaging stations. Therefore, water quality data collected at those locations may be analyzed in combination with detailed streamflow data. While many of these 17 sites are located in the direct vicinity of the USGS gaging station, some are located farther from the associated stream gage. Table 2.8 provides station identification numbers for those USGS stream gages located in the vicinity of selected stream monitoring sites for this Study. Approximate distances between the stream monitoring sites and USGS stream gages are also provided.

Map 2.11
Stream Monitoring Sites for the Chloride Impact Study



Source: SEWRPC

Table 2.8
Stream Monitoring Sites for the Chloride Impact Study

SEWRPC Site ID[a]	Site Name	Major Watershed	Site County	Counties Within Drainage Area[b]	Drainage Area Size (sq mi)	SWIMS Station ID	Nearest USGS Streamgage	Latitude	Longitude	Site Location
1	Fox River at Waukesha	Fox River	Waukesha	Waukesha, Washington	126.3	683310	05543830	43.00501682	-88.24428955	Fox River about 100 feet downstream of Prairie Avenue near USGS Gage 05543830 at Waukesha (City of Waukesha)
2	Fox River at New Munster	Fox River	Kenosha	Waukesha, Walworth, Racine, Kenosha, Jefferson, Milwaukee, Washington	807.1	523093	05545750	42.61102994	-88.22575534	Fox River about 30 feet downstream of CTH JB near USGS Gage 05545750 at New Munster (Town of Wheatland)
3	Mukwonago River at Mukwonago	Fox River	Waukesha	Waukesha, Walworth, Jefferson	85.4	10032435	05544200	42.85698382	-88.32736057	Mukwonago River 35 feet downstream of STH 83 and 200 feet downstream of USGS Gage 05544200 at Mukwonago (Village of Mukwonago)
4	Sugar Creek	Fox River	Walworth	Walworth	60.5	10029083	--	42.71494642	-88.34238151	Sugar Creek about 60 feet upstream of Potter Road (Town of Spring Prairie)
6	White River near Burlington	Fox River	Walworth	Walworth, Racine, Kenosha	112.2	653104	--	42.68340253	-88.30797773	White River 40 feet downstream of CTH JS near Burlington (Town of Spring Prairie)
8	Pewaukee River	Fox River	Waukesha	Waukesha	38.1	10051685	--	43.04793066	-88.21308887	Pewaukee River at Steinhafels about 1,000 feet downstream of Busse Road (City of Pewaukee)
9	Oak Creek	Oak Creek	Milwaukee	Milwaukee	25.8	413913	04087204	42.92486133	-87.86938351	Oak Creek 385 feet downstream of 15th Avenue and USGS Gage 04087204 at South Milwaukee (City of South Milwaukee)
10	Pike River	Pike River	Kenosha	Kenosha, Racine	36.6	10034961	04087257	42.64700492	-87.86516338	Pike River at Petrifying Springs Park about 1,500 feet upstream of USGS Gage 04087257 (Village of Somers)
11	Bark River Upstream	Rock River	Waukesha	Waukesha, Washington	35.0	683427	05426067	43.15954154	-88.36944299	Bark River about 100 feet downstream of STH 83 and about 3,950 feet upstream of USGS Gage 05426067 at Nagawicka Road (City of Delafield)
12	Lincoln Creek	Milwaukee River	Milwaukee	Milwaukee	11.0	10047562	040869416	43.09927104	-87.97527082	Lincoln Creek about 400 feet downstream of 51st Blvd and about 2,500 feet upstream of USGS 040869416 Gage at Sherman Boulevard (City of Milwaukee)
13	Ulao Creek	Milwaukee River	Ozaukee	Ozaukee	9.2	10050932	--	43.28115708	-87.92473975	Ulao Creek about 40 feet downstream of CTH W (Town of Grafton)
14	Sauk Creek	Sauk Creek	Ozaukee	Ozaukee, Sheboygan	31.7	10030655	--	43.38648777	-87.87253643	Sauk Creek about 400 feet upstream of Wisconsin Street (City of Port Washington)
15	Kilbourn Road Ditch	Des Plaines River	Kenosha	Racine, Kenosha	8.5	10051686	--	42.65507120	-87.94899341	Kilbourn Road Ditch at CTH A (Village of Somers)

Table continued on next page.

Table 2.8 (Continued)

SEWRPC Site ID[a]	Site Name	Major Watershed	Site County	Counties Within Drainage Area[b]	Drainage Area Size (sq mi)	SWIMS Station ID	Nearest USGS Streamgage	Latitude	Longitude	Site Location
16	Jackson Creek	Rock River	Walworth	Walworth	9.8	10051687	05431016	42.64536095	-88.55068624	Jackson Creek about 3,000 feet downstream of STH 67 and about 4,400 feet upstream of USGS Gage 05431016 at Mound Road (Town of Delavan)
18	Oconomowoc River Upstream	Rock River	Waukesha	Washington, Waukesha	41.3	683245	--	43.11796620	-88.51890233	Oconomowoc River about 325 feet upstream of STH 83 (Town of Merton)
20	Oconomowoc River Downstream	Rock River	Waukesha	Waukesha, Washington, Dodge, Jefferson	100.4	10051688	--	43.47604420	-88.38240756	Oconomowoc River near Lac La Belle Outlet about 75 feet downstream of STH 16 (City of Oconomowoc)
21	East Branch Milwaukee River	Milwaukee River	Washington	Sheboygan, Fond Du Lac, Washington	49.4	10051139	--	43.52109322	-88.20310120	East Branch Milwaukee River at STH 28 (Town of Kewaskum)
23	Milwaukee River Downstream of Newburg	Milwaukee River	Ozaukee	Fond Du Lac, Washington, Sheboygan, Ozaukee, Dodge	264.6	10051689	--	43.46025398	-88.03691368	Milwaukee River about 1,000 feet upstream of Hickory Drive (extended) and Washington/Ozaukee County line (Town of Fredonia)
25	Root River Canal	Root River	Racine	Racine, Kenosha	58.8	10016596	04087233	42.81548800	-87.99495284	Root River Canal at USGS Gage 04087233 at 6 Mile Road (Village of Raymond)
28	East Branch Rock River	Rock River	Washington	Washington, Dodge	54.7	10032027	--	42.62553785	-88.74234642	East Branch Rock River about 80 feet downstream of CTH D (Town of Wayne)
30	Des Plaines River	Des Plaines River	Kenosha	Kenosha, Racine	114.6	303054	05527800	42.50164176	-87.92539857	Des Plaines River at 122nd St (CTH ML) about 7,800 feet upstream of USGS Gage 05527800 at Russel Road, Illinois (Village of Pleasant Prairie)
32	Turtle Creek	Rock River	Walworth	Walworth	94.0	10051690	--	43.31952281	-88.38667623	Turtle Creek about 230 feet upstream of USH 14 (Town of Darien)
33	Pebble Brook	Fox River	Waukesha	Waukesha	16.0	10008183	--	42.93472331	-88.25683580	Pebble Brook about 300 feet upstream of CTH XX (Town of Waukesha)
35	Honey Creek Upstream of East Troy	Fox River	Walworth	Walworth	37.7	10032440	--	42.78177625	-88.42317446	Honey Creek about 800 feet downstream of Townline Road at Michael Fields Agricultural Institute (Town of East Troy)
36	Honey Creek Downstream of East Troy	Fox River	Walworth	Walworth	44.6	653244	--	42.78823546	-88.36653679	Honey Creek at Carver School Road (Town of East Troy)
38	North Branch Milwaukee River	Milwaukee River	Washington	Sheboygan, Ozaukee, Washington	105.8	10029089	--	43.51262786	-88.07534337	North Branch Milwaukee River about 25 feet downstream of CTH XX (Town of Farmington)
40	Stony Creek	Milwaukee River	Washington	Washington, Sheboygan, Fond Du Lac	17.8	673267	--	43.52741053	-88.08937392	Stony Creek at CTH X (Town of Farmington)
41	Milwaukee River near Saukville	Milwaukee River	Ozaukee	Fond Du Lac, Washington, Sheboygan, Ozaukee, Dodge	448.3	10051691	--	43.39366252	-87.94024145	Milwaukee River near Friendship Lane (extended) (Town of Saukville)
45	Mukwonago River at Nature Road	Fox River	Walworth	Walworth, Waukesha, Jefferson	24.4	10029287	--	42.83108888	-88.46375625	Mukwonago River about 150 feet downstream of Nature Road and upstream of Lulu Lake (Town of Troy)

Table continued on next page.

Table 2.8 (Continued)

SEWRPC Site ID[a]	Site Name	Major Watershed	Site County	Counties Within Drainage Area[b]	Drainage Area Size (sq mi)	SWIMS Station ID	Nearest USGS Streamgage	Latitude	Longitude	Site Location
47	Fox River at Rochester	Fox River	Racine	Waukesha, Racine, Walworth, Jefferson, Milwaukee, Washington	455.6	10032438	05544475[c]	42.74014301	-88.22477829	Fox River about 1,700 feet upstream of Rochester Dam near USGS Gage 05544475 at Rochester (Village of Rochester)
48	White River at Lake Geneva	Fox River	Walworth	Walworth	29.1	10051692	055451345	42.59328722	-88.43008313	White River about 1,430 feet downstream of Geneva Lake outlet and USGS Gage 055451345 (City of Lake Geneva)
51	Rubicon River	Rock River	Washington	Washington, Dodge	27.5	10051693	--	42.80382218	-88.70293308	Rubicon River at West Side Park about 250 feet upstream of Grant Street (City of Hartford)
52	Cedar Creek	Milwaukee River	Washington	Washington, Ozaukee	53.6	673048	--	43.32350934	-88.14256630	Cedar Creek about 150 feet upstream of STH 60 (Town of Jackson)
53	Honey Creek at Wauwatosa	Menomonee River	Milwaukee	Milwaukee	10.7	10030407	04087119	43.04426929	-88.00683244	Honey Creek about 1,500 feet upstream of the confluence with the Menomonee River and about 600 feet upstream of USGS Gage 04087119 (City of Wauwatosa)
54	Whitewater Creek	Rock River	Walworth	Walworth	18.8	653291	--	43.04745799	-88.45981016	Whitewater Creek about 30 feet upstream of Millis Road (Town of Whitewater)
55	Bark River Downstream	Rock River	Waukesha	Waukesha, Washington	53.2	683424	--	43.15954154	-88.36944299	Bark River about 50 feet upstream of Genesee Lake Road (Village of Summit)
57	Menomonee River at Wauwatosa	Menomonee River	Milwaukee	Milwaukee, Waukesha, Washington, Ozaukee	124.5	10012584	04087120	43.04348983	-87.99543034	Menomonee River near Jacobus Park and about 1,500 feet downstream of USGS Gage 04087120 at 70th Street (City of Wauwatosa)
58	Milwaukee River at Estabrook Park	Milwaukee River	Milwaukee	Washington, Ozaukee, Fond Du Lac, Sheboygan, Milwaukee, Dodge	684.7	413640	04087000	43.10080823	-87.90949931	Milwaukee River at Estabrook Park about 2,100 feet downstream of Port Washington Road and 330 feet upstream of USGS Gage 04087000 (City of Milwaukee)
59	Root River near Horlick Dam	Root River	Racine	Racine, Milwaukee, Waukesha, Kenosha	189.7	10044817	04087240	42.74522748	-87.82038887	Root River at Racine Country Club Golf Course Bridge and about 2,600 feet downstream USGS Gage 04087240 at STH 38 (Village of Mount Pleasant)
60	Root River at Grange Avenue	Root River	Milwaukee	Milwaukee, Waukesha	15.0	413716	04087214	42.94500273	-88.01399744	Root River near USGS Gage 04087214 (Village of Greendale)
87	Underwood Creek	Menomonee River	Milwaukee	Waukesha, Milwaukee	19.0	10031613	04087088	43.05008628	-88.04639671	Underwood Creek at Gravel Sholes Park about 870 feet downstream of STH 100 at USGS Gage 04087088 (City of Wauwatosa)

[a] *See Map 2.11 for locations and Figure 2.1 for photographs of each monitored stream.*

[b] *Counties are listed in the order of largest proportion of the drainage area.*

[c] *The USGS gage on the Fox River at Rochester only measures water level and does not measure streamflow discharge.*

Source: SEWRPC

Table 2.9
Stream Monitoring Site Drainage Areas Containing Additional Monitoring Sites

SEWRPC Site ID[a]	Site Name	Monitoring Sites Nested Within Drainage Area[b]
1	Fox River at Waukesha	Site 8 (Pewaukee River)
2	Fox River at New Munster	Site 8 (Pewaukee River) Site 1 (Fox River at Waukesha) Site 33 (Pebble Brook) Site 45 (Mukwonago River at Nature Road) Site 3 (Mukwonago River at Mukwonago) Site 47 (Fox River at Rochester) Site 35 (Honey Creek Upstream of East Troy) Site 36 (Honey Creek Downstream of East Troy) Site 4 (Sugar Creek) Site 48 (White River at Lake Geneva) Site 6 (White River at Burlington)
3	Mukwonago River at Mukwonago	Site 45 (Mukwonago River at Nature Road)
6	White River near Burlington	Site 48 (White River at Lake Geneva)
20	Oconomowoc River Downstream	Site 18 (Oconomowoc River Upstream)
23	Milwaukee River Downstream of Newburg	Site 21 (East Branch Milwaukee River)
30	Des Plaines River	Site 15 (Kilbourn Road Ditch)
32	Turtle Creek	Site 16 (Jackson Creek)
36	Honey Creek Downstream of East Troy	Site 35 (Honey Creek Upstream of East Troy)
41	Milwaukee River near Saukville	Site 21 (East Branch Milwaukee River) Site 23 (Milwaukee River Downstream of Newburg) Site 40 (Stony Creek) Site 38 (North Branch Milwaukee River)
47	Fox River at Rochester	Site 8 (Pewaukee River) Site 1 (Fox River at Waukesha) Site 33 (Pebble Brook) Site 45 (Mukwonago River at Nature Road) Site 3 (Mukwonago River at Mukwonago)
55	Bark River Downstream	Site 11 (Bark River Upstream)
57	Menomonee River at Wauwatosa	Site 87 (Underwood Creek) Site 53 (Honey Creek at Wauwatosa)
58	Milwaukee River at Estabrook Park	Site 21 (East Branch Milwaukee River) Site 23 (Milwaukee River Downstream of Newburg) Site 40 (Stony Creek) Site 38 (North Branch Milwaukee River) Site 41 (Milwaukee River near Saukville) Site 52 (Cedar Creek) Site 13 (Ulao Creek) Site 12 (Lincoln Creek)
59	Root River near Horlick Dam	Site 60 (Root River at Grange Avenue) Site 25 (Root River Canal)

[a] *See Map 2.11 for locations of monitoring sites.*

[b] *Monitoring sites are listed in order from upstream to downstream.*

Source: SEWRPC

As described earlier in this Chapter, Commission staff were interested in examining the influence that treated wastewater effluent has on chloride levels in streams. To examine the impact of wastewater effluent, 16 monitoring sites were selected for this Study at stream locations that receive streamflow carrying treated wastewater effluent from one or more public wastewater treatment facilities. Those stream monitoring sites and the wastewater treatment facilities discharging treated effluent to surface water upstream of each site are provided in Table 2.10. Conversely, there are 25 locations selected for this Study that monitored streams without upstream wastewater effluent contributions.

Table 2.10
Stream Monitoring Sites that Receive Streamflow Containing Treated Wastewater Effluent

SEWRPC Site ID[a]	Site Name	Wastewater Facility Discharging Effluent to Surface Water[b]
1	Fox River at Waukesha	Sussex Wastewater Treatment Facility Fox River Water Pollution Control Center
2	Fox River at New Munster	Sussex Wastewater Treatment Facility Fox River Water Pollution Control Center Waukesha Wastewater Treatment Facility Mukwonago Wastewater Treatment Plant Town of Norway Sanitary District No. 1 Wastewater Treatment Facility Western Racine County Sewerage District Eagle Lake Sewer Utility District East Troy Wastewater Treatment Facility Lyons Sanitary District No. 2 Burlington Water Pollution Control
6	White River near Burlington	Lyons Sanitary District No. 2
23	Milwaukee River Downstream of Newburg	Campbellsport Wastewater Treatment Facility Kewaskum Wastewater Treatment Plant City of West Bend Sewage Treatment Facility Village of Newburg Sanitary Sewer Treatment Facility
25	Root River Canal	Union Grove Wastewater Treatment Plant
28	East Branch Rock River	Allenton Sanitary District Wastewater Treatment Plant
30	Des Plaines River	Paddock Lake Wastewater Treatment Facility Bristol Utility District No. 1
32	Turtle Creek	Walworth County Metropolitan Sewerage District
36	Honey Creek Downstream of East Troy	East Troy Wastewater Treatment Facility
38	North Branch Milwaukee River	Cascade Wastewater Treatment Facility Random Lake Sewage Treatment Plant
41	Milwaukee River near Saukville	Campbellsport Wastewater Treatment Facility Kewaskum Wastewater Treatment Plant City of West Bend Sewage Treatment Facility Village of Newburg Sanitary Sewer Treatment Facility Cascade Wastewater Treatment Facility Random Lake Sewage Treatment Plant Fredonia Municipal Sewer and Water Utility
47	Fox River at Rochester	Sussex Wastewater Treatment Facility Fox River Water Pollution Control Center Waukesha Wastewater Treatment Facility Mukwonago Wastewater Treatment Plant Town of Norway Sanitary District No. 1 Wastewater Treatment Facility
51	Rubicon River	Slinger Wastewater Treatment Facility
52	Cedar Creek	Jackson Wastewater Treatment Plant
58	Milwaukee River at Estabrook Park	Campbellsport Wastewater Treatment Facility Kewaskum Wastewater Treatment Plant City of West Bend Sewage Treatment Facility Village of Newburg Sanitary Sewer Treatment Facility Cascade Wastewater Treatment Facility Random Lake Sewage Treatment Plant Fredonia Municipal Sewer and Water Utility Saukville Sewer Utility Grafton Water and Wastewater Utility Jackson Wastewater Treatment Plant Cedarburg Wastewater Treatment Facility
59	Root River near Horlick Dam	Union Grove Wastewater Treatment Plant Yorkville Sewer Utility District No.1

[a] *See Map 2.11 for locations of monitoring sites.*

[b] *See Appendix B for wastewater treatment facility locations within each stream monitoring site drainage area.*

Source: Wisconsin Department of Natural Resources and SEWRPC

Lake Monitoring Site Selection

There are over 100 major lakes with surface areas of 50 acres or more within the Southeastern Wisconsin Region. These lakes account for a combined surface area of approximately 57 square miles, or about 2 percent of the Region. The distribution of major lakes ranges from none in Milwaukee County to 33 in Waukesha County. The remaining five counties of Walworth, Kenosha, Washington, Racine, and Ozaukee each contain 25, 15, 15, 10, and 2 major lakes, respectively. In addition, there are 228 minor lakes and ponds in the Region of less than 50 acres in size.

Collection of lake water quality data for the Chloride Impact Study was necessary for understanding current chloride conditions in lakes that are representative of the Region. Additionally, it was envisioned that collection of chloride and specific conductance data will help illustrate how chloride moves through lakes and how it may impact the seasonal functions and ecology of the lakes in the Region. Lake sampling was to be conducted quarterly over a two-year sampling period, including during winter (water quality sampling procedures and methodology are provided in detail in Chapter 3).

For this Study, lakes were selected to provide a balanced geographic spread across the Region and include different lake types as discussed in the following section. During sampling periods when lakes were clear of ice (spring, summer, and fall sampling periods) Commission staff also required the assistance of volunteers to provide lake access and the use of a boat in order to reach specific sampling locations. Therefore, a determining factor for lake selection was willing volunteers based on known contacts from previous Commission projects, or members of a lake organization.

Lake Types

In addition to the considerations described above, Commission staff also sought to select a variety of lake types that are commonly found in the Region. Lakes in Wisconsin can be classified into four main types based on how water enters and exits the lake. These lake types include seepage, spring, drainage, and drained lakes. The water quality of a lake and the species of fish within a lake are significantly influenced by lake type.[25] A description of each lake type is provided below.

- Seepage lakes do not have an inlet or an outlet, and only occasionally overflow. As these lakes have no inlet, the main source of water is direct precipitation or runoff from the immediate drainage area, supplemented by groundwater inflows. Since seepage lakes commonly mirror groundwater levels and rainfall patterns, water levels can vary depending on the season and hydrologic conditions. Seepage lakes tend to have smaller drainage areas which could account for lower levels of nutrients and other pollutants when compared to other lake types.

- Spring lakes have no inlet but have an outlet. The primary source of water for spring lakes is groundwater flowing into the bottom of the lake from inside and outside the immediate surface water drainage area. Spring lakes are often located at the headwaters of many streams.

- Drainage lakes have both an inlet and outlet where the main water source is streamflow and surface water runoff. Most major rivers in Wisconsin have drainage lakes along their course. These lakes typically have higher levels of nutrients and other pollutants compared to many natural seepage or spring lakes. Drainage lakes owing one-half or more of their maximum depth to a dam are considered to be artificial lakes, or impoundments.

- Drained lakes have no inlet, but similar to spring lakes, they have a continuously flowing outlet. However, drained lakes are not groundwater-fed. Their primary source of water is from precipitation and direct runoff from the surrounding land. Frequently, the water levels in drained lakes will fluctuate depending on the supply of the water. Under severe drought conditions, the outlets from drained lakes may become intermittent. These are the least-common lake type found in Wisconsin.

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[25] *Wisconsin Department of Natural Resources Bureau of Fisheries and Habitat Management Publication No. PUB-FH-800,* Wisconsin Lakes, *2009.*

Lake Monitoring Sites

A total of six lakes located throughout the Region were selected for collection of water quality data for the Chloride Impact Study. These lakes include Big Cedar, Geneva, Little Muskego, Moose, Silver (Washington County), and Voltz Lakes (see Map 2.12). These lakes provide a balanced geographic representation of the Region and include each of lake types described above. Moose Lake represents seepage lakes; Big Cedar Lake, Geneva Lake, and Silver Lake represent spring lakes; Little Muskego Lake represents drainage lakes; and Voltz Lake represents drained lakes. A characterization of each monitored lake and their watersheds are provided later in this Chapter.

2.4 CHARACTERIZATION OF MONITORING SITES AND DRAINAGE AREAS

Descriptions of Stream Monitoring Sites and Drainage Areas

As described earlier in the Chapter, a total of 41 stream locations were selected for installation of water quality monitoring equipment and for water quality grab sampling (see Map 2.11 and Table 2.8). Photos of the stream near each monitoring site are shown in Figure 2.1.

The upstream contributing drainage area for each installed stream monitoring site was delineated using the SEWRPC watershed and subbasin datasets along with the latest-available topographic data. Land use maps, civil division maps, and important characteristics for the drainage areas upstream of each of these sites are provided in Appendix B. Short descriptions of each of the monitoring site locations and drainage areas are provided in the following sections.

Site 1 – Fox River at Waukesha

Monitoring Site 1 was located on the Fox River just downstream of Prairie Avenue near the USGS stream gage 05543830, in the City of Waukesha. The Fox River channel at this location is about 65 feet wide and is classified by the WDNR as a fifth-order "warm mainstem" stream, with a modeled low flow estimated to be about 33 cfs (see Table 2.11).[26] The drainage area upstream of Site 1 encompasses 126 square miles and is located largely within Waukesha County with a small portion within Washington County. The drainage area also includes Site 8 (Pewaukee River). In 2015, the land use within this drainage area was slightly more urban (54 percent) than rural (46 percent). The most common land uses consisted of lower-density residential (18.6 percent), wetlands (15.4 percent), roads and parking lots (14.4 percent) including nearly 14 miles of IH 94 corridor, and agricultural lands (12.1 percent) (see Table 2.12 and Map B.1). This drainage area covers portions of 17 civil divisions including urbanized portions of the Cities of Brookfield, Pewaukee, New Berlin, and Waukesha and the Village of Pewaukee (see Map B.2 and Table B.1). About 73 percent of the drainage area is contained within portions of 13 planned public sanitary sewer service areas. Flows to Site 1 include treated wastewater effluent from the Village of Sussex Wastewater Treatment Plant which discharges into Sussex Creek and the Fox River Water Pollution Control Center which discharges into the Fox River (see Table 2.10).

Site 2 – Fox River at New Munster

Monitoring Site 2 was located just downstream of CTH JB near USGS stream gage 05545750, in the Town of Wheatland. The Fox River channel at this location is about 180 feet wide and is classified by the WDNR as a sixth-order "large river," with a modeled low flow estimated to be 224 cfs (see Table 2.11).[27] This was the largest drainage area monitored for this Study encompassing 807 square miles and containing portions of (in order of largest to smallest proportion) Waukesha, Walworth, Racine, Kenosha, Jefferson, Milwaukee, and Washington Counties. In 2015, the land use within this drainage area was largely rural (72.9 percent) with the most common land use types consisting of agricultural lands (37.1 percent), wetlands (13.3 percent), lower-density residential (10.8 percent), and woodlands (10.1 percent) (see Table 2.12 and Map B.3). Although the drainage area primarily consisted of non-urban land uses, there were also several significant urbanized areas. The most common urban land uses included lower-density residential (10.8 percent) and roads and parking lots (7.0 percent). Nearly 30 miles of IH 43 corridor and 14 miles of IH 94 corridor traverse this drainage area. This drainage area covers portions of 61 civil divisions including some relatively urbanized municipalities (see Map B.4 and Table B.1). The

[26] *Based on USGS stream gage data collected at this location, the Fox River had a 90 percent exceedance flow of approximately 57 cfs for water year 2020 and 24 cfs for the full period of record from 1963 through 2020.*

[27] *Based on USGS stream gage data collected at this location, the Fox River had a 90 percent exceedance flow of approximately 536 cfs for water year 2020 and 222 cfs for the full period of record from 1994 through 2020.*

Map 2.12
Lakes Monitored for the Chloride Impact Study

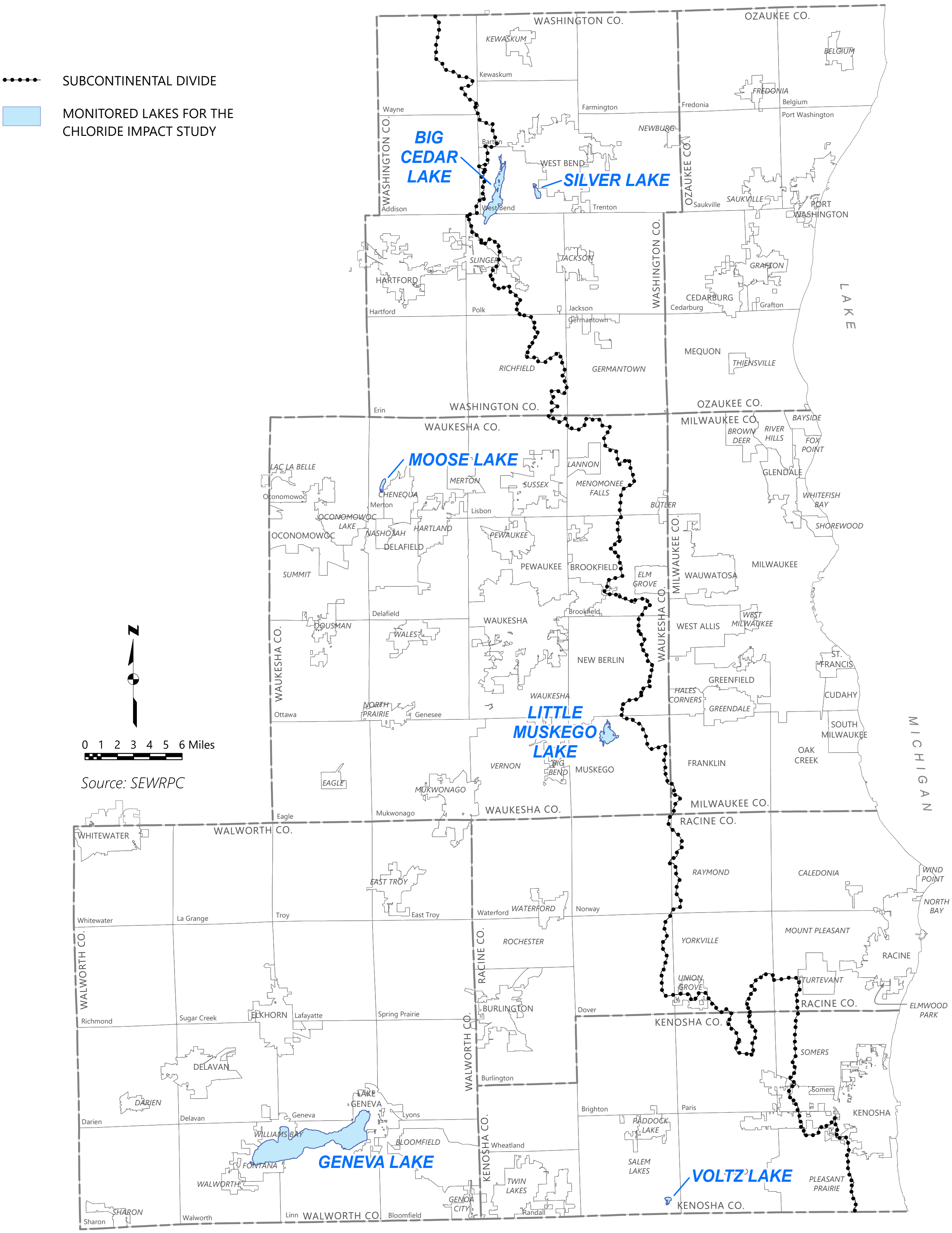
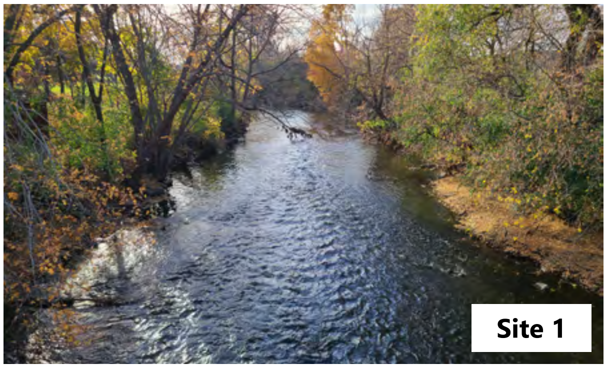


Figure 2.1
Monitored Streams for the Chloride Impact Study

Fox River at Waukesha



Fox River at New Munster

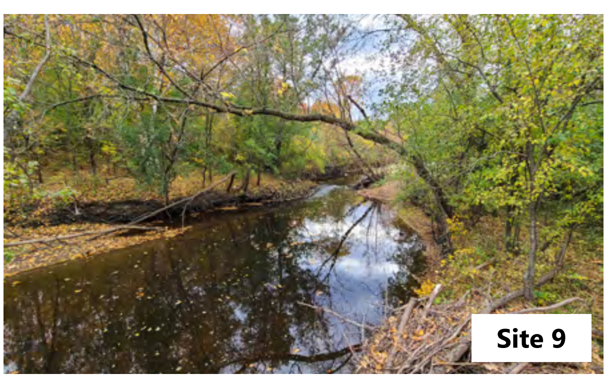
Mukwonago River at Mukwonago

Sugar Creek

White River near Burlington

Pewaukee River

Oak Creek



Pike River

Figure 2.1 (Continued)

Bark River Upstream

Lincoln Creek

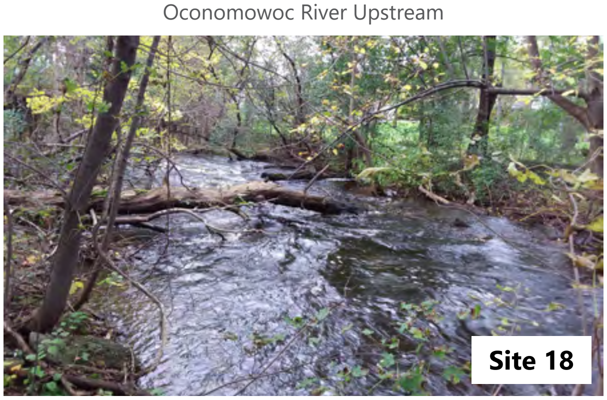
Ulao Creek

Sauk Creek

Kilbourn Road Ditch

Jackson Creek

Oconomowoc River Upstream



Oconomowoc River Downstream

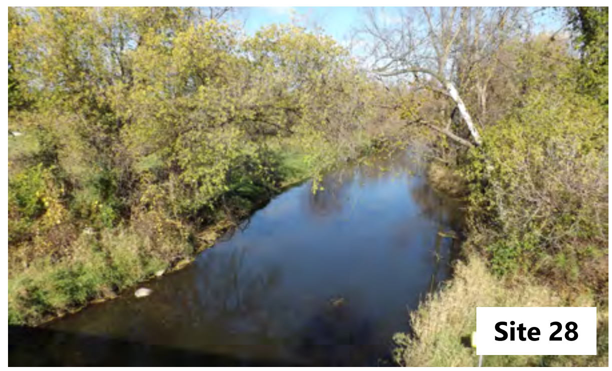
Figure 2.1 (Continued)

East Branch Milwaukee River

Milwaukee River Downstream of Newburg

Root River Canal

East Branch Rock River



Des Plaines River

Turtle Creek

Pebble Brook

Honey Creek Upstream of East Troy

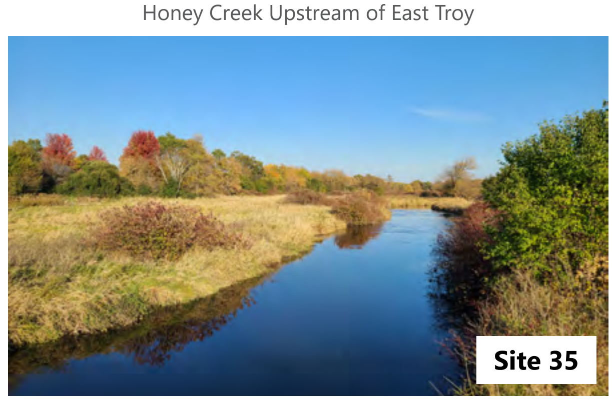


Figure 2.1 (Continued)

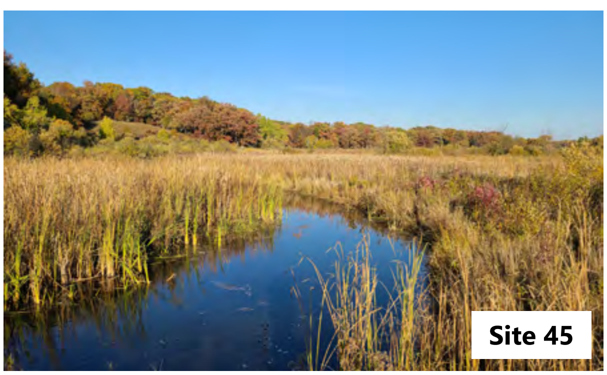
Honey Creek Downstream of East Troy

North Branch Milwaukee River

Stony Creek

Milwaukee River near Saukville

Mukwonago River at Nature Road



Fox River at Rochester

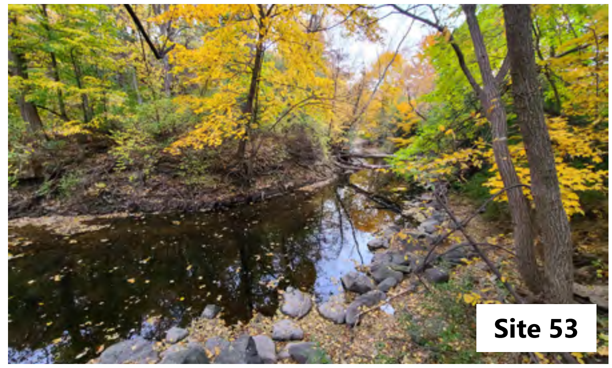
White River at Lake Geneva

Rubicon River

Figure 2.1 (Continued)

Cedar Creek

Honey Creek at Wauwatosa



Whitewater Creek

Bark River Downstream

Menomonee River at Wauwatosa

Milwaukee River at Estabrook Park

Root River near Horlick Dam

Root River at Grange Avenue

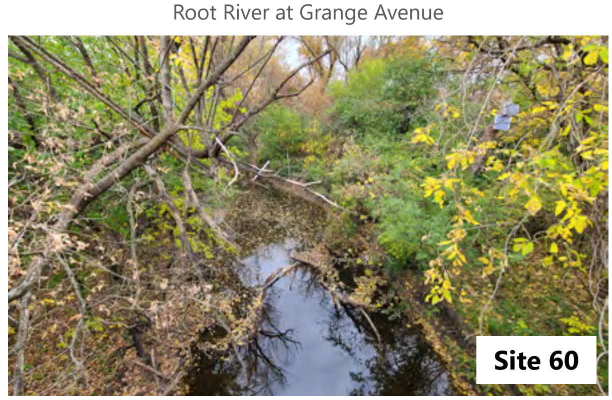


Figure 2.1 (Continued)

Underwood Creek

Source: SEWRPC Staff

Fox River flows through (from upstream to downstream) the Villages of Menomonee Falls and Lannon, Town and City of Brookfield, City of Pewaukee, City and Village of Waukesha, Village of Vernon, Town and Village of Mukwonago, Village of Big Bend, Town and Village of Waterford, Village of Rochester, and Town and City of Burlington before reaching Monitoring Site 2. Many tributary streams flow into the Fox River upstream of this monitoring site and this drainage area includes 11 other stream sites monitored for the Chloride Impact Study (see Table 2.9). In addition, Little Muskego Lake and Geneva Lake were monitored for this Study and are located within the drainage area of Site 2. About 30 percent of the drainage area is contained within portions of 38 public sanitary sewer service areas. Flows to Site 2 include treated wastewater effluent from 10 wastewater treatment facilities (see Table 2.10).[28]

Site 3 – Mukwonago River at Mukwonago

Monitoring Site 3 was located on the Mukwonago River just downstream of STH 83 near USGS stream gage 05544200, in the Village of Mukwonago. The Mukwonago River channel at this location is about 55 feet wide and is classified by the WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about 23 cfs (see Table 2.11).[29] The drainage area upstream of Site 3 encompasses 85 square miles located within portions of Waukesha, Walworth, and Jefferson Counties and is part of the Fox River watershed. In 2015, land use in the drainage area was largely rural (73.6 percent), consisting mostly of agricultural lands (29.7 percent), woodlands (20.3 percent), lower-density residential (15.5 percent), and rural unused lands (10.1 percent) (see Table 2.12 and Map B.5). Roads and parking lots accounted for about 5.2 percent of this drainage area. This includes a three-mile stretch of IH 43 corridor and a nearly two mile stretch of USH 83 that both traverse the eastern corner of the drainage area. USH 83 crosses the Mukwonago River just upstream of the monitoring site. This drainage area covers portions of 13 civil divisions including a relatively urbanized portion of the Village of Mukwonago near the monitoring site (see Map B.6 and Table B.1). Monitoring Site 45 (Mukwonago River at Nature Road) is located in the upstream headwaters portion of this drainage area. About 11 percent of the drainage area is contained within portions of four public sanitary sewer service areas including the Mukwonago, Eagle Springs Lake/Mukwonago County Park/Rainbow Springs, East Troy, and Wales sanitary sewer service areas. This site is located upstream of the Village of Mukwonago Wastewater Treatment Facility and therefore flows to Site 3 do not include effluent from wastewater treatment facilities.

Site 4 – Sugar Creek

Monitoring Site 4 was located on Sugar Creek just upstream of Potter Road in the Town of Spring Prairie. The Sugar Creek channel at this location is about 35 feet wide and is classified by the WDNR as a third-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about 16 cfs (see Table 2.11). The drainage area upstream of Site 4 encompasses about 60 square miles located completely within Walworth County and is part of the Fox River watershed. In 2015, land use within this drainage area consisted largely of rural land uses (86.9 percent) with the most common land use types being agricultural lands (57.5 percent), wetlands (11.5 percent), woodlands (10.4 percent), and rural unused lands (5.6 percent) (see Table 2.12 and Map B.7). Roads and parking lots accounted for about 4.7 percent of the drainage area and include a six-mile stretch of IH 43 corridor. This drainage area covers portions of six civil divisions, primarily the Towns of Lafayette, Sugar Creek, and Spring Prairie, and the City of Elkhorn (see Map B.8 and Table B.1). About 8.5 percent of the drainage area is contained within the Walworth County Metropolitan Sewerage District sanitary sewer service area. A very small portion of the drainage area is contained within the East Troy sewer service area. Flows to Site 4 do not include effluent from wastewater treatment facilities.

[28] *In addition, the Lake Geneva Wastewater Utility discharges treated wastewater effluent to soil and eventually to groundwater.*

[29] *Based on USGS stream gage data collected near this location, the Mukwonago River had a 90 percent exceedance flow of approximately 50 cfs for water year 2020 and 22 cfs for the full period of record from 1994 through 2020.*

Table 2.11
Characteristics Related to Size of Streams at Selected Monitoring Sites

SEWRPC Site ID[a]	Site Name	Drainage Area Size (sq mi)	Channel Width (ft)	Stream Order	WDNR Natural Community Classification	WDNR Modeled Annual 90 Percent Exceedance Flow (cfs)	USGS Annual 90 Percent Exceedance Flow Based on Latest Water Year (cfs)[b]	USGS Annual 90 Percent Exceedance Flow Based on Full Period of Record (cfs)[c]
1	Fox River at Waukesha	126	65	5th order	Warm Mainstem	33	57	24
2	Fox River at New Munster	807	180	6th order	Large River	224	536	222
3	Mukwonago River at Mukwonago	85	55	4th order	Warm Mainstem	23	50	22
4	Sugar Creek	60	35	3rd order	Cool-Warm Mainstem	16	--	--
6	White River near Burlington	112	85	4th order	Warm Mainstem	34	--	--
8	Pewaukee River	38	35	4th order	Warm Mainstem	6	--	--
9	Oak Creek	26	25	4th order	Cool-Warm Headwater	2	6	2
10	Pike River	37	35	4th order	Cool-Cold Mainstem	6	12	6
11	Bark River Upstream	35	30	3rd order	Cool-Warm Mainstem	13	27	14
12	Lincoln Creek	11	30	2nd order	Cool-Warm Headwater	2	3	2
13	Ulao Creek	9	25	3rd order	Cool-Warm Headwater	0.5	--	--
14	Sauk Creek	32	20	3rd order	Cool-Warm Headwater	2	--	--
15	Kilbourn Road Ditch	9	15	2nd order	Cool-Cold Headwater	0.3	--	--
16	Jackson Creek	10	25	2nd order	Cool-Warm Headwater	0.2	4	1
18	Oconomowoc River Upstream	41	15	4th order	Cool-Warm Mainstem	6	--	--
20	Oconomowoc River Downstream	100	30	4th order	Warm Mainstem	19	--	--
21	East Branch Milwaukee River	49	40	4th order	Cool-Warm Mainstem	11	--	--
23	Milwaukee River Downstream of Newburg	265	75	5th order	Cool-Warm Mainstem	54	--	--
25	Root River Canal	59	40	4th order	Cool-Cold Headwater	3	9	2
28	East Branch Rock River	55	60	4th order	Cool-Warm Mainstem	7	--	--
30	Des Plaines River	115	160	4th order	Cool-Warm Mainstem	7	16	3
32	Turtle Creek	94	90	4th order	Warm Mainstem	25	--	--
33	Pebble Brook	16	30	3rd order	Cool-Warm Mainstem	4	--	--
35	Honey Creek Upstream of East Troy	38	35	4th order	Warm Mainstem	10	--	--
36	Honey Creek Downstream of East Troy	45	45	4th order	Warm Mainstem	11	--	--
38	North Branch Milwaukee River	106	75	4th order	Cool-Warm Mainstem	26	--	--
40	Stony Creek	18	20	2nd order	Cool-Warm Mainstem	5	--	--
41	Milwaukee River near Saukville	448	200	5th order	Warm Mainstem	90	--	--
45	Mukwonago River at Nature Road	24	25	3rd order	Cool-Cold Mainstem	4	--	--

Table continued on next page.

Table 2.11 (Continued)

SEWRPC Site ID[a]	Site Name	Drainage Area Size (sq mi)	Channel Width (ft)	Stream Order	WDNR Natural Community Classification	WDNR Modeled Annual 90 Percent Exceedance Flow (cfs)	USGS Annual 90 Percent Exceedance Flow Based on Latest Water Year (cfs)[b]	USGS Annual 90 Percent Exceedance Flow Based on Full Period of Record (cfs)[c]
47	Fox River at Rochester	456	180	6th order	Warm Mainstem	115	--	--
48	White River at Lake Geneva	29	18	3rd order	Warm Mainstem	6	28	0.2
51	Rubicon River	27	20	3rd order	Warm Headwater	3	--	--
52	Cedar Creek	54	40	4th order	Warm Mainstem	8	--	--
53	Honey Creek at Wauwatosa	11	20	2nd order	Cool-Warm Headwater	1	2	1
54	Whitewater Creek	19	15	3rd order	Cool-Warm Mainstem	5	--	--
55	Bark River Downstream	53	40	3rd order	Warm Mainstem	11	--	--
57	Menomonee River at Wauwatosa	124	80	4th order	Warm Mainstem	19	45	14
58	Milwaukee River at Estabrook Park	685	220	5th order	Warm Mainstem	137	433	78
59	Root River near Horlick Dam	190	85	5th order	Warm Mainstem	11	44	10
60	Root River at Grange Avenue	15	30	3rd order	Cool-Warm Headwater	1	4	1
87	Underwood Creek	19	13	3rd order	Cool-Warm Mainstem	4	7	3

Note: Annual 90 percent exceedance flow values reported by WDNR and USGS that are greater than one have been rounded to the nearest whole number in this table. Flow values that are less than one have been rounded to the nearest tenth.

[a] *See Map 2.11 for locations and Figure 2.1 for photographs of each monitored stream.*

[b] *Year 2020 was the latest available water year data for all USGS stream gage sites reported in this table except for Honey Creek at Wauwatosa. The latest available water year for that USGS gage site was 2019.*

[c] *For the purposes of this Technical Report, this number is referred to as the "modeled low flow."*

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

Table 2.12
Existing Land Use for Drainage Areas of Monitored Streams

	Site 1 Fox River at Waukesha		Site 2 Fox River at New Munster		Site 3 Mukwonago River at Mukwonago		Site 4 Sugar Creek		Site 6 White River near Burlington		Site 8 Pewaukee River	
Land Use Categories[a]	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area
Urban												
Lower-Density Residential	15,018	18.6	55,604	10.8	8,468	15.5	1,705	4.4	4,916	6.8	4,504	18.5
Medium-Density Residential	3,757	4.6	14,170	2.7	780	1.4	346	0.9	1,484	2.1	1,223	5.0
High-Density Residential	1,841	2.3	3,936	0.8	89	0.2	120	0.3	423	0.6	558	2.3
Commercial	1,231	1.5	2,608	0.5	112	0.2	79	0.2	314	0.4	240	1.0
Industrial	1,609	2.0	3,227	0.6	73	0.1	102	0.3	171	0.2	176	0.7
Government and Institutional	1,151	1.4	3,273	0.6	235	0.4	127	0.3	358	0.5	322	1.3
Roads and Parking Lots	11,667	14.4	36,369	7.0	2,857	5.2	1,830	4.7	4,116	5.7	3,342	13.7
Transportation, Communication, and Utilities	996	1.2	2,271	0.4	135	0.2	30	0.1	161	0.2	406	1.7
Recreational	2,748	3.4	10,419	2.0	1,385	2.5	559	1.4	2,252	3.1	776	3.2
Urban Unused Lands	3,621	4.5	7,974	1.5	314	0.6	180	0.5	621	0.9	1,290	5.3
Urban Subtotal	43,639	54.0	139,851	27.1	14,448	26.4	5,078	13.1	14,816	20.6	12,837	52.7
Nonurban												
Agricultural	9,762	12.1	191,440	37.1	16,256	29.7	22,265	57.5	27,547	38.4	2,756	11.3
Wetlands	12,486	15.4	68,785	13.3	4,908	9.0	4,445	11.5	8,183	11.4	2,943	12.1
Woodlands	3,883	4.8	51,998	10.1	11,115	20.3	4,034	10.4	8,652	12.0	1,395	5.7
Rural Unused Lands	6,350	7.9	35,644	6.9	5,529	10.1	2,165	5.6	5,250	7.3	1,791	7.3
Extractive and Landfills	1,507	1.9	5,153	1.0	118	0.2	249	0.6	386	0.5	8	0.0
Surface Water	3,200	4.0	23,658	4.6	2,270	4.2	469	1.2	6,974	9.7	2,643	10.8
Nonurban Subtotal	37,188	46.0	376,678	72.9	40,196	73.6	33,627	86.9	56,992	79.4	11,536	47.3
Total	80,827	--	516,529	--	54,644	--	38,705	--	71,808	--	24,373	--

Table continued on next page.

Table 2.12 (Continued)

Land Use Categories[a]	Site 9 Oak Creek		Site 10 Pike River		Site 11 Bark River Upstream		Site 12 Lincoln Creek		Site 13 Ulao Creek		Site 14 Sauk Creek	
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area
Urban												
Lower-Density Residential	1,750	10.6	1,561	6.7	5,753	25.7	46	0.6	681	11.5	475	2.3
Medium-Density Residential	1,816	11.0	1,055	4.5	435	1.9	241	3.4	52	0.9	381	1.9
High-Density Residential	743	4.5	382	1.6	142	0.6	2,371	33.6	60	1.0	56	0.3
Commercial	354	2.1	335	1.4	94	0.4	186	2.6	75	1.3	28	0.1
Industrial	528	3.2	703	3.0	106	0.5	239	3.4	61	1.0	66	0.3
Government and Institutional	440	2.7	420	1.8	274	1.2	602	8.5	20	0.3	137	0.7
Roads and Parking Lots	3,284	19.9	2,461	10.5	1,968	8.8	1,981	28.1	739	12.5	928	4.6
Transportation, Communication, and Utilities	510	3.1	819	3.5	90	0.4	84	1.2	45	0.8	83	0.4
Recreational	544	3.3	375	1.6	521	2.3	451	6.4	42	0.7	70	0.3
Urban Unused Lands	1,965	11.9	1,517	6.5	456	2.0	669	9.5	144	2.4	115	0.6
Urban Subtotal	11,934	72.3	9,628	41.1	9,839	43.9	6,870	97.4	1,919	32.5	2,339	11.5
Nonurban												
Agricultural	1,663	10.1	11,149	47.6	5,266	23.5	9	0.1	1,745	29.6	15,536	76.7
Wetlands	1,328	8.0	648	2.8	2,579	11.5	66	0.9	861	14.6	1,200	5.9
Woodlands	748	4.5	375	1.6	2,057	9.2	87	1.2	252	4.3	503	2.5
Rural Unused Lands	715	4.3	1,176	5.0	1,428	6.4	0	0.0	961	16.3	631	3.1
Extractive and Landfills	32	0.2	206	0.9	884	3.9	7	0.1	116	2.0	0	0.0
Surface Water	92	0.6	250	1.1	340	1.5	15	0.2	45	0.8	58	0.3
Nonurban Subtotal	4,578	27.7	13,804	58.9	12,554	56.1	184	2.6	3,980	67.5	17,928	88.5
Total	16,512	--	23,432	--	22,393	--	7,054	--	5,899	--	20,267	--

Table continued on next page.

Table 2.12 (Continued)

Land Use Categories[a]	Site 15 Kilbourn Road Ditch		Site 16 Jackson Creek		Site 18 Oconomowoc River Upstream		Site 20 Oconomowoc River Downstream		Site 21 East Branch Milwaukee River		Site 23 Milwaukee River Downstream of Newburg	
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area
Urban												
Lower-Density Residential	164	3.0	118	1.9	4,071	15.4	9,777	15.2	587	1.9	6,588	3.9
Medium-Density Residential	30	0.6	43	0.7	56	0.2	880	1.4	49	0.2	2,271	1.3
High-Density Residential	0	0.0	20	0.3	5	0.0	184	0.3	0	0.0	892	0.5
Commercial	9	0.2	18	0.3	29	0.1	162	0.3	16	0.1	387	0.2
Industrial	50	0.9	12	0.2	18	0.1	94	0.1	7	0.0	514	0.3
Government and Institutional	6	0.1	33	0.5	77	0.3	352	0.5	100	0.3	713	0.4
Roads and Parking Lots	361	6.6	323	5.1	1,199	4.5	3,817	5.9	817	2.6	7,681	4.5
Transportation, Communication, and Utilities	22	0.4	2	0.0	70	0.3	208	0.3	7	0.0	410	0.2
Recreational	15	0.3	43	0.7	336	1.3	1,000	1.6	291	0.9	1,643	1.0
Urban Unused Lands	15	0.3	71	1.1	21	0.1	520	0.8	21	0.1	785	0.5
Urban Subtotal	672	12.3	683	10.9	5,882	22.3	16,994	26.4	1,895	6.0	21,884	12.9
Nonurban												
Agricultural	3,890	71.3	4,942	78.6	9,713	36.8	19,718	30.7	11,646	36.9	82,837	48.9
Wetlands	291	5.3	256	4.1	3,548	13.4	8,241	12.8	7,286	23.1	33,653	19.9
Woodlands	436	8.0	148	2.4	4,660	17.6	8,809	13.7	9,430	29.9	21,486	12.7
Rural Unused Lands	141	2.6	234	3.7	1,903	7.2	4,320	6.7	488	1.5	6,177	3.6
Extractive and Landfills	0	0.0	5	0.1	122	0.5	149	0.2	6	0.0	599	0.4
Surface Water	23	0.4	18	0.3	601	2.3	6,048	9.4	834	2.6	2,734	1.6
Nonurban Subtotal	4,781	87.7	5,603	89.1	20,547	77.7	47,285	73.6	29,690	94.0	147,486	87.1
Total	5,453	--	6,286	--	26,429	--	64,279	--	31,585	--	169,370	--

Table continued on next page.

Table 2.12 (Continued)

Land Use Categories[a]	Site 25 Root River Canal		Site 28 East Branch Rock River		Site 30 Des Plaines River		Site32 Turtle Creek		Site 33 Pebble Brook		Site 35 Honey Creek Upstream of East Troy	
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area
Urban												
Lower-Density Residential	2,606	6.9	1,373	3.9	3,491	4.8	2,250	3.7	2,311	22.6	1,150	4.8
Medium-Density Residential	168	0.4	65	0.2	1,438	2.0	1,265	2.1	328	3.2	275	1.1
High-Density Residential	26	0.1	13	0.0	191	0.3	286	0.5	181	1.8	3	0.0
Commercial	74	0.2	56	0.2	317	0.4	274	0.5	51	0.5	13	0.1
Industrial	172	0.5	76	0.2	874	1.2	339	0.6	42	0.4	43	0.2
Government and Institutional	163	0.4	47	0.1	296	0.4	358	0.6	17	0.2	18	0.1
Roads and Parking Lots	1,562	4.1	1,998	5.7	4,739	6.5	3,285	5.5	977	9.5	823	3.4
Transportation, Communication, and Utilities	93	0.2	50	0.1	542	0.7	217	0.4	36	0.3	1	0.0
Recreational	318	0.8	11	0.0	1,058	1.4	689	1.1	192	1.9	175	0.7
Urban Unused Lands	160	0.4	26	0.1	1,147	1.6	753	1.3	149	1.5	8	0.0
Urban Subtotal	5,342	14.2	3,715	10.6	14,093	19.2	9,716	16.2	4,284	41.9	2,509	10.4
Nonurban												
Agricultural	27,757	73.7	22,852	65.2	40,704	55.5	35,767	59.5	1,898	18.6	14,323	59.4
Wetlands	1,805	4.8	5,266	15.0	7,050	9.6	5,204	8.7	2,098	20.5	1,643	6.8
Woodlands	1,383	3.7	1,633	4.7	4,456	6.1	3,799	6.3	934	9.1	3,144	13.0
Rural Unused Lands	1,033	2.7	1,106	3.2	5,290	7.2	2,821	4.7	838	8.2	1,340	5.6
Extractive and Landfills	17	0.0	409	1.2	462	0.6	252	0.4	134	1.3	102	0.4
Surface Water	319	0.8	48	0.1	1,290	1.8	2,576	4.3	44	0.4	1,047	4.3
Nonurban Subtotal	32,314	85.8	31,314	89.4	59,252	80.8	50,419	83.8	5,946	58.1	21,599	89.6
Total	37,656	--	35,029	--	73,345	--	60,135	--	10,230	--	24,108	--

Table continued on next page.

Table 2.12 (Continued)

Land Use Categories[a]	Site 36 Honey Creek Downstream of East Troy		Site 38 North Branch Milwaukee River		Site 40 Stony Creek		Site 41 Milwaukee River near Saukville		Site 45 Mukwonago River at Nature Road		Site 47 Fox River at Rochester	
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area
Urban												
Lower-Density Residential	1,306	4.6	1,923	2.8	527	4.6	11,811	4.1	1,044	6.7	44,045	15.1
Medium-Density Residential	587	2.1	157	0.2	1	0.0	2,662	0.9	0	0.0	9,911	3.4
High-Density Residential	56	0.2	21	0.0	3	0.0	945	0.3	0	0.0	3,182	1.1
Commercial	59	0.2	75	0.1	7	0.1	511	0.2	15	0.1	1,931	0.7
Industrial	117	0.4	128	0.2	3	0.0	842	0.3	3	0.0	2,461	0.8
Government and Institutional	126	0.4	109	0.2	8	0.1	888	0.3	11	0.1	2,378	0.8
Roads and Parking Lots	1,457	5.1	2,105	3.1	377	3.3	11,840	4.1	486	3.1	25,458	8.7
Transportation, Communication, and Utilities	110	0.4	92	0.1	0	0.0	571	0.2	10	0.1	1,566	0.5
Recreational	202	0.7	206	0.3	9	0.1	2,387	0.8	266	1.7	6,673	2.3
Urban Unused Lands	350	1.2	171	0.3	4	0.0	1,085	0.4	0	0.0	6,156	2.1
Urban Subtotal	4,370	15.3	4,987	7.4	939	8.3	33,542	11.7	1,835	11.8	103,761	35.6
Nonurban												
Agricultural	15,446	54.2	42,597	62.9	5,806	51.0	151,189	52.7	6,512	41.7	80,390	27.6
Wetlands	2,251	7.9	10,880	16.1	1,877	16.5	51,693	18.0	876	5.6	43,802	15.0
Woodlands	3,467	12.2	6,708	9.9	2,004	17.6	33,547	11.7	4,982	31.9	26,663	9.1
Rural Unused Lands	1,646	5.8	1,343	2.0	679	6.0	11,557	4.0	1,215	7.8	21,444	7.4
Extractive and Landfills	243	0.9	392	0.6	2	0.0	1,009	0.4	0	0.0	3,060	1.0
Surface Water	1,095	3.8	806	1.2	71	0.6	4,359	1.5	204	1.3	12,472	4.3
Nonurban Subtotal	24,148	84.7	62,726	92.6	10,439	91.7	253,354	88.3	13,789	88.2	187,831	64.4
Total	28,518	--	67,713	--	11,378	--	286,896	--	15,624	--	291,592	--

Table continued on next page.

Table 2.12 (Continued)

Land Use Categories[a]	Site 48 White River at Lake Geneva		Site 51 Rubicon River		Site 52 Cedar Creek		Site 53 Honey Creek at Wauwatosa		Site 54 Whitewater Creek		Site 55 Bark River Downstream	
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area
Urban												
Lower-Density Residential	1,993	10.7	1,166	6.6	3,400	9.9	230	3.3	697	5.8	8,333	24.5
Medium-Density Residential	1,176	6.3	709	4.0	333	1.0	1,138	16.6	94	0.8	611	1.8
High-Density Residential	226	1.2	277	1.6	127	0.4	2,035	29.6	0	0.0	240	0.7
Commercial	105	0.6	94	0.5	147	0.4	157	2.3	11	0.1	194	0.6
Industrial	44	0.2	106	0.6	285	0.8	70	1.0	5	0.0	135	0.4
Government and Institutional	198	1.1	141	0.8	64	0.2	361	5.2	13	0.1	470	1.4
Roads and Parking Lots	1,252	6.7	1,265	7.2	2,749	8.0	2,086	30.4	407	3.4	3,166	9.3
Transportation, Communication, and Utilities	20	0.1	151	0.9	232	0.7	94	1.4	4	0.0	161	0.5
Recreational	691	3.7	342	1.9	424	1.2	384	5.6	115	1.0	766	2.3
Urban Unused Lands	214	1.2	283	1.6	243	0.7	217	3.2	3	0.0	664	1.9
Urban Subtotal	5,919	31.8	4,534	25.8	8,004	23.3	6,772	98.5	1,349	11.2	14,740	43.3
Nonurban												
Agricultural	2,717	14.6	7,490	42.6	14,867	43.4	0	0.0	5,467	45.5	6,697	19.7
Wetlands	683	3.7	2,912	16.6	3,399	9.9	45	0.7	1,085	9.0	3,220	9.5
Woodlands	2,530	13.6	1,233	7.0	2,977	8.7	44	0.6	2,496	20.8	3,836	11.3
Rural Unused Lands	1,132	6.1	769	4.4	3,101	9.0	0	0.0	558	4.6	2,426	7.1
Extractive and Landfills	140	0.8	70	0.4	357	1.0	0	0.0	18	0.1	884	2.6
Surface Water	5,489	29.5	564	3.2	1,589	4.6	12	0.2	1,047	8.7	2,238	6.6
Nonurban Subtotal	12,691	68.2	13,038	74.2	26,290	76.7	101	1.5	10,671	88.8	19,301	56.7
Total	18,610	--	17,572	--	34,294	--	6,873	--	12,020	--	34,041	--

Table continued on next page.

Table 2.12 (Continued)

Land Use Categories[a]	Site 57 Menomonee River at Wauwatosa		Site 58 Milwaukee River at Estabrook Park		Site 59 Root River near Horlick Dam		Site 60 Root River at Grange Avenue		Site 87 Underwood Creek	
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area
Urban										
Lower-Density Residential	11,442	14.4	29,504	6.7	14,666	12.1	2,209	23.1	3,505	28.8
Medium-Density Residential	6,988	8.8	8,568	2.0	5,715	4.7	1,496	15.6	1,187	9.8
High-Density Residential	5,592	7.0	7,668	1.7	1,707	1.4	839	8.8	505	4.2
Commercial	1,580	2.0	1,921	0.4	887	0.7	294	3.1	375	3.1
Industrial	2,228	2.8	2,560	0.6	1,014	0.8	37	0.4	184	1.5
Government and Institutional	2,198	2.8	3,151	0.7	1,075	0.9	306	3.2	449	3.7
Roads and Parking Lots	15,552	19.5	28,742	6.6	11,418	9.4	2,526	26.4	3,100	25.5
Transportation, Communication, and Utilities	1,138	1.4	1,647	0.4	552	0.5	129	1.3	285	2.3
Recreational	2,753	3.5	6,475	1.5	2,839	2.3	336	3.5	536	4.4
Urban Unused Lands	4,185	5.3	4,942	1.1	2,595	2.1	621	6.5	635	5.2
Urban Subtotal	53,656	67.3	95,178	21.7	42,468	35.0	8,793	91.9	10,761	88.4
Nonurban										
Agricultural	11,461	14.4	194,368	44.4	56,163	46.3	26	0.3	61	0.5
Wetlands	7,520	9.4	71,605	16.3	9,271	7.6	477	5.0	891	7.3
Woodlands	2,623	3.3	42,151	9.6	5,840	4.8	222	2.3	304	2.5
Rural Unused Lands	3,164	4.0	24,904	5.7	5,700	4.7	36	0.4	58	0.5
Extractive and Landfills	599	0.8	1,764	0.4	611	0.5	0	0.0	0	0.0
Surface Water	650	0.8	8,266	1.9	1,368	1.1	15	0.2	97	0.8
Nonurban Subtotal	26,017	32.7	343,058	78.3	78,953	65.0	776	8.1	1,411	11.6
Total	79,673	--	438,236	--	121,421	--	9,569	--	12,172	--

Note: Site locations are shown on Map 2.11 and a photograph of each monitored stream are included in Figure 2.1.

[a] *See Table 2.3 for detailed land use categories that comprise each land use group.*

Source: SEWRPC

Site 6 – White River near Burlington

Monitoring Site 6 was located on the White River at CTH JS, just upstream of the City of Burlington. The White River channel at this location is about 85 feet wide and is classified by the WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about 34 cfs (see Table 2.11). The drainage area upstream of Site 6 encompasses about 112 square miles located mostly within Walworth County with small portions of Racine and Kenosha Counties. This drainage area is part of the Fox River watershed and also includes Site 48 (White River at Lake Geneva). In addition, Geneva Lake was monitored for this Study and is located within the upstream drainage area of Site 6. In 2015, land use within this drainage area consisted largely of rural land uses (79.4 percent) with the most common land use types consisting of agricultural (38.4 percent), woodlands (12.0 precent), wetlands (11.4 percent), and rural unused lands (7.3 percent) (see Table 2.12 and Map B.9). Roads and parking lots accounted for about 5.7 percent of this drainage area and included a nine-mile stretch of USH 12. This drainage area covers portions of 16 civil divisions (see Map B.10 and Table B.1). About 21 percent of the drainage area is contained within portions of eight public sanitary sewer service areas. Flows to Site 6 include treated wastewater effluent from the Town of Lyons Sewage Treatment Facility. Treated wastewater effluent was also discharged to groundwater in this drainage area through soil infiltration from the Lake Geneva Wastewater Treatment Facility.

Site 8 – Pewaukee River

Monitoring Site 8 was located on the Pewaukee River about 1,000 feet downstream of Busse Road near the Steinhafels furniture store in the City of Pewaukee. The Pewaukee River channel at this location is about 35 feet wide and is classified by the WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about six cfs (see Table 2.11). The drainage area upstream of Site 8 encompasses about 38 square miles located completely within Waukesha County and is part of the Fox River watershed. In 2015, the land use in this drainage area was slightly more urban (52.7 percent) than rural (47.3 percent) with the most common land use types consisting of lower-density residential (18.5 percent), roads and parking lots (13.7 percent), wetlands (12.1 percent), and agricultural lands (11.3 percent) (see Table 2.12 and Map B.11). About seven miles of IH 94 traverse the southern portion of the drainage area. This highway crosses the Pewaukee River just upstream of the monitoring site. An additional seven miles of USH 16 traverse the drainage area. This highway crosses an upstream reach of the Pewaukee River. Water from Pewaukee Lake flows into the Pewaukee River upstream from the monitoring site in the Village of Pewaukee. This includes water from Coco Creek, Meadowbrook Creek, and Zion Creek which are tributary streams to Pewaukee Lake. The drainage area covers portions of nine civil divisions (see Map B.12 and Table B.1). About 83 percent of the drainage area is contained within five public sanitary sewer service areas. Flows to Site 8 do not include effluent from wastewater treatment facilities.

Site 9 – Oak Creek

Monitoring Site 9 was located on Oak Creek near USGS stream gage 04087204 in the City of Oak Creek. The Oak Creek channel at this location is about 25 feet wide and is classified by the WDNR as a fourth-order "cool-warm headwater" stream, with a modeled low flow estimated to be about two cfs (see Table 2.11).[30] The drainage area upstream of Site 9 encompasses about 26 square miles, located completely within Milwaukee County. Downstream of the monitoring site, the stream flows into Lake Michigan. Flow to the monitoring site includes contributions from two major tributaries: the North Branch Oak Creek and the Mitchell Field Drainage Ditch. In 2015, land use in this drainage area to this site was highly urbanized (72.3 percent) with the most common land use types consisting of roads and parking lots (19.9 percent), urban unused lands (11.9 percent), medium-density residential (11.0 percent), lower-density residential (10.6 percent), and agricultural lands (10.1 percent) (see Table 2.12 and Map B.13). Almost 6 miles of IH 94 runs north-south through the western portion of the drainage area. This highway crosses an upstream reach of Oak Creek. The drainage area also contains a portion of the Milwaukee Mitchell International Airport that drains to the Mitchell Field Drainage Ditch before flowing into Oak Creek upstream of Site 9. The drainage area covers portions of six civil divisions including (in order of largest to smallest proportion) the Cities of Oak Creek, Milwaukee, Franklin, South Milwaukee, Greenfield, and Cudahy (see Map B.14 and Table B.1). The entire drainage area upstream of Site 9 is contained within public sanitary sewer service areas, with about 93 percent of the drainage contained within the MMSD sanitary sewer service area and the remaining seven percent within the City of South Milwaukee sanitary sewer service area. Flows to Site 9 do not include effluent from wastewater treatment facilities.

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[30] *Based on USGS stream gage data collected near this location, Oak Creek had a 90 percent exceedance flow of approximately six cfs for water year 2020 and two cfs for the full period of record from 1964 through 2020.*

Site 10 – Pike River

Monitoring Site 10 was located on the Pike River in Petrifying Springs County Park in the Village of Somers. This monitoring site was about 1,500 feet upstream of USGS stream gage 04087257. The Pike River channel at this location is about 35 feet wide and is classified by the WDNR as a fourth-order "cool-cold mainstem" stream, with a modeled low flow estimated to be about six cfs (see Table 2.11).[31] The drainage area upstream of Site 10 encompasses about 37 square miles within Racine and Kenosha Counties. Downstream of the monitoring site, the river flows into Lake Michigan. In 2015, land use within the drainage area was more rural (58.9 percent) than urban (41.1 percent), with the most common land uses consisting of agricultural (47.6 percent), roads and parking lots (10.5 percent), lower-density residential (6.7 percent), urban unused lands (6.5 percent), rural unused lands (5.0 percent), and medium-density residential (4.5 percent) (see Table 2.12 and Map B.15). The drainage area covers portions of seven civil divisions including (in order of largest to smallest proportion) the Village of Sommers, Village of Mount Pleasant, City of Kenosha, Village of Sturtevant, Town of Sommers, City of Racine, and Village of Pleasant Prairie (see Map B.16 and Table B.1). The entire drainage area is contained within the Greater Kenosha or Greater Racine public sanitary sewer service areas. Flows to Site 10 do not include effluent from wastewater treatment facilities.

Site 11 – Bark River Upstream

Monitoring Site 11 was located on the Bark River just downstream of STH 83 and about 3,900 feet upstream of USGS stream gage 05426067. The Bark River channel at this location is about 30 feet wide and is classified by the WDNR as a third-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about 13 cfs (see Table 2.11).[32] The drainage area upstream of Site 11 encompasses about 35 square miles located within Waukesha and Washington Counties and is part of the Rock River watershed. This monitoring site is located about 7.6 stream miles upstream of Monitoring Site 55 (Bark River Downstream). In 2015, land use within this drainage area was slightly more rural (56.1 percent) than urban (43.9 percent) with the most common land uses consisting of lower-density residential (25.7 percent), agricultural lands (23.5 percent), wetlands (11.5 percent), and woodlands (9.2 percent) (see Table 2.12 and Map B.17). Roads and parking lots accounted for 8.8 percent of this drainage area and include a 1.5-mile stretch of STH 16 that crosses the Bark River about 2.5 miles upstream of the monitoring site and a one-mile stretch STH 83 that crosses the river immediately upstream of the monitoring site. This drainage area covers portions of eight civil divisions including (in order of largest to smallest proportion) the Village of Richfield, Town of Lisbon, Village of Hartland, Village and Town of Merton, and small portions of the City of Delafield, Village of Sussex, and Town of Delafield (see Appendix Map B.18 and Table B.1). About 23 percent of the drainage area is contained within portions of seven public sanitary sewer service areas. Flows to Site 11 do not include effluent from wastewater treatment facilities.

Site 12 – Lincoln Creek

Monitoring Site 12 was located on Lincoln Creek about 2,500 feet upstream of USGS stream gage 040869416 in the City of Milwaukee. The Lincoln Creek channel at this location is about 30 feet wide and is classified by the WDNR as a second-order "cool-warm headwater" stream, with a modeled low flow estimated to be about two cfs (see Table 2.11).[33] The drainage area upstream of Site 12 encompasses about 11 square miles and is part of the Milwaukee River watershed. In 2015, this was the second most urbanized drainage area that was monitored for the Chloride Impact Study, with urban development constituting 97.4 percent of the drainage area. The most common land uses consist of high-density residential (33.6 percent), roads and parking lots (28.1 percent), urban unused land (9.5 percent), and government and institutional (8.5 percent) (see Table 2.12 and Map B.19). This drainage area covers portions of the City of Milwaukee and Village of Brown Deer (see Map B.20 and Table B.1). The entire drainage area is contained within the MMSD sanitary sewer service area. This portion of the MMSD service area contains both combined and separated sanitary and storm sewers. Flows to Site 12 do not include effluent from wastewater treatment facilities.

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[31] *Based on USGS stream gage data collected downstream of this location, the Pike River had a 90 percent exceedance flow of approximately 12 cfs for water year 2020 and six cfs for the full period of record from 1972 through 2020.*

[32] *Based on USGS stream gage data collected downstream of this location, the Bark River had a 90 percent exceedance flow of approximately 27 cfs for water year 2020 and 14 cfs for the full period of record from 2003 through 2020.*

[33] *Based on USGS stream gage data collected near this location, Lincoln Creek had a 90 percent exceedance flow of approximately three cfs for water year 2020 and two cfs for the full period of record from 2003 through 2020.*

Site 13 – Ulao Creek

Monitoring Site 13 was located on Ulao Creek at CTH W (Port Washington Road) in the Town of Grafton. The Ulao Creek channel at this location is about 25 feet wide and is classified by the WDNR as a third-order "cool-warm headwater" stream, with a modeled low flow estimated to be about 0.5 cfs (see Table 2.11). The drainage area upstream of Site 13 encompasses about nine square miles located entirely within Ozaukee County and is part of the Milwaukee River watershed. In 2015, land use in the drainage area was more rural (67.5 percent) than urban (32.5 percent) with the most common land uses consisting of agricultural lands (29.6 percent), rural unused lands (16.3 percent), wetlands (14.6 percent), roads and parking lots (12.5 percent), and lower-density residential (11.5 percent) (see Table 2.12 and Map B.21). Nearly 6 miles of IH 43 run north-south across the entire drainage area. This highway crosses Ulao Creek and runs parallel to it just upstream of the monitoring site. The drainage area covers portions of five civil divisions, including (in order of largest to smallest proportion) the Town of Grafton, Village of Grafton, City of Port Washington, City of Mequon, and Town of Port Washington (see Map B.22 and Table B.1). About 22 percent of the drainage area is contained within the Grafton or Port Washington sanitary sewer service areas. Flows to Site 13 do not include effluent from wastewater treatment facilities.

Site 14 – Sauk Creek

Monitoring Site 14 was located on Sauk Creek about 1,500 feet upstream of the outlet to Lake Michigan in the City of Port Washington. The Sauk Creek channel at this location is about 20 feet wide and is classified by the WDNR as a third-order "cool-warm headwater" stream, with a modeled low flow estimated to be about two cfs (see Table 2.11). The drainage area upstream of Site 14 encompasses about 32 square miles located within Ozaukee County and a small portion of Sheboygan County. In 2015, land use in the drainage area was mostly rural (88.5 percent), consisting primarily of agricultural lands (76.7 percent). The downstream portion of the drainage area is located in the City of Port Washington and had relatively urban land use, accounting for most of the roads and parking lots (4.6 percent) and lower- and medium-density residential land uses (4.2 percent) in the drainage area (see Table 2.12 and Map B.23). Nearly two miles of IH 43 run east-west across the drainage area. This highway crosses Sauk Creek about two miles upstream of the monitoring site. This drainage area covers portions of nine civil divisions (see Map B.24 and Table B.1). About nine percent of the drainage area is contained within the Port Washington and Fredonia public sanitary sewer service areas. A very small portion of the drainage area is located in the Belgium public sanitary sewer service areas. Flows to Site 14 do not include effluent from wastewater treatment facilities.

Site 15 – Kilbourn Road Ditch

Monitoring Site 15 was located on Kilbourn Road Ditch at CTH A in the Village of Somers. The Kilbourn Road Ditch channel at this location is about 15 feet wide and is classified by the WDNR as a second-order "cool-cold headwater" stream, with a modeled low flow estimated to be about 0.3 cfs (see Table 2.11). The drainage area upstream of Site 15 encompasses about nine square miles within Racine and Kenosha Counties and is a part of the Des Plaines River watershed. In 2015, land use in the drainage area was mostly rural (87.7 percent) consisting primarily of agricultural lands (71.3 percent). Other common land uses within the drainage area included woodlands (8.0 percent), roads and parking lots (6.6 percent), wetlands (5.3 percent), and lower-density residential (3.0 percent) (see Table 2.12 and Map B.25). Roads in the drainage area include a three-mile stretch of IH-94, which runs north-south bisecting the drainage area. It is important to note that this drainage area is home to a large industrial and business park for the FoxConn Technology Group in the Village of Mount Pleasant that was developed after the 2015 land use inventory was conducted. The drainage area covers portions of four civil divisions, including (in order of largest to smallest proportion) the Village of Yorkville, Village of Mount Pleasant, Town of Paris, and Village of Sommers (see Map B.26 and Table B.1). About 52 percent of the drainage area is contained within the Greater Racine or Greater Kenosha public sanitary sewer service areas. Flows to Site 15 do not include effluent from wastewater treatment facilities.

Site 16 – Jackson Creek

Monitoring Site 16 was located on Jackson Creek about 3,000 feet downstream of STH 67 and about 4,400 feet upstream of USGS stream gage 05431016 in the Town of Delavan. The Jackson Creek channel at this location is about 25 feet wide and is classified by the WDNR as a second-order "cool-warm headwater" stream, with a modeled low flow estimated to be about 0.2 cfs (see Table 2.11).[34] The drainage area upstream

[34] *Based on USGS stream gage data collected downstream of this location, Jackson Creek had a 90 percent exceedance flow of approximately four cfs for water year 2020 and one cfs for the full period of record from 1993 through 2020.*

of Site 16 encompasses about 10 square miles entirely within Walworth County and is part of the Rock River watershed. In 2015, land use in the drainage area was mostly rural (89.1 percent), consisting primarily of agricultural lands (78.6 percent). Other common land uses in this drainage area included roads and parking lots (5.1 percent), wetlands (4.1 percent), and rural unused lands (3.7 percent) (see Table 2.12 and Map B.27). A two-mile stretch of USH 12 traverses the drainage area. This highway crosses an upstream reach of Jackson Creek. This drainage area covered portions of four civil divisions, including (in order of largest to smallest proportion) the Town of Geneva, City of Elkhorn, Town of Delavan, and Town of Lafayette (see Map B.28 and Table B.1). About 20 percent of the drainage area is contained within the Elkhorn or Williams Bay/Geneva National/Lake Como public sanitary sewer service areas. Flows to Site 16 do not include effluent from wastewater treatment facilities.

Site 18 – Oconomowoc River Upstream

Monitoring Site 18 was located on the Oconomowoc River just upstream of STH 83 in the Town of Merton. The Oconomowoc River channel at this location is about 15 feet wide and is classified by the WDNR as a fourth-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about six cfs (see Table 2.11). The drainage area upstream of Site 18 encompasses 41 square miles located within Washington and Waukesha Counties and is part of the Rock River watershed. In 2015, land use in the drainage area was mostly rural (77.7 percent). The most common land use categories included agricultural lands (36.8 percent), woodlands (17.6 percent), lower-density residential (15.4 percent), wetlands (13.4 percent), and rural unused lands (7.2 percent) (see Table 2.12 and Map B.29). Roads and parking lots accounted for 4.5 percent of the drainage area. This drainage area covers portions of seven civil divisions (see Map B.30 and Table B.1). About 7 percent of the drainage area is contained within four public sanitary sewer service areas. Flows to Site 18 do not include effluent from wastewater treatment facilities.

Site 20 – Oconomowoc River Downstream

Monitoring Site 20 was located on the Oconomowoc River just downstream of the Lac La Belle outlet in the City of Oconomowoc. The Oconomowoc River channel at this location is about 30 feet wide and is classified by the WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about 19 cfs (see Table 2.11). The drainage area upstream of Site 20 encompasses about 100 square miles located mostly within Washington and Waukesha Counties, with small portions in Dodge and Jefferson Counties. The drainage area is part of the Rock River watershed. This monitoring site was located about 12.6 stream miles downstream of Monitoring Site 18 (Oconomowoc River Upstream). From Monitoring Site 18, the Oconomowoc River flows through a chain of five lakes (North Lake, Okauchee Lake, Oconomowoc Lake, Fowler Lake, and Lac La Belle) before reaching Site 20. Moose Lake, a seepage lake that was monitored for this Study, is also located within this drainage area. In 2015, land use in the drainage area was mostly rural (73.6 percent). The most common land uses included agricultural lands (30.7 percent), lower-density residential (15.2 percent), woodlands (13.7 percent), wetlands (12.8 percent), and rural unused lands (6.7 percent) (see Table 2.12 and Map B.31). Roads and parking lots accounted for 5.9 percent of the drainage area and included a six mile stretch of USH 16. The drainage area covers portions of 20 civil divisions (see Map B.32 and Table B.1). About 35 percent of the drainage area is contained within portions of 14 public sanitary sewer service areas. Flows to Site 20 do not include effluent from wastewater treatment facilities.

Site 21 – East Branch Milwaukee River

Monitoring Site 21 was located on the East Branch Milwaukee River at STH 28 in the Town of Kewaskum. The East Branch Milwaukee River channel at this location is about 40 feet wide and is classified by the WDNR as a fourth-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about 11 cfs (see Table 2.11). The drainage area upstream of Site 21 encompasses 49 square miles within Sheboygan, Fond du Lac, and Washington Counties and is part of the Milwaukee River watershed. In 2015, land use in the drainage area was almost entirely rural (94.0 percent). The most common land uses included agricultural lands (36.9 percent), woodlands (29.9 percent), and wetlands (23.1 percent). The most common urban land uses included roads and parking lots and lower-density residential at only 2.6 percent and 1.9 percent, respectively (see Table 2.12 and Map B.33). The drainage area covers portions of eight civil divisions (see Map B.34 and Table B.1). Less than 1 percent of the drainage area is contained within the Village of Kewaskum public sanitary sewer service area. Flows to Site 21 do not include effluent from wastewater treatment facilities.

Site 23 – Milwaukee River Downstream of Newburg

Monitoring Site 23 was located on the Milwaukee River about 1,000 feet upstream of Hickory Drive (extended) and the Washington-Ozaukee County line in the Town of Fredonia. The Milwaukee River channel at this location is about 75 feet wide and is classified by the WDNR as a fifth-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about 54 cfs (see Table 2.11). The drainage area upstream of Site 23 encompasses 265 square miles and includes Site 21 (East Branch Milwaukee River). Silver Lake, a spring lake that was monitored for this study, is also located within the drainage area of Site 23. This drainage area contains portions of Fond du Lac, Washington, Sheboygan, and Ozaukee Counties. In 2015, land use in the drainage area was largely rural (87.1 percent) consisting mostly of agricultural lands (48.9 percent), wetlands (19.9 percent), and woodlands (12.7 percent). The largest urban land uses included roads and parking lots (4.5 percent) and lower-density residential (3.9 percent) (see Table 2.12 and Map B.35). A roughly 28-mile stretch of USH 45 runs north-south across much of the drainage area. This highway crosses the river upstream of the monitoring site in multiple locations. This drainage area covers portions of 26 civil divisions (see Map B.36 and Table B.1). About 12 percent of the drainage area is contained within the West Bend, Kewaskum, or Newburg public sanitary sewer service areas. Less than 1 percent of the drainage area is contained within the Campbellsport, Eden, and Jackson sanitary sewer service area. Flows to Site 23 include treated wastewater effluent from the Campbellsport, Kewaskum, West Bend, and Newburg wastewater treatment facilities.

Site 25 – Root River Canal

Monitoring Site 25 was located on the Root River Canal at USGS stream gage 04087233 and CTH G in the Village of Raymond. The Root River Canal at this location is about 40 feet wide and is classified by the WDNR as a fourth-order "cool-cold headwater" stream, with a modeled low flow estimated to be about three cfs (see Table 2.11).[35] The drainage area upstream of Site 25 encompasses 59 square miles located within Racine and Kenosha Counties and is part of the Root River watershed. In 2015, land use in the drainage area was mostly rural (85.8 percent), consisting primarily of agricultural lands (73.7 percent). Other common land uses included lower-density residential (6.9 percent), wetlands (4.8 percent), and roads and parking lots (4.1 percent) and included a 3.8-mile section of IH 94 (see Table 2.12 and Map B.37). The drainage area covers portions of eight civil divisions (see Map B.38 and Table B.1). About 8 percent of the drainage area is contained within portions of five public sanitary sewer service areas. Flows to this monitoring site include treated wastewater effluent from the Union Grove Wastewater Treatment Facility.

Site 28 – East Branch Rock River

Monitoring Site 28 was located on the East Branch Rock River at CTH D in the Town of Wayne. The East Branch Rock River channel at this location is about 60 feet wide and is classified by the WDNR as a fourth-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about seven cfs (see Table 2.11). The drainage area upstream of Site 28 encompasses 55 square miles within Washington and Dodge Counties and is part of the Rock River watershed. In 2015, land use in the drainage area was mostly rural (89.4 percent), consisting primarily of agricultural lands (65.2 percent). Other common land uses included wetlands (15.0 percent), roads and parking lots (5.7 percent) including an eight mile stretch of IH 41, woodlands (4.7 percent), and lower-density residential (3.9 percent) (see Table 2.12 and Map B.39). The drainage area covers portions of eight civil divisions (see Map B.40 and Table B.1). About 2 percent of the drainage area is contained within the Allenton public sanitary sewer service area, the remaining 98 percent is outside of public SSSAs. Flows to this monitoring site include effluent from the Allenton Sanitary District Wastewater Treatment Facility.

Site 30 – Des Plaines River

Monitoring Site 30 was located on the Des Plaines River at CTH ML in the Village of Pleasant Prairie. The monitoring site was located about 7,800 feet upstream USGS stream gage 05527800 in Russell, Illinois. The Des Plaines River channel at this location is about 160 feet wide and is classified by the WDNR as a fourth-order "cool-warm mainstem" stream, with a modeled low flow estimated to be seven cfs (see Table 2.11).[36]

[35] *Based on USGS stream gage data collected at this location, the Root River Canal had a 90 percent exceedance flow of approximately nine cfs for water year 2020 and two cfs for the full period of record from 1964 through 2020.*

[36] *Based on USGS stream gage data collected downstream of this location, the Des Plaines River had a 90 percent exceedance flow of approximately 16 cfs for water year 2020 and three cfs for the full period of record from 1967 through 2020.*

The drainage area upstream of Site 30 encompasses 115 square miles within Kenosha and Racine Counties. Monitoring Site 15 (Kilbourn Road Ditch) was also located within this drainage area. In 2015, land use in the drainage area was mostly rural (80.8 percent), consisting primarily of agricultural lands (55.5 percent). Other common land uses included wetlands (9.6 percent), rural unused lands (7.2 percent), roads and parking lots (6.5 percent), woodlands (6.1 percent), and lower-density residential (4.8 percent) (see Table 2.12 and Map B.41). About 14 miles of the IH 94 corridor runs north-south through the entire length of the drainage area. The drainage area contained portions of 13 civil divisions (see Map B.42 and Table B.1). About 44 percent of the drainage area is contained within portions of eight public SSSAs. Flows to this monitoring site include effluent from the Bristol and Paddock Lake wastewater treatment facilities.

Site 32 – Turtle Creek

Monitoring Site 32 was located on Turtle Creek near USH 14 in the Town of Darien. The Turtle Creek channel at this location is about 90 feet wide and is classified by the WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about 25 cfs (see Table 2.11). The drainage area upstream of Site 32 encompasses 94 square miles located entirely within Walworth County and includes the drainage area to Site 16 (Jackson Creek). This drainage area is part of the Rock River watershed. In 2015, land use in the drainage area was mostly rural (83.8 percent), consisting primarily of agricultural lands (59.5 percent), wetlands (8.7 percent), woodlands (6.3 percent), and unused rural lands (4.7 percent). The most common urban land uses included roads and parking lots (5.5 percent), lower-density residential (3.7 percent), and medium-density residential (2.1 percent) (see Table 2.12 and Map B.43). The IH 43 corridor bisects the drainage area, running almost 11 miles northeast to southwest. The drainage area covers portions of 11 civil divisions (see Map B.44 and Table B.1). About 32 percent of the drainage area is contained within five sanitary sewer service areas. Flows to this monitoring site include treated wastewater effluent from the Walworth County Metropolitan Sewerage District (WALCOMET) wastewater treatment plant.

Site 33 – Pebble Brook

Monitoring Site 33 was located on Pebble Brook upstream of CTH XX in the Village of Waukesha. The Pebble Brook channel at this location is about 30 feet wide and is classified by WDNR as a third-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about four cfs (see Table 2.11). The drainage area upstream of Site 33 encompasses 16 square miles located entirely within Waukesha County and is part of the Fox River watershed. In 2015, land use in the drainage area was more rural (58.1 percent) than urban (41.9 percent) with the most common land uses consisting of lower-density residential (22.6 percent), wetlands (20.5 percent), agricultural lands (18.6 percent), and roads and parking lots (9.5 percent) (see Table 2.12 and Map B.45). The drainage area covers portions of five civil divisions, primarily consisting of the Village and City of Waukesha, and the City of New Berlin (see Map B.46 and Table B.1). About 81 percent of the drainage area is contained within the Waukesha sanitary sewer service area. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 35 – Honey Creek Upstream of East Troy

Monitoring Site 35 was located on Honey Creek at the Michael Fields Agricultural Institute in the Town of East Troy. The Honey Creek channel at this location is about 35 feet wide and is classified by WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about 10 cfs (see Table 2.11). The drainage area upstream of Site 35 encompasses about 38 square miles located entirely within Walworth County and is part of the Fox River watershed. In 2015, land use in the drainage area was mostly rural (89.6 percent), consisting primarily of agricultural lands (59.4 percent), woodlands (13.0 percent), and wetlands (6.8 percent) (see Table 2.12 and Map B.47). The most common urban land uses included lower-density residential (4.8 percent), roads and parking lots (3.4 percent), and medium-density residential (1.1 percent). About two miles of the IH 43 corridor traverses the southeastern corner of this drainage area. The drainage area covers portions of seven civil divisions, primarily (in order of largest to smallest proportion) the Towns of Troy, La Grange, Lafayette, and Sugar Creek (see Map B.48 and Table B.1). A small portion of this drainage area is contained within the East Troy sanitary sewer service area (1.7 percent) however flows to this site do not include effluent from wastewater treatment facilities. This monitoring site was about 4.1 miles upstream of Monitoring Site 36 and was chosen in combination with that site to bracket the East Troy Wastewater Treatment Facility in order to examine the influence that treated wastewater effluent has on chloride levels within Honey Creek.

Site 36 – Honey Creek Downstream of East Troy

Monitoring Site 36 was located on Honey Creek at Carver School Road in the Town of East Troy. The Honey Creek channel at this location is about 45 feet wide and is classified by the WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about 11 cfs (see Table 2.11). The drainage area upstream of Site 36 encompasses about 45 square miles located entirely within Walworth County and is part of the Fox River watershed. In 2015, land use in the drainage area was mostly rural (84.7 percent), consisting primarily of agricultural lands (54.2 percent), woodlands (12.2 percent), and wetlands (7.9 percent) (see Table 2.12 and Map B.49). The most common urban land uses included roads and parking lots (5.1 percent), lower-density residential (4.6 percent), and medium-density residential (2.1 percent). Nearly six miles of IH 43 corridor traverses the eastern portion of the drainage area and crosses Honey Creek approximately two miles upstream of the monitoring location. The drainage area covers portions of seven civil divisions (see Map B.50 and Table B.1). About 14 percent of the drainage area is contained within the East Troy sanitary sewer service area. This monitoring site was located about 2.4 miles downstream of the East Troy Wastewater Treatment Facility and flows to the site included treated wastewater effluent from this facility. This monitoring location was chosen in combination with Monitoring Site 35 to bracket the wastewater treatment facility, in part to examine the influence that treated wastewater effluent has on chloride levels within Honey Creek. This monitoring site was located about 4.1 stream miles downstream of Monitoring Site 35. An impoundment of Honey Creek approximately 3.1 stream miles upstream of Site 36 was drawn down during the monitoring period for this Study in preparation for the removal of the impounding dam. The removal of the dam was completed after the monitoring period for this Study had concluded.

Site 38 – North Branch Milwaukee River

Monitoring Site 38 was located on the North Branch Milwaukee River near CTH XX in the Town of Farmington. The North Branch Milwaukee River channel at this location is about 75 feet wide and is classified by the WDNR as a fourth-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about 26 cfs (see Table 2.11). The drainage area upstream of Site 38 encompasses about 106 square miles located within Sheboygan, Fond du Lac, Ozaukee, and Washington Counties and is part of the Milwaukee River watershed. In 2015, land use in the drainage area was largely rural (92.6 percent), consisting mostly of agricultural lands (62.9 percent), wetlands (16.1 percent), and woodlands (9.9 percent) (see Table 2.12 and Map B.51). The most common urban land uses included roads and parking lots (3.1 percent) and lower-density residential (2.8 percent). The drainage area covers portions of 10 civil divisions (see Map B.52 and Table B.1). Less than 4 percent of the drainage area is contained within public sanitary sewer service areas. Flows to this monitoring site include treated wastewater effluent from the Cascade and Random Lake wastewater treatment facilities. Town of Scott Sanitary District No.1 is also located upstream of Site 38, but the treated effluent is discharged to soil.

Site 40 – Stony Creek

Monitoring Site 40 was located on Stony Creek at CTH X in the Town of Farmington. The Stony Creek channel at this location is about 20 feet wide and is classified by the WDNR as a second-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about five cfs (see Table 2.11). The drainage area upstream of Site 40 encompasses about 18 square miles located within Washington, Sheboygan, and Fond du Lac Counties and is part of the Milwaukee River watershed. In 2015, land use in the drainage area was largely rural (91.7 percent), consisting mostly of agricultural lands (51.0 percent), woodlands (17.6 percent), wetlands (16.5 percent), and rural unused lands (6.0 percent). The most common urban land uses included lower-density residential (4.6 percent) and roads and parking lots (3.3 percent) (see Table 2.12 and Map B.53). The drainage area covers portions of four civil divisions including (in order of largest to smallest proportion) the Towns of Farmington, Scott, Kewaskum, and Auburn (see Map B.54 and Table B.1). None of the drainage area is within a public SSSA indicating any development used onsite sewage disposal systems. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 41 – Milwaukee River near Saukville

Monitoring Site 41 was located on the Milwaukee River in the Town of Saukville. The Milwaukee River channel at this location is about 200 feet wide and is classified by the WDNR as a fifth-order "warm mainstem" stream, with a modeled low flow estimated to be about 90 cfs (see Table 2.11). The drainage area upstream of Site 41 encompasses about 448 square miles located within Washington, Fond du Lac, Sheboygan, Ozaukee, and Dodge Counties. This drainage area includes four other stream sites that were monitored for this Study, including (from upstream to downstream) Site 40 (Stony Creek), Site 38 (North Branch Milwaukee River), Site 23 (Milwaukee River Downstream of Newburg), and Site 21 (East Branch Milwaukee River). Silver Lake, a spring lake that was monitored for this study, is also located within this drainage area. In 2015, land use in the drainage area was mostly rural (88.3 percent), consisting mainly of agricultural lands (52.7 percent), wetlands (18.0 percent), and woodlands (11.7 percent). The most common urban land uses included lower-density residential and roads and parking lots, each comprising 4.1 percent of the drainage area (see Table 2.12 and Map B.55). About 28 miles of the USH 45 corridor runs north-south through the entire length of the drainage area and about three miles of the IH 41 corridor skirts the western edge of the drainage area. The drainage area covers portions of 36 civil divisions (see Map B.56 and Table B.1). About 8 percent of this drainage area is contained within portions of 15 public SSSAs. Flows to this monitoring site include treated wastewater effluent from the Campbellsport, Kewaskum, West Bend, Newburg, Cascade, Random Lake, and Fredonia wastewater treatment facilities. The Town of Scott Sanitary District No.1 is also located upstream of Site 41, but the treated effluent is discharged to soil.

Site 45 – Mukwonago River at Nature Road

Monitoring Site 45 was located on the Mukwonago River upstream of Lulu Lake in the Town of Troy. The Mukwonago River channel at this location has a width of about 25 feet and is classified by the WDNR as a third-order "cool-cold mainstem" stream, with a modeled low flow estimated to be about four cfs (see Table 2.11). The drainage area upstream of Site 45 encompasses about 24 square miles located within Walworth, Waukesha, and Jefferson Counties and is part of the Fox River watershed. This drainage area is part of the drainage area to Monitoring Site 3 (Mukwonago River at Mukwonago), which was located about 12.3 stream miles downstream of Site 45. In 2015, land use in the drainage area was mostly rural (88.2 percent). This drainage area had the largest amount of "natural" land uses when compared to the drainage areas of other stream sites monitored as part of this Study, with woodlands and wetlands accounting for 31.9 percent and 5.6 percent of the drainage area, respectively. Agricultural lands accounted for 41.7 percent of the drainage area. The most common urban land uses included lower-density residential (6.7 percent) and roads and parking lots (3.1 percent) (see Table 2.12 and Map B.57). Approximately five miles of USH 67 bisects the drainage area from southwest to northeast. The drainage area covered portions of four civil divisions including (in order of largest to smallest proportion) the Towns of Troy, LaGrange, Eagle, and Palmyra (see Map B.58 and Table B.1). None of the drainage area is contained within a public sanitary sewer service area, indicating that any development is served by onsite sewage disposal systems. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 47 – Fox River at Rochester

Monitoring Site 47 was located on the Fox River about 1,700 feet upstream of the Rochester Dam near USGS stream gage 05544475 in the Village of Rochester. The Fox River channel at this location is about 180 feet wide and is classified by the WDNR as a sixth-order "warm mainstem" stream, with a modeled low flow estimated to be about 115 cfs (see Table 2.11).[37] The drainage area upstream of Site 47 encompasses about 456 square miles, located primarily within Waukesha, Racine, Walworth Counties, with small portions of the drainage area extending into Jefferson, Washington, and Milwaukee Counties. The drainage area to Site 47 also includes five other stream monitoring sites: From upstream to downstream they are Site 8 (Pewaukee River), Site 1 (Fox River at Waukesha), Site 33 (Pebble Brook), Site 45 (Mukwonago River at Nature Road), and Site 3 (Mukwonago River at Mukwonago). In addition, Little Muskego Lake was monitored for this study and is also located within the drainage area of Site 47. In 2015, land use in this drainage area was more rural (64.4 percent) than urban (35.6 percent). The most common land uses included agricultural lands (27.6 percent), lower-density residential (15.1 percent), wetlands (15.0 percent), woodlands (9.1 percent), and roads and parking lots (8.7 percent) (see Table 2.12 and Map B.59). Approximately 17 miles of the IH 43 corridor and 14 miles of the IH 94 corridor traverse this drainage area. This drainage area covers portions of 40 civil divisions (see Map B.60 and Table B.1). About 40 percent of the drainage area is contained within portions of 27 public sanitary sewer service areas. Flows to this monitoring site include treated wastewater effluent from five wastewater treatment facilities. From upstream to downstream they are: the Village of Sussex Wastewater Treatment Plant (via Sussex Creek), the Fox River Water Pollution Control Center operated by the City of Brookfield, the Waukesha Wastewater Treatment Facility, the Mukwonago Wastewater Treatment Facility (via the Mukwonago River), and the Town of Norway Sanitary District No. 1 (via Wind Lake Drainage Canal).

[37] *The USGS stream gage near this location does not collect daily discharge data.*

Site 48 – White River at Lake Geneva

Monitoring Site 48 was located on the White River about 1,400 feet downstream of USGS stream gage 055451345 and the Geneva Lake outlet, in the City of Lake Geneva. The White River channel at this location is typically about 18 feet wide and is classified by the WDNR as a third-order "warm mainstem" stream, with a modeled low flow estimated to be about seven cfs (see Table 2.11).[38] It is important to note that stream flows at this monitoring site vary greatly and are highly dependent on the operation of the Geneva Lake outlet. This also leads to a varied steam width at this monitoring site. Geneva Lake was also monitored for this Study. The drainage area upstream of Site 48 encompasses about 29 square miles located entirely within Walworth County and is part of the Fox River watershed. In 2015, land use in this drainage area was more rural (68.2 percent) than urban (31.8 percent). The most common land uses consisted of surface water – mainly Geneva Lake (29.5 percent), agricultural lands (14.6 percent), and woodlands (13.6 percent). The most common urban land uses included lower-density residential (10.7 percent), roads and parking lots (6.7 percent), and medium-density residential (6.3 percent) (see Table 2.12 and Map B.61). This drainage area covers portions of 11 civil divisions (see Map B.62 and Table B.1). About 40 percent of the drainage area is contained within three public sanitary sewer service areas (Fontana – Walworth, Williams Bay/Geneva National/Lake Como, and Lake Geneva). This percentage increases to about 57 percent if the area of Geneva Lake is excluded from the calculation. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 51 – Rubicon River

Monitoring Site 51 was located on the Rubicon River in West Side Park in the City of Hartford. The Rubicon River channel at this location has a width of about 20 feet and is classified by the WDNR as a third-order "warm headwater" stream, with a modeled low flow estimated to be about three cfs (see Table 2.11). The drainage area upstream of Site 51 encompasses about 27 square miles mostly located within Washington County with a small portion extending into Dodge County. This drainage area is part of the Rock River watershed. In 2015, land use in the drainage area was mostly rural (74.2 percent), consisting primarily of agricultural lands (42.6 percent), wetlands (16.6 percent), and woodlands (7.0 percent). The most common urban land uses included roads and parking lots (7.2 percent), lower-density residential (6.6 percent), and medium-density residential (4.0 percent) (see Table 2.12 and Map B.63). Approximately two miles of IH 41 traverse the eastern edge of the drainage area. The drainage area covers portions of six civil divisions (see Map B.64 and Table B.1). Approximately 54 percent of the drainage area is contained within the Hartford or Slinger public SSSAs. Flows to this monitoring site include treated wastewater effluent from the Slinger Wastewater Treatment Facility which is located about 6.8 miles upstream of the site.

Site 52 – Cedar Creek

Monitoring Site 52 was located on Cedar Creek near STH 60 in the Town of Jackson. The Cedar Creek channel at this location is about 40 feet wide and is classified by the WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about eight cfs (see Table 2.11). The drainage area upstream of Site 52 encompasses about 54 square miles located mostly within Washington County with a small portion extending into Ozaukee County. The drainage area is part of the Milwaukee River watershed. In 2015, land use in the drainage area was largely rural (76.7 percent), consisting mostly of agricultural lands (43.4 percent), wetlands (9.9 percent), rural unused (9.0 percent), and woodlands (8.7 percent). The most common urban land uses included lower-density residential (9.9 percent) and roads and parking lots (8.0 percent) (see Table 2.12 and Map B.65). About 10 miles of IH 41 and nearly five miles of USH 45 traverse the drainage area. The drainage area covers portions of 12 civil divisions (see Map B.66 and Table B.1). About 13 percent of the drainage area is contained within four public SSSAs. This monitoring site was located about 1,200 feet downstream of the Jackson Wastewater Treatment Facility and flows to the site include treated wastewater effluent from this facility. Big Cedar Lake, a spring lake that was monitored for this Study, is also located within the upstream drainage area of Site 52.

Site 53 – Honey Creek at Wauwatosa

Monitoring Site 53 was located on Honey Creek about 0.3 mile upstream from its confluence with the Menomonee River in the City of Wauwatosa. The monitoring site was situated near USGS stream gage 04087119. The Honey Creek channel at this location has a width of about 20 feet and is classified by the WDNR

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[38] *Based on USGS stream gage data collected upstream of this location, the White River had a 90 percent exceedance flow of approximately 28 cfs for water year 2020 and 0.2 cfs for the full period of record from 1998 through 2020.*

as a second-order "cool-warm headwater" stream, with a modeled low flow estimated to be about one cfs (see Table 2.11).[39] The drainage area upstream of Site 53 encompasses about 11 square miles located entirely within Milwaukee County and is part of the Menomonee River watershed. In 2015, this was the most highly urbanized stream drainage area that was monitored as part of the Chloride Impact Study, with urban land use constituting 98.5 percent of the area. The most common land uses consisted of roads and parking lots (30.4 percent), high-density residential (29.6 percent), medium-density residential (16.6 percent), recreational (5.6 percent), and governmental and institutional (5.2 percent) (see Table 2.12 and Map B.67). Nearly two miles of IH 94 traverse the northern portion of the drainage area. In addition, about two miles of IH 41 runs along the northwestern boundary of the drainage area. A 2.4-mile reach of Honey Creek flows underground through an enclosed culvert upstream of the monitoring site. The drainage area covers portions of five civil divisions (see Map B.68 and Table B.1) and the entire drainage area is located within the MMSD sanitary sewer service area. This portion of the MMSD service area contains separated and partially separated sanitary and storm sewers. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 54 – Whitewater Creek

Monitoring Site 54 was located on Whitewater Creek near the Millis Road crossing in the Town of Whitewater. The Whitewater Creek channel at this location has a width of about 15 feet and is classified by the WDNR as a third-order "cool-warm mainstem" stream, with a modeled low flow estimated to be about five cfs (see Table 2.11). The drainage area upstream of Site 54 encompasses about 19 square miles located entirely within Walworth County and is part of the Rock River watershed. In 2015, land use in the drainage area was mostly rural (88.8 percent), consisting mainly of agricultural lands (45.5 percent), woodlands (20.8 percent), and wetlands (9.0 percent). The most common urban land uses included lower-density residential (5.8 percent) and roads and parking lots (3.4 percent) (see Table 2.12 and Map B.69). The drainage area covers portions of four civil divisions including (in order of largest to smallest proportion) the Towns of Whitewater, Richmond, LaGrange, and Sugar Creek (see Map B.70 and Table B.1). None of the drainage area is contained within a public sanitary sewer service area, indicating that any development in the area is served by onsite sewage disposal systems. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 55 – Bark River Downstream

Monitoring Site 55 was located on the Bark River near Genesee Lake Road in the Village of Summit. The Bark River channel at this location has a width of about 40 feet and is classified by the WDNR as a third-order "warm mainstem" stream, with a modeled low flow estimated to be about 11 cfs (see Table 2.11). The drainage area upstream of Site 55 encompasses about 53 square miles located within Waukesha and Washington Counties and is part of the Rock River watershed. This drainage area also includes Monitoring Site 11 (Bark River Upstream) which was located about 7.6 stream miles upstream of Site 55. Between Site 11 and Site 55, the Bark River flows through Nagawicka Lake, Upper and Lower Nemahbin Lakes, and Crooked Lake. In 2015, land use in the drainage area was slightly more rural (56.7 percent) than urban (43.3 percent). The most common land uses included lower-density residential (24.5 percent), agricultural (19.7 percent), woodlands (11.3 percent), wetlands (9.5 percent), and roads and parking lots (9.3 percent) including about five miles of IH 94 that crosses the drainage area upstream of the monitoring site (see Table 2.12 and Map B.71). The drainage area covers portions of 13 civil divisions (see Map B.72 and Table B.1). About 44 percent of the drainage area is contained within 12 public sanitary sewer service areas. While the Delafield-Hartland Water Pollution Control Commission facility is located about 3.7 miles upstream of the site, effluent from this treatment facility is pumped via force main and discharged into the Bark River at a location downstream of Site 55. Therefore, flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 57 – Menomonee River at Wauwatosa

Monitoring Site 57 was located on the Menomonee River near USGS stream gage 04087120 in the City of Wauwatosa. The Menomonee River channel at this location has a width of about 80 feet and is classified by the WDNR as a fourth-order "warm mainstem" stream, with a modeled low flow estimated to be about 19 cfs (see Table 2.11).[40] The drainage area upstream of Site 57 encompasses about 124 square miles located within Milwaukee, Washington, Waukesha, and Ozaukee Counties. This drainage area also includes

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[39] *Based on USGS stream gage data collected near this location, Honey Creek had a 90 percent exceedance flow of approximately two cfs for water year 2019 and one cfs for the full period of record from 1975 through 2019.*

[40] *Based on USGS stream gage data collected near this location, the Menomonee River had a 90 percent exceedance flow of approximately 45 cfs for water year 2020 and 14 cfs for the full period of record from 1962 through 2020.*

monitoring sites on two tributary streams to the Menomonee River: Site 53 (Honey Creek at Wauwatosa) and Site 87 (Underwood Creek). In 2015, land use in the drainage area was more urban (67.3 percent) than rural (32.7 percent) and the portion of the drainage area nearest to the monitoring site was heavily urbanized. The most common land uses included roads and parking lots (19.5 percent), lower-density residential (14.4 percent), agricultural lands (14.4 percent), wetlands (9.4 percent), medium-density residential (8.8 percent), and high-density residential (7.0 percent) (see Table 2.12 and Map B.73). In addition to many miles of collector streets, this drainage area includes almost 20 miles of the IH 41 and 5 miles of the IH 94 corridors. Portions of 16 civil divisions were within this drainage area (see Map B.74 and Table B.1). About 77 percent of the drainage area is contained within nine public sanitary sewer service areas, primarily the MMSD, Menomonee Falls (MMSD), Brookfield (East), and Germantown (MMSD) service areas. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 58 – Milwaukee River at Estabrook Park

Monitoring Site 58 was located on the Milwaukee River in Estabrook Park near USGS stream gage 04087000 in the City of Milwaukee. The Milwaukee River channel at this location is about 220 feet wide and is classified by the WDNR as a fifth-order "warm mainstem" stream, with a modeled low flow estimated to be about 137 cfs (see Table 2.11).[41] With an area of 685 square miles, this was the second largest drainage area monitored for the Chloride Impact Study. It encompasses portions of Washington, Fond du Lac, Ozaukee, Sheboygan, Milwaukee, and Dodge Counties. This drainage area also includes eight other stream monitoring sites (see Table 2.9). In addition, Big Cedar Lake and Silver Lake were monitored for this Study and are located within the drainage area of Site 58. In 2015, land use in this drainage area was mostly rural (78.3 percent), consisting primarily of agricultural lands (44.4 percent), wetlands (16.3 percent), and woodlands (9.6 percent). Urban land uses such as lower-density residential (6.7 percent), roads and parking lots (6.6 percent), and medium-density residential (2.0 percent) were less common in the drainage area; however they were concentrated in the downstream portion of the drainage area and nearest to the monitoring site (see Table 2.12 and Map B.75). In addition to the many miles of collector streets, this drainage area contained about 20 miles of the IH 43, eight miles of the IH 41, and 34 miles of the USH 45 corridors. This drainage area covers portions of 56 civil divisions (see Map B.76 and Table B.1). About 20 percent of the drainage area is contained within 23 public sanitary sewer service areas. Flows to this site include wastewater effluent from 11 wastewater treatment facilities. From upstream to downstream these are: The Campbellsport, Cascade, Random Lake, Kewaskum, West Bend, Newburg, Fredonia, Saukville, Grafton, Jackson, and Cedarburg wastewater treatment facilities. The Town of Scott Sanitary District No.1 is also located upstream of Site 58, but the treated effluent is discharged to soil.

Site 59 – Root River near Horlick Dam

Monitoring Site 59 was located on the Root River at the Racine County Club in the Village of Mount Pleasant. The site was located about 2,600 feet downstream of the Horlick dam and USGS stream gage 04087240. The Root River flows into Lake Michigan approximately five miles downstream of this monitoring site. The Root River channel at this location is about 85 feet wide and is classified by the WDNR as a fifth-order "warm mainstem" stream, with a modeled low flow estimated to be about 11 cfs (see Table 2.11).[42] The drainage area upstream of Site 59 encompasses about 190 square miles within Racine, Milwaukee, Waukesha, and Kenosha Counties. The drainage area also includes Site 60 (Root River at Grange Avenue) and Site 25 (Root River Canal). In 2015, land use in the drainage area was more rural (65.0 percent) than urban (35.0 percent). The most common land uses included agricultural (46.3 percent), lower-density residential (12.1 percent), roads and parking lots (9.4 percent), wetlands (7.6 percent), woodlands (4.8 percent), and medium-density residential (4.7 percent) (see Table 2.12 and Map B.77). About 11 miles of the IH 94 corridor run north and south across this drainage area. The drainage area covers portions of 19 civil divisions (see Map B.78 and Table B.1). About 55 percent of the drainage area is contained within 11 public sanitary sewer service areas. Flows to this monitoring site as of 2022 include treated wastewater effluent from the Yorkville Sewer Utility District No. 1 and Union Grove Wastewater Treatment Facilities.[43]

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[41] *Based on USGS stream gage data collected near this location, the Milwaukee River had a 90 percent exceedance flow of approximately 433 cfs for water year 2020 and 78 cfs for the full period of record from 1914 through 2020.*

[42] *Based on USGS stream gage data collected upstream of this location, the Root River had a 90 percent exceedance flow of approximately 44 cfs for water year 2020 and 10 cfs for the full period of record from 1963 through 2020.*

[43] *The City of Waukesha Water Utility will transition to Lake Michigan water supply in 2023. As part of this transition, the Waukesha Wastewater Treatment Facility will return treated wastewater effluent to Lake Michigan via the Root River. Therefore, beginning in 2023 flows to Site 59 will also include treated wastewater effluent from the Waukesha Wastewater Utility.*

Site 60 – Root River at Grange Avenue

Monitoring Site 60 was located on the Root River near USGS stream gage 04087214 at Grange Avenue in the Village of Greendale. The Root River channel at this location is about 30 feet wide and is classified by the WDNR as a third order "cool-warm headwater" stream, with a modeled low flow estimated to be about one cfs (see Table 2.11).[44] The drainage area upstream of Site 60 encompasses about 15 square miles within Milwaukee and Waukesha Counties. In 2015, land use in this drainage area was largely urban (91.9 percent), consisting of mostly of roads and parking lots (26.4 percent), lower-density residential (23.1 percent), medium-density residential (15.6 percent), and high-density residential (8.8 percent) (see Table 2.12 and Map B.79). About 4 miles of the IH 43 and 3 miles of the IH 41 corridors traverse this drainage area. This drainage area covers portions of six civil divisions (see Map B.80 and Table B.1). The entire drainage area is contained within public sanitary sewer service areas, with 69 percent and 31 percent of the area within the MMSD and New Berlin sanitary sewer service areas, respectively. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Site 87 – Underwood Creek

Monitoring Site 87 was located on Underwood Creek at Gravel Sholes Park and near USGS stream gage 04087088 in the City of Wauwatosa. A major restoration project within this reach of Underwood Creek was completed in 2009 and restored the channel to a more naturalized condition. The restoration included removing an existing concrete-lined channel and replacing it with a naturalized bioengineered channel with meanders and alternating pool and riffle structures to enhance the natural functions of the Creek and widen the floodway to maintain a 100-year flood event within the limits of the project design. The restored Underwood Creek channel at the monitoring site location is about 13 feet wide and is classified by the WDNR as a third order "cool-warm mainstem" stream, with a modeled low flow estimated to be about four cfs (see Table 2.11).[45] The drainage area upstream of Site 87 encompasses about 19 square miles within Waukesha and Milwaukee Counties and is part of the Menomonee River watershed. In 2015, land use in the drainage area was largely urban (88.4 percent), consisting mostly of lower-density residential (28.8 percent), roads and parking lots (25.5 percent), medium-density residential (9.8 percent), wetlands (7.3 percent), and high-density residential (4.2 percent) land uses (see Table 2.12 and Map B.81). About three miles of the IH 94 corridor run though the drainage area. The drainage area covers portions of seven civil divisions (see Map B.82 and Table B.1). The entire drainage area is contained within four public sanitary sewer service areas. Flows to this monitoring site do not include effluent from wastewater treatment facilities.

Descriptions of Selected Lake Monitoring Sites and Drainage Areas

As described previously in the Chapter, six lakes within the Region were selected to be monitored for the Chloride Impact Study including Big Cedar, Geneva, Little Muskego, Moose, Silver (Washington County), and Voltz Lakes (see Map 2.12). Land use maps, civil division maps, and important characteristics for the drainage areas each of these monitored lakes are provided in Appendix C. A description of these lakes and their watersheds are provided below.

Big Cedar Lake

Big Cedar Lake is a 955-acre lake located immediately southwest of the City of West Bend in the Towns of Polk and West Bend in Washington County. The Lake is situated at the headwaters of Cedar Creek within the Milwaukee River watershed. Big Cedar Lake is a spring lake, having a clearly defined outlet, but lacking a definite inlet, except for the navigational channel linking Gilbert Lake to the north.[46] The primary sources of inflow to Big Cedar Lake are runoff from those lands directly tributary to the Lake, groundwater inflows,

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[44] *Based on USGS stream gage data collected near this location, the Root River had a 90 percent exceedance flow of approximately four cfs for water year 2020 and one cfs for the full period of record from 2004 through 2020.*

[45] *Based on USGS stream gage data collected near this location, Underwood Creek had a 90 percent exceedance flow of approximately seven cfs for water year 2020 and three cfs for the full period of record from 1975 through 2020.*

[46] *The WDNR natural community classification for Big Cedar Lake is a two-story lake. Two-story lakes are deep stratified lakes with sufficient oxythermal habitat to support both warmwater and coldwater fisheries. It is important to note that this classification is based on the waterbody's potential and the waterbody may not be meeting this community status. While classified as a two-story lake, Big Cedar Lake is not currently thought to be supporting a two-story fishery. The WDNR uses these parameters to set water quality goals.*

and tributary flows into the Lake from Gilbert Lake.[47] Additional water is provided to the Lake through direct precipitation onto the Lake surface. The water level for the Lake is maintained by a small dam located in Timmer's Bay on the eastern shore. The dam is owned and operated by the Cedar Lake Conservation Foundation. Outflow from Big Cedar Lake is through Cedar Creek, which flows into Little Cedar Lake and ultimately into the Milwaukee River. Big Cedar Lake has a maximum depth of about 105 feet, a mean depth of 34 feet, a total volume of almost 32,000 acre-feet, and a residence time of about 5.5 years.[48] The lake shoreline runs about 11 miles. The major axis of the Lake lies in a north-south direction and the Lake has two distinct basins, a north and a south basin. The monitoring site for the Chloride Impact Study was located at the deep hole of the Lake in the southern basin (see Map 2.13).

The drainage area tributary to Big Cedar Lake is approximately 8.3 square miles (not including the surface area of the Lake) and covers portions of (in order of largest to smallest proportion) the Towns of West Bend, Polk, Addison, Barton, and the Village of Slinger (see Map C.1 and Table C.1). In 2015, land use in this drainage area was more rural (72.8 percent) than urban (27.2 percent). The most common land uses included agricultural lands (31.9 percent), woodlands (18.9 percent), lower-density residential (17.0 percent), rural unused lands (11.9 percent), wetlands (7.9 percent), and roads and parking lots (7.5 percent) (see Table 2.13 and Map C.2).[49] About 3 percent of the drainage area is contained within the West Bend or Slinger sanitary sewer service areas. The remaining 97 percent of the drainage area is not within a public sanitary sewer service area, indicating that any development in those areas use onsite sewage disposal systems. As of 1995, approximately 900 onsite sewage disposal systems existed in the riparian lands area surrounding Big Cedar Lake.[50] This lake does not receive effluent from wastewater treatment facilities.

Geneva Lake

Geneva Lake is a 5,422-acre spring lake, which although fed by numerous small tributary streams, depends principally on groundwater and rainfall onto the lake surface for its source water.[51] Outflow from Geneva Lake is through the White River which was also monitored as part of the Chloride Impact Study (see drainage area descriptions for Site 48 – White River Lake Geneva and Site 6—White River near Burlington). Geneva Lake has a maximum depth of about 140 feet, a mean depth of about 61 feet, and a total volume of almost 321,000 acre-feet.[52] The lake shoreline runs about 20 miles, and the major axis of the Lake lies in an east-west direction. The water level for the Lake is maintained by a dam located in the City of Lake Geneva at the outlet of the Lake to the White River at the northeastern lobe of the Lake. The dam is owned and operated by the Geneva Lake Level Corporation. The monitoring site for the Chloride Impact Study was located at the deep hole in the west bay of the Lake (see Map 2.14).

The drainage area tributary to Geneva Lake is approximately 20.4 square miles (not including the surface area of the Lake) and covers portions of the Towns of Bloomfield, Delavan, Geneva, Linn, and Walworth; the City of Lake Geneva; and the Villages of Fontana-on-Geneva Lake, Walworth, and Williams Bay (see Map C.3 and Table C.1). With a surface area of about 8.5 square miles, the Lake has a very low watershed-to-lake surface area ratio and, consequently, has a relatively long residence time of 13.9 years.[53] Geneva Lake is fed by direct precipitation, terrestrial springs, artesian wells, underwater springs, groundwater seepage,

[47] *SEWRPC Memorandum Report No. 137,* A Water Quality Protection and Stormwater Management Plan for Big Cedar Lake, Washington County, Wisconsin, *August 2001.*

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

[49] *Land use quantities presented in this section exclude the surface area of Big Cedar Lake itself.*

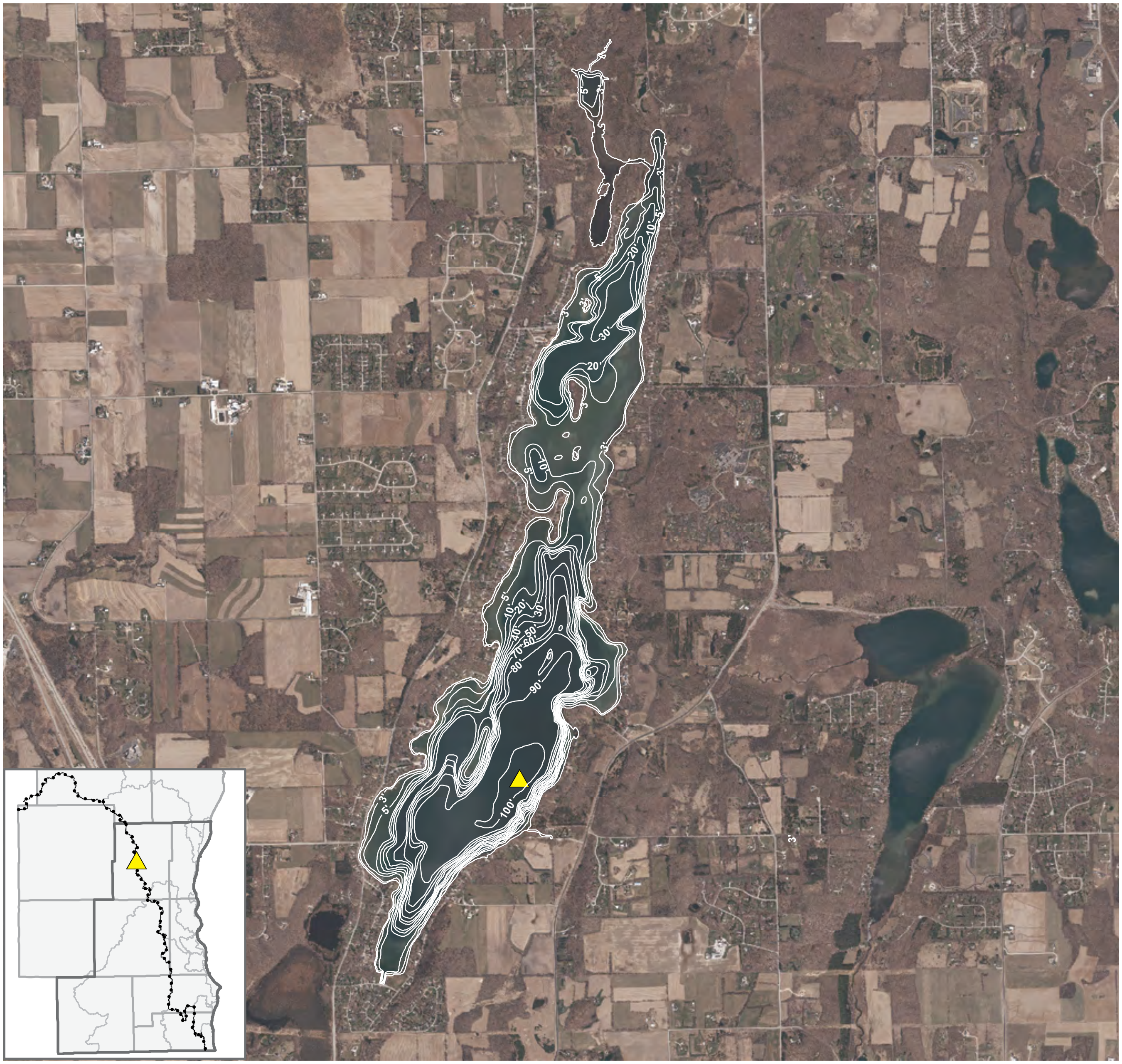
[50] *SEWRPC Memorandum Report No. 137, 2001, op. cit.*

[51] *The WDNR natural community classification for Geneva Lake is a two-story lake. Two-story lakes are deep stratified lakes with sufficient oxythermal habitat to support both warmwater and coldwater fisheries. The WDNR uses these parameters to set water quality goals.*

[52] *Wisconsin Department of Natural Resources Bureau of Fisheries and Habitat Management Publication No. PUB-FH-800,* Wisconsin Lakes, *2009.*

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

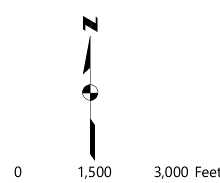
Map 2.13
Big Cedar Lake Water Quality Sampling Location and Bathymetry



△ WATER QUALITY SAMPLING LOCATION

—20'— WATER DEPTH CONTOUR IN FEET

NOTE: Date of Photograph 2020



Source: Wisconsin Department of Natural Resources and SEWRPC

Table 2.13
Existing Land Use for Drainage Areas of Monitored Lakes: 2015

Land Use Categories[a]	Big Cedar Lake		Geneva Lake		Little Muskego Lake		Moose Lake		Silver Lake		Voltz Lake	
	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area	Acres	Percent of Area
Urban												
Lower-Density Residential	907	17.0	1,942	14.9	1,384	20.6	82	14.3	39	21.9	34	10.9
Medium-Density Residential	54	1.0	1,171	9.0	654	9.7	41	7.2	48	26.7	8	2.5
High-Density Residential	1	0.0	210	1.6	91	1.3	0	0.0	0	0.0	0	0.0
Commercial	16	0.3	79	0.6	68	1.0	3	0.5	0	0.1	0	0.0
Industrial	22	0.4	28	0.2	73	1.1	0	0.0	0	0.0	0	0.0
Government and Institutional	23	0.4	198	1.5	51	0.7	8	1.4	0	0.0	0	0.0
Roads and Parking Lots	396	7.5	1,183	9.1	1,037	15.4	40	7.0	17	9.3	15	4.7
Transportation, Communication, and Utilities	3	0.1	17	0.2	6	0.1	0	0.0	0	0.0	0	0.0
Recreational	10	0.2	690	5.3	73	1.1	10	1.8	1	0.4	0	0.0
Urban Unused Lands	17	0.3	195	1.5	167	2.5	1	0.2	0	0.0	1	0.4
Urban Subtotal	1,449	27.2	5,713	43.9	3,604	53.5	185	32.4	105	58.4	58	18.5
Nonurban												
Agricultural	1,696	31.9	2,764	21.2	1,135	16.9	69	12.0	0	0.0	155	48.8
Wetlands	420	7.9	679	5.2	414	6.1	23	4.1	25	13.9	30	9.3
Woodlands	1,004	18.9	2,516	19.3	559	8.3	194	34.0	44	24.2	68	21.4
Rural Unused Lands	631	11.9	1,135	8.7	694	10.3	92	16.1	6	3.5	6	2.0
Extractive and Landfills	31	0.6	156	1.2	275	4.1	0	0.0	0	0.0	0	0.0
Surface Water[b]	87	1.6	66	0.5	54	0.8	8	1.4	0	0.0	0	0.0
Nonurban Subtotal	3,869	72.8	7,316	56.1	3,131	46.5	386	67.6	75	41.6	259	81.5
Total	5,318	--	13,029	--	6,735	--	571	--	180	--	317	--

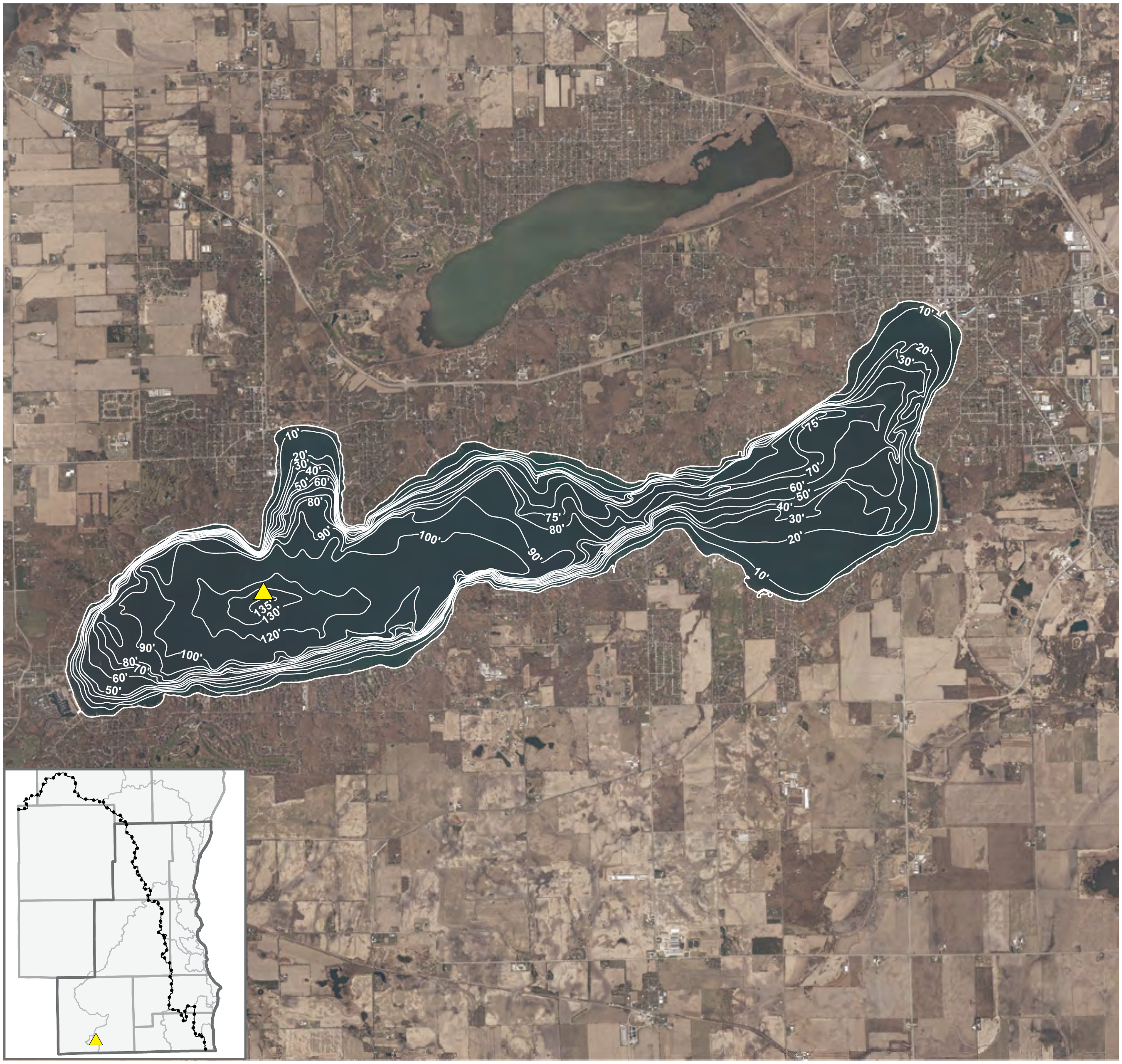
Note: Locations of monitored lakes are shown on Map 2.12.

[a] *See Table 2.3 for detailed land use categories that comprise each land use group.*

[b] *The surface area for the monitored lake in each column is not included in the acreage of surface water.*

Source: SEWRPC

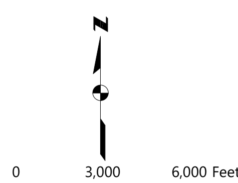
Map 2.14
Geneva Lake Water Quality Sampling Location and Bathymetry



WATER QUALITY SAMPLING LOCATION

—20'— WATER DEPTH CONTOUR IN FEET

NOTE: Date of Photograph 2020



Source: Wisconsin Department of Natural Resources and SEWRPC

and numerous small perennial and intermittent streams. Numerous springs and artesian wells exist in the moraines surrounding the Lake, particularly along the southern and western shores and many of these are located within 100 feet of the Lake, as well as within the Lake itself.[54]

In 2015, land use in the Geneva Lake drainage area was more rural (56.1 percent) than urban (43.9 percent). The most common land uses included agricultural lands (21.2 percent), woodlands (19.3 percent), lower-density residential (14.9 percent), roads and parking lots (9.1 percent), and medium-density residential (9.0 percent) (see Table 2.13 and Map C.4).[55] The shoreline of Geneva Lake is mostly developed for residential uses, with some scattered commercial uses comprised primarily of restaurants and businesses catering to lake users. Almost 55 percent of the drainage area is contained within one of three public sanitary sewer service areas. Although many homes in the Geneva Lake drainage area are serviced by public sewerage systems, onsite sewage systems continue to be in use especially in homes located in areas away from shore.[56] Geneva Lake does not receive effluent from wastewater treatment facilities.

Little Muskego Lake

Little Muskego Lake is a 478-acre drainage lake located in the City of Muskego in Waukesha County.[57] This is the second in a chain of lakes that receives water principally from Jewel Creek, which passes through Linnie Lac prior to entering Little Muskego Lake from the north. Little Muskego Lake has a maximum water depth of about 65 feet, a mean depth of 14 feet, a total volume of about 7,170 acre-feet, and a residence time of about 0.9 year.[58] The lake levels are maintained by a fixed height dam on the south shore of the Lake, which discharges into Muskego Creek, and then into Big Muskego Lake, Wind Lake, and ultimately, the Fox River, about 10 miles downstream of the Little Muskego Lake outlet. The lake shoreline runs about seven miles long and the general orientation of the Lake lies in a north-south direction. The most steeply sloped portions of the lakebed are located at the southern end of the Lake adjacent to the deep hole, where the monitoring site for Chloride Impact Study was located (see Map 2.15).

The direct drainage area, which drains directly to Little Muskego Lake without passing through any upstream waterbody, is about 2.2 square miles (not including the surface area of the Lake). That area is located almost entirely within the City of Muskego. The total drainage area tributary to Little Muskego Lake, which includes lands upstream of the Lake that are tributary to Linnie Lac, is approximately 10.5 square miles (not including the surface area of the Lake). This total drainage area covers portions of the Cities of New Berlin and Muskego (see Map C.5 and Table C.1). In 2015, land use in the total drainage area was slightly more urban (53.5 percent) than rural (46.5 percent). The most common land uses included lower-density residential (20.6 percent), agricultural (16.9 percent), roads and parking lots (15.4 percent), rural unused lands (10.3 percent), and medium-density residential (9.7 percent) (see Table 2.13 and Map C.6).[59] The shoreline of the Lake is almost entirely developed for residential uses. Almost 55 percent of the total drainage area to the Lake is contained within the Muskego or New Berlin sanitary sewer service area and most of the urban development is served by sanitary sewer. Little Muskego Lake does not receive effluent from wastewater treatment facilities.

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[54] *Wisconsin Geological and Natural History Survey Open-File Report No. 2006-02,* Groundwater Data Compilation for the Geneva Lake, Wisconsin, Area, *2006. The authors note that the name of the Village of Fontana-on-Geneva Lake is derived from the Italian term for groundwater springs, or fontana, that testify to the prevalence of these features in the Geneva Lake area.*

[55] *Land use quantities presented in this section exclude the surface area of Geneva Lake itself.*

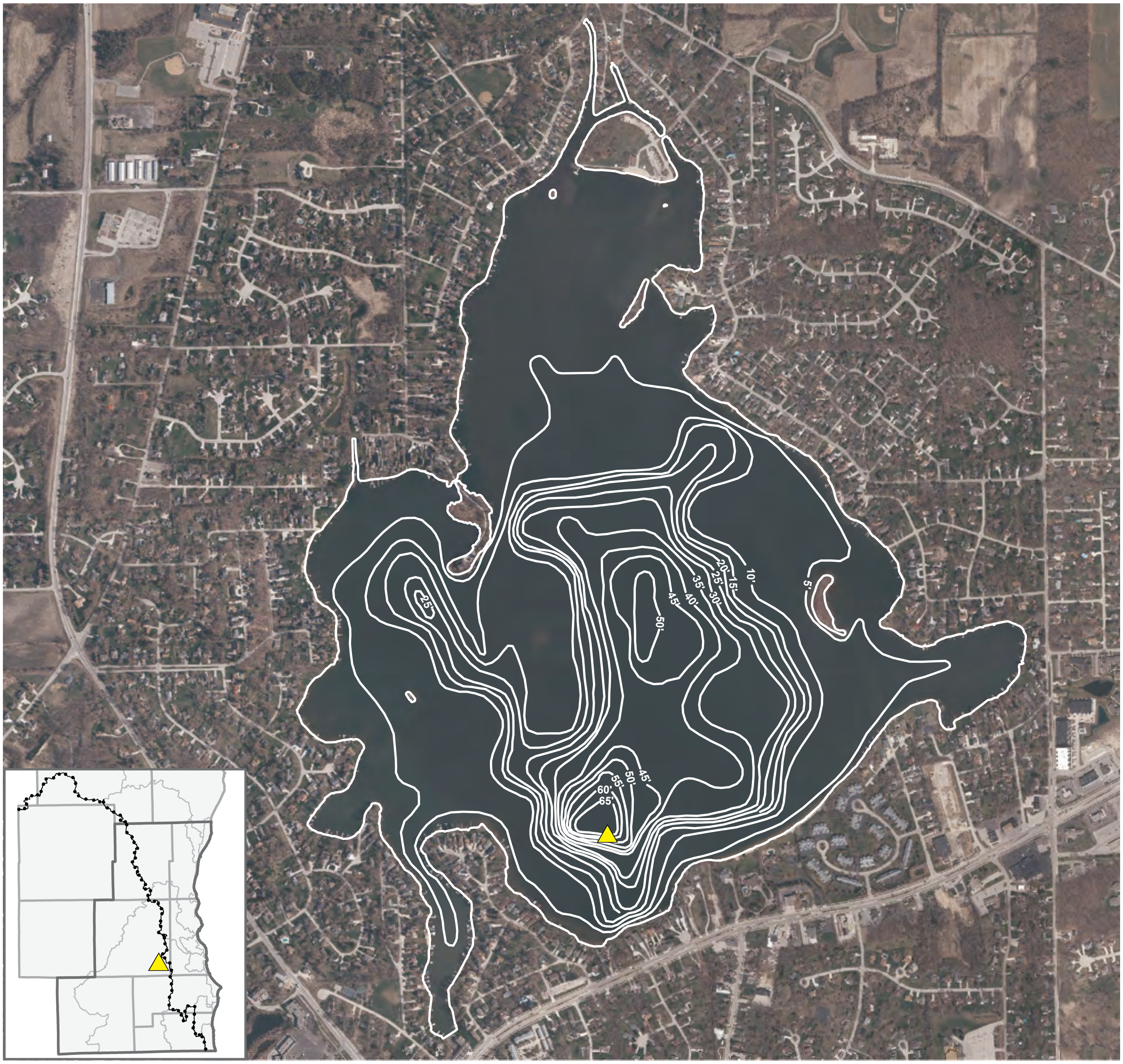
[56] *SEWRPC Community Assistance Planning Report No. 60, 2nd Edition, 2008, op. cit.*

[57] *The WDNR natural community classification for Little Muskego Lake is a deep lowland lake. Deep lowland lakes have a watershed area greater than four square miles and stratify to form separate layers of water during the summer months. The WDNR uses these parameters to set water quality goals.*

[58] *SEWRPC Memorandum Report No. 155, 3rd Edition,* An Aquatic Plant Management Plan for Little Muskego Lake, Waukesha, Wisconsin, *June 2019.*

[59] *Land use quantities presented in this section exclude the surface area of Little Muskego Lake itself.*

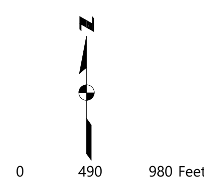
Map 2.15
Little Muskego Lake Water Quality Sampling Location and Bathymetry



WATER QUALITY SAMPLING LOCATION

—20'— WATER DEPTH CONTOUR IN FEET

NOTE: Date of Photograph 2020



Source: Wisconsin Department of Natural Resources and SEWRPC

Moose Lake

Moose Lake is an 87-acre spring-fed seepage lake located in the Town of Merton, in Waukesha County.[60] The Lake has a maximum depth of 61 feet and a mean depth of 40 feet.[61] As a seepage lake, Moose Lake does not currently have outlet.[62] The Moose Lake shoreline runs about 2.4 miles, and the general orientation of the Lake runs north-south. The monitoring site for the Chloride Impact Study was located at the Lake's deep hole in the north-central region of the Lake (see Map 2.16).

The drainage area tributary to Moose Lake is about 0.9 square mile (not including the surface area of the Lake) and covers portions of the Town of Merton and the Village of Chenequa (see Map C.7 and Table C.1). In 2015, land use in the drainage area to Moose Lake was more rural (67.6 percent) than urban (32.4 percent). The most common land uses included woodlands (34.0 percent), rural unused lands (16.1 percent), lower-density residential (14.3 percent), agricultural (12.0 percent), and medium-density residential (7.2 percent). Roads and parking lots accounted for 7.0 percent of the drainage area (see Table 2.13 and Map C.8).[63] The entire watershed of Moose Lake is within a public sanitary sewer service area, primarily the Pine Lake or Okauchee Lake service areas. A small portion of the drainage area extends into the North Lake sewer service area. Moose Lake does not receive effluent from wastewater treatment facilities.

Silver Lake

Silver Lake is a 125-acre spring lake located in the Town of West Bend in Washington County (see Map C.9 and Table C.1).[64] The Lake has a maximum depth of 47 feet, a mean depth of about 18 feet, a total volume of 2,306 acre-feet, and a residence time of 3.2 years under average weather conditions.[65] Silver Lake is a groundwater-fed lake, receiving much of its water supply from springs located along its western and southern shores. The water level for the lake is maintained by a small, privately-owned dam located at the northern end of the Lake where it flows to Silver Creek. The Silver Lake shoreline runs about 2.8 miles and the general orientation of the Lake runs north-south. The monitoring site for the Chloride Impact Study was located at the Lake's deep hole in the north-central region of the Lake (see Map 2.17).

The drainage area tributary to Silver Lake is extremely small, at less than 0.3 square mile, indicating that surface water runoff draining to the Lake is minimal. At 1.3 square miles, the groundwatershed to Silver Lake is more than four times larger than the surface water drainage area to the Lake.[66] Both the surface and groundwater drainage areas are completely within the Town of West Bend.

In 2015, the most common land uses in the drainage area to Silver Lake included medium-density residential (26.7 percent), woodlands (24.2 percent), lower-density residential (21.9 percent), wetlands (13.9 percent), and roads and parking lots (9.3 percent) (see Table 2.13 and Map C.10).[67] About 81 percent of the Silver Lake watershed (not including the Lake itself) is contained within the West Bend sanitary sewer service area. A large area near Big Cedar Lake, outside of the Silver Lake watershed, but within the groundwatershed of

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[60] *The WDNR natural community classification for Moose Lake is a deep seepage lake. Deep seepage lakes have a watershed area greater than 10 acres, stratify to form separate layers of water during the summer months, and have no inlet or outlet. The WDNR uses these parameters to set water quality goals.*

[61] *Wisconsin Department of Natural Resources Bureau of Fisheries and Habitat Management Publication No. PUB-FH-800, 2009, op. cit.*

[62] *Original U.S. Public Land Survey maps from 1837 for the Town of Merton show there was once an outlet connecting Moose Lake to the Oconomowoc River. However, due to urban development that has occurred over time, that outlet no longer exists.*

[63] *Land use quantities presented in this section exclude the surface area of Moose Lake itself.*

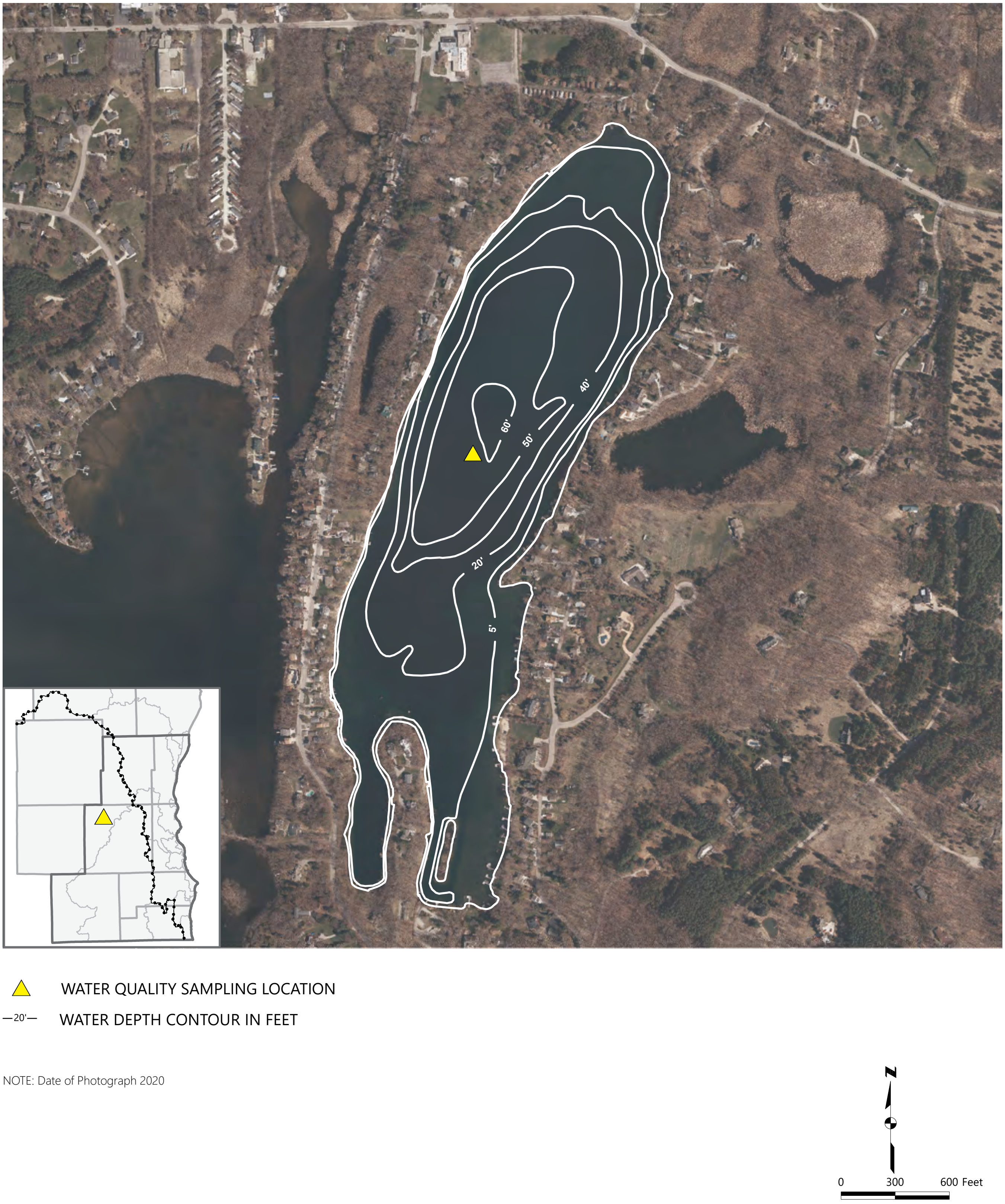
[64] *The WDNR natural community classification for Silver Lake is a deep headwater lake. Deep headwater lakes are relatively deep and are therefore likely to stratify during summer. Furthermore, these lakes receive most of their water supply from surface runoff and discharge most of their water via an outlet stream, a situation also classifying the Lake as a drained lake. The WDNR uses these parameters to set water quality goals.*

[65] *SEWPRC Memorandum Report No. 123, 3rd Edition,* A Lake Management Plan for Silver Lake, Washington County, Wisconsin, *December 2021.*

[66] *Ibid.*

[67] *Land use quantities presented in this section exclude the surface area of Silver Lake itself.*

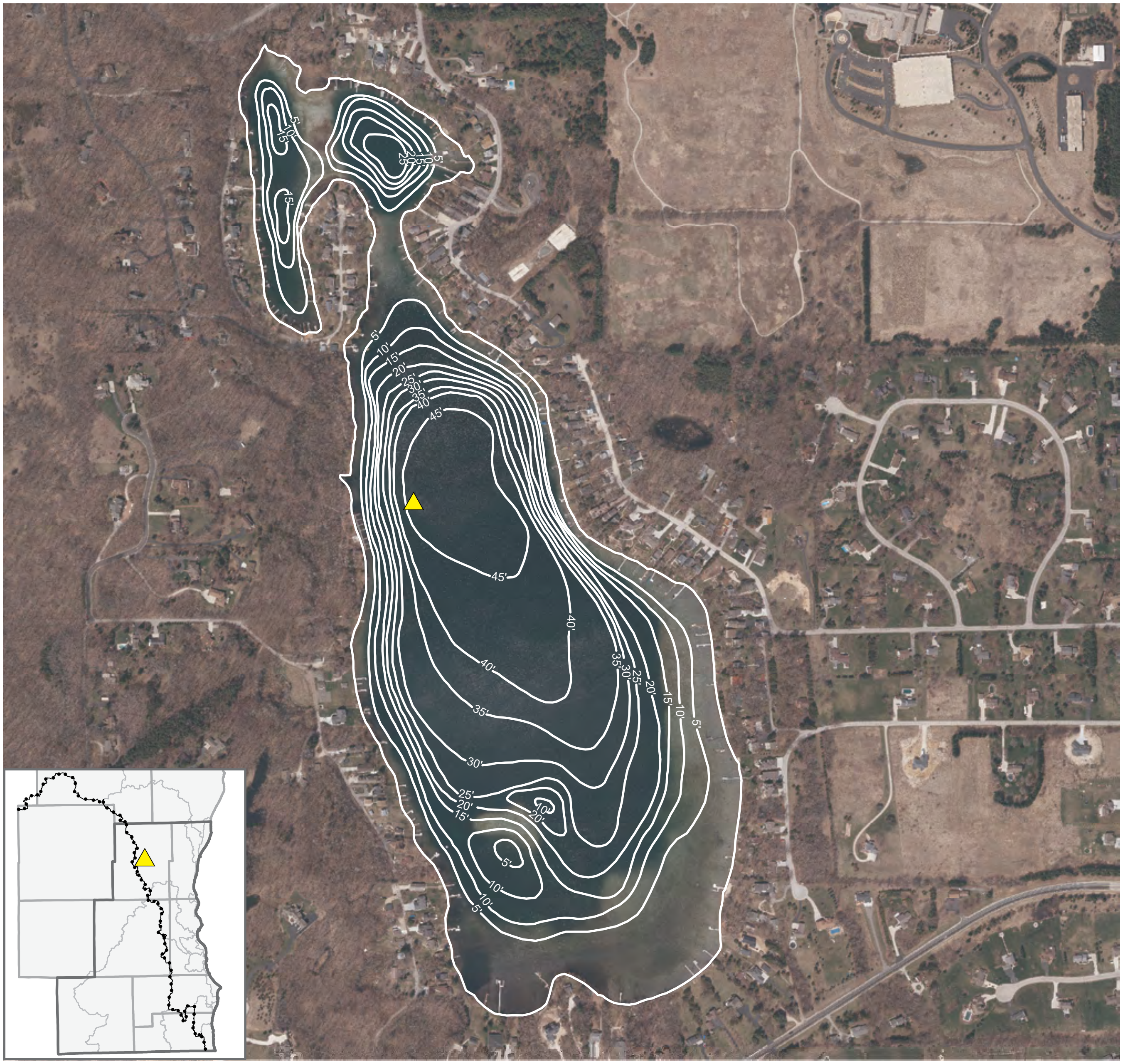
Map 2.16
Moose Lake Water Quality Sampling Location and Bathymetry



NOTE: Date of Photograph 2020

Source: Wisconsin Department of Natural Resources and SEWRPC

Map 2.17
Silver Lake Water Quality Sampling Location and Bathymetry



WATER QUALITY SAMPLING LOCATION

—20'— WATER DEPTH CONTOUR IN FEET

NOTE: Date of Photograph 2020

N

0 300 600 Feet

Source: Wisconsin Department of Natural Resources and SEWRPC

the Lake is also served by sanitary sewers. When considering the larger groundwatershed to Silver Lake, about 24 percent of the area is contained within the West Bend sanitary sewer service area. No wastewater treatment plants are located within the Silver Lake watershed. Instead, sewage is pumped to the City of West Bend sanitary sewer system for treatment and discharged to the Milwaukee River. Silver Lake does not receive effluent from wastewater treatment facilities.

Voltz Lake

Voltz Lake is a 63-acre drained lake located in the Village of Salem Lakes in Kenosha County.[68] The Lake has a maximum depth of 24 feet, a mean depth of seven feet, a total volume of 362 acre-feet, and an estimated residence time of 2.2 years under average weather conditions.[69] The Lake has an elongated basin with a north-south orientation and a shoreline that runs about 2.3 miles. There is no defined, permanently flowing inflow channel into Voltz Lake, however there is an inflow channel on the north shore that seasonally (primarily in spring) carries water into the Lake from woodlands and agricultural lands. At the south end of the Lake, there is a streambed that intermittently carries water into the Lake from nearby Cross Lake. The Lake likely receives some groundwater, but not in sufficient quantities to produce sustained discharge. Outflow from the Lake is regulated through a culvert located at the northwestern corner of the Lake, which enters an unnamed stream that flows to Trevor Creek, a tributary of the Fox River. The deep hole of the lake is located in the center of the northern lobe and was the location for the monitoring site for Chloride Impact Study (see Map 2.18).

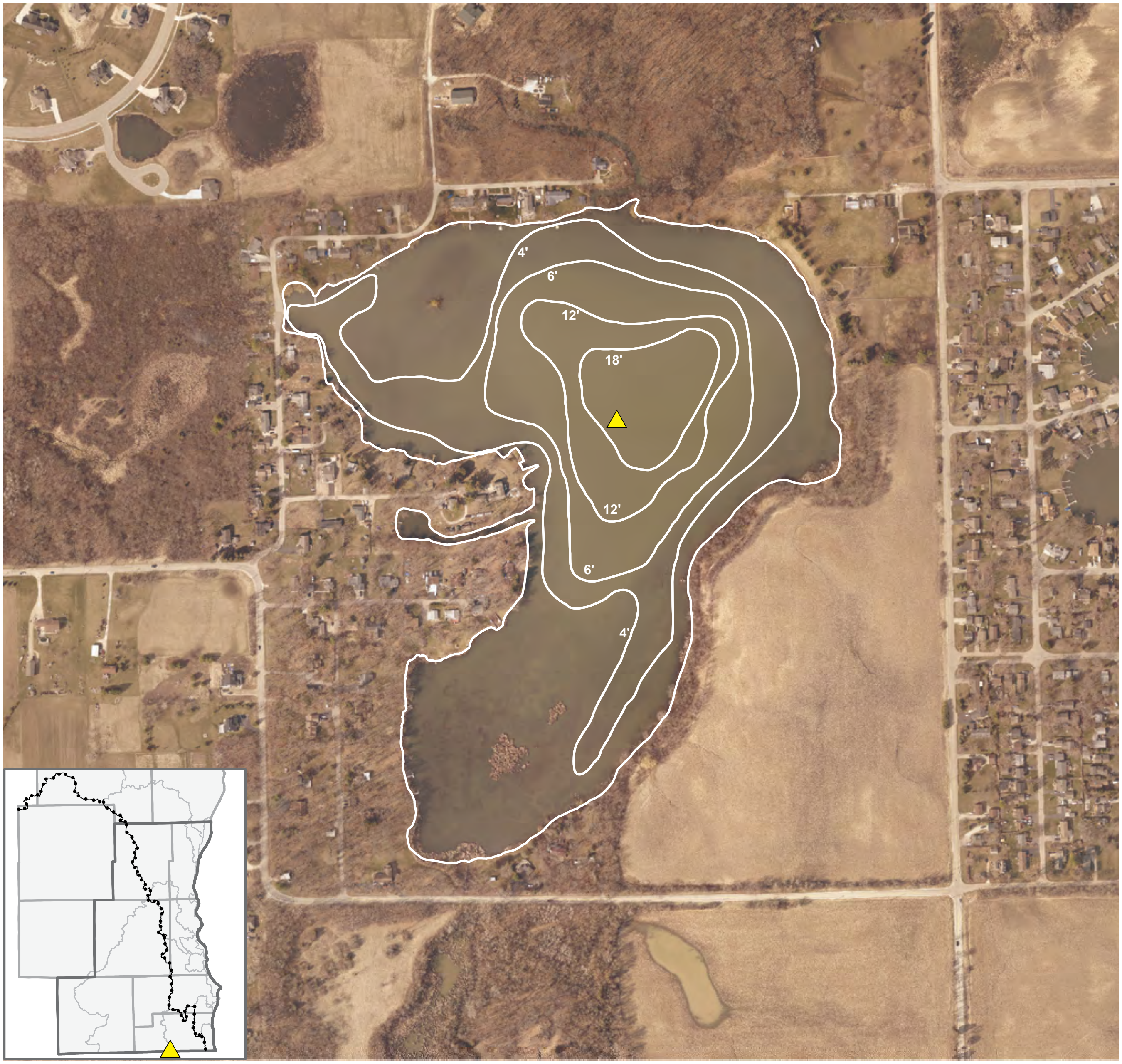
The drainage area tributary to Voltz Lake is about 0.5 square mile, lies primarily to the north and south of the Lake, and is completely within the Village of Salem Lakes (see Map C.11 and Table C.1). In 2015, land use in this drainage area was mostly rural (81.5 percent). The most common land uses included agricultural (48.8 percent), woodlands (21.4 percent), lower-density residential (10.9 percent), wetlands (9.3 percent), and roads and parking lots (4.7 percent) (see Table 2.13 and Map C.12).[70] About 72 percent of the Voltz Lake watershed is contained within the Salem sanitary sewer service area. The remaining 27 percent of the watershed is mostly undeveloped and was in agricultural uses or woodlands. Voltz Lake does not receive effluent from wastewater treatment facilities.

[68] *The WDNR also classifies Voltz Lake as a deep headwater lake. Deep headwater lakes are relatively deep and are therefore likely to stratify during summer. Furthermore, these lakes receive most of their water supply from surface runoff and discharge most of their water via an outlet stream, a situation also classifying the Lake as a drained lake. The WDNR uses these parameters to set water quality goals.*

[69] *SEWRPC Lake Use Report Update No. LR-12,* Voltz Lake Use Report, Kenosha County, Wisconsin, *October 2017.*

[70] *Land use quantities presented in this section exclude the surface area of Voltz Lake itself.*

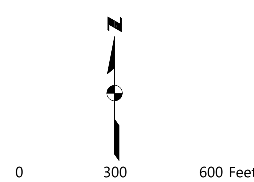
Map 2.18
Voltz Lake Water Quality Sampling Location and Bathymetry



WATER QUALITY SAMPLING LOCATION

—20'— WATER DEPTH CONTOUR IN FEET

NOTE: Date of Photograph 2020



Source: Wisconsin Department of Natural Resources and SEWRPC

MONITORING SITE INSTALLATION, FIELD EQUIPMENT, AND DATA COLLECTION PROCEDURES

3

Credit: SEWRPC Staff

3.1 INTRODUCTION

Chapter 2 of this Report describes how 41 stream monitoring sites and six lakes were selected throughout the Southeastern Wisconsin Region (Region) to assess current chloride conditions at an array of locations representative of the Region as a whole. The process for selecting these monitoring sites and a characterization of each monitoring site drainage area is detailed in Chapter 2.

This Chapter describes the methods and procedures used for collecting water quality data at the stream and lake monitoring sites. Included is a description of the equipment used for continuous monitoring of streams and how this equipment was deployed and maintained. The Chapter also describes the methods used for collecting water samples at stream and lake monitoring locations that were sent to the Wisconsin State Laboratory of Hygiene (WSLH) for chemical analysis.

3.2 STREAM MONITORING

As described in Chapter 2, Southeastern Wisconsin Regional Planning Commission (Commission) staff selected stream monitoring locations throughout the Region for the Chloride Impact Study (see Map 2.11 and Table 2.8). Three methods were used to assess water quality constituents at each of the monitoring sites.

1. Streams were continuously monitored using CTD-10 sensors to record specific conductance, water temperature, and relative water depth above the sensors.

2. Monthly water quality samples were collected at each monitoring site and sent to the WSLH for chemical analysis of chloride and some of the other chemical constituents that comprise specific conductance.

3. Event water quality samples were collected at selected monitoring sites during winter weather events or snowmelt events to capture the impacts of deicing practices. Event water quality samples were also sent to the WSLH for analysis of the same constituents as the monthly samples.

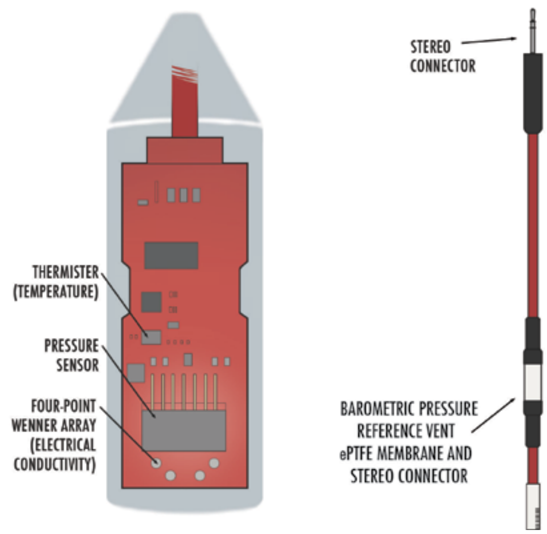
Continuous Stream Monitoring

Data collection for this Study was designed to continuously collect specific conductance, water temperature, and water depth over the course of 25 months, including over two winter seasons. The collection of specific conductance data was supplemented by the collection of surface water samples at the same locations to be analyzed for concentrations of chloride and some of the other constituent chemicals that comprise specific conductance. It is well cited in the literature that specific conductance can be converted to estimates of chloride concentrations through empirical relationships. The subsequent sections describe the equipment used for continuous stream monitoring, monitoring site installation, and monitoring methods and procedures.

Continuous Stream Monitoring Equipment

CTD-10 sensors produced by METER Group Inc., USA (METER Group) were used to continuously monitor electrical conductivity, water temperature, and water level at selected stream monitoring sites.[71,72] The CTD10 sensor is a small cylindrical device that was deployed in-stream and connected by a stereo cable to an external data logger (see Figure 3.1).[73] The sensor calculates water depth using a pressure transducer that measures the pressure applied by the water column above the device. The reference port of the pressure transducer is vented through the cable to the atmosphere removing the effects of barometric pressure. A thermistor located near the conductivity sensor measures water temperature. The CTD-10 sensor measures electrical conductivity using a four-electrode array. Alternating current is applied to two electrodes that measure current flow. The sensor then measures voltage drop through a second set of electrodes. The conductance is the ratio of current to voltage. Software within the sensor automatically corrects electrical conductivity measurements to 25 degrees Celsius (°C). This adjusted value is referred to as specific conductance and is a measure of the ability for water to conduct electrical current. Specific conductance is commonly reported in units of microsiemens per centimeter (μS/cm) at 25°C. The presence of ions in water allow it to carry an electrical current. Solutions that contain inorganic salts are good conductors of electricity. Therefore, higher specific conductance levels in water are an indication of higher concentrations of dissolved solids and ions such as chloride. The specifications for the CTD-10 sensor used in this Study are shown in Table 3.1.

Figure 3.1
CTD-10 Sensor Diagram



Source: METER Group Inc.

Each CTD-10 sensor was paired with an EM60G or ZL6 combined data logger and telemetry unit produced by METER Group (see Figure 3.2).[74,75,76] The telemetry units are self-contained data loggers that are equipped

[71] *Commission staff researched eight different conductivity and temperature sensors and data loggers prior to the Study. The CTD-10 sensors were selected to be used for this Study based on attributes including, but not limited to, accuracy, range of conductivity measured, operational temperature range, availability of telemetry to access data remotely, cost of units, battery life, and recommendations from prior users.*

[72] *METER Group Inc., USA,* CTD-10 Electrical Conductivity, Temperature & Depth Sensor Product Manual, Version 13869-4, *Pullman, WA, June 6, 2018.*

[73] *Cables for the CTD-10 sensors could be custom ordered to various lengths. Cable lengths ranging from 10 meters to 23 meters were used for this Study. Selection of cable length depended on the size of the stream and the distance necessary to locate the telemetry unit at a safe location.*

[74] *Initially all monitoring sites were equipped with EM60G telemetry units. During the study period, some of the EM60G units malfunctioned and were replaced with the manufacturer's next-generation model of data loggers, known as the ZL6. While the functionality of the two different models were similar, the ZL6 included enhanced features such as an internal antenna, Bluetooth capabilities, and improved battery efficiency.*

[75] *METER Group Inc., USA,* EM60G User Manual, *Pullman, WA, 2017.*

[76] *METER Group Inc., USA,* ZL6 User Manual, *Pullman, WA, 2018.*

Table 3.1
CTD-10 Sensor Specifications

Water Depth	
Accuracy	0.05 percent of full scale @ 20°C (68°F)
Resolution	2 mm[a]
Range	0 to 10,000 mm
Temperature	
Accuracy	±1°C (±1°F)
Resolution	±0.1°C (±1°F)
Range	-11 to 49°C (12 to 120°F)
Bulk Electrical Conductivity	
Accuracy	±0.01 dS/m[b] or ±10% (whichever is greater)
Resolution	0.001 dS/m
Range	0 to 120 dS/m (bulk)
Power Requirements	
Idle	3.6 to 15 VDC, 0.03 mA[c,d]
Active	0.5 mA during 300 ms measurement[e]
General	
Dimensions	length: 9 cm (3.5 in) width: 3.4 cm (1.4 in)
Measurement Time	300 ms[e]
Output	Serial (TTL), 3.6 voltage levels or SDI-12
Operating Temperature	0 to 50°C (32 to 122°F)
Connector Types	3.5 mm (stereo) plug
Cable Length	10 m (32 feet) standard, custom length available

[a] *Millimeter (mm)*

[b] *deciSiemens per meter (dS/m), equivalent to 10 microSiemens per centimeter (μS/cm)*

[c] *Volts of Direct Current (VDC)*

[d] *Milliampere (mA)*

[e] *Millisecond (ms)*

Source: METER Group

with software and a SIM card, and are compatible with the METER Group's proprietary ZENTRA Cloud, a cloud-based data management platform. The telemetry units are able to transmit the in-stream data that were collected by the CTD-10 sensors via the cellular network to the ZENTRA Cloud platform where the data were stored on servers. Through the ZENTRA Cloud interface, Commission staff could remotely monitor and visualize data from each monitoring site in near-real time, download data, modify equipment operational settings, and troubleshoot equipment issues. The housing for the telemetry units are weather resistant, which allowed for long-term remote data collection in all seasons and weather conditions. Integrated solar panels on the units allow for the use of rechargeable batteries. At monitoring sites where solar panels were shaded by foliage or consistently covered by snow and ice, alkaline batteries were utilized and were replaced approximately every five months.

The CTD-10 sensors used for this Study were factory calibrated and could not be recalibrated in the field. For this reason, a second device was used as a periodic check on the accuracy of the sensor readings. The Aqua TROLL 500 Multiparameter Sonde, produced by In-Situ Inc. (In-Situ), was used to collect specific conductance and temperature measurements during site visits throughout the Study (see Figure 3.3).[77,78] A wireless TROLL Com communication device provides power to the handheld sonde and can deliver water quality data wirelessly to the VuSitu mobile application (app), that was downloaded on a mobile device, such as a smart phone or tablet. The sonde is compatible with a variety of interchangeable sensors. For this

[77] *In-Situ Inc.,* Aqua TROLL 500 Operator's Manual*, Fort Collins, CO, 2018.*

[78] *The sonde was also used extensively to record specific conductance and temperature profiles at various depths in the six lakes that were monitored for this Study. The use of this sonde for lake monitoring is detailed later in this Chapter.*

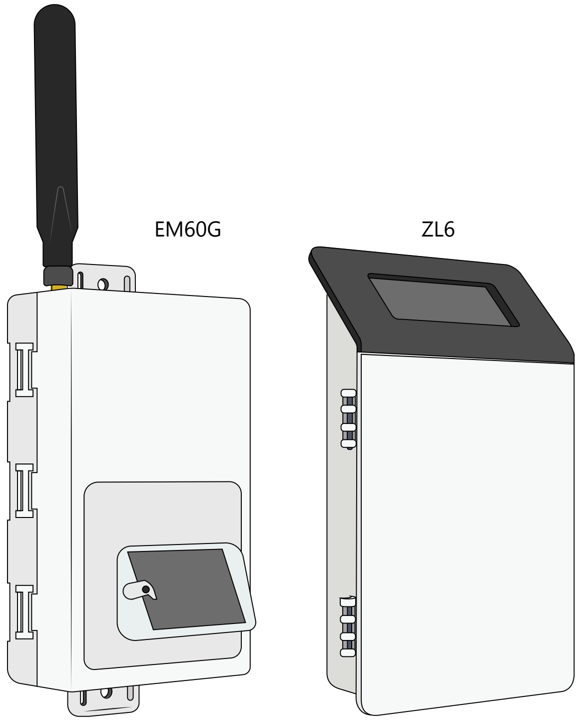
Study it was equipped with a water temperature sensor and a specific conductance sensor (see Table 3.2). The specific conductance sensor was calibrated daily by Commission staff before each use in the field. The conductivity sensor is calibrated using the calibration function on the VuSitu app and a potassium chloride (KCl) standard calibration fluid made by Exaxol.

Continuous Stream Monitoring Site Installation

Once desired stream reaches were identified for continuous stream monitoring, selection of the exact sites to install the monitoring equipment was based on several factors including sites providing easy and safe access for Commission staff, sites having sufficient water depths to prevent the CTD-10 sensors from freezing in the winter, sites with stable channel bottom substrates to support the sensor, and sites allowing for monitoring equipment to be out of public view (for details on site selection, see Chapter 2 of this Report). To protect the sensors from the elements and wildlife, each CTD-10 sensor was placed into a protective housing made from two-inch diameter polyvinyl chloride (PVC) pipe. The protective housings were 12 inches in length and had multiple half-inch diameter holes drilled along the entire length of the pipe to allow water to freely flow towards the sensor. A two-inch PVC cap with a half-inch hole drilled through the top was placed on one end of the housing to provide access for the CTD-10 cable. The opposite end of the housing was left uncapped to promote flow through the housing and flushing of sediment and other debris. The entire length of cable was fed through a half-inch flexible PVC conduit to protect it from damage.[79] Once secured within the protective housing, the CTD-10 sensor assembly was attached to a concrete cinder block using plastic cable ties (see Figure 3.4).[80]

As described in Chapter 2, specific site selection required a stream location that had normal water depths of approximately three feet. This target depth ensured that the site was safely wadable but deep enough that the water column would be unlikely to freeze down to the depth of the sensor in the winter. When site conditions were met, the completed CTD-10 assembly was placed in the water on stable channel bottom substrates with the length of the PVC housing oriented perpendicular to the direction of streamflow. When available, natural substrates such cobbles and boulders were placed around the sensor assembly to keep it from tipping over during high streamflow conditions or if impacted by debris. The sensor cable and protective conduit were run through several low-profile cinder blocks that were placed at strategic locations along the bottom of the stream channel and near the streambank to prevent it from being snagged by passing debris (see Figure 3.5). Cobbles and other natural substrates were employed to further camouflage and secure the conduit.

Figure 3.2
Combined Data Logger and Telemetry Unit Devices



Source: METER Group Inc. and SEWRPC

Figure 3.3
Aqua TROLL 500 Multiparameter Sonde and Wireless TROLL Com

Source: In-Situ Inc.

[79] *This conduit is commonly referred to as non-metallic PVC Liquid Tight or "flex PVC."*

[80] *Typically a 16-inch by 8-inch by 8-inch concrete cinder block was used, but water level conditions at a few monitoring sites required a lower profile 16-inch by 4-inch by 8-inch concrete cinder block.*

Table 3.2
In-Situ Aqua TROLL 500 Specifications

Conductivity Sensor	
Accuracy	±0.5 percent of reading plus 1 µS/cm[a] from 0 to 100,000 µS/cm
Range	0 to 350,000 µS/cm
Resolution	0.1 µS/cm
Response Time	T63<1s, T90<3s, T95<5s[b]
Units of Measure	Actual conductivity: µS/cm; Specific conductivity: µS/cm
Temperature Sensor	
Accuracy	±0.1°C
Range	-5 to 50°C (23 to 122°F)
Resolution	0.01°C
Response Time	T63<2s, T90<15s, T95<30s
Units of Measure	°C, °F
Level/Pressure Sensor	
Accuracy	±0.1 percent full scale
Range	Non-vented or Vented 9.0 m (30 ft) - Burst: 27 m (90 ft) 30 m (100 ft) - Burst: 40 m (130 ft) 76 m (250 ft) - Burst: 107 m (350 ft) 100 m (325 ft) - Burst: 200 m (650 ft)
Resolution	±0.01 percent full scale
Response Time	T63<1s, T90<1s, T95<1s
Units of Measure	Level: in, ft

[a] *MicroSiemens per centimeter (µS/cm)*

[b] *Seconds (s)*

Source: In-Situ

The telemetry units were installed on the streambank nearest to the location of the submerged CTD-10 sensor. Telemetry units were secured in a variety of ways depending on riparian conditions, including placing them in trees on the streambank, on roadway guardrails, or on fence posts (see Figure 3.6). Additionally, the units had to be secured at a height that would be above any potential flood flows. It was critical to position the telemetry unit with the solar panel facing south to get full sun exposure to fully charge its batteries, and to melt ice or snow that would collect on the solar panel in the colder seasons.

Continuous Stream Monitoring Methods, Procedures, and Maintenance

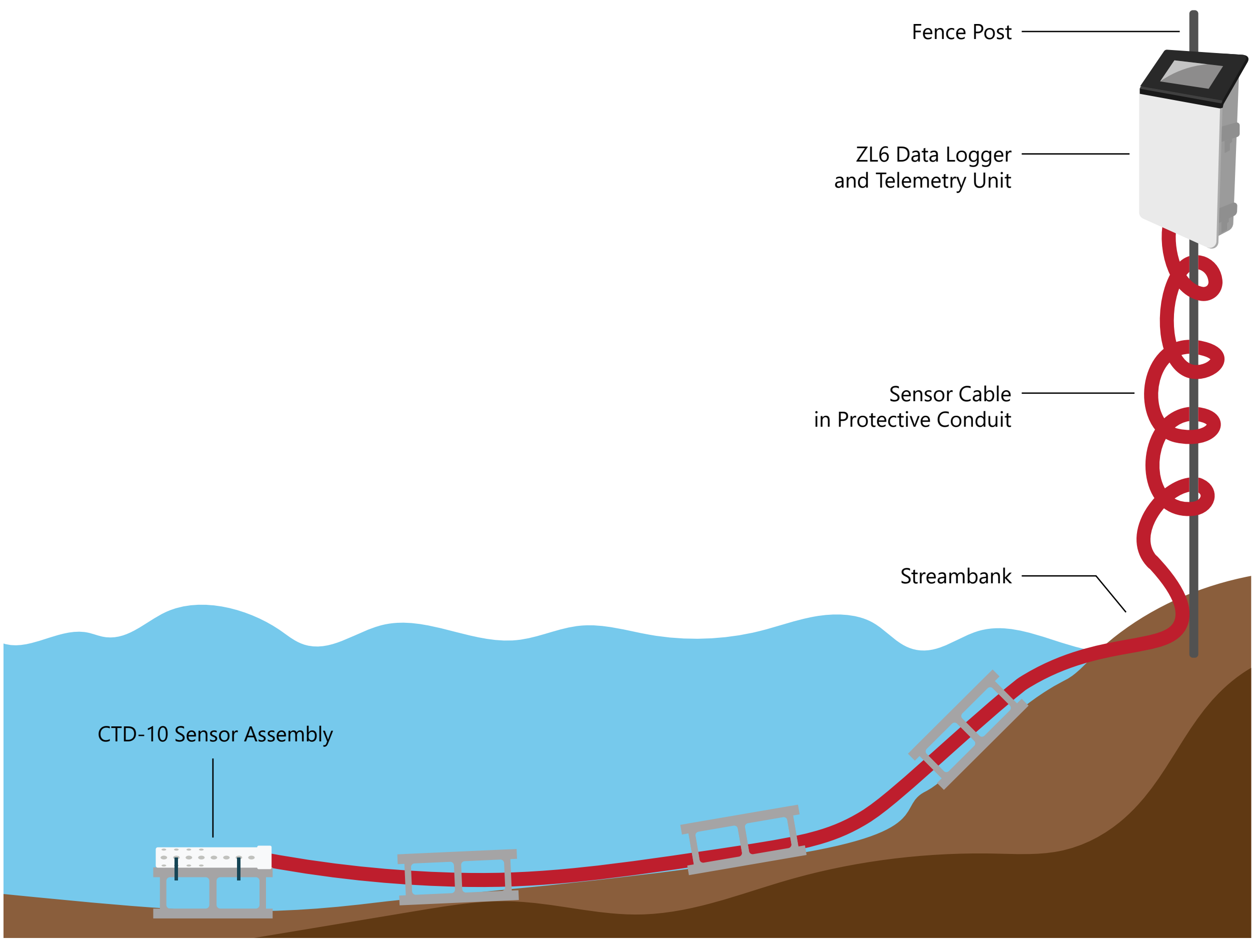
After the continuous stream monitoring equipment installation was completed in the field, sensors and telemetry units were programmed to record measurements of specific conductance, water temperature, and water depth above the sensor every five minutes. Data logged on the telemetry units was uploaded several times a day to the ZENTRA Cloud platform. Commission staff routinely monitored the CTD-10 sensors remotely via the ZENTRA Cloud interface to ensure that the sensors and telemetry units were functioning properly. The following examples were indications that the CTD-10 sensors or telemetry units were not functioning properly.

- Telemetry units not transmitting the recorded data to the ZENTRA Cloud interface at programmed intervals typically indicated a communication issue and could be fixed by resetting the unit using the onboard reset button
- Telemetry units reporting batteries that had low or no charge could indicate an obstruction of the solar panels or a problem with the batteries that would require replacement
- Water depths observed to be unusually high or low compared to typical site conditions could mean a pressure sensor malfunction, or could indicate that the sensor assembly was moved to a shallow-water location by high streamflow, waterborne debris, or human intervention
- Reported water temperatures at or near freezing indicated that the sensor might be encased in ice during winter

Figure 3.4
CTD-10 Sensor and Housing Assembly

Source: SEWRPC

Figure 3.5
Illustration of Stream Monitoring Site Equipment Installation



Source: SEWRPC

Figure 3.6
Examples of Telemetry Unit Mounting Configurations at Stream Monitoring Sites

Source: SEWRPC

- Unusually high water temperatures during the summer could suggest that the sensor assembly was out of the water and was recording air temperature

- Reported specific conductance levels that were unexpectedly low or appeared to be dampened could indicate sensor fouling, sedimentation, or a buried sensor assembly

- Gaps in the CTD-10 sensor data were indicative of damage to the sensor cable or a loose cable connection, which could be caused by ice movement or debris pulling on the cable and protective conduit

When routine review of the in-stream data indicated that the equipment was malfunctioning or experiencing a problem, Commission staff promptly mobilized and completed site investigation visits. Notes detailing what was encountered in the field during each site visit were recorded in a field book for later reference. The individual components of the CTD-10 sensor could not be replaced, therefore if one sensor component malfunctioned, the entire device was replaced with a new CTD-10 sensor. Occasionally, telemetry unit communication issues could be resolved by replacing the SIM card or upgrading the internal telemetry hardware component from 3G to 4G telecommunications technology. In most cases, data logger and telemetry units that failed to communicate with the ZENTRA Cloud platform were replaced with a new unit.

<u>Continuous Monitoring Equipment Cleaning and Maintenance</u>

In addition to unplanned site visits prompted by ZENTRA Cloud indications of equipment issues, Commission field staff visited each of the continuous stream monitoring sites every month to collect water quality samples for laboratory analysis (details of monthly sample collection methods and procedures are provided later in this

Chapter). During these site visits, Commission field staff visually examined the monitoring equipment. The cable tie securing the door to the telemetry unit housing was removed and the interior was inspected. The cable plug connection from the CTD-10 sensor was checked to ensure it was secure. Occasionally, insects such as ants or spiders would infest the interior of the telemetry unit housings. Commission field staff carefully cleared any insects and debris from the interior of the telemetry housing and installed protective rubber covers in the unused ports to keep them free of debris, webs, or larva. When batteries were replaced or a sensor cable was unplugged and plugged back into the unit the reset button was engaged to reset the unit and reestablish connection with the CTD-10 sensor and the cellular network used to upload data to the ZENTRA Cloud platform. Following the inspection, the housing door was secured with a cable tie to discourage tampering.

Additionally, Commission field staff visually assessed the entire length of sensor cable and conduit along the stream channel bottom for damage and to ensure that no large debris was entangled in the cable. Commission staff located the concrete cinder block and CTD-10 sensor assembly to confirm the block and sensor were still oriented perpendicular to flow. When deemed necessary due to site conditions and best professional judgement, Commission field staff carefully picked up the concrete block and attached sensor and gently shook the block while still submerged to clear any debris or sediment from the sensor housing. When water depths were too high to reach the concrete block by hand, a large forceps tool was used to lift the block and gently shake debris loose (see Figure 3.7 for depiction of tool). The large forceps were a custom-made tool, bent from a 10-foot long piece of half-inch rebar. When water depths or streamflow conditions were considered unsafe, Commission staff did not enter the stream and skipped this in-stream cleaning step. Whenever the block and sensor assembly were moved or adjusted, the depth of water above the sensor was remeasured. All site visit details including the time and date of visit, cleaning activities, equipment adjustments, and measurements were recorded in a field book for later reference.

Figure 3.7
Forceps Tool for CTD-10 Sensor Retrieval

Source: SEWRPC

At least twice a year, the CTD-10 sensors were pulled out of the water for a thorough inspection and cleaning. The sensor assemblies were not removed from the water during cold weather months because the pressure transducers on the CTD-10 sensors were very sensitive to cold air temperatures and drastic temperature changes. Typically, thorough sensor cleanings occurred in the spring and fall when the air temperature was above 45 degrees Fahrenheit (°F). Cleaning in air temperatures below this could cause the pressure transducer to fail. In addition, sensor cleanings were performed when water levels and streamflow conditions were not elevated to allow Commission staff to safely enter the stream and retrieve the sensor assembly from the bottom of the stream channel.

The biannual cleaning procedure was completed in this sequence. First, a four-foot step ladder was placed on the bottom of the stream channel near the concrete cinder block and attached sensor assembly. The block and sensor were retrieved from the channel bottom either by hand or using the large forceps tool, lifted above the water surface, and set on top of the step ladder platform (see Figure 3.8). The CTD-10 sensor was removed from the PVC housing by removing the PVC cap and pulling the sensor and cable completely out of the housing. Removing the PVC cap would occasionally require the use of a hammer and prybar with a flat edge. The sensor was gently swirled in the stream water to clear any accumulated sediments. Next, a variety of small tweezers were used to remove any invertebrates, algae, and various debris that commonly attached to the sensor (see Figure 3.9 for examples of sensor fouling that was encountered during the Study). A small nylon brush was used to gently remove any biofilm that accumulated on the sensor electrodes. A large brush was used to clean any remaining sediment or other debris out of the PVC housing. After the sensor was cleaned, it was put back into the PVC housing and the cap was reattached. If necessary, the cable ties securing the sensor and housing assembly to the concrete cinder block were replaced. The cinder block was placed back into the water in the same location and positioned so the length of the sensor assembly was perpendicular to the direction of flow within the stream. Finally, a depth measurement was taken to verify the depth of water above the sensor.

An Aqua TROLL 500 Multiparameter Sonde (described previously) was used to record specific conductance and temperature after every CTD-10 sensor cleaning and with every monthly grab sample. The data collected using the handheld sonde were compared to the corresponding data collected by the CTD-10 sensors to make sure they were measuring the specific conductance accurately. Large differences between the CTD-10 sensor data and the sonde data indicated a potential issue with the CTD-10 sensor performance. All cleaning activities, time of cleaning, sonde readings, water depth above the sensor before and after cleaning, and any other pertinent notes were recorded in the field book for future reference.

Figure 3.8
CTD-10 Sensor Cleaning and Maintenance

Source: SEWRPC

Stream Water Quality Sample Collection

As previously described, specific conductance can be used to estimate chloride concentrations in water through mathematical relationships. However, to develop reliable relationships, it was necessary to collect an adequate number of paired simultaneous water quality samples and specific conductance measurements. The water quality samples were analyzed for some of the chemical constituents that comprise specific conductance, including chloride. The collection of continuous specific conductance data for this Study was previously described in the Continuous Stream Monitoring section.

Water quality samples were collected at the stream monitoring sites through routine monthly samples and weather event "grab" samples. Grab samples are defined as surface water samples collected at a monitoring site location to capture water quality conditions at one point in time. The following sections describe the equipment, methods, and procedures used to collect the water quality samples. These sections also summarize the chemical constituents that were analyzed, quality control procedures, and laboratory methods.

Water Quality Sample Collection Equipment

The equipment necessary to collect grab samples at stream monitoring sites included:

- Sample bottles – Samples of stream water were collected in 250 milliliter (ml) plastic bottles with screw-on caps that were provided by the WSLH. Each bottle had a label to hand-write information such as site identification, date and time of sample, type of laboratory analysis to be conducted, and the sample preservative that was added, if any.

Figure 3.9
Examples of Fouling Observed on CTD-10 Sensors

Source: SEWRPC

- WSLH datasheet – A lab datasheet was completed for each sample and sent with the water samples to the WSLH. Lab datasheets included information to identify the sample location and collection details as well as the lab analyses requested. Much of the information was pre-filled to reduce errors and increase efficiency in the field.

- Sample preservative – 2.0 ml of 1:1 nitric acid provided by the WSLH was required to be added as a preservative to each water sample that was analyzed for metals. The purpose of sample acidification is to lower the pH so the sample will remain chemically stable until the lab analysis was completed.

- Plastic resealable bags – Resealable bags were used to hold the sample bottles and the lab datasheet for transport to the WSLH.

- Cooler and ice – These items were used to store, preserve, and transport the samples after collection.

- Aqua TROLL 500 Multiparameter Sonde – This handheld sonde was used to measure specific conductance and water temperature at the time the water quality sample was collected. This information was recorded in a field book for future reference.

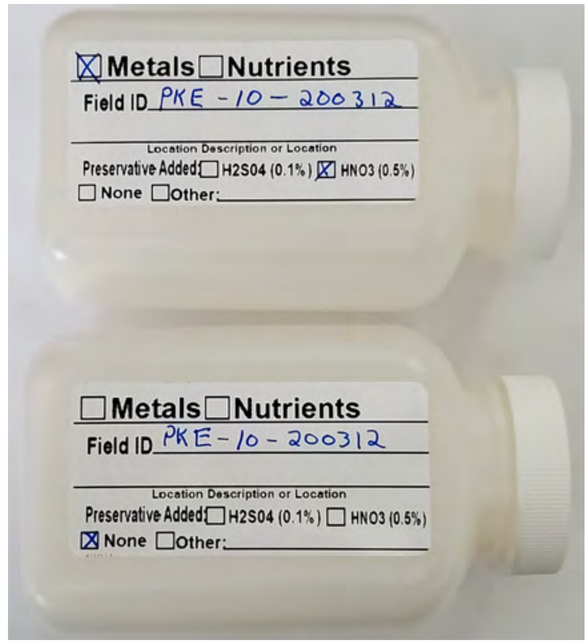
- Assisted sampler – An extension pole that was used to collect surface water samples from streams and rivers at a safe distance from the streambank or bridge. Two sample bottles were attached to the pole using cable ties, and the pole could be extended up to 25 feet to allow for safe sample collection.

- Spud bar – A spud bar is a long cast iron weighted tool that was used to break through ice to collect a grab sample.

Monthly Water Quality Sample Collection Methods and Procedures

Water quality samples were collected monthly at each of the established stream monitoring sites over a 25-month study period from October 2018 through October 2020. A total of 954 stream water quality samples were collected during this period.[81] Water samples were typically collected during the middle two weeks of each month, regardless of weather conditions, to develop a water quality dataset that captured a variety of conditions representative of each stream monitoring site.

Figure 3.10
Sample Bottles for Water Quality Sampling



Source: SEWRPC

When collecting water quality samples during periods of low streamflow and safe conditions, Commission staff entered the water downstream of the monitoring site and walked upstream toward the CTD-10 sensor. Water samples were collected as close to the CTD-10 sensor as practical. Once at the sampling location, extra care was taken to avoid disturbing streambed sediments. Samples were always collected facing upstream to avoid capturing any sediment or debris that may have been disturbed while walking through the stream. Samples were collected in two separate 250 ml plastic bottles, labeled with sample identification and analysis information (see Figure 3.10). With the caps removed, the two sample bottles were submerged at the same time about six inches below the water surface to allow the bottles to fill with stream water. The Commission staff were careful to avoid collecting any surface water that could be contaminated with floating debris. The caps were placed back onto the bottles and the bottles were lightly shaken before the water was poured out. This process was repeated a total of three times to clean any contaminants on the interior of each bottle and bottle cap. The bottles were submerged a final time to collect the sample. The nitric acid preservative was added to one of the sample bottles that was marked to be analyzed for metals such as calcium, magnesium, potassium, and sodium. The preservative lot number sticker was removed from the acid vile and adhered to the WSLH datasheet for documentation. Additional information such as sample ID, sample date, and sample time were recorded on the WSLH datasheet as presented in Appendix D. The WSLH datasheet and both sample bottles were promptly placed into a one-gallon resealable plastic bag, labeled with the site identification and sample date, and placed in a cooler filled with ice. Samples were stored in a refrigerator at the Commission offices at the end of the sampling day until they were transported to the WSLH for analysis. Samples were analyzed for chloride, calcium, magnesium, hardness, potassium, sodium, and sulfate as described in the Laboratory Analysis section.

Occasionally, site conditions such as high streamflow, in-stream ice cover, or hazardous conditions along the streambanks did not allow for Commission staff to enter the streams to collect grab samples by hand at the location of the CTD-10 sensors. In these instances, grab samples were collected from a safe location as close to the sensor location as conditions allowed. In some cases, it was necessary to collect samples from the streambank or a nearby bridge crossing using the assisted sampler. When the assisted sampler was required, the two sample bottles were attached to the end of the extension bar using cable ties (see Figure 3.11). The assisted sampler was extended to the length necessary to reach the stream sample location and bottles were submerged about six inches below the water surface, following the same procedure as previously described to rinse the bottles and collect the water samples. Occasionally, a weighted spud bar was necessary to break through ice cover on a stream to retrieve a water sample.

[81] *Additional monthly water quality samples were collected through August 2021 at select stream monitoring sites to expand the datasets for sites that were established later in the project.*

Quality Control Sample Collection

The collection of quality control samples was performed to provide confidence in the results of the water quality sampling program and was part of the overall quality assurance for this Study. Field blank and field replicate samples were collected to evaluate the quality of the field sample collection and the precision of the laboratory analysis.

Figure 3.11
Assisted Sampler for Safe Sample Collection

Source: SEWRPC

Field blank samples were collected in the same type of sample bottles as the water quality samples and were subject to all aspects of sample collection including field-processing, preservation, transportation, and laboratory handling and analysis. Distilled water, which is free of contaminants or dissolved solids, was purchased locally and used to fill the field blank sample bottles. Thus, any detection of analytes in a field blank sample was assumed to be due to contamination. Two field blank samples were collected during each monthly sampling period and were assigned to a specific monitoring site using a random number generator. Field blank sample bottles were labeled with the randomly assigned monitoring site information. While at the assigned monitoring site, and shortly after the stream water quality samples were collected, the blank bottles were rinsed with distilled water three times and then filled a final time with distilled water and capped. Nitric acid preservative was added to one of the bottles and was marked to indicate the presence of preservative. If the laboratory analysis detected any analyte in a field blank sample, the sample was flagged for further review.

Field replicate samples were independent water quality samples that were collected as close as possible to the same point in space and time as a field sample. Replicate samples were collected in two separate 250 ml sampling bottles simultaneously with the monthly grab samples and were collected using identical techniques and procedures as described previously. Field replicate samples were also stored, transported, and analyzed in the same manner as the field samples. Field replicate samples were taken at two randomly selected monitoring sites during each monthly sampling period, representing approximately 5 percent of the total water quality samples collected each month. Field replicate samples that had significant differences in measured analytes when compared to the field water quality samples collected at the same site were flagged for further review.

Winter Event Sample Collection Methods and Procedures

To develop a relationship between specific conductance and chloride it is critical to collect paired samples representing a wide range of chloride concentrations. As previously described, monthly grab sampling was conducted routinely and without regard for weather conditions to avoid introducing sample bias. The application of chloride-based deicing materials to roadways, parking lots, sidewalks, and driveways, in anticipation of or response to winter weather events, are a primary source of chloride in the surface waters of the Region. Thus, it can be expected that during and after winter precipitation events or significant snowmelt events, the applied deicing materials mobilize and reach surface waters via runoff. The streams receiving the chloride-laden runoff would experience an increase in chloride concentrations. This phenomenon was observed at stream monitoring sites as a spike, or rapid increase, in specific conductance to levels several times higher than levels typically observed under normal conditions. In order to supplement data collected during monthly grab sampling, Commission staff employed a targeted winter event grab sampling program throughout the study period and extending through the 2020-2021 winter season to capture specific conductance peaks that were likely representative of high chloride concentrations in waterways.

The timing of winter event sampling was less predictable when compared to the monthly grab sampling. It was necessary to monitor weather forecasts simultaneously with specific conductance data from the ZENTRA Cloud interface to watch for indications of increasing specific conductance. When specific conductance spikes were observed to be developing, Commission staff were dispatched to collect a sample of the elevated chloride conditions, extending the range of paired chloride and specific conductance data collected at stream monitoring sites.

Other than the timing of sampling, weather event samples were collected in the identical manner as the monthly grab samples. However when weather conditions, including snow and ice, made collection of samples at the monitoring site unsafe, the event sample was collected at a safer location nearest to the site. Commission staff wore appropriate winter clothing and high visibility reflective vests when sampling. Similarly to monthly grab sampling, detailed notes were collected to describe the conditions at the sites during sample collection. Any deviation from standard sampling protocols due to unsafe sampling conditions were detailed in the field books, along with the following information.

- Location where sample was collected if the collection point needed to be adjusted due to unsafe conditions
- Amount of ice cover at or near the monitoring site and the sample collection site
- Presence and extent of stream flooding
- Presence of nearby ice dams
- Deicing applications observed near the site

Weather event samples and WSLH datasheets were marked to indicate their difference from routine monthly sampling. Sample bottles and datasheets were placed in individual resealable bags and kept on ice or in a refrigerator until they were delivered to WSLH for analysis. The weather event samples were analyzed for the same constituents as monthly samples as previously described. A total 111 event samples were collected for the Study.

Laboratory Analysis

The WSLH was selected to conduct the laboratory analysis for the Chloride Impact Study. The WSLH offers a wide range of toxicological, microbiological, and chemical testing services to support the programs and research of academic institutions, government agencies, and municipalities, and serves as the testing laboratory for the Wisconsin Department of Natural Resources (WDNR). The Organic and Inorganic Chemistry Unit of the WSLH is certified by the U.S. Environmental Protection Agency (USEPA) through the WDNR laboratory certification program and holds a current certification by the National Environmental Laboratory Accreditation Program. A complete quality assurance program is maintained to help assure the highest quality analyses and reliable results.

Upon receiving the stream water quality samples, the samples were refrigerated until analysis was conducted. The maximum holding time for water samples was 28 days. The WSLH analyzed the following constituents using the lab analysis methods listed below.

- Chloride concentrations were measured using Standard Method SM 4500-CL^- E[82]
- Metals (calcium, magnesium, potassium, and sodium) were measured using USEPA Method 200.7[83]
- Sulfate levels were measured using automated colorimetry using USEPA Method 375.2[84]
- Hardness was calculated from the separate determinations of magnesium and calcium in accordance with Standard Method SM 2340B[85]

[82] *Standard Methods Committee of the American Public Health Association, American Water Works Association, and Water Environmental Federation.* Method 4500-Cl^- Chloride In: Standard Methods for the Examination of Water and Wastewater, 21st Edition, *Washington DC: APHA Press, 2005.*

[83] *Environmental Monitoring Systems Laboratory Office of Research and Development, U.S. Environmental Protection Agency,* Method 200.7: Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry, Revision 4.4*, Cincinnati, OH, 1994.*

[84] *Environmental Monitoring Systems Laboratory Office of Research and Development, U.S. Environmental Protection Agency,* Method 375.2: Determination of Sulfate by Automated Colorimetry, Revision 2.0*, Cincinnati, OH, August 1993.*

[85] *Standard Methods Committee of the American Public Health Association, American Water Works Association, and Water Environmental Federation.* Method 2340 Hardness In: Standard Methods for the Examination of Water and Wastewater, 21st Edition, *Washington DC: APHA Press, 2005.*

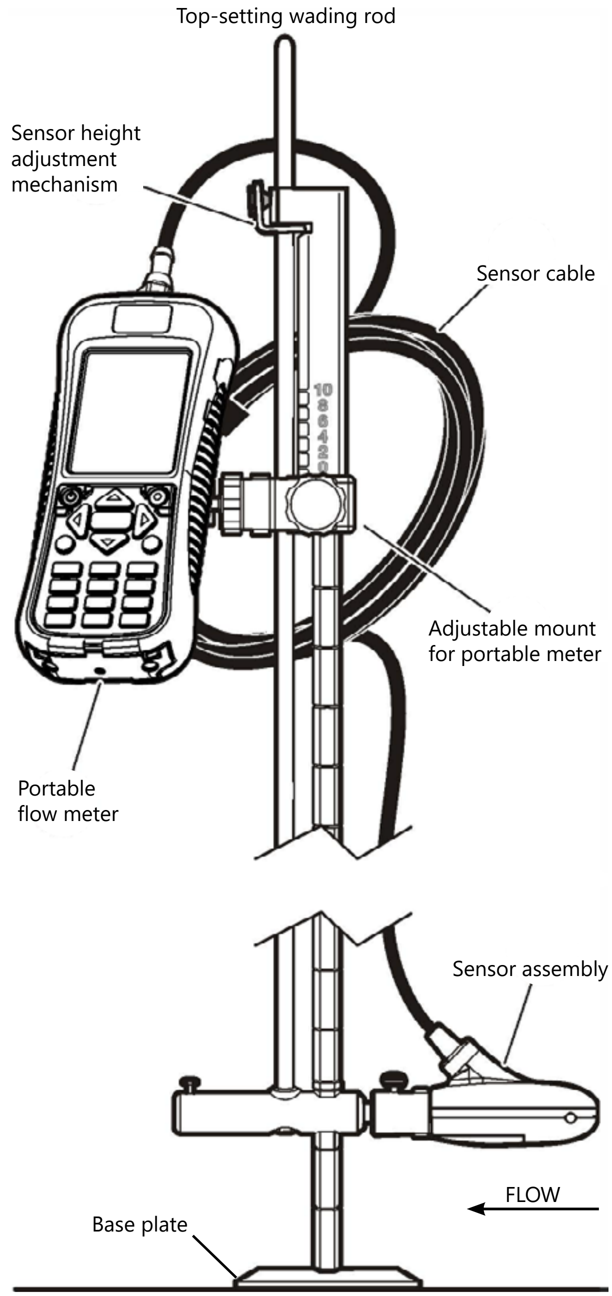
Streamflow Measurement

As described previously in this Chapter, the CTD-10 sensors deployed at the stream monitoring sites recorded the depth of water above the sensor at five-minute intervals. The water level was measured relative to the location and depth of the in-stream sensor, which was not fixed in one location. The CTD-10 sensors were subject to relocation, either by the natural forces within the stream or by human intervention. Streamflow measurements were performed at select monitoring sites to support the interpretation of the water level data where U.S. Geological Survey (USGS) streamflow gage data was not available.

Streamflow Measurement Equipment

Streamflow measurements were taken using the OTT MF pro portable flow meter (see Figure 3.12).[86] This device, when placed in flowing water, estimates flow velocity with a submerged electromagnetic sensor. The sensor transmits the flow velocity data through a cable to a digital display on the flow meter, which is mounted on a top-setting wading rod. The top-setting wading rod is composed of two connected rods. One rod has a base plate that rests on the stream bed and has graduated markings in 0.1-foot intervals that can be used to measure water depth. The second rod is connected to the sensor and uses a sliding adjustment mechanism to position the sensor at the appropriate depth for velocity measurements. The flow meter was calibrated per the manufacturer's specifications at the beginning of each field season. Additional equipment used for streamflow measurements included long measuring tapes, measuring rods, flow measurement field data sheets, and peripheral equipment such as clamps and stakes used to affix the measuring tape to the stream banks.

Figure 3.12
Flow Meter Component Diagram



Source: OTT Hydromet and SEWRPC

Streamflow Measurement Methods

Streamflow measurements were performed at select monitoring sites when the weather and the streamflow conditions were favorable for such work. To better understand how the water depth recorded by the CTD10 sensor is related to the flow regime at a stream monitoring site, it was necessary to collect streamflow measurements at a range of water levels. Each morning prior to visiting the sites, the most-recently observed water levels for each site were reviewed using the ZENTRA Cloud interface and evaluated to determine which sites had water levels within a targeted range and therefore would be prioritized for streamflow measurements. The streamflow measurement procedure is summarized as follows:

- The OTT MF pro flow meter was assembled in the field. Upon startup, the flow meter self-test results were reviewed to ensure each component was operating properly.

[86] *OTT HydroMet,* OTT MF pro Operating Instructions, Edition 7, *2018.*

- The flow measurement cross section was established near the monitoring site and perpendicular to the direction of flow in an area of the stream where flow was relatively straight, uniform, and free of large obstructions. A measuring tape was extended across the width of the stream at the cross section and was secured to stakes on each stream bank using clamps. The stake locations were maintained throughout the project to ensure that the collection of streamflow measurements for each site was repeated at the same cross section location.

- The measuring tape was used to measure the wetted width of the stream and split the stream into segments of equal width; typically, a minimum of 20 stream segments were used for each flow measurement cross section.

- At each stream segment, the top-setting rod was used to measure the depth of water in the stream and to adjust the vertical position of the sensor to the proper position within the water column to measure flow velocity. For this Study, the six-tenths depth method was employed, which utilizes one velocity measurement at 60 percent of the depth below the surface to estimate the mean velocity for the water column.[87]

- Once the sensor was positioned at the proper depth, it was pointed directly into the flow and held steadily in place. The flow meter operator was positioned behind and to the side of the sensor to minimize interference with the flow. The flow meter reports velocity readings at 20-second intervals and following any sensor movement or disturbance the sensor was allowed to settle or equilibrate over several readings before recording the velocity. The depth and velocity were measured and recorded for each stream segment along the entire cross section (see Figure 3.13).

Following data collection in the field, the computation of streamflow was performed using the mid-section method.[88] This method calculates the streamflow discharge within each stream segment, and the total streamflow was estimated by summing the flows calculated for all the individual stream segments. The estimated streamflow discharge was compared to the corresponding water depth recorded by the CTD-10 sensor during the collection of streamflow measurements. These data were used to interpret the CTD water depth dataset and to plan for future flow measurement visits. In all, 66 streamflow measurement surveys were conducted at 18 different stream monitoring sites throughout the Study.

3.3 LAKE MONITORING

Surface water impacted by chloride increases in density which means that water laden with chloride will settle to the deepest part of a waterbody. If the water contains too much chloride, chemical stratification could interfere with lake mixing in the fall and spring. Chemical stratification can delay the mixing of oxygen into the benthic zone at the bottom of the lake, affecting aquatic life. As described in Chapter 2 of this Report, six lakes in the Region were selected for collection of water quality data for the Chloride Impact Study including Big Cedar, Geneva, Little Muskego, Moose, Silver (Washington County), and Voltz Lakes. Water quality constituents were assessed using two methods at each of the lake monitoring sites.

1. Lake water temperature and specific conductance data were collected along a vertical profile at the deepest location of the lake

2. Water quality samples were collected at multiple selected depths along the same vertical profile and the analysis for chloride concentrations was performed by the WSLH

The sections below describe the equipment and methodology used to monitor lakes for the Chloride Impact Study.

[87] *S.E. Rantz and others,* Measurement and Computation of Streamflow: Volume 1, Measurement of Stage and Discharge*, Geological Survey Water-Supply Paper 2175, 1982.*

[88] Ibid.

Lake Monitoring Equipment

The following types of equipment were used to collect water temperature and specific conductance profiles and water quality grab samples at monitored lakes.

- Aqua TROLL 500 Multiparameter Sonde – Manufactured by In-Situ, the handheld sonde was used to measure water depth, specific conductance, and water temperature along a vertical profile in each lake. This information was viewed and recorded with VuSitu software specifically developed to pair with the Aqua TROLL sonde (Figure 3.3).

- 200-foot rugged non-vented communication cable and reel – The communication cable was connected to the Aqua TROLL 500 Multiparameter Sonde and the wireless TROLL Com device to send real-time data collected by the sonde sensors to the VuSitu software on an electronic mobile device.

Figure 3.13
Streamflow Data Collection

Source: SEWRPC

- Niskin-style, 3-liter vertical water sampler – The vertical sampler was used to capture lake water samples at selected depths along a vertical profile. The Niskin-style sampler is a 35-inch long by 5inch diameter cylinder that was constructed of clear polycarbonate with a spring-loaded hinged door at each end. The sampler was attached to a 150-foot leader line rope that was used to lower the device to the desired sampling depth. A 250-gram (0.55 pound) brass messenger weight was fed through the leader line and, when dropped, followed the line to the sampler and released a pin upon impact to close the sampler doors and capture a sample.

- Sample bottles – 250 ml plastic sample bottles with screw-on caps were provided by the WSLH and were used to hold the collected lake water quality samples. Each bottle had a label to hand-write information such as site identification, date and time of sample, and the type of laboratory analysis to be conducted (Figure 3.10).

- WSLH datasheet – A lab datasheet was required to be completed for each sample and sent along with the water sample bottles to the WSLH. Information on the datasheet was filled out as demonstrated in Appendix D.

- Plastic resealable bags – Resealable bags were used to hold the sample bottles that were collected at each lake along with the corresponding lab datasheet for transport to the WSLH. Bags were labeled with the lake name and sample date.

- Cooler and ice – These items were used to store, preserve, and transport the samples after collection in the field.
- Propane-powered ice auger – The ice auger was used to drill holes through the ice for winter lake sampling. The ice auger was also used to confirm safe ice depths as the Commission field staff made their way to the sampling location during winter.

- Spud bar – A spud bar is a long cast iron weighted tool that was used along with the propane-powered ice auger during lake sampling to confirm that ice thickness was adequate for safe access.

- Boats – When the lakes were free of ice, boats were used to transport Commission field staff to the lake sampling locations during spring, summer, and fall sampling.

- Anchors – Anchors were used to hold the boats steady at lake sampling locations while samples and profile data were collected.

- Portable fish finder – The sonar function was used to locate the deep hole of the lakes where the sampling sites were established.

- Personal floatation devices – These safety devices were worn by Commission staff during all lake sampling activities.

Lake Monitoring Methods and Procedures

Water quality data were collected quarterly from each of the six lakes selected for the Study, from August 2018 through February 2021. The sampling locations for each lake were positioned at the deepest part of the lake, often referred to as the "deep hole." The WDNR has maintained long-term sampling stations at the deep hole of all the lakes that were selected for monitoring for this Study. Depths to be sampled for each lake at all quarterly visits were determined during the first summer visit in August 2018, when the lakes were thermally stratified.[89] All lakes were sampled at three feet of depth, which was referred to as the surface sample. Additional sampling depths were selected at the depths determined to be directly above the thermocline, directly below the thermocline, and as close to the lake bottom as possible without disturbing sediments.[90] The typical depths sampled for each lake included:[91]

- Big Cedar Lake: 3 feet, 30 feet, 55 feet, 80 feet, 95 feet

- Geneva Lake: 3 feet, 30 feet, 50 feet, 70 feet, 90 feet, 135 feet

- Little Muskego Lake: 3 feet, 10 feet, 30 feet, 40 feet, 50 feet, 65 feet

- Moose Lake: 3 feet, 15 feet, 30 feet, 40 feet, 55 feet

- Silver Lake: 3 feet, 10 feet, 25 feet, 35 feet, 45 feet

- Volz Lake: 3 feet, 10 feet, 15 feet, 20 feet

During the spring, summer, and fall sampling periods, lake monitoring was conducted from a boat. Boats were provided and operated by volunteers to assist Commission staff. Volunteers were either residents of the lake, members of a lake organization, or both.[92] A sonar-equipped portable fish finder was used to confirm the location of the deep hole. Once at the sampling location, one or more anchors were lowered overboard to steady the position of the boat.

Water temperature and specific conductance vertical profile data were collected using the Aqua TROLL 500 multiparameter sonde equipped with depth, water temperature, and specific conductance sensors. The specific conductance sensor was calibrated at the Commission office prior to each field visit. Calibration of the depth sensor was conducted onsite at each lake using a known measurement that was marked on the communication cable. The sonde was connected to a 200-foot non-vented communication cable that was on a reel for steady deployment below the lake surface. A wireless TROLL Com device was connected to the other end of the communication cable to enable data collected by the sonde to be visualized and saved by Commission staff onboard the boat using the VuSitu software on an electronic mobile device. The sonde cable

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[89] *Stratification is a natural condition in a lake when temperature differences (and associated density differences) between surface waters (the epilimnion), the transitional zone (the metalimnion), and deep waters (the hypolimnion) are great enough to form thermal layers that can impede mixing of gases and dissolved substances between these layers.*

[90] *A thermocline is a horizontal layer within the metalimnion, that separates the warmer, less dense, epilimnion from the cooler, denser, hypolimnion. Typically, the depth of the thermocline can range from less than 10 feet to greater than 20 feet below the surface for lakes in southeastern Wisconsin, with depth varying by lake, month, and year. The thermocline is generally characterized by a temperature change of approximately 0.5°F per foot of water depth.*

[91] *Exact sampling depths varied slightly due to field conditions such as wind, waves, lake water levels, and other environmental variables. Exact depths of each sample are recorded in the field documentation and lab analysis data. Samples were occasionally collected at additional depths for exploratory analysis.*

[92] *Special acknowledgement is extended to the lake monitoring volunteers for their time, efforts, and equipment. Volunteers included Laura Herrick (Big Cedar Lake), Ted Peters (Geneva Lake), Greg O'Hearn (Moose Lake), Joanie Hoppe (Little Muskego Lake), Jim Ketter (Silver Lake), and Mike Borst (Voltz Lake).*

was marked at each foot-length to assist the Commission field staff with adjusting the depth of the sonde. The sonde was attached to the Niskin-style water sampler using cable ties and the sampler was armed by opening the doors at both ends of the sampler (see Figure 3.14).

Figure 3.14
Niskin-Style Vertical Water Sampler and Aqua TROLL 500 Multiparameter Sonde Assembly

Source: SEWRPC

Figure 3.15
Lake Water Quality Sample Collection

Source: SEWRPC

The Niskin-style water sampler and attached sonde were lowered into the water three feet below the lake surface, guided by both the cable attached to the sonde and the leader line attached to the sampler. The devices were left in place for five minutes to allow the sonde sensors to equilibrate. The devices were then slowly lowered along a vertical profile at an approximate rate of two feet every 10 seconds, stopping at the pre-determined sampling depths to allow the sensors to adjust to water temperature and specific conductance. Sonde readings were continuously recorded via the VuSitu software and Commission staff recorded discrete temperature and specific conductance readings at each sampling depth in a field book. The depths of the thermocline were also noted when Commission field staff observed the rapid change in temperature along the vertical profile.

Once the temperature and specific conductance profiles were completed and the devices were still located near the bottom of the lake, the first water sample was collected. It was critical to not disturb the lake bottom sediments to avoid collecting a contaminated water sample. The weighted messenger was deployed down the leader line that was attached to the Niskin-style sampler. Upon impact with the device, the sampler doors closed, and a sample of lake water at the desired depth was captured. The sampling devices were retrieved by slowly pulling the leader line attached to the Niskin-style sampler and the cable attached to the sonde.

Once the Niskin-style sampler was retrieved onto the boat, the collected sample was observed through the Niskin-style device to detect any sediment contamination. If sediments were present in the sample, the retrieved water was dumped, the Niskin-style was rinsed in surface lake water, and a new sample was collected. If the collected water appeared acceptable, a vent on the sampler was opened to allow for sub-sampling through the drain hose. Water was allowed to run freely through the hose onto the boat deck to clear the hose of any previous water. Using the hose, a labeled 250 ml sample bottle was filled and rinsed three times to clean the bottle of any contaminants before filling the bottle a final time for the sample (see Figure 3.15). The sample bottle was placed into a resealable bag along with the WSLH datasheet and placed into a cooler with ice. Additional lake samples were collected at the pre-selected depths in an identical fashion, typically collecting the deepest samples and moving onto the shallower samples until complete. At the end of each field day, samples were stored in a refrigerator at the Commission office until transportation to the WSLH for analysis of chloride concentrations. A total of 343 lake water quality samples were collected and analyzed for this Study.

Lake Monitoring in Winter

Sampling for chloride in the lakes required sample collection during winter months, typically in freezing air temperatures and on ice-covered lakes. Winter sampling had its advantages and disadvantages. For instance, it was sometimes easier to collect samples when standing on solid ice instead of in a boat, which can be easily blown around by the wind and waves. However, sampling was dependent on having safe ice conditions and was often more difficult to schedule. Additionally, water quality sampling in very cold air temperatures can be difficult for several reasons. First, collecting water quality samples in cold air temperatures was hard on sampling equipment, causing freezing and ice accumulation. Vacuum grease was applied to all the cable twist-lock connections to keep them lubricated, enhance the ability to twist in the cold dry air, and to prevent the connection from icing up. All equipment calibrations were performed at the Commission office prior to each field day.

Sampling through lake ice required Commission staff to transport the necessary equipment over the ice to the sampling location. Therefore, sufficient ice thickness was a necessity for safe passage. Safety was always the top priority. If there were any concerns about unsafe conditions, sample collection was postponed until a later date.[93] Before leaving the office, Commission staff reached out to volunteer lake contacts with local knowledge for reports on ice cover conditions. Once onsite, initial precautions from shore included visual inspection of ice for any signs of open water, ice cracking, or slush. Observations of ice fisherman or snowmobiles out on the ice were helpful as a guide but were not decisive indications of ice safety. After reconnaissance and visual inspection of the ice indicated that ice cover was sufficient to begin to walk on, Commission staff loaded the monitoring equipment into a sled for transport to the sampling location (see Figure 3.16). Wearing personal floatation devices, Commission field staff carefully trekked towards the monitoring site. A spud bar was used to probe the ice along the route and a propane-powered ice auger was used to drill holes approximately every 100 feet to check ice depths along the path to the site location.

Figure 3.16
Equipment Used for Winter Lake Sampling

Source: SEWRPC

Once on location, a 10-inch diameter hole was drilled into the ice with the propane-powered ice auger and slush was removed from the hole. The Aqua TROLL 500 sonde was attached to the Niskin-style sampler and lowered into the water. The water temperature and specific conductance profiles were completed using the same procedure as described previously. However, when pulling the water samples and the devices to the surface, the leader line and cable were raised in parallel by Commission field staff and walked backwards, laying them in a straight line on the top of the ice, instead of rolling the cable onto the reel. By doing so, the leader line and communication cable were frozen in a straight position and could be more easily lowered down to the next depth to collect the remainder of the water samples. Water samples were placed in a resealable bag and placed in a cooler for transportation back to the Commission office until delivery to the WSLH for analysis.

[93] *After several postponements, Commission staff were unable to collect water quality data for Geneva Lake during the 2019-2020 winter season due to unsafe ice conditions and open water.*

DATA MANAGEMENT AND DOCUMENTATION 4

Credit: SEWRPC Staff

4.1 INTRODUCTION

Due to the large quantity of data collected for the Chloride Impact Study, significant planning and effort were invested in the organization, storage, accessibility, and the quality assurance and quality control of the project datasets. Quality assurance (QA) includes the planning and processes established to ensure data quality and prevent issues that could arise from various aspects of the Study including field work activities, data collection, and data management. Quality control (QC) includes examining the data collected to ensure the quality of the datasets and final products. A wide array of data management strategies were established to effectively manage the transfer of data from field collection to the desktop for data interpretation and analysis.

The primary objective of data management for the Chloride Impact Study was to adhere to the following principles.

- Data Security – included the storage and maintenance of the datasets on Southeastern Wisconsin Regional Planning Commission (Commission) servers and protection against data loss
- Data Accessibility – included the systematic organization and documentation of data such that the data were accessible as needed and available in a format that was both usable and understandable
- Data Consistency – included the strategies and standardized processes that were performed at regular intervals to develop the datasets in a clear and repeatable manner
- Data Quality – included the processes employed throughout the data collection period and during post-processing to discover and resolve data issues and ensure that the quality of the data collected was adequate for Study purposes

Several protocols and procedures were developed for the Chloride Impact Study to support data management objectives and principles. The protocols and procedures cover various aspects of the Study from field work and data collection to data management. Field work procedures were utilized throughout the Study to address pre-deployment equipment preparation and testing, monitoring site installation and maintenance, and monitoring site decommissioning. Field data collection procedures were employed to standardize water quality sample collection and documentation. Data management procedures facilitated the organization and handling of project-related data. Additionally, record-keeping procedures and checklists allowed for tracking project assets, workflows, and data.

This Chapter describes the general data management QA/QC protocols employed for the Chloride Impact Study along with the data management processes specific to the datasets collected and maintained by Commission staff. Furthermore, this Chapter discusses the post-processing of the continuous datasets collected at the stream monitoring sites.

4.2 DATA MANAGEMENT PROCESSES AND DOCUMENTATION

General best practices for data organization and storage were established early in the Study. These practices include frequent data transfers to the Commission network where data are stored on servers that are routinely backed up to protect against data loss; preserving a copy of the raw, unaltered datasets and download files; reviewing the data and preserving a copy of the data used in the QC review process; and summarizing the data to create workable datasets for further evaluation and analysis. Standardized naming conventions were established for data stored on the Commission network to aid in data accessibility and organization. Additionally, detailed documentation of field work activities, data collection, data summaries, and data management were maintained throughout the Study.

Monthly checklists and workflow processes were developed to track and standardize data collection and data management throughout the Study from site installation through site decommissioning. To promote efficiency and reduce errors/typos, templates were developed for some elements of data collection and data management. The incremental development and review of project datasets at regular intervals allowed for the identification of issues as they arose. Because the project generated substantial amounts of data on a daily basis, investing time on assembling and proofing datasets throughout the Study rather than waiting until the data collection phase was complete, was instrumental to producing quality datasets. The following sections describe the data management practices employed for various datasets collected throughout the Study, including the continuous datasets collected at stream monitoring sites, the handheld sonde data, and the water quality sample data and associated laboratory analysis results.

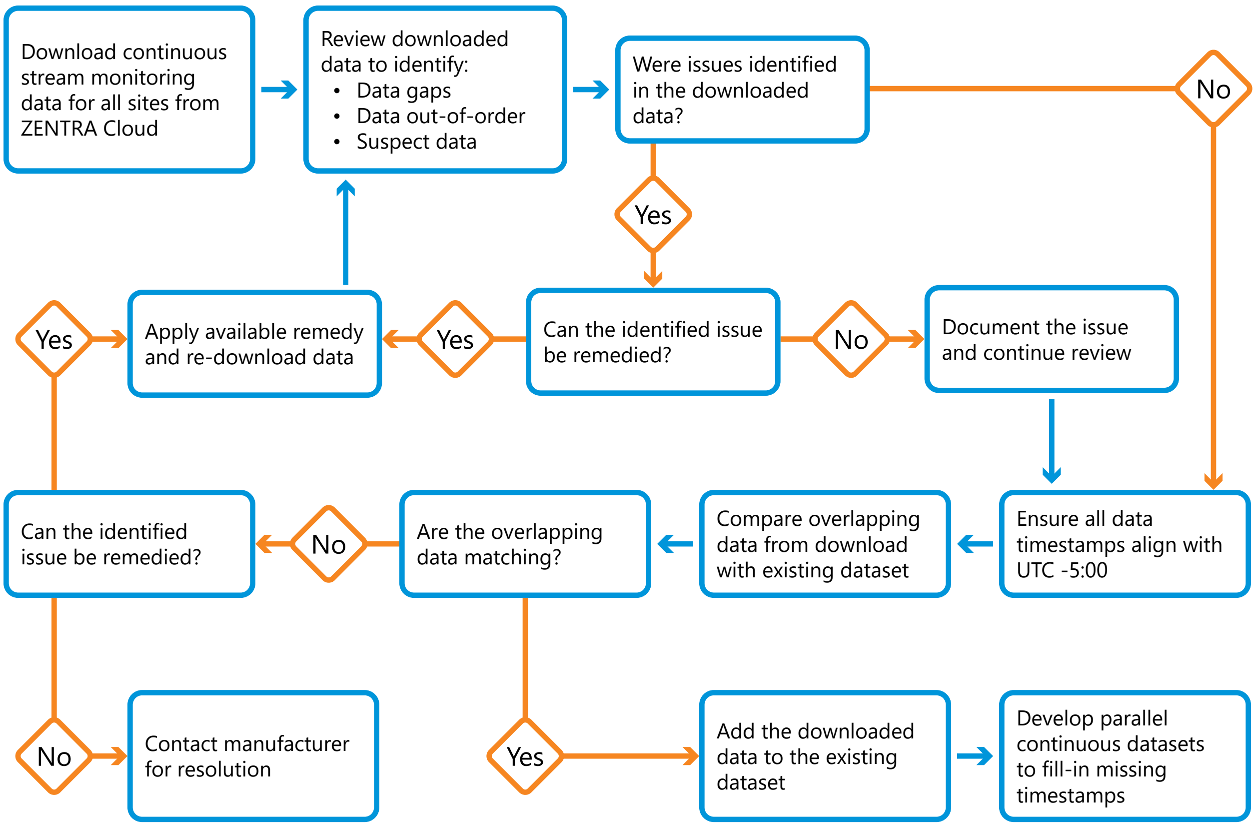
Continuous Datasets Collected at Stream Monitoring Sites

The equipment and methods used to collect in-stream data from the stream monitoring sites are presented in Chapter 3. Following the completion of the water quality sample collection each month, the data recorded at every stream monitoring site were downloaded from the ZENTRA Cloud, a cloud-based data storage system discussed in Chapter 3. To ensure the integrity of the data stored on the ZENTRA Cloud platform, the dates of each data download were specified to overlap several days with the previous download at each site to verify that the data for overlapping periods were consistently matching. Any differences between the overlapping data could indicate an issue with the cloud-based data storage system. The monthly download frequency allowed for reasonably efficient download speeds and helped limit the time spent retrieving data for every monitoring site in the Southeastern Wisconsin Region (Region). The raw data download files were preserved with Read-Only permissions on the Commission network and organized by download date and monitoring site.

Raw continuous datasets for the stream monitoring sites were constructed incrementally from the periodic downloads, starting from site installation through decommission. However, before the downloaded data were added to the raw continuous dataset for each site, the data were reviewed and evaluated for acceptability. The continuous monitoring data download and review process described in the following paragraphs is illustrated in Figure 4.1.

During review, the datasets were examined to identify data gaps, repeated data, data with timestamps out of chronological order, or suspect data that might indicate an issue with the equipment. The continuous datasets were subject to two different types of data gaps: sensor gaps occurred when the in-stream sensor was unable to communicate with the data logger, while telemetry gaps occurred when the data loggers were unable to either record data or upload data. Telemetry gaps could be caused by the loss of battery power or an equipment problem, preventing the device from recording data. Telemetry gaps could also occur when a device was unable to upload data to the ZENTRA Cloud platform due to an issue with the

Figure 4.1
Continuous Stream Monitoring Data Download and Review Process



Source: SEWRPC

communication components or problems with ZENTRA Cloud. For sensor gaps, the timestamps are present in the dataset during the sensor gap periods, but "NA" is displayed in place of the missing sensor data. In contrast, for telemetry gaps both the sensor data and timestamps are missing from the continuous record for each 5-minute interval over the data gap period. In rare cases, data recorded during a telemetry gap were saved on the data logger and were recovered by downloading the data directly from the data logger device in the field. The results of the reviews were documented, and separate QC files were maintained for project records. Problematic or unacceptable data were discussed with the equipment manufacturer and were typically resolved by the manufacturer's technical support team.[94] Periods of equipment malfunction, and other situations for which the questionable data could not be resolved, were flagged and noted.

If the downloaded data were considered acceptable, they were formatted and appended to the raw continuous dataset for each site. The raw continuous datasets did not adhere to the biannual time changes for Daylight Savings, and all of the timestamps were aligned with Central Daylight Time (CDT), which is 5 hours behind Universal Coordinated Time (UTC -5:00). To maintain consistency throughout the year, data collected during the winter months when the local time was aligned with Central Standard Time (UTC -6:00) were manually adjusted by one hour. This convention required careful coordination and documentation of the data downloads and manual adjustments used for timestamp conversions to ensure proper interpretation of the data and alignment with other datasets that are recorded using local time, which was observed using both standard time and daylight savings time. The ZENTRA Cloud platform evolved throughout the Study and programming updates included a timezone override function, allowing the user to select which timezone should be applied to the data. Commission staff utilized this function later in the Study to align the continuous data with UTC -5:00 prior to download, rather than manually adjusting the data downloaded for each monitoring site.

[94] *The equipment manufacturer, METER Group, was also the host of the ZENTRA Cloud data management platform as discussed in Chapter 3.*

The raw continuous datasets for the stream monitoring sites were not modified, with the exception of adjusting the timestamps by one hour for data that were recorded during local standard time. A parallel dataset was developed for each monitoring site using the R programming language with the "tidyverse" package to fill-in missing timestamp data.[95,96] This dataset provided a continuous data record with a complete set of date and time to be used for analysis. This dataset was referred to as the continuous CTD data with shared time intervals because every 5-minute interval during the study period was represented in the continuous dataset for each stream monitoring site. The timestamps that were filled in during telemetry gaps were assigned "NA" to represent the missing data. The format of the shared time interval datasets was similar to the raw continuous dataset, except the start date for every dataset was October 1, 2018, which was the first month of the routine monthly water quality sampling period for the Study.

Commission staff collaborated with other agencies such as the U.S. Geological Survey (USGS) and the Milwaukee Metropolitan Sewerage District (MMSD) to discuss issues with field deployment as well as data interpretation. Continuous data post-processing procedures are discussed later in this Chapter.

Sonde Data

The collection of handheld sonde data in the field is detailed in Chapter 3. The sonde data were downloaded at the end of each day of data collection. The daily frequency of data downloads from the mobile device used to the collect sonde data was initiated to reduce the risk for accidental data loss during field work. Copies of the raw data downloaded from the device were preserved and organized according to the collection date. The sonde data were reviewed and extracted from the raw data files and input into a summary spreadsheet. A sonde data summary spreadsheet was developed for each sampling period using a standardized format that facilitated further usage and analysis of the dataset. Sonde calibration reports, generated during the equipment calibration performed at the beginning of each day of water quality sampling, were maintained throughout the Study.

Water Quality Sample Collection and Laboratory Analysis Results

As discussed in Chapter 3, water quality samples were collected from streams and lakes across the Region and sent to the Wisconsin State Laboratory of Hygiene (WSLH) for chemical analysis. Lab datasheets and sample bottle labels were filled out consistently for each sampling period (see Appendix D). The lab datasheets were printed on water-resistant paper to minimize the risk of water damage in the field, and templates were created to utilize pre-filled fields that increased documentation efficiency and reduced the chance for errors. The forms were typically completed in the field after sample collection and were reviewed for completeness and compared to the sample collection bottle labels to ensure consistency. Any missing or suspect data were checked against the field book and other project documentation. Following review, the forms were scanned prior to submission to the WSLH, and the electronic copies were preserved for project records to support the tracking of water quality samples collected for the Study. A consistent file naming convention was established using the Sample ID which included information related to the site and the sample date and the files were organized by sampling period.

After collection, surface water quality samples were stored in a dedicated refrigerator at the Commission for no more than 7 days, as described in Chapter 3. Submissions to WSLH were timed to accommodate the lab schedule and to avoid exceeding the maximum holding time requirements for lab analyses. The samples were delivered directly to WSLH intake staff, at which time the individual lab datasheets and sample bottle labels were reviewed to ensure they matched, and custody of the water quality samples was officially transferred to WSLH.

The lab normally analyzed the water quality samples in batches, and the full set of samples from a given sampling period were often processed in multiple batches. In addition, individual analysis batches sometimes consisted of samples from stream monitoring sites along with lake samples. The lab analysis results for each sample batch were summarized in a single PDF file and transmitted via email by WSLH. The original WSLH PDF files were preserved on the Commission network. For each individual sampling period, the analysis results for each monitoring site were extracted from the separate WSLH-generated PDF files

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[95] *R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing. cran.r-project.org.*

[96] *H. Wickham, et al.,* "Welcome to the Tidyverse." *Journal of Open Source Software, 4 (43), 1686, 2019.*

and consolidated into a single PDF per sampling period. The lab results and comments were reviewed for errors and suspect data. Any issues discovered during review were discussed with WSLH staff for further investigation and correction when warranted.

The lab results were also transmitted directly from WSLH to the Wisconsin Department of Natural Resources (WDNR) Surface Water Integrated Monitoring System (SWIMS) database. Typically, these data were available for download from SWIMS the day after the lab released the PDF results. The lab data were routinely downloaded from SWIMS and the raw downloads were preserved on the Commission network. Each download was evaluated to check for missing samples and other issues. The individual downloads were used to construct a readily useable dataset. Commission staff collaborated with WDNR and WSLH staff to correct typographic errors and ensure that all of the lab results samples collected for the Study would be available for download from SWIMS using the project identification code (Project ID) to query the database.[97]

Chapter 3 describes the procedures used to collect water quality samples and the measures taken to avoid contamination or introducing bias during field collection. These quality assurance measures included the collection of field blank samples and replicate samples. As discussed in Chapter 3, field blanks were samples of distilled water, subject to the same conditions and sample collection processes as the routine water quality samples and submitted to the lab for analysis. The detection of analytes in a field blank sample could be an indication of contamination resulting from the sample handling process or through atmospheric exposure. Analytes were detected in a small number of the Study field blank samples. The detects were dispersed among several sites over different dates, showing no pattern temporally or spatially that would indicate a quality issue with the field procedures. The concentrations of analytes detected in field blanks were very low, typically between the limit of detection and limit of quantification. Furthermore, when compared to the routine monthly water quality samples, the detected analyte levels were insignificant and on the order of one percent or less when compared to the measured concentrations in the field samples. While the detection of analytes in a field blank sample could be an indication of contamination, the concentrations were so low that they would not have had an appreciable effect on the lab results and were considered acceptable for quality control purposes.

Similar to field blank samples, replicate samples were part of the QA/QC framework for the Study. Replicate samples were collected simultaneously with and in close proximity to routine field samples and were subject to the same conditions and processes, as detailed in Chapter 3. Because the field sample and replicate samples were not drawn or split from a common collection vessel, there could be differences in chemical composition between the two samples, given the heterogeneity of surface water flowing in the stream. The results for the replicate samples were compared to the corresponding field samples, and the replicate samples were considered acceptable if the relative percent difference (RPD) was less than or equal to 20 percent. Only one replicate sample failed to meet the acceptance criteria throughout the entire Study, with an RPD of approximately 30 percent for one analyte. For this particular replicate sample, the measured analyte concentration was approximately five times the limit of quantification, and with such a low concentration the elevated RPD of the replicate sample was considered acceptable. Another sample had five different analytes with RPD values ranging between 10 and 20 percent, and while the RPD levels were in the acceptable range, this sample was considered unique because of the number of analytes involved and was reviewed further. Documentation recorded in the field book for that sample revealed that high water levels at the monitoring site hampered the sample collection effort and prevented Commission staff from entering the stream. Under these circumstances, the samples were collected using the assisted sampler as described in Chapter 3 of this Report. As a result, the replicate sample could not be taken simultaneously with the field sample but instead was collected a short time later. This deviation in the sample collection time is likely the cause of the differences in the sample analysis results and was considered an isolated occurrence rather than an indication of a problem with the sample collection process. Furthermore, there were no discernable patterns or trends identified in the lab results for field blank samples or replicate samples and thus no indication of a widespread quality issue.

[97] *The SWIMS database Project ID for the Chloride Impact Study for the Southeastern Wisconsin Region is GLPF2018_LM1802_CS.*

Additional Documentation

Additional documentation maintained throughout the Study included a comprehensive accounting of field work activities and logs, data collection, data summaries, and data management. Field work documentation included maintaining a field visit log, which was the electronic version of the field book. The field visit log summarized all the site visit work notes for water quality sampling, equipment cleaning and maintenance, battery changes, water depth measurements, and any other relevant site or equipment information. A separate water sampling log was maintained to summarize the detailed sampling data collected during each sampling period. Data were regularly transferred from the field books into these logs, which prevented accidental data loss and provided readily accessible field information for Commission staff that may not otherwise have access to the physical field books. Additionally, weather logs were maintained during each winter season throughout the Study to document winter weather events and provide anecdotal information related to the regional distribution, type of precipitation, and estimated precipitation quantities when available. These weather logs were useful for data interpretation.

Commission staff maintained detailed equipment records tracking the equipment purchased and deployed for the Study. The equipment logs included information related to the equipment types, identification numbers, configuration specifications, and deployment locations and dates. The equipment logs also tracked equipment issues and replacements. Data recorded on a data logger remains associated with that specific device on the ZENTRA Cloud platform; therefore, it was necessary to track equipment movements, particularly for equipment deployed at multiple sites over the course of the Study, to ensure that the data downloaded from individual data loggers were attributed to the correct monitoring site. In order to construct a continuous dataset for a particular monitoring site, a record of the different equipment deployed at each site was necessary. A separate battery status log was maintained for the data logger devices to monitor battery conditions at certain sites where drastic drops in battery power created problems for the equipment and data collection. As discussed in Chapter 3, battery loss posed a risk for data loss, especially during the colder months of the year when the batteries drained more rapidly.

During the field data collection phase of the Study, documentation was maintained to verify equipment operation and performance. Following data collection, these data summaries were also useful for data interpretation. As described in Chapter 3, the depth of water above the CTD-10 sensor was measured during each field visit. A spreadsheet was developed to compare the field depth measurements with the simultaneous depth reading from the CTD-10 sensor and evaluate the performance of the pressure sensors throughout the Study. These summaries allowed Commission staff to identify large differences or diverging trends that would lead to the replacement of the CTD-10 sensors when necessary. During each field visit, a handheld sonde was used to collect specific conductance data, as detailed in Chapter 3. To evaluate the CTD-10 performance, a spreadsheet was created to compare the sonde data with the specific conductance simultaneously recorded by the CTD-10. Differences greater than the CTD-10 sensor accuracy (plus or minus 10 percent) were an indication of potential sensor fouling, and the CTD-10 sensors were prioritized for cleaning and maintenance. The documentation kept for cleaning and maintenance visits provided additional information related to equipment performance. The specific conductance and water depth data observed by the CTD-10 sensor immediately before and after the sensor cleaning were summarized in a spreadsheet and the percent difference was computed. Large changes in specific conductance before and after a sensor cleaning were an indication that the CTD-10 had been fouled, buried, or was performing poorly prior to the cleaning. The before and after cleaning data summary was instrumental for post-processing of the continuous datasets, described later in this Chapter.

Some of the project documentation included data summaries that would be useful for further evaluation and analysis. One of these documents was the River Sample Master Table, which summarized three datasets: the lab analysis results for water quality samples, the corresponding data collected in-stream by the CTD10 sensor, and the handheld sonde data recorded at the time of the sample. A single datapoint was manually selected from the continuous specific conductance dataset to pair with the lab data. Typically, the specific conductance data was chosen to match the timing of the water quality sample collection; however, site visits during which the sensor was cleaned or adjusted, the specific conductance datapoint was selected after the sensor disturbance. The River Sample Master Table summary also served as a QC review tool to ensure consistency across the datasets.

4.3 CONTINUOUS DATA POST-PROCESSING

Chapter 3 described how the Chloride Impact Study used CTD-10 sensors at stream monitoring sites to collect specific conductance, temperature, and water level data measurements at five-minute intervals. Rivers and streams are dynamic environments where water quality conditions can fluctuate rapidly. Using sensors to collect continuous data can provide researchers with a high-resolution dataset to capture these rapidly changing conditions; however, aquatic environments can have deleterious effects on electronic sensors. The growth of biofilms, algae, resident invertebrates, and the accumulation of sediment on the sensor and in the sensor housing, are examples of sensor fouling that erode the ability of the sensor to record accurate measurements over time. Consequently, CTD-10 sensor data needed to be reviewed carefully and, when appropriate, adjusted for fouling to produce the high quality datasets to be used for future Study analyses.

This Study used methods that were modified from the USGS Guidelines and Standard Procedures for Continuous Water-Quality Monitors to adjust data due to sensor fouling.[98] This is an accepted practice to adjust for sensor issues that can arise between monitoring site visits. These methods assume that fouling takes place at a constant rate over time. The data adjustment method used for this Study also assumed that a CTD-10 sensor was recording accurate readings after being cleaned during a field maintenance or monthly water sampling visit. This assumption was necessary because the CTD-10 sensors cannot be calibrated in the field. Occasionally, a large disparity was recorded between sensor readings before and after cleaning. These differences were an indication of potential sensor fouling. This section describes the methods and procedures used to identify and adjust CTD-10 sensor data affected by sensor fouling during the Chloride Impact Study.

Examination of Continuous Datasets

Commission staff initially examined the record of each stream monitoring site individually to locate common signatures in the data. Each record was plotted using the dygraph package in R.[99] This package creates interactive plots that allow the user to adjust the scaling of the axes, in order to view the entire time series or any portion of the time series in detail. The plots were constructed by graphing water level and specific conductance data that were collected by the CTD-10 sensors on separate vertical axes and time on the horizontal axis for the entire period of record.

Simultaneous visualization of specific conductance and water level highlighted the relationship between the two variables and was critical to the process of identifying data potentially affected by fouling. Specific conductance measures the ability of water to conduct electricity. Water level is related to the amount of water flowing in the stream. In many situations, there is an inverse relationship between specific conductance and water level. As the amount of water flowing in a stream increases, water levels rise. Under some conditions this increase in water volume will dilute the number of ions in the water, causing a decrease in specific conductance. Figure 4.2 shows an example of this dilution effect that was observed during a precipitation event at a stream monitored for this Study. When the amount of water entering the stream due to the rainfall and runoff decreased, water levels receded, and specific conductance levels typically rebounded. Additionally, a different signal may occur under other conditions. For example, during spring thaw in an urbanized area, water from melting snow may transport additional chloride to waterways. Under these conditions, specific conductance may increase as water levels increase.

The examples given in the previous paragraph highlight the importance of using other types of information to interpret the specific conductance and water level signatures shown in the visualizations. During examination of the CTD-10 sensor data, Commission staff consulted other references as needed. These references included field books containing notes on the condition of the sensors, a weather logbook describing localized precipitation events, and National Weather Service records.

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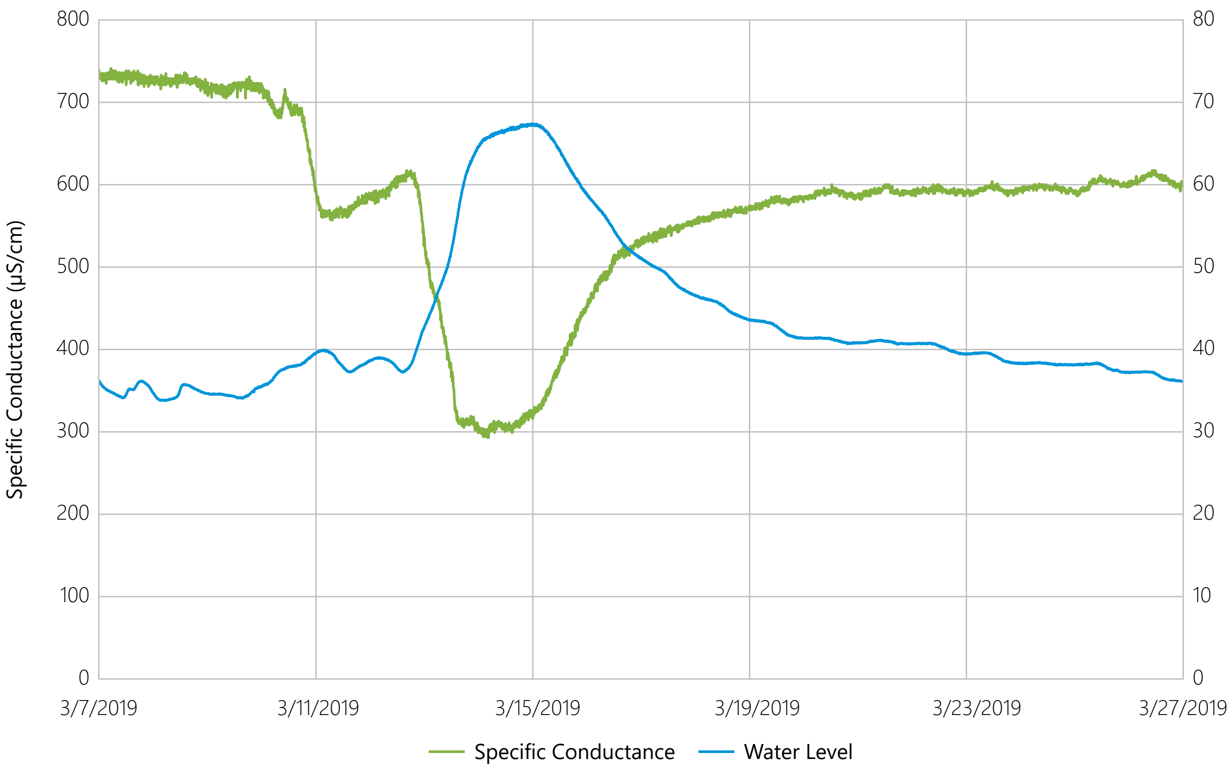
[98] *R.J. Wagner, R.W., Boulger, Jr., C.J. Oblinger, and B.A., Smith,* Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting*, U.S. Geological Survey Techniques and Methods 1-D3, 2006.*

[99] *D. Vanderkam, J.J. Allaire, J. Owen, D. Gromer, and B. Thieurmel,* Dygraphs: Interface to 'Dygraphs' Interactive Time Series Charting Library. *R package version 1.1.1.6, 2018.*

Figure 4.2
Stream Water Level and Specific Conductance During a Precipitation Event



Source: SEWRPC

Identification of Data Signatures

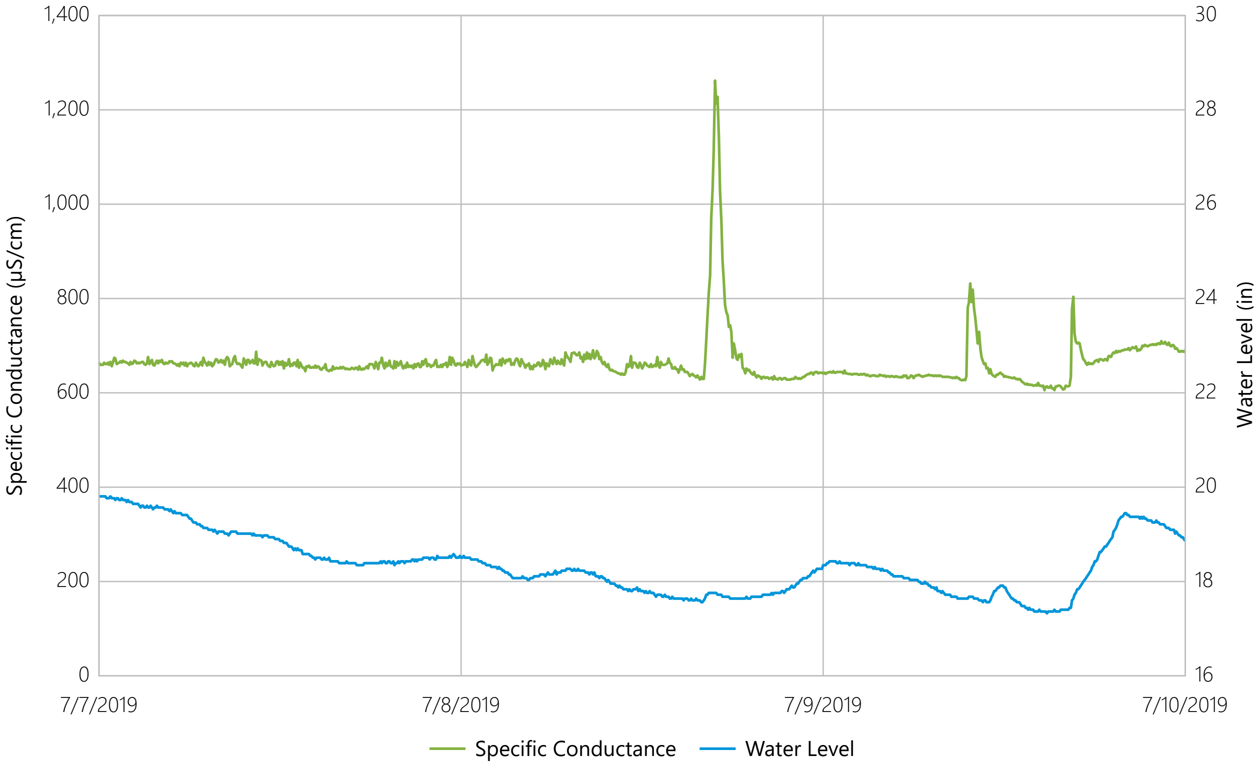
Each monitoring site dygraph was initially examined to identify and define common signatures in the data for each site. The most common data signatures and the frequency at which each occurred were recorded in a spreadsheet. The most commonly observed signatures throughout the CTD-10 continuous datasets for all monitoring sites were referred to as spikes, noise, teeth, and dampened data.

A spike in the continuous dataset is characterized by an unusually high, short duration increase in specific conductance that rapidly returns to its prior level (see Figure 4.3). Spikes that had greater than 25 percent divergence from the initial reading were investigated further, as such spikes could result from legitimate increase in conductance caused by the first flush of chloride-laden runoff into the stream due to a precipitation event. The majority of the specific conductance spikes examined were explained by changes in water level or in the meteorological records and did not require any adjustment. When a water level increase or weather event did not precede the spike, it was flagged as potentially erroneous data. Given their short duration, spikes are likely to have little effect on future analyses for this Study. Because of this, no adjustments were made to specific conductance spikes in the Study dataset.

Noise in the data was defined by repeated high frequency fluctuations in specific conductance (see Figure 4.4). Some noise events in the CTD-10 dataset lasted for a few hours, while others lasted for weeks or months. The cause of these fluctuations could not be identified. Potential explanations include radio frequency interference or invertebrates interfering with the electrodes in the sensor, but these hypotheses could not be substantiated. The short duration and relatively small magnitude of individual fluctuations during noise events suggested that noise would have limited impact on analyses for this Study. Because of this, no adjustments were made to noise in the continuous specific conductance datasets.

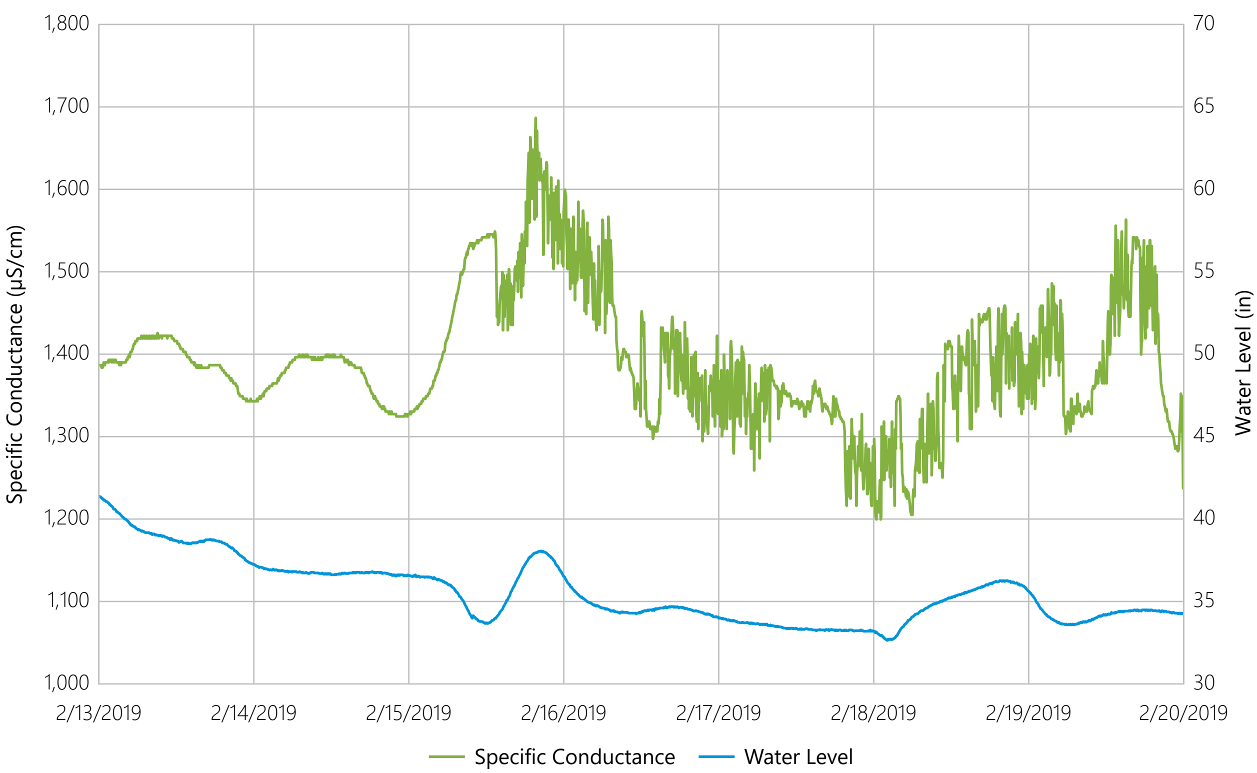
A tooth in the data was characterized by sudden decrease or increase in specific conductance followed by a period during which conductance remains at the lower or higher level. This period is followed by a sudden return to the original level (see Figure 4.5). Tooth-type signatures were identified when changes in measured specific conductance of at least 10 percent occurred over periods of 15 minutes or less. These

Figure 4.3
Example of Specific Conductance Spike Data Signature



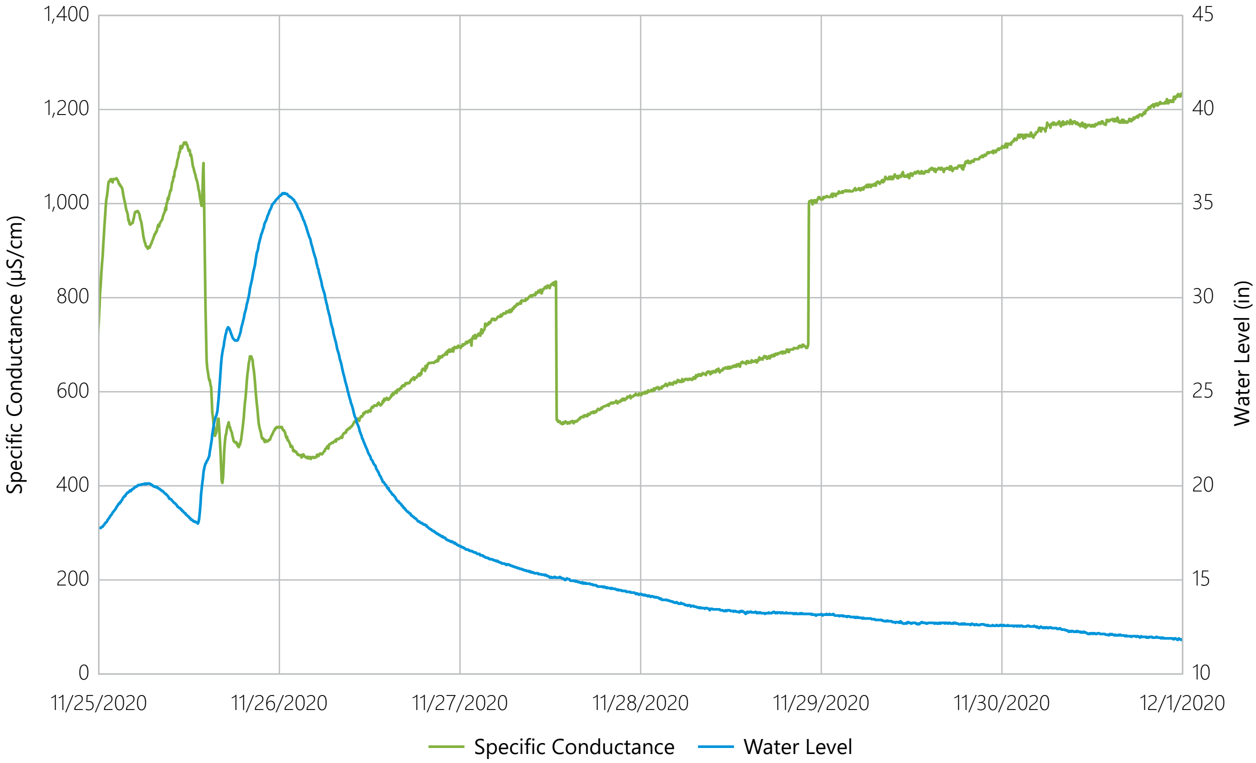
Source: SEWRPC

Figure 4.4
Example of Specific Conductance Noise Data Signature



Source: SEWRPC

Figure 4.5
Example of Specific Conductance Tooth Data Signature



Source: SEWRPC

were less common than some of the other signatures and only five instances of this example were recorded. The cause of this data signature could not be identified. Because of their rarity, no adjustments were made to the continuous specific conductance datasets for these instances.

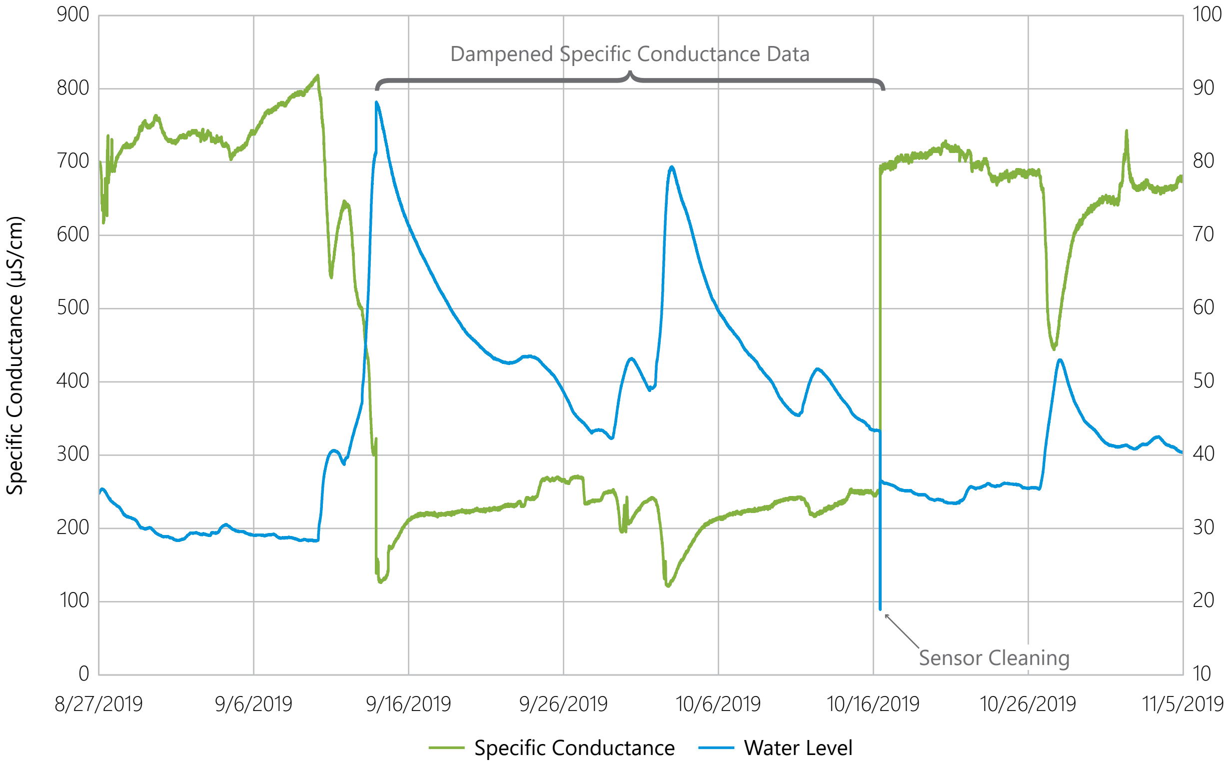
Dampened data was characterized by magnitudes of specific conductance that were unusually low given the other data at the site and the specific hydrologic context (see Figure 4.6). The amplitude of fluctuations in specific conductance was also often reduced during dampening. Three signatures in the specific conductance data suggested that dampening might be affecting readings. First, a large increase in specific conductance following cleaning of a CTD-10 sensor was considered a sign of dampening. Second, failure of the specific conductance readings to recover to the pre-event level following a hydrologic event was an indication that the CTD-10 sensor data were dampened. Third, specific conductance readings taken by the handheld sonde that were substantially higher than those taken simultaneously by the CTD-10 sensor were signs of potential dampening.[100] The presence of more than one indicator was considered stronger evidence of potential dampening. The dampened data was likely the result of CTD-10 sensor fouling that affected the performance of the CTD-10 sensor and lowered specific conductance readings. Since this artificial lowering of specific conductance could lead to underestimates of calculated instream chloride concentrations, instances of dampened data due to sensor fouling were investigated as described in the following section.

Identification and Interpretation of Sensor Fouling

Considering the challenges inherent to long-term, in-stream water quality monitoring, sensor fouling was expected as the CTD-10 sensors were exposed to conditions that can affect the accuracy of the recorded measurements over time. Several steps were taken during continuous data post-processing to verify sensor fouling. First, periods of potential sensor fouling were identified in the continuous specific conductance

[100] *As noted in Chapter 3, the handheld sonde was calibrated daily before field visits and the sonde data had higher accuracy than the CTD-10 data. In some instances, the locations at which sonde readings were taken were some distance from the CTD-10 sensor. In those instances, a difference between the sonde and CTD-10 readings was not considered an indicator of fouling.*

Figure 4.6
Example of Dampened Specific Conductance Data Signature



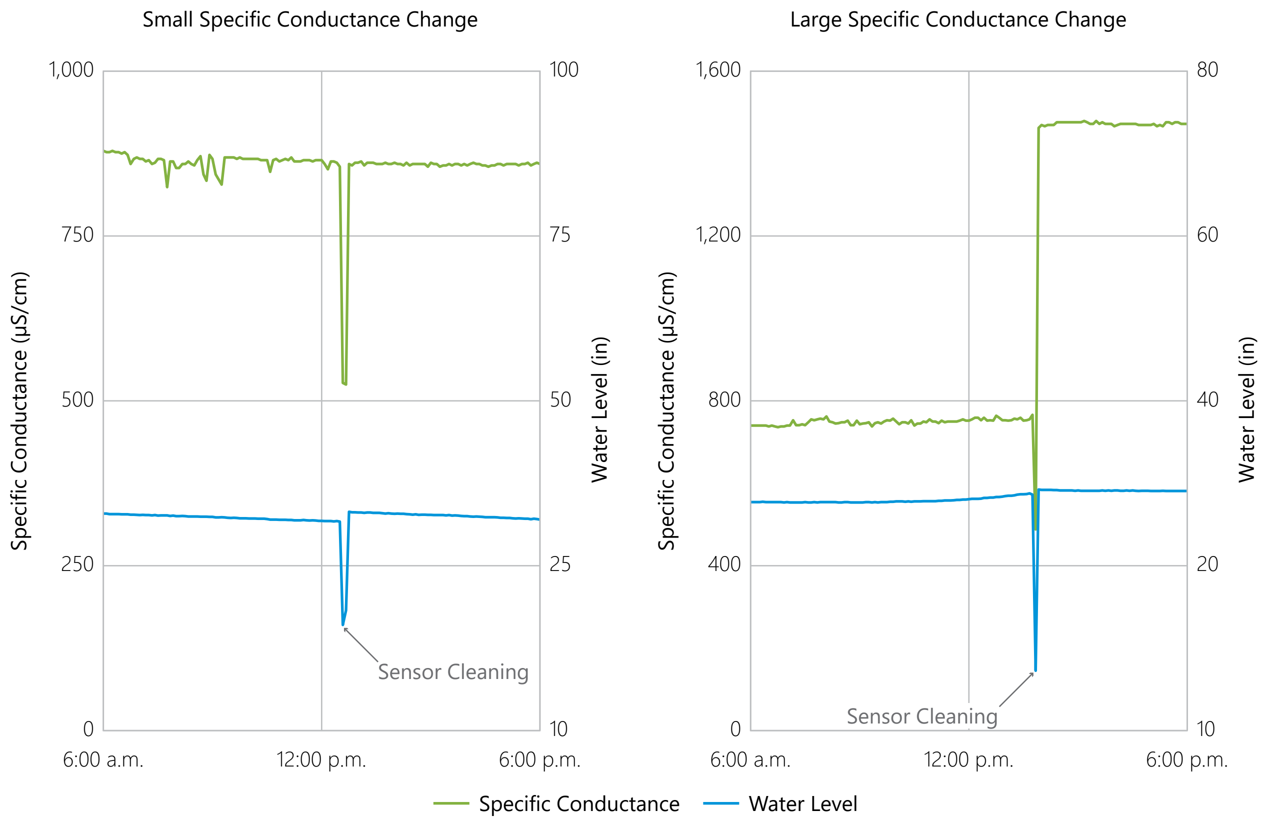
Source: SEWRPC

datasets. Further investigation was performed to estimate the magnitude and duration of the sensor fouling, and to determine a cause. Finally, this information was evaluated to determine whether it would be appropriate to adjust the data affected by sensor fouling using the methodology described later in the Data Adjustment Calculation and Application Procedures section.

Sensor fouling was typically identified by reviewing data from site visits during which the CTD-10 sensor was replaced, cleaned, or otherwise maintained. As previously mentioned, large differences in specific conductance values measured by the sensor before and after maintenance were an indication that the sensor had been fouled or was performing poorly prior to the site visit. Figure 4.7 illustrates some typical data signatures observed in the continuous datasets during a sensor cleaning, showing how the specific conductance and water level data abruptly decreased to near zero while the sensor was removed from the stream for maintenance. The figure also demonstrates how sensor maintenance can affect specific conductance measurements, comparing small and large differences in specific conductance values before and after cleaning.

The extent of sensor fouling was estimated based on the magnitude of the change in specific conductance values prior to and following CTD-10 sensor replacements and equipment maintenance. Specific conductance changes of less than 10 percent fall within the range of sensor accuracy and were not considered for data adjustment, even if there was additional evidence in the field notes that the sensor had been fouled. When the difference in specific conductance before and after CTD-10 sensor cleanings was greater than 10 percent, the specific conductance data were assumed to be affected by significant sensor fouling and were considered for data adjustment using the procedure describe in the next section. Typically, when the change in specific conductance resulting from a sensor cleaning was greater than 50 percent, the data prior to the cleaning were not considered for data adjustment as these data were deemed too greatly impacted to be adjusted. In these situations, the affected data were flagged such that concerns about the accuracy of the specific conductance readings could be reviewed for subsequent Study analyses. Furthermore large, abrupt changes in specific conductance that occurred between site visits were not considered candidates for data adjustment.

Figure 4.7
Examples of Data Signatures Associated with CTD-10 Sensor Cleanings



Source: SEWRPC

Following the identification of suspected sensor fouling, the specific conductance and water level data records preceding the site visit were inspected in order to estimate the duration of sensor fouling. The inspection sought to identify a potentially significant fouling event that occurred between site visits to establish a starting point for the sensor fouling. For example, the start of sensor fouling occasionally appeared to coincide with a large flooding event. If a specific event causing fouling could not be clearly identified, sensor fouling was assumed to begin after the previous sensor cleaning or deployment. The periods of data suspected to be affected by sensor fouling were further investigated using several resources to try to determine a cause of the sensor fouling. Notes recorded in the field book during site visits provided information related to the condition of the sensor and relevant site conditions. Meteorological data and streamflow data, where available, were useful for identifying initiating conditions for sensor fouling. In general, when a cause of sensor fouling could not be determined or explained, the affected data were not considered for data adjustment.

Information obtained through the investigation of suspected periods of sensor fouling was evaluated in context with other site data and individual site characteristics to determine whether portions of the continuous specific conductance datasets should be considered for data adjustment. For the periods of suspected sensor fouling that were considered candidates for data adjustment, the estimated magnitude and duration of sensor fouling were used in the data adjustment procedure described in the next section.

Data Adjustment Calculation and Application Procedures

Modifications to the continuous specific conductance datasets were considered only after rigorous review and verification using the evidence that was described in the previous two sections. Specific conductance data were considered for adjustment in those cases where there was strong evidence that the CTD-10 sensor had been fouled.

This Study used methods to adjust data affected by sensor fouling that originated in the guidelines and standard procedures for continuous water quality monitoring developed by the USGS in 2006 and a separate study that expanded upon these methods in 2011.[101, 102] An R programming package named driftR was developed based on these methods.[103] This software package provides a free, publicly available open-source option for adjusting data affected by sensor drift, which can be caused by fouling. Commission staff used driftR to assist with adjustments of dampened datasets collected for this Study. The same adjustment procedure was used for this Study regardless of the severity or type of sensor fouling.

The data adjustment procedure makes two assumptions. First, the procedure assumes that fouling happens linearly over time. For any given specific conductance value in a data record:

$$f_t = \left(\frac{t}{\sum t}\right)$$

Where:
f_t = adjustment factor
t = interval of time from the start of the fouling
$\sum t$ = total duration of fouling

This equation creates a time-weighted factor that adjusts the data for increased error due to fouling over the period affected. Because of the time-weighting, the data at the beginning of the fouling period are adjusted less than the data at the end of the fouling period.

Second, the procedure assumes that the values read by the CTD-10 sensor after being cleaned were accurate, in lieu of field calibration.[104] This post-cleaning specific conductance value was used as a calibration standard to create a one-point adjustment using the factor calculated in the previous equation. The adjusted specific conductance is expressed as:

$$C = m + f_t\,(s_i - s_f)$$

Where:
C = adjusted value of the specific conductance
M = raw specific conductance data value
s_i = specific conductance value from the cleaned sensor
s_f = specific conductance value from immediately before the sensor was cleaned

The calculations for the data adjustment were performed by the driftR program. Data for the affected duration and the specific conductance values before and after the cleaning of the sensor were entered into the program. The software calculated an adjusted value for each reading in the portion of the data record that was affected by fouling which can be seen represented in orange in Figure 4.8.

The adjusted data were reviewed visually using dygraphs that show both the raw and corrected specific conductance data. This review examined whether the adjusted data followed patterns similar to those in data records not affected by fouling. These patterns included whether specific conductance fluctuations occurred in response to hydrological events and whether patterns were similar to those observed elsewhere in the data record. Table 4.1 summarizes the portions of the specific conductance datasets for which adjustments were made.

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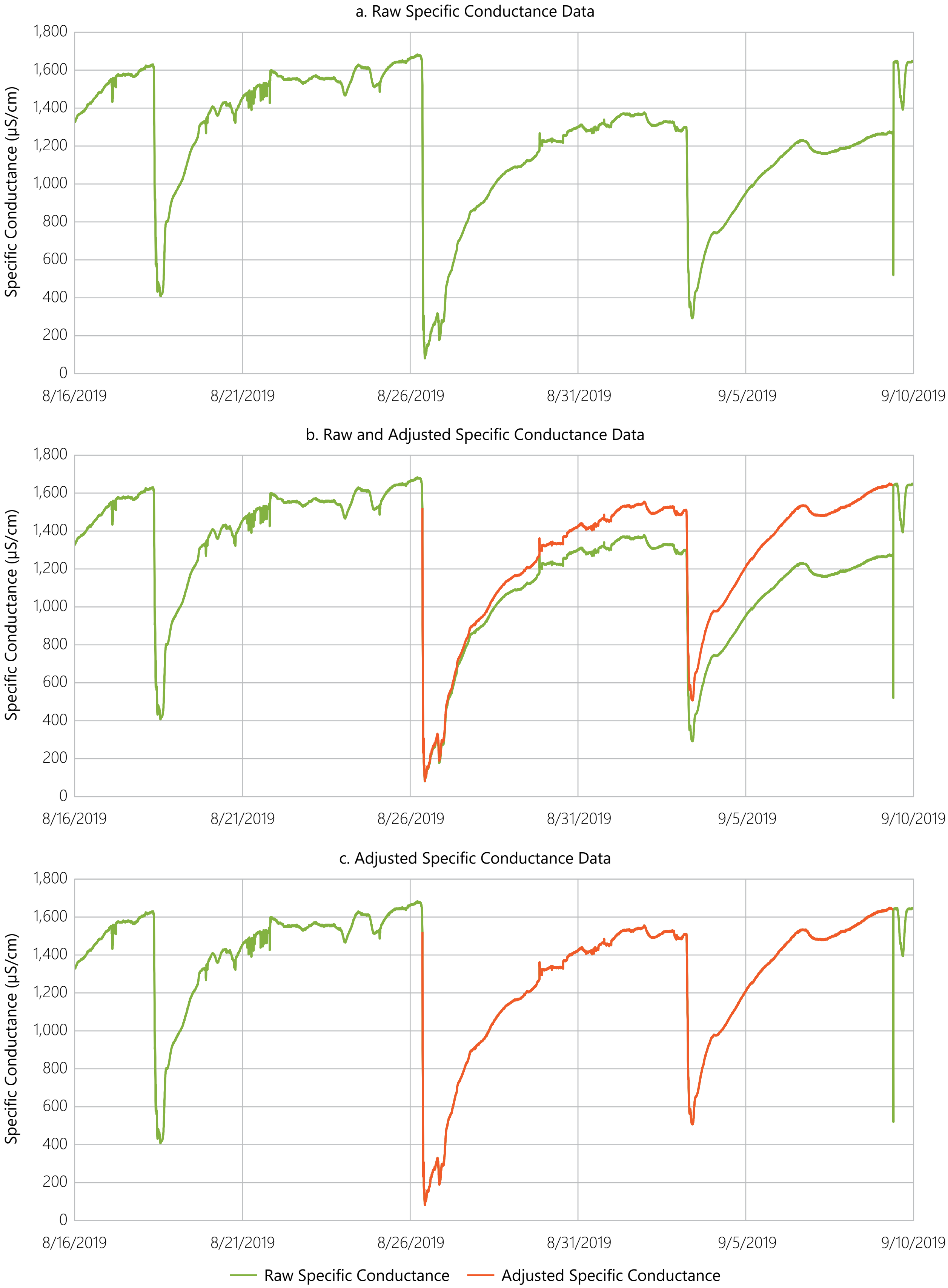
[101] *Wagner, Boulger, Jr., Oblinger, and Smith, 2006,* op. cit.

[102] *E.A. Hasenmueller,* "The hydrology and geochemistry of urban and rural watersheds in east-central Missouri," *Washington University in St. Louis, 2011.*

[103] *A.R. Shaughnessy, C.G. Prener, and E. A. Hasenmueller, "An R Package for Correcting Continuous Water Quality Monitoring Data for Drift," Environmental Monitoring and Assessment, 191:1-10, 2019.*

[104] *The CTD-10 sensors were factory-calibrated and could not be calibrated in the field; therefore, a cleaned sensor was assumed to be reading as accurately as a calibrated sensor.*

Figure 4.8
Specific Conductance Data Adjustment Example



Source: SEWRPC

Table 4.1
Summary of Data Adjustments

Site ID	Site Name	Adjustment Start (CDT)[a]	Adjustment End (CDT)[a]	Specific Conductance Difference[b] (μS/cm)	Adjustment Span (days)	Percent of Total Record Adjusted[c]
3	Mukwonago River at Mukwonago	2019-03-14 12:00:00	2019-04-09 10:50:00	86	26.0	3.4
4	Sugar Creek	2018-10-01 00:00:00	2018-10-19 11:00:00	122	18.5	7.4
		2019-03-12 18:00:00	2019-04-10 11:10:00	80	28.7	
		2019-09-10 07:00:00	2019-09-19 10:20:00	169	9.1	
8	Pewaukee River	2019-05-23 15:55:00	2020-05-12 11:10:00	262	354.8	46.6
9	Oak Creek	2020-08-02 15:20:00	2020-10-08 15:55:00	397	67.0	7.6
10	Pike River	2018-10-30 18:05:00	2018-11-12 13:10:00	127	12.8	7.9
		2019-04-15 12:30:00	2019-06-11 11:55:00	109	57.0	
11	Bark River Upstream	2019-03-13 12:40:00	2019-04-09 13:55:00	134	27.1	10.3
		2019-04-22 23:20:00	2019-06-13 11:50:00	107	51.5	
13	Ulao Creek	2020-03-28 22:20:00	2020-04-07 09:55:00	435	9.5	3.6
		2020-05-17 09:35:00	2020-06-15 13:35:00	185	29.2	
14	Sauk Creek	2019-06-12 19:40:00	2019-06-14 13:00:00	180	1.7	11.4
		2019-09-13 17:35:00	2019-09-20 14:10:00	170	6.9	
		2020-07-09 20:25:00	2020-10-09 09:20:00	104	91.5	
15	Kilbourn Road Ditch	2018-10-10 17:00:00	2018-12-12 13:00:00	103	62.8	14.2
		2019-03-14 04:45:00	2019-04-15 11:25:00	344	32.3	
		2020-09-08 16:20:00	2020-10-08 11:45:00	290	29.8	
16	Jackson Creek	2018-10-06 01:35:00	2018-10-12 12:00:00	72	6.4	0.8
18	Oconomowoc River Upstream	2019-02-01 01:30:00	2019-04-09 14:25:00	101	67.5	17.2
		2020-03-09 16:55:00	2020-05-12 10:15:00	185	63.7	
20	Oconomowoc River Downstream	2020-03-08 23:25:00	2020-07-16 12:40:00	203	129.6	17.0
21	East Branch Milwaukee River	2019-03-17 07:15:00	2019-06-03 11:25:00	119	78.2	10.3
23	Milwaukee River Downstream of Newburg	2019-03-13 17:00:00	2019-04-08 12:00:00	59	25.8	3.4
25	Root River Canal	2018-10-01 00:20:00	2018-10-24 14:50:00	376	23.6	3.9
		2018-12-01 18:00:00	2018-12-12 13:35:00	121	10.8	
28	East Branch Rock River	2018-10-30 16:30:00	2018-12-07 11:50:00	135	37.8	11.9
		2019-07-20 12:25:00	2019-09-11 11:25:00	97	53.0	
30	Des Plaines River	2019-10-27 06:20:00	2019-11-20 11:40:00	235	24.2	2.7
32	Turtle Creek	2018-12-21 00:35:00	2019-04-12 11:55:00	248	112.5	19.5
		2020-03-09 14:40:00	2020-04-14 11:20:00	162	35.9	
33	Pebble Brook	2020-06-22 21:45:00	2020-10-07 10:35:00	131	106.5	14.0

Table continued on next page.

Table 4.1 (Continued)

Site ID	Site Name	Adjustment Start (CDT)[a]	Adjustment End (CDT)[a]	Specific Conductance Difference[b] (μS/cm)	Adjustment Span (days)	Percent of Total Record Adjusted[c]
36	Honey Creek Downstream of East Troy	2018-10-01 12:30:00	2018-10-19 11:40:00	237	18.0	2.4
38	North Branch Milwaukee River	2019-07-20 12:20:00	2019-09-24 11:00:00	83	65.9	8.7
40	Stony Creek	2019-03-14 06:30:00	2019-04-08 13:00:00	86	25.3	3.3
41	Milwaukee River near Saukville	2019-03-13 14:00:00	2019-04-08 11:10:00	246	25.9	9.3
		2020-08-25 07:00:00	2020-10-09 10:20:00	80	45.1	
47	Fox River at Rochester	2019-03-14 11:40:00	2019-04-10 10:35:00	92	27.0	3.5
51	Rubicon River	2019-09-10 02:00:00	2019-09-11 12:10:00	155	1.4	13.1
		2019-10-01 09:20:00	2020-01-14 15:20:00	215	105.3	
		2020-06-20 12:25:00	2020-06-25 11:45:00	104	5.0	
53	Honey Creek at Wauwatosa	2019-08-26 08:40:00	2019-09-09 09:25:00	376	14.0	7.3
		2020-05-17 04:00:00	2020-07-06 13:35:00	206	50.4	
54	Whitewater Creek	2019-02-03 14:20:00	2019-04-12 10:55:00	130	67.9	21.8
		2020-07-13 11:05:00	2020-07-22 10:35:00	161	9.0	
		2020-07-22 10:45:00	2020-10-19 11:30:00	112	89.0	
55	Bark River Downstream	2019-03-09 17:00:00	2019-04-09 12:20:00	343	30.8	15.7
		2020-07-09 19:15:00	2020-10-06 13:40:00	80	88.8	
57	Menomonee River at Wauwatosa	2020-05-17 03:50:00	2020-06-15 10:20:00	226	29.3	8.7
		2020-08-02 21:30:00	2020-08-10 10:35:00	-80	7.5	
		2021-04-11 22:50:00	2021-04-15 11:50:00	257	3.5	
		2021-05-04 11:55:00	2021-05-12 11:20:00	702	8.0	
58	Milwaukee River at Estabrook Park	2021-05-03 20:00:00	2021-05-12 11:55:00	76	8.7	1.6
59	Root River near Horlick Dam	2018-10-03 00:00:00	2018-10-16 12:10:00	316	13.5	6.6
		2020-08-10 22:45:00	2020-10-08 14:05:00	266	58.6	
87	Underwood Creek	2021-04-10 17:10:00	2021-04-26 16:55:00	464	16.0	7.5

[a] *Central Daylight Time (CDT) or UTC -5:00.*

[b] *The specific conductance difference is calculated by subtracting the specific conductance value immediately before the sensor was cleaned (s_f) from the specific conductance value immediately after the sensor was cleaned (s_i).*

[c] *Considering all 41 stream monitoring sites, approximately 8 percent of the entire specific conductance continuous dataset was adjusted overall.*

Source: SEWRPC

APPENDICES

APPENDIX A

REQUEST LETTER FOR PRIVATE LAND ACCESS

COPY

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

W239 N1812 ROCKWOOD DRIVE • PO BOX 1607 • WAUKESHA, WI 53187-1607 • TELEPHONE (262) 547-6721
FAX (262) 547-1103

Serving the Counties of: KENOSHA
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OZAUKEE
RACINE
WALWORTH
WASHINGTON
WAUKESHA

Date

«Title» «First» «Last»
«Job_Title»
«Company»
«Business_Address_Street»
«Business_Address_City», «Business_Address_State» «Business_Address_Postal_Code»

Dear «Title» «Last»:

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has initiated a Chloride Impact Study for the Southeastern Wisconsin Region. As part of this study SEWRPC staff will install sensors in streams in the seven-county Region. A white telemetry unit will accompany each sensor and be placed within 25 feet of the stream bank. The telemetry unit transmits the water quality data using cell communication. Depending on site conditions, the telemetry unit may be placed on a six foot metal fence post or on a nearby tree using cable ties. Cables with PVC casing will run along the bank and connect the telemetry unit to the sensor at the bottom of the stream. A picture of the proposed telemetry unit is attached as Exhibit A.

The sensors and telemetry will continuously monitor the stream for two full years (2018-2020). Chloride concentrations will be derived from the data using monthly in-stream sampling. Additional and ongoing information on the study can be found at www.sewrpc.org/chloridestudy. This information will be of benefit to the region generally, and it would be useful in identifying the water quality of the stream adjacent to your property.

The purpose of this letter is to obtain permission to place the telemetry unit on your property at ____________ for the two year study period, and to allow SEWRPC staff access to maintain the telemetry unit as needed. The approximate location is shown on the map attached as Exhibit B. Staff will walk along the stream to access the telemetry unit on your property. SEWRPC will hold you harmless from any injury suffered by SEWRPC staff while on your property.

Upon completion of the study, the telemetry unit and cables will be fully removed from your property. SEWRPC does not anticipate any disturbance to your property, but SEWRPC will refill any stake holes and reasonably repair any other damage due to placement of the equipment.

If you have any questions regarding this request or would like to meet with staff in the field to review the proposed location, please contact Laura K. Herrick, Chief Environmental Engineer, at lherrick@sewrpc.org or 262-953-3224.

If permission is granted or denied, please sign as indicated at the bottom of this page and return the signed copy in the enclosed envelope for our records. We appreciate your willingness to consider providing support for this important study.

Sincerely,

Michael G. Hahn, P.E., P.H.
Executive Director

Enclosures

Property Address:

Address: ____

City: _______________________________ State: _____________ Zip: ______________

ACCESS PERMISSION GRANTED:

_______________________________________ Date ____________________________
Name

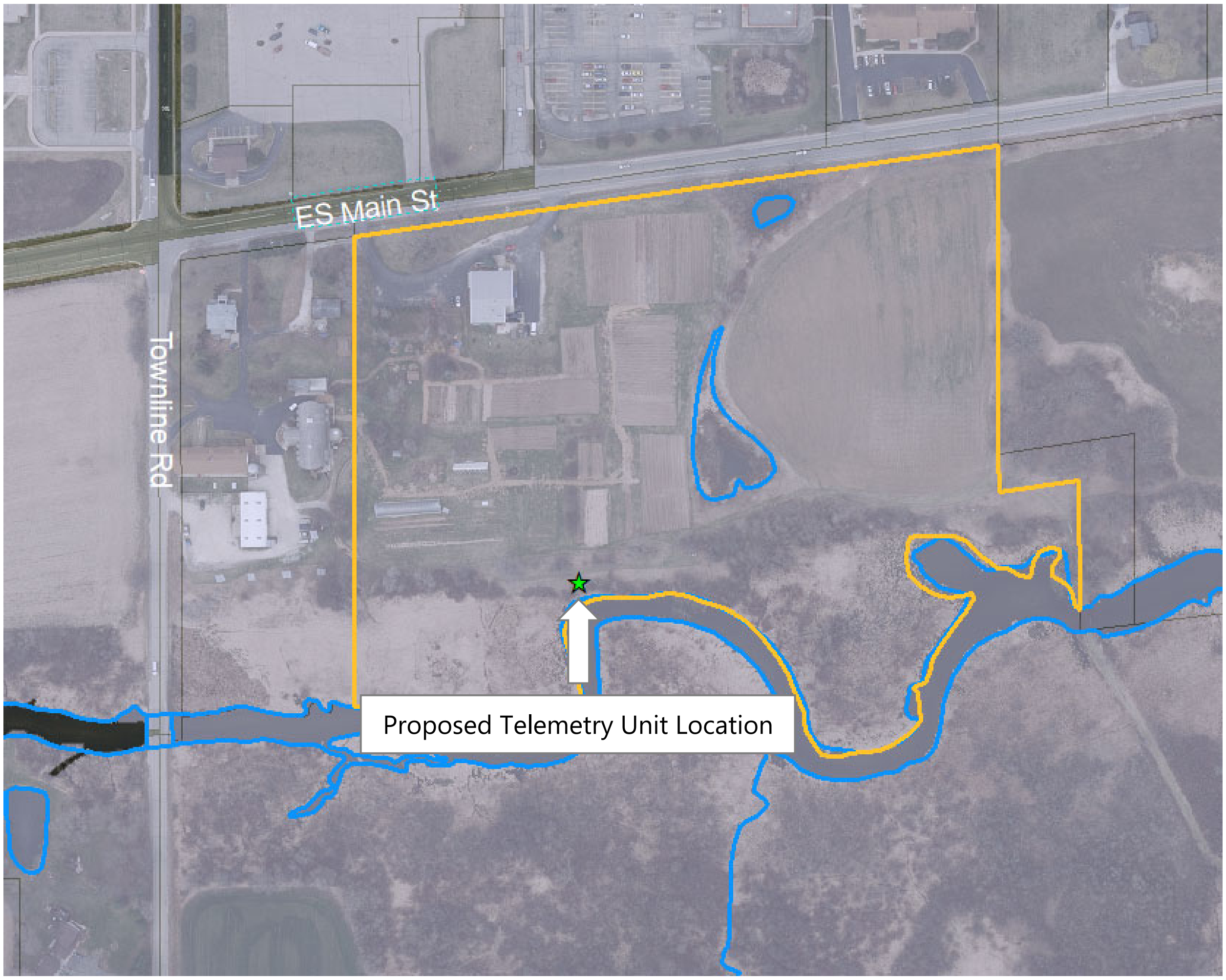
Exhibit A
Photos of Telemetry Unit

Post Installation

Tree Installation

Source: SEWRPC

Exhibit B
Example Telemetry Unit Location Map



Source: SEWRPC

DRAINAGE AREA CHARACTERISTICS FOR STREAM MONITORING SITES

APPENDIX B

Table B.1
Civil Divisions Within Drainage Areas of Monitored Streams

Civil Division Name	Acres	Percent of Drainage Area
Site 1: Fox River at Waukesha		
City of Pewaukee	13,489	16.7
City of New Berlin	10,838	13.4
Town of Lisbon	10,068	12.5
Village of Menomonee Falls	9,460	11.7
City of Brookfield	9,066	11.2
Town of Delafield	6,879	8.5
City of Waukesha	6,391	7.9
Village of Sussex	5,075	6.3
Town of Brookfield	3,174	3.9
Village of Pewaukee	2,896	3.6
Village of Lannon	1,597	2.0
Village of Hartland	789	1.0
Village of Waukesha	494	0.6
Town of Merton	315	0.4
Village of Richfield	196	0.2
City of Delafield	71	0.1
Village of Merton	29	0.0
Site 1 Total	80,827	100.0
Site 2: Fox River at New Munster		
Town of Spring Prairie	22,917	4.4
Town of Norway	22,760	4.4
Town of Troy	22,731	4.4
Town of Lafayette	21,846	4.2
Town of Lyons	21,720	4.2
Town of Waterford	21,541	4.2
Town of Burlington	21,032	4.1
City of Muskego	20,508	4.0
Town of Dover	19,918	3.9
Village of Vernon	19,845	3.8
Town of Mukwonago	19,801	3.8
Town of East Troy	18,916	3.7
Town of LaGrange	18,091	3.5
City of New Berlin	17,226	3.3
Town of Genesee	17,177	3.3
City of Waukesha	16,474	3.2
Town of Sugar Creek	16,093	3.1
City of Pewaukee	13,649	2.6
Village of Waukesha	13,320	2.6
Town of Eagle	12,865	2.5
Town of Geneva	12,850	2.5
Village of Rochester	11,313	2.2
Town of Lisbon	10,068	1.9
Village of Menomonee Falls	9,460	1.8
Town of Delafield	9,278	1.8
City of Brookfield	9,066	1.8
Town of Linn	8,726	1.7
Village of Mukwonago	5,266	1.0
Village of Sussex	5,075	1.0
City of Burlington	5,072	1.0
Town of Brighton	4,996	1.0
City of Lake Geneva	4,780	0.9
Village of Bloomfield	3,489	0.7
Town of Brookfield	3,174	0.6

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 2: Fox River at New Munster (continued)		
Town of Bloomfield	3,022	0.6
Village of East Troy	2,916	0.6
Village of Pewaukee	2,896	0.6
City of Elkhorn	2,503	0.5
Village of Fontana-On-Geneva-Lake	2,437	0.5
Town of Palmyra	2,270	0.4
Village of Big Bend	2,114	0.4
Village of Williams Bay	1,892	0.4
Town of Ottawa	1,801	0.3
Village of North Prairie	1,774	0.3
Village of Waterford	1,620	0.3
Village of Lannon	1,597	0.3
Town of Walworth	1,377	0.3
Village of Wales	1,129	0.2
Village of Raymond	1,104	0.2
Town of Wheatland	1,102	0.2
Village of Eagle	870	0.2
Village of Hartland	789	0.2
Town of Whitewater	694	0.1
Town of Delavan	339	0.1
Town of Merton	315	0.1
City of Franklin	286	0.1
Town of Richmond	208	0.0
Village of Richfield	196	0.0
Village of Walworth	135	0.0
City of Delafield	71	0.0
Village of Merton	29	0.0
Site 2 Total	516,529	100.0
Site 3: Mukwonago River at Mukwonago		
Town of Eagle	12,865	23.5
Town of Troy	10,805	19.8
Town of Mukwonago	9,758	17.9
Town of East Troy	5,940	10.9
Town of LaGrange	3,367	6.2
Town of Genesee	3,218	5.9
Town of Palmyra	2,270	4.1
Village of Mukwonago	2,019	3.7
Town of Ottawa	1,801	3.3
Village of North Prairie	1,172	2.1
Village of Eagle	870	1.6
Village of Wales	402	0.7
Village of East Troy	157	0.3
Site 3 Total	54,644	100.0
Site 4: Sugar Creek		
Town of Lafayette	16,747	43.2
Town of Sugar Creek	12,392	32.0
Town of Spring Prairie	6,856	17.7
City of Elkhorn	2,503	6.5
Town of Geneva	182	0.5
Town of Troy	25	0.1
Site 4 Total	38,705	100.0
Site 6: White River near Burlington		
Town of Lyons	21,533	30.0
Town of Geneva	12,669	17.6

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 6: White River near Burlington (continued)		
Town of Linn	8,726	12.1
Town of Spring Prairie	7,737	10.8
City of Lake Geneva	4,780	6.7
Village of Bloomfield	3,489	4.9
Town of Bloomfield	3,022	4.2
Town of Lafayette	2,804	3.9
Village of Fontana-On-Geneva-Lake	2,437	3.4
Village of Williams Bay	1,892	2.6
Town of Walworth	1,377	1.9
Town of Burlington	629	0.9
Town of Delavan	339	0.5
City of Burlington	220	0.3
Village of Walworth	135	0.2
Town of Wheatland	19	0.0
Site 6 Total	71,808	100.0
Site 8: Pewaukee River		
City of Pewaukee	7,682	31.5
Town of Delafield	6,879	28.2
Village of Pewaukee	2,896	11.9
City of Waukesha	2,427	10.0
Town of Lisbon	2,272	9.3
Village of Sussex	1,042	4.3
Village of Hartland	789	3.2
Town of Merton	315	1.3
City of Delafield	71	0.3
Site 8 Total	24,373	100.0
Site 9: Oak Creek		
City of Oak Creek	11,691	70.8
City of Milwaukee	1,831	11.1
City of Franklin	1,645	10.0
City of South Milwaukee	1,104	6.7
City of Greenfield	150	0.9
City of Cudahy	91	0.5
Site 9 Total	16,512	100.0
Site 10: Pike River		
Village of Somers	8,578	36.6
Village of Mount Pleasant	7,914	33.8
City of Kenosha	2,747	11.7
Village of Sturtevant	2,597	11.1
Town of Somers	787	3.3
City of Racine	460	2.0
Village of Pleasant Prairie	349	1.5
Site 10 Total	23,432	100.0
Site 11: Bark River Upstream		
Village of Richfield	9,067	40.5
Town of Lisbon	6,627	29.6
Village of Hartland	2,410	10.8
Village of Merton	2,098	9.4
Town of Merton	1,886	8.4
City of Delafield	228	1.0
Village of Sussex	47	0.2
Town of Delafield	30	0.1
Site 11 Total	22,393	100.0

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 12: Lincoln Creek		
City of Milwaukee	6,898	97.8
Village of Brown Deer	156	2.2
Site 12 Total	7,054	100.0
Site 13: Ulao Creek		
Town of Grafton	5,046	85.5
Village of Grafton	718	12.2
City of Port Washington	101	1.7
City of Mequon	20	0.3
Town of Port Washington	14	0.3
Site 13 Total	5,899	100.0
Site 14: Sauk Creek		
Town of Belgium	8,177	40.3
Town of Port Washington	5,917	29.2
Town of Fredonia	4,193	20.7
City of Port Washington	985	4.9
Town of Sherman	415	2.0
Village of Fredonia	386	1.9
Town of Holland	153	0.8
Village of Belgium	34	0.2
Town of Saukville	7	0.0
Site 14 Total	20,267	100.0
Site 15: Kilbourn Road Ditch		
Village of Yorkville	1,901	34.9
Village of Mount Pleasant	1,771	32.5
Town of Paris	942	17.3
Village of Somers	839	15.3
Site 15 Total	5,453	100.0
Site 16: Jackson Creek		
Town of Geneva	5,615	89.3
City of Elkhorn	514	8.2
Town of Delavan	128	2.0
Town of Lafayette	29	0.5
Site 16 Total	6,286	100.0
Site 18: Oconomowoc River Upstream		
Village of Richfield	9,534	36.1
Town of Erin	6,752	25.6
Town of Merton	4,742	17.9
Town of Polk	4,149	15.7
Town of Hartford	615	2.3
Town of Lisbon	483	1.8
Village of Slinger	152	0.6
City of Hartford	2	0.0
Site 18 Total	26,429	100.0
Site 20: Oconomowoc River Downstream		
Town of Erin	14,842	23.1
Town of Merton	14,669	22.8
Town of Oconomowoc	9,785	15.2
Village of Richfield	9,534	14.8
Town of Polk	4,149	6.5
Village of Chenequa	2,952	4.6
City of Oconomowoc	2,919	4.5
Village of Oconomowoc Lake	2,017	3.1
Town of Hartford	615	1.0
Village of Lac La Belle	527	0.8

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 20: Oconomowoc River Downstream (continued)		
Town of Lisbon	483	0.8
Town of Ashippun	442	0.7
Village of Summit	339	0.5
Town of Ixonia	245	0.4
Village of Nashotah	244	0.4
City of Delafield	229	0.4
Village of Slinger	152	0.2
Village of Hartland	105	0.2
Village of Merton	29	0.0
City of Hartford	2	0.0
Site 20 Total	64,279	100.0
Site 21: East Branch Milwaukee River		
Town of Mitchell	11,958	37.9
Town of Auburn	5,962	18.9
Town of Osceola	5,863	18.5
Town of Scott	3,066	9.7
Town of Greenbush	2,336	7.4
Town of Kewaskum	1,799	5.7
Town of Forest	547	1.7
Village of Kewaskum	54	0.2
Site 21 Total	31,585	100.0
Site 23: Milwaukee River Downstream of Newburg		
Town of Auburn	21,567	12.7
Town of Osceola	21,503	12.7
Town of Eden	19,001	11.2
Town of Ashford	18,327	10.8
Town of Kewaskum	12,283	7.3
Town of Mitchell	11,958	7.1
Town of Trenton	10,778	6.4
Town of Barton	10,484	6.2
City of West Bend	9,710	5.7
Town of Wayne	5,850	3.5
Town of Byron	5,665	3.3
Town of West Bend	4,524	2.7
Town of Saukville	3,763	2.2
Town of Scott	3,066	1.8
Town of Lomira	2,779	1.6
Town of Greenbush	2,336	1.4
Village of Kewaskum	1,506	0.9
Town of Polk	1,101	0.7
Town of Fredonia	946	0.6
Village of Campbellsport	888	0.5
Village of Newburg	573	0.3
Town of Forest	551	0.3
Village of Lomira	139	0.1
Village of Eden	34	0.0
Town of Jackson	21	0.0
Town of Empire	17	0.0
Site 23 Total	169,370	100.0
Site 25: Root River Canal		
Village of Yorkville	17,680	47.0
Village of Raymond	14,304	38.0
Town of Paris	1,763	4.7
Town of Dover	1,677	4.5

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 25: Root River Canal (continued)		
Village of Caledonia	1,029	2.7
Village of Union Grove	883	2.3
Village of Mount Pleasant	302	0.8
Town of Norway	18	0.0
Site 25 Total	37,656	100.0
Site 28: East Branch Rock River		
Town of Addison	19,251	55.0
Town of Herman	9,830	28.1
Town of Theresa	2,980	8.5
Town of Wayne	2,007	5.7
Town of Hartford	514	1.5
Town of West Bend	319	0.9
Town of Polk	117	0.3
Village of Slinger	11	0.0
Site 28 Total	35,029	100.0
Site 30: Des Plaines River		
Town of Paris	20,591	28.1
Village of Bristol	13,304	18.1
Village of Pleasant Prairie	10,989	15.0
Town of Brighton	9,678	13.2
City of Kenosha	3,946	5.4
Village of Salem Lakes	2,961	4.0
Village of Somers	2,957	4.0
Village of Yorkville	2,800	3.8
Village of Mount Pleasant	1,771	2.4
Village of Paddock Lake	1,679	2.3
Town of Dover	1,551	2.1
Village of Union Grove	778	1.1
Town of Somers	340	0.5
Site 30 Total	73,345	100.0
Site 32: Turtle Creek		
Town of Delavan	17,352	28.9
Town of Richmond	9,629	16.0
Town of Darien	9,202	15.3
Town of Geneva	6,434	10.7
Town of Sugar Creek	5,482	9.1
City of Delavan	4,737	7.9
Town of Walworth	3,945	6.5
City of Elkhorn	2,703	4.5
Village of Williams Bay	432	0.7
Village of Fontana-On-Geneva-Lake	184	0.3
Town of Lafayette	35	0.1
Site 32 Total	60,135	100.0
Site 33: Pebble Brook		
Village of Waukesha	6,328	61.9
City of Waukesha	1,945	19.0
City of New Berlin	1,944	19.0
Village of Vernon	13	0.1
Site 33 Total	10,230	100.0
Site 35: Honey Creek Upstream of East Troy		
Town of Troy	11,820	49.0
Town of LaGrange	9,453	39.2
Town of Lafayette	2,294	9.5
Town of Sugar Creek	417	1.8

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 35: Honey Creek Upstream of East Troy (continued)		
Town of East Troy	69	0.3
Village of East Troy	52	0.2
Town of Spring Prairie	3	0.0
Site 35 Total	24,108	100.0
Site 36: Honey Creek Downstream of East Troy		
Town of Troy	11,901	41.7
Town of LaGrange	9,453	33.2
Village of East Troy	2,477	8.7
Town of Lafayette	2,294	8.0
Town of East Troy	1,973	6.9
Town of Sugar Creek	417	1.5
Town of Spring Prairie	3	0.0
Site 36 Total	28,518	100.0
Site 38: North Branch Milwaukee River		
Town of Sherman	20,773	30.7
Town of Scott	16,842	24.9
Town of Mitchell	9,456	14.0
Town of Lyndon	7,992	11.8
Town of Fredonia	7,008	10.3
Town of Farmington	3,293	4.9
Village of Random Lake	1,176	1.7
Village of Cascade	532	0.8
Village of Adell	359	0.5
Town of Holland	282	0.4
Site 38 Total	67,713	100.0
Site 40: Stoney Creek		
Town of Farmington	5,014	44.0
Town of Scott	3,480	30.6
Town of Kewaskum	1,544	13.6
Town of Auburn	1,340	11.8
Site 40 Total	11,378	100.0
Site 41: Milwaukee River near Saukville		
Town of Farmington	23,541	8.2
Town of Scott	23,388	8.2
Town of Auburn	22,907	8.0
Town of Osceola	21,503	7.5
Town of Mitchell	21,414	7.5
Town of Sherman	20,773	7.2
Town of Eden	19,001	6.6
Town of Ashford	18,327	6.4
Town of Fredonia	17,832	6.2
Town of Kewaskum	14,116	4.9
Town of Trenton	13,290	4.6
Town of Saukville	11,459	4.0
Town of Barton	11,368	4.0
City of West Bend	9,712	3.4
Town of Lyndon	7,992	2.8
Town of Wayne	5,850	2.0
Town of Byron	5,665	2.0
Town of West Bend	4,524	1.6
Town of Lomira	2,779	1.0
Town of Greenbush	2,336	0.8
Village of Kewaskum	1,506	0.5
Village of Random Lake	1,176	0.4

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 41: Milwaukee River near Saukville (continued)		
Town of Polk	1,101	0.4
Village of Fredonia	956	0.3
Village of Campbellsport	888	0.3
Town of Port Washington	836	0.3
Village of Newburg	573	0.2
Town of Forest	551	0.2
Village of Cascade	532	0.2
Village of Adell	359	0.1
Town of Holland	282	0.1
Village of Saukville	148	0.1
Village of Lomira	139	0.0
Village of Eden	34	0.0
Town of Jackson	21	0.0
Town of Empire	17	0.0
Site 41 Total	286,896	100.0
Site 45: Mukwonago River at Nature Road		
Town of Troy	6,803	43.5
Town of LaGrange	3,367	21.6
Town of Eagle	3,184	20.4
Town of Palmyra	2,270	14.5
Site 45 Total	15,624	100.0
Site 47: Fox River at Rochester		
Town of Norway	22,760	7.8
City of Muskego	20,508	7.0
Village of Vernon	19,845	6.8
Town of Mukwonago	19,801	6.8
City of New Berlin	17,226	5.9
Town of Genesee	17,177	5.9
Town of Waterford	16,615	5.7
City of Waukesha	16,474	5.6
City of Pewaukee	13,649	4.7
Village of Waukesha	13,320	4.6
Town of Eagle	12,865	4.4
Town of Troy	10,805	3.7
Town of Lisbon	10,068	3.5
Village of Menomonee Falls	9,460	3.2
Town of Delafield	9,278	3.2
City of Brookfield	9,066	3.1
Town of Dover	8,596	2.9
Town of East Troy	6,247	2.1
Village of Sussex	5,075	1.7
Village of Mukwonago	4,942	1.7
Town of LaGrange	3,367	1.2
Town of Brookfield	3,174	1.1
Village of Pewaukee	2,896	1.0
Town of Palmyra	2,270	0.8
Village of Rochester	2,256	0.8
Village of Big Bend	2,114	0.7
Town of Ottawa	1,801	0.6
Village of North Prairie	1,774	0.6
Village of Waterford	1,620	0.6
Village of Lannon	1,597	0.5
Village of Wales	1,129	0.4
Village of Raymond	1,104	0.4

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 47: Fox River at Rochester (continued)		
Village of Eagle	870	0.3
Village of Hartland	789	0.3
Town of Merton	315	0.1
City of Franklin	286	0.1
Village of Richfield	196	0.1
Village of East Troy	157	0.1
City of Delafield	71	0.0
Village of Merton	29	0.0
Site 47 Total	291,592	100.0
Site 48: White River at Lake Geneva		
Town of Linn	8,726	46.9
City of Lake Geneva	2,612	14.0
Village of Fontana-On-Geneva-Lake	2,437	13.1
Village of Williams Bay	1,892	10.2
Town of Walworth	1,377	7.4
Town of Geneva	881	4.7
Town of Delavan	314	1.7
Town of Bloomfield	233	1.3
Village of Walworth	135	0.7
Town of Lyons	2	0.0
Village of Bloomfield	1	0.0
Site 48 Total	18,610	100.0
Site 51: Rubicon River		
Town of Hartford	10,464	59.6
City of Hartford	2,447	13.9
Village of Slinger	2,410	13.7
Town of Addison	1,452	8.3
Town of Polk	603	3.4
Town of Herman	196	1.1
Site 51 Total	17,572	100.0
Site 52: Cedar Creek		
Town of Polk	12,660	36.9
Town of Jackson	5,948	17.4
Town of West Bend	5,087	14.8
Village of Richfield	3,531	10.3
Village of Germantown	3,217	9.4
Village of Jackson	1,709	5.0
Village of Slinger	794	2.3
Town of Germantown	678	2.0
Town of Cedarburg	423	1.2
Town of Addison	117	0.3
Town of Barton	90	0.3
City of Mequon	40	0.1
Site 52 Total	34,294	100.0
Site 53: Honey Creek at Wauwatosa		
City of West Allis	2,258	32.9
City of Milwaukee	2,228	32.4
City of Greenfield	1,847	26.9
City of Wauwatosa	468	6.8
Village of Greendale	72	1.0
Site 53 Total	6,873	100.0
Site 54: Whitewater Creek		
Town of Whitewater	8,289	69.0
Town of Richmond	3,587	29.8

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 54: Whitewater Creek (continued)		
Town of LaGrange	114	1.0
Town of Sugar Creek	30	0.2
Site 54 Total	12,020	100.0
Site 55: Bark River Downstream		
Village of Richfield	9,067	26.6
City of Delafield	6,670	19.6
Town of Lisbon	6,627	19.5
Village of Summit	2,746	8.1
Village of Hartland	2,626	7.7
Village of Merton	2,098	6.2
Town of Merton	1,886	5.5
Town of Delafield	1,296	3.8
Village of Nashotah	814	2.4
City of Oconomowoc	102	0.3
Village of Oconomowoc Lake	53	0.2
Village of Sussex	47	0.1
Village of Chenequa	9	0.0
Site 55 Total	34,041	100.0
Site 57: Menomonee River at Wauwatosa		
Village of Germantown	18,797	23.6
City of Milwaukee	14,479	18.2
Village of Menomonee Falls	11,860	14.9
City of Brookfield	8,636	10.8
City of Wauwatosa	7,677	9.7
City of Mequon	7,442	9.3
City of West Allis	4,014	5.0
Village of Elm Grove	2,106	2.6
City of Greenfield	1,847	2.3
Village of Richfield	996	1.3
Village of Butler	509	0.7
Town of Germantown	487	0.6
City of New Berlin	441	0.6
Town of Lisbon	197	0.2
Town of Brookfield	113	0.1
Village of Greendale	72	0.1
Site 57 Total	79,673	100.0
Site 58: Milwaukee River at Estabrook Park		
Town of Farmington	23,541	5.4
Town of Scott	23,388	5.3
Town of Auburn	22,907	5.2
Town of Osceola	21,503	4.9
Town of Jackson	21,435	4.9
Town of Mitchell	21,414	4.9
Town of Saukville	21,037	4.8
Town of Sherman	20,773	4.8
Town of Trenton	20,761	4.8
City of Mequon	20,183	4.6
Town of Eden	19,001	4.4
Town of Ashford	18,327	4.2
Town of Fredonia	17,832	4.1
Town of Cedarburg	15,921	3.6
City of Milwaukee	15,780	3.6
Town of Polk	15,225	3.5
Town of Kewaskum	14,116	3.2

Table continued on next page.

Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 58: Milwaukee River at Estabrook Park (continued)		
Town of Barton	11,458	2.6
City of West Bend	10,052	2.3
Town of West Bend	9,765	2.2
Town of Grafton	9,634	2.2
Town of Lyndon	7,992	1.8
Town of Wayne	5,850	1.3
Town of Byron	5,665	1.3
City of Glendale	3,628	0.8
Village of Richfield	3,531	0.8
Village of Grafton	3,287	0.8
Village of Germantown	3,217	0.7
City of Cedarburg	3,133	0.7
Village of Brown Deer	2,812	0.7
Town of Lomira	2,779	0.7
Village of River Hills	2,744	0.6
Town of Greenbush	2,336	0.5
Village of Saukville	2,288	0.5
Village of Jackson	2,177	0.5
Village of Kewaskum	1,506	0.3
Town of Port Washington	1,451	0.3
Village of Random Lake	1,176	0.3
Village of Fox Point	1,028	0.2
Village of Fredonia	956	0.2
Village of Campbellsport	888	0.2
Village of Slinger	794	0.2
Village of Thiensville	693	0.2
Town of Germantown	678	0.2
Village of Newburg	583	0.1
Town of Forest	551	0.1
Village of Cascade	532	0.1
Village of Whitefish Bay	476	0.1
Village of Adell	359	0.1
Village of Bayside	289	0.1
Town of Holland	282	0.1
City of Port Washington	195	0.0
Village of Lomira	139	0.0
Town of Addison	117	0.0
Village of Eden	34	0.0
Town of Empire	17	0.0
Site 58 Total	438,236	100.0
Site 59: Root River near Horlick Dam		
Village of Caledonia	22,935	18.9
Village of Raymond	21,775	17.9
City of Franklin	20,268	16.7
Village of Yorkville	18,736	15.4
Village of Mount Pleasant	7,679	6.3
City of New Berlin	5,926	4.9
City of Oak Creek	4,571	3.8
City of Greenfield	3,971	3.3
Village of Greendale	3,493	2.9
City of Muskego	2,512	2.1
Village of Hales Corners	2,046	1.7
City of West Allis	1,894	1.5
Town of Paris	1,763	1.4

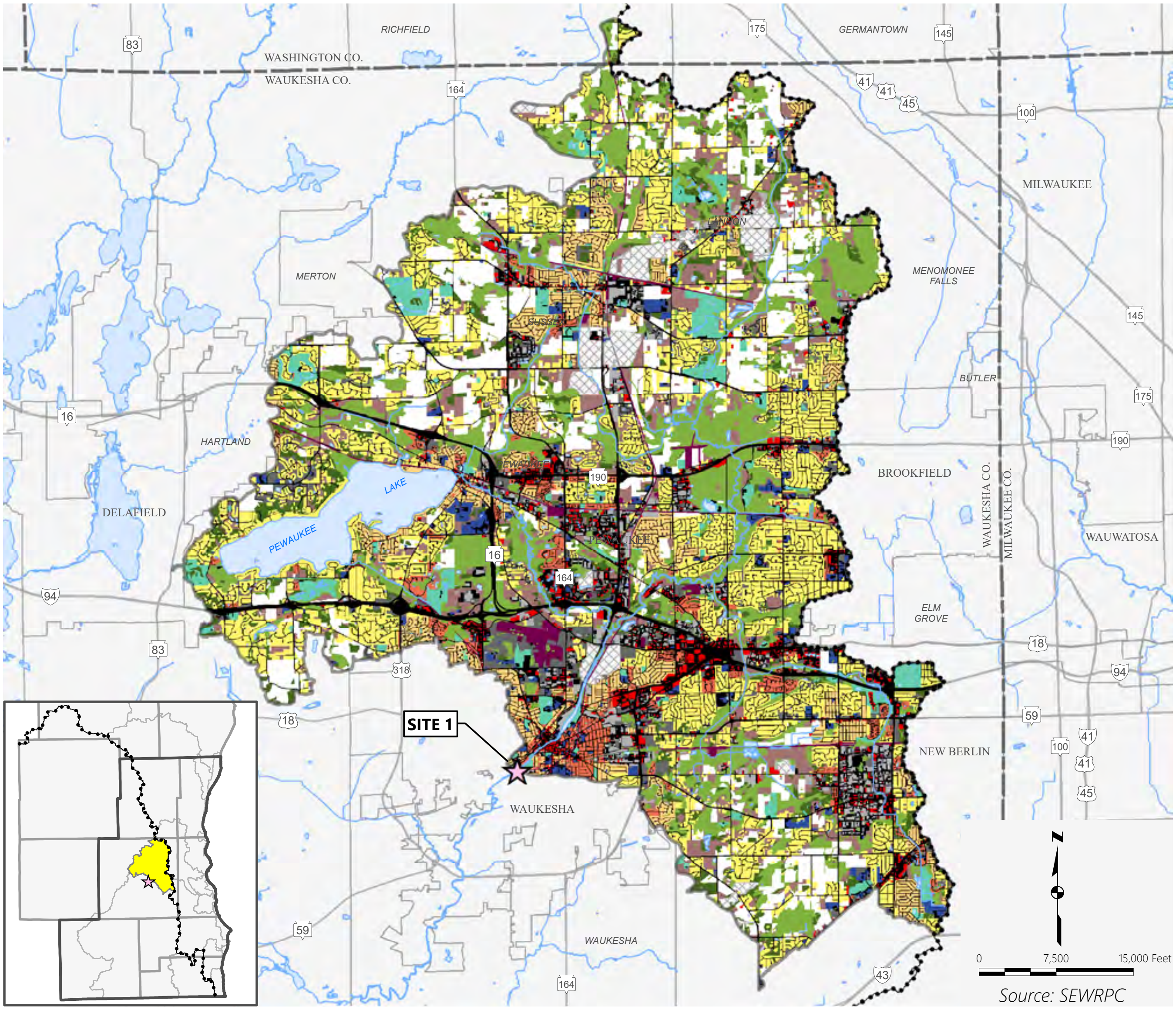
Table continued on next page.

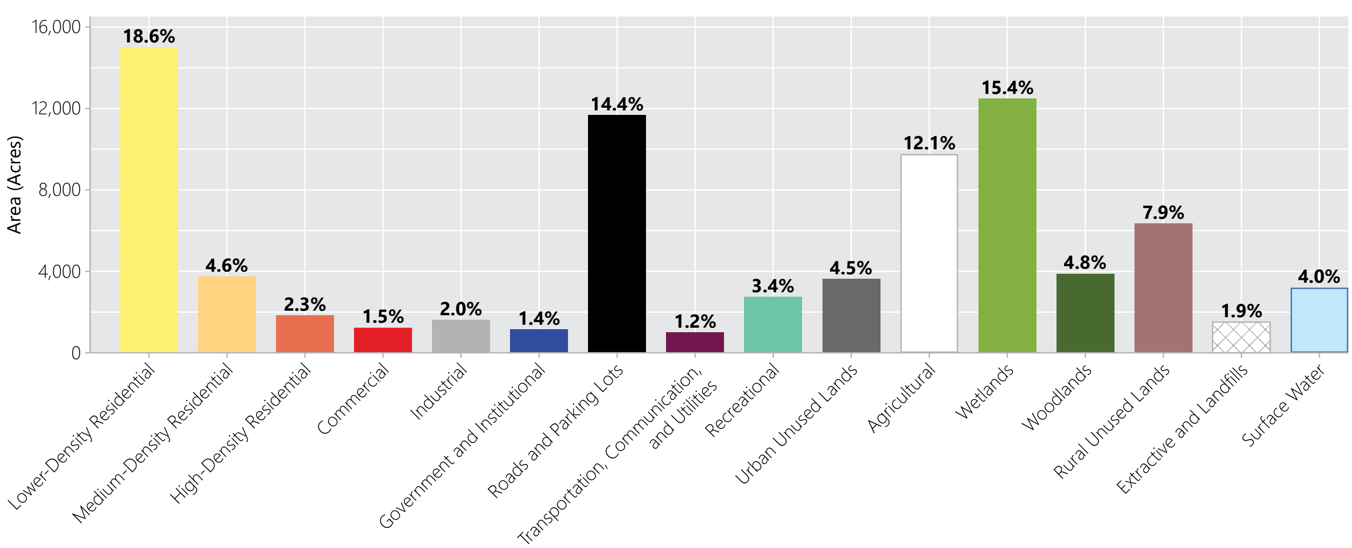
Table B.1 (Continued)

Civil Division Name	Acres	Percent of Drainage Area
Site 59: Root River near Horlick Dam (continued)		
Town of Dover	1,677	1.4
Village of Union Grove	883	0.7
City of Milwaukee	687	0.6
City of Racine	488	0.4
Town of Norway	77	0.1
Village of Sturtevant	40	0.0
Site 59 Total	121,421	100.0
Site 60: Root River at Grange Avenue		
City of Greenfield	3,503	36.6
City of New Berlin	3,013	31.5
City of West Allis	1,894	19.8
Village of Greendale	472	4.9
City of Milwaukee	365	3.8
Village of Hales Corners	322	3.4
Site 60 Total	9,569	100.0
Site 87: Underwood Creek		
City of Brookfield	5,535	45.5
Village of Elm Grove	2,106	17.3
City of Wauwatosa	1,966	16.2
City of West Allis	1,757	14.4
City of New Berlin	441	3.6
City of Milwaukee	254	2.1
Town of Brookfield	113	0.9
Site 87 Total	12,172	100.0

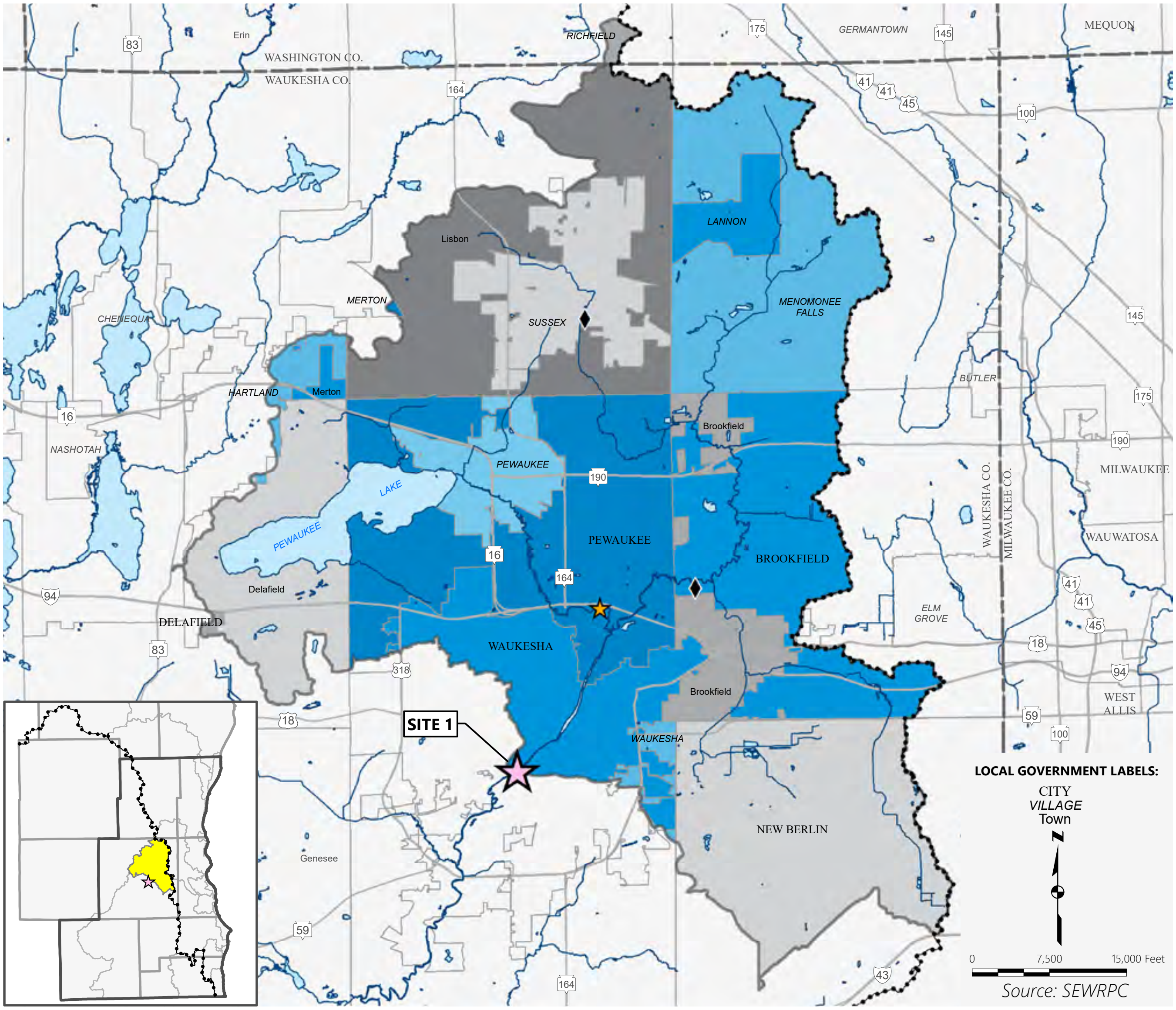
Source: SEWRPC

Map B.1
Site 1: Fox River at Waukesha Drainage Area – Existing Land Use





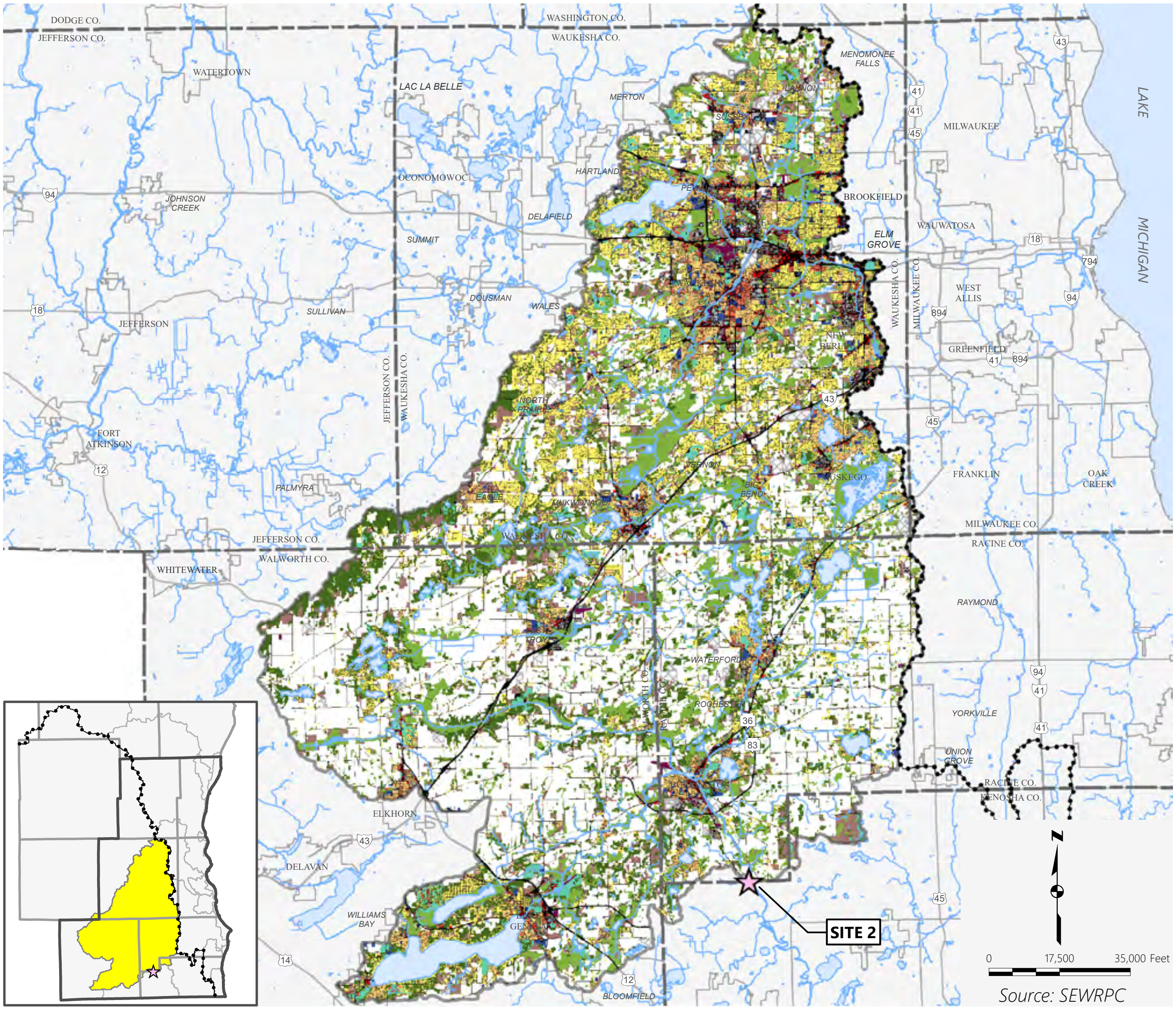
Map B.2
Site 1: Fox River at Waukesha Drainage Area – Characteristics

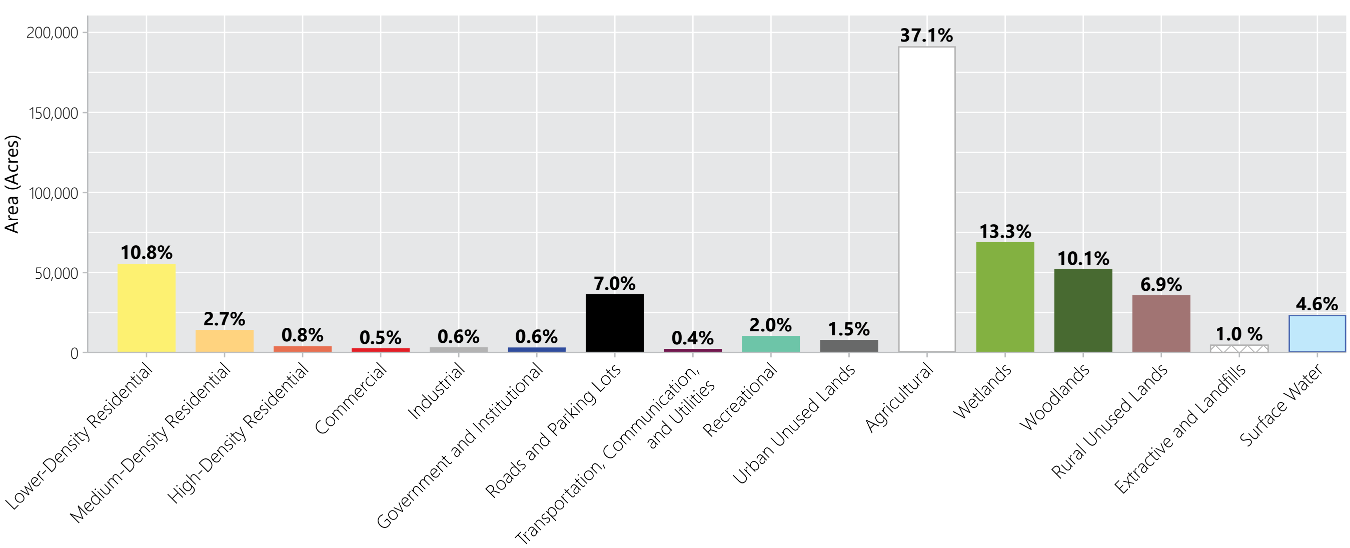


Facts at a Glance

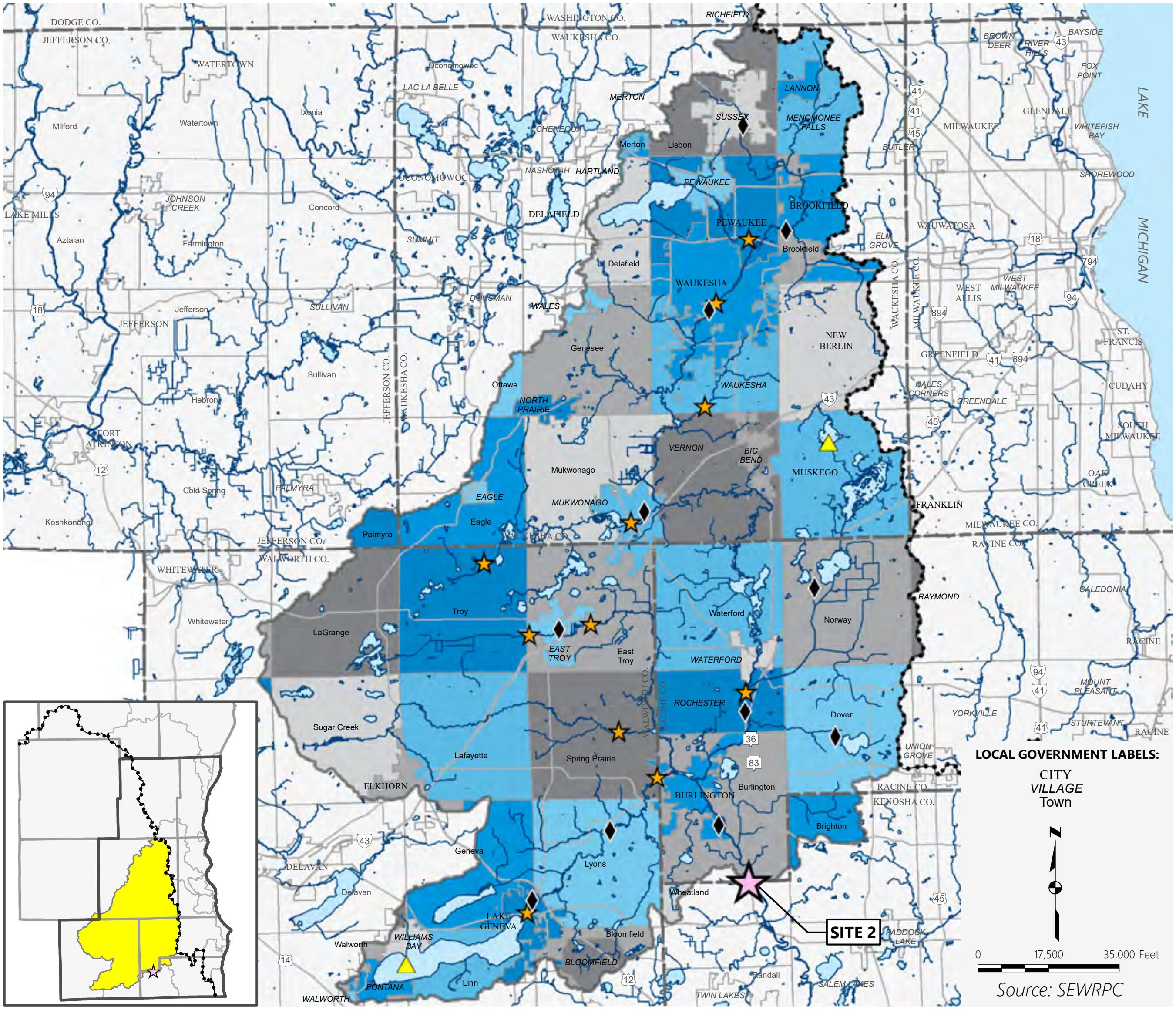
- **Drainage Area Size:** 126 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 54.0%; Rural – 46.0%
- **Roads and Parking Lots (% of drainage area):** 14.4
- **Estimated Population (2010):** 120,800
- **Estimated Households (2010):** 49,480
- **Nearest USGS Streamgage:** Fox River at Waukesha (05543830)
- **Other Monitoring Sites Within this Drainage Area (☆):** Site 8 (Pewaukee River)
- **Upstream Wastewater Treatment Facilities (⧫):** Sussex and Fox River Water Pollution Control Center
- **Planned Sanitary Sewer Service Area (% of drainage area):** 73
- **Water Supply Source:** Groundwater (water supplied by the City of Waukesha is planned to be converted from groundwater to Lake Michigan supply in 2023)

Map B.3
Site 2: Fox River at New Munster Drainage Area – Existing Land Use





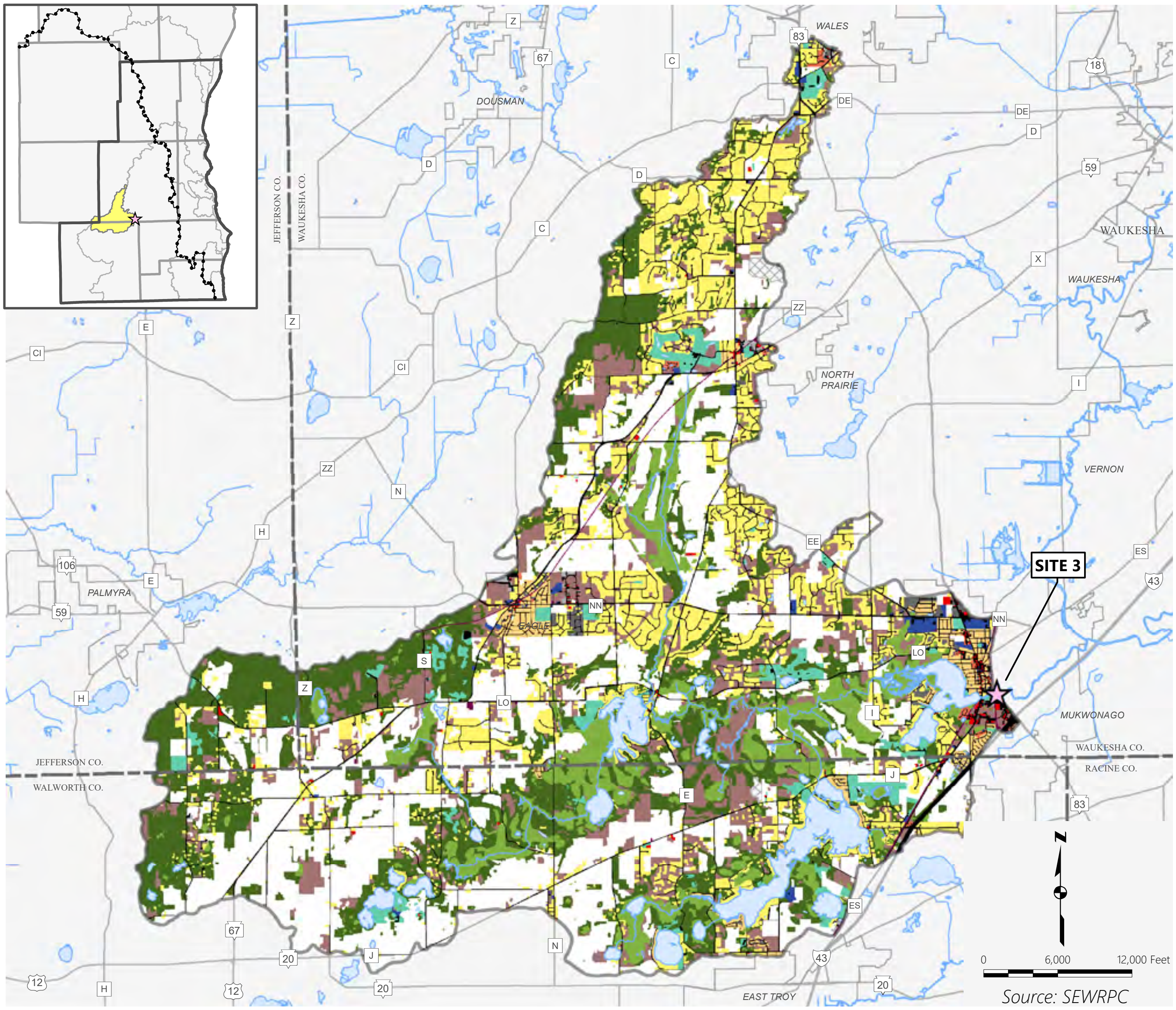
Map B.4
Site 2: Fox River at New Munster Drainage Area – Characteristics

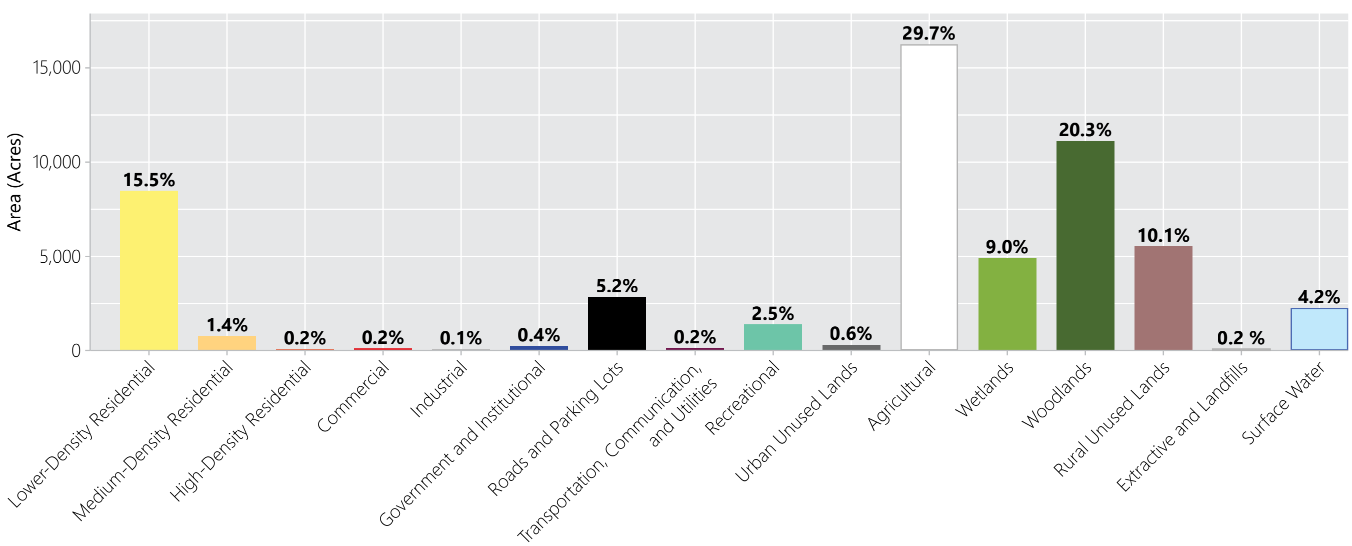


Facts at a Glance

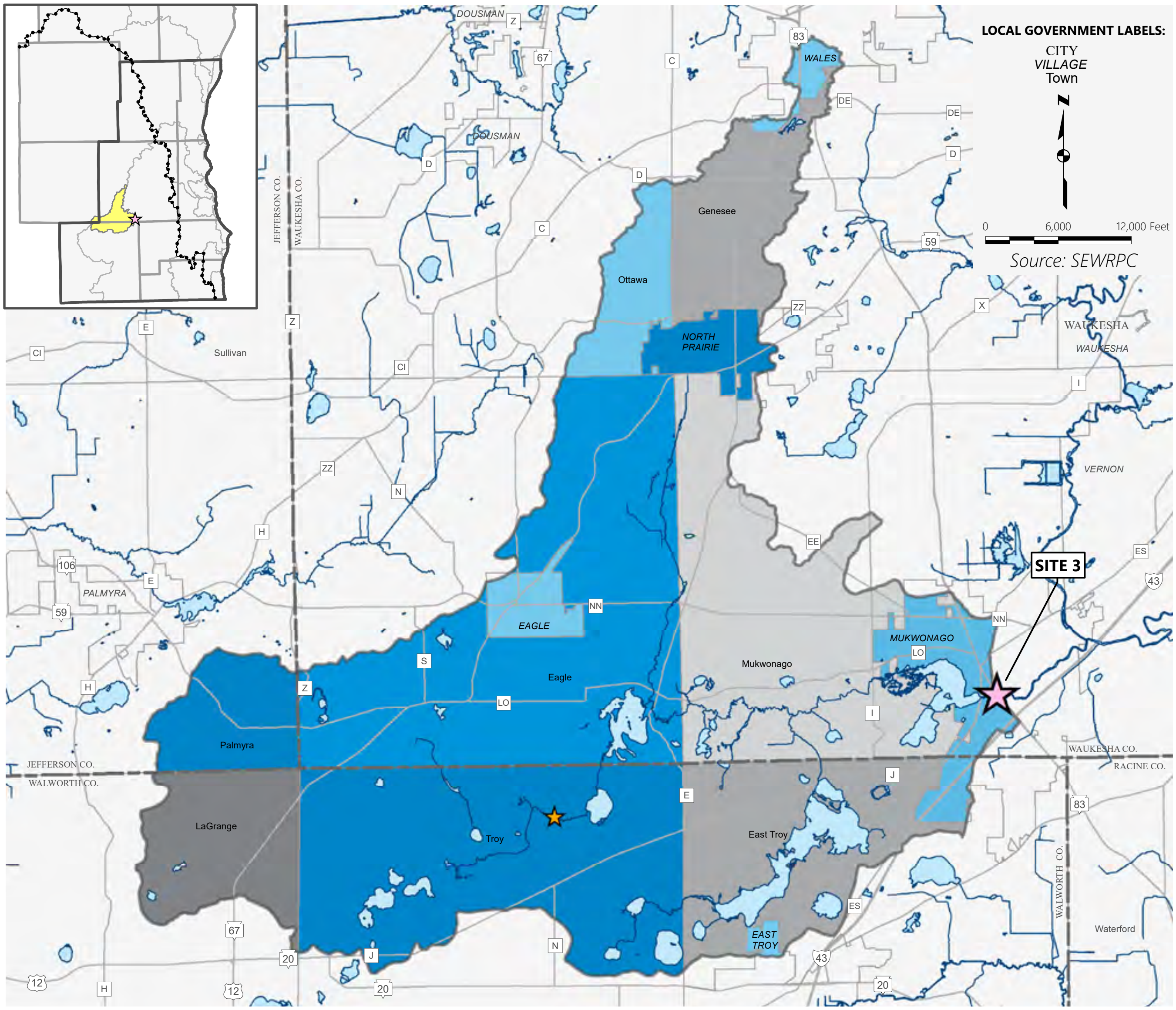
- **Drainage Area Size:** 807 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 27.1%; Rural – 72.9%
- **Roads and Parking Lots (% of drainage area):** 7.0
- **Estimated Population (2010):** 332,920
- **Estimated Households (2010):** 130,580
- **Nearest USGS Streamgage:** Fox River at New Munster (05545750)
- **Other Monitoring Sites Within this Drainage Area (★):** Site 8 (Pewaukee River), Site 1 (Fox River at Waukesha), Site 33 (Pebble Brook), Site 45 (Mukwonago River at Nature Road), Site 3 (Mukwonago River at Mukwonago), Site 47 (Fox River at Rochester), Site 35 (Honey Creek Upstream), Site 36 (Honey Creek Downstream), Site 4 (Sugar Creek), Site 48 (White River at Lake Geneva), and Site 6 (White River at Burlington)
- **Lakes Monitored Within this Drainage Area (△):** Little Muskego and Geneva Lake
- **Upstream Wastewater Treatment Facilities (⧫):** Sussex, Fox River Water Pollution Control Center, Waukesha, Mukwonago, Town of Norway Sanitary District No. 1, Western Racine County Sewerage District, Eagle Lake Sanitary Sewer Utility District, East Troy, Lake Geneva (Lake Geneva discharges to groundwater through soil infiltration), Town of Lyons Sanitary District No. 2, and Burlington
- **Planned Sanitary Sewer Service Area (% of drainage area):** 30
- **Water Supply Source:** Groundwater (water supplied by the City of Waukesha is planned to be converted from groundwater to Lake Michigan supply in 2023)

Map B.5
Site 3: Muwonago River at Mukwonago Drainage Area – Existing Land Use





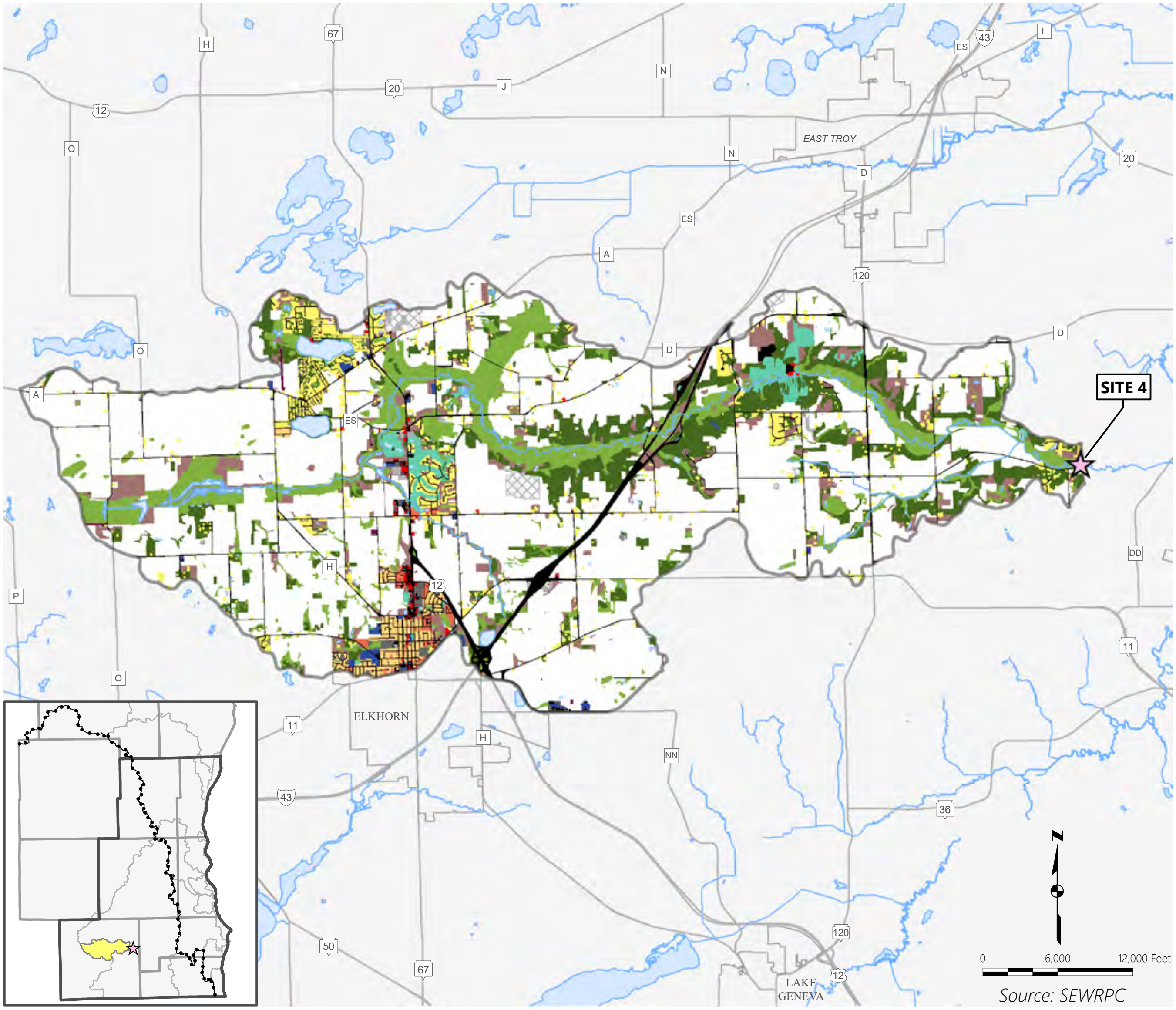
Map B.6
Site 3: Muwonago River at Mukwonago Drainage Area – Characteristics

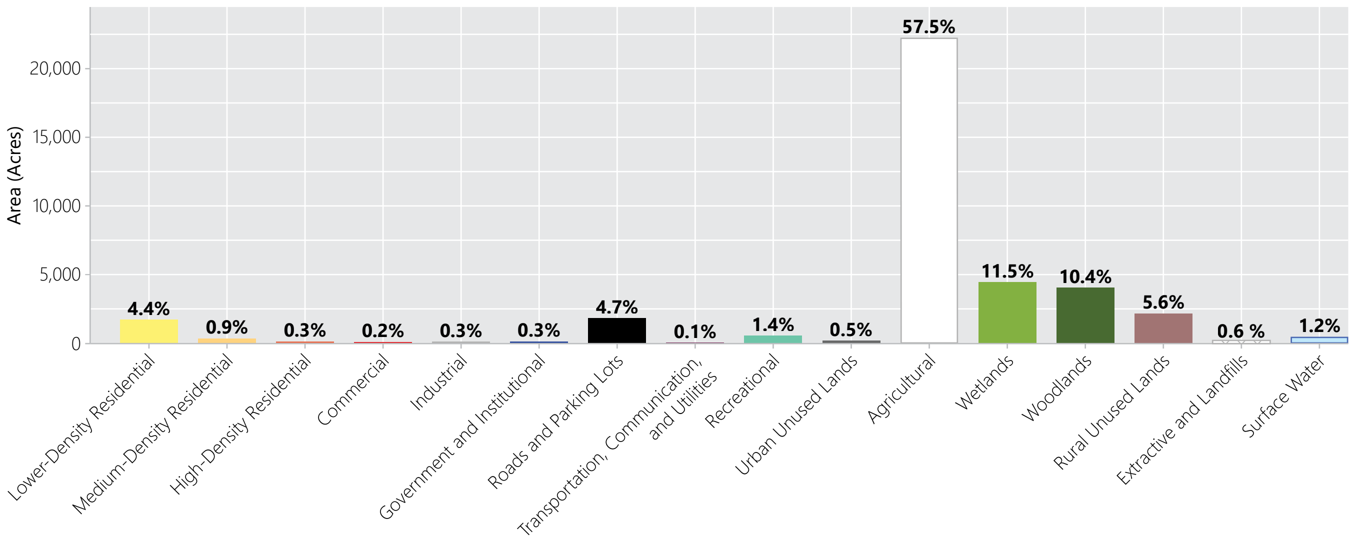


Facts at a Glance

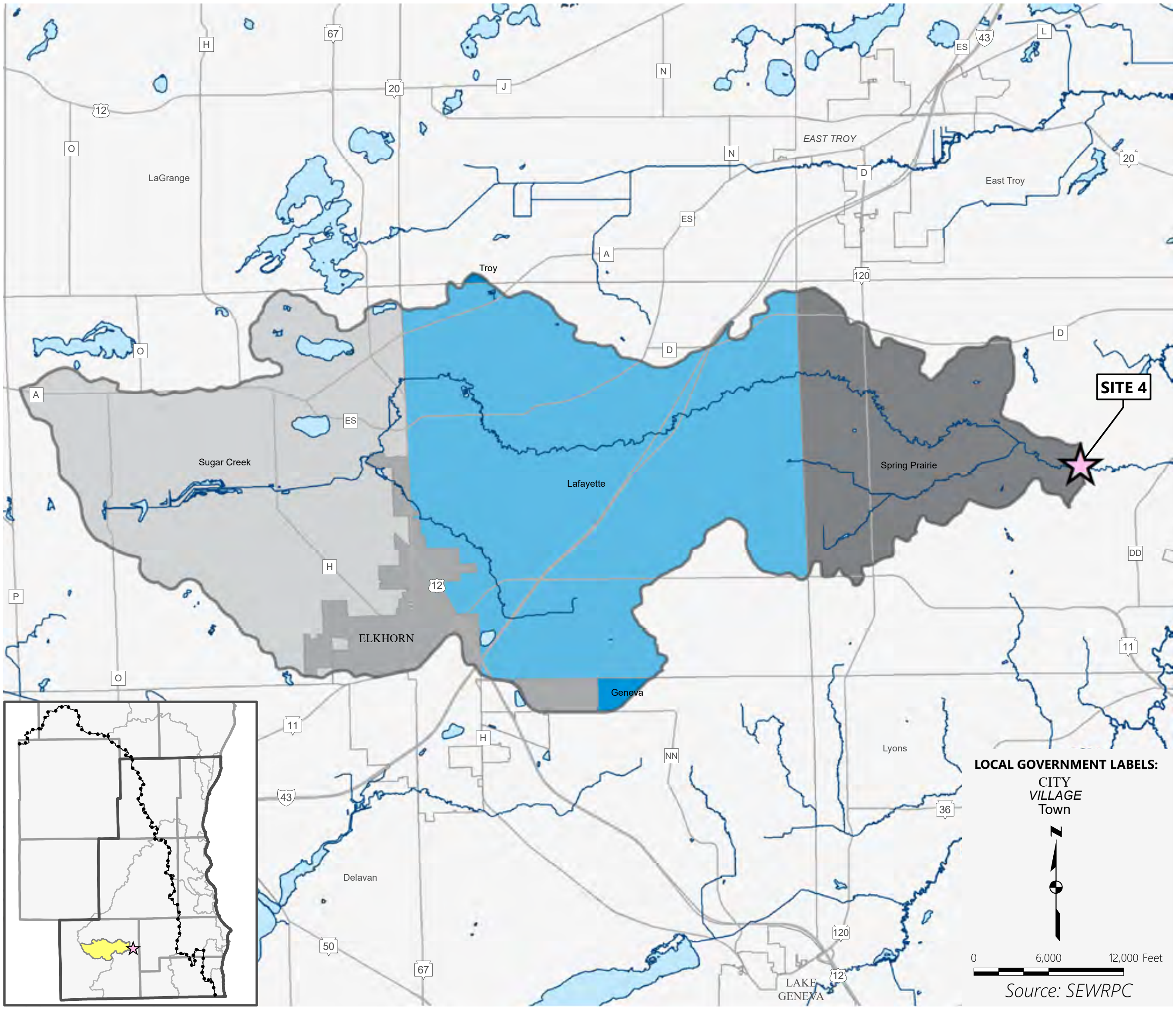
- **Drainage Area Size:** 85 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 26.4%; Rural – 73.6%
- **Roads and Parking Lots (% of drainage area):** 5.2
- **Estimated Population (2010):** 20,670
- **Estimated Households (2010):** 7,610
- **Nearest USGS Streamgage:** Mukwonago River at Mukwonago (05544200)
- **Other Monitoring Sites Within this Drainage Area (★):** Site 45 (Mukwonago River at Nature Road)
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 11
- **Water Supply Source:** Groundwater

Map B.7
Site 4: Sugar Creek Drainage Area – Existing Land Use





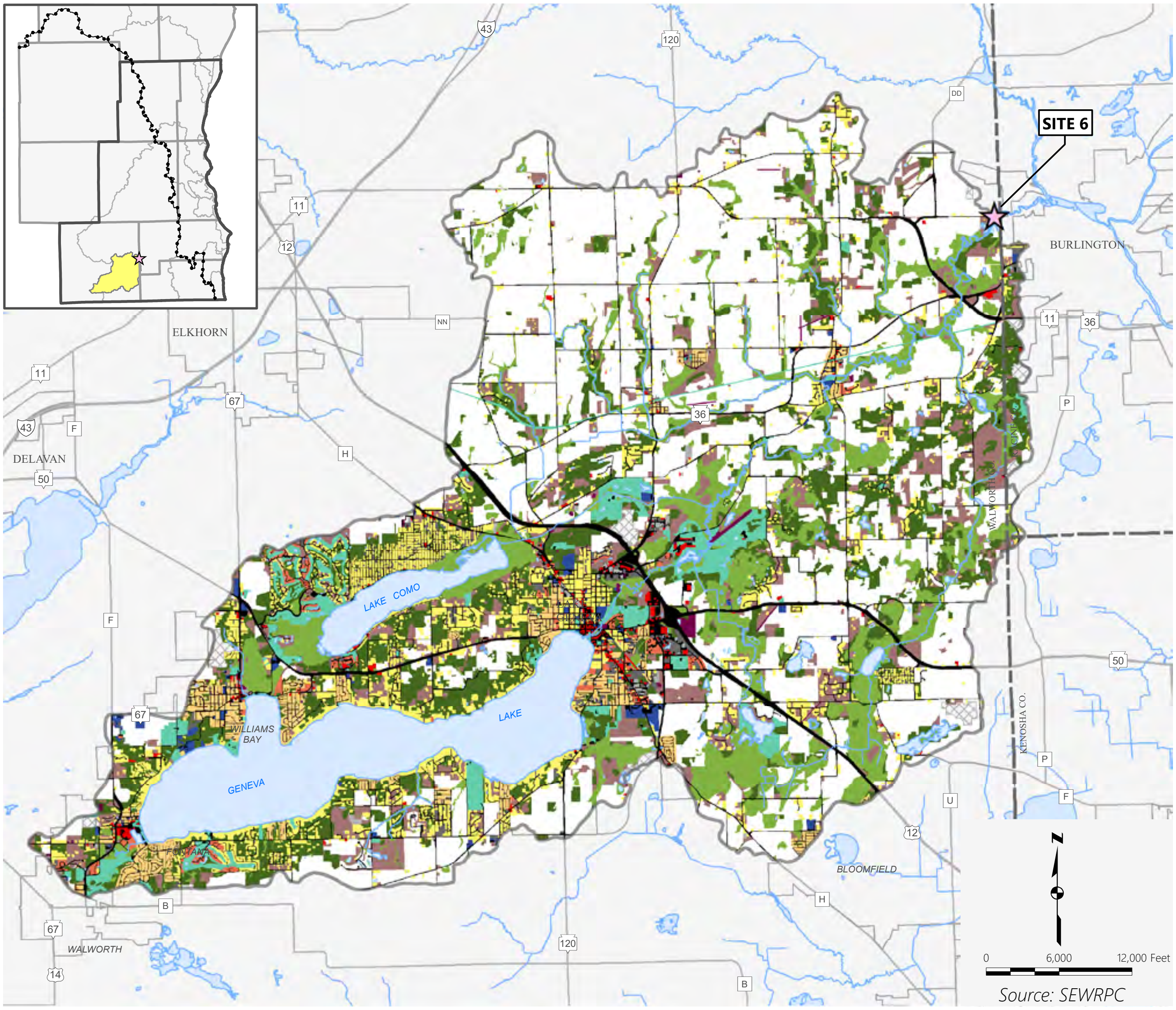
Map B.8
Site 4: Sugar Creek Drainage Area – Characteristics

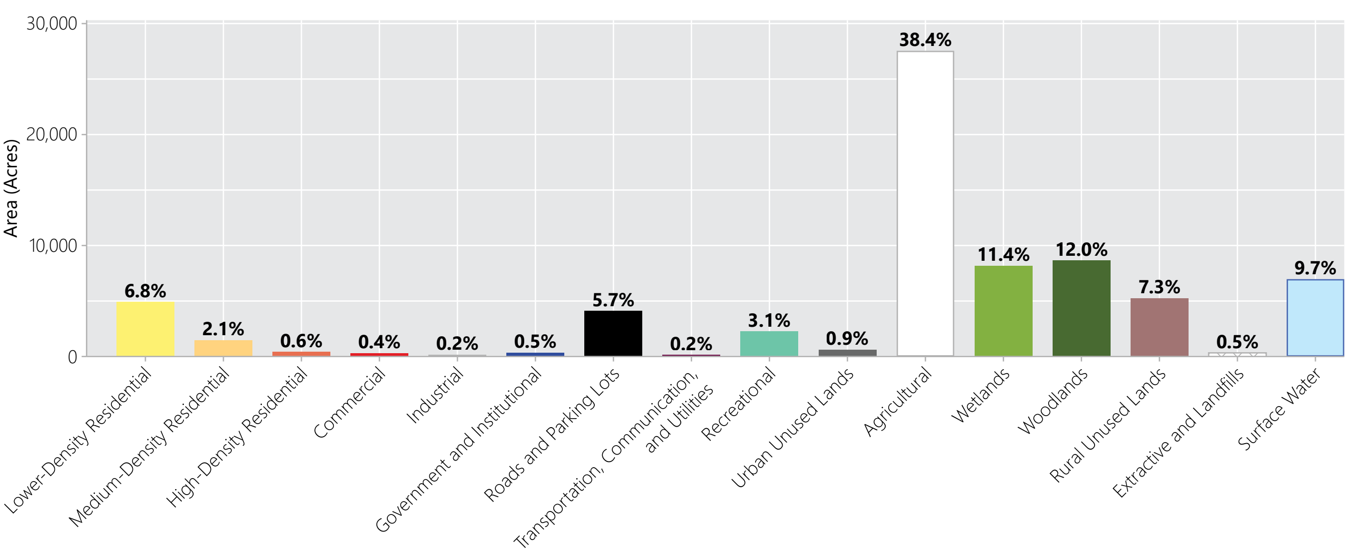


Facts at a Glance

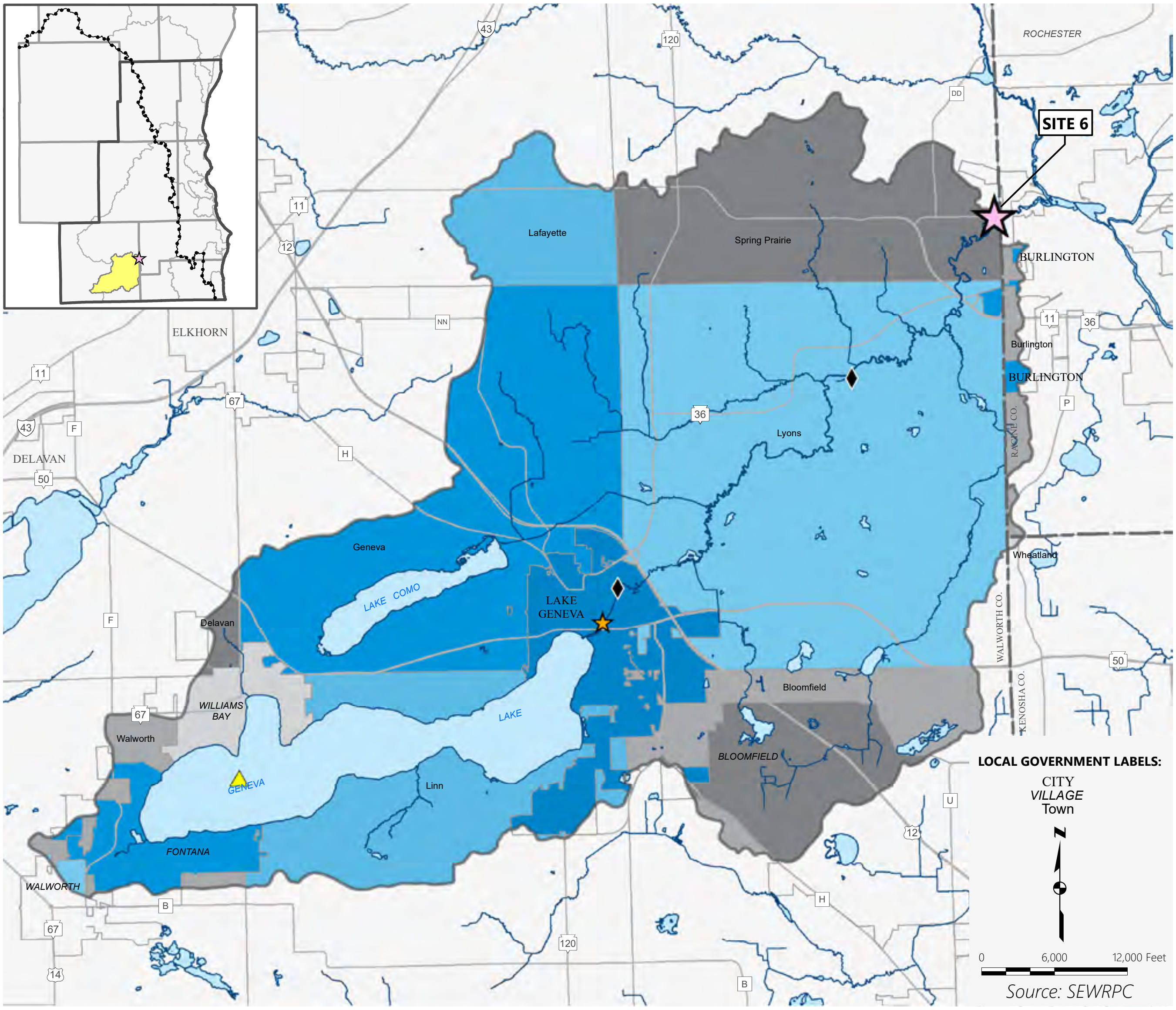
- **Drainage Area Size:** 60 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 13.1%; Rural – 86.9%
- **Roads and Parking Lots (% of drainage area):** 4.7
- **Estimated Population (2010):** 10,970
- **Estimated Households (2010):** 4,070
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 9
- **Water Supply Source:** Groundwater

Map B.9
Site 6: White River near Burlington Drainage Area – Existing Land Use





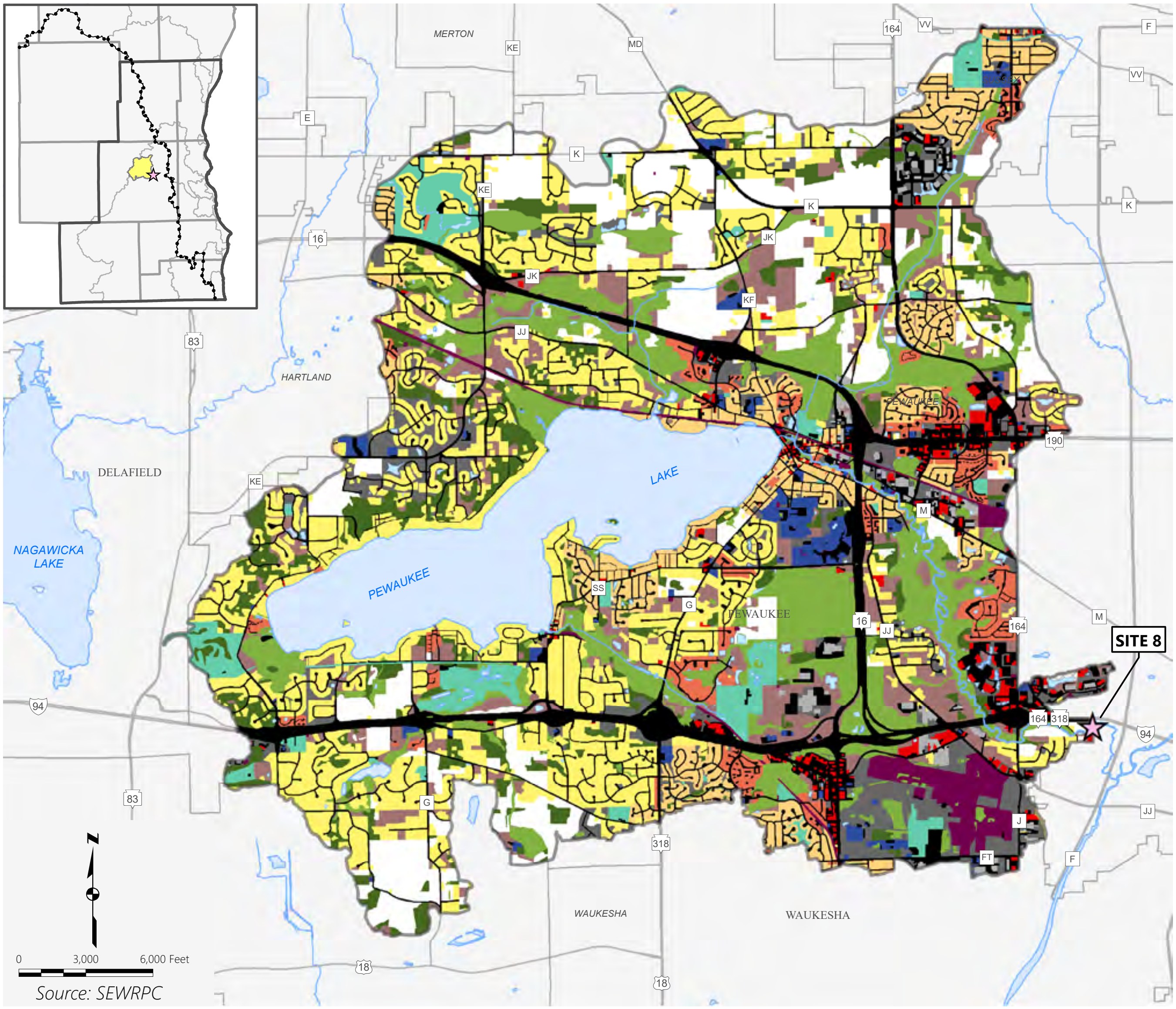
Map B.10
Site 6: White River near Burlington Drainage Area – Characteristics



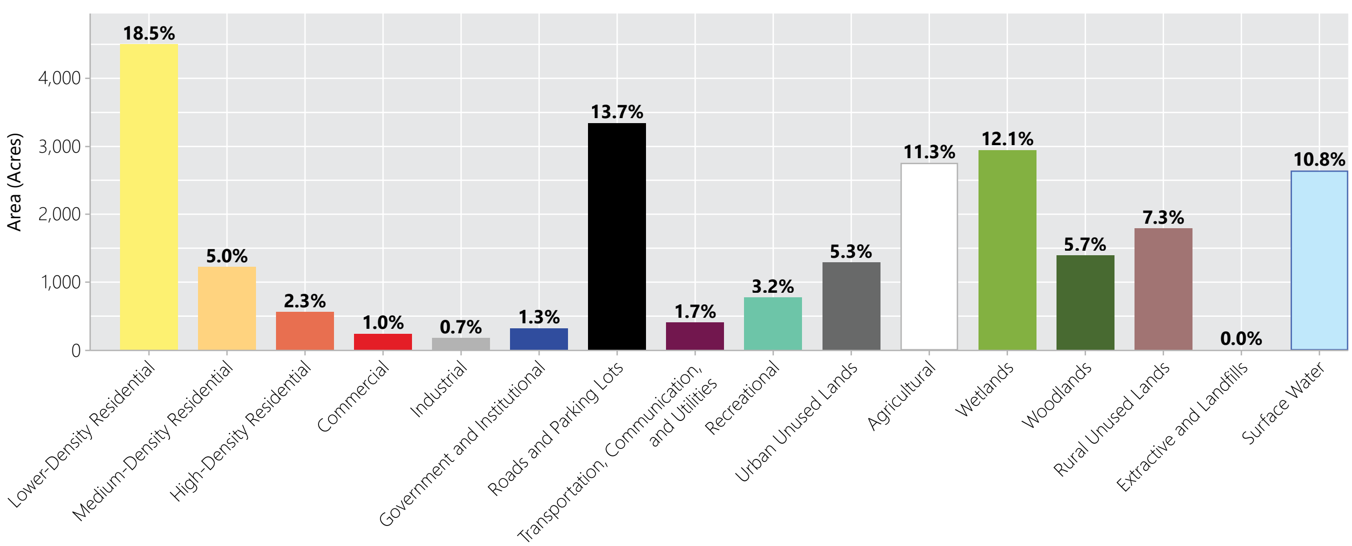
Facts at a Glance

- **Drainage Area Size:** 112 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 20.6%; Rural – 79.4%
- **Roads and Parking Lots (% of drainage area):** 5.7
- **Estimated Population (2010):** 25,010
- **Estimated Households (2010):** 10,370
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** Site 48 (White River Lake Geneva)
- **Lakes Monitored Within this Drainage Area (△):** Geneva Lake
- **Upstream Wastewater Treatment Facilities (♦):** Lyons and Lake Geneva (Lake Geneva discharges to groundwater through soil infiltration)
- **Planned Sanitary Sewer Service Area (% of drainage area):** 21
- **Water Supply Source:** Groundwater

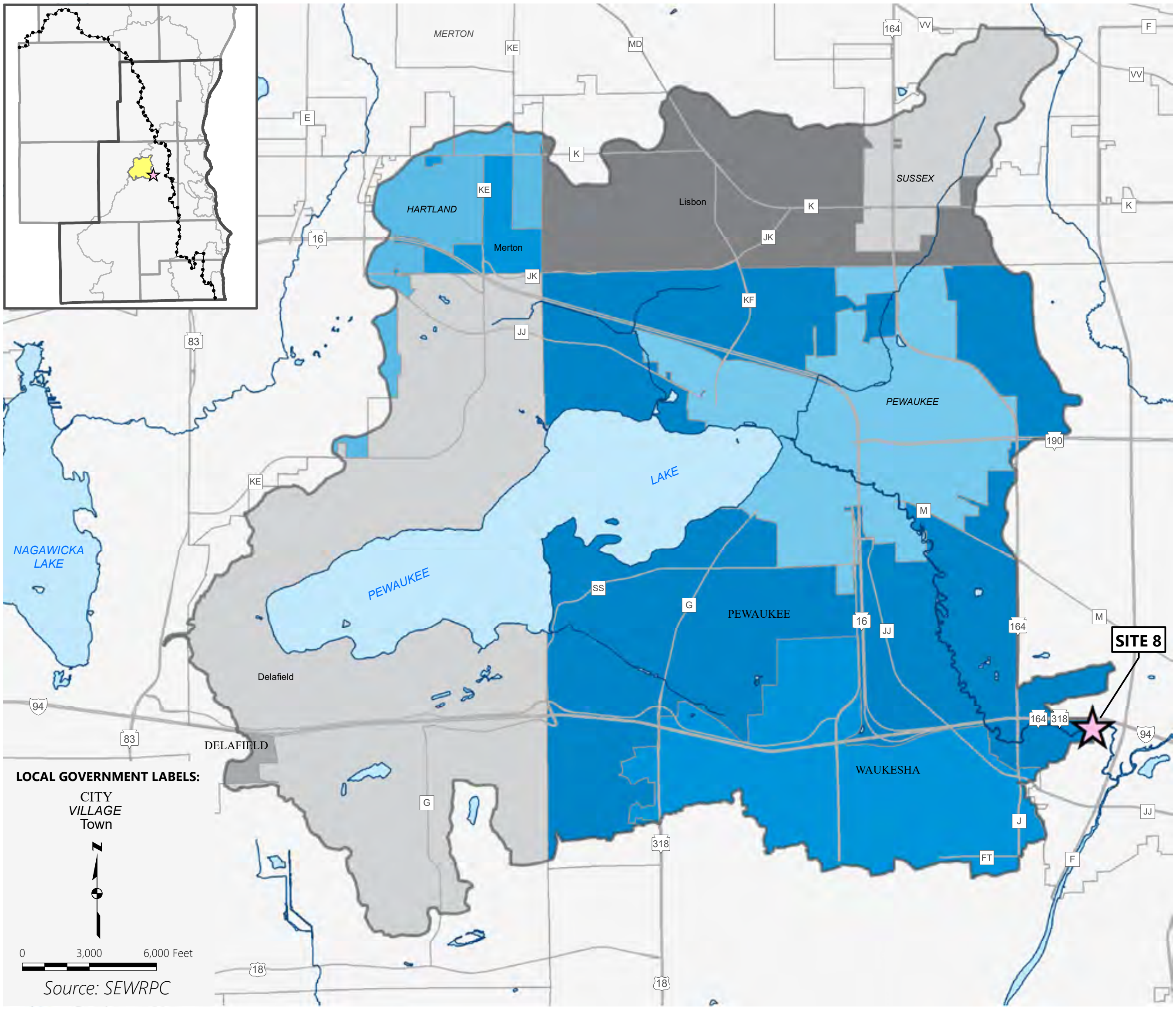
Map B.11
Site 8: Pewaukee River Drainage Area – Existing Land Use



Source: SEWRPC



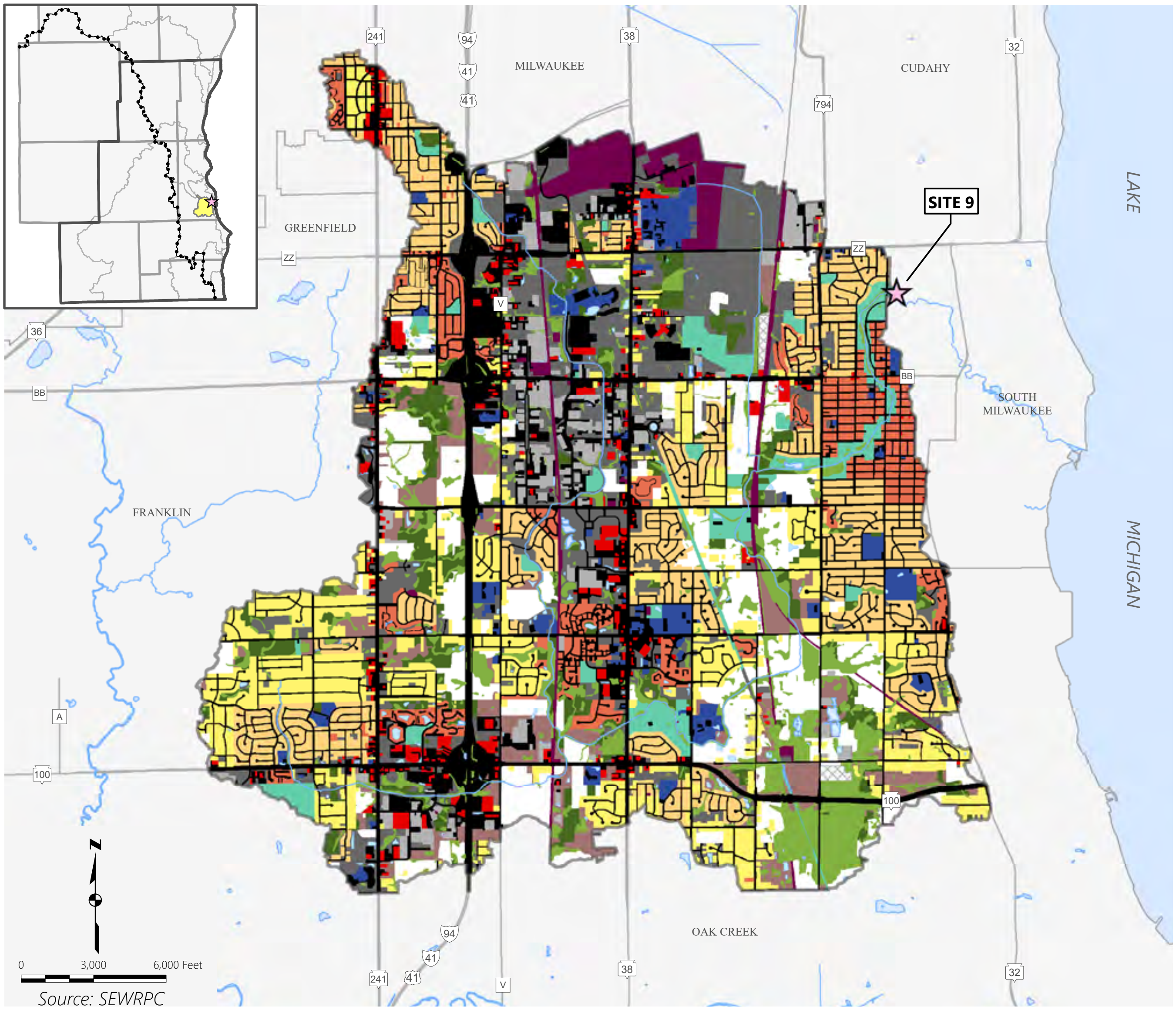
Map B.12
Site 8: Pewaukee River Drainage Area – Characteristics



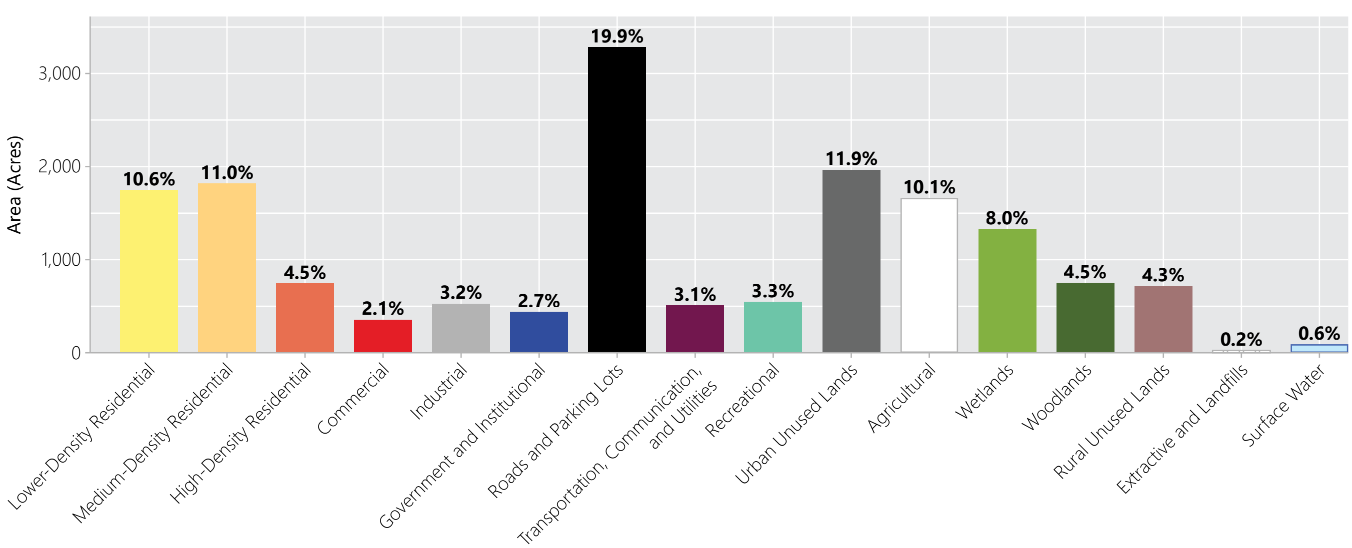
Facts at a Glance

- **Drainage Area Size:** 38 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 52.7%; Rural – 47.3%
- **Roads and Parking Lots (% of drainage area):** 13.7
- **Estimated Population (2010):** 32,830
- **Estimated Households (2010):** 13,340
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 83
- **Water Supply Source:** Groundwater (water supplied by the City of Waukesha is planned to be converted from groundwater to Lake Michigan supply in 2023)

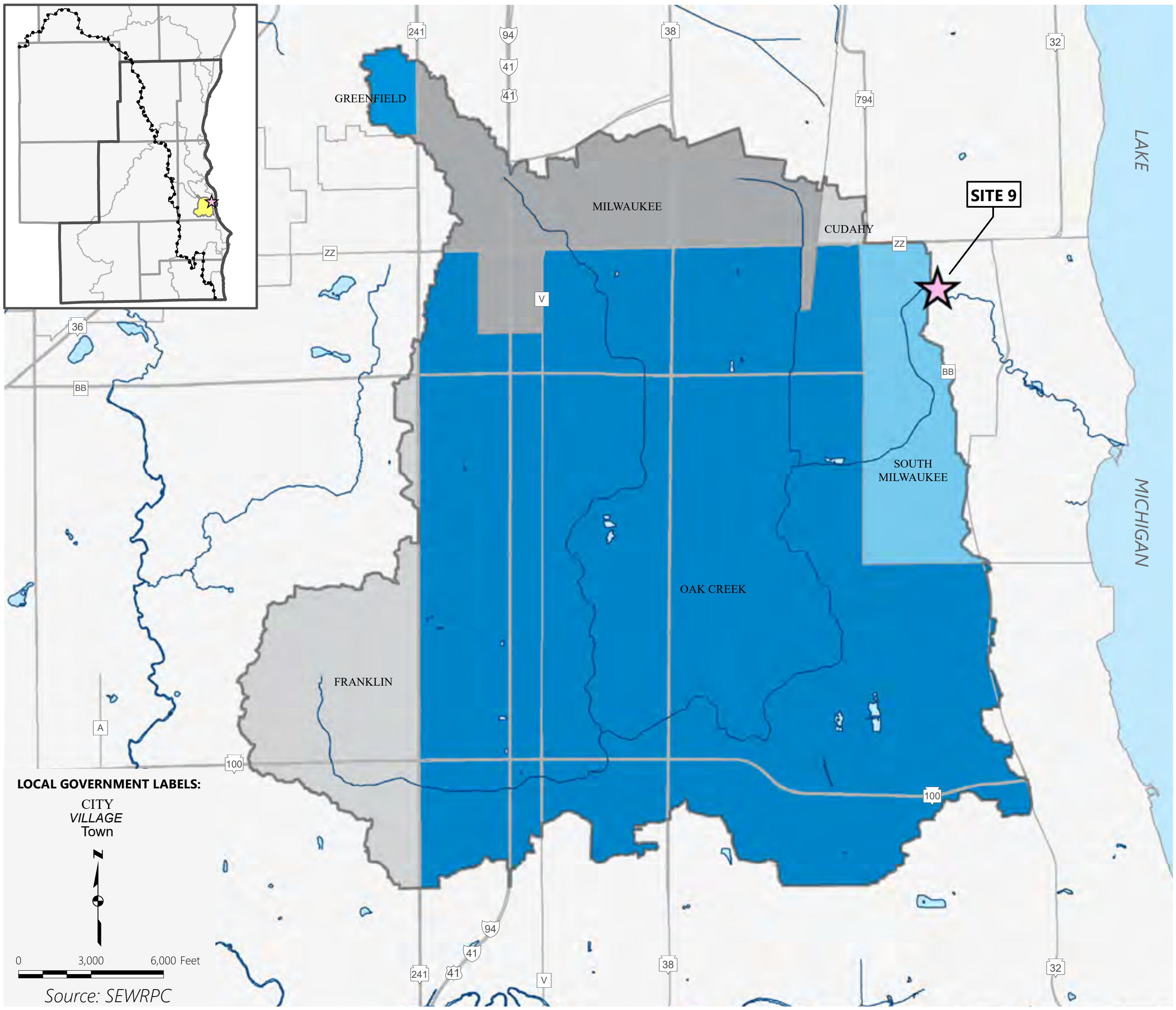
Map B.13
Site 9: Oak Creek Drainage Area – Existing Land Use



Source: SEWRPC



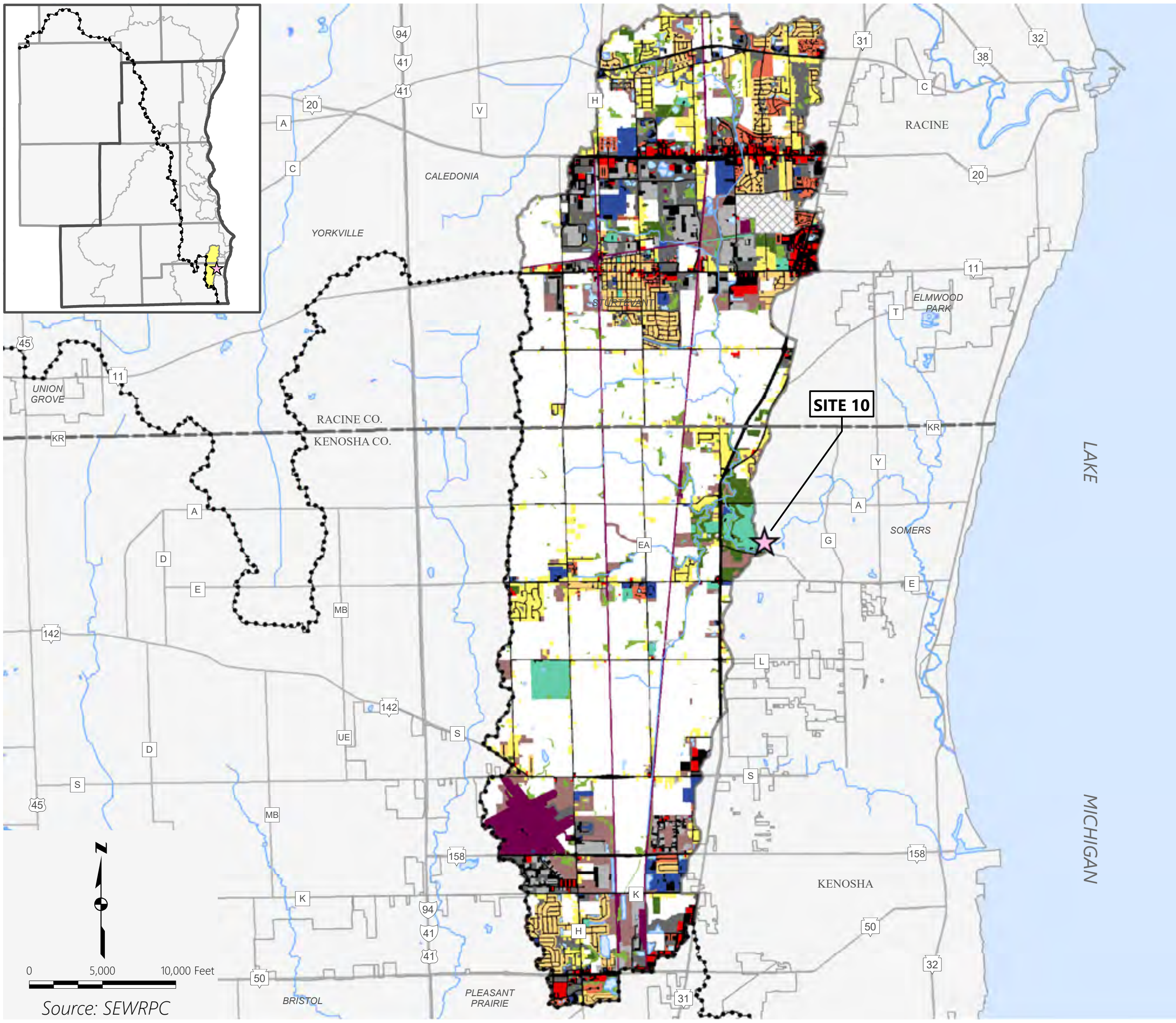
Map B.14
Site 9: Oak Creek Drainage Area – Characteristics

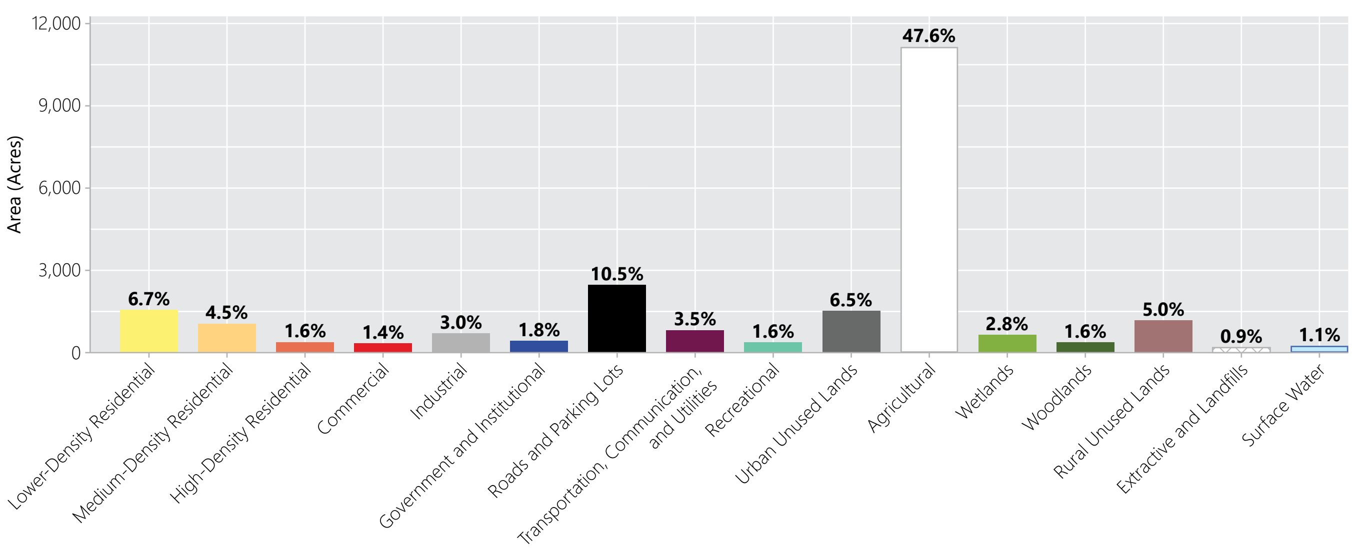


Facts at a Glance

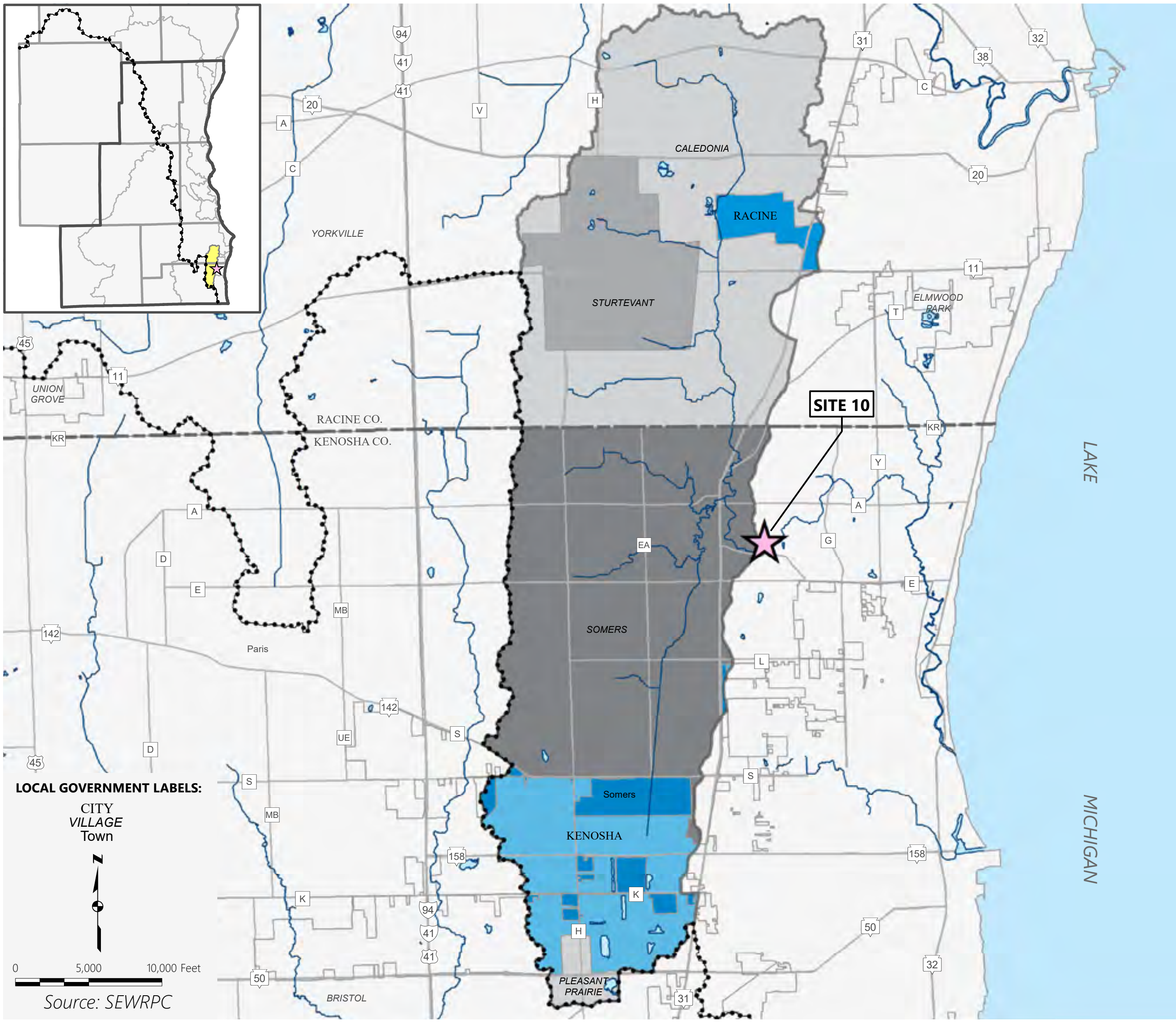
- **Drainage Area Size:** 26 square miles
- **Major Watershed:** Oak Creek
- **Land Use:** Urban – 72.3%; Rural – 27.7%
- **Roads and Parking Lots (% of drainage area):** 19.9
- **Estimated Population (2010):** 47,130
- **Estimated Households (2010):** 19,840
- **Nearest USGS Streamgage:** Oak Creek at South Milwaukee (04087204)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 100
- **Water Supply Source:** Lake Michigan

Map B.15
Site 10: Pike River Drainage Area – Existing Land Use





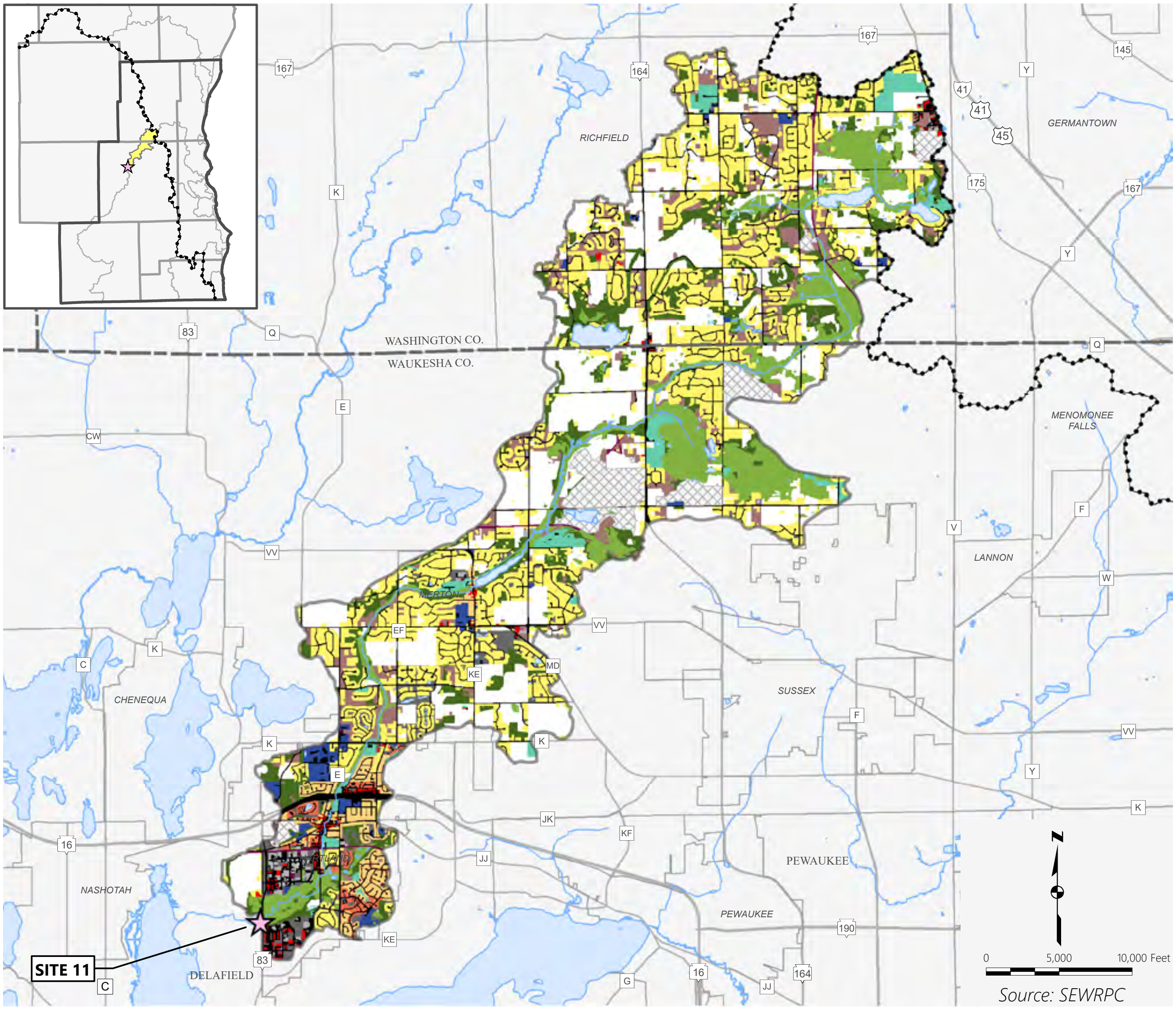
Map B.16
Site 10: Pike River Drainage Area – Characteristics



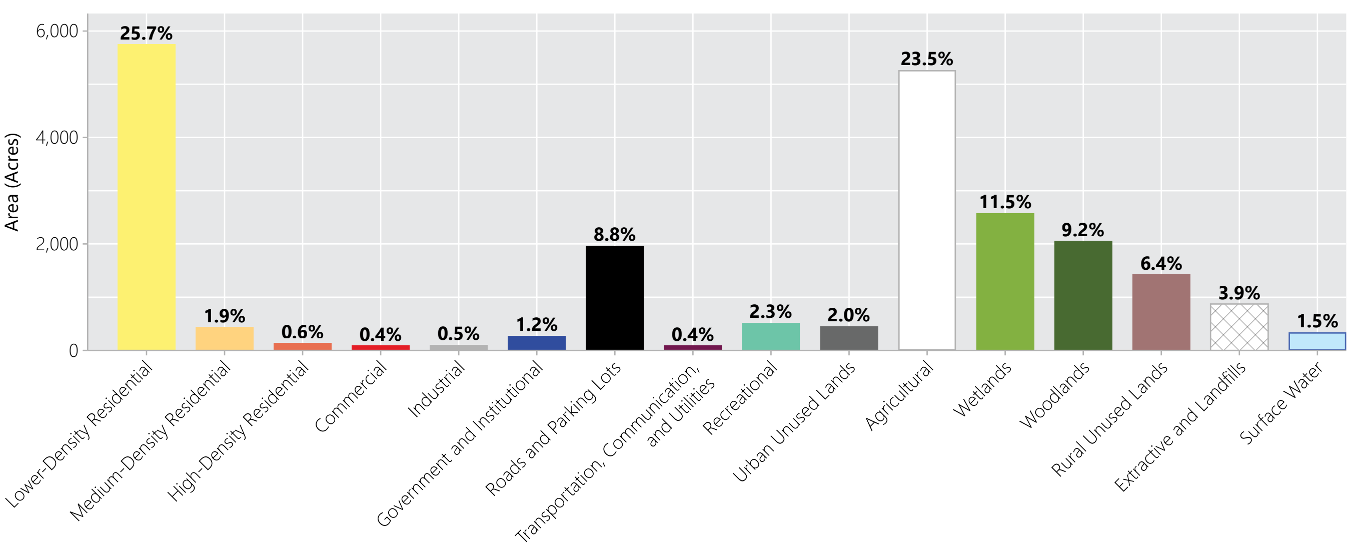
Facts at a Glance

- **Drainage Area Size:** 37 square miles
- **Major Watershed:** Pike River
- **Land Use:** Urban – 41.1%; Rural – 58.9%
- **Roads and Parking Lots (% of drainage area):** 10.5
- **Estimated Population (2010):** 25,790
- **Estimated Households (2010):** 9,930
- **Nearest USGS Streamgage:** Pike River near Racine (04087257)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 100
- **Water Supply Source:** Lake Michigan

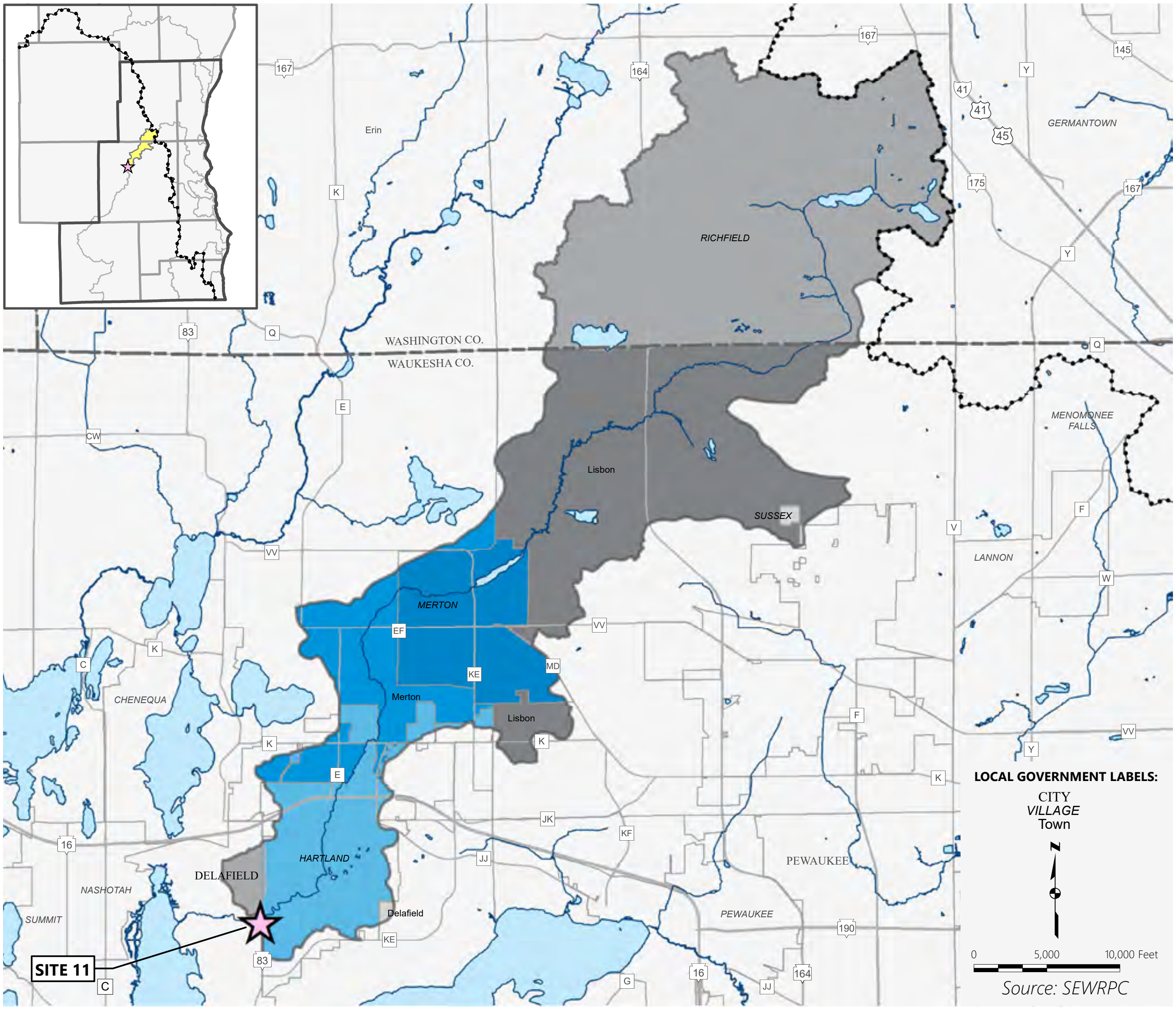
Map B.17
Site 11: Bark River Upstream Drainage Area – Existing Land Use



Source: SEWRPC



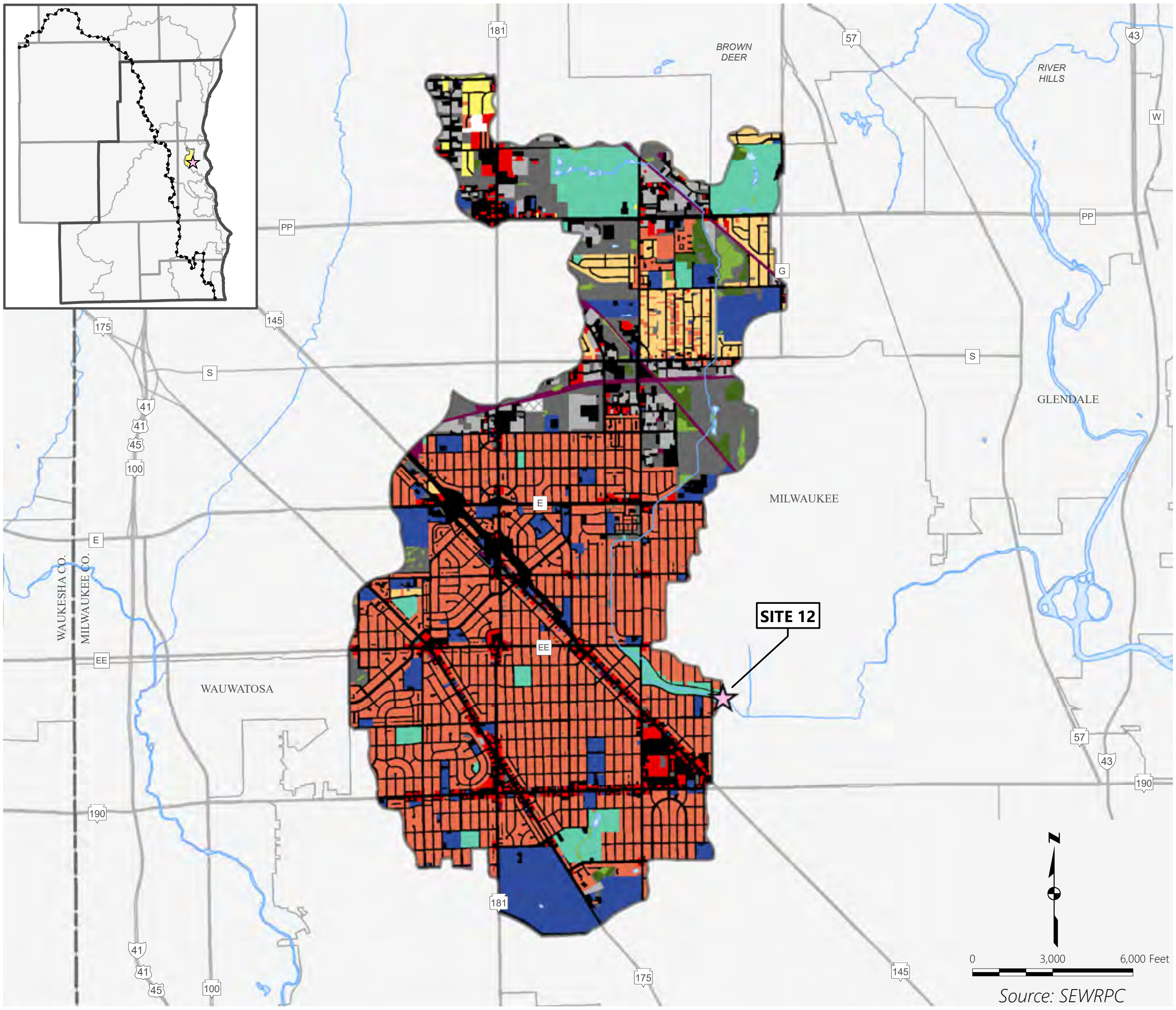
Map B.18
Site 11: Bark River Upstream Drainage Area – Characteristics

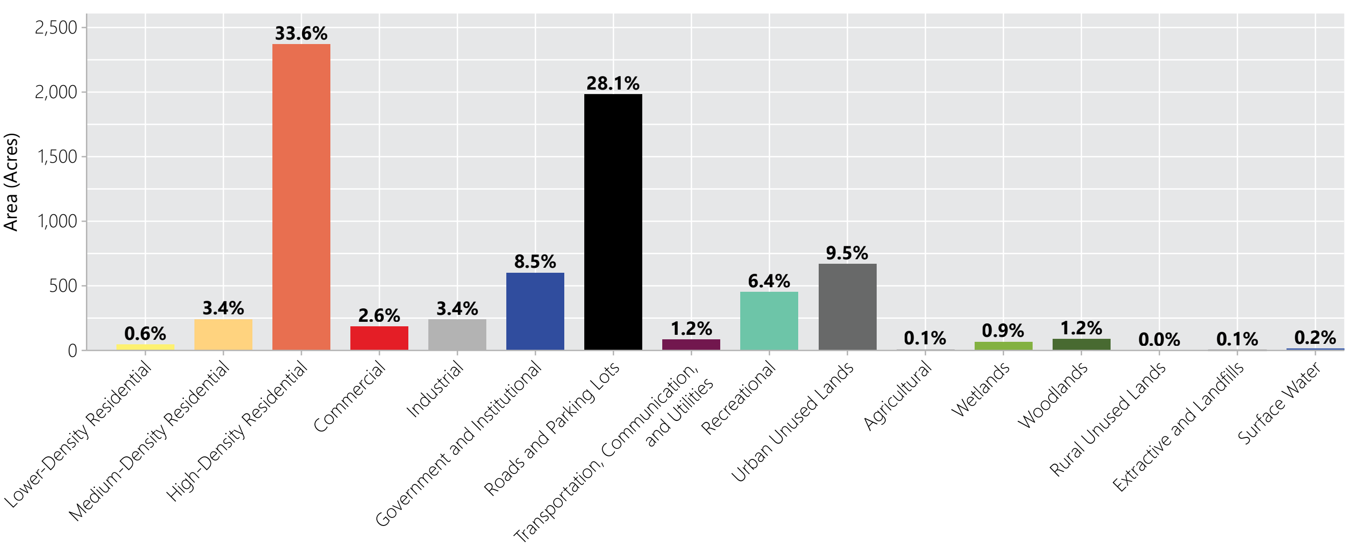


Facts at a Glance

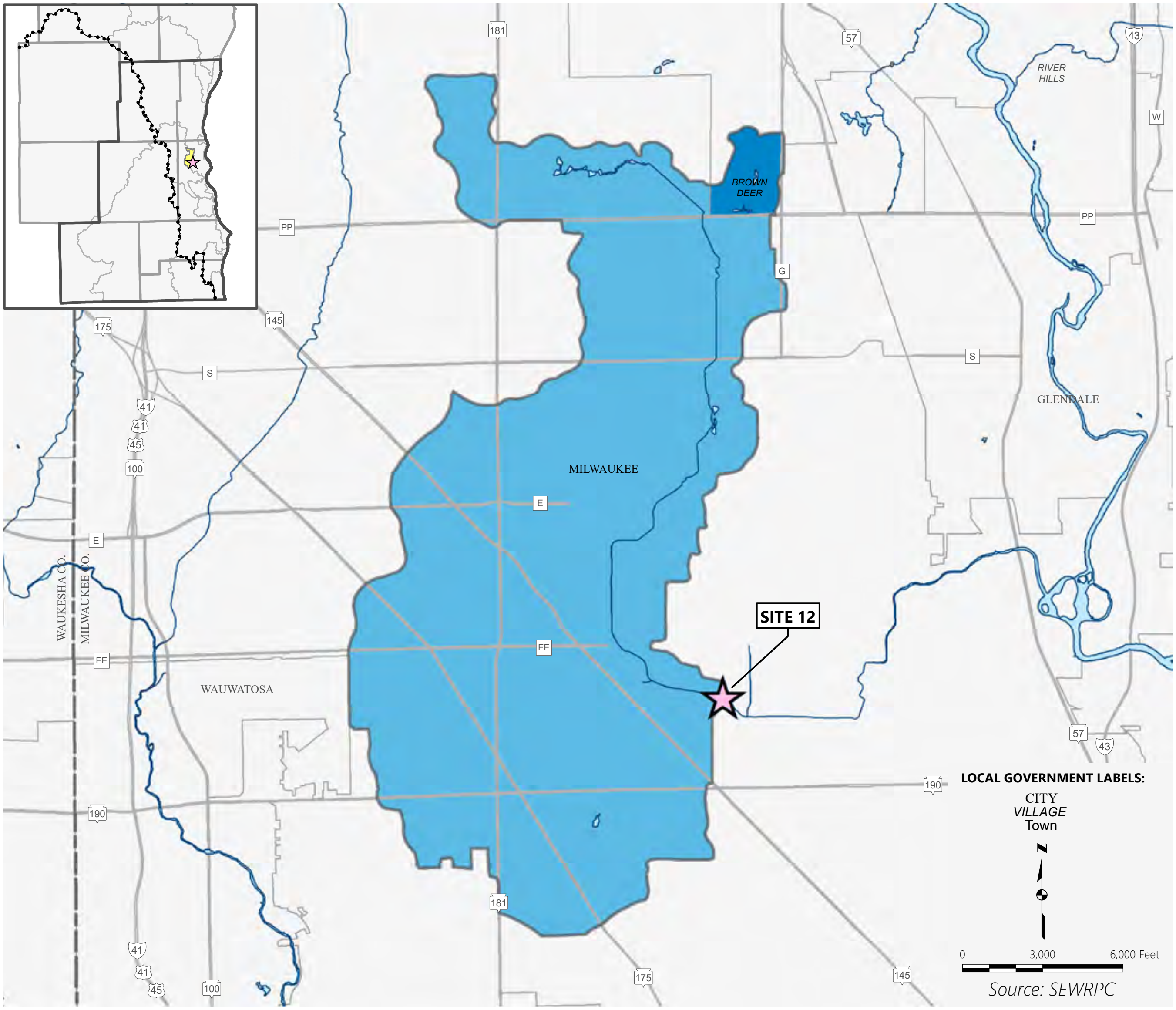
- **Drainage Area Size:** 35 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 43.9%; Rural – 56.1%
- **Roads and Parking Lots (% of drainage area):** 8.8
- **Estimated Population (2010):** 19,970
- **Estimated Households (2010):** 7,330
- **Nearest USGS Streamgage:** Bark River at Nagawicka Road (05426067)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (♦):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 23
- **Water Supply Source:** Groundwater

Map B.19
Site 12: Lincoln Creek Drainage Area – Existing Land Use





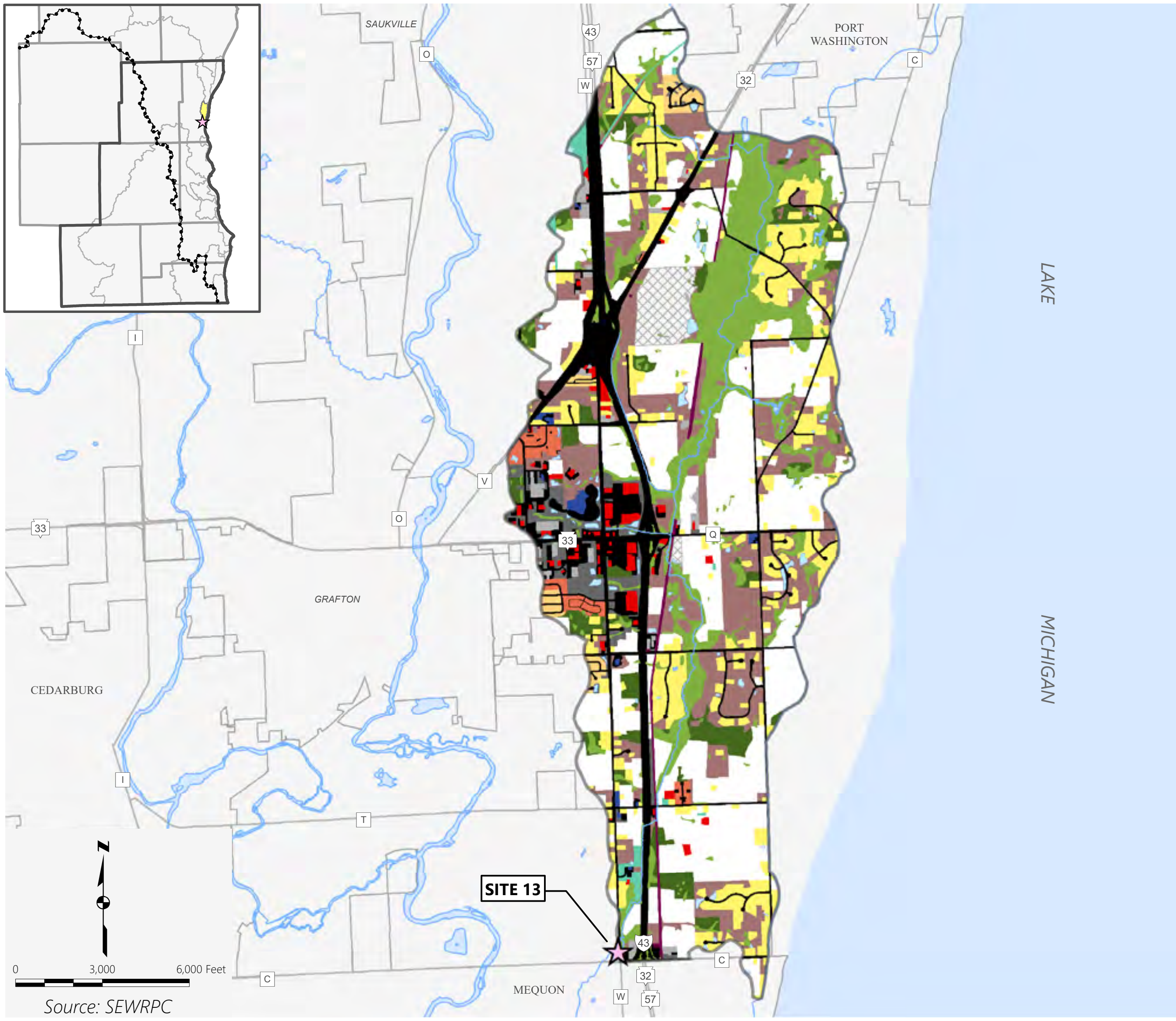
Map B.20
Site 12: Lincoln Creek Drainage Area – Characteristics

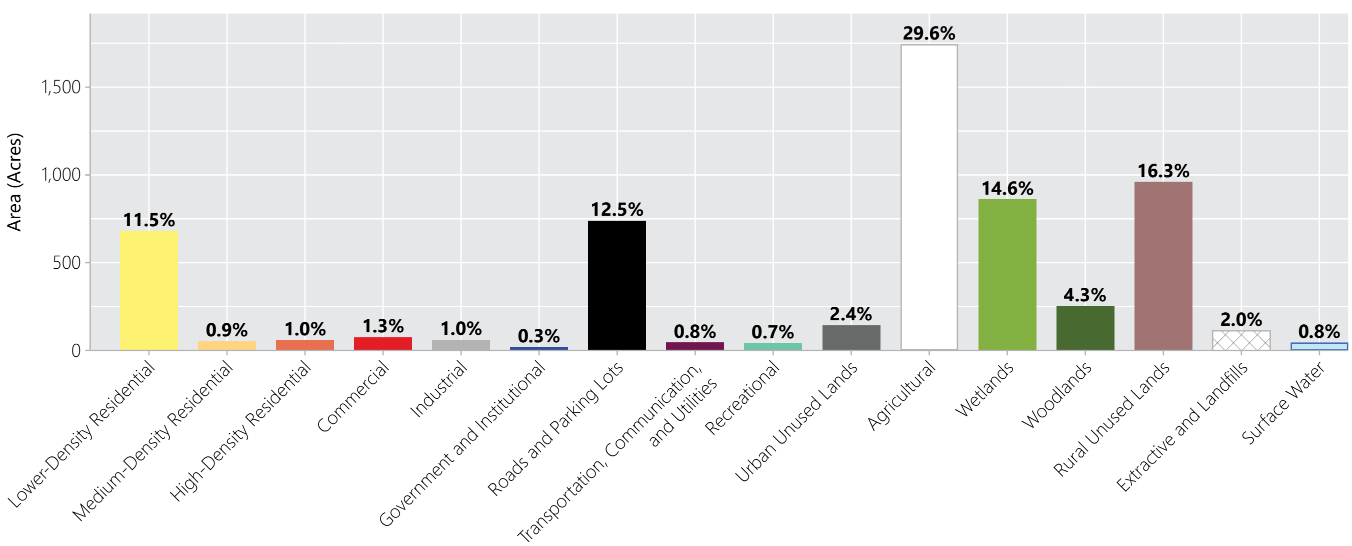


Facts at a Glance

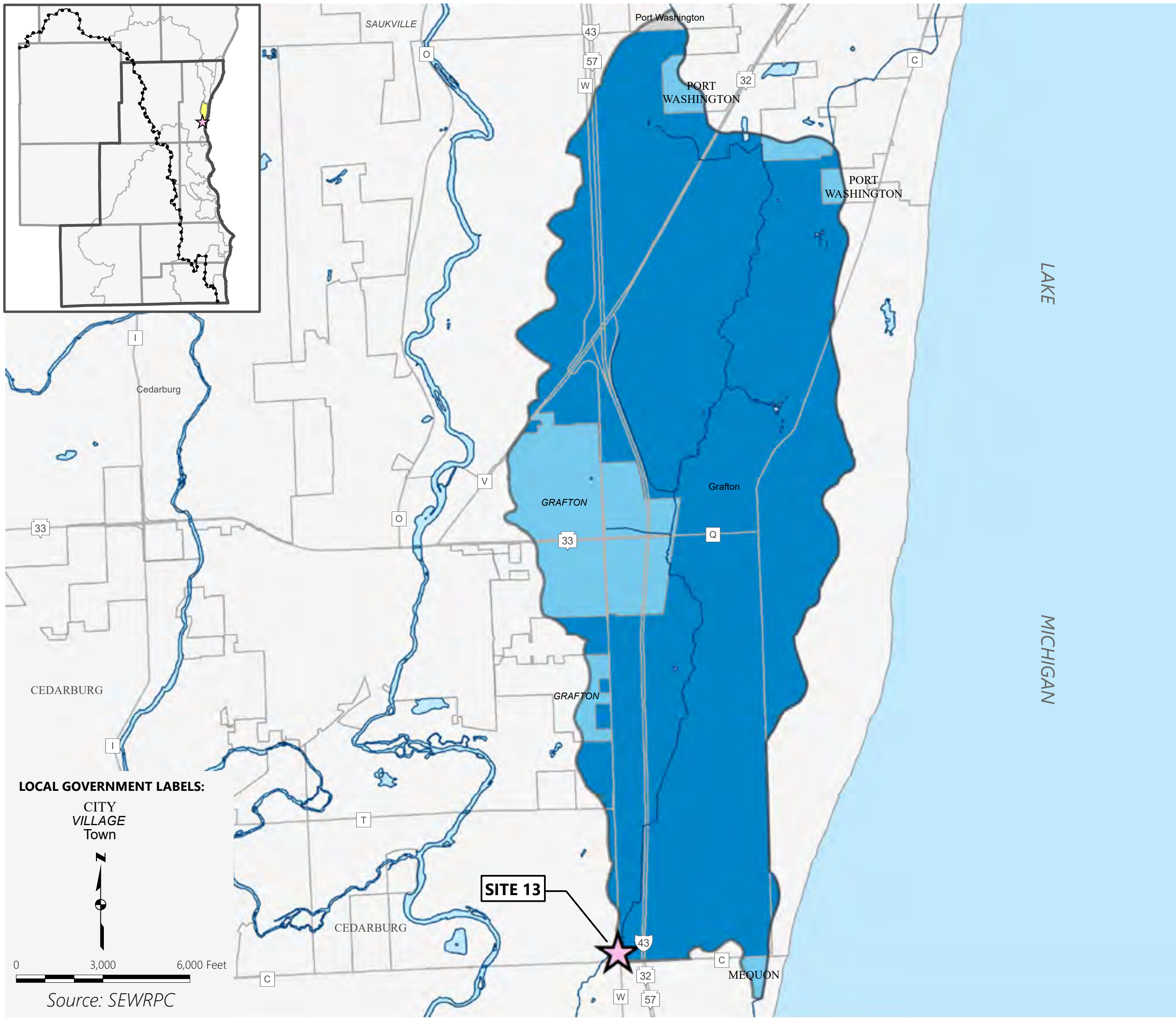
- **Drainage Area Size:** 11 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 97.4%; Rural – 2.6%
- **Roads and Parking Lots (% of drainage area):** 28.1
- **Estimated Population (2010):** 60,500
- **Estimated Households (2010):** 22,210
- **Nearest USGS Streamgage:** Lincoln Creek at Sherman Boulevard (040869416)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 100
- **Water Supply Source:** Lake Michigan

Map B.21
Site 13: Ulao Creek Drainage Area – Existing Land Use





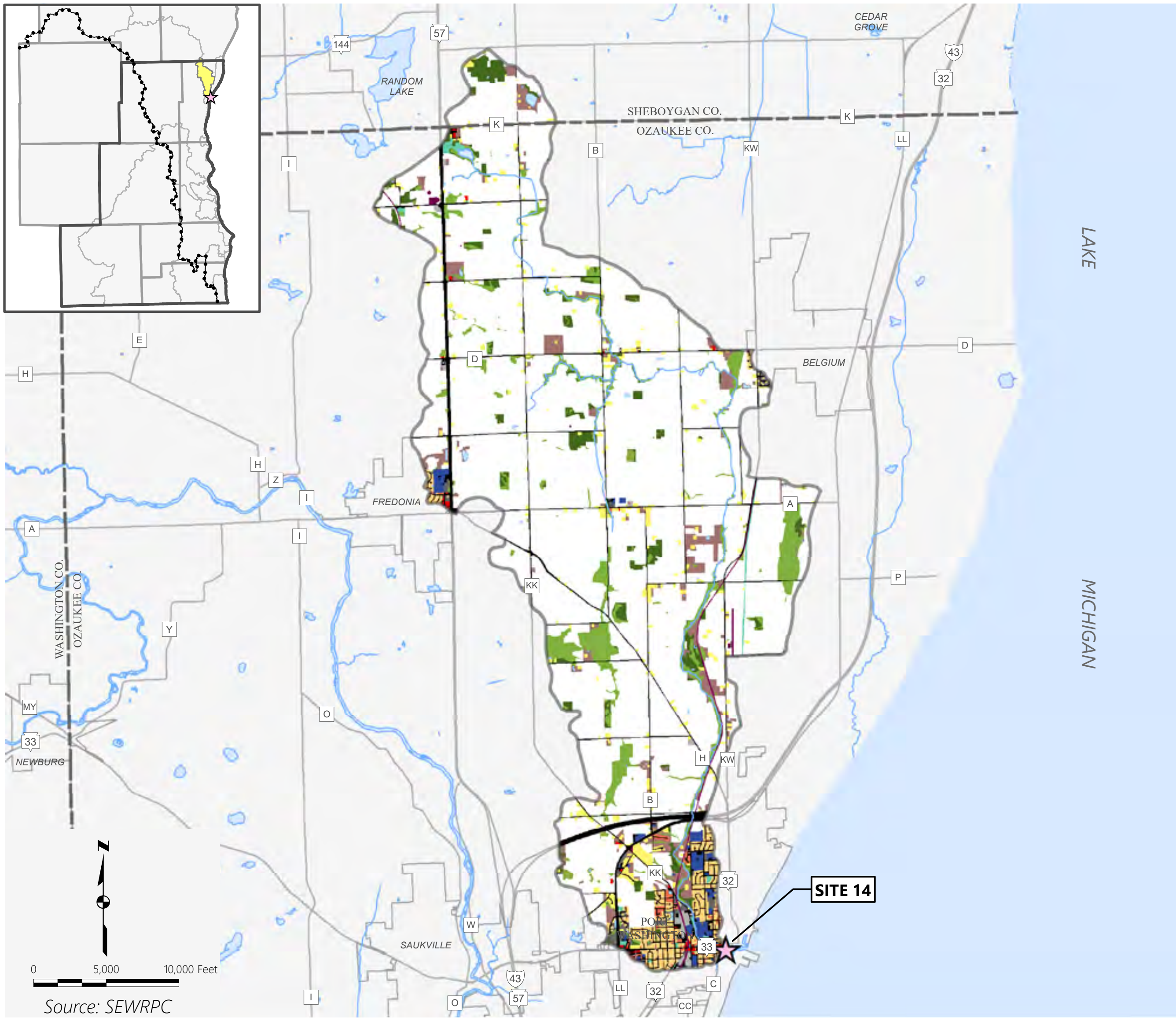
Map B.22
Site 13: Ulao Creek Drainage Area – Characteristics

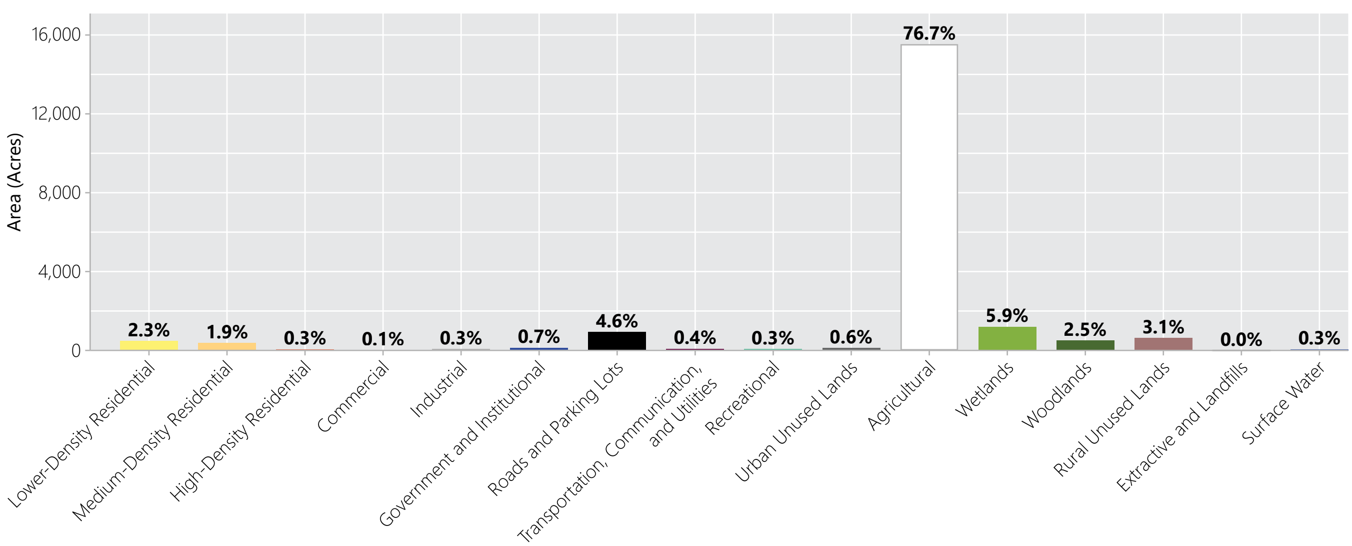


Facts at a Glance

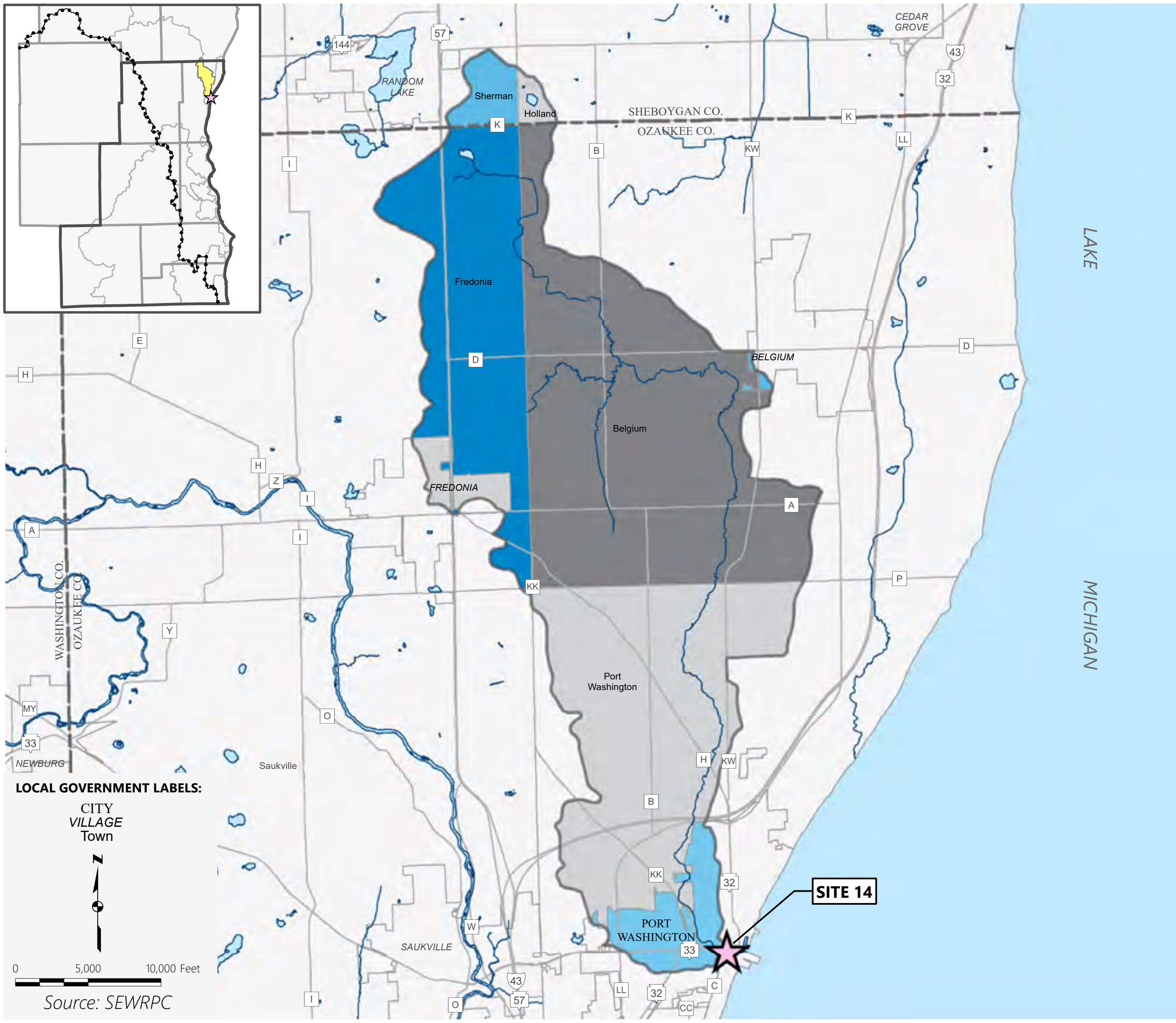
- **Drainage Area Size:** 9 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 32.5%; Rural – 67.5%
- **Roads and Parking Lots (% of drainage area):** 12.5
- **Estimated Population (2010):** 2,130
- **Estimated Households (2010):** 920
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 22
- **Water Supply Source:** Lake Michigan

Map B.23
Site 14: Sauk Creek Drainage Area – Existing Land Use





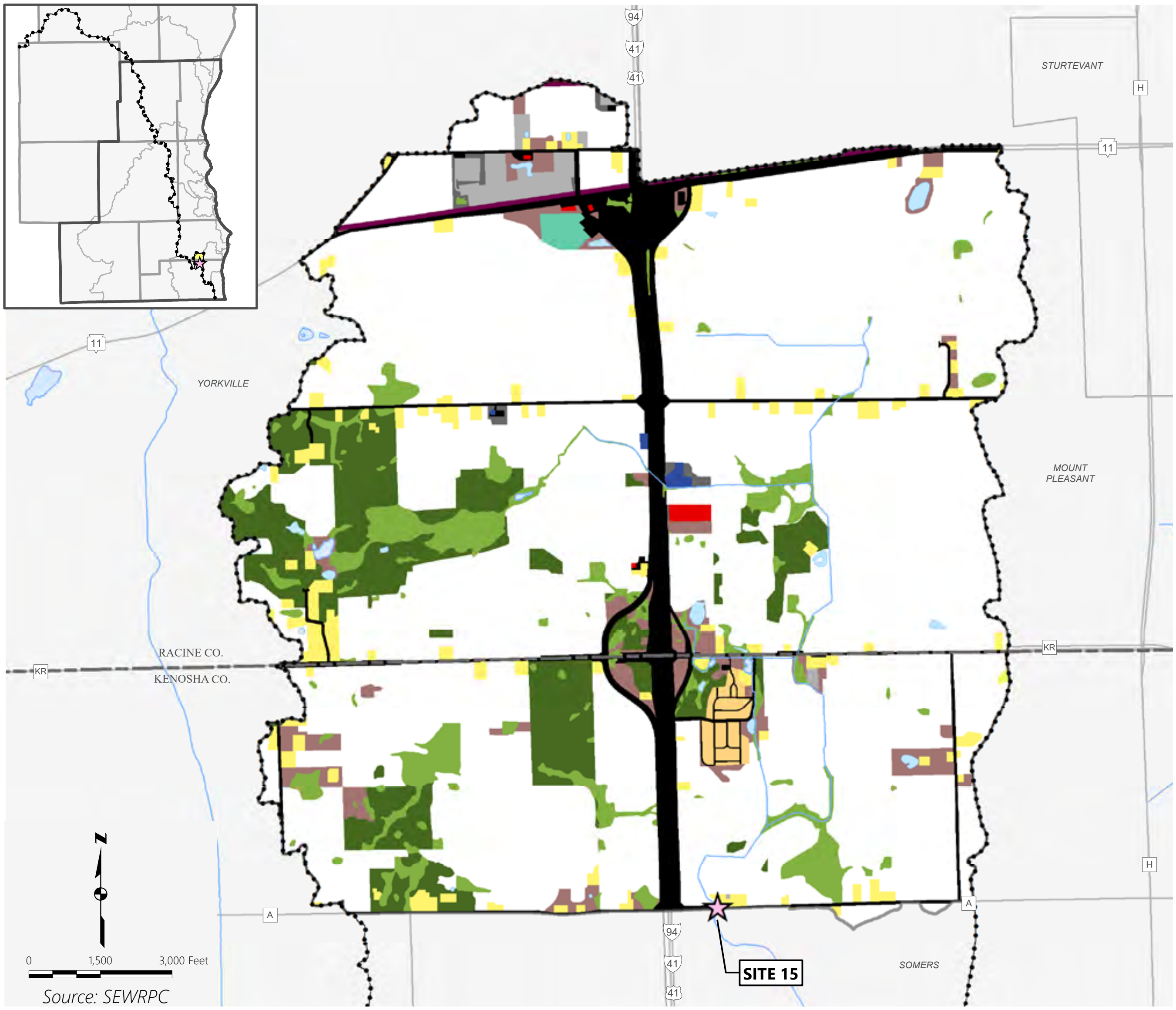
Map B.24
Site 14: Sauk Creek Drainage Area – Characteristics

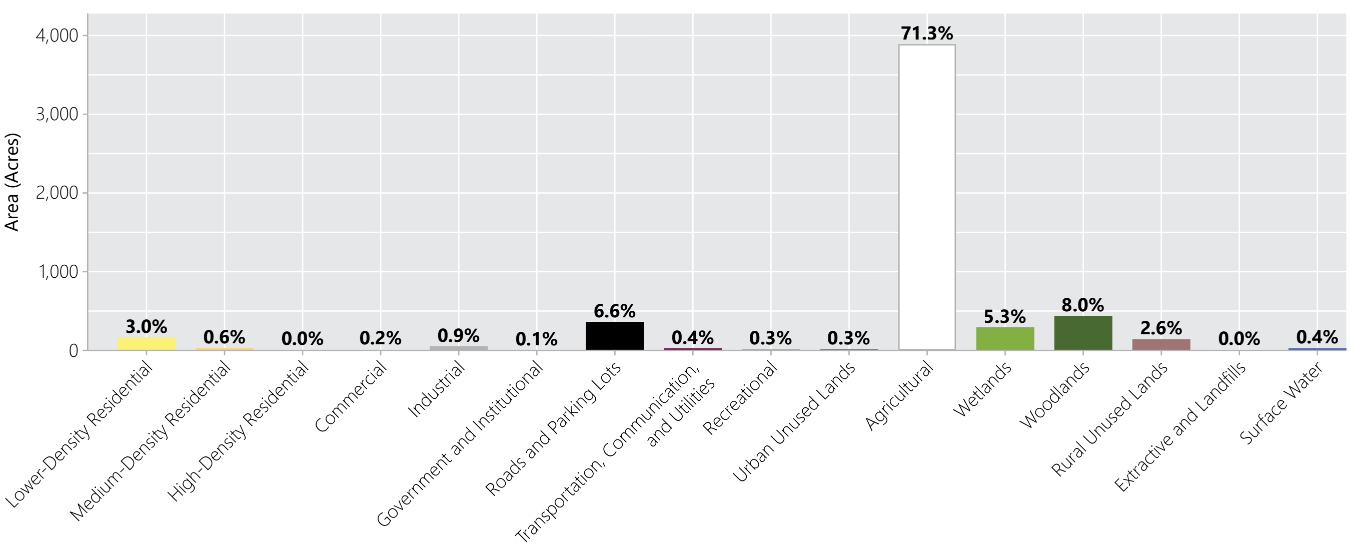


Facts at a Glance

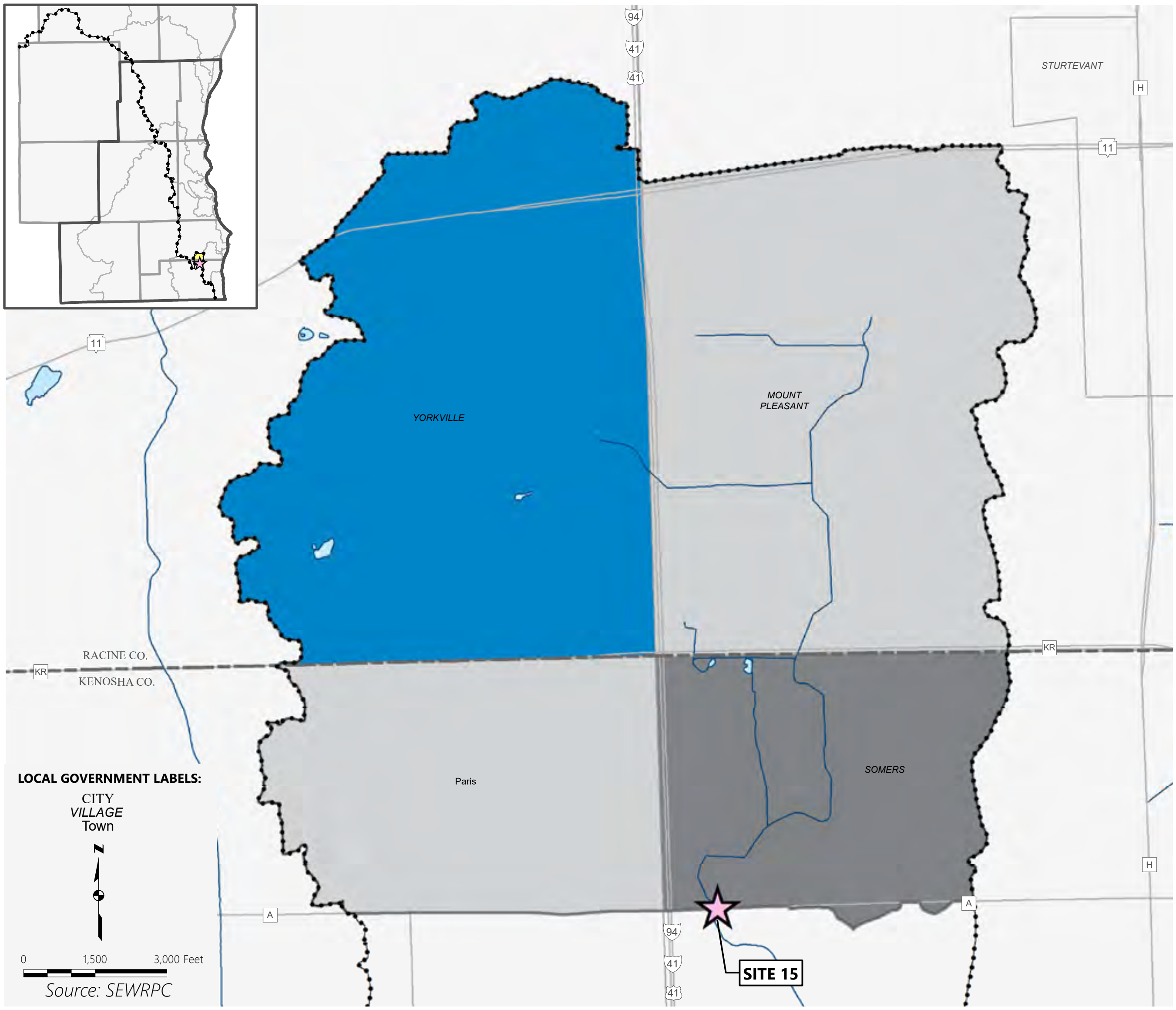
- **Drainage Area Size:** 32 square miles
- **Major Watershed:** Sauk Creek
- **Land Use:** Urban – 11.5%; Rural – 88.5%
- **Roads and Parking Lots (% of drainage area):** 4.6
- **Estimated Population (2010):** 6,700
- **Estimated Households (2010):** 2,730
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 9
- **Water Supply Source:** Lake Michigan and Groundwater

Map B.25
Site 15: Kilbourn Road Ditch Drainage Area – Existing Land Use





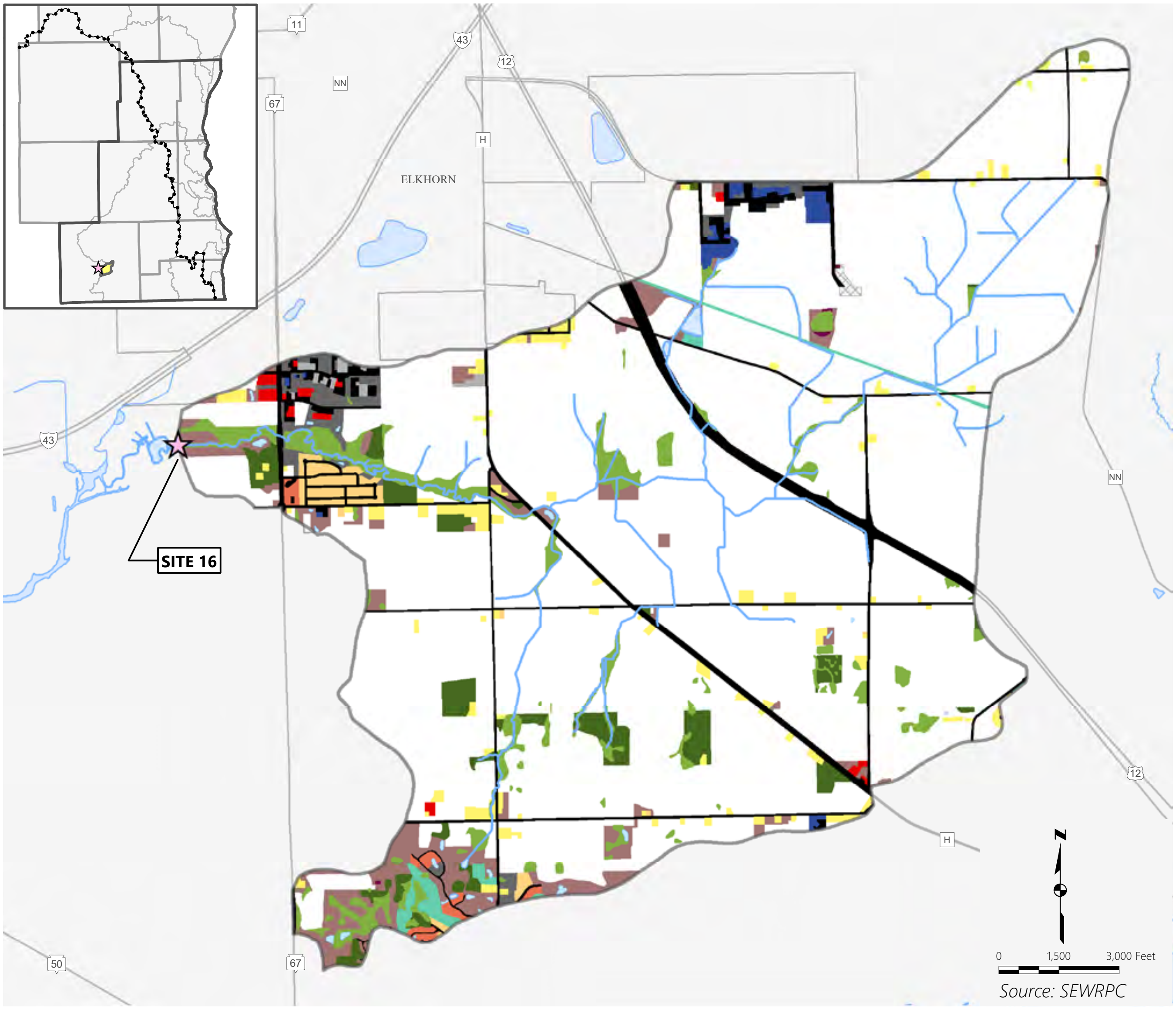
Map B.26
Site 15: Kilbourn Road Ditch Drainage Area – Characteristics

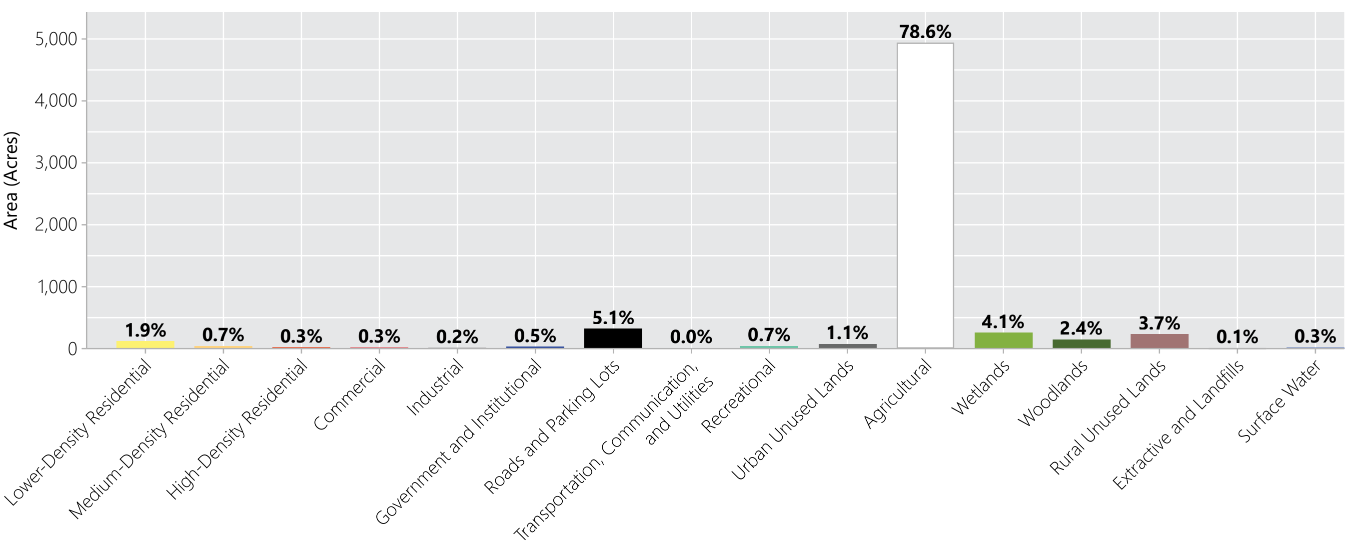


Facts at a Glance

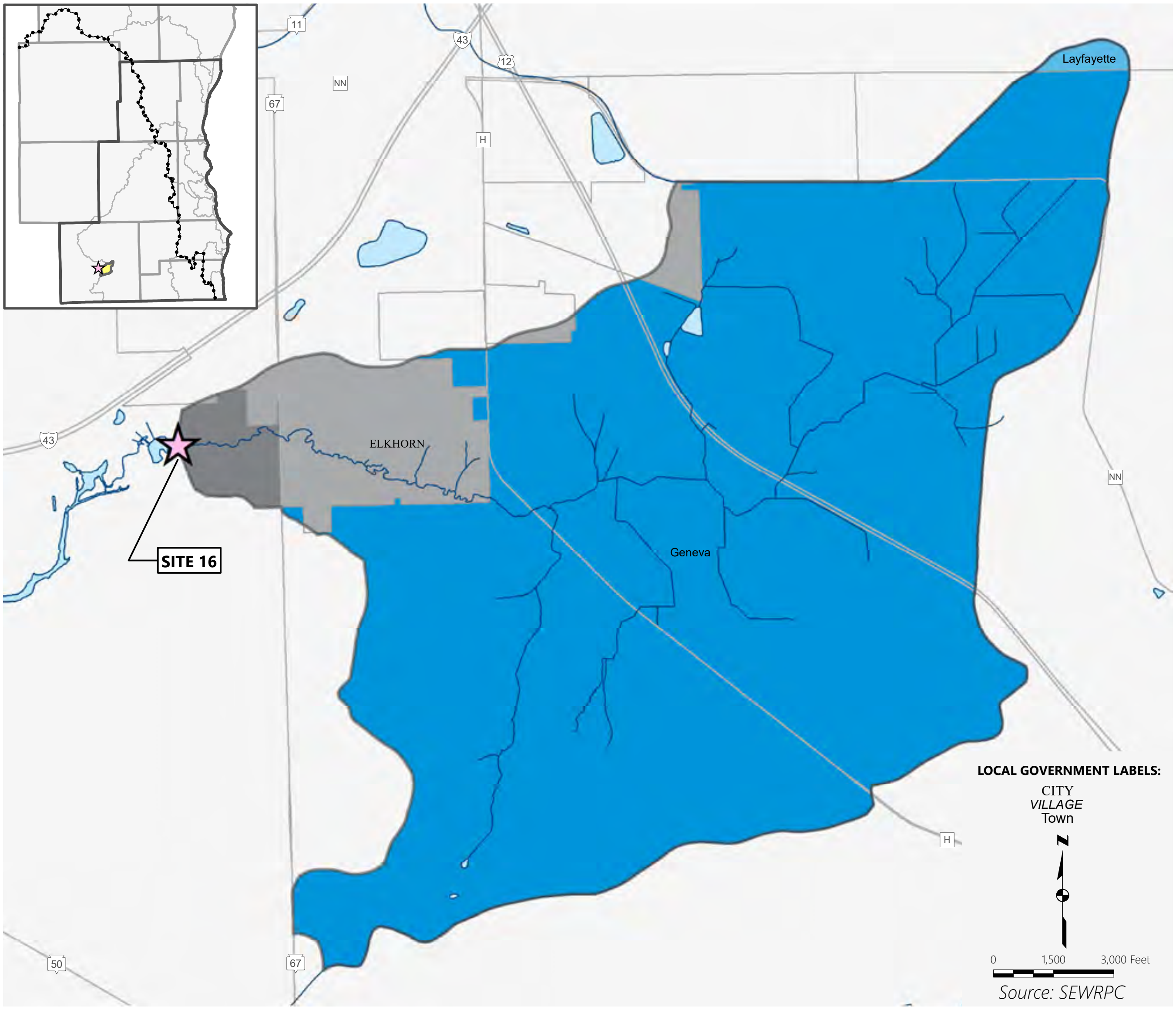
- **Drainage Area Size:** 9 square miles
- **Major Watershed:** Des Plaines River
- **Land Use:** Urban – 12.3%; Rural – 87.7%
- **Roads and Parking Lots (% of drainage area):** 6.6
- **Estimated Population (2010):** 570
- **Estimated Households (2010):** 290
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 52
- **Water Supply Source:** Lake Michigan and Groundwater

Map B.27
Site 16: Jackson Creek Drainage Area – Existing Land Use





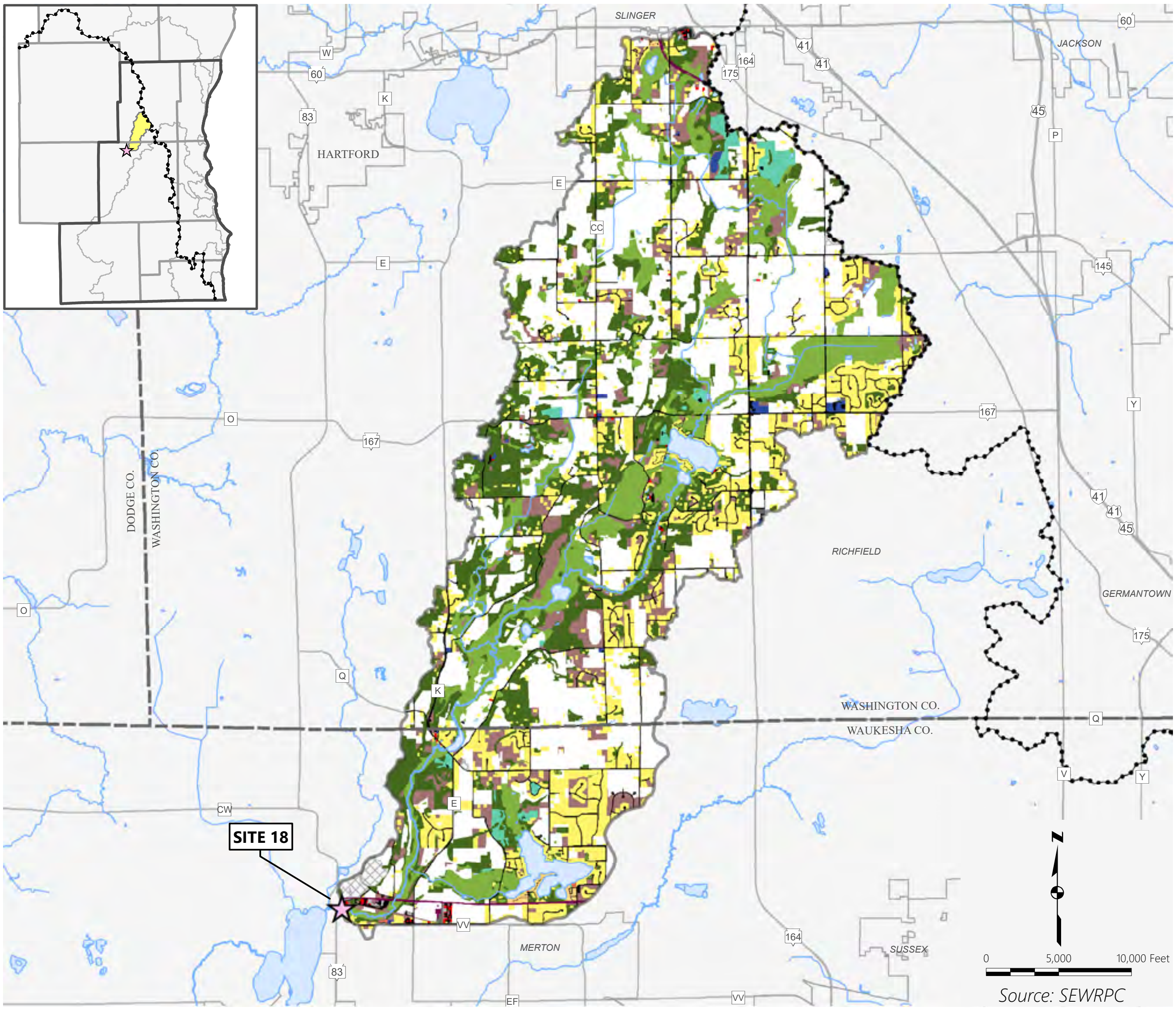
Map B.28
Site 16: Jackson Creek Drainage Area – Characteristics



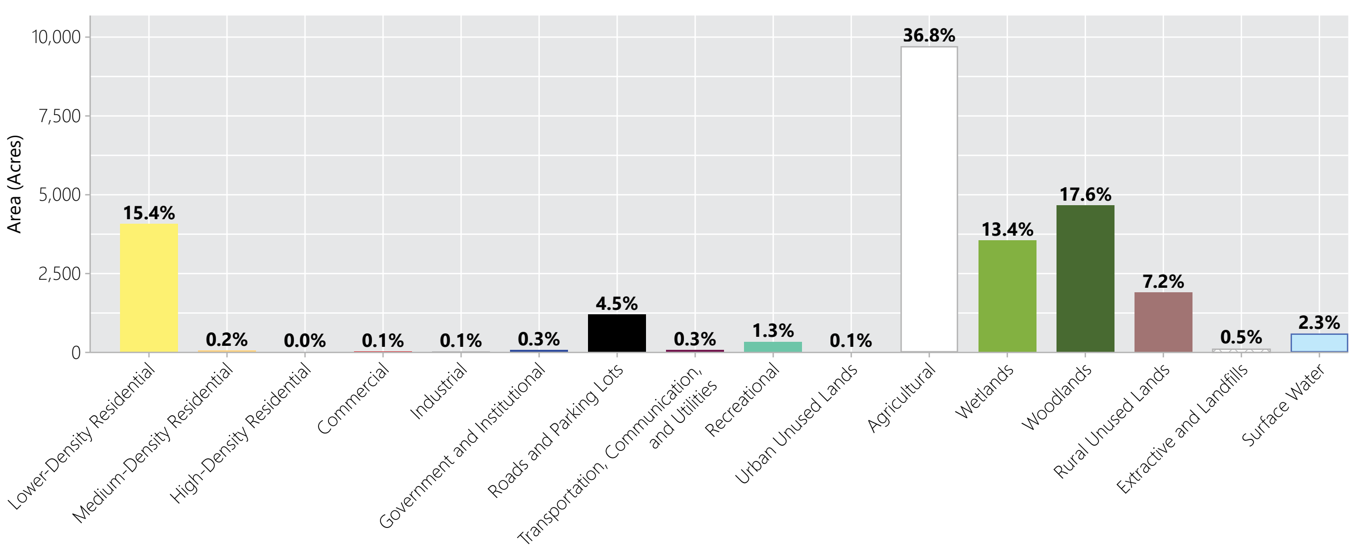
Facts at a Glance

- **Drainage Area Size:** 10 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 10.9%; Rural – 89.1%
- **Roads and Parking Lots (% of drainage area):** 5.1
- **Estimated Population (2010):** 820
- **Estimated Households (2010):** 330
- **Nearest USGS Streamgage:** Jackson Creek at Mound Road (05431016)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 20
- **Water Supply Source:** Groundwater

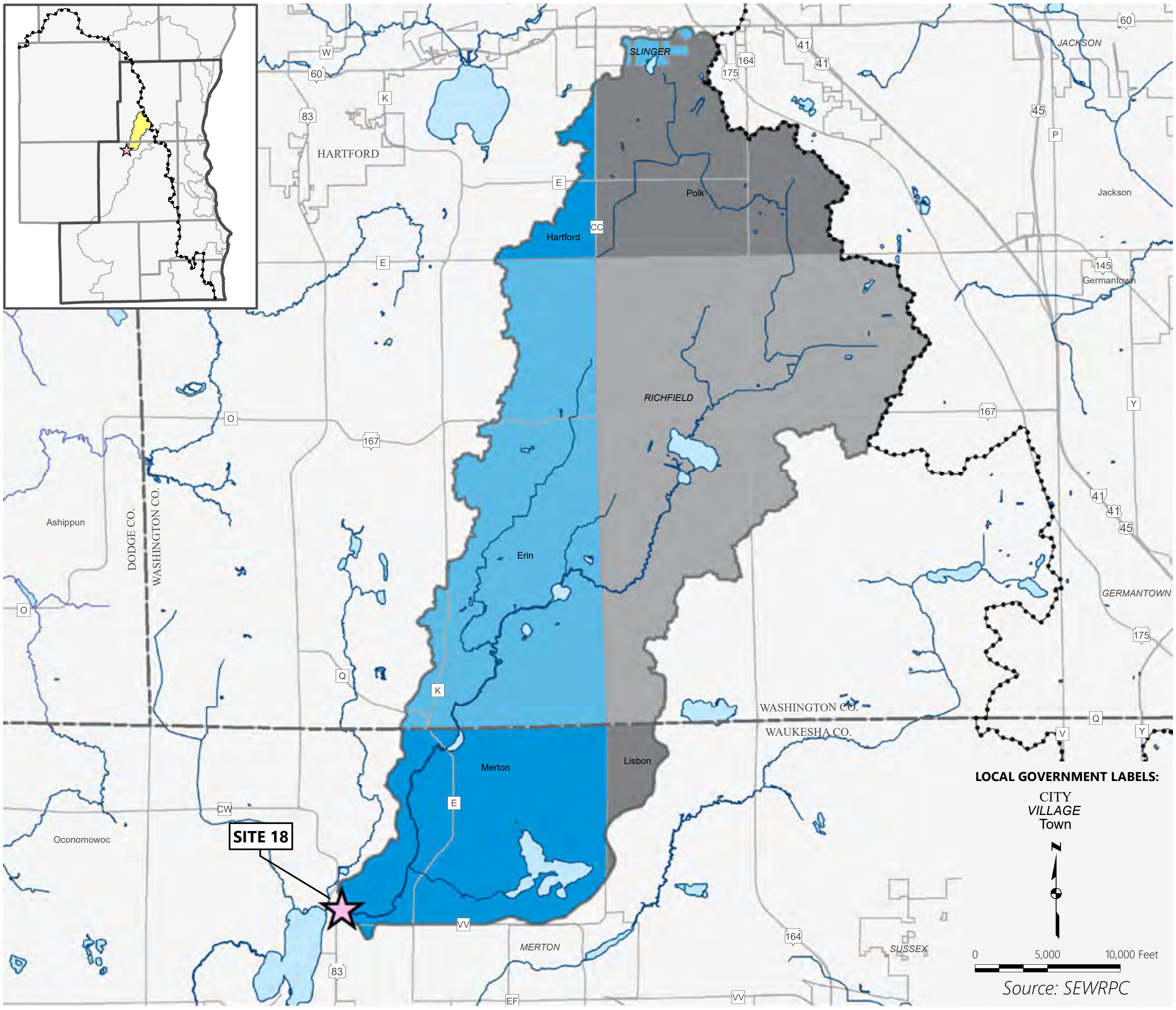
Map B.29
Site 18: Oconomowoc River Upstream Drainage Area – Existing Land Use



Source: SEWRPC



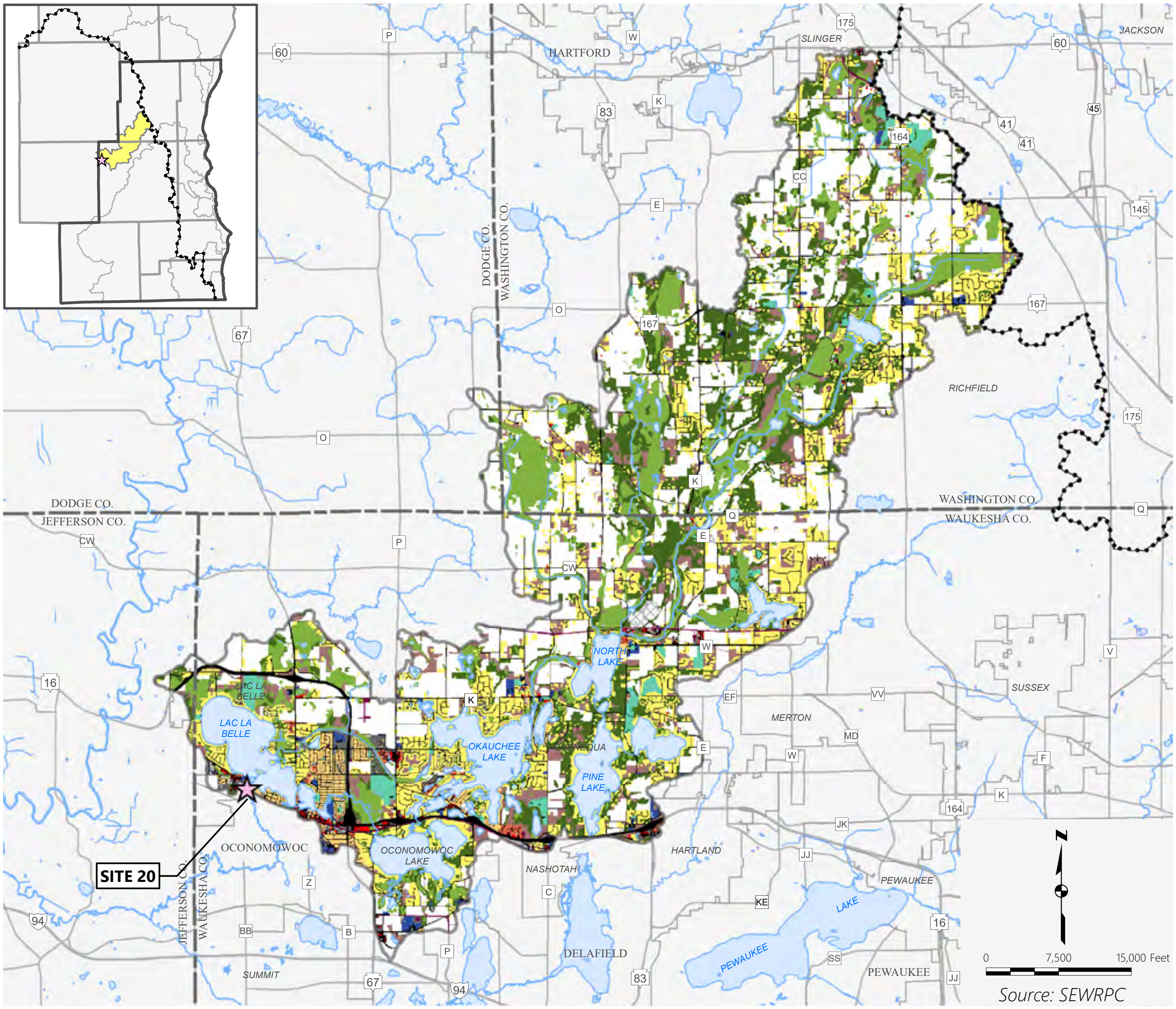
Map B.30
Site 18: Oconomowoc River Upstream Drainage Area – Characteristics

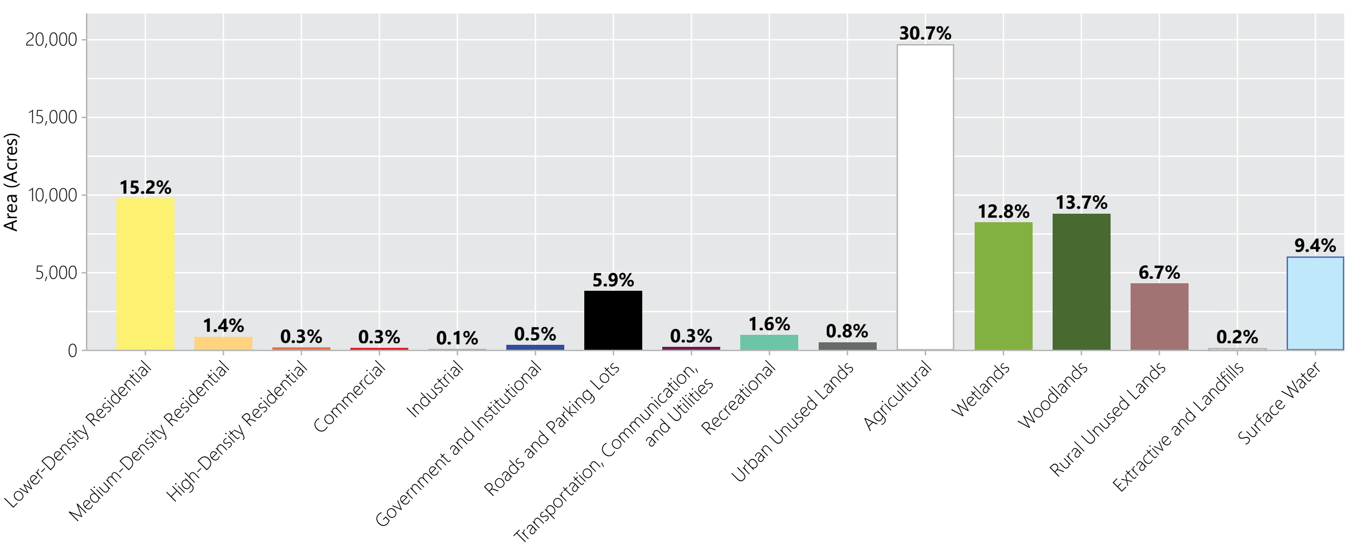


Facts at a Glance

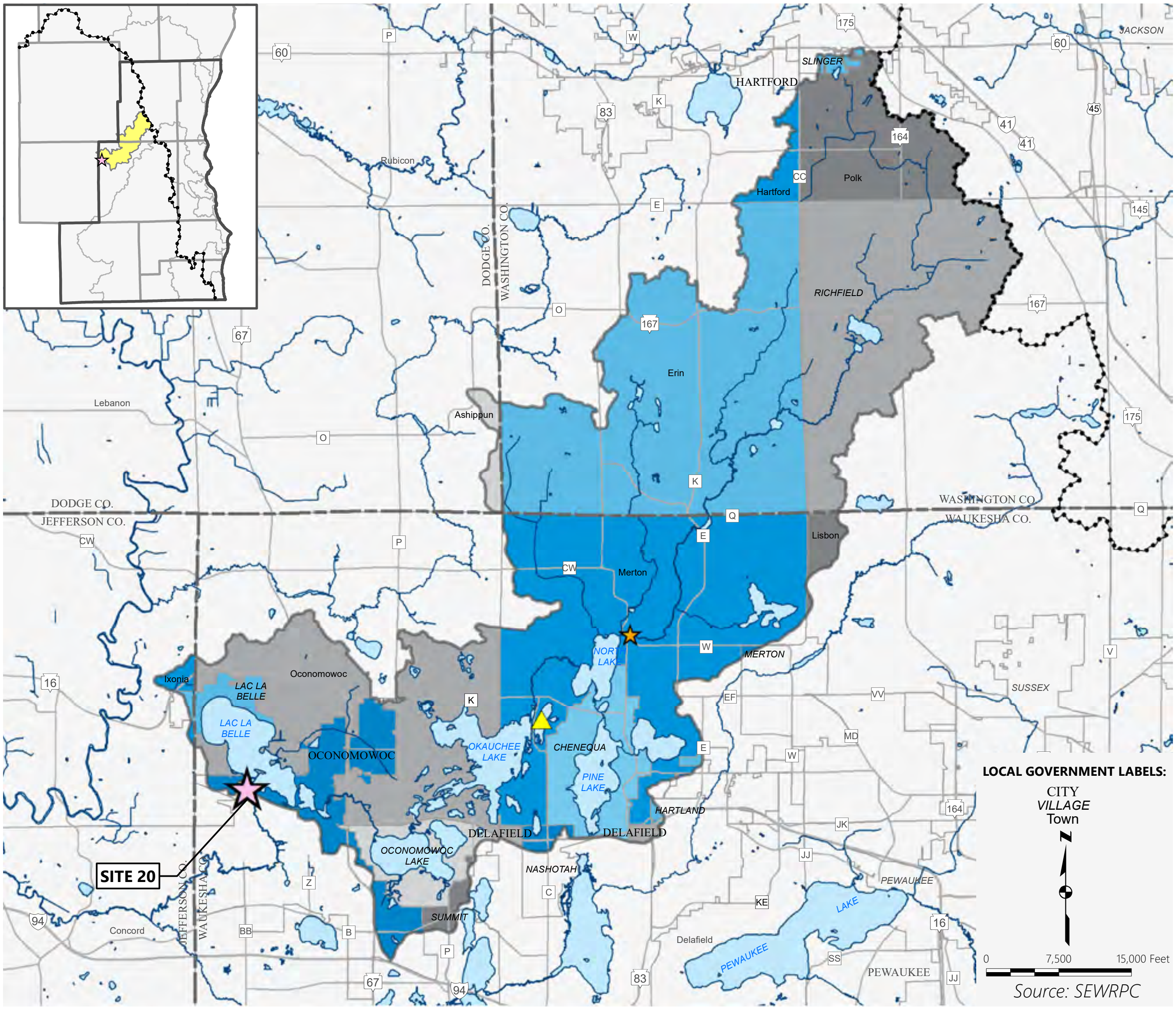
- **Drainage Area Size:** 41 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 22.3%; Rural – 77.7%
- **Roads and Parking Lots (% of drainage area):** 4.5
- **Estimated Population (2010):** 7,980
- **Estimated Households (2010):** 2,900
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (☆):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 7
- **Water Supply Source:** Groundwater

Map B.31
Site 20: Oconomowoc River Downstream Drainage Area – Existing Land Use





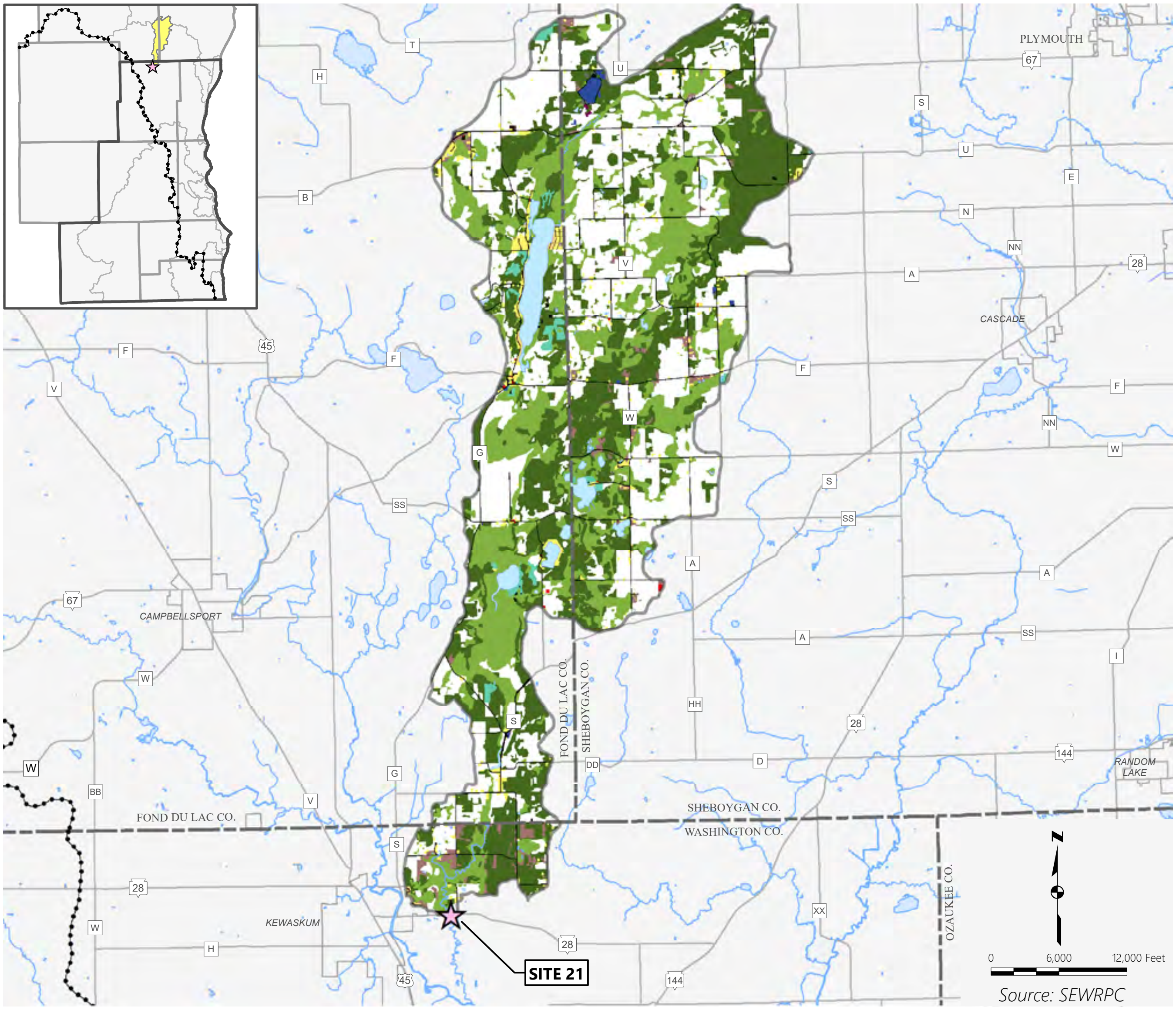
Map B.32
Site 20: Oconomowoc River Downstream Drainage Area – Characteristics

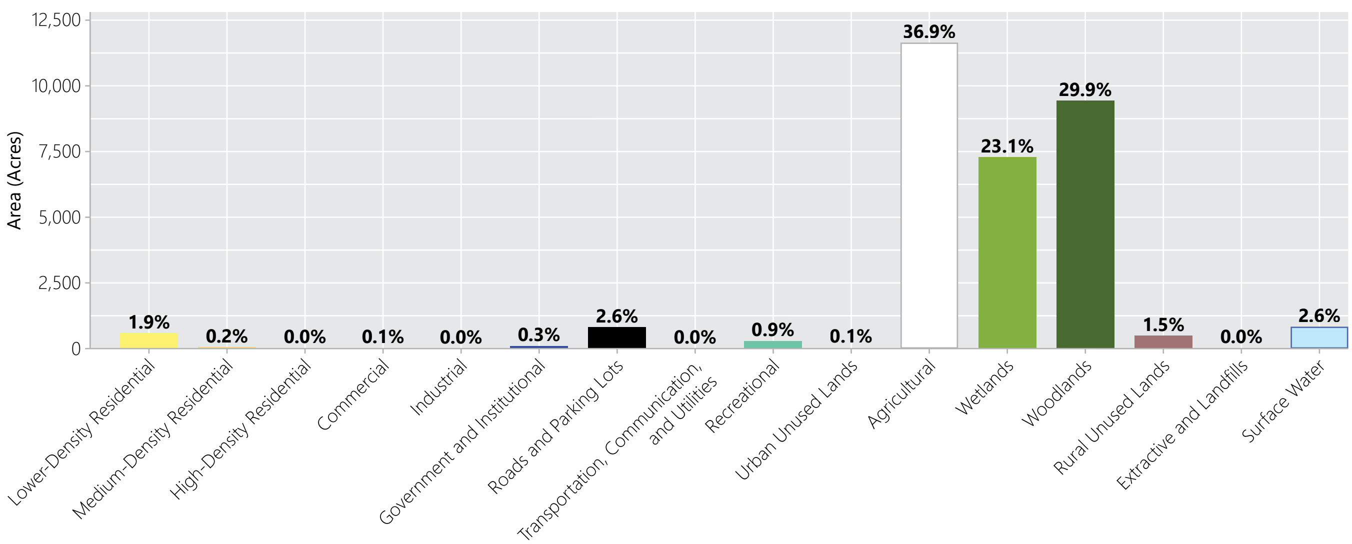


Facts at a Glance

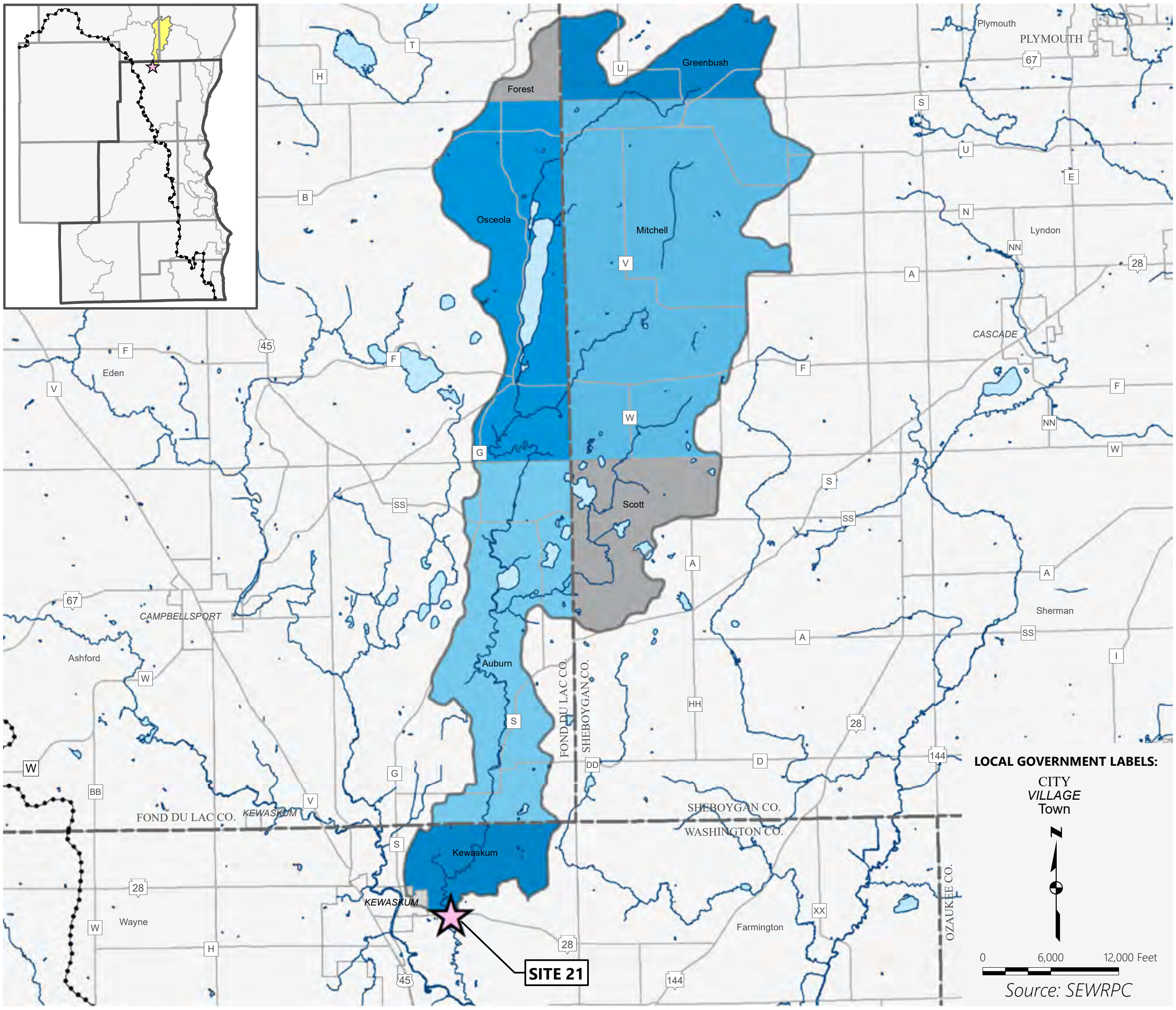
- **Drainage Area Size:** 100 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 26.4%; Rural – 73.6%
- **Roads and Parking Lots (% of drainage area):** 5.9
- **Estimated Population (2010):** 29,290
- **Estimated Households (2010):** 11,340
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** Site 18 (Oconomowoc River Upstream)
- **Lakes Monitored Within this Drainage Area (△):** Moose Lake
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 35
- **Water Supply Source:** Groundwater

Map B.33
Site 21: East Branch Milwaukee River Drainage Area – Existing Land Use





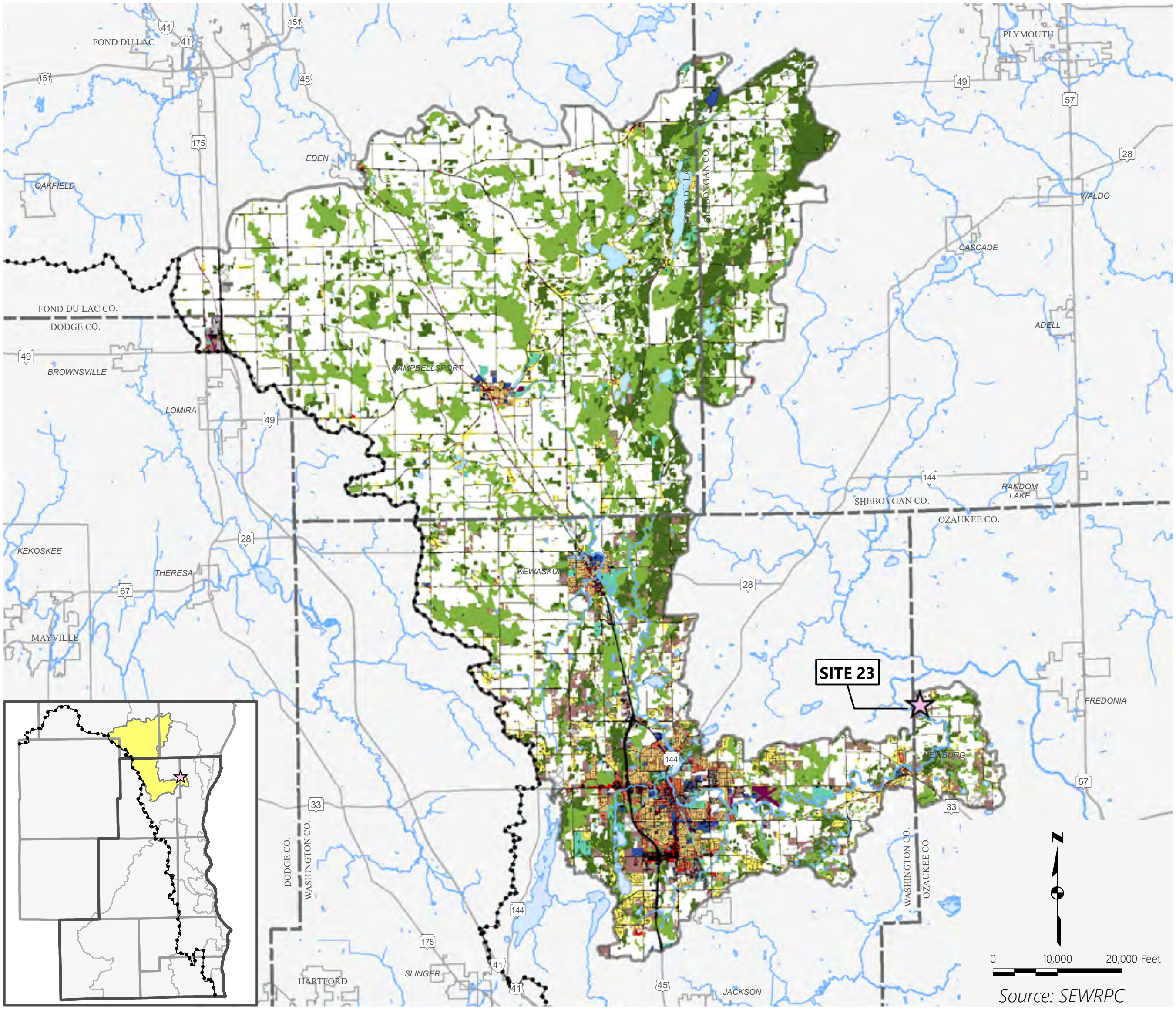
Map B.34
Site 21: East Branch Milwaukee River Drainage Area – Characteristics

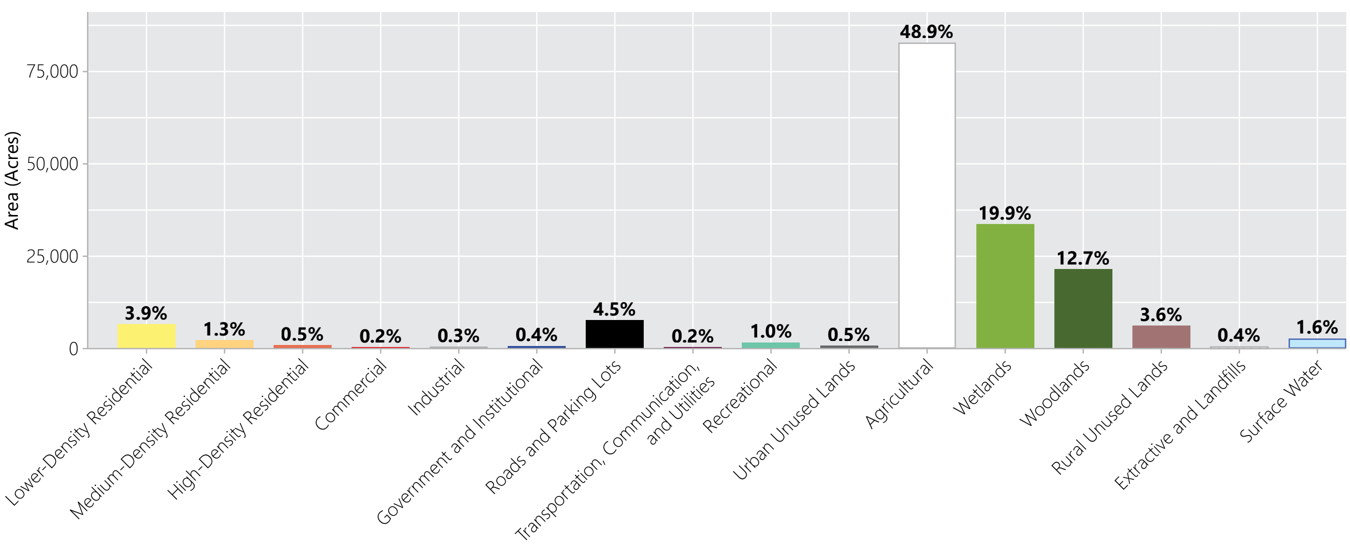


Facts at a Glance

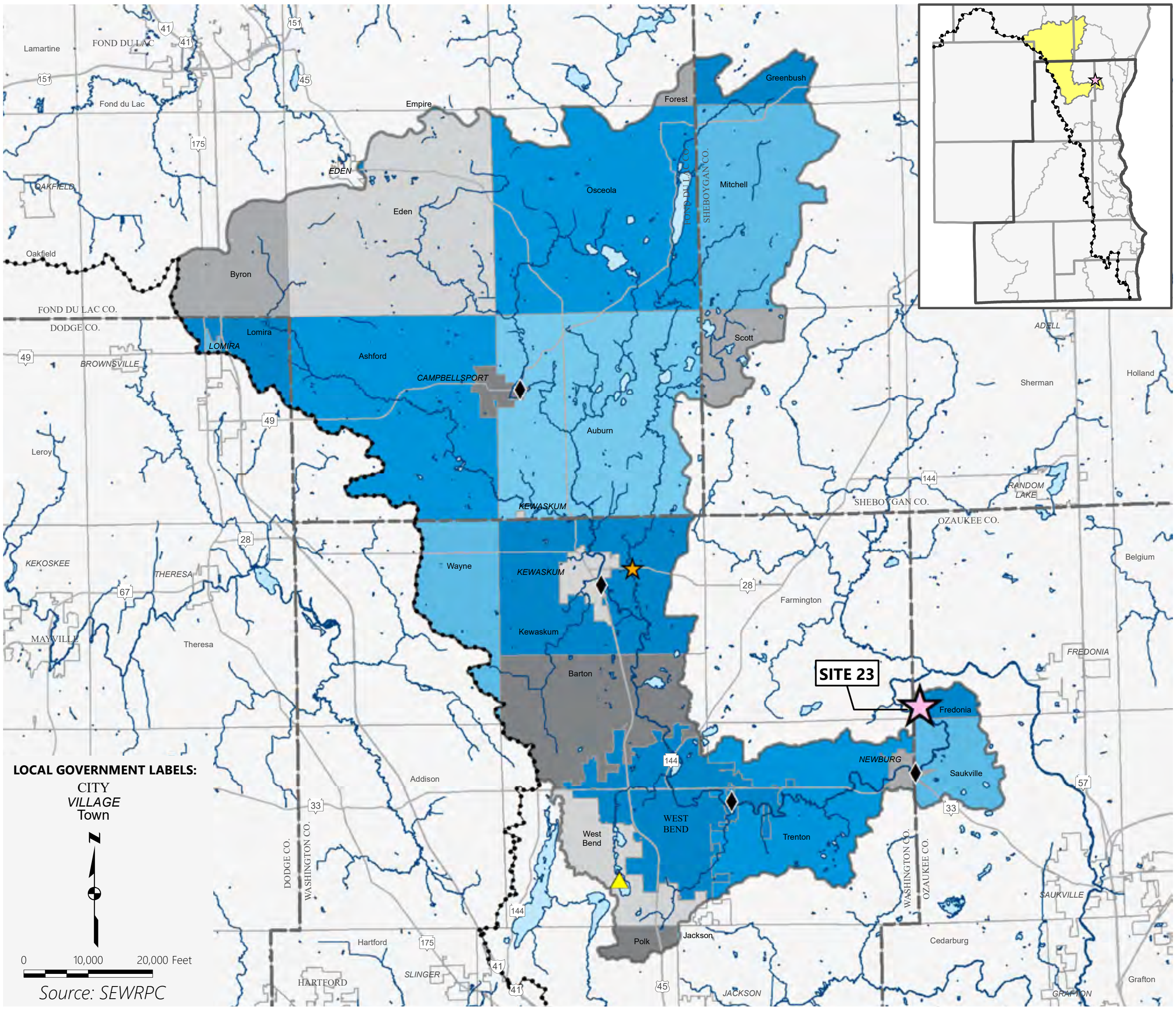
- **Drainage Area Size:** 49 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 6.0%; Rural – 94.0%
- **Roads and Parking Lots (% of drainage area):** 2.6
- **Estimated Population (2010):** 2,790
- **Estimated Households (2010):** 670
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (☆):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 1
- **Water Supply Source:** Groundwater

Map B.35
Site 23: Milwaukee River Downstream of Newburg Drainage Area – Existing Land Use





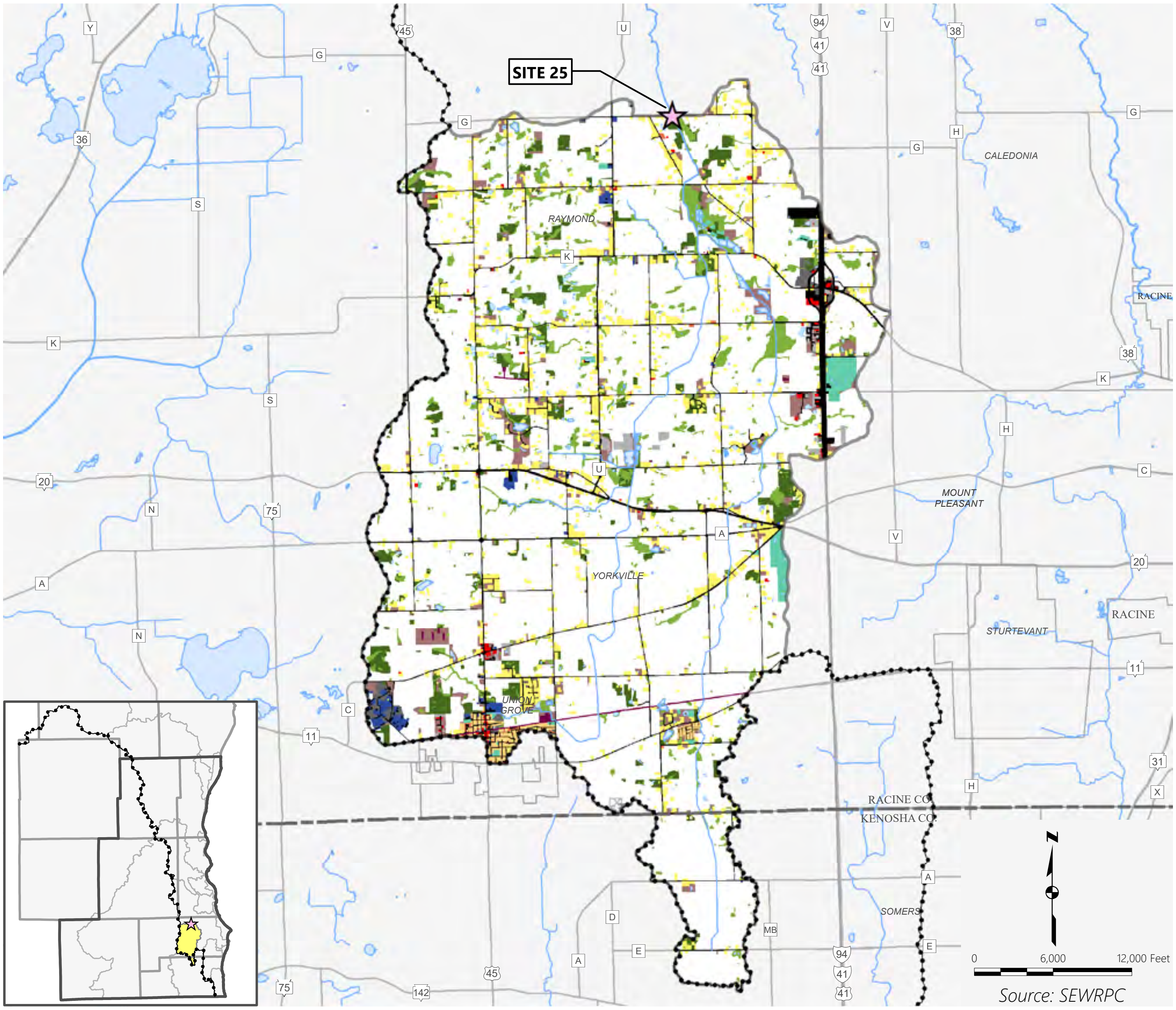
Map B.36
Site 23: Milwaukee River Downstream of Newburg Drainage Area – Characteristics

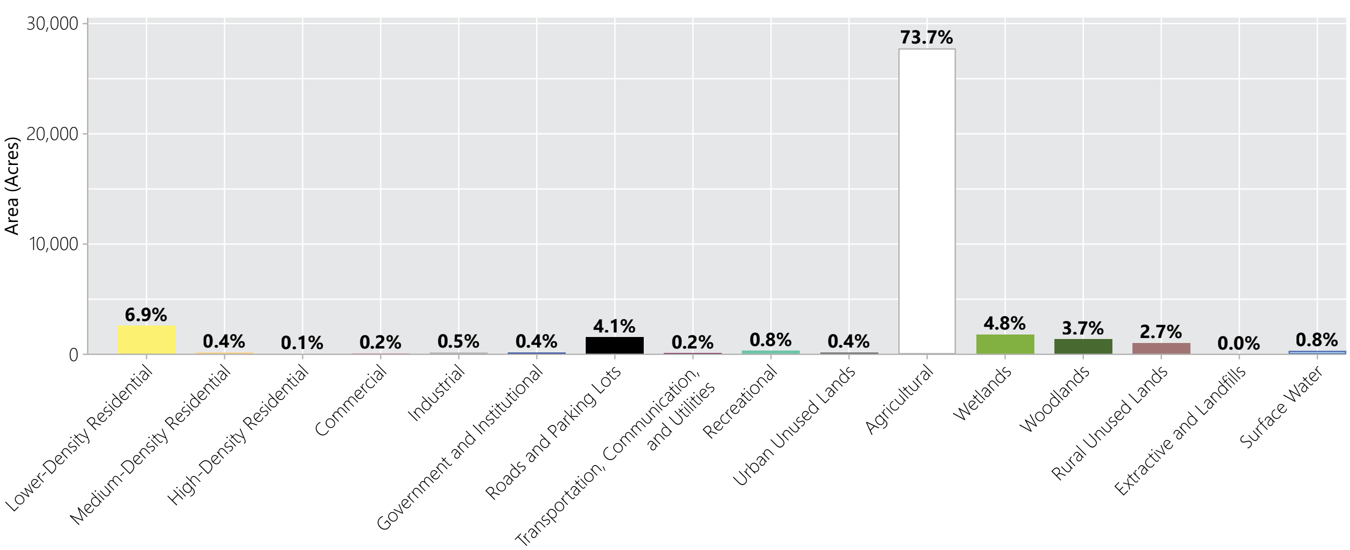


Facts at a Glance

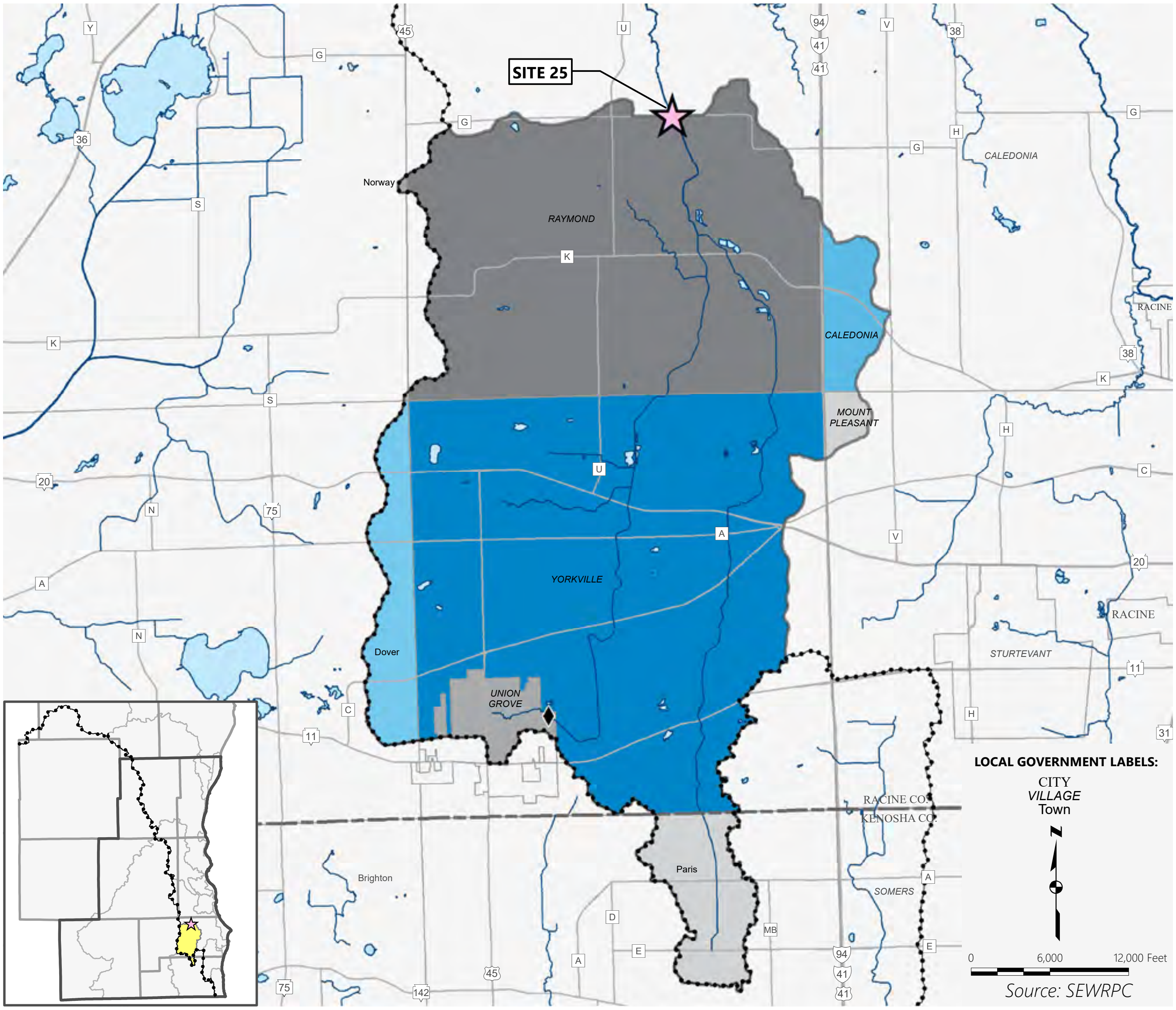
- **Drainage Area Size:** 265 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 12.9%; Rural – 87.1%
- **Roads and Parking Lots (% of drainage area):** 4.5
- **Estimated Population (2010):** 56,690
- **Estimated Households (2010):** 22,120
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** Site 21 (East Branch Milwaukee River)
- **Lakes Monitored Within this Drainage Area (△):** Silver Lake
- **Upstream Wastewater Treatment Facilities (♦):** Campbellsport, Kewaskum, West Bend, and Newburg
- **Planned Sanitary Sewer Service Area (% of drainage area):** 12
- **Water Supply Source:** Groundwater

Map B.37
Site 25: Root River Canal Drainage Area – Existing Land Use





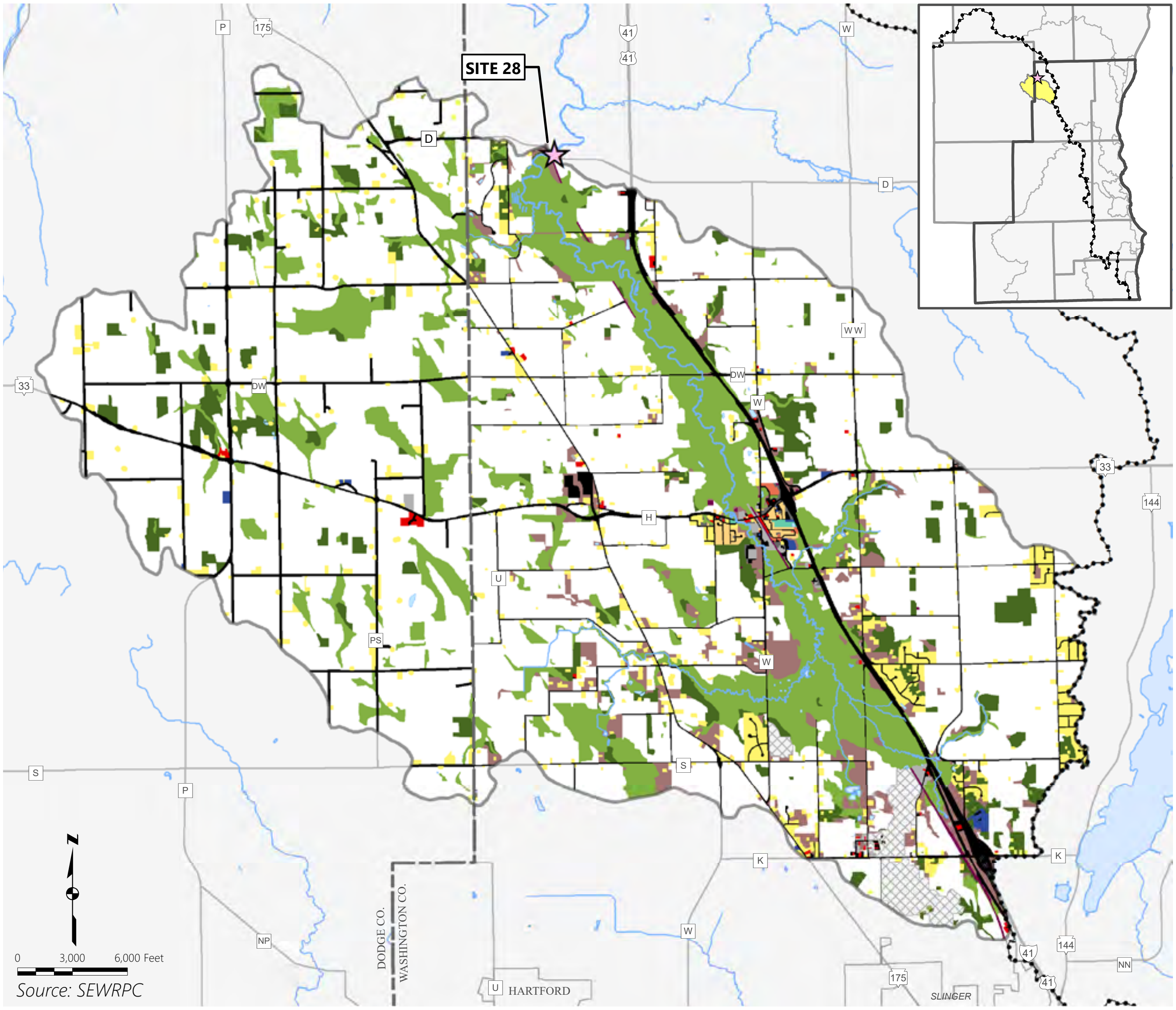
Map B.38
Site 25: Root River Canal Drainage Area – Characteristics



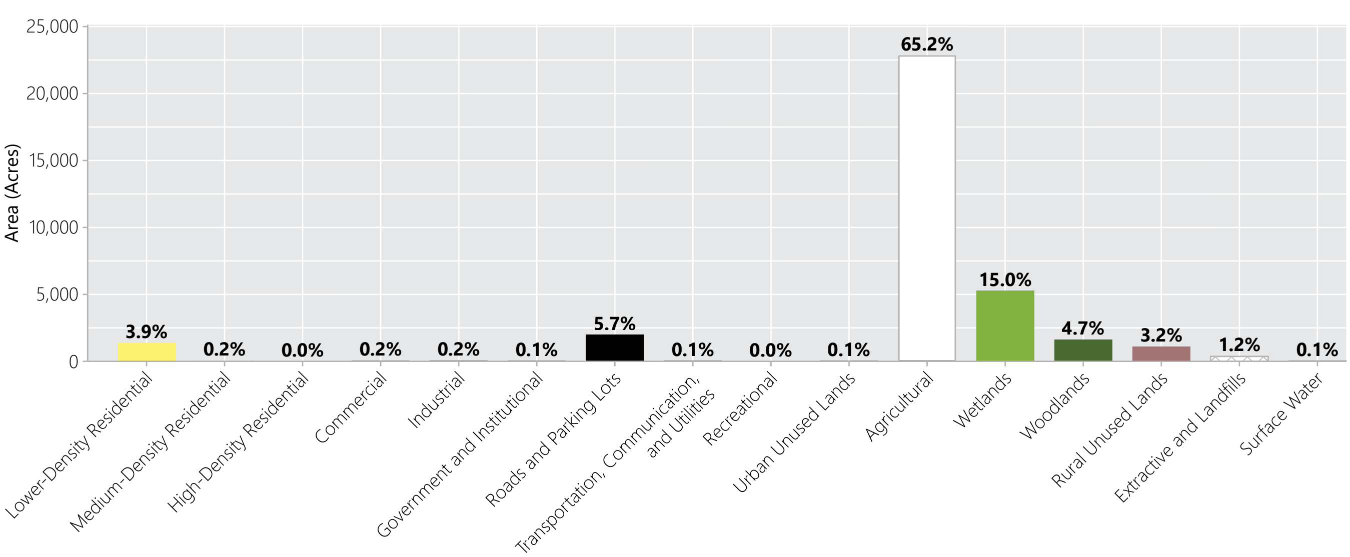
Facts at a Glance

- **Drainage Area Size:** 59 square miles
- **Major Watershed:** Root River
- **Land Use:** Urban – 14.2%; Rural – 85.8%
- **Roads and Parking Lots (% of drainage area):** 4.1
- **Estimated Population (2010):** 8,080
- **Estimated Households (2010):** 2,880
- **Nearest USGS Streamgage:** Root River Canal near Franklin (04087233)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** Union Grove
- **Planned Sanitary Sewer Service Area (% of drainage area):** 8
- **Water Supply Source:** Groundwater

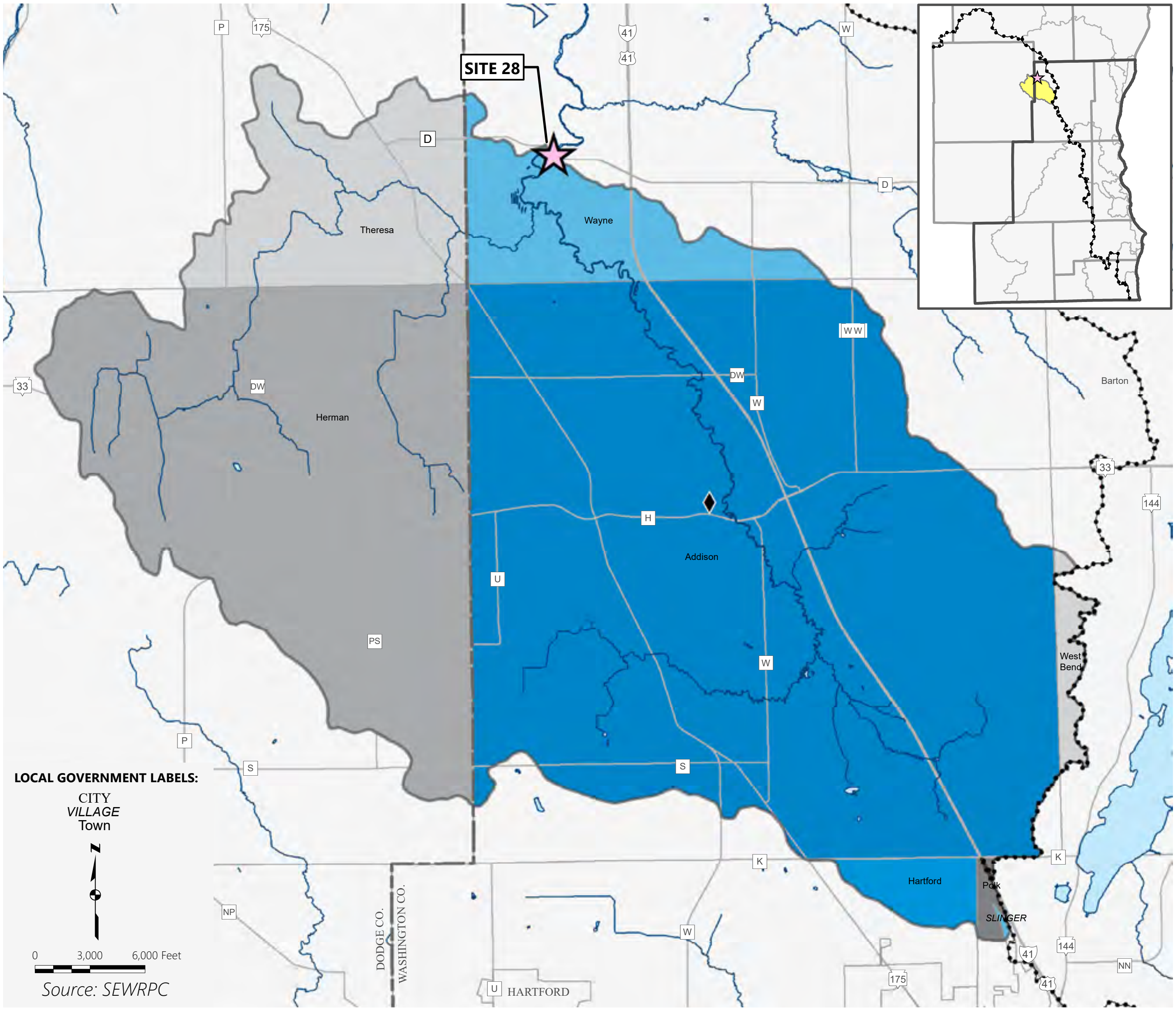
Map B.39
Site 28: East Branch Rock River Drainage Area – Existing Land Use



Source: SEWRPC



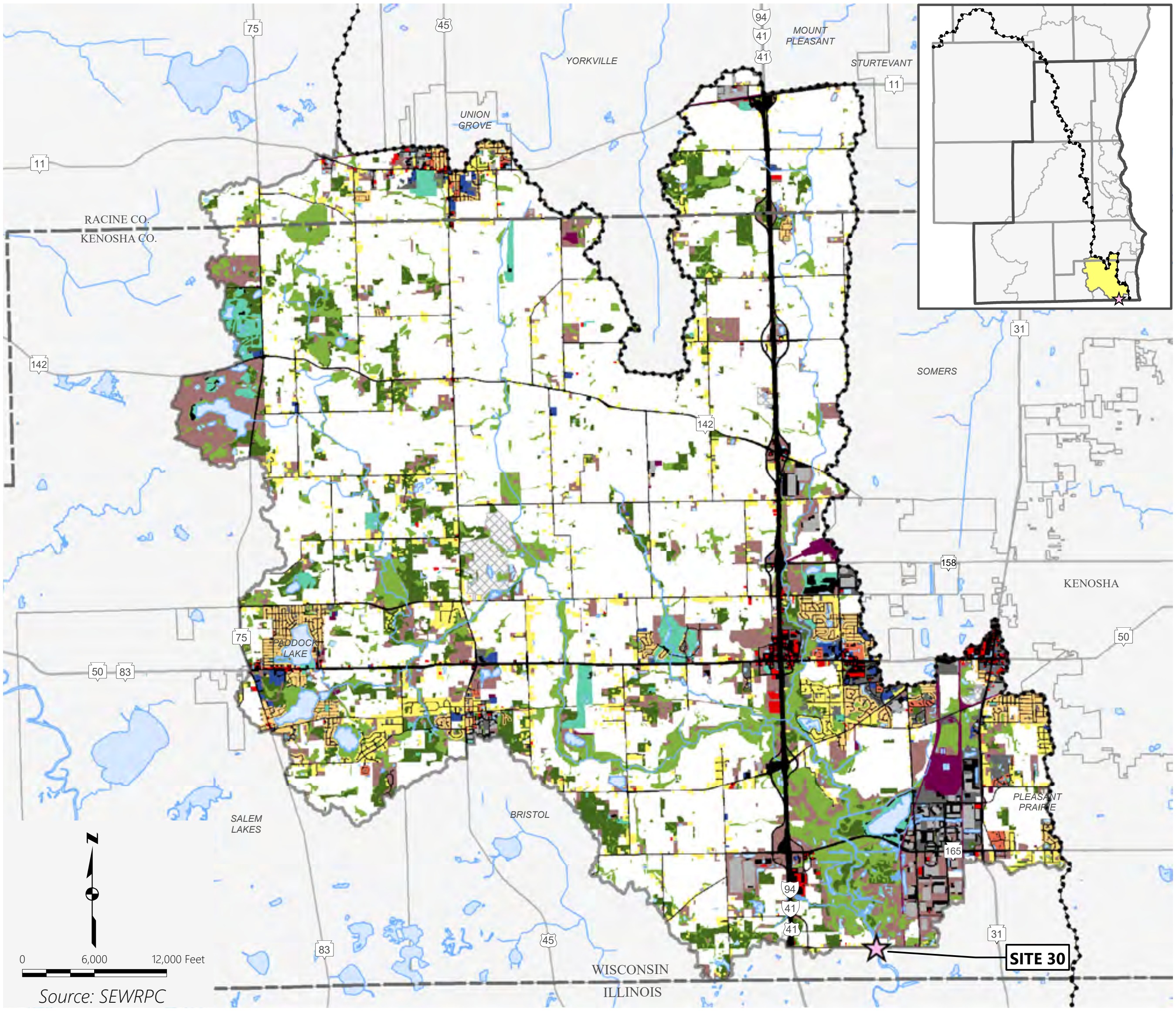
Map B.40
Site 28: East Branch Rock River Drainage Area – Characteristics

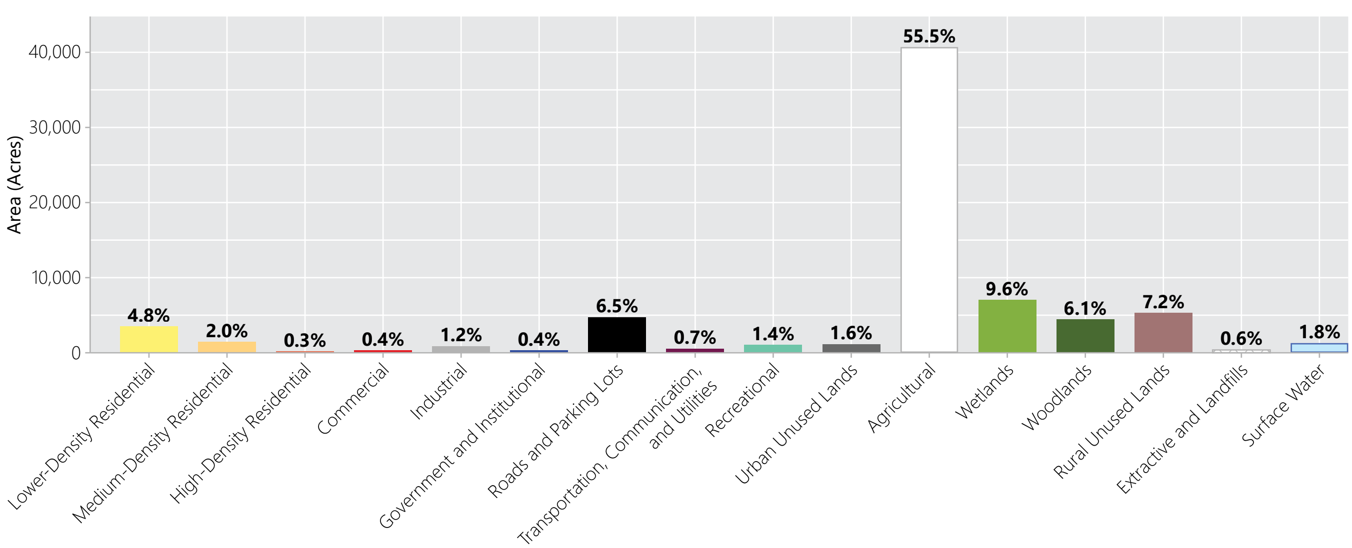


Facts at a Glance

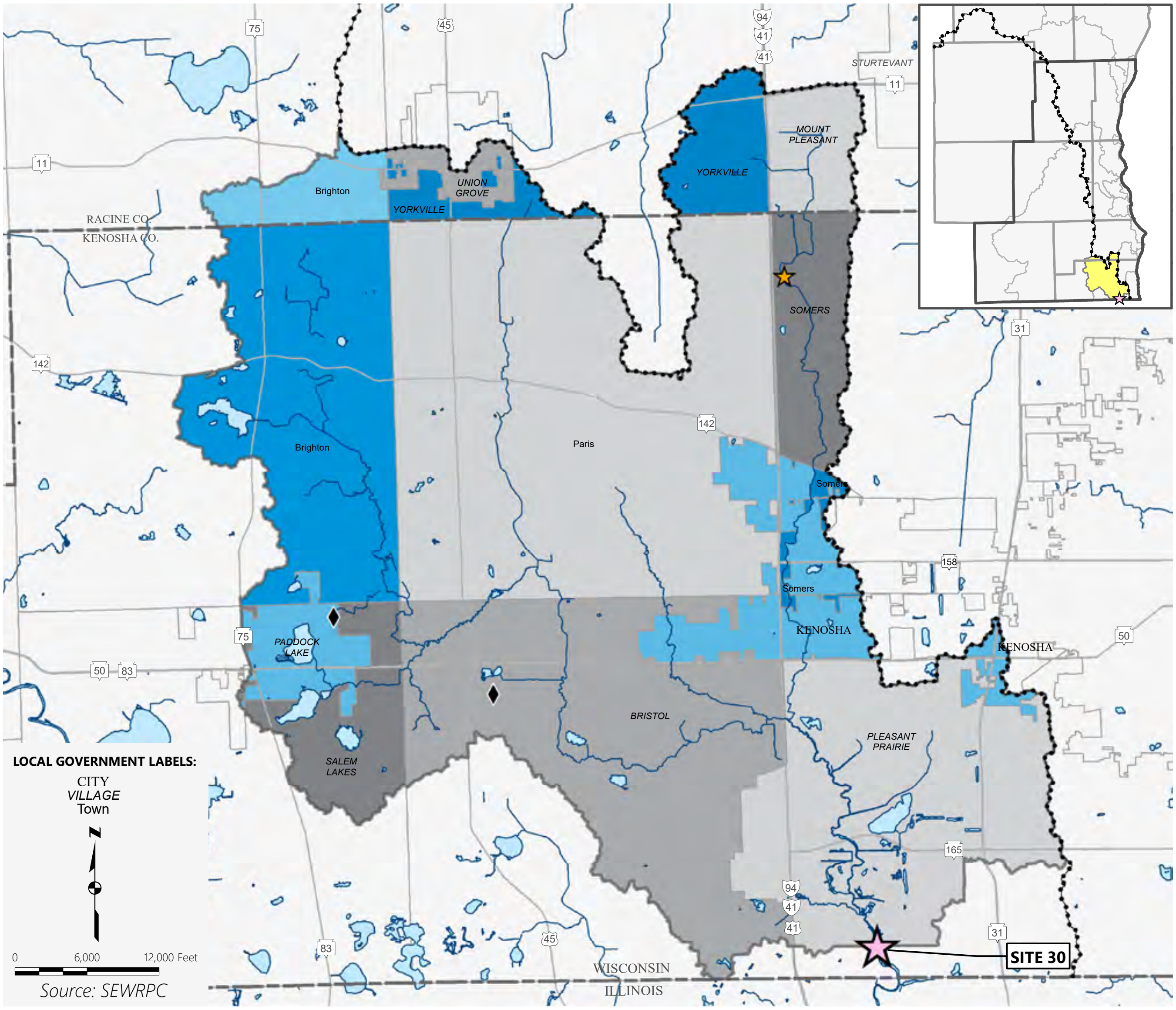
- **Drainage Area Size:** 55 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 10.6%; Rural – 89.4%
- **Roads and Parking Lots (% of drainage area):** 5.7
- **Estimated Population (2010):** 4,310
- **Estimated Households (2010):** 1,610
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** Allenton
- **Planned Sanitary Sewer Service Area (% of drainage area):** 2
- **Water Supply Source:** Groundwater

Map B.41
Site 30: Des Plaines River Drainage Area – Existing Land Use





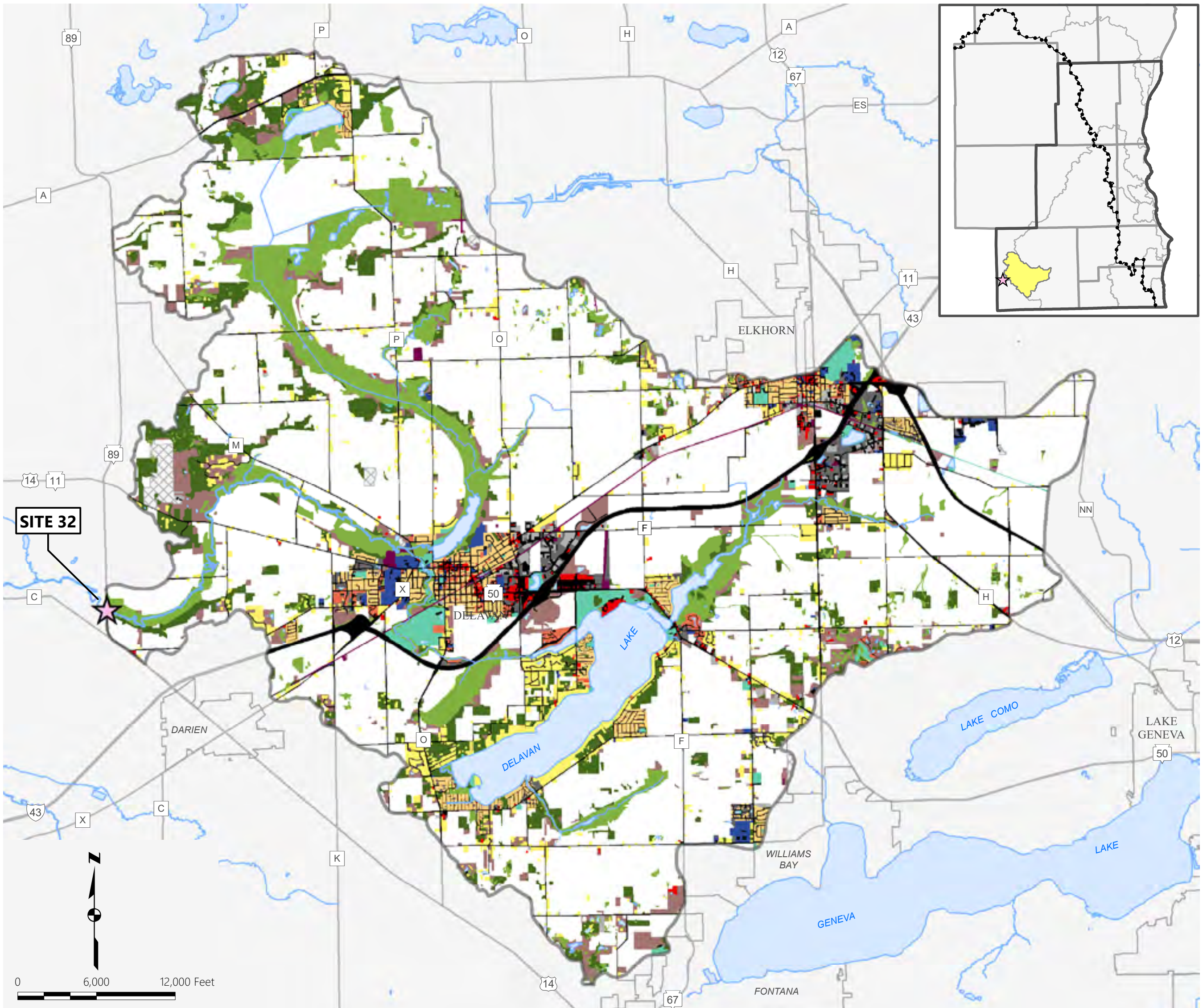
Map B.42
Site 30: Des Plaines River Drainage Area – Characteristics



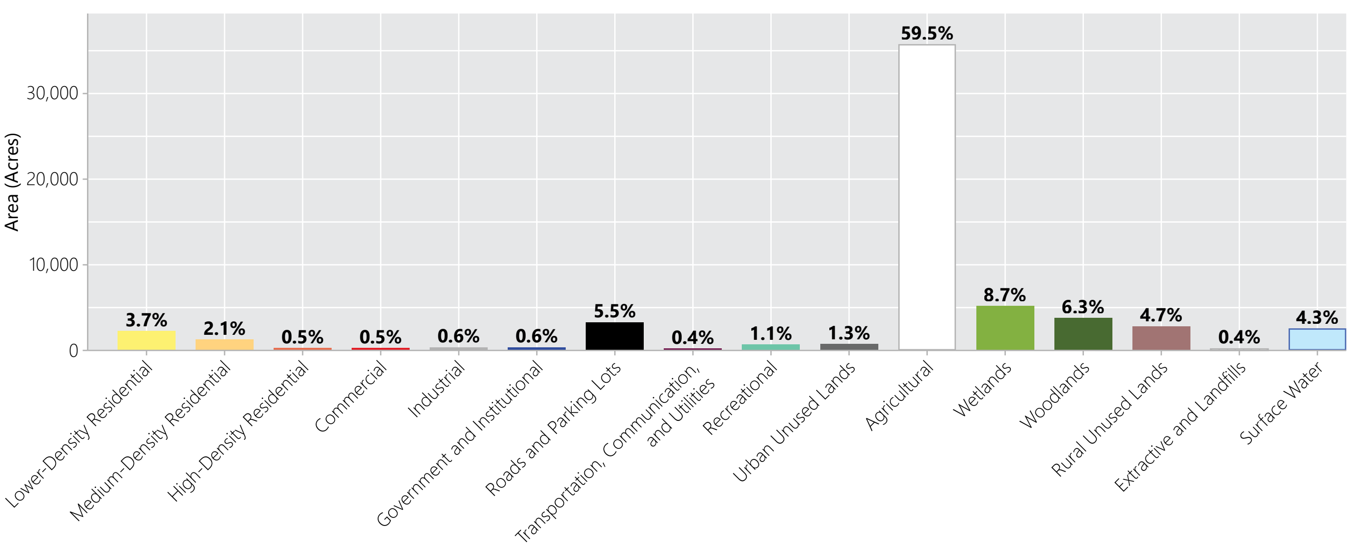
Facts at a Glance

- **Drainage Area Size:** 115 square miles
- **Major Watershed:** Des Plaines River
- **Land Use:** Urban – 19.2%; Rural – 80.8%
- **Roads and Parking Lots (% of drainage area):** 6.5
- **Estimated Population (2010):** 27,850
- **Estimated Households (2010):** 10,170
- **Nearest USGS Streamgage:** Des Plaines River at Russell, IL (05527800)
- **Other Monitoring Sites Within this Drainage Area (☆):** Site 15 (Kilbourn Road Ditch)
- **Upstream Wastewater Treatment Facilities (⧫):** Paddock Lake and Bristol
- **Planned Sanitary Sewer Service Area (% of drainage area):** 43
- **Water Supply Source:** Lake Michigan and Groundwater

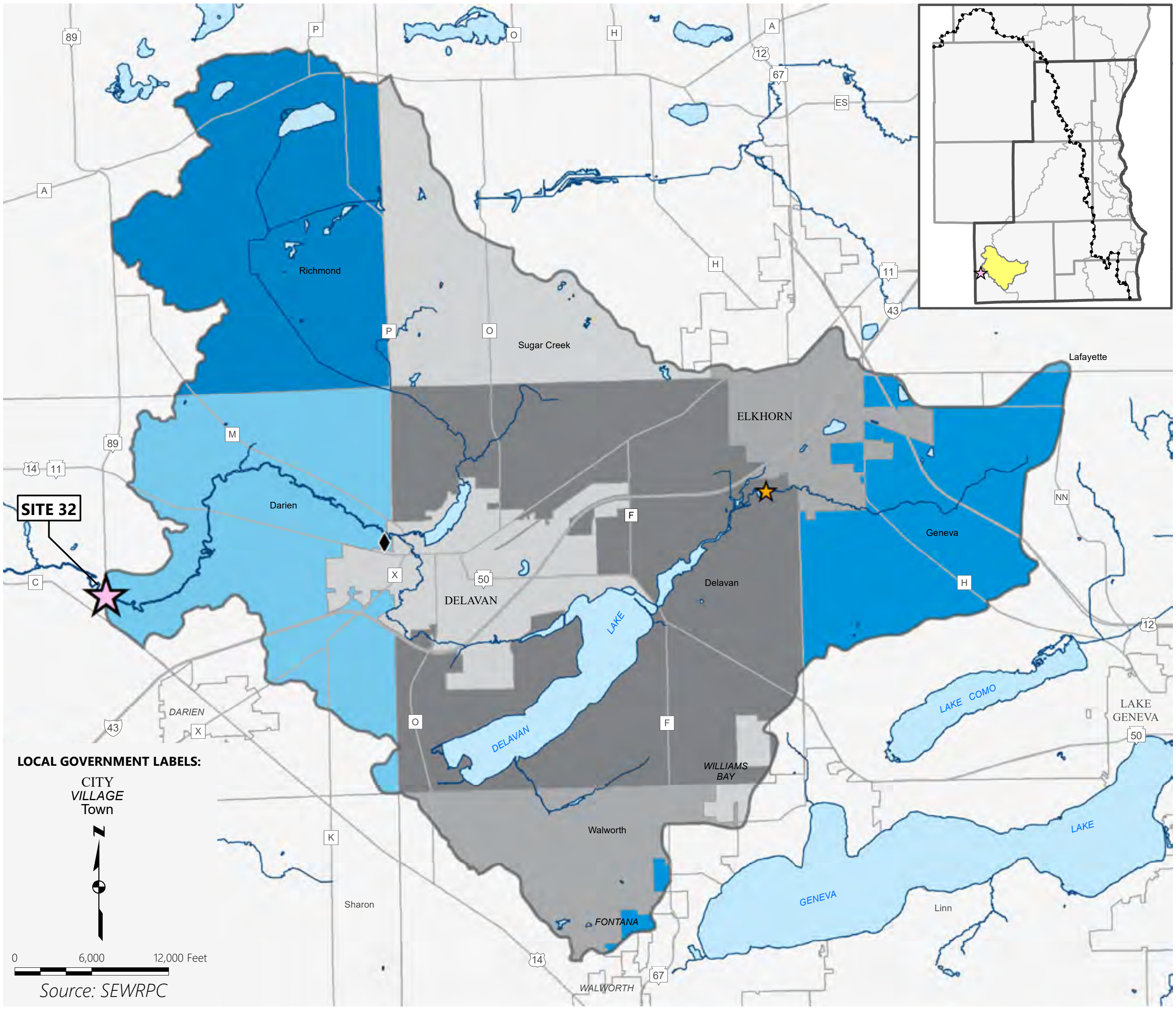
Map B.43
Site 32: Turtle Creek Drainage Area – Existing Land Use



Source: SEWRPC



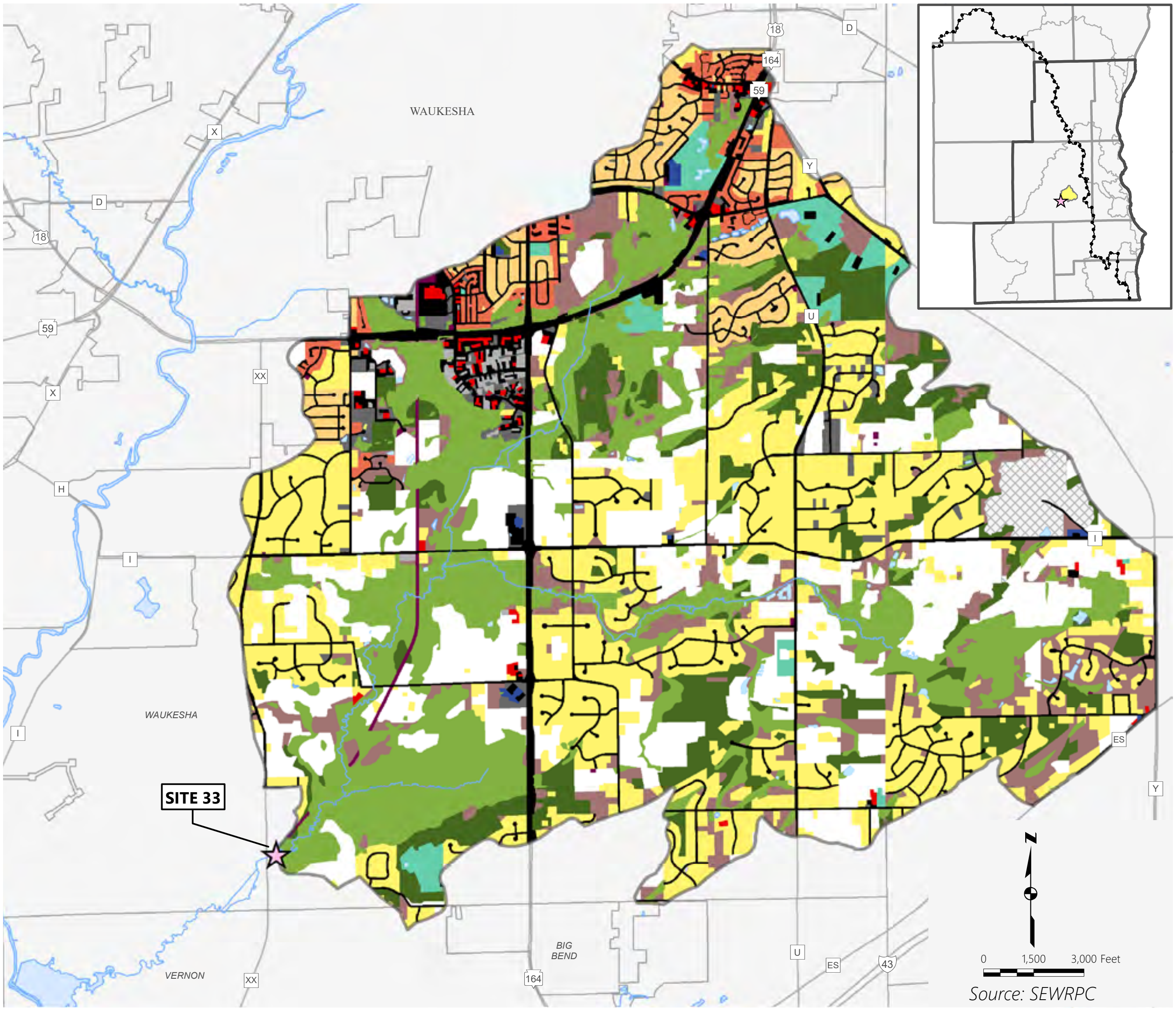
Map B.44
Site 32: Turtle Creek Drainage Area – Characteristics

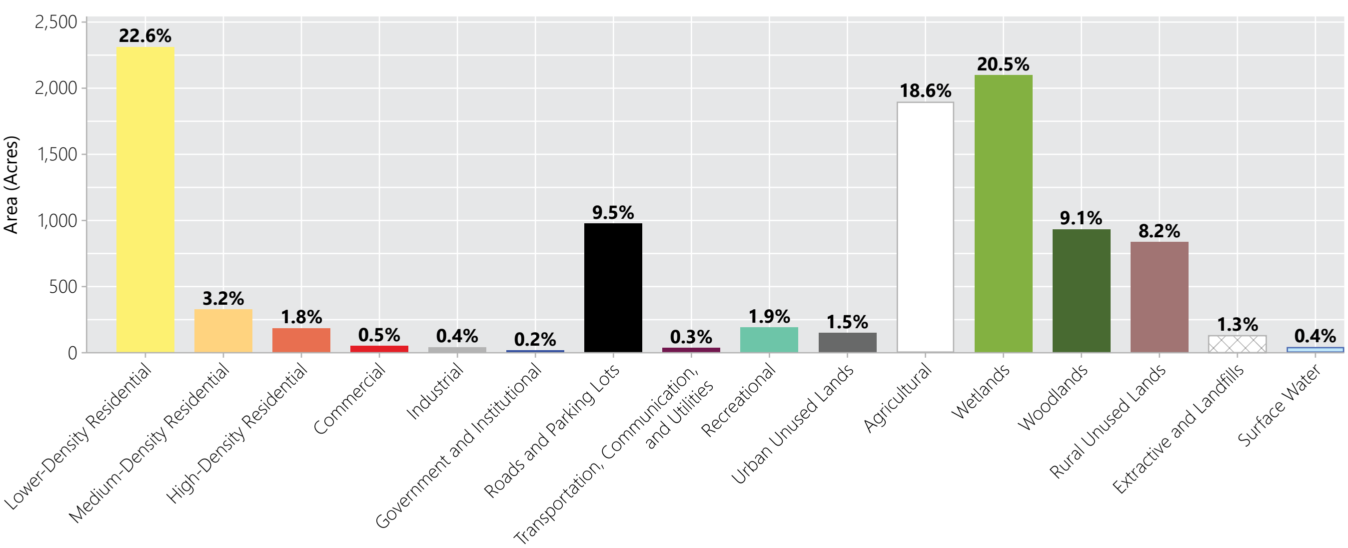


Facts at a Glance

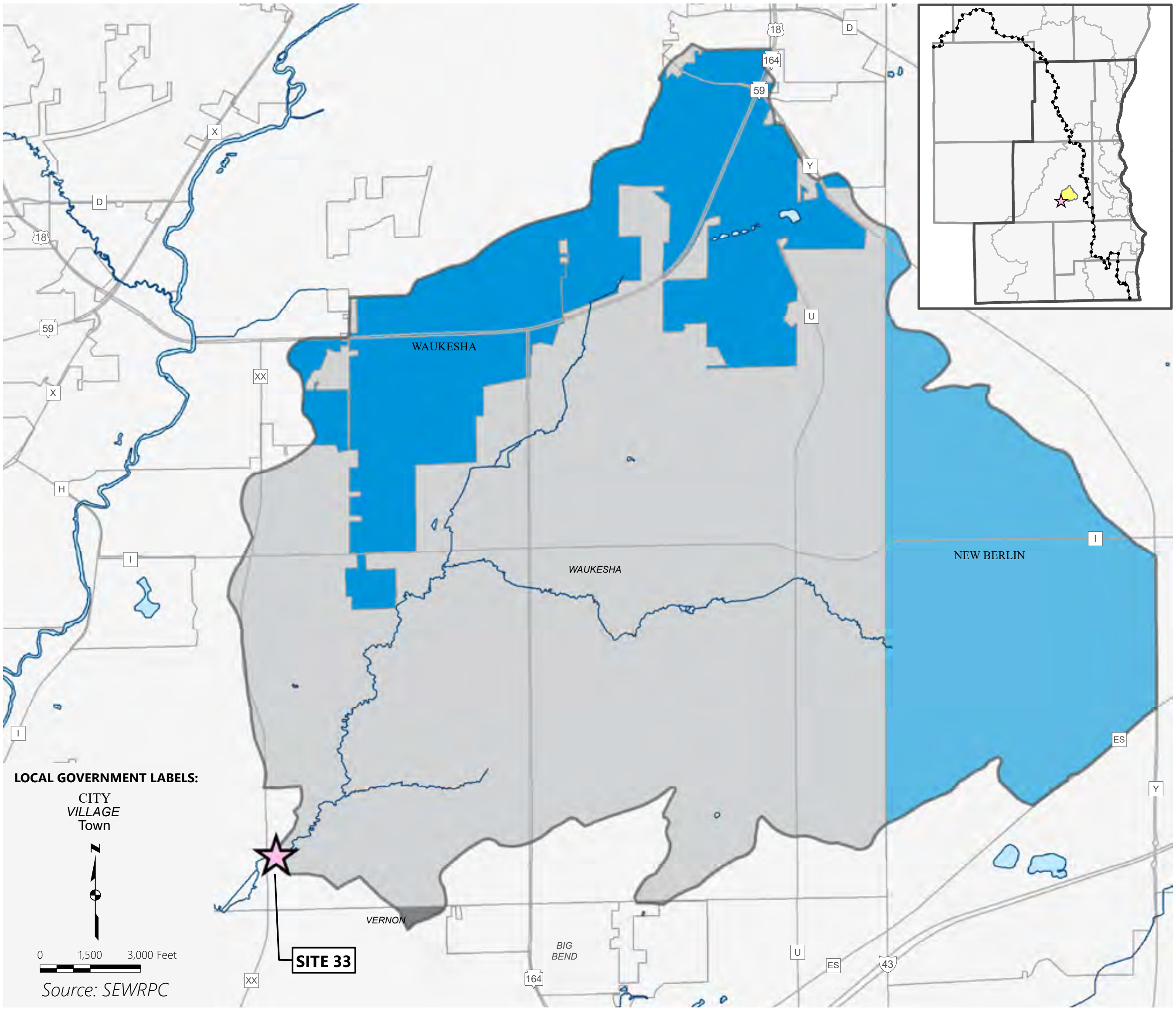
- **Drainage Area Size:** 94 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 16.2%; Rural – 83.8%
- **Roads and Parking Lots (% of drainage area):** 5.5
- **Estimated Population (2010):** 20,720
- **Estimated Households (2010):** 8,020
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** Site 16 (Jackson Creek)
- **Upstream Wastewater Treatment Facilities (♦):** Walworth County Metropolitan Sewerage District
- **Planned Sanitary Sewer Service Area (% of drainage area):** 32
- **Water Supply Source:** Groundwater

Map B.45
Site 33: Pebble Brook Drainage Area – Existing Land Use





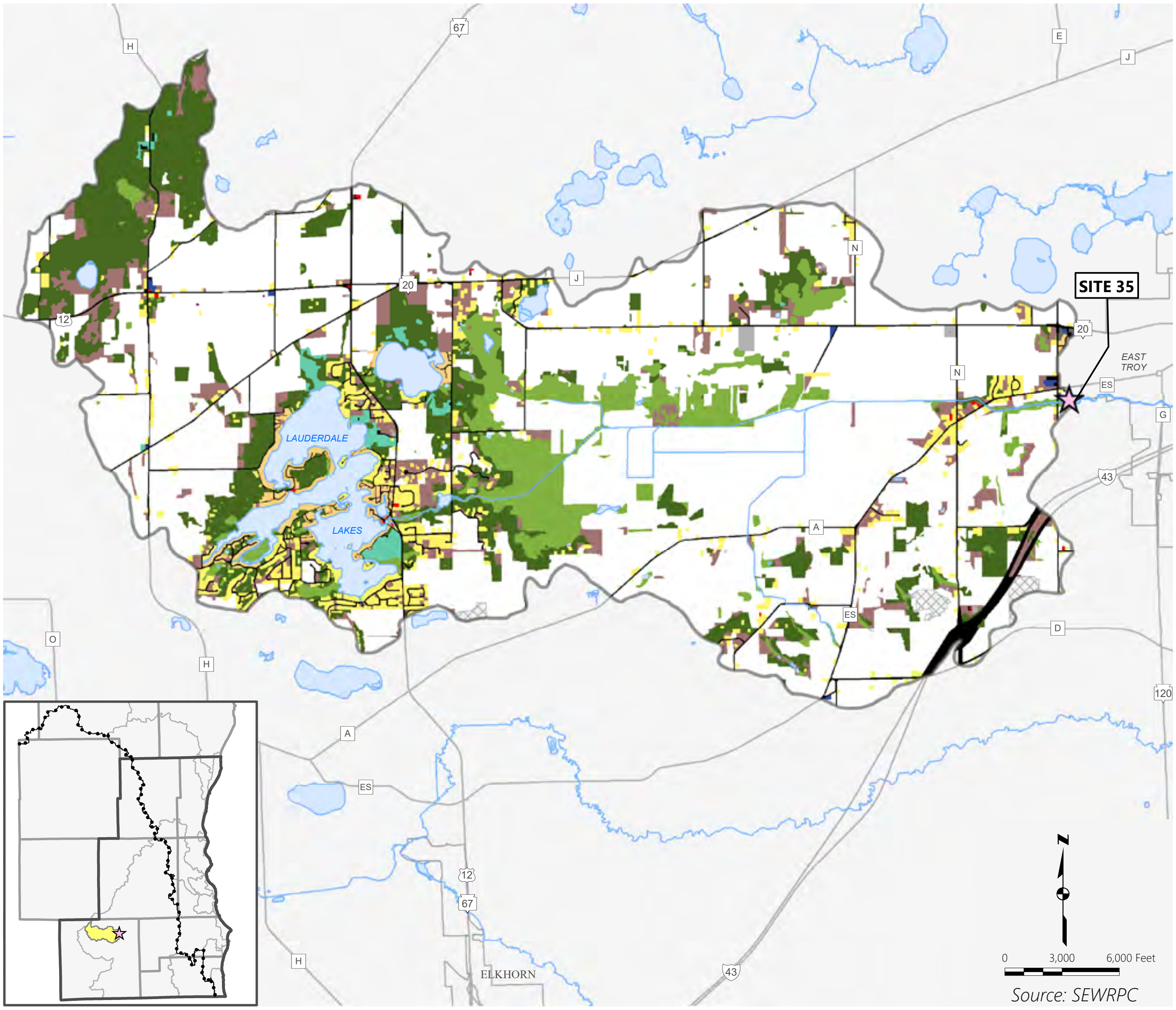
Map B.46
Site 33: Pebble Brook Drainage Area – Characteristics

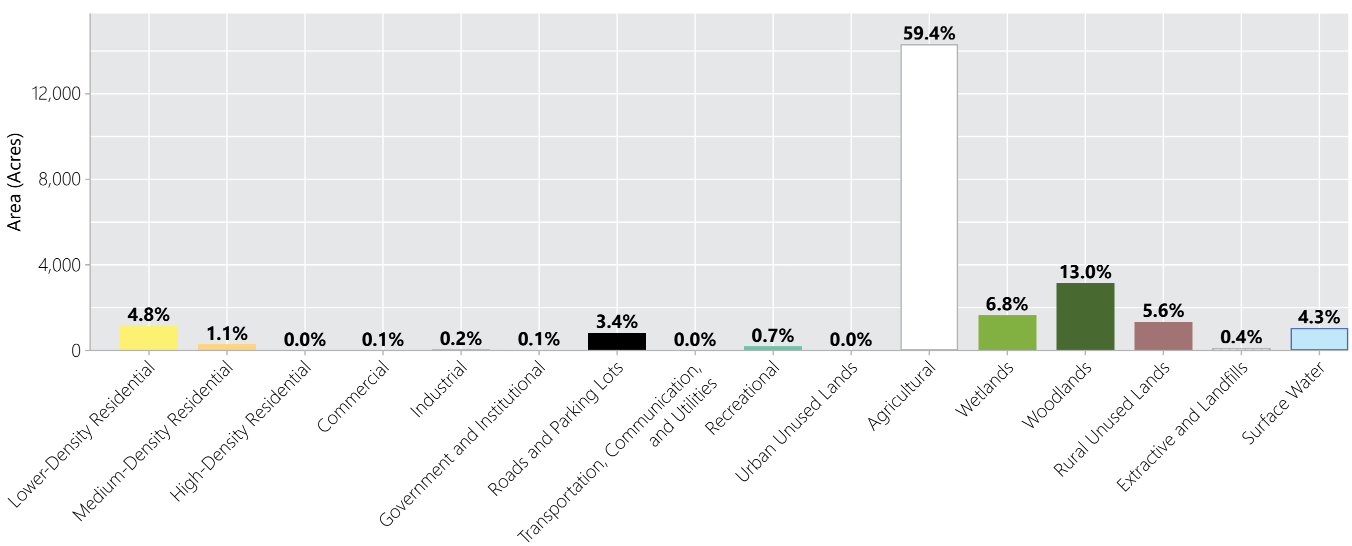


Facts at a Glance

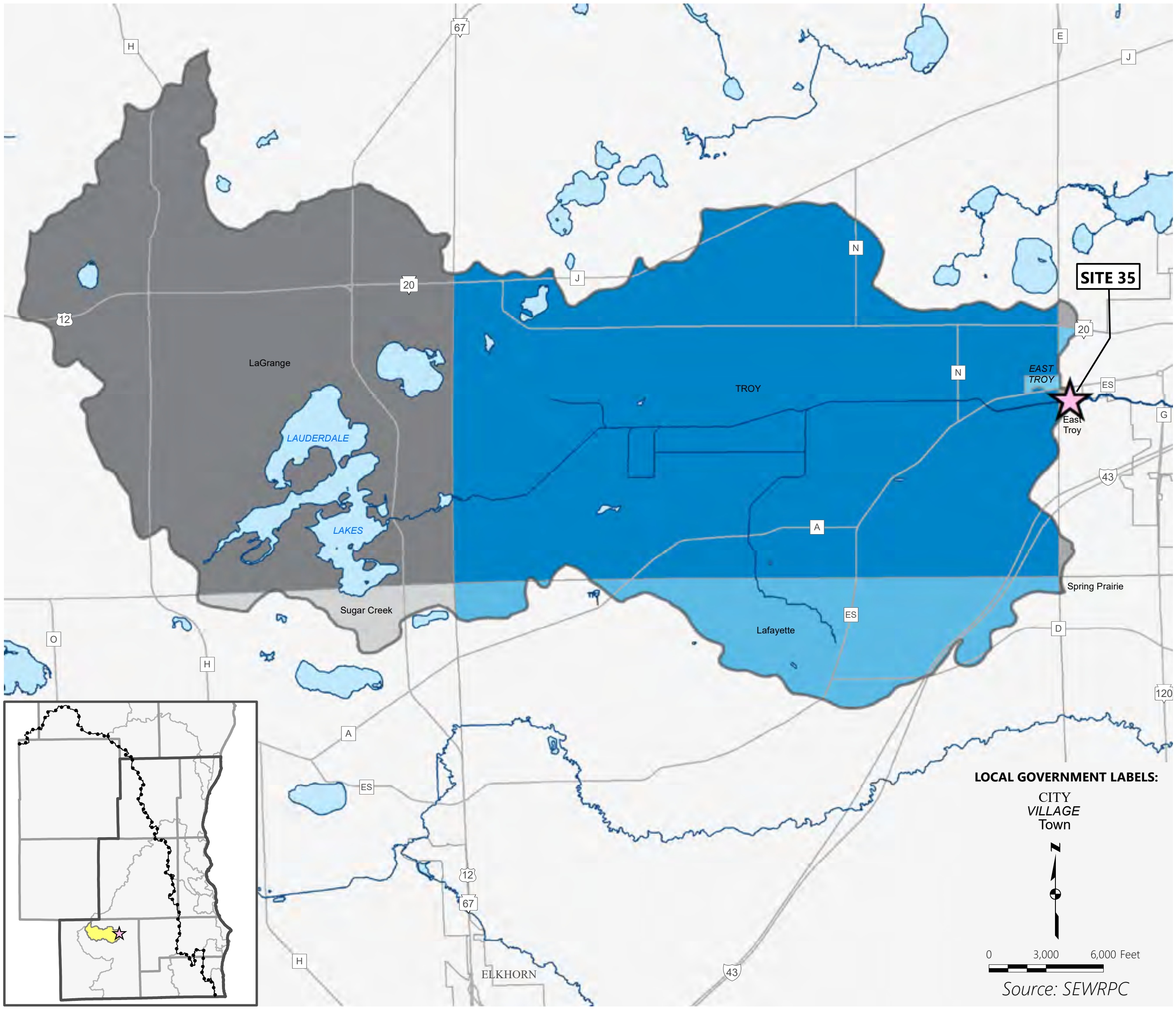
- **Drainage Area Size:** 16 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 41.9%; Rural – 58.1%
- **Roads and Parking Lots (% of drainage area):** 9.5
- **Estimated Population (2010):** 13,420
- **Estimated Households (2010):** 5,170
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (☆):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 81
- **Water Supply Source:** Groundwater (water supplied by the City of Waukesha is planned to be converted from groundwater to Lake Michigan supply in 2023)

Map B.47
Site 35: Honey Creek Upstream of East Troy Drainage Area – Existing Land Use





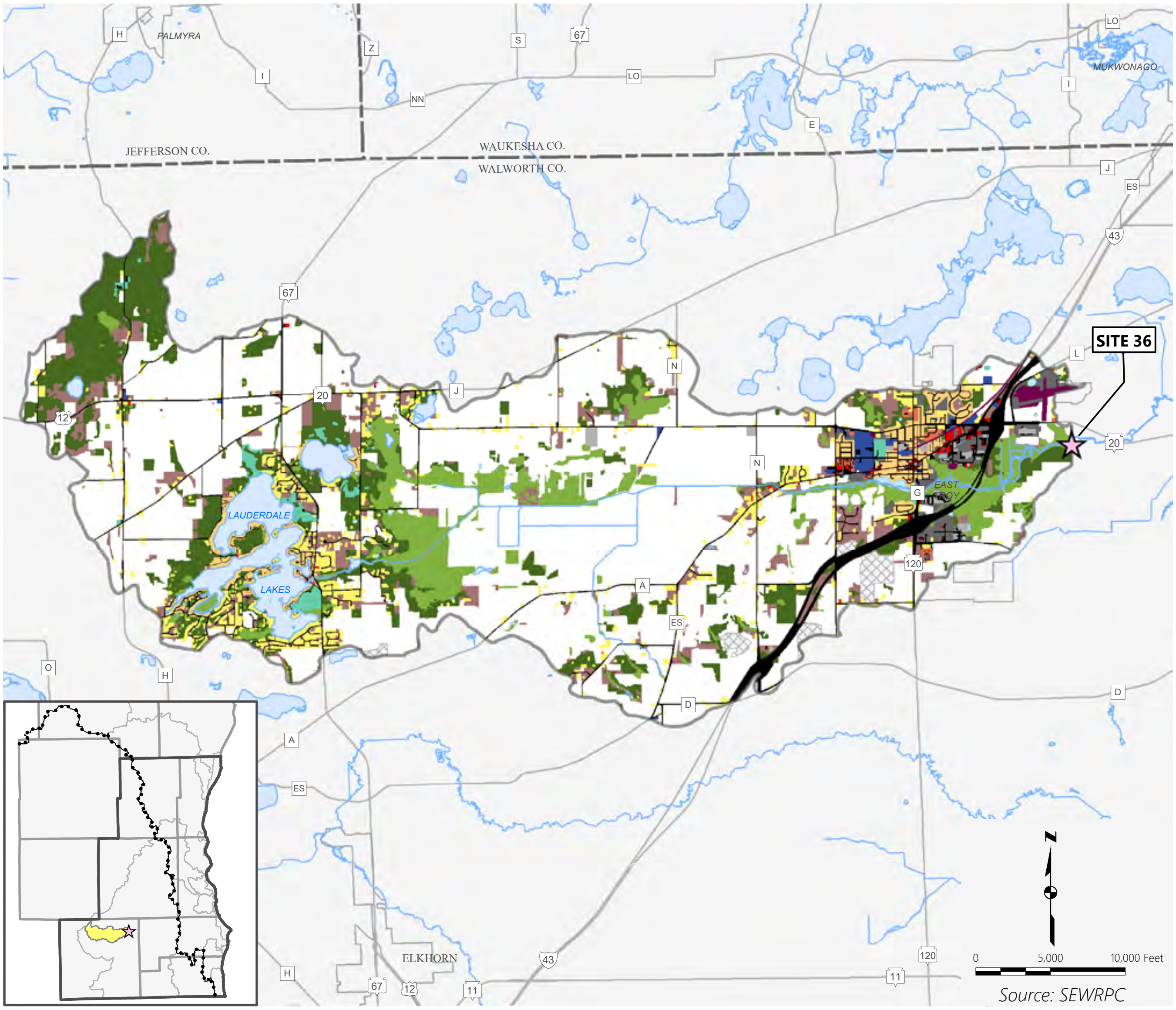
Map B.48
Site 35: Honey Creek Upstream of East Troy Drainage Area – Characteristics

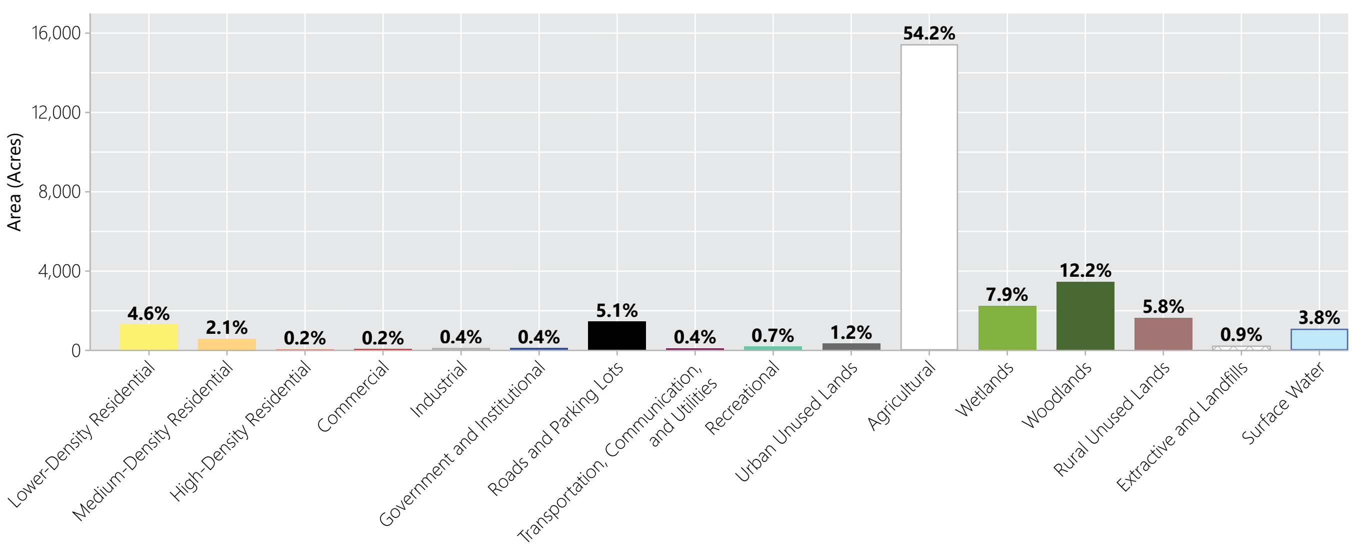


Facts at a Glance

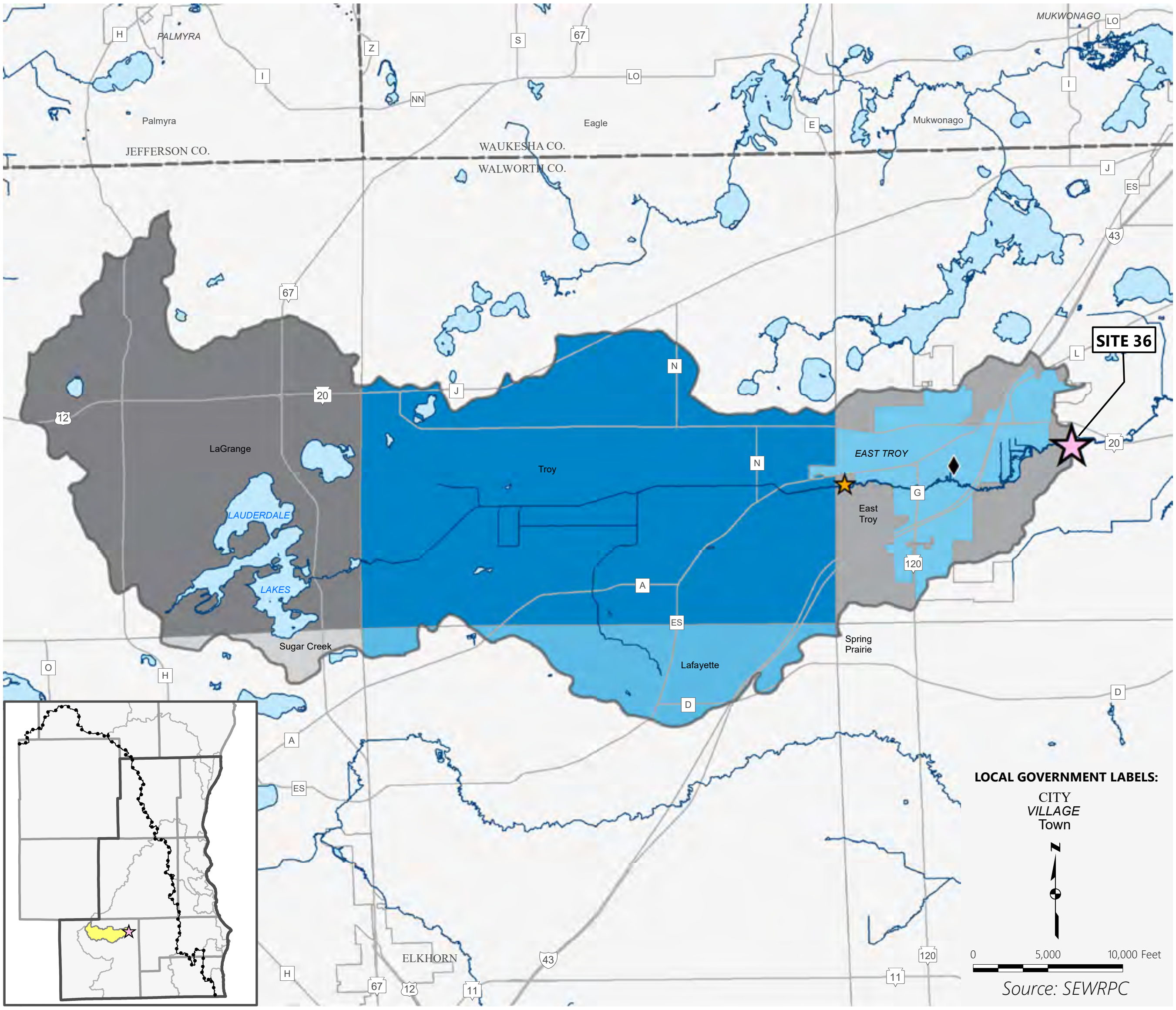
- **Drainage Area Size:** 38 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 10.4%; Rural – 89.6%
- **Roads and Parking Lots (% of drainage area):** 3.4
- **Estimated Population (2010):** 2,910
- **Estimated Households (2010):** 1,140
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (☆):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 2
- **Water Supply Source:** Groundwater

Map B.49
Site 36: Honey Creek Downstream of East Troy Drainage Area – Existing Land Use





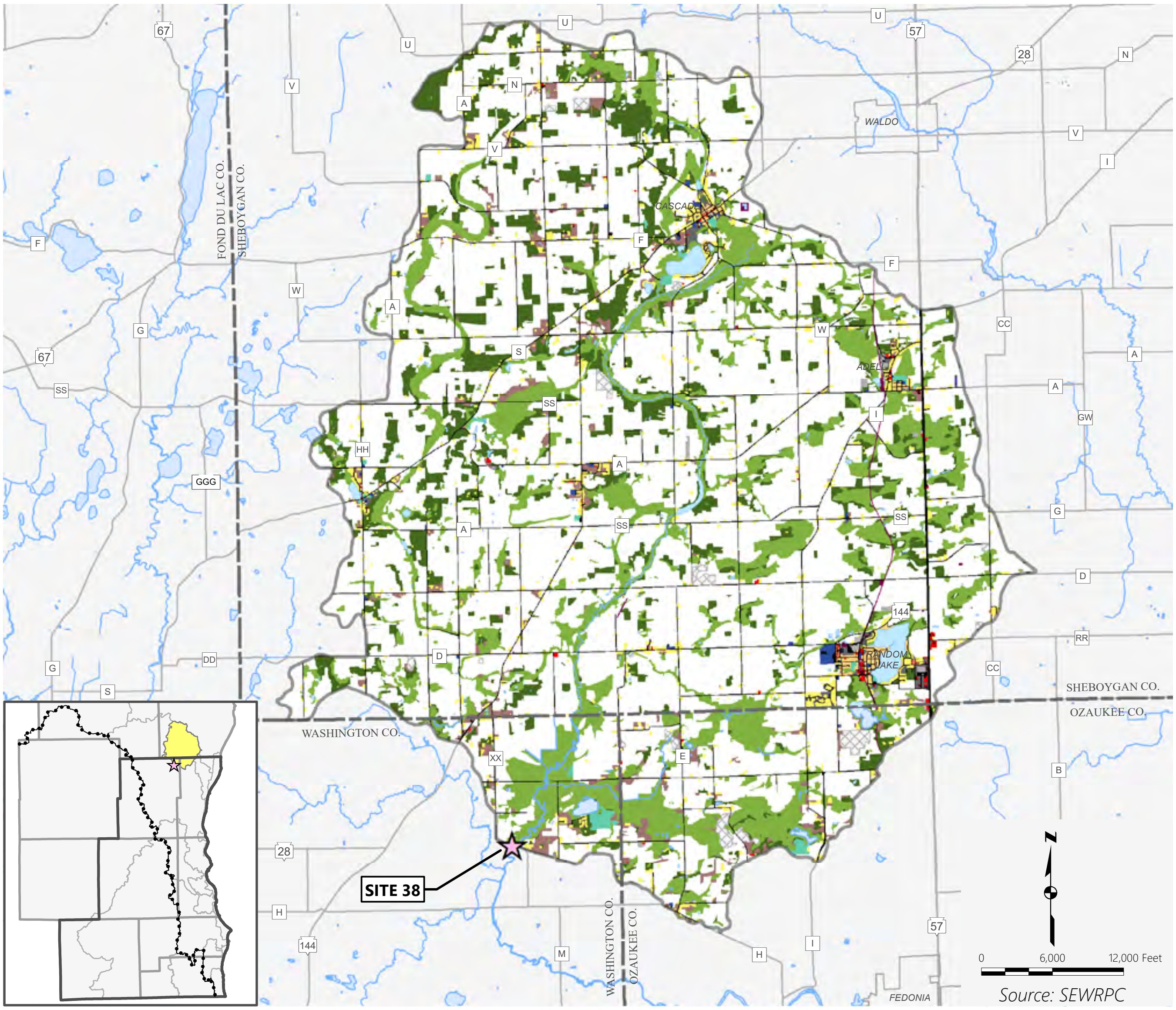
Map B.50
Site 36: Honey Creek Downstream of East Troy Drainage Area – Characteristics

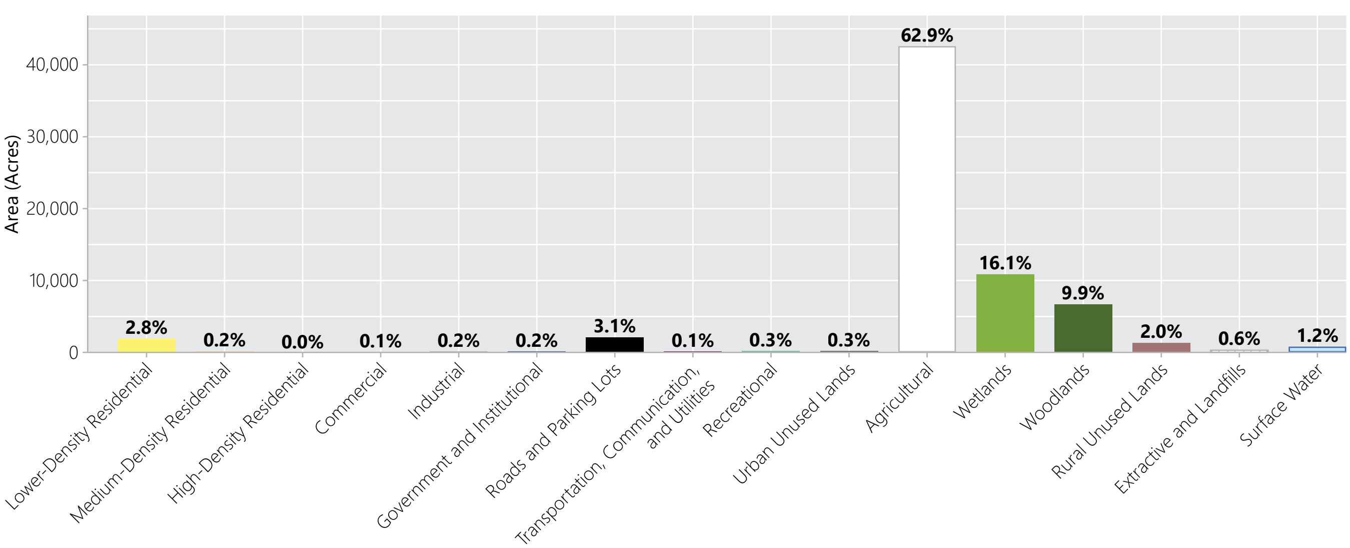


Facts at a Glance

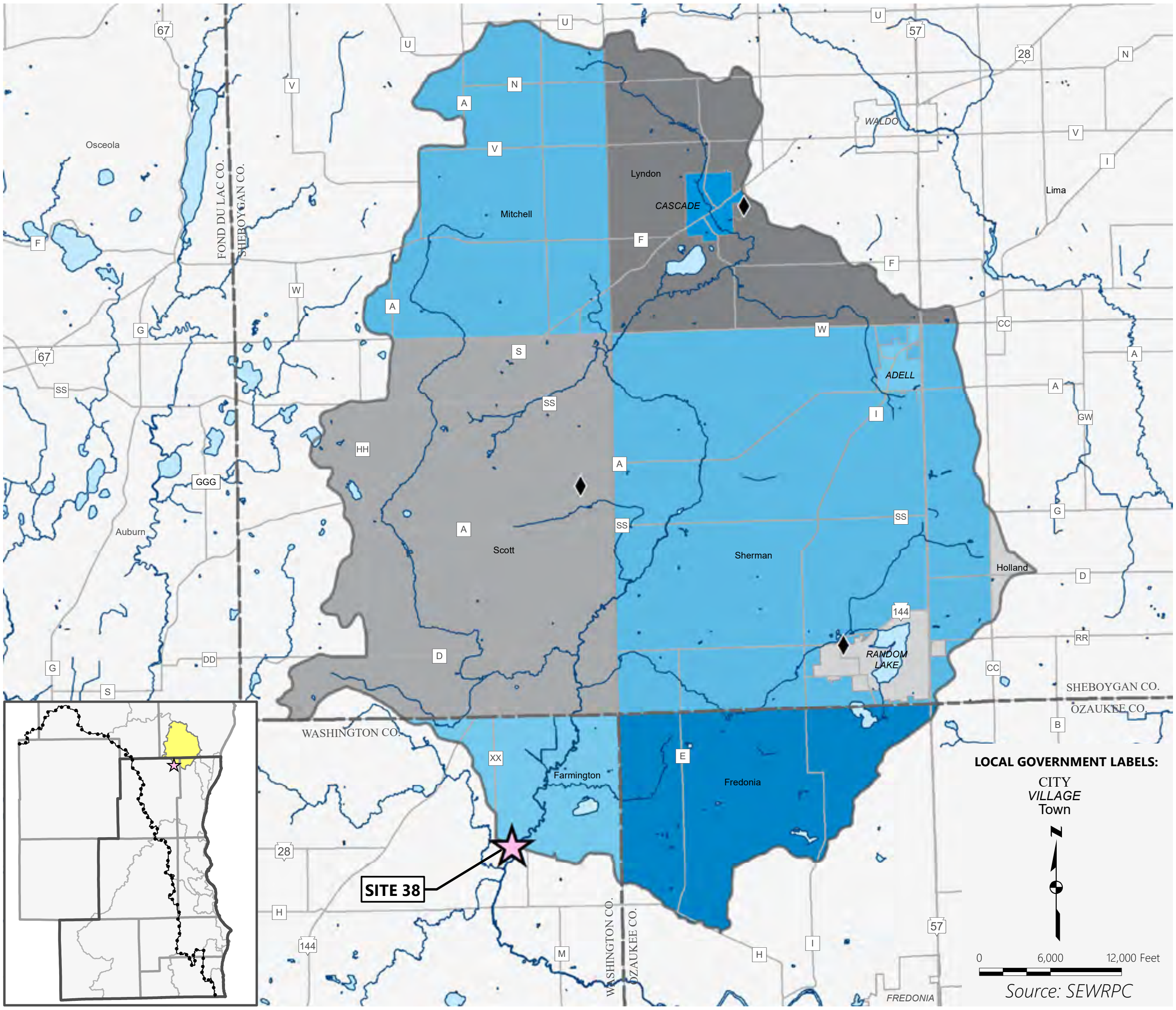
- **Drainage Area Size:** 45 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 15.3%; Rural – 84.7%
- **Roads and Parking Lots (% of drainage area):** 5.1
- **Estimated Population (2010):** 7,490
- **Estimated Households (2010):** 2,980
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (☆):** Site 35 (Honey Creek Upstream of East Troy)
- **Upstream Wastewater Treatment Facilities (⧫):** East Troy
- **Planned Sanitary Sewer Service Area (% of drainage area):** 13
- **Water Supply Source:** Groundwater

Map B.51
Site 38: North Branch Milwaukee River Drainage Area – Existing Land Use





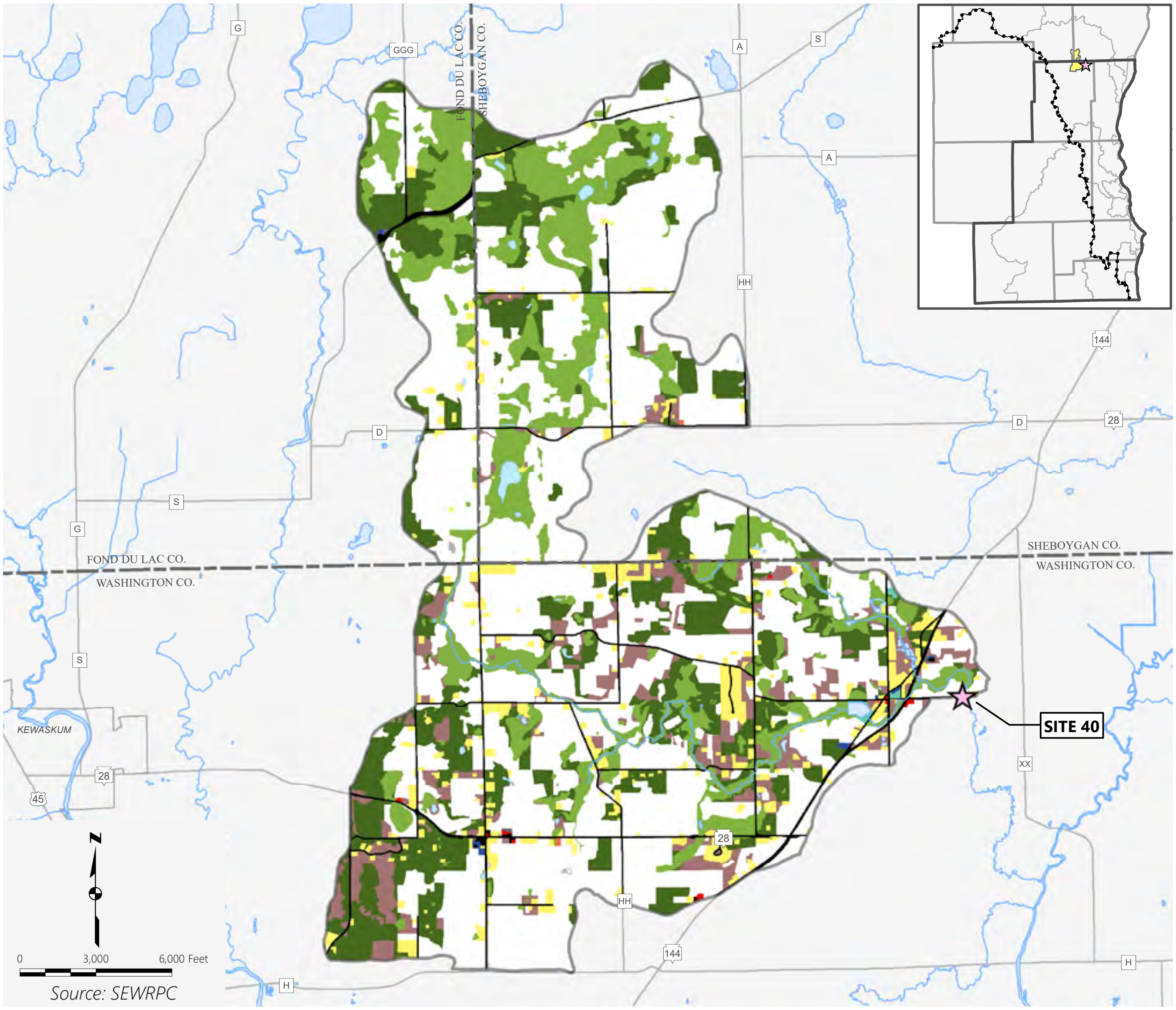
Map B.52
Site 38: North Branch Milwaukee River Drainage Area – Characteristics



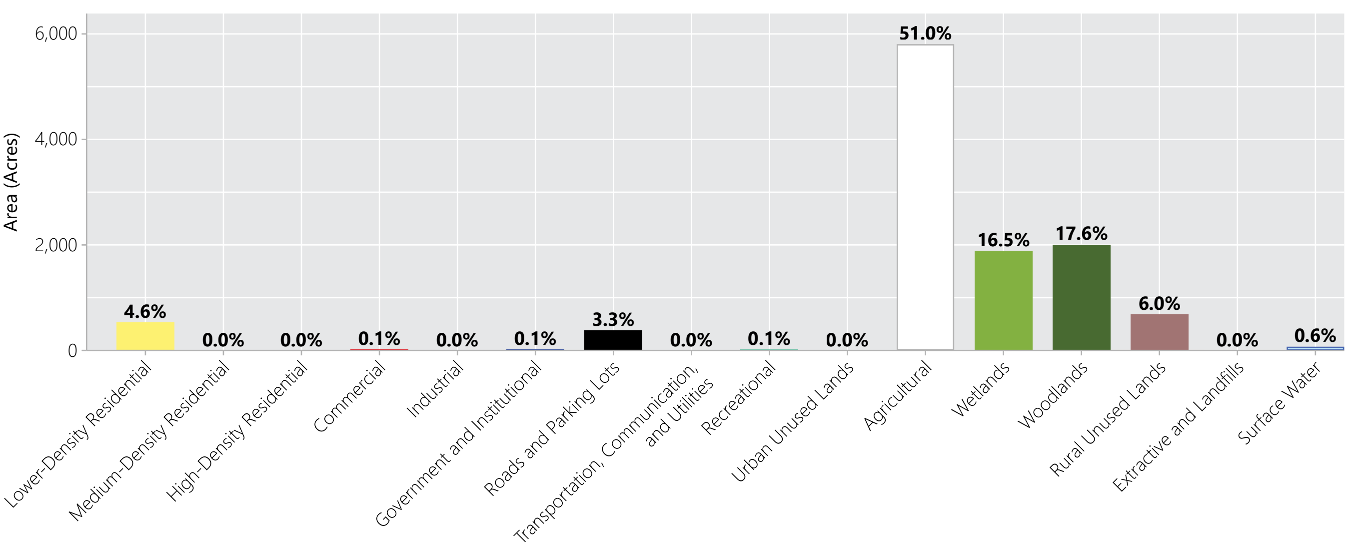
Facts at a Glance

- **Drainage Area Size:** 106 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 7.4%; Rural – 92.6%
- **Roads and Parking Lots (% of drainage area):** 3.1
- **Estimated Population (2010):** 7,910
- **Estimated Households (2010):** 3,080
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (☆):** None
- **Upstream Wastewater Treatment Facilities (♦):** Cascade, Scott (discharges to groundwater through soil infiltration), and Random Lake
- **Planned Sanitary Sewer Service Area (% of drainage area):** 4
- **Water Supply Source:** Groundwater

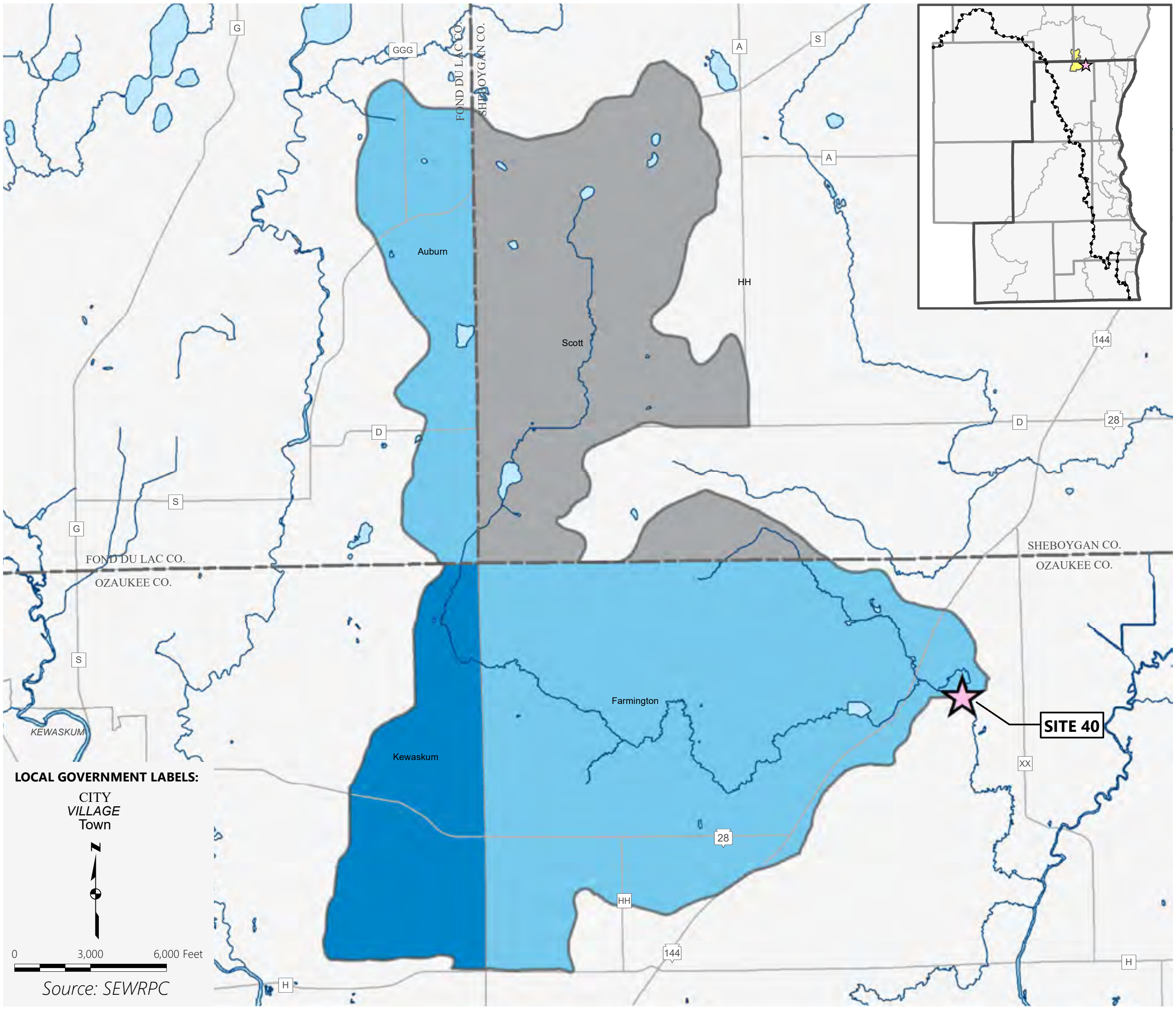
Map B.53
Site 40: Stony Creek Drainage Area – Existing Land Use



Source: SEWRPC



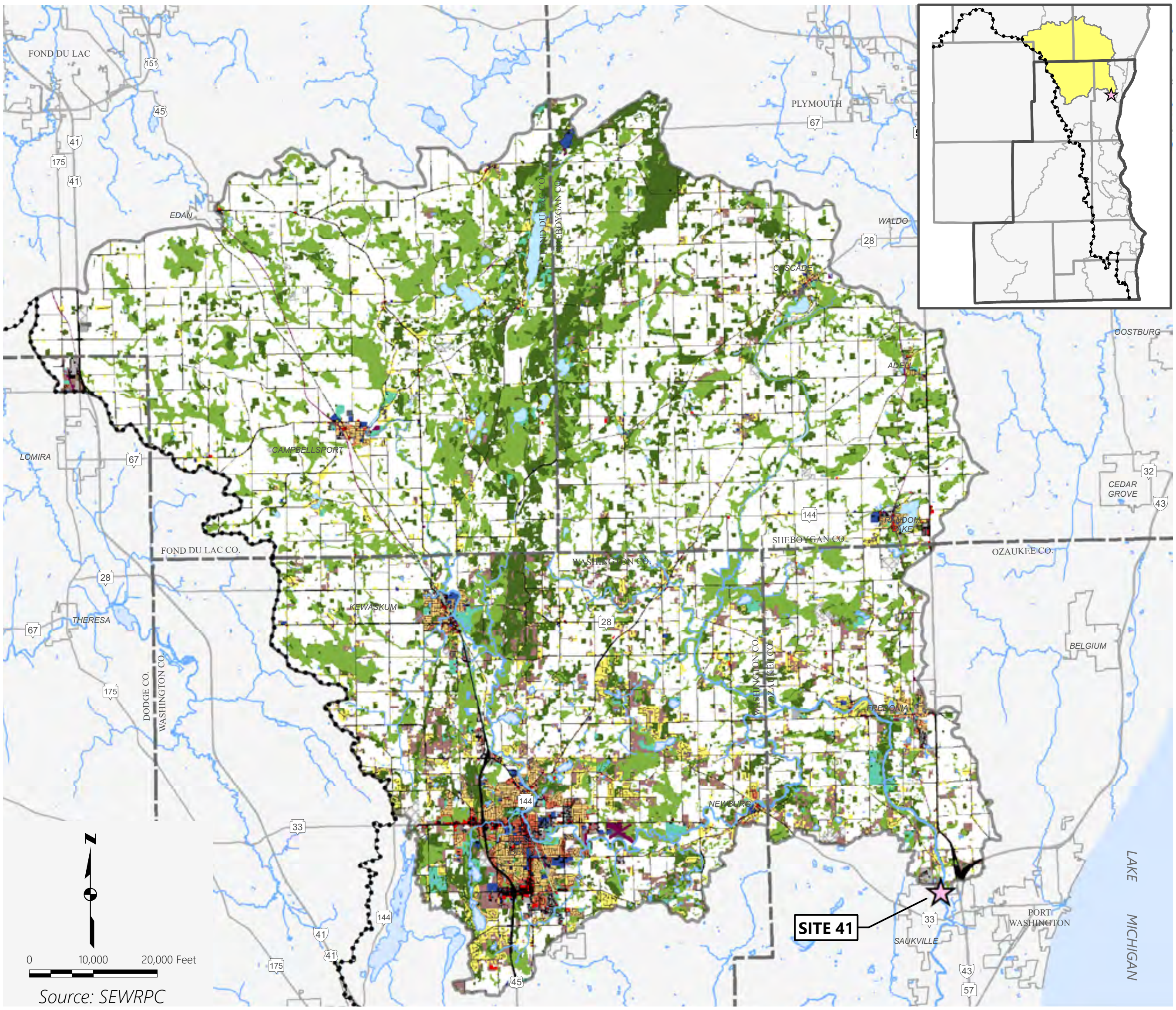
Map B.54
Site 40: Stony Creek Drainage Area – Characteristics

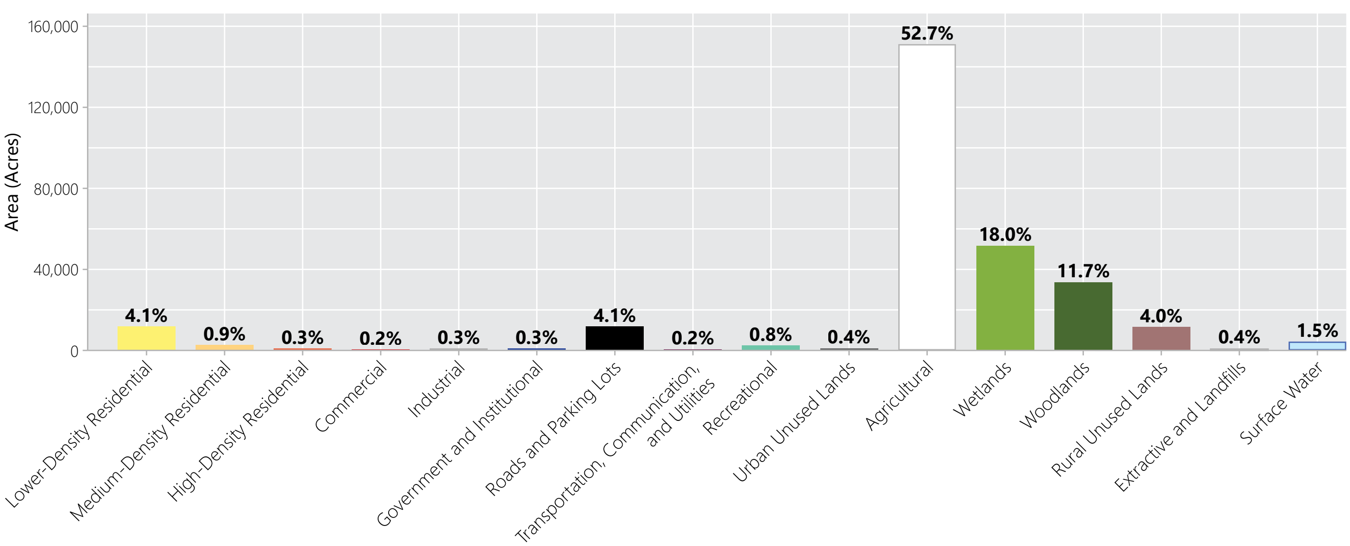


Facts at a Glance

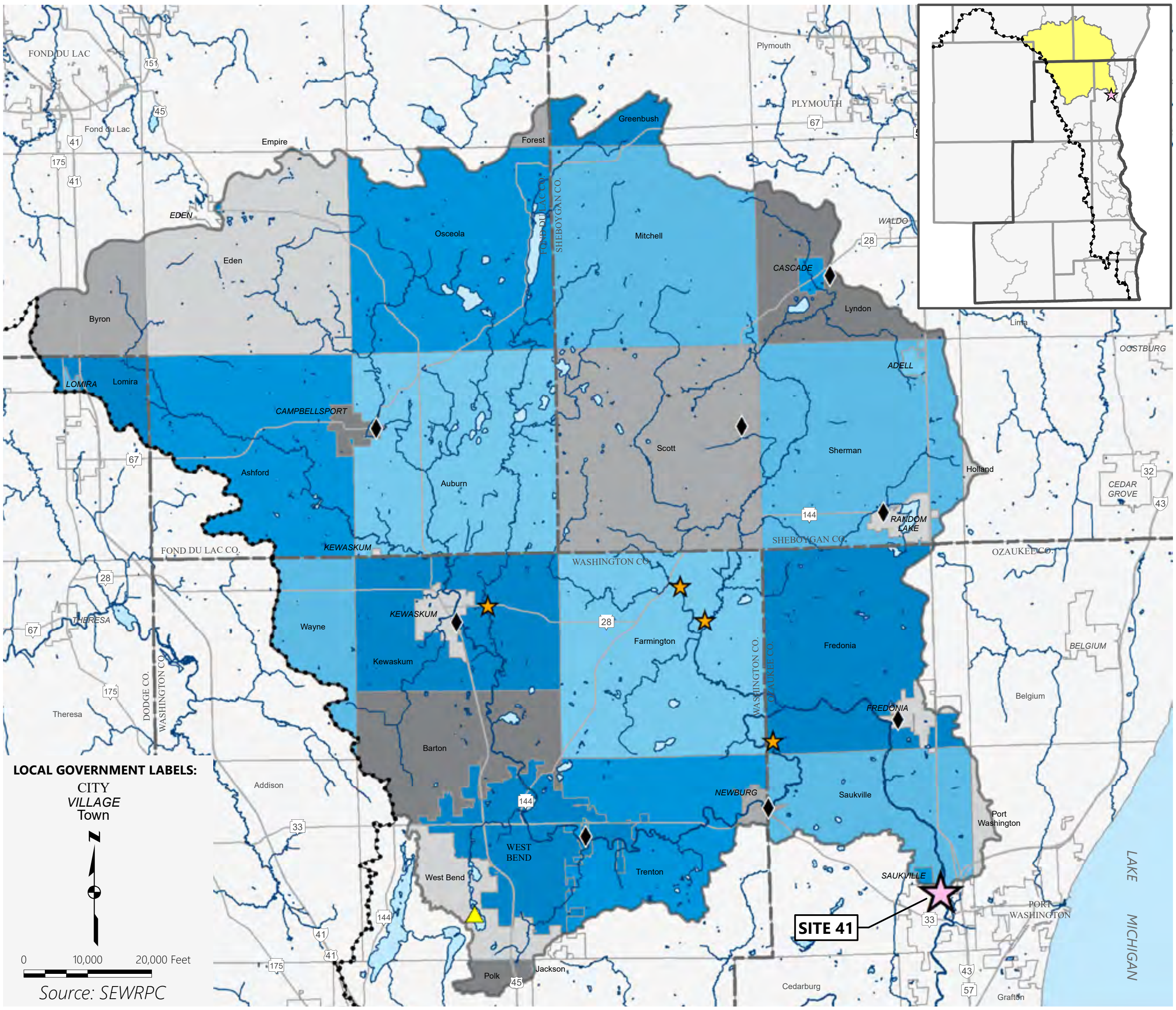
- **Drainage Area Size:** 18 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 8.3%; Rural – 91.7%
- **Roads and Parking Lots (% of drainage area):** 3.3
- **Estimated Population (2010):** 1,280
- **Estimated Households (2010):** 480
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 0
- **Water Supply Source:** Groundwater

Map B.55
Site 41: Milwaukee River near Saukville Drainage Area – Existing Land Use





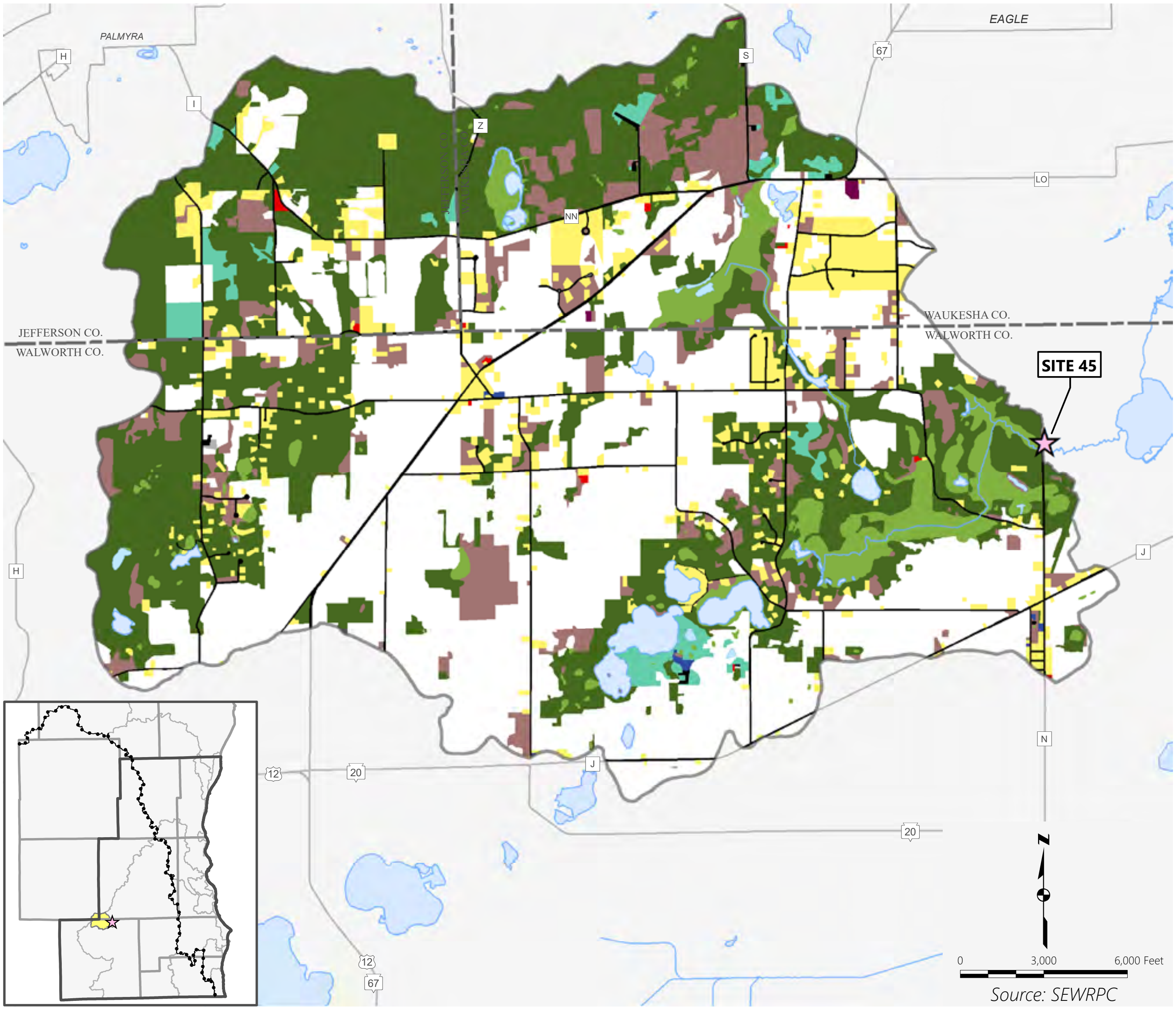
Map B.56
Site 41: Milwaukee River near Saukville Drainage Area – Characteristics

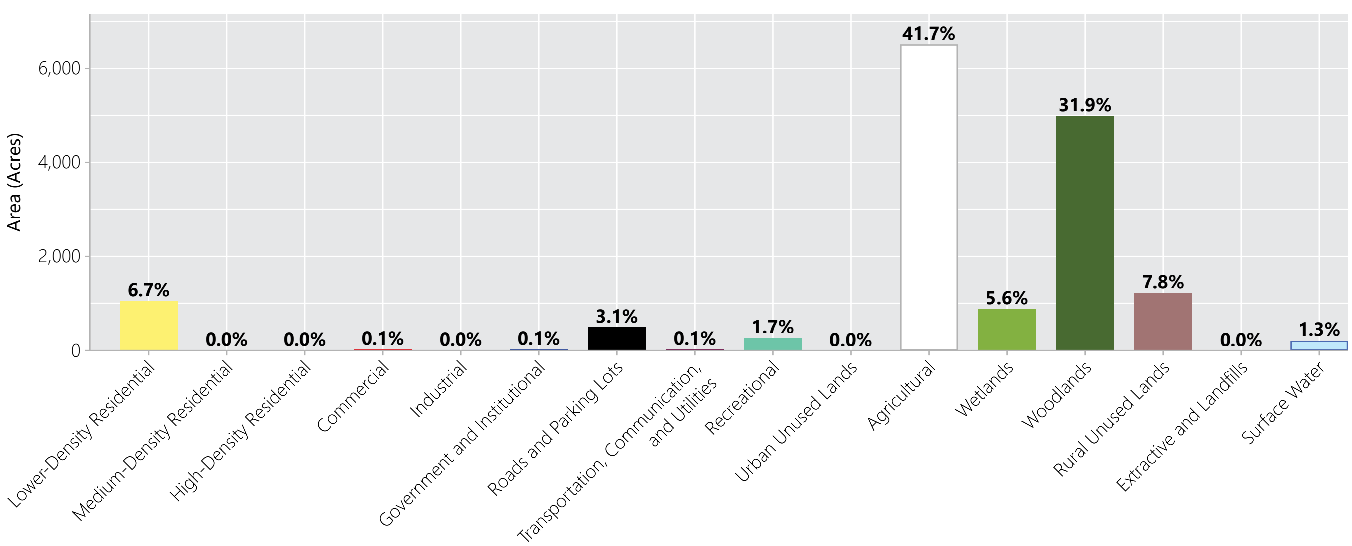


Facts at a Glance

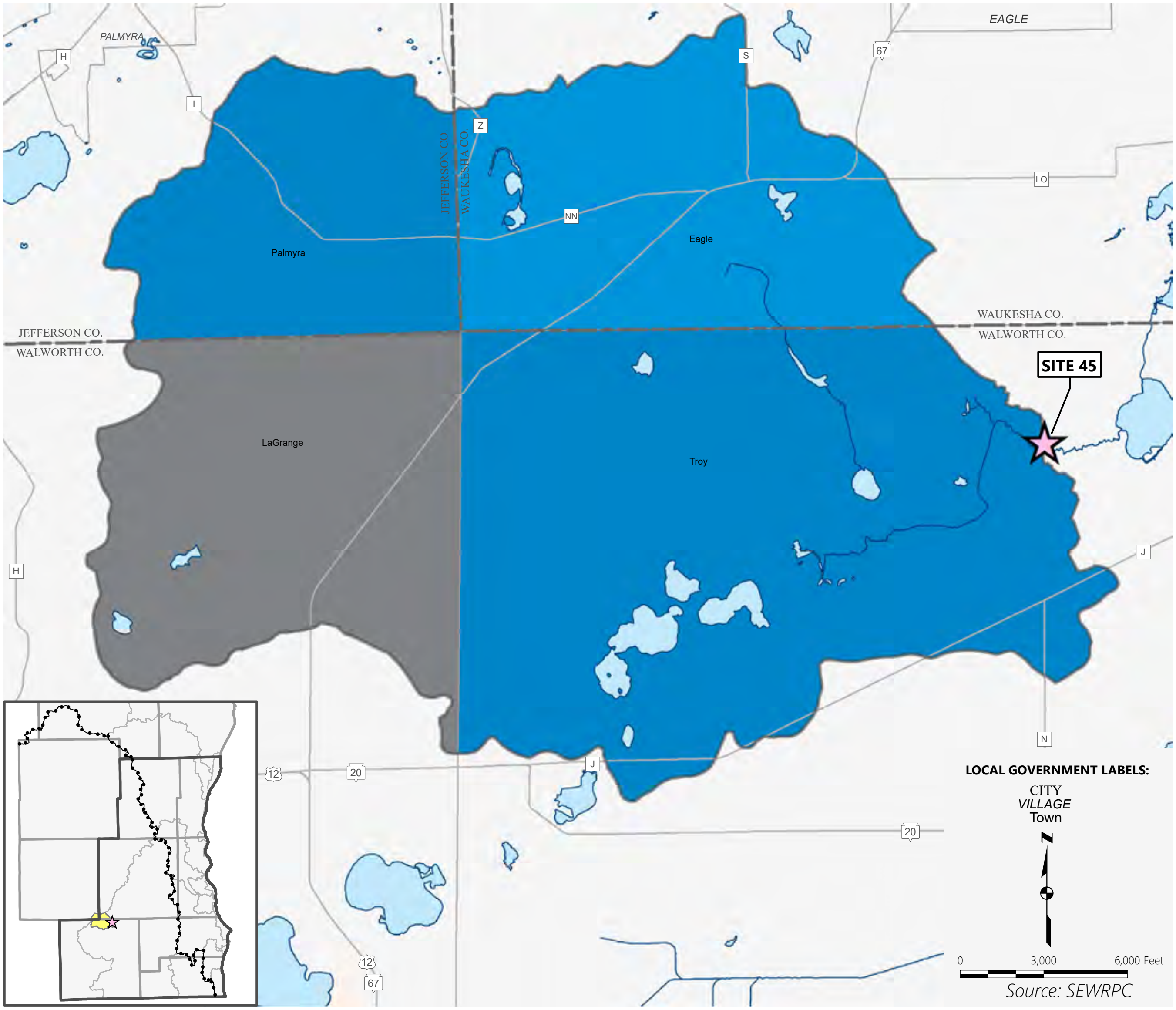
- **Drainage Area Size:** 448 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 11.7%; Rural – 88.3%
- **Roads and Parking Lots (% of drainage area):** 4.1
- **Estimated Population (2010):** 74,210
- **Estimated Households (2010):** 28,800
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** Site 21 (East Branch Milwaukee River), Site 23 (Milwaukee River Downstream of Newburg), Site 40 (Stony Creek), and Site 38 (North Branch Milwaukee River)
- **Lakes Monitored Within this Drainage Area (△):** Silver Lake
- **Upstream Wastewater Treatment Facilities (⧫):** Campbellsport, Kewaskum, West Bend, Newburg, Cascade, Scott (discharges to groundwater through soil infiltration), Random Lake, and Fredonia
- **Planned Sanitary Sewer Service Area (% of drainage area):** 9
- **Water Supply Source:** Groundwater

Map B.57
Site 45: Mukwonago River at Nature Road Drainage Area – Existing Land Use





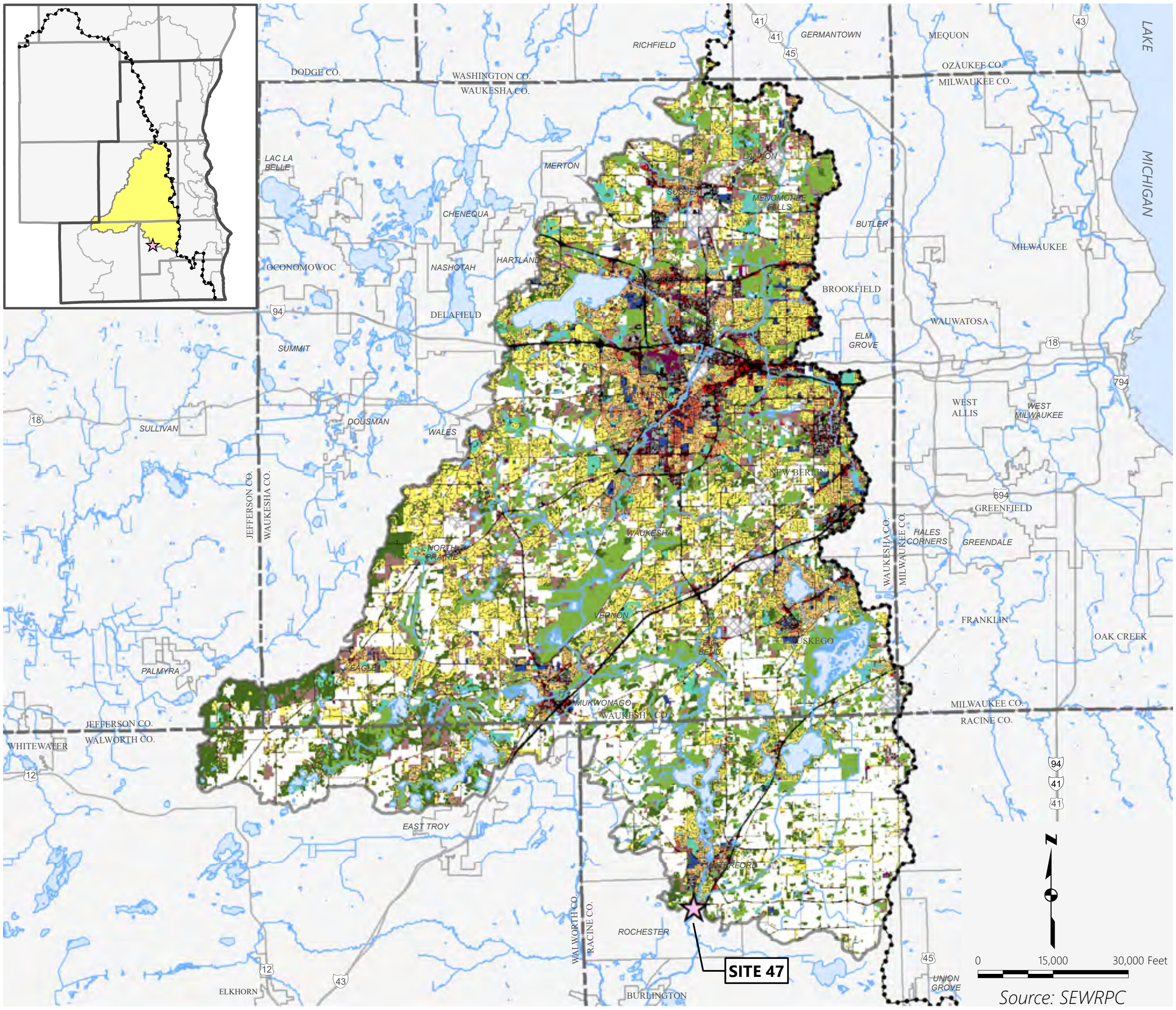
Map B.58
Site 45: Mukwonago River at Nature Road Drainage Area – Characteristics

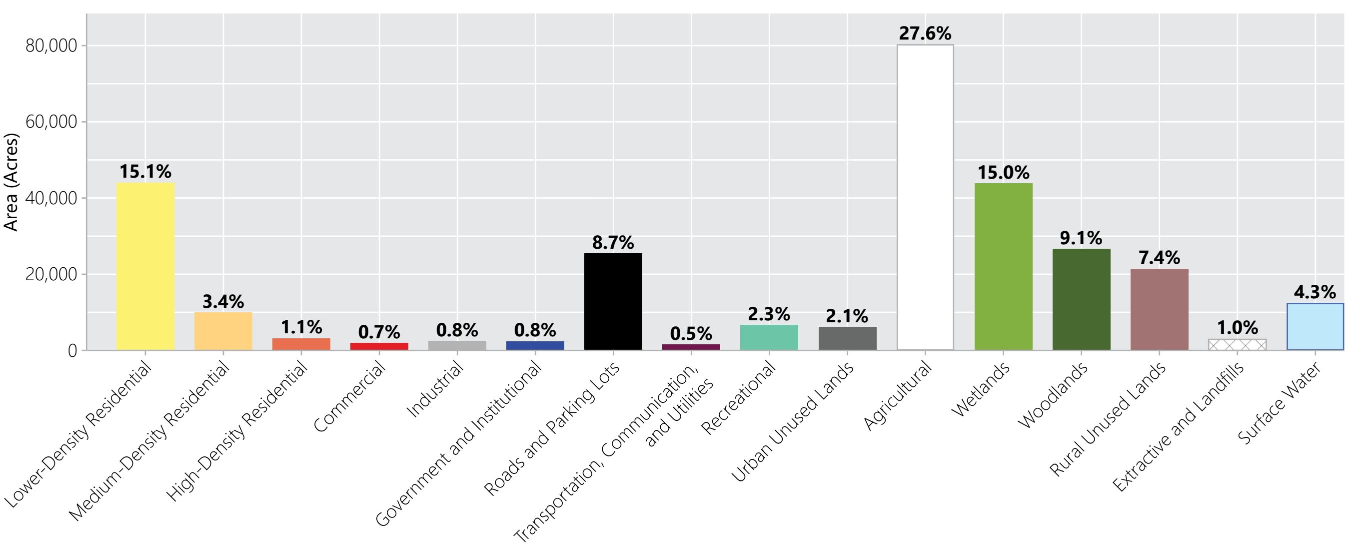


Facts at a Glance

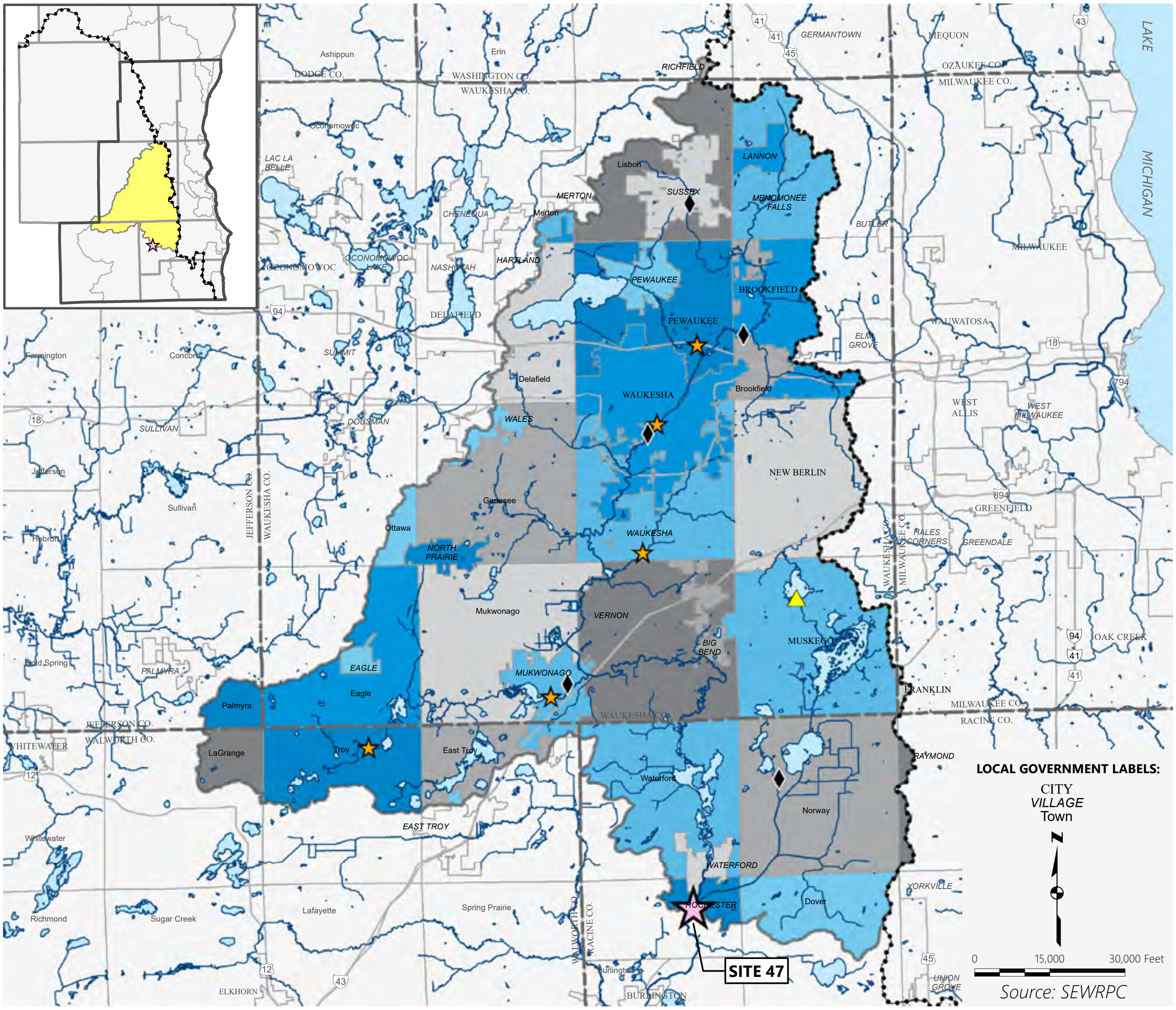
- **Drainage Area Size:** 24 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 11.8%; Rural – 88.2%
- **Roads and Parking Lots (% of drainage area):** 3.1
- **Estimated Population (2010):** 2,290
- **Estimated Households (2010):** 900
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 0
- **Water Supply Source:** Groundwater

Map B.59
Site 47: Fox River at Rochester Drainage Area – Existing Land Use





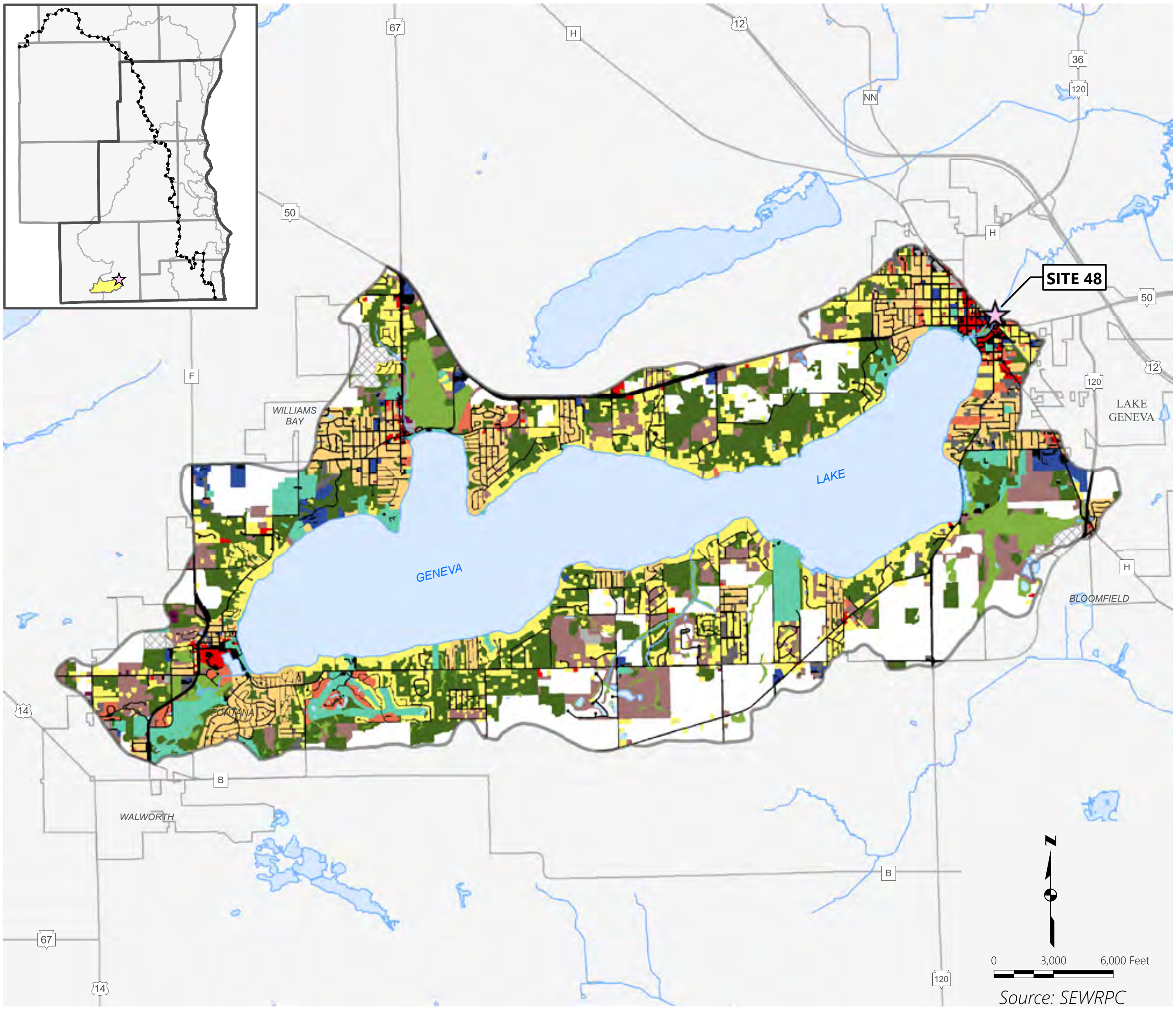
Map B.60
Site 47: Fox River at Rochester Drainage Area – Characteristics

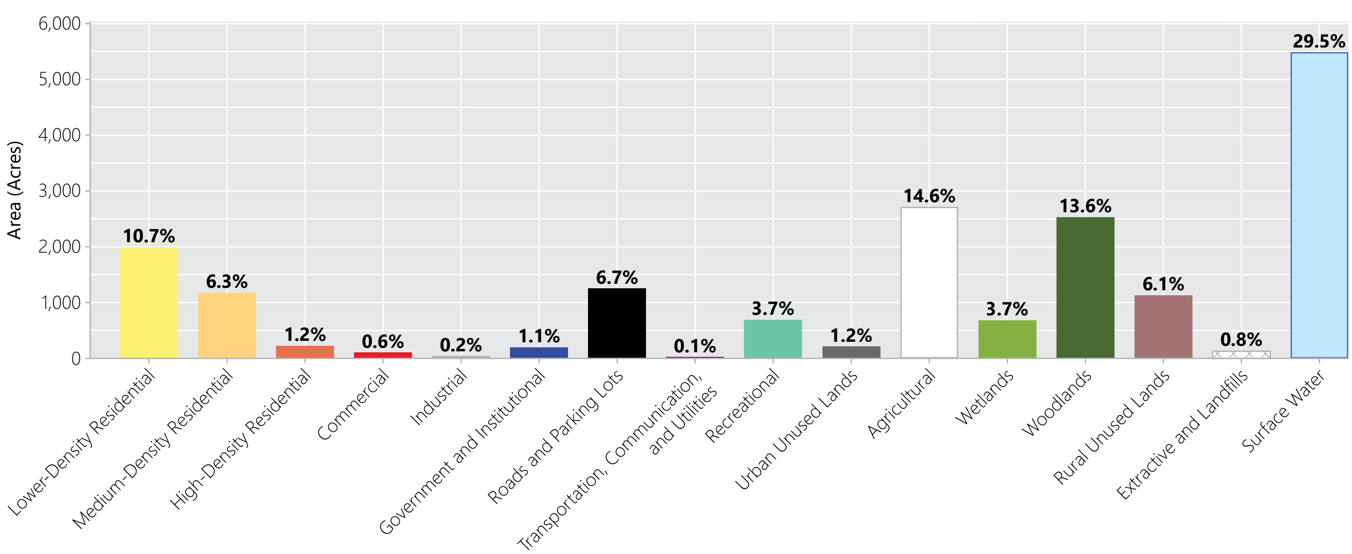


Facts at a Glance

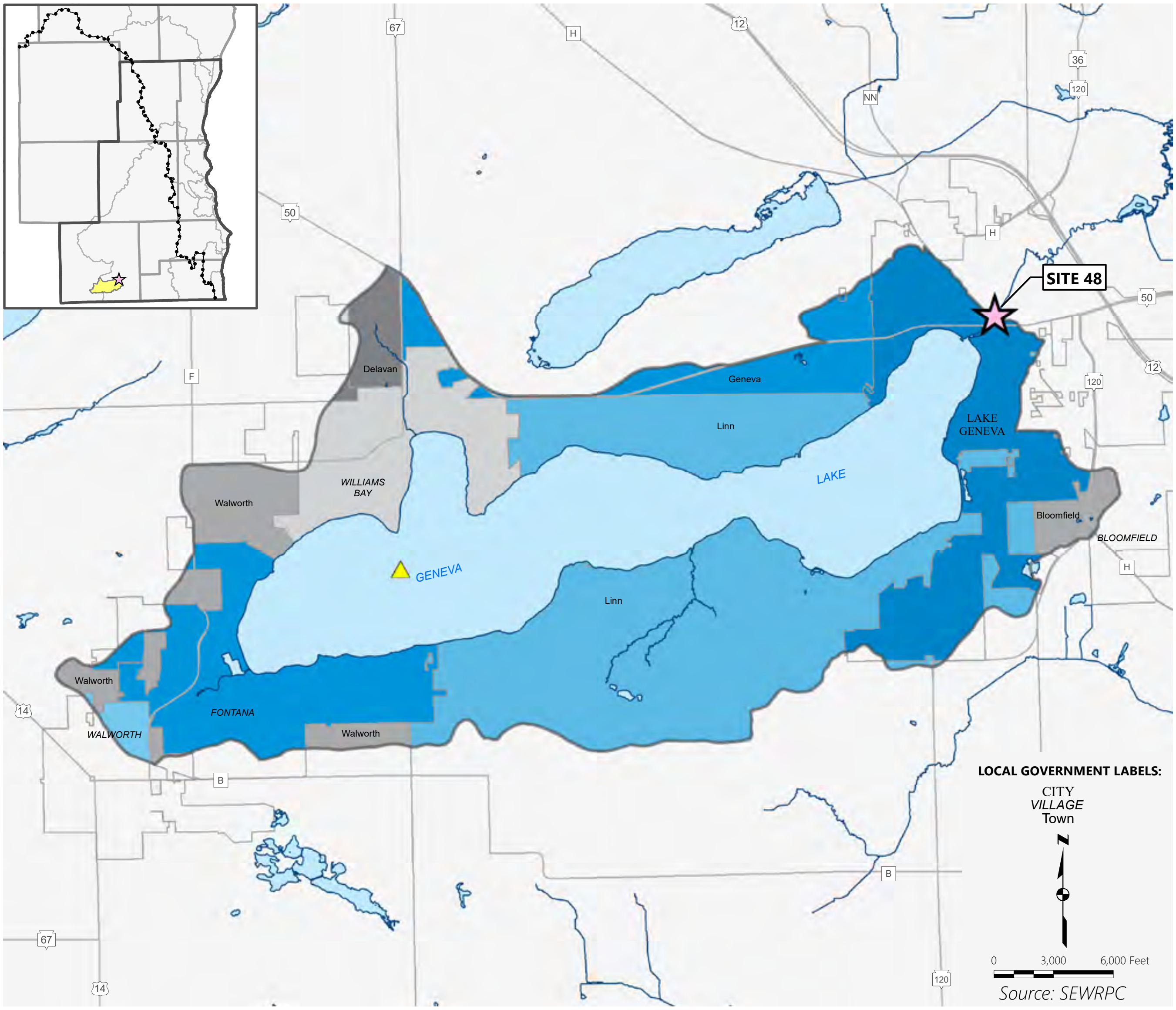
- **Drainage Area Size:** 456 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 35.6%; Rural – 64.4%
- **Roads and Parking Lots (% of drainage area):** 8.7
- **Estimated Population (2010):** 263,270
- **Estimated Households (2010):** 103,030
- **Nearest USGS Streamgage:** Fox River at Rochester (05544475)
- **Other Monitoring Sites Within this Drainage Area (☆):** Site 8 (Pewaukee River), Site 1 (Fox River at Waukesha), Site 33 (Pebble Brook), Site 45 (Mukwonago River at Nature Road), and Site 3 (Mukwonago River at Mukwonago)
- **Lakes Monitored Within this Drainage Area (△):** Little Muskego Lake
- **Upstream Wastewater Treatment Facilities (♦):** Sussex, Fox River Water Pollution Control Center, Waukesha, Mukwonago, and Norway Sanitary District No. 1
- **Planned Sanitary Sewer Service Area (% of drainage area):** 40
- **Water Supply Source:** Groundwater (water supplied by the City of Waukesha is planned to be converted from groundwater to Lake Michigan supply in 2023)

Map B.61
Site 48: White River at Lake Geneva Drainage Area – Existing Land Use





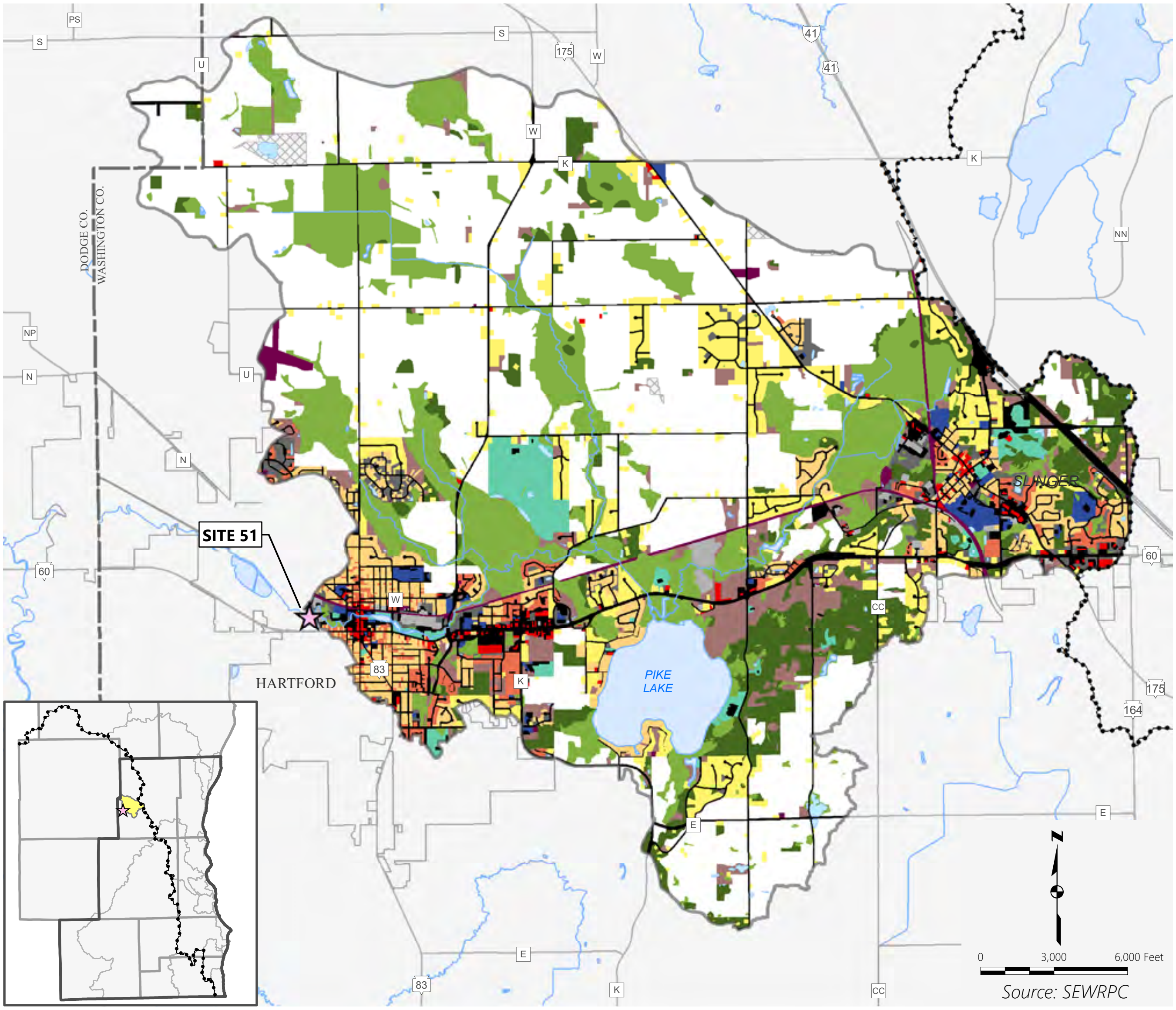
Map B.62
Site 48: White River at Lake Geneva Drainage Area – Characteristics

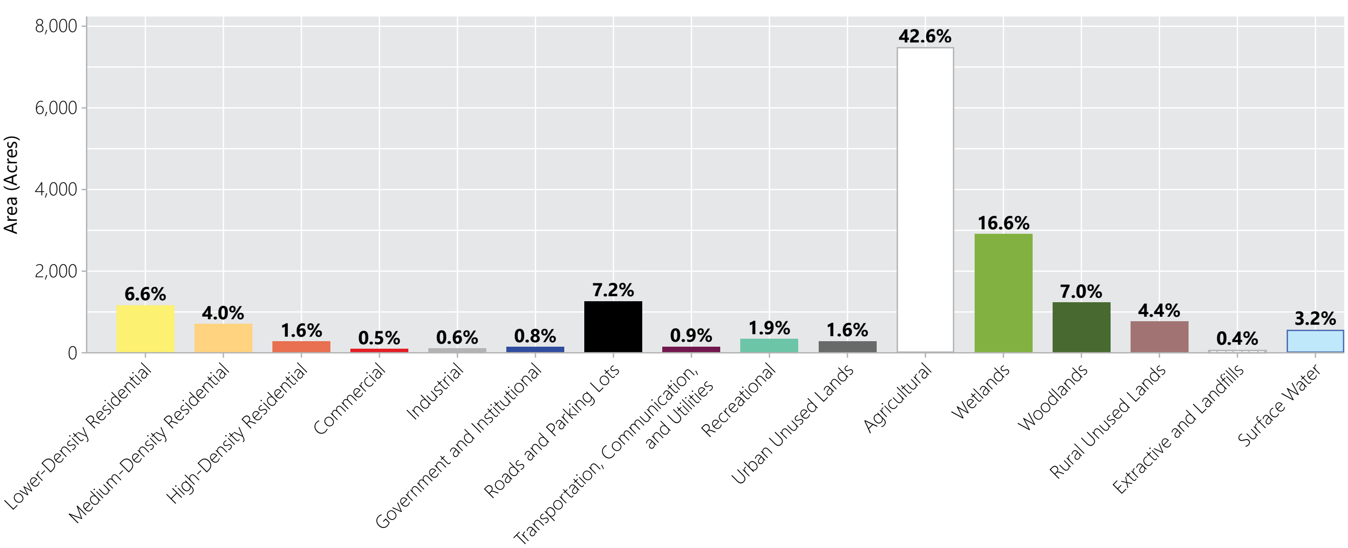


Facts at a Glance

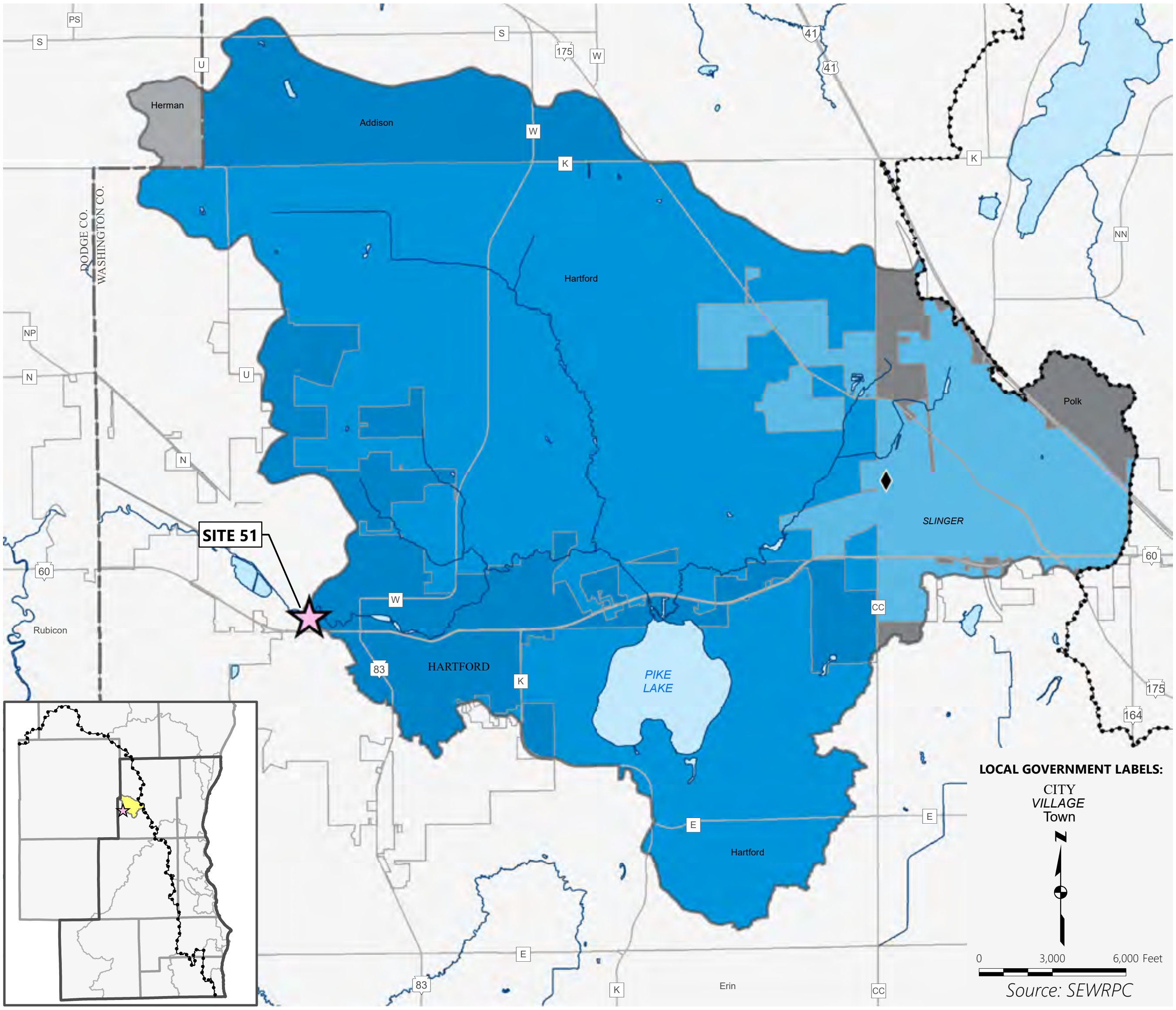
- **Drainage Area Size:** 29 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 31.8%; Rural – 68.2%
- **Roads and Parking Lots (% of drainage area):** 6.7
- **Estimated Population (2010):** 9,910
- **Estimated Households (2010):** 4,280
- **Nearest USGS Streamgage:** White River at Center Street (055451345)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Lakes Monitored Within this Drainage Area (△):** Geneva Lake
- **Upstream Wastewater Treatment Facilities (♦):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 57
- **Water Supply Source:** Groundwater

Map B.63
Site 51: Rubicon River Drainage Area – Existing Land Use





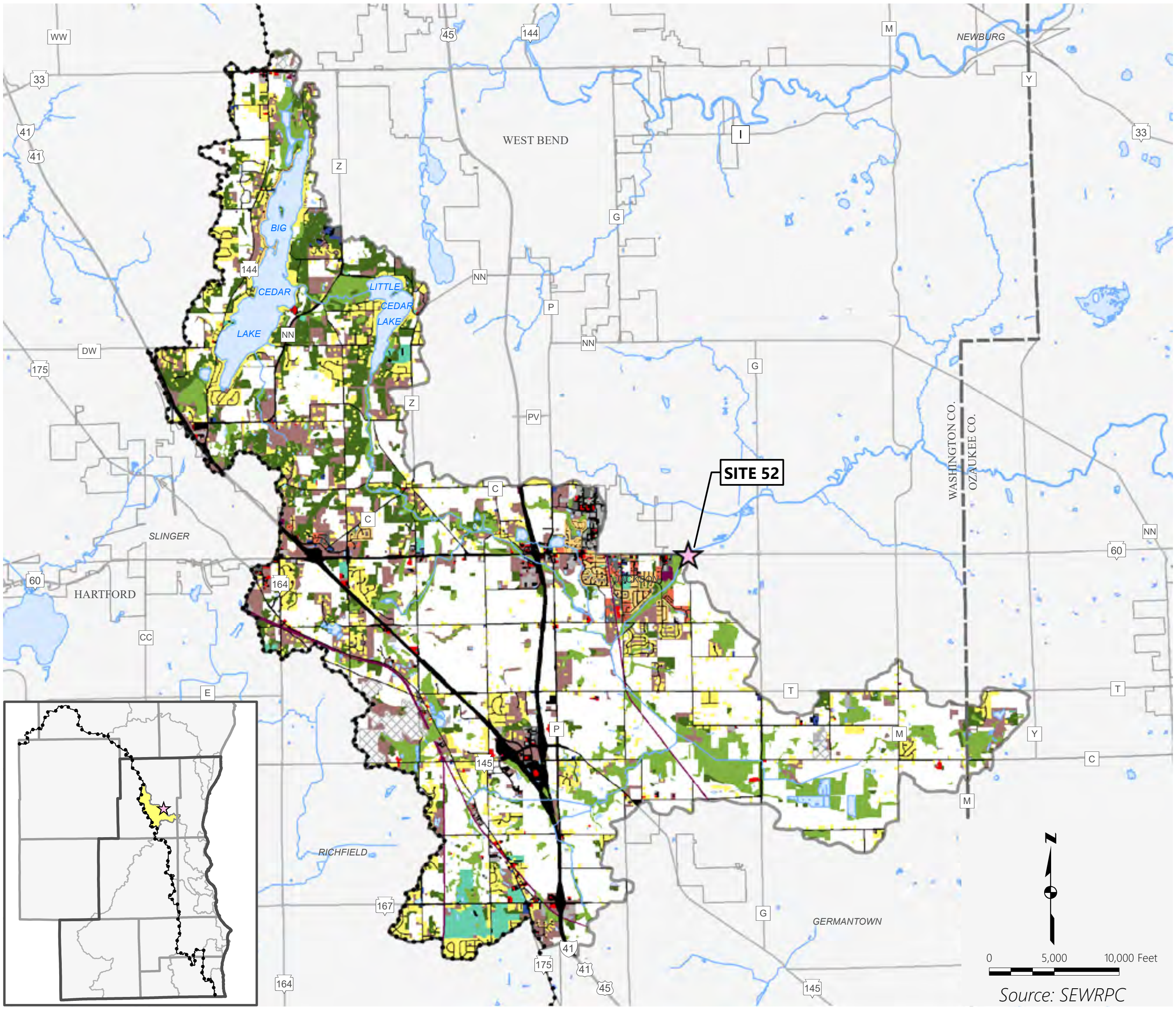
Map B.64
Site 51: Rubicon River Drainage Area – Characteristics

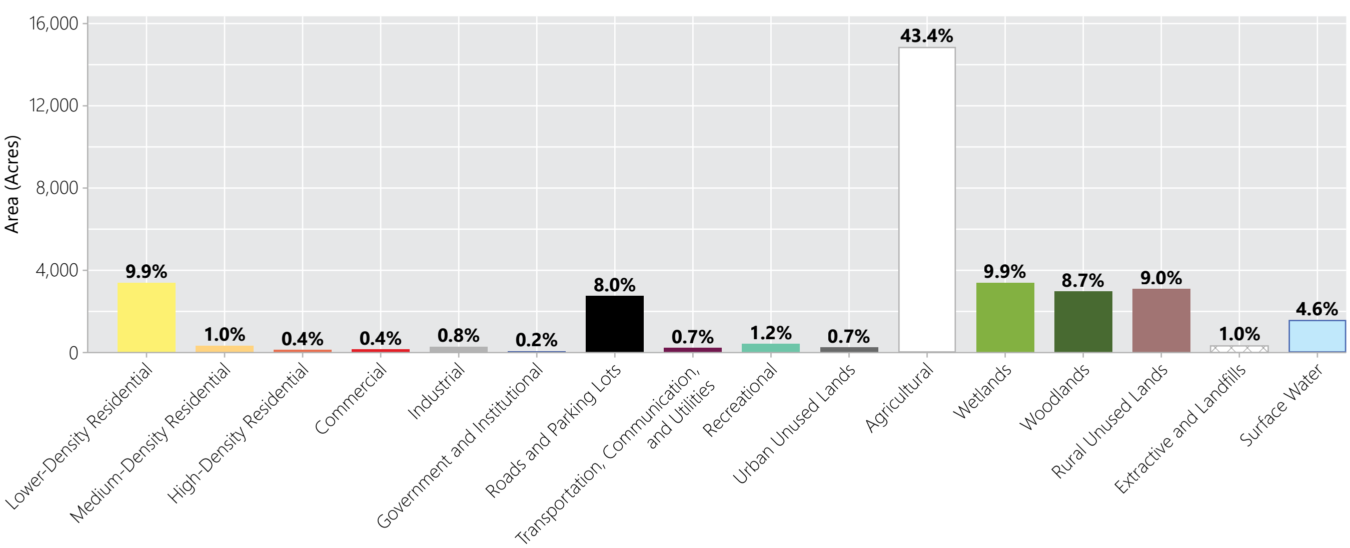


Facts at a Glance

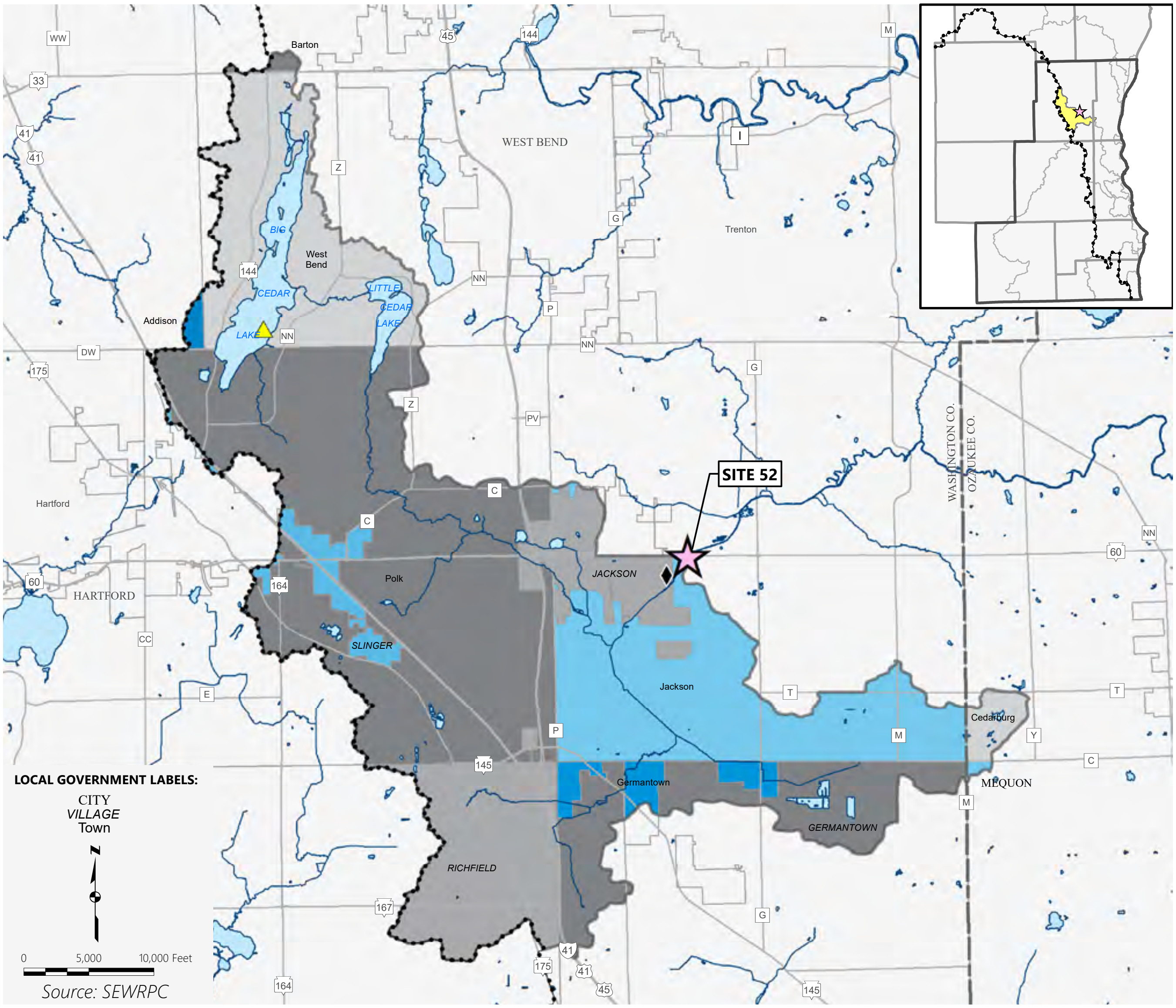
- **Drainage Area Size:** 27 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 25.8%; Rural – 74.2%
- **Roads and Parking Lots (% of drainage area):** 7.2
- **Estimated Population (2010):** 14,160
- **Estimated Households (2010):** 5,830
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** Slinger
- **Planned Sanitary Sewer Service Area (% of drainage area):** 54
- **Water Supply Source:** Groundwater

Map B.65
Site 52: Cedar Creek Drainage Area – Existing Land Use





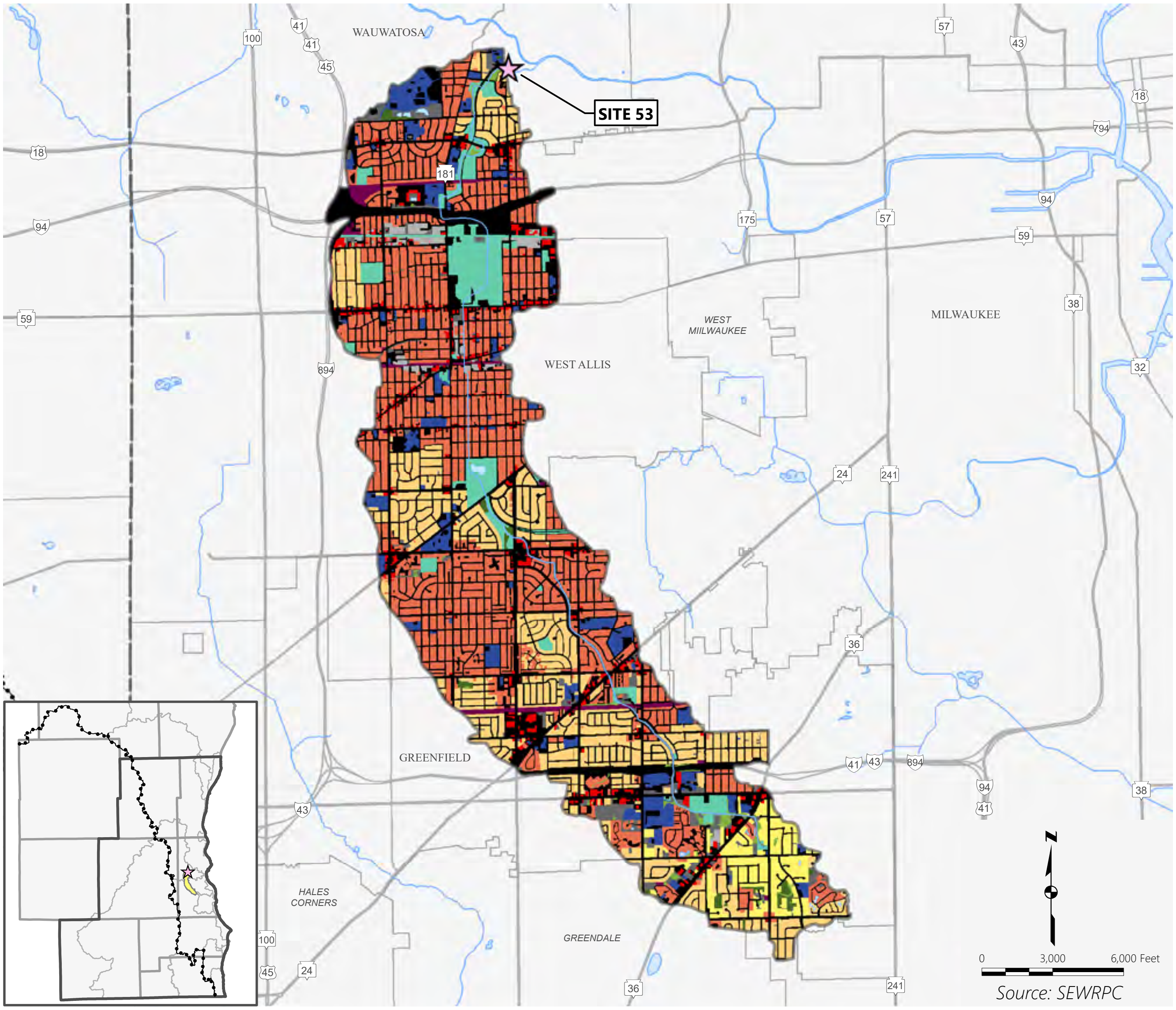
Map B.66
Site 52: Cedar Creek Drainage Area – Characteristics

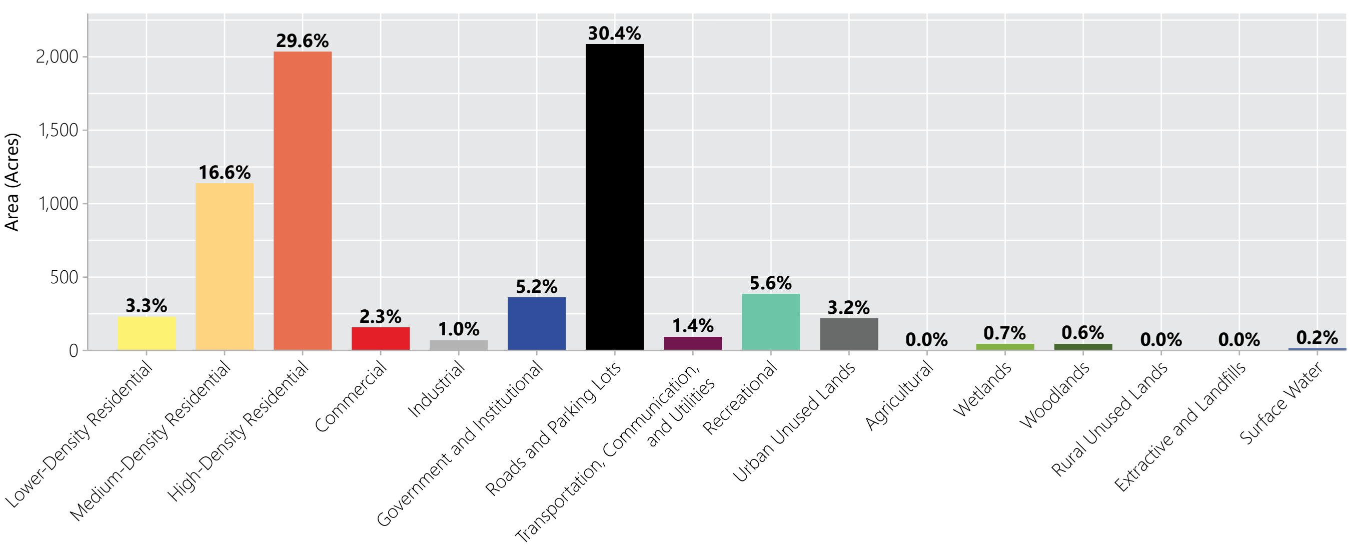


Facts at a Glance

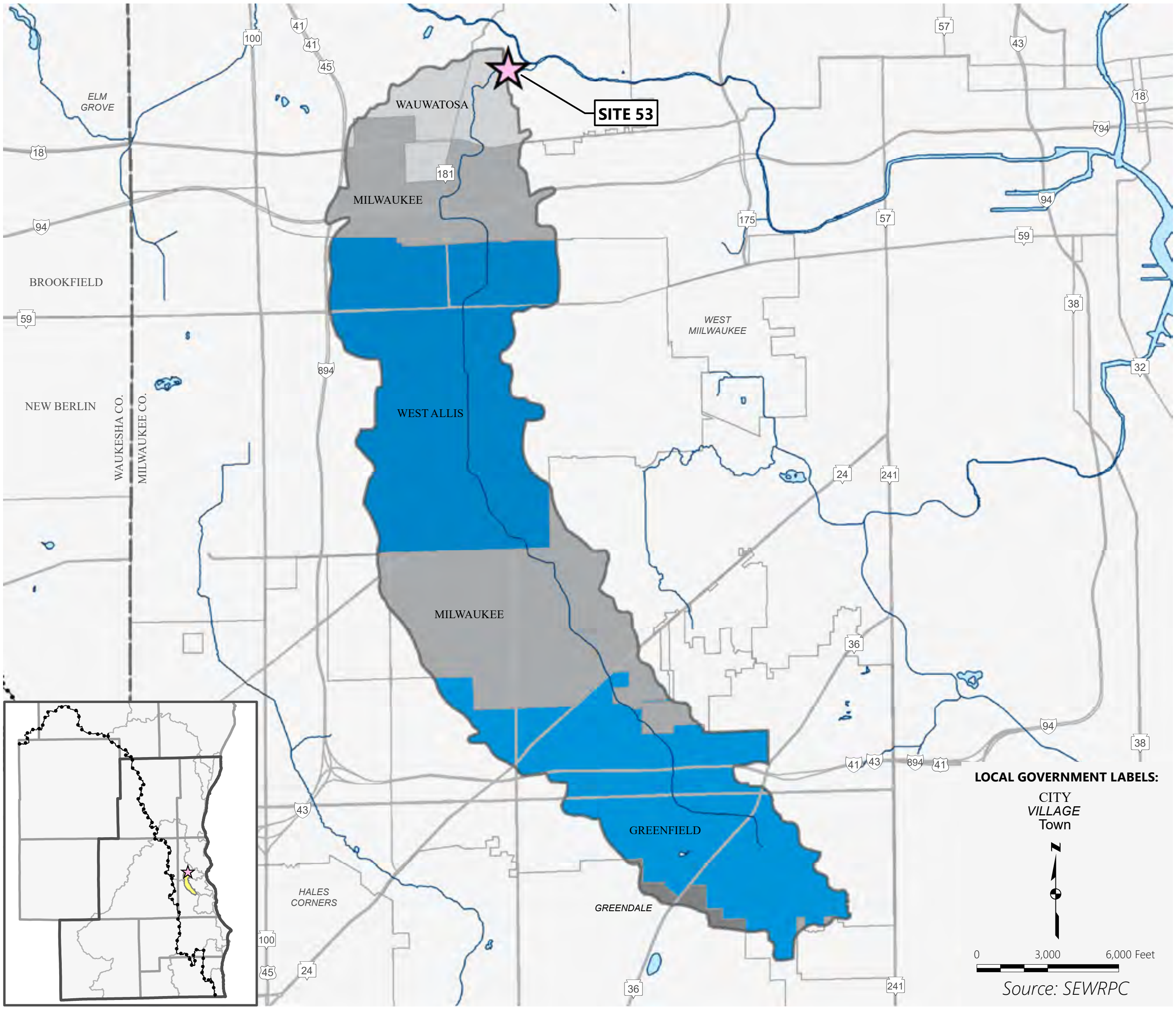
- **Drainage Area Size:** 54 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 23.3%; Rural – 76.7%
- **Roads and Parking Lots (% of drainage area):** 8.0
- **Estimated Population (2010):** 13,460
- **Estimated Households (2010):** 5,380
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (☆):** None
- **Lakes Monitored Within this Drainage Area (△):** Big Cedar Lake
- **Upstream Wastewater Treatment Facilities (♦):** Jackson
- **Planned Sanitary Sewer Service Area (% of drainage area):** 13
- **Water Supply Source:** Groundwater

Map B.67
Site 53: Honey Creek at Wauwatosa Drainage Area – Existing Land Use





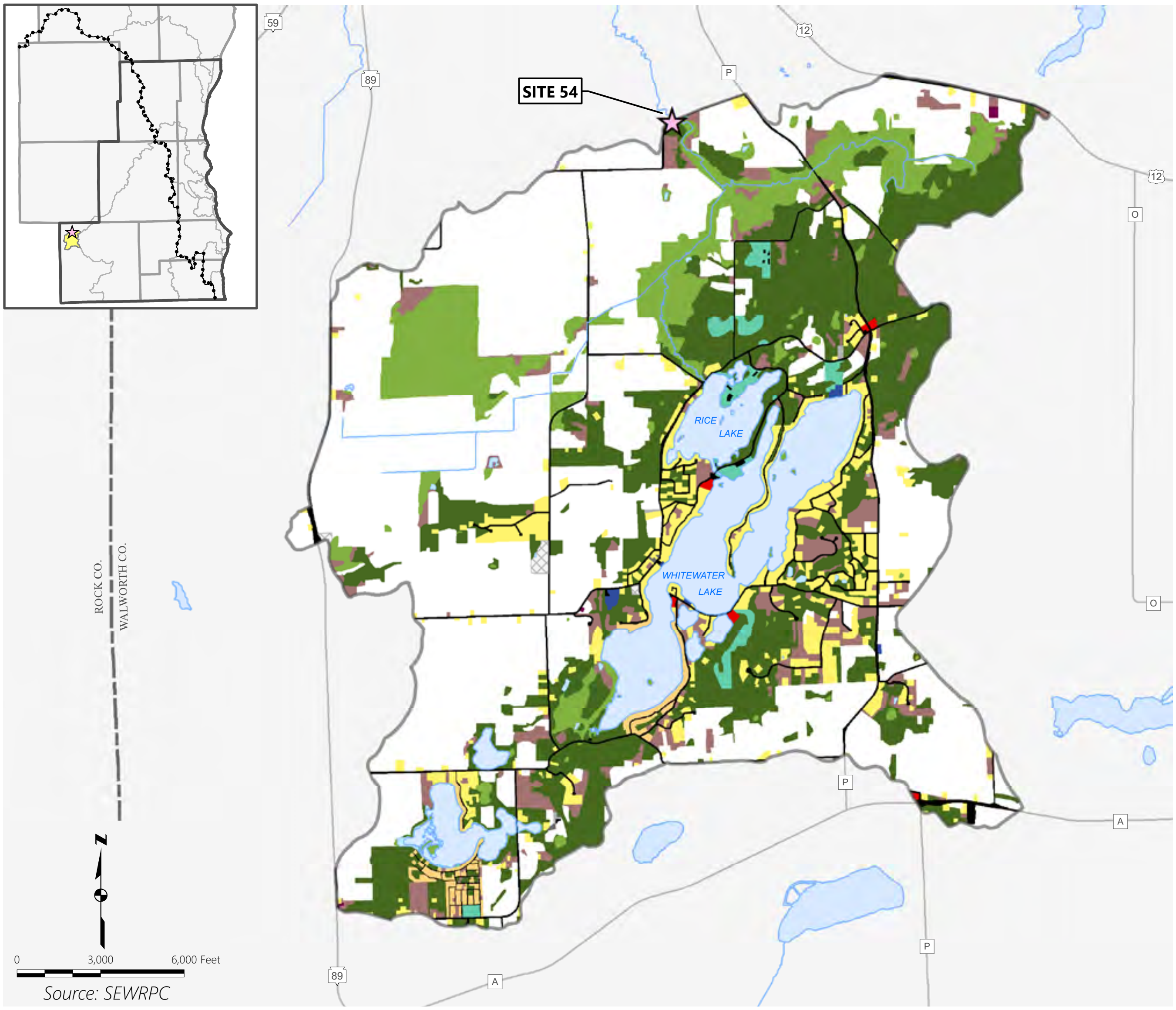
Map B.68
Site 53: Honey Creek at Wauwatosa Drainage Area – Characteristics

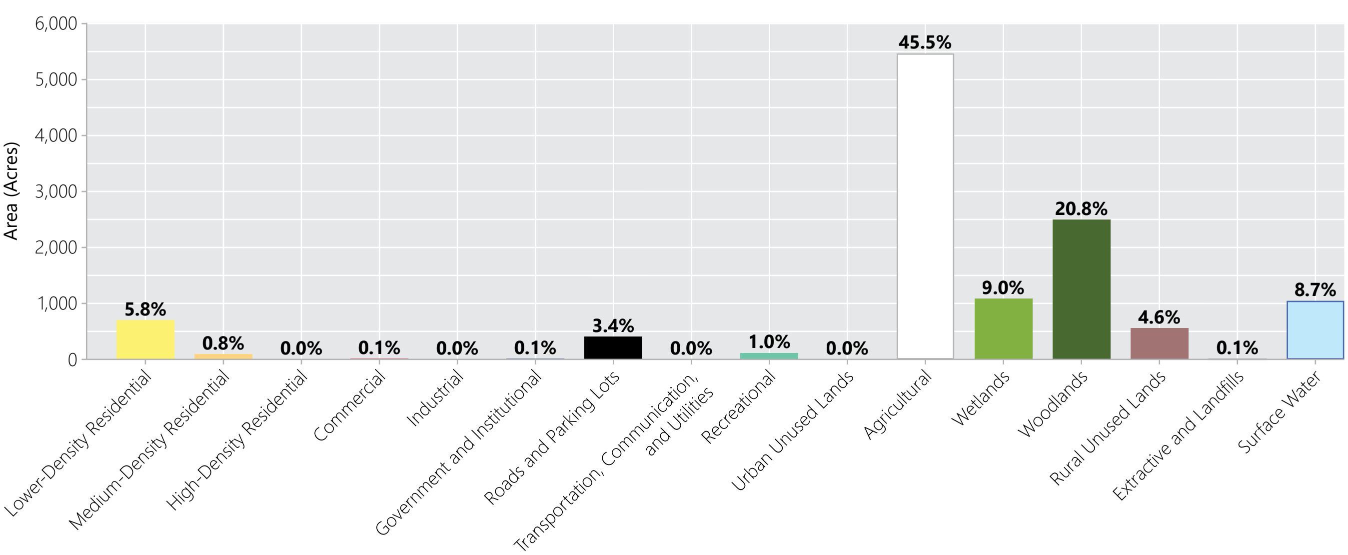


Facts at a Glance

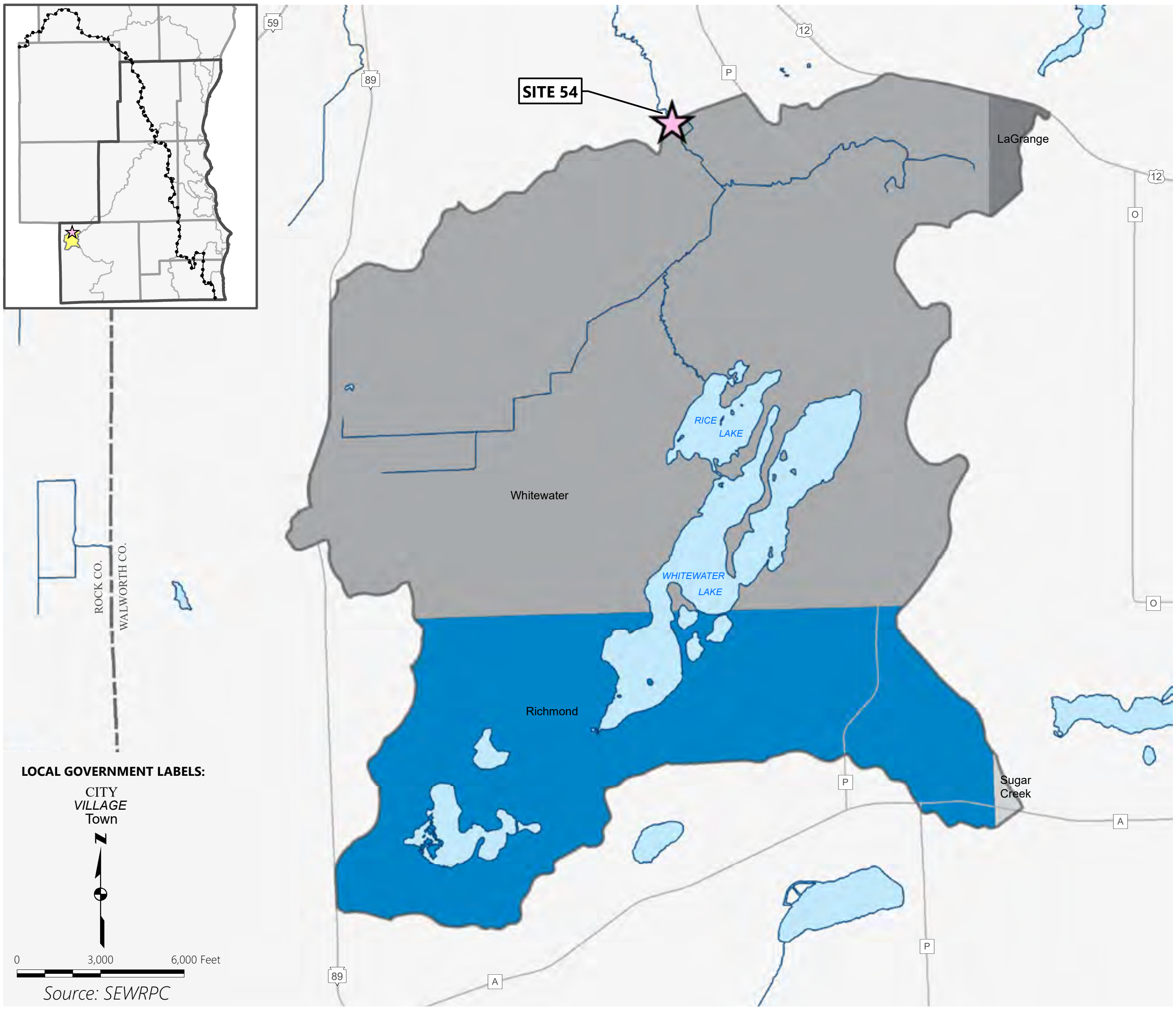
- **Drainage Area Size:** 11 square miles
- **Major Watershed:** Menomonee River
- **Land Use:** Urban – 98.5%; Rural – 1.5%
- **Roads and Parking Lots (% of drainage area):** 30.4
- **Estimated Population (2010):** 59,170
- **Estimated Households (2010):** 26,680
- **Nearest USGS Streamgage:** Honey Creek at Wauwatosa (04087119)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 100
- **Water Supply Source:** Lake Michigan

Map B.69
Site 54: Whitewater Creek Drainage Area – Existing Land Use





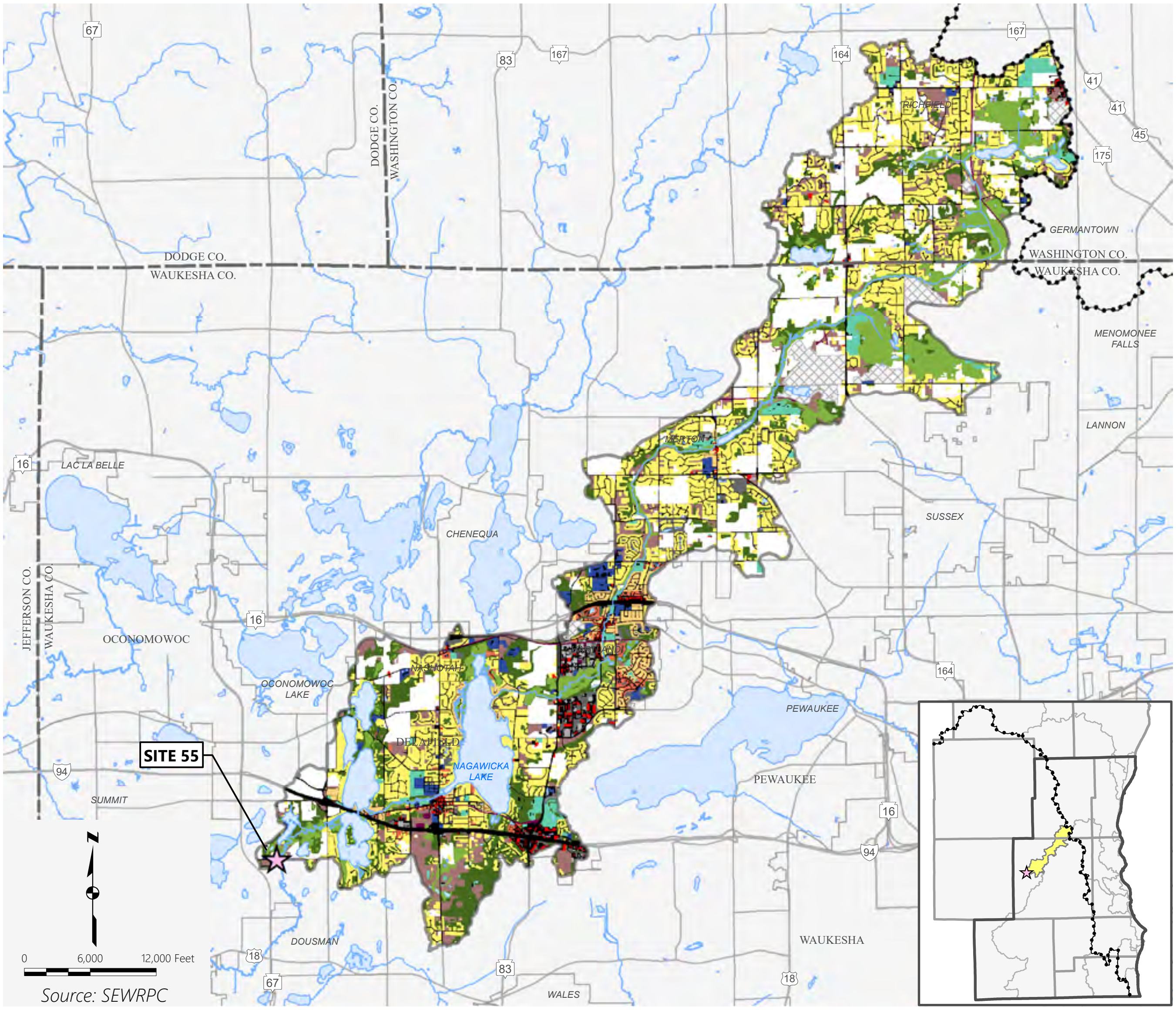
Map B.70
Site 54: Whitewater Creek Drainage Area – Characteristics

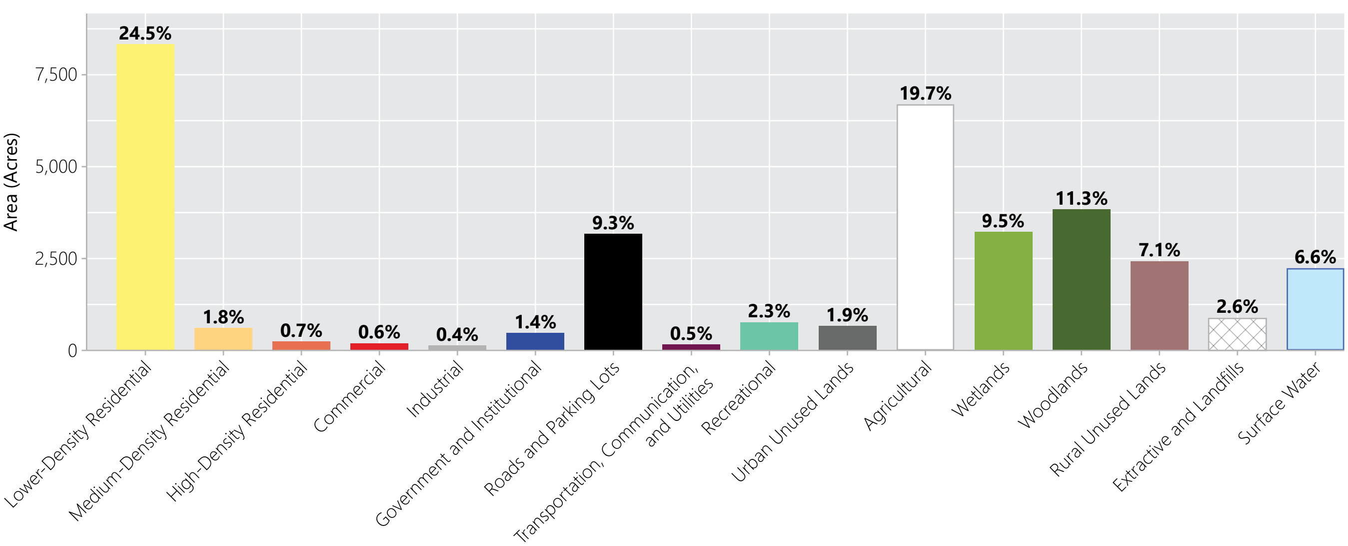


Facts at a Glance

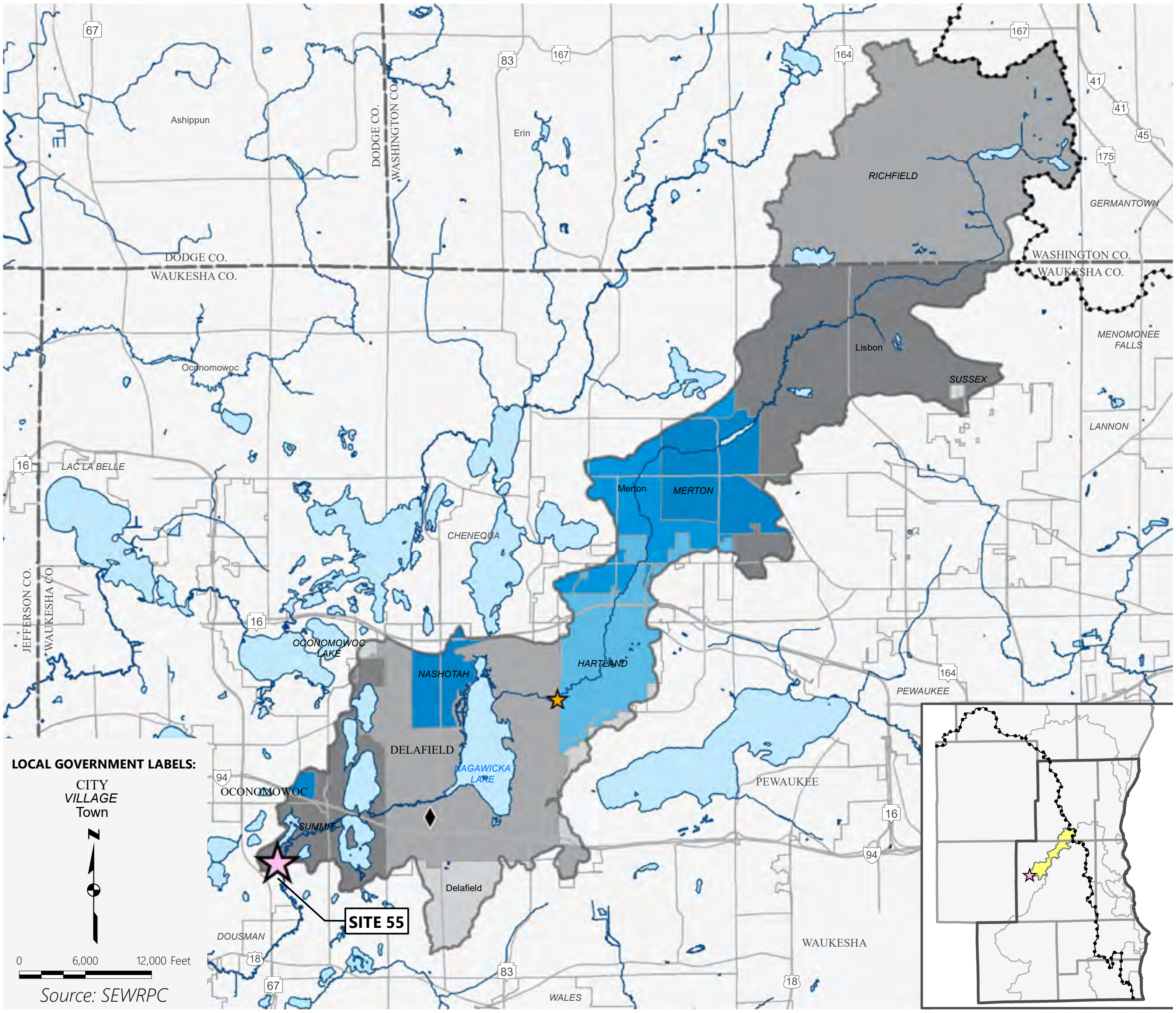
- **Drainage Area Size:** 19 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 11.2%; Rural – 88.8%
- **Roads and Parking Lots (% of drainage area):** 3.4
- **Estimated Population (2010):** 1,640
- **Estimated Households (2010):** 670
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (♦):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 0
- **Water Supply Source:** Groundwater

Map B.71
Site 55: Bark River Downstream Drainage Area – Existing Land Use





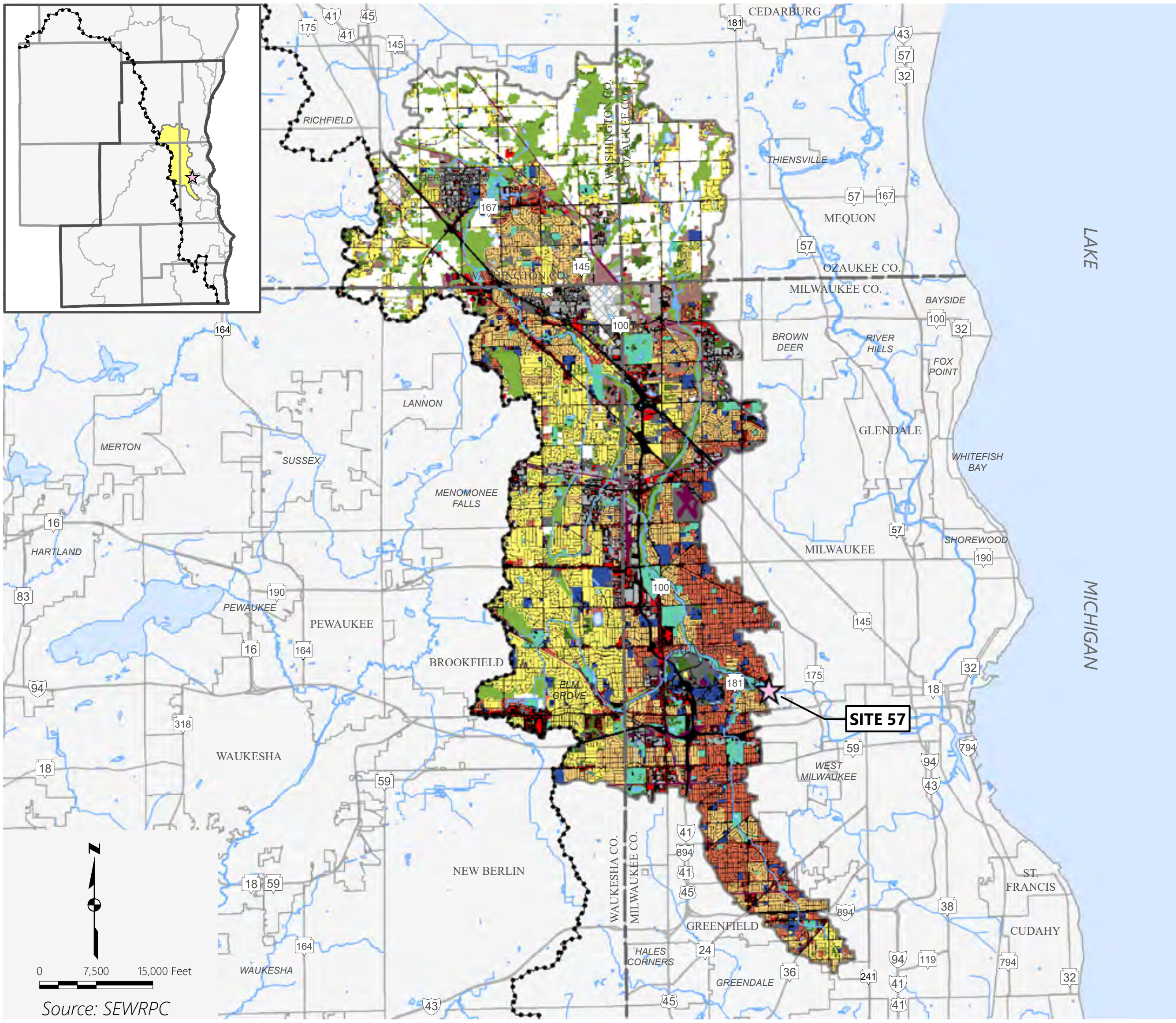
Map B.72
Site 55: Bark River Downstream Drainage Area – Characteristics



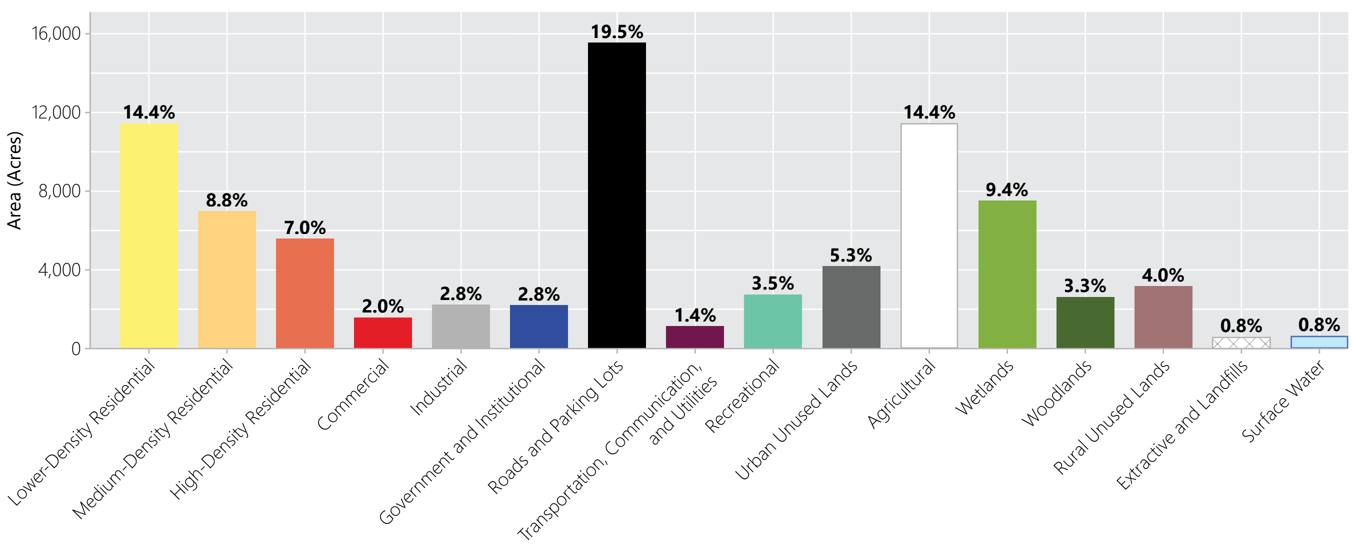
Facts at a Glance

- **Drainage Area Size:** 53 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 43.3%; Rural – 56.7%
- **Roads and Parking Lots (% of drainage area):** 9.3
- **Estimated Population (2010):** 29,480
- **Estimated Households (2010):** 10,860
- **Nearest USGS Streamgage:** None
- **Other Monitoring Sites Within this Drainage Area (★):** Monitoring Site 11 (Bark River Upstream)
- **Upstream Wastewater Treatment Facilities (⧫):** Delafield – Hartland Water Pollution Control Commission (effluent from this facility is pumped and discharged downstream of Site 55)
- **Planned Sanitary Sewer Service Area (% of drainage area):** 44
- **Water Supply Source:** Groundwater

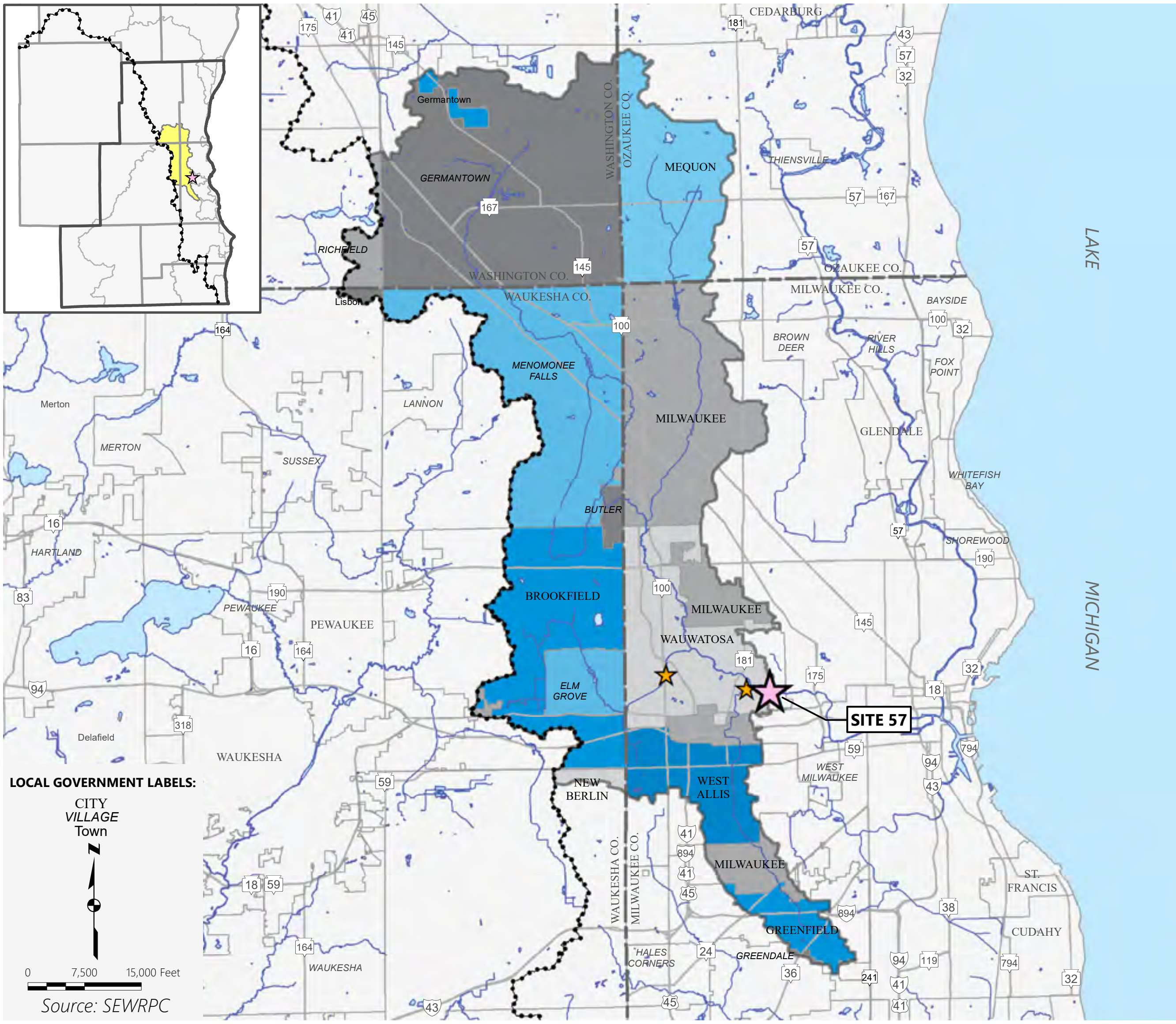
Map B.73
Site 57: Menomonee River at Wauwatosa Drainage Area – Existing Land Use



Source: SEWRPC



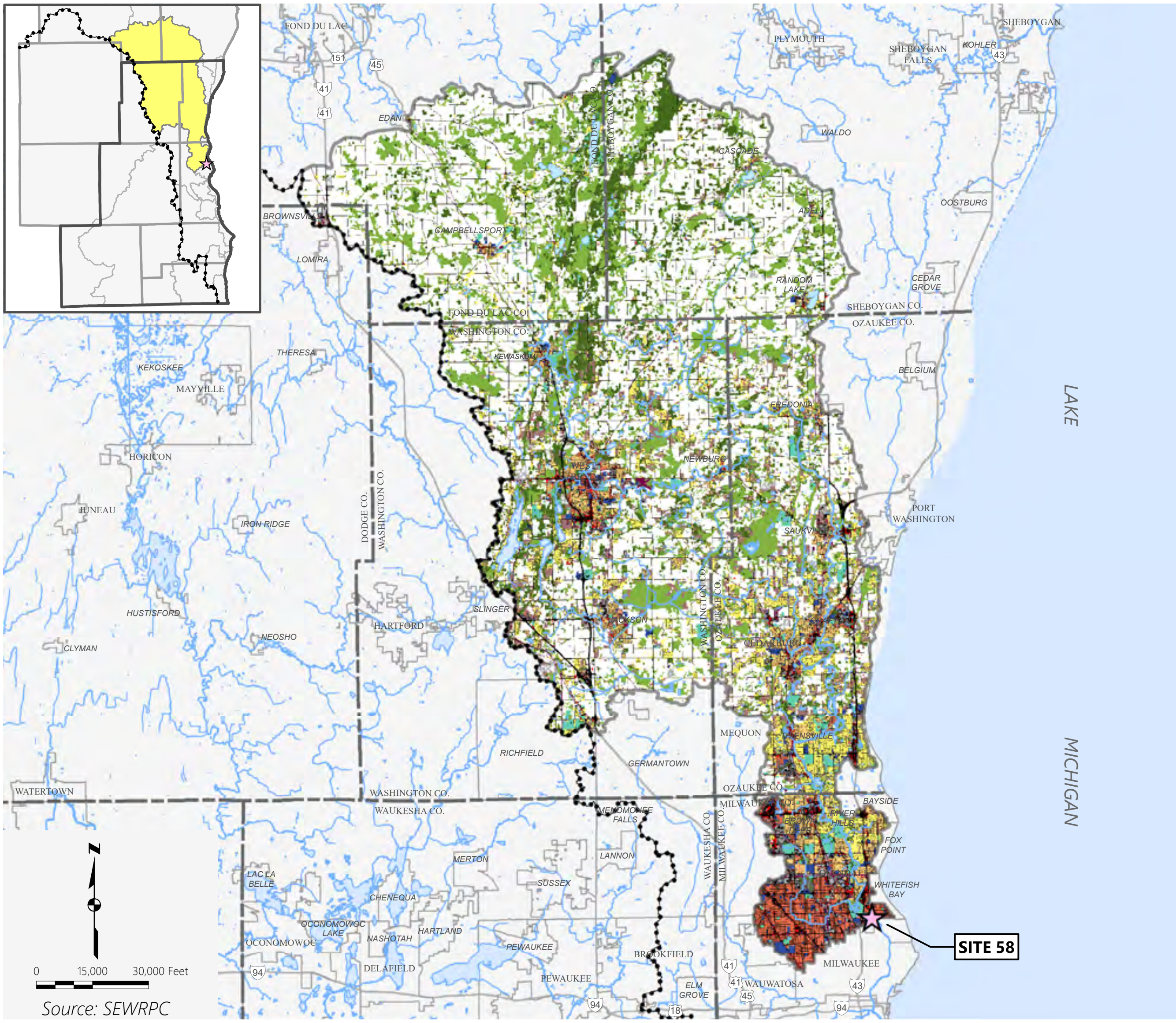
Map B.74
Site 57: Menomonee River at Wauwatosa Drainage Area – Characteristics

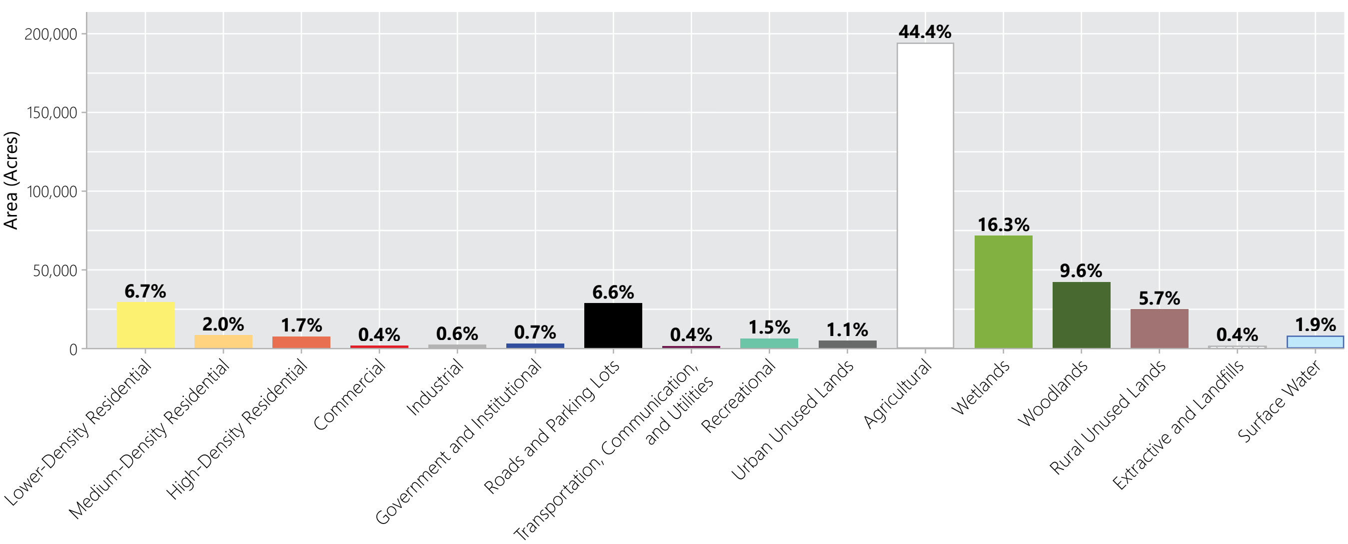


Facts at a Glance

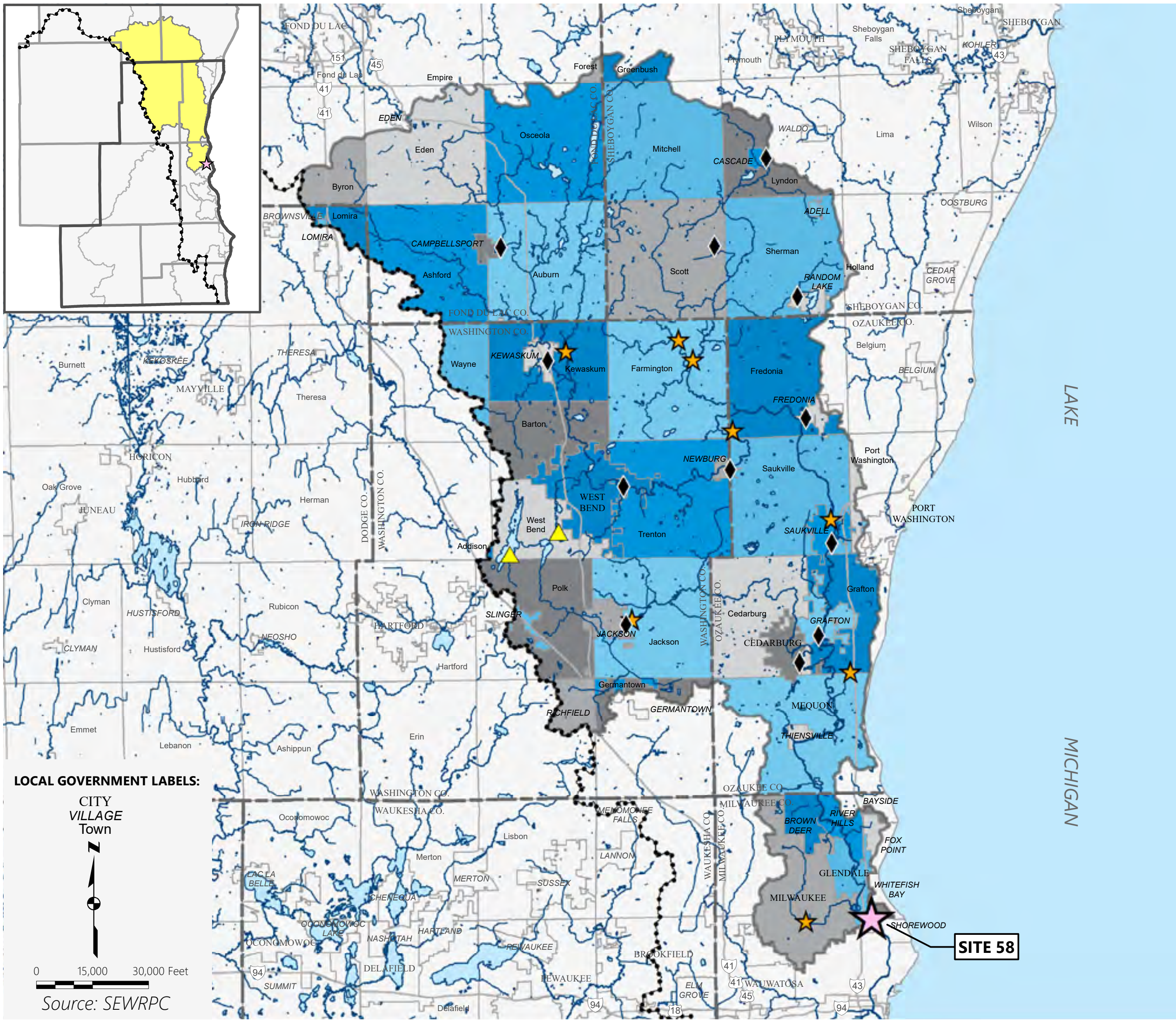
- **Drainage Area Size:** 124 square miles
- **Major Watershed:** Menomonee River
- **Land Use:** Urban – 67.3%; Rural – 32.7%
- **Roads and Parking Lots (% of drainage area):** 19.5
- **Estimated Population (2010):** 239,730
- **Estimated Households (2010):** 99,950
- **Nearest USGS Streamgage:** Menomonee River at Wauwatosa (04087120)
- **Other Monitoring Sites Within this Drainage Area (★):** Site 53 (Honey Creek at Wauwatosa) and Site 87 (Underwood Creek)
- **Upstream Wastewater Treatment Facilities (♦):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 77
- **Water Supply Source:** Lake Michigan and Groundwater

Map B.75
Site 58: Milwaukee River at Estabrook Park Drainage Area – Existing Land Use





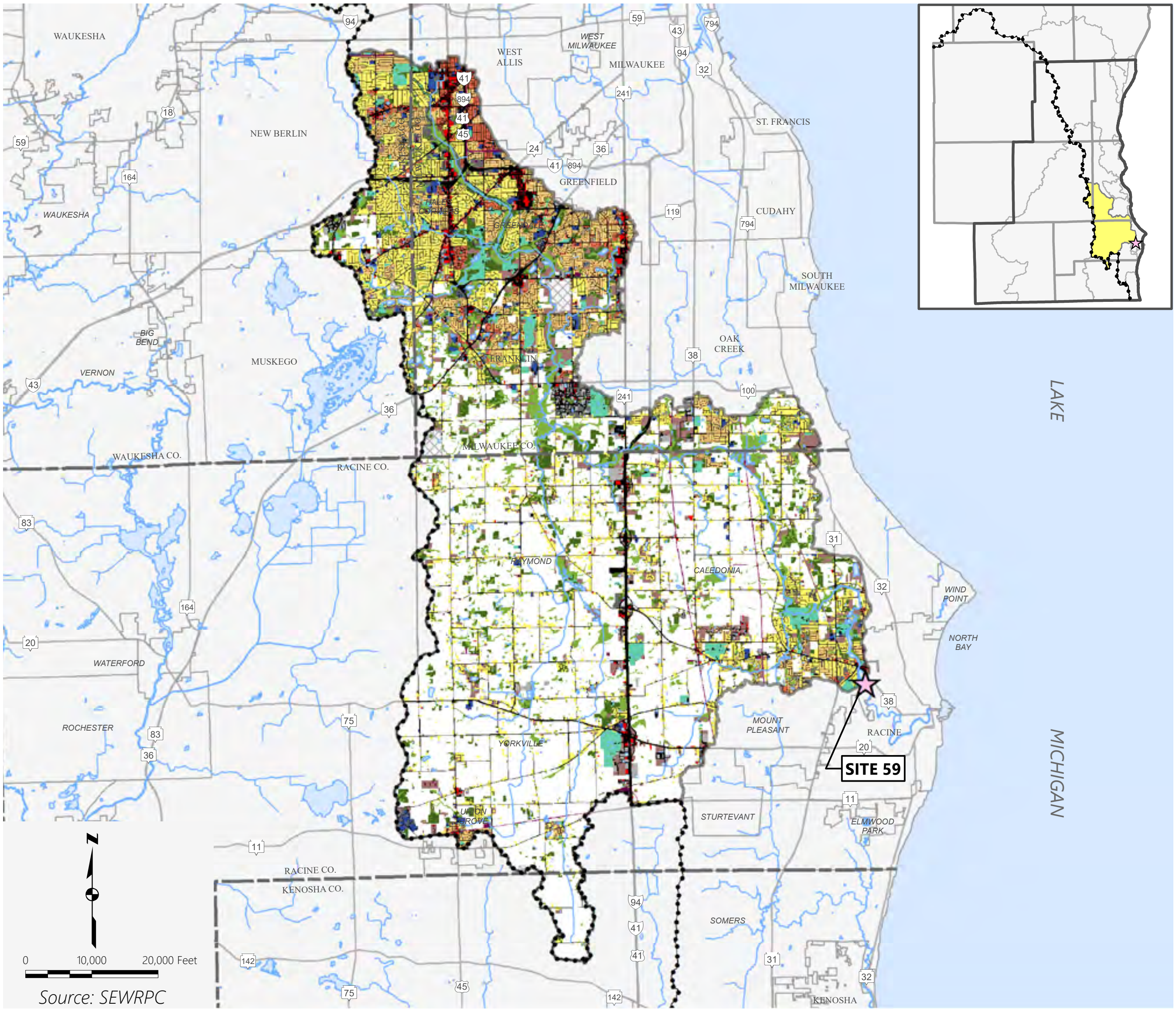
Map B.76
Site 58: Milwaukee River at Estabrook Park Drainage Area – Characteristics

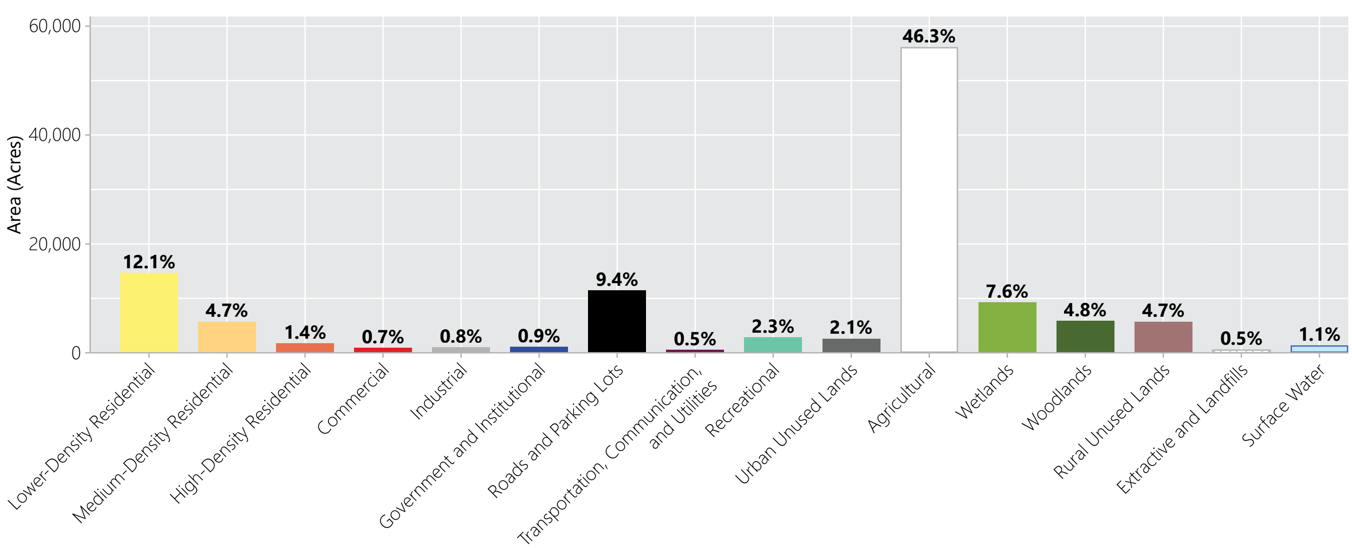


Facts at a Glance

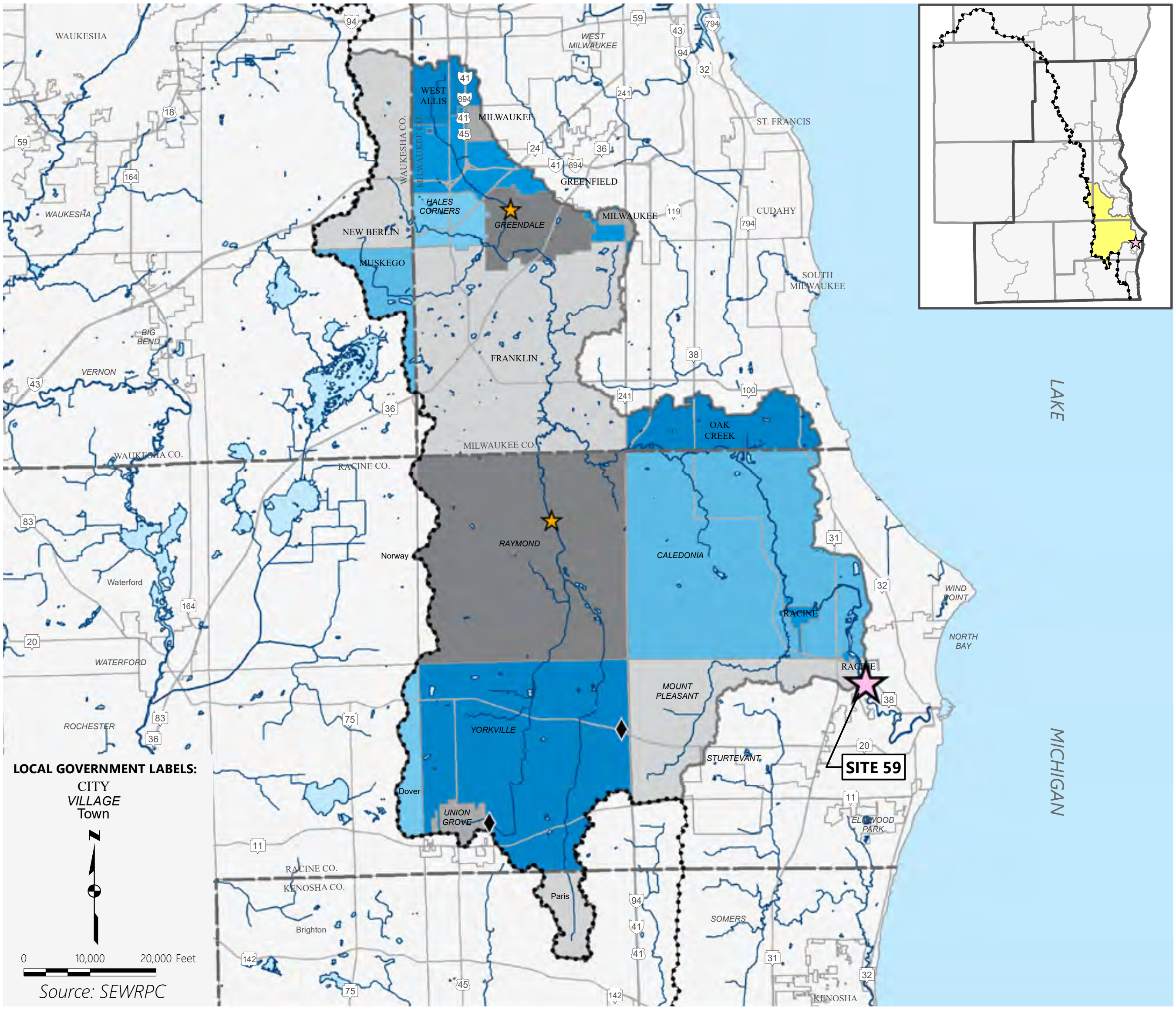
- **Drainage Area Size:** 685 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 21.7%; Rural – 78.3%
- **Roads and Parking Lots (% of drainage area):** 6.6
- **Estimated Population (2010):** 336,700
- **Estimated Households (2010):** 132,100
- **Nearest USGS Streamgage:** Milwaukee River at Milwaukee (04087000)
- **Other Monitoring Sites Within this Drainage Area (★):** Site 21 (East Branch Milwaukee River), Site 23 (Milwaukee River Downstream of Newburg), Site 40 (Stony Creek), Site 38 (North Branch Milwaukee River), Site 41 (Milwaukee River near Saukville), Site 52 (Cedar Creek), Site 13 (Ulao Creek), and Site 12 (Lincoln Creek)
- **Lakes Monitored Within this Drainage Area (△):** Big Cedar Lake and Silver Lake
- **Upstream Wastewater Treatment Facilities (♦):** Campbellsport, Kewaskum, West Bend, Newburg, Cascade, Scott (discharges to groundwater through soil infiltration), Random Lake, Fredonia, Saukville, Grafton, Jackson, and Cedarburg
- **Planned Sanitary Sewer Service Area (% of drainage area):** 20
- **Water Supply Source:** Lake Michigan and Groundwater

Map B.77
Site 59: Root River near Horlick Dam Drainage Area – Existing Land Use





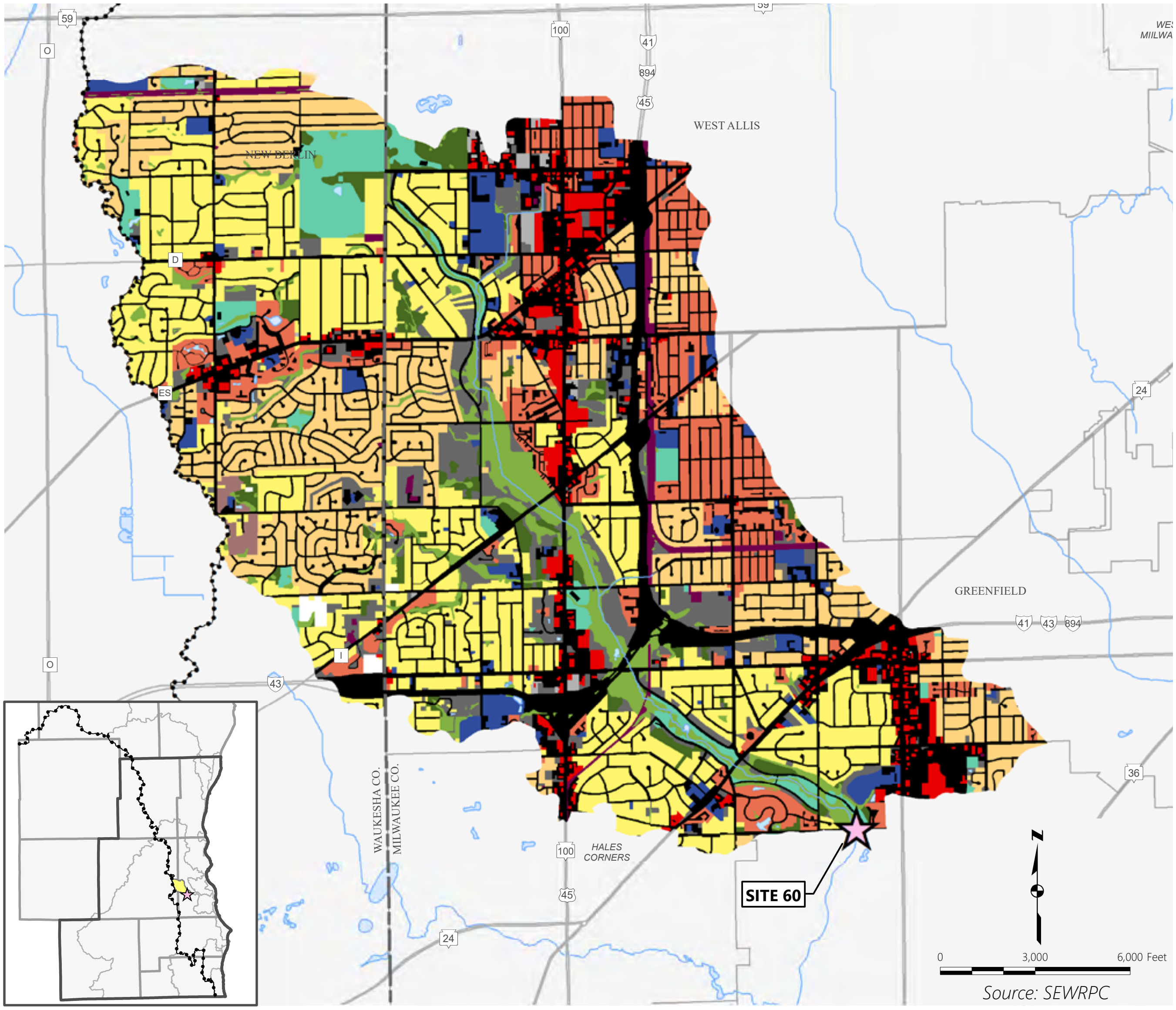
Map B.78
Site 59: Root River near Horlick Dam Drainage Area – Characteristics

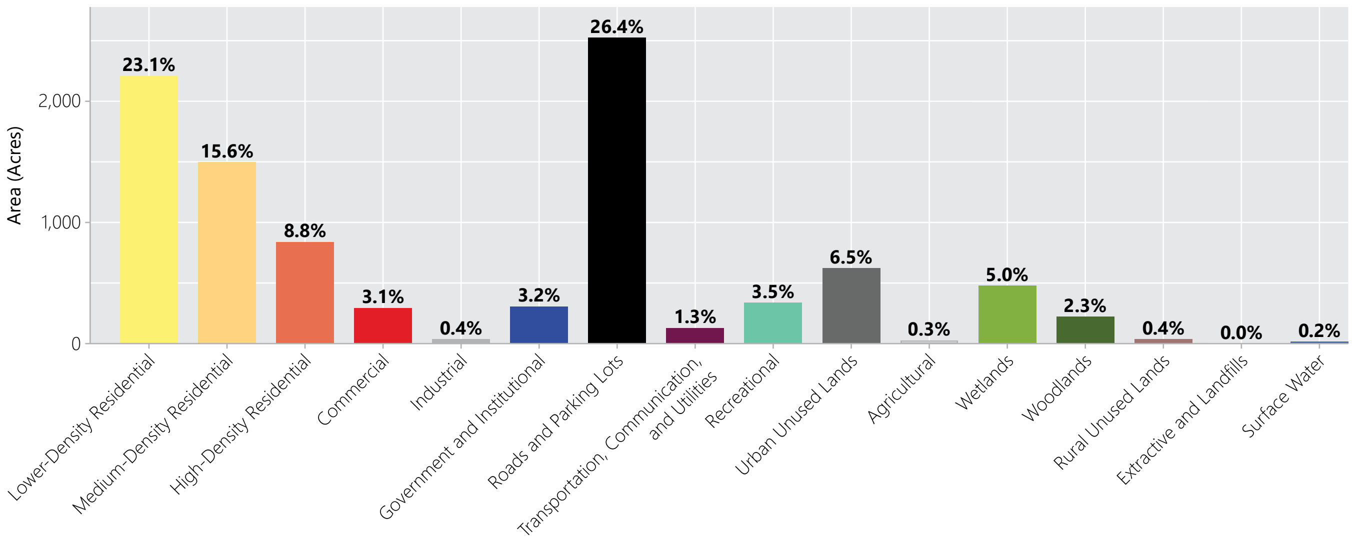


Facts at a Glance

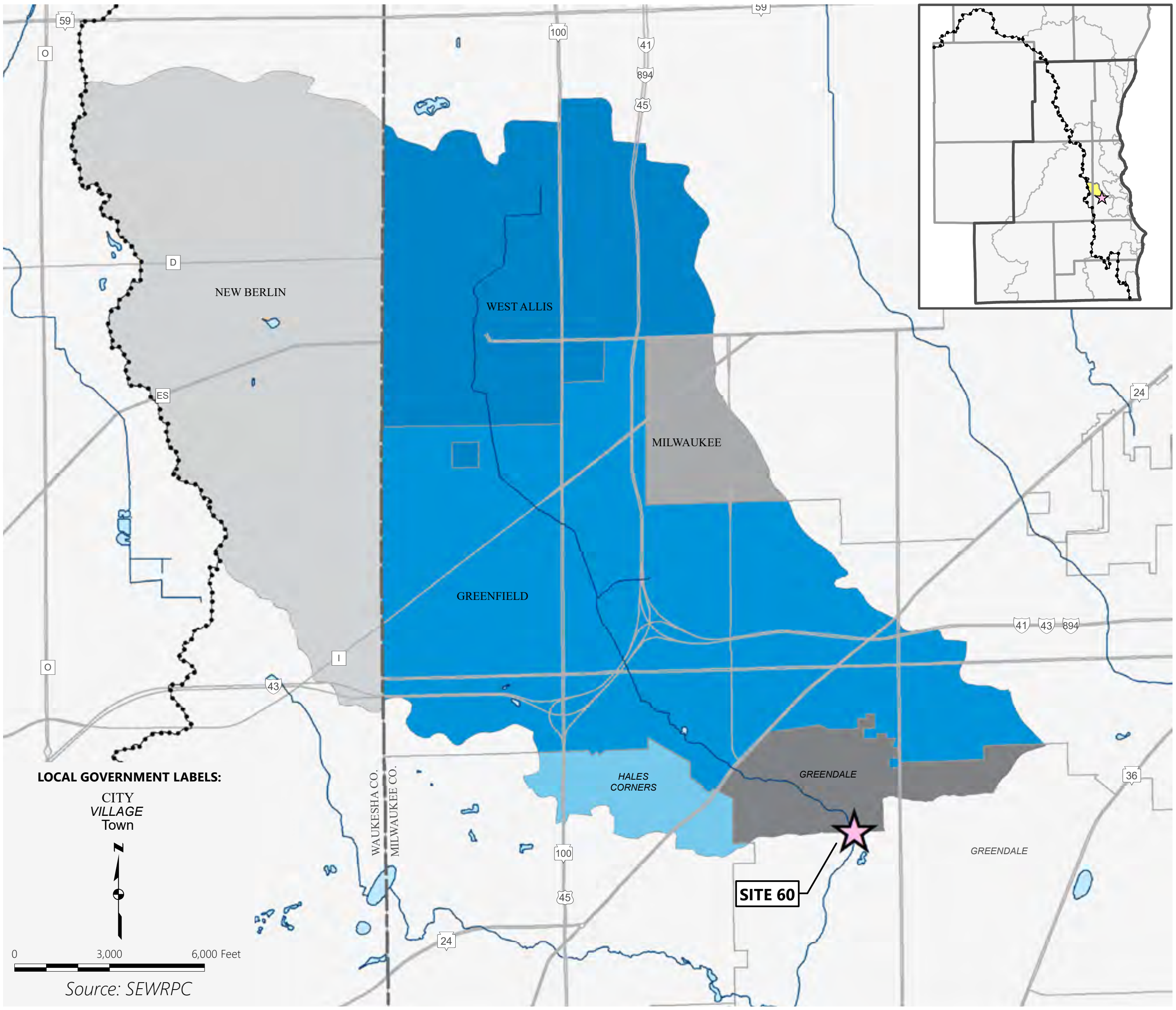
- **Drainage Area Size:** 190 square miles
- **Major Watershed:** Root River
- **Land Use:** Urban – 35.0%; Rural – 65.0%
- **Roads and Parking Lots (% of drainage area):** 9.4
- **Estimated Population (2010):** 141,920
- **Estimated Households (2010):** 57,370
- **Nearest USGS Streamgage:** Root River at Racine (04087240)
- **Other Monitoring Sites Within this Drainage Area (★):** Site 60 (Root River at Grange Avenue) and Site 25 (Root River Canal)
- **Upstream Wastewater Treatment Facilities (⧫):** Yorkville and Union Grove
- **Planned Sanitary Sewer Service Area (% of drainage area):** 55
- **Water Supply Source:** Lake Michigan and Groundwater

Map B.79
Site 60: Root River at Grange Avenue Drainage Area – Existing Land Use





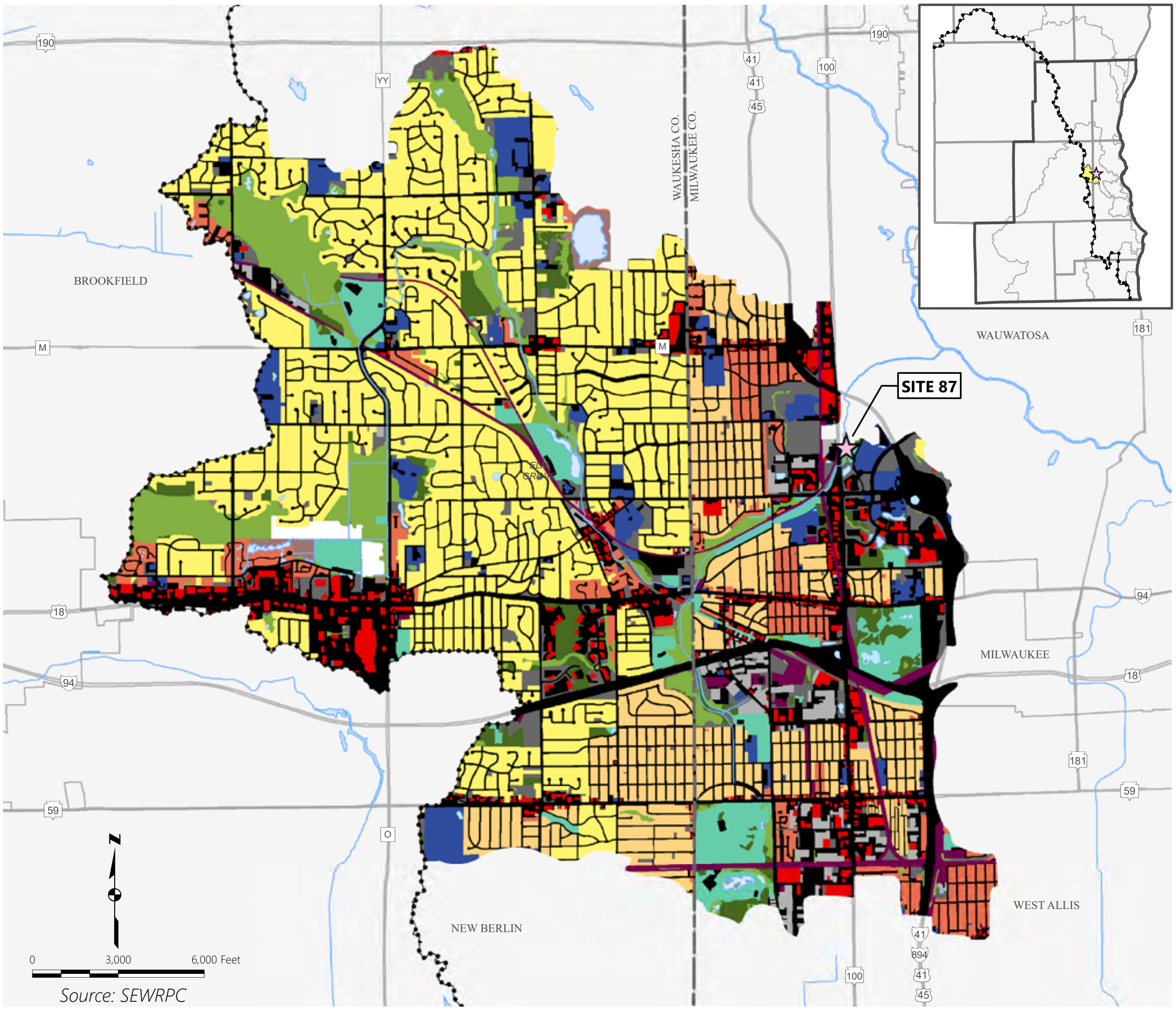
Map B.80
Site 60: Root River at Grange Avenue Drainage Area – Characteristics

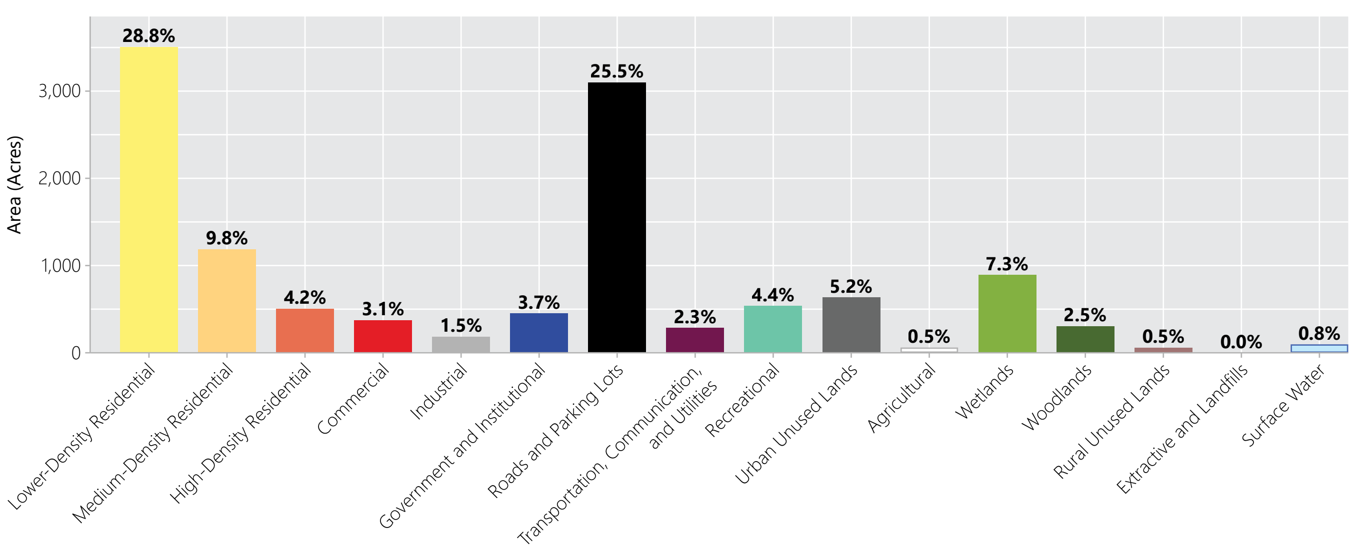


Facts at a Glance

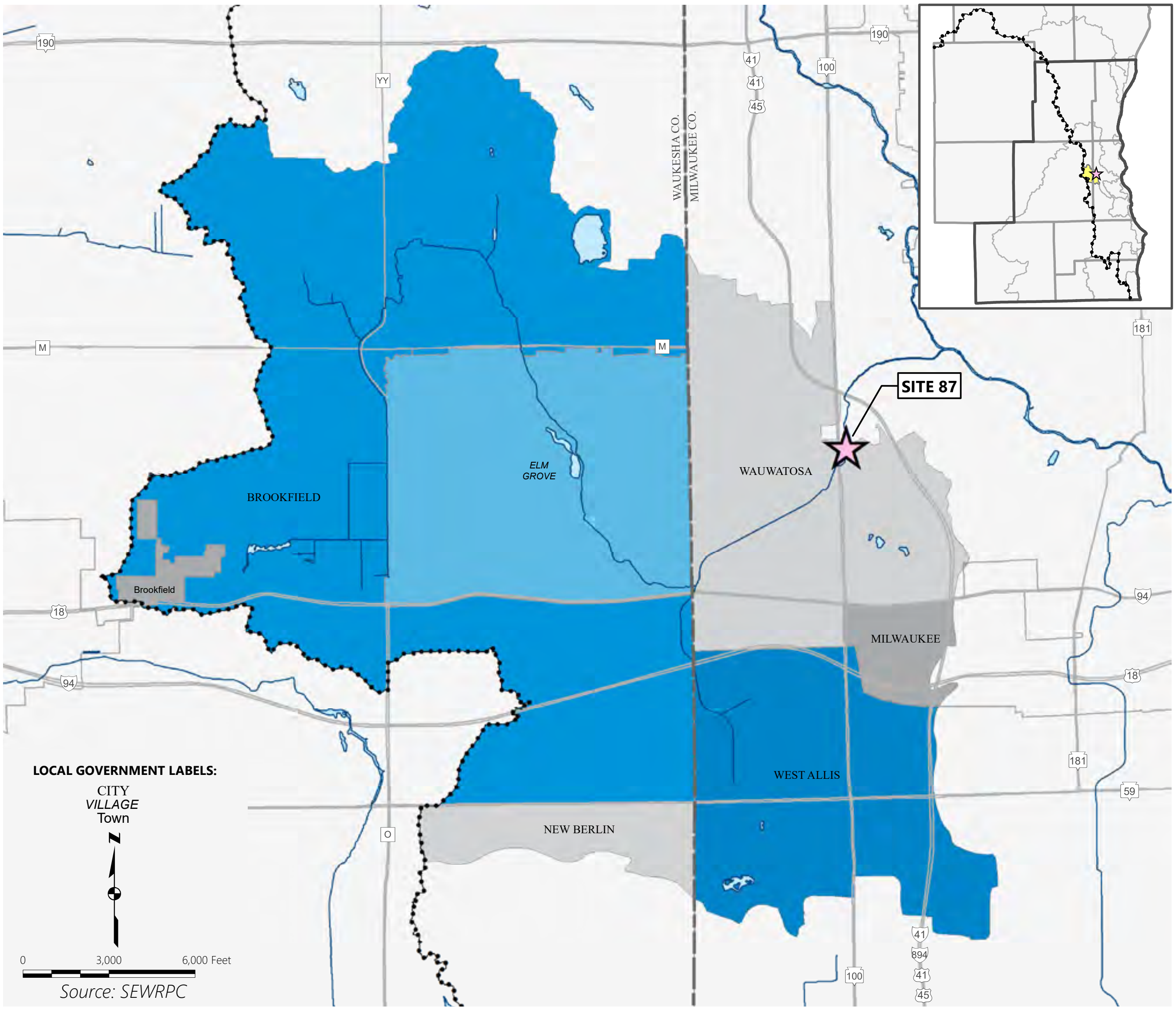
- **Drainage Area Size:** 15 square miles
- **Major Watershed:** Root River
- **Land Use:** Urban – 91.9%; Rural – 8.1%
- **Roads and Parking Lots (% of drainage area):** 26.4
- **Estimated Population (2010):** 43,470
- **Estimated Households (2010):** 19,530
- **Nearest USGS Streamgage:** Root River at Grange Avenue (04087214)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 100
- **Water Supply Source:** Lake Michigan

Map B.81
Site 87: Underwood Creek Drainage Area – Existing Land Use





Map B.82
Site 87: Underwood Creek Drainage Area – Characteristics



Facts at a Glance

- **Drainage Area Size:** 19 square miles
- **Major Watershed:** Menomonee River
- **Land Use:** Urban – 88.4%; Rural – 11.6%
- **Roads and Parking Lots (% of drainage area):** 25.5
- **Estimated Population (2010):** 34,500
- **Estimated Households (2010):** 14,850
- **Nearest USGS Streamgage:** Underwood Creek at Wauwatosa (04087088)
- **Other Monitoring Sites Within this Drainage Area (★):** None
- **Upstream Wastewater Treatment Facilities (⧫):** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 100
- **Water Supply Source:** Lake Michigan and Groundwater

DRAINAGE AREA CHARACTERISTICS FOR MONITORED LAKES

APPENDIX C

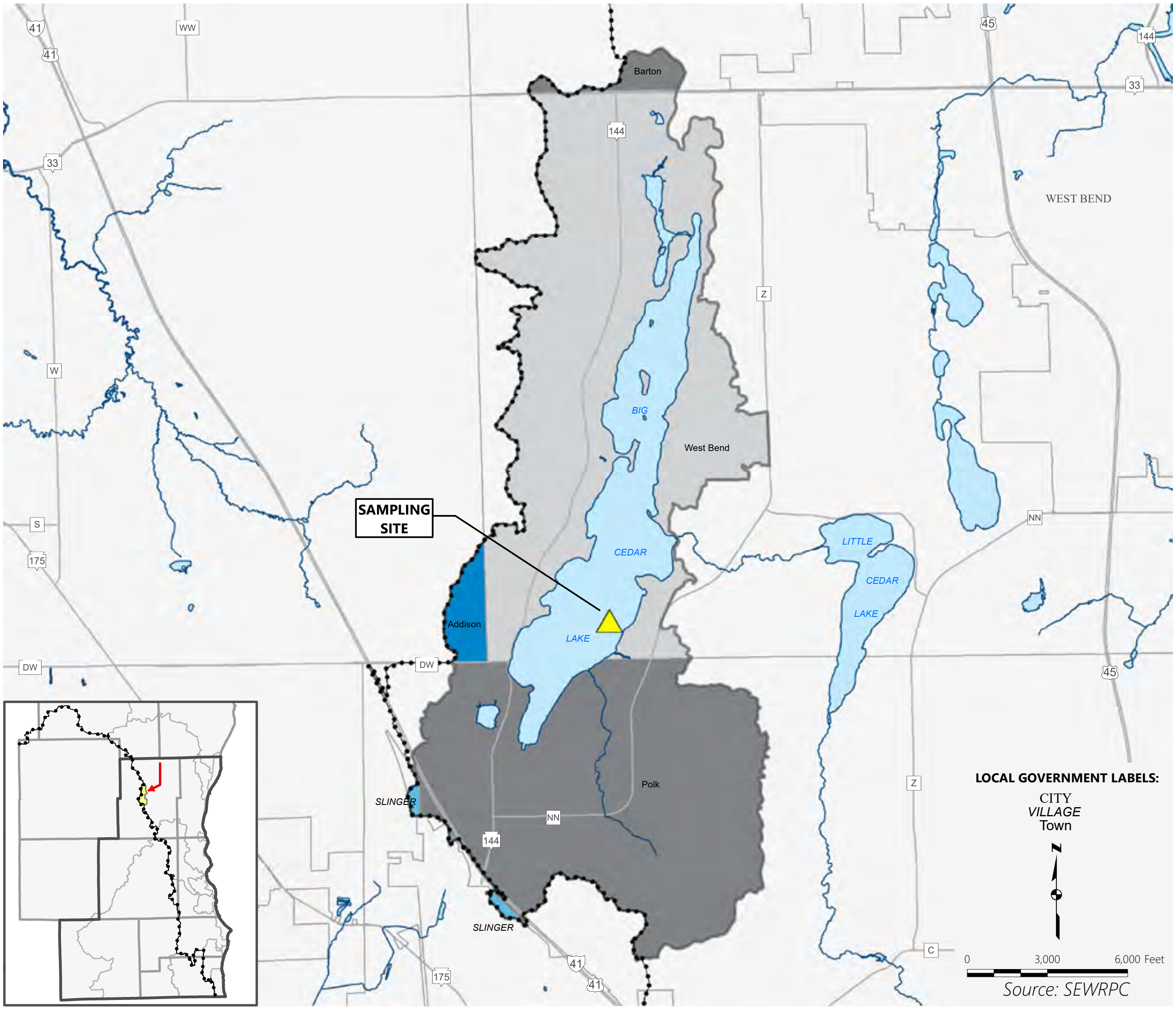
Table C.1
Civil Divisions Within Drainage Areas of Monitored Lakes

Civil Division Name	Acres	Percent of Drainage Area
Big Cedar Lake Drainage Area		
Town of West Bend	2,698	50.7
Town of Polk	2,391	45.0
Town of Addison	117	2.2
Town of Barton	90	1.7
Village of Slinger	22	0.4
Drainage Area Total	5,318	100
Geneva Lake Drainage Area		
Town of Linn	5,488	42.1
Village of Fontana-On-Geneva-Lake	1,805	13.9
City of Lake Geneva	1,797	13.8
Village of Williams Bay	1,371	10.5
Town of Walworth	942	7.2
Town of Geneva	899	6.9
Town of Delavan	358	2.8
Town of Bloomfield	233	1.8
Village of Walworth	135	1.0
Village of Bloomfield	29	0.0
Drainage Area Total	13,029	100
Little Muskego Lake Drainage Area		
City of New Berlin	4,113	61.1
City of Muskego	2,622	38.9
Drainage Area Total	6,735	100
Moose Lake Drainage Area		
Village of Chenequa	308	54.0
Town of Merton	263	46.0
Drainage Area Total	571	100
Silver Lake Drainage Area		
Town of West Bend	180	100
Drainage Area Total	180	100
Voltz Lake Drainage Area		
Village of Salem Lakes	317	100
Drainage Area Total	317	100

Note: The surface areas of each lake were removed from the acreages reported in this table.

Source: SEWRPC

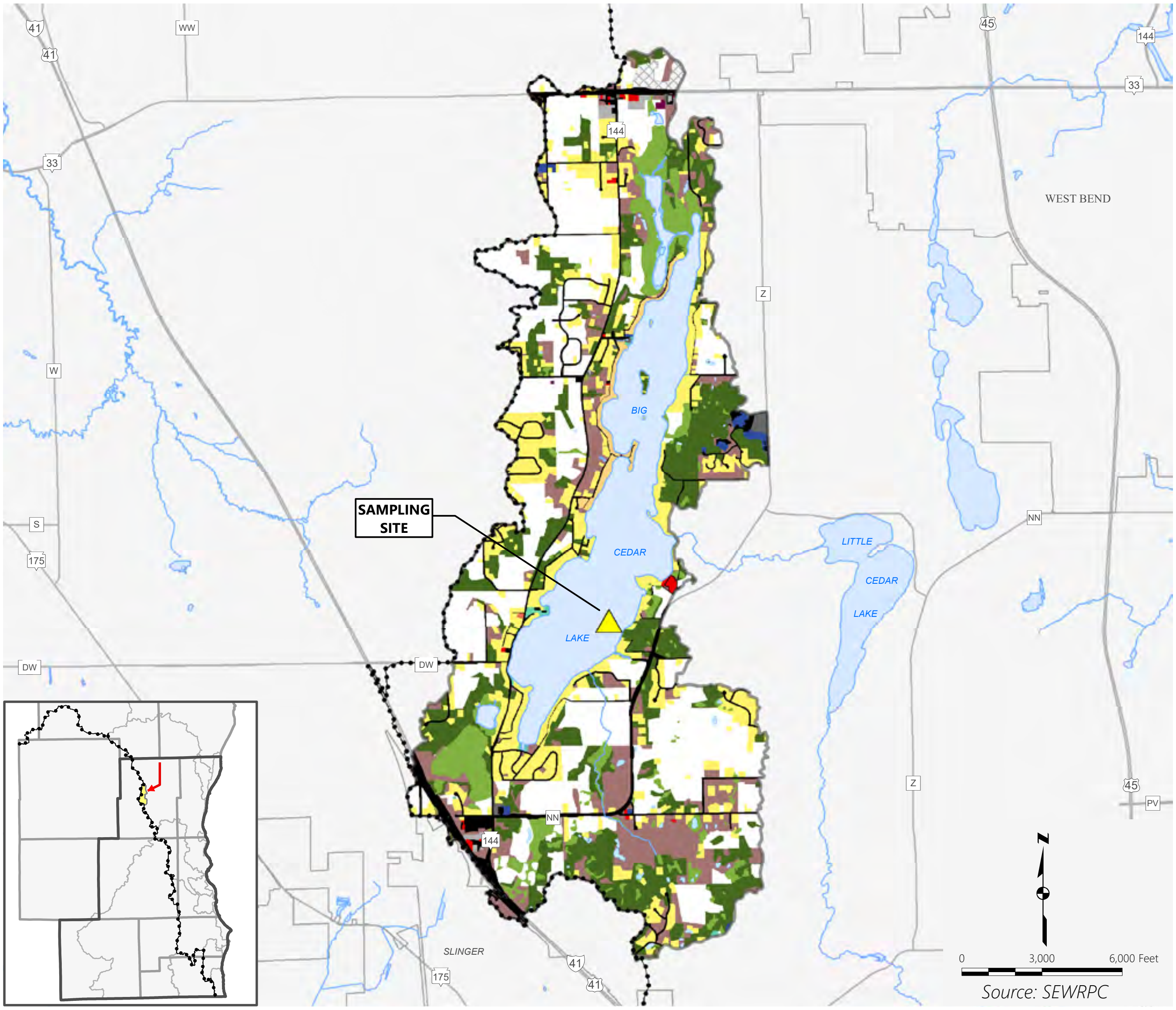
Map C.1
Big Cedar Lake Drainage Area – Characteristics

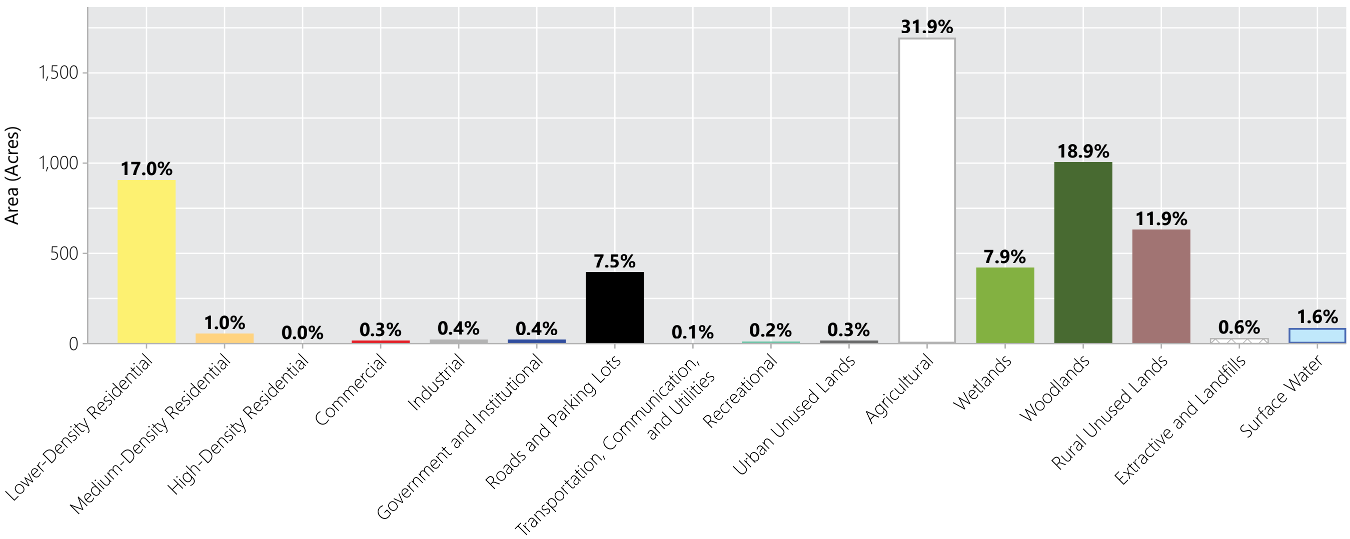


Facts at a Glance

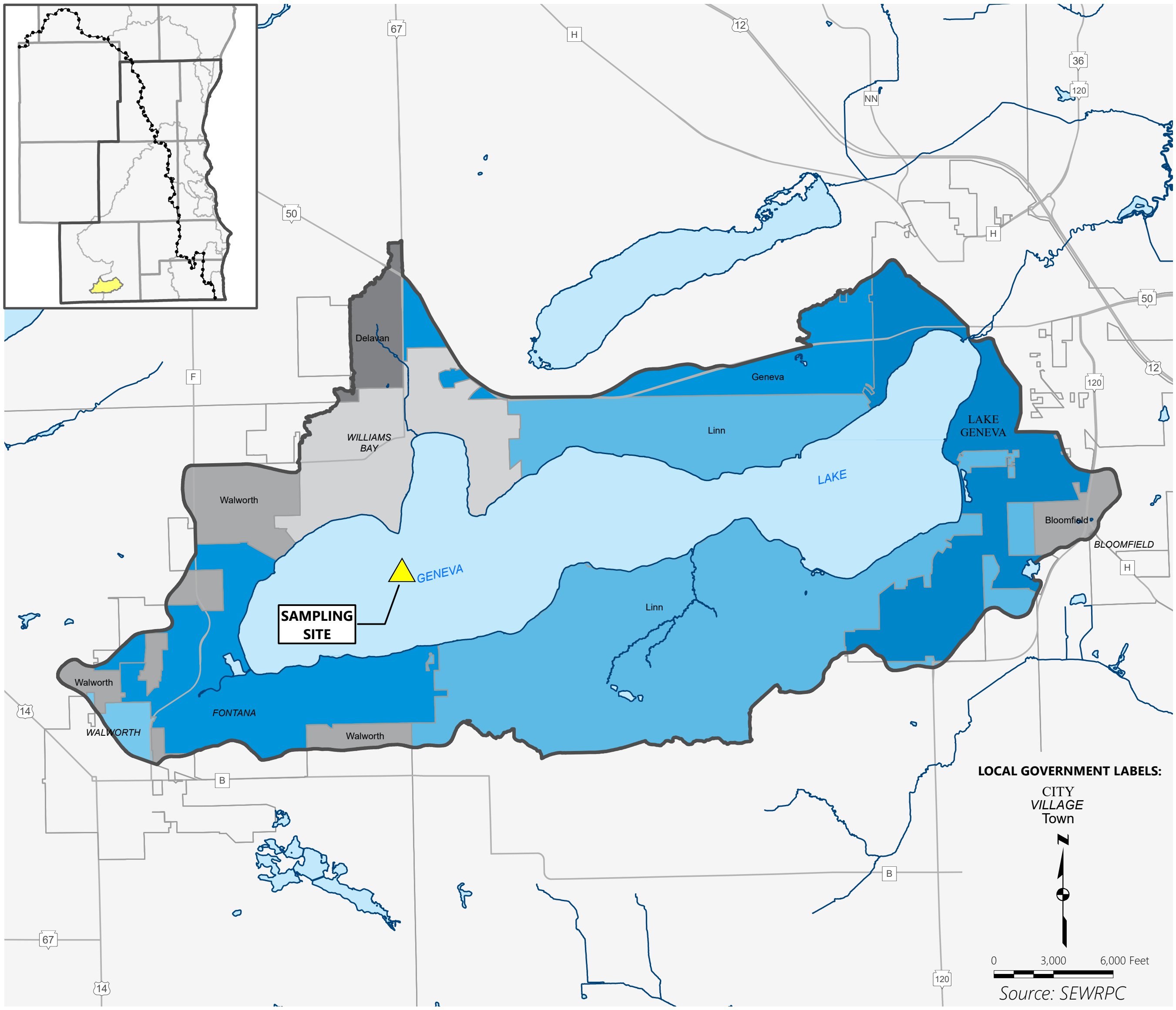
- **Drainage Area Size:** 8 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 27.2%; Rural – 72.8%
- **Roads and Parking Lots (% of drainage area):** 7.5
- **Estimated Population (2010):** 2,830
- **Estimated Households (2010):** 1,126
- **Upstream Wastewater Treatment Facilities:** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 3
- **Water Supply Source:** Groundwater

Map C.2
Big Cedar Lake Drainage Area – Existing Land Use





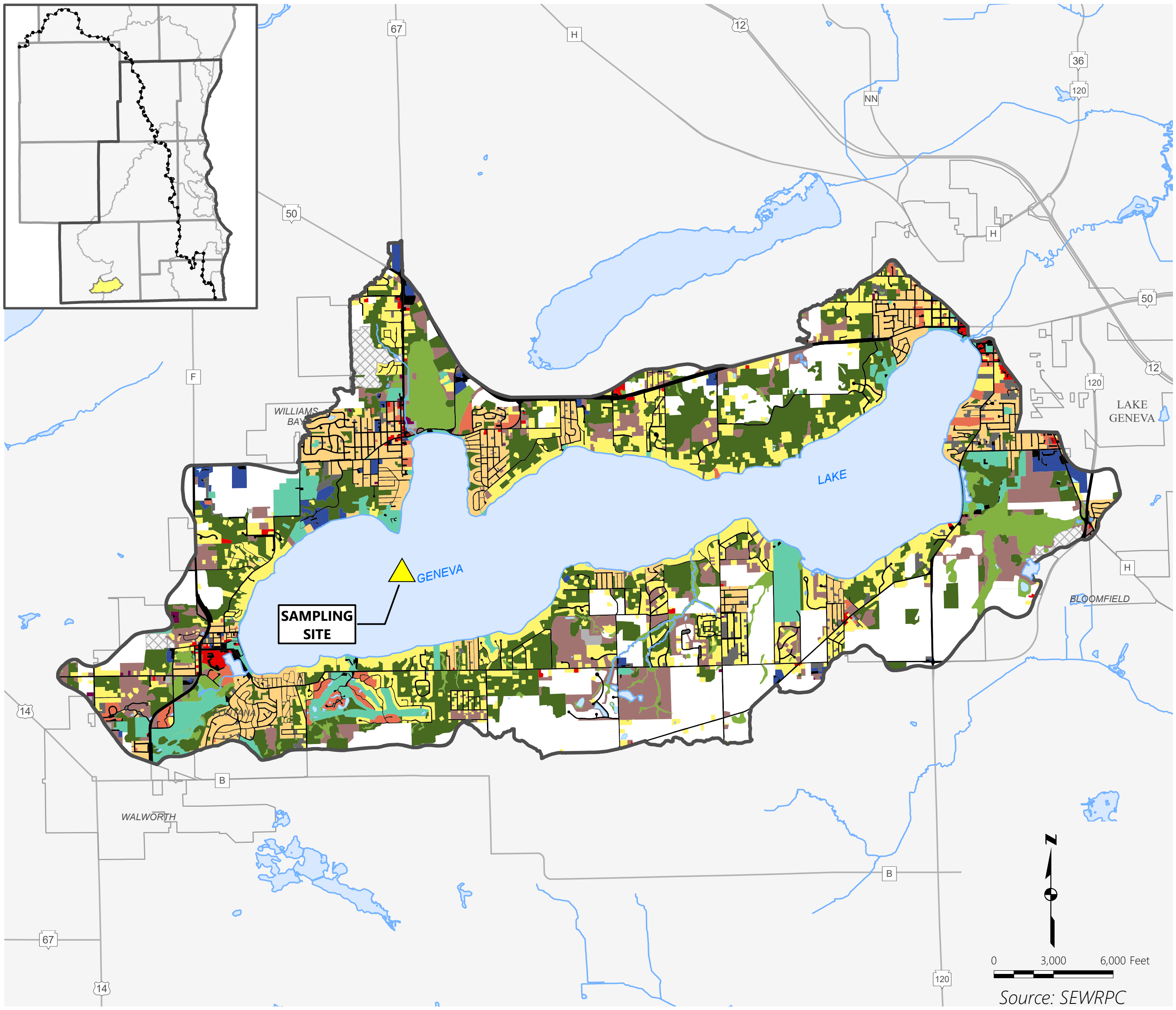
Map C.3
Geneva Lake Drainage Area – Characteristics

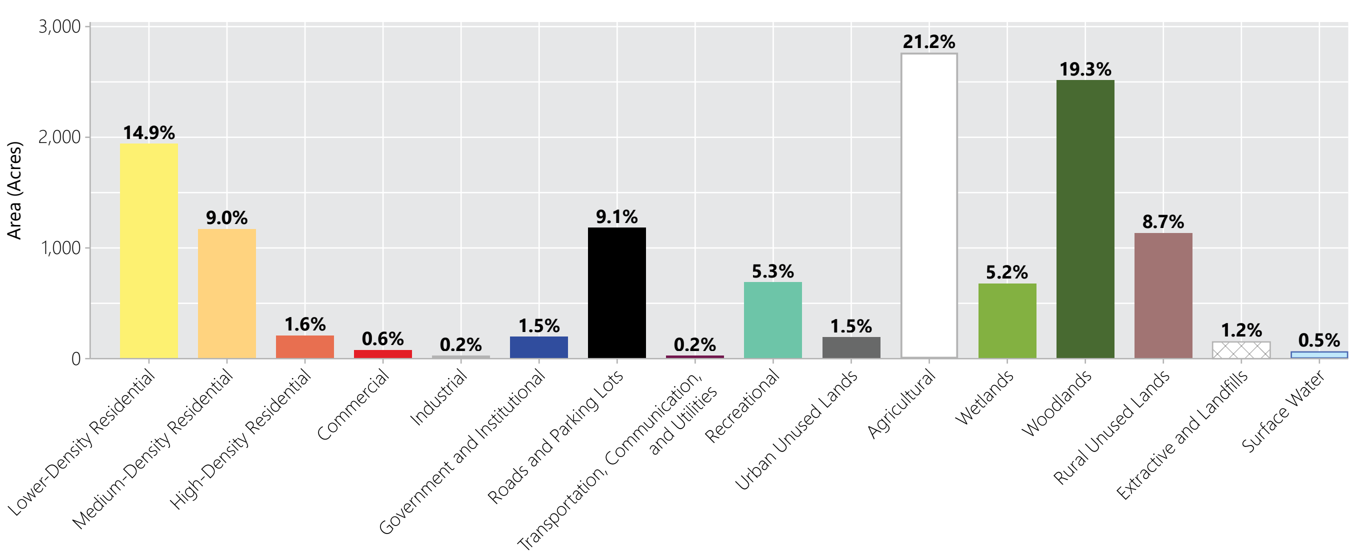


Facts at a Glance

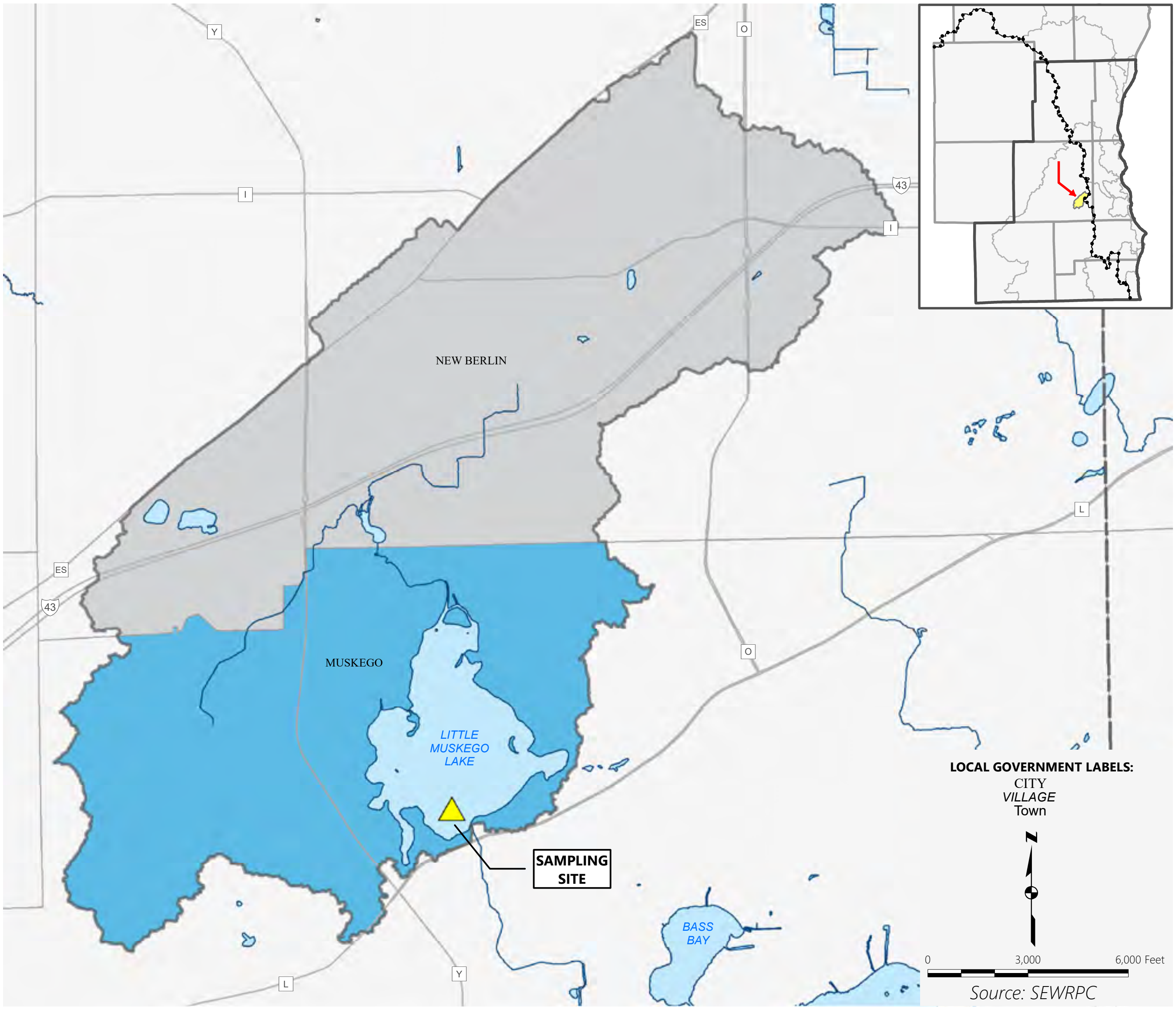
- **Drainage Area Size:** 20 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 43.9%; Rural – 56.1%
- **Roads and Parking Lots (% of drainage area):** 9.1
- **Estimated Population (2010):** 9,910
- **Estimated Households (2010):** 4,278
- **Upstream Wastewater Treatment Facilities:** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 55
- **Water Supply Source:** Groundwater

Map C.4
Geneva Lake Drainage Area – Existing Land Use





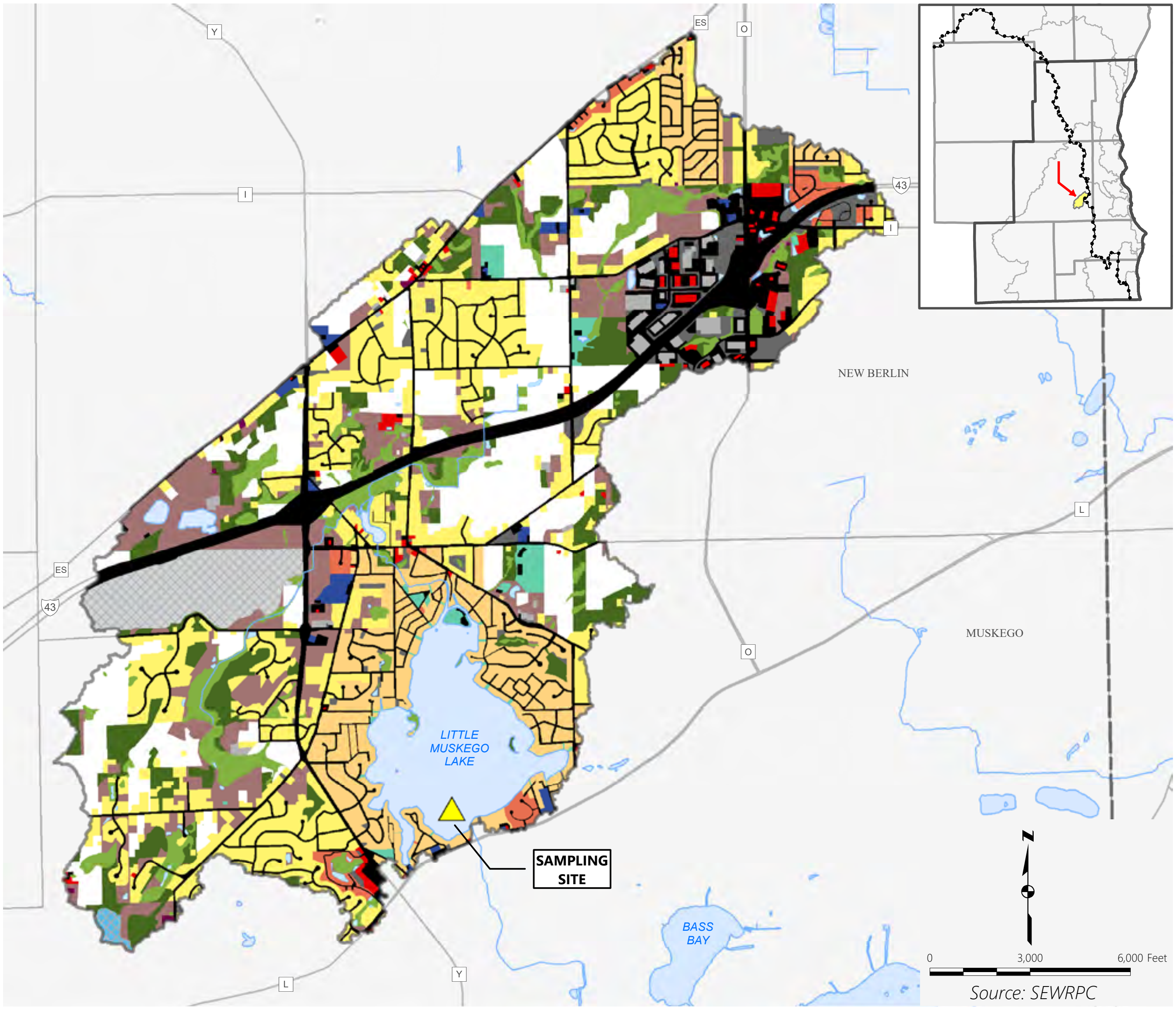
Map C.5
Little Muskego Lake Drainage Area – Characteristics

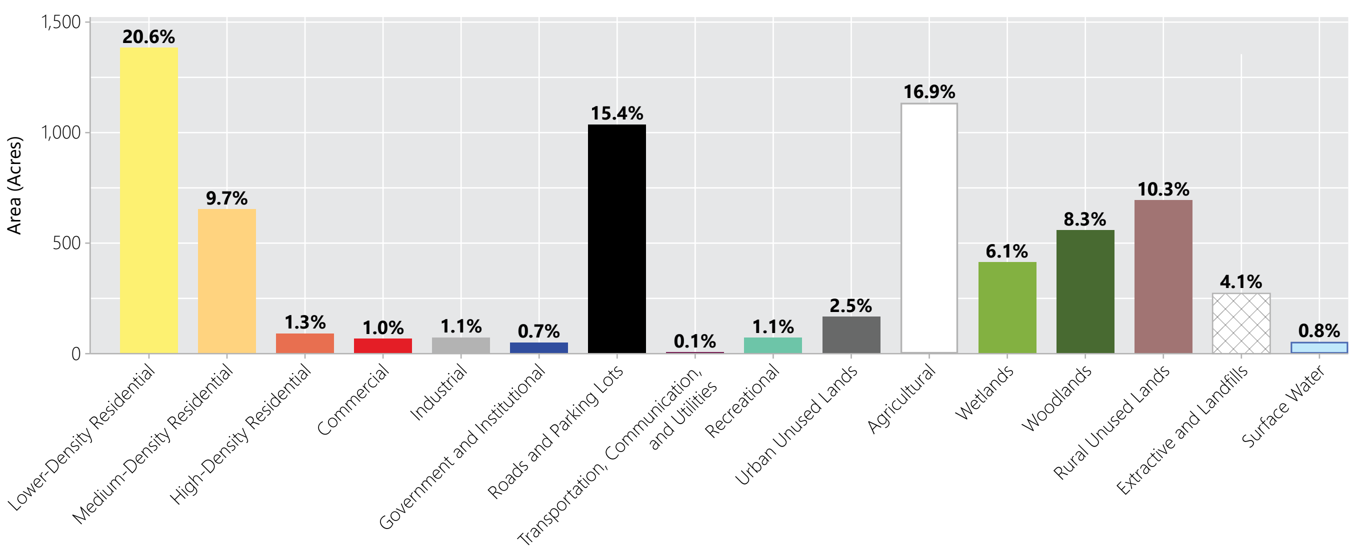


Facts at a Glance

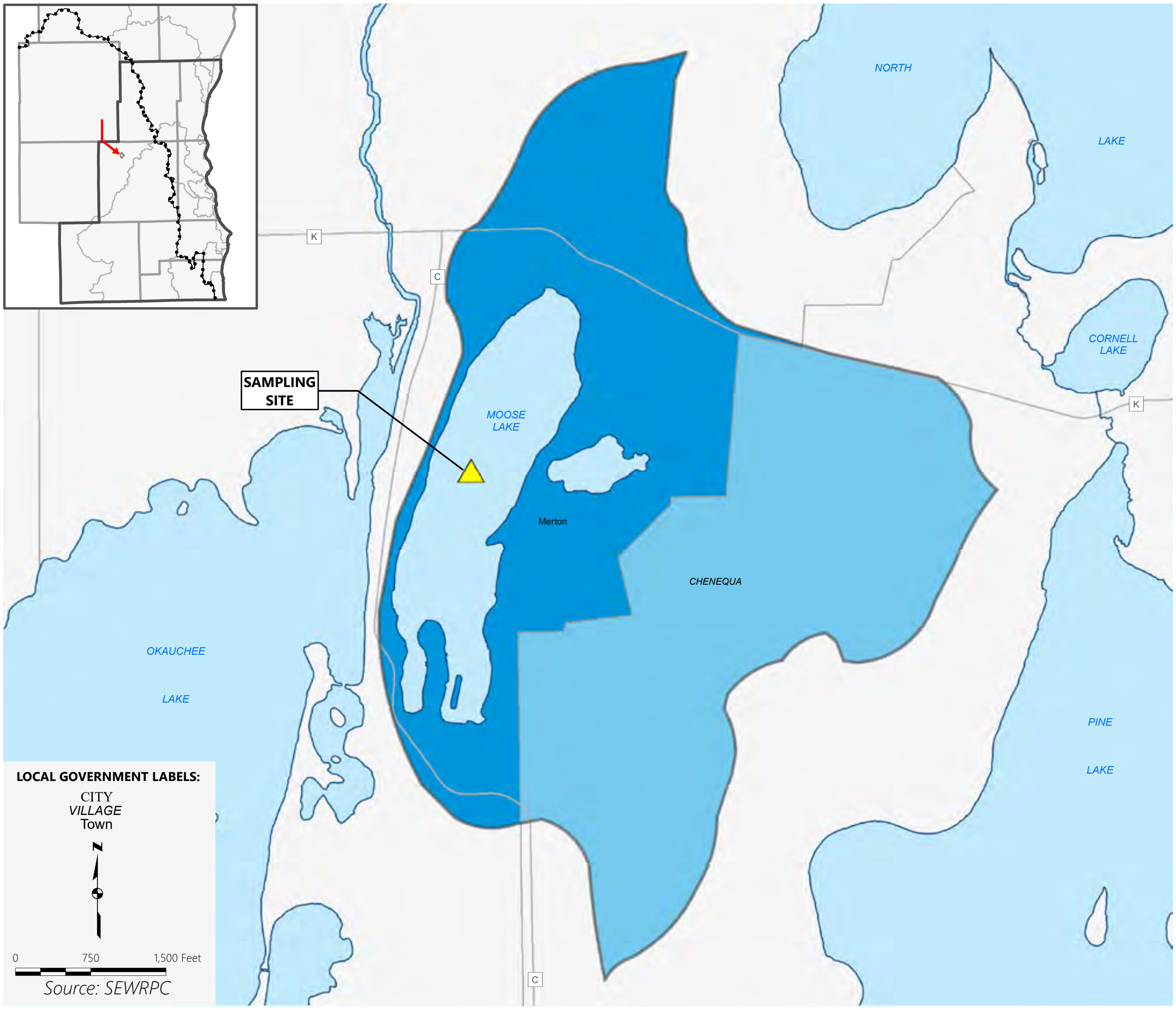
- **Drainage Area Size:** 11 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 53.5%; Rural – 46.5%
- **Roads and Parking Lots (% of drainage area):** 15.4
- **Estimated Population (2010):** 10,663
- **Estimated Households (2010):** 4,121
- **Upstream Wastewater Treatment Facilities:** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 55
- **Water Supply Source:** Groundwater

Map C.6
Little Muskego Lake Drainage Area – Existing Land Use





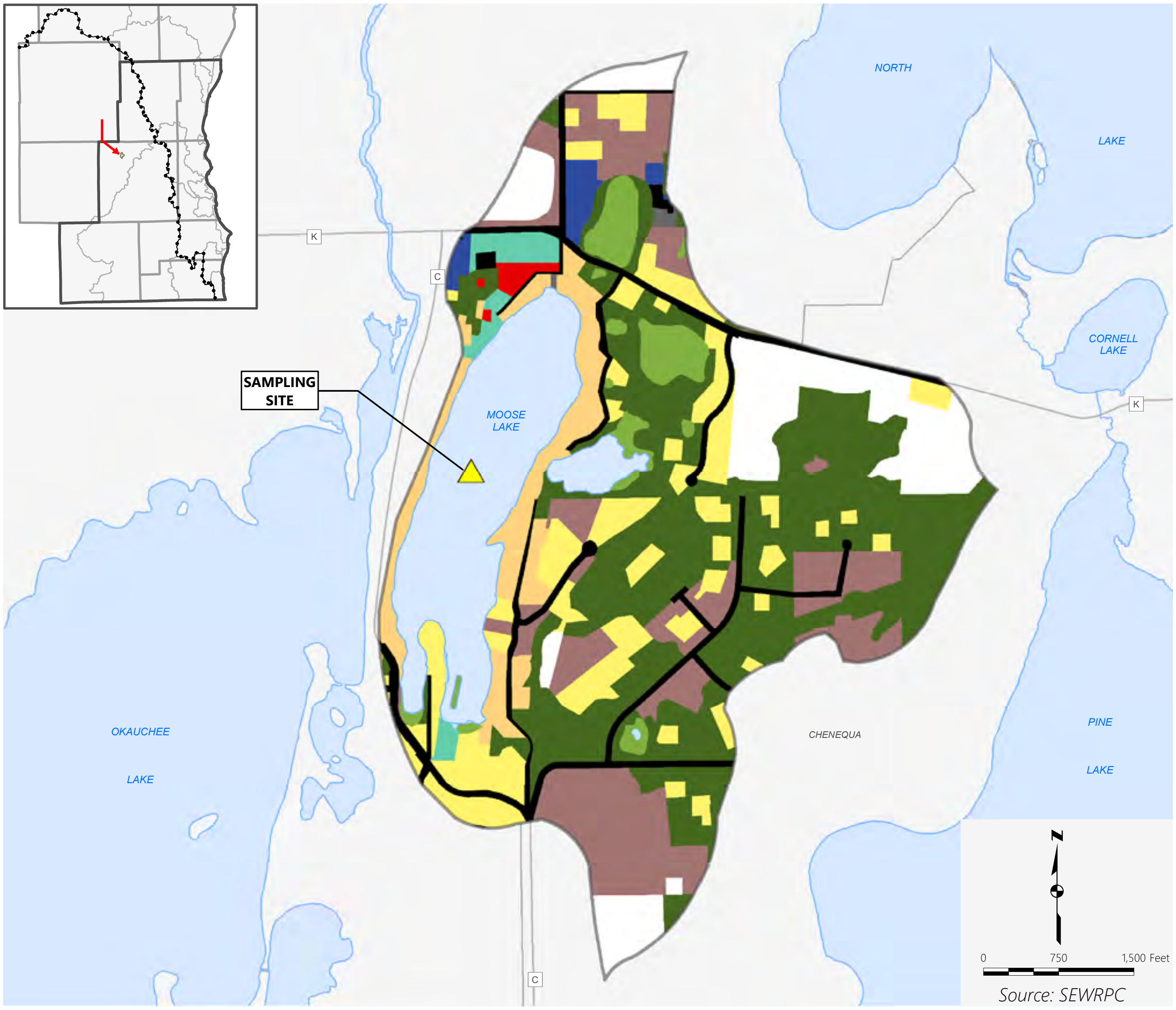
Map C.7
Moose Lake Drainage Area – Characteristics

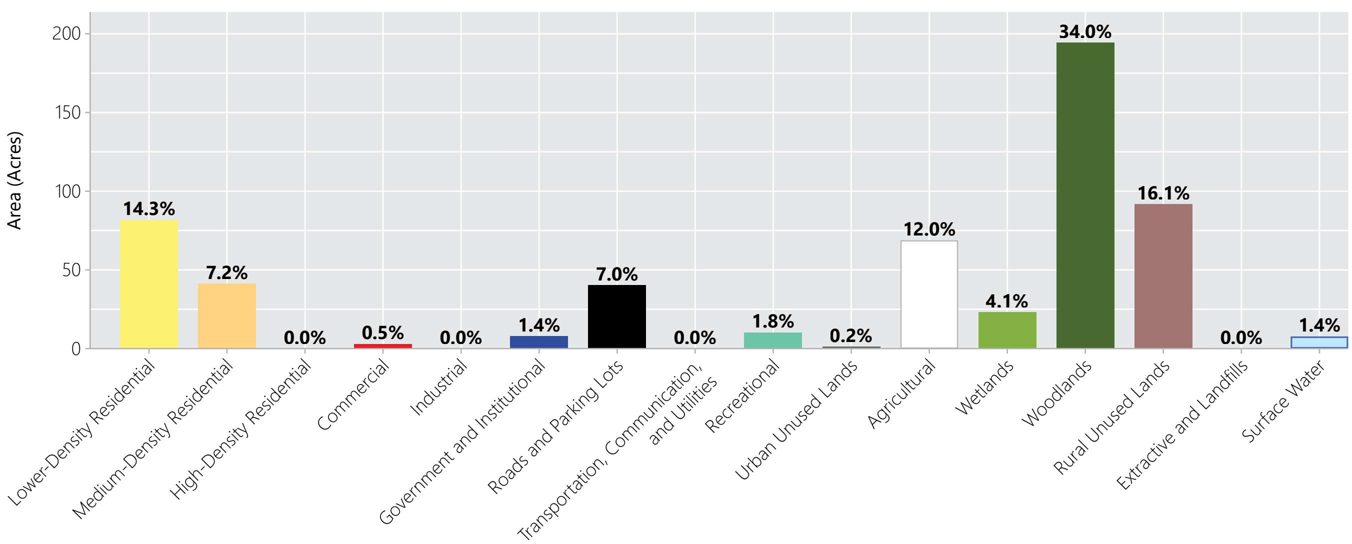


Facts at a Glance

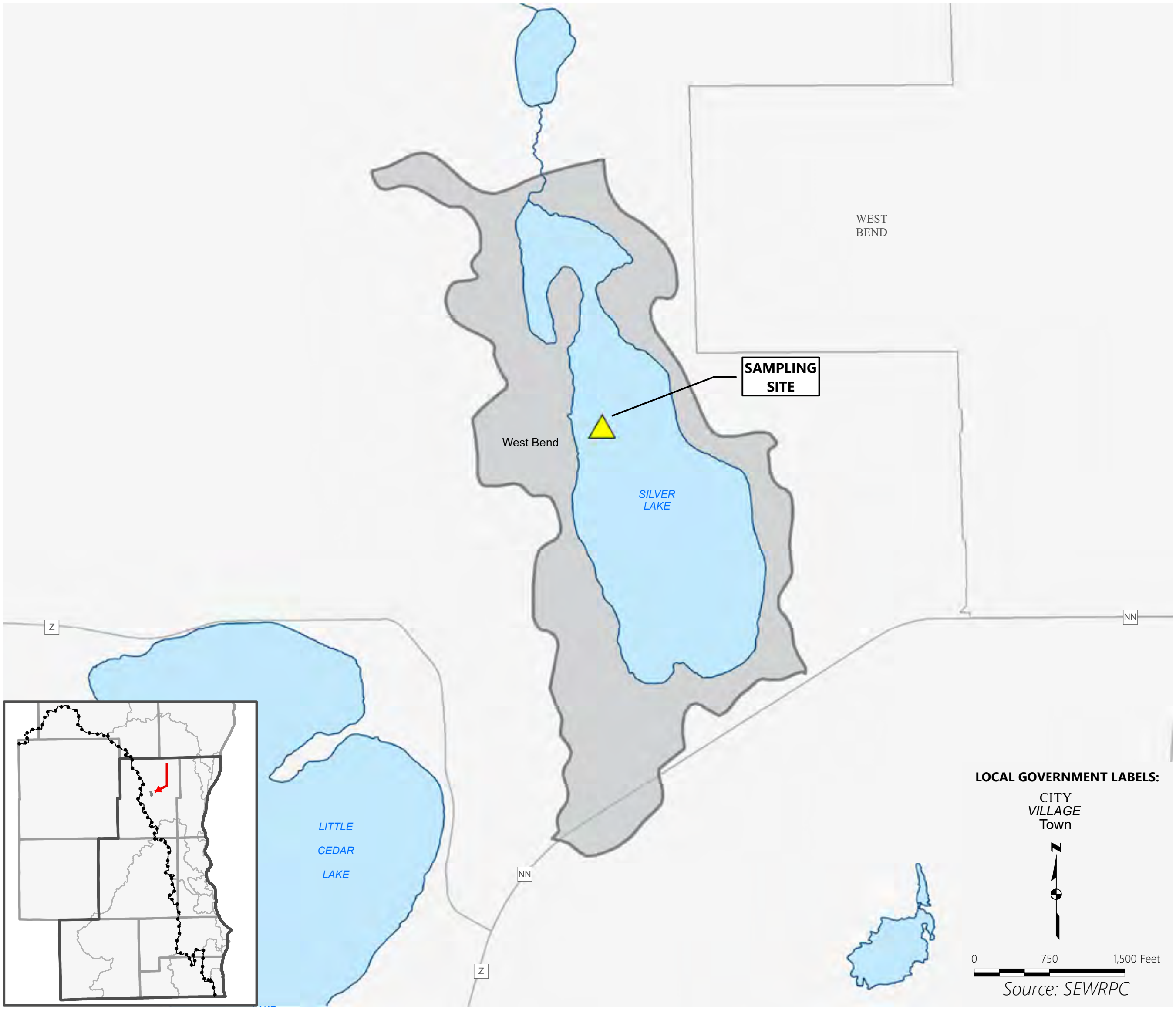
- **Drainage Area Size:** 0.9 square miles
- **Major Watershed:** Rock River
- **Land Use:** Urban – 32.4%; Rural – 67.6 %
- **Roads and Parking Lots (% of drainage area):** 7.0
- **Estimated Population (2010):** 459
- **Estimated Households (2010):** 197
- **Upstream Wastewater Treatment Facilities:** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 100
- **Water Supply Source:** Groundwater

Map C.8
Moose Lake Drainage Area – Existing Land Use





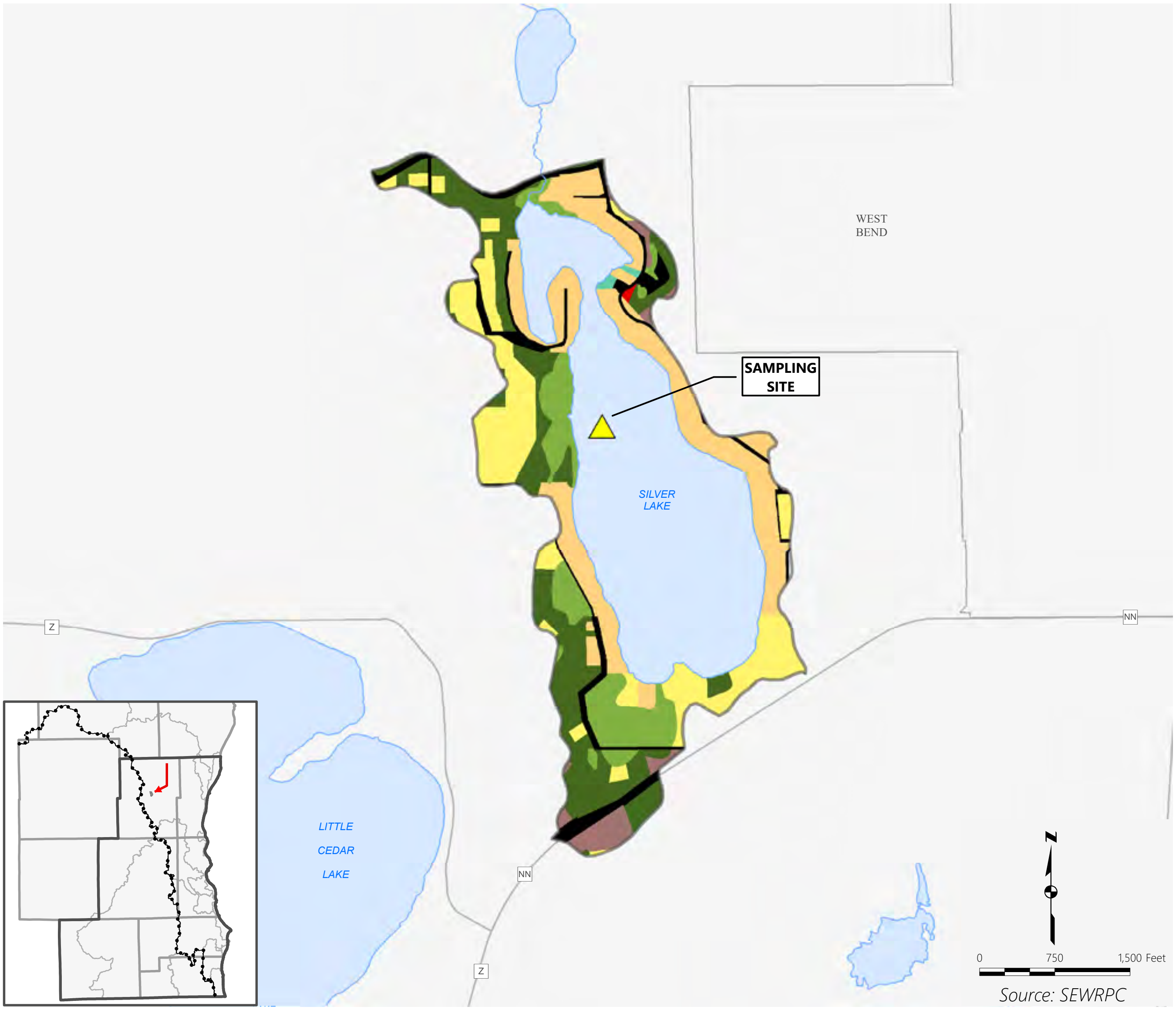
Map C.9
Silver Lake Drainage Area – Characteristics

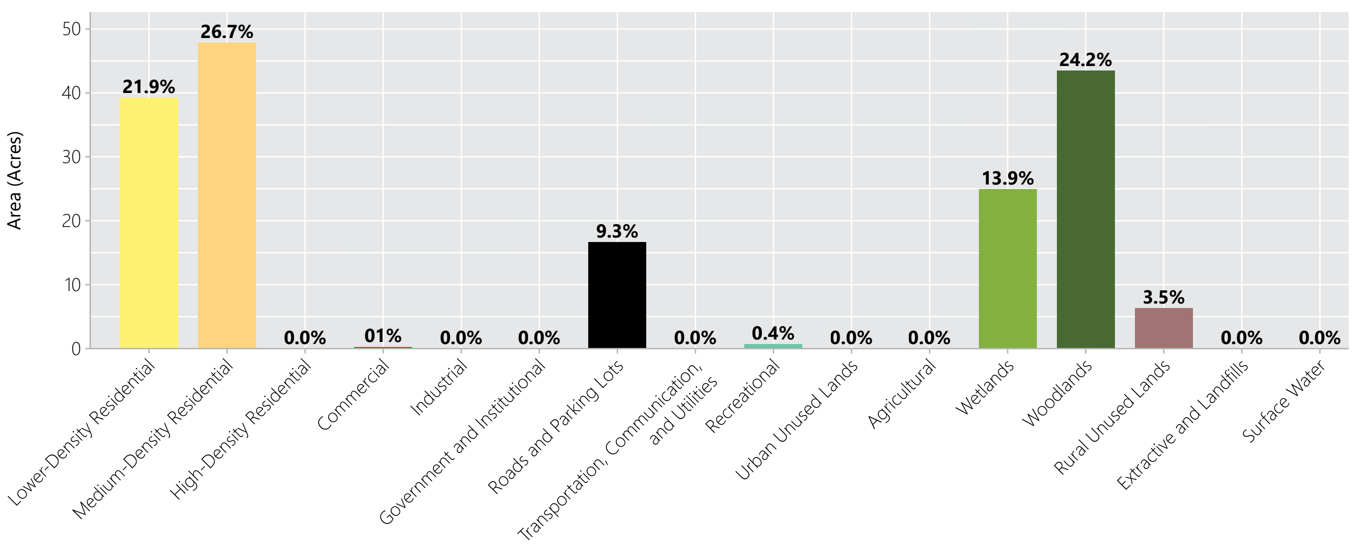


Facts at a Glance

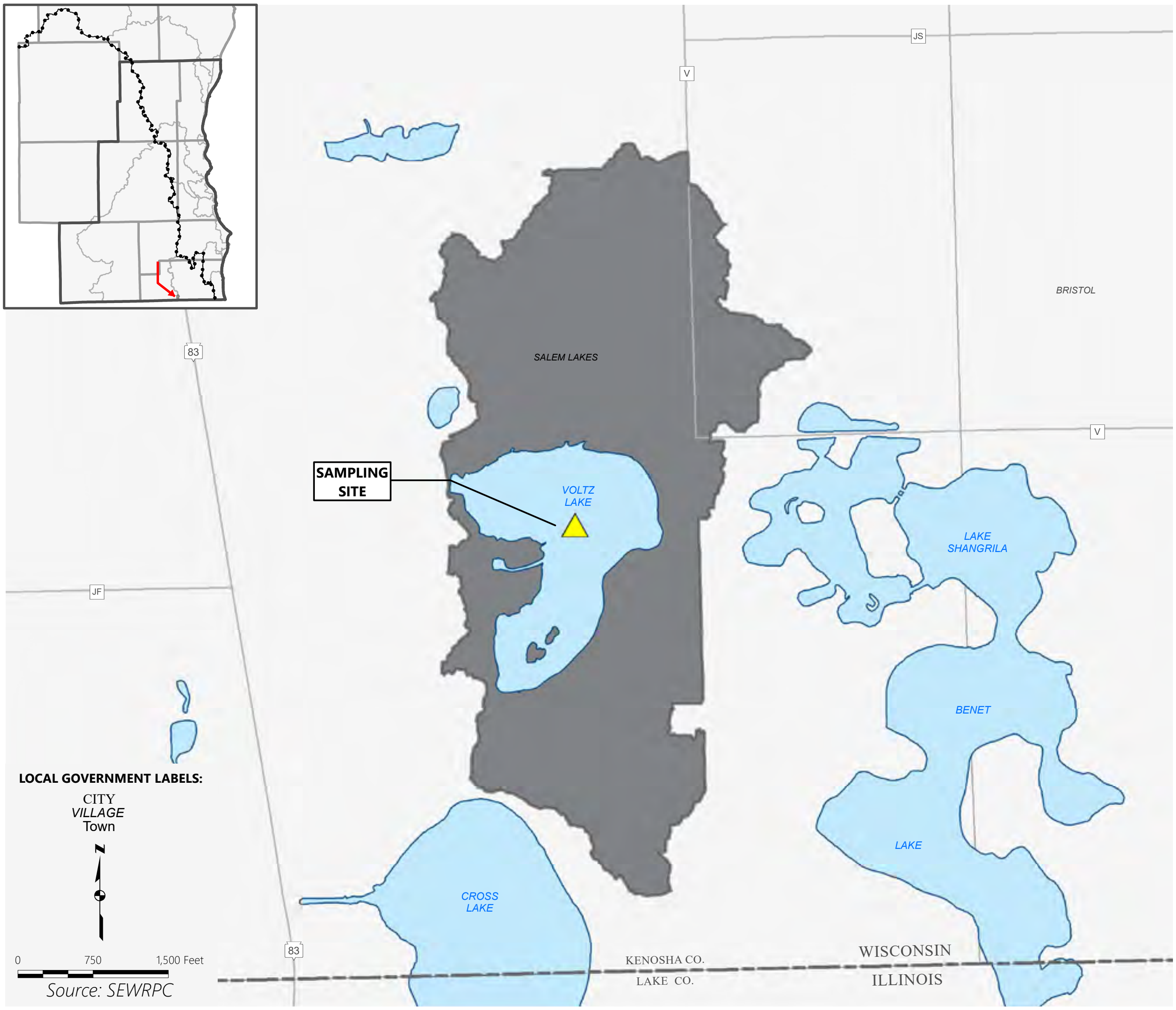
- **Drainage Area Size:** 0.3 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 58.4%; Rural – 41.6%
- **Roads and Parking Lots (% of drainage area):** 9.3
- **Estimated Population (2010):** 623
- **Estimated Households (2010):** 231
- **Upstream Wastewater Treatment Facilities:** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 81
- **Water Supply Source:** Groundwater

Map C.10
Silver Lake Drainage Area – Existing Land Use





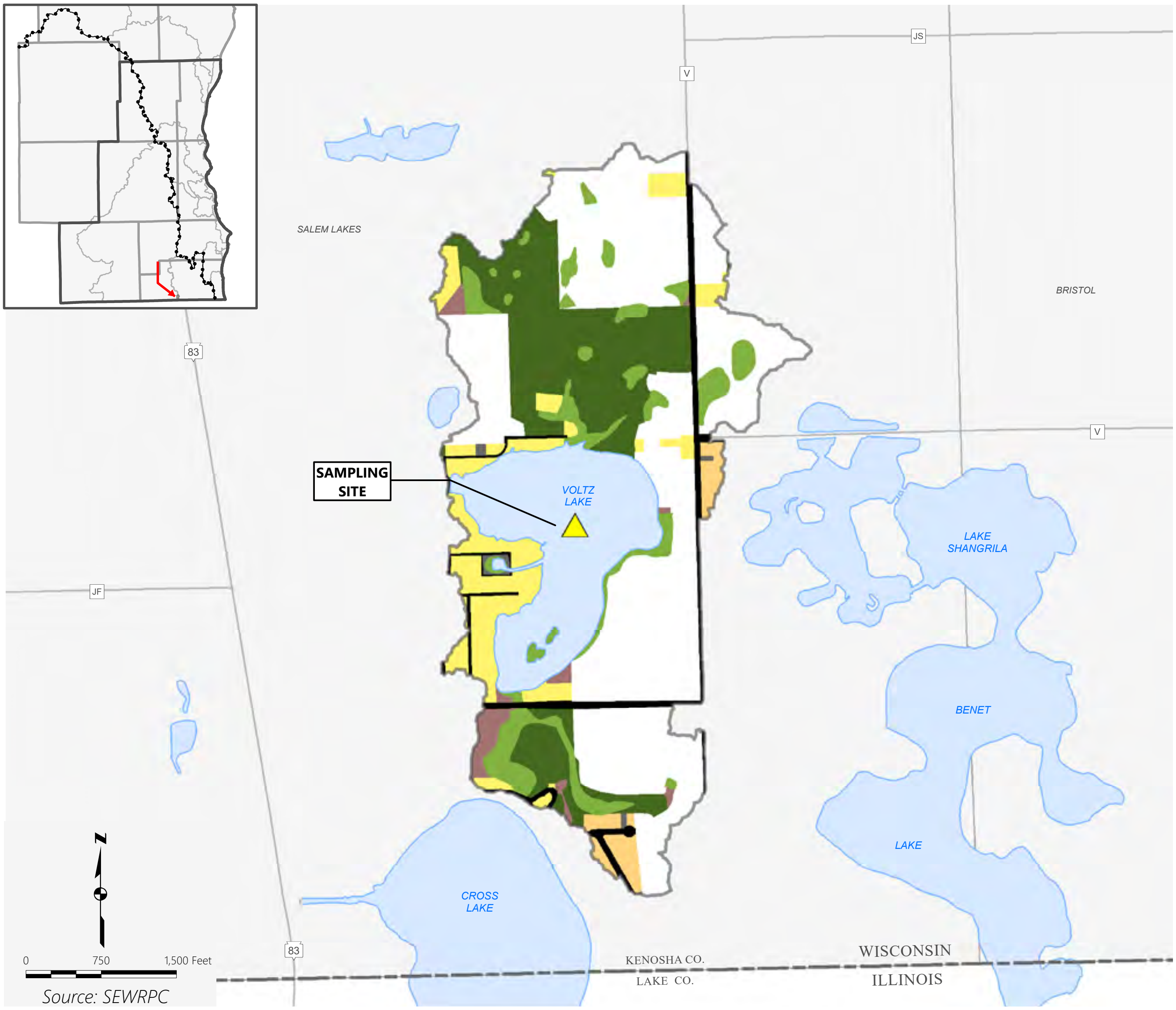
Map C.11
Voltz Lake Drainage Area – Characteristics

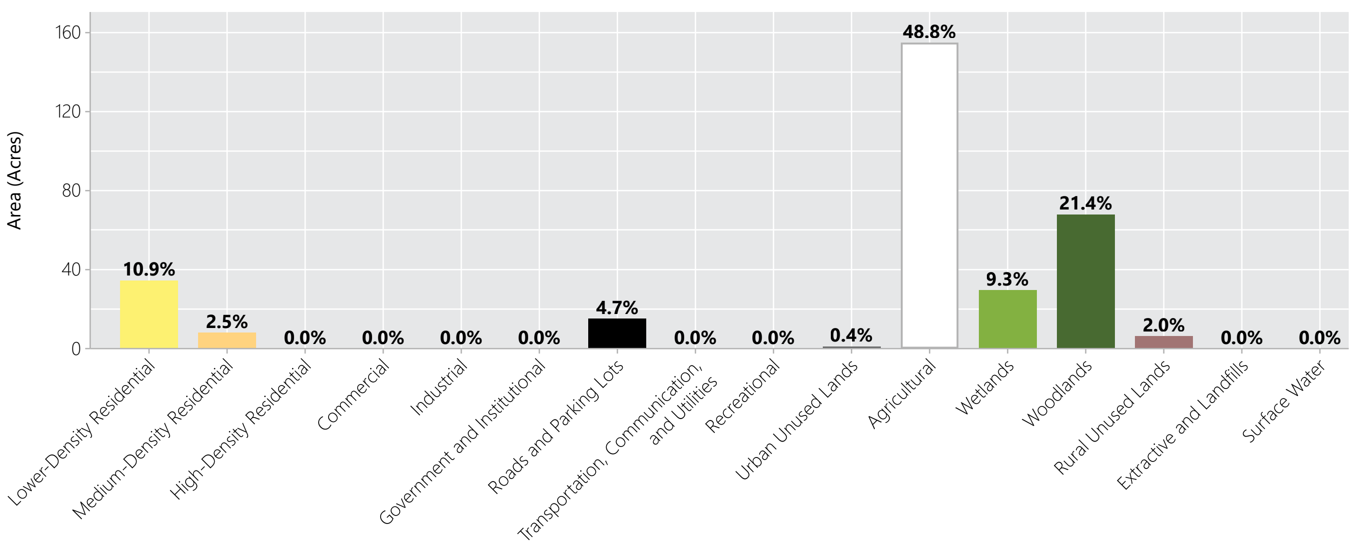


Facts at a Glance

- **Drainage Area Size:** 0.5 square miles
- **Major Watershed:** Fox River
- **Land Use:** Urban – 18.5%; Rural – 81.5%
- **Roads and Parking Lots (% of drainage area):** 4.7
- **Estimated Population (2010):** 289
- **Estimated Households (2010):** 104
- **Upstream Wastewater Treatment Facilities:** None
- **Planned Sanitary Sewer Service Area (% of drainage area):** 72
- **Water Supply Source:** Groundwater

Map C.12
Voltz Lake Drainage Area – Existing Land Use





WISCONSIN STATE LABORATORY OF HYGIENE SAMPLE DATASHEET

APPENDIX D

State of Wisconsin
Department of Natural Resources
and Laboratory of Hygiene

Test Request – Inorganic Surface Water & Microbiology

Form 4800-024 (R 7/14)

Page 1 of 2

Billing and Reporting

Account Number: 352107	Field Number (Bottle Label ID): PKE-10- 200312	Report to Address (Non-DNR only): PO Box 1607
DNR User ID:	Report To Name: SEWRPC c/o Laura Herrick	City: Waukesha; State: WI; ZIP: 53187
Date Results Needed (mm/dd/yyyy):		Report to Email (Non-DNR only): lherrick@sewrpc.org

Date and Time of Sample Collection

Date (mm/dd/yyyy)	Time (24-hr clock)	End Date (mm/dd/yyyy)	End Time
03/12/2020	12:00		

Sample Type

Sample Type: (select one)
(●) SU Surface Water ( ) NP Storm Water ( ) EF Effluent (Treated Wastewater) ( ) IF Influent (Untreated wastewater)
( ) D Public Drinking Water ( ) MW Monitoring Well ( ) PO Private Well ( ) SE Sediment
( ) SL Sludge ( ) SO Soil ( ) TI Tissue ( )

Who collected the sample

Collected By Name	Telephone	Email
Nick Neureuther	(262) 953-3225	nneureuther@sewrpc.org

Where the sample was collected

Station ID (STORET #): 10034961	Sample Address or Location Description: Pike River at Petrifying Springs Park 1500ft U/S of USGS Gage	
County: 30 - Kenosha	Waterbody ID (WBIC): 1300	Point / Outfall (or SWIMS Fieldwork Seq No):

Sample Details

Sample Description / Device Description: Grab Sample

Enforcement? ( ) Yes (●) No
If yes, include chain of custody form.
Is Sample Disinfected? ( ) Yes (●) No
If yes, how?

If Field QC Sample (select one): ( ) Duplicate ( ) Blank ( )
Grant or Project Number: GLPF2018_LM1802_CS

Depth of Sample: ________ ( ) ft ( ) m ( ) in ( ) cm
Or Top and Bottom of Sample Interval: ________ - ________ ( ) ft ( ) m ( ) in ( ) cm

Analyses Requested

If field filtered, indicate by checking the box on this sheet and noting on the lid of the sample bottle.

Plastic Quart Bottle (No chemical preservation)
[ ] Sample field filtered? (Check box if yes)
[ ] Alkalinity, pH, Conductivity
[ ] BOD5 Dissolved
[ ] BOD5 Total (900 ml needed)
[ ] CBOD5 Total (carbonaceous)
[X] Chloride
[ ] Chlorophyl A (if Field Filtered, give ml ________ filtered)
[ ] Color
[ ] Fluoride
[ ] MBAs Screening
[ ] pH only (non compliance)
[X] Sulfate
[ ] Turbidity
[ ] ________

Solids
[ ] Suspended Sediment
[ ] Total Dissolved Solids
[ ] Total Solids
[ ] Total Volatile Solids (includes total solids)
[ ] % Sand, Silt, Clay
[ ] Total Suspended Solids (500 ml needed)
[ ] Total Vol. Susp. Solids (includes Total Susp. Solids)

60 ml Bottle (No chemical preservation)
[ ] Sample field filtered? (Check box if yes)
[ ] Orthophosphate
[ ] Silica
[ ] NO2+NO3 as Nitrogen (drinking water)
[ ] Nitrite (NO2) as Nitrogen

Quart Mason Jar
[ ] Oil Grease (3 qts) [ ] pH (waste only)

250 ml Metals Bottle (Acidify w/ Nitric Acid)
[ ] Sample field filtered? (Check box if yes)
[ ] Low Level Metals. Note: Clean sampling with special bottles
[ ] TCLP (Toxicity Characteristic Leaching Procedure - use mason jar)
Total recoverable metals will be run unless otherwise instructed.
[ ] Aluminum
[ ] Antimony
[ ] Arsenic
[ ] Barium
[ ] Beryllium
[ ] Boron
[ ] Cadmium
[X] Calcium
[ ] Chromium, Total
[ ] Cobalt
[ ] Copper
[X] Hardness-as CaCO3
[ ] Iron
[ ] Lead
[X] Magnesium
[ ] Manganese
[ ] Mercury
[ ] Molybdenum
[ ] Nickel
[X] Potassium
[ ] Selenium
[ ] Silver
[X] Sodiun
[ ] Stronti
[ ] Thalliu
[ ] Titaniu
[ ] Vanadi
[ ] Zinc
[ ] ________
[ ] ________

Contains: 1:1 HNO3
Lot No.: NA9189080
Expires: 07/08/20
See Safety Data Sheet (SDS)

250 ml Nutrients Bottle (Acidify w/ Sulfuric Acid)
[ ] Sample field filtered? (Check box if yes)
[ ] Tot.-Phosphorus
[ ] Ammonia-N
[ ] NO2 + NO3 as Nitrogen
[ ] COD
[ ] To ...hl-N
[ ] Total Nitrogen
[ ] Tot. Dis. Phosphorus (filter, then acid preserve in 60 ml bottle)

250 ml Round Bacteria Bottle
[ ] E. coli by MPN, non-potable
[ ] Enterococci by MPN, non-potable

For lab use:
Sample Temp ______ °C
[ ] Iced

Please enclose this form in the mailer along with the sample and send to the State Lab of Hygiene.
Additional parameters or instructions to laboratory:

Test Request – Inorganic Surface Water & Microbiology

Form 4800-024 (R 7/14)

Field Parameters - Optional **Only fill out if directed by your project coordinator.**

Temperature - Sample (°C)	__ __ . __	Gage Height (ft)	__ __ __ __ . __
Temperature - Ambient Air (°C)	__ __ . __	Flow (cfs)	__ __ __ __ __ __ . __
DO (mg/l)	__ __ . __	Flow (MGD)	__ __ __ __ __ __
% Saturation	__ __ __ . __	Depth to Groundwater ___ ft or m	__ __ __ __ __ . __ __
pH (su)	__ __ . __	Turbidity (NTU)	__ __ __ . __ __
Secchi Depth (feet or meters) ___ ft or m	__ __ __ . __	Transparency Tube (cm)	__ __ __ __ . __ __
Secchi Depth Hit Bottom?	☐ Yes ☐ No	Nitrates (mg/l)	__ __ __ __ __ __
Cloud Cover (%)	__ __ __		
Cond (µS/CM@25°C)	__ __ __ __ __		

Tips

See Chapter 4 "Lab Slips" of the Field Procedures Manual (see http://intranet.dnr.state.wi.us/int/es/science/ls/Forms/Instructions.htm) for further instructions and definitions.

The **Account Number** must be completed in order for the samples to be billed to the correct funding source. If you are unsure what the proper account number is refer to http://intranet/int/es/science/ls/Account.htm or contact the DNR Laboratory Coordinator or the State Laboratory of Hygiene.

The **Lake Grant or Project Number field** should include the Lake Planning Grant Number or the Project Number.

Sample Depth – If you sample in a lake, this is required.

Field Parameters – If you do fill this out, the data will go into SWIMS automatically. Please do not re-enter. Also, you must QA the data once it arrives in SWIMS.