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Technical Report No. 63

CHLORIDE CONDITIONS AND TRENDS IN SOUTHEASTERN WISCONSIN

Chapter 2

STUDY AREA BACKGROUND

2.1 STUDY AREA CHARACTERISTICS

Civil Divisions and Major Watersheds

The study area for the Chloride Impact Study encompasses approximately 2,982 square miles, including all or portions of 11 counties, 29 cities, 75 villages, and 73 townships. Geographic boundaries of civil divisions are an important factor to be considered in this Study because they form the basic foundation of the public decision-making framework within which intergovernmental, environmental, and development issues must be addressed. However, addressing water quality problems in surface water and groundwater resources often requires assessing conditions that go beyond county and municipal boundaries. Assessing water quality conditions on a watershed basis is a more comprehensive approach for understanding the factors that contribute to the health of a waterbody. A watershed approach also helps to guide more effective management strategies to improve the health of a waterbody. Therefore, the major watersheds in the study area will be the main framework for assessing chloride conditions and trends throughout the remainder of this Report.[1]

The study area 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 land draining directly to Lake Michigan. Map 2.1 shows the major watershed boundaries superimposed on the pattern of local political boundaries.

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[1] *Analyses within this Report will also assess chloride conditions at finer scales than the major watersheds of the study area such as lake watersheds, subwatersheds, subbasins, and stream reaches.*

The study area contains over 5,500 lakes and ponds and almost 3,900 miles of mapped streams and rivers as shown on Map 2.2.[2] Surface water resources consisting of rivers, streams, lakes, ponds, and wetlands form a critical element of the natural resource base of the Southeastern Wisconsin Region (Region). In addition, groundwater resources 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 economic development, recreational activity, and aesthetic quality of the Region is immeasurable. Furthermore, the residents and businesses of the Region rely on both Lake Michigan water and groundwater resources to provide a reliable source of domestic, municipal, and industrial water supply. For these reasons, the impacts of chloride to the environment affect all of the counties and local communities in the study area to some extent.

Population and Land Use

Because chloride pollution can typically be traced back to human activities that introduce it into the environment, population and land use characteristics can help to explain the degree to which chloride is impacting the surface water and groundwater of the study area. The study area had an estimated population of 2,038,900 in 2010. Population density for the watersheds in the study area ranges from about 100 people per square mile in the Sauk Creek and Sheboygan River watersheds to more than 6,200 people per square mile in the Kinnickinnic River watershed, as shown on Map 2.3.

Historical Land Use and Urban Development

This Technical Report will examine both the recent chloride conditions in the water resources of the study area and the chloride trends over time. The type, intensity, and spatial distribution of land uses determine, to a large extent, the resource demands and human impacts that will be experienced within an area. The existing land use pattern in an area can best be understood within the context of historical development. Historical urban growth within the Region is shown on Map 2.4.[3] The use of road salt in Wisconsin began in the early 1950s and became widespread by the mid-1950s. By then only about 5 percent of the Region

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

[3] *Some datasets used for analyses in this Report are only available for the seven county Southeastern Wisconsin Region that the Commission serves. This seven county Region includes Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties. References to the "Region" in this Report is a reference to these seven counties only. The study area for the Chloride Impact Study includes the seven counties of the Region as well as significant areas outside of the Region that drain into it, including about 293 square miles of Dodge, Fond du Lac, Jefferson, and Sheboygan Counties. Analyses presenting data for this entire area will reference the "study area."*

had been developed for urban uses (as shown in red on Map 2.4). The period between 1950 and 1963 saw the largest expansion of urban development throughout the Region when the extent of urban development increased from about 5 percent to almost 11 percent. The decades of the 1960s, 1970s, 1980s, 1990s, and 2000s experienced increases in urban development within the Region of 2.1, 3.9, 2.4, 2.6, and 2.1 percent, respectively. By 2010, almost 24 percent of the Region had been developed for urban purposes.

Examining the Southeastern Wisconsin Regional Planning Commission (Commission) land use inventories between 1963 and 2020 at the watershed and subwatershed level can show the trends in urban development at a finer scale.[4] Figure 2.1 shows the increasing trends in urban land uses of each major watershed in the Region between 1963 and 2020. Every watershed in the Region has experienced some degree of urban development during this time period. The Kinnickinnic River watershed has been nearly built-out with urban land uses since the first land use inventory was completed in 1963 and therefore has experienced limited additional urbanization over the last 57 years. Other watersheds, such as the Oak Creek and Pike River watersheds, have experienced extensive urbanization, with an increase in urban land use of 39 and 26 percent, respectively. The Region as a whole has seen an increase of 15 percent in urban land uses from 1963 to 2020.

Figure 2.2 shows, geographically, the percent of urban land use of subwatersheds from 1963 to 2020, indicating the locations and extent of urbanization that has occurred in the Region over the last six decades. Finally, Map 2.5 presents the increase of urban land use that each subwatershed within the Region has experienced over the same time period. As indicated on Map 2.5, the western Oak Creek watershed, portions of the northern Fox River watershed, northern Pike River watershed, southeastern Des Plaines River watershed, northeastern Rock River watershed, northwestern Menomonee River watershed, and central direct drainage area to Lake Michigan have seen to greatest increases in urban land use when compared to the same areas in 1963.

The largest source of chloride to the environment is a result of winter road and parking lot deicing.[5] The increase in the urban land uses and density of roads and parking lots in the Region has likely played a significant role in increasing concentrations of chloride in the surface waters and groundwater. Figure 2.3 presents the increase of road and parking lot density of each of the portions of the major watersheds within

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[4] *Comparison of land use trends from 1963 to 2020 is only possible for portions of the watersheds and subwatersheds that are within the seven-county Southeastern Wisconsin Region where historical land use inventories are available.*

[5] *Technical Report No. 65,* Mass Balance Analysis for Chloride in Southeastern Wisconsin, *in preparation.*

the Region between 1963 and 2020. Similar to the trends in urban development, each watershed in the Region has experienced increasing trends in road density to some extent. The Oak Creek watershed has experienced the largest increase, with an additional 14 percent of land use allocated to roads and parking lots since 1963. The Menomonee, Kinnickinnic, and Pike River watersheds were close behind, adding 9.6, 9.5, and 8.1 percent to their total road and parking lot densities, respectively. The Kinnickinnic River watershed had the largest portion of its area consisting of roads and parking lots, outpacing the next closest watershed by roughly 10 percent in each year of Regional land use inventories. Road and parking lot density for the Region as a whole increased over 4 percent during the 57 year period.

Figure 2.4 shows, geographically, the percent of subwatersheds dedicated to road and parking lots for each decade, indicating the locations and extent of growth in road and parking lot land uses over the last six decades. Map 2.6 shows the increase in road and parking lot density in each subwatershed between 1963 to 2020. The areas shown in dark orange, red, and brown have experienced the greatest increase in roads and parking lot density. These areas include much of the Menomonee River watershed, the Oak Creek watershed, the southern Kinnickinnic River watershed, the northern Fox River watershed, the northern and southcentral Root River watershed, and northern Pike River watershed.

Existing Land Use

While historical land use inventories were only available for the seven-county Southeastern Wisconsin Region, as part of the Chloride Impact Study Commission staff assembled a uniform land use inventory representing existing conditions for the entire study area, including out-of-Region areas.[6] The geographic distribution of the Chloride Impact Study land use groups within the study area are shown on Map 2.7. The total acreage and percentage of each major watershed for each land use group is provided in Table 2.1. Map 2.8 shows the percentage of urban land uses within each subwatershed of the study area.[7] Similarly, Map 2.9 shows the density of roads and parking lots within each subwatershed under existing conditions.

While over 70 percent of the study area has existing land uses considered to be nonurban, large areas of highly urbanized development with a high density of roads and parking lots are evident in the central and eastern portion of the study area. The areas with the highest percentage of existing urban land uses were

[6] *See Technical Report No. 61 for a detailed description of the assembly and integration of existing land use inventories for the study area.*

[7] *Urban land uses include lower-, medium-, and high-density residential; commercial; industrial; government and institutional; roads and parking lots; transportation, communication, and utilities; recreational; and unused urban lands.*

observed in the Kinnickinnic River watershed, Menomonee River watershed, southern Milwaukee River watershed, Oak Creek watershed, northern Root River watershed, the northeastern portion of the Fox River watershed, and portions of the direct drainage area to Lake Michigan, as represented in red, orange, and yellow in Map 2.8.[8] As might be expected, most portions of the study area that exhibit the highest percentage of urban land uses also contain the highest road and parking lot densities, as represented by the dark orange and browns in Map 2.9.

Conversely, the areas shown in darker shades of green on Map 2.8, and shown in white, tan, and yellow on Map 2.9, indicate areas consisting mostly of agricultural, wetland, or woodland land uses.[9] Further descriptions of the land use composition and distribution as well as detailed land use maps for each major watershed in the study area will be provided later in this Chapter and in Appendix A.

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. These sources and pathways of chlorides in wastewater are discussed in further detail in Technical Report No. 62 and Technical Report No. 65, and will also be summarized later in this Chapter.[10] Wastewater treatment plants (WWTPs) in the study area 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 2.10 indicates the locations of active public WWTPs and the planned sanitary sewer service areas (SSSAs) that these treatment facilities serve. In addition, Map 2.10 shows the locations of 27 WWTPs that were once in use in the study area, but have been abandoned. There are currently 48 active WWTPs in operation within the study area. Table 2.2 provides additional information for these public WWTPs, including the major watershed where the facility is located, SSSAs from which each facility currently (or formerly) receives wastewater, the estimated population served, the annual average design flow for the facility, the

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[8] *For Chloride Study land use groups and detailed land use category descriptions, see Table 2.3 in Technical Report No. 61.*

[9] *Agricultural areas in the study area may experience chloride impacts related to the use of certain agricultural fertilizers such as potash (potassium chloride) in addition to road salting on nearby county and State highway systems.*

[10] *Technical Report No.62,* Impacts of Chloride on the Natural and Built Environment, *April 2024, and Technical Report No. 65,* Mass Balance Analysis for Chloride in Southeastern Wisconsin, *in development.*

facility status and year abandoned, and the water body that receives (or formerly received) effluent from the facility after treatment. Treated wastewater is typically discharged to waterways in close vicinity to the WWTP locations shown on Map 2.10.[11] Map 2.10 also indicates areas that are within planned SSSAs. Planned SSSAs can include a combination of areas 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. The location of current and former WWTPs, and more specifically the locations of effluent discharged from these facilities may assist in analyzing chloride conditions in water bodies in the study area as well as trends in chloride conditions over time.

It also may be important to consider the potential impacts of urban development that is not served by public sanitary sewerage systems. Areas identified in orange on Map 2.11 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 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.[12] Areas identified in blue on Map 2.11 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.[13] These areas are different than the planned sanitary sewer service areas indicated on Map 2.10 which include both areas currently served by public sanitary sewer treatment facilities as well as the extent of areas that are planned to be served in the future.

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 permittees to reduce the urban pollutants entering local waterways via any stormwater conveyance system.

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[11] *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.*

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

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

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 maintain stormwater facilities, including mapping their systems. Each MS4-permmitted 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, 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, road salt 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; the Universities of Wisconsin-Milwaukee, - Parkside, and – Whitewater; the Wisconsin State Fair Park; and the Southeastern Wisconsin Professional Baseball Park District are required to have an MS4 permit under the WPDES program. These municipalities and entities are shown on Map 2.12.

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 helpful in analyses of chloride conditions and trends in the study area. 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.

Sources of Water Supply

Aquifers composed of soluble rock types that contain calcium- and magnesium-bearing minerals can produce hard and very hard water. These types of aquifers include those found in glacial deposits, sandstone, and carbonated rock, and are commonly used as sources of water supply in southeastern Wisconsin.[14] Hard water is often treated at homes and businesses 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 considerations related to WWTPs, and later in this Chapter in the Sources of Chloride section, 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. 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 as of 2005 are shown on Map 2.13. To examine the influence that softening practices may have on chloride levels in streams, lakes, and groundwater of the study area, it may be necessary to consider whether an area is primarily served by groundwater supply or by Lake Michigan supply.[15]

Areas Vulnerable to Groundwater Contamination

Groundwater quality conditions can be impacted by sources of pollution such as infiltration of stormwater runoff, landfill leachate, agricultural fertilizer and pesticide runoff, manure storage and application sites,

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[14] *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.*

[15] *The Lake Michigan water supply is not known to be hard water and therefore is less likely to need treatment using water softening salts containing chloride.*

chemical spills, leaking surface or underground storage tanks, and onsite sewage disposal systems. Compared to the deep aquifer, shallow aquifers are more susceptible to pollution from the surface because they are nearer to the source, thus minimizing the potential for dilution, filtration, and other natural processes that tend to reduce the potential detrimental effects of pollutants. The potential for groundwater pollution in the shallow aquifer is dependent on the depth to groundwater; the depth and type of soils through which infiltrated runoff, leachate, outflows from onsite sewage disposal systems, and spills must percolate; the location of groundwater recharge areas; and the subsurface geology. Map 2.14 shows the depth to shallow groundwater within the study area. Groundwater aquifers are estimated to be within 0 to 25 feet below the ground surface for approximately 34 percent of the study area, which means there is a moderate to high potential for contamination of the shallow aquifers in these areas.

The Commission completed a regional water supply study for the Southeastern Wisconsin Region that included, in part, the development of basic groundwater inventories, the development of a groundwater simulation model, and a technical report on groundwater recharge.[16] One aspect of the water supply study was to better understand and protect recharge areas that contribute most to baseflow of the lakes, streams, springs, and wetlands of the Region. Map 2.15 shows the groundwater recharge potential as derived from a soil water balance recharge model developed for the Region. Groundwater recharge was classified into four main categories defined as low, moderate, high, and very high. Areas that could not be classified were placed into a fifth category as undefined, and often corresponded to areas of groundwater discharge. The highest concentration of the areas of high and very high groundwater recharge potential in the Region are located in the upper Milwaukee River watershed, the central Rock River watershed, and the western and central Fox River watershed, as indicated on Map 2.15 in green and yellow. Many of these areas are along or adjacent to rivers, streams, and lakes. While these areas are critical for replenishing groundwater aquifers and maintaining baseflows in surface waters, they also may act as direct conduits for chloride pollution to infiltrate the groundwater.

Watershed Characteristics

The following subsections provide a short description the major watersheds in the study area. Land use maps, civil division maps and important characteristics for the watersheds are provided in Appendix A.

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[16] *Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin, *December 2012; Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin, *June 2002; Technical Report No. 41,* A Regional Aquifer Simulation Model for Southeastern Wisconsin, *June 2005; and Technical Report No. 47,* Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water-Balance Model, *July 2008.*

Des Plaines River Watershed

The Des Plaines River watershed is located in the southeastern portion of the study area. The watershed area within the study area encompasses approximately 133 square miles and is located within Kenosha and Racine Counties. The Des Plaines River originates at the southern edge of Racine County and flows in a south-southeast direction through Kenosha County approximately 22.5 miles where it flows out of the study area and into Illinois. The Des Plaines River flows an additional 111 miles until its confluence with the Illinois River. Rivers and streams in the watershed are part of the Mississippi River drainage system as the watershed lies west of the subcontinental divide.

In 2015, existing land use in the watershed was mostly rural (81.1 percent), consisting primarily of agricultural lands (55.2 percent). Other common land uses included wetlands (10.2 percent), rural unused lands (7.1 percent), roads and parking lots (6.2 percent), woodlands (6.1 percent), and lower-density residential (5.0 percent) (see Table 2.1 and Map A.1). About 14 miles of the IH 94 corridor runs north-south through the entire length of the watershed. The southeastern portion of the watershed that includes the Jerome Creek subwatershed and encompasses part of the City of Kenosha and Village of Somers contains the highest percentage of urban land uses and highest density of roads and parking lots (see Map 2.8 and Map 2.9). The same portion of the watershed has also experienced the largest increase in urban land use since 1963 (see Map 2.5).

The Des Plaines River watershed contained portions of 13 civil divisions (see Map A.2). In 2010, the watershed had an estimated population of 31,480. Approximately 78 percent of that population resided in areas that had connections to public sanitary sewers and wastewater treatment facilities as of 2010. Currently there are two active WWTPs that discharge treated wastewater within the watershed; the Bristol facility discharges to a tributary of the Des Plaines River, and the Paddock Lake facility discharges to a tributary of Brighton Creek. There were an additional three WWTPs that once operated in the watershed but have since been abandoned (see Map A.2 for active and abandoned facility locations). A portion of the watershed is served by public water utilities providing both groundwater and Lake Michigan water supply.

Fox River Watershed

The Fox River watershed is located in the central and southwestern part of the study area. The portion of the Fox River watershed that is within the study area of the Chloride Impact Study encompasses approximately 938 square miles containing portions of (in order of largest to smallest proportion) Waukesha, Walworth, Racine, Kenosha, Jefferson, Milwaukee, and Washington Counties. The Fox River originates in northeastern Waukesha County and flows approximately 84 miles through the study area in a southerly direction. The Fox River continues another 118 miles until its confluence with the Illinois River. Rivers and streams in the watershed are part of the Mississippi River drainage system as the watershed lies west of the subcontinental divide.

In 2015, existing land use in the watershed was mostly rural (74.3 percent), consisting primarily of agricultural lands (39.0 percent). Other common land uses included wetlands (13.2 percent), lower-density residential (10.1 percent), woodlands (9.7 percent), rural unused lands (6.9 percent), and roads and parking lots (6.7 percent) (see Table 2.1 and Map A.3). Nearly 30 miles of IH 43 and 14 miles of IH 94 corridor traverse this watershed. The northeastern portion of the watershed that includes the Deer Creek, Upper Fox River, and Pewaukee River subwatersheds, and encompasses part of the Cities of New Berlin, Brookfield, Pewaukee, and Waukesha contained the highest percentage of urban land uses and the highest density of roads and parking lots (see Map 2.8 and Map 2.9). The same portion of the watershed, as well as the Jericho Creek subwatershed in the west-central region of the watershed experienced the largest increase of urban land use since 1963 (see Map 2.5).

The Fox River watershed covers portions of 63 civil divisions including some relatively urban municipalities (see Map A.4). In 2010, the watershed had an estimated population of 365,070. Approximately 73 percent of that population resided in areas that had connections to public sanitary sewers and wastewater treatment facilities as of 2010. Currently there are 14 active WWTPs that discharge treated wastewater within the watershed. There were an additional seven WWTPs that once operated in the watershed but have since been abandoned (see Map A.4 for active and abandoned facility locations and Table 2.2 for receiving waters and other facility information). A portion of the watershed is served by public water utilities providing both groundwater and Lake Michigan water supply.[17]

Kinnickinnic River Watershed

The Kinnickinnic River is located in the east-central portion of the study area and covers an area of approximately 25 square miles entirely within Milwaukee County. The Kinnickinnic River originates in central Milwaukee County and flows approximately eight miles in an easterly direction to its confluence with the Milwaukee River. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide.

[17] *Water supplied by the City of Waukesha was converted from groundwater to Lake Michigan supply in 2023.*

The Kinnickinnic River watershed is one of the most densely urbanized areas in the State. In 2015, existing land use in the watershed was almost exclusively urban (97.4 percent), consisting primarily of roads and parking lots (29.7 percent) and high-density residential (25.9 percent). Other common land uses included transportation, communication, and utilities (7.7 percent); medium-density residential (7.1 percent); and government and institutional (6.8 percent) (see Table 2.1 and Map A.5). Nearly 7 miles of IH 94 and 2 miles of IH 43 corridor traverse the watershed, connecting with an extremely dense grid of local roadways. In addition, Milwaukee Mitchell International Airport (MMIA), the State's largest and busiest international airport is located primarily within the Kinnickinnic River watershed. The density of urban land use is relatively evenly distributed throughout the watershed, with no subwatersheds having significantly more urban development than others (see Map 2.8). The southwestern portion of the watershed (west of MMIA) that includes the Holmes Avenue Creek and Villa Mann Creek subwatersheds has the highest density of roads and parking lots (see Map 2.9). The same area has experienced the largest increase in road and parking lot density since 1963 (see Maps 2.6).

Six civil divisions lie partially within the Kinnickinnic River watershed (see Map A.6). In 2010, the watershed had an estimated population of 156,810, all of which resided in areas that had connections to public sanitary sewers and the MMSD wastewater treatment facilities, which are located outside of the watershed. The entire watershed is served by a public water utility serving Lake Michigan water supply.

Menomonee River Watershed

The Menomonee River watershed is located in the east-central part of the study area and encompasses approximately 136 square miles. The watershed is within portions of Milwaukee, Waukesha, Washington, and Ozaukee Counties. The Menomonee River originates in southeastern Washington County and flows approximately 28 miles through the northeastern corner of Waukesha County and through western and central Milwaukee County to its confluence with the Milwaukee River near downtown Milwaukee. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide.

In 2015, existing land use in the watershed was more urban (69.9 percent) than rural (30.1 percent). The most common land uses included roads and parking lots (20.8 percent), agricultural (13.2 percent), lower-density residential (13.2 percent), high-density residential (8.8 percent), wetlands (8.7 percent), and medium-density residential (8.2 percent) (see Table 2.1 and Map A.7). In addition to many miles of local collector streets, this watershed includes almost 20 miles of the IH 41 and 10 miles of the IH 94 corridors. The southern portion of the watershed that includes the Honey Creek, Lower Menomonee River, South

Branch Underwood Creek, Butler Ditch, Underwood Creek, Lilly Creek, and Dousman Ditch subwatershed is particularly urbanized, with subwatersheds ranging from over 81 percent to over 98 percent urban land uses with between 21 and 30 percent of those totals consisting of roads and parking lots. The Lily Creek and Nor-X-Way Channel subwatersheds experienced the largest increase in urban land uses since 1963 (see Map 2.5). Much of the watershed has seen more than a ten percent increase in road and parking lot density since 1963 (see Map 2.6).

The Menomonee River watershed contained portions of 17 civil divisions (see Map A.8). In 2010, the watershed was home to an estimated 320,850 people. Approximately 98 percent of that population resided in areas that had connections to public sanitary sewers and the MMSD wastewater treatment facilities, which are located outside of the watershed. There are no active WWTPs that discharge within the watershed, however there were three WWTPs that once operated in the watershed that have since been abandoned (see Map A.8 for active and abandoned facility locations and Table 2.2 for receiving waters and other facility information). A portion of the watershed is served by public water utilities providing both groundwater and Lake Michigan water supply.

Milwaukee River Watershed

The Milwaukee River watershed is located in the north-central and northeastern portion of the study area and covers 701 square miles. The mainstem of the Milwaukee River originates in southeastern Fond Du Lac County and flows approximately 101 miles in a southerly and easterly direction to its confluence with Lake Michigan in the City of Milwaukee. Tributaries of the Milwaukee River extend into (listed from largest to smallest portion of the watershed) Washington, Fond du Lac, Ozaukee, Sheboygan, Milwaukee, and Dodge Counties. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide. Approximately 62 percent, or 435 square miles, of the watershed is located within the seven-county Commission planning area. The remaining 38 percent, or 266 square miles are located in Dodge, Fond du Lac, and Sheboygan Counties.

Recent existing land use inventories in the watershed indicate that the watershed was mostly rural (76.6 percent), consisting primarily of agricultural lands (43.3 percent), wetlands (16.0 percent), and woodlands (9.4 percent) (see Table 2.1 and Map A.9). Urban land uses such as roads and parking lots (7.2 percent), lower-density residential (6.6 percent), and high-density residential (2.5 percent) were less common in the watershed but were very concentrated in the downstream (southern) portion of the watershed. Urban land uses were particularly dense in the Lincoln Creek and Lower Milwaukee River subwatersheds where almost 98 percent and 64 percent of the land, respectively, was developed for urban uses (see Map 2.8); 32 percent and 29 percent of those subwatershed areas, respectively, were developed as roads or parking lots (see Map 2.9). In addition to the many miles of local collector streets, this watershed contained about 24 miles of the IH 43, eight miles of the IH 41, and 34 miles of the USH 45 corridors. The Silver Creek and Lower Milwaukee River subwatersheds have experienced the largest increases in urban land use since 1963 (see Map 2.5).[18]

The Milwaukee River watershed covers portions of 56 civil divisions (see Map A.10). In 2010, the watershed was home to an estimated 493,200 residents. Approximately 89 percent of that population resided in areas of the watershed that had connections to public sanitary sewers and wastewater treatment facilities as of 2010. There are currently 12 active WWTPs that discharge treated wastewater within the watershed. The southern portion of the watershed is served by the MMSD wastewater treatment facilities that are located just outside of the watershed in the direct drainage area to Lake Michigan. There was one additional WWTP that once operated in the watershed but has since been abandoned (see Map A.10 for active and abandoned facility locations and Table 2.2 for receiving waters and other facility information). A portion of the watershed is served by public water utilities providing both groundwater and Lake Michigan water supply.

Oak Creek Watershed

The Oak Creek watershed is located in the east-central portion of the study area and covers approximately 28 square miles entirely within Milwaukee County. Oak Creek originates in southern Milwaukee County and flows approximately 14 miles in a northeasterly direction to its confluence with Lake Michigan. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide.

In 2015, existing land use in the watershed was mostly urban (73.5 percent), consisting primarily of roads and parking lots (20.1 percent), medium-density residential (11.5 percent), urban unused lands (11.4 percent), and lower-density residential (9.8 percent) (see Table 2.1 and Map A.11). Other common land uses included agricultural lands (9.2 percent) and wetlands (7.7 percent). Almost 6 miles of the IH 94 corridor runs north-south through the western portion of the watershed and crosses an upstream reach of Oak Creek. The watershed also contains a portion of the Milwaukee Mitchell International Airport that drains into the Mitchell Field Drainage Ditch before flowing into Oak Creek. While every subwatershed within the Oak Creek watershed is quite urbanized, the Lower Oak Creek and Mitchell Field Drainage Ditch

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[18] Comparison of land use trends from 1963 to 2020 is only possible for portions of the watersheds and subwatersheds that are within the seven-county Commission planning area where historical land use inventories are available.

subwatersheds had the highest density of urban land uses, accounting for 90 and 81 percent of those areas, respectively (see Map 2.8). The North Branch Oak Creek, Upper Oak Creek, and Lower Oak Creek subwatersheds each have more than 20 percent of their lands developed as roads and parking lots (see Map 2.9). All subwatersheds have experienced significant urbanization since 1963, with the western portion of the watershed, consisting of the Upper Oak Creek and North Branch Oak Creek subwatersheds, seeing the greatest increases at 57 and 45 percent of their areas, respectively (see Map 2.5). These subwatersheds also experienced the largest increase in roads and parking lot development since 1963 (see Map 2.6).

The Oak Creek watershed encompassed portions of six civil divisions (see Map A.12). In 2010, the watershed had an estimated population of 56,580, and all areas had connections to public sanitary sewers and wastewater treatment facilities as of 2010. The watershed is served by the MMSD and the South Milwaukee wastewater treatment facilities, which are located outside of the watershed in the direct drainage area to Lake Michigan. There were no other WWTPs that operated within the watershed in the past. A portion of the watershed is served by a public water utility providing Lake Michigan water supply.

Pike River Watershed

The Pike River watershed is located in the southeast portion of the study area and covers approximately 51 square miles. The mainstem of the Pike River originates at the confluence of the North Branch and South Branch Pike Rivers in northeastern Kenosha County and flows approximately 9.6 miles in an easterly and then southerly direction to its confluence with Lake Michigan. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide.

In 2015, existing land use in the watershed was more rural (54.8 percent) than urban (45.2 percent), with the most common land uses consisting of agricultural lands (39.5 percent), roads and parking lots (11.2 percent), lower-density residential (8.6 percent), medium-density residential (6.9 percent), and rural unused lands (6.6 percent) (see Table 2.1 and Map A.13). The northern and eastern portion of the watershed, including the Lower Pike River and Upper Pike River subwatersheds contain the most urban development, with urban land uses accounting for over 50 percent of each area (see Map 2.8). These two subwatersheds also contain the largest amount of roads and parking lots in the watershed, accounting for 14 and 13 percent of their total areas, respectively (see Map 2.9). The Upper Pike River subwatershed has experienced the largest increase in both urban land use and road and parking lot density since 1963 (see Map 2.5 and Map 2.6).

The Pike River watershed contains portions of eight civil divisions (see Map A.14). In 2010, the watershed had an estimated population of 51,610. Approximately 98 percent of that population resided in areas that had connections to public sanitary sewers and were served by either the Racine or Kenosha wastewater treatment facilities which are located outside of the watershed. There were two wastewater treatment facilities (Sommers and Sturtevant) that once operated in the watershed but have since been abandoned (see Map A.14 for locations of abandoned facilities and Table 2.2 for receiving waters and other facility information). A portion of the watershed is served by public water utilities providing Lake Michigan supply.

Rock River Watershed

The mainstem of the Rock River does not flow within the study area of the Chloride Impact Study, however, many tributaries to the River drain approximately 632 square miles of the watershed that covers much of the western edge of the study area. The portion of the Rock River watershed that is within the study area includes the western potions of Washington, Waukesha, and Walworth Counties. Rivers and streams in the watershed are part of the Mississippi River drainage system as the watershed lies west of the subcontinental divide.

Recent existing land use inventories in the watershed indicate that the watershed was mostly rural (80.6 percent) consisting primarily of agricultural lands (47.9 percent) and wetlands (13.0 percent). Other common land uses include woodlands (9.2 percent), lower-density residential (8.5 percent), rural unused lands (6 percent), and roads and parking lots (5.5 percent) (see Table 2.1 and Maps A.15 and A.17). While the Rock River watershed does not have any subwatersheds with more urban than rural land uses, the most urban subwatersheds are located in the west-central portion of the watershed in the Genesee Lake, Bark River, Pine Lake, and Oconomowoc River subwatersheds, with urban land use ranging from 31 to 38 percent of those areas (see Map 2.8). The watershed has a relatively low road and parking lot density compared to other watersheds in the study area, with only the Genesee Lake subwatershed rising above 10 percent (see Map 2.9). However, the watershed does contain approximately 16 miles of IH 41 corridor, 10 miles of IH 94 corridor, and 16 miles of IH 43 corridor. The Genesee Lake and Bark River subwatersheds have experienced the largest increase in urban land uses since 1963 (see Map 2.5). The Genessee Lake and Battle Creek subwatersheds have seen the largest increase in roads and parking lot density (see Map 2.6).

The portion of the Rock River watershed that is within the study area covers portions of 56 civil divisions (see Maps A.16 and A.18). In 2010, the watershed had an estimated population of 155,440. Approximately 61 percent of that population resided in areas that had connections to public sanitary sewers and wastewater treatment facilities as of 2010. Currently there are ten active WWTPs that discharge treated wastewater within the watershed. There were an additional six WWTPs that once operated in the watershed but have since been abandoned (see Maps A.16 and A.18 for active and abandoned facility locations and

Table 2.2 for receiving waters and other facility information). A portion of the watershed is served by public water utilities providing groundwater.

Root River Watershed

The Root River watershed is located in the southeastern portion of the study area and covers approximately 198 square miles. The mainstem of the Root River originates in eastern Waukesha County and flows approximately 44 miles in a southerly and easterly direction to its confluence with Lake Michigan in the City of Racine. Tributaries of the Root River extend into Kenosha, Milwaukee, Racine, and Waukesha Counties. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide.

In 2015, existing land use in the watershed was mostly rural (62.6 percent) consisting primarily of agricultural lands (44.4 percent). Other common land uses include lower-density residential (11.8 percent), roads and parking lots (10 percent), wetlands (7.4 percent), and medium-density residential (5.1 percent) (see Table 2.1 and Map A.19). Approximately 11 miles of the IH 94 corridor traverses north-south across the watershed. The northern part of the watershed that includes the Upper Root River, East Branch Root River, and Whitnall Park Creek subwatersheds are highly urban, with 91, 75, and 71 percent of their areas in urban land uses, respectively (see Map 2.8). The same subwatersheds also have the highest density of roads and parking lots, ranging from 16 to 26 percent of the subwatershed areas (see Map 2.9). The East Branch Root River subwatershed has experienced the largest increase in urban land use since 1963 (see Map 2.5). In addition to the subwatersheds described above, the southeastern downstream-most portion of the watershed, where the Root River runs through the City of Racine near its confluence with Lake Michigan, is also highly urbanized.[19]

The Root River watershed includes portions of 19 civil divisions (see Map A.20). In 2010, the watershed was home to an estimated 179,010 residents. Approximately 94 percent of that population resided in areas of the watershed that had connections to public sanitary sewers and wastewater treatment facilities as of 2010. The Union Grove and Yorkville WWTPs are currently active and discharge treated wastewater within the watershed. There were an additional four WWTPs that once operated in the watershed but have since been abandoned (see Map A.20 for locations of active and abandoned facilities and Table 2.2 for receiving waters

[19] *This area is located within the Lower Root River subwatershed, a large area that also contains a large amount of agricultural lands. For this reason, Maps 2.8 and 2.9 are somewhat misleading in the representation of this highly concentrated urban area in the City of Racine near the Root River confluence with Lake Michigan.*

and other facility information). A portion of the watershed is served by public water utilities providing both groundwater and Lake Michigan water supply.

Sauk Creek Watershed

The Sauk Creek watershed is located in the northeastern part of the study area and covers approximately 35 square miles of Ozaukee County and a small part of Sheboygan County. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide. The headwaters of the mainstem of Sauk Creek begin northeast of the Village of Fredonia. From there, the Creek flows east and then south to its confluence with Lake Michigan in the City of Port Washington.

Recent existing land use inventories in the watershed indicate that the watershed was largely rural (85.6 percent), consisting primarily of agricultural lands (72.5 percent). The eastern portion of the Village of Fredonia near the Sauk Creek headwaters and the downstream portion of the watershed located in the City of Port Washington were the only urbanized areas in the watershed, accounting for the majority of the roads and parking lots (5.4 percent), and lower- and medium-density residential land uses (2.4 and 2.3 percent, respectively) (see Table 2.1 and Map A.21). While the watershed has one of the lowest road densities in the study area, approximately two miles of IH 43 corridor runs east-west across the watershed and crosses Sauk Creek about two miles upstream of the confluence with Lake Michigan. The watershed has experienced relatively small increases in urban land uses and road and parking lot density since 1963 (see Map 2.5 and Map 2.6).

The Sauk Creek watershed contains portions of 10 civil divisions (see Map A.22). In 2010, the watershed had an estimated population of 9,730. Approximately 88 percent of that population resided in areas that had connections to public sanitary sewers and were served by either the City of Port Washington or the Village of Fredonia WWTPs which are both located outside of the watershed. There are no active or abandoned WWTPs that have discharged treated wastewater within the Sauk Creek watershed. A portion of the watershed is served by public water utilities providing both groundwater and Lake Michigan water supply.

Sheboygan River Watershed

The portion of the Sheboygan River watershed that is within the study area of the Chloride Impact Study covers 11 square miles in the northern portion of Ozaukee County. This portion of the watershed contains the headwaters of the Onion River which flows north, out of the study area, and eventually into the

Sheboygan River near the City of Sheboygan Falls. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide.

In 2015, existing land use in the portion of the watershed in the study area was largely rural (90.8 percent), consisting primarily of agricultural lands (68.3 percent), wetlands (11.9 percent), and rural unused lands (8.8 percent) (see Table 2.1 and Map A.23). The watershed had very little urban land uses with roads and parking lots (3.0 percent), lower-density residential (1.7 percent), and medium-density residential (1.4 percent) the most common urban development in the watershed. This area has experienced minimal increases in urban development since 1963 (see Map 2.5 and Map 2.6).

This portion of the watershed contains parts of the Town and Village of Belgium and had an estimated population of 1,550 in 2010. Approximately 87 percent of that population resided in areas that had connections to public sanitary sewers and were served by the Belgium Wastewater Treatment Facility, which discharges the treated wastewater within the watershed (see Map A.24 for locations of active and abandoned facilities and Table 2.2 for receiving waters and other facility information). A small portion of the watershed is served by a public water utility providing groundwater water supply.

Direct Drainage Area to Lake Michigan

The Lake Michigan direct drainage area is a limited area drained by many small streams, drainage swales, and storm sewers discharging directly to Lake Michigan. This collection of small watersheds covers an area of approximately 94 square miles stretching along much of the coastline in the study area. The boundaries of the drainage areas and the streams within them are shown adjacent to (from north to south) the Sheboygan River, Sauk Creek, Milwaukee River, Kinnickinnic River, Oak Creek, Root River, Pike River, and Des Plaines River watersheds (see Map 2.2).

In 2015, existing land use in this area was more urban (63.4 percent) than rural (36.6 percent), however the largest land use category in the drainage area was agricultural lands (18.7 percent). Other common land uses included roads and parking lots (16.0 percent), lower-density residential (11.3 percent), medium-density residential (9.6 percent), and high-density residential (9.1 percent) (see Table 2.1, Figure A.1, and Maps A.5, A.9, A.13. A.19, and A.23). The Pike Creek (located in the southern portion of the drainage area, adjacent to the Pike River watershed) and Fish Creek (located in the central portion of the drainage area, adjacent to the Milwaukee River watershed) subwatersheds are heavily urbanized, with 92 and 86 percent of their drainage areas in urban land uses, respectively (see Map 2.8). The Pike Creek subwatershed also has the highest density of roads and parking lots (see Map 2.9). The Fish Creek, Barnes Creek, and Pike Creek subwatersheds experienced the largest increases in urban land uses since 1963 (see Map 2.5).

The Direct Drainage Area to Lake Michigan covers portions of 27 civil divisions (see Maps A.6, A.10, A.14, A.20, and A.24). In 2010, the drainage area had an estimated population of 217,570. Approximately 99 percent of that population resided in areas that had connections to public sanitary sewers and were served by wastewater treatment facilities. Currently there are six active wastewater treatment facilities within the Direct Drainage Area to Lake Michigan, all of them discharge treated wastewater to Lake Michigan. There were two additional WWTPs that once operated within the drainage area but have since been abandoned (see Map 2.10 for active and abandoned facility locations and Table 2.2 for receiving waters and other facility information). A portion of the drainage area is served by public water utilities providing Lake Michigan water supply and a very small area near the Village of Belgium is served by a public water utility supplying groundwater.

2.2 REGIONAL CLIMATE CONDITIONS AND TRENDS

Climate is a primary driver of the hydrologic cycle and can have a significant effect on chloride in the environment, as discussed in a separate technical report prepared for this Study.[20] The mid-continental location of the Southeastern Wisconsin Region, far removed from the moderating effect of the oceans, gives the study area a typical continental climate, characterized primarily by a continuous progression of markedly different seasons and a large range in annual temperature. Low temperatures during winter are intensified by prevailing frigid northwesterly winds, while summer high temperatures are reinforced by the warm southwesterly winds common during that season.[21]

The Region exhibits spatial variations in weather due primarily to its proximity to Lake Michigan, particularly during the spring, summer, and autumn seasons, when the temperature differential between the lake water and the land air masses tends to be the greatest. During these periods, the presence of the Lake tends to moderate the climate of the eastern portion of the Study Area.

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[20] *Technical Report No. 62,* Impacts of Chloride on the Natural and Built Environment, *April 2024.*

[21] *In meteorology and climatology, the seasons are defined based on the calendar with three-month durations as follows: Winter spans from December through February, Spring runs from March through May, Summer extends from June through August, and Autumn covers the period from September through November.*

Despite the weather variability across the Region, from a climate perspective the Southeastern Wisconsin Region is considered similar enough to be entirely encompassed by one of the nine climate divisions in Wisconsin. The U.S. Climate Divisional Dataset was developed by the National Oceanic and Atmospheric Administration (NOAA) to divide the contiguous United States into regional areas that have relatively uniform climate characteristics. The boundaries of Wisconsin Climate Division 9 match the seven-county Region in Southeastern Wisconsin, and the climate data for Climate Division 9 were used to characterize the climatological conditions in the Region as presented in the following paragraphs.

Climate Data

NOAA's National Centers for Environmental Information (NCEI, formerly the National Climatic Data Center or NCDC) maintains one of the most comprehensive climate data archives in the world. The NCEI climate datasets provide the underlying data source for most of the information presented in this section. The national climate datasets for temperature and precipitation within Wisconsin Climate Division 9 extend back to 1895 and have been compiled from meteorological data collected at stations within the Region.[22] The NCEI does not provide similar long-term datasets for snowfall. Monthly snowfall data for the Region was obtained from the Wisconsin State Climatology Office, which maintains snowfall datasets for each climate division from 1950 to present.[23]

Historical climate trends and associated data were also obtained from the 2011 and 2021 WICCI reports on Wisconsin's changing climate and the latest climate trend data published on the WICCI website, which covers the period of record from 1950 to 2023.[24] Longer-term trends for temperature and precipitation data in the Region were obtained from the NCEI.[25] While some long-term variability data is presented herein, the climate trends discussed in this section largely focus on a more recent period extending back to 1950, matching the Wisconsin Initiative on Climate Change Impacts (WICCI) approach to reporting climate trends. The 2011 WICCI report on climate change explains that using 1950 as the starting point for analyzing climate

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[22] *NOAA National Centers for Environmental Information,* Climate Division Datasets (nClimDiv), *www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ncdc:C00005, accessed August 2024.*

[23] *Wisconsin State Climatology Office,* Wisconsin Climate Divisions: Divisional 12-Month Snowfall, *climatology.nelson.wisc.edu/wisconsin-climate-divisions/divisional-12-month-snowfall, accessed August 2024.*

[24] *Wisconsin Initiative on Climate Change Impacts (WICCI),* Trends and Projections, wicci.wisc.edu/wisconsin-climate-trends-and-projection, *accessed August 2024.*

[25] *NOAA National Centers for Environmental Information,* Climate at a Glance: Divisional Time Series, *www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/divisional/time-series/4709, accessed August 2024.*

trends is preferrable because the data collected at weather stations since 1950 are more reliable and consistent than earlier data.[26] Furthermore, many of the water quality datasets gathered for this technical report start in the 1960s which coincides well with the WICCI climate trend period.

Climate Normals

U.S. Climate Normals are developed by NOAA's NCEI every 10 years and represent typical or average climatological conditions over a 30-year period. Climate normals are often used as a baseline for climate data comparisons, and departures from normal represent the difference between a specific meteorological observation and the 30-year average. The 30-year period is considered long enough to dampen the influence of short-term fluctuations and anomalies. The 1991-2020 climate normals for the Region are presented in Table 2.ClimateNorms, and show the 30-year averages for temperature, precipitation, and snowfall on a monthly basis, along with average annual temperatures and annual precipitation and snowfall totals.

Data for the three most-recent climate normals was obtained from the Wisconsin State Climatology Office website, covering the periods 1971-2000, 1981-2010, and 1991-2020.[27] The 1991-2020 climate normals represent the current average conditions for the Region, and comparisons with previous climate normals highlight how average conditions have changed over time. Figure 2.ClimNormCompTemp compares the monthly mean temperature from the three climate normal periods. The figure demonstrates a slight increasing mean temperature trend when looking at 30-year averages, with a more significant increase observed during the fall and winter months (September through February). Similar comparisons of monthly precipitation and snowfall totals are presented in Figure 2.ClimNormCompPrecip and Figure 2.ClimNormCompSnow, respectively. While the 30-year average annual precipitation totals show an increase over time, the monthly precipitation totals demonstrate mixed trends. The 30-year average annual snowfall totals indicate an overall decrease, with decreasing trends for most months except for February which shows a significant increase in snowfall over time.

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

[27] *Wisconsin State Climatology Office,* Wisconsin Climate Divisions: Divisional Climate Normals, *climatology.nelson.wisc.edu/wisconsin-climate-divisions/climate-normals, accessed August 2024. (Note: the climate normal data was compiled by the NCEI)*

Temperature

The average annual mean temperature in the Region is 47.1 degrees Fahrenheit (ºF) based on the most recent climate normals (1991-2020). Throughout the year the average daily temperatures range from 20.7ºF in January to 71.3ºF in July as shown in Table 2.ClimateNorms. Mean monthly temperatures during the study period from 2018 through 2021 are shown in Table 2.MeanTemps. Figure 2.TempDepart presents the monthly temperature departures from normal during the study period; positive departures indicate warmer than normal temperatures and negative departures represent colder than normal conditions. During the winter months, typically defined by meteorologists and climatologists as December, January, and February, the normal daily high temperatures range from 28.3ºF to 33.5ºF and the normal daily low temperatures range from 13.0ºF to 19.2ºF. For the 2018-2021 study period, the mean monthly temperature departures from normal were fairly random, with the exception of a warmer than normal winter 2019-2020 and a warmer overall 2021.

When evaluated over a variety of timescales, mean temperatures show increasing trends across the Region. The latest historical climate trends published on the WICCI website cover the period from 1950 to 2023. Figure 2.TempTrends presents the change in annual average daily temperatures and average daily winter temperatures from 1950 to 2023. The annual average daily temperature in the Region has increased by 2ºF to 3ºF since 1950. The warming trends are more significant during the winter months, with average daily winter temperatures increasing by about 4ºF to 5ºF over the same time period. Long-term temperature variability for the Region can also be evaluated going back to 1895, and Figure 2.TempLongTerm presents the average annual daily mean temperature compared to the long-term 1901-2000 average daily temperature. The long-term average winter temperatures for the Region are shown in Figure 2. WinterTempLongTerm and demonstrate a significant winter warming trend. The average rate of increase for winter season mean temperatures from 1950 to 2023 is approximately 0.6 degrees per decade, which is double the average rate of increase for annual mean temperatures over the same period. The long term data extending back to 1895 indicate that for the study period of 2018-2021 both the annual and winter air temperatures were warmer than the long term average, but not atypical for temperatures observed since about 2000.

The 2021 WICCI report indicates that Wisconsin winters are warming more rapidly than summers and nighttime low temperatures are warming faster than daytime high temperatures.[28] Overall, Wisconsin's warming climate is having the greatest effect on colder weather periods with fewer extended stretches of extreme cold temperatures.

Precipitation

Precipitation within the Southeastern Wisconsin Region takes the form of rain, sleet, hail, and snow. Climatological records for precipitation data represent the liquid water equivalent and depth totals include all forms of liquid and frozen precipitation. The Southeastern Wisconsin Region receives on average 35.3 inches of precipitation per year, and nearly three-quarters of this precipitation falls within the months of April through October. June is typically the wettest month of the year and the driest periods occur during the winter months. Precipitation conditions varied widely over the course of the Chloride Impact Study, and monthly precipitation totals during the study period are summarized in Table 2.PrecipStudyPeriod. Overall, 2018 and 2019 were much wetter than average. Based on climate division rankings for the period from 1895 to 2024, 2019 holds the record as the wettest year in Southeastern Wisconsin and 2018 ranks as the second wettest year.[29] Figure 2.PrecipDepart presents the monthly precipitation departures from normal during the study period; positive departures indicate wetter than normal conditions and negative departures represent drier than normal conditions. Wetter than normal conditions at the beginning of the Study transitioned to predominantly drier than normal conditions by the end of the Study.

Recent precipitation trends indicate that Wisconsin is getting wetter, and the decade from 2010-2019 was the wettest decade on record.[30] Figure 2.PrecipTrends shows the statewide historical changes in annual precipitation and winter season precipitation from 1950 to 2023. While there was substantial variability in the change in precipitation statewide, five out of seven counties in the Region exhibited significant increasing precipitation trends. During the winter months, the seasonal precipitation total for the entire Region shows a significant increasing trend of approximately 20% from 1950 to 2023. The long-term variability of total annual precipitation in the Southeastern Wisconsin Region from 1895 to 2023 is shown

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[28] *Wisconsin Initiative on Climate Change Impacts (WICCI),* Wisconsin's Changing Climate: Impacts and Solutions for a Warmer Climate, *Nelson Institute for Environmental Studies, University of Wisconsin-Madison and Wisconsin Department of Natural Resources, 2021.*

[29] *NOAA National Centers for Environmental Information,* Climate at a Glance: Divisional Rankings, *www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/divisional/rankings, accessed August 2024.*

[30] *WICCI, 2021,* op. cit.

in Figure 2.PrecipLongTerm, comparing the annual precipitation with the long-term 1901-2000 average of 31.9 inches.[31] Based on the NCEI climate divisional time series for Southeastern Wisconsin, annual precipitation totals in the Region have increased at an average rate of +0.46 inches per decade from 1895 to 2023. More significant precipitation trends have been observed in recent decades with an average rate of increase of +0.72 inches per decade from 1950 to 2023. Overall, the WICCI study concluded that Wisconsin is experiencing more extreme rainfall events, with increased frequency and magnitude.[32]

Snowfall

Based on the 1991-2020 climate normals, the Region receives on average 42.3 inches of snow annually, with nearly 80 percent falling within the months spanning from December through February. The snowfall data is reported as the average of the actual snowfall depth measured at all available stations across the Region. Table 2.SnowStudyPeriod presents the monthly snowfall totals for each winter season of the Chloride Study. Figure 2.SnowDepart presents the monthly snowfall departures from normal during the study period. Based on this data, the 2018-2021 study period had significant monthly departures from normal snowfall totals; however, considering the winter season snowfall totals overall, winter 2018-2019 had higher than normal snowfall, while the snowfall totals for the winters 2019-2020 and 2020-2021 were near normal.

The WICCI evaluation does not include data on snowfall trends, but some conclusions may be drawn from the snowfall dataset for the Southeastern Wisconsin Region maintained by the State Climatology Office. Figure 2.SnowSeasonRegion presents the total snowfall for every winter season from 1950-1951 to 2023-2024. The average seasonal snowfall for the Region over the entire period of record is 42.5 inches. The maximum snowfall for one winter season was 93.8 inches recorded during the 2007-2008 winter. The highest seasonal snowfall is over 18 inches greater than the second highest snowfall total recorded during winter 1951-1952. The lowest snowfall total of 12.3 inches was recorded during the 1967-1968 winter season, nearly 10 inches less than the second lowest seasonal snowfall on record. This data show the variability of snowfall from one winter to another, but no discernible trend was observed. Additionally, the seasonal snowfall totals during the 2018-2021 study period were within the range of historical values.

[31] When working with annual precipitation data, it's important to note that the total precipitation in a year may be relatively close to the average but the monthly precipitation totals can vary widely from extreme drought conditions to severe flood conditions.

[32] WICCI, 2021, op. cit.

The Wisconsin State Climatology Office also tracks weather extremes and records. The statewide record one-day snowfall for February occurred in Walworth County on February 2, 2011 during the Groundhog Day blizzard. Much of the Region was blanketed in snow and 26 inches of snow was recorded at the former Pell Lake wastewater treatment facility in the Village of Bloomfield, tying the all-time statewide one-day snowfall record.[33]

2.3 RELATIVE MEASURES OF WINTER SEVERITY

Several factors affect the amount of road salt applied to transportation networks during any given winter season. These factors include the extent of the transportation network, winter maintenance policies, public expectations, and the harshness or severity of the winter season. Weather conditions have a significant influence on the timing and quantity of salt applications and can vary widely from year to year. Across the United States, different methods and indices have been developed to represent the harshness of winter weather conditions, and the two relative measures of winter severity that were considered for the Chloride Impact Study are described below. These measures of winter severity are intended to be used for comparing the relative severity of winter seasons to one another; hence, the absolute value is not as meaningful as a relative comparison with other winter seasons to provide historical context.

WisDOT Winter Severity Index

In 1995, the Wisconsin Department of Transportation (WisDOT) began developing a metric to compare severity of winter seasons. The Winter Severity Index (WSI) was developed to support winter road maintenance management using storm report data submitted by each County. This index is derived from several weather and transportation related criteria that are important to highway maintenance authorities including snow events, freezing rain events, snow amount, storm duration, and occurrence of incidents such as blowing and drifting snow, frost, and cleanup runs. The WisDOT WSI data were obtained from two sources for the Chloride Impact Study. The end-of-season WSI values for the seven counties in the Southeastern Wisconsin Region from the 2001-2002 winter season through the 2022-2023 winter season were obtained from the winter storm report system end-of-season reports through the WisTransPortal system. This system is maintained by the Wisconsin Traffic Operations and Safety (TOPS) Laboratory,

[33] *Wisconsin State Climatology Office,* Historic Climate Data: Statewide Extremes*, climatology.nelson.wisc.edu/wisconsin-historic-climate-data/statewide-extremes, accessed September 2024*.

established at the University of Wisconsin-Madison in partnership with WisDOT.[34] Published WSI values from the 1992-1993 winter season to the 2000-2001 winter season were obtained from the Annual Winter Maintenance Report for the 2001-2002 winter season.[35] Additional information related to the WSI is available through the WisDOT Annual Winter Maintenance Reports.

Figure 2.WSI presents the average WSI for the Southeastern Wisconsin Region for the full period of record from 1992-1993 to 2022-2023. The WSI scale is unitless and the average WSI for the Region ranges from 44.4 for the 2001-2002 winter season to 119.3 for the 2013-2014 winter season. The regional average WSI was computed from the annual WSIs published for each County in the Region, with an adjustment factor applied to WSI values prior to the 2013-2014 winter season. The adjustment was necessary because the WSI equation has been modified slightly over the 30-year data record, and the baseline data used for comparison has evolved over time; however, a standard baseline for comparison was established for the 2013-2014 winter season and has been used consistently for each winter season since then.[36] The average WSI computed for the Region correlates well with the Regional snowfall data maintained by the Wisconsin State Climatology Office, as shown in Figure 2.WSIsnow. The computed WSI also correlates well with historical WisDOT road salt usage in the Region. Figure 2.WSIsalt demonstrates how trends in the regional average WSI generally correspond to the quantity of road salt applied to State Highways and Interstates in the Region from the 2001-2002 winter season to 2022-2023.

MRCC Accumulated Winter Season Severity Index

The Midwestern Regional Climate Center (MRCC) at Purdue University developed the Accumulated Winter Season Severity Index (AWSSI) to describe the relative severity of winter seasons from year to year.[37] The AWSSI is an objective index computed using daily temperature, snowfall, and snow depth data collected at National Weather Service (NWS) weather stations. Additionally, the MRCC uses data collected at these

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[34] *University of Wisconsin-Madison Wisconsin Traffic Operations and Safety (TOPS) Laboratory,* WisTransPortal System*, www.transportal.cee.wisc.edu/storm-report, accessed July 25, 2023.*

[35] *T.J. Martinelli,* Wisconsin Department of Transportation Annual Winter Maintenance Report: 2001-2002 Season*, July 2002.*

[36] *To account for the baseline data shift and to allow for relative comparisons over the entire period of the published WSI data record, an adjustment factor of 2.985 has been applied to WSI data prior to the 2013-2014 winter season based on discussions with WisDOT.*

[37] *B.E. Mayes Boustead, S.D. Hilberg, M.D. Shulski, and K.G. Hubbard,* The Accumulated Winter Season Severity Index (AWSSI)*, Journal of Applied Meteorology and Climatology, 54(8): 1693-1712, August 2015.*

stations to define the duration of each winter season in the record employing consistent, objective criteria to retrospectively establish the start and end dates each year. Milwaukee Mitchell International Airport (MMIA) is the only station in the Southeastern Wisconsin Region with AWSSI data, and the data for this station were downloaded directly from the MRCC website.[38] Figure 2.AWSSI shows the AWSSI for Milwaukee from the 1950-1951 winter season through 2022-2023. Similar to the WSI, the AWSSI scale is unitless and the values range from 337 for the 2011-2012 winter season to 1537 for the 1978-1979 winter season.

Comparison of Winter Severity Indexes

The two indices were evaluated and compared to one another for use in the Chloride Impact Study. For most purposes, the WisDOT WSI is the preferred relative measure of winter severity for the Study because it provides good coverage of the Region and is better correlated to winter road maintenance activities and road salt usage than the AWSSI. It should be noted that the AWSSI does not account for some winter weather conditions that can influence the application of road salt such as freezing rain, mixed precipitation, blowing or drifting snow, and frost. Additionally, the AWSSI considers only temperature and snowfall observed at one location in the Region. Despite these limitations, the AWSSI is an objective, data-driven metric that allows for comparisons of winter seasons from 1950 to present day.

While the WisDOT WSI was originally developed to facilitate winter road maintenance management, the index has some limitations. Changes to the WSI equation and the baseline comparison data over time may pose issues when comparing WSI values across the full 30-year data record. Additionally, the input data used to compute this index are subjective. Historically these data have been self-reported by the Counties, and the subjective nature of the data reporting may create inconsistencies between counties or from one year to another. In 2014, WisDOT started computing the WSI using data automatically collected and reported through the Maintenance Decision Support System (MDSS) instead of the storm report data submitted by the Counties. This change allowed for a more objective representation of winter weather conditions across the state while addressing some of the limitations of the earlier WSI data.

The AWSSI data trends generally compare well with WisDOT WSI trends, supporting the validity of the latter. Figure 2.WSIvAWSSI shows the WisDOT WSI and the AWSSI from 1992-1993 to 2022-2023. While the index scales are different, the figure illustrates how the index trends generally correspond to each other. Overall, the WisDOT WSI is considered acceptable for comparing winter seasons and provides context for salt usage

[38] *Midwestern Regional Climate Center*, Accumulated Winter Season Severity Index (AWSSI), *accessed February 13, 2024 through www.mrcc.purdue.edu/research/awssi.*

and chloride data over the last 30 years for the Study. Both the WSI and AWSSI indicate that the winters during the 2018-2021 study period were fairly representative of past winters and not unusually severe as compared to the periods of record.

2.4 SOURCES OF CHLORIDE

[To be completed.]

2.5 WATER QUALITY STANDARDS

The State of Wisconsin has issued water quality standards for surface water, groundwater, and drinking water to protect human health and the quality of the environment. Water quality standards describe how clean the water needs to be for the desired uses. By setting limits on the amounts of pollutants that can be present, these standards serve as the basis for regulation of water resources.

Surface Water Quality Standards

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

Surface water quality standards consist of three elements: designated uses, water quality criteria, and antidegradation policy. Designated uses consist of goals for the types of uses that each waterbody is expected to support. A given designated use may include levels of use applying to different types of waterbodies. Waterbodies in Wisconsin have uses designated for fish and aquatic life, public health and welfare, recreation, and wildlife.

Water quality criteria consist of statements that set the level of water quality needed to support a designated use. These statements may consist of numerical thresholds that set limits on the levels of water quality constituents or narrative statements describing conditions that support or do not support the designated use. Water quality criteria are used both to evaluate water quality conditions and to develop effluent limitations on pollutants as part of developing discharge permits under the Wisconsin Pollutant Discharge Elimination System.

Antidegradation policy consists of policies and implementation procedures designed to protect surface waters from degradation. Antidegradation policy includes the protection of high-quality waters. The State of Wisconsin has identified these by designating surface waters that are not significantly impacted by human activities that provide valuable fisheries, hydrologically or geologically unique features, outstanding recreational opportunities, or unique environmental settings as either outstanding or exceptional resource waters. Classification as an outstanding or exceptional resource water places some limitations on new or increased discharges into the waterbody from point sources. Outstanding resource waters typically do not have any point source discharges, while exceptional resource waters had existing point sources at the time of designation. The outstanding and exceptional resource waters located in the study area for the Chloride Impact Study are shown on Map 2.ORW_ERW and listed in Table 2. ORWandERW. For the entire study area there are six outstanding resource waters and seven exceptional resource waters. These waters are predominantly in more upstream and rural subwatersheds.

Wisconsin Chloride Aquatic Toxicity Standards

Wisconsin surface water quality standards are set forth in Chapters NR 102, "Water Quality Standards for Wisconsin Surface Waters," NR 103, "Water Quality Standards for Wetlands," NR 104, "Uses and Designated Standards," NR 105, "Surface Water Quality Criteria and Secondary Values for Toxic Substances," and NR 207, "Water Quality Antidegradation and Antibacksliding," of the *Wisconsin Administrative Code*.

Water quality standards specify certain criteria that must be met to ensure that the designated uses of waterbodies are supported. Wisconsin has issued two water quality criteria for chloride that support the fish and aquatic life use for all streams and lakes. The chronic toxicity criterion for chloride is 395 milligrams per liter (mg/l). A waterbody exceeds this criterion if the four-day average of the daily maximum concentrations of chloride taken over four consecutive days is greater than this value more than once in a three-year period. The acute toxicity criterion is 757 mg/l. A waterbody exceeds this criterion if the daily maximum concentration of chloride is greater than this value more than once in a three-year period. A waterbody that does not meet either of these criteria is considered to be not supporting its fish and aquatic life use.

Under the CWA, waterbodies that are not attaining their designated uses are considered impaired waters. Section 303(d) of the CWA requires that states periodically submit a list of impaired waters to the U.S. Environmental Protection Agency (USEPA) for approval. The State of Wisconsin most recent list was approved by the USEPA in 2024. Table 2.ChlorideImpaired and Map 2.Chloride_Impaired indicate the stream reaches in the Southeastern Wisconsin Region (Region) that were listed as impaired for chloride as of 2024. Currently, impairments are present in 33 streams for chronic toxicity due to chloride. In addition, 23 of these streams are impaired for acute toxicity due to chloride. No lakes in the Region have been listed as impaired due to acute or chronic toxicity from chloride. It should be noted that the absence of a waterbody or a particular impairment for a waterbody from the impaired waters list does not necessarily mean that conditions in the waterbody meet all applicable water quality standards. In some instances, this absence reflects a lack of adequate or sufficient data to determine whether impairments are present.

USEPA Recommended Aquatic Toxicity Standards

The USEPA has also issued recommended water quality criteria for chloride to support the aquatic life use in freshwater surface waterbodies. These criteria are recommendations to states and tribes and do not have regulatory significance unless a state adopts them into their water quality standards. States may either adopt the recommended criteria or adopt alternative criteria that are scientifically defensible. As discussed in the previous section, Wisconsin has adopted other criteria for chloride that serve as the basis for regulation in the State. Despite this, the USEPA recommended criteria provide an additional basis for evaluating potential impacts of chloride concentrations in waterbodies.

USEPA has issued two aquatic life criteria for chloride. The criterion continuous concentration (CCC) is analogous to the chronic toxicity criterion. Under the CCC, the four-day average concentration of chloride is not to exceed 230 mg/l more than once in three years. The criterion maximum concentration (CMC) is analogous to the acute toxicity criterion. Under the CMC, the one-hour average concentration of chloride is not to exceed 860 mg/l more than once in three years. USEPA guidance notes that these criteria were developed using chloride that is associated with sodium and that they probably will not be adequately protective of aquatic life when chloride is associated with potassium, calcium, or magnesium.[39]

Groundwater and Drinking Water Quality Standards

Wisconsin has issued groundwater quality and drinking water quality standards for chloride. Groundwater standards are set forth in Chapter NR 140, "Groundwater Quality," of the *Wisconsin Administrative Code*. Drinking water quality standards are set forth in Chapter NR 809, "Safe Drinking Water," of the *Wisconsin Administrative Code*.

[39] *U.S. Environmental Protection Agency,* Ambient Water Quality for Chloride—1988, *EPA 440/5-88-01, 1988.*

Groundwater Quality Standards

Wisconsin has issued two groundwater quality standards for chloride: a preventive action limit and an enforcement standard. The preventive action limit sets the concentration at which efforts are required to control contamination to minimize concentrations of chloride in groundwater and prevent exceedance of the enforcement standard. It also serves as a design standard for several activities that can affect groundwater quality including contaminated site remediation, authorized discharges of liquid and solid wastes, use of approved agricultural chemicals, regulation of landfills, and regulation of beneficial use of industrial byproducts. The preventive action limit for chloride in Wisconsin is 125 mg/l.

The enforcement standard for chloride sets the concentration at which a response action is required to achieve compliance. The specific type of response can vary depending on the nature of the contamination. It can include such actions as:

- Conducting investigations of the contamination
- Making operational changes to the facility, activity, or practice
- Making design or construction changes to the facility, activity, or practice
- Closure of a facility
- Prohibition of a practice or activity
- Conduct of remediation activities

The enforcement standard for chloride in Wisconsin is 250 mg/l.

Specific conductance, a measure of the ability of water to conduct electricity, is often used as a surrogate for chloride concentration. Wisconsin has issued a protective action limit for specific conductance in groundwater. Under this standard, an increase in specific conductance above background conditions of 200 microSiemens per centimeter or more is considered an exceedance of the preventive action limit. Wisconsin has not issued an enforcement standard for specific conductance.

Drinking Water Standards

In accordance with the Federal Safe Drinking Water Act (SDWA), Wisconsin has established drinking water quality standards to protect public health, safety, and welfare. These standards apply to public drinking water systems, which are defined as systems that provide water to the public. Any water system that has 15 or more service connections or serves an average of 25 or more people for at least 60 days during the year is considered a public drinking water system.[40]

Drinking water standards include both primary standard and secondary standards. Primary drinking water standards represent minimum standards to protect public health. Secondary drinking water standards are limits on aesthetic parameters that represent public welfare concerns but not public health concerns. Secondary drinking water standards are set for substances that can cause undesirable tastes, odors, or colors in water; damage water equipment; reduce efficiency of treatment for other contaminants; or cause other undesirable effects. Secondary drinking water standards are not Federally enforceable. They serve as guidelines to public water systems in managing drinking water for aesthetic considerations.

Drinking water standards are expressed in terms of a maximum contaminant level (MCL) that is defined as the maximum permissible level of a contaminant in water that is delivered to a public water supply system. Wisconsin has set an MCL for chloride of 250 mg/l. This is a secondary drinking water standard.

If the Wisconsin Department of Natural Resources receives complaints regarding the aesthetic quality of water provided by a public water supply system, that system may be required to implement a monitoring program to determine whether the quality of the water that it provides complies with the secondary MCL. Should the Department find that the concentration of the substance is objectionable to an appreciable number of people and is detrimental to public welfare, it may require that the water system to take remedial action.

Other Guidelines Related to Chloride

Other guidelines that describe good and poor water quality are available for chloride and related substances. Water quality criteria for chloride from surrounding states and Canada may also provide guidance for interpreting concentrations of chloride in surface waters. Because chloride is often associated with sodium, drinking water advisories for sodium may provide guidance for interpreting concentrations of chloride in drinking water. While these guidelines have no regulatory significance in Wisconsin, they may

[40] *Under the SDWA, serves is defined as making water available to people, not that they are known to drink it.*

indicate chloride concentrations where adverse effects on aquatic organisms and adverse effects on human health might be expected to occur.

Surface Water Quality Standards from Surrounding Jurisdictions

Table 2.WQCriteria shows water quality criteria for Canada and three states surrounding Wisconsin. Minnesota has adopted the chloride toxicity criteria recommended by USEPA. Michigan has adopted final chronic and final acute values, which are analogous to acute and chronic toxicity criteria. Illinois has adopted a single water quality criterion for chloride. The Canadian government has also adopted chloride standards for aquatic life related to acute and chronic toxicity.

Two states, Indiana and Iowa, have adopted water quality criteria for chloride that are dependent on the ambient concentrations of hardness and sulfate. These two states have adopted the same criteria as outlined below. The acute aquatic criterion (AAC) for chloride, which is analogous to the acute toxicity criterion, can be calculated using the formula:

$$AAC = 287.8 \times [hardness]^{0.205797} \times [sulfate]^{-0.07452},$$

where [hardness] indicates the concentration of hardness as $CaCO_3$ and [sulfate] indicates the concentration of sulfate. The units for chloride, hardness and sulfate are mg/l. The chronic aquatic criterion (CAC) for chloride, which is analogous to the chronic toxicity criterion, can be calculated using the formula:

$$CAC = 177.87 \times [hardness]^{0.205797} \times [sulfate]^{-0.07452},$$

where [hardness] indicates the concentration of hardness as $CaCO_3$ and [sulfate] indicates the concentration of sulfate. For water with hardness of 200 mg/l and sulfate concentration of 63 mg/l, the AAC would be 629 mg/l and the CAC would be 389 mg/l.

Drinking Water Advisories

Because much of the chloride that is introduced into the environment consists of sodium chloride, concentrations of sodium in drinking water are also of concern. While no drinking water standards have been issued for sodium, the USEPA has issued two drinking water advisories. These advisories are not regulations. Rather they serve as guidelines to public water supply systems regarding the quality of the water they provide. One advisory is based on the taste that sodium can impart to water and recommends that sodium concentrations in drinking water not exceed 30 to 60 mg/l. The other is a health advisory based on the risks posed by sodium to individuals with salt restricted diets.[41] This advisory recommends that concentrations of sodium in drinking water not exceed 20 mg/l. In addition, water utilities are required to report exceedances of this 20 mg/l level to public health officials so that physicians can advise high-risk patients.

Protectiveness of Existing Standards

The water quality criteria for chloride described previously in this Chapter, including the Wisconsin chloride criteria and the USEPA recommended chloride criteria, were developed using data from laboratory toxicity studies on a small number of species.[42] The effects of chloride and chloride salts on biological communities were not considered in developing these standards. Development and application of these criteria assumes that if the criteria are generally protective for the organisms that were tested, they will be protective for the biological communities in which these organisms reside. This assumption may not be valid.

The impacts of chloride and chloride salts on the natural environment were reviewed in a separate technical report.[43] The studies reviewed in that report document many effects of chloride and chloride salts on organisms and biological communities. These effects occur over a wide range of chloride concentrations. A few of the studies present thresholds at which community effects appear. These thresholds are summarized in Table 2.Thresholds. Impacts for which thresholds have been reported include decreases in organism abundance, reductions in community diversity, changes in community composition, changes in organism physiological processes, and changes in behavior related to the use of habitats by organisms.

Most of the thresholds presented in Table 2.Thresholds are lower than Wisconsin's chronic water quality criterion for chloride (395 mg/l) and many are lower than the USEPA recommended criterion continuous concentration (230 mg/l). This suggests that these water quality criteria may be too high to be fully protective of aquatic communities. It should be noted that these thresholds derive from a small number of studies and may not fully characterize the range of responses aquatic communities might show to chloride enrichment.

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[41] *U.S. Environmental Protection Agency,* Drinking Water Advisory: Consumer Acceptability and Health Effects Analysis on Sodium*, EPA 822-R-03-006, 2003.*

[42] *For Wisconsin criteria, see: Chapter NR 105, Surface Water Quality Criteria and Secondary Values for Toxic Substances,* Wisconsin Administrative Code*. For USPEA criteria, see: U.S. Environmental Protection Agency 1988* op. cit.

[43] *Technical Report No. 62,* Impacts of Chloride on the Natural and Built Environment, *April 2024.*

A recent study presents stronger evidence that current water quality criteria may not be fully protective of aquatic communities.[44] This study established an experimental network of mesocosm experiments at 16 lake sites across North America and Europe. Experiments at these sites used standardized methods to examine the effects of chloride on zooplankton and phytoplankton from natural lake habitats. Each experiment incubated zooplankton and phytoplankton from nearby lakes in 20-32 mesocosms at chloride concentrations ranging between 2 mg/l and 1,500 mg/l. These mesocosms were incubated for 41-51 days. The study examined changes in the abundance of zooplankton species from four groups and phytoplankton biomass over the course of the experiment.

At each study site, the study assessed the concentration of chloride that reduced the abundance of zooplankton in each group by 50 percent. At most sites, this concentration was lower than 230 mg/l, the USEPA recommended criterion continuous concentration (see Table 2.Zooplankton). The study also assessed the magnitude of reductions seen in each of the zooplankton groups at a chloride concentration of 230 mg/l. While there was considerable variation among sites, for all groups reductions greater than 80 percent occurred at some sites (see Table 2.Zooplankton). Food web effects also occurred at some sites, with phytoplankton biomass increasing at 47 percent of sites.

Based on these results, the authors concluded that the current criterion continuous concentration does not protect lake food webs from impacts from chloride salts. Based on a similar analysis, they also concluded that the Canadian chronic toxicity standard of 120 mg/l fails to protect lake food webs. The study authors recommended that these criteria be reassessed.

Total Maximum Daily Loads

Under the CWA, states are required to develop Total Maximum Daily Loads (TMDLs) to address impaired waterbodies that are not meeting water quality standards. A TMDL includes both a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that load among the various sources of that pollutant. The TMDL must also account for

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[44] *W.D. Hintz, S.E. Arnott, C.C. Symons, D.A. Greco, A. McClymont, J.A. Brentrup, M. Canedo-Arguelles, A.M. Derry, A.L. Downing, D.K. Gray, S.J. Melles, R.A. Relyea, J.A. Rusak, C.L. Searle, L. Astorg, H.K. Baker, B.E. Beisner, K.L. Cottingham, Z. Ersoy, C. Espinosa, J. Franceschini, A.T. Giorgio, N. Gobeler, E. Hassal, M.P. Hebert, M. Huynh, S. Hylander, K.L. Jonasen, A.E. Kirkwood, S. Langenheder, O. Langvall, H. Laudon, L. Lind, M. Lundgren, L. Proia, M.S. Schuler, J.B. Shurin, C.F. Steiner, M. Striebel, S. Thibodeau P Urrutia-Cordero, L. Vendrell-Puigmitja, and G.A. Weyhenmeyer, "Current Water Quality Guidelines Across North America and Europe Do Not Protect Lakes from Salinization,"* Proceedings of the National Academy of Sciences*, 119:e2115033119, 2022.*

seasonal variations in water quality and include a margin of safety to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards.

A TMDL allocates the allowable load between a wasteload allocation for point sources such as municipal wastewater treatment plants, industrial dischargers, concentrated animal feeding operations, and municipal separate storm sewer systems (MS4s); a load allocation for nonpoint sources such as agricultural sources, urban sources not covered under a discharge permit, and natural background loads; and a margin of safety. Wasteload allocations are implemented through limits established in discharge permits under the Wisconsin Pollutant Discharge Elimination System (WPDES). Load allocations are implemented through a wide variety of Federal, State, and local programs as well as voluntary action by citizens. These programs may include regulatory, non-regulatory, or incentive-based elements, depending on the program. Implementation of load allocations is typically an adaptive process, requiring the collaboration of diverse stakeholders and the prioritization and targeting of available programmatic, regulatory, financial, and technical resources.

Wisconsin has not developed any TMDLs for chloride. As of 2023, Wisconsin was considering including chloride among the pollutants to be addressed in a TMDL for the Wisconsin portion of the Fox (Illinois) River Watershed. Several TMDLs for chloride have been developed in neighboring states. For example, Minnesota has developed chloride TMDLs for Nine Mile Creek,[45] Shingle Creek,[46] and the Twin Cities Metropolitan Area.[47] Similarly, Illinois has developed several chloride TMDLs including studies for the Des Plaines River[48] and the Middle Illinois River.[49]

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[45] *Barr Engineering,* Nine Mile Creek Watershed Chloride Total Maximum Daily Load Report, *Report to the Nine Mile Creek Watershed District and Minnesota Pollution Control Agency, wq-iw11-08e, September 2010.*

[46] *Wenck Associates, Inc.,* Shingle Creek Chloride TMDL Report*, Report to the Shingle Creek Water Management Commission and Minnesota Pollution Control Agency, wq-iw8-02e, December 2006.*

[47] *Minnesota Pollution Control Agency,* Twin Cities Metropolitan Area Chloride Total Maximum Daily Load Study*, wq-iw11-06e, February 2016.*

[48] *Illinois Environmental Protection Agency,* Des Plaines River/Higgins Creek Watershed TMDL Report*, IEPA/BOW/12-003, May 2013.*

[49] *Tetra Tech,* Middle Illinois River Total Maximum Daily Load and Load Reduction Strategies*, Report to the U.S. Environmental Protection Agency-Region 5 and Illinois Environmental Protection Agency, August 9, 2012.*

Technical Report No. 63

CHLORIDE CONDITIONS AND TRENDS IN SOUTHEASTERN WISCONSIN

Chapter 2

STUDY AREA BACKGROUND

TABLES

#274536 – TR-63 (Chloride Study Conditions and Trends) Table 2.1
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Table 2.1
Existing Land Use for Major Watersheds Within the Study Area

Land Use Categories[a]	Des Plaines River Watershed		Fox River Watershed		Kinnickinnic River Watershed		Menomonee River Watershed		Milwaukee River Watershed		Oak Creek Waterhsed	
	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	4,243	5.0	60,365	10.1	127	0.8	11,449	13.2	29,506	6.6	1,763	9.8
Medium-Density Residential	1,681	2.0	16,809	2.8	1,111	7.1	7,112	8.2	8,642	1.9	2,077	11.5
High-Density Residential	191	0.2	4,048	0.7	4,092	25.9	7,639	8.8	11,208	2.5	964	5.3
Commercial	364	0.4	2,845	0.5	554	3.5	1,871	2.2	2,422	0.5	395	2.2
Industrial	929	1.1	3,489	0.6	857	5.4	2,739	3.1	2,945	0.7	636	3.5
Government and Institutional	328	0.4	3,557	0.6	1,066	6.8	2,711	3.1	3,846	0.9	524	2.9
Roads and Parking Lots	5,272	6.2	40,380	6.7	4,698	29.7	18,078	20.8	32,331	7.2	3,622	20.1
Transportation, Communication, and Utilities	594	0.7	2,564	0.4	1,219	7.7	1,395	1.6	1,729	0.4	546	3.0
Recreational	1,260	1.5	11,503	1.9	608	3.8	3,138	3.6	6,861	1.5	691	3.8
Urban Unused Lands	1,190	1.4	8,571	1.4	1,061	6.7	4,586	5.3	5,573	1.2	2,066	11.4
Urban Subtotal	16,050	18.9	154,131	25.7	15,393	97.4	60,720	69.9	105,063	23.4	13,283	73.5
Nonurban												
Agricultural	46,998	55.2	234,028	39.0	33	0.2	11,461	13.2	194,368	43.3	1,663	9.2
Wetlands	8,644	10.2	79,269	13.2	123	0.8	7,530	8.7	71,657	16.0	1,384	7.7
Woodlands	5,212	6.1	58,026	9.7	91	0.6	2,672	3.1	42,247	9.4	849	4.7
Rural Unused Lands	6,052	7.1	41,384	6.9	0	0.0	3,164	3.6	24,904	5.6	715	4.0
Extractive and Landfills	462	0.5	5,523	0.9	0	0.0	599	0.7	1,764	0.4	49	0.3
Surface Water	1,695	2.0	27,683	4.6	156	1.0	751	0.8	8,431	1.9	100	0.6
Nonurban Subtotal	69,063	81.1	445,913	74.3	403	2.6	26,177	30.1	343,370	76.6	4,761	26.5
Total	85,114	- -	600,044	- -	15,796	- -	86,897	- -	448,433	- -	18,044	- -

Table continued on next page.

Table 2.1 (Continued)

Land Use Categories[a]	Pike River Watershed		Rock River Watershed		Root River Watershed		Sauk Creek Watershed		Sheboygan River Watershed		Direct Drainage Area to Lake Michigan	
	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	2,796	8.6	34,252	8.5	14,866	11.8	527	2.4	126	1.7	6,789	11.3
Medium-Density Residential	2,256	6.9	6,187	1.5	6,494	5.1	517	2.3	102	1.4	5,810	9.6
High-Density Residential	731	2.2	1,422	0.3	2,755	2.2	130	0.6	15	0.2	5,462	9.1
Commercial	380	1.2	1,183	0.3	1,020	0.8	54	0.2	11	0.1	798	1.3
Industrial	749	2.3	1,568	0.4	1,122	0.9	148	0.7	37	0.5	991	1.6
Government and Institutional	665	2.0	2,346	0.6	1,396	1.1	161	0.7	11	0.2	1,548	2.6
Roads and Parking Lots	3,644	11.2	22,096	5.5	12,706	10.0	1,202	5.4	224	3.0	9,662	16.0
Transportation, Communication, and Utilities	865	2.6	1,458	0.4	618	0.5	107	0.5	50	0.7	1,353	2.3
Recreational	743	2.3	4,681	1.1	3,339	2.7	113	0.5	41	0.6	2,140	3.6
Urban Unused Lands	1,915	5.9	3,279	0.8	2,917	2.3	238	1.1	56	0.8	3,636	6.0
Urban Subtotal	14,744	45.2	78,472	19.4	47,233	37.4	3,197	14.4	674	9.2	38,188	63.4
Nonurban												
Agricultural	12,897	39.5	193,897	47.9	56,230	44.4	16,055	72.5	4,999	68.3	11,253	18.7
Wetlands	1,069	3.3	52,641	13.0	9,374	7.4	1,396	6.3	873	11.9	2,952	4.9
Woodlands	1,190	3.6	37,287	9.2	5,931	4.7	522	2.4	106	1.4	2,938	4.9
Rural Unused Lands	2,147	6.6	24,407	6.0	5,702	4.5	870	3.9	642	8.8	4,234	7.0
Extractive and Landfills	206	0.6	2,644	0.7	611	0.5	11	0.1	8	0.1	274	0.5
Surface Water	389	1.2	15,301	3.8	1,447	1.1	88	0.4	20	0.3	388	0.6
Nonurban Subtotal	17,899	54.8	326,176	80.6	79,295	62.6	18,942	85.6	6,648	90.8	22,040	36.6
Total	32,643	- -	404,649	- -	126,528	- -	22,139	- -	7,322	- -	60,228	- -

[a] *See Table 2.3 in SEWRPC Technical Report No. 61 for detailed land use categories that comprise each land use group.*

Source: SEWRPC

Table 2.2
Active and Abandoned Public Wastewater Treatment Facilities Within the Study Area

Facility Name	Sewer Service Areas	Population Served[a]	Annual Average Design Flow (MGD)	Facility Status	Receiving Water
Des Plaines Watershed					
Bristol Utility District No. 1	Bristol	1,780	0.87	Active	Tributary to Des Plaines River
Paddock Lake Wastewater Treatment Facility	Paddock Lake	3,000	0.80	Active	Tributary to Brighton Creek
Hooker Lake	*Hooker Lake*	--[c]	--[c]	--[c]	--[c]
Pleasant Prairie Sanitary District No. 73-1	*Pleasant Prairie*	--[c]	--[c]	*Abandoned (2010)*	*Des Plaines River via Unnamed Tributary*
Pleasant Prairie Sewer Utility District D	*Pleasant Prairie*	--[c]	--[c]	*Abandoned (2010)*	*Des Plaines River via Pleasant Prairie Tributary*
Direct Drainage Area Tributary to Lake Michigan					
Kenosha Wastewater Treatment Facility	Greater Kenosha	124,870	28.6	Active	Lake Michigan
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[e]	310	Active	Milwaukee River Outer Harbor and Lake Michigan[f]
Port Washington Wastewater Treatment Plant	Port Washington	11,470	3.10	Active	Lake Michigan
Racine Wastewater Utility	Greater Racine	134,930	36.0	Active	Lake Michigan
South Milwaukee Wastewater Treatment Facility	South Milwaukee	21,130	6.00	Active	Lake Michigan
North Park	*Wind Point*	--[c]	--[c]	*Abandoned (1988)*	*Lake Michigan*
Pleasant Park Utility Company	*Kenosha*	--[c]	--[c]	*Abandoned (1990)*	*Lake Michigan*
Fox River Watershed					
Village of Bloomfield Utility Department	Bloomfield, Powers–Benedict-Tombeau Lakes	3,670	0.46	Active	Tributary to East Branch Nippersink Creek
Burlington Water Pollution Control	Burlington, Bohner Lake, Browns Lake	15,040	3.50	Active	Fox River
Eagle Lake Sewer Utility District	Eagle Lake	1,640	0.40	Active	Eagle Creek

Table continued on next page.

Table 2.2 (Continued)

Facility Name	Sewer Service Areas	Population Served[a]	Annual Average Design Flow (MGD)	Facility Status	Receiving Water
		Fox River Watershed (continued)			
East Troy Wastewater Treatment Facility	East Troy	5,690	0.81	Active	Honey Creek
Fox River Water Pollution Control Center	Brookfield West, Menomonee Falls South, New Berlin (part), Pewaukee	53,070	12.5	Active	Fox River
Genoa City Water Treatment Plant	Genoa City	3,070	0.58	Active	North Branch Nippersink Creek
Lake Geneva Wastewater Treatment Plant	Lake Geneva	8,600	2.50	Active	Discharge to Soil
Lyons Sanitary District No. 2	Lyons, Country Estates	1,390	0.21	Active	White River
Mukwonago Wastewater Treatment Plant	Eagle Spring Lake/Mukwonago County Park/Rainbow Springs, Mukwonago	7,380	1.50	Active	Mukwonago River
Salem Lakes – Salem Wastewater Treatment Plant[d]	Salem	11,130	2.13	Active	Fox River
Salem Lakes – Silver Lake Wastewater Treatment Plant[d]	*Silver Lake*	*2,380*	*0.47*	*Abandoned (2021)*	*Fox River*
Sussex Wastewater Treatment Facility	Lannon, Menomonee Falls South, Sussex	16,740	5.10	Active	Spring Creek
Town of Norway Sanitary District No. 1 Wastewater Treatment Facility	Norway/Wind Lake	6,660	1.60	Active	Tributary to Wind Lake Drainage Canal
Twin Lakes Wastewater Treatment Facility	Twin Lakes	5,980	1.30	Active	Tributary to Bassett Creek (to Fox River)
Waukesha Wastewater Treatment Facility	Delafield-Fox River, Genesee East, Wales, Waukesha	73,580	14.0	Active	Fox River
Western Racine County Sewerage District	Waterford/Rochester	12,370	2.50	Active	Fox River
Brookfield	*Brookfield*	--[c]	*Flow now received by Fox River Water Pollution Control Center*	*Abandoned (Between 1980-1990)*	*Fox River*
Fontana	*Fontana-on-Geneva Lake*	--[c]	*Flow now received by Fontana – Walworth Water Pollution Control Commission*	*Abandoned (1986)*	*Discharged to Soil*
Muskego-Big Muskego	*Muskego*	--[c]	*Flow now received by MMSD*	*Abandoned (1984)*	*Big Muskego Lake*
New Berlin Regal Manor Greenridge Plant	*New Berlin*	--[c]	*Flow now received by MMSD*	*Abandoned (1984)*	*Deer Creek*
Pewaukee	*Pewaukee*	--[c]	*Flow now received by Fox River Water Pollution Control Center*	*Abandoned (1981)*	*Pewaukee River*

Table continued on next page.

Table 2.2 (Continued)

Facility Name	Sewer Service Areas	Population Served[a]	Annual Average Design Flow (MGD)	Facility Status	Receiving Water
Fox River Watershed (continued)					
Williams Bay	*Williams Bay*	--[c]	*Flow now received by Walworth County Metropolitan Sewerage District*	*Abandoned (1986)*	*Discharged to Soil*
Menomonee River Watershed					
Germantown	*Germantown*	--[c]	*Flow now received by MMSD*	*Abandoned (1986)*	*Menomonee River*
Menomonee Falls – Lilly Road	*Menomonee Falls*	--[c]	*Flow now received by MMSD*	*Abandoned (year unknown)*	*Menomonee River*
Menomonee Falls – Pilgrim Road	*Menomonee Falls*	--[c]	*Flow now received by MMSD*	*Abandoned (year unknown)*	*Menomonee River*
Milwaukee River Watershed					
Campbellsport Wastewater Treatment Facility	Campbellsport	--[b]	0.47	Active	Milwaukee River
Cascade Wastewater Treatment Facility	Cascade, Lake Ellen	--[b]	0.13	Active	North Branch Milwaukee River
Cedarburg Wastewater Treatment Facility	Cedarburg	11,610	2.75	Active	Cedar Creek
Fredonia Municipal Sewer and Water Utility	Fredonia, Waubeka	2,260	0.60	Active	Milwaukee River
Grafton Water and Wastewater Utility	Grafton	11,950	2.50	Active	Milwaukee River
Jackson Wastewater Treatment Plant	Jackson	7,350	1.69	Active	Cedar Creek
Kewaskum Wastewater Treatment Plant	Kewaskum	4,030	0.75	Active	Milwaukee River
Village of Newburg Sanitary Sewer Treatment Facility	Newburg	1,170	0.12	Active	Milwaukee River
Random Lake Sewage Treatment Plant	Random Lake	--[b]	0.45	Active	Silver Creek
Saukville Sewer Utility	Saukville	4,460	1.61	Active	Milwaukee River
Town of Scott Sanitary District No.1	Batavia (Town of Scott)	--[b]	0.03	Active	Discharge to Soil
City of West Bend Sewage Treatment Facility	West Bend	33,630	9.00	Active	Milwaukee River
Thiensville	*Thiensville*	--[c]	*Flow now received by MMSD*	*Abandoned (year unknown)*	*Milwaukee River*
Pike River Watershed					
Sommers Utility District No. 1	*Sommers*	--[c]	*Flow now received by Kenosha Wastewater Treatment Facility*	*Abandoned (1986)*	*Tributary of Pike River*
Sturtevant	*Sturtevant*	--[c]	*Flow now received by Racine Wastewater Treatment Facility*	*Abandoned (1980)*	*Tributary of Pike River*

Table continued on next page.

Table 2.2 (Continued)

Facility Name	Sewer Service Areas	Population Served[a]	Annual Average Design Flow (MGD)	Facility Status	Receiving Water
		Rock River Watershed			
Allenton Sanitary District Wastewater Treatment Plant	Allenton	740	0.35	Active	East Branch Rock River
Delafield – Hartland Water Pollution Control Commission	Delafield-Nashotah, Delafield South, Hartland	18,210	3.23	Active	Bark River[h]
Dousman Wastewater Treatment Facility	Dousman, Genesee Lake, Golden Lake	2,710	0.57	Active	Bark River
Fontana – Walworth Water Pollution Control Commission	Fontana/Walworth	4,700	1.77	Active	Picasaw Creek
Hartford Water Pollution Control Facility	Hartford	15,190	3.60	Active	Rubicon 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	Active	Oconomowoc River
Sharon Wastewater Treatment Facility	Sharon	1,640	0.26	Active	Little Turtle Creek
Slinger Wastewater Treatment Facility	Slinger	5,530	1.50	Active	Tributary to the Rubicon River
Walworth County Metropolitan Sewerage District	Darien, Delavan/Delavan Lake, Elkhorn, Mallard Ridge Landfill, Williams Bay/Geneva National/Lake Como	30,530	7.00	Active	Turtle Creek
Whitewater Wastewater Treatment Facility	Whitewater	11,110	3.65	Active	Whitewater Creek[g]
Darien	*Darien*	--[c]	*Flow now received by Walworth County Metropolitan Sewerage District*	*Abandoned (1994)*	*Tributary of Darien Creek*
Delavan	*Delavan*	--[c]	*Flow now received by Walworth County Metropolitan Sewerage District*	*Abandoned (1981)*	*Turtle Creek*
Elkhorn	*Elkhorn*	--[c]	*Flow now received by Walworth County Metropolitan Sewerage District*	*Abandoned (1981)*	*Tributary of Jackson Creek*
Hartland	*Hartland*	--[c]	*Flow now received by Delafield – Hartland Water Pollution Control Commission*	*Abandoned (1980)*	*Bark River*
Slinger (old)	*Slinger*	--[c]	*Flow now received by new Slinger Wastewater Treatment Facility*	*Abandoned (year unknown)*	*Tributary to the Rubicon River*

Table continued on next page.

Table 2.2 (Continued)

Facility Name	Sewer Service Areas	Population Served[a]	Annual Average Design Flow (MGD)	Facility Status	Receiving Water
Rock River Watershed (continued)					
Walworth	*Walworth*	--[c]	*Flow now received by Fontana – Walworth Water Pollution Control Commission*	*Abandoned (1986)*	*Tributary of Piscasaw Creek*
Root River Watershed					
Union Grove Wastewater Treatment Plant	Southern Wisconsin Center, Union Grove	5,730	2.00	Active	West Branch Root River Canal
Yorkville Sewer Utility District No. 1	Yorkville	250	0.15	Active	Ives Grove Ditch (to Hoods Creek)
Caddy Vista	*Caledonia*	--[c]	*Flow now received by MMSD*	*Abandoned (1982)*	*Root River*
Hales Corners	*Hales Corners*	--[c]	*Flow now received by MMSD*	*Abandoned (1981)*	*Whitnall Park Creek Tributary*
Muskego-Northeast District	*Muskego*	--[c]	*Flow now received by MMSD*	*Abandoned (1985)*	*Tess Corners Creek*
Rawson Homes Sewer and Water Trust	*Greendale*	--[c]	*Flow now received by MMSD*	*Abandoned (1977)*	*East Branch Root River*
Sheboygan River Watershed					
Belgium Wastewater Treatment Facility	Belgium, Lake Church	2,260	0.63	Active	Belgian-Holland Ditch[g]

Note: Italic text in this table represents information for WWTFs that have been abandoned.

See sanitary sewer service areas and the active wastewater treatment facilities that serve them on Map 2.10. Sanitary sewer service areas represent the latest available service areas and do not necessarily represent former service areas of abandoned WWTFs.

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

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

[c] *Information about the abandoned facility is unknown.*

[d] *The Town of Salem and Village of Silver Lake merged to create the Village of Salem Lakes in 2017. There were 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.*

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

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

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

[h] *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

Table 2.ClimateNorms
30-Year Climate Normals for Southeastern Wisconsin: 1991-2020

Month	Mean Daily Temperature (°F)	Maximum Daily Temperature (°F)	Minimum Daily Temperature (°F)	Precipitation (inches)[a]	Snowfall (inches)
January	20.7	28.3	13.0	1.64	12.6
February	24.2	32.2	16.1	1.56	10.7
March	34.3	43.3	25.3	2.05	5.3
April	45.4	55.8	35.1	3.67	1.7
May	56.7	67.6	45.8	3.96	0.1
June	66.7	77.5	55.8	4.60	0.0
July	71.3	81.8	60.8	3.67	0.0
August	69.6	79.8	59.4	3.80	0.0
September	62.3	72.9	51.8	3.33	0.0
October	50.2	60.1	40.3	2.91	0.2
November	37.5	45.5	29.4	2.22	2.1
December	26.3	33.5	19.2	1.87	9.8
Annual Average/Total	47.1	56.5	37.7	35.28	42.3

[a] *Precipitation totals include the liquid water equivalent of all forms of liquid and frozen precipitation.*

Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Table 2.MeanTemps
Monthly Mean Temperatures for Southeastern Wisconsin: 2018-2021

Month	2018 Mean Temperature (°F)	2019 Mean Temperature (°F)	2020 Mean Temperature (°F)	2021 Mean Temperature (°F)
January	20.8	18.4	27.1	24.0
February	23.5	20.9	24.8	15.2
March	33.2	30.6	38.0	39.5
April	36.7	45.6	43.0	47.9
May	62.1	53.9	55.0	56.9
June	66.8	64.3	68.3	70.9
July	71.6	73.8	74.5	71.1
August	71.2	68.4	70.7	72.8
September	64.2	65.4	60.8	65.0
October	48.4	48.3	45.8	56.6
November	31.7	31.3	43.5	36.9
December	29.4	30.9	28.6	32.2

Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Table 2.PrecipStudyPeriod
Monthly Precipitation Totals for Southeastern Wisconsin: 2018-2021

Month	2018 Precipitation (inches)	2019 Precipitation (inches)	2020 Precipitation (inches)	2021 Precipitation (inches)
January	1.66	2.22	2.03	1.72
February	2.79	3.04	0.82	0.83
March	0.64	1.18	3.60	1.12
April	2.53	3.19	3.43	1.38
May	6.05	5.86	4.90	2.50
June	6.40	4.11	3.59	3.14
July	2.63	4.05	4.61	1.94
August	7.19	4.11	4.05	4.71
September	5.96	7.24	3.24	1.48
October	5.28	6.20	2.91	3.76
November	1.99	1.93	1.91	0.46
December	1.74	1.89	1.67	2.21
Annual Total	44.86	45.02	36.76	25.25

Note: Precipitation totals include the liquid water equivalent of all forms of liquid and frozen precipitation.

Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Table 2.SnowStudyPeriod
Monthly Snowfall Totals for Southeastern Wisconsin: Winter 2018-2019 to Winter 2020-2021

Month	Winter 2018-2019 Snowfall (inches)	Winter 2019-2020 Snowfall (inches)	Winter 2020-2021 Snowfall (inches)
October	0	2.9	0.1
November	5.9	7.9	0.2
December	1.0	3.1	7.0
January	19.3	12.4	19.2
February	15.9	9.8	12.8
March	1.5	1.6	0.9
April	5.8	0.1	0.5
Winter Total	49.4	37.8	40.7

Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Table 2.ORWandERW
Outstanding and Exceptional Resource Waters in the Chloride Impact Study Area

Waterbody	Watershed	County	Extent
Outstanding Resource Waters			
Bluff Creek	Rock River	Walworth	Entire stream
Lulu Lake	Fox River	Walworth	Entire lake
Nichols Creek	Milwaukee River	Sheboygan	Entire stream
Potawatomi Creek	Fox River	Walworth	Entire stream
Spring Lake	Fox River	Waukesha	Entire lake
Van Slyke Creek	Fox River	Walworth	Entire stream
Exceptional Resource Waters			
Auburn Lake Creek	Milwaukee River	Fond du Lac	Entire stream above and below Auburn Lake
Chambers Creek	Milwaukee River	Sheboygan	Entire stream
East Branch Milwaukee River	Milwaukee River	Fond du Lac and Washington	From Long Lake outlet to STH 28
Genesee Creek	Fox River	Waukesha	Above STH 59
Gooseville Creek	Milwaukee River	Sheboygan	Entire stream
Mukwonago River	Fox River	Waukesha	From Eagle Springs Lake to Upper Phantom Lake
Oconomowoc River	Rock River	Waukesha	From below North Lake to Okauchee Lake

Source: Wisconsin Department of Natural Resources

Table 2.ChlorideImpaired
Waterbodies Listed as Impaired Due to Chloride in Southeastern Wisconsin: 2024

Name	WBIC[a]	County	Extent (River mile)[b]	Impairment		Listing Date
				Acute Toxicity	Chronic Toxicity	
Beaver Creek	20000	Milwaukee	0.00-2.65	--	X	2020
Brown Deer Creek	19700	Milwaukee	0.00-2.30	X	X	2018
Butler Ditch	18100	Waukesha	0.00-2.85	--	X	2020
Crestwood Creek	19450	Milwaukee	0.00-1.35	X	X	2020
Dousman Ditch	17100	Waukesha	0.00-2.50	X	X	2022
Gateway Tributary to Ulao Creek	5032660	Ozaukee	0.0-0.85	--	X	2024
Honey Creek	16300	Milwaukee	0.00-8.96	X	X	2018
Indian Creek	19600	Milwaukee	0.00-2.63	X	X	2018
Kilbourn Road Ditch	736900	Racine, Kenosha	0.0-14.3	--	X	2022
Kinnickinnic River	15100	Milwaukee	5.49-9.93	X	X	2018
Kinnickinnic River	15100	Milwaukee	3.16-5.49	X	X	2014
Kinnickinnic River	15100	Milwaukee	0.00-3.16	X	X	2022
Lilly Creek	18400	Waukesha	0.00-4.70	--	X	2016
Lincoln Creek	19400	Milwaukee	0.0-9.7	X	X	2014
Little Menomonee River	17600	Ozaukee, Milwaukee	0.0-9.0	X	X	2016
Meadowbrook Creek	772300	Waukesha	0.00-3.14	--	X	2018
Menomonee River	16000	Washington, Waukesha, Milwaukee	0.00-24.81	X	X	2018
Mitchell Field Drainage Ditch	14800	Milwaukee	0.0-2.3	X	X	2020
North Branch Oak Creek	14900	Milwaukee	0.0-5.7	X	X	2018
North Branch Pike River	1900	Racine, Kenosha	5.23-7.87	--	X	2018
Nor-X-Way Channel	18450	Ozaukee, Washington, Waukesha	0.0-4.9	--	X	2020
Noyes Creek	17700	Milwaukee	0.00-3.54	X	X	2020
Oak Creek	14500	Milwaukee	0.00-13.32	X	X	2014
Pewaukee River above Pewaukee Lake	771800	Waukesha	0.00-4.45	--	X	2020
Pike Creek	1200	Kenosha	0.00-3.69	X	X	2016
Pike River	1300	Kenosha	1.45-9.50	X	X	2016
Pike River	1300	Kenosha	0.00-1.45	--	X	2016
Root River	2900	Waukesha, Milwaukee	25.80-43.69	X	X	2014
Root River	2900	Milwaukee, Racine	5.82-20.48	--	X	2022
South 43rd Street Ditch	15900	Milwaukee	0.00-1.16	X	X	2022
Southbranch Creek	3000073	Milwaukee	0.00-2.36	X	X	2018

Table continued on next page.

Table 2.ChlorideImpaired (Continued)

Name	WBIC[a]	County	Extent (River mile)[b]	Impairment		Listing Date
				Acute Toxicity	Chronic Toxicity	
South Branch of Underwood Creek	16800	Waukesha, Milwaukee	0.00-1.11	X	X	2018
Ulao Creek	21200	Ozaukee	0.0-8.6	X	X	2016
Underwood Creek	16700	Waukesha, Milwaukee	0.00-8.54	X	X	2018
Unnamed Tributary to North Branch Pike River	2450	Racine	0.00-0.58	--	X	2016
Wilson Park Creek	15200	Milwaukee	0.0-3.5	X	X	2018
Zablocki Park Creek	5036633	Milwaukee	0.0-0.9	X	X	2022

[a] The WBIC is a unique identification number for a waterbody assigned and used by the Wisconsin Department of Natural Resources.

[b] River mile is measured upstream from the mouth of the waterbody.

Source: Wisconsin Department of Natural Resources

Table 2.WQCriteria
Water Quality Criteria for Chloride for Canada and Three States Surrounding Wisconsin

Jurisdiction	Chronic Toxicity Criterion (mg/l)	Acute Toxicity Criterion (mg/l)	General Chloride Criterion (mg/l)
Canada	120	640	--
Illinois	--	--	500
Michigan	150	640	--
Minnesota	230	860	--
Wisconsin	395	757	--

Source: Environment Canada, Illinois Pollution Control Board, Michigan Department of Environment, Energy, and Great Lakes, Minnesota Pollution Control Agency, and Wisconsin Department of Natural Resources

Table 2.Thresholds
Some Chloride Concentration Thresholds for Changes in Biological Communities

Chloride Concentration (mg/l)	Reported Impact	References
5-40	Decreased reproduction and increased mortality in six *Daphnia* Species	Arnott et al., 2020, *Environmental Science and Technology*, 54:9,398-9,407.
16	Reduced bacteria density in biofilms	Cochero et al., 2017, *Science of the Total Environment*, 579:1,496-1,503.
33-108	Reductions in fish diversity	Morgan et al., 2012, *North American Journal of Fisheries Management*, 32:941-952.
35	Substantial changes in composition of periphytic diatom assemblages	Porter-Goff et al., 2013, *Ecological Indicators*, 32:97-106
54	Reductions in wetland plant species richness	Richburg et al., 2001, *Wetlands*, 21:247-255.
100	Decrease in photosynthetic production in common waterweed	Zimmerman-Timm, 2007, In: Lozar, et al., *Water Uses and Human Impacts on the Water Budget*
185	Substantial shift in phytoplankton community composition and reduction in ciliates	Astorg et al., 2023, *Limnology and Oceanography Letters*, 8:38-47.
250	Reductions in zooplankton abundance and diversity	Sinclair and Arnott, 2018, *Freshwater Biology* 63:1,273-1,286.
250-260	Wood frogs and spring peepers stop using ponds for breeding	Sadowski, 2002, *Prairie Perspectives*, 5:144-162; Gallagher et al., 2014, *Wetlands Ecology and Management*, 22:551-564
2,000	Inhibition of denitrification in forested wetlands	Lancaster et al., 2016, *Environmental Pollution*

Source: SEWRPC

Table 2.Zooplankton
Reductions in Zooplankton Abundance Relative to the USEPA Recommended Criterion Continuous Maximum Concentration

Zooplankton Group	Percent of Sites Showing 50 Percent Reductions at Chloride Concentrations Below 230 mg/l	Range of Reductions Observed at a Chloride Concentration of 230 mg/l (percent)
Cladocera	86	22-83
Calanoid copepods	90	15-96
Cyclopoid copepods	60	13-96
Rotifers	82	10-100

Source: W.D. Hintz et al., "Current Water Quality Guidelines Across North America Do Not Protect Lakes from Salinization," Proceedings of the National Academy of Sciences,*" 119:e2115033119, 2022*

Technical Report No. 63

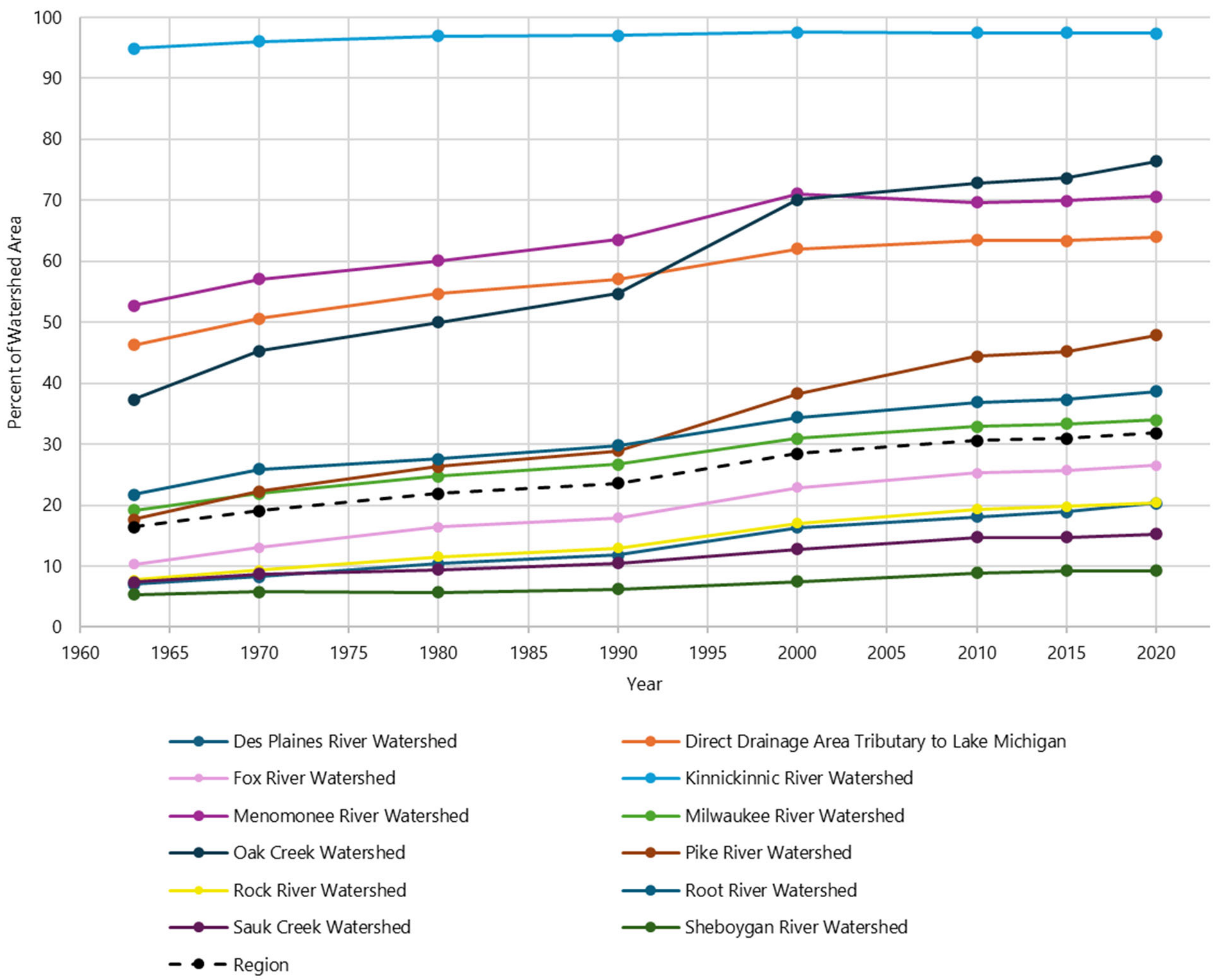
CHLORIDE CONDITIONS AND TRENDS IN SOUTHEASTERN WISCONSIN

Chapter 2

STUDY AREA BACKGROUND

FIGURES

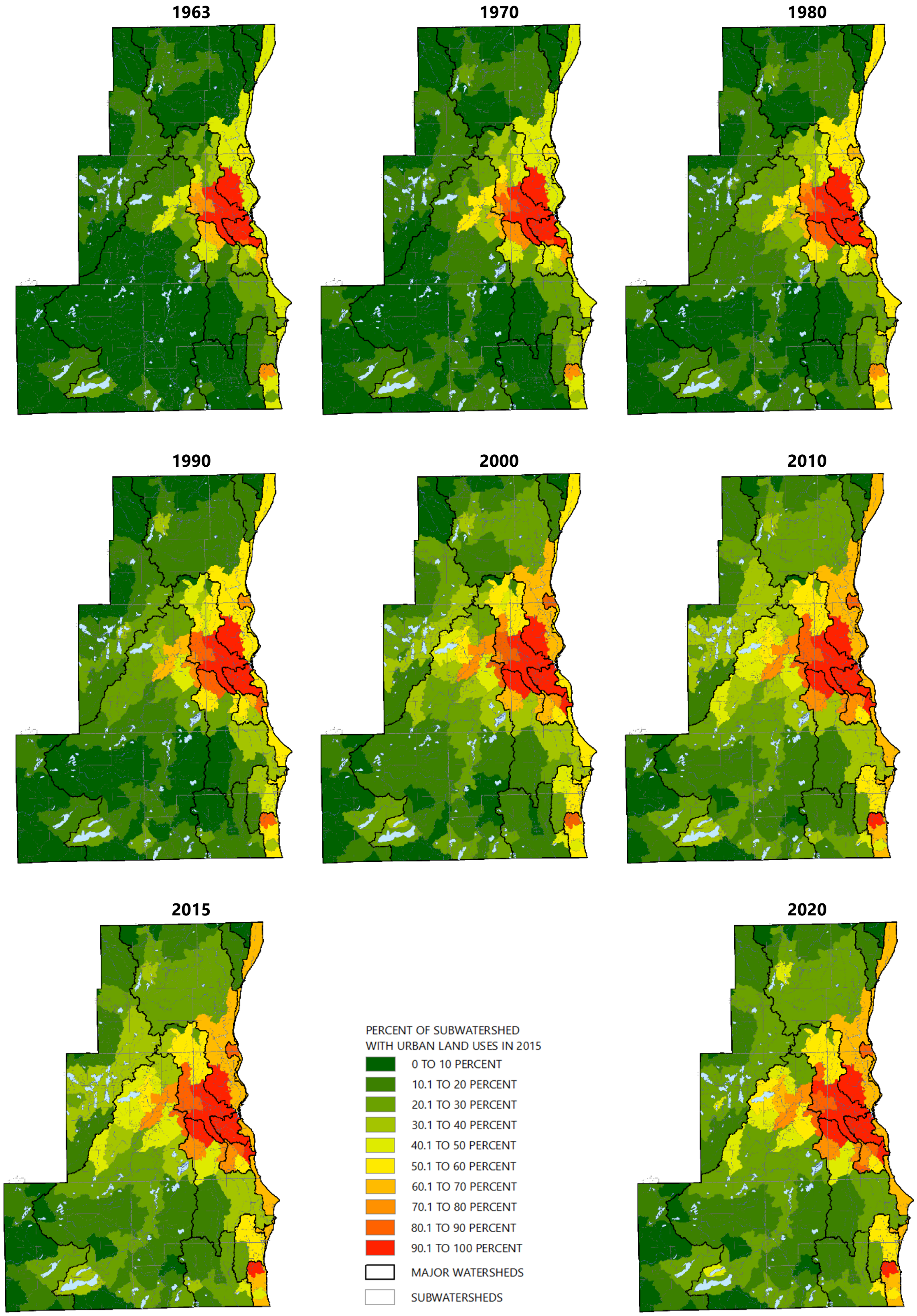
Figure 2.1
Trends in Urban Land Uses Within the Watersheds of the Region: 1963 to 2020



Note: SEWRPC land use inventories are only available for the seven-county Southeastern Wisconsin Region including Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties. Portions of the study area outside of these counties are not included in this figure.

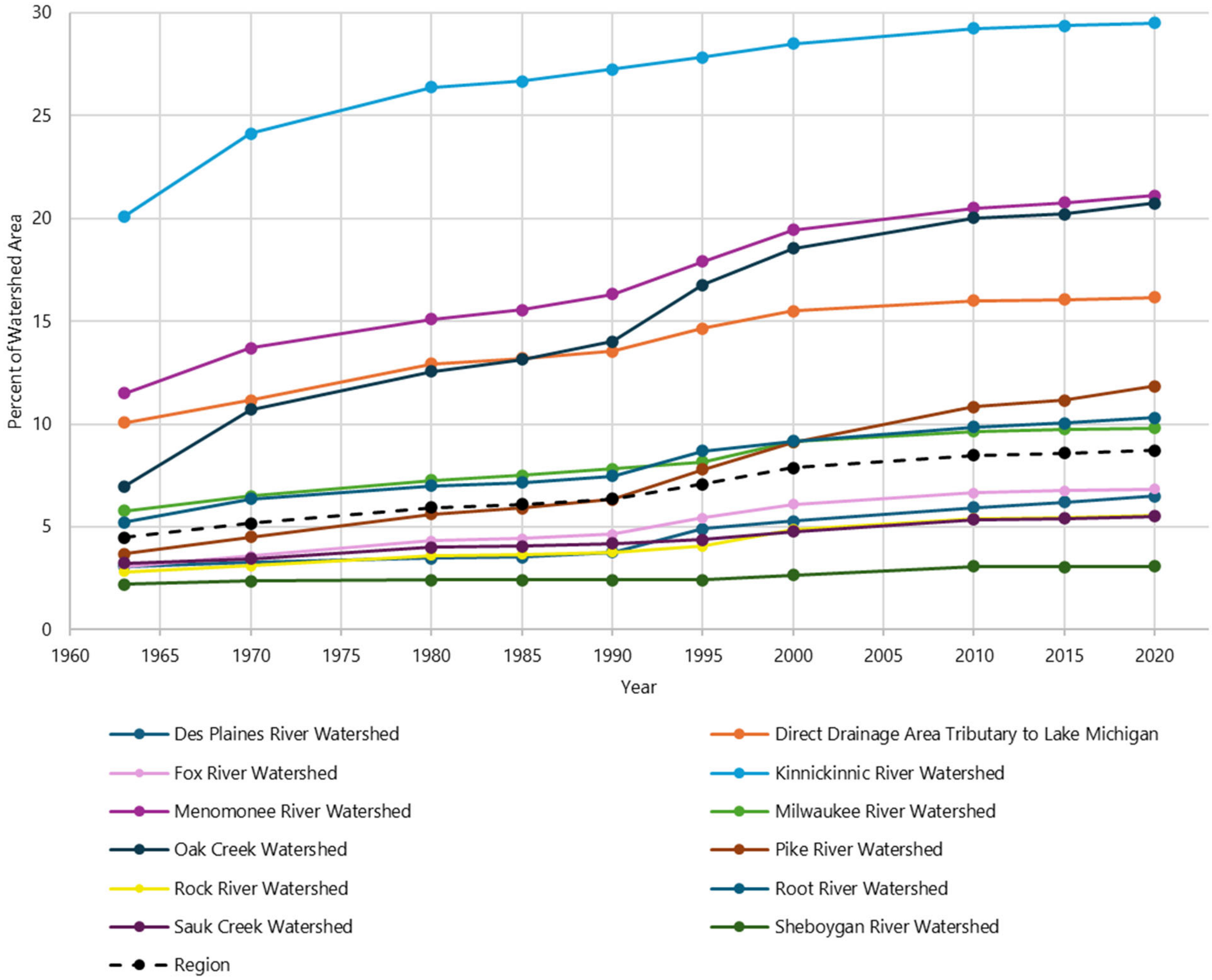
Source: SEWRPC

Figure 2.2
Geographic Trends in Urban Land Use in the Region: 1963 to 2020



Source: SEWRPC

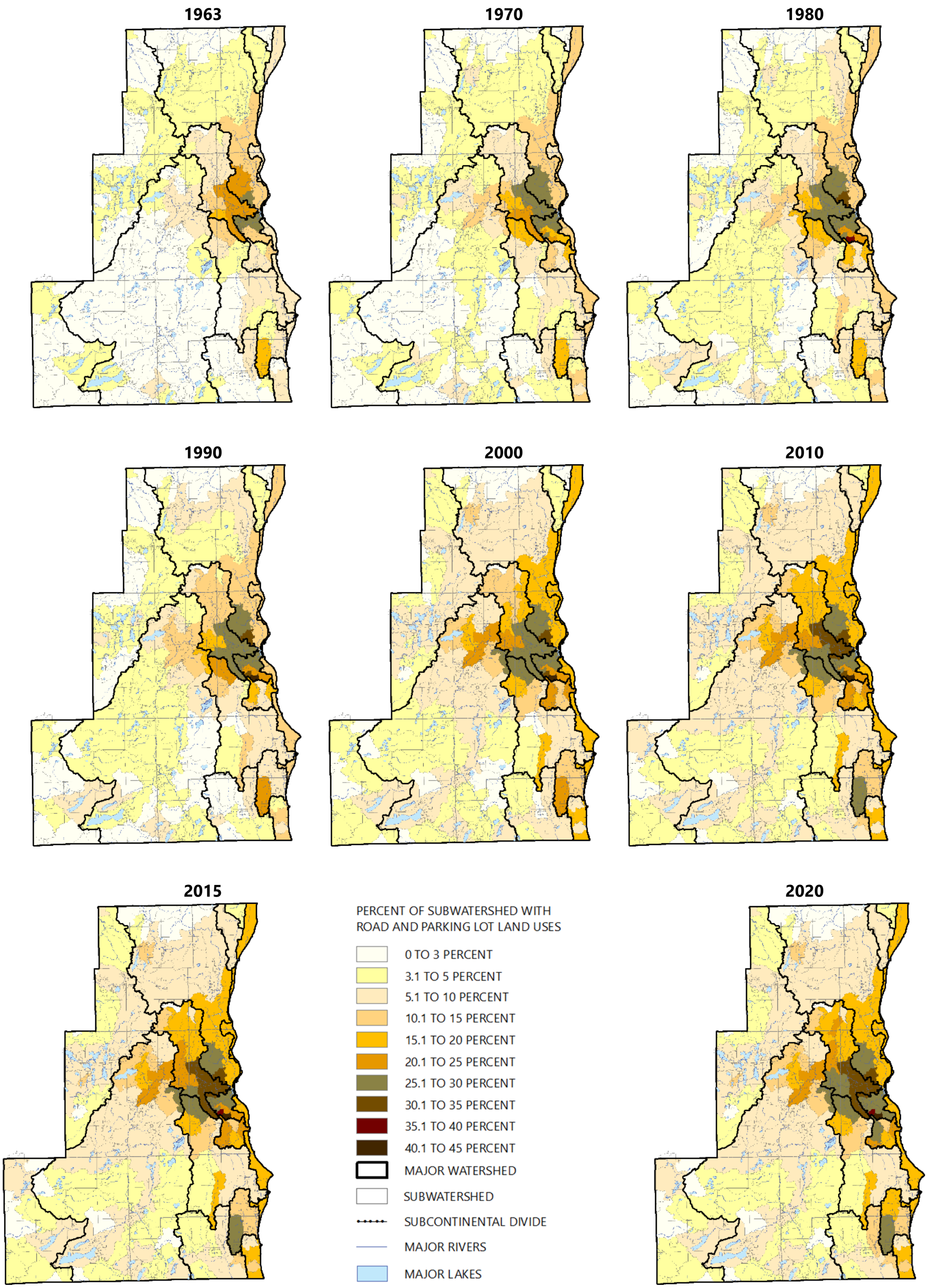
Figure 2.3
Trends in the Density of Roads and Parking Lots
Within the Watersheds of the Region: 1963 to 2020



Note: SEWRPC land use inventories are only available for the seven-county Southeastern Wisconsin Region including Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties. Portions of the study area outside of these counties are not included in this figure.

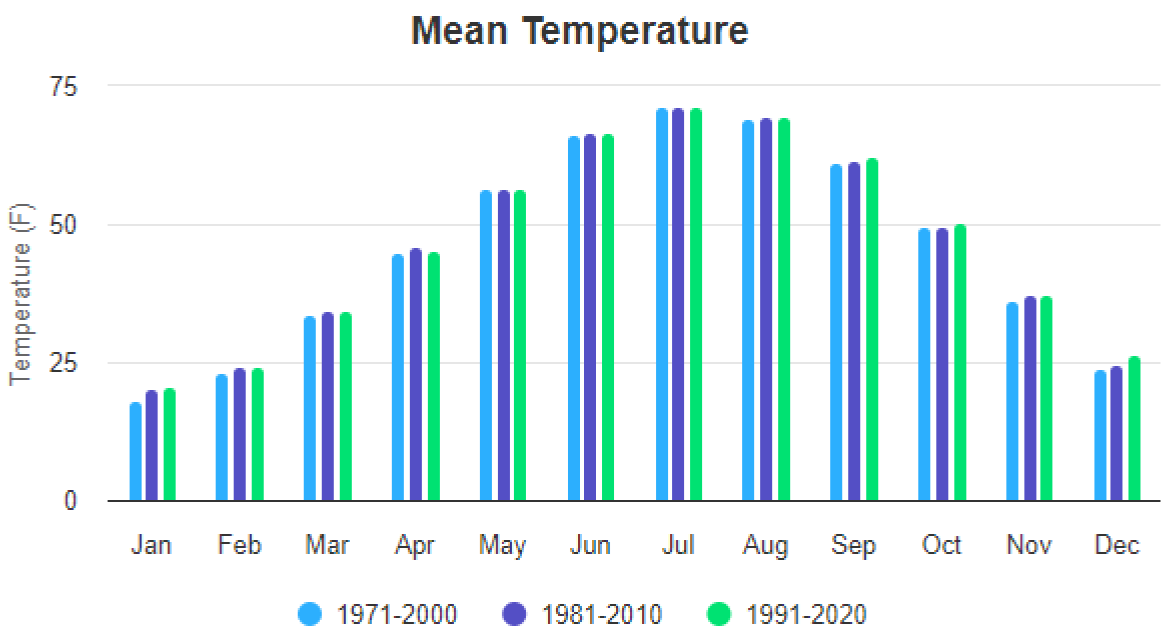
Source: SEWRPC

Figure 2.4
Geographic Trends in Roads and Parking Lot Density in the Region: 1963 to 2020



Source: SEWRPC

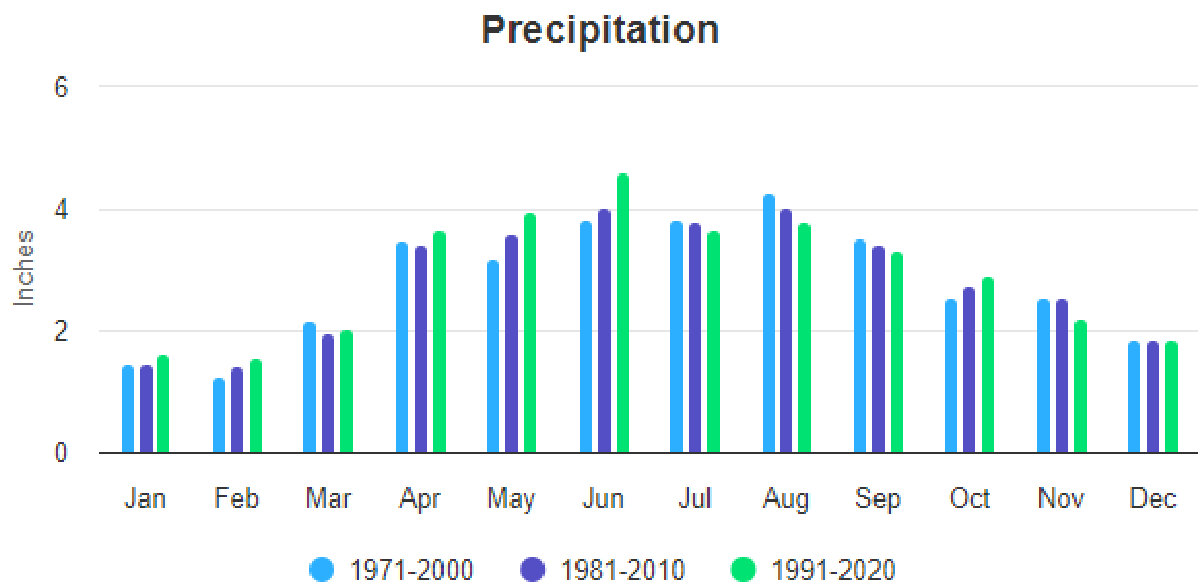
Figure 2.ClimNormCompTemp
Climate Normal Comparison for Southeastern Wisconsin: Mean Temperature



Annual Mean Temperature Averages
1971-2000: 46.2
1981-2010: 46.9
1991-2020: 47.1

Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Figure 2.ClimNormCompPrecip
Climate Normal Comparison for Southeastern Wisconsin: Precipitation

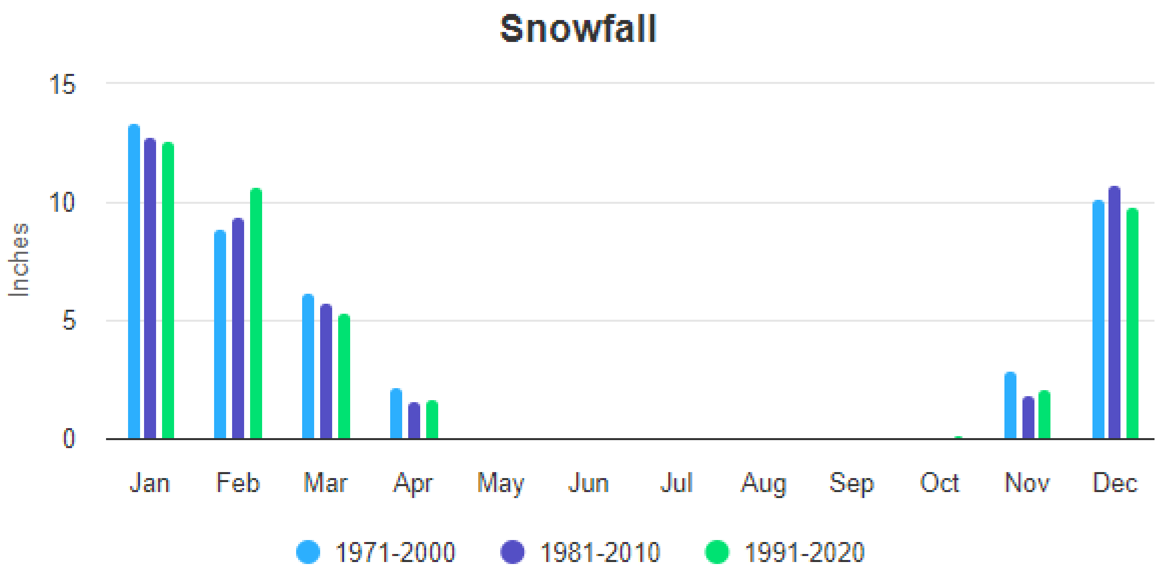


Annual Precipitation Totals

1971-2000: 33.96
1981-2010: 34.29
1991-2020: 35.28

Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Figure 2.ClimNormCompSnow
Climate Normal Comparison for Southeastern Wisconsin: Snowfall

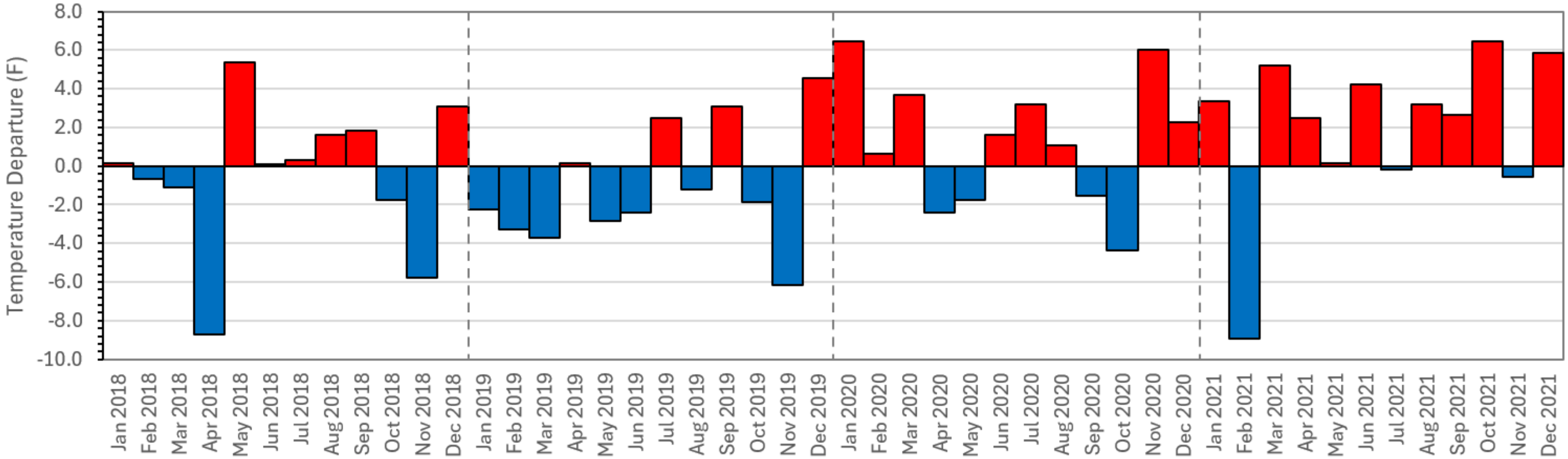


Annual Snowfall Totals

1971-2000: 44.2
1981-2010: 42.5
1991-2020: 42.3

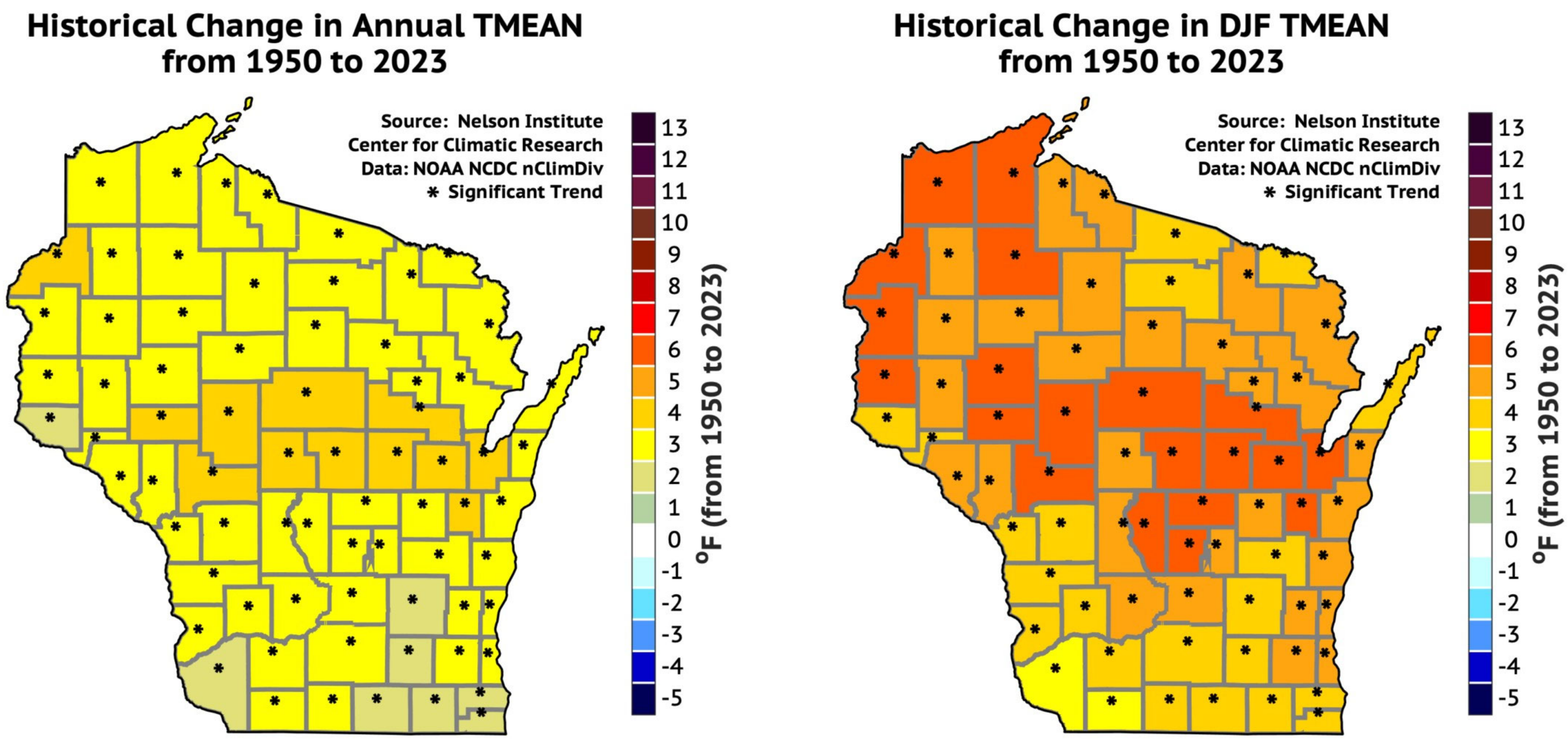
Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Figure 2.TempDepart
Monthly Mean Temperature Departures from 1991-2020 Normals for the Region: Study Period (2018-2021)



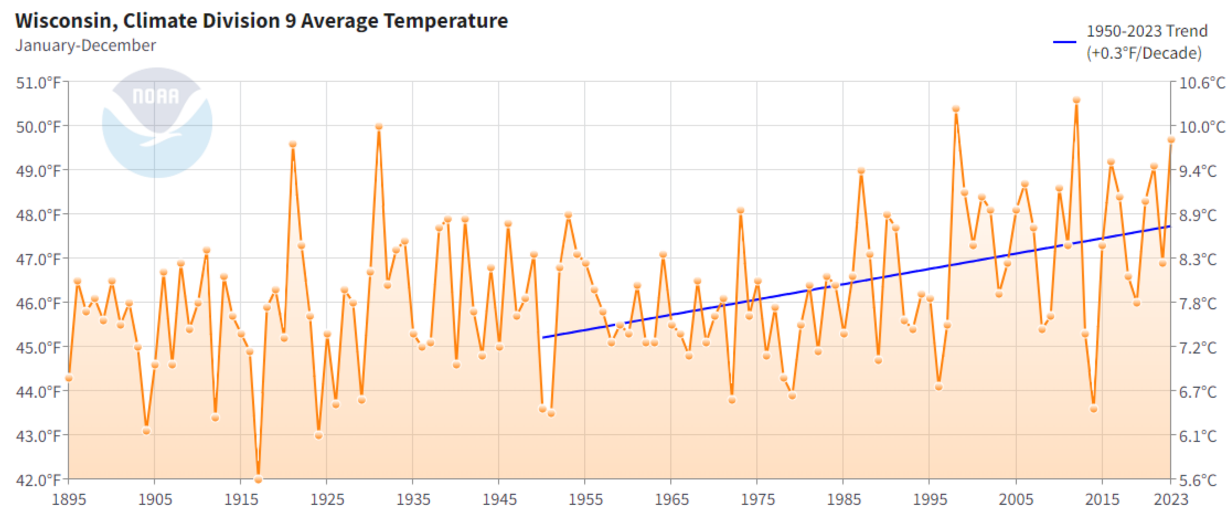
Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Figure 2.TempTrends
Historical Change in Annual Average Temperature and Average Winter Temperature: 1950-2023



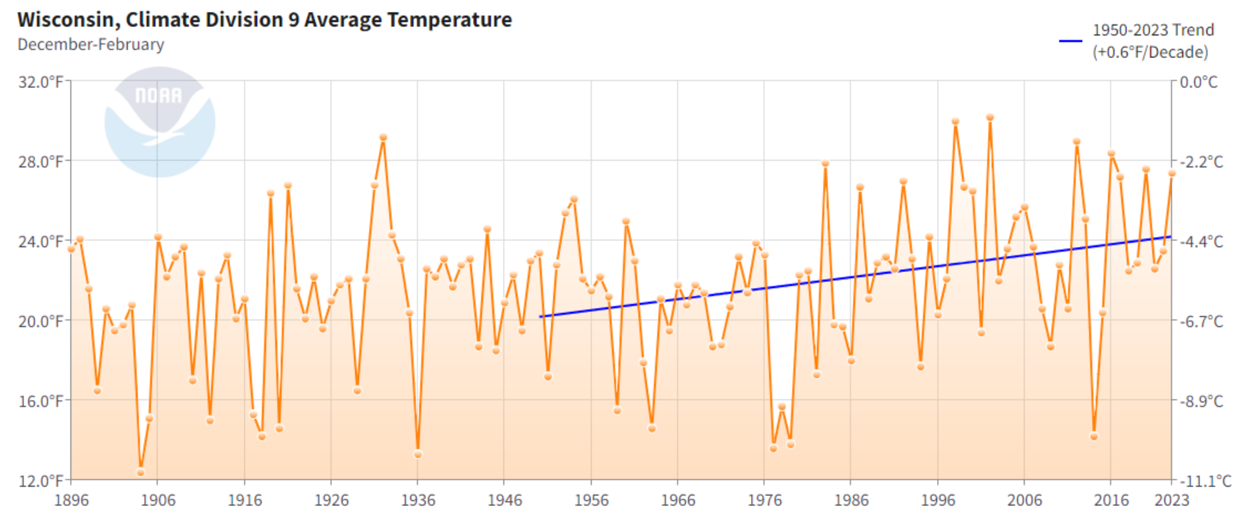
Source: Wisconsin Initiative on Climate Change Impacts, wicci.wisc.edu/wisconsin-climate-trends-and-projections

Figure 2.TempLongTerm
Annual Average Temperature for Southeastern Wisconsin: 1895-2023



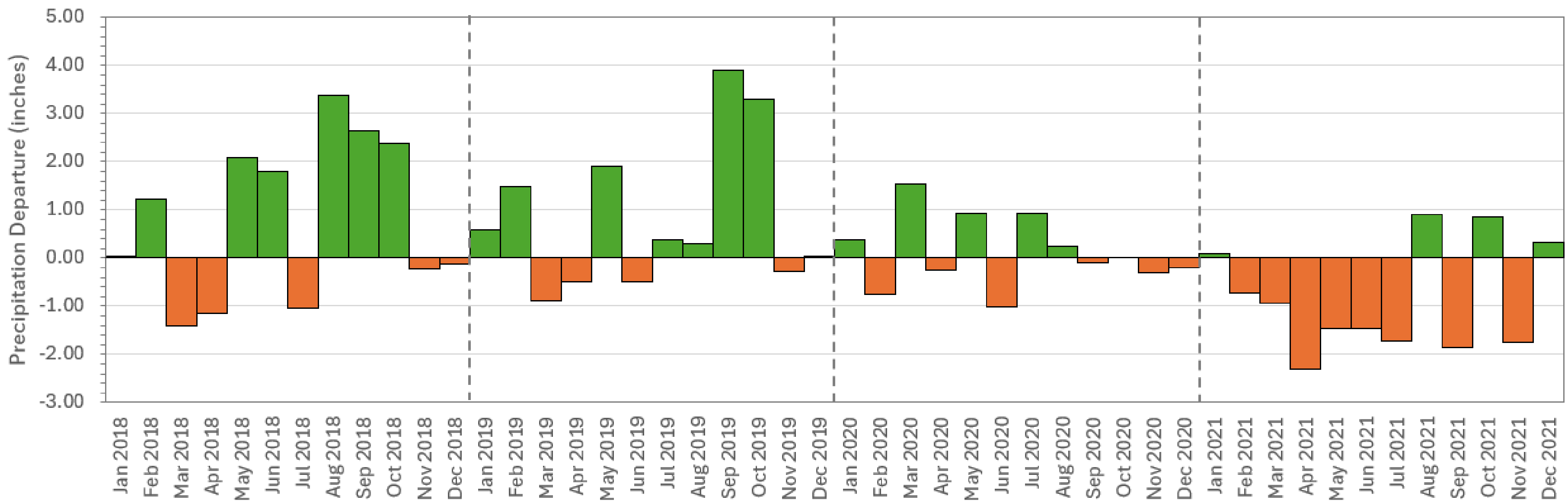
Source: NOAA National Centers for Environmental Information

Figure 2. WinterTempLongTerm
Average Winter Temperature for Southeastern Wisconsin: 1895-2023



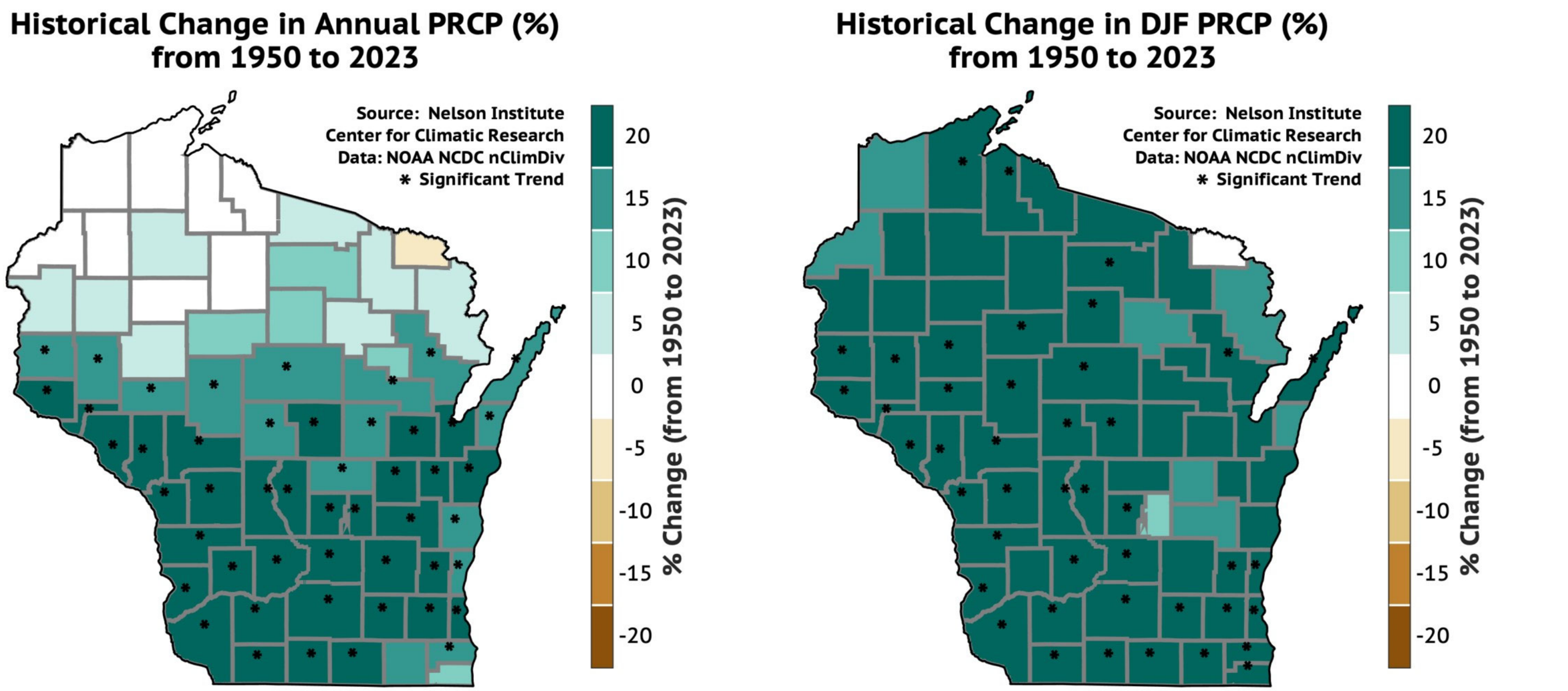
Source: NOAA National Centers for Environmental Information

Figure 2.PrecipDepart
Monthly Precipitation Departures from 1991-2020 Normals for Southeastern Wisconsin: Study Period (2018-2021)



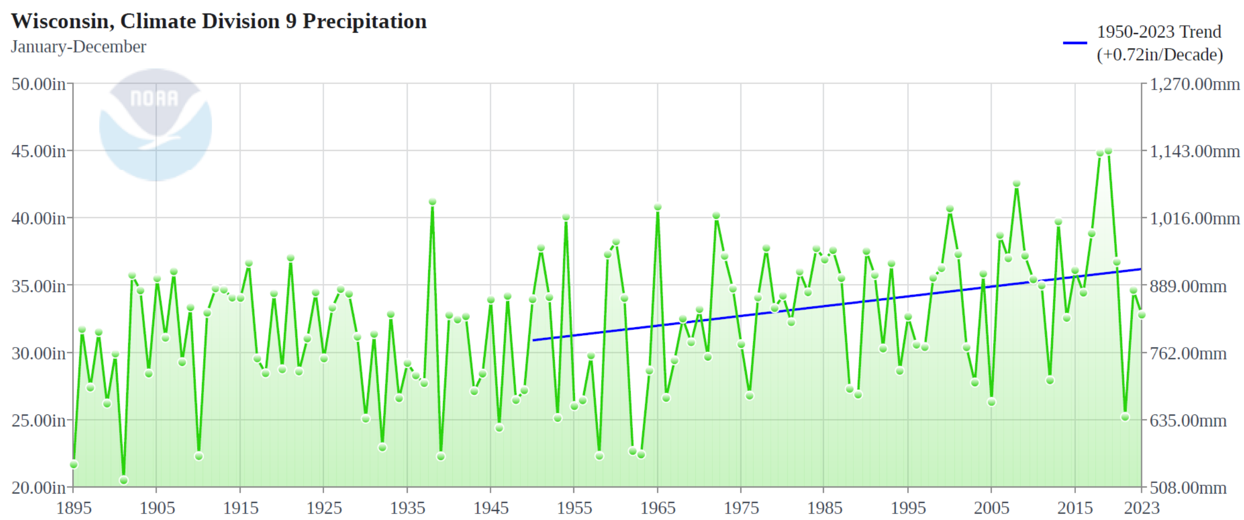
Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Figure 2.PrecipTrends
Historical Change in Annual Precipitation and Winter Season Precipitation: 1950-2023



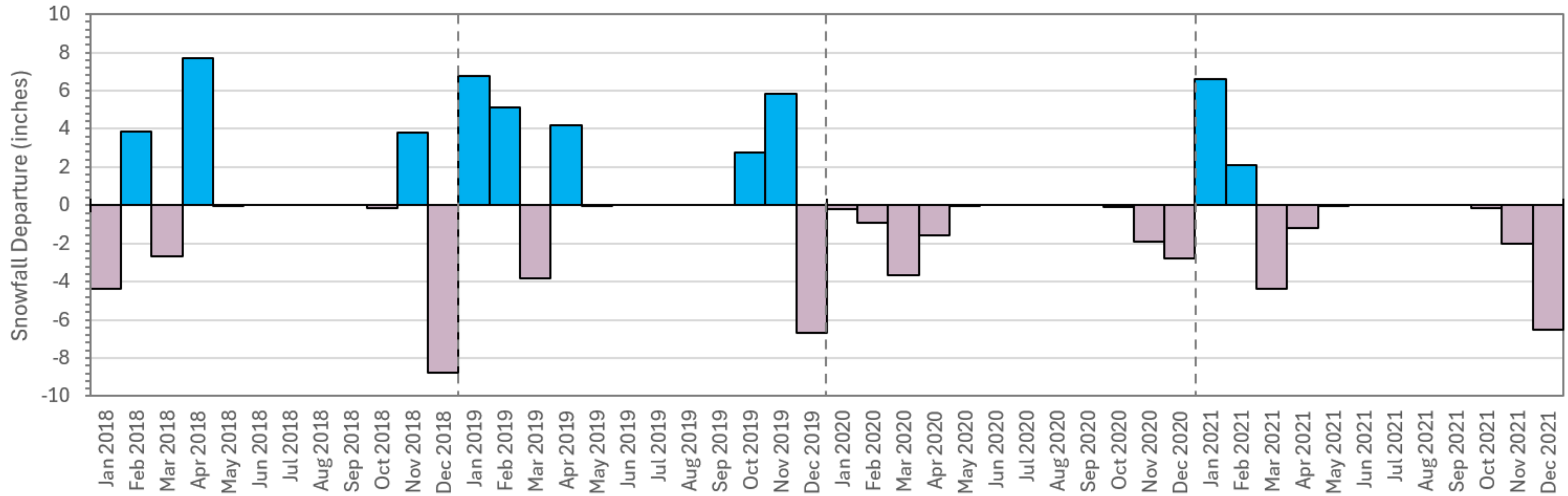
Source: Wisconsin Initiative on Climate Change Impacts, wicci.wisc.edu/wisconsin-climate-trends-and-projections

Figure 2.PrecipLongTerm
Annual Precipitation for Southeastern Wisconsin: 1895-2023



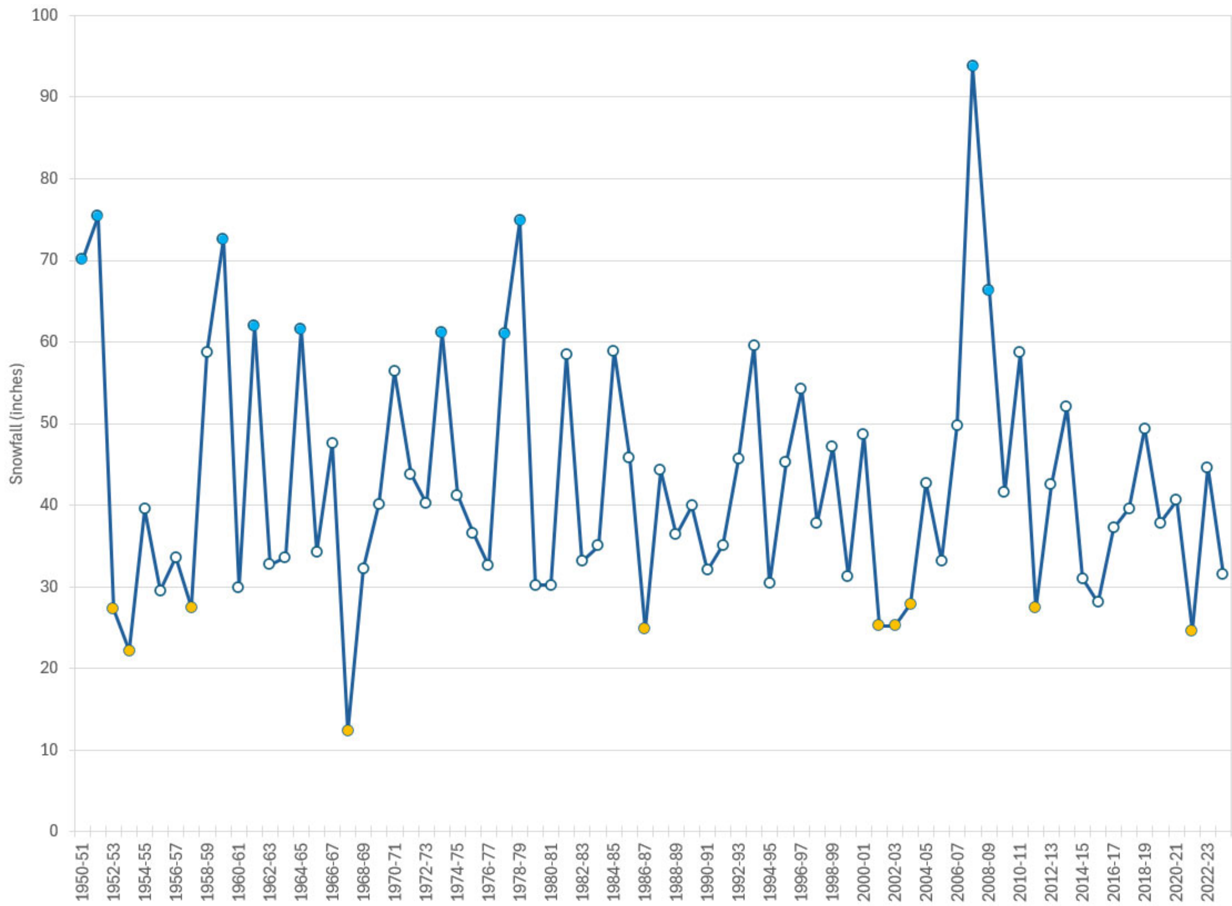
Source: NOAA National Centers for Environmental Information

Figure 2.SnowDepart
Monthly Snowfall Departures from 1991-2020 Normals for Southeastern Wisconsin: Study Period (2018-2021)



Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

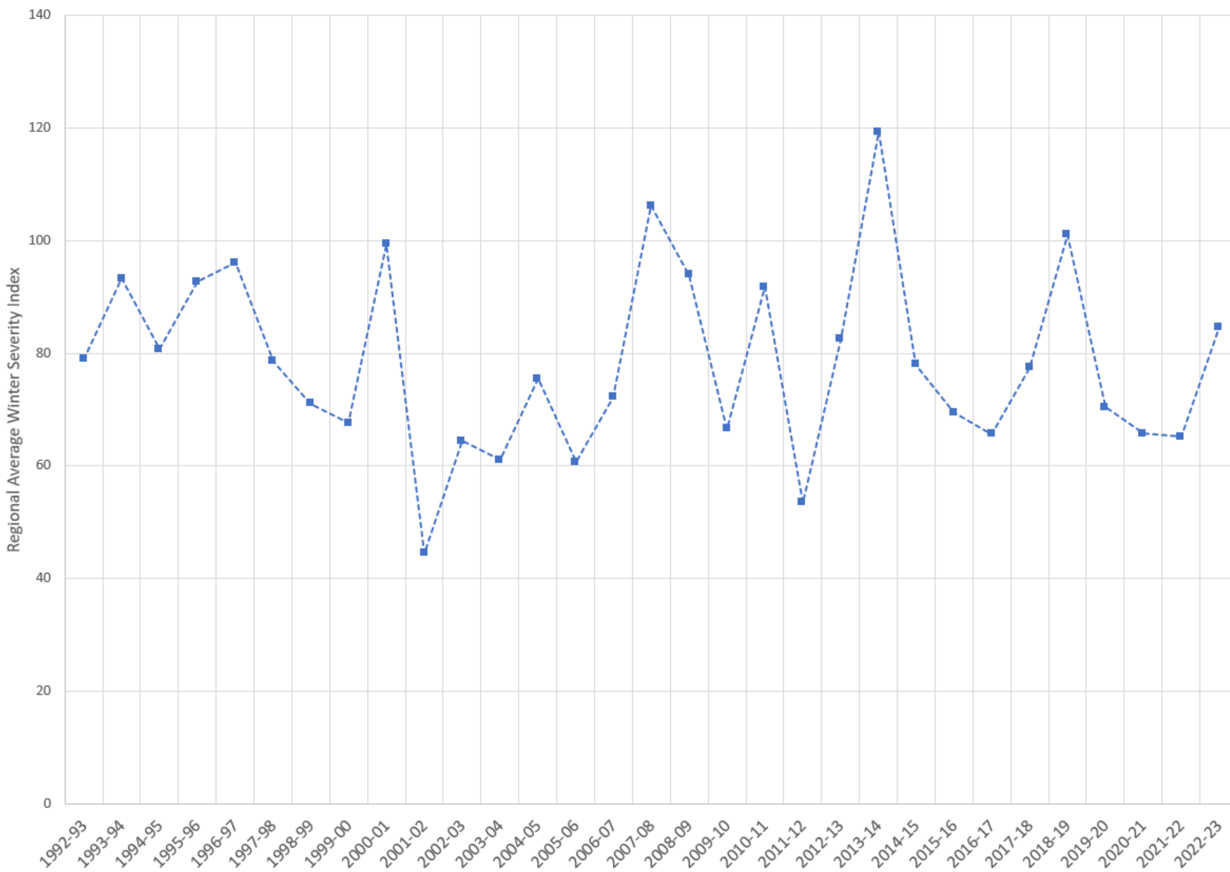
Figure 2.SnowSeasonRegion
Total Winter Season Snowfall for Southeastern Wisconsin: 1950-1951 to 2023-2024



Note: The 10 winters with the most snow are highlighted blue and the 10 winters with the least snow are highlighted orange.

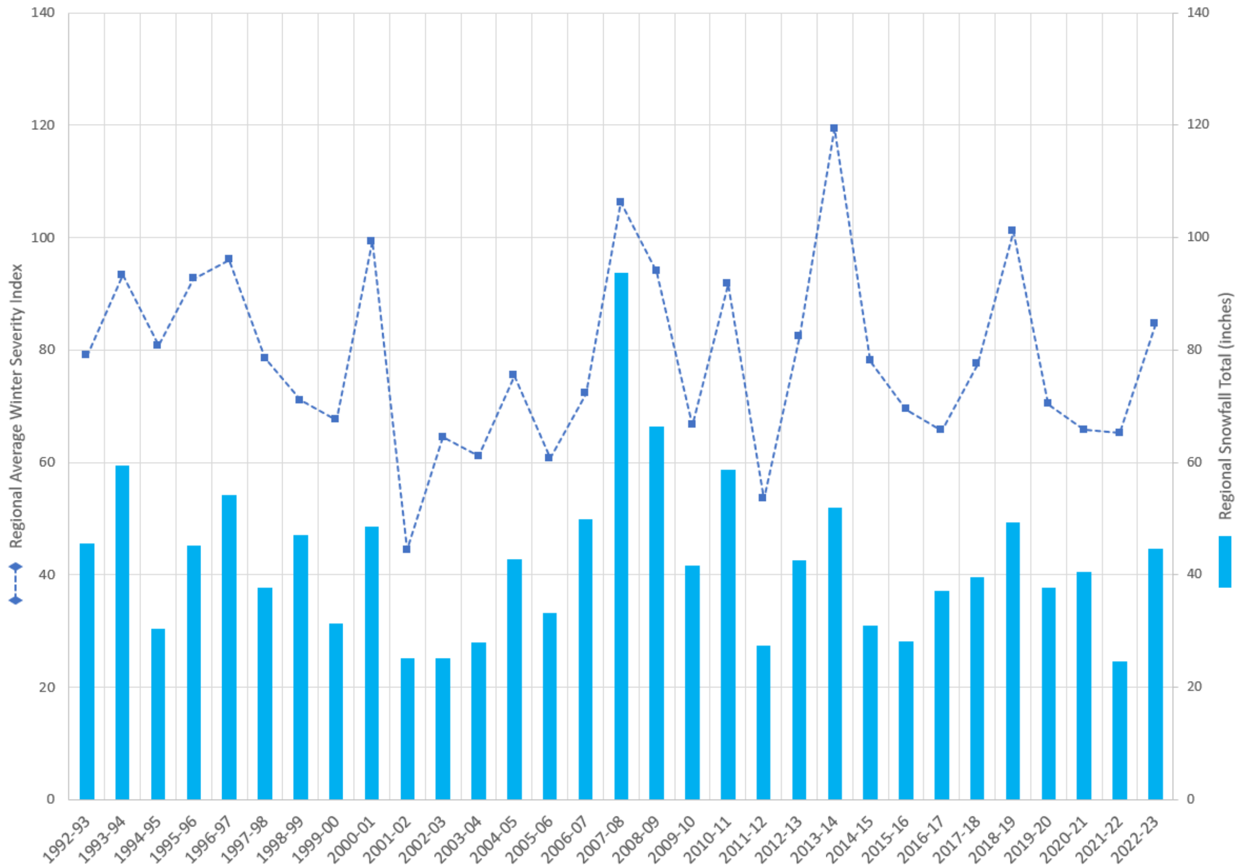
Source: Wisconsin State Climatology Office

Figure 2.WSI
WisDOT Winter Severity Index: Regional Average (1992-1993 to 2022-2023)



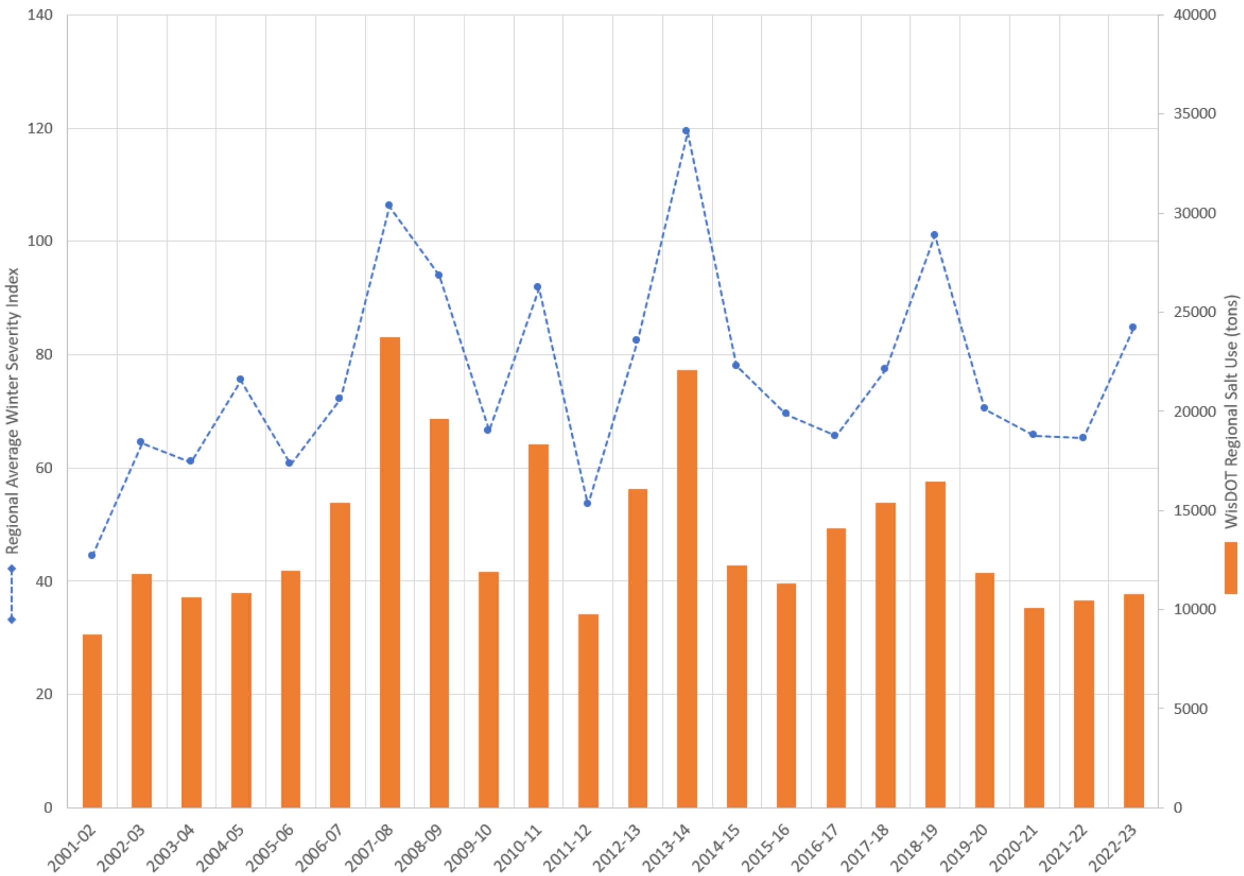
Source: Wisconsin Department of Transportation

Figure 2.WSIsnow
Regional Average WSI and Total Winter Season Snowfall: (1992-1993 to 2022-2023)



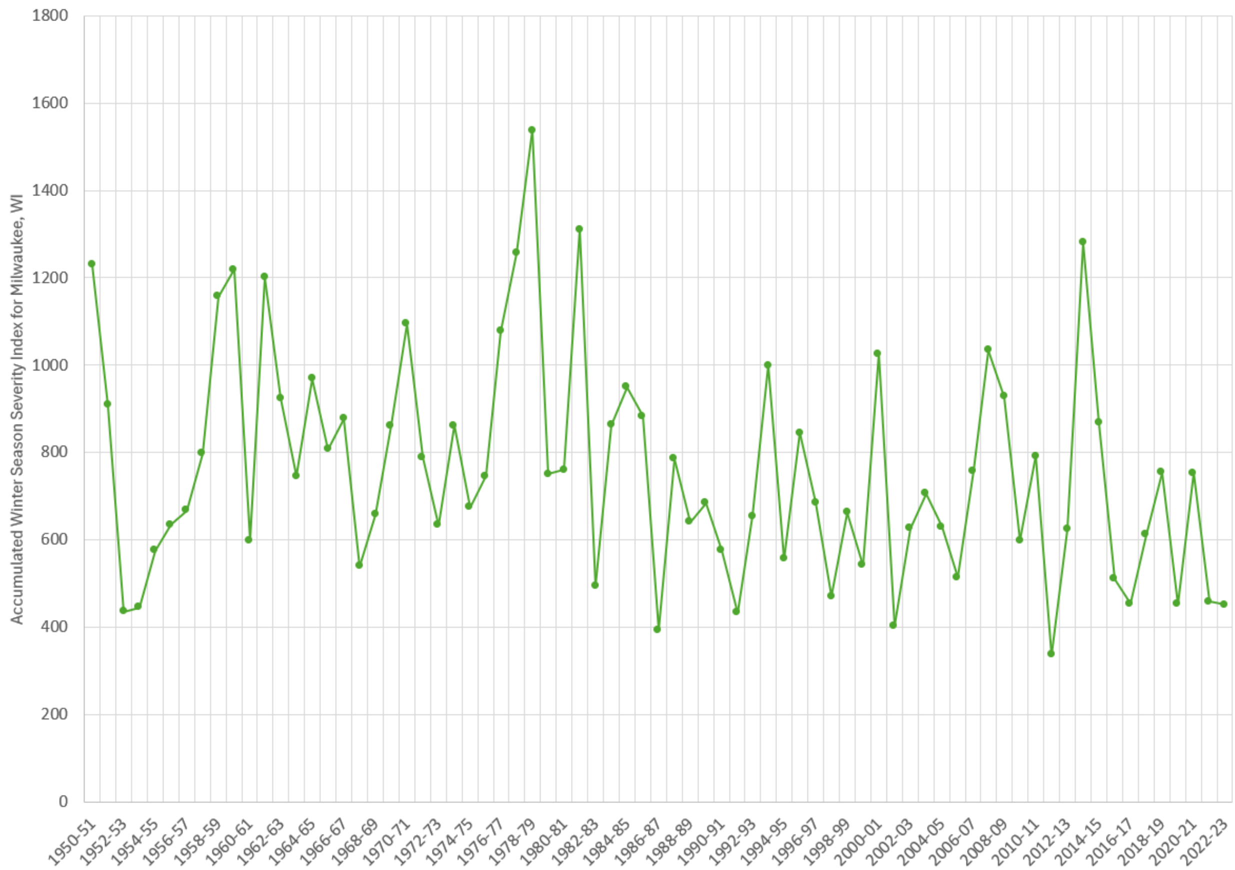
Source: Wisconsin Department of Transportation and Wisconsin State Climatology Office

Figure 2.WSIsalt
Regional Average WSI and WisDOT Regional Road Salt Use: (2001-2002 to 2022-2023)



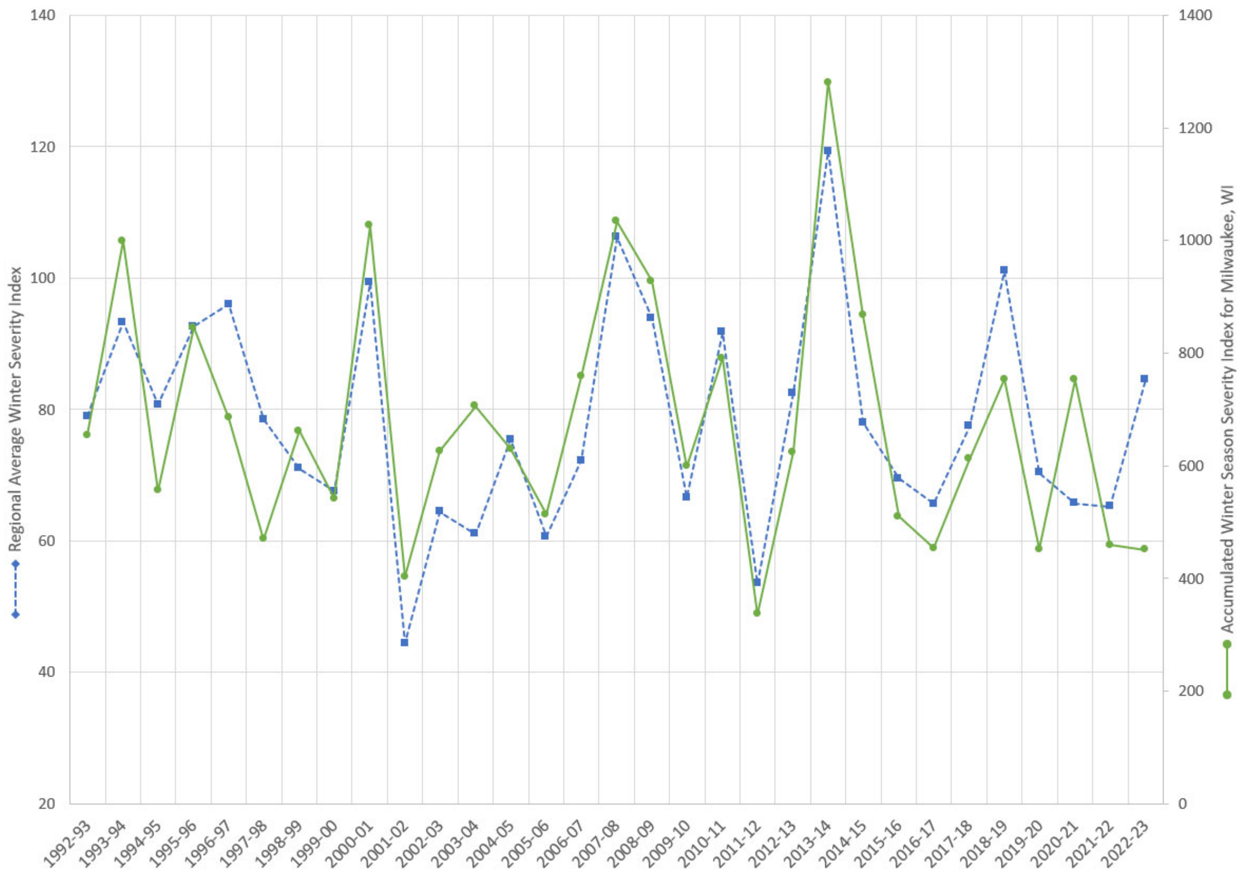
Source: Wisconsin Department of Transportation

Figure 2.AWSSI
MRCC Accumulated Winter Season Severity Index: Milwaukee (1950-1951 to 2022-2023)



Source: Midwestern Regional Climate Center

Figure 2.WSIvAWSSI
Comparison of the Regional Average WSI and Milwaukee AWSSI (1992-1993 to 2022-2023)



Source: Wisconsin Department of Transportation and Midwestern Regional Climate Center

Technical Report No. 63

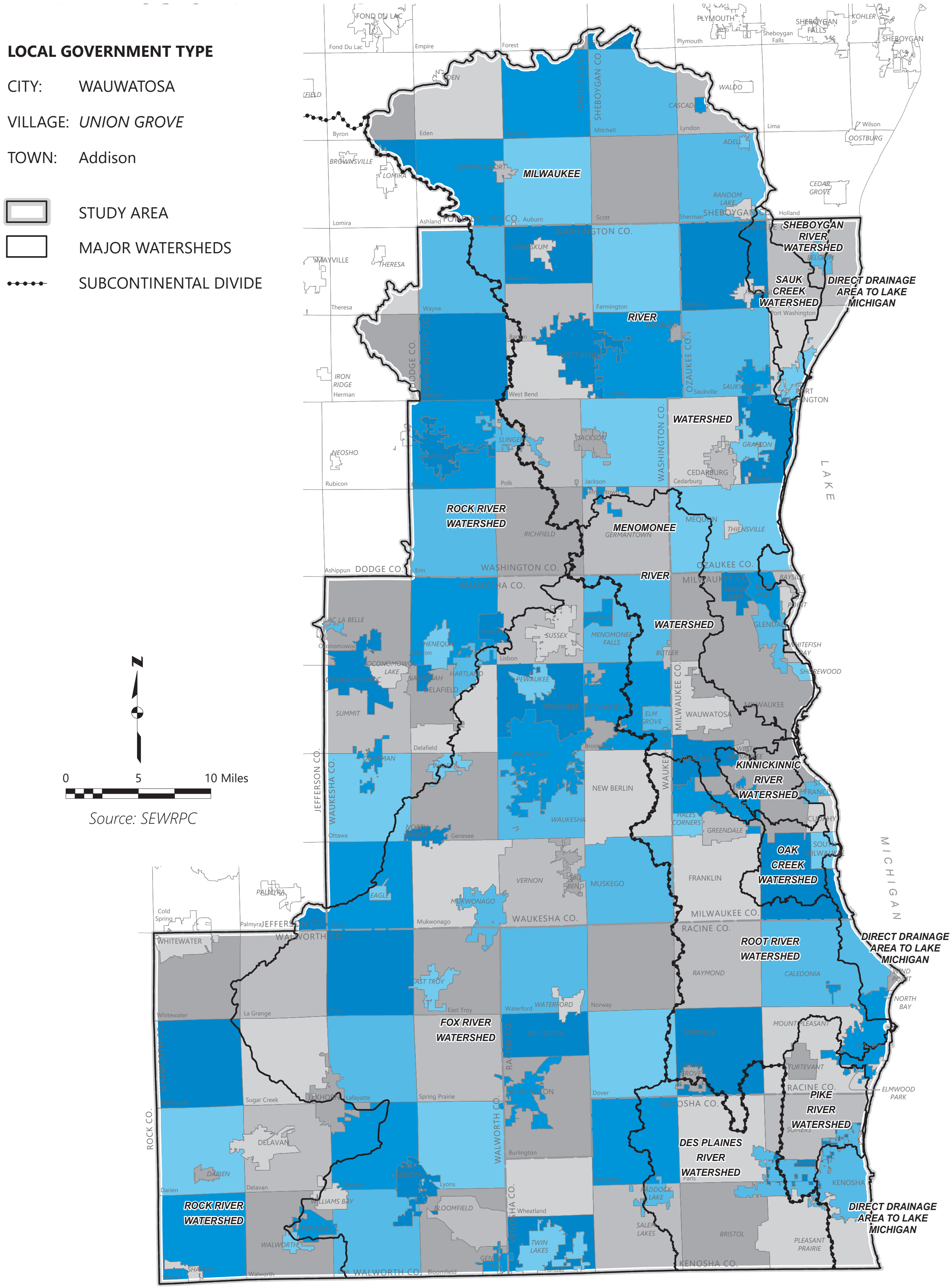
CHLORIDE CONDITIONS AND TRENDS IN SOUTHEASTERN WISCONSIN

Chapter 2

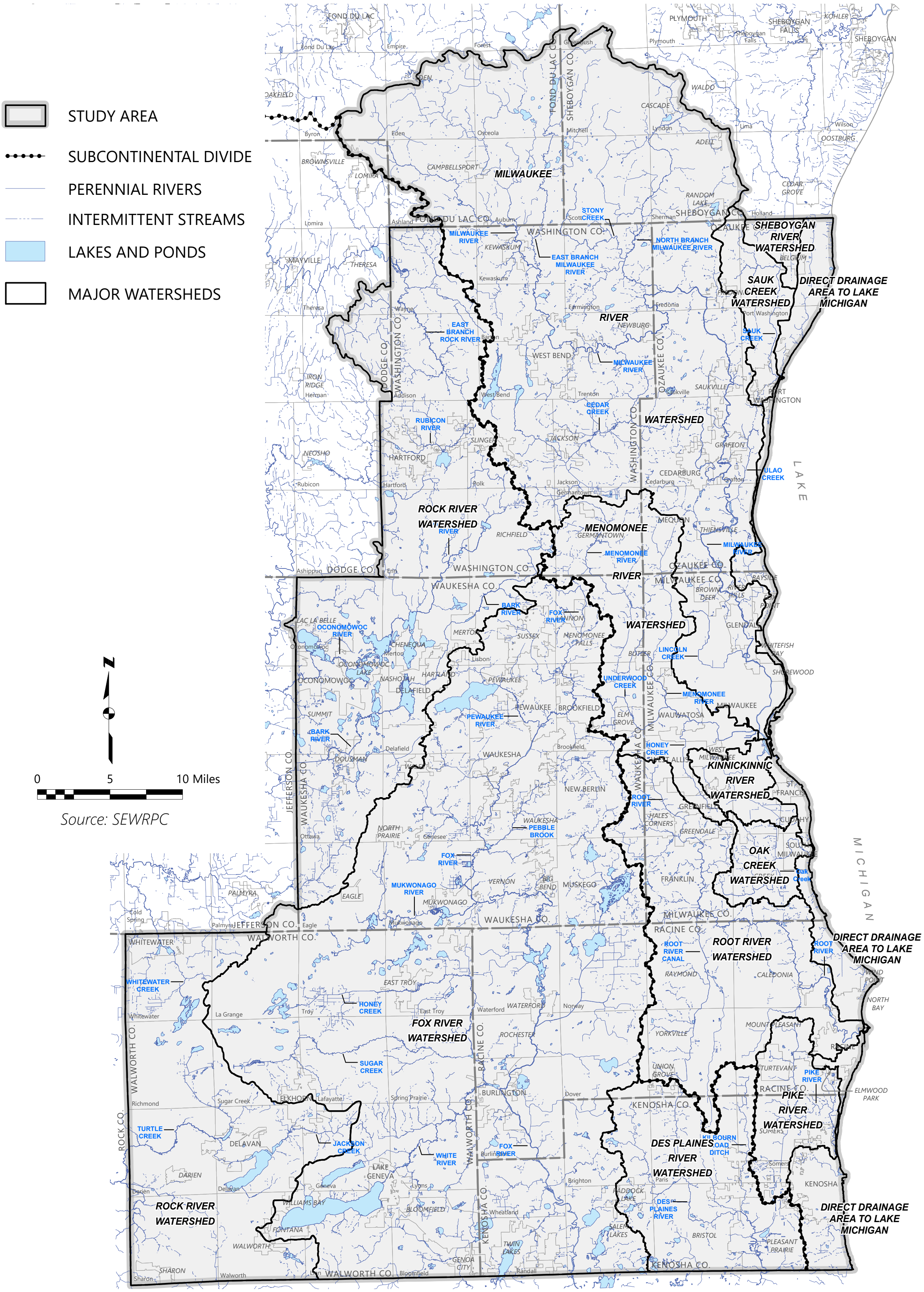
STUDY AREA BACKGROUND

MAPS

Map 2.1
Major Watersheds and Civil Divisions Within the Study Area

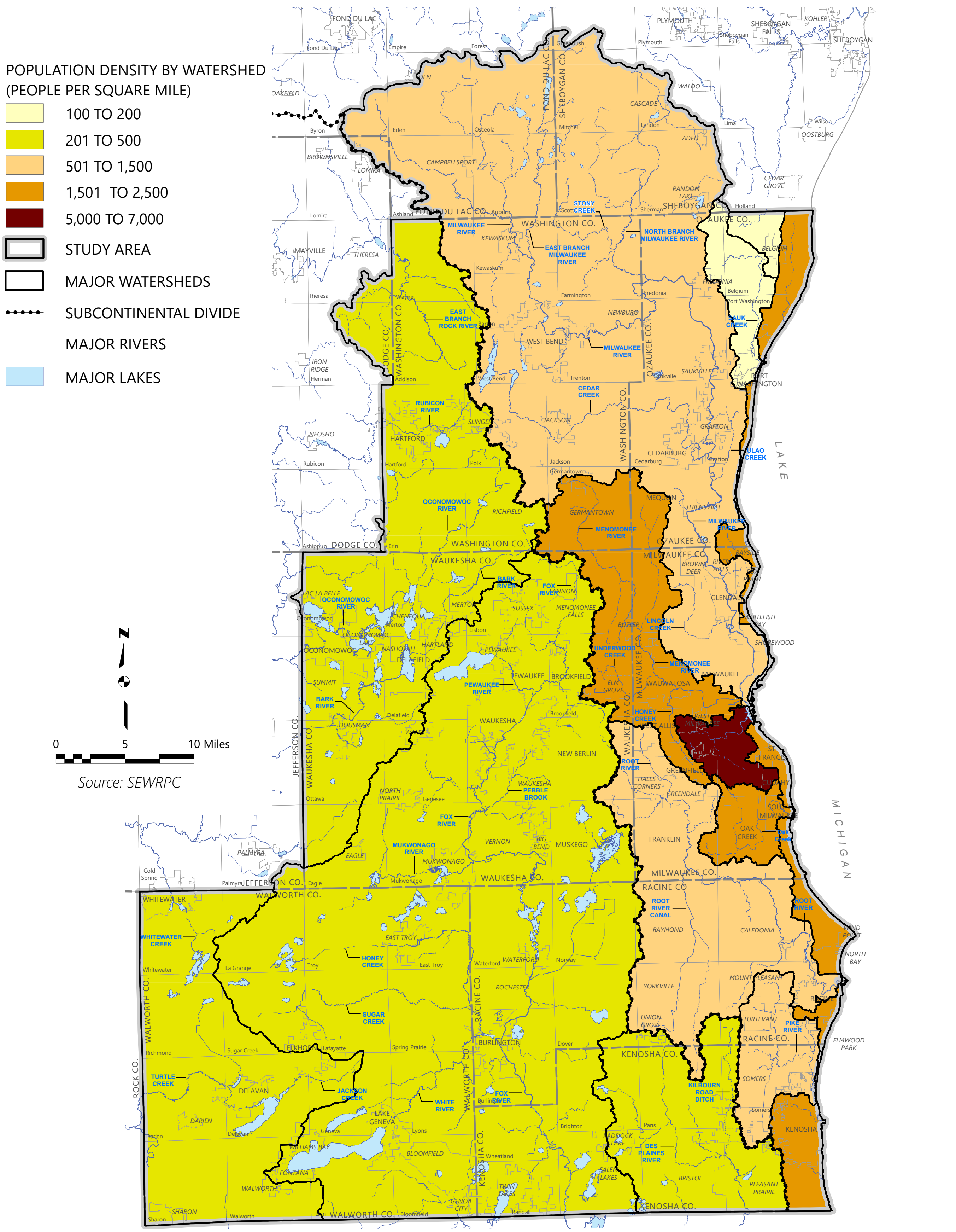


Map 2.2
Surface Waters Within the Study Area



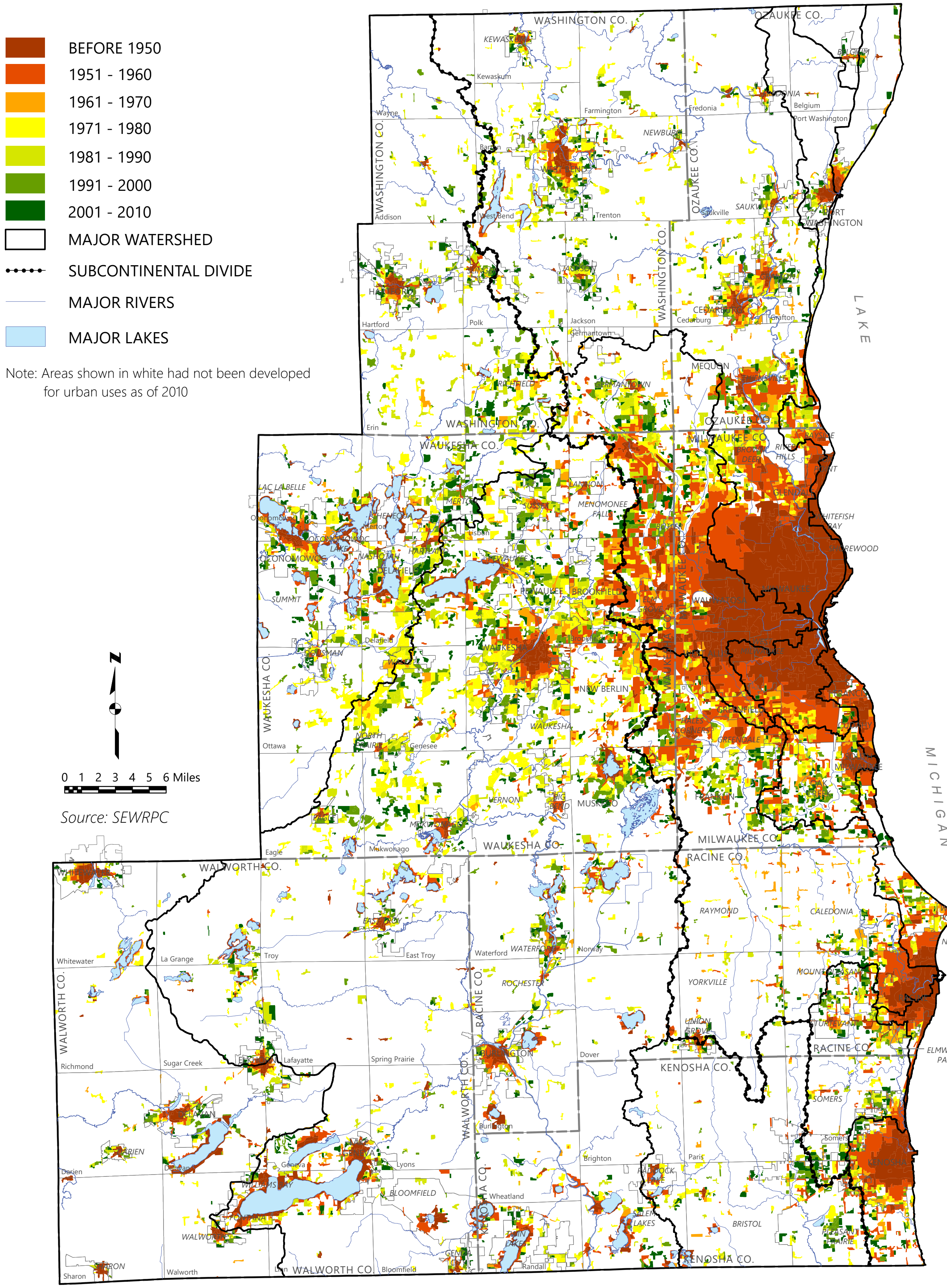
Source: SEWRPC

Map 2.3
Population Density by Watersheds Within the Study Area: 2010

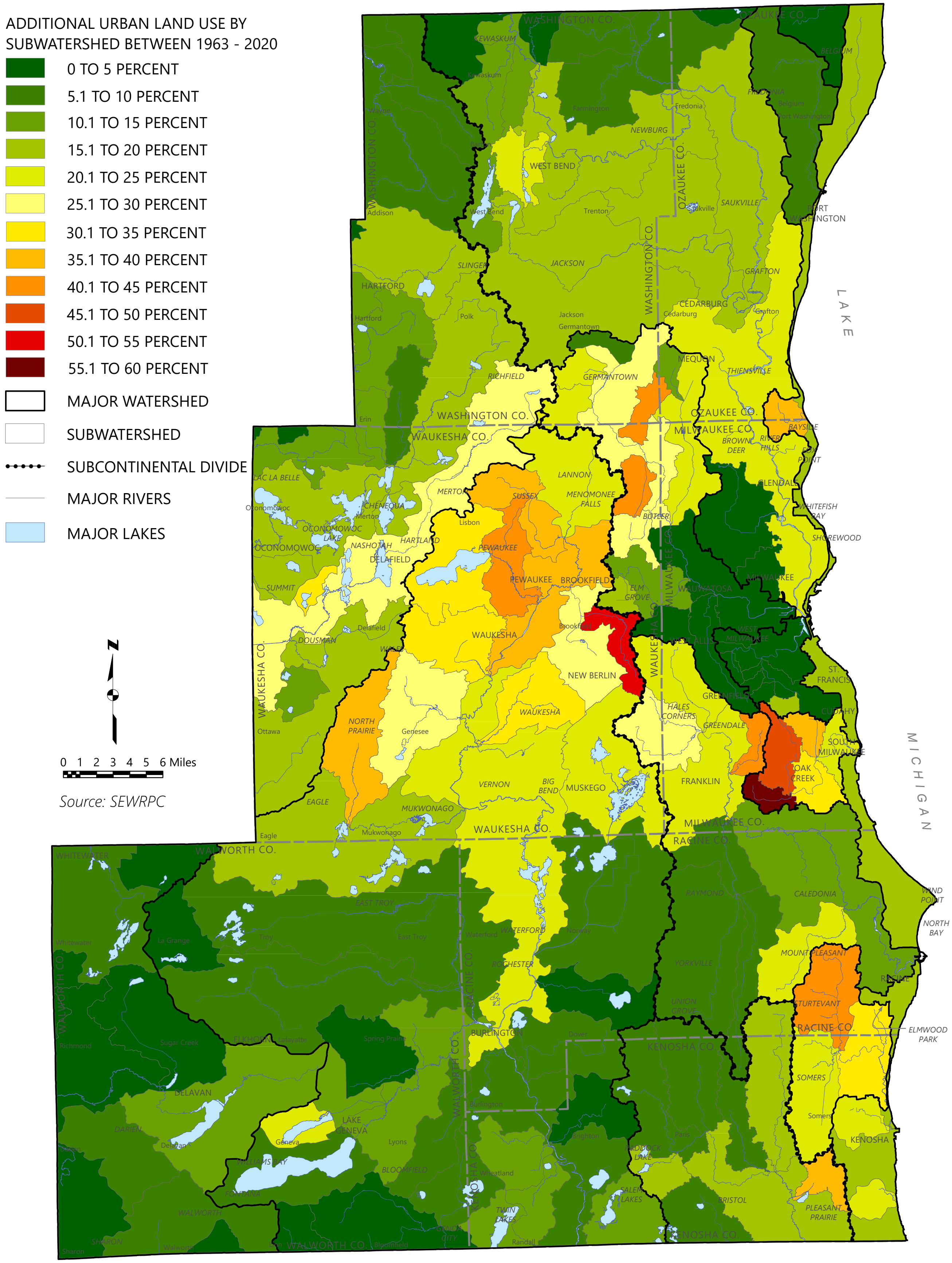


Source: SEWRPC

Map 2.4
Historical Urban Growth in the Southeastern Wisconsin Region: 1850-2010

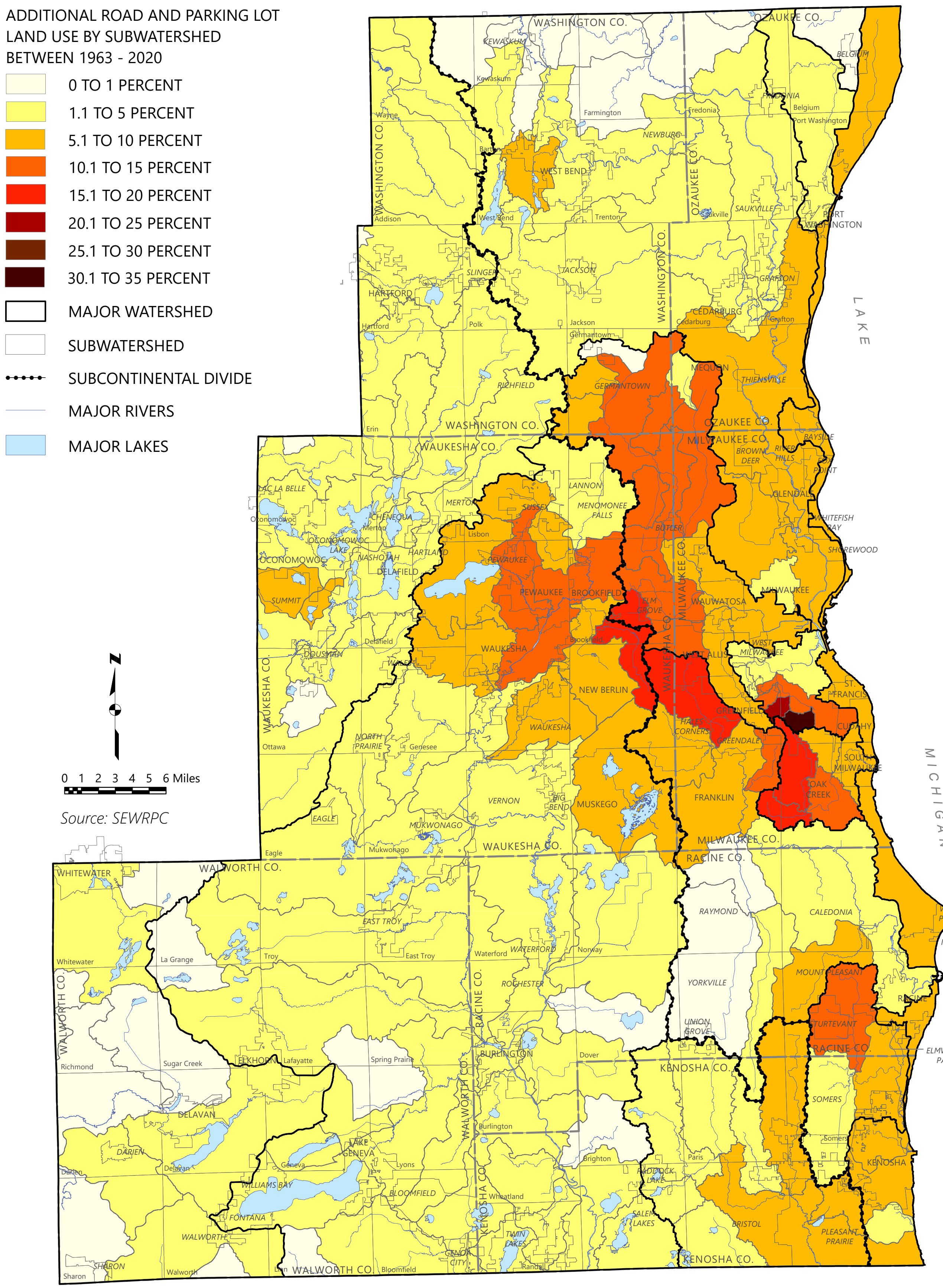


Map 2.5
Increases in Urban Land Use Within Subwatersheds of the Region Between 1963 and 2020



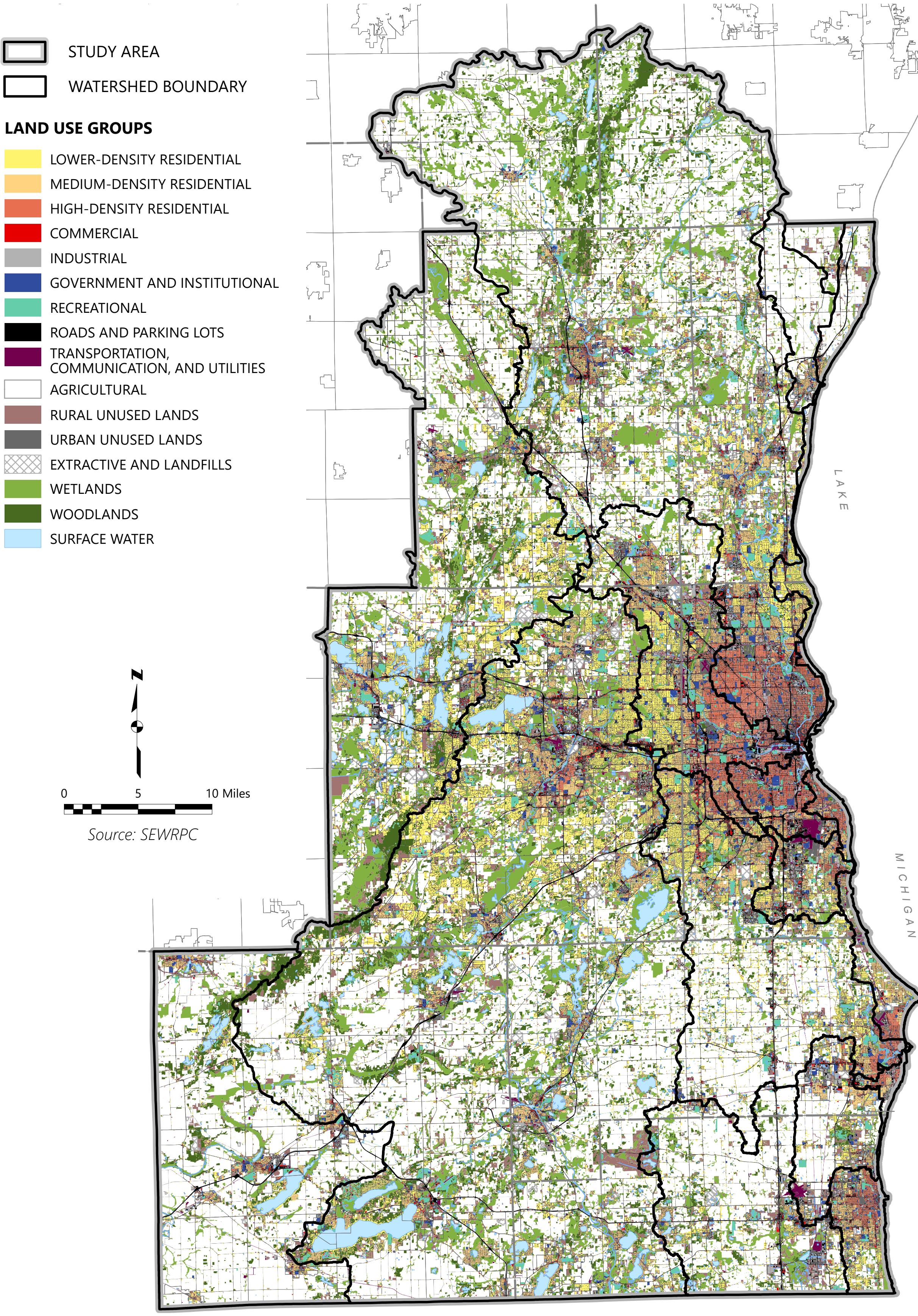
Source: SEWRPC

Map 2.6
Increases in Roads and Parking Lot Density Within Subwatersheds of the Region Between 1963 and 2020



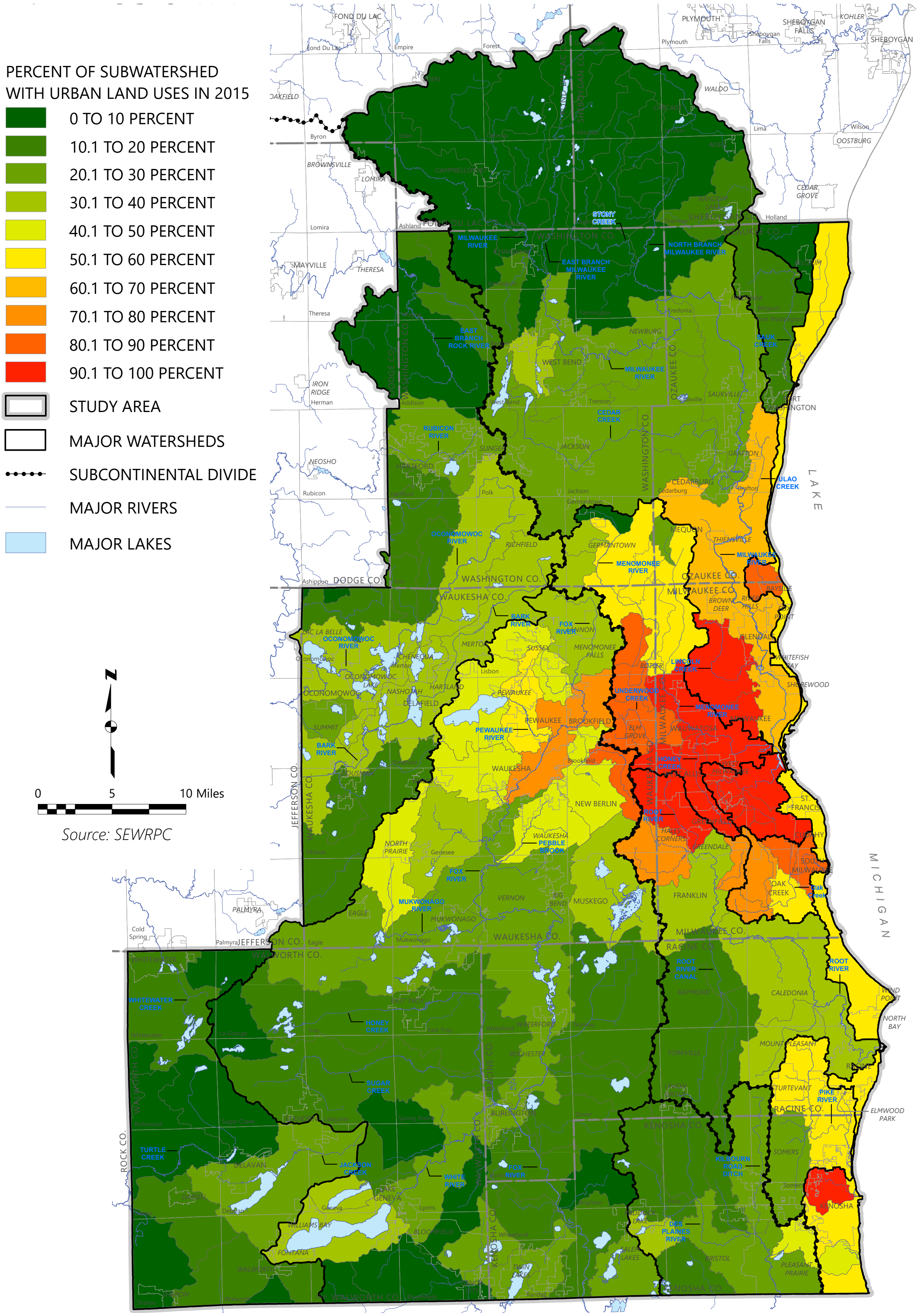
Source: SEWRPC

Map 2.7
Existing Land Use Within the Study Area

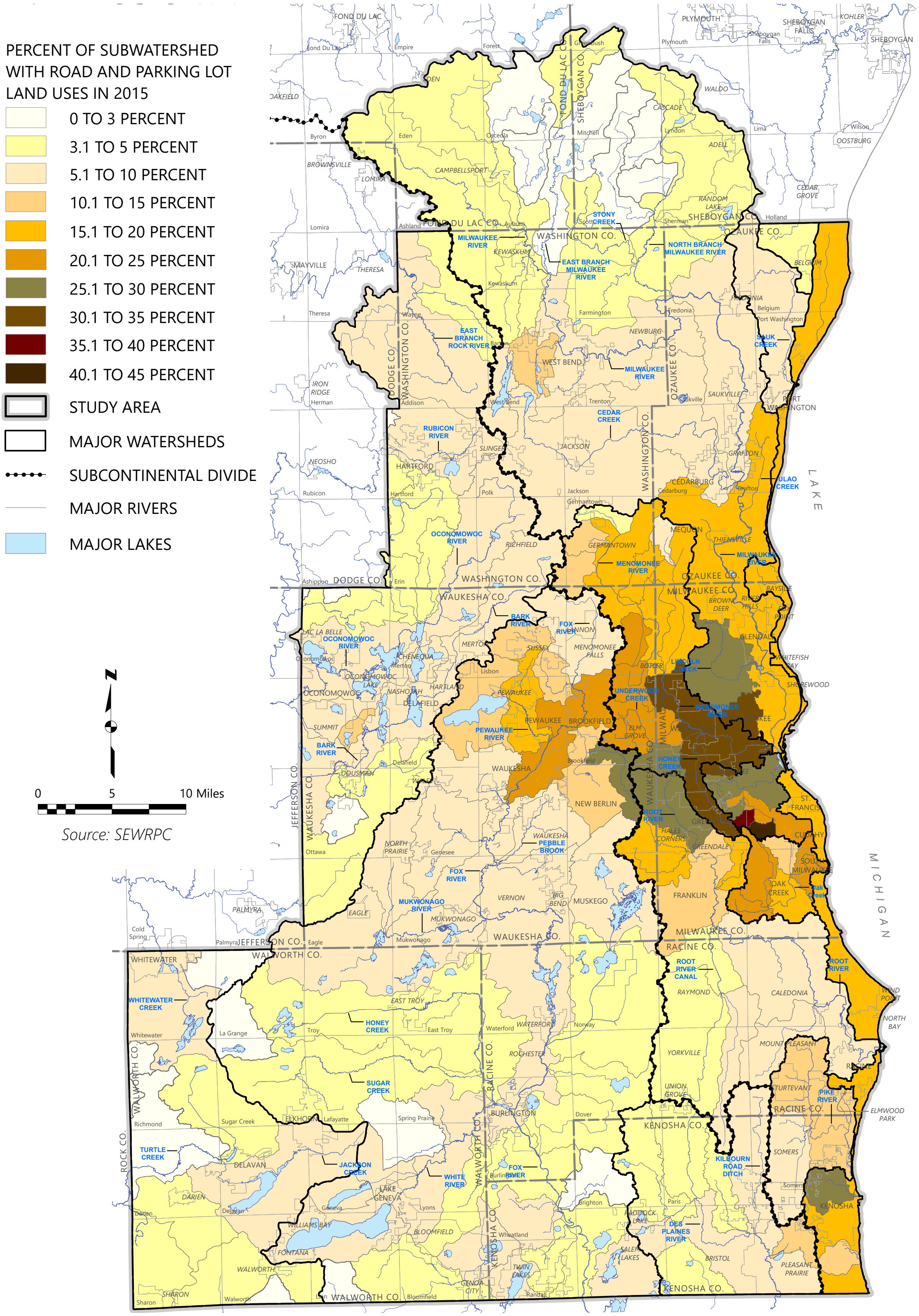


Source: SEWRPC

Map 2.8
Percent Urban Land Use by Subwatersheds Within the Study Area: Existing Conditions



Map 2.9
Density of Roads and Parking Lots by Subwatersheds Within the Study Area: Existing Conditions



Map 2.10
Existing and Abandoned Wastewater Treatment Facilities and Planned Sanitary Sewer Service Areas

EXISTING WASTEWATER TREATMENT FACILITY (DISCHARGES TO SURFACE WATER)

EXISTING WASTEWATER TREATMENT FACILITY (DISCHARGES TO SOIL)

ABANDONED WASTEWATER TREATMENT FACILITY (DISCHARGED TO SURFACE WATER)

STUDY AREA

MAJOR WATERSHEDS

SUBCONTINENTAL DIVIDE

MAJOR RIVERS

MAJOR LAKES

Notes: See Table 2.2 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.

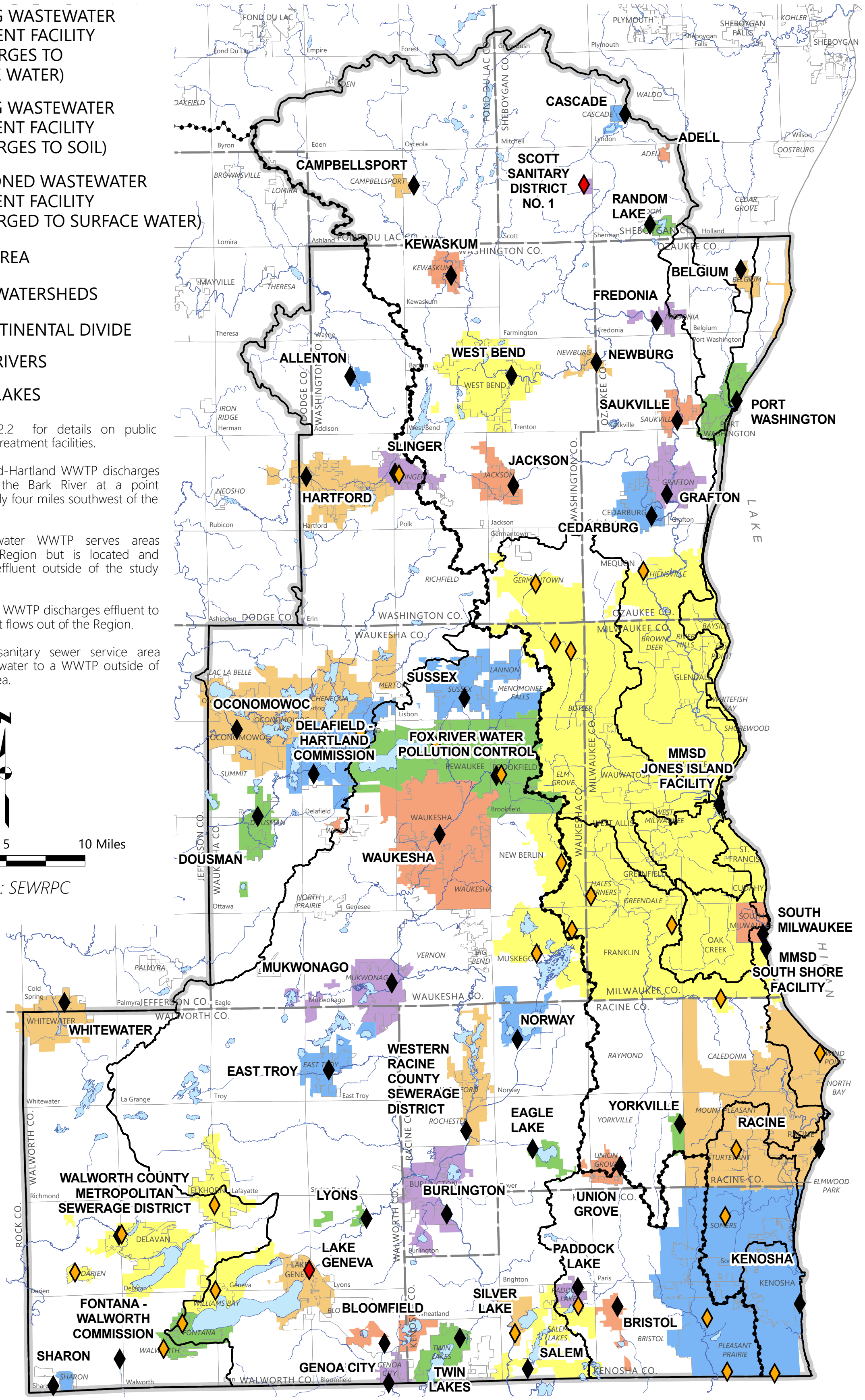
The Whitewater WWTP serves areas within the Region but is located and discharges effluent outside of the study area.

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

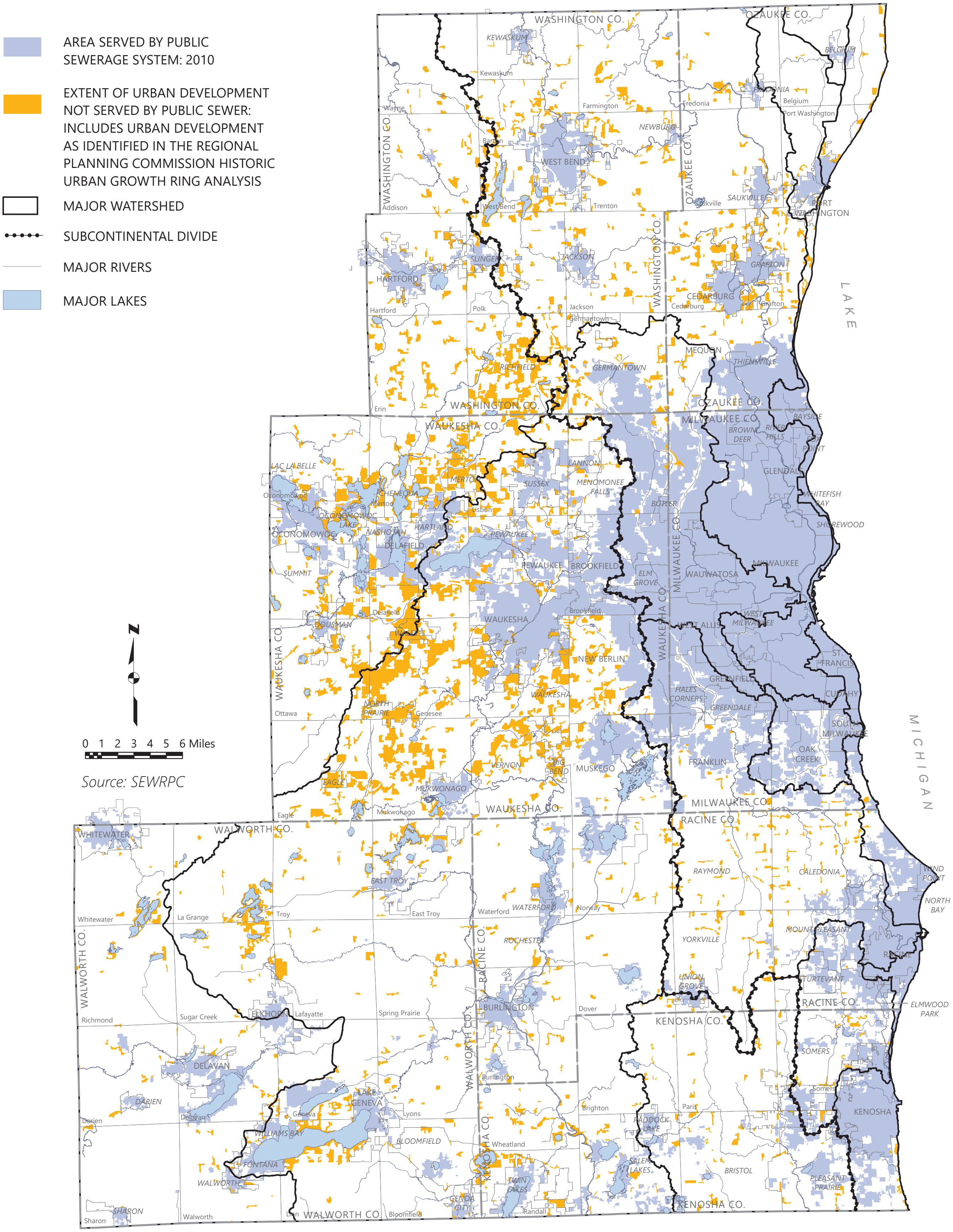
The Adell sanitary sewer service area sends wastewater to a WWTP outside of the study area.

0 5 10 Miles

Source: SEWRPC



Map 2.11
Areas Served by Public Sanitary Sewerage Systems in the Southeastern Wisconsin Region: 2010



Map 2.12
MS4 Permitted Communities and Other Entities Within the Study Area

LOCAL GOVERNMENT TYPE

CITY: WAUWATOSA

VILLAGE: *UNION GROVE*

TOWN: Addison

COMMUNITY WITH MS4 PERMIT

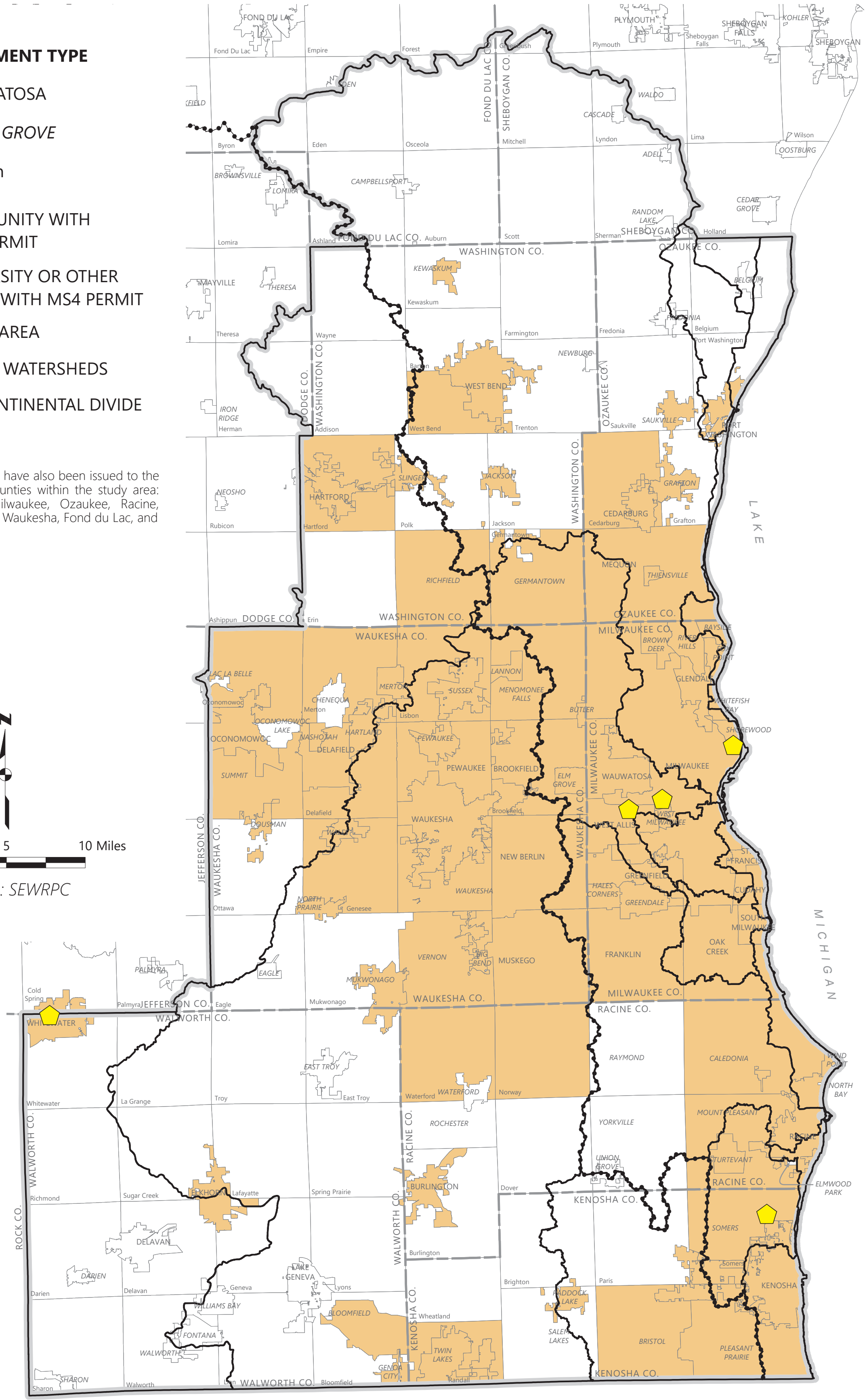
UNIVERSITY OR OTHER ENTITY WITH MS4 PERMIT

STUDY AREA

MAJOR WATERSHEDS

SUBCONTINENTAL DIVIDE

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.



0 5 10 Miles

Source: SEWRPC

Map 2.13
Municipal Water Supply Service Areas and Sources of Supply in the Southeastern Wisconsin Region: 2005

AREAS SERVED BY MUNICIPAL WATER UTILITIES PROVIDING WATER FROM LAKE MICHIGAN: 2005

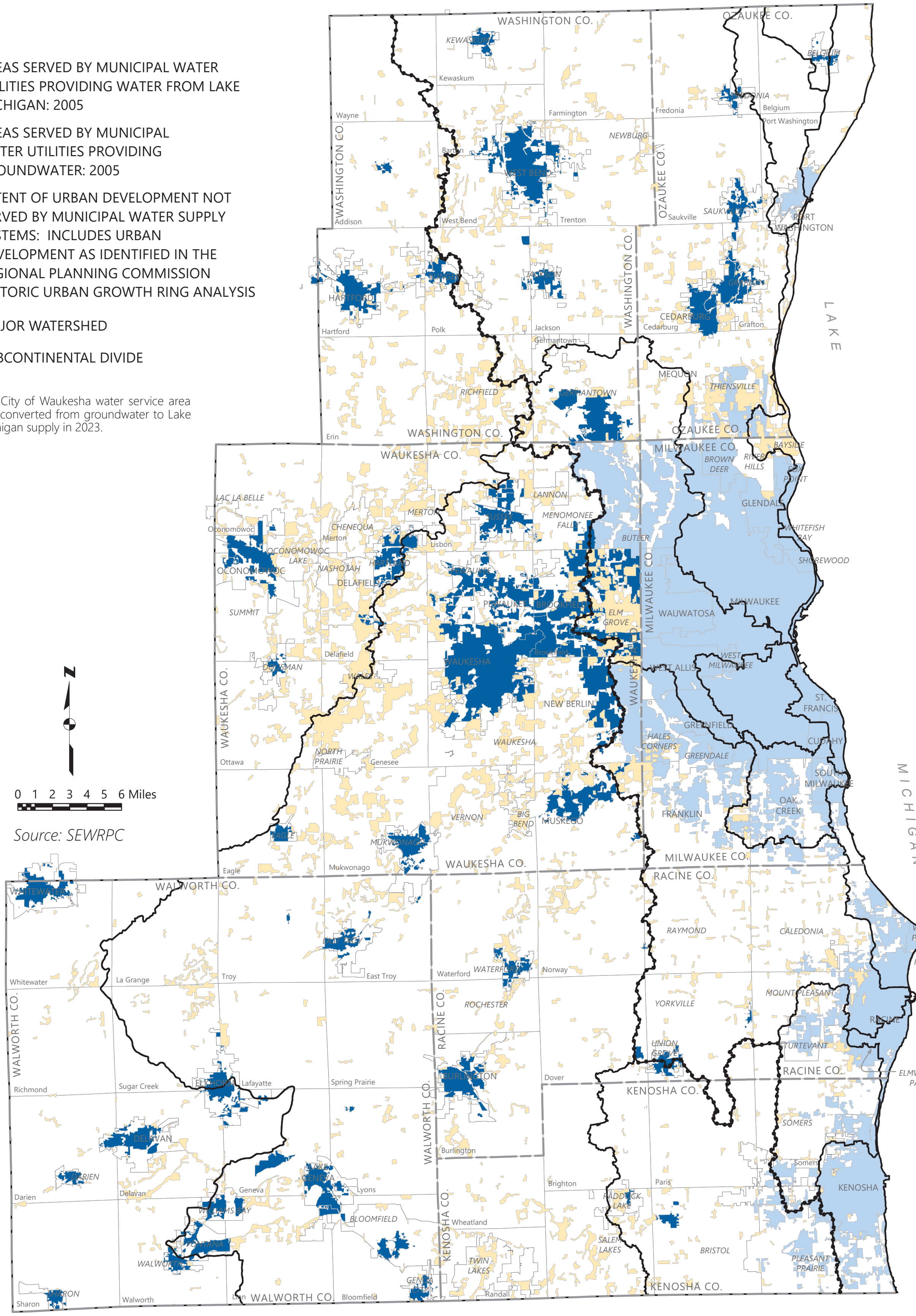
AREAS SERVED BY MUNICIPAL WATER UTILITIES PROVIDING GROUNDWATER: 2005

EXTENT OF URBAN DEVELOPMENT NOT SERVED BY MUNICIPAL WATER SUPPLY SYSTEMS: INCLUDES URBAN DEVELOPMENT AS IDENTIFIED IN THE REGIONAL PLANNING COMMISSION HISTORIC URBAN GROWTH RING ANALYSIS

MAJOR WATERSHED

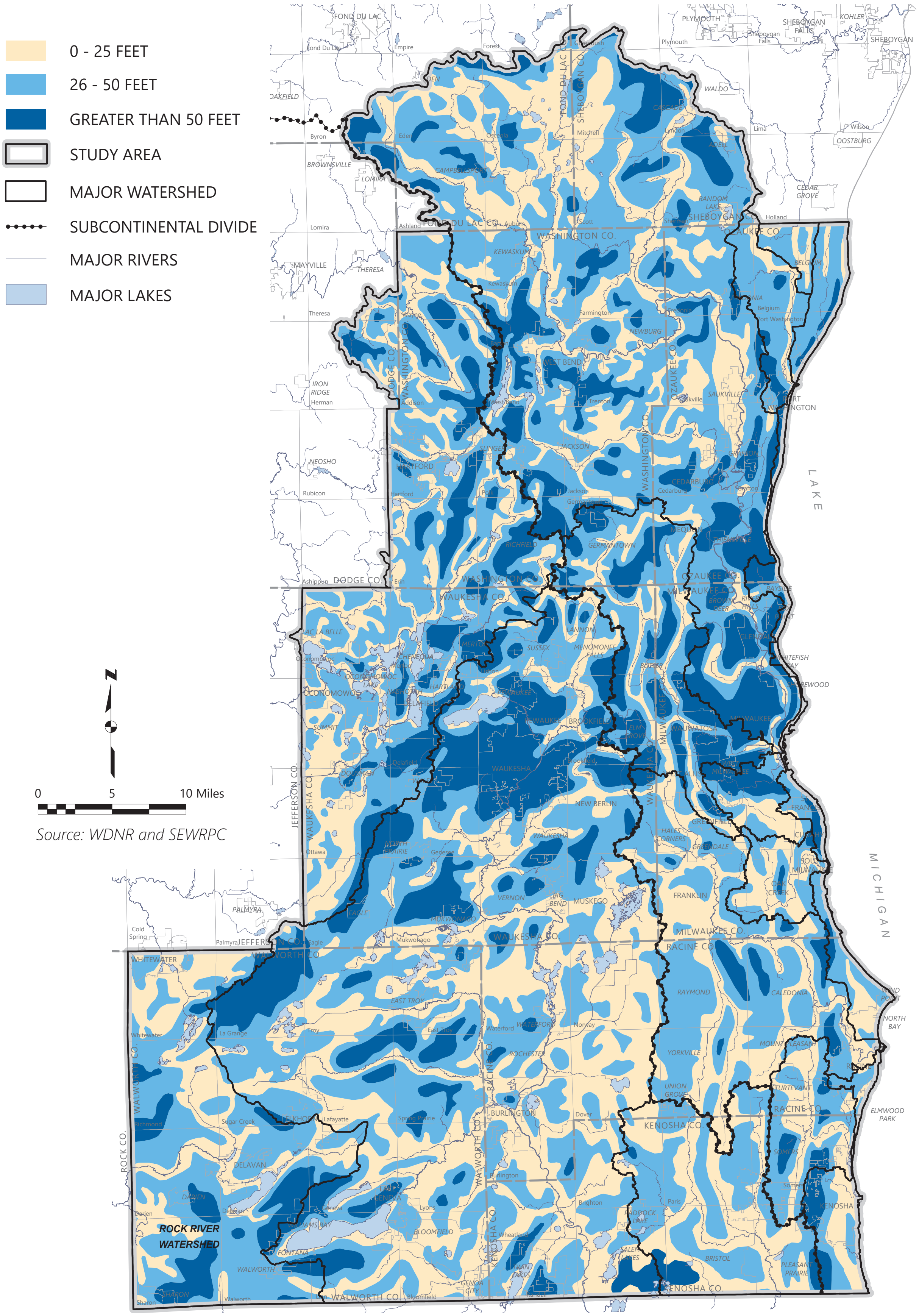
SUBCONTINENTAL DIVIDE

Notes: The City of Waukesha water service area was converted from groundwater to Lake Michigan supply in 2023.



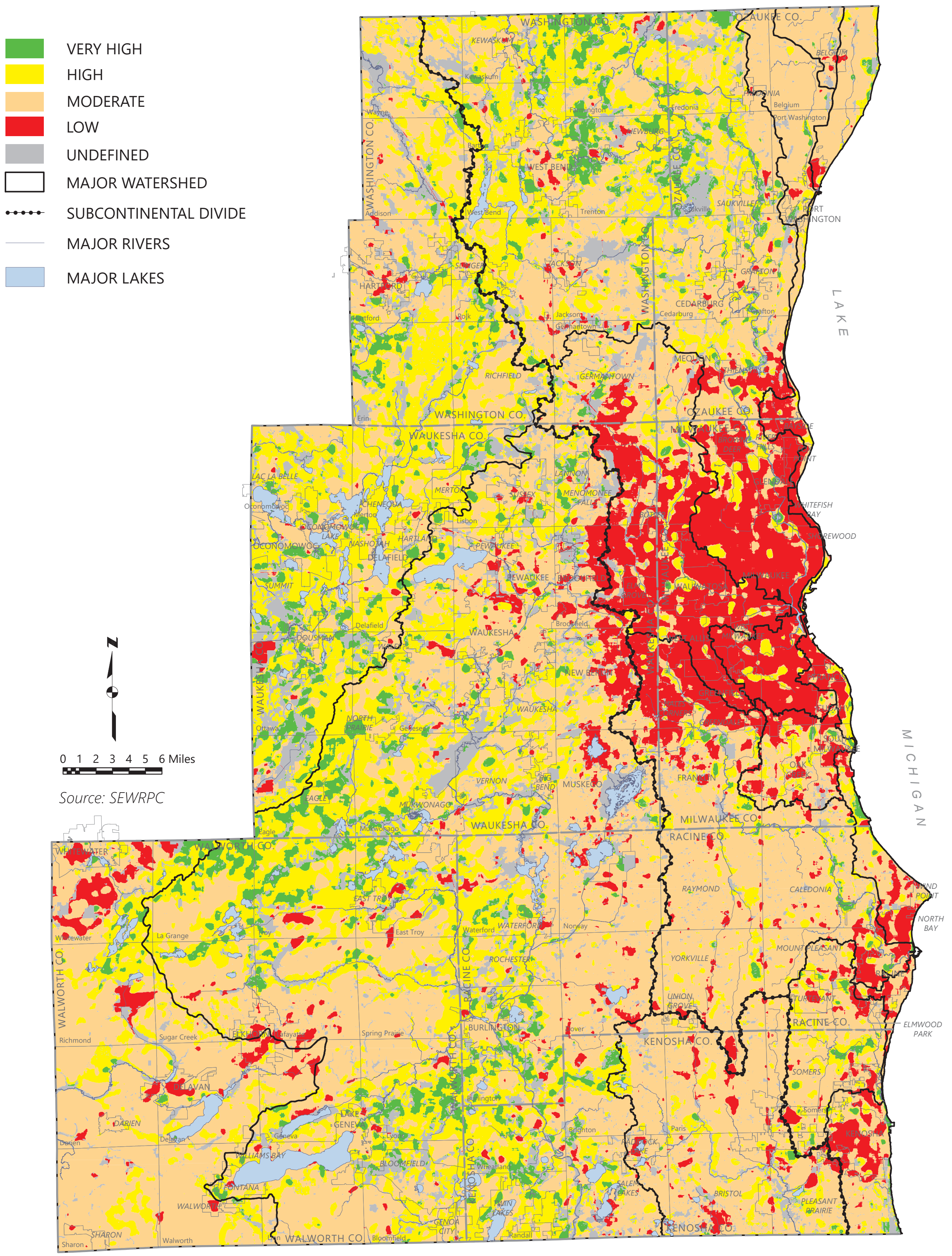
Source: SEWRPC

Map 2.14
Depth to Groundwater in the Southeastern Wisconsin Region Based on the Groundwater Contamination Susceptibility Model

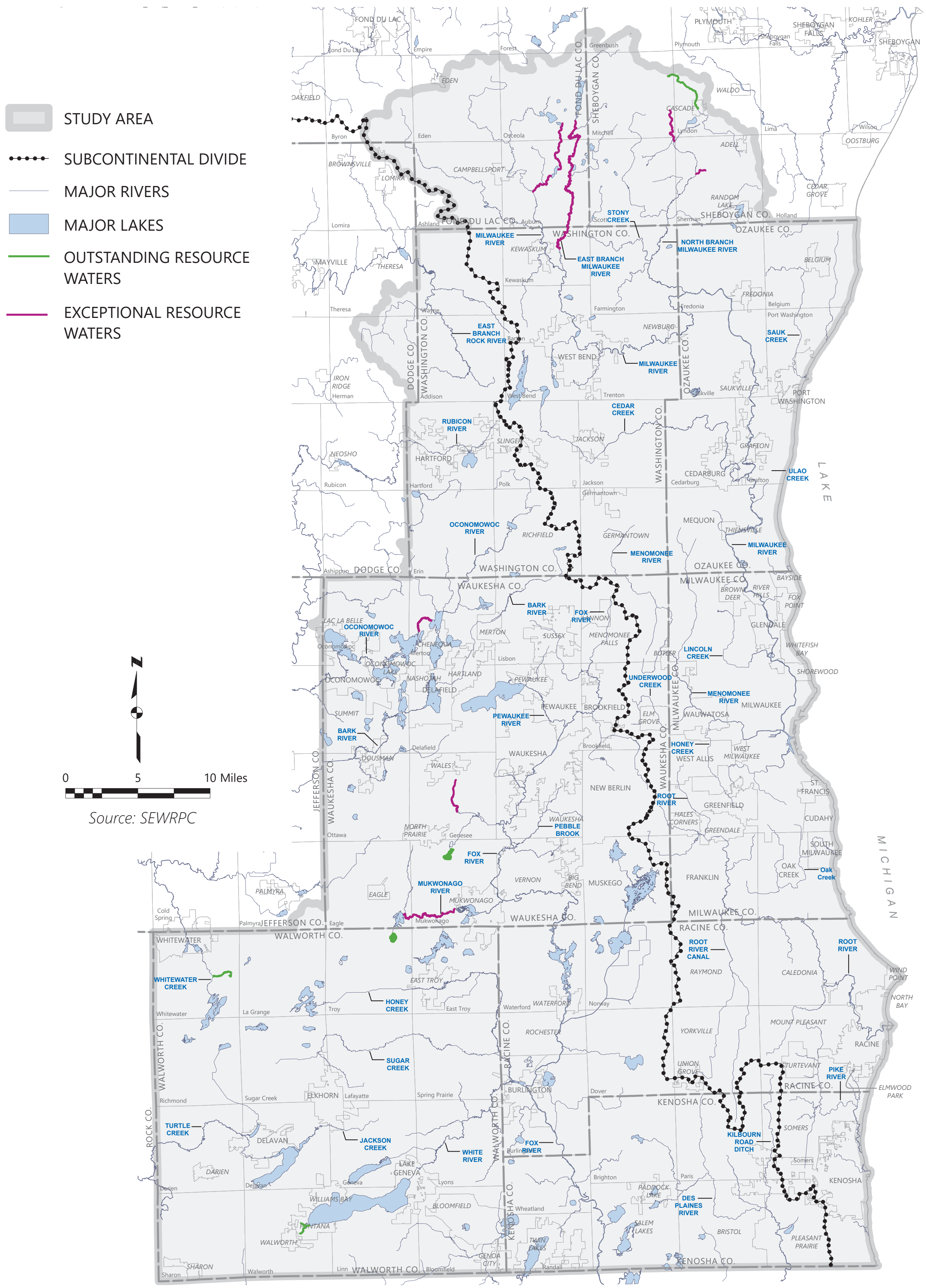


Source: WDNR and SEWRPC

Map 2.15
Estimates of Groundwater Recharge Potential in the Southeastern Wisconsin Region



Map 2.ORW_ERW
Outstanding and Exceptional Resource Waters



Map 2.Chloride_Impaired
Impaired for Chloride: 2024