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Technical Report No. 65

MASS BALANCE ANALYSIS FOR CHLORIDE IN SOUTHEASTERN WISCONSIN

Chapter 2

CHLORIDE SOURCES AND DATA FOR CHLORIDE LOADING AND MASS BALANCE ANALYSIS

2.1 STUDY AREA OVERVIEW

The Southeastern Wisconsin Region (Region) covers approximately 2,690 square miles across seven counties (from north to south): Washington, Ozaukee, Waukesha, Milwaukee, Walworth, Racine, and Kenosha. The Region borders Lake Michigan to the east and encompasses roughly 5 percent of the total land area of Wisconsin. These seven counties are home to approximately 2.05 million people, accounting for about 35 percent of the population of the State. The Region is an economic hub of the State, spanning heavily urbanized metropolitan areas, highly productive agricultural lands, and high-quality natural lands. The residents and businesses of the Region rely on surface water and groundwater resources to provide a reliable source of domestic, municipal, and industrial water supply. These interconnected surface water and groundwater resources are also important to the economic development, recreational activity, and aesthetic quality of the Region. In response to growing public concern regarding the environmental impacts of chloride salts, particularly to the surface and groundwater resources of the Region, the Southeastern Wisconsin Regional Planning Commission (Commission or SEWRPC) developed and conducted the Regional Chloride Impact Study (Study).

Addressing water quality issues in surface and groundwater resources often requires assessing conditions that go beyond regional and municipal boundaries. Contributing drainage areas upstream of a waterbody can have large impacts on downstream water quality conditions, regardless of political boundaries. Therefore, the study area for the Chloride Impact Study was expanded beyond the seven counties to include the areas outside the Region that drain into it, including adjacent portions of Dodge, Fond du Lac, Jefferson, and Sheboygan

Counties. The full study area for the Chloride Impact Study encompasses approximately 2,982 square miles and is shown on Map 2.1. The map highlights the 12 major watersheds that are located within the study area, including the Des Plaines River, Fox River, Kinnickinnic River, Menomonee River, Milwaukee River, Oak Creek, Pike River, Rock River, Root River, Sauk Creek, and Sheboygan River watersheds, as well as the areas draining directly to Lake Michigan. The study area covers all or portions of 11 counties, 29 cities, 75 villages, and 73 townships, as presented in SEWRPC Technical Report No. 61 (TR-61).[1]

Land Use

The type, intensity, and spatial distribution of different land uses within a watershed is critical in determining where, how, and the extent to which a particular pollutant may impact the waterways of the Region. Since 1963, the Commission has regularly conducted definitive inventories of existing land use patterns within the seven-county 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.[2] Areas considered "urban" under the Commission land use inventory include areas identified as residential; commercial; industrial; transportation, communication, and utility; governmental and institutional; intensive recreational uses; and unused urban lands. Areas considered "nonurban" under the land use inventory include agricultural lands, wetlands, woodlands, surface water, extractive and landfill sites, and unused rural lands. For the purpose of this Study, 16 major land use groupings were developed consisting of ten urban groups and six nonurban groups. The existing land use data for the study area, including the total acreage and percent of the study area represented by the 16 Study land use groups, is shown in Table 2.1. While over 70 percent of the existing land use in the study area is considered to be nonurban, large areas of highly urbanized development with a high density of roads and parking lots are prevalent throughout the central and eastern portions of the study area. The geographic distribution of the existing land use in the Region is presented in TR-61 on Map 2.5.[3]

Chloride-Impaired Waterbodies

The State of Wisconsin has established two surface water quality criteria for chloride meant to protect aquatic organisms from toxic effects. Under the acute toxicity criterion, the maximum daily concentration

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[1] *Refer to Map 2.3 and Table B.1 for a complete list of the civil divisions within the study area as presented in SEWRPC Technical Report No. 61,* Field Monitoring and Data Collection for the Chloride Impact Study, *September 2023.*

[2] *A detailed description of the assembly and integration of existing land use inventories for the study area is provided in SEWRPC Technical Report No. 61, 2023,* op. cit.

[3] *SEWRPC Technical Report No. 61, 2023,* op. cit.

of chloride is not to exceed 757 milligrams per liter (mg/l) more than once every three years. Under the chronic toxicity criterion, the four-day average of maximum daily chloride concentration is not to exceed 395 mg/l more than once every three years. Surface waterbodies that exceed either of these criteria are considered impaired for chloride under Section 303(d) of the Federal Clean Water Act. The Wisconsin Department of Natural Resources (WDNR) is required to submit a list of impaired waterbodies to the U.S. Environmental Protection Agency (USEPA) in even-numbered years. In 2022, 35 streams in southeastern Wisconsin were listed as impaired due to exceeding either the chronic or both the chronic and acute criteria, as listed in Table 2.2. Map 2.2 shows the locations of the chloride-impaired waterbodies in the Region. Technical Report No. 63 (TR-63) provides additional information related to chloride trends and conditions within the study area.[4]

Stream Monitoring Sites

Commission staff conducted water quality monitoring for the Study, collecting data at 41 stream sampling sites within the Region for the study period from October 2018 through October 2020. Map 2.3 shows the locations of the 41 stream monitoring sites installed for the Study, broken out by major watershed. Table 2.3 lists additional information for the 41 monitoring sites established for the Study. Appendix B presents maps with detailed land use and drainage area characteristics for each stream monitoring site. Several monitoring sites were located on the same stream, such that the upstream drainage areas of some monitoring sites were nested within the drainage areas of the sites located further downstream. The 15 stream monitoring sites with other Study monitoring sites nested within their drainage areas are provided in Table 2.4. The table is organized by the downstream-most monitoring site, as some site drainage areas have nested sites within other nested sites. Refer to TR-61 for detailed information related to the stream monitoring sites deployed for the Study, along with a description of the site selection process and data collection methods.[5]

Continuous monitoring using in-stream sensors was conducted at stream monitoring sites to collect specific conductance, water temperature, and water depth over the course of the study period, including over two winter seasons. The continuous monitoring for specific conductance data was supplemented by regular surface water sample collection at the same locations to be analyzed for concentrations of chloride and some of the other constituent chemicals that comprise specific conductance. The data collected at stream

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

[5] *SEWRPC Technical Report No. 61, 2023,* op. cit.

monitoring sites is discussed in Section 2.3, and the evaluation of the water quality data collected during the study period is detailed in TR-63.[6]

Climate and Weather Conditions During the Study Period

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.[7] The mid-continental location of the Southeastern Wisconsin Region 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.[8]

While the Region exhibits spatial variations in weather due primarily to its proximity to Lake Michigan, 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.

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.[9] The

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[6] *SEWRPC Technical Report No. 63, in preparation,* op. cit.

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

[8] *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.*

[9] *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.*

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.[10]

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 2.5, 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.

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 normal average daily temperatures ranged from 20.7ºF in January to 71.3ºF in July (see Table 2.5). 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. Figure 2.1 presents the monthly mean temperature during the study period from October 2018 through October 2020 along with the monthly temperature normals. For the study period, the mean monthly temperatures were near normal, with a slightly cooler than normal winter 2018-2019 followed by a slightly warmer than normal winter 2019-2020. Chapter 2 of TR-63 compares temperatures during the study period with long term temperature data dating back to 1895.[11] While the annual temperatures and winter temperatures during the study period were warmer than long term averages, the study period was not atypical when compared to temperatures observed since about 2000.

Precipitation

Precipitation within the Region takes the form of rain, sleet, hail, and snow. Climatological records for precipitation data represent the liquid water equivalent and depth totals for all forms of liquid and frozen precipitation. The Region receives on average 35.3 inches of precipitation per year, and nearly three-

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[10] *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.*

[11] *SEWRPC Technical Report No. 63, in preparation,* op. cit.

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 along with the monthly precipitation normals are shown in Figure 2.2. Wetter than normal conditions at the beginning of the Study were punctuated by some months with precipitation departures as large as 4 inches higher than normal and transitioned to more normal and drier than normal conditions by the end of the Study. 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.[12]

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 (see Table 2.5). The snowfall data is reported as the average of the actual snowfall depth measured at all available stations across the Region. Figure 2.3 presents the monthly snowfall totals for each winter season of the Chloride Study along with the normal snowfall totals. Considering the winter season snowfall totals overall, winter 2018-2019 had higher than normal snowfall, while the snowfall totals for the winter 2019-2020 were near normal.

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 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.

[12] *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.*

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 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, established at the University of Wisconsin-Madison in partnership with WisDOT.[13] 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.[14] Additional information related to the WSI is available through the WisDOT Annual Winter Maintenance Reports.

Figure 2.4 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.[15] 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 2.5. The computed WSI also correlates well with historical

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

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

[15] *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.*

WisDOT road salt usage in the Region. Figure 2.6 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.[16] 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 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.[17] Figure 2.7 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

[16] *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.*

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

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 2.8 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 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.

2.2 CHLORIDE SOURCES AND INPUT DATA

There are many different sources of chloride in the Region. While some chloride sources occur naturally, a vast majority of chloride contributions to the environment are from anthropogenic sources. As discussed in TR-62, chloride salts are highly soluble, and chloride ions move with water through the natural environment. Also discussed in TR-62, chloride and chloride salts entering the environment can have a wide range of impacts, including physical and chemical interactions with the natural environment, impacts on biological systems, infrastructure, and manmade systems, as well as positive and negative effects on human health and activities.[18] That same report presents a figure (see TR-62 Figure 2.4) showing the principal sources of chloride and detailed pathways through the environment. Chloride, a highly mobile pollutant, is transported by water through the hydrologic system of a watershed along a variety of pathways with a wide range of timescales. Figure 2.9 highlights major and minor sources of chloride in the Region and defines simplified transport pathways through the environment. A 2015 U.S. Geological Survey (USGS) report detailing methods for evaluating potential sources of chloride to the environment provided a collection of references

[18] *SEWRPC Technical Report No. 62, 2024,* op. cit.

that were useful for the analysis.[19] The following paragraphs present the sources of chloride that were investigated for this Report and summarize the data obtained for each chloride source. Chapter 3 details the methodology and assumptions used to estimate chloride loads for many of these chloride sources.

Winter Maintenance Operations

Chemical compounds containing chloride are often used to manage snow and ice on paved surfaces such as roads, parking lots, and walkways. In general terms, salt and other deicing chemicals work by lowering the freezing point of water to prevent snow and ice from adhering to paved surfaces and to facilitate the removal of snow and ice through plowing or other mechanical removal methods. Sodium chloride (NaCl), also known as road salt, is the most common chemical used for winter maintenance and can be applied as solid rock salt or a liquid brine for use in prewetting, anti-icing, and deicing applications. The effectiveness of NaCl is reduced at very low temperatures and other chemicals may be employed for deicing under these conditions, such as calcium chloride ($CaCl_2$) or magnesium chloride ($MgCl_2$). Alternative deicing materials are used less often in southeastern Wisconsin, and include proprietary chemical blends, organic deicers, and industrial byproducts such as cheese brine. Alternative deicers are discussed further in Technical Report No. 66 (TR-66), and this Report focuses primarily on chloride-based deicers such as NaCl, $CaCl_2$, and $MgCl_2$.[20]

Chloride-containing compounds used for winter road maintenance can travel through the environment through a variety of pathways. Solid deicing salts applied to impervious surfaces may be subject to bouncing and scattering, spreading chloride beyond the intended target area. Deicing salts can be plowed onto adjacent roadside areas, and roadway traffic can further the spread chlorides through splash or spray onto nearby vegetation and lands. Deicing salts may dissolve in melting snow and ice and can be transported with runoff directly into surface waters. Chloride-laden runoff that flows onto pervious surfaces may infiltrate through underlying soils into groundwater. Salt residues on roadways and adjacent roadsides can be mobilized into the air through aerosolization, be transported by wind and settle on surfaces.

Road salt is critical to public safety and traffic operations, providing significant benefits to the public by allowing access to roadways and vehicular travel during severe winter weather conditions or shortly thereafter. Chloride-based deicers also improve pedestrian safety by reducing the risk of injury that could

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[19] *G.E. Granato, L.A. DeSimone, J.R. Barbaro, and L. C. Jeznach,* Methods for Evaluating Potential Sources of Chloride in Surface Waters and Groundwaters of the Conterminous United States*, U.S. Geological Survey Open-File Report No. 2015-1080, 2015.*

[20] *SEWRPC Technical Report No. 66,* State of the Art for Chloride Management*, in preparation.*

result from the accumulation of snow and ice on walkways and parking lots. Public expectations and perception influence winter road maintenance practices for public road deicing, while the risk of slip and fall liability is a consideration that impacts private winter maintenance practices. These topics and other legal and policy considerations related to chloride management are discussed in Technical Report No. 67 (TR-67).[21]

Public Road Deicing and Anti-Icing

Public roadways in Wisconsin fall under various jurisdictions, designating the entities responsible for maintaining the roadway. There are three types of State and Federal roadways in Wisconsin, Interstate Highways (IH), U.S. Highways (USH), and State Trunk Highways (STH). While the State and Federal roadways are under the jurisdiction of the Wisconsin Department of Transportation (WisDOT), winter road maintenance operations for these roadways are contracted out to the individual County Highway Departments. The Counties maintain separate stockpiles and accounting of deicing and anti-icing materials used on State and Federal roads and regularly report winter maintenance activity data to WisDOT. Furthermore, each County Highway Department is responsible for maintaining the County Trunk Highway (CTH) network throughout the entire county.[22] Many of the communities within the Region are responsible for the winter maintenance of the local roads within their corporate limits. Some smaller communities may contract winter road maintenance work to another municipality, the County, or to a private entity.

Winter Maintenance Material (Road Salt) Usage Data

Data for Road Salt and Deicing/Anti-Icing Materials Applied to State and Federal Roadways

Data related to the usage of various deicing and anti-icing materials used for winter maintenance on State and Federal highways was obtained from WisDOT. The Counties perform winter maintenance operations on state and federal roadways and report data to WisDOT via weekly storm reports. The weekly storm reports provide information related to the dates, times and types of storms, deicing/anti-icing material usage, and snow depth, among other data relevant to winter maintenance operations. Weekly storm reports and winter season summaries for each County were obtained from the WisTransPortal database to

[21] *SEWRPC Technical Report No. 67,* Legal and Policy Considerations for the Management of Chloride*, April 2024.*

[22] *In Wisconsin, County Trunk Highways are assigned a highway letter designation, whereas State and Federal Highways have numerical route designations.*

determine the deicing/anti-icing material usage across the study area for each month within the study period.[23]

Data for Road Salt and Deicing/Anti-Icing Materials Applied to County and Local Roadways

Winter road maintenance data for County and local roadways was obtained primarily from two sources: annual reports submitted to satisfy the WDNR municipal separate storm sewer system (MS4) permit requirements and data that was submitted directly to the Commission. MS4 permittees are required to implement best management practices and stormwater runoff pollution reduction measures. Communities that participate in the MS4 permit program are also required to submit an annual report to the WDNR detailing water quality-related information, including a section related to winter road maintenance operations.[24] The annual report data includes the monthly totals for road salt and other materials used for winter road maintenance activities, total lane miles maintained, and additional information related to equipment calibration and staff training. MS4 report data were available for many municipalities within the Region, along with six out of seven counties in the Region, plus two additional counties located within the greater study area.

Commission staff sent a letter requesting information on winter maintenance operations and deicing/anti-icing material usage to all communities in the Region, including communities that are not required to hold an MS4 permit and report winter maintenance data to WDNR. A small number of non-MS4 municipalities in the Region reported data separately to the Commission in response to the request letter, while a few MS4 communities provided supplemental data. Additionally, some towns in the Region contract with their County to provide winter maintenance operations. Map 2.4 shows the different sources of winter road maintenance data for county and local roadways in the study area, highlighting the communities with MS4 permits, the communities that have reported data separately to the Commission, and those that contract their winter road maintenance to the County. The winter road maintenance data that was reported separately were relatively limited and the data reported separately was combined with the MS4 data for analysis purposes.

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

[24] *Wisconsin Department of Natural Resources,* Annual Report Under Municipal Separate Storm Sewer System (MS4) Permit*, Form 3400-224, revised 10/2018.*

Geospatial Data for Transportation Networks, Site Drainage Areas, and Civil Divisions

Regional transportation network data for Federal, State, and County roadways within southeastern Wisconsin for the year 2020 was obtained from the transportation inventory data maintained by the Commission and presented on Map 2.5. The transportation network shapefile provided geospatial information as well as attribute data for the roadways related to the number of lanes and the lengths of roadway segments which facilitated the computation of lane miles throughout different areas of the Region.

For roadways within the portions of the study area located outside the Region, Federal, State, and County highway mapping data were obtained from two sources: directly from the County by request or from GeoData@Wisconsin, an online geoportal maintained by the UW-Madison Geography Department's Robinson Map Library and the State Cartographer's Office.[25,26,27]

Additional geospatial datasets were used to geographically distribute the deicing/anti-icing material usage for analysis. For each monitoring site deployed for the Chloride Impact Study, the upstream contributing drainage area was delineated as presented in TR-61.[28] Civil Division mapping defines the municipal boundaries for towns, villages, and cities throughout the Region and within the larger study area. The civil divisions within each monitoring site drainage area are shown on the individual monitoring site maps presented in Appendix B. These municipal boundaries were used to geographically distribute the winter maintenance materials applied to local roadways, as discussed in Chapter 3.

Private Deicing and Anti-Icing

In addition to winter maintenance on public roadways, deicing and anti-icing materials can also be applied to sidewalks, walkways, driveways, and parking lots on private residential or commercial properties. Private owners of large commercial parking lots and walkways oftentimes utilize a private winter maintenance contractor. Residential winter maintenance may involve the application of deicing materials on private driveways and sidewalks. Previous studies have indicated that while residential salt usage is likely small, the

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[25] *Email correspondence between Dodge County Staff (J. O'Neill) and Commission Staff (M. Gosetti), October 5, 2020.*

[26] *Sheboygan County (2020),* Roads Sheboygan County, WI 2020, *geodata.wisc.edu/catalog/2CC6F51E-EA0E-4ABA-BA13-40B248CA631B, accessed June 2023.*

[27] *Fond du Lac County (2021),* Roads and ROW Fond du Lac County, WI 2021, *geodata.wisc.edu/catalog/0C80F62E-0F4B-44DF-8273-AAFAF669913A, accessed June 2023.*

[28] *SEWRPC Technical Report No. 61, 2023,* op. cit.

salt applied to parking lots can be a significant source of chloride to the environment.[29,30] For the Chloride Impact Study, private salt usage was estimated for parking lots but not residential driveways and walkways.

Data for private salt usage was not readily available; however, a range of private salt application rates were compiled from previous studies through a literature review. A New Hampshire study estimated annual private salt application rates ranging from 4.8 to 6.4 tons per acre (0.22 to 0.29 pounds per square foot) per winter season.[31] A 2006 report on salt use prepared for the City of Madison included salt application data gathered from private contractors who perform winter maintenance on parking lots in the City. This study estimated that private salt applications rates for parking lots ranged from 0.14 to 0.30 tons per acre per application (6 to 14 pounds per 1,000 square feet per application), with 20 to 30 applications per winter season.[32] Wisconsin Salt Wise provided anecdotal data for parking lot salt application rates estimated by private contractors, indicating an industry standard of approximately 600 pounds per acre per application with a recommended smart salting rate of 200 pounds per acre per application.[33] Values and assumptions for private salting used in the analysis are presented in Chapter 3.

The SEWRPC existing land use dataset was used to identify off-street parking lot areas. The land use dataset identifies off-street parking areas with space to accommodate 10 or more vehicles, related to a wide array of land uses such as residential, commercial, transportation, and recreation. The computational methodology for estimating the chloride load resulting from winter maintenance activities for private parking lots in the Region is described in Chapter 3.

Salt Storage Areas

In Wisconsin, any public or private facility that stores more than 1,000 pounds of road salt or similar materials used for winter maintenance must be registered with WisDOT and must adhere to permitted

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[29] *K.W.F. Howard and J. Haynes, "Groundwater Contamination Due to Road-Deicing Chemicals: Salt-Balance Implication," Geoscience Canada, 20:1-8, 1993.*

[30] *Madison Wisconsin Salt Use Subcommittee,* Report of the Salt Use Subcommittee to the Commission on the Environment on Road Salt Use and Recommendations*, Madison, WI, December 11, 2006.*

[31] *D. Sassan and S. Kahl,* Salt Loading Due to Private Winter Maintenance Practices*, Beaver Brook/Policy Brook I-93 Chloride TMDL, Plymouth State University, June 30, 2007.*

[32] *Madison Wisconsin Salt Use Subcommittee 2006,* op. cit.

[33] *Email correspondence between Wisconsin Salt Wise Staff (A. Madison) and Commission Staff (L. Herrick), October 5, 2024.*

storage practices and facility requirements.[34] Potential pathways for chlorides entering the environment from storage areas include material spillage and tracking, which leaves salt on surfaces exposed to environmental elements such as precipitation, resulting in chloride-laden runoff that enters surface water or infiltrates through the soil into groundwater. Best management practices may reduce or eliminate chloride contributions to the environment from salt storage areas. Storage facilities should be covered and on impervious surfaces to protect against the elements, moisture, and contamination. Collection and containment systems prevent runoff that has been potentially exposed to chloride from leaving the facility. Additionally, any registered salt storage facility may not be located within 50 feet of any lake or stream and must be at least 250 feet from existing private wells and 1,200 feet from municipal wells. Regular and thorough cleaning and housekeeping practices in salt storage and loading areas further safeguard against the release of chloride from these facilities. Similar practices should be applied to the cleaning, storage, and maintenance of vehicles and equipment used to transport and/or apply deicing materials. Following these best management practices would reduce or largely prevent chloride from entering the environment from salt storage facilities. Therefore, salt storage facilities are not considered a significant source of chloride in the Region when proper management, handling, and housekeeping practices are maintained. Therefore, chloride contributions from salt storage facilities were not included in the analysis.

Wastewater

Wastewater can be described in general as either sewage or non-sewage, or it may be categorized according to the underlying anthropogenic source as domestic, industrial, or agricultural wastewater. This section addresses domestic and industrial sources of wastewater, while agricultural sources are described later in this chapter. Throughout the Region, wastewater is generated from a variety of private and public sources including homes, commercial businesses, government institutions, agricultural operations, and industrial facilities. Wastewater from these sources typically undergo some level of treatment to improve water quality prior to being discharged into the environment. Domestic and industrial wastewater contains varying levels of chloride concentrations, and conventional treatment practices do not remove chloride from wastewater. Treated wastewater from the various sources follow different pathways into and through the environment, as discussed in TR-62 and in the following sections.[35]

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[34] *Wisconsin Administrative Code,* Trans 277: Highway Salt Storage Requirements*, March 2012.*

[35] *SEWRPC Technical Report No. 62, 2024*, op. cit.

Public Wastewater Treatment Facilities

Wastewater treatment facility (WWTF) effluent can be a significant point source for chloride pollution to the environment. Wastewater generated from a variety of sources is typically conveyed to public WWTFs through an underground sewer network or transported to the facility by licensed waste haulers. Following treatment at the facility, wastewater effluent is discharged to nearby surface water or to groundwater through infiltration ponds. Standard wastewater treatment technology does not remove chloride from water, so chloride present in wastewater passes through the facility and is discharged into the environment.

There are many different sources of chloride in the wastewater received by WWTFs. While the mass balance analysis considers WTTF effluent as a point source for chloride loading, this Study does not attempt to quantify the individual sources of chloride conveyed to each facility. WWTF effluent may contain chloride from water softening salt, domestic and sanitary waste (human excreta and household products), industrial wastewater, and wastewater from commercial operations such as laundromats, hotels, or car washes. On the water supply side, the raw water sources across the Region contain varying levels of background chloride concentrations, and additional chloride may be added to the water supply through chemicals used for disinfection or other drinking water treatment processes. Some WWTFs use chloride-containing chemical additives in the treatment process, for example ferric chloride or ferrous chloride are commonly used for phosphorus removal. Another potential source of chloride to WWTFs is road salt inflow and infiltration into the underground pipe network. For this Report all the sources of chloride that are conveyed to WWTFs were collectively represented by the total chloride in the WWTF effluent at the location where the WWTF discharges to the receiving waterbody.

The WDNR regulates wastewater treatment facilities under the Wisconsin Pollution Discharge Elimination System (WPDES), which permits these facilities to discharge municipal waste to surface water or groundwater. A majority of the permitted facilities in the Region are publicly owned municipal treatment plants. Map 2.6 shows the 49 public WWTFs within the study area that were in operation during the study period, along with the planned sanitary sewer service areas served by these treatment facilities. There are nine private facilities that serve manufactured home communities, institutional populations, or are limited to seasonal recreational usage. All public and private WWTFs within the study area are listed in Table 2.6.

The WDNR provided chloride sample and flow data for all WWTFs in the study area.[36] Treatment facilities monitor and report daily flow data according to their individual permitting requirements. Many facilities

[36] *Email correspondence between WDNR Staff (B. Hartsook) and Commission Staff (K. Hollister), March 24, 2021.*

report daily effluent flow data, while other facilities report only daily influent flow data. Some facilities are not required to monitor chloride if the effluent chloride concentrations are demonstrably below acceptable limits in the receiving waterbody. For WWTFs that are required to monitor chloride, the frequency of chloride sampling varies by facility, ranging from quarterly sampling to daily sampling. The flow data and chloride sample datasets were used to estimate the average monthly chloride load from WWTF effluent, as detailed in Chapter 3.

Additional waste generated from WWTF processes includes biosolids or sludge. These types of waste are typically stored onsite until the waste can be hauled for disposal at a permitted facility. The waste may be land applied at permitted locations during specific times of the year, landfilled, or processed into commercial fertilizer products. Fields used for land spreading are rotated and may receive sludge every three to five years based on discussions with WNDR.[37] WDNR permit requirements limit the total amount of land-applied chloride to 340 pounds per acre per two year period. While biosolids and sludge generated at WWTFs were recognized as another source of chloride to the environment, the chloride load from these sources was not estimated for the analysis. This was due to a lack of chloride data and limited locational data for land spreading.

Private Onsite Wastewater Treatment Systems

Private onsite wastewater treatment systems collect domestic wastewater from households that are not connected to a public sanitary sewer system. Onsite wastewater treatment systems are typically used in rural areas, outside of municipal sanitary sewer service areas. The domestic wastewater that is collected by onsite wastewater treatment systems is generated from typical household activities such as cooking, cleaning, bathing, laundry, sanitary-related, and dishwashing. Domestic wastewater contains chloride from various sources including water softening salt, household consumer products, and human excreta. Onsite wastewater treatment systems may be categorized based on their wastewater treatment and disposal methods into two general types, septic systems and holding tanks.

Septic systems collect wastewater in a septic tank, which allows solids to settle out before discharging effluent to a subsurface drain field where it infiltrates through the soil for further treatment and disposal. Depending on site conditions, septic systems may be designed as conventional gravity-fed systems or as mound systems which are built above-grade in places where groundwater is high or bedrock is shallow.

[37] Online meeting between WDNR Staff (B. Hartsook and S. Warrner) and Commission Staff (L. Herrick, J. Boxhorn, and K. Hollister), June 9, 2022.

Holding tanks may be installed where space is limited for a drain field or as a replacement for a failed septic system. Onsite wastewater treatment systems with holding tanks provide temporary storage of wastewater. Holding tanks are pumped and wastewater is transported by a permitted waste hauler. The waste may be transported to a permitted treatment facility, typically a public WWTF, or land spread.[38] Within the Region, holding tanks are not permitted for new residential construction and generally they are only allowed when there are no other feasible alternatives. Septic systems are recognized as a source of chloride to the environment with a potential to have an impact on water quality. The chloride load from septic systems was estimated for the Regional chloride budget; however, this source of chloride was not included in the individual site mass balance analyses as discussed in Chapter 3.

The following data sources were used to determine the quantity and distribution of private onsite wastewater treatment systems throughout the Region. The Vision 2050 project summarized the existing 2010 sewered and unsewered populations and households in the Region on a quarter-section scale based on 2010 census data.[39] The relatively coarse quarter-section scale allowed for an approximate geospatial distribution of 2010 population and household data and quantified how many were served by a public sanitary sewer system versus those that utilize an onsite wastewater system. The quarter-section data were geographically assigned to watersheds and subwatersheds and combined as needed to estimate the sewered and unsewered population and households for individual monitoring site drainage areas and the major watersheds in the Study. For areas outside of the Region but within the study area, the population and households were determined using census block data from the 2010 census. Households located within the corporate limits of a village were assumed to be served by the public sanitary sewer system and the other households were assumed to be unsewered.

Since conventional treatment and onsite wastewater treatment systems do not remove chloride from wastewater, the total chloride in domestic wastewater that enters an onsite wastewater treatment system will pass through the system and be discharged into the environment. Several studies have provided a wide range of estimates for the concentration of chloride in the wastewater discharged from private septic systems.[40] Chloride samples collected from septic effluent for an Illinois study indicated concentrations

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[38] *In southeastern Wisconsin an estimated 60 to 70 percent of septage waste is transported to a public WWTF for treatment and disposal, per discussion during an online meeting between WDNR Staff and Commission Staff June 9, 2020,* op. cit.

[39] *SEWRPC Planning Report No. 55,* Vision 2050 Volume III: Recommended Regional Land Use and Transportation Plan, Appendix O*, 2nd Edition, June 2020.*

[40] *Granato et al. 2015,* op. cit.

ranging from 21 to 5,260 mg/l, with a mean chloride concentration of 334 mg/l and a median concentration of 91 mg/l.[41]

The following data were used to estimate the potential chloride loading from different domestic chloride sources to onsite wastewater treatment systems. As mentioned in TR-62, one study estimated that human excretion contributed approximately 9,000 milligrams (mg) of chloride per person per day, with consumer household products contributing an additional 25,000 mg per person per day.[42] Water softener salt usage can be highly variable and is dependent on several factors including the source water hardness, the household water usage, along with the water softener type, age, and efficiency. Wisconsin Salt Wise recommends servicing or replacing residential water softeners that use one 40 pound bag of salt or more per month.[43] The upper limit of water softener salt usage considered for the Study was 480 pounds of salt per household per year, corresponding to one 40 pound bag of water softener salt per month. The assumptions used to estimate residential water softener salt usage and the methodology used evaluate the potential contribution of chloride from private septic systems serving the unsewered households and population in the Region are discussed further in Chapter 3.

Industrial Wastewater Dischargers

Southeastern Wisconsin is home to a wide array of industries and water is a foundational component for many different industrial processes. Industrial facilities that are permitted to discharge wastewater to surface water and groundwater may contribute chloride in the environment. Chloride and chloride salt brines are used in a variety of industrial operations and manufacturing processes. Chloride can be an industrial product ingredient, as is common in food processing operations such as meat packing, vegetable canning, and dairy processing. Chloride can also be an industrial waste by-product, commonly resulting from chemical manufacturing as well as metal smelting and refining processes. Additionally, some industrial processes require conditioning of the raw supply water to improve water quality prior to use and wastewater streams from water softening systems can also contain high levels of chloride. Some of the industrial facilities included in this analysis were chemical manufacturers, water/wastewater equipment manufacturers, metal

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[41] *S.V. Panno, K.C. Hackley, H.H. Hwang, S.E. Greenberg, I.G. Krapac, S. Landberger, and D.J. O'Kelly, "Characterization and Identification of NaCl Sources in Ground Water," Ground Water, 44(2): 176–187, 2006.*

[42] *V.R. Kelly, G.M. Lovett, K.C. Weathers, S.E.G. Findlay, D.L. Strayer, D.J. Burns, and G.E. Likens, "Long-Term Sodium Chloride Retention in a Rural Watershed—Legacy Effects of Road Salt on Streamwater Concentration," Environmental Science & Technology, 42:410-415, 2008.*

[43] *Wisconsin Salt Wise, Water Softeners, wisaltwise.com/Take-Action/Home-Water-Softeners, accessed December 2024.*

forges, and food processing facilities such as meat processing plants, vegetable canning, and dairy operations.

Industrial facilities that discharge wastewater to surface water and groundwater in the State are regulated by the WDNR under the WPDES program. Industrial facilities that are permitted to discharge wastewater are subject to the water quality monitoring requirements set forth in their individual facility permit. Some industrial facilities are required to monitor chloride in wastewater effluent, while other facilities with high chloride concentrations in their effluent send wastewater to municipal wastewater treatment facilities. The industrial permittees located within the study area that were required to monitor chloride during the 25-month study period were included in the analysis. The list of facilities was developed in conjunction with WDNR staff and there were 12 industrial facilities that met these criteria, including facilities operating within the food processing, chemical manufacturing, and metal manufacturing industries. Table 2.7 presents a list of the facilities within the study area that were considered in the analysis, identified by the type of industry served and are shown on Map 2.7. The WDNR provided effluent water quality data for each of the 12 facilities.[44] The WDNR data included effluent chloride concentrations and flow rates, which were used to estimate the monthly chloride mass load for each industrial facility that discharged to surface waters within the study area. Details related to the chloride load computation for permitted industrial wastewater dischargers are presented in Chapter 3.

Agricultural Sources of Chloride

Wisconsin has a rich agricultural history, earning the nickname "America's Dairyland" in 1940 when the Wisconsin Legislature adopted the slogan for use on state license plates.[45] While agriculture has played a significant role in Wisconsin's economy, it has a smaller footprint in southeastern Wisconsin compared to other parts of the state. Nonetheless, chloride can be released into the environment through various agricultural products and practices used in the Region, including synthetic fertilizers, livestock feed, manure, and irrigation water.

The primary environmental pathway for agricultural chlorides is through soils, and as discussed in TR-62, chloride can travel through subsurface soils into surface water or groundwater.[46] It should be noted that subsurface drain tile networks have been installed under some of the agricultural fields in the Region to

[44] *Email correspondence between WDNR Staff (B. Hartsook) and Commission Staff (K. Hollister), February 26, 2024.*

[45] *Wisconsin State Historical Society, wisconsinhistory.org/Records/Article/CS2908, accessed May 2025.*

[46] *SEWRPC Technical Report No. 62, 2024, op. cit.*

promote the drainage of soils. Runoff collected by drain tiles typically discharges directly to surface water ditches or streams. Agricultural fields with underlying drain tiles transport more water to surface water resources at much faster rates than those without drain tiles. Drain tiles divert water that would naturally percolate through the soil into the groundwater.

The primary agricultural sources of chloride to the environment within the Region and wider study area are summarized in the following sections.

Agricultural Fertilizer

While chloride deficiency is effectively non-existent in Wisconsin soils underlying agricultural fields, chloride is commonly combined with potassium and applied to Wisconsin cropland as "potash" fertilizer. Potash is a catch-all term describing a range of potassium-containing fertilizers including potassium chloride (KCl) which is also called muriate of potash, potassium sulfate (K_2SO_4), potassium-magnesium sulfate (K_2SO_4-$MgSO_4$), potassium thiosulfate ($K_2S_2O_3$), and potassium nitrate (KNO_3). Of these potash forms, KCl is the most commonly applied fertilizer since it is the most economical to produce, the least costly to purchase, and has the highest concentration of potassium within the compound. Several references estimate that about 95 percent of potash used in the United States is applied as muriate of potash, or KCl.[47] Potash fertilizer usage is typically reported as an equivalent mass of K_2O, which can be converted to chloride using stoichiometry as discussed in Chapter 3.

Potash fertilizer applications primarily add potassium and chloride to the soil to satisfy plant nutrient requirements in areas where the native soil potassium levels are low. Potassium is a macronutrient for plants, while chloride is a micronutrient. Therefore, when applied together as KCl much more of the potassium is utilized by the plant than the chloride, leaving excess chloride ions in the soil. KCl readily dissolves in water, with the potassium ions either taken up by the plant or remaining bound to soil particles, while the excess chloride ions move with water through the environment. Nutrient requirements vary by crop and in general, fruiting and flowering plants as well as potatoes require higher levels of potassium.[48] The general sources

[47] *D.L. Armstrong, and K.P. Griffin, "Production and Use of Potassium,"* Better Crops with Plant Food*, 82(3):6-8, 1998; S.M. Jasinski, D.A. Kramer, J.A. Ober, and J.P. Searls,* Fertilizers—Sustaining Global Food Supplies*, U.S. Geological Survey Fact Sheet No. 99-155, 1999; J.P. Searls,* Potash*, U.S. Geological Survey Commodity Statistics and Information, 2000; California Fertilizer Foundation,* Plant Nutrients*, 2011.*

[48] *C.A.M. Laboski and J.B. Peters,* Nutrient Allocation Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin (A2809)*, University of Wisconsin-Extension, 2012.*

of data used to estimate the chloride load from potash fertilizer are presented below, while analysis details and assumptions are addressed in Chapter 3.

Geospatial crop data was obtained through the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) CropScape Cropland Data Layer (CDL) program to characterize the type and location of crops grown during the study period.[49] The CDL program produces a georeferenced raster land cover dataset providing annual crop-specific information for each growing season or year. These data are collected using satellite imagery and "extensive agricultural ground reference data."[50] Annual cropland datasets were obtained from the CropScape-CDL website.

Information on fertilizer use was obtained from the NASS Agricultural Chemical Use Program, which surveys U.S. farmers to collect data on the chemicals applied on-farm through fertilizers and pest management practices.[51] Survey data in the top-producing states for a particular crop are summarized in agricultural chemical use reports. The reports include fertilizer average annual application rates along with the percentage of acres fertilized for specific crops grown in the surveyed states. For Wisconsin, the agricultural chemical use data were limited to barley, corn, and soybeans.

For Wisconsin crops that receive potash fertilizer but are not surveyed as part of the NASS Agricultural Chemical Use Program, the fertilizer application rate guidelines presented in Table 7.4 of the Nutrient Allocation Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin were used.[52] That document provides recommended potash application rates for different crops based on potassium soil conditions and target crop yield goals. Potassium soil conditions were estimated using available soil testing data

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[49] *USDA National Agricultural Statistics Service,* Cropland Data Layer: USDA NASS*, USDA NASS Marketing and Information Services Office, Washington, D.C., nassgeodata.gmu.edu/CropScape, accessed December 2022.*

[50] *USDA National Agricultural Statistics Service,* "Cropland Data Layer – FAQs," *nass.usda.gov/Research_and_Science/Cropland/sarsfaqs2.php, accessed December 2022.*

[51] *USDA National Agricultural Statistics Service,* Agricultural Chemical Use Program, *nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use, accessed December 2022.*

[52] *C.A.M. Laboski and J.B. Peters 2012,* op. cit.

summarized by County for all farmer field samples analyzed in the State of Wisconsin.[53,54] The potassium soil testing data were interpreted and assigned a test level based on the guidelines set forth in Table 4 of the Optimum Soil Test Levels for Wisconsin publication.[55] Actual crop yield data was used to inform target crop yield goals and fertilizer applications as discussed in Chapter 3.[56]

Livestock Feeding Operations and Manure Spreading

Chloride is prevalent in livestock feed, typically supplemented to satisfy nutritional requirements and maintain livestock health. Most of the chloride consumed by livestock enters the environment through manure. Livestock manure is typically stored until it can be applied to permitted agricultural fields. Manure can contain varying chloride concentrations, depending on the type of livestock, differences in feed, or whether the manure is in solid or liquid form. Chloride testing of manure is not as common as testing for other nutrients, and chloride data were not only sparsely available but also broadly variable across references. Several studies provide data that can be used to estimate chloride content in manure for different types of animals, with chloride concentrations ranging from 400 mg/l for horse manure to 1,650 mg/l for dairy cow manure.[57,58] The specific data and references used in the livestock manure chloride analysis are discussed in Chapter 3.

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[53] *University of Wisconsin-Madison College of Agricultural and Life Sciences,* Soil Test K: 2005-2009, *uwlab.webhosting.cals.wisc.edu/wp-content/uploads/sites/17/2016/06/K_05-09.pdf, accessed December 2022.*

[54] *Wisconsin Department of Agriculture, Trade and Consumer Protection,* DATCP Soil Summaries: 2010-2014 and 2015-2019, *uwlab.soils.wisc.edu/soil-samples/datcp-soil-summary, accessed May 2025.*

[55] *K.A. Kelling, L.G. Bundy, S.M. Combs, and J.B. Peters,* Optimum Soil Test Levels for Wisconsin (A3030), *University of Wisconsin-Extension R-11-99-2M-100, 1999.*

[56] *United States Department of Agriculture National Agricultural Statistics Service in cooperation with the Wisconsin Department of Agriculture, Trade and Consumer Protection,* Wisconsin 2022 Agricultural Statistics, *September 2022.*

[57] *S.V. Panno, K.C. Hackley, H.H. Hwang, S.E. Greenberg, I.G. Krapac, S. Landberger, and D.J. O'Kelly,* Database for the Characterization and Identification of NaCl Sources in Natural Waters of Illinois*, Illinois State Geological Survey Open File Series 2005-1, 2005.*

[58] *J.P. Zublena, J.C. Barker, and D.P. Wessen,* Soil Facts: Dairy Manure as a Fertilizer Source*, North Carolina State University Agricultural Extension Service Publication AG-439-28 WQWM-122, 2012.*

The USDA Census of Agriculture is published every five years and provides livestock inventories for every county in Wisconsin.[59] The Census of Agriculture includes approximate headcounts for many different categories of livestock including various types of cattle, cows, and calves; goats; hogs and pigs; horses and ponies; sheep and lambs; along with various types of chickens, turkeys, and other poultry. While this dataset does not have a detailed geospatial component finer than county-level, it was used to estimate the total amount of livestock in the Region. Table 2.8 provides the livestock inventories by county from the 2017 Census of Agriculture, representing the total number or head of livestock in the Region as of December 31, 2017.

In Wisconsin, a livestock operation with 1,000 animal units (AU) or more is defined as a Concentrated Animal Feeding Operation (CAFO).[60,61] Under state and federal law, CAFOs must have a WDNR-issued WPDES permit to protect surface and ground waters from excessive runoff and animal waste. Consequently, CAFOs are more stringently monitored and regulated than smaller livestock operations. CAFOs are required to have a minimum 180-day manure storage capacity to provide adequate manure storage throughout the winter season and prevent manure spreading on frozen or snow-covered ground. The CAFOs located within the Region and larger study area are listed in Table 2.9. The WDNR provided CAFO locations as shown on Map 2.8.[62] The map identifies the main farm site where livestock are housed and does not include any satellite facilities or agricultural fields used for land-spreading manure generated by the CAFO. The facilities associated with CAFO operations are typically located relatively close to the main farm site to be within a reasonable hauling distance. However, with proper storage and housekeeping practices at the main farm site, there should be a minimal amount of chloride entering the environment at that location. CAFO data including the type and number of animals, AU calculation worksheets, spreading reports, and other operational information were obtained from CAFO permit program documents downloaded from the

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[59] *United States Department of Agriculture, National Agricultural Statistics Service,* 2017 U.S. Census of Agriculture: Wisconsin State and County Data, *Volume 1, Geographic Area Series, Part 49, April 2019.*

[60] *Animal units (AU) are a standard unit of measure that allows for the comparison between different animal types and sizes by converting the number of animals to a common mass equivalent. One AU is equal to the normalized mass of 1,000 pounds of live animal(s).*

[61] *Wisconsin Administrative Code, NR 243: Animal Feeding Operations, relates an AU to the impact of one beef steer or cow. Therefore, 1,000 beef cattle are equivalent to 1,000 AU, and other livestock animals have differing ratios. For example, the following numbers of animals are equivalent to 1000 AU: 500 horses, 715 dairy cows, 5,000 calves, and 10,000 sheep.*

[62] *Email correspondence between WDNR Staff (B. Benninghoff) and Commission Staff (L. Herrick), March 24, 2021.*

WDNR Water Permit Application website.[63] Information and methods used to estimate the chloride load generated by the livestock at each CAFO in the study area are discussed in Chapter 3.

Irrigation

Irrigation practices supplement soil moisture from groundwater or surface water sources to meet water requirements for crops and other vegetation, or to increase crop yields and improve crop quality. Irrigation practices vary year to year, and are influenced by weather conditions, crop type, and farming practices. In general, agricultural irrigation is not a widespread practice within the Region. The USGS estimated that in 2015 approximately 12,200 acres or only two percent of the agricultural land in the Region were irrigated in the seven counties in southeastern Wisconsin, with an average application of 9.5 million gallons per day (mgd).[64] On irrigated lands, background chloride in the irrigation water is transferred to the soil and most is not taken up by plants. Chapter 3 provides computational details related to the estimated total annual chloride load resulting from irrigation within the Region.

Other Sources of Chloride

The following sections describe minor sources of chloride, most of which have not been analyzed in detail for the Chloride Impact Study.

Atmospheric Deposition

Atmospheric deposition is a natural process by which ions or particles in the atmosphere fall to the ground through either wet or dry deposition. Much of the chloride in the atmosphere comes from the oceans as marine aerosols, mobilized to the atmosphere through processes like wave action and sea spray.[65] Atmospheric chloride is also generated from anthropogenic sources such as emissions from fossil fuel combustion or large-scale incineration, which can release hydrochloric acid (HCl) and other compounds to

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[63] *Wisconsin Department of Natural Resources,* Water Permit Applications, *https://dnr.wisconsin.gov/permits/water, accessed November 2024.*

[64] *U.S. Geological Survey,* USGS Water Use Data for Wisconsin: 1985-2015, *waterdata.usgs.gov/wi/nwis/wu, accessed April 2025.*

[65] *T.E. Graedel, and W.C. Keene;* "The Budget and Cycle of Earth's Natural Chlorine," *Pure & Applied Chemistry, 68(9): 1,689-1,697, 1996.*

the atmosphere.[66] Wet deposition occurs through precipitation sources including rain, snow, ice and fog, which carry dissolved chloride from the atmosphere to the ground. During dry deposition, chloride particles in dust, gases, or aerosols settle directly on the Earth's surface. In southeastern Wisconsin a majority of the total atmospheric deposition of chloride falls in the form of wet deposition. Wetter years with higher than normal precipitation are correlated with greater quantities of chloride atmospheric deposition compared to drier years. The highest levels of chloride deposition are observed along the coasts, while chloride concentrations in atmospheric deposition are relatively low within the interior of the continental United States.[67]

The interagency National Atmospheric Deposition Program (NADP), led by the USGS, has been monitoring precipitation chemistry and atmospheric deposition across the United States since 1978. The NADP produces maps and gridded geospatial data for concentrations and annual rates of wet, dry, and total deposition of major ions. The total chloride deposition rate maps and gridded raster data for the study area were obtained from the NADP website.[68] These data were used to compute the total chloride load from atmospheric deposition, as presented in Chapter 3.

Natural Weathering of Rock and Soil Minerals

Chemical weathering is a natural process that breaks down rock and soil minerals, releasing ions that can contribute chloride to groundwater and surface water. Natural sources include the dissolution of chloride-bearing rock, such as halite, when exposed to water or acidic solutions. These are minor sources of chloride to the environment in southeastern Wisconsin because chloride is a minor component of the bedrock underlying the Region. As such, natural weathering was not evaluated as a source of chloride for this analysis.

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[66] *J.D. Haskins, L. Jaegle, and J.A. Thornton,* "Significant Decrease in Wet Deposition of Anthropogenic Chloride Across the Eastern United States, 1998-2018," *Geophysical Research Letters, 47: e2020GL090195, doi 10.1029/2020GL090195, 2020.*

[67] *J.H. Feth,* Chloride in Natural Continental Water--A Review*, U.S. Geological Survey Water-Supply Paper No. 2176, 1981, and J.W. Munger and S.J. Einsenreich,* Continental-scale Variations in Precipitation Chemistry, *Environmental Science and Technology, 17(1), 32A-42A, 1983, as cited in Granato et al. 2015,* op. cit.

[68] *National Atmospheric Deposition Program, 2021.* Total Deposition Maps*, version 2021.01. nadp.slh.wisc.edu/committees/tdep/, accessed October 2022.*

Dust Suppression

Chloride compounds such as calcium chloride and magnesium chloride are commonly used to control dust on unpaved road surfaces.[69] Dust suppression is not a widely used practice in southeastern Wisconsin, primarily because there are very few unpaved roads in the Region. Dust suppression is typically required during construction operations as part of an overall erosion control plan. Due to the relatively small and temporary nature of dust suppression usage in the Region, this chloride source was not evaluated for the Study analysis.

Landfill Leachate

There are different types of landfills that accept various types of waste such as solid municipal waste, industrial waste, or hazardous waste. Within southeastern Wisconsin there are six municipal solid waste landfills currently in operation and two additional landfills that are used to dispose of coal combustion residuals (CCR). Landfill leachate is the liquid generated from the waste itself or when precipitation infiltrates through the waste buried in a landfill. Modern landfills are designed with highly impermeable liners and leachate collection systems to prevent leachate from seeping out of the landfill into the surrounding soils. Over time, however, landfill liners may deteriorate or fail and allow leachate to permeate through to the soils surrounding the landfill. A landfill leachate plume could migrate through the soil, eventually contaminating groundwater or surface water resources. While landfills are recognized as a potential source of chloride to the environment if leachate is not properly contained, as data was not available this chloride source was not evaluated in detail for this analysis.

2.3 IN-STREAM CHLORIDE LOAD DATA

To estimate the amount of chloride that is carried by a stream over time, the mass load of chloride within a stream is computed using reliable streamflow discharge data and chloride concentration data. The following sections present the data that were used to estimate in-stream chloride loads at stream monitoring sites deployed for the Chloride Impact Study.

Streamflow Discharge

The USGS maintains several stream gage stations within the Region as part of the greater USGS national streamgaging network (NSN). While the stream gage stations are primarily operated and maintained by the

[69] *Wisconsin Transportation Information Center,* Wisconsin Transportation Bulletin No. 13: Dust Control on Unpaved Roads, *January 1997.*

USGS, they are funded in partnership with one or more federal, state, and local agencies or organizations.[70] These stations continuously monitor streamflow throughout the year by measuring stream water levels and computing streamflow discharge from those measurements using a rating curve. Rating curves are developed for individual stream gage stations to provide a relationship between water levels and streamflow discharge and are periodically refined over time. In 2018, there were 34 continuous recording stream gaging stations within the study area, and the 14 stations near Study monitoring sites and used for the mass balance analysis are shown on Map 2.9.[71] Additionally, Table 2.10 presents details related to the USGS stream gage stations used in the analysis. Streamflow discharge data for each of the 14 USGS stream gage stations were downloaded from the individual gage station webpages through the USGS Water Data for the Nation website for the entire study period.[72]

Commission staff investigated the feasibility of developing streamflow datasets for sites not located near USGS stations. Staff considered using streamflow data collected in the field by the Commission as well as several different agencies and organizations, paired with water depth measurements recorded by the in-stream monitoring equipment. Some Study monitoring sites had enough data to establish a relationship between the depth of water measured above the in-stream sensor and the estimated streamflow; however, the range of flow measurements was relatively limited, covering only a wadable range of water levels. Additionally, the water depth data collected by the in-stream sensors at the Study monitoring sites was determined to not be reliable enough to use for flow estimates, as the depth sensor was subject to malfunction. Furthermore, because the in-stream sensors were not secured in position on the stream bed, they could be moved during high flow events or human intervention, or become buried in the streambed substrate. These challenging conditions limited the development of a reliable streamflow record at ungaged stream monitoring sites; hence in-stream chloride loads were computed only for the Study stream monitoring sites located near USGS stream gage stations.

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[70] *USGS National Streamgaging Network website: www.usgs.gov/mission-areas/water-resources/science/usgs-national-streamgaging-network, accessed May 2025.*

[71] *The total includes the USGS stream gage on the Des Plaines River at Russell, Illinois, located just outside of the study area.*

[72] *U.S. Geological Survey, National Water Information System (NWIS) data available on the World Wide Web (USGS Water Data for the Nation), 2016, waterdata.usgs.gov/nwis, accessed April 2022.*

Stream Water Quality Monitoring Data

The continuous and discrete water quality data collected at stream monitoring sites for the Chloride Impact Study are briefly described in the following sections. TR-61 provides a detailed description of the data collection equipment and methods, along with data management and post-processing procedures.

Continuous Data Collection

Continuous water quality data were collected at 41 stream monitoring sites using in-stream sensors deployed for the 25-month study period from October 2018 through October 2020.[73] The in-stream sensors collected data at 5-minute intervals, including water temperature, specific conductance, and the depth of water above the sensor. This analysis focuses primarily on the specific conductance dataset as previous studies have demonstrated that specific conductance is a good predictor of chloride once a reliable relationship is established between the two constituents.[74] The monitoring period was extended into 2021 at several sites to enable collection of paired specific-conductance-chloride samples during winter storm and spring snowmelt events to better define the regression models.

Discrete Water Quality Sampling

Regular chloride samples were collected monthly during the 25-month study period at each stream monitoring site to measure chloride concentrations, among other water quality constituents. Targeted event sampling was employed at some sites to collect water samples during winter storms and snowmelt events in order to capture paired data during periods of high specific conductance and represent the full range of chloride concentrations and specific conductance levels observed throughout the study period.

Chloride-Specific Conductance Regression Relationship

SEWRPC Technical Report No. 64 (TR-64) presents the development of the Study regression relationship between chloride and specific conductance.[75] The regression equations that were developed based on paired specific conductance and chloride data collected for the Chloride Impact Study were used to convert the 5-minute continuous specific conductance data observed at stream monitoring sites to chloride concentrations. The piecewise regression model was used to estimate chloride concentrations for the 14

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[73] *Additional monitoring sites were installed over the course of the Study and the water quality data collected at these sites cover a shorter period of record.*

[74] *Howard and Haynes 1993,* op. cit.

[75] *SEWRPC Technical Report No. 64,* Regression Analysis of Specific Conductance and Chloride Concentrations*, May 2024*.

stream monitoring sites included in the mass balance analysis. Chapter 3 describes how these estimated chloride concentrations were used to calculate in-stream chloride loads.

Technical Report No. 65

MASS BALANCE ANALYSIS FOR CHLORIDE IN SOUTHEASTERN WISCONSIN

Chapter 2

CHLORIDE SOURCES AND DATA FOR CHLORIDE LOADING AND MASS BALANCE ANALYSIS

TABLES

Table 2.1
Existing Land Use Within the Study Area

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

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

Source: SEWRPC

Table 2.2
Waterbodies Listed as Impaired Due to Chloride in Southeastern Wisconsin: 2022

Name	WBIC[a]	County	Extent (River mile)[b]	Impairment: Acute Toxicity	Impairment: Chronic Toxicity	Listing Date
Beaver Creek	20000	Milwaukee	0.00-2.65	--	X	2020
Brown Deer Creek	19700	Milwaukee	0.00-2.30	X	X	2018
Burnham Canal	3000042	Milwaukee	0.00-1.05	--	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
Fish Creek	44700	Ozaukee, Milwaukee	0.00-3.38	--	X	2018
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	0.0-14.3	--	X	2022
Kinnickinnic River (and Lyons Park Creek)	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
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

Table continued on next page.

Table 2.2 (Continued)

Note: See Map 2.2 for the locations of the chloride-impaired waterbodies in the Region.

[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 or downstream confluence.*

Source: WDNR

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Table 2.3
Stream Monitoring Sites for the Chloride Impact Study

SEWRPC Site No.[a]	Site Name	Major Watershed	Site County	Counties Within Drainage Area[b]	Drainage Area Size (sq mi)	SWIMS Station ID	Nearest USGS Streamgage	Latitude	Longitude	Site Location
1[c]	Fox River at Waukesha	Fox River	Waukesha	Waukesha, Washington	126.3	683310	05543830	43.00501682	-88.24428955	Fox River about 100 feet downstream of Prairie Avenue near USGS Gage 05543830 at Waukesha (City of Waukesha)
2[c]	Fox River at New Munster	Fox River	Kenosha	Waukesha, Walworth, Racine, Kenosha, Jefferson, Milwaukee, Washington	807.1	523093	05545750	42.61102994	-88.22575534	Fox River about 30 feet downstream of CTH JB near USGS Gage 05545750 at New Munster (Town of Wheatland)
3[c]	Mukwonago River at Mukwonago	Fox River	Waukesha	Waukesha, Walworth, Jefferson	85.4	10032435	05544200	42.85698382	-88.32736057	Mukwonago River 35 feet downstream of STH 83 and 200 feet downstream of USGS Gage 05544200 at Mukwonago (Village of Mukwonago)
4	Sugar Creek	Fox River	Walworth	Walworth	60.5	10029083	--	42.71494642	-88.34238151	Sugar Creek about 60 feet upstream of Potter Road (Town of Spring Prairie)
6	White River near Burlington	Fox River	Walworth	Walworth, Racine, Kenosha	112.2	653104	--	42.68340253	-88.30797773	White River 40 feet downstream of CTH JS near Burlington (Town of Spring Prairie)
8	Pewaukee River	Fox River	Waukesha	Waukesha	38.1	10051685	--	43.04793066	-88.21308887	Pewaukee River at Steinhafels about 1,000 feet downstream of Busse Road (City of Pewaukee)
9[c]	Oak Creek	Oak Creek	Milwaukee	Milwaukee	25.8	413913	04087204	42.92486133	-87.86938351	Oak Creek 385 feet downstream of 15th Avenue and USGS Gage 04087204 at South Milwaukee (City of South Milwaukee)
10[c]	Pike River	Pike River	Kenosha	Kenosha, Racine	36.6	10034961	04087257	42.64700492	-87.86516338	Pike River at Petrifying Springs Park about 1,500 feet upstream of USGS Gage 04087257 (Village of Somers)
11[c]	Bark River Upstream	Rock River	Waukesha	Waukesha, Washington	35.0	683427	05426067	43.15954154	-88.36944299	Bark River about 100 feet downstream of STH 83 and about 3,950 feet upstream of USGS Gage 05426067 at Nagawicka Road (City of Delafield)
12[c]	Lincoln Creek	Milwaukee River	Milwaukee	Milwaukee	11.0	10047562	040869416	43.09927104	-87.97527082	Lincoln Creek about 400 feet downstream of 51st Blvd and about 2,500 feet upstream of USGS 040869416 Gage at Sherman Boulevard (City of Milwaukee)
13	Ulao Creek	Milwaukee River	Ozaukee	Ozaukee	9.2	10050932	--	43.28115708	-87.92473975	Ulao Creek about 40 feet downstream of CTH W (Town of Grafton)
14	Sauk Creek	Sauk Creek	Ozaukee	Ozaukee, Sheboygan	31.7	10030655	--	43.38648777	-87.87253643	Sauk Creek about 400 feet upstream of Wisconsin Street (City of Port Washington)

Table continued on next page.

Table 2.3 (Continued)

SEWRPC Site No.[a]	Site Name	Major Watershed	Site County	Counties Within Drainage Area[b]	Drainage Area Size (sq mi)	SWIMS Station ID	Nearest USGS Streamgage	Latitude	Longitude	Site Location
15	Kilbourn Road Ditch	Des Plaines River	Kenosha	Racine, Kenosha	8.5	10051686	--	42.65507120	-87.94899341	Kilbourn Road Ditch at CTH A (Village of Somers)
16[c]	Jackson Creek	Rock River	Walworth	Walworth	9.8	10051687	05431016	42.64536095	-88.55068624	Jackson Creek about 3,000 feet downstream of STH 67 and about 4,400 feet upstream of USGS Gage 05431016 at Mound Road (Town of Delavan)
18	Oconomowoc River Upstream	Rock River	Waukesha	Washington, Waukesha	41.3	683245	--	43.11796620	-88.51890233	Oconomowoc River about 325 feet upstream of STH 83 (Town of Merton)
20	Oconomowoc River Downstream	Rock River	Waukesha	Waukesha, Washington, Dodge, Jefferson	100.4	10051688	--	43.47604420	-88.38240756	Oconomowoc River near Lac La Belle Outlet about 75 feet downstream of STH 16 (City of Oconomowoc)
21	East Branch Milwaukee River	Milwaukee River	Washington	Sheboygan, Fond Du Lac, Washington	49.4	10051139	--	43.52109322	-88.20310120	East Branch Milwaukee River at STH 28 (Town of Kewaskum)
23	Milwaukee River Downstream of Newburg	Milwaukee River	Ozaukee	Fond Du Lac, Washington, Sheboygan, Ozaukee, Dodge	264.6	10051689	--	43.46025398	-88.03691368	Milwaukee River about 1,000 feet upstream of Hickory Drive (extended) and Washington/Ozaukee County line (Town of Fredonia)
25[c]	Root River Canal	Root River	Racine	Racine, Kenosha	58.8	10016596	04087233	42.81548800	-87.99495284	Root River Canal at USGS Gage 04087233 at 6 Mile Road (Village of Raymond)
28	East Branch Rock River	Rock River	Washington	Washington, Dodge	54.7	10032027	--	42.62553785	-88.74234642	East Branch Rock River about 80 feet downstream of CTH D (Town of Wayne)
30[c]	Des Plaines River	Des Plaines River	Kenosha	Kenosha, Racine	114.6	303054	05527800	42.50164176	-87.92539857	Des Plaines River at 122nd St (CTH ML) about 7,800 feet upstream of USGS Gage 05527800 at Russel Road, Illinois (Village of Pleasant Prairie)
32	Turtle Creek	Rock River	Walworth	Walworth	94.0	10051690	--	43.31952281	-88.38667623	Turtle Creek about 230 feet upstream of USH 14 (Town of Darien)
33	Pebble Brook	Fox River	Waukesha	Waukesha	16.0	10008183	--	42.93472331	-88.25683580	Pebble Brook about 300 feet upstream of CTH XX (Town of Waukesha)
35	Honey Creek Upstream of East Troy	Fox River	Walworth	Walworth	37.7	10032440	--	42.78177625	-88.42317446	Honey Creek about 800 feet downstream of Townline Road at Michael Fields Agricultural Institute (Town of East Troy)
36	Honey Creek Downstream of East Troy	Fox River	Walworth	Walworth	44.6	653244	--	42.78823546	-88.36653679	Honey Creek at Carver School Road (Town of East Troy)
38	North Branch Milwaukee River	Milwaukee River	Washington	Sheboygan, Ozaukee, Washington	105.8	10029089	--	43.51262786	-88.07534337	North Branch Milwaukee River about 25 feet downstream of CTH XX (Town of Farmington)
40	Stony Creek	Milwaukee River	Washington	Washington, Sheboygan, Fond Du Lac	17.8	673267	--	43.52741053	-88.08937392	Stony Creek at CTH X (Town of Farmington)
41	Milwaukee River near Saukville	Milwaukee River	Ozaukee	Fond Du Lac, Washington, Sheboygan, Ozaukee, Dodge	448.3	10051691	--	43.39366252	-87.94024145	Milwaukee River near Friendship Lane (extended) (Town of Saukville)
45	Mukwonago River at Nature Road	Fox River	Walworth	Walworth, Waukesha, Jefferson	24.4	10029287	--	42.83108888	-88.46375625	Mukwonago River about 150 feet downstream of Nature Road and upstream of Lulu Lake (Town of Troy)

Table continued on next page.

Table 2.3 (Continued)

SEWRPC Site No.[a]	Site Name	Major Watershed	Site County	Counties Within Drainage Area[b]	Drainage Area Size (sq mi)	SWIMS Station ID	Nearest USGS Streamgage	Latitude	Longitude	Site Location
47	Fox River at Rochester	Fox River	Racine	Waukesha, Racine, Walworth, Jefferson, Milwaukee, Washington	455.6	10032438	05544475[d]	42.74014301	-88.22477829	Fox River about 1,700 feet upstream of Rochester Dam near USGS Gage 05544475 at Rochester (Village of Rochester)
48	White River at Lake Geneva	Fox River	Walworth	Walworth	29.1	10051692	055451345	42.59328722	-88.43008313	White River about 1,430 feet downstream of Geneva Lake outlet and USGS Gage 055451345 (City of Lake Geneva)
51	Rubicon River	Rock River	Washington	Washington, Dodge	27.5	10051693	--	42.80382218	-88.70293308	Rubicon River at West Side Park about 250 feet upstream of Grant Street (City of Hartford)
52	Cedar Creek	Milwaukee River	Washington	Washington, Ozaukee	53.6	673048	--	43.32350934	-88.14256630	Cedar Creek about 150 feet upstream of STH 60 (Town of Jackson)
53[c]	Honey Creek at Wauwatosa	Menomonee River	Milwaukee	Milwaukee	10.7	10030407	04087119	43.04426929	-88.00683244	Honey Creek about 1,500 feet upstream of the confluence with the Menomonee River and about 600 feet upstream of USGS Gage 04087119 (City of Wauwatosa)
54	Whitewater Creek	Rock River	Walworth	Walworth	18.8	653291	--	43.04745799	-88.45981016	Whitewater Creek about 30 feet upstream of Millis Road (Town of Whitewater)
55	Bark River Downstream	Rock River	Waukesha	Waukesha, Washington	53.2	683424	--	43.15954154	-88.36944299	Bark River about 50 feet upstream of Genesee Lake Road (Village of Summit)
57[c]	Menomonee River at Wauwatosa	Menomonee River	Milwaukee	Milwaukee, Waukesha, Washington, Ozaukee	124.5	10012584	04087120	43.04348983	-87.99543034	Menomonee River near Jacobus Park and about 1,500 feet downstream of USGS Gage 04087120 at 70th Street (City of Wauwatosa)
58[c]	Milwaukee River at Estabrook Park	Milwaukee River	Milwaukee	Washington, Ozaukee, Fond Du Lac, Sheboygan, Milwaukee, Dodge	684.7	413640	04087000	43.10080823	-87.90949931	Milwaukee River at Estabrook Park about 2,100 feet downstream of Port Washington Road and 330 feet upstream of USGS Gage 04087000 (City of Milwaukee)
59[c]	Root River near Horlick Dam	Root River	Racine	Racine, Milwaukee, Waukesha, Kenosha	189.7	10044817	04087240	42.74522748	-87.82038887	Root River at Racine Country Club Golf Course Bridge and about 2,600 feet downstream USGS Gage 04087240 at STH 38 (Village of Mount Pleasant)
60	Root River at Grange Avenue	Root River	Milwaukee	Milwaukee, Waukesha	15.0	413716	04087214	42.94500273	-88.01399744	Root River near USGS Gage 04087214 (Village of Greendale)
87	Underwood Creek	Menomonee River	Milwaukee	Waukesha, Milwaukee	19.0	10031613	04087088	43.05008628	-88.04639671	Underwood Creek at Gravel Sholes Park about 870 feet downstream of STH 100 at USGS Gage 04087088 (City of Wauwatosa)

[a] *The SEWRPC site numbering is nonconsecutive, see Map 2.3 for the location of each stream monitoring site.*

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

[c] *Stream monitoring site included in the mass balance analysis.*

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

Source: SEWRPC

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Table 2.4
Stream Monitoring Site Drainage Areas Containing Additional Monitoring Sites

SEWRPC Site No.[a]	Downstream-Most Site Name	Monitoring Sites Nested Within Upstream Drainage Area[b]
1	Fox River at Waukesha	Site 8 (Pewaukee River)
2	Fox River at New Munster	Site 8 (Pewaukee River) Site 1 (Fox River at Waukesha) Site 33 (Pebble Brook) Site 45 (Mukwonago River at Nature Road) Site 3 (Mukwonago River at Mukwonago) Site 47 (Fox River at Rochester) Site 35 (Honey Creek Upstream of East Troy) Site 36 (Honey Creek Downstream of East Troy) Site 4 (Sugar Creek) Site 48 (White River at Lake Geneva) Site 6 (White River at Burlington)
3	Mukwonago River at Mukwonago	Site 45 (Mukwonago River at Nature Road)
6	White River near Burlington	Site 48 (White River at Lake Geneva)
20	Oconomowoc River Downstream	Site 18 (Oconomowoc River Upstream)
23	Milwaukee River Downstream of Newburg	Site 21 (East Branch Milwaukee River)
30	Des Plaines River	Site 15 (Kilbourn Road Ditch)
32	Turtle Creek	Site 16 (Jackson Creek)
36	Honey Creek Downstream of East Troy	Site 35 (Honey Creek Upstream of East Troy)
41	Milwaukee River near Saukville	Site 21 (East Branch Milwaukee River) Site 23 (Milwaukee River Downstream of Newburg) Site 40 (Stony Creek) Site 38 (North Branch Milwaukee River)
47	Fox River at Rochester	Site 8 (Pewaukee River) Site 1 (Fox River at Waukesha) Site 33 (Pebble Brook) Site 45 (Mukwonago River at Nature Road) Site 3 (Mukwonago River at Mukwonago)
55	Bark River Downstream	Site 11 (Bark River Upstream)
57	Menomonee River at Wauwatosa	Site 87 (Underwood Creek) Site 53 (Honey Creek at Wauwatosa)
58	Milwaukee River at Estabrook Park	Site 21 (East Branch Milwaukee River) Site 23 (Milwaukee River Downstream of Newburg) Site 40 (Stony Creek) Site 38 (North Branch Milwaukee River) Site 41 (Milwaukee River near Saukville) Site 52 (Cedar Creek) Site 13 (Ulao Creek) Site 12 (Lincoln Creek)
59	Root River near Horlick Dam	Site 60 (Root River at Grange Avenue) Site 25 (Root River Canal)

[a] *See Map 2.3 for the locations of the stream monitoring sites.*

[b] *The nested monitoring sites are listed in order from upstream to downstream.*

Source: SEWRPC

Table 2.5
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 NCEI

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Table 2.6
Active Wastewater Treatment Facilities Within the Study Area: 2018–2020

Facility Name	Receiving Water	County	Ownership	Annual Average Design Flow (MGD)	SEWRPC Sites Downstream (Site No.)
	Des Plaines Watershed				
Brighton Dale Links Wastewater Treatment Plant	Unnamed wetland-marsh complex (Brighton Creek Watershed)	Kenosha	Private	0.004	30
Bristol Utility District No.1	Tributary to Des Plaines River	Kenosha	Public	0.87	30
Fonks Home Center Inc, Hickory Haven	Tributary to Des Plaines River	Kenosha	Private	0.031	30
MHC Rainbow Lake, LLC	Diffuse wetland draining to Mud Lake (Dutch Gap Canal Watershed)	Kenosha	Private	0.04	--
Paddock Lake Wastewater Treatment Facility	Tributary to Brighton Creek	Kenosha	Public	0.80	30
	Direct Drainage Area Tributary to Lake Michigan				
Kenosha Wastewater Treatment Facility	Lake Michigan	Kenosha	Public	28.6	--
Milwaukee Metropolitan Sewerage District – Jones Island	Milwaukee River Outer Harbor	Milwaukee	Public	123	--
Milwaukee Metropolitan Sewerage District –South Shore	Lake Michigan	Milwaukee	Public	113	--
Port Washington Wastewater Treatment Plant	Lake Michigan	Ozaukee	Public	3.10	--
Racine Wastewater Utility	Lake Michigan	Racine	Public	36.0	--
South Milwaukee Wastewater Treatment Facility	Lake Michigan	Milwaukee	Public	6.00	--
	Fox River Watershed				
Village of Bloomfield Utility Department	Tributary to East Branch Nippersink Creek	Walworth	Public	0.46	--
Burlington Water Pollution Control	Fox River	Racine	Public	3.50	2
Eagle Lake Sewer Utility District	Eagle Creek	Racine	Public	0.40	2
East Troy Wastewater Treatment Facility	Honey Creek	Walworth	Public	0.81	36, 2
Fox River Water Pollution Control Center	Fox River	Waukesha	Public	12.5	1, 47, 2
Genoa City Water Treatment Plant	North Branch Nippersink Creek	Walworth	Public	0.58	--
Grand Geneva Resort and Spa	Wetland adjacent to Como Creek	Fox River	Private	0.40	6, 2
Lake Geneva Wastewater Treatment Plant	Discharge to Soil/Groundwater	Walworth	Public	2.50	--
Lakeview Neurological Rehab Center - Midwest	Dover Ditch	Racine	Private	0.025	47, 2
Lyons Sanitary District No. 2	White River	Walworth	Public	0.21	6, 2
Mukwonago Wastewater Treatment Plant	Mukwonago River	Waukesha	Public	1.50	47, 2
Town of Norway Sanitary District No. 1 Wastewater Treatment Facility	Tributary to Wind Lake Drainage Canal	Racine	Public	1.60	47, 2
Salem Lakes – Salem Wastewater Treatment Plant[a]	Fox River	Kenosha	Public	2.13	--

Table continued on next page.

Table 2.6 (Continued)

Facility Name	Receiving Water	County	Ownership	Annual Average Design Flow (MGD)	SEWRPC Sites Downstream (Site No.)
	Fox River Watershed (continued)				
Salem Lakes – Silver Lake Wastewater Treatment Plant[a]	Fox River	Kenosha	Public	0.47	--
Sussex Wastewater Treatment Facility	Spring Creek	Waukesha	Public	5.10	1, 47, 2
Twin Lakes Wastewater Treatment Facility	Tributary to Bassett Creek	Kenosha	Public	1.30	--
Waukesha Wastewater Treatment Facility[b]	Fox River	Waukesha	Public	14.0	47, 2
Western Racine County Sewerage District	Fox River	Racine	Public	2.50	2
Wheatland Estates MHC	Fox River	Kenosha	Private	0.058	--
	Milwaukee River Watershed				
Campbellsport Wastewater Treatment Facility	Milwaukee River	Fond du Lac	Public	0.47	23, 41, 58
Cascade Wastewater Treatment Facility	North Branch Milwaukee River	Sheboygan	Public	0.13	38, 41, 58
Cedarburg Wastewater Treatment Facility	Cedar Creek	Ozaukee	Public	2.75	58
Fredonia Municipal Sewer and Water Utility	Milwaukee River	Ozaukee	Public	0.60	41, 58
Grafton Water and Wastewater Utility	Milwaukee River	Ozaukee	Public	2.50	58
Jackson Wastewater Treatment Plant	Cedar Creek	Washington	Public	1.69	52, 58
Kettle Moraine Correctional Facility	Discharge to Soil/Groundwater	Sheboygan	Private	0.19	--
Kewaskum Wastewater Treatment Plant	Milwaukee River	Washington	Public	0.75	23, 41, 58
Long Lake Recreation Area Wastewater Treatment Facility	Discharge to Soil/Groundwater	Fond du Lac	Private	0.016	--
Village of Newburg Sanitary Sewer Treatment Facility	Milwaukee River	Washington	Public	0.12	23, 41, 58
Random Lake Sewage Treatment Plant	Silver Creek	Sheboygan	Public	0.45	38, 41, 58
Saukville Sewer Utility	Milwaukee River	Ozaukee	Public	1.61	58
Town of Scott Sanitary District No.1	Discharge to Soil/Groundwater	Sheboygan	Public	0.03	--
City of West Bend Sewage Treatment Facility	Milwaukee River	Washington	Public	9.00	23, 41, 58
	Rock River Watershed				
Allenton Sanitary District Wastewater Treatment Plant	East Branch Rock River	Washington	Public	0.35	28
Delafield – Hartland Water Pollution Control Commission	Bark River[c]	Waukesha	Public	3.23	--
Dousman Wastewater Treatment Facility	Bark River	Waukesha	Public	0.57	--
Fontana – Walworth Water Pollution Control Commission	Picasaw Creek	Walworth	Public	1.77	--
Hartford Water Pollution Control Facility	Rubicon River	Washington	Public	3.60	--
Oconomowoc Wastewater Treatment Plant	Oconomowoc River	Waukesha	Public	4.02	--
Sharon Wastewater Treatment Facility	Little Turtle Creek	Walworth	Public	0.26	--
Slinger Wastewater Treatment Facility	Tributary to the Rubicon River	Washington	Public	1.50	51
Walworth County Metropolitan Sewerage District	Turtle Creek	Walworth	Public	7.00	32
Whitewater Wastewater Treatment Facility	Whitewater Creek[d]	Walworth	Public	3.65	--
	Root River Watershed				
Fonks Home Center Inc, Harvest View Estates	East Branch Root River Canal	Racine	Private	0.10	25, 59
Union Grove Wastewater Treatment Plant	West Branch Root River Canal	Racine	Public	2.00	25, 59
Yorkville Sewer Utility District No. 1	Ives Grove Ditch (to Hoods Creek)	Racine	Public	0.15	59

Table continued on next page.

Table 2.6 (Continued)

Facility Name	Receiving Water	County	Ownership	Annual Average Design Flow (MGD)	SEWRPC Sites Downstream (Site No.)
	Sheboygan River Watershed				
Belgium Wastewater Treatment Facility	Belgian-Holland Ditch[d]	Ozaukee	Public	0.63	--

Note: See Map 2.6 for the locations of the public wastewater treatment facilities.

[a] *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.*

[b] *Following the transition of the water supply from groundwater to Lake Michigan in October 2023, effluent from the City of Waukesha facility is primarily discharged to the Root River in Milwaukee County in Franklin to satisfy the Great Lakes Basin return flow requirements. The Fox River outfall was the only discharge location during the study period and remains in operation as a secondary outfall after October 2023.*

[c] *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.*

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

Source: WDNR and SEWRPC

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Table 2.7
Industrial Wastewater Dischargers Within the Study Area that Monitor Chloride

Facility ID	Industrial Facility Type	Receiving Water	Major Watershed	Civil Division	County	SEWRPC Sites Downstream (Site No.)
I-1	Chemical Manufacturer	Fox River	Fox River	Burlington	Racine	2
I-2	Metal Manufacturer/Forge	Edgerton Ditch & Lake Michigan Direct	Lake Michigan	Cudahy	Milwaukee	--
I-3	Food Processing	Tributary to Sauk Creek	Sauk Creek	Belgium	Ozaukee	14
I-4	Chemical Manufacturer	Bark River	Rock River	Merton	Waukesha	11, 55
I-5	Food Processing	Unnamed Tributary to Root River (Des Plaines Watershed)	Des Plaines	Town of Paris	Kenosha	30
I-6	Food Processing	Silver Creek to North Branch Milwaukee River	Milwaukee River	Random Lake	Sheboygan	38, 41, 58
I-7	Food Processing	Unnamed tributary to Belgium-Holland Drainage Ditch then to Onion River	Sheboygan River	Belgium	Ozaukee	--
I-8	Food Processing	North Branch Milwaukee River	Milwaukee River	Adell	Sheboygan	38, 41, 58
I-9	Manufacturer	Roadside swale tributary to Swan Creek (Turtle Creek Watershed)	Rock River	Delavan	Walworth	32
I-10	Manufacturer	Tributary to Root River	Root River	Oak Creek	Milwaukee	59
I-11	Food Processing	Cedar Creek	Milwaukee River	West Bend	Washington	58
I-12	Fish Hatchery	Unnamed tributary to Melius Creek to North Branch Milwaukee River	Milwaukee River	Adell	Sheboygan	38, 41, 58

Note: See Map 2.7 for the industrial facility locations.

Source: WDNR and SEWRPC

Table 2.8
County Livestock Inventories by Head: 2017 U.S. Census of Agriculture

Type of Livestock	Kenosha	Milwaukee	Ozaukee	Racine	Walworth	Washington	Waukesha	Region
Chickens (broilers)	796	(D)	(D)	2,747	458	636	261	4,898
Cattle and Calves[a]	9,805	(D)	26,421	10,079	38,419	45,180	7,765	137,669
Beef Cows	987	(D)	431	1,515	2,325	1,218	1,024	7,500
Milk Cows	3,520	(D)	9,163	3,209	14,786	15,290	1,627	47,595
Other Cattle	5,298	(D)	16,827	5,355	21,308	28,672	5,114	82,574
Goats	108	86	965	603	1,952	53	131	3,898
Hogs and Pigs	546	6	145	1,951	13,329	165	(D)	16,142
Horses and Ponies	1,589	(D)	384	865	1,482	799	1,640	6,759
Chickens (layers)	4,527	554	(D)	3,288	3,191	(D)	2,566	14,126
Pullets	94	(D)	(D)	909	400	148	122	1.673
Sheep and Lambs	513	(D)	186	905	2,568	532	1,041	5,745
Turkeys	184	(D)	--	224	95	72	79	654

Note: (D) indicates that data was withheld to avoid disclosing data for individual operations.

[a] *The Cattle and Calves inventory is broken into three subgroups: Beef Cows, Milk Cows and Other Cattle. The Other Cattle subgroup includes heifers that had not calved, steers, calves, and bulls.*

Source: USDA NASS

Table 2.9
Concentrated Animal Feeding Operations Located Within the Study Area: 2020

Farm Name	County	Major Watershed	Animal Type	2019 Animal Units[a]	Within SEWRPC Site Drainage Areas[b] (Site No.)
Melichar Broad Acres	Ozaukee	Milwaukee River	Dairy	2,484	41, 58
Opitz Dairy Farm	Ozaukee	Milwaukee River	Dairy	1,369	41, 58
Paulus Dairy	Ozaukee	Milwaukee River	Dairy	2,426	41, 58
Maple Leaf Farms Downy Duck Farm	Racine	Milwaukee River	Ducks	847	47, 2
S&R Egg Farms LaGrange	Walworth	Rock River	Layers[c]	14,921	45, 3, 47, 2
Katzman Farms	Walworth	Fox River	Dairy	2,442	2
Merry Water Farms	Walworth	Fox River	Dairy	2,667	--
Snudden Farms, LLC	Walworth	Fox River	Dairy	4,975	--
Beck Dairy Farm, LLC	Washington	Milwaukee River	Dairy	2,080	23, 41, 58
Golden E Dairy, LLC	Washington	Milwaukee River	Dairy	3,855	41, 58
Kettle Moraine Egg Ranch, LLC	Washington	Rock River	Layers[c]	1,433	40, 41, 58
Sunset Farms, Inc	Washington	Milwaukee River	Dairy	2,865	28
T. Volm Farms/Iron Ridge Dairy	Washington	Fox River	Dairy	1,349	23, 41, 58
S&R Egg Farms Genesee	Waukesha	Rock River	Layers[c]	1,951	47, 2
Second Look Holsteins, LLC	Fond Du Lac	Milwaukee River	Dairy	1,654	23, 41, 58
Hickory Lawn Dairy Farm	Sheboygan	Milwaukee River	Dairy	1,545	38, 41, 58
Rockland Dairy, Inc	Sheboygan	Milwaukee River	Dairy	3,258	38, 41, 58

Note: See Map 2.8 for the locations of each CAFO.

[a] *Animal units are a standard unit of measure used to compare different animal types and sizes converted to a common unit equivalent, and the values in the table represent the total animal units computed for the 2019 CAFO permit documents.*

[b] *The CAFO main farm that houses livestock is located within the upstream contributing drainage area of the SEWRPC monitoring site identified by site number. If no site number is listed, the CAFO is not located upstream of a stream monitoring site.*

[c] *Layers refers to chickens that are raised to produce eggs.*

Source: WDNR and SEWRPC

Table 2.10
USGS Stream Gage Stations Located near Stream Monitoring Sites for the Mass Balance Analysis

USGS Station Number	USGS Station Name	Drainage Area (sq mi)	Streamflow Data Interval (minutes)	Period of Record	Nearby Stream Monitoring Site[a]
05543830	Fox River at Waukesha, WI	126	15	1986 - present	1
05545750	Fox River at New Munster, WI	811	15	1993 - present	2
05544200	Mukwonago River at Mukwonago, WI	74.1	15	1986 - present	3
04087204	Oak Creek at South Milwaukee, WI	25	15	1986 - present	9
04087257	Pike River near Racine, WI	38.5	15	1986 - present	10
05426067	Bark River at Nagawicka Road at Delafield, WI	35.9	15	2002 - present	11
040869416	Lincoln Creek at Sherman Blvd at Milwaukee, WI	13.48	5	2003 - present	12
05431016	Jackson Creek at Mound Rd near Elkhorn, WI	16.8	5	1993 - present	16
04087233	Root River Canal near Franklin, WI	57	15	1986 - present	25
05527800	Des Plaines River at Russell, IL	123	15	1986 - present	30
04087119	Honey Creek at Wauwatosa, WI	10.3	5	2004 - present	53
04087120	Menomonee River at Wauwatosa, WI	123	15	1986 - present	57
04087000	Milwaukee River at Milwaukee, WI	696	15	1986 - present	58
04087240	Root River at Racine, WI	190	15	1986 - present	59

Note: See Map 2.9 for the locations of each stream gage station.

[a] *Stream monitoring sites are listed by site number, refer to Table 2.3 for additional monitoring site information.*

Source: USGS and SEWRPC

Technical Report No. 65

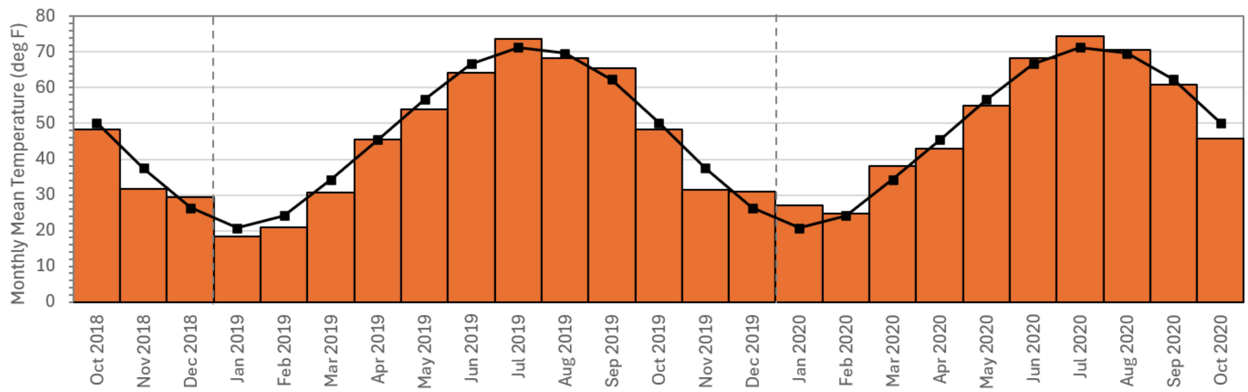
MASS BALANCE ANALYSIS FOR CHLORIDE IN SOUTHEASTERN WISCONSIN

Chapter 2

CHLORIDE SOURCES AND DATA FOR CHLORIDE LOADING AND MASS BALANCE ANALYSIS

FIGURES

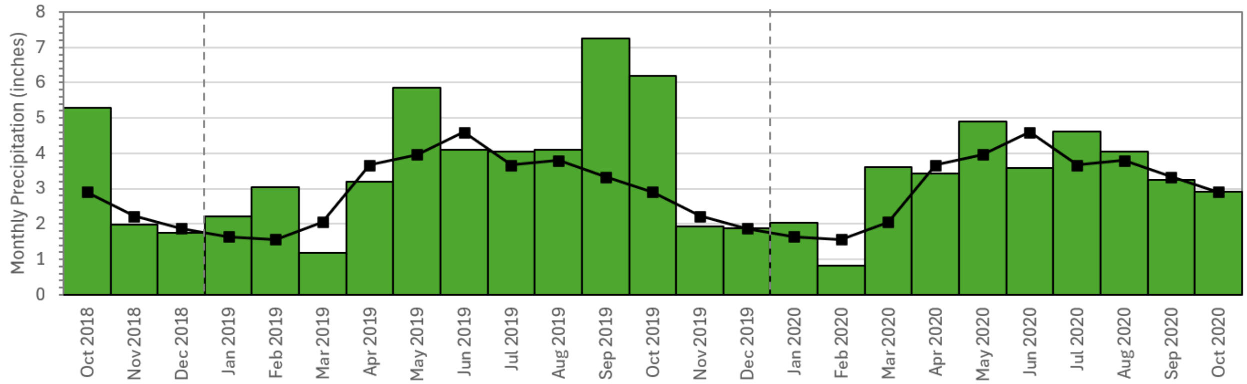
Figure 2.1
Monthly Mean Temperatures for Southeastern Wisconsin: Study Period (Oct 2018–Oct 2020)



Note: The solid line represents the 30-year normal or average monthly temperatures.

Source: Wisconsin State Climatology Office and NOAA NCEI

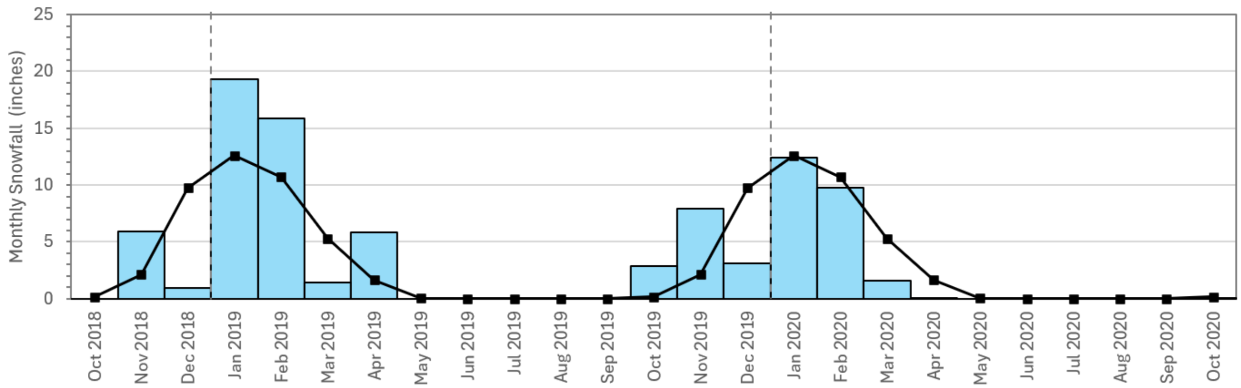
Figure 2.2
Monthly Precipitation Totals for Southeastern Wisconsin: Study Period (Oct 2018–Oct 2020)



Note: The solid line represents the 30-year normal or average monthly precipitation.

Source: Wisconsin State Climatology Office and NOAA NCEI

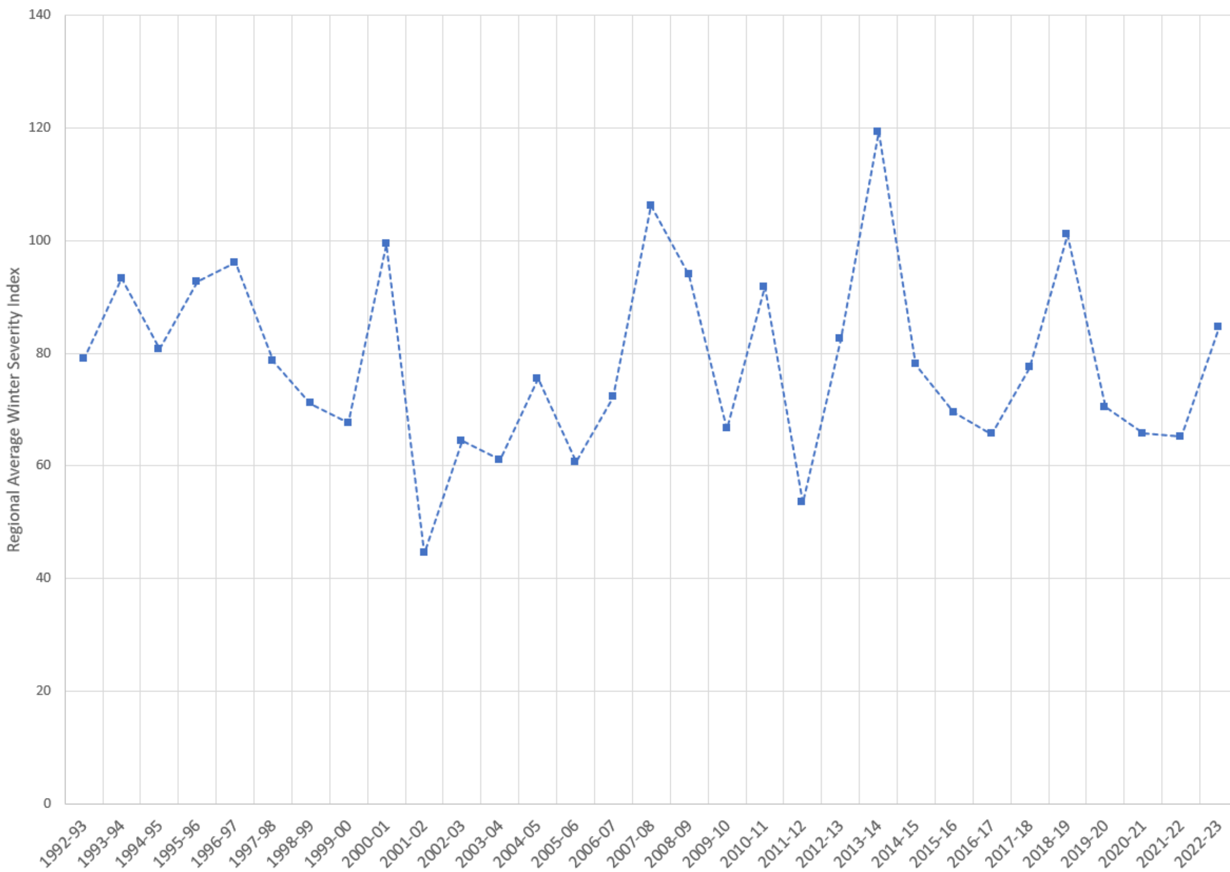
Figure 2.3
Monthly Snowfall Totals for Southeastern Wisconsin: Study Period (Oct 2018–Oct 2020)



Note: The solid line represents the 30-year normal or average monthly snowfall.

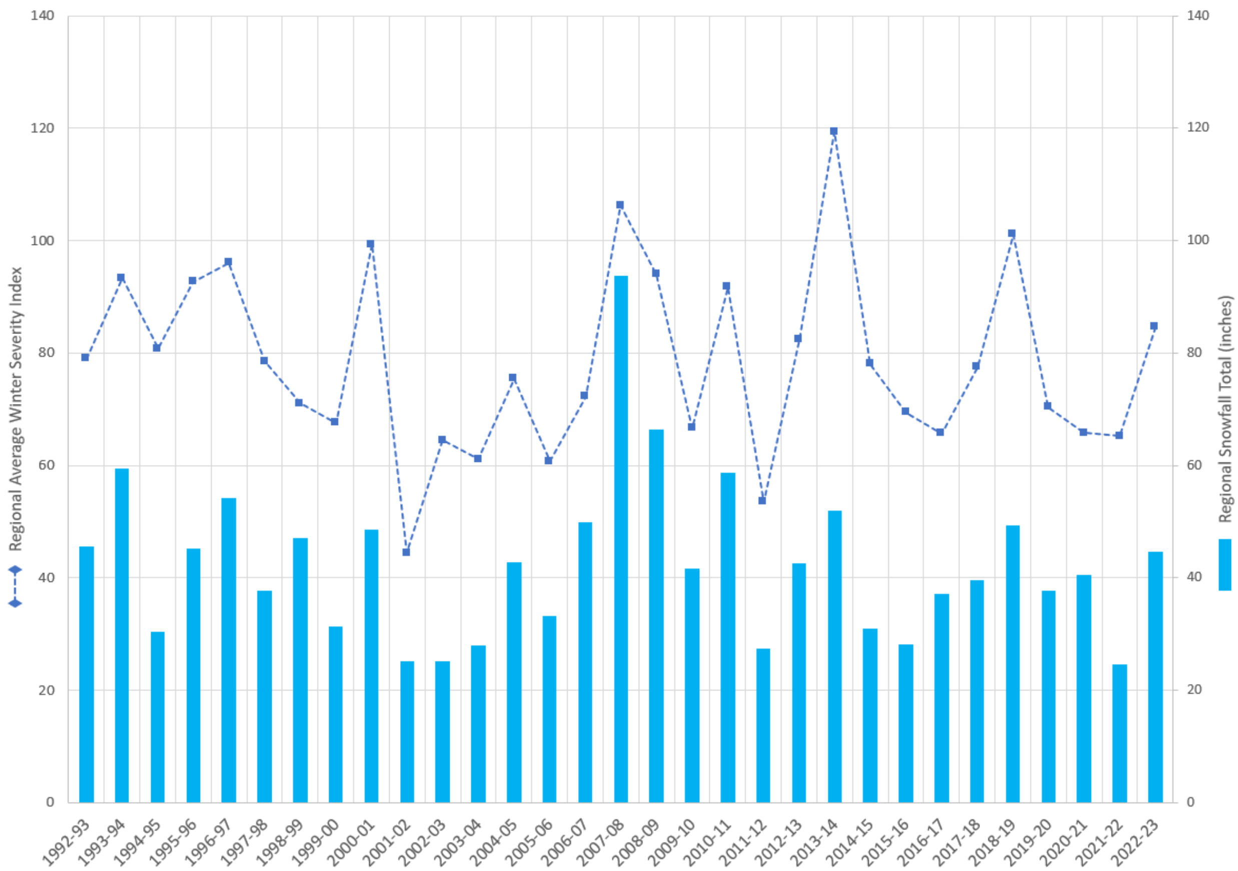
Source: Wisconsin State Climatology Office and NOAA NCEI

Figure 2.4
WisDOT Winter Severity Index: Regional Average (1992-1993 to 2022-2023)



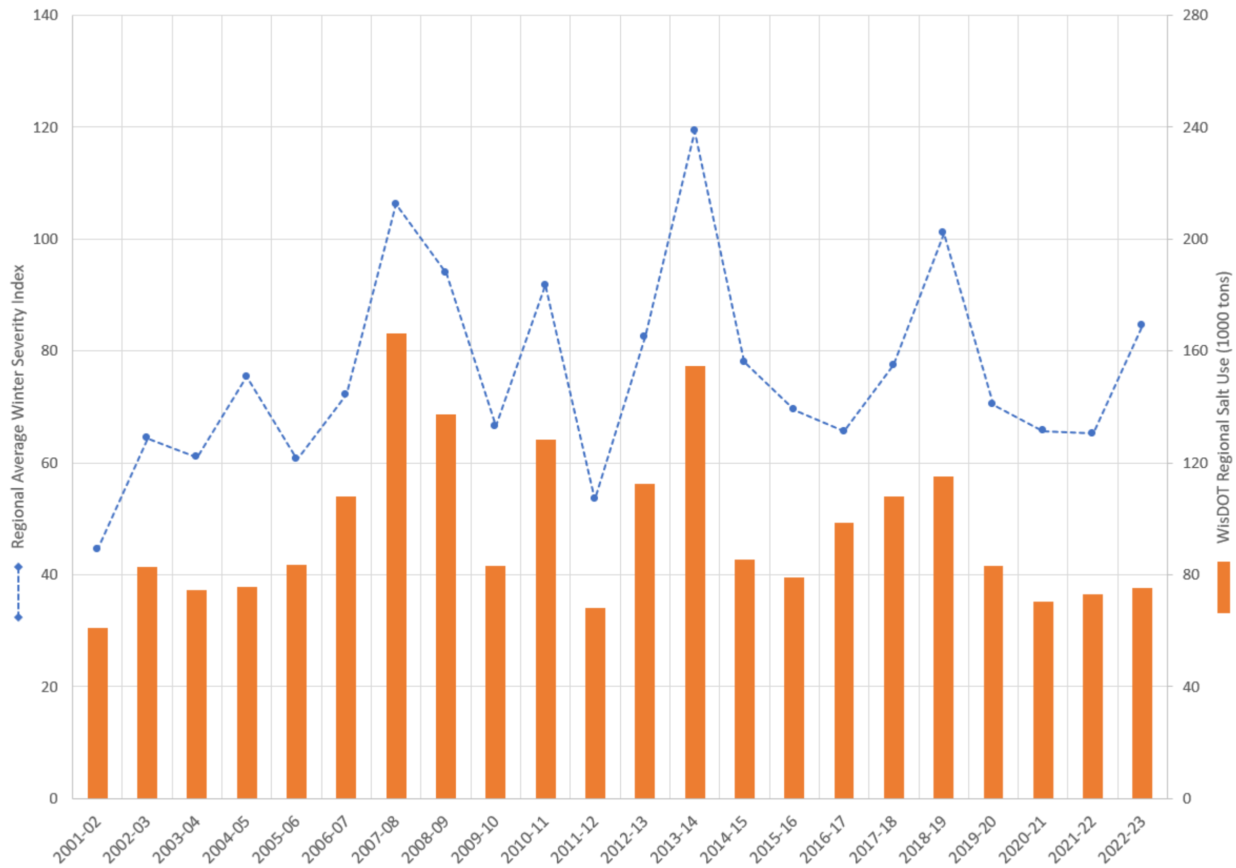
Source: WisDOT and SEWRPC

Figure 2.5
Regional Average WSI and Total Winter Season Snowfall: (1992-1993 to 2022-2023)



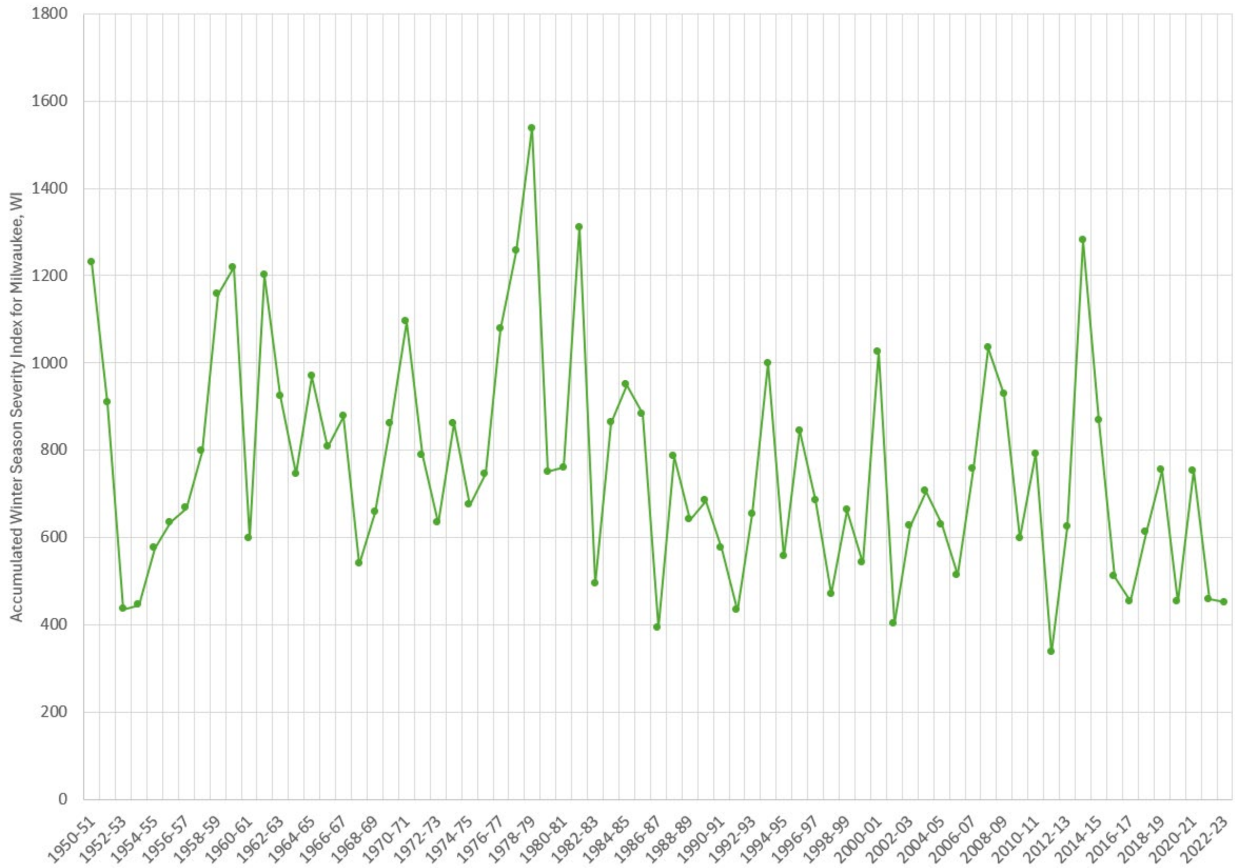
Source: Wisconsin State Climatology Office and WisDOT

Figure 2.6
Regional Average WSI and WisDOT Regional Road Salt Use: (2001-2002 to 2022-2023)



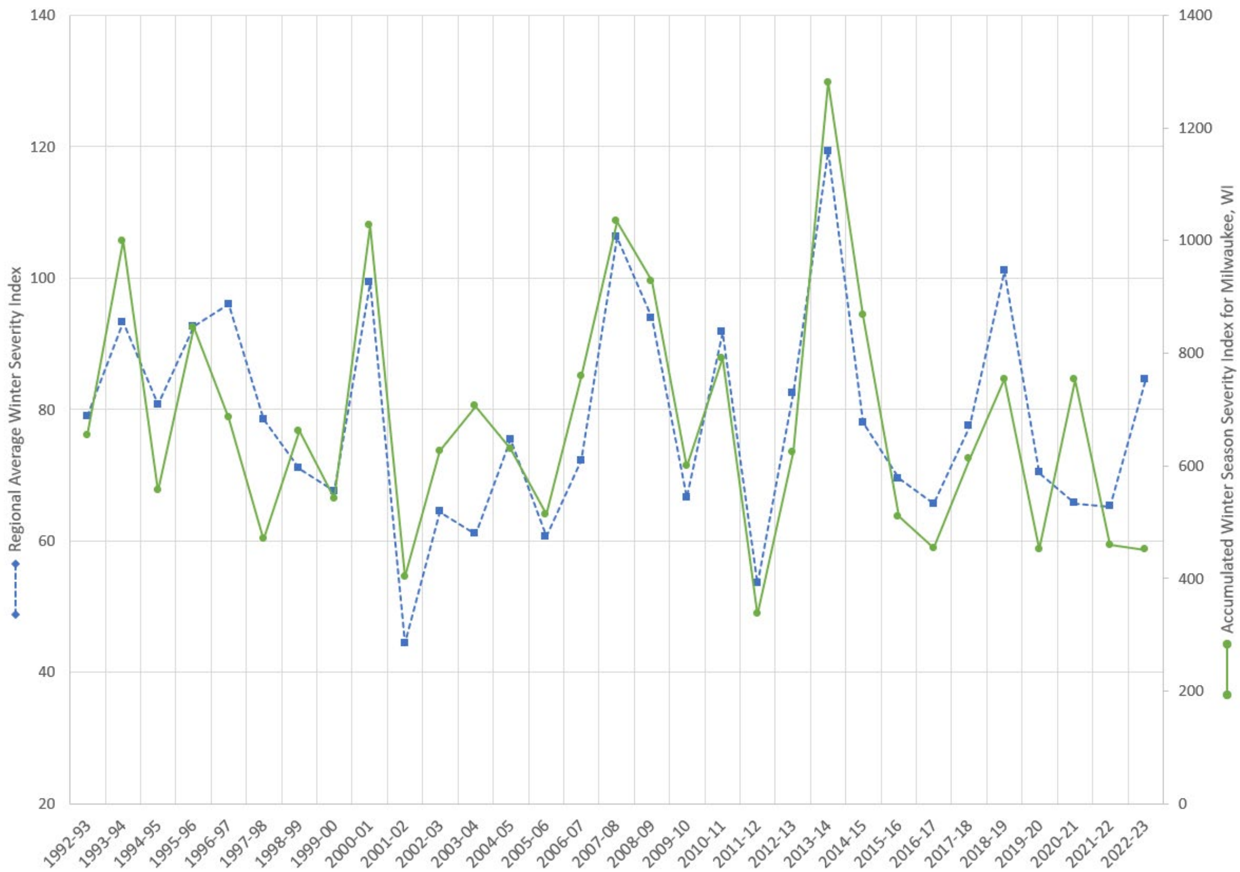
Source: WisDOT and SEWRPC

Figure 2.7
MRCC Accumulated Winter Season Severity Index: Milwaukee (1950-1951 to 2022-2023)



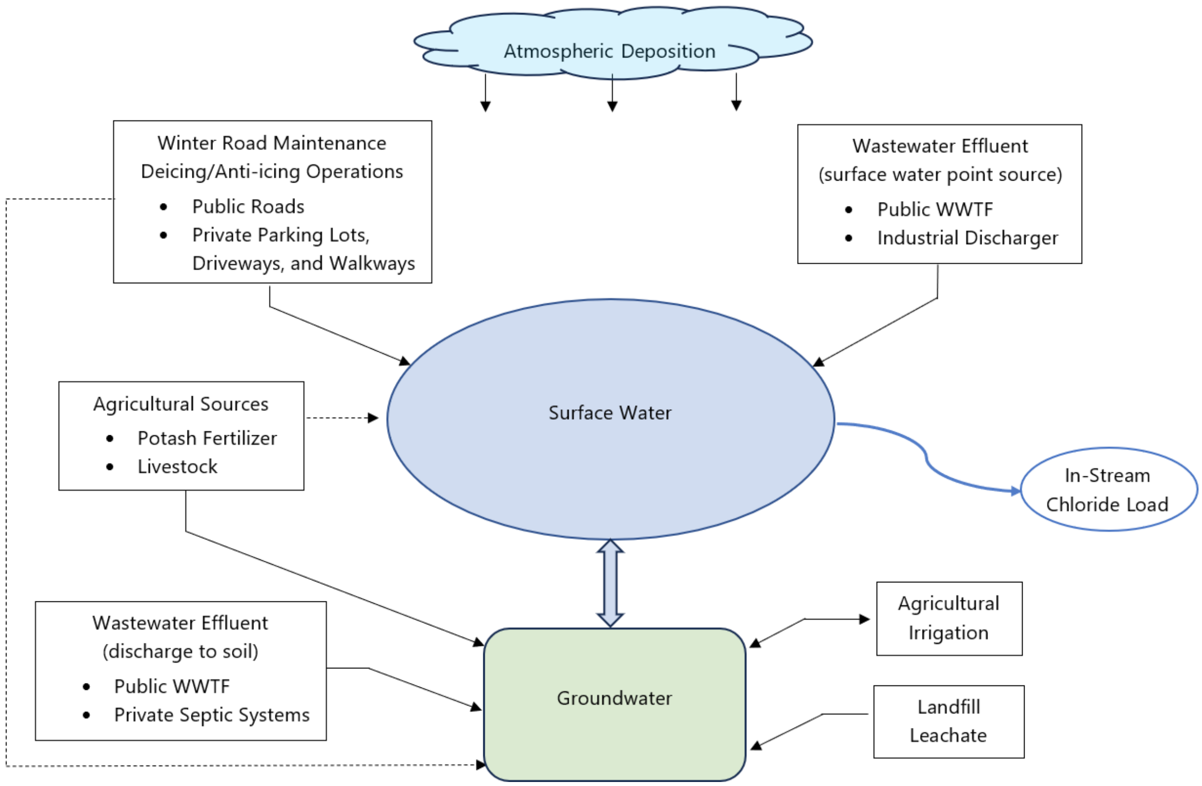
Source: MRCC

Figure 2.8
Comparison of the Regional Average WSI and Milwaukee AWSSI (1992-1993 to 2022-2023)



Source: WisDOT and MRCC

Figure 2.9
Regional Chloride Sources and Simplified Transport Schematic



Note: Solid arrows define primary transport pathways and arrows with dashed lines define secondary transport pathways. For agricultural sources, the transport pathway to surface water may be considered primary for agricultural fields underlain by drain tiles.

Source: SEWRPC

Technical Report No. 65

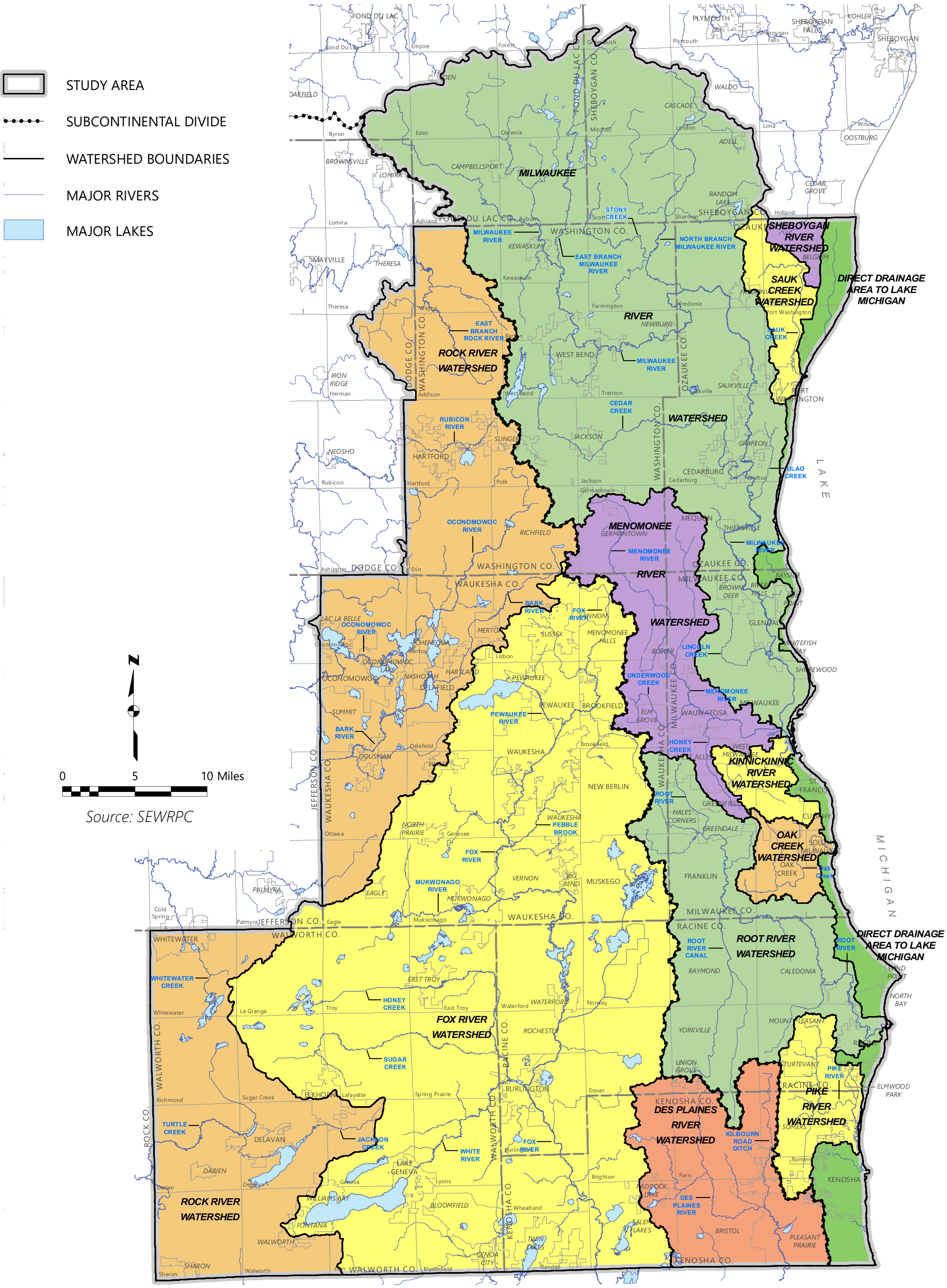
MASS BALANCE ANALYSIS FOR CHLORIDE IN SOUTHEASTERN WISCONSIN

Chapter 2

CHLORIDE SOURCES AND DATA FOR CHLORIDE LOADING AND MASS BALANCE ANALYSIS

MAPS

Map 2.1
Major Watersheds Within the Study Area for the Regional Chloride Impact Study



Map 2.2
Waterbodies Impaired for Chloride: 2022

STUDY AREA

SUBCONTINENTAL DIVIDE

MAJOR WATERSHEDS

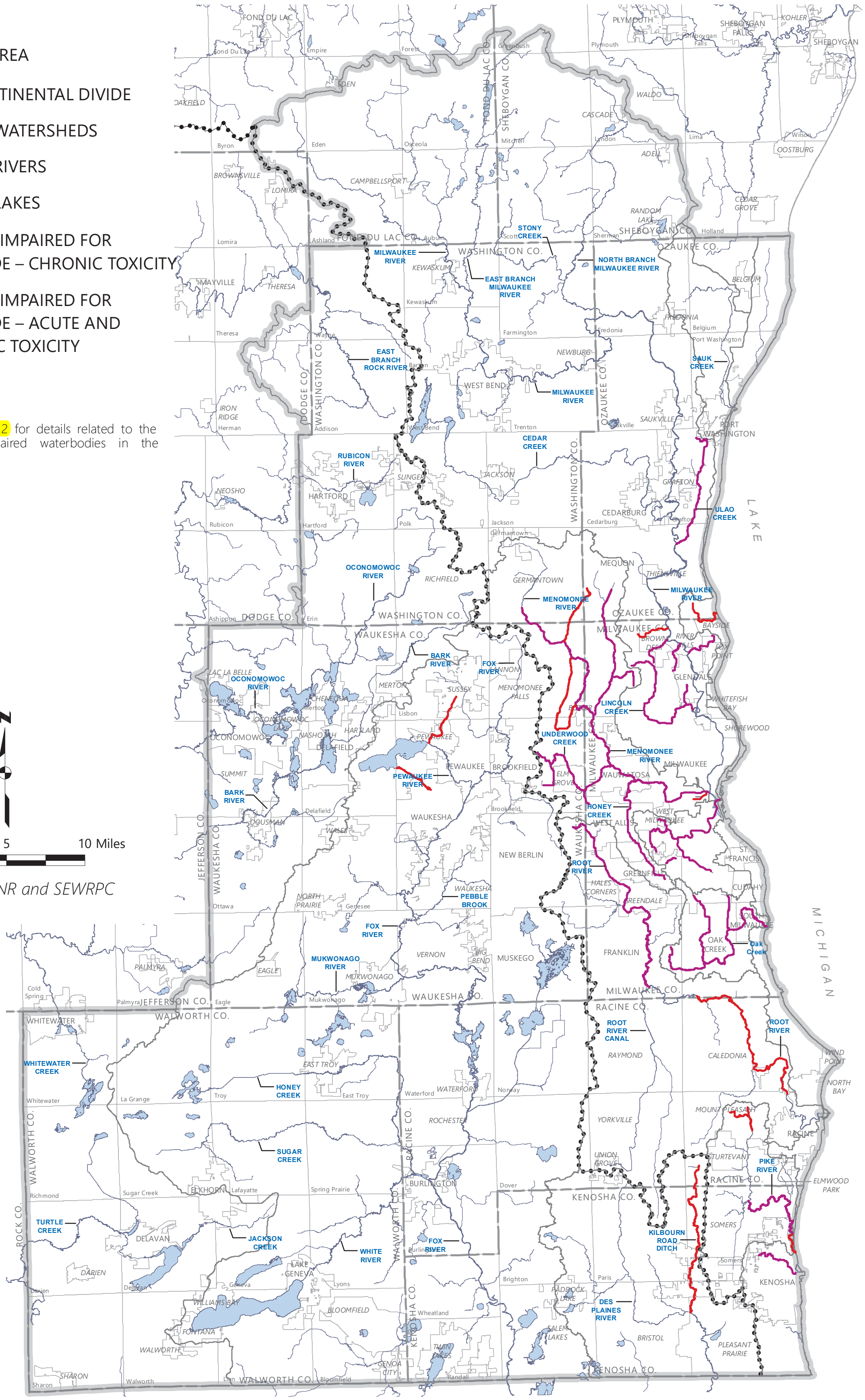
MAJOR RIVERS

MAJOR LAKES

STREAM IMPAIRED FOR CHLORIDE – CHRONIC TOXICITY

STREAM IMPAIRED FOR CHLORIDE – ACUTE AND CHRONIC TOXICITY

Notes: See Table 2.2 for details related to the chloride-impaired waterbodies in the Region.



Source: WDNR and SEWRPC

Map 2.3
Stream Monitoring Sites for the Chloride Impact Study

MONITORING SITE

STUDY AREA

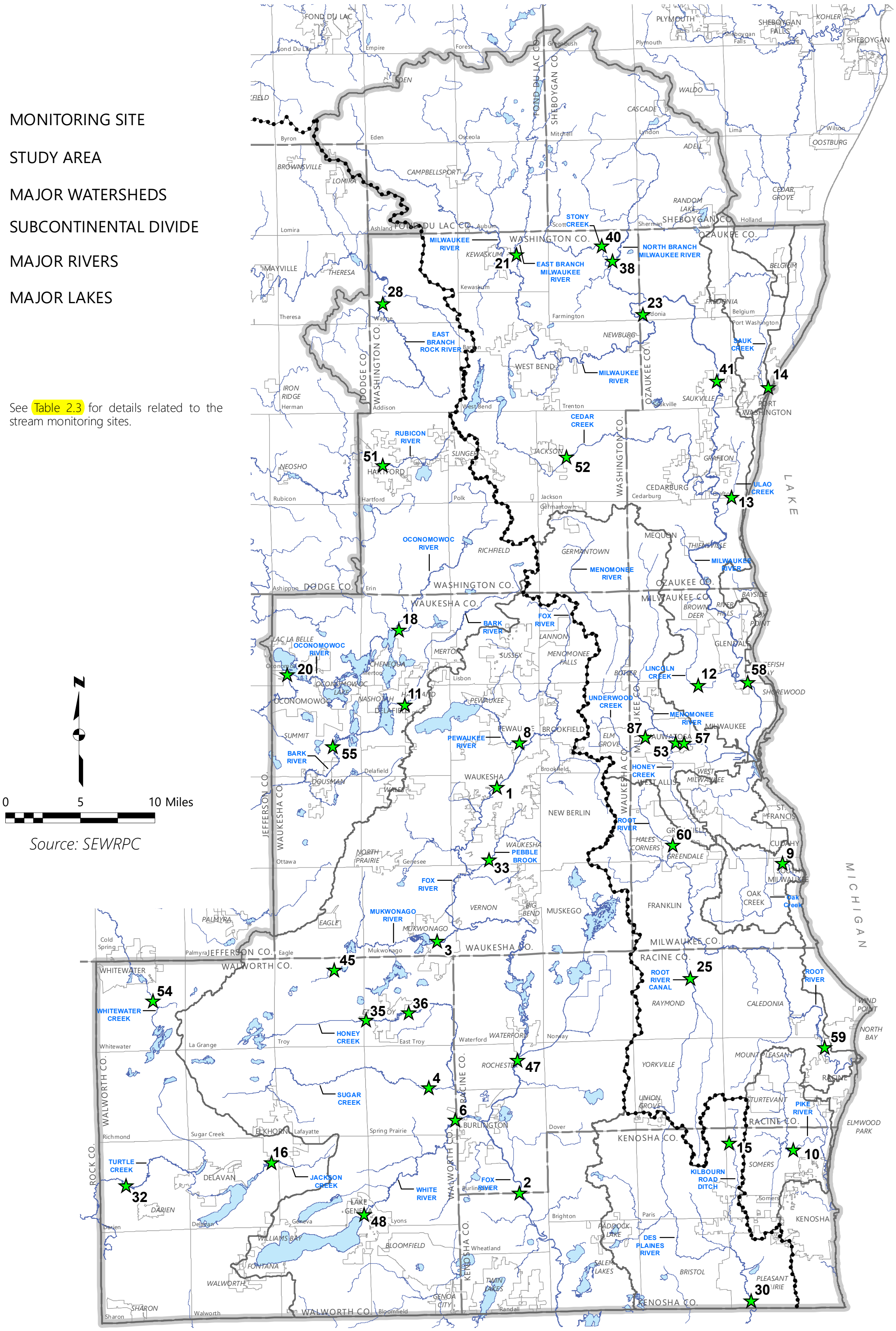
MAJOR WATERSHEDS

SUBCONTINENTAL DIVIDE

MAJOR RIVERS

MAJOR LAKES

Notes: See Table 2.3 for details related to the stream monitoring sites.



Source: SEWRPC

Map 2.4
Communities Reporting Public Winter Road Maintenance Data Within the Study Area

LOCAL GOVERNMENT TYPE

CITY: WAUWATOSA

VILLAGE: *UNION GROVE*

TOWN: Addison

MS4 PERMIT REPORT DATA

DATA REPORTED SEPARATELY

MAINTAINED BY COUNTY

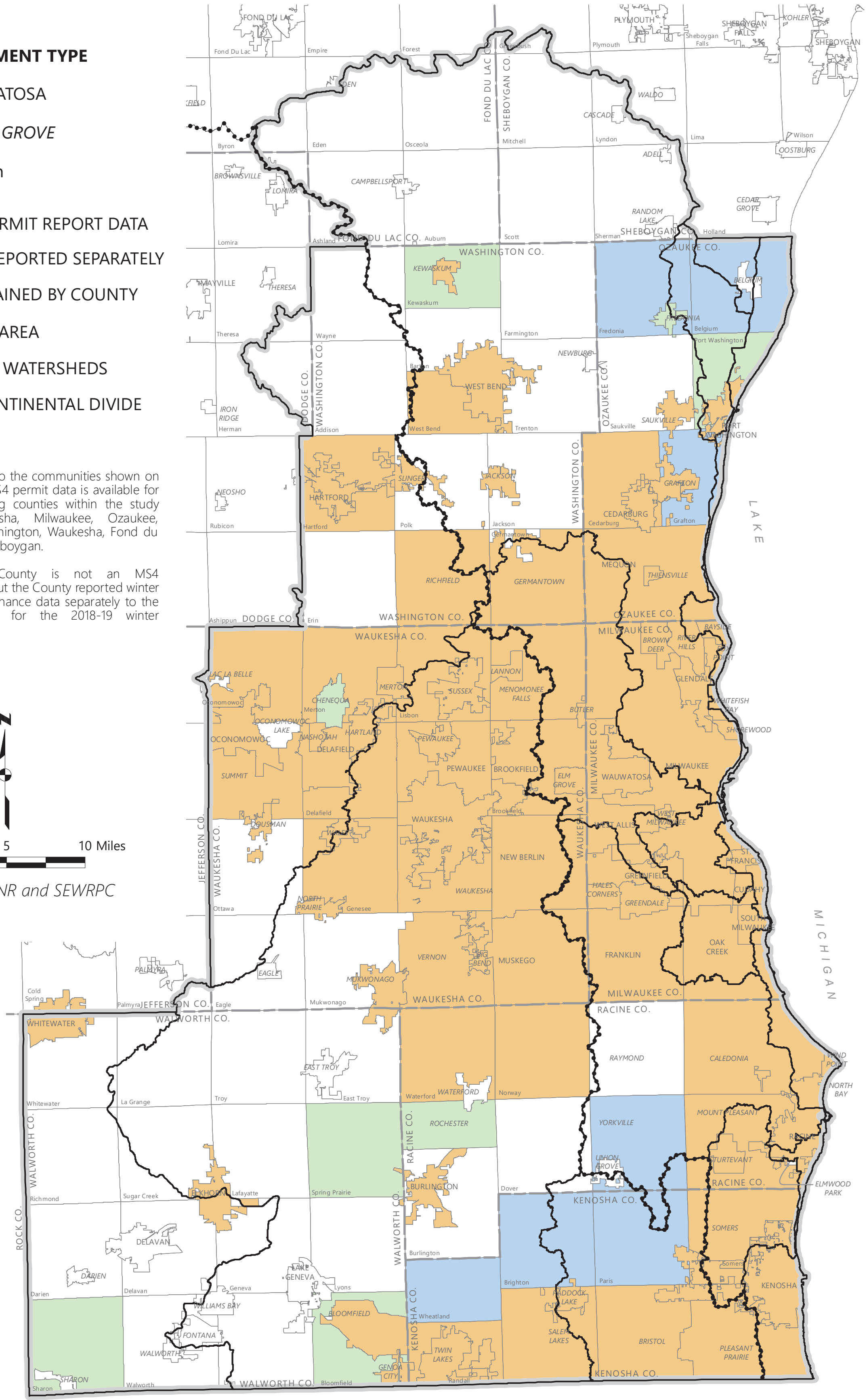
STUDY AREA

MAJOR WATERSHEDS

SUBCONTINENTAL DIVIDE

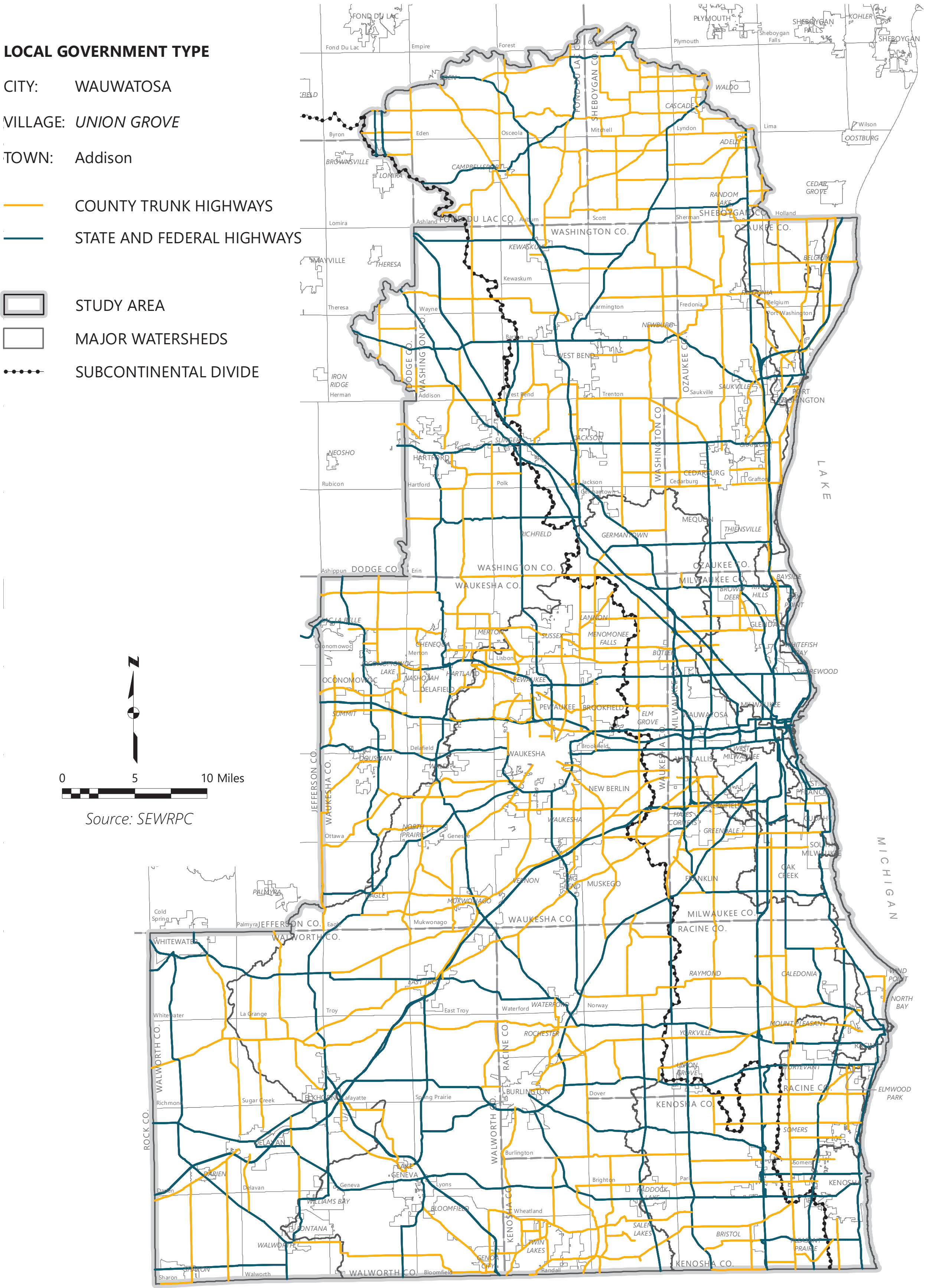
Notes: In addition to the communities shown on the map, MS4 permit data is available for the following counties within the study area: Kenosha, Milwaukee, Ozaukee, Racine, Washington, Waukesha, Fond du Lac, and Sheboygan.

Walworth County is not an MS4 permittee, but the County reported winter road maintenance data separately to the Commission for the 2018-19 winter season.



Source: WDNR and SEWRPC

Map 2.5
County, State, and Federal Highways Within the Study Area: 2020



Map 2.6
Public Wastewater Treatment Facilities and Planned Sanitary Sewer Service Areas Within the Study Area

PUBLIC WASTEWATER TREATMENT FACILITY (DISCHARGES TO SURFACE WATER)

PUBLIC WASTEWATER TREATMENT FACILITY (DISCHARGES TO SOIL)

PLANNED SANITARY SEWER SERVICE AREA

STUDY AREA

MAJOR WATERSHEDS

SUBCONTINENTAL DIVIDE

MAJOR RIVERS

MAJOR LAKES

Notes: See Table 2.6 for details related to wastewater treatment facilities.

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

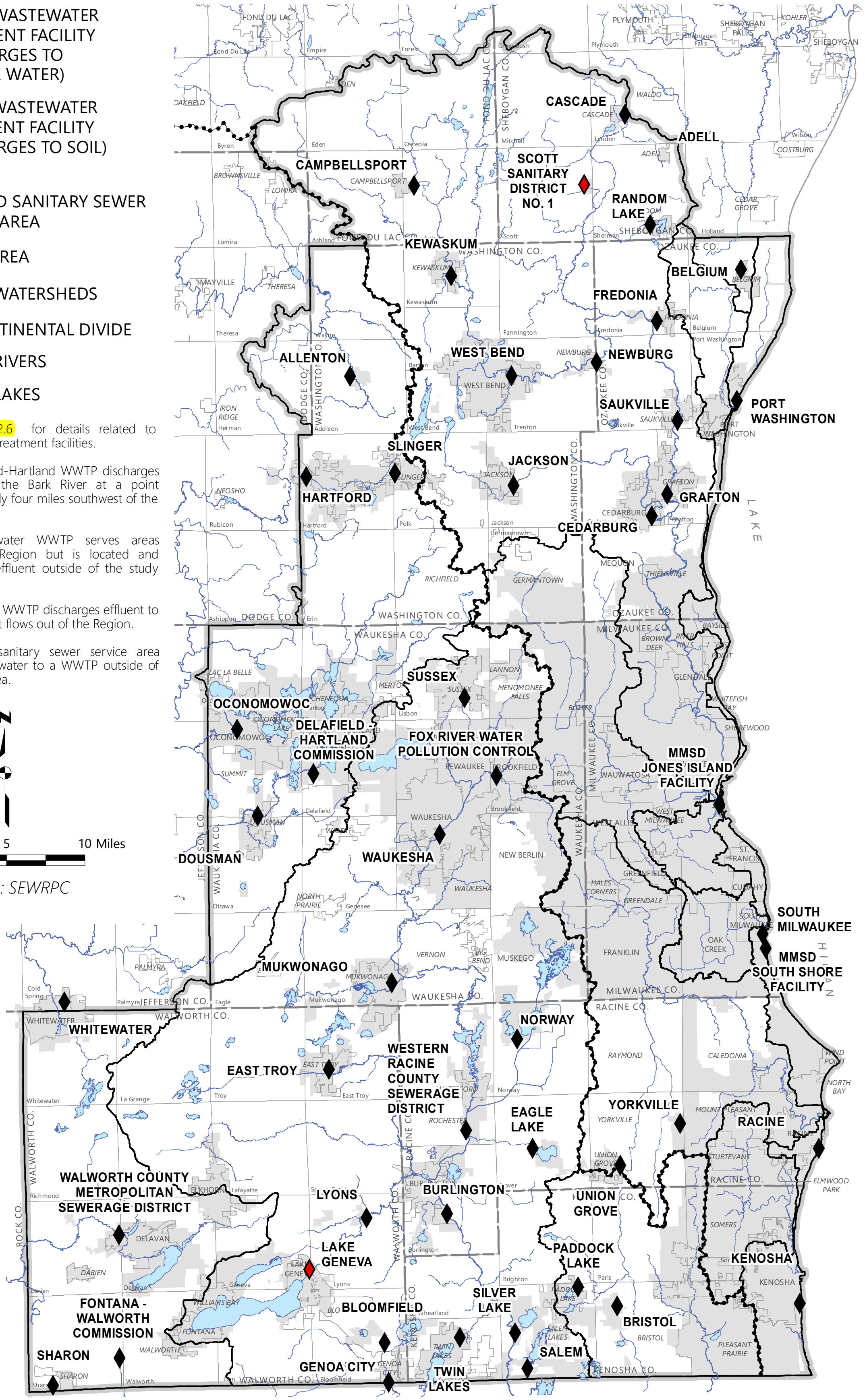
The Whitewater WWTP serves areas within the Region but is located and discharges effluent outside of the study area.

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

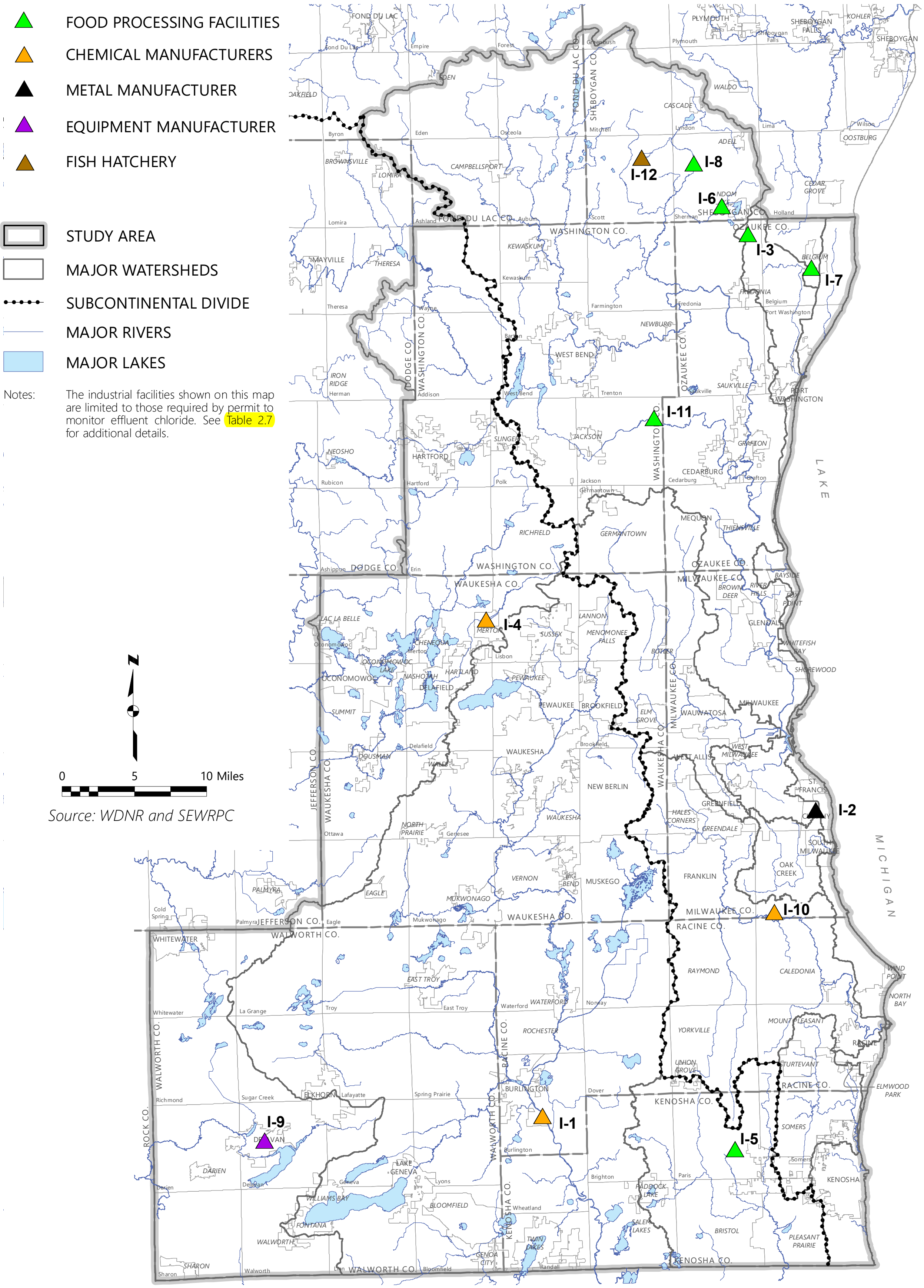
The Adell sanitary sewer service area sends wastewater to a WWTP outside of the study area.

0 5 10 Miles

Source: SEWRPC

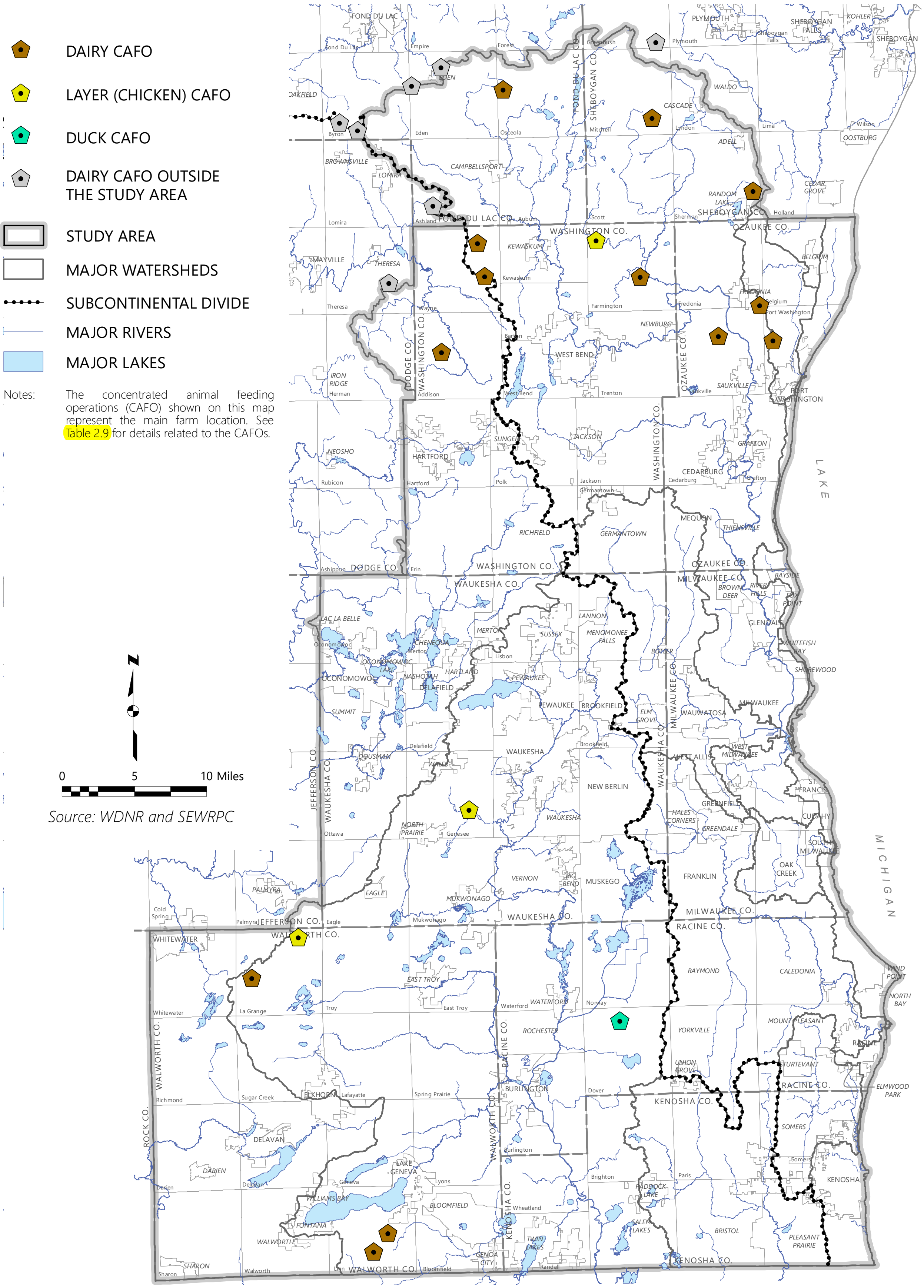


Map 2.7
Industrial Wastewater Dischargers with Chloride Monitoring Within the Study Area



Source: WDNR and SEWRPC

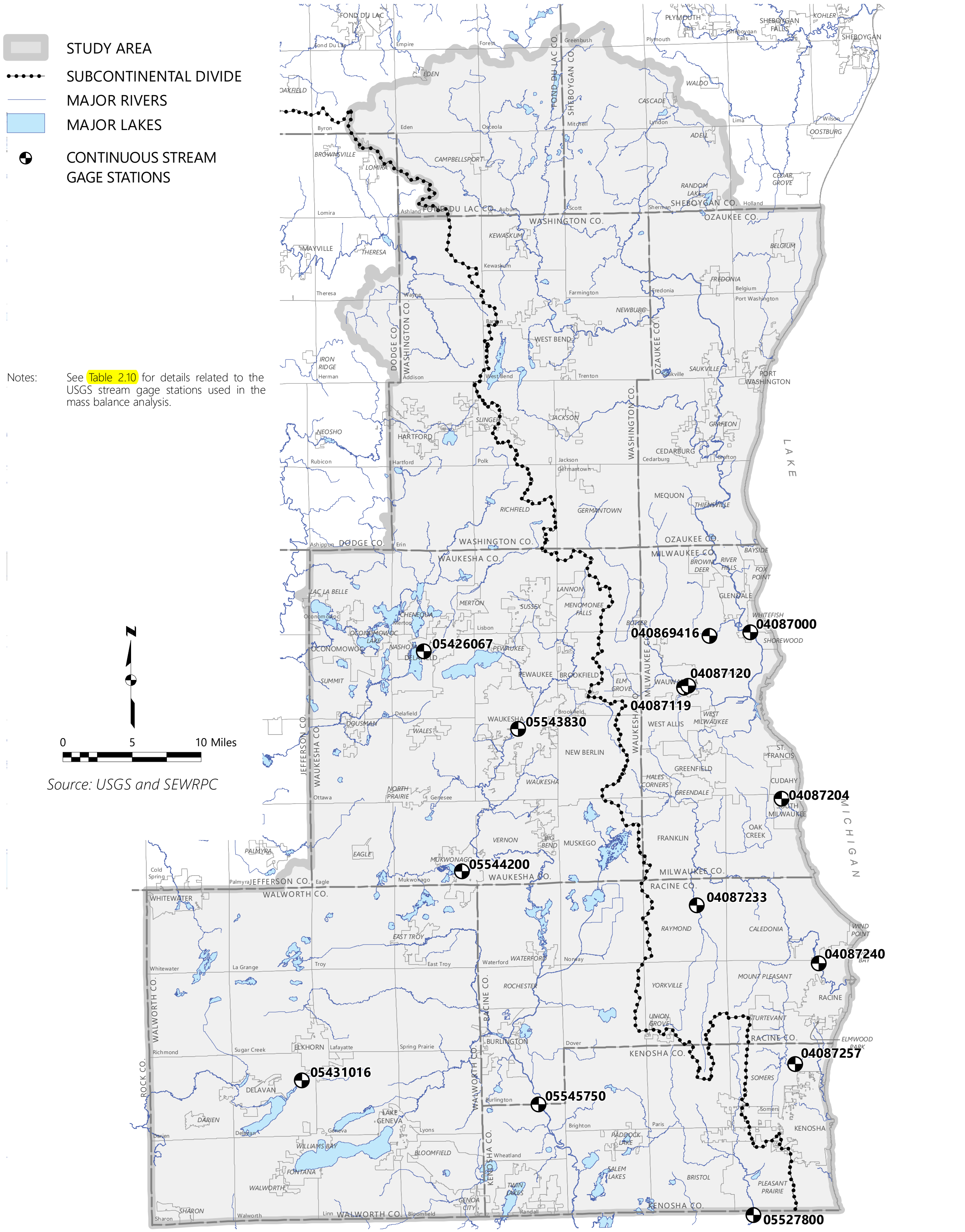
Map 2.8
Concentrated Animal Feeding Operations Within and Surrounding the Study Area: 2020



Notes: The concentrated animal feeding operations (CAFO) shown on this map represent the main farm location. See Table 2.9 for details related to the CAFOs.

Source: WDNR and SEWRPC

Map 2.9
Locations of U.S. Geological Survey Stream Gage Stations used in the Mass Balance Analysis: 2018



Notes: See Table 2.10 for details related to the USGS stream gage stations used in the mass balance analysis.

Source: USGS and SEWRPC