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Technical Report No. 63

CHLORIDE CONDITIONS AND TRENDS IN SOUTHEASTERN WISCONSIN

Chapter 4

CHLORIDE CONDITIONS AND TRENDS: RIVERS AND STREAMS

4.1 INTRODUCTION

Chlorides are highly soluble in water and are present in some concentration in all surface waters. Natural chloride concentrations in surface water reflect the composition of the underlying bedrock and soils, as well as deposition from precipitation. In southeastern Wisconsin, streams and rivers typically have very low natural chloride concentrations due to the prevalence of dolomite bedrock that is rich in carbonates and contains little chloride. While chloride can enter surface waters through various pathways, in the study area for the Chloride Impact Study, the sources are largely anthropogenic.[1]

Due to the high solubility of chloride in water, rainfall and stormwater runoff readily transport chloride from the land surface or topsoil to receiving waters. High chloride concentrations can harm aquatic plant growth and threaten aquatic organisms. Chloride contamination can begin to negatively affect freshwater aquatic life (both lethal and sublethal impacts) at concentrations as low as 15 to 35 mg/l and become more severe among all trophic levels within aquatic ecosystems with increasing concentrations.[2]

As detailed in Chapter 2 of this Report, the State of Wisconsin has established two water quality criteria for chloride that apply to waterbodies in the study area, an acute toxicity criterion and a chronic toxicity

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[1] *Sources and pathways of chloride to surface waters of the Region are discussed in detail in SEWRPC Technical Report No. 62,* Impacts of Chloride on the Natural and Built Environment, *April 2024.*

[2] Ibid.

criterion. The acute toxicity criterion states that the maximum daily chloride concentration must not exceed 757 mg/l more than once every three years. The chronic toxicity criterion states that the four-day average of daily maximum chloride concentration is not to exceed 395 mg/l more than once every three years. However, due to concerns that these water quality criteria may be too high to be fully protective of aquatic communities (see *Protectiveness of Existing Standards* section in Chapter 2 of this Report) several additional thresholds at 10, 35, 120, and 230 mg/l were analyzed in this Chapter to more fully characterize potential negative impacts of chloride enrichment to aquatic communities.

Chloride conditions and trends in this Chapter will primarily be analyzed using laboratory chloride measurements of water samples collected in the field. When sufficient chloride sampling data is unavailable for certain stream reaches, specific conductance measurements may be used as a general indicator of chloride conditions and trends over time. Conductance measures the ability of water to conduct an electric current. Because water temperature influences this ability, conductance values are corrected to a standard temperature of 25°C (77 degrees Fahrenheit) and referred to as specific conductance. The ability of water to conduct a current depends upon the presence, chemical identity, total concentration, mobility, and electrical charge of ions in the water. Solutions of many inorganic compounds, such as salts, are relatively good conductors. Therefore, specific conductance indicates the concentration of dissolved solids in water, with higher specific conductance values indicating higher dissolved solid concentrations.

Under certain circumstances, specific conductance measurements can effectively represent the concentrations of particular dissolved materials. For example, specific conductance measurements can generally indicate chloride concentrations in streams and lakes. Data analysis by the U.S. Geological Survey (USGS) suggests a linear relationship between specific conductance and chloride concentrations at higher values of both parameters.[3] Similarly, as part of the Chloride Impact Study, Commission staff developed and refined regression models to predict chloride concentrations from specific conductance for parts of the Region.[4] For some streams in the Region, specific conductance data may be available while chloride data is not. In addition, using specific conductance as a surrogate for chloride offers the advantage of inexpensive field measurement, whereas chloride concentration measurements require laboratory analysis. Consequently, some streams and rivers in the study area may have extensive historical records of specific conductance, while chloride samples may be infrequent or not exist.

[3] *S.R. Corsi, D.J. Graczyk, S.W. Geis, N.L. Boot, and K.D. Richards, "A Fresh Look at Road Salt: Aquatic Toxicity and Water Quality Impacts on Local, Regional, and National Scales,"* Environmental Science and Technology, *44: 7,376-7,382, 2010.*

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

4.2 STREAM BACKGROUND INFORMATION AND DETAILS

Rainfall and snowmelt reach stream systems through two pathways; direct overland flow as surface water runoff, or infiltrating into the soil, eventually flowing into streams as groundwater. Streams that flow only during the wet season or at high rainfall events are called intermittent streams. Perennial streams, that flow year-round, are primarily sustained by groundwater during dry periods. The surface water drainage systems and the 3,880 miles of mapped streams in the Chloride Impact Study area are shown on Map 2.2. Approximately half of the streams in the study area are considered perennial (1,946 miles), and half are considered intermittent (1,934 miles).[5]

Stream Order

Viewed from above, the network of water channels forming a river system resembles a branching pattern, as shown in Figure 4.1. Stream size increases downstream as more and more tributary segments join the main channel. A classification system called the Strahler stream order categorizes streams based on their position within this tributary network.[6] These designations offer a simple way to classify stream and river segments by number of upstream tributaries. Generally, lower stream order numbers indicate smaller headwater tributaries, designated as first-order streams in Figure 4.1. When two first order streams converge, the downstream segment becomes a second-order stream. Similarly, the confluence of two second-order streams forms a third-order stream. This pattern continues, with higher-order streams forming from the joining of lower-order streams, up to sixth-order large rivers.

As the stream order increases, streams generally become wider, deeper, and carry more water. In the study area, streams range up to sixth-order rivers. For example, the Fox River downstream of Tichigan Lake is the only sixth-order river in the study area. Other examples of higher-order rivers in the study area include specific reaches of the Fox, Milwaukee, and Root Rivers, which are designated as fifth-order rivers. Notably, headwater streams (first- and second-order) make up nearly 75 percent of the total stream length in the study area. Table 4.1 provides the length and percentage of streams for each stream order classification within the study area.

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

[6] *A.N. Strahler, "Hyposomertic Area-Altitude Analysis of Erosional Topography,"* Geological Society of American Bulletin, 63: 1117-1142, 1942.

4.3 DATA COMPILATION AND ORGANIZATION

Chloride conditions and trends in the streams and rivers of the study area were assessed using a variety of data sources. These data were collected through the efforts of numerous entities, including Federal, State, county, and local agencies; local units of government (e.g., lake districts and sanitary districts); universities; nonprofit organizations; and citizen monitoring groups. The earliest water quality sampling in the study area measuring chloride and specific conductance in streams was conducted in 1961. Regular water quality monitoring began in certain areas of the study area in 1964 as part of the Southeastern Wisconsin Reginal Planning Commission's (Commission or SEWRPC) study on the water quality of lakes and streams.[7]

Data Sources and Retrieval

Water quality data for streams and rivers in the study area were compiled from ten different agencies and organizations. The primary sources for chloride and/or specific conductance data included the Milwaukee Metropolitan Sewerage District (MMSD), WDNR, SEWRPC, U.S. Geological Survey (USGS), Milwaukee Riverkeeper, City of Racine Public Health Department, City of Oconomowoc, Eagle Spring Lake Management District, the University of Wisconsin – Milwaukee (UWM), and the U.S. Environmental Protection Agency (USEPA).

Chloride and specific conductance data from these sources were accessed through several databases. These include the USEPA National Water Quality Portal (WQP),[8] the USGS National Water Information System (NWIS),[9] the USEPA Storage and Retrieval database (STORET), and the WDNR Surface Water Integrated Monitoring System (SWIMS).[10] Data from SEWRPC were obtained from internal Commission databases.[11] In

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

[8] *The National Water Quality Data Portal is a cooperative service sponsored by the USGS, USEPA, and the National Water Quality Monitoring Council. For the application in this Report, the Portal was used to retrieve chloride and specific conductance data from the MMSD and USEPA.*

[9] *To access the USGS NWIS database, use the following link: nwis.waterdata.usgs.gov/usa/nwis/qwdata.*

[10] *SWIMS integrates data from multiple sources, including governmental agencies; academic institutions; citizen monitoring groups, mostly through the WDNR and University of Wisconsin-Extension Water Action Volunteers Program; and nonprofit organizations.*

[11] *Data included chloride and specific conductance measurement collected as part of SEWRPC Technical Reports No. 4 and 17, as well as sampling that was part of this Chloride Impact Study.*

addition to these major databases, water quality data were also directly provided by municipalities, lake organizations, and universities.

Integrating chloride and specific conductance data from multiple datasets and diverse sources into a single, cohesive database required significant effort. To ensure all samples within the study area were included without duplication, Commission staff queried the WQP, NWIS, and SWIMS databases and then identified and removed any duplicate records.

Commission staff used the R programing language and the "dataRetrieval" package (version 2.7.14) to retrieve data from the WQP. Using the "readWQPdata" function, staff queried for data labeled "chloride" and "specific conductance" across all SEWRPC Regional counties (Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties) and additional counties outside of the Region but within the study area (Dodge, Fond du Lac, Jefferson, and Sheboygan Counties). The USGS NWIS database was queried using the "readNWISwq" function within the same "dataRetrieval" package. For this search, specific parameter codes were used (00940 and 99220 for chloride, and 00095 for specific conductance). Since there is no equivalent R package for the SWIMS database, Commission staff used the SWIMS website interface to search for chloride data (using codes 940 and 941) and specific conductance (using codes 94, 95, and 402) across the same set of counties.

Data Formatting and Aggregation

Because different agencies store their water quality data using varying formats within their databases, Commission staff needed to identify, standardize, and reconcile these differences. Fortunately, all downloaded chloride data was already reported in milligrams per liter (mg/l), and all specific conductance data was in microsiemens per centimeter at 25° Celsius (μS/cm @ 25°C), so no unit conversions were needed. However, the timestamps for data collection were varied across datasets. To standardize this, all timestamps were converted to a "Year/Month/Day Hour:Minute:Second" format if that level of time specificity was provided. For records with only a date, the time was assumed to be noon. Each chloride and specific conductance measurement in the WQP, NWIS, and SWIMS databases included GPS coordinates based on the World Geodetic System 84 (WGS 84). Some data, like that from SEWRPC Technical Reports No. 4 and 17, lacked GPS coordinates.[12] In these cases, location descriptions (often mentioning road

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[12] *SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin, *November 1967, and SEWRPC Technical Report No. 17,* Water Quality of Lakes and Streams in Southeastern Wisconsin: 1964-1975, *June 1978.*

crossings) were used to determine the sample locations, and coordinates were assigned using ESRI ArcGIS version 10.7.7.

The collected data covered a wide geographic area, extending beyond the specific boundaries of the study area within the queried counties. To focus only on data within the study area, Commission staff used ArcGIS to clip the Statewide WDNR 24K hydrography geodatabase to the boundary of the study area.[13] This clipped hydrography layer was then spatially joined to the geographic points representing the monitoring stations from the aggregated chloride and specific conductance datasets. This process removed data from monitoring stations located on streams outside of the defined study area for the Chloride Impact Study.

Database Quality Assurance and Control

Ensuring the data was accurate and reliable was equally critical. Commission staff examined the data to identify any unusual or unexpected values and marked them for possible removal if necessary. Duplicate data entries were also a frequent issue to resolve. For example, a single chloride sample might be recorded in both the SWIMS and NWIS databases, leading to it also appearing twice in the WQP. When observations shared the same location, time, and measurement value but came from different organizations (like WDNR and USGS), staff identified these duplicates and kept only the record from the original reporting source. These redundant entries were removed from the final dataset to guarantee the accuracy of any statistical analyses.

Developing Assessment Reaches for Analysis of Water Quality Conditions

The final dataset for this study included measurements of either chloride or specific conductance from a total of 1,152 monitoring stations. These stations were located on 230 distinct streams within the study area. The locations of the chloride sampling stations are shown on Map 4.1, while the locations for specific conductance measurements are displayed on Map 4.2. The complete water chemistry data analyzed for this study spanned the years 1961 through 2022 and comprised 47,669 chloride measurements and 50,914 specific conductance measurements.[14]

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

[14] *There were occasionally multiple specific conductance samples reported at the same time and location as a single chloride sample. In these cases, the mean of the multiple specific conductance samples was used.*

To evaluate chloride levels and historical trends in the streams and rivers of the study area, Commission staff first identified stream segments containing at least one of the 1,152 monitoring stations where chloride and/or specific conductance data had been collected. Stream segments with similar hydrologic characteristics were then grouped together to create Chloride Impact Study stream "assessment reaches." These assessment reaches were defined using GIS analysis incorporating shapefiles of the monitoring station locations and the WDNR 24K Hydrography geodatabase. Key information from the WDNR 24K Hydrography layer used to delineate the assessment reaches included the river system waterbody ID code (WBIC), stream order, and a 14-digit "Reach Code" originally developed by the USGS for their National Hydrography Dataset.[15] Additionally, assessment reaches were divided at the discharge points of active municipal wastewater treatment plants (WWTPs) to account for potential chloride contributions from their effluent. Finally, in some cases, professional judgement was used to further combine or divide stream assessment reaches based on hydrological features or land use patterns in the surrounding drainage areas. This process resulted in 412 assessment reaches. The spatial extent of these assessment reaches is shown on Map 4.3, and a simplified representation using centroid points is provided in Map 4.4. A summary of each assessment reach can be found in Table 4.2.

Full Record Assessment Reach Dataset (1961 Through 2022)

As previously described, the complete ("full") dataset for this analysis, spanning from 1961 through 2022, contained 47,669 chloride and 50,914 specific conductance measurements.[16] It is important to note that the amount of available water quality data varied significantly across the 412 assessment reaches. Specifically, 154 assessment reaches had no chloride measurements, 18 reaches had only one, 24 reaches had between two and four, and 30 reaches had between five and ten chloride measurements (see Map 4.5 and Table 4.2). The total number of chloride samples per assessment reach ranged from zero to 4,186, with an average of 115 samples per reach for reaches with chloride data.

For assessment reaches with limited or no chloride data, specific conductance measurements could be used as a general indicator of chloride conditions and trends. The number of specific conductance measurements for the full period of record ranged from zero to 3,879 measurements per assessment reach, averaging 123 samples per reach for reaches with specific conductance data (see Map 4.6 and Table 4.2).

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[15] U.S. Geological Survey National Hydrography Dataset, 2004.

[16] Although the "full" dataset is consistently defined as 1961 through 2022 throughout this Chapter, the collection years for chloride and specific conductance samples differ among individual reaches and watersheds. The specific "full" data time-period range for each watershed will be addressed in the respective watershed assessment in Section 4.5.

The number of assessment reaches across different watersheds varied. The Milwaukee River watershed contained the most assessment reaches (115) in the full record dataset, followed by the Fox River watershed (102) the Rock River watershed (71), the Menomonee River watershed (33), the Root River and Lake Michigan direct drainage watersheds (23 each), the Des Plaines River watershed (12), the Kinnickinnic and Pike River watersheds (10 each), the Oak Creek watershed (8), the Sauk Creek watershed (5), and the Sheboygan River watershed (2) (see Table 4.2).

Recent Record Assessment Reach Datasets (2013 Through 2022)

To evaluate recent chloride conditions in the study area, Commission staff used "recent" datasets of chloride and specific conductance measurements collected from 2013 through 2022, where available.[17] During this recent period, 312 assessment reaches had either chloride or specific conductance samples. These reaches contained a total of 15,565 chloride samples and 21,332 specific conductance measurements (see Map 4.7 and Map 4.8).

Among the major watersheds, the Milwaukee River watershed had the most assessment reaches with data from this recent period (104 reaches). Following were the Fox River watershed (71), the Rock River watershed (41), the Menomonee River watershed (29), the Root River watershed (12), the Kinnickinnic River watershed and the Direct Drainage to Lake Michigan (10 reaches each), the Pike River and Oak Creek watersheds (8 reaches each), the Sauk Creek watershed (5), and the Des Plaines River watershed (4). The portion of the Sheboygan River watershed within the study area did not have chloride or specific conductance data collected during this recent 2013 through 2022 timeframe.

Assessing Robustness and Balance of Assessment Reach Datasets

It is important to recognize that the assembled datasets for each assessment reach have inherent differences that can complicate direct comparisons between them. First, assessment of chloride conditions in streams is particularly dependent on the number of samples that have been collected within a particular assessment reach. Second, chloride conditions are dependent on when sampling of a stream took place, including temporally, seasonally, and on much finer scale – during specific weather conditions. Some examples of dataset variabilities that may hinder direct comparison of conditions and trends of assessment reaches include the following:

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[17] *Although the "recent" dataset is consistently defined as 2013 through 2022 throughout this Chapter, the collection years for chloride and specific conductance samples differ among individual reaches and watersheds. The specific "recent" data time-period range for each watershed will be addressed in the respective watershed assessment in Section 4.5.*

- **Number of Samples** – First, the reliability of assessing chloride conditions depends heavily on the number of samples collected within an assessment reach. A reach with only a few samples might not accurately reflect typical conditions compared to one with extensive data. To address this, the analyses will report the total number of samples which will be a factor in determining if a dataset is robust enough for certain analyses.

- **Time Period of Sample** – Second, the overall time period when the data was collected (e.g., only in the 1960s versus only during the recent period of 2013 through 2022) can impact how well the data reflects overall true conditions in a stream reach. Assessment reaches with data concentrated in a single time period might not be fairly compared to those with data spread across many years. While focusing on the "recent" period (2013 through 2022) reduces this issue, comparisons can still be problematic if data within that period is limited to just one year. The spread of sampling dates will be a factor in determining if a dataset is considered "balanced" or "imbalanced." Although summary statistics will be presented for all available data, even from reaches with limited sampling, these will be identified as imbalanced datasets. These imbalanced datasets may be excluded from analyses comparing conditions across reaches or assessing trends over time.

- **Seasonal Coverage** – Third, assessment reaches lacking winter samples might not be comparable to those with winter data, as chloride levels can vary significantly seasonally. Figure 4.2 illustrates the percentage of annual chloride samples that were collected in the winter season for the full study area dataset from 1961 - 2022 (the size of the circle in represents the size of the full chloride dataset for that year). The proportion of winter sampling generally ranged from about one percent to 25 percent, with many years falling below 10 percent (1965 was an outlier with 61 percent of the samples collected in winter). A steady increase of both winter sampling and overall number of annual chloride samples began in the early 2000s.

  Similarly, a dataset heavily skewed towards a single season might not be representative of year-round conditions compared to a reach with data across all seasons. To account for this, seasonal proportions of data for each assessment reach will be reported in their corresponding watershed assessments in Section 4.4, defining seasons as winter (December through February), spring (March through May), summer (June through August), and fall (September through November). Furthermore, this Report will analyze the seasonality of chloride conditions and may exclude reaches with insufficient seasonal data for certain analyses. The amount of seasonal data will also be a criterion for identifying balanced and imbalanced datasets.

- **Influence of Weather Events** – Finally, assessment reaches with a disproportionate number of samples collected during or immediately after winter weather events or snowmelt might not reflect typical chloride conditions. While event-based sampling is valuable for capturing extreme high and low concentrations, a dataset dominated by such samples can be misleading when assessing overall conditions. Identifying this bias in this large dataset is challenging, as it would require detailed review for closely spaced sampling, comparisons with historical weather records, and subjective judgement. Therefore, a comprehensive analysis of weather-related sampling bias is impractical for this study.

To ensure fair comparisons, reliable trend analyses, and transparency, Commission staff categorized the chloride and specific conductance datasets for each assessment reach as either "balanced" or "imbalanced." This categorization helps the reader in evaluating and interpreting the presented data. Specific criteria were established to make these determinations. While imbalanced datasets can still offer valuable insights into conditions of an assessment reach, identifying them is crucial as their summary statistics might not be directly comparable to those from other assessment reaches. These criteria were applied separately to the chloride and specific conductance datasets for each assessment reach. Some analyses in this Chapter will exclusively use balanced datasets, and this will be clearly stated in associated tables, figures, and maps. If not explicitly stated, both balanced and imbalanced datasets were utilized. Where appropriate, each table, figure, and map within this Chapter will identify whether datasets are balanced.

Balanced Dataset Criteria

For the Full Period of Record (1961-2022) datasets to be considered balanced the chloride and/or specific conductance data must meet all of the following conditions:

- Had at least 20 total samples

- Included samples collected over a span of at least 15 years

- Contained at least one sample collected in the year 2000 or later

- Had at least 5 total samples or 10 percent of its total samples collected during the winter months (December through February)

- Had at least 20 percent of its total samples collected during either the summer (June through August) or fall (September through November) seasons

For the Recent Period of Record (2013-2022) datasets to be considered balanced the chloride and/or specific conductance data must meet all of the following conditions:

- Had at least 10 total samples
- Had at least 4 total samples or 10 percent of its total samples collected during the winter months (December through February)
- Had at least 20 percent of its total samples collected during either the summer (June through August) or fall (September through November) seasons

From the full historical record (1961 through 2022), 74 assessment reaches had balanced chloride datasets, and 86 reaches had balanced specific conductance datasets. These balanced chloride datasets comprised 39,537 chloride samples (83 percent of all chloride data), and the balanced specific conductance datasets included 40,656 specific conductance samples (80 percent of all specific conductance data). For the recent period (2013 through 2022), 84 assessment reaches had balanced chloride datasets, and 133 had balanced specific conductance datasets. These recent balanced datasets included 13,172 chloride samples (85 percent of all recent chloride data) and 19,156 specific conductance samples (90 percent of all recent specific conductance data).

Data from assessment reaches with imbalanced datasets will be clearly identified in tables using red text. While direct comparisons to other stream assessment reaches or trend analyses might be limited for these imbalanced datasets, they still provide valuable information about the chloride conditions in those specific stream locations at the time of measurement. These are real-time snapshots of the water quality in those reaches.

Additional Formatting and Spatial Data Operations

To facilitate statistical analysis and visualize the assessment reach data, several additional formatting and spatial data operations were performed. This included creating new data fields to represent the year, month, decade, and season of each sample collection. Additional stream characteristics were integrated into the assessment reach data, such as river miles, natural community type, watershed, subwatershed, drainage catchments, municipality, and county.

Major watersheds, subwatersheds, and subbasins were used to evaluate factors that might contribute chlorides to streams and rivers of the study area and influence chloride conditions and trends (these characteristics are described in detail in Chapter 2). Watershed, subwatershed, and subbasin boundaries were obtained from Commission databases.

4.4 AN OVERVIEW OF CHLORIDE CONDITIONS AND TRENDS IN THE STREAMS AND RIVERS OF THE STUDY AREA

The purpose of this Chapter is to determine the extent to which streams and rivers in the study area have been impacted by chloride pollution. The following sections also seek to identify if, and to what degree, chloride conditions in the waterways of the study area are improving, becoming worse, or remaining stable. Temporal trends, geographic trends, and seasonal trends in chloride conditions will be assessed and summarized where sufficient data is available to do so for both the recent and full datasets. This section is meant to give a general overview of historical and recent chloride conditions and trends in the entire study area. More detailed assessments for each major watershed in the study area will be provided in Section 4.5.

Historical Conditions and General Trends in the Study Area for the Full Period of Record (1961 Through 2022)

Historical conditions and general trends within the study area, spanning the period from 1961 through 2022, will be assessed in this section using chloride and specific conductance data. To provide a comprehensive overview, the data will be analyzed at multiple spatial scales: the study area as a whole, major watersheds within the study area, and the 412 individual stream reaches detailed earlier (see Map 4.4 and Table 4.2).

Table 4.3 provides chloride summary statistics for each watershed in the study area. However, the availability of chloride data varied considerably across watersheds. The most extensive datasets are from the Menomonee River, Milwaukee River, and Kinnickinnic River watersheds. A second group of watersheds – Oak Creek, Fox River, Root River, Rock River, and Pike River – still had substantial data with each having between one thousand and three thousand chloride samples over the 62-year period. In contrast, the Des Plaines River watershed and the direct drainage area to Lake Michigan had a modest amount of sampling (around 400 samples each), the Sauk Creek watershed had less than 100 samples, and the portion of the Sheboygan River watershed within the study area had only six chloride samples. This limited dataset for the Sheboygan River watershed does not provide robust summary statistics compared to those of the other watersheds.

This Chapter will often use box plot figures to visually display large amounts of data. An explanation of box plot symbols is given in Figure 4.3. The distribution of all chloride samples observed during the full period of record are presented by watershed in Figure 4.4 (also see Table 4.3 for summary statistics), note that chloride concentrations are presented on a log scale. Median chloride concentrations range from 46 mg/l in the Des Plaines watershed to 180 mg/l for the Oak Creek watershed and the direct drainage area to Lake Michigan. The Root River watershed also exhibits a slightly elevated median chloride concentration when compared to the other watersheds. Given the interquartile ranges of the watersheds, chloride samples generally range from 50 mg/l to 250 mg/l. However, most watersheds exhibit many datapoints that fall well outside the interquartile range, indicating that extreme high and very low chloride concentrations occur relatively often within most watersheds. In all watersheds, the mean chloride concentration is higher than the median suggesting the presence of outliers on the higher end are driving the mean values up. Hence, unless otherwise noted, median concentrations were used to compare among reaches because it is a more conservative value than mean concentrations.

Map 4.9 displays median chloride concentrations for stream assessment reaches over the full period of record.[18] For reaches with balanced datasets, median concentrations ranged from 14 mg/l at FX71 (Mukwonago River: 13.6 to 15.9 miles) to 663 mg/l at OC04 (Mitchell Field Drainage Ditch). Considering all reaches (balanced and imbalanced datasets), maximum chloride concentrations varied from 8 mg/l at RK71 (Lower Pine River) to 9,800 mg/l at MN21 (Noyes Creek).[19] Higher median chloride concentrations were predominantly observed in Milwaukee County and eastern Waukesha County, as shown by the yellow, olive, orange and brown colors on Map 4.9. Chloride summary statistics for all assessment reaches can be found in their corresponding watershed sections later in the Chapter.

During the full period of record (1961 through 2022), 2,964 chloride samples (6.2 percent of all samples) exceeded the State's chronic toxicity concentration threshold of 395 mg/l, and 935 samples (2.0 percent of all samples) exceeded the acute toxicity threshold of 757 mg/l. It is important to note that some of these samples were collected before the chloride toxicity criteria were established. Figure 4.5 illustrates the percentage of samples exceeding the chronic toxicity concentration by year. As the figure shows, the

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[18] *The circles on Map 4.9 represent assessment reaches determined to have balanced datasets and the triangles represent assessment reaches with imbalanced datasets. The process for determining balanced and imbalanced datasets is described earlier in this Chapter.*

[19] *Higher chloride concentrations of 44,000 mg/l, 26,300 mg/l, 19,700 mg/l, 17,000 mg/l, and 14,000 mg./l were observed at KK06 (Wilson Park Creek: 3.4 to 4.4 miles) but were considered outliers.*

percentage of exceedances generally increased from 1961 to 2022. Initially, exceedances were at or near zero percent until the mid-1970s, after which a noticeable increase and greater variability occurred.[20]

Chloride can harm aquatic ecosystems at levels well below regulatory toxicity thresholds. Studies have documented a range of harmful effects – from lethal impacts to subtle changes in behavior and physiology – at chloride concentrations between 16 mg/l and 185 mg/l.[21] To provide a comprehensive understanding of the impact of chloride in the streams of the study area, this Chapter will analyze exceedances not only against the Wisconsin chronic (395 mg/l) and acute (757 mg/l) toxicity thresholds but also against lower impact thresholds (10, 35, 120, and 230 mg/l) and an extreme impact threshold of 1,400 mg/l (for detailed explanation of these thresholds, refer to Table 2.Thresholds in Chapter 2 of this Report). The full chloride dataset for the study area revealed the following:

- **Historical Background Concentration (10 mg/l):** Nearly 99 percent of all chloride samples in the full period of record exceeded this threshold, and all but two assessment reaches (RK71 and FX72) had at least one sample exceeding it.

- **Conservative Lower Impact Concentration (35 mg/l):[22]** Nearly 87 percent of all chloride samples exceeded this threshold, and 92 percent of all assessment reaches had at least one sample exceeding it.

[20] *The percentage of exceedances in 1979 is far greater than any other year partially due to the small amount of sampling that was conducted during that year.*

[21] *See Table 3.17 in SEWRPC Technical Report No. 62, Impacts of Chloride on the Natural and Built Environment, April 2024, for chloride concentration thresholds in which studies have found biological impacts occur. Impacts for which thresholds have been reported include decreases in organism abundance, reductions in diversity, changes in community composition, changes in organism physiological processes, and changes in organism behavior related to the use of habitats.*

[22] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[23] Approximately 37 percent of chloride samples exceeded this guideline, and 58 percent of all assessment reaches had at least one sample exceeding it.

- **USEPA Chronic Toxicity Threshold (230 mg/l):** [24] More than 16 percent of chloride samples exceeded this threshold, and 44 percent of all assessment reaches had at least one sample meeting or exceeding it.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Over 6 percent of chloride samples exceeded this threshold, and almost 34 percent of all assessment reaches had at least one sample surpassing it.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** Approximately 2 percent of chloride exceeded this threshold, and almost 26 percent of all assessment reaches had at least one sample exceeding it.

- **Extreme Impact Threshold (1,400 mg/l):** 346 chloride samples (0.7 percent of all samples) exceeded this concentration, and almost 16 percent of all assessment reaches had at least one sample exceeding it.

As described earlier, specific conductance can be used as a general indicator of chloride conditions. In this Chapter, when particular stream assessment reaches have no, or very little chloride data, inferences of chloride conditions within a stream may be made where appropriate using specific conductance data. Map 4.10 show median specific conductance levels for stream assessment reaches over the full period of record.[25] For reaches with balanced datasets, median values ranged from 503 μS/cm at MK85 (East Branch Milwaukee River: 0 to 11.0 miles) to 2,700 μS/cm at KK08 (Villa Mann Creek: 0 to 1.4 miles). Considering all

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[23] The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.

[24] This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.

[25] The circles on Map 4.10 represent assessment reaches determined to have balanced specific conductance datasets and the triangles represent assessment reaches with imbalanced datasets. The process for determining balanced and imbalanced datasets is described earlier in this Chapter.

reaches (balanced and imbalanced datasets) with more than one sample, maximum specific conductance values varied from 185 μS/cm at MN32 (Unnamed Tributary to Dousman Ditch: 0 to 2.7 miles) to 24,900 μS/cm at DD13 (Unnamed Tributary to Lake Michigan: 0 to 0.9 miles). Higher median specific conductance levels were predominantly observed in Milwaukee County, as indicated by the olive and orange colors on Map 4.10. Specific conductance summary statistics for all assessment reaches can be found in their corresponding watershed sections later in the Chapter.

Temporal Trends

Figure 4.6 shows the median chloride concentrations for each water year and includes all chloride data collected in the study area from 1961 through 2022.[26] The figure shows a general rapidly increasing trend in median chloride concentrations over time. Linear regression analysis indicates an increase in the yearly medians of chloride concentrations of about 1.6 mg/l per water year. The lowest median of 14 mg/l is observed in water year 1961, the first year of the full period of record, while the highest median of 170 mg/l was observed in 2003. While the linear trend in Figure 4.6 shows a clear and statistically significant increasing trend over the full period of record (P-value < 0.01, R^2 = 0.66) there is notable variability in median chloride concentrations as might be expected with many other factors likely playing a role in chloride conditions over time. In addition, there appears to be a plateau or even slight decrease in median chloride concentrations in the most recent years, although it is unclear if the lower values represent normal variability or are part of a more significant trend.

To further assess changes in chloride concentrations over time, the full dataset ranging from 1961 through 2022 was divided into five time periods: 1961-1977, 1978-1986, 1987-1993, 1994-2021, and the "recent" time period of 2013-2022.[27] Figure 4.7 illustrates the distribution of all chloride concentrations (on a log scale) for data collected in the study area over the full period of record by time period. An Analysis of Variance (ANOVA) statistical test was used to determine the difference in chloride concentrations among the five time periods noted above throughout the full period of record (1961-2022). Application of that statistical test generates a parameter, designated the "P-value," which relates to statistical significance. To determine the pairwise differences, the post-hoc Tukey's Honestly Significant Difference (Tukey HSD) test was used. All statistical analyses were performed using R and a P-value less than 0.001 indicated a significant

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[26] The water year for analyses in this Chapter is defined as a 12-month period from October 1st to September 30th. The water year is designated by the calendar year in which it ends. Water years are used in some analyses because they provide a more accurate representation of the impacts of the cold and snow season on chloride concentrations.

[27] These time periods were used for comparability to past water quality studies conducted by the Commission.

result. The ANOVA and the post-hoc Tukey HSD test results revealed a statistically significant difference in chloride concentrations between all time periods except 1978-1986 and 1987-1993. Hence, except for no difference between 1987 through 1993, there is a statistically significant general increasing trend in chloride concentrations evident from 1961 through 2022.

The median chloride concentration (indicated in Figure 4.7 by the horizontal line within each box or the 50th percentile) for the 1961-1977 time period was about 50 mg/l. The next two time periods from 1978-1993 shows that more than 75 percent of the chloride concentrations observed were greater than 50 mg/l, which is a significant increase. However, maximum concentrations from 1978-1993 (i.e., outlier points) were the lowest compared to all time periods and barely exceeded 1,000 mg/l. Between the 1987-1993 and the 1994-2012 time periods, there was a significant increase in chloride concentration. Once again, nearly 75 percent of the observed chloride concentrations in 1994-2012 were above the median concentration of about 75 mg/l for the 1987-1993 time period. The highest maximum and most concerning chloride concentrations occurred in the 1994-2012 and 2013-2022 periods as shown by the outliers above the third quartile (upper whisker on Figure 4.7). While the most recent period (2013-2022) contained the greatest mean chloride concentration among all the time periods at 203 mg/l, it is important to note that the median concentration is very similar compared to the 1994-2012 period of about 110 mg/l. Hence, this may indicate a possible stabilization in chloride concentrations in recent years.

The observed general increase in chloride concentrations over time could be attributed to various factors, such as increased road salt application during winter months, changes in land use patterns and/or wastewater discharge, variability in weather conditions, or even changes in the amount or timing of sampling. The plateau in observed chloride concentrations in the most recent periods may be linked to variations in precipitation or temperature patterns, increased awareness and changes in de-icing practices, or other environmental factors.

Map 4.11 shows balanced assessment reaches within the study area that have exhibited statistically significant increasing or decreasing trends over their full sampling period. There were 60 assessment reaches (81 percent of reaches that had balanced datasets for which trend analysis was conducted) that showed statistically significant increases in chloride concentrations (indicated by the red "up" arrows) and two assessment reaches that showed statistically significant decreases (indicated by the dark green "down" arrows). Table 4.4 provides the slope of these trends (presented as mg/l/year), the sampling span, and coefficient of determination (R^2) values for the linear regressions for all balanced assessment reaches in the study area with statistically significant chloride trends. Assessment reaches in Table 4.4 are listed in order of highest to lowest slope of the observed trend in chloride concentration. It should be noted that while all assessment reaches in Table 4.4 show statistically significant trends (P-values less than 0.05),[28] some of the trends have low R^2 values, indicating high variability and weak relationship over time. These reaches are likely also being influenced by changes or differences in seasonal variation, precipitation patterns, changes in land use, or variations in stream flow, to name a few.

In addition to trends in chloride, Map 4.11 shows statistically significant trends in specific conductance among assessment reaches with balanced datasets. There were 55 assessment reaches (64 percent of reaches with balanced datasets) that had statistically significant increasing trends in specific conductance levels (indicated by the orange "up" arrows) and two reaches that had decreasing trends for specific conductance (indicated by the light green "down" arrows). It should be noted that many of the assessment reaches with statistically significant trends in chloride concentrations shown on Map 4.11 also have the same trend direction in specific conductance data. In those cases, only the trends in chloride concentrations are shown on the map. There is one instance, at FX29 (White River 14.1 to 18.9 miles), where chloride concentrations show an increasing trend while specific conductance levels show a decreasing trend. Both the chloride and specific conductance trends for this assessment reach are very minor and are likely being impacted by the dilution effect of Geneva Lake which is located immediately upstream of this assessment reach.[29]

Seasonal Trends

Seasonal trends in this Chapter will be assessed in two ways – by month, and by simple season designations. Simple season designations in these analyses will be represented by winter (December through February), spring (March through May), summer (June through August) and fall (September through November).

Chloride concentrations in the study area have increased across all four seasons throughout the full period of record (1961-2022), as shown by the upward slopes of the linear regression lines in Figure 4.8 (using a log scale). However, both the overall chloride concentration values and the rate of increase vary by season. The winter season exhibits the steepest increase, with a slope of 4.3 mg/l per year, followed by spring (2.9 mg/l/year), summer (1.7 mg/l/year), and fall (1.7 mg/l/year). There is considerable variability around the trend lines, especially during winter and spring. This variability is likely due to two main factors: first, winter

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[28] *All but two linear regressions for these assessment reaches had P-values less than 0.001.*

[29] *Geneva Lake has a residence time of 13.9 years and a total volume of 320,948 acre-feet. For more information on chloride conditions in Geneva Lake, see Chapter 3 and Chapter 5 of this Report.*

deicing activities can cause sharp increases in chloride levels; and second, snowmelt events introduce runoff that can both increase chloride concentrations and dilute existing chloride levels in waterways.

Chloride levels in the study area have shown a trend of increasing exceedances of the State toxicity thresholds over time. During winter and spring, samples began to regularly surpass the chronic toxicity threshold (395 mg/l) after 1975, and the acute toxicity threshold (797 mg/l) after 1995. In summer and fall, chronic exceedances became common after 2000. Summer samples showed only several instances of acute exceedances starting in 2003, while fall samples had occasional acute exceedances beginning in 1976. It should be noted that while these dates indicate general trends, earlier exceptions to these patterns exist, with some samples exceeding chloride thresholds prior to the stated years. In addition, many samples exceeding current toxicity thresholds were collected before the WDNR established the chloride toxicity standards in 2010.

Figure 4.9 displays the distribution of chloride concentrations (on a log scale) by month across the full period of record. The highest chloride concentrations and greatest variability was observed in February, with a median of 230 mg/l and mean of 526 mg/l. From March through August, chloride concentrations generally decrease, reaching a low in August with a median of 69 mg/l and a mean of 92 mg/l. Concentrations then rise from September (median: 82 mg/l, mean: 103 mg/l) through January (median: 180 mg/l, mean: 460 mg/l). In all months, the mean chloride concentration exceeds the median concentration for the full dataset. This difference is most pronounced in December, January, and February where the mean chloride concentration is 2.2, 2.6, and 2.3 times greater than the median, respectively. These large discrepancies suggest that the mean values in these winter months are strongly influenced by infrequent, but substantial spikes in chloride concentrations, likely driven by deicing activities during winter weather events. Figure 4.9 also demonstrates that chloride concentrations exceeded both the State's chronic (orange dotted line) and acute (red dotted line) toxicity thresholds in every month of the year where measurements were taken, and were often substantially above levels known to cause biological harm.[30] In January and February, the 75th percentile of chloride samples surpassed the State chronic toxicity concentration threshold, indicating frequent exceedances during these months.

Seasonal patterns are evident in the frequency of exceedances of the chronic toxicity threshold as shown in Figure 4.10. Most exceedances of the 395 mg/l chronic threshold occurred in colder months, highlighting the significant impact of winter deicing practices on stream chloride levels in the study area. February

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

exhibited the highest frequency of exceedances of this threshold (over one-third of samples collected in this month), followed by January (26 percent), March (19 percent), and December (11 percent). However, the percentage of samples exceeding the chronic toxicity threshold decreased significantly from May through November, falling below 5 percent. This decrease was most pronounced from August through October when less than 1 percent of all samples collected in the study area exceeded the threshold. Despite the lower exceedance rates in summer and fall, a total of 387 exceedances of the chronic chloride concentration threshold still occurred during the months of June through November across the full period of record. This indicates that harmful chloride concentrations can occur in the study area streams even outside of winter. Potential contributing factors during warmer months include runoff from agricultural fertilizers, leaching of residual deicing salts from soil, baseflow contributions from chloride-polluted shallow groundwater aquifers and wastewater treatment plant effluent.

Stream Size

Strahler stream order reflects a stream's position within the drainage network with higher-order streams typically further downstream and draining larger areas. Stream order appears to have a complex relationship with observed chloride concentrations. While larger streams can carry greater total chloride loads due to the larger contributing drainage areas and increased discharge, dilution effects can also lower chloride concentrations, making direct comparisons of chloride concentrations between streams of different sizes challenging. Figure 4.11 displays the distribution of chloride concentrations for the entire dataset (on a log scale) by Strahler stream order classification. Median chloride concentrations generally decrease from smaller to larger stream orders, ranging from 50 mg/l (6th order) to 130 mg/l (2nd order). Mean chloride concentrations vary more widely, from 64 mg/l (6th order) to 284 mg/l (2nd order) and 222 mg/l (1st order), indicating the influence of high chloride spikes, particularly in smaller streams. Notably, maximum chloride concentrations are elevated across all orders, but especially in stream orders 1, 2, and 3.

Recent Conditions in the Study Area (2013 Through 2022)

Table 4.5 provides chloride summary statistics for each watershed in the study area for chloride data collected in the recent period of record. Similarly to the full period of record, the most extensive datasets are from the Menomonee River, Milwaukee River, and Kinnickinnic River watersheds. The Oak Creek, Fox River, Root River, Rock River, and Pike River watersheds had smaller datasets, but still sufficient for a 10-year period. In contrast, the direct drainage area to Lake Michigan had relatively modest chloride sampling, and the Des Plaines River and Sauk Creek watersheds had less than 100 chloride samples for the recent dataset. The portion of the Sheboygan River watershed within the study area had no chloride samples during the recent period of record.

Figure 4.12 displays the distribution of chloride samples for the recent period of record across watersheds, with chloride concentrations presented on a log scale. Chloride concentrations vary considerably among watersheds. Many watersheds exhibit numerous outliers, indicating extreme chloride concentration values, with particularly large numbers of high outliers observed in the Kinnickinnic River, Milwaukee River, and Menomonee River watersheds. The Milwaukee River watershed also shows many low concentration outliers, suggesting frequent occurrences of very diluted chloride conditions.[31] The Rock River and Sauk Creek watersheds generally have the lowest chloride values, with median concentrations of 56 mg/l and 64 mg/l, respectively. Conversely, the Oak Creek watershed (310 mg/l), Root River watershed (180 mg/l), and direct drainage area tributary to Lake Michigan (229 mg/l) exhibit the highest median chloride concentrations. Compared to the full record (see Table 4.3 for 1961-2022), recent median concentrations have increased in every watershed. The Fox River, Oak Creek, and Des Plaines River watersheds show the most substantial percentage increases in median chloride concentrations (99, 75, and 75 percent, respectively). Consistent with the full period analysis, the mean concentration exceeds the median concentration in all watersheds during the recent period of record, indicating that higher-end outliers are skewing the average values.

There were 312 assessment reaches within the study area that had either chloride or specific conductance data collected in the recent period of 2013 through 2022. This includes 161 assessment reaches that had chloride data and 294 assessment reaches that had specific conductance data (see Map 4.7 and Map 4.8). Map 4.12 shows median chloride concentrations for stream assessment reaches during this period.[32] In reaches with balanced datasets, median chloride concentrations ranged from 13 mg/l at PK10 (Unnamed Tributary to Pike River: 0 to 1.8 miles) to 400 mg/l at MN11 (Honey Creek: 0 to 3.1 miles). Considering the entire dataset (balanced and imbalanced datasets), maximum chloride concentrations ranged from 19 mg/l at RK27 (Unnamed Tributary to Whitewater Creek) to 7,800 mg/l at KK09 (43rd Street Ditch: 0 to 1.2 miles).[33] Similar to the full period of record, the highest median and maximum chloride concentrations are generally found in Milwaukee County and eastern Waukesha County (see Map 4.12), suggesting consistently elevated chloride concentrations going back in time. Recent period chloride summary statistics for all assessment reaches can be found in their corresponding watershed sections later in the Chapter.

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[31] *It should be noted that the increased sampling frequency in these three watersheds may contribute to capturing more chloride high and low extremes.*

[32] *The circles on Map 4.12 represent assessment reaches determined to have balanced datasets and the triangles represent assessment reaches with imbalanced datasets.*

[33] *A maximum chloride concentration of 26,300 mg/l was observed at KK06 (Wilson Park Creek) but was considered an outlier.*

During the recent period of record there were 1,677 chloride samples (10.7 percent of all recent samples) that exceeded the State's chronic toxicity concentration threshold of 395 mg/l and 506 chloride samples (3.3 percent of all recent samples) that exceeded the acute toxicity threshold of 757 mg/l.[34] As described in Chapter 2 of this Report, 33 waterbodies in the study area meet the State's criterion for chloride impairment as of 2024 (see Map 2.Chloride_Impaired). Of these, 33 are impaired for chronic chloride toxicity, and 23 are impaired for both chronic and acute toxicity. These impaired streams encompass 61 of the Chloride Impact Study assessment reaches, 54 of which had chloride data collected in the recent period of record.[35] Among those 54 reaches, 43 were within streams impaired for both chronic and acute toxicity and 11 are within streams listed as impaired for chronic toxicity only as displayed on Map 4.13. It is important to consider that only 13 percent of the 3,880 miles of mapped perennial and intermittent streams in the study area had chloride data collected in the recent period, and far fewer had sufficient data to assess water quality criteria impairments.

Figure 4.13 presents a comparison of recent chloride concentrations in assessment reaches within streams that are already designated as impaired. The figure illustrates several key metrics for each assessment reach: 1) the mean chloride concentration from all samples taken in the recent period (blue bars), 2) the mean chloride concentration of only those samples that exceed the chronic toxicity threshold of 395 mg/l (red bars), and 3) number of days and the percentage of sampled days exceeding the chronic threshold. Mean values were used for this evaluation, instead of median values, as high chloride values are better reflected in the mean values and are important when comparing to the toxicity standards. The assessment reaches are listed in descending order based on the percentage of sampled days where measured chloride concentrations exceeded the chronic toxicity threshold. It is important to note that this figure provides a relative comparison of impairment levels within a subset of already impaired streams and did not determine the 303(d) listing status.

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[34] Having individual chloride concentrations exceeding the chronic and acute toxicity levels does not necessarily indicate that the stream is listed as impaired for chloride on the 303(d) list as there are other criterion that need to be met for listing.

[35] Of the 54 assessment reaches, there were five reaches that had chloride samples in the recent period of record but did not have any samples that exceeded the chronic or acute toxicity thresholds and therefore do not appear in Figure 4.13. This includes reaches MN20, MK32, MK34, and MK35 that are within streams listed for chronic and acute toxicity and reach PK05 that is listed for only chronic toxicity.

In Figure 4.13, assessment reaches represented by only a blue bar (with no corresponding red bar) indicate that every chloride sample collected in those reaches during the recent period exceeded the chronic toxicity threshold. These reaches are MN26, MN23, MN18, MN03, MK26, MK25, MK23, KK10, and FX91.[36] Overall, 16 assessment reaches have mean chloride concentrations exceeding the chronic toxicity threshold, and in 5 of those reaches the mean also exceed the acute toxicity threshold. Figure 4.13 also facilitates a comparison between frequency and severity of chloride exceedances. For instance, reaches listed higher on the figure may exhibit higher exceedance frequencies, but the difference between the mean of all samples (blue bars) and the mean of exceedances (red bars) may be less pronounced compared to some reaches lower on the list. This suggests that some reaches listed lower on Figure 4.13, while potentially having lower percentages of sampled days with exceedances, may experience more severe chloride spikes when they do occur.

An additional 26 stream assessment reaches, within streams not currently classified as chloride-impaired, have been identified as "high risk" for future impairment. This "high risk" classification was assigned to reaches with at least one recent-period chloride sample greater than 355 mg/l, which is within 10 percent of the State's chronic toxicity threshold. The locations of these high-risk reaches are shown in Map 4.14. Figure 4.14 compares these high-risk reaches using the same metrics as Figure 4.13 with the exception that this figure displays the mean concentration of those samples within 10 percent of the chronic standard as red bars. Mean values were used for this evaluation, instead of median values, as high chloride values are better reflected in the mean values and are important when comparing to the toxicity standards. In Figure 4.14, the reaches are listed in descending order based on the percentage of sampled days exceeding the 355 mg/l threshold. To note, some stream reaches have very limited recent chloride data. In total, 8 of the high-risk assessment reaches have mean chloride concentrations in the recent period of record (blue bars) exceeding the chronic toxicity threshold, and 6 of these 8 reaches also have mean concentrations exceeding the acute toxicity threshold. Comparing mean concentrations for data above 355 mg/l (red bars) helps to understand the severity of chloride concentration spikes in these reaches. Identifying high-risk stream assessment reaches can help prioritize streams for additional chloride monitoring. Furthermore, streams in close proximity to these high-risk reaches are also likely impacted by chloride pollution and could be prioritized for monitoring. Finally, winter deicing activities near these stream reaches could be reviewed to optimize chloride management and potentially reduce chloride inputs.

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[36] *It should be noted that these assessment reaches also had relatively few chloride samples collected in the recent period compared to other assessment reaches shown in Figure 4.13.*

Chloride data from the recent period of record indicates that most streams in the study area are reaching levels known to impact aquatic life. Applying the same set of ecological and toxicity thresholds discussed previously (see Table 2.Thresholds in Chapter 2 of this Report), the recent period of record reveals the following exceedance results:

- **Historical Background Concentration (10 mg/l):** 99.7 percent of all chloride samples in the recent period of record exceeded this threshold, and all assessment reaches had at least one sample exceeding it.

- **Conservative Lower Impact Concentration (35 mg/l):**[37] Nearly 94 percent of recent chloride samples exceeded this threshold, and 96 percent of all assessment reaches had at least one sample exceeding it.

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[38] Approximately 44 percent of recent chloride samples exceeded this guideline, and 65 percent of all assessment reaches had at least one sample exceeding it.

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[39] Nearly 24 percent of recent chloride samples exceeded this threshold, and 56 percent of all assessment reaches had at least one sample meeting or exceeding it.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Nearly 11 percent of recent chloride samples exceeded this threshold, and 45 percent of all assessment reaches had at least one sample surpassing it.

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[37] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[38] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[39] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** More than 3 percent of recent chloride samples exceeded this threshold, and almost 37 percent of all assessment reaches had at least one sample exceeding it.

- **Extreme Impact Threshold (1,400 mg/l):** 158 recent chloride samples (1 percent of all recent samples) exceeded this concentration, and almost 20 percent of all assessment reaches had at least one sample exceeding it.

In the absence of sufficient chloride data for some assessment reaches, general indications of chloride conditions can be made based on specific conductance levels. Map 4.15 shows median specific conductance levels for stream assessment reaches over the recent period of record.[40] For reaches with balanced datasets, median values ranged widely, from 541 µS/cm at FX29 (White River: 14.1 to 18.9 miles) to 2,700 µS/cm at KK08 (Villa Mann Creek: 0 to 1.4 miles) and MN21 (Noyes Creek: 0 to 3.0 miles). Considering all reaches (balanced and imbalanced datasets) with more than one sample, maximum specific conductance values varied from 581 µS/cm at FX36 (Honey Creek: 25.0 to 26.2 miles) to 24,900 µS/cm at DD13 (Unnamed Tributary to Lake Michigan: 0 to 0.9 miles). Map 4.15 reveals that higher median specific conductance levels were concentrated in Milwaukee County and central/eastern Waukesha County. Comparing recent data (Map 4.15) to the long-term dataset (Map 4.10) shows an increase in specific conductance, with a higher proportion of stream reaches now falling into the higher median categories (greater than 821 µS/cm). This increase is especially noticeable in northern Milwaukee County and central Waukesha County. Summary statistics for recent period specific conductance for each assessment reach can be found in the watershed sections later in the Chapter.

Land Use

Figure 4.15 shows the relationship between median chloride concentrations in stream assessment reaches with balanced datasets (2013 – 2022) and three land use categories and/or sub-categories within their subwatersheds (2015 conditions): urban land use, roads and parking lots, and agricultural land use. The graphs reveal a positive correlation between chloride concentration and both urban land use (R^2 = 0.61) and roads and parking lot coverage (R^2 = 0.60). This indicates that as the percentage of urban areas and impervious surfaces increases, so do chloride concentrations in streams of the study area, likely due to

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[40] On Map 4.15 the circles represent assessment reaches determined to have balanced specific conductance datasets and the triangles represent assessment reaches with imbalanced datasets. The process for determining balanced and imbalanced datasets is described earlier in this Chapter.

runoff from deicing activities. The slightly stronger correlation with overall urban land use, which includes roads and parking lots plus residential, commercial, and industrial land uses, suggests that deicing from other sources like sidewalks and driveways also contribute to the chloride levels in streams. Specifically, streams tend to have median chloride concentrations exceeding 50 mg/l when urban land use is above approximately 35 percent or when road and parking lot coverage exceeds roughly 8 percent. This is generally consistent with relationships between percent urban land use and chloride concentrations among the Chloride Impact Study's 41 stream monitoring sites and among lake watersheds, as described in Chapters 3 and 5 of this Report, respectively.

In contrast, Figure 4.15 shows a negative relationship between chloride concentrations and agricultural land use (R^2 = 0.45), indicating that chloride levels generally decrease as agricultural land use increases. Generally, when agricultural land use in a subwatershed exceeds 50 percent, median chloride levels in stream assessment reaches tend to be below 50 mg/. This suggests that, within the assessment reaches in the study area, agricultural sources like potash (potassium chloride) fertilizers or feedlots have a less pronounced influence on stream chloride compared to deicing salts. Table 4.6 provides statistics for these and other land use relationships. Several other land use categories also show correlations with median chloride concentrations, including residential (R^2 = 0.53),[41] high-density residential (R^2 = 0.46), commercial (R^2 = 0.50), and rural land use (R^2 = 0.61). Rural land use, being the inverse of urban land use, exhibits a negative correlation. While most of the remaining relationships are statistically significant, the strength of the linear relationships (as indicated by the R^2) are weaker.

Map 4.16 and Map 4.17 geographically support the relationships observed in Figure 4.15. Map 4.16 demonstrates a clear positive association between urban land use and recent median chloride concentrations; subwatersheds with higher percentages of urban land (red, orange, and yellow areas) generally correspond to stream reaches with higher chloride levels, while subwatersheds with lower urban land use (green colors) generally have lower chloride concentrations. There are some exceptions to this general pattern in the middle portion of the Milwaukee River watershed in Washington County where several imbalanced assessment reaches have elevated median values while residing in relatively low urban subwatersheds. However, these assessment reaches (MK50, MK52, MK55, and MK84) have very few chloride samples and all were collected in winter.

[41] *The residential land use group includes a combination of lower-, medium-, and high-density residential sub-categories.*

Similarly, Map 4.17 shows a general trend of increasing recent median chloride concentrations with increasing percentages of roads and parking lots. Subwatersheds with higher percentage of roads and parking lots (oranges and browns) tend to have assessment reaches with higher median chloride levels. Conversely, subwatersheds with less road and parking lot coverage (below 10 percent as indicated by peach, yellow, and white) generally contain reaches with lower chloride concentrations, mostly below 100 mg/l. As with Map 4.16, there are the same outlier reaches in Washington County that exhibit high median chloride but have limited sampling that was all conducted in winter. Nonetheless, these results are generally consistent with relationships between percent roads and parking lots and chloride concentrations among the Chloride Impact Study's 41 stream monitoring sites and among lake watersheds, as described in Chapters 3 and 5 of this Report, respectively.

Temporal Trends

Map 4.18 shows statistically significant trends in chloride and specific conductance for balanced stream assessment reaches over the recent period of 2013 through 2022. Compared to the full period of record, fewer reaches showed statistically significant trends in the recent period. Only one assessment reach showed a statistically significant increase in chloride (indicated by the red "up" arrow) and 14 reaches indicated an increase in specific conductance (indicated by the orange "up" arrows). Conversely, 11 reaches showed a decrease in chloride (indicated by the dark green "down" arrow) and 10 showed a decrease in specific conductance (indicated by the light green "down arrow"). Because seven assessment reaches had decreasing trends in both chloride and specific conductance, only the chloride trends are displayed on Map 4.18. Table 4.7 provides trend slopes (mg/l/year), sampling span, and coefficient of determination (R^2) values for chloride trends. While all trends in Table 4.7 are statistically significant (P-values <0.01) most have low R^2 values, indicating substantial variation around the trend line due to other factors that could include seasonal variation, precipitation patterns, changes in land use, variations in stream flow, or influence of historically high Lake Michigan water levels.

Seasonal Trends

Figure 4.16 illustrates the distribution of chloride concentrations (on a log scale) by month for all chloride samples collected in the recent period of record. Box plots represent the monthly distributions, and the number in parentheses above each month indicates sample size. February exhibits the highest chloride concentrations and greatest variability (median: of 272 mg/l, mean: 616 mg/l), followed by March (median: 226 mg/l, mean: 352 mg/l), and January (median: 180 mg/l, mean: 514). The monthly patterns in the recent period generally resemble those observed in the full period of record (see Figure 4.9) with less outliers. Chloride concentrations generally decrease from March through August, reaching a low in August (median

84 mg/l, mean: 121 mg/l), and then increase from September through January. In all months, the mean chloride concentration exceeds the median, most notably in January and February, where the mean is 2.9 and 2.3 times greater than the median, respectively. This suggests that infrequent high chloride spikes, likely due to winter deicing, strongly influence the mean concentrations during these months. Figure 4.16 also shows that chloride concentrations exceeded both the State's chronic (orange dotted line) and acute (red dotted line) toxicity thresholds throughout the year, and were often significantly surpassing levels known to harm aquatic life (33 to 250 mg/l) in every month.[42] From January through March, the 75th percentile of all recent chloride concentrations were above the State's chronic toxicity threshold, indicating frequent exceedances in those months. Notably, March also shows several low-end outliers, suggesting an infrequent dilution effect, possibly from snowmelt or rain.

Seasonal patterns are also evident in the frequency of chronic toxicity threshold exceedances during the recent period, as shown in Figure 4.17. The highest percentages of threshold exceedances occurred during the winter and early spring months, highlighting the significant impact of winter deicing practices and snow melt on stream chloride levels in the study area. February had the highest exceedance frequency (39 percent of samples), followed by January (32 percent), March (30 percent), and April (14 percent). In contrast, exceedances dropped sharply from May (10 percent) to a low in October (1.2 percent), before increasing again in November and December. Despite lower exceedance rates in summer and fall, 345 exceedances of the chronic threshold still occurred from June through November in the recent period. This indicates that harmful chloride concentrations can occur in the study area streams even outside of winter. Potential contributing factors to higher chloride levels in warmer months include runoff from agricultural fertilizers, leaching of residual deicing salts from soil, and baseflow contributions from chloride-polluted shallow groundwater aquifers. Compared to the full period of record (see Figure 4.10), the recent period shows an increase in chronic threshold exceedances. This suggests a potential worsening of chloride conditions in the study area streams in the recent period. However, it is important to note that increased sampling focused on high-chloride conditions may have occurred in recent years due to greater awareness of chloride pollution and its impacts (see percentages of winter chloride sampling in Figure 4.2).

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

4.5 CHLORIDE CONDITIONS AND TRENDS WITHIN THE MAJOR WATERSHEDS

Des Plaines River Watershed

The Des Plaines River watershed, located in the southeastern portion of the study area in Kenosha and Racine Counties, is mostly rural (81 percent), consisting primarily of agricultural lands (55 percent). Interstate Highway 94 (IH 94) transects about 14 miles of the watershed from north to south (see Map A.1). Currently, there are two active WWTPs that discharge treated wastewater within the watershed; three others that once operated in the watershed have been abandoned (see Map A.2).

Chloride conditions and trends in the Des Plaines River watershed were evaluated across 12 assessment reaches (see Map 4.19 and Table 4.8). This analysis utilized 404 chloride measurements and 289 specific conductance measurements collected at 17 monitoring stations between 1961 and 2021 (see Map 4.20).[43, 44] The watershed had a limited water quality dataset and availability of water quality data varied among the 12 assessment reaches (see Table 4.8). The number of chloride samples per assessment reach ranged from zero to 183. For assessment reaches with limited or no chloride data, specific conductance measurements can serve as a general indicator of chloride conditions and trends, however, specific conductance measurements were also limited for this watershed. The number of specific conductance measurements per reach ranged from 2 to 88.

Historical Conditions and Trends (1961 Through 2022)

The robustness and balance of chloride and specific conductance datasets for each assessment reach over the full period of record were evaluated based on the criteria described earlier in this Chapter, including the need for relatively even seasonal data collection. Table 4.9 shows the seasonal distribution of chloride and specific conductance samples for each reach in the watershed. Only one assessment reach, DP01 (Des Plaines River: 110.6 to 111.9 miles), met the criteria to be considered a balanced dataset for chloride. Of the remaining assessment reaches in the watershed, four had no chloride data (DP03, DP04, DP11, and DP12) and seven had chloride datasets that were considered imbalanced (DP02, DP05, DP06, DP07, DP08, DP09, and DP10) because of small datasets, short record length, and/or insufficient winter sampling. Reaches with imbalanced chloride or specific conductance datasets are highlighted in red text in Table 4.9 and other

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[43] *Although data for this watershed was collected from 1961-2021, in this Chapter, the full period of record is consistently referred to as 1961-2022, and the recent period of record as 2013-2022, for comparability across all watersheds.*

[44] *There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.*

tables in this analysis. Imbalanced datasets are less likely to accurately represent conditions in those assessment reaches and may not be comparable to other reaches.

Table 4.10 presents summary statistics (number of samples, minimum, mean, median, and maximum) for chloride and specific conductance in each Des Plaines River watershed assessment reach. Map 4.21 displays the median chloride concentrations across all reaches with chloride data. Des Plaines River mainstem reach DP01, the only reach with a balanced dataset (indicated by a black circle), had a relatively low median chloride concentration of 60 mg/l. Maximum chloride concentrations varied significantly across all reaches (balanced and imbalanced), ranging from 38 mg/l at DP10 (Brighton Creek: 0 to 2.9 mg/l) to 1,650 mg/l at DP02 (Des Plaines River 115.2 to 116.6 miles). It is important to note that five reaches lacked winter chloride samples (see Table 4.9). Since chloride levels are typically highest in winter, the reported median and maximum concentrations for these reaches are likely underestimated.

Map 4.22 illustrates median specific conductance within the Des Plaines River watershed assessment reaches over the full period of record. These conditions generally mirrored median chloride conditions, with high conductance corresponding to high chloride. Similar to the chloride dataset, only Des Plaines River reach DP01 had a balanced specific conductance dataset for the full period, showing a median value of 899 µS/cm (see Table 4.10). Across all assessment reaches (balanced and imbalanced), maximum specific conductance ranged from 865 µS/cm at DP 09 (Center Creek: 1.0 to 3.5 miles) to 5,645 µS/cm at DP08 (Kilbourn Road Ditch: 7.3 to 11.4 miles). While lacking chloride data, Des Plaines River reaches DP03 (992 µS/cm) and DP04 (1,220 µS/cm), Brighton Creek reach DP11 (966 µS/cm), and Unnamed Tributary to Brighton Creek DP12 (1,120 µS/cm) had slightly elevated maximum specific conductance measurements, suggesting dissolved salts, including chloride, are present in moderate concentrations. However, all four of these reaches had small, imbalanced specific conductance datasets, missing winter samples which would likely further increase the conductance measurement.

Table 4.11 presents the percentage of chloride samples exceeding the various water quality and biological thresholds established in Chapter 2 of this Report for each assessment reach in the watershed for the full period of record (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:[45]

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[45] All assessment reaches, with the exception of DP01, had imbalanced chloride datasets for the full period of record. Five reaches (DP05, DP06, DP07, DP09, DP10) had no chloride data collected during winter which likely reduced the number of observed exceedances for many of these thresholds.

- **Historical Background Concentration (10 mg/l):** 96 percent of all chloride samples in the watershed exceeded this threshold. The threshold was exceeded by 100 percent of samples collected in all assessment reaches, with the following exceptions – Des Plaines River reaches DP02 (97.8 percent of samples) and DP05 (98.4 percent), and Brighton Creek reach DP10 (60.7 percent).

- **Conservative Lower Impact Concentration (35 mg/l):**[46] Almost 66 percent of all chloride samples in the watershed exceeded this threshold, and most reaches had a significant portion of samples exceeding it, with exceedances ranging from 7 percent at DP10 to 100 percent at DP06 and DP07. Notably, Des Plaines River reach DP01, the only reach in the watershed with a balanced dataset, exceeded this threshold in over 84 percent of its samples.

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[47] About 10 percent of all chloride samples in the watershed exceeded this guideline concentration, and all reaches had at least one sample exceed this it except for DP06, DP09, and DP10. These three exceptions, however, had small datasets and no winter data. In Des Plaines River reach DP01, the only reach in the watershed with a balanced dataset, 9 percent of the samples exceeded this concentration.

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[48] Almost 6 percent of samples collected in the watershed exceeded this threshold. At least one sample in six of the reaches with chloride data exceeded this toxicity threshold; the exceptions included reaches DP06, DP07, DP09, and DP10, though these had limited data and no winter data. Notably, Des Plaines River reach DP01, the only reach with a balanced dataset, exceeded this threshold in almost 7 percent of samples. Even more concerning, Des Plaines River reach DP05, despite lacking winter samples, showed nearly 13 percent

[46] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[47] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[48] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

of its samples exceeding the threshold. This suggests elevated chloride conditions are present even in non-deicing months in reach DP05.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Approximately 2.5 percent of all samples collected in the watershed exceeded this threshold. Three of the eight reaches in the watershed that had chloride data collected had at least one sample exceeding it. Exceedances ranged from 0 (DP05, DP06, DP07, DP09, DP10) to 21 percent (Kilbourn Road Ditch reach DP08). Des Plaines River reach DP02 had one sample exceeding this threshold.[49] The only reach in the watershed with a balanced dataset (DP01) exceeded this threshold in less than 3 percent of samples.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** About 1.2 percent of all chloride samples in the watershed exceed the acute toxicity threshold. The exceedances of this concentration occurred at two assessment reaches; DP02 had one sample exceeding and DP08 had four samples (12 percent) exceeding.[50]

- **Extreme Impact Level Concentration (1,400 mg/l):** Two chloride samples exceeded this concentration with in the watershed during the full period of record; one sample at DP02 and one sample at DP08.

Figure 4.18 displays the distribution of the 404 chloride samples collected in the Des Plaines River watershed from 1961 through 2022, categorized by various water quality and biological impact thresholds. Only a small fraction of samples, 3.7 percent, fell at or below the chloride concentration considered to be the historical background in surface waters in southeastern Wisconsin. The vast majority of samples indicated potential harm to aquatic life, with 30.7 percent falling into the 10-35 mg/l range where the onset of biological effects is observed, and an even larger 55.4 percent in the 35-120 mg/l range associated with considerable biological impacts (see Table 2.Thresholds in Chapter 2 of this Report).[51] Notably, almost 94 percent of chloride samples collected in the watershed exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State.

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[49] *DP02 and DP08 have imbalanced datasets because they did not have samples collected over a span of at least 15 years.*

[50] Ibid.

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

The Des Plaines River watershed contributed to less than one percent of both the observed exceedances of the State's chronic and acute chloride toxicity thresholds across full period of record for the broader Chloride Impact Study area.[52] Over the full period of record, 10 chloride samples (2.5 percent of the samples collected in the watershed) exceeded the State's chronic toxicity threshold of 395 mg/l, and 5 samples (1.2 percent of watershed samples) exceeded the acute toxicity threshold of 757 mg/l. Its worth noting that one of these exceedances–also the highest chloride concentration recorded in the watershed – was collected in 1976, predating the WDNR's establishment of chloride toxicity standards in 2010.

Temporal Trends

The top series of box plots in Figure 4.19 illustrates the distribution of chloride concentrations (log scale) for all samples collected across three time periods for mainstem Des Plaines River reaches: DP05 (upstream), DP02, and DP01 (downstream). For DP01, the only reach with a balanced dataset and data across multiple time periods, chloride concentrations show a general increase over time. The median concentration rose from 55 mg/l (1961-1977) to 77 mg/l (1994-2012), with a slight further increase to 83 mg/l in the most recent period (2013-2022). While the first two periods for DP01 exhibited modest variation, the recent period showed greater variability, with chloride concentrations ranging from 24 mg/l to 517 mg/l. The other two Des Plaines River reaches, DP05 and DP02, were only sampled in the earliest period (1961-1977). Their median concentrations were 45 mg/l (DP05) and 41 mg/l (DP02). Notably, DP02 had the greatest variation in chloride concentration among all Des Plaines river assessment reaches and time periods, ranging from 7 mg/l to a peak of 1,650 mg/l during 1961-1977.

The bottom series of box plots in Figure 4.19 presents chloride concentrations (log scale) for two assessment reaches of the Kilbourn Road Ditch, a major tributary to the Des Plaines River: DP08 (upstream) and DP07 (downstream). It is important to note that data availability for these reaches is limited and both have imbalanced datasets. In addition, the available data for these reaches occurs in non-overlapping time periods, with DP08 only having chloride samples in the 2013-2022 period, and DP07 having samples exclusively from the 1994-2012 period. This lack of concurrent data prevents direct temporal or spatial comparisons between these two reaches; however, some general observations can be made. Assessment reaches in the Kilbourn Road Ditch, in their respective time periods, show moderately elevated chloride concentrations. For instance, DP08 (2013-2022) exhibits a median chloride concentration of 73 mg/l with a range from 18 mg/l to a peak of 1,470 mg/l. Downstream reach DP07 (1994-2012) shows a higher median

[52] *It should be noted that this watershed had a fairly small chloride dataset over the full period of record when compared to most of the other watersheds in the study area (see Table 4.3).*

of 90 mg/l, but a much smaller variation of concentrations, ranging from 61 mg/l to 208 mg/l. The observed differences between DP07 and DP08 are likely influenced by the distinct characteristics of their datasets. The higher median chloride concentration at DP07 is notable, especially since its dataset lacks any winter samples, a season typically associated with peak chloride levels due to road salt application. In contrast, 42 percent of the dataset for DP08 consisted of winter samples, which likely contribute to its wider concentration range, including higher maximums (see Table 4.9). Furthermore, the markedly smaller variation in concentrations at DP07 is probably a direct result of its very limited dataset, comprised of only seven samples. This small sample size and lack of winter samples inherently restricts the range of chloride concentrations compared to a more extensive dataset.

Only Des Plaines River reach DP01 had sufficient data during the full period of record (1961 through 2022) to analyze for long-term chloride trends. This analysis revealed a statistically significant increase in chloride concentration of 1.4 mg/l per year for DP01, indicated by the red "up" arrow on Map 4.23 (also see Table 4.4). No Des Plaines River watershed assessment reaches had balanced specific conductance datasets for similar trend assessments for conductance.

Seasonal Trends

Figure 4.20 illustrates seasonal chloride concentration patterns at Des Plaines River reach DP01. Winter exhibits the highest median chloride concentration of 95 mg/l, which is over 1.6 times higher than the next closest season, summer (59 mg/l). Winter also showed the largest range in chloride concentrations (50 to 517 mg/l). While the watershed is primarily agricultural, the IH 94 corridor runs north/south through its length, with runoff from deicing operations along the interstate and adjacent business parking lots ultimately draining to this downstream reach. This likely explains the concentrations fluctuating in the winter, from high spikes due to the deicing to dilution during snowmelt or rain events. In contrast, summer, spring (59 mg/l), and fall (54 mg/l) had very similar and lower median chloride concentrations, with summer displaying the smallest range of concentrations.

Figure 4.21 demonstrates a clear seasonal pattern in chronic toxicity threshold (395 mg/l) exceedances throughout the watershed for the full dataset (1961 through 2022) with all exceedances occurring in the winter months. This strongly suggests that winter deicing significantly impacts chloride levels, even in this predominantly rural watershed.

February recorded the highest frequency of exceedances (nearly 13 percent of all samples collected in the month), followed by January (5.6 percent) and December (5.3 percent). No exceedances were observed in any other month throughout the entire record. This indicates that despite potentially higher potassium chloride fertilizer applications in this watershed compared to more urban watersheds, winter deicing remains the primary driver of elevated chloride in Des Plaines River watershed streams.

Recent Conditions (2013 Through 2022)

For the recent period of record, the Des Plaines River watershed had a very limited chloride dataset of just 63 chloride samples from only two assessment reaches: Des Plaines River reach DP01 and Kilbourn Road Ditch reach DP08. In fact, the recent chloride and specific conductance dataset for all the Des Plaines River watershed assessment reaches spanned only from October 2018 to February 2021.[53] Nevertheless, both reaches met the criteria for balanced chloride and specific conductance datasets for the recent period.[54] Two additional reaches, Des Plaines River reach DP05 and Brighton Creek reach DP11, that didn't have chloride data, each had only one specific conductance sample.

Table 4.12 presents detailed summary statistics (number of samples, minimum, maximum, mean, and median) for recent chloride and specific conductance measurements in these assessment reaches. As shown in Table 4.12 and Map 4.25, both DP01 and DP08 had recent median chloride concentrations below 100 mg/l, (DP08 at 73 mg/l; DP01 at 83 mg/l). However, the maximum chloride concentration at DP08 (1,470 mg/l) was significantly higher than the maximum observed at DP01 (517 mg/l). The Kilbourn Road Ditch reach (DP08) runs alongside IH 94 for its entire length, suggesting that winter deicing runoff from the interstate and nearby impervious surfaces likely contribute to these elevated chloride levels. The recent median concentration for DP01, the only reach in the watershed that had balanced datasets for both the full and the recent period of record, increased by 38 percent from the full historical period. However, it is important to consider that the full dataset median was calculated from a larger dataset than the recent median.

Map 4.25 displays median specific conductance for Des Plaines River watershed assessment reaches during the recent period of record. Reaches with balanced specific conductance datasets (DP01 and DP08) are marked with black circles on the map. Similar to chloride concentrations, Des Plaines River reach DP01 had

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[53] Although recent data for this watershed only spanned from October 2018 to February 2021, in this Chapter, the recent period of record is consistently referred to as 2013-2022 for comparability across all watersheds.

[54] Criteria for a balanced dataset for the recent period of record includes: more than 10 total samples, at least 10 percent or 4 samples collected in the winter season (December through February), and at least 20 percent of samples collected in either summer or fall.

a slightly higher median specific conductance (756 μS/cm) than Kilbourn Road Ditch reach DP08 (685 μS/cm). However, DP08 again showed a significantly higher maximum conductance measurement, 2.4 times that of DP01, reinforcing the idea that higher conductance levels occur in the stream adjacent to the interstate. Two other reaches, DP05 and DP10, which lacked chloride data, exhibited slightly elevated specific conductance levels (874 and 966 μS/cm, respectively), but these were based on only one measurement each.

Table 4.13 presents the percentage of recent period chloride samples exceeding the various water quality and biological thresholds established in Chapter 2 of this Report for each assessment reach in the Des Plaines River watershed (see Table 2.Thresholds). Examining the two assessment reaches with recent-period chloride datasets revealed the following:

- **Historical Background Concentration (10 mg/l):** Exceeded by 100 percent of recent samples in both DP01 and DP08 assessment reaches.
- **Conservative Lower Impact Concentration (35 mg/l):**[55] More than 84 percent of all recent chloride samples in the watershed exceeded this threshold, including 87 percent of recent samples at DP01 and nearly 82 percent at DP08.
- **Canadian Chronic Toxicity Threshold (120 mg/l):**[56] Exceeded by nearly 32 percent of all recent chloride samples in the watershed, including 23 percent at DP01 and 39 percent at DP08.
- **USEPA Chronic Toxicity Threshold (230 mg/l):**[57] Exceeded by 22 percent of all recent samples in the watershed, including nearly 17 percent of samples at DP01 and 27 percent of samples at DP08.

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[55] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal es of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l).*

[56] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[57] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Exceeded by 14 percent of recent chloride samples in the watershed, including nearly 7 percent of samples at DP01 and 21 percent of samples at DP08.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** Exceeded by 4 recent chloride samples in the watershed (6.3 percent) all of which occurred at reach DP08, accounting for about 12 percent of recent samples at that assessment reach.[58]

- **Extreme Impact Level Concentration (1,400 mg/l):** Exceeded by one recent chloride sample in the watershed at reach DP08.

Figure 4.22 displays the distribution of the 63 chloride samples collected in the Des Plaines River watershed from the recent period of record, categorized by various water quality and biological impact thresholds. There were no samples collected that fell at or below the chloride concentration considered to be the historical background in surface waters in southeastern Wisconsin, down from 3.7 percent of samples for the full period of record (see Figure 4.18). The vast majority of samples from the recent record indicated potential harm to aquatic life, with nearly 16 percent falling into the 10-35 mg/l range where the onset of biological effects is observed, and an even larger 52.4 percent in the 35-120 mg/l range associated with considerable biological impacts (see Table 2.Thresholds in Chapter 2 of this Report).[59] Notably, almost 86 percent of chloride samples collected in the watershed for the recent period of record exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State.

The Des Plaines River watershed accounted for less than one percent of the recent chronic and 1.8 percent of acute chloride threshold exceedances within the broader Chloride Impact Study area. This watershed, however, had a relatively small chloride dataset over the recent period compared to most others in the study area. Despite the limited data, a notable 14.3 percent of recent chloride samples (9 samples) in the watershed surpassed the State’s chronic toxicity threshold of 395 mg/l. Additionally, 6.4 percent of recent samples (4 samples) in the watershed exceeded the acute toxicity threshold of 757 mg/l.

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[58] Ibid.

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

As of 2024, one stream in the Des Plaines River watershed was listed as chloride-impaired under Section 303(d) of the Clean Water Act. As shown on Map 4.26, the entire length of Kilbourn Road Ditch (0 to 14.3 miles) was listed for chronic chloride toxicity. This impairment encompasses two of the twelve assessment reaches analyzed in this watershed (DP08 and DP07). While reach DP07 did not have chloride data collected during the recent period, DP08 had a maximum observed chloride concentration of 1,470 mg/l collected in February 2021. Des Plaines River assessment reach DP01 also had two observed chloride concentrations above the chronic toxicity threshold during the recent period of record, but is not on the 303(d) list, likely due to a limited dataset. This assessment reach is identified as a "high risk" stream reach on Map 4.26 and on Figure 4.14 in Section 4.4 of this Chapter.[60]

Land Use

Map 4.27 and Map 4.28 illustrate that assessment reaches DP01 and DP08 are in predominantly rural areas with low urban development and road and parking lot densities. These land use characteristics likely contribute to their relatively moderate recent median chloride concentrations of 83 mg/l at DP01 and 73 mg/l at DP08.

However, the maximum chloride concentrations at these reaches (517 mg/l at DP01 and 1,470 mg/l at DP08), as shown in Map 4.29 and Map 4.30, appear to conflict with their rural setting. This suggests that even relatively rural streams can experience severe chloride peaks. The presence of the IH 94 corridor, running north-south across the length of the watershed and relatively close to both reaches (especially DP08), likely explain these extreme peaks. During winter deicing events, intense chloride-loaded runoff from the interstate highway can cause these localized elevated conditions, despite the overall rural land use.[61]

Temporal Trends

Figure 4.23 displays recent chloride concentrations at two assessment reaches in the watershed: Des Plaines River reach DP01 and Kilbourn Road Ditch reach DP08. These are the only two reaches in the watershed

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[60] For this Report, assessment reaches that were not listed as impaired were considered high risk for impairment if they had a chloride sample within 10 percent of the State's chronic toxicity threshold, or 355 mg/l.

[61] For the Chloride Impact Study, SEWRPC's chloride and specific conductance data collection efforts included monitoring sites at both the DP01 and DP08 reaches. Staff specifically targeted sampling during and immediately after winter storm events to capture peak chloride conditions, which resulted in the collection of the maximum chloride measurements at both DP01 and DP08. At Kilbourn Road Ditch monitoring site reach DP08, it was observed that a drainage ditch, flowing from the west and carrying runoff from the interstate, emptied into the stream directly upstream of the collection point, likely contributing to the peak chloride conditions in DP08.

that have balanced recent datasets. All chloride data for these streams, collected by SEWRPC staff for the Chloride Impact Study, spans less than three years. While no statistically significant chloride trend was found at either site, several observations can be made:

- Kilborn Road Ditch (DP08), a second-order stream, showed more elevated chloride conditions than the larger, fourth-order Des Plaines River mainstem (DP01). Both have exceeded the chronic chloride toxicity threshold (395 mg/l), and the Kilbourn Road Ditch reach has also exceeded the acute toxicity threshold (795 mg/l).

- Seasonal patterns are evident across both assessment reaches, with higher chloride concentrations in the winter months and peak concentrations leading to toxicity threshold exceedances. In 2021, Commission staff specifically targeted sampling during and immediately after winter storm events to capture these peak conditions, which assisted with the development of the chloride-specific conductance regression analysis.[62] Consequently, the extreme chloride concentrations observed in February 2021 likely overrepresent the typical frequency of peak conditions in these streams.

- Further monitoring is needed to accurately assess recent chloride trends in the watershed.

Seasonal Trends

Figure 4.24 demonstrates a clear seasonal pattern of exceedances of Wisconsin's chronic toxicity threshold (395 mg/l) in the watershed, with all exceedances occurring in the winter months. This again strongly suggests that winter deicing significantly impacts chloride levels, even in this predominantly rural watershed.

February had the highest frequency of exceedances, with 50 percent of samples collected that month surpassing the threshold. January also observed chronic threshold exceedances in 20 percent of samples. No exceedances were recorded in any other month during the recent period. Again, it should be noted that Commission staff specifically targeted sampling during and immediately after winter storm events to capture peak chloride conditions. Because of this, frequency of exceedance during these months is likely overrepresented. Nonetheless, the measurements indicate that winter deicing is the primary driver of elevated chloride in the streams of the watershed, despite potentially higher potassium chloride fertilizer applications compared to more urban watersheds.

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

Other Factors Potentially Influencing Instream Chloride Conditions

The Des Plaines River watershed contains two active wastewater treatment plants (WWTPs) that discharge treated wastewater within the watershed (see Map A.2). These facilities are not designed to remove chloride ions, meaning any chloride entering these facilities will remain in the treated wastewater and will be discharged into adjacent waterways.

The Village of Paddock Lake WWTP served roughly 3,000 people (as of 2010) and had an estimated average effluent flow of 0.53 million gallons per day during the Chloride Impact Study period.[63,64] The facility discharges into an unnamed tributary that flows to Brighton Creek downstream of assessment reach DP11 and upstream of reach DP10. Due to a lack of recent-period chloride data on the receiving stream, the impact of this WWTP on instream chloride levels could not be assessed.

The Village of Bristol WWTP served approximately 1,780 people (as of 2010) with an estimated average effluent flow of 0.57 MGD during the Chloride Impact Study period. The facility discharges into an unnamed tributary that joins the Des Plaines River just downstream of assessment reach DP05 and approximately 1.8 stream miles upstream of DP04. Similar to the Paddock Lake facility, a lack of recent chloride data for these assessment reaches prevented an evaluation of the WWTP's impact on chloride conditions.

For more information on active and abandoned wastewater treatment facilities in the study area, see Table 2.2 in Chapter 2 of this Report.

Fox River Watershed

The Fox River watershed, spanning 938 square miles in the central and southwestern parts of the study area, is predominantly rural (74.3 percent), with agricultural uses covering 39 percent of the land. Despite the rural nature, urbanized areas exist, particularly in the northern sections of the watershed within the Cities of New Berlin, Brookfield, Pewaukee, and Waukesha. Major interstate highways, IH 43 (30 miles) and IH94 (14 miles), also traverse the watershed. Currently, 14 active WWTPs discharge treated wastewater within the watershed. Additionally, seven WWTPs previously operated in the area but are now abandoned (see Table 2.2 for facility information including receiving waters). More details about the watershed characteristics can be found in Chapter 2 of this Report and Maps A.3 and A.4.

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[63] *The Chloride Impact Study period was from October 2018 through October 2020.*

[64] *Also see SEWRPC Technical Report No. 65,* Mass Balance Analysis for Chloride in Southeastern Wisconsin, *in preparation.*

Despite its size and extensive stream network, the Fox River watershed had a fairly limited chloride dataset. Chloride conditions and trends were evaluated across 102 stream assessment reaches (see Map 4.31 and Table 4.14). This analysis incorporated 2,558 chloride measurements and 5,965 specific conductance measurements, collected at 247 monitoring stations from 1961 through 2022 (see Map 4.32).[65,66] The number of chloride samples varied significantly per assessment reach, ranging from zero to 271 for the full period of record. For assessment reaches with limited or no chloride data, specific conductance measurements can serve as a general indicator of chloride conditions and trends. The number of specific conductance measurements per reach ranged from zero to 652 for the full period of record.

Historical Conditions and Trends (1961 Through 2022)

The robustness and balance of chloride and specific conductance datasets for each assessment were evaluated over the full period of record, using the previously outlined criteria (see "Assessing Robustness and Balance of Assessment Reach Datasets" section). A balanced dataset required relatively even data collection across all seasons. Table 4.15 details the seasonal distribution of chloride and specific conductance samples for each reach in the watershed.

A total of 13 assessment reaches in the Fox River watershed met the criteria for balanced chloride datasets, and 18 reaches had balanced specific conductance datasets. Imbalanced datasets, highlighted in red text in Table 4.15 and other tables in this analysis, are less likely to accurately reflect actual conditions and may hinder comparisons to other reaches.

Table 4.16 summarizes the chloride and specific conductance data (number of samples, minimum, mean, median, and maximum) for each assessment reach in the Fox River watershed. Map 4.33 displays median chloride concentrations across all reaches with available chloride data. Median chloride concentrations for reaches with balanced chloride datasets (indicated by black circles on Map 4.33) ranged from 14 mg/l at Mukwonago River reaches FX67 and FX71 to an elevated concentration of 150 mg/l at Fox River mainstem reach FX09. While some balanced Fox River mainstem assessment reaches had elevated median chloride levels, all remained well below the USEPA Chronic Toxicity Threshold of 230 mg/l. Most major tributaries to

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[65] There were occasionally multiple specific conductance samples reported at the same time and location as a single chloride sample. To match these multiple specific conductance samples with one chloride sample, the mean of the multiple specific conductance samples was used.

[66] Some of these monitoring stations may be at the same or similar locations but data was collected by a different agency, typically at different times.

the Fox River with balanced datasets had relatively low median chloride concentrations, with FX87 (Pewaukee River: 0 to 6.3 miles) exhibiting the highest median at 66 mg/l (see Map 4.33 and Table 4.16). Across all assessment reaches (balanced and imbalanced), maximum chloride concentrations varied significantly, from 9 mg/l at FX72 (Pickeral Lake Outlet) – below the historical baseline concentration – to a very high 2,112 mg/l at FX82 (Pebble Creek: 0 to 3.3 miles).

Map 4.34 shows median specific conductance across the Fox River watershed assessment reaches for the full period of record. Generally, median specific conductance mirrored median chloride levels, with high conductance streams corresponding to high chloride streams.[67] For reaches with balanced datasets (marked by black circles on Map 4.34), median specific conductance ranged from 505 μS/cm at Mukwonago River reach FX67 to 1,100 μS/cm at Fox River mainstem reaches FX09 and FX11. These are the same reaches that showed the lowest and highest chloride concentrations (see Table 4.16). Across all assessment reaches (balanced and imbalanced), maximum specific conductance measurements varied significantly, from 297 μS/cm at FX102 (an unnamed tributary to Lauderdale Lakes) to 11,750 μS/cm at FX96 (Sussex Creek). It is important to note that 44 assessment reaches in the watershed lacked chloride data but had specific conductance data; however, most of these reaches had a very limited number of measurements and all had imbalanced specific conductance datasets.

Table 4.17 presents the percentage of chloride samples exceeding the various water quality and biological thresholds established in Chapter 2 of this Report for each assessment reach in the Fox River watershed for the full period of record (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:[68]

- **Historical Background Concentration (10 mg/l):** Almost 96 percent of all chloride samples in the watershed exceeded this level. All assessment reaches, except Pickeral Lake Outlet reach FX72, had at least 68 percent of samples exceeding this concentration.

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[67] An exception to this pattern was observed at FX82 (Pebble Creek: 0 to 3.3 miles) that exhibited an elevated median chloride concentration of 1,099 mg/l but a relatively moderate specific conductance measurement of 807 μS/cm. However the chloride dataset at this reach consisted of only two samples.

[68] There were 45 assessment reaches in the Fox River watershed that had imbalanced chloride datasets that may not fairly represent chloride conditions due to a small sample size or uneven sampling throughout the years or throughout all seasons.

- **Conservative Lower Impact Concentration (35 mg/l):**[69] Nearly 65 percent of all watershed samples surpassed this threshold. All but four reaches (FX30, FX39, FX71, and FX72) had at least one exceedance. For reaches with balanced datasets, exceedance rates ranged from zero to 97.6 percent of samples.

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[70] Approximately 19 percent of all watershed samples exceeded this guideline, with 48 percent of assessment reaches recording at least one exceedance. For reaches with balanced datasets, exceedance rates varied from 0 percent (at six reaches) to 61 percent (at Fox River reach FX09).

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[71] Approximately 5.6 percent of all watershed samples exceeded this threshold. For reaches with balanced datasets, exceedance rates ranged from zero percent (at seven reaches) to almost 30 percent (at Fox River reach FX12).

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Fewer than 1 percent of all watershed samples (25 samples) surpassed this threshold, with only 8 reaches showing at least one exceedance. For balanced reaches, exceedance rates ranged from zero percent (at ten reaches) to 3.9 percent of samples (FX12).

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** Only 3 chloride samples (approximately 0.1 percent of all samples) in the watershed exceeded this acute toxicity threshold. Exceedances occurred at Genessee Creek (FX79), Pebble Creek (FX82), and Pewaukee River (FX88).

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[69] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[70] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[71] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

- **Extreme Impact Level Concentration (1,400 mg/l):** Only 2 chloride samples collected in the watershed exceeded this concentration, observed at reaches FX79 and FX82.

Figure 4.25 presents the distribution of the 2,558 chloride samples collected within the Fox River watershed during the full period of record, categorized by various water quality and biological impact thresholds. (see Table 2.Thresholds in Chapter 2 of this Report).[72] While 4.3 percent of samples were at or below the historical background concentration of 10 mg/l (a higher proportion than in most watersheds), most of the samples still indicated potential harm to aquatic life. Specifically, 31 percent were in the 10-35 mg/l range, where biological effects begin, and the largest proportion, 45.8 percent, fell into the 35-120 mg/l range associated with considerable biological impacts. Overall, 94.7 percent of samples collected in the watershed exceeded thresholds for biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, yet remained below the threshold for potential regulatory action in the State. This is concerning, as a large percentage of samples may be causing biological harm, though the watershed has a smaller proportion of samples (less than 1 percent) at or above the State's chronic toxicity threshold.

Although the Fox River watershed contributed 5.4 percent of the total chloride samples in the study area during the full period of record, it accounted for a disproportionately lower percentage of exceedances: approximately 0.8 percent of chronic and 0.3 percent of acute chloride threshold exceedances across the study area. Within the Fox River watershed itself, only 25 chloride samples (slightly under 1 percent) surpassed Wisconsin's chronic toxicity threshold of 395 mg/l, and three samples (about 0.1 percent) exceeded the acute toxicity threshold of 757 mg/l.

Temporal Trends

The distribution of chloride concentrations (on a log scale) across the 17 assessment reaches of the Fox River mainstem from 1961 through 2022 is shown in Figure 4.26. Data were analyzed over five distinct periods: 1961-1977, 1978-1986, 1987-1993, 1994-2012, and 2013-2022. Overall, chloride levels consistently increased over time in all mainstem reaches with multi-period data. Median chloride concentrations in balanced datasets significantly rose from the earliest (1961-1977) to the most recent (2013-2022) period. Notably, percentage increases included FX16 (1,812 percent), FX12 (166 percent), FX11 (96 percent), FX09 (190 percent), FX07 (152 percent), and FX02 (217 percent). However, the extreme increase at FX16 is likely skewed because the earliest period is based on a single 1961 sample, taken outside the peak winter deicing season. Differences in minimum and maximum chloride values across reaches and time periods appeared

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

to depend more on sample size than on any discernible spatial or environmental factors. Longitudinally along the mainstem of the Fox River, chloride concentrations were generally lower in the upstream (FX17-FX13) and downstream (FX08-FX01) reaches. Conversely, the middle assessment reaches (FX12-FX09) showed slightly higher concentrations, especially during the more recent 1994-2012 and 2013-2022 periods. These middle reaches also coincide with areas of greater urbanization.

Figure 4.27 shows chloride concentrations (on a log scale) from 1961 through 2022 for five major Fox River tributaries: the White River, Honey Creek, Sugar Creek, Mukwonago River, and Pewaukee River.[73] The White River generally showed moderate chloride levels, with all measurements remaining below 100 mg/l. Median concentrations at both upstream (FX29) and downstream (FX28) reaches increased over time, particularly between 1961-1977 and 1994-2012, rising by approximately 53 percent (19.5 mg/l) at FX29 and 68 percent (19.8 mg/l) at FX28. While median concentrations at FX29 slightly declined from 1994-2012 to 2013-2022, concentrations at FX28 plateaued with a slight increase. Chloride concentrations varied most during the 1961-1977 period for both reaches, with FX29 typically higher than FX28, except in the most recent period.

Honey Creek maintained relatively low chloride conditions, with all measurements below 60 mg/l from. At reach FX34, the only balanced assessment reach for the full period, median chloride concentrations rose significantly by 244 percent, from 13.5 mg/l (1961-1977) to 46.4 mg/l (2013-2022). Longitudinally, median concentrations in the recent period (2013-2022) increased by almost 42 percent from upstream FX35 to FX34, possibly due to impacts from the East Troy WWTP located between these reaches, before decreasing at the next downstream reach, FX31.

Sugar Creek also exhibited relatively low chloride conditions, with all measurements remaining below 62 mg/l. In the 1961-1977 period, upstream reach FX39 reached a 54 percent higher median chloride concentration than downstream FX37, potentially due to dilution from higher discharge downstream. At FX37, the only reach with a balanced chloride dataset, median concentrations significantly increased 218 percent, from 13 mg/l (1961-1977) to 41 mg/l (2013-2022), though they remained relatively low overall.

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[73] The following assessment reaches have imbalanced datasets: Honey Creek reaches FX30, FX31, and FX35; Sugar Creek reach FX39; Mukwonago River reaches FX68, FX69, and FX70; and Pewaukee River reach FX88. Imbalanced datasets may not accurately represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

The Mukwonago River consistently maintained relatively low chloride concentrations across all assessment reaches throughout the full period of record, with all measurements remaining below 85 mg/l and median concentrations below 55 mg/l. Despite these low levels, median chloride concentrations still increased over time at each assessment reach. At the two balanced reaches, upstream FX71 saw a 72 percent (7.2 mg/l) increase in median chloride from 1994-2012 to 2013-2022, and downstream Mukwonago river reach FX67 increased by 87 percent (19.5 mg/l) during the same time. From 1961-1977 to 2013-2022, median concentration at FX67 rose by 282 percent (31 mg/l).

The Pewaukee River displayed considerably higher chloride conditions than the other tributaries shown in Figure 4.27. Upstream reach FX88 had a concerning median chloride concentration of 447 mg/l during the 2013-2022 period, exceeding the Wisconsin chronic toxicity threshold (395 mg/l). It also had an extreme observation of 991 mg/l, far surpassing the acute threshold (757 mg/l). At downstream reach FX87, the only balanced reach with multi-period data, median chloride rose concerningly by 331 percent, from 49 mg/l (1961-1977) to 211 mg/l (2013-2022). This reach also recorded two samples above the State's chronic toxicity threshold during the 2013-2022 period.

Map 4.35 shows statistically significant trends in both chloride and specific conductance within the Fox River watershed over the full period of record (1962 through 2022). For chloride, 12 assessment reaches (all but one reach with balanced chloride datasets necessary for trend analysis) showed statistically significant increasing concentrations (indicated by the red "up" arrows) and no reaches showed decreasing trends. Table 4.4 provides the slope (mg/l/year), sampling period, and R^2 values for these chloride trends. The largest increasing chloride trend for the full period of record in the Fox River watershed was 4 mg/l per year at Fox River mainstem reach FX12. Regarding specific conductance, 13 reaches (72 percent of those with balanced datasets) had statistically significant increasing trends (orange "up" arrows), and one reach showed a statistically significant decreasing trend (light green "down" arrow). It is worth noting that nine reaches with increasing chloride concentrations also displayed increasing trends for specific conductance. One reach, FX29 (White River: 14.9 to 18.9 miles) indicates an increasing chloride trend while specific conductance levels show a decreasing trend. Both the chloride and specific conductance trends for this assessment reach are very minor and are likely being impacted by the dilution effect of Geneva Lake which is located immediately upstream of this assessment reach.[74]

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[74] *Geneva Lake has a residence time of 13.9 years and a total volume of 320,948 acre-feet. For more information on chloride conditions in Geneva Lake, see Chapter 3 and Chapter 5 of this Report.*

Seasonal Trends

Figure 4.28 displays seasonal chloride concentration patterns in six Fox River mainstem assessment reaches from 1961 through 2022. The y-axis scale varies between reaches to accommodate the range of chloride measurement and should be considered when assessing the magnitude of seasonal patterns. Typically, chloride concentrations are highest in winter and second highest in spring, largely due to deicing operations, with summer and fall typically showing the lowest concentrations.

Five of the six assessment reaches observed their highest median chloride concentrations in winter: FX02 (107 mg/l), FX09 (170 mg/l), FX11 (118 mg/l), FX12 (254 mg/l), and FX16 (127 mg/l). However, in these five reaches, fall, not spring, records the second-highest median concentrations, and summer generally shows the lowest, except for FX11, where spring has the lowest median. These atypical patterns may be due to earlier than usual flushing of deicing salts before the spring season, the continuous influence of wastewater treatment plant effluent (particularly notable at FX02, FX07, and FX11), or delayed groundwater contributions of chloride that may emerge more strongly in summer and fall. Additionally, evaporation during drier summer and fall months can concentrate existing chloride. Seasonal sampling frequency may also influence observed patterns.

FX07 exhibits the most unique seasonal chloride pattern in Figure 4.28. Its highest median chloride concentration occurred in fall (60 mg/l), followed by summer (58 mg/l), and then winter (50 mg/l), with spring showing the lowest (40 mg/l). Located 3.4 miles downstream from the Mukwonago River confluence with the Fox River, FX07 is likely influenced by treated wastewater effluent from the Mukwonago Wastewater Treatment Plant. This pattern could be influenced by chloride-containing wastewater effluent comprising a larger portion of the stream flow during drier summer and fall seasons, thereby increasing chloride concentrations. Additionally, as FX07 is in a rural area, agricultural runoff with fertilizers containing chloride may be more prevalent during the summer or fall precipitation events. It is important to note that this assessment reach has a relatively small chloride dataset, with only five samples each in winter, spring, and fall, which may influence the observed seasonal patterns.

During the full period of record (1961-2022), the Fox River watershed experienced only 25 exceedances of the chronic toxicity threshold (395 mg/l) for chloride, representing approximately 1 percent of the total watershed chloride samples. Figure 4.29 reveals a seasonal pattern in these infrequent exceedances, predominantly occurring in colder months. January recorded the highest frequency of chronic threshold exceedances with 12.1 percent of its samples (12 total exceedances), followed by February at 7 percent (8 total exceedances), and March at 1.2 percent (2 total exceedances). August, September, and December each had one sample surpassing the chronic toxicity threshold. This pattern suggests that, despite their infrequency, peaks chloride concentrations reaching toxicity levels in the streams of the watershed are primarily a result of winter deicing operations.

Recent Conditions (2013 Through 2022)

Analysis of recent conditions for the Fox River watershed used chloride and specific conductance measurements collected at monitoring stations throughout the watershed from 2013 through 2022. This data included 577 chloride samples and 2,606 specific conductance measurements.

Among the 32 assessment reaches with recent chloride data, only 14 had datasets that met the established criteria to be considered balanced.[75] Reaches with imbalanced chloride datasets during the recent period are shown in red text in subsequent tables discussed in this section. An additional 70 assessment reaches lacked chloride data but 38 of those reaches did have specific conductance data, potentially useful as a general indicator of chloride conditions.

Table 4.18 summarizes chloride and specific conductance data (number of samples, minimum, maximum, mean, and median) for each Fox River watershed assessment reach. Map 4.36 displays the median chloride concentrations for these reaches during the recent period of record. For assessment reaches with balanced datasets (marked by black circles on Map 4.36), median chloride concentrations ranged from 33 mg/l at FX35 (Honey Creek: 17.1 to 21.5 miles) to 258 mg/l at Fox River mainstem reach FX12 (176.5 to 180.3 miles). Across all assessment reaches (both balanced and imbalanced), maximum chloride concentrations varied widely, from 26 mg/l at FX71 (Mukwonago River: 13.6 to 15.9 miles) to 991 mg/l at FX88 (Pewaukee River: 6.3 to 10.7 miles).

Median chloride concentrations for the recent period were consistently higher than those from the full period of record (1961-2022) as shown in Table 4.16. In cases where recent and full period medians were identical, the recent chloride samples constituted the entire full period dataset. For reaches with balanced datasets, the largest increases in median chloride were observed at Pewaukee River reach FX87 (220 percent), Honey Creek reach FX34 (207 percent), and Mukwonago River reach FX67 (200 percent). While historical medians are based on a significantly larger dataset, these findings align with increased chloride

[75] Criteria for a balanced dataset for the recent period of record includes: More than 10 total samples, at least 10 percent or 4 samples collected in the winter season (December through February), and at least 20 percent of samples collected in either summer or fall.

concentrations and specific conductance patterns observed in lakes throughout the study area, with the highest levels recorded in the most recent period (summarized in Chapter 5 of this Report).

Map 4.37 illustrates median specific conductance in the Fox River watershed for the recent period. Generally, reaches with high median specific conductance also show high median chloride, though conductance sometimes shifted to an adjacent color category compared to the chloride map (Map 4.36). For reaches with balanced conductance datasets, median specific conductance ranged from 541 μS/cm at FX29 (White River: 14.1 to 18.9 miles) to 1,776 μS/cm at FX11 (Fox River 174.5 to 176.5 miles). Across all assessment reaches (balanced and imbalanced), maximum specific conductance varied significantly from 581 μS/cm at Honey Creek reach FX36 to 7,912 μS/cm at FX50 (Como Creek: 0 to 3.3 miles).[76]

During the recent period, 38 reaches lacked chloride data but had specific conductance data; however, many of these had very limited and imbalanced specific conductance datasets. Nonetheless, four assessment reaches without chloride data did have balanced specific conductance datasets, providing a potential indication of chloride conditions in those streams. FX55 (Wind Lake Drainage Canal: 6.8 to 7.3 miles) and FX86 (Pewaukee Lake Outlet) showed moderate median specific conductance levels of 825 μS/cm and 850 μS/cm, respectively, suggesting moderate chloride conditions. The other two reaches, FX83 (Pebble Creek 3.3 to 4.7 miles) and FX90 (Coco Creek: 0.9 to 3.9 miles), had elevated median specific conductance measurements of 1,270 μS/cm and 1,100 μS/cm, respectively, potentially indicating elevated chloride conditions.

Table 4.19 presents the percentage of recent period chloride samples exceeding the various water quality and biological thresholds established in Chapter 2 of this Report for each assessment reach in the Fox River watershed (see Table 2.Thresholds). Examining assessment reaches with recent-period chloride datasets revealed the following:

- **Historical Background Concentration (10 mg/l):** 100 percent of recent samples exceeded this concentration.

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[76] *It should be noted that two reaches, Sussex Creek reach FX96 (11,750 μS/cm) and Fox River mainstem reach FX02 (9,552 μS/cm), had higher maximum specific conductance measurements, but these were considered extreme outliers and potential errors when compared to other samples in those reaches.*

- **Conservative Lower Impact Concentration (35 mg/l):**[77] About 85 percent of recent chloride samples in the watershed surpassed this threshold. All but two assessment reaches recorded at least one exceedance, with most showing a significant portion of samples above this level.

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[78] Nearly 42 percent of recent chloride samples in the watershed exceeded this guideline. Approximately 56 percent of assessment reaches had at least one exceedance, with balanced reach exceedance rates ranging from zero percent (at eight reaches) to 100 percent (at Pewaukee River reach FX87).

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[79] About 15 percent of recent watershed samples in exceeded this threshold, and 31 percent of assessment reaches had at least one sample surpassing it. For balanced reaches, exceedances ranged from zero percent (at nine reaches) to almost 68 percent (at Fox River reach FX12).

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** 19 recent chloride samples (3.3 percent) in the watershed surpassed this threshold. Exceedances occurred at six assessment reaches (FX09, FX12, FX87, FX88, FX91, and FX96). Notably, for balanced reaches, Fox River reach FX12 and Pewaukee River reach FX87saw exceedance rates of 10.8 percent and 6.1 percent, respectively.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** Only one recent chloride sample in the watershed exceeded this acute toxicity threshold, observed at Pewaukee River reach FX88.

- **Extreme Impact Level Concentration (1,400 mg/l):** No recent chloride samples in the watershed exceeded this level.

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[77] See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal es of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l).

[78] The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.

[79] This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.

Figure 4.30 illustrates the distribution of the 577 recent period chloride samples from the Fox River watershed, categorized by various water quality and biological impact thresholds (see Table 2.Thresholds in Chapter 2 of this Report).[80] Notably, no recent chloride samples were at or below the historical background concentration of 10 mg/l. The majority of recent samples indicated potential harm to aquatic life: almost 15 percent fell in the 10-35 mg/l range, where the onset of biological effects are observed, and the largest group, 43.3 percent were in the 35-120 mg/l range associated with considerable biological impacts. In total, 96.6 percent of recent samples exceeded thresholds for biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, but remained below the State's regulatory action threshold, a slight increase from the full period of record.

Compared to the full period of record, the watershed's recent period contributions to study area exceedances increased slightly, accounting for approximately 1.1 percent of chronic and 0.2 percent of acute chloride threshold exceedances across the study area. Within the Fox River watershed itself, 19 recent period samples (about 3.3 percent of recent samples) surpassed the Wisconsin's chronic toxicity threshold of 395 mg/l, and one sample (about 0.2 percent) exceeded the acute toxicity threshold of 757 mg/l. These also represented increases compared to the full period of record.

Two streams in the Fox River watershed were listed in 2024 as chloride-impaired under Section 303(d) of the Clean Water Act, both listed for chronic chloride toxicity. These 303(d) impaired streams encompass two of the 102 (approximately 2 percent) assessment reaches analyzed in this watershed (see Table 4.20). Additional assessment reaches had observed recent maximum chloride concentrations above the chronic toxicity threshold (FX09, FX12, FX87, and FX96) during the recent period of record but the streams are not on the 303(d) list, likely due to limited datasets. These four assessment reaches are identified as "high risk" stream reaches on Map 4.38 and on Figure 4.14 in Section 4.4 of this Chapter.[81]

<u>Land Use</u>

Map 4.39 illustrates a general correlation between higher recent chloride levels in assessment reaches and increased urban land use within their subbasins. For example, FX12, FX87, FX04, and FX16, which have elevated recent median chloride levels, are located entirely or partly within highly urbanized subbasins. Conversely, reaches with the lowest recent median chloride (FX71, FX35, FX37, and FX34) primarily drain

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

[81] *For this Report, assessment reaches that were not listed as impaired were considered high risk for impairment if they had a chloride sample within 10 percent of the State's chronic toxicity threshold, or 355 mg/l.*

rural subbasins. However, exceptions exist. Fox River mainstem reach FX09, despite flowing through a rural area, has the second-highest median chloride concentration among balanced reaches. Conversely, White River reach FX29, with a relatively low recent median chloride concentration of 53 mg/l, flows partially through a highly urbanized subbasin; this is likely due to the reach location at the outlet of Geneva Lake, which accounts for most of its flow.

Similarly, Map 4.40 indicates a relationship between elevated recent chloride conditions and higher road and parking lot density. Assessment reaches with elevated median chloride concentrations (FX12, FX87, FX04, and FX16) are located in subbasins with some of the highest densities of these impervious surfaces. Conversely, reaches with lower median chloride (FX71, FX37, and FX28) are within subbasins with lower densities of roads and parking lots. Exceptions to this pattern include Fox River mainstem reach FX09, which has an elevated recent median chloride concentration (247 mg/l) but is surrounded by subbasins with minimal roads and parking lots, suggesting a chloride source other than road salt is potentially impacting this stream reach. Additionally, Honey Creek reaches FX35 and FX34, despite having lower recent median chloride levels, are partially within subbasins with somewhat elevated road and parking lot densities.

<u>Temporal Trends</u>

From 2013 through 2022, the Fox River watershed showed no statistically significant increasing or decreasing trends in chloride levels. However, during the same period, four assessment reaches within the watershed did exhibit statistically significant increasing trends in specific conductance. These trends are represented by orange "up" arrows on Map 4.43.[82] Specifically reach FX31 (Honey Creek) saw an increase of 25 μS/cm per year, reach FX71 (Mukwonago River) saw an increase of 23 μS/cm per year, reach FX87 (Pewaukee River) saw an increase of 26 μS/cm per year, and reach FX90 (Coco Creek) saw an increase of 28 μS/cm per year.

Figure 4.31 presents recent period chloride samples for five balanced Fox River mainstem assessment reaches, ordered from downstream to upstream. There were no statistically significant trends for recent chloride data (2013-2022) for Fox River mainstem reaches. Despite the lack of statistical significance, several observations can be made:

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[82] *Only assessment reaches with balanced recent period datasets were assessed for trends.*

- FX09 and FX12 appear to show slight increases in chloride concentrations. Many samples exceeded the USEPA chronic toxicity threshold (230 mg/l), with a few also surpassing Wisconsin's chronic toxicity threshold (395 mg/l).

- FX04 and FX16 may have decreasing concentrations over the recent period, though both have short recent period records that makes it hard to draw any concrete conclusions. However, samples at both frequently exceeded the Canadian chronic toxicity threshold (120 mg/l).

- FX02 chloride levels fluctuate seasonally, often exceeding the Canadian chronic threshold. There was no apparent overall increasing or decreasing trend over the entire recent period, however, an increasing trend can be seen from the beginning of 2020 through 2022.

Figure 4.32 displays recent period chloride samples for nine balanced assessment reaches on major Fox River tributaries: White River (FX28 and FX29), Honey Creek (FX34 and FX35), Sugar Creek (FX37), Mukwonago River (FX67 and FX71), Pebble Brook (FX77), and Pewaukee River (FX87). None of these tributary reaches were found to show statistically significant trends. Most only have two years of data collected by SEWRPC staff during the Chloride Impact Study, which is likely insufficient to observe clear trends. However, these still indicate recent chloride conditions:

- White River, Honey Creek, Sugar Creek, and Mukwonago River reaches show relatively low to moderate chloride concentrations with apparent seasonal fluctuations.

- Pebble Brook (FX77) has slightly higher chloride levels, with a median of 108 mg/l and one sample reaching 178 mg/l, exceeding the Canadian chronic toxicity threshold (120 mg/l).

- Pewaukee River (FX87) exhibits the most concerning chloride conditions among the major Fox River tributaries with balanced chloride datasets. Many samples exceed the USEPA chronic toxicity threshold (230 mg/l), and two samples surpass Wisconsin's chronic toxicity threshold (395 mg/l).

Seasonal Trends

During the recent period of record (2013-2022), the Fox River watershed experienced only 19 exceedances of the chronic chloride toxicity threshold for (395 mg/l), representing 3.3 percent of all recent period chloride samples collected in the watershed. Figure 4.33 reveals a distinct seasonal pattern in these infrequent exceedances, as they occur in only three months. January recorded the highest frequency, with

21.6 percent of samples (11 total) surpassing the threshold, followed by February with 17.5 percent of samples (7 total), and March with 2.5 percent of the samples (1 total). These recent period chronic exceedances accounted for all but one of the chronic threshold exceedances for each these three corresponding months across the entire period of record. No other months observed exceedances of the chronic threshold during the recent period of record.

Other Factors Potentially Influencing Instream Chloride Conditions

The Fox River watershed currently has 15 active wastewater treatment plants (WWTPs) that discharge treated wastewater. An additional seven WWTPs previously operated in the watershed but are now abandoned. Locations of both active and abandoned facilities are shown in Map A.4, with receiving waters and other facility information provided in Table 2.2 in Chapter 2 of this Report. These facilities are not designed to remove chloride ions, meaning that any chloride entering them is discharged with the treated wastewater into nearby waterways or, less commonly, into infiltration ponds that allow effluent to permeate soils and eventually reach groundwater.

Five WWTPs discharge directly into the Fox River mainstem: the Fox River Pollution Control Center (includes portions of Brookfield, New Berlin, Pewaukee, and Menomonee Falls), Waukesha, Western Racine County Sewerage District (Waterford and Rochester), Burlington, and Salem Lakes, listed in upstream to downstream order. In addition to these, nine other facilities discharge into tributaries of the Fox River, conveying chloride-carrying treated wastewater to the mainstem. The Lake Geneva WWTP discharges its effluent to groundwater via infiltration basins. Map A.4 shows the locations of Fox River watershed assessment reaches in relation to these facilities.

While chloride loads in stream reaches downstream from these WWTPs are undoubtedly increased by upstream dischargers, pinpointing the direct impact of these facilities on in-stream chloride concentrations is challenging due to several factors:

- **Assessment Reach Locations:** Identifying WWTP impacts on chloride concentrations requires assessment reaches immediately upstream and downstream of discharge locations. Such arrangements were rare in the study area.

- **Chloride Data Availability and Timing:** Even in locations with chloride data for both upstream and downstream assessment reaches, the data are often sparse or collected at different times, seasons, or periods. A planned monitoring schedule would be necessary to collect relatively synchronized upstream and downstream data for accurate assessment of impacts.

- **Adjacent Land Use:** Land use in drainage areas immediately adjacent to stream reaches can significantly influence in-stream chloride conditions, independent of WWTP discharges.

- **Discharge Data Limitations:** Flow discharge data are largely unavailable for most assessment reaches. Furthermore, the magnitude of discharge from upstream tributaries, stormwater outfalls, and other point and nonpoint sources is unknown. These additional flows can either elevate or dilute chloride concentrations, making it difficult to attribute changes solely to WWTPs.

An analysis of several of these factors within Fox River watershed streams is presented in the "Stream Chloride Dynamics and Influencing Factors" section of Chapter 3. As part of the Chloride Impact Study data collection, SEWRPC staff specifically chose monitoring sites that bracketed the East Troy Wastewater Treatment Facility to quantify its effect on chloride levels in Honey Creek. This analysis revealed that effluent from this plant does increase in-stream chloride levels in Honey Creek. As presented in Table 4.18, median chloride concentrations in the recent period of record (2013-2022) increased from 33 mg/l at the upstream Honey Creek reach (FX35) to 46 mg/l at the downstream Honey Creek reach (FX34). In addition, Table 4.19 indicates that while under 27 percent of recent chloride samples exceeded 35 mg/l (the conservative lower impact threshold for biological impacts) at the upstream Honey Creek reach (FX35), 92 percent of samples surpassed that level at the downstream Honey Creek reach (FX34). The consistent and relatively stable concentration differences between upstream and downstream assessment reaches throughout the year, as discussed in Chapter 3, suggests that a continuous source, likely the WWTP, is a major contributor to the increased downstream chloride concentrations. Additionally, the analysis indicated that salt used to recharge water softeners is a probably major source of the chloride passing through the East Troy WWTP and entering Honey Creek.

Chapter 3 also includes an analysis comparing stream discharge in the Fox River mainstem at the USGS stream gage in Waukesha (located within Fox River mainstem reach FX12) with discharge from two upstream WWTPs (Sussex and Brookfield) to assess potential impacts to downstream chloride concentrations. This analysis suggests that at the 10th percentile of flows at the Waukesha stream gage, treated effluent discharge from the upstream WWTPs may account for over 80 percent of the flow from July through September. This indicates that during these months, treated effluent may represent about 80 percent of the flow at the gage approximately 10 percent of the time. Outside of winter, these months may be most critical for aquatic organisms in streams receiving chloride-containing WWTP discharges, potentially increasing in-stream chloride concentrations to levels that could be stressful or harmful.

Kinnickinnic River Watershed

The Kinnickinnic River watershed, located in east-central Milwaukee County, is almost exclusively urban (97.4 percent in 2015), consisting primarily of roads and parking lots (29.7 percent), high-density residential (25.9 percent), transportation, communication, and utilities (7.7 percent), and medium-density residential (7.1 percent). Nearly 7 miles of the IH 94 corridor and 2 miles of the IH 43 corridor traverse the watershed. Additionally, a portion of the Milwaukee Mitchell International Airport lies within the watershed, draining into Wilson Park Creek before reaching the Kinnickinnic River. No active WWTPs currently discharge into streams within the watershed. More details about the watershed characteristics can be found in Chapter 2 of this Report and Maps A.5 and A.6.

Chloride conditions and trends were evaluated across ten assessment reaches within the Kinnickinnic River watershed (see Map 4.44 and Table 4.21). This analysis incorporated 7,279 chloride measurements and 7,086 specific conductance measurements, collected at 48 monitoring stations between 1964 through 2022 (see Map 4.45).[83,84,85] The number of chloride samples per assessment reach ranged from zero to 3,695 for the full period of record. For assessment reaches with limited or no chloride data, specific conductance measurements can serve as a general indicator of chloride conditions and trends. The number of specific conductance measurements per reach ranged from 10 to 3,691 for the full period of record.

Historical Conditions and Trends (1961 Through 2022)

The robustness and balance of chloride and specific conductance datasets for each assessment reach over the full period of record were evaluated using the criteria outlined previously in this Chapter. A balanced dataset requires relatively even data collection across all seasons. Table 4.22 details the seasonal distribution of chloride and specific conductance samples for each reach in the watershed.

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[83] *Although data for this watershed was collected from 1964-2021, in this Chapter, the full period of record is consistently referred to as 1961-2022, and the recent period of record as 2013-2022, for comparability across all watersheds.*

[84] *There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.*

[85] *Some of these monitoring stations may be at the same or similar locations as others but data was collected by a different agency, typically at different times.*

Seven assessment reaches – Kinnickinnic River mainstem reaches KK01, KK02, and KK03, and Wilson Park Creek reaches KK05, KK06, KK07, and 43rd Street Ditch reach KK09 – met the criteria for balanced chloride datasets. Six reaches – KK01, KK02, KK03, KK05, KK06, and KK09 – had balanced specific conductance datasets. Imbalanced datasets, highlighted in red text in Table 4.22 and other tables in this analysis, are less likely to accurately reflect actual conditions and may hinder comparisons to other reaches.

Table 4.23 summarizes the chloride and specific conductance data (number of samples, minimum, mean, median, and maximum) for each assessment reach in the Kinnickinnic River watershed. Map 4.46 displays median chloride concentrations across all reaches with available chloride data. All reaches with balanced chloride datasets (indicated by black circles on Map 4.46), exhibited elevated median chloride concentrations. For the Kinnickinnic River mainstem, median chloride concentrations were highest upstream at KK03 (260 mg/l) and progressively decreased to KK02 (160 mg/l) and KK01 (64 mg/l), with the two upstream reaches above the Canadian chronic toxicity threshold of 120 mg/l. Wilson Park Creek reaches had similar median concentrations for the full period of record, although overall the chloride concentrations increased upstream to downstream. The highest median chloride concentration for balanced reaches was observed in the 43rd Street Ditch (300 mg/l). All of the balanced datasets for reaches within the Kinnickinnic River watershed had relatively even distributions of chloride samples over the four seasons (see Table 4.36).[86]

Maximum chloride concentrations across all reaches (balanced and imbalanced) were concerning and highly variable, ranging from 870 mg/l at KK01 to an extremely elevated 44,000 mg/l at Wilson Park Creek reach KK06 (see Table 4.23). The next highest maximum chloride concentration in the Kinnickinnic River watershed, was observed at the downstream Wilson Park Creek reach (KK05) at 8,630 mg/l, exceeding the State's acute toxicity threshold of 757 mg/l by more than 11 times.

Map 4.47 shows specific conductance conditions in the Kinnickinnic River watershed assessment reaches across the full period of record. Generally, these conductance levels mirrored median chloride concentrations, with higher conductance indicating higher chloride. Kinnickinnic River mainstem reach KK01 had a fairly low specific conductance measurement (586 µS/cm) while middle Kinnickinnic River reaches KK02 and KK03 had somewhat elevated median specific conductance concentrations (1,060 and 1,342

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[86] *While Kinnickinnic River mainstem reach KK01 only had 5.2 percent of its samples collected in the winter season, the assessment reach had a large dataset, meaning 192 chloride samples were collected in the winter season, meeting the criteria for a balanced dataset.*

μS/cm, respectively). Conductance in these three assessment reaches matched the chloride categories (as shown on Map 4.46). Similar to chloride conditions, reach KK04 (43rd Street Ditch) exhibited the highest median specific conductance (1,530 μS/cm) among all reaches with balanced datasets.

Maximum specific conductance measurements, similar to maximum chloride concentrations, were concerning and highly variable across all reaches (balanced and imbalanced). They ranged from 2,400 μS/cm at KK04 to an exceptionally high 19,800 μS/cm at Villa Mann Creek reach KK08 (see Table 4.23). Although Lyons Park Creek reach KK04 lacked chloride data, its somewhat elevated specific conductance levels suggests high concentrations of dissolved salts, including chloride; however the dataset was considered imbalanced due to limited sample size.

Table 4.24 presents the percentage of chloride samples exceeding the various water quality and biological thresholds established in Chapter 2 of this Report for each assessment reach in the Kinnickinnic River watershed for the full period of record (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:[87]

- **Historical Background Concentration (10 mg/l):** A significant 99 percent of all chloride samples in the watershed exceeded this level. All assessment reaches, except for Wilson Park Creek KK06 (78.3 percent), showed greater than 90 percent exceedance. The relatively large number of samples below 10 mg/l on KK06 when compared to all other reaches may indicate sampling conducted during rain events on Milwaukee Mitchell International Airport property.

- **Conservative Lower Impact Concentration (35 mg/l):[88]** Approximately 86 percent of all watershed samples surpassed this threshold. One Kinnickinnic River mainstem reach (KK02), one Wilson Park Creek reach (KK05), and Villa Mann Creek (KK08), 43rd Street Ditch (KK09), and Zablocki Park Creek (KK10) showed greater than 90 percent exceedance.

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[87] *Assessment reaches KK08 and KK10 had imbalanced chloride datasets for the full period of record and KK04 lacked chloride data.*

[88] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[89] About 41 percent of all samples in the watershed exceeded this guideline, with every reach recording at least one exceedance. For reaches with balanced datasets, exceedance rates ranged from 15 percent at KK01 to nearly 90 percent at 43rd Street Ditch reach KK09.

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[90] Approximately 23 percent of all watershed samples exceeded this threshold. All reaches with chloride data except KK01 (4 percent exceedance) had a significant portion of samples surpass this level. Notably, the other reaches with balanced datasets had exceedances ranging from about 34 percent at KK02 to almost 65 percent at KK09.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Approximately 10 percent of all watershed samples surpassed this threshold. Every reach with chloride data recorded at least one exceedance. For balanced datasets, exceedance rates of this threshold ranged from less than 1 percent of samples at KK01 to almost 40 percent at KK06.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** A total of 282 chloride samples (about 4 percent of all samples) in the watershed exceed this acute toxicity threshold. For balanced datasets, exceedance rates of this threshold ranged from 0.1 percent of samples at KK01 to 29 percent at KK06.

- **Extreme Impact Level Concentration (1,400 mg/l):** 116 chloride samples (1.6 percent) collected in the watershed exceeded this concentration. Only one reach in the watershed, Kinnickinnic River downstream reach KK01, did not have a sample exceeding this threshold. For balanced datasets, the maximum exceedance rate for this threshold was almost 17 percent at Wilson Park Creek reach KK06.

Figure 4.34 presents the distribution of the 7,279 chloride samples collected within the Kinnickinnic River watershed during the full period of record, categorized by various water quality and biological impact thresholds. (see Table 2.Thresholds in Chapter 2 of this Report).[91] Only 1 percent of samples were at or below the historical background chloride concentration of 10 mg/l for southeastern Wisconsin surface

[89] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[90] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

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

waters. A larger proportion of samples (12.6 percent) fell within the 10-35 mg/l range, which is indicative of the onset of biological effects. Almost half (44.9 percent) of samples were in the 35-120 mg/l range, associated with considerable biological impacts. The next largest proportion of samples (18.4 percent) exceeded the Canadian chronic toxicity threshold, falling into the 120-230 mg/l range, yet remained below the USEPA chronic threshold. The vast majority (89 percent) of chloride samples collected in the watershed exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State (395 mg/l).

While the Kinnickinnic River watershed accounted for 15.3 percent of the total chloride samples collected in the study area during the full period of record, the watershed accounted for a disproportionately higher percentage of exceedances. Specifically, the watershed contributed 25.2 percent of the study area's total chronic chloride threshold exceedances and 30.2 percent of acute chloride threshold exceedances, with many of the acute exceedances surpassing the extreme impact threshold of 1,400 mg/l. Within the Kinnickinnic River watershed itself, 747 chloride samples (10.2 percent) surpassed the Wisconsin's chronic toxicity threshold of 395 mg/l, and 282 samples (3.9 percent) exceeded the acute toxicity threshold of 757 mg/l.

Temporal Trends

The top series of box plots in Figure 4.35 presents the distribution of chloride concentrations (on a log scale) for the mainstem Kinnickinnic River reaches KK03 (upstream), KK02, and KK01 (downstream) across five time periods 1961-1977, 1978-1986, 1987-1993, 1994-2012, and 2013-2022. All three reaches possess balanced datasets for the full period of record, however KK03 did not have any chloride data for the second or third time periods.

Figure 4.35 illustrates significant increases in chloride concentrations across all Kinnickinnic River mainstem assessment reaches (KK01, KK02, and KK03) from 1961 to 2022. Median chloride concentrations rose substantially from the first period to the most recent period: 1,470 percent at KK03, 695 percent at KK02, and 131 percent at KK01. It should be noted that there was very minimal winter chloride sampling in all Kinnickinnic River watershed reaches during the 1961-1977 time period, which is likely a major factor in the low median concentrations observed during this period. The Kinnickinnic River watershed was already highly urbanized in the 1960s (above 92 percent), thus the steep rise in chloride medians for all Kinnickinnic River reaches was likely not due to additional urbanization but most likely reflects more winter sampling in later time periods, in addition to the increased use of road salt for deicing operations (for urban land use see Map 2.5 in Chapter 2 of this Report).

As mentioned above, the earliest period (1961-1977) exhibited the lowest median chloride levels which most likely was due to minimal winter data, with KK03 at 21 mg/l and KK01 at 35 mg/l. A minor decrease in median chloride was observed at KK01 from 1978-1986 to 1987-1993 (44 mg/l to 40 mg/l). For all other time periods, all mainstem Kinnickinnic River reaches showed a consistent increase in median chloride concentrations over time. The most substantial rise in median concentrations occurred between 1961-1977 and 1978-1986 for KK02 (150 percent), and between 1961-1977 and 1994-2012 for KK03 (1,067 percent). Critically, by the 1994-2012 period, median chloride concentrations at KK03 exceeded the USEPA chronic toxicity threshold of 230 mg/l. The Wisconsin chronic toxicity threshold (395 mg/l) was surpassed across all Kinnickinnic River mainstem reaches in most time periods. Furthermore, most time periods in KK02 and KK03 showed exceedances in the acute toxicity threshold (757 mg/l). The acute threshold was exceeded in all reaches during the 2013-2022 period. All reaches consistently show a wide range in chloride concentrations, with steep peaks likely caused by deicing operations and low concentrations likely due to dilution events caused by snow melt or rain events. Chloride concentrations often surpassed the extreme impact threshold (1,400 mg/l) in reaches KK02 and KK03.

The middle panel of Figure 4.35 illustrates the chloride concentrations in Wilson Park Creek (KK07, KK06, KK05). Although the dataset for all these reaches is balanced, data was only available for three time periods, 1961-1977, 1994-2012, and 2013-2022. A significant increase in chloride concentrations was observed between the three periods at all reaches. Median chloride concentrations increased between 1994-2012 and 2013-2022 by 70 percent for KK07, 11 percent for KK06, and 30 percent for KK05. Critically, the chronic and acute chloride toxicity thresholds were often exceeded at all Wilson Park Creek assessment reaches during the 1994-2012 and 2013-2022 periods. In fact, median chloride values during the 2013-2022 period were above the Wisconsin chronic toxicity threshold (395 mg/l) at KK07 and KK06, and median chloride at KK06 approached the acute threshold (757 mg/l), indicating almost half of the samples surpassed this acute threshold. Both later periods show a wide range of chloride values, indicating high variability.

The lower panel of Figure 4.35 displays chloride distributions for the balanced 43rd Street Ditch (KK09) assessment reach. Median concentrations increased at this reach from 230 mg/l in 1994-2012 to 370 mg/l in 2013-2022, approaching the State’s chronic toxicity threshold. In the 2013-2022 period, approximately 14 percent of samples exceeded the acute toxicity threshold.

Map 4.48 shows statistically significant trends in both chloride and specific conductance within the Kinnickinnic River watershed over the full period of record. For chloride, six of the seven assessment reaches with balanced datasets showed statistically significant increasing trends (indicated by the red "up" arrows), while no reaches exhibited statistically significant decreasing trends. Table 4.4 provides the slope (mg/l/year), sampling period, and coefficient of determination (R^2) values for these chloride trends. Notably, five of the seven largest increasing trends for chloride concentration for the full period of record in entire Chloride Impact Study area were observed in the Kinnickinnic River watershed, with the highest at KK06 at an estimated 53 mg/l/year. Regarding specific conductance, five of the seven reaches with balanced datasets had statistically significant increasing trends (orange "up" arrows), and no reaches showed a statistically significant decreasing trend.

Seasonal Trends

Figure 4.36 displays seasonal chloride concentration patterns in the seven balanced Kinnickinnic River watershed assessment reaches over the full period of record. The y-axis scale varies between reaches to accommodate the range of chloride measurements. All watershed reaches exhibited typical seasonal patterns for chloride concentrations in urban watersheds, with winter (December-February) showing the highest chloride concentrations followed by spring, and then summer or fall. Notably, the median winter concentrations at all balanced reaches in the watershed except reaches KK01 and KK02 exceeded the State's chronic toxicity threshold, and the median winter concentration for KK06 surpassed the acute toxicity threshold. While summer and fall exhibited the lowest chloride conditions in all Kinnickinnic River watershed reaches, the chronic toxicity threshold was still exceeded in all balanced assessment reaches except for Kinnickinnic River mainstem reach KK01, where chloride concentrations are likely impacted by Lake Michigan backwater effects. Furthermore, the acute toxicity threshold was exceeded in either summer or fall at least once at Kinnickinnic River mainstem reaches KK02 and KK03; Wilson Park Creek reaches KK05, KK06, and KK07; and 43rd Street Ditch reach KK09, indicating that concerning chloride concentrations are observed throughout the watershed, even in these warmer months.

Figure 4.37 highlights a concerning seasonal pattern of exceedances of Wisconsin's chronic toxicity threshold (395 mg/l) across the Kinnickinnic River watershed for the full dataset (1961-2022). The data reveals that exceedances occur most frequently in the colder months (winter and spring) and at higher frequencies than was seen in most other watersheds in the broader Chloride Impact Study area. This pattern strongly suggests that winter and spring deicing operations significantly impact chloride levels in the streams of this watershed. February and January show the highest frequency of exceedances, with approximately 65 percent and 59 percent of samples, respectively, exceeding the chronic toxicity threshold.

March (37 percent) and April (nearly 15 percent) also demonstrate higher exceedance rates. While exceedances declined through the summer, reaching a low of 0.9 percent in September, they began to rise again in November. Even during the summer and fall, 125 chronic toxicity threshold exceedances were recorded between June and the end of November. This indicates that harmful chloride levels can infiltrate the shallow aquifer and take time to flush out of both the groundwater and surface water systems, meaning that harmful chloride levels can occur outside of winter and early spring. Potential warmer-month sources of chloride to streams in the watershed include the leaching of residual deicing salts and baseflow contributions from chloride-polluted shallow groundwater aquifers.[92]

Recent Conditions (2013 Through 2022)

For the recent period, the Kinnickinnic River watershed had a fairly robust dataset, comprised of 2,523 samples collected from 2013-2022. The recent period specific conductance dataset was similar, with 2,571 measurements collected from 2013-2022. Nine assessment reaches had chloride data during this period. Of those, five (KK01, KK02, KK03, KK05, and KK09) had a balanced dataset.[93] The remaining four reaches with chloride data (KK06, KKO7, KK08, and KK10) had imbalanced datasets due to limited samples and/or insufficient winter sampling. There were no chloride samples collected at Lyons Park Creek reach KK04, however a limited and imbalanced specific conductance dataset was available for this reach and may provide a general indication of chloride conditions. All ten assessment reaches had specific conductance data during the recent period of record, and seven (KK01, KK02, KK03, KK05, KK08, KK09, and KK10) had recent specific conductance datasets that met the criteria to be considered balanced.

Recent chloride and specific conductance data for Kinnickinnic River assessment reaches are summarized in Table 4.25, with median chloride concentrations shown on Map 4.49. The Kinnickinnic River balanced reaches had median chloride concentrations ranging from 81 mg/l to 370 mg/l. All assessment reaches (balanced and imbalanced) had maximum chloride concentrations exceeding Wisconsin's acute toxicity threshold of 757 mg/l, with maximum values ranging from 870 mg/l (KK01) to an extreme high of 26,300 mg/l at Wilson Park Creek reach KK06 – the second highest chloride concentration in the entire study area. Notably, the Kinnickinnic River watershed had 12 of the 15 highest recent chloride measurements in the

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[92] *Examples of elevated chloride concentrations during prolonged drought conditions at monitoring sites for the Chloride Impact Study are described in the "Responses to Meteorological Events" section in Chapter 3 of this Report.*

[93] *Criteria for a balanced dataset for the recent period of record includes: more than 10 total samples, at least 10 percent or 4 samples collected in the winter season (December through February), and at least 20 percent of samples collected in either summer or fall.*

study area. Additionally, all balanced reach median chloride concentrations in the recent period were higher compared to the full period of record (1961-2022, see Table 4.23). Reach KK02, for instance, showed a 119 percent increase in median chloride concentration.

Map 4.50 and Table 4.25 both indicate elevated median specific conductance across all reaches in the Kinnickinnic River watershed during the recent period of record, except for the downstream Kinnickinnic River (KK01) which is likely impacted by Lake Michigan backwater effects. For reaches with balanced specific conductance datasets (marked with black circles on Map 4.50), median measurements ranged from 660 µS/cm at Kinnickinnic River mainstem reach KK01 to 2,700 µS/cm at Villa Mann Creek reach KK08. Maximum specific conductance levels across all reaches (balanced and imbalanced) varied widely, from 1,470 µS/cm at Wilson Park Creek reach KK07 to an extreme 19,800 µS/cm at Villa Mann Creek reach KK08, which was the fourth highest recent measurement in the entire study area. Additionally, recent median specific conductance values were the same or higher than those from the full record (1961-2022, see Table 4.23) for all balanced reaches, with Kinnickinnic River mainstem reach KK02 showing the largest increase (56 percent).

Table 4.26 presents the percentage of recent chloride samples exceeding the various water quality and biological thresholds, established in Chapter 2 of this Report, for each assessment reach in the Kinnickinnic River watershed (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:

- **Historical Background Concentration (10 mg/l):** All recent chloride samples in the watershed exceeded this level.

- **Conservative Lower Impact Concentration (35 mg/l):**[94] About 93 percent of recent samples from all Kinnickinnic River reaches exceeded this concentration. For all reaches, the lowest percent exceedance of this concentration was 90 percent for the balanced dataset in Kinnickinnic River mainstem reach KK01.

[94] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[95] Nearly 52 percent of recent samples exceeded this guideline, with at least one exceedance occurring in every reach. All but one of the Kinnickinnic River watershed reaches surpassed this threshold by more than 83 percent. The one exception was Kinnickinnic River mainstem reach KK01, which still had a fairly significant exceedance frequency of about 25 percent of samples. The lower exceedance frequency in this downstream assessment reach may be due to dilution from Lake Michigan.

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[96] Approximately 36 percent of recent watershed samples exceeded this threshold. All reaches except KK01 (7.7 percent) had significant exceedances, including 76 percent of samples in balanced reaches KK02 and KK09.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Approximately 17 percent of recent watershed samples exceeded this threshold, with significant exceedances in every reach except for KK01 (1 percent). The balanced KK09 reach had 46 percent of recent samples surpassing this threshold.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** 159 recent chloride samples (about 6 percent of all recent samples) in the watershed exceed this threshold. All reaches had at least one exceedance, and 14 percent of samples in the balanced KK09 reach surpassed it.

- **Extreme Impact Level Concentration (1,400 mg/l):** 62 recent chloride samples (over 2 percent of all recent samples) exceeded this concentration. All assessment reaches except KK01 had exceedances, with about 5 percent of samples in balanced KK02 exceeding this extreme threshold.

Figure 4.38 displays the distribution of the 2,523 chloride samples in the Kinnickinnic River Creek watershed collected during the recent period of record, categorized by various water quality and biological impact thresholds. No recent chloride samples fell at or below the concentration considered to be the historical background in surface waters in southeastern Wisconsin. Compared to most other watersheds in the study area, the Kinnickinnic River watershed showed a higher proportion of recent samples in more harmful ranges; for instance, almost 83 percent of recent samples exceeded thresholds associated with biological

[95] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[96] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

impacts or established guidelines and regulatory thresholds from outside of Wisconsin, though they remained below the State's regulatory action level.[97] Furthermore, a significant portion of samples surpassed Wisconsin's toxicity thresholds: more than 17 percent exceeded the chronic toxicity threshold of 395 mg/l, over 6 percent surpassed the acute toxicity threshold of 757 mg/l, and almost 3 percent of samples surpassed the extreme impact threshold of 1,400 mg/l, which were higher exceedance rates of these three categories than any watershed in the study area other than Oak Creek. Based on the available data, the Kinnickinnic River watershed accounts for a significant share of recent chloride toxicity threshold exceedances within the study area, representing almost 15 percent of chronic toxicity threshold exceedances, 17 percent of acute threshold exceedances, and 18 percent of extreme impact threshold exceedances while accounting for about 16 percent of the total recent chloride samples in the study area.

As of 2024, four Kinnickinnic River watershed streams were listed as chloride-impaired under Section 303(d) of the Clean Water Act: the entire Kinnickinnic River mainstem, the 43rd Street Ditch, part of Wilson Park Creek, and part of Zablocki Park Creek. All four were listed for both chronic and acute toxicity. These impaired stream segments include seven of the ten assessment reaches analyzed in this watershed (see Table 4.27 and Map 4.51). The upstream end of Wilson Park Creek reaches KK07 and KK06 had extremely high recent maximum chloride concentrations of 2,930 mg/l and 26,300 mg/l respectively, but were not listed on the 303(d) list, likely due to limited datasets. Villa Mann Creek reach KK08 had a recent maximum chloride concentration of 6,220 mg/l, but was also not listed on the 303(d) list, likely due to having only four samples collected during the recent period. These three reaches are identified as "high risk" stream reaches on Map 4.51 and on Figure 4.14 in Section 4.4 of this Report.[98]

Land Use

Map 4.52 and Map 4.53 illustrate that all the assessment reaches (balanced and imbalanced) in the watershed run through highly urbanized subbasins with significant road and parking lot densities. These land use characteristics likely explain the elevated recent median chloride concentrations for balanced assessment reaches ranging from 300 mg/l (KK05) to 370 mg/l (KK09). As previously discussed, the Kinnickinnic River mainstem reach KK01 has a fairly low recent median (81 mg/l) considering its highly urbanized subbasins, but is unique as chloride concentrations are likely diluted by the backwater influences of Lake Michigan.

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

[98] *For this Report, assessment reaches that were not listed as impaired were considered high risk for impairment if they had a chloride sample within 10 percent of the State's chronic toxicity threshold, or 355 mg/l.*

Similarly, Map 4.54 and Map 4.55 shows recent maximum chloride concentrations across all assessment reaches in the watershed (balanced and imbalanced). Eight of the nine assessment reaches with recent chloride data exhibit maximum concentrations above the 1,400 mg/l extreme impact threshold. Even downstream Kinnickinnic River mainstem reach KK01, which typically observed diluted chloride concentrations due to the backwater effects of Lake Michigan, observed a maximum concentration (870 mg/l) which is above the State's acute toxicity threshold. The heavily urbanized land use in this watershed appears to be the primary driver of the extreme maximum chloride concentrations found in its assessment reaches.

Temporal Trends

Map 4.56 shows chloride and specific conductance trends in Kinnickinnic River watershed assessment reaches from 2013 through 2022. Only reaches with balanced datasets were included in this trend analysis. During this period, no statistically significant trends (increasing or decreasing) were observed for four of the five balanced reaches in the watershed for either chloride or specific conductance. Only the 43rd Street Ditch (KK09) showed a statistically significant trend, an increasing trend for specific conductance.

Figure 4.39 displays all recent chloride samples for the five Kinnickinnic River watershed assessment reaches with balanced recent datasets, arranged from downstream to upstream. As described in the previous paragraph, there were no statistically significant trends for recent chloride data (2013-2022). Despite the lack of statistical significance, several observations can be made:

- Seasonal patterns are evident across all balanced assessment reaches in the watershed.

- All balanced reaches, except Kinnickinnic River mainstem reach KK01, frequently exceeded the chronic chloride toxicity threshold and commonly surpassed the acute threshold. KK01 also exceeded both thresholds in the recent period, but much less frequently.

- Acute toxicity threshold exceedances in Kinnickinnic River mainstem reach KK03 and Wilson Park Creek reach KK05, while occurring throughout the recent period, appear less frequent in 2020-2022.

Seasonal Trends

Figure 4.40 again reveals a concerning seasonal pattern of chronic chloride toxicity exceedances in the Kinnickinnic River watershed for the recent period (2013-2022). These exceedances were most frequent in the winter and spring, occurring at higher rates than any other watershed in the Chloride Impact Study area except the Oak Creek watershed. This strongly suggests winter and spring deicing operations significantly impact chloride levels in the streams of this watershed.

Frequency in chronic toxicity threshold exceedances in the recent period of record peaked in February (84 percent) and January (70 percent), with high rates continuing into March (48 percent) and April (22 percent). Significant exceedance frequencies persisted into late spring (May: 18 percent) and early summer (June: nearly 14 percent). Although summer saw a decline, reaching 2 percent in August, levels began to rise again in September. During the summer and fall, 84 chronic toxicity threshold exceedances were recorded between June and the end of November. This suggests that harmful chloride levels can linger in the shallow aquifer, causing elevated concentrations well beyond winter and early spring. Furthermore, recent period exceedance frequencies were generally higher than the full period, most notably in January, February, March, and May.

Menomonee River Watershed

The Menomonee River watershed, located in parts of Milwaukee, Waukesha, Washington, and Ozaukee Counties, is predominantly urban, has no active wastewater treatment plant discharges, and is influenced by Lake Michigan water levels at the mouth of the Menomonee River mainstem (see Maps A.7 and A.8). This watershed boasts the most comprehensive chloride and specific conductance dataset in the study area, largely due to robust monitoring efforts by MMSD. Chloride conditions and trends within the Menomonee River watershed were evaluated across 33 assessment reaches (see Map 4.57 and Table 4.28). The analysis used water chloride and/or specific conductance measurements collected at 149 monitoring stations throughout the watershed (shown on Map 4.58) between 1962 and 2022.[99] This dataset includes 16,964 chloride measurements and 14,206 specific conductance measurements.[100,101]

The availability of water quality data varied considerably among the 33 assessment reaches (see Table 4.28). The number of chloride samples per assessment reach ranged from zero to 4,186. For assessment reaches with limited or no chloride data, specific conductance measurements were used as a general indicator of

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[99] *Some monitoring stations may be at the same or similar locations as other stations; however, data was collected by a different agency, typically at different times.*

[100] *Although data for this watershed was collected from 1962-2022, in this Chapter, the full period of record is consistently referred to as 1961-2022, and the recent period of record as 2013-2022, for comparability across all watersheds.*

[101] *There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.*

chloride conditions and trends. The number of specific conductance measurements per reach ranged from one to 3,879.

Historical Conditions and Trends (1961 Through 2022)

The robustness and balance of chloride and specific conductance datasets for each assessment reach over the full period of record were evaluated based on the criteria described earlier in this Chapter. A balanced dataset requires relatively even data collection across all seasons. Table 4.29 shows the seasonal distribution of chloride and specific conductance samples for each reach. Fourteen assessment reaches had balanced chloride datasets, and 16 reaches had balanced specific conductance datasets. Reaches with imbalanced datasets are highlighted in red text in Table 4.29 and other tables in this analysis. Imbalanced datasets might not accurately represent chloride conditions in those assessment reaches and may not be comparable to other reaches.

Table 4.30 provides summary statistics (number of samples, minimum, maximum, mean, and median) for chloride and specific conductance in each assessment reach in the Menomonee River watershed. Map 4.59 displays median chloride concentrations for stream assessment reaches over the full period of record. For assessment reaches with balanced datasets (indicated by black circles on the Map 4.59), median concentrations ranged from 45 mg/l at MN20 (Little Menomonee River: 7.3 to 10.9 miles) to 230 mg/l at MN14 (Underwood Creek: 0 to 2.8 miles). Across all assessment reaches (balanced and imbalanced), maximum chloride concentrations varied significantly, from 71 mg/l at MN22 (Little Menomonee Creek: 0 to 3.9) to 9,800 mg/l at MN21 (Noyes Creek: 0 to 3.0 miles), which was the sixth-highest recorded chloride concentration in the entire study area. Considering assessment reaches with balanced datasets, median chloride levels for the Menomonee River mainstem were all well under 200 mg/l.

Map 4.60 shows median specific conductance in the Menomonee River watershed assessment reaches over the full period of record. Median specific conductance conditions generally mirrored median chloride conditions, with high conductance corresponding to high chloride. In reaches with balanced datasets, median specific conductance ranged from 680 μS/cm at Little Menomonee River reach MN20 to 1,390 μS/cm at Underwood Creek reach MN14 – the same reaches with the lowest and highest median chloride concentrations (see Table 4.30). Considering all assessment reaches (balanced and imbalanced), maximum specific conductance measurements in the watershed varied from 1,148 μS/cm at MN 20 to 19,200 μS/cm at MN 11 (Honey Creek: 0 to 3.1 miles). MN28 (Goldendale Creek: 0 to 1.2 miles) and MN31 (Grantosa Creek: 0 to 1.0 miles) lacked chloride data but had specific conductance data, with elevated median values of 1,095 and 1,310 μS/cm at those reaches, respectively. However, both reaches had imbalanced datasets.

Table 4.31 presents the percentage of chloride samples exceeding the various water quality and biological impact thresholds established in Chapter 2 of this Report for each assessment reach in the watershed over the full period of record (see Table 2.Thresholds). Examining all assessment reaches in the watershed revealed the following[102]:

- **Historical Background Concentration (10 mg/l):** 98 percent of all chloride samples in the watershed exceeded this threshold. All assessment reaches had a significant portion of samples exceeding it, with 58 percent of all reaches showing exceedance in every sample. For reaches with balanced datasets, exceedance frequencies were consistently high, ranging from 97.9 percent (Honey Creek reach MN11) to 100 percent (MN01, MN06, MN10, MN14, and MN27).

- **Conservative Lower Impact Concentration (35 mg/l):[103]** Approximately 92 percent of all chloride samples in the watershed exceeded this threshold, and all assessment reaches had a significant portion of samples surpassing it. Considering reaches with balanced datasets, exceedance frequencies ranged from 74 percent (MN20) to 100 percent (MN27).

- **Canadian Chronic Toxicity Threshold (120 mg/l):[104]** About 45 percent of all chloride samples in the watershed exceeded this guideline concentration, and every assessment reach had at least one sample exceed it except for Menomonee River reach MN10 and Little Menomonee Creek reach MN22. When considering reaches with balanced datasets, exceedance frequencies ranged from 0 percent (MN10) to almost 77 percent of samples at Underwood Creek reach MN14.

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[102] Assessment reaches with imbalanced datasets are shown in red text in Table 4.31. Caution should be used when interpreting percentages of exceedances for imbalanced datasets.

[103] See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.

[104] The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[105] Over 19 percent of samples collected in the watershed exceeded this threshold, and at least one sample exceeded it at all assessment reaches except MN10 and Little Menomonee Creek reach MN22. Considering reaches with balanced datasets, the highest percentage of exceedances occurred at Underwood Creek reach MN14 (approximately 49 percent). Honey Creek reach MN11 (45 percent) and Noyes Creek reach MN21 (30 percent) also had a large portion of samples exceeding this threshold.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Over 7 percent of all chloride samples in the watershed exceeded this threshold, and 79 percent of all reaches had at least one sample exceeding it. For reaches with balanced datasets, exceedances ranged from 0 (MN06, MN10, MN20) to 22 percent (MN11), with MN14 (18 percent) and MN21 (16 percent) also showing high percentages of exceedances.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** About 2 percent of all chloride samples in the watershed exceeded this threshold, and 76 percent of all reaches had at least one sample exceeding it. For reaches with balanced datasets, exceedances ranged from 0 (MN06, MN10, MN20) to 8 percent of samples (MN11), with reaches MN14 and MN21 exceeding the threshold in over 5 percent of samples.

- **Extreme Impact Level Concentration (1,400 mg/l):** 141 chloride samples (0.8 percent of all samples collected in the watershed) exceeded this concentration, and 42 percent of all reaches had at least one sample exceeding it. The threshold was exceeded in 5 percent of samples at MN21 and 4 percent at MN11.

Figure 4.41 displays the distribution of all chloride samples collected in the Menomonee River watershed from 1961 through 2022, categorized by various water quality and biological impact thresholds. Only a small fraction of samples (2 percent) fell at or below the chloride concentration considered to be the historical background in surface waters in southeastern Wisconsin. The vast majority of samples indicated potential harm to aquatic life, with 6.1 percent falling into the 10-35 mg/l range where the onset of biological effects is observed, and an even larger 46.5 percent in the 35-120 mg/l range associated with considerable biological impacts (see Table 2.Thresholds in Chapter 2 of this Report).[106] Notably, almost 91

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[105] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

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

percent of chloride samples collected in the watershed exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State.

Notably, the Menomonee River watershed accounted for nearly 42 percent of all chronic threshold, almost 40 percent of all acute threshold, and almost 41 percent of all extreme impact threshold exceedances observed in the broader study area of the Chloride Impact Study. It should be noted that many samples exceeding the current toxicity thresholds were collected before the WDNR established the chloride toxicity standards in 2010. In addition, this watershed had significantly more chloride monitoring than any other watershed within the study area (see Table 4.3). The data does however indicate frequent exceedances of State chloride thresholds within the streams of the Menomonee River watershed.

Temporal Trends

Figure 4.42 illustrates the distribution of chloride concentrations (log scale) for all samples collected across the ten assessment reaches of the Menomonee River mainstem. Chloride data spanning 1961 through 2022 were analyzed across five time periods: 1961-1977, 1978-1986, 1987-1993, 1994-2012, and the recent period of 2013-2022. Generally, chloride concentrations increased in all mainstem reaches over the full period of record. However, reaches MN05 (Menomonee River: 12.6 to 14.5 miles), MN04 (Menomonee River: 8.4 to 12.6 miles), MN02 (Menomonee River: 1.8 to 6.3 miles), and MN01 (Menomonee River: 0 to 1.8 miles) initially showed a decrease in median chloride concentrations between the earliest period (1961-1977) and the third period (1987-1993) before rising in median chloride concentration through the most recent period. Reach MN08 (Menomonee River: 20.4 to 24.2 miles) showed an initial increase from the first to the second time period, a slight decrease in the 1987-1993, and subsequent increases through the recent period. Conversely, reaches MN09 (Menomonee River: 24.8 to 27.1 miles) and MN06, sampled in only two time periods each, displayed a consistent increase in median chloride levels. Reach MN10 showed a rise in median chloride concentrations over time, but the chloride levels were low overall.

Most Menomonee River mainstem reaches exhibited wide variations between minimum and maximum chloride values across most time periods, particularly the downstream Menomonee River reaches MN02 and MN01 (see Figure 4.42). MN03 was the only reach where median chloride levels exceeded the chronic toxicity standard in any period, however, only five chloride samples were collected there. Notably, all reaches except MN10, MN 07, and MN06 had individual samples exceeding both chronic and acute toxicity thresholds in most time periods. Lower chloride concentrations were observed at the most upstream reaches (MN10 and MN09) compared to others. This is likely due to less urban land use in the upstream reaches. The furthest downstream assessment reach (MN01) can be impacted by backwater storm surge and seiche effects from Lake Michigan,[107] which can have a diluting effect on chloride concentrations and may explain the lower concentrations in reach MN01 compared to MN02 upstream.

Figure 4.43 shows chloride concentrations (log scale) over time for three major Menomonee River tributaries, all of which displayed wide chloride variability.[108] Honey Creek and Underwood Creek are among the most chloride-impacted streams in the study area, with maximum observed chloride concentrations of 6,470 mg/l and 6,400 mg/l, respectively. In Honey Creek, both chronic and acute toxicity thresholds were exceeded in all reaches and time periods where data was collected. Median chloride concentrations in Honey Creek assessment reaches MN12 and MN11 sharply increased over time, exceeding the State chronic toxicity threshold in the latest period, with the 75th percentile approaching the acute threshold. Similarly, Underwood Creek reaches MN15 and MN14 showed sharp increases in median chloride concentrations over time; MN14 increased by 157 percent from the first period (1961-1977) to the latest period (2013-2022) and approached the chronic toxicity threshold.

In contrast, the Little Menomonee River had considerably lower chloride levels. The upstream reach (MN20) showed relatively little variation and consistently remained well below chronic toxicity levels (see Figure 4.43). The downstream reach MN19 (Little Menomonee River: 0 to 7.3 miles) exhibited more variability, with most measurements below the chronic threshold, but both chronic and acute levels were exceeded in each time period, including a maximum of 4,190 mg/l in the most recent period. Median chloride in the upstream reach (MN20) increased from 36 mg/l (1961-1977) to 54 mg/l (2013-2022), while the downstream reach (MN19) slightly decreased from 75 mg/l in the earliest period to 66 mg/l in the recent period.

Map 4.61 shows statistically significant trends in both chloride and specific conductance within the Menomonee River watershed over the full period of record. For chloride, 11 assessment reaches (nearly 79

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[107] University of Wisconsin Sea Grant, "Storm Surges, Seiches and Edge Waves," www.seagrant.wisc.edu/our-work/focus-areas/coastal-processes-and-engineering/coastal-processes/storm-surges-seiches-and-edge-waves/ (date accessed: June 15, 2025)

[108] Figure 4.43 represents all chloride data collected from Honey Creek, Underwood Creek, and Little Menomonee River during the full period of record. Honey Creek assessment reaches MN13 and MN12 and Underwood Creek reach MN15 have imbalanced datasets. Imbalanced datasets may not accurately represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

percent of those with balanced datasets necessary for trend analysis) showed statistically significant increasing concentrations (indicated by the red “up” arrows), while only one reach (MN19) exhibited a statistically significant decreasing trend (dark green “down” arrow). Table 4.4 provides the slope (mg/l/year), sampling period, and coefficient of determination (R^2) values for these chloride trends. The largest increasing chloride trend for the full period of record in the Menomonee River watershed was 6.7 mg/l per year at Honey Creek reach MN 11. Regarding specific conductance, 10 reaches (63 percent of those with balanced datasets) had statistically significant increasing trends (orange “up” arrows), and no reaches showed a statistically significant decreasing trend. It is worth noting that nine reaches with increasing chloride concentrations also displayed increasing trends for specific conductance.

Seasonal Trends

Figure 4.44 illustrates seasonal chloride concentration patterns in seven Menomonee River mainstem assessment reaches. The box plots in the figure show the distribution of chloride levels across winter, spring, summer, and fall for samples collected at balanced assessment reaches over the full period of record. While the scale of the y-axis on the figure varies between reaches to accommodate the range of chloride measurements, a general seasonal trend is apparent across most reaches. Winter typically shows the highest median and peak chloride concentrations, likely due to deicing practices, with slightly less elevated levels persisting into spring from continued deicing and snowmelt (particularly evident in downstream reaches MN01, MN02, MN04 and MN05). Summer and fall generally exhibit the lowest chloride concentrations, though the relative order between these two seasons varies between reaches.

Upstream Menomonee River mainstem reaches MN06, MN08, an MN10 show less pronounced variation between the snow-impacted seasons (winter and spring) and warmer seasons (summer and fall) compared to downstream reaches. This may reflect less urban development and therefore less deicing impact from their contributing drainage areas (particularly at MN10). Furthermore, groundwater contributions may also be influencing the observed chloride dynamics in these upstream segments. Notably, these reaches, and MN10 in particular, displayed comparatively higher median fall chloride concentrations relative to other seasons. Reach MN10 observed the highest median and maximum concentrations in the fall season. The elevated fall chloride concentrations may result from reduced streamflow commonly associated with dry seasons and droughts. During such low precipitation periods, shallow groundwater baseflow constitutes a greater proportion of the total streamflow, and this baseflow may carry slightly elevated chloride levels, potentially impacting the measured concentrations within the stream.[109]

Figure 4.45 reveals a seasonal pattern in exceedances of the Wisconsin chronic toxicity threshold (395 mg/l) for the full dataset, with most occurring in colder months. For the Menomonee River watershed this highlights the significant impact of winter deicing on chloride levels. February had the highest chronic threshold exceedance frequency (nearly 45 percent of samples), followed by January (26 percent), March (20 percent), and December (14 percent). Exceedances decreased from the high in February to a low of 1 percent in September. Despite the low summer and fall chronic exceedance rates, 205 threshold exceedances still occurred between June and November, indicating that harmful chloride levels infiltrate into the shallow aquifer and take time to flush out of the shallow groundwater system and surface water. Therefore, harmful chloride levels can occur outside of winter and early spring. Potential warmer-month chloride contributors include runoff from agricultural fertilizers, leaching of residual deicing salts, and baseflow contributions from chloride-polluted shallow groundwater aquifers.[110]

Recent Conditions (2013 Through 2022)

The analysis of recent conditions for the Menomonee River watershed used water chloride and/or specific conductance measurements collected at monitoring stations throughout the watershed from 2013 through 2022. This dataset includes 4,379 recent chloride measurements and 4,388 recent specific conductance measurements.[111]

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[109] *Kincaid, D.W. and Findlay, S.E.G.,* Sources of elevated chloride in local streams: groundwater and soils as potential reservoirs, Water, Air, and Soil Pollution*, 203: 335-342, 2009, and Dechant, L.E., Wahl, T.J., Sniadach, A.T., Thomas, R.S., Paradis, C.J., "Salt Fate and Transport on the Root River: Investigating the potential sources and pathways of chloride to surface waters," Poster presented at 46th annual meeting of the Wisconsin Section of the American Water Resources Association, 2023.*

[110] *Examples of elevated chloride concentrations during prolonged drought conditions at monitoring sites for the Chloride Impact Study are described in the "Responses to Meteorological Events" section in Chapter 3 of this Report.*

[111] *There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.*

The recent chloride dataset for the Menomonee River watershed included chloride samples across 24 assessment reaches. Only 10 of these reaches had datasets considered to be balanced.[112] Reaches with imbalanced datasets are indicated by red text in the tables discussed in this section. Five additional reaches lacked chloride data but had specific conductance data, potentially useful as a general indicator of chloride conditions.

Table 4.32 presents summary statistics (number of samples, minimum, maximum, mean, and median) for chloride and specific conductance in each Menomonee River watershed assessment reach. Map 4.62 shows median chloride concentrations for these reaches over the recent period of record. For assessment reaches with balanced datasets (identified with black circles on Map 4.62), median concentrations ranged from 50 mg/l at MN10 (Menomonee River: 27.1 to 27.8) to 400 mg/l at MN11 (Honey Creek: 0 to 3.1 miles). Across all assessment reaches (balanced and imbalanced), maximum chloride concentrations varied widely from 71 mg/l at Little Menomonee Creek reach MN22 to 6,400 mg/l at Underwood Creek reach MN14, which was the seventh-highest recent chloride concentration recorded in the entire study area. Median chloride concentrations for the recent period of record were higher than in the full period of record (1961 through 2022, see Table 4.30) for almost all assessment reaches with balanced datasets; Little Menomonee Ricer reach MN19 was the exception, with a slight decrease. For those assessment reaches with balanced recent datasets, the greatest increases in median chloride were observed at Honey Creek reach MN11 (104 percent), Menomonee River reach MN02 (83 percent), and Underwood Creek reach MN14 (57 percent). It is important to consider that the historical medians are calculated from a significantly larger dataset than the recent medians, but this result is also consistent with increased chloride concentrations and specific conductance patterns among lakes, with the highest levels found within the most recent time period throughout the study area as summarized in Chapter 5 of this Report.

Map 4.63 shows median specific conductance in the Menomonee River watershed during the recent period of record. Generally, high median specific conductance corresponded with high median chloride, though conductance often fell into the next highest color category as compared to the chloride categories (shown on Map 4.63). For reaches with balanced datasets, median specific conductance ranged from 771 μS/cm at Menomonee River reach MN10 (also had the lowest median chloride) to 2,700 μS/cm at Noyes Creek reach MN21. Across all assessment reaches (balanced and imbalanced), maximum specific conductance varied

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[112] *Criteria for a balanced dataset for the recent period of record includes: More than 10 total samples, at least 10 percent or 4 samples collected in the winter season (December through February), and at least 20 percent of samples collected in either summer or fall.*

greatly from 10 μS/cm at MN18 (Dousman Ditch: 0 to 1.6 miles) to 16,100 μS/cm at Underwood Creek reach MN14 (also had the highest maximum chloride) (see Table 4.32). Five reaches with no recent chloride data (MN06, MN07, MN09, MN28, and MN31) exhibited elevated median specific conductance (1,095 – 1,310 μS/cm), but only the Menomonee River reach MN09 dataset was balanced.

Table 4.33 presents the percentage of recent period chloride samples exceeding the various water quality and biological impact thresholds established in Chapter 2 of this Report for each assessment reach in the Menomonee River watershed (see Table 2.Thresholds). Examining all assessment reaches in the watershed revealed the following[113]:

- **Historical Background Concentration (10 mg/l):** Exceeded by 100 percent of recent samples in all assessment reaches with chloride data.

- **Conservative Lower Impact Concentration (35 mg/l):[114]** More than 98 percent of recent chloride samples in the watershed exceeded this threshold and all assessment reaches had a significant portion of samples surpassing it. Considering reaches with balanced datasets, exceedance frequencies ranged from 89 percent (MN10) to 100 percent (MN02, MN08, and MN29).

- **Canadian Chronic Toxicity Threshold (120 mg/l):[115]** Almost 62 percent of recent samples in the watershed exceeded this threshold and every assessment reach had at least one sample exceeding this guideline except for Menomonee River reach MN10 and Little Menomonee River reach MN20. When considering only reaches with balanced datasets, exceedance frequencies ranged from 0 percent (MN10) to almost 94 percent at Underwood Creek reach MN14.

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[113] *Assessment reaches with imbalanced datasets are shown in red text in Table 4.31. Caution should be used when interpreting percentages of exceedances for imbalanced datasets.*

[114] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[115] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

- **USEPA Chronic Toxicity Threshold (230 mg/l):[116]** Approximately 31 percent of recent chloride samples in the watershed exceeded this threshold, and all reaches except Menomonee River reach MN10 and Little Menomonee River reach MN20 had at least one recent sample exceeding it. Considering only reaches with balanced datasets the highest percentage of exceedances occurred at Underwood Creek reach MN14 and Honey Creek reach MN11 (approximately 81 percent each). Five other balanced reaches (MN02, MN05, MN04, MN01, and MN29)[117] had exceedance percentages above 20 percent.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Over 13 percent of recent samples in the watershed exceeded this threshold, and nearly 88 percent of all assessment reaches had at least one sample exceeding it. When considering only the reaches with balanced datasets, exceedances ranged from 0 (MN10) to 51.5 percent at Honey Creek reach MN11, with MN14 (nearly 41 percent) and MN02 (nearly 16 percent) also showing high percent exceedances. Notably, the Menomonee watershed accounted for approximately 35 percent of all recent chronic toxicity threshold exceedances within the broader Chloride Impact Study area.[118]

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** Almost 4 percent of recent samples in the watershed exceeded this threshold, and over 83 percent of all assessment reaches had at least one sample exceeding it. When considering only the reaches with balanced datasets, exceedances ranged from 0 (MN10) to 21 percent (MN11), with MN14 and MN02 exceeding the threshold in over 5 percent of samples. Notably, the Menomonee watershed accounted for approximately 32 percent of all recent chronic toxicity threshold exceedances within the broader Chloride Impact Study area.[119]

- **Extreme Impact Level Concentration (1,400 mg/l):** 43 recent chloride samples in the watershed (almost 1 percent of recent watershed samples) exceeded this concentration, and nearly 46 percent of all assessment reaches had at least one sample exceeding it. For reaches with balanced datasets, the highest exceedance frequencies occurred at MN11 (nearly 10 percent) and MN14 (3 percent).

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[116] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

[117] *Assessment reaches are listed here in order of highest percentage of exceedances to lowest percentage of exceedance.*

[118] *It is important to note, however, that the Menomonee River watershed had substantially more recent chloride monitoring data compared to other watersheds in the study.*

[119] Ibid.

Figure 4.46 illustrates the distribution of chloride samples in the Menomonee River watershed from 2013-2022, categorized by various water quality and biological impact thresholds. No recent samples fell at or below the chloride concentration considered to be the historical background in surface waters in southeastern Wisconsin. The vast majority of samples indicated potential harm to aquatic life, with 1.6 percent falling into the 10-35 mg/l range where the onset of biological effects are observed, and nearly 37 percent in the 35-120 mg/l range associated with considerable biological impacts (see Table 2.Thresholds in Chapter 2 of this Report).[120] Notably, almost 87 percent of all chloride samples collected in the watershed exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State.

Ten streams in the Menomonee River watershed were listed in 2024 as chloride-impaired under Section 303(d) of the Clean Water Act. Three of these streams are listed for chronic chloride toxicity, and seven are listed for both chronic and acute toxicity. These 303(d) impaired streams encompass 21 of the 33 (64 percent) assessment reaches analyzed in this watershed (see Table 4.34). Specifically, 18 of these reaches are within streams with both chronic and acute impairments, and three are within chronically impaired streams (see Map 4.64).[121] Additional assessment reaches had observed maximum chloride concentrations above the chronic and acute toxicity thresholds (MN17, MN24, MN27, and MN29)[122] during the recent period of record but the streams are not on the 303(d) list, likely due to limited datasets.[123] These four reaches are identified as "high risk" streams reaches on Map 4.64 and on Figure 4.14 in Section 4.4 of this Chapter.[124]

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

[121] *Three of the assessment reaches (MN06, MN07 and MN13) within streams listed as impaired for chronic and acute toxicity had no chloride data collected during the recent period of record.*

[122] *Assessment reaches MN17 and MN24 had recent maximum chloride concentrations well above the 1,400 mg/l extreme impact threshold.*

[123] *Assessment reaches MN17, MN24, and MN27 had recent chloride datasets that are considered imbalanced. However, reach MN17 was considered imbalanced because it did not meet the criterion for winter samples. Thus, it can be assumed that if additional winter sampling occurs on this reach, observed chloride levels would increase.*

[124] *For this Report, assessment reaches that were not listed as impaired were considered high risk for impairment if they had a chloride sample within 10 percent of the State's chronic toxicity threshold, or 355 mg/l.*

Land Use

Map 4.65 illustrates that higher recent median chloride concentrations in assessment reaches generally coincide with subbasins having a greater percentage of urban land use (indicated by red, orange, and yellow areas).[125] For instance, reaches MN11, MN14, and MN02, which exhibit the highest median chloride levels (see Table 4.32 for values), are located in predominantly urbanized subbasins. Conversely, Menomonee River reach MN10, with the watershed's lowest median chloride (50 mg/l), drains very rural subbasins. The Little Menomonee River reach MN19 is an exception; despite many of the subbasins adjacent to the reach being highly urban, it shows the second-lowest median chloride concentration in the watershed (66 mg/l), likely due to the rural upper drainage areas. While Menomonee River mainstem reaches MN01, MN02, MN04, and MN05 receive flow from very urban subbasins, they are all larger 4th-order streams with greater water volume that may dilute chloride concentrations (refer to Table 4.32).

Map 4.66 similarly suggests a relationship between elevated recent median chloride concentrations and increased road and parking lot density.[126] The assessment reaches with the highest median chloride concentrations (MN11, MN14, MN02) are associated with subbasins having some of the highest densities of these impervious surfaces in the watershed. Little Menomonee River reach MN19 again appears as an anomaly, having a relatively low median recent chloride concentration despite the subbasins directly adjacent to it having relatively high percentages of roads and parking lots. Similarly to urban land use, upstream drainage areas to MN19 have very low amounts of roads and parking lots, likely contributing to lower chloride concentrations than perhaps expected.

Map 4.67 indicates a more direct positive correlation between higher maximum chloride concentrations and greater urban land use. The highest maximum chloride levels (2,240 mg/l and greater) are found in reaches draining highly urbanized subbasins (MN14, MN11, MN19, MN24, MN21, MN18, and MN02), while the lowest maximums (113 mg/l and lower) are observed in reaches draining rural subbasins (MN22, MN10, and MN20) (see Table 4.32). Likewise, Map 4.68 shows a trend of increasing maximum chloride concentrations with increasing densities of roads and parking lots.[127]

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[125] *Map 4.65 only includes assessment reaches with balanced datasets.*

[126] *Map 4.66 only includes assessment reaches with balanced datasets.*

[127] *Map 4.67 and Map 4.68 show maximum chloride concentrations for all assessment reaches, both balanced and imbalanced datasets.*

Temporal Trends

Map 4.69 shows assessment reaches with statistically significant trends in both chloride and specific conductance within the Menomonee River watershed from 2013 through 2022 (also see Table 4.7).[128] For chloride, Honey Creek reach MN11 was the only reach in the entire study area with a statistically significant increasing trend (indicated by the red "up" arrow on Map 4.69), while five reaches (50 percent of those with balanced recent datasets) showed statistically significant decreasing trends (dark green "down" arrow). For specific conductance, only Menomonee River reach MN09 showed a statistically significant increasing trend (orange "up" arrow), while six reaches had statistically significant decreasing trends (light green "down" arrows). Notably, five reaches with decreasing chloride concentrations also displayed decreasing trends for specific conductance.

Figure 4.47 displays recent chloride samples from six Menomonee River mainstem assessment reaches with balanced datasets, ordered downstream to upstream. Statistically significant decreasing trends were observed at MN01, MN08, and MN10, indicated by downward trendlines in Figure 4.47. While the other three balanced Menomonee River mainstem reaches did not show statistically significant trends, several observations can be made:

- Seasonal patterns are evident across all balanced assessment reaches due to robust recent period sampling.

- MN01, MN02, MN04, and MN05 often exceeded the chronic toxicity threshold and occasionally the acute threshold. MN08 had significantly fewer exceedances, with two samples exceeding the chronic threshold, one of those also surpassing the acute threshold. No samples have surpassed the State's toxicity standards at MN08 since 2014.

- MN10 consistently showed chloride concentrations well below the State's toxicity thresholds and below the Canadian chronic toxicity threshold (120 mg/l).

- Though not statistically significant, chloride concentrations in MN04 and MN05 may be slightly decreasing over the recent period. However, both reaches still commonly exceeded the chronic toxicity threshold and several times the acute threshold.

[128] *Only assessment reaches with balanced recent period datasets were assessed for trends.*

- Chloride concentrations at MN02 generally remained stable over the recent period (seasonal patterns notwithstanding), however acute toxicity threshold exceedances became more frequent from 2019 through 2022. Some of these exceedances likely stem from targeted winter storm event sampling conducted by SEWRPC staff for the Chloride Impact Study.

Figure 4.48 illustrates recent period chloride samples from four major Menomonee River tributary assessment reaches with balanced datasets (2013-2022). Several observations for these major tributaries can be made:

- MN11 (Honey Creek) and MN14 (Underwood Creek) frequently exceeded both the chronic and acute toxicity thresholds during the recent period.

- MN19 (Little Menomonee River) and MN29 (Burnham Canal) also exceeded both thresholds, but much less often. Notably, MN29 has not shown exceedances since 2018.

- MN11 shows a statistically significant increasing trend, with chloride concentrations rapidly rising by an estimated 46.9 mg/l/year (see Table 4.7 for linear regression statistics).[129]

- Conversely, MN19 and MN29 exhibit statistically significant decreasing trends. MN19 was the second-largest decreasing trend in the entire Chloride Impact Study area (11.9 mg/l/year).

- The Burnham Canal (MN29), previously listed as chloride-impaired on the 303(d) list, was delisted in 2024. However, some of the decreasing trend might be due to backwater effects from exceptionally high Lake Michigan water levels in 20139 and 2020.

- Chloride concentrations at MN14 (Underwood Creek) remained generally stable over the recent period.

The observed decrease in recent chloride levels in many of the assessment reaches in the Menomonee River watershed may be due to several factors: a limited temporal dataset, winter weather patterns, annual precipitation, and the influence of historically high Lake Michigan levels during a portion of the recent

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[129] *This rapid increase at Honey Creek assessment reach MN11 is at least partially driven by targeted snow event-based chloride monitoring conducted by SEWRPC staff as part of this study.*

period. Additionally, localized reductions might also reflect a growing awareness of the negative effects of deicing salts and subsequent efforts by municipal public works departments in the watershed to minimize their application.

Seasonal Trends

Although linear regression trendlines are shown in Figure 4.47 and Figure 4.48 for those reaches in the watershed that have statistically significant trends over the entire recent period, chloride concentrations vary significantly within each year. Most assessment reaches exhibit a clear seasonal pattern: winter and early spring peaks due to deicing are followed by declines through summer and fall, repeating annually over the recent period of record. This seasonality is less pronounced in more rural reaches like Menomonee River reach MN10 and the mixed rural/urban Little Menomonee River reach MN19, potentially due to the reduced amount of impervious surfaces requiring winter deicing.

Figure 4.49 shows a clear seasonal pattern in exceedances of the Wisconsin chronic toxicity threshold concentration in the Menomonee River watershed, with the highest frequencies occurring during winter and early spring. This highlights the significant impacts of winter deicing and snowmelt, with February (49 percent of all samples collected in the month), January and March (39 percent each), and April (15 percent) showing the highest frequencies of chronic threshold level exceedances. Chronic threshold exceedances sharply decline after March, reaching a low in October (2 percent) before rising again in November (12 percent). Despite the lower summer and fall rates, 151 threshold exceedances (26 percent of all recent exceedances in the watershed) occurred from June through November, indicating harmful chloride levels are not limited to winter. Compared to the full record (see Figure 4.45), the recent period shows a higher proportion of samples have exceeded the chronic threshold in every month, suggesting a potential worsening of peak observations of chloride in the watershed. However, recent sampling that focused on high-chloride events might partially explain this trend.

Milwaukee River Watershed

The Milwaukee River watershed, spanning 701 square miles, is located in the north-central and northeastern parts of the study area. Although approximately 77 percent rural – comprising agricultural lands, wetlands, and woodlands – it also contains some of the most urbanized parts of the entire study area. For instance, the Lincoln Creek and Lower Milwaukee River subwatersheds where 98 percent and 64 percent urban, respectively, with roads and parking lots accounting for 32 percent and 29 of the land uses. Major transportation corridors, including IH 43, IH 41, USH 45, also run through the watershed (see Map A.9).

Currently, 12 active WWTPs discharge treated wastewater within the watershed, and one additional WWTP that once operated in the watershed but has since been abandoned (see Map A.10 and Table 2.2).

The Milwaukee River watershed has one of the most comprehensive chloride and specific conductance datasets in the study area, largely due to the extensive monitoring by MMSD. Chloride conditions and trends were assessed across 115 assessment reaches (see Map 4.70 and Table 4.35). The analysis utilized 11,562 chloride and 10,718 specific conductance measurements collected at 353 monitoring stations throughout the watershed from 1961 through 2022 (shown on Map 4.71).[130,131]

The availability of water quality data varied considerably among the 115 assessment reaches (see Table 4.35). Chloride sample counts per assessment reach ranged from zero to 3,053. For reaches with limited or no chloride data, specific conductance measurements, ranging from zero to 2,941, served as a general indicator of chloride conditions and trends.

Historical Conditions and Trends (1961 Through 2022)

The robustness and balance of chloride and specific conductance datasets were evaluated for each assessment reach over the full period of record. A balanced dataset requires relatively even data collection across all seasons. Table 4.36 shows the seasonal distribution of chloride and specific conductance samples for each reach. Fifteen assessment reaches had balanced chloride datasets, and 22 reaches had balanced specific conductance datasets. Reaches with imbalanced datasets are highlighted in red text in Table 4.36 and other tables in this analysis. Imbalanced datasets might not accurately represent chloride conditions in those assessment reaches and may not be comparable to other reaches.

Table 4.37 provides summary statistics—including number of samples, minimum, maximum, mean, and median—for chloride and specific conductance in each assessment reach in the Milwaukee River watershed. Map 4.72 shows median chloride concentrations for all assessment reaches over the full period of record. For reaches with balanced datasets (indicated by black circles on Map 4.72), median concentrations ranged from 19 mg/l at MK85 (East Branch Milwaukee River: 0 to 11.0 miles) to 210 mg/l at MK21 (Lincoln Creek: 0 to 5.0 miles). When considering all assessment reaches (balanced and imbalanced), maximum chloride

[130] Some monitoring stations may be at the same or similar locations as other stations; however, data was collected by a different agency, typically at different times.

[131] There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.

concentrations varied significantly, from 19 mg/l at MK76 (Melius Creek) to an extremely high 6,630 mg/l at MK113 (Gateway Drive Tributary to Ulao Creek), which was the 13th highest chloride measurement in the entire study area. On the Milwaukee River mainstem, median chloride levels for all reaches with balanced datasets remained well below the Canadian chronic toxicity threshold (120 mg/l).

Map 4.73 shows the median specific conductance in Milwaukee River watershed assessment reaches over the full period of record. Median specific conductance conditions generally reflected median chloride conditions at balanced reaches, with high conductance corresponding to high chloride. For these balanced reaches, median specific conductance ranged from 503 µS/cm at MK85 (East Branch Milwaukee River: 0 to 11 miles) to 1,271 µS/cm at Lincoln Creek reach MK21 – the same reach with the highest median chloride concentration (see Table 4.37). Across all assessment reaches (balanced and imbalanced), the maximum specific conductance measurements in the watershed varied from 564 µS/cm at MK103 (Auburn Lake Creek) to 20,645 µS/cm at MK113 (Gateway Drive Tributary to Ulao Creek) – the same reach with the highest maximum chloride concentration.

Table 4.38 summarizes the percentage of chloride samples that exceeded the various water quality and biological impact thresholds established in Chapter 2 for each assessment reach in the watershed over the full period of record (see Table 2.Thresholds). An examination of all assessment reaches in the watershed revealed the following[132]:

- **Historical Background Concentration (10 mg/l):** Nearly 99 percent of all chloride samples in the watershed exceeded this threshold. Every assessment reach had a significant portion of samples above this level, with 76 percent of all reaches showing exceedance in every single sample. For reaches with balanced datasets, exceedance frequencies were consistently high, ranging from 87.5 percent at MK85 (East Branch Milwaukee River: 0 to 11.0 miles) to 100 percent at many other balanced reaches.

[132] Assessment reaches with imbalanced datasets are shown in red text in Table 4.38. Caution should be used when interpreting percentages of exceedances for imbalanced datasets.

- **Conservative Lower Impact Concentration (35 mg/l):**[133] Approximately 84 percent of all chloride samples in the watershed exceeded this threshold. Many assessment reaches had a substantial portion of samples surpassing this concentration. However, when looking at reaches with balanced datasets, the East Branch Milwaukee River reach MK85 had no samples exceeding this concentration. For other balanced reaches, exceedance frequencies ranged from about 26 percent at MK71 (Stony Creek) to 100 percent at MK40 (Cedar Creek: 20.7 to 21.2 miles).

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[134] Approximately 15 percent of all samples in the watershed exceeded this guideline concentration At least one sample exceeded this threshold at 51 percent of assessment reaches. For reaches with balanced datasets, exceedance frequencies ranged from 0 percent (at MK71,MK85, and MK96) to nearly 74 percent at MK24 (Indian Creek).

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[135] About 7 percent of samples exceeded this threshold, and at least one sample exceeded it at 34 percent of all assessment reaches with chloride data. For reaches with balanced datasets, exceedance frequencies ranged from 0 percent at several locations (MK06, MK37, MK40, MN71, MK85, and MK96) to about 46 percent at MK21 (Lincoln Creek: 0 to 5.0 miles). Other high exceedance frequencies occurred at Indian Creek (MK24, 40 percent), upstream Lincoln Creek (MK22, 26 percent), and Southbranch Creek (MK 107, 30 percent).

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** A total of 290 samples (2.5 percent of all chloride samples in the watershed) exceeded this threshold. At least one sample exceeded it in about 25 percent of all reaches. For reaches with balanced datasets, exceedances ranged from 0 percent at multiple locations to 19 percent at downstream Lincoln Creek reach (MK21), with other relatively high percentages at MK24 (12 percent), MK22 (8 percent), and MK107 (8 percent).

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[133] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[134] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[135] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** A total of 100 samples (approximately 0.9 percent of all samples in the watershed) exceeded this threshold. At least one sample exceeded it in about 19 percent of all reaches. For balanced reaches, exceedances ranged from 0 percent at 11 reaches to almost 8 percent of samples (MK21).

- **Extreme Impact Level Concentration (1,400 mg/l):** A total of 41 chloride samples (0.4 percent of all samples collected in the watershed) exceeded this extreme concentration. At least one exceedance of this level was recorded at reaches MK21, MK22, MK24, MK33, and MK113.

Figure 4.50 displays the distribution of all chloride samples collected in the Milwaukee River watershed from 1961 through 2022, sorted by various water quality and biological impact thresholds. The data shows that 115 samples (1.3 percent of all samples) were at or below the historical background chloride concentration for Wisconsin surface waters. A large majority of samples indicated potential harm to aquatic life. Approximately 15 percent fell within the 10-35 mg/l range, where the onset of biological effects is observed. An even larger portion—68 percent—was in the 35-120 mg/l range, which is associated with significant biological impacts (see Table 2.Thresholds in Chapter 2).[136] Notably, over 96 percent of chloride samples exceeded thresholds for biological impacts or other established guidelines from agencies outside of Wisconsin, yet remained below Wisconsin's regulatory threshold of 395 mg/l.

The Milwaukee River watershed accounted for a significant portion of the total chloride toxicity threshold exceedance observed in the broader Chloride Impact Study. Specifically, it was responsible for 9.8 percent of all chronic, 10.7 percent of all acute, and 11.8 percent of all extreme impact threshold exceedances. It is important to note that many of these exceedances occurred before the WDNR established chloride toxicity standards in 2010. The Milwaukee River watershed had significantly more chloride monitoring than most other watersheds within the study area, making up 24.2 percent of the entire chloride dataset (see Table 4.3). Despite this, the still indicates that exceedances of the State's chloride thresholds are frequent in some of the streams within the watershed.

<u>Temporal Trends</u>

Figure 4.51 shows the distribution of chloride concentrations (on a log scale) for the 15 assessment reaches of the Milwaukee River mainstem from 1961 through 2022. The data was analyzed across five periods: 1961-1977, 1978-1986, 1987-1993, 1994-2012, and 2013-2022. Overall, chloride levels consistently rose over time

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

in all mainstem reaches with multi-period data, except for reach MK17, which saw a decrease from the 1961-1977 to the 1994-2012 periods. However, the dataset for MK17 was imbalanced and had limited winter data.

In reaches with balanced datasets (MK01, MK02, MK03, MK04, MK06, and MK10) median chloride concentrations increased considerably from the earliest period (1961-1977) to the most recent (2013-2022). Percentage increases were notable: MK01 (105 percent), MK02 (99 percent), MK03 (71 percent), MK04 (143 percent), MK06 (59 percent), and MK10 (73 percent). Despite this overall trend, chloride levels appeared to decline slightly between the 1994-2012 and 2013-2020 periods at MK02 (-1 percent), MK03 (-15 percent), MK04 (-10 percent), and MK06 (-10 percent), while increasing at MK01 (11 percent).

The data also showed several exceedances of toxicity thresholds. In the most recent period (2013-2022), several samples at MK10 exceeded the chronic toxicity threshold. At reaches MK01 and MK02, exceedances were found in both the 1994-2012 and 2013-2022 periods. Additionally, MK01 had one sample that surpassed the acute toxicity threshold.

Longitudinally, median chloride concentrations at balanced reaches during the recent period decreased steadily from upstream (MK10 at 52 mg/l) to downstream (MK01 at 82 mg/l), which correlates with the increasing urban development. It is important to note that the two furthest downstream reaches (MK01 and a portion of MK02) can be affected by backwater from Lake Michigan, which reached near-record water levels in 2020. This can have a diluting effect on chloride concentrations. Despite this, MK01 and MK02 still had the highest median chloride concentrations of all mainstem reaches.

Figure 4.52 shows chloride concentrations (on a log scale) over time for four major tributaries to the Milwaukee River.[137] Lincoln Creek is one of the most chloride-impacted streams in the study area, with maximum observed chloride concentrations reaching 4,770 mg/l (MK21) and 2,100 mg/l (MK22).

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[137] *Figure 4.52 represents all chloride data collected from Lincoln Creek, Cedar Creek, East Branch Milwaukee River, and West Branch Milwaukee River during the full period of record. Cedar Creek assessment reaches MK36, MK38, MK39, MK41, and MK44 and West Branch Milwaukee River reaches MK99 and MK100 have imbalanced datasets. Imbalanced datasets may not accurately represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.*

- Downstream Lincoln Creek (MK21): This reach exceeded both Wisconsin's chronic and acute toxicity thresholds in every period data was collected. In the most recent periods (1994-2012 and 2013-2022), nearly 20 percent of samples surpassed the chronic threshold. Median chloride concentrations increased 300 percent over time, reaching a median of 280 mg/l in the most recent period, which is above the USEPA's chronic toxicity threshold of 230 mg/l.

- Upstream Lincoln Creek (MK22): This reach also exceeded both toxicity thresholds in the 1994-2012 and 2013-2022 periods, though it was well below the thresholds in the earliest period (1961-1977). Median concentrations increased by 33 percent over time, reaching a median of 160 mg/l in the most recent period, which is above the Canadian Chronic toxicity threshold of 120 mg/l.

Chloride levels in Cedar Creek were considerably lower. All samples remained below the State's chronic and acute toxicity thresholds, and median concentrations at all reaches stayed well below 100 mg/l across all periods.

- Median concentrations at MK37, the only reach with data from every period, rose steadily by 165 percent from 1961-1977 to 2013-2022.

- Median concentrations at MK40 during the most recent period (82 mg/l) were 19 percent higher than at the downstream MK37 (69 mg/l). The higher levels at MK40 may be influenced by treated wastewater that is discharged from the Jackson Wastewater Treatment Facility just upstream of this reach.

The East and West Branch of the Milwaukee River had some of the lowest median chloride concentrations in the entire study area.

- East Branch Milwaukee River MK85 (0 to 11.0 miles): Median concentrations in this reach never exceeded 20 mg/l across all time periods with available data. This is below the conservative lower impact concentration of 35 mg/l. While concentrations increased by 78 percent over time, this only represented a modest 8 mg/l rise.

- West Branch Milwaukee River (MK96, MK99, and MK100): Median concentrations in this river remained below 50 mg/l for all time periods. At MK96, the only reach with a balanced dataset, median concentrations remained steady between 1994-2012 and 2013-2022.

Map 4.74 shows the statistically significant trends for both chloride and specific conductance within the Milwaukee River watershed over the full period of record. For chloride, nine assessment reaches (60 percent of those with balanced datasets necessary for trend analysis) showed a statistically significant increasing trend (indicated by the red "up" arrows). No reaches showed a statistically significant decreasing chloride trend. Table 4.4 provides the slope (mg/l/year), sampling period, and coefficient of determination (R^2) values for these chloride trends. The largest increasing chloride trend in the watershed was 12 mg/l/year at Southbranch Creek (MK107).

For specific conductance, ten reaches (over 45 percent of those with balanced conductance datasets) had a statistically significant increasing trend (orange "up" arrows on Map 4.74). No reaches showed a statistically significant decreasing trend. Notably, eight of the reaches with increasing chloride concentrations also had increasing trends for specific conductance, suggesting a strong correlation between the two.

Seasonal Trends

Figure 4.53 displays seasonal chloride concentration patterns in six Milwaukee River mainstem assessment reaches. The box plots show chloride levels across winter, spring, summer, and fall for balanced assessment reaches over the full period of record. The y-axis scale varies between reaches to accommodate the range of chloride measurements. Five of the six reaches had their highest median chloride concentrations in winter: MK01 (110 mg/l), MK02 (90 mg/l), MK03 (93 mg/l), MK06 (76 mg/l), and MK10 (49 mg/l).

- Fall had the highest median concentration at MK04 (70 mg/l) and the second-highest median at MK02 (77 mg/l), MK03 (88 mg/l), and MK06 (73 mg/l).

- Summer had the second-highest median concentration at MK10 (39 mg/l).

- Spring consistently had the lowest median chloride concentration at most reaches: MK02 (67 mg/l), MK03 (66 mg/l), MK04 (56 mg/l), MK06 (53 mg/l), and MK10 (34 mg/l).

These patterns might be due to several factors, including early flushing of deicing salts, continuous effluent from wastewater treatment plants, or delayed groundwater contributions of chloride that appear more strongly in summer and fall. Additionally, evaporation during drier summer and fall months can concentrate existing chloride.[138] The frequency of seasonal sampling may also influence these observed patterns.

Figure 4.54 reveals a clear seasonal pattern in exceedances of the Wisconsin chronic toxicity threshold (395 mg/l) for the full dataset. The vast majority of exceedances occurred in colder months. Although 290 samples in the watershed exceeded this threshold, they only accounted for 2.5 percent of all watershed samples, which highlights the significant impact of winter deicing. February had the highest chronic threshold exceedance frequency (18.6 percent), followed by January (10.7 percent), March (7.4 percent), and December (5.7 percent). Exceedances decreased from the high in February to a low in October, when no exceedances were recorded. This indicates that while some rural reaches may have elevated chloride levels in late summer and early fall relative to concentrations during other months of the year (as described in the previous paragraph), these concentrations rarely reach the State's toxicity thresholds. However, there were 26 instances where chloride samples surpassed the chronic threshold during June through November, indicating that harmful chloride levels were not exclusive to winter and spring.

Recent Conditions (2013 Through 2022)

The analysis of recent conditions for the Milwaukee River watershed used water chloride and/or specific conductance measurements collected at monitoring stations throughout the watershed from 2013 through 2022. This dataset includes 4,856 recent chloride samples and 5,695 recent specific conductance measurements.[139]

The recent chloride dataset included chloride samples at 39 of the 115 assessment reaches in the watershed, of which 21 had datasets considered to be balanced.[140] Reaches with imbalanced datasets are indicated by red text in the tables discussed in this section. An additional 65 reaches lacked chloride data, but had specific conductance data, potentially useful as a general indicator of chloride conditions.

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[138] Examples of elevated chloride concentrations during prolonged drought conditions at monitoring sites in the Chloride Impact Study area are described in the "Responses to Meteorological Events" section in Chapter 3 of this Report.

[139] There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.

[140] Criteria for a balanced dataset for the recent period of record includes: More than 10 total samples, at least 10 percent or 4 samples collected in the winter season (December through February), and at least 20 percent of samples collected in either summer or fall.

Table 4.39 provides summary statistics for chloride and specific conductance in each Milwaukee River watershed assessment reach. Map 4.75 displays median chloride concentrations for these reaches over the recent period of record. For assessment reaches with balanced datasets (indicated by black circles on Map 4.75), median concentrations ranged from 19 mg/l at MK85 (East Branch Milwaukee River) to 546 mg/l at MK113 (Gateway Tributary to Ulao Creek). Across all assessment reaches (balanced and imbalanced), maximum chloride concentrations varied widely from 25 mg/l again at MK85 to an extremely high 6,630 mg/l at MK113, which was the sixth-highest recent chloride concentration recorded in the entire study area.

Median chloride concentrations for the recent period of record were the same or higher than in the full period of record (1961-2022, see Table 4.30) for almost all assessment reaches with balanced datasets. The only exceptions were a slight decrease at Milwaukee River mainstem reach MK03 and West Branch Milwaukee River reach MK96. Among assessment reaches with balanced datasets, the greatest increases in median chloride (approximately 33 percent each) were observed at Milwaukee River mainstem reach MK10, Lincoln Creek reach MK21, and Cedar Creek reach MK37. While historical medians were calculated from a much larger dataset, these results align with findings in Chapter 5, which show that the highest chloride and specific conductance levels among lakes within the study area were found during the most recent time period.

Map 4.76 shows median specific conductance measurements in the Milwaukee River watershed during the recent period of record. Generally, high median specific conductance corresponded with high median chloride, though the color categories often differed slightly between the two maps (see Map 4.76). For reaches with balanced datasets, median specific conductance ranged from 597 mg/l at MK34 (Ulao Creek: 5.3 to 6.2 miles) to 2,200 μS/cm at MK25 (Brown Deer Creek). Across all assessment reaches (balanced and imbalanced), maximum specific conductance varied greatly, from 564 μS/cm at MK103 (Auburn Lake Creek) to and extremely high 20,645 at MK113 (Gateway Drive Tributary to Ulao Creek), which also had the highest maximum recent chloride concentration (see Table 4.39).

Twelve reaches—MK07, MK29, MK27, MK28, MK43, MK48, MK49, MK53, MK58, MK62, MK79, and MK110—had no recent chloride data but did have balanced specific conductance datasets. These reaches all showed relatively low to moderate specific conductance levels, which may provide a general indication of chloride conditions.

Table 4.40 presents the percentage of chloride samples from the recent period that exceeded various water quality and biological impact thresholds (see Table 2.Thresholds). An analysis of all assessment reaches in the watershed revealed the following:[141]

- **Historical Background Concentration (10 mg/l):** More than 99 percent of recent samples exceeded this threshold. All reaches with chloride data, except for Lincoln Creek reach MK21 (99 percent) and West Branch Milwaukee River reach MK100 (86 percent), had 100 percent of samples surpass this level

- **Conservative Lower Impact Concentration (35 mg/l):[142]** Approximately 91 percent of recent samples in the watershed exceeded this threshold. Most assessment reaches had a significant portion of samples surpassing it, though three reaches (MK69, MK85, and MK101) never exceeded this concentration. For reaches with balanced datasets, exceedance frequencies ranged from 0 percent at MK85 to 100 percent at MK40, MK107, MK111, and MK113.

- **Canadian Chronic Toxicity Threshold (120 mg/l):[143]** About 16 percent of recent samples in the watershed exceeded this threshold. Notably, 20 percent of all reaches had 100 percent of samples exceed this concentration, while nearly 36 never surpassed it. For balanced datasets, exceedance frequencies ranged from 0 percent (at MK37, MK65, MK71, MK85, MK96, and MK100) to 100 percent at MK111 (Helm's Creek Tributary to Ulao Creek).

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[141] Assessment reaches with imbalanced datasets are shown in red text in Table 4.40. Caution should be used when interpreting percentages of exceedances for imbalanced datasets.

[142] See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.

[143] The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[144] Approximately 7 percent of recent samples in the watershed exceeded this threshold. For reaches with balanced datasets, exceedance frequencies ranged from 0 percent at nine different reaches to 91.7 percent (MK113).

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Almost 4 percent of recent samples exceeded this threshold, with nearly 44 percent of all reaches having at least one exceedance. In reaches with balanced datasets, exceedances ranged from 0 percent at 13 reaches to almost 67 percent at MK113. High exceedance frequencies were also seen at MK21 (29 percent), MK107 (27 percent), MK10 (13 percent), and MK33 (12 percent).

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** A total of 64 recent samples (1.3 percent) in the watershed exceeded this threshold, and nearly 36 percent of all reaches with chloride data had at least one exceedance. For balanced datasets, the highest exceedance rate was 33 percent at MK113.

- **Extreme Impact Level Concentration (1,400 mg/l):** A total of 16 recent samples (about 0.3 percent of recent watershed samples) exceeded this concentration, with at least one exceedance occurring in about 10 percent of all reaches. For balanced datasets, the highest exceedance frequency was nearly 17 percent at MK113.

Figure 4.55 shows the distribution of chloride samples in the Milwaukee River watershed from 2013-2022, categorized by various water quality and biological impact thresholds. According to available data, 30 recent samples (0.6 percent of all recent watershed samples) were at or below the historical background chloride concentration for surface waters in southeastern Wisconsin. The majority of samples indicated potential harm to aquatic life. Approximately 8.5 percent of samples were in the 10-35 mg/l range, where initial biological effects are observed, and a significant 74.4 percent in the 35-120 mg/l range, which is associated with considerable biological impacts (see Table 2.Thresholds in Chapter 2).[145] Notably, almost 96 percent of recent chloride samples collected in the watershed exceeded thresholds for biological impact or other established guidelines, yet remained below the State's regulatory action threshold (395 mg/l).

Eight streams in the Milwaukee River watershed were listed in 2024 as chloride-impaired under Section 303(d) of the Clean Water Act. Two of these streams are listed for chronic toxicity only, while six are listed

[144] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

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

for both chronic and acute toxicity. These impaired streams include 12 of the 115 assessment reaches in this watershed (see Table 4.41). Specifically, ten of these reaches are in streams with both chronic and acute impairments, and two are in chronically impaired streams (see Map 4.77).[146] Additionally, six assessment reaches had maximum chloride concentrations that exceeded the acute toxicity threshold during the recent period, and three more exceeded the chronic threshold. These reaches—MK01, MK52, MK55, MK84, and MK111 (acute) and MK02, MK10, and MK50 (chronic)—are not on the 303(d) list, likely due to limited data or a small number of exceedance samples. They are identified as "high risk" on Map 4.77 and on Figure 4.4.[147]

Land Use

Map 4.78 shows that the lowest recent median chloride concentrations occur in reaches located in subbasins with less urban land use (indicated by the green areas).[148] For example, reaches MK85, MK100, MK71, and MK65, have the lowest median chloride levels and are in predominately rural subbasins. In contrast, reaches with high median chloride levels, MK21 and MK107, are in very urban subbasins. However, this pattern is not universal. The Milwaukee River mainstem reaches MK01, MK02, MK03, and MK04 are located in highly urban subbasins but have relatively low median chloride concentrations. This is likely due to their large size as 5th-order streams, where a greater volume of water dilutes chloride concentrations despite significant chloride loads.

Similarly, Map 4.79 suggests a link between low recent median chloride concentrations and low road/parking lot density.[149] The reaches with the lowest median chloride concentrations (MK85, MK71, and MK65) are associated with subbasins where these impervious surfaces cover less than 10 percent of the total area. As expected, reaches with the highest densities of roads and parking lots, such as MK21 and MK107, also have elevated median chloride concentrations. However, just like with urban land use, high road density does not always lead to the highest median chloride, particularly in larger river reaches where dilution occurs.

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[146] *Three of the assessment reaches within Ulao Creek had no recent period exceedances of either the acut or chronic toxicity threshold.*

[147] *For this Report, assessment reaches that were not listed as impaired were considered high risk for impairment if they had a chloride sample within 10 percent of the State's chronic toxicity threshold, or 355 mg/l.*

[148] *Map 4.78 only includes assessment reaches with balanced datasets.*

[149] *Map 4.79 only includes assessment reaches with balanced datasets.*

Map 4.80 shows a similar correlation between higher maximum chloride concentrations and greater urban land use, even in the larger 5th-order streams. This relationship, however, is complex. Some of the highest maximum chloride levels are found in reaches draining highly urbanized subbasins, such as MK21 and MK24. Some reaches with extreme maximum chloride concentrations, like MK33 (Ulao Creek) and MK113 (Gateway Tributary to Ulao Creek), are in only moderately urbanized subbasins. A closer look reveals that these reaches are directly impacted by nearby infrastructure. MK33 runs alongside IH43, while MK113 flows directly under it. The subbasins for these streams, while not entirely urban, have large portions of their land covered in roads and parking lots, as indicated by Map 4.81. This suggests that deicing salts from the interstate and large snow piles from adjacent parking lots are likely draining directly into these streams, acting as direct conduit for dissolved chloride. While Map 4.81 shows a general trend of increasing maximum chloride with road density, high chloride levels are not exclusive to these areas. For instance, Milwaukee River mainstem reach MK10, which runs through subbasins with low road densities, still has recorded a maximum chloride concentration that significantly exceeds the State's chronic toxicity threshold.[150]

Temporal Trends

Map 4.82 shows recent median chloride concentrations and statistically significant trends for both chloride and specific conductance in the Milwaukee River watershed for balanced assessment reaches from 2013 through 2022 (also see Table 4.7). No reaches showed statistically significant increasing trends in chloride concentrations. However, three reaches (MK01, MK02, and MK33) had statistically significant decreasing trends, which are indicated by dark green downward arrows on Map 4.82. For specific conductance, four reaches (MK28, MK29, MK52, and MK110) showed a statistically significant increasing trend (orange upward arrows), while another four reaches (MK01, MK04, MK06, and MK33) showed statistically significant decreasing trends (light green downward arrows). Two reaches, MK01 and MK33, showed decreasing trends for both chloride and specific conductance.

Figure 4.56 displays recent chloride samples from seven Milwaukee River mainstem assessment reaches with balanced datasets, ordered from downstream to upstream. Downward trendlines on the figure show slight, but statistically significant decreasing trends at MK01 (-1.9 mg/l per year) and MK02 (-1.2 mg/l per year) (see Table 4.7). The other five balanced reaches did not show statistically significant trends, but several other observations about recent chloride conditions can be made:

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[150] Map 4.80 and Map 4.81 show maximum chloride concentrations for all assessment reaches, both balanced and imbalanced datasets.

- Seasonal patterns are evident across all balanced assessment reaches, though the patterns are more pronounced at some reaches.

- Chronic toxicity threshold exceedances were rare. They occurred at MK01 (6 samples), MK02 (3 samples), and MK10 (4 samples). One exceedance at MK01 also surpassed the acute toxicity threshold.

- All four exceedances at MK10 were outliers, occurring over a four-day period from January 25-28, 2020. All other samples from this reach during the recent period were below 100 mg/l. These four exceedances were collected just downstream of the Fredonia Wastewater Treatment Plant discharge location, while all other samples in this reach were collected much further downstream.

Figure 4.57 shows recent period chloride samples from 12 balanced assessment reaches on Milwaukee River tributary streams. The Ulao Creek reach MK33 was the only one to show a statistically significant decreasing trend. However, this trend is likely skewed by a small number of early samples and outliers, as the linear trendline fits the data poorly. While the other Milwaukee River tributary reaches did not show statistically significant trends, a few key observations can be made:

- Exceedances Wisconsin's chloride toxicity thresholds were recorded at MK21 (Lincoln Creek), MK33 (Ulao Creek), and MK107 (Southbranch Creek)

    - MK21 had frequent exceedances of both chronic and acute thresholds (29 percent of recent samples), with 10 samples surpassing the extreme impact threshold of 1,400 mg/l.

    - MK107 also had frequent chronic (27 percent) and acute (6 percent) toxicity thresholds exceedances but remained below the extreme impact threshold.

    - MK33 had less frequent exceedances, but they reached extreme levels.

- Other tributary reaches with balanced datasets showed significantly lower chloride levels.

    - All recent samples at MK37 (Cedar Creek) and MK96 (West Branch Milwaukee River) remained below 100 mg/l.

  - MK65 (North Branch Milwaukee River), MK71 (Stony Creek), and MK100 (West Branch Milwaukee River) remained below 50 mg/l.

  - MK85 (East Branch Milwaukee River) remained below 30 mg/l.

- MK21 shows clear seasonal patterns in chloride concentrations, while other tributary reaches have less pronounced seasonal trends.

<u>Seasonal Trends</u>

While Figure 4.56 and Figure 4.57 show linear trendlines for reaches with statistically significant trends over the recent period, chloride concentrations still vary significantly throughout each year. Most assessment reaches show some seasonal pattern, with levels typically peaking in winter and early spring due to deicing, then declining through summer and fall. This seasonality is less pronounced in more rural reaches, likely due to fewer impervious surfaces needing winter deicing. As discussed previously, some rural reaches even see higher concentrations in late summer and fall because lower stream flows reduce dilution. Even in these cases, however, chloride concentrations rarely elevate to Wisconsin's chronic toxicity levels.

Figure 4.58 shows a clear seasonal pattern for exceedances Wisconsin's chronic toxicity threshold concentration in the Milwaukee River watershed, with the vast majority occurring in the colder months. This highlights the significant impacts of winter deicing. February (28.5 percent), January (13.8 percent), and March (12.5 percent) had the highest frequencies of chronic threshold level exceedances. Exceedances dropped sharply after March, reaching a low in October with no exceedances. While some rural assessment reaches have higher chloride levels in late summer and early fall, concentrations rarely rise to levels exceeding the State's toxicity thresholds. That said, there were 16 instances of chloride samples surpassing the chronic threshold during the months of June through November, indicating that harmful chloride levels are not exclusive to winter and spring. Compared to the full historical record (see Figure 4.54), the recent period showed a higher or equal proportion of samples exceeding the chronic threshold in every month except July and December, suggesting a potential increase in peak chloride observations. However, this trend could be partly due to more targeted sampling of high-chloride events in recent years.

<u>Other Factors Potentially Influencing Instream Chloride Conditions</u>

The Milwaukee River watershed currently has 12 active wastewater treatment plants (WWTPs) that discharge treated wastewater. An additional facility (Thiensville) previously operated in the watershed but is now abandoned. These facilities are not designed to remove chloride ions, so any chloride entering them is discharged with the treated wastewater into nearby waterways or, less commonly, into soil or infiltration ponds, eventually reaching groundwater. Locations of active and abandoned facilities in the watershed are shown in Map A.10, and more detailed facility information is provided in Table 2.2 in Chapter 2 of this Report.

Seven of the active WWTPs discharge directly into the Milwaukee River mainstem: Campbellsport, Kewaskum, West Bend, Newburg, Fredonia, Saukville, and Grafton. Four other facilities discharge into tributaries of the Milwaukee River: Cascade (North Branch Milwaukee River); Jackson and Cedarburg (Cedar Creek); and Random Lake (Silver Creek). The Town of Scott Sanitary District is the only facility in the watershed that discharges into soil.

Pinpointing the direct impact of these WWTPs on instream chloride concentrations is challenging due to a lack of sufficient data. Most reaches downstream of the facilities had little to no chloride data. The Milwaukee River mainstem assessment reach was an exception, with a limited but balanced recent chloride dataset. Out of 31 recent samples from MK10, four (12.9 percent) taken over four consecutive days in January 2020 exceeded the Wisconsin Chronic Toxicity threshold of 395 mg/l (see Figure 4.56). These four samples were outliers compared to the rest of the data, which was at or well below 100 mg/l. While these exceedances certainly are not enough to prove an impact from the Fredonia WWTP, it is worth noting that these four specific samples were collected at a site immediately downstream of the discharge location and all other recent period samples for MK10 were collected at a monitoring site much further downstream, suggesting there could be a localized effect.

Oak Creek Watershed

The Oak Creek watershed, located in southeastern Milwaukee County, is largely urban (73.5 percent in 2015), consisting primarily of roads and parking lots (20.1 percent), medium-density residential (11.5 percent), urban unused lands (11.4 percent), and lower-density residential (9.8 percent). The watershed has experienced one of the study area's most significant increases in urban land, particularly roads and parking lots, since 1963. Nearly 6 miles of the IH 94 corridor traverses the western part of the watershed, crossing an upstream segment of Oak Creek. Additionally, a portion of the Milwaukee Mitchell International Airport lies within the watershed, draining into the Mitchell Field Drainage Ditch before reaching Oak Creek. No active WWTPs currently discharge into streams within the watershed. More details about the watershed characteristics can be found in Chapter 2 of this Report and Maps A.11 and A.12.

Chloride conditions and trends were evaluated across eight assessment reaches within the Oak Creek watershed (see Map 4.83 and Table 4.42). This analysis incorporated 3,243 chloride measurements and 5,281 specific conductance measurements, collected at 68 monitoring stations between 1964 through 2022 (see Map 4.84).[151,152,153] The number of chloride samples per assessment reach ranged from zero to 1,864 for the full period of record. For assessment reaches with limited or no chloride data, specific conductance measurements can serve as a general indicator of chloride conditions and trends. The number of specific conductance measurements per reach ranged from 21 to 3,029 for the full period of record.

Historical Conditions and Trends (1961 Through 2022)

The robustness and balance of chloride and specific conductance datasets for each assessment reach over the full period of record were evaluated using the criteria outlined previously in this Chapter. A balanced dataset requires relatively even data collection across all seasons. Table 4.43 details the seasonal distribution of chloride and specific conductance samples for each reach in the watershed.

Four assessment reaches – Oak Creek mainstem reaches OC01, OC02, and OC03, and Mitchell Field Drainage Ditch reach OC04 – met the criteria for balanced chloride datasets. Four reaches – OC01, OC02, OC03, and North Branch Oak Creek reach OC07 – had balanced specific conductance datasets. Imbalanced datasets, highlighted in red text in Table 4.43 and other tables in this analysis, are less likely to accurately reflect actual conditions and may hinder comparisons to other reaches.

Table 4.44 summarizes the chloride and specific conductance data (number of samples, minimum, mean, median, and maximum) for each assessment reach in the Oak Creek watershed. Map 4.85 displays median chloride concentrations across all reaches with available chloride data. All reaches with balanced chloride datasets (indicated by black circles on Map 4.85), exhibited elevated median chloride concentrations. For the Oak Creek mainstem, median concentrations were highest upstream at OC03 (200 mg/l) and progressively decreased to OC02 (192 mg/l) and OC01 (168 mg/l), all notably above the Canadian chronic toxicity threshold of 120 mg/l. The Mitchell Field Drainage Ditch (OC04) had a significantly higher median

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[151] Although data for this watershed was collected from 1964-2021, in this Chapter, the full period of record is consistently referred to as 1961-2022, and the recent period of record as 2013-2022, for comparability across all watersheds.

[152] There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.

[153] Some of these monitoring stations may be at the same or similar locations as others but data was collected by a different agency, typically at different times.

concentration of 663 mg/l, though it is worth noting that over 50 percent its smaller dataset of chloride samples were collected in winter. In contrast, the Oak Creek mainstem reaches had much larger datasets, but only 1.2 percent to 4.1 percent of the samples were from winter (see Table 4.43).

Maximum chloride concentrations across all reaches (balanced and imbalanced) were concerning and highly variable, ranging from 960 mg/l at OC03 to an extremely elevated 7,120 mg/l at Mitchell Field Drainage Ditch reach OC04 (see Table 4.44). Notably, reach OC05 (North Branch Oak Creek: 1.1 to 2.1 miles), despite having no winter chloride samples, recorded a maximum chloride concentration of 2,600 mg/l, exceeding the State's acute toxicity threshold of 757 mg/l by more than three times.

Map 4.86 shows specific conductance conditions in the Oak Creek watershed assessment reaches across the full period of record. Generally, these conductance levels mirrored median chloride concentrations, with higher conductance indicating higher chloride. The Oak Creek mainstem (OC01, OC02, and OC03) had elevated median specific conductance concentrations of 1,260, 1,270, and 1,390 μS/cm, respectively. However, conductance in these reaches appeared in the next highest conductance category compared to chloride categories (as shown on Map 4.86). This suggests that other dissolved salts, in addition to chloride, contribute to the elevated specific conductance levels in Oak Creek. North Branch Oak Creek reach OC07 exhibited the highest median specific conductance (1,846 μS/cm) among all reaches with balanced datasets.

Maximum specific conductance measurements, similar to maximum chloride concentrations, were concerning and highly variable across all reaches (balanced and imbalanced). They ranged from 3,571 μS/cm at North Branch Oak Creek reach OC06 to an exceptionally high 20,000 μS/cm at Mitchell Field Drainage Ditch reach OC04 (see Table 4.44). Although North Branch Oak Creek reach OC06 lacked chloride data, its elevated median specific conductance of 1,543 μS/cm suggests high concentrations of dissolved salts, including chloride. While the dataset at OC06 meets three of the four criteria for a balanced dataset, it falls short of the minimum of 15 years of data, as samples were only collected from 2012 to 2016. Nevertheless, it serves as a general indicator of chloride conditions in this reach during that time span.

Table 4.45 presents the percentage of chloride samples exceeding the various water quality and biological thresholds established in Chapter 2 of this Report for each assessment reach in the Oak Creek watershed for the full period of record (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:[154]

- **Historical Background Concentration (10 mg/l):** A significant 99.5 percent of all chloride samples in the watershed exceeded this level. All assessment reaches, except for Oak Creek mainstem reaches OC01, OC02, and OC03 (all at 99.5 percent), showed 100 percent exceedance.

- **Conservative Lower Impact Concentration (35 mg/l):[155]** 98.6 percent of all watershed samples surpassed this threshold. Again, all reaches except for Oak Creek mainstem reaches OC01 (98.7 percent), OC02 (98.4 percent), and OC03 (98.6 percent) showed 100 percent exceedance.

- **Canadian Chronic Toxicity Threshold (120 mg/l):[156]** Nearly 77 percent of all samples in the watershed exceeded this guideline, with every reach recording at least one exceedance. For reaches with balanced datasets, exceedance rates ranged from 73 percent at OC01 to nearly 96 percent at Mitchell Field Drainage Ditch reach OC04.

- **USEPA Chronic Toxicity Threshold (230 mg/l):[157]** Approximately 31 percent of all watershed samples exceeded this threshold. All reaches with chloride data had a significant portion of samples surpass this level. Notably, the reaches with balanced datasets had exceedances ranging from about 26 percent at OC01 to almost 84 percent at OC04.

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[154] *Assessment reaches OC05, OC07, and OC08 had imbalanced chloride datasets for the full period of record and OC06 lacked chloride data.*

[155] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[156] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[157] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Approximately 10.8 percent of all watershed samples surpassed this threshold. Every reach with chloride data recorded at least one exceedance. For balanced datasets, exceedance rates of this threshold ranged from nearly 9 percent of samples at OC01 to 67 percent at OC04.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** A total of 97 chloride samples (about 3 percent of all samples) in the watershed exceed this acute toxicity threshold. For balanced datasets, exceedance rates of this threshold ranged from nearly 2.2 percent of samples at OC01 to almost 43 percent at OC04.

- **Extreme Impact Level Concentration (1,400 mg/l):** 27 chloride samples (0.8 percent) collected in the watershed exceeded this concentration. Notably, almost 22 percent of samples collected at Mitchell Field Drainage Ditch reach OC04 exceeded this extreme threshold.

Figure 4.59 presents the distribution of the 3,243 chloride samples collected within the Oak Creek watershed during the full period of record, categorized by various water quality and biological impact thresholds. (see Table 2.Thresholds in Chapter 2 of this Report).[158] Only 0.5 percent of samples were at or below the historical background chloride concentration of 10 mg/l for southeastern Wisconsin surface waters. Compared to some other watersheds, a smaller proportion of samples (0.9 percent) fell within the 10-35 mg/l range, which is indicative of the onset of biological effects. However, 22 percent of samples were in the 35-120 mg/l range, associated with considerable biological impacts. The largest proportion of samples (45.7 percent) exceeded the Canadian chronic toxicity threshold, falling into the 120-230 mg/l range, yet remained below the USEPA chronic threshold. The vast majority (89 percent) of chloride samples collected in the watershed exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State (395 mg/l).

While the Oak Creek watershed accounted for 6.8 percent of the total chloride samples collected in the study area during the full period of record, the watershed accounted for a disproportionately higher percentage of exceedances. Specifically, the watershed contributed 11.8 percent of the study area's total chronic chloride threshold exceedances and 10.4 percent of acute chloride threshold exceedances. Within the Oak Creek watershed itself, 351 chloride samples (10.8 percent) surpassed the Wisconsin's chronic

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

toxicity threshold of 395 mg/l, and 97 samples (3.0 percent) exceeded the acute toxicity threshold of 757 mg/l.

Temporal Trends

The top series of box plots in Figure 4.60 presents the distribution of chloride concentrations (on a log scale) for the mainstem Oak Creek reaches OC03 (upstream), OC02, and OC01 (downstream) across five time periods 1961-1977, 1978-1986, 1987-1993, 1994-2012, and 2013-2022. All three reaches possess balanced datasets for the full period of record, however OC03 did not have any chloride data for the first period.

Figure 4.60 illustrates significant increases in chloride concentrations across all Oak Creek mainstem assessment reaches (OC01, OC02, and OC3) from 1961 to 2022. Median chloride concentrations rose substantially from the first period to the most recent period: 95 percent at OC03, 135 percent at OC02, and 229 percent at OC01. These increases align with considerable watershed urbanization, as urban land use expanded 57 percent in OC03, 34 percent in OC02, and 24 percent in OC01 between 1963 and 2020 (see Map 2.5 in Chapter 2 of this Report).

The earliest period (1961-1977) exhibited the lowest median chloride levels when the watershed was predominantly agricultural, with OC01 at 82 mg/l and OC02 at 136 mg/l. A notable, but temporary, decrease in median chloride was observed from 1978-1986 to 1987-1993, with OC03 declining by nearly 20 percent and OC02 by 7.5 percent, while OC01 remained stable. However, from 1987-1993 onward, all mainstem Oak Creek reaches showed a consistent increase in chloride. The most substantial rise in median concentrations occurred between 1994-2012 and 2013-2022, with increases of 87 percent for OC03, 55 percent for OC02, and 46 percent for OC01. Critically, by the 2013-2022 period, median chloride concentrations at all three mainstem reaches exceeded the USEPA chronic toxicity threshold of 230 mg/l. The Wisconsin chronic toxicity threshold was surpassed across all Oak Creek mainstem reaches in most time periods. Furthermore, the acute toxicity threshold was exceeded in all reaches during the 1994-2012 and 2013-2022 periods. All reaches consistently show a wide range in chloride concentrations, with steep peaks likely caused by deicing operations and low concentrations likely due to dilution events caused by snow melt or rain events. The highest chloride concentrations were observed in the most recent 2013-2022 period for OC02 and OC01, while the maximum concentration for OC03 was slightly higher in the 1994-2012 period.

The middle panel of Figure 4.60 illustrates the chloride concentrations in the Mitchell Field Drainage Ditch (OC04). Although the dataset for this reach is balanced, data was only available for two time periods, 1994-2012 and 2013-2022. A significant increase in chloride concentrations was observed between the two periods. The median chloride concentration rose from 270 mg/l in 1994-2012 to 716 mg/l in 2013-2022. This latter median value is well above the Wisconsin chronic toxicity threshold (395 mg/l) and approaches the acute threshold (757 mg/l). Both periods show a wide range of chloride values, indicating high variability. The chronic toxicity threshold was frequently exceeded in the 1994-2012 period, and the acute toxicity threshold was surpassed in nearly half of the samples during the 2013-2022 period.

The lower panel of Figure 4.60 displays chloride distributions for the North Branch Oak Creek's upstream (OC07) and downstream (OC05) assessment reaches. Both reaches have imbalanced chloride datasets, which may not accurately represent conditions due to small sample sizes and uneven seasonal sampling. For OC07, median concentrations increased dramatically from 75 mg/l in 1961-1977 to 1,221 mg/l in 2013-2022. In the 2013-2022 period, every sample in this reach exceeded the State's acute toxicity threshold. However, due to very limited sample sizes (three samples in 1961-1977 and two in 2013-2022), comprehensive conclusions beyond the presence of extremely high chloride levels cannot be made for OC07. For the downstream reach OC05, samples were collected in 1987-1993, 1994-2012, and 2013-2022. Median concentrations rose from 54 mg/l in the 1987-1993 period to 262 mg/l in 1994-2012 and 260 mg/l in 2013-2022. Wide ranges in chloride concentrations were observed in the two later periods, with the 2013-2022 period showing three exceedances of the chronic toxicity threshold and one of the acute threshold. Similar to reach OC07, OC05 had a very limited dataset.

Map 4.87 shows statistically significant trends in both chloride and specific conductance within the Oak Creek watershed over the full period of record. For chloride, all four assessment reaches with balanced datasets showed statistically significant increasing trends (indicated by the red "up" arrows), while no reaches exhibited statistically significant decreasing trends. Table 4.4 provides the slope (mg/l/year), sampling period, and coefficient of determination (R^2) values for these chloride trends. The largest annual increasing trend for the full period of record in entire chloride impact study area was observed at Mitchell Field Drainage Ditch reach OC04, at an estimated 77 mg/l/year. Regarding specific conductance, three of the four reaches with balanced datasets had statistically significant increasing trends (orange "up" arrows), and no reaches showed a statistically significant decreasing trend.

Seasonal Trends

Figure 4.61 displays seasonal chloride concentration patterns in the four balanced Oak Creek watershed assessment reaches over the full period of record. The y-axis scale varies between reaches to accommodate the range of chloride measurements. Oak Creek mainstem reach OC01 and Mitchell Field Drainage Ditch reach OC04 exhibit typical seasonal patterns. Winter (December-February) shows the highest median chloride concentrations (456 mg/l for OC01 and 760 mg/l for OC04), followed by spring (240 mg/l for OC01 and 712 mg/l for OC04). Notably, the median winter concentration at OC01 exceeds the chronic toxicity threshold, and the median winter concentration for at OC04 surpasses the acute toxicity threshold, with its median spring concentration also approaching the acute threshold. Summer (June-August) and fall (September-November) in these reaches exhibit the lowest chloride concentrations and smallest concentration ranges.

Conversely, Oak Creek mainstem reaches OC02 and OC03 exhibit unconventional seasonal patterns (see Figure 4.61). Spring has the highest median chloride concentrations (280 mg/l for OC02 and 260 mg/l for OC03), with summer showing the second highest median values for each reach (186 mg/l for OC02 and 193 mg/l for OC03), both very elevated concentrations for summer sampling. OC03 notably shows its lowest median chloride concentration in winter. However, the very small proportion of winter samples (1.3 percent for OC02 and 1.2 percent for OC03) may explain some of these atypical patterns.

Figure 4.62 highlights a concerning seasonal pattern of exceedances of Wisconsin's chronic toxicity threshold (395 mg/l) across the Oak Creek watershed for the full dataset (1961-2022). The data reveals that exceedances occur most frequently in the colder months (winter and spring) and at higher frequencies than was seen in any other watershed in the broader Chloride Impact Study area. This pattern strongly suggests that winter and spring deicing operations significantly impact chloride levels in the streams of this watershed. January and February show the highest frequency of exceedances, with approximately 85 percent and 90 percent of samples, respectively, exceeding the chronic toxicity threshold. March (65 percent) and April (nearly 25 percent) also demonstrate high exceedance rates. While exceedances declined though the summer, reaching a low of 0.3 percent in October, they began to rise again in November. Even during the summer and fall, 60 chronic toxicity threshold exceedances were recorded between June and the end of November. This indicates that harmful chloride levels can infiltrate the shallow aquifer and take time to flush out of both the groundwater and surface water systems, meaning that harmful chloride levels can occur outside of winter and early spring. Potential warmer-month sources of chloride to streams in the watershed include agricultural fertilizers, the leaching of residual deicing salts, and baseflow contributions from chloride-polluted shallow groundwater aquifers.[159]

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[159] *Examples of elevated chloride concentrations during prolonged drought conditions at monitoring sites for the Chloride Impact Study are described in the "Responses to Meteorological Events" section in Chapter 3 of this Report.*

Recent Conditions (2013 Through 2022)

For the recent period, the Oak Creek watershed had a somewhat limited chloride dataset, comprised of 730 samples collected from 2013-2022. The recent period specific conductance dataset was more robust, with 2,371 measurements collected from 2014-2022.[160] Seven assessment reaches had chloride data during this period. Of those, only one – Oak Creek mainstem reach OC01 – had a balanced dataset.[161] The remaining six reaches with chloride data (OC02, OC03, OC04, OC05, OC07, and OC08) had imbalanced datasets due to limited samples and/or insufficient winter sampling. There were no chloride samples collected at North Branch Oak Creek reach OC06. For those reaches that had limited or no chloride, specific conductance could be useful as a general indicator of chloride conditions. All eight assessment reaches had specific conductance data during the recent period of record, and seven (OC01, OC02, OC03, OC04, OC06, OC07, and OC08) had recent specific conductance datasets that met the criteria to be considered balanced.

Recent chloride and specific conductance data for Oak Creek assessment reaches are summarized in Table 4.46, with median chloride concentrations shown on Map 4.88. The Oak Creek mainstem reach OC01, the only reach in the watershed with a balanced recent chloride dataset, had a median chloride concentration of 270 mg/l. All assessment reaches (balanced and imbalanced) had maximum chloride concentrations exceeding Wisconsin's acute toxicity threshold of 757 mg/l, with maximum values ranging from 940 mg/l (OC03) to a high of 7,120 mg/l at the Mitchell Field Drainage Ditch (OC04) – the fifth highest chloride concentration in the entire study area. Additionally, all median chloride concentrations in the recent period were elevated compared to the full period of record (1961-2022, see Table 4.44). Reach OC01, for instance, showed an approximate 61 percent increase.

Map 4.89 and Table 4.46 both indicate elevated median specific conductance across all reaches in the Oak Creek watershed during the recent period of record. For reaches with balanced specific conductance datasets (marked with black circles on Map 4.89), median measurements ranged from 1,447 μS/cm at Oak Creek mainstem reach OC03 to 2,023 μS/cm at Mitchell Field Drainage Ditch reach OC04. Maximum specific conductance levels across all reaches (balanced and imbalanced) varied widely, from 3,460 μS/cm (OC03) to an extreme 20,000 μS/cm at OC04, which was the third highest recent measurement in the entire study

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[160] Although recent specific conductance data for this watershed was collected from 2014-2022, in this Chapter, the recent period of record is consistently referred to as 2013-2022 for comparability across all watersheds.

[161] Criteria for a balanced dataset for the recent period of record includes: more than 10 total samples, at least 10 percent or 4 samples collected in the winter season (December through February), and at least 20 percent of samples collected in either summer or fall.

area. Additionally, recent median specific conductance values were higher than those from the full record (1961-2022, see Table 4.44) for all balanced reaches, with Oak Creek mainstem reaches OC02 (21.5 percent) and OC01 (19 percent) showing the largest increases.

Table 4.47 presents the percentage of recent chloride samples exceeding the various water quality and biological thresholds, established in Chapter 2 of this Report, for each assessment reach in the Oak Creek watershed (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:[162]

- **Historical Background Concentration (10 mg/l):** All recent chloride samples in the watershed exceeded this level.

- **Conservative Lower Impact Concentration (35 mg/l):[163]** All but one chloride sample (from OC03) exceeded this concentration.

- **Canadian Chronic Toxicity Threshold (120 mg/l):[164]** Nearly 95 percent of recent samples exceeded this guideline, with at least one exceedance occurring in every reach. In the balanced Oak Creek mainstem reach OC01, over 93 percent of samples exceed the threshold.

- **USEPA Chronic Toxicity Threshold (230 mg/l):[165]** Approximately 71 percent of recent watershed samples exceeded this threshold. All reaches had significant exceedances, including 64 percent of samples in the balanced OC01 dataset.

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[162] *Only Oak Creek downstream reach OC01 had a balanced dataset for the recent period of record.*

[163] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[164] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[165] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Approximately 35 percent of recent watershed samples exceeded this threshold, with significant percentages of exceedances in every reach. The balanced OC01 reach saw 28 percent of recent samples exceed it.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** 64 recent chloride samples (about 8.8 percent of all recent samples) in the watershed exceed this threshold. All reaches had at least one exceedance, and 4.5 percent of samples in the balanced OC01 reach exceeded it.

- **Extreme Impact Level Concentration (1,400 mg/l):** 26 recent chloride samples (3.6 percent of all recent samples) exceeded this concentration. All assessment reaches except OC03 had exceedances, with 1.5 percent of samples in OC01 exceeding this extreme threshold.

Figure 4.63 displays the distribution of 730 chloride samples in the Oak Creek watershed during the recent period of record, categorized by various water quality and biological impact thresholds. No recent chloride samples fell at or below the concentration considered to be the historical background in surface waters in southeastern Wisconsin. Compared to other watersheds in the study area, the Oak Creek watershed showed a higher proportion of recent samples in more harmful ranges; for instance, 65 percent of recent samples exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from outside of Wisconsin, though they remained below the State's regulatory action level.[166] Furthermore, a significant portion of samples surpassed Wisconsin's toxicity thresholds: 35 percent exceeded the chronic toxicity threshold of 395 mg/l, and nearly 9 percent surpassed the acute toxicity threshold of 757 mg/l, the highest proportion of samples for any watershed in the Chloride Impact Study area. Based on the available data, the Oak Creek watershed accounts for a disproportionately large share of recent chloride toxicity threshold exceedances within the study area, representing 15.2 percent of chronic and 12.6 percent of acute toxicity threshold exceedances, despite contributing to less than 5 percent of the total recent chloride samples in the study area.

As of 2024, three Oak Creek watershed streams were listed as chloride-impaired under Section 303(d) of the Clean Water Act: the entire Oak Creek mainstem, the Mitchell Field Drainage Ditch, and the North Branch Oak Creek. All three were listed for both chronic and acute toxicity. These impaired stream segments include

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

all but one of the assessment reaches analyzed in this watershed (see Table 4.48 and Map 4.90).[167] Drexel Avenue Tributary reach OC08 had a maximum chloride concentration of 1,940 mg/l but was not listed on the 303(d) list, likely due to having only one sample collected during the recent period. This reach is identified as a "high risk" stream reach on Map 4.90 and on Figure 4.14 in Section 4.4 of this Chapter.[168]

Land Use

Map 4.91 and Map 4.92 illustrate that assessment reach OC01, the only reach in the watershed with a balanced dataset, runs through highly urbanized subbasins with significant road and parking lot densities. These land use characteristics likely explain the elevated recent median chloride concentration of 270 mg/l observed at OC01.

Similarly, Map 4.93 and Map 4.94 shows recent maximum chloride concentrations across all assessment reaches in the watershed (balanced and imbalanced). Almost all reaches exhibit maximum concentrations above the 1,400 mg/l extreme impact threshold. While a few subbasins traversed by these reaches have lower urbanization and road density, the majority are heavily urbanized. These heavily urbanized subbasins appear to be the primary drivers of the extreme maximum chloride concentrations found in the assessment reaches of the watershed.

Temporal Trends

Map 4.95 shows chloride and specific conductance trends in Oak Creek watershed assessment reaches from 2013 through 2022. Only reaches with balanced datasets were included in this trend analysis. During this period, no statistically significant chloride trends (increasing or decreasing) were observed for OC01, the watershed's only balanced recent chloride dataset. However, statistically significant increasing trends were found for specific conductance in four balanced reaches (as indicated by the orange "up" arrows on Map 4.95): Oak Creek mainstem reaches OC01 (29 µS/cm per year) and OC03 (69 µS/cm per year), and North Branch Oak Creek reaches OC06 (345 µS/cm per year) and OC07 (450 µS/cm per year). No statistically significant decreasing trends in specific conductance were observed.

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[167] *While assessment reach OC06 was within a segment of the North Branch Oak Creek that is listed as impaired for chronic and acute toxicity, the reach had no chloride samples collected during the recent period of record (2013-2022).*

[168] *For this Report, assessment reaches that were not listed as impaired were considered high risk for impairment if they had a chloride sample within 10 percent of the State's chronic toxicity threshold, or 355 mg/l.*

Figure 4.64 shows individual chloride samples for Oak Creek mainstem reach OC01, the only assessment reach in the watershed with a balanced recent period dataset. Throughout this period, chloride concentrations at OC01 frequently exceeded the chronic toxicity threshold and commonly the acute threshold. More frequent acute threshold exceedances were observed from 2019-2022, likely resulting from SEWRPC staff's targeted snow event sampling aimed at capturing peak chloride conditions. Despite these exceedances, concentrations at OC01 appear to have decreased slightly, though this trend was not statistically significant. Additionally, OC01 shows a clear seasonal pattern, with chloride concentrations typically rising in winter and early spring, then declining to lower levels in summer and fall each year.

Seasonal Trends

Figure 4.65 again highlights a concerning seasonal pattern of exceedances of the Wisconsin's chronic toxicity threshold (395 mg/l) in the Oak Creek watershed for the recent dataset (2013-2022). Exceedances occurred more frequently in the winter and spring, at higher rates than any other watershed in the Chloride Impact Study area. This pattern strongly suggests that winter and spring deicing operations significantly impact chloride levels in the streams of this watershed.

January and February showed the highest frequency of exceedances, with approximately 87 percent and 96 percent of samples, respectively, surpassing the chronic toxicity threshold. March (nearly 82 percent) and April (nearly 64 percent) also demonstrate high exceedance rates. While exceedances declined though the summer, reaching a low of 1.4 percent in October, they began to rise again in November. Even during the summer and fall, 56 chronic toxicity threshold exceedances were recorded between June and the end of November. This indicates that harmful chloride levels can infiltrate the shallow aquifer and take time to flush out, leading to elevated levels outside of winter and early spring. Notably, exceedances for every month in the recent period were higher than those during the full period, particularly in March, April, May, and December.

Pike River Watershed

The Pike River watershed, located in the southeastern portion of the study area in Kenosha County, is slightly more rural (54.8 percent) than urban (45.2 percent). There are currently no active WWTPs discharging to streams within the watershed, although two facilities – Somers and Sturtevant – previously discharged within the watershed before being abandoned. More details about the watershed characteristics can be found in Chapter 2 of this Report and Maps A.13 and A.14.

Chloride conditions and trends in the Pike River watershed were evaluated across 10 assessment reaches (see Map 4.96 and Table 4.49). This analysis utilized 1,114 chloride measurements and 1,308 specific conductance measurements collected at 31 monitoring stations from 1964 through 2021 (see Map 97).[169,170] The number of chloride samples per assessment reach ranged from zero to 475 for the full period of record. For assessment reaches with limited or no chloride data, specific conductance measurements can serve as a general indicator of chloride conditions and trends, however, specific conductance measurements were also limited at those assessment reaches lacking chloride data. The number of specific conductance measurements per reach ranged from one to 524.

Historical Conditions and Trends (1961 Through 2022)

The robustness and balance of chloride and specific conductance datasets for each assessment reach across the full period of record were evaluated using the criteria outlined previously in this Chapter. A balanced dataset requires relatively even data collection across all seasons. Table 4.50 details the seasonal distribution of chloride and specific conductance samples for each reach in the watershed.

Only reaches PK01 (Pike River: 0 to 4.5 miles) and PK02 (Pike River: 5.2 to 9.5 miles) met the criteria for balanced chloride and specific conductance datasets over the full period of record. Of the remaining assessment reaches, three (PK07, PK08, and PK09) had no chloride data while five reaches (PK03, PK04, PK05, PK06, and PK10) had imbalanced chloride datasets due to limited samples, short record lengths, and/or insufficient winter sampling. Reaches with imbalanced chloride or specific conductance datasets, highlighted in red text in Table 4.50 and other tables in this analysis, are less likely to accurately reflect actual conditions and may hinder comparisons to other reaches.

Table 4.51 provides summary statistics (number of samples, minimum, mean, median, and maximum) for chloride and specific conductance in each Pike River watershed assessment reach. Map 4.98 shows median chloride concentrations across all reaches with chloride data. Pike River mainstem reaches PK01 and PK02, the only reaches with balanced datasets (indicated by black circles on Map 4.98), showed elevated median chloride concentrations of 132 mg/l and 126 mg/l, respectively. Maximum chloride concentrations varied widely across all reaches (balanced and imbalanced), from 85 mg/l at PK03 (North Branch Pike River: 0 to

[169] Although data for this watershed was collected from 1964-2021, in this Chapter, the full period of record is consistently referred to as 1961-2022, and the recent period of record as 2013-2022, for comparability across all watersheds.

[170] There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.

1.9 miles) to 1,255 mg/l at Pike River reach PK01. It is important to note that most of the imbalanced reaches, as detailed in Table 4.50, had limited winter chloride data. Since chloride levels typically peak in winter, the reported median and maximum concentrations for these reaches are likely underestimated.

Map 4.99 displays specific conductance conditions in the Pike River watershed assessment reaches across the entire period of record. Generally, these conductance levels mirrored median chloride concentrations, with high conductance indicating high chloride. However, conductance often appeared in the next highest color category compared to chloride categories (as shown on Map 4.98). Similar to the chloride dataset, only Pike River reaches PK01 and PK02 had balanced specific conductance datasets for the full period of record, showing slightly elevated median values of 862 and 773 μS/cm, respectively (see Table 4.51). Across all assessment reaches (balanced and imbalanced), maximum specific conductance ranged from 1,032 μS/cm at PK09 (Unnamed tributary to the Pike River) to 3,450 μS/cm at Pike River reach PK02. While lacking chloride data, two unnamed tributaries to the South branch Pike River (PK07 and PK08) and another unnamed tributary to the Pike River (PK09) exhibited slightly elevated median specific conductance measurement, ranging from 1,032 to 1,148 μS/cm. This suggests the presence of moderate concentrations of dissolved salts, including chloride. It is important to note, however, that these reaches had only one or two conductance samples collected over the entire period, and none were taken during the winter.

Table 4.52 presents the percentage of chloride samples exceeding the various water quality and biological thresholds established in Chapter 2 of this Report for each assessment reach in the Pike River watershed for the full period of record (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:[171]

- **Historical Background Concentration (10 mg/l):** A significant 98 percent of all chloride samples in the watershed exceeded this level. All assessment reaches, except for North Branch Pike River reaches PK03 (99 percent) and PKK10 (86 percent), showed 100 percent exceedance.

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[171] All assessment reaches, with the exception of PK01 and PK02, had imbalanced chloride datasets for the full period of record.

- **Conservative Lower Impact Concentration (35 mg/l):**[172] Nearly 78 percent of all watershed samples surpassed this threshold. Most reaches had substantial exceedances, ranging from about 15 percent at PK03 to 100 percent at PK10. Notably, PK01 and PK02, the only reaches with balanced datasets, exceeded this threshold in over 95 and 81 percent of samples, respectively.

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[173] Almost 46 percent of all samples in the watershed exceeded this guideline. All reaches, except for Pike River reach PK03 and South Branch Pike River reach PK06, had at least one sample above this level. For reaches with balanced datasets, Pike River reaches PK01 and PK02 showed exceedances in 57 percent and 53 percent of samples, respectively.

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[174] Approximately 16 percent of all watershed samples exceeded this threshold. At least one sample in five of the reaches with chloride data surpassed this level; exceptions included reaches PK03 and PK06. Notably, PK01 and PK02, the only reaches with balanced datasets, each exceeded this threshold in about 19% of samples.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Roughly 3.6 percent of all watershed samples exceeded this threshold. Four of the seven reaches with chloride data had at least one sample above this level. The balanced datasets for PK01 and PK02 showed exceedances in approximately 4 and 5 percent of samples, respectively.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** Only five chloride samples (about 0.4 percent of all samples) in the watershed exceed this acute toxicity threshold. These exceedances occurred at PK01 and PK02, with less than one percent of samples at each location surpassing this level.

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[172] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[173] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[174] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

- **Extreme Impact Level Concentration (1,400 mg/l):** No chloride samples collected in the watershed exceeded this concentration.

Figure 4.66 shows the distribution of the 1,114 chloride samples collected in the Pike River watershed from 1961 through 2022, categorized by various water quality and biological impact thresholds. Only a small fraction of samples (1.8 percent) fell at or below the chloride concentration considered to be the historical background in surface waters in southeastern Wisconsin. The vast majority of chloride samples indicated potential harm to aquatic life, with 20.6 percent falling into the 10-35 mg/l range where the onset of biological effects is observed, and 31.8 percent in the 35-120 mg/l range associated with considerable biological impacts (see Table 2.Thresholds in Chapter 2 of this Report).[175] Notably, almost 95 percent of chloride samples collected in the watershed exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State (395 mg/l).

The Pike River watershed accounted for a small fraction of the total chloride exceedances within the broader Chloride Impact Study area for the full period of record: 1.4 percent of the chronic chloride threshold exceedances and 0.5 percent of the acute chloride threshold exceedances. However, this watershed's chloride dataset was relatively small compared to other watersheds in the study area. Specifically, 41 chloride samples (3.6 percent) in the watershed surpassed the State's chronic toxicity threshold of 395 mg/l, while 5 samples (0.4 percent) exceeded the acute toxicity threshold of 757 mg/l. Notably, nearly all (39 out of 41) chronic exceedances occurred in the recent period (2013-2022), with the remaining two collected in 2012.

Temporal Trends

The top series of box plots in Figure 4.67 presents the distribution of chloride concentrations (on a log scale) for the mainstem Pike River reaches PK02 (upstream) and PK01 (downstream) across three time periods: 1961-1977, 1994-2012, and 2013-2022. Both reaches possess balanced datasets for the full period of record.

A clear increasing trend in chloride concentrations is evident over time for both mainstem reaches. For PK02, the median chloride concentration rose from approximately 19 mg/l in 1961-1977 to 86 mg/l in 1994-2012, and further to 146 mg/l in the most recent period. Similarly, PK01, located downstream, also showed an increase, with median concentrations rising from 42 mg/l (1961-1977) to 100 mg/l (1994-2012), and

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

reaching a nearly identical 145 mg/l in the 2013-2022 period. While the earliest time period displayed modest variation in chloride levels, both the 1994-2012 and 2013-2022 periods exhibited greater variability. During these later periods, chloride concentrations at PK02 ranged from 12 mg/l to 1,016 mg/l, and at PK01 they ranged from 22 mg/l to 1,255 mg/l, with the maximums likely occurring due to winter deicing operations. Notably, median chloride concentrations for both PK01 and PK02 in the 2013-2022 period exceed the Canadian chronic toxicity threshold of 120 mg/l. Furthermore, a significant number of samples in the more recent periods for both reaches surpass the USEPA chronic toxicity threshold (230 mg/l) and even the Wisconsin chronic toxicity threshold (395 mg/l), with some individual samples approaching or exceeding the State's acute toxicity threshold (757 mg/l).

For the North Branch Pike river reaches PK04 (upstream) and PK03 (downstream), the distribution of chloride levels shown on Figure 4.67 are based on imbalanced datasets, that may not fully represent actual chloride conditions due to limited sample sizes or uneven distribution across years or seasons. Despite these limitations, the available data show an increasing trend in chloride concentrations over time for both reaches. For PK04, the median concentration rose from 149 mg/l in 1994-2012 to 202 mg/l in 2033-2022, with both medians exceeding the Canadian chronic toxicity threshold. PK03 had chloride data for 1961-1977 as well as 1994-2012, showing an increase in median chloride concentrations from 18 mg/l to 34 mg/l.

The South Branch Pike River reach PK06, shown on the bottom of Figure 4.67, also had an imbalanced dataset, which should be considered when interpreting the chloride concentrations shown. Chloride data for this assessment reach were available for the 1961-1977 and 1994-2012 periods. The median chloride concentration showed a modest increase from 50 mg/l to 59 mg/l over these periods. While this potentially suggests an increasing trend, the overall concentrations remain lower than those in the mainstem Pike River. The maximum chloride concentrations in PK06 reached approximately 90 mg/l in both observed time periods.

Only Pike River mainstem reaches PK01 and PK02 had sufficient data during the full period of record to analyze for long-term chloride trends. This analysis revealed a statistically significant increase in chloride concentration of 2.8 mg/l/year and 4.2 mg/l/year, indicated by the red "up" arrows on Map 4.100 (also see Table 4.4). These two Pike River reaches also showed statistically significant increases in specific conductance measurements.

Seasonal Trends

Figure 4.68 displays seasonal chloride concentration patterns for the balanced datasets for Pike River mainstem reaches PK01 and PK02 over the full period of record. The y-axis scale varies between reaches to accommodate the range of chloride measurements. For both PK01 and PK02, spring (March-May) exhibits the highest median chloride concentrations at 187 mg/l and 199 mg/l, respectively. Winter (December-February) shows slightly lower, yet still elevated, median chloride concentrations of 171 mg/l for PK01 and 174 mg/l for PK02. Spring and winter also display the largest range of chloride concentrations for both reaches. This fluctuation, from high spikes to diluted concentrations, is likely due to deicing operations and subsequent snowmelt or rain events. Conversely, summer (June-August) and fall (September-November) exhibit the lowest chloride concentrations and smallest concentration range. The lowest median concentration for PK01 occurred in summer at 48 mg/l, while the lowest median for PK02 occurred in fall at 82 mg/l. Notably, the median chloride concentrations for both reaches in spring and winter exceeded the Canadian chronic toxicity threshold (120 mg/l). Maximum concentrations during the spring at both reaches surpassed the Wisconsin chronic and acute toxicity thresholds. In winter, PK01 only exceeded the chronic threshold, while PK02 exceeded both the chronic and acute thresholds. No exceedances of the Wisconsin chloride toxicity standards occurred outside of spring and winter.

Figure 4.69 illustrates a distinct seasonal pattern in the State's chronic toxicity threshold exceedances across the watershed for the full dataset (1961-2022), with all exceedances across the watershed occurring exclusively in winter and spring. This strongly suggests that winter and spring deicing operations significantly impact chloride levels. February recorded the highest frequency of exceedances at 9.4 percent of all samples collected in that month, followed by April (9.1 percent), March (7.1 percent), and January (4.5 percent). A small number of chronic toxicity threshold exceedances extended into May. Both Figure 4.69 and Figure 4.68 indicate that waterways in this watershed are heavily impacted by chloride during spring.

Recent Conditions (2013 Through 2022)

For the recent period, the Pike River watershed had somewhat limited datasets, comprised of 743 chloride samples and 792 specific conductance samples collected from 2013-2021.[176] Five assessment reaches had chloride data during this period. Of these, only three – Pike River reaches PK01, PK02, and an unnamed

[176] *Although recent data for this watershed was collected from 2013-2021, in this Chapter, the recent period of record is consistently referred to as 2013-2022 for comparability across all watersheds.*

tributary to the Pike River (PK10) – had balanced chloride datasets.[177] The remaining two reaches with chloride data (PK04 and PK05) had imbalanced datasets due to limited samples, short record lengths, and/or insufficient winter sampling. Additionally, three other reaches – unnamed tributaries to South Branch Pike Creek (PK07 and PK08) and an unnamed tributary to the Pike River (PK09) – lacked chloride data and had very minimal specific conductance sampling.

Table 4.53 provides detailed summary statistics (number of samples, minimum, maximum, mean, and median) for recent chloride and specific conductance measurements in these assessment reaches. As shown in both Table 4.53 and Map 4.101, PK01 and PK02 had nearly identical recent median chloride concentrations of 145 mg/l and 146 mg/l, respectively. In contrast, the unnamed tributary to the Pike River (PK10) had a much lower recent median chloride concentration of 13 mg/l, the lowest recent median chloride concentration among all balanced datasets in the study area and just above the historical background concentration for surface waters in the Region (10 mg/l). Maximum chloride concentrations across all assessment reaches (balanced and imbalanced) varied widely, ranging from 290 mg/l (PK10) to 1,255 mg/l (PK01). For all assessment reaches except for PK05 and PK10, recent median chloride concentrations were moderately higher than those observed in the full period of record (see Table 4.51). Among assessment reaches with balanced recent datasets, PK02 showed the largest increase in median chloride, with a nearly 16 percent increase from the full period of record.

Map 4.102 shows median specific conductance for Pike River watershed assessment reaches during the recent period of record. Reaches with balanced specific conductance datasets (PK01, PK02, and PK10) are marked with black circles on the map. Similar to chloride concentrations, Pike River Reaches PK01 and PK02 had very similar median specific conductance levels of 899 μS/cm and 890 μS/cm, respectively. PK10, however, exhibited a higher median specific conductance measurement (732 μS/cm) that was closer to the median values of PK01 and PK02 than its median chloride concentration was, potentially indicating that dissolved salts other than chloride are influencing the conductance in that stream. Across all assessment reaches (balanced and imbalanced), maximum specific conductance ranged from 1,032 μS/cm (PK09) to 3,450 μS/cm (PK02). Three reaches lacking chloride data (PK07, PK08, PK09) showed somewhat elevated median specific conductance (1,032 to 1,148 μS/cm), though each had only one or two samples during the recent period.

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[177] *Criteria for a balanced dataset for the recent period of record includes: more than 10 total samples, at least 10 percent or 4 samples collected in the winter season (December through February), and at least 20 percent of samples collected in either summer or fall.*

Table 4.54 presents the percentage of recent chloride samples exceeding the various water quality and biological thresholds, established in Chapter 2 of this Report, for each assessment reach in the Pike River watershed (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:[178]

- **Historical Background Concentration (10 mg/l):** Almost 98 percent of all recent chloride samples in the watershed exceeded this level. All assessment reaches, except for Unnamed Tributary to the Pike River reach PK10 (84 percent), showed 100 percent exceedance.

- **Conservative Lower Impact Concentration (35 mg/l):[179]** A notable 82 percent of all recent period watershed samples surpassed this threshold. Among the reaches with balanced recent datasets (PK01, PK02, and PK10), exceedances ranged from 11 percent at PK10 to over 99 percent at PK01 (with PK02 at over 94 percent).

- **Canadian Chronic Toxicity Threshold (120 mg/l):[180]** Almost 60 percent of all recent samples in the watershed exceeded this guideline, with at least one exceedance occurring in every reach. Among reaches with balanced recent datasets, Pike River reaches PK01 and PK02 showed high exceedance rates of 67 percent and 64 percent respectively, while PK10 had a much lower exceedance rate of only 6 percent.

- **USEPA Chronic Toxicity Threshold (230 mg/l):[181]** Approximately 22 percent of all recent watershed samples exceeded this threshold. Among reaches with balanced recent datasets, Pike River reaches

[178] *Assessment reaches PK04 and PK05 had imbalanced chloride datasets for the recent period of record.*

[179] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[180] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[181] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

PK01 and PK02 again showed higher exceedance rates of 23 percent and 25 percent, while PK10 had a much lower exceedance rate of just over 1 percent.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Roughly 5.3 percent of all recent watershed samples exceeded this threshold. Three of the five reaches with recent chloride data had at least one sample above this level. The balanced datasets for PK01 and PK02 showed exceedances in approximately 6 percent of samples at each location, while PK10 had no exceedances of this threshold.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** Only five recent chloride samples (about 0.7 percent of all recent samples) in the watershed exceed this acute toxicity threshold. Two samples exceeded at PK01 and three samples exceeded at PK02.

- **Extreme Impact Level Concentration (1,400 mg/l):** No recent chloride samples collected in the watershed exceeded this concentration.

Figure 4.70 displays the distribution of 743 chloride samples in the Pike River watershed during the recent period of record, categorized by various water quality and biological impact thresholds. About 2.4 percent of recent samples collected fell at or below the chloride concentration considered to be the historical background in surface waters in southeastern Wisconsin. The significant proportion of samples from the recent record indicated potential harm to aquatic life, with nearly 10 percent falling into the 10-35 mg/l range where the onset of biological effects is observed, and 28 percent in the 35-120 mg/l range associated with considerable biological impacts. Notably, over 92 percent of chloride samples collected in the recent period of record exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State (see Table 2.Thresholds in Chapter 2 of this Report).[182]

Based on the available data, the Pike River watershed contributed to a small fraction of the recent chloride toxicity threshold exceedances within the broader Chloride Impact Study area, accounting for 2.3 percent of chronic and 1 percent of acute toxicity chloride threshold exceedances. However, this watershed's recent chloride dataset was relatively small compared to other watersheds in the study area. Approximately 5.3 percent (39 samples) of recent chloride samples in the Pike River watershed exceeded the State's chronic

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

toxicity threshold of 395 mg/l, and about 0.7 percent (5 samples) surpassed the acute toxicity threshold of 757 mg/l.

As of 2024, segments of three streams in the Pike River watershed were listed as chloride-impaired under Section 303(d) of the Clean Water Act. The North Branch Pike River and an unnamed tributary to it were listed for chronic chloride toxicity, and the lower Pike River mainstem was listed for both chronic and acute toxicity. These impaired stream segments represent 40 percent (four of the ten) of the assessment reaches analyzed in this watershed (see Table 4.55 and Map 4.103). Notably, one reach (PK05) had no recent exceedances, but two samples from 2012 surpassed the chronic threshold. Although no other assessment reaches were identified as "high risk" (see Figure 4.14), many streams in the watershed remain unmonitored for chloride.[183]

Land Use

Map 4.104 and Map 4.105 illustrate recent median chloride concentrations in Pike River watershed assessment reaches alongside urban land use percentages and road/parking lot densities within their subbasins. Generally, streams with moderate to high urban land use and greater road/parking lot density show elevated chloride levels. This pattern holds true for parts of Pike River mainstem reaches PK01 and PK02, which have elevated median chloride, even though some segments of these reaches also traverse less developed areas.

Conversely, reach PK10 exhibits the lowest recent median chloride concentration (13 mg/l) among all balanced datasets in the study area, despite its two subbasins being 44 and 89 percent urban. This unusual occurrence is likely due to PK10 traversing the perimeter of an active quarry. While quarries are categorized as urban land use in this Report, their nature lacks the typical impervious surfaces and dense urban development that can contribute to high chloride conditions. Furthermore, quarries often pump out accumulated water (from groundwater and precipitation) directly into adjacent waterways to maintain dry conditions. If this is occurring at this quarry and stream, it could be introducing cleaner water, thereby lowering chloride concentrations in assessment reach PK10.

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[183] *For this Report, assessment reaches that were not listed as impaired were considered high risk for impairment if they had a chloride sample within 10 percent of the State's chronic toxicity threshold, or 355 mg/l.*

Temporal Trends

Map 4.106 shows chloride and specific conductance trends in Pike River watershed assessment reaches from 2013 through 2022.[184] Only reach PK10 showed a statistically significant decreasing trend for chloride, estimated at 9.8 mg/l/year. This decrease in PK10 during the recent period may be linked to the adjacent quarry, which aerial photographs suggest has deepened during this period, potentially necessitating increased dewatering and thus diluting the chloride concentrations. No statistically significant trends were observed for specific conductance in any balanced reaches.

Figure 4.71 displays all chloride samples for balanced assessment reaches PK01, PK02, and PK10 over the recent period of record (2013-2022). The following are observations from the recent period chloride data for these assessment reaches:

- PK10 (Unnamed Tributary to the Pike was the only reach to display a statistically significant decreasing trend, even though the linear model fit the data poorly. Notably, PK10 had elevated chloride concentrations in spring 2013, often exceeding the Canadian chronic toxicity threshold (120 mg/l). However, after spring 2013, concentrations sharply dropped, generally staying below the conservative lower biological impact concentration (35 mg/l) and frequently near or below the historical background level of 10 mg/l. This unnamed tributary runs along the perimeter of an active quarry and may receive flow from dewatering, potentially introducing additional water and thus lowering chloride concentrations.

- While not statistically significant, chloride concentrations at PK01 and PK02 also appear to have decreased slightly over this period. These two reaches commonly exceeded the chronic toxicity threshold and occasionally surpassed the acute threshold.

- Both PK01 and PK02 also exhibited a clear seasonal pattern, with chloride concentrations typically rise to elevated levels in winter and early spring, then fall to lower levels in summer and fall each year.

Seasonal Trends

Figure 4.72 clearly shows a seasonal pattern in recent period exceedances of the State chronic toxicity threshold (395 mg/l). All watershed exceedances of this threshold occurred only during winter and spring, suggesting a significant impact from winter and spring deicing operations on instream chloride levels.

[184] *Only assessment reaches with balanced recent period datasets were assessed for trends.*

Consistent with the full period of record, recent exceedances peaked in February, accounting for 12.7 percent of all samples collected that month, followed by April (9.8 percent), March (7.9 percent) and January (5.3 percent). Also similar to the full period of record, a small number of chronic toxicity threshold exceedances in this watershed extended into May.

Rock River Watershed

Root River Watershed

The Root River watershed, located in southern Milwaukee County and middle Racine County, is a mix of urban (37.4 percent in 2015) and rural (62.6 percent) land uses. Urban areas are clustered in the northern portion of the watershed in Milwaukee and Waukesha Counties and at the mouth of the Root River mainstem in the City of Racine. Urban land uses are comprised primarily of lower density residential (11.8 percent) and roads and parking lots (10.0 percent). Rural land uses primarily include agricultural (44.4 percent) and wetlands (7.4 percent). Approximately 11 miles of the IH 94, 4 miles of IH 894, and 2 miles of the IH 43 corridors traverse the watershed. Additionally, much of the southwestern and southcentral portion of the watershed is dominated by rural land uses. Two active WWTPs currently discharge into streams within watershed at the Villages of Union Grove and Yorkville. It is important to note that the analysis conducted for this Study did not include any data collected after the City of Waukesha began returning flow to the Root River in Franklin, which began in October 2023. More details about the watershed characteristics can be found in Chapter 2 of this Report and Maps A.19 and A.20.

Chloride conditions and trends were evaluated across 23 assessment reaches within the Root River watershed (see Map 4.130 and Table 4.62). This analysis incorporated 2,232 chloride measurements and 2,645 specific conductance measurements, collected at 66 monitoring stations between 1961 through 2022 (see Map 4.131).[185,186] The number of chloride samples per assessment reach ranged from zero to 537 for the full period of record. For assessment reaches with limited or no chloride data, specific conductance measurements can serve as a general indicator of chloride conditions and trends. The number of specific conductance measurements per reach ranged from 1 to 679 for the full period of record.

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[185] *There are instances where multiple specific conductance samples were reported at the same time and location. The mean of the multiple specific conductance measurements was used in these instances.*

[186] *Some of these monitoring stations may be at the same or similar locations as others but data was collected by a different agency, typically at different times.*

Historical Conditions and Trends (1961 Through 2022)

The robustness and balance of chloride and specific conductance datasets for each assessment reach over the full period of record were evaluated using the criteria outlined previously in this Chapter. A balanced dataset requires relatively even data collection across all seasons. Table 4.63 details the seasonal distribution of chloride and specific conductance samples for each reach in the watershed.

Four assessment reaches – Root River mainstem reaches RT02, RT05, RT06, and Root River Canal reach RT13 – met the criteria for balanced chloride datasets. Five reaches – RT02, RT05, RT06, RT08, and RT13 – had balanced specific conductance datasets. Imbalanced datasets, highlighted in red text in Table 4.63 and other tables in this analysis, are less likely to accurately reflect actual conditions and may hinder comparisons to other reaches.

Table 4.64 summarizes the chloride and specific conductance data (number of samples, minimum, mean, median, and maximum) for each assessment reach in the Root River watershed. Map 4.132 displays median chloride concentrations across all reaches with available chloride data. Two reaches with balanced chloride datasets (indicated by black circles on Map 4.132), exhibited elevated median chloride concentrations (RT05 and RT06), while the other two balanced reaches (RT02 and RT13) were had moderate median concentrations. For the Root River mainstem, median chloride concentrations were highest upstream at RT06 (260 mg/l) and progressively decreased to RT02 (74 mg/l) and RT01 (82 mg/l), with the four upstream reaches above the Canadian chronic toxicity threshold of 120 mg/l. Root River Canal reach RT13 was the only reach in the Root River Canal subwatershed with a balanced dataset, and had a median chloride concentration of 99 mg/l. All of the balanced datasets for reaches within the Root River watershed had somewhat skewed distributions of chloride sampling to the summer and fall, ranging from 62 percent to 85 percent of samples collected in these seasons (see Table 4.63).[187]

Considering all assessment reaches in the watershed (balanced and imbalanced), maximum chloride concentrations were highly variable and often reaching concerning levels, ranging from 45 mg/l at East Branch Root River Canal reach RT19 to an extremely high 4,130 mg/l at Root River mainstem reach RT06 (see Table 4.64). Tributaries with high maximum chloride concentrations included Hoods Creek RT08 (531 mg/l) and Scout Lake Creek RT23 (738 mg/l). Five of the seven Root River mainstem reaches had maximum

[187] *While the Root River mainstem reaches RT05 and RT06 relatively small proportions of their datasets collected in winter (2.7 and 3.9 percent, respectively), these assessment reaches had larger datasets, thus 9 and 21 chloride samples were collected in the winter season at these reaches, respectively, meeting the criteria for a balanced dataset.*

chloride levels during that exceeded the State's acute toxicity threshold of 757 mg/l during the full period of record (1961-2022).

Map 4.133 shows specific conductance conditions in the Root River watershed assessment reaches across the full period of record. Generally, these conductance levels mirrored median chloride concentrations, with higher conductance indicating higher chloride (see Map 4.132). One major exception was for the Root River Canal, where median specific conductance fell into the next highest corresponding color category compared to median chloride levels. This may reflect other ions from the contributing drainage areas that are highly agricultural influencing conductance levels. Root River mainstem reach RT01 had a fairly low median specific conductance (798 µS/cm) while middle and upper mainstem reaches (RT03, RT04, RT05, and RT06) had somewhat elevated median specific conductance concentrations, ranging from 867 to 1,494 µS/cm. Of note, Unnamed Tributary to Crawfish Creek reach RT21 exhibited the highest median specific conductance (2,540 µS/cm) among all Root River watershed reaches, balanced and imbalanced.

Similar to maximum chloride concentrations, maximum specific conductance measurements were highly variable across all reaches (balanced and imbalanced). Measurements ranged from 719 µS/cm at Kilbournville Tributary (RT12) to an exceptionally high 12,700 µS/cm at Root River RT06 (see Table 4.64). Although the Scout Lake Inlet (RT22) lacked chloride data, its somewhat elevated maximum specific conductance levels suggest high concentrations of dissolved salts, including chloride are occasionally observed there; however the dataset was considered imbalanced due to only one year of data (1980-1981).

Table 4.65 presents the percentage of chloride samples exceeding the various water quality and biological thresholds established in Chapter 2 of this Report for each assessment reach in the Root River watershed for the full period of record (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:[188]

- **Historical Background Concentration (10 mg/l):** A significant 99.5 percent of all chloride samples in the watershed exceeded this level. All assessment reaches exceeded this concentration in all of their samples except RT02 (97.4 percent) and RT07 (99.8 percent).

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[188] *Assessment reaches for the Root River mainstem (RT02, RT05, RT06) and Root River Canal (RT13) were the only reaches that had balanced chloride datasets for the full period of record.*

- **Conservative Lower Impact Concentration (35 mg/l):** [189] Approximately 97 percent of all watershed samples surpassed this threshold. All but seven reaches exceeded this concentration in every sample. Considering balanced datasets, exceedance frequencies of this threshold ranged from 86 percent (RT02) to 97.7 percent (RT05).

- **Canadian Chronic Toxicity Threshold (120 mg/l):** [190] About 56 percent of all samples in the watershed exceeded this guideline, with all but five reaches recording at least one exceedance. For reaches with balanced datasets, exceedance rates ranged from 14 percent at Root River mainstem RT02 to about 83 percent at Root River mainstem reach RT06.

- **USEPA Chronic Toxicity Threshold (230 mg/l):** [191] Approximately 25 percent of all watershed samples exceeded this threshold. Nine of the 20 Root River assessment reaches with chloride data surpassed this level. For reaches with balanced datasets the exceedances ranged from about 2 percent at RT02 to almost 57 percent at RT06.

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Approximately 9 percent of all watershed samples surpassed this threshold. Seven of the 20 watershed assessment reaches with chloride data exceeded this threshold. For balanced datasets, exceedance rates of this threshold ranged from less than 1 percent of samples at RT02 to about 19 percent at RT06.

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** A total of 61 chloride samples (about 3 percent of all samples) in the watershed exceed this acute toxicity threshold. For balanced datasets, exceedance rates of this threshold ranged from 0 percent at RT02 to 7 percent at RT06.

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[189] *See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.*

[190] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[191] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

- **Extreme Impact Level Concentration (1,400 mg/l):** Only 15 chloride samples (0.7 percent) collected in the watershed exceeded this concentration. All exceedances of this extreme threshold occurred at Root River mainstem reaches RT06 and RT07.

Figure 4.78 presents the distribution of the 2,232 chloride samples collected within the Root River watershed during the full period of record, categorized by various water quality and biological impact thresholds. (see Table 2.Thresholds in Chapter 2 of this Report).[192] Only 0.5 percent of samples were at or below the historical background chloride concentration of 10 mg/l for southeastern Wisconsin surface waters. A slightly bigger proportion of samples (2.6 percent) fell within the 10-35 mg/l range, which is indicative of the onset of biological effects. Almost half (40.6 percent) of samples were in the 35-120 mg/l range, associated with considerable biological impacts. The next largest proportion of samples (31.5 percent) exceeded the Canadian chronic toxicity threshold, falling into the 120-230 mg/l range, yet remained below the USEPA chronic threshold. The vast majority (92 percent) of chloride samples collected in the watershed exceeded thresholds associated with biological impacts or established guidelines and regulatory thresholds from agencies outside of Wisconsin, while remaining below the threshold for potential regulatory action in the State (395 mg/l).

While the Root River watershed accounted for 4.7 percent of the total chloride samples collected in the study area during the full period of record, the watershed accounted for a slightly higher percentage of exceedances. Specifically, the watershed contributed almost 7 percent of the study area's total chronic chloride threshold exceedances, 6.5 percent of acute threshold exceedances, and 4.3 percent of exceedances of the extreme impact threshold of 1,400 mg/l. Within the Root River watershed itself, 207 chloride samples (9.3 percent of watershed samples) surpassed Wisconsin's chronic toxicity threshold, 62 samples (2.8 percent) exceeded the acute threshold, and 15 samples (0.7 percent) surpassed the extreme impact threshold.

Temporal Trends

The top series of box plots in Figure 4.79 presents the distribution of chloride concentrations (on a log scale) for the mainstem Root River reaches RT07 (upstream) to RT01 (downstream) across three of the time periods: 1961-1977, 1994-2012, and 2013-2022. Note that there is no chloride data for 1978-1993 for the Root River mainstem reaches. Only Root River mainstem reaches RT02, RT05, and RT06 possess balanced datasets for the full period of record.

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

Figure 4.79 illustrates significant increases in chloride concentrations across all Root River mainstem assessment reaches (RT01 to RT07) from 1961 to 2022. Median chloride concentrations rose substantially for each reach from its first period to the most recent period, ranging from an increase of 6 percent at RT07 to a high of 220 percent at RT06. The next highest percent increase in median chloride concentrations was at RT01 at 141 percent. Both of the remaining balanced reaches on the Root River mainstem (RT02, RT05) had median values increase 60 percent from the first time period to the most recent one. The majority of the assessment reaches on the Root River mainstem are located in largely urban parts of the watershed, thus the rise in chloride medians over time for these reaches was likely due to a combination of additional urbanization, increased use of road salt for deicing operations, and targeted sampling during winter seasons in the later time periods (for urban land use see Map 2.5 in Chapter 2 of this Report).

As mentioned above, the earliest period (1961-1977) exhibited the lowest median chloride levels, with RT02 at 69 mg/l and RT01 at 81 mg/l. The most substantial rise in median concentrations for the consecutive time period 1994-2012 to 2013-2022 occurred for RT06 (33 percent), followed by RT04 (29 percent) and RT05 (20 percent). Critically, by the 1994-2012 period, median chloride concentrations at RT06 exceeded the USEPA chronic toxicity threshold of 230 mg/l. The Wisconsin chronic toxicity threshold (395 mg/l) was surpassed for upstream Root River mainstem reaches (RT07, RT06, RT05) in most time periods. Furthermore, later time periods for these three upstream reaches showed exceedances of the acute toxicity threshold (757 mg/l). All reaches consistently show a wide range in chloride concentrations, with high values likely caused by deicing operations and low concentrations likely due to dilution events caused by snow melt or rain events. Chloride concentrations surpassed the extreme impact threshold (1,400 mg/l) in reaches RT06 and RT07.

The middle panel of Figure 4.79 illustrates the chloride concentrations in the Root River Canal (RT13) which was the only other balanced reach in the watershed. Although the dataset is balanced, data was only available for three time periods, 1961-1977, 1994-2012, and 2013-2022. A significant decrease in chloride concentrations was observed between the three periods for this reach, with median concentrations decreasing by 52 percent between 1961-1977 and 2013-2022 periods. The State's chronic and acute chloride toxicity thresholds were never exceeded on the Root River Canal. The Canal also showed a tighter range of chloride values as compared to the Root River mainstem, which may reflect the rural land uses in this portion of the Root River watershed, reducing extreme peaks.

The lower panel of Figure 4.79 displays chloride distributions for the imbalanced Hoods Creek (RT08) assessment reach. Data was only available for the 1994-2012 and 2013-2022 time periods. Median concentrations increased at this reach from 144 mg/l in 1994-2012 to 159 mg/l in 2013-2022. Notably one sample in the most recent time period (2013-2022) time period exceeded the State's chronic toxicity threshold.

Map 4.134 shows statistically significant trends in both chloride and specific conductance within the Root River watershed over the full period of record.[193] For chloride, mainstem assessment reaches RT02, RT05, and RT06 showed statistically significant increasing trends (indicated by the red "up" arrows), and one reach (Root River Canal RT13) exhibited a statistically significant decreasing trend (indicated by the dark green "down" arrows). Table 4.4 provides the slope (mg/l/year), sampling period, and coefficient of determination (R^2) values for these chloride trends. The highest increasing trend in the Root River watershed was at RT06 at an estimated 8 mg/l/year over the full period of record. Regarding specific conductance, mainstem Root River reaches RT05 and RT06 had statistically significant increasing trends (orange "up" arrows), and RT13 showed a statistically significant decreasing trend.

<u>Seasonal Trends</u>

Figure 4.80 displays seasonal chloride concentration patterns in the four balanced Root River watershed assessment reaches over the full period of record. The y-axis scale varies between reaches to accommodate the range of chloride measurements. The Root River mainstem reaches (RT02, RT05, RT060) overall exhibited typical seasonal patterns for chloride concentrations in more urban watersheds, with winter (December-February) showing the highest chloride concentrations. Notably, the median winter concentrations at RT05 (581 mg/l) exceeded the State's chronic toxicity threshold and the median winter concentration for RT06 surpassed the acute toxicity and the extreme impact thresholds. While summer and fall exhibited lower chloride conditions for the Root River mainstem reaches, the chronic toxicity threshold was still exceeded for samples in RT05 and RT06. The most downstream mainstem Root River reach (RT02) exhibit a unique pattern, with spring having the lowest median concentration (62 mg/l) and overall much lower chloride concentrations than the upstream reaches. Reach RT02 would not be influenced by Lake Michigan but likely reflects the large upstream contributing area and higher flows that dilute chloride concentrations. In contrast to the mainstem assessment reaches, the Root River Canal (RT13) observed its highest median chloride concentration in fall (190 mg/l). The effluent from the two WWTPs located upstream from RT13 may be contributing to this unusual seasonal trend by contributing to a larger proportion of the streamflow during drier months, potentially increasing chloride concentrations.

[193] *Trends analysis was conducted for balanced assessment reaches only.*

Figure 4.81 highlights a seasonal pattern of exceedances of Wisconsin's chronic toxicity threshold (395 mg/l) across the Root River watershed for the full dataset (1961-2022). The data reveals that exceedances occur most frequently in the colder months (winter and spring) and at higher frequencies as compared to several other watersheds in the broader Chloride Impact Study area. This pattern strongly suggests that winter and spring deicing operations impact chloride levels in the streams of this watershed. January, February and March show the highest frequency of exceedances, with approximately 29 percent, 38 percent, and 39 percent of samples, respectively, exceeding the chronic toxicity threshold. April (about 17 percent) also demonstrates a higher exceedance rate. While exceedances declined through the summer, reaching a low of 2.2 percent in September, a relatively sharp rise in exceedances was observed in November (9 percent), potentially indicating influences from agricultural land uses and potash fertilizer runoff after crops had been harvested. Notably, no chronic threshold exceedances were recorded in December. While the lowest percentages of exceedances occurred during the summer and fall, the watershed did record 77 chronic toxicity threshold exceedances between June and the end of November. This indicates that harmful chloride levels can infiltrate the shallow aquifer and take time to flush out of both the groundwater and surface water systems, meaning that harmful chloride levels can occur outside of winter and early spring. Potential warmer-month sources of chloride to streams in the watershed include the leaching of residual deicing salts, fertilizer runoff and drain tiles, and baseflow contributions from chloride-polluted shallow groundwater aquifers.[194]

Recent Conditions (2013 Through 2022)

For the recent period, the Root River watershed had a more limited dataset, comprised of 626 samples collected from 2013-2022. The recent period specific conductance dataset was similar, with 711 measurements collected from 2013-2022. Eleven assessment reaches had chloride data during this period. Of those, three (RT02, RT06, and RT13) had balanced datasets.[195] The remaining seven reaches with chloride data (RT01, RT04, RT05, RT07, RT08, RT10, RT18, and RT21) had imbalanced datasets due to limited samples and/or scarce winter sampling. Twelve assessment reaches had specific conductance data during the recent period of record, and four (RT02, RT05, RT06, and RT13) had recent specific conductance datasets that met the criteria to be considered balanced.

[194] *Examples of elevated chloride concentrations during prolonged drought conditions at monitoring sites for the Chloride Impact Study are described in the "Responses to Meteorological Events" section in Chapter 3 of this Report.*

[195] *Criteria for a balanced dataset for the recent period of record includes: more than 10 total samples, at least 10 percent or 4 samples collected in the winter season (December through February), and at least 20 percent of samples collected in either summer or fall.*

Recent chloride and specific conductance data for Root River assessment reaches are summarized in Table 4.66, with median chloride concentrations shown on Map 4.135. The Root River balanced reaches had a median chloride concentrations ranging from 73 mg/l (RT13) to 320 mg/l (RT06). Considering all assessment reaches with chloride data (balanced and imbalanced), five had maximum chloride concentrations exceeding Wisconsin's chronic toxicity threshold of 395 mg/l, four of which also exceeded the acute toxicity threshold of 757 mg/l. Maximum values ranging from 88 mg/l at Crawfish Creek (RT10) to an extreme high of 3,600 mg/l at balanced Root River mainstem reach RT06. Additionally, two of the three balanced reaches (RT02 and RT06) had median chloride concentrations in the recent period that were higher compared to the full period of record (1961-2022, see Table 4.64). Notably, balanced Root River Canal reach RT13 had a lower median chloride concentration in the recent period.

Map 4.136 and Table 4.66 both indicate elevated median specific conductance across most assessment reaches in the Root River watershed during the recent period of record. For reaches with balanced specific conductance datasets (marked with black circles on Map 4.136), median measurements ranged from 809 µS/cm at the Root River Canal (RT13) to 1,630 µS/cm at Root River mainstem reach RT06. Maximum specific conductance levels across all reaches (balanced and imbalanced) varied widely, from 1,170 µS/cm at RT10 to an extreme 12,300 µS/cm at Root River mainstem reach RT06.

Table 4.67 presents the percentage of recent chloride samples exceeding the various water quality and biological thresholds, established in Chapter 2 of this Report, for each assessment reach in the Root River watershed (see Table 2.Thresholds). Examining assessment reaches in the watershed revealed the following:

- **Historical Background Concentration (10 mg/l):** All recent chloride samples in the watershed exceeded this level.

- **Conservative Lower Impact Concentration (35 mg/l):**[196] About 98 percent of recent samples from all Root River reaches exceeded this concentration. For balanced reaches, the lowest percent exceedance of this concentration occurred at Root River Canal reach RT13 (89 percent).

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[196] See SEWRPC Technical Report No. 62 for discussion of studies documenting both lethal and/or sublethal effects of chloride on organisms and biological communities at this threshold and below. Impacts documented include substantial changes in composition of periphytic diatom assemblages (35 mg/l), reductions in fish diversity (33 mg/l), reduced bacteria density in biofilms (16 mg/l), and decreased reproduction and increased mortality in six Daphnia species (5 mg/l), among others.

- **Canadian Chronic Toxicity Threshold (120 mg/l):**[197] Nearly 75 percent of recent samples exceeded this guideline, with at least one exceedance occurring in all reaches except Crawfish Creek (RT10) and East Branch Root River Canal (RT18). For balanced reaches in the watershed the exceedance rate for this threshold was 18 percent (RT13), 38 percent (RT02), and 92 percent (RT06).

- **USEPA Chronic Toxicity Threshold (230 mg/l):**[198] Approximately 39 percent of recent watershed samples exceeded this threshold. For balanced reaches the exceedance rate for this threshold was 4 percent (RT13), 8 percent (RT02), and 69 percent (RT06).

- **Wisconsin Chronic Toxicity Threshold (395 mg/l):** Approximately 18 percent of recent watershed samples (111 samples) exceeded this threshold, with a significant exceedance at Root River mainstem reach RT06 (32 percent).

- **Wisconsin Acute Toxicity Threshold (757 mg/l):** 42 recent chloride samples (about 7 percent of all recent samples) in the watershed exceed this threshold. Four reaches had at least one exceedance, and 13 percent of samples in the balanced RT06 reach surpassed it.

- **Extreme Impact Level Concentration (1,400 mg/l):** 8 recent chloride samples (1 percent of all recent samples) exceeded this concentration. Only RT06 (3.6 percent) and RT07 (0.6 percent) surpassed this extreme threshold.

Figure 4.82 displays the distribution of the 626 chloride samples in the Root River watershed collected during the recent period of record, categorized by various water quality and biological impact thresholds. No recent chloride samples fell at or below the concentration considered to be the historical background in surface waters in southeastern Wisconsin. Compared to some other watersheds in the study area, the Root River watershed showed a higher proportion of recent samples in more harmful ranges. For instance, 17.7 percent of recent samples exceeded the State's chronic toxicity threshold, with 6.7 percent also exceeding the acute threshold, and 1.3 percent exceeding the extreme impact threshold (1,400 mg/l), higher exceedance rates of these three categories than any watershed in the study area other than the Kinnickinnic River and Oak Creek watersheds. Additionally, about 82 percent of recent samples exceeded thresholds

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[197] *The Canadian Council of Ministers of the Environment has established 120 mg/l as the long-term (chronic) exposure guideline for chloride in freshwater. Prolonged exposure to chloride concentrations at or above this level can pose elevated risks to aquatic life.*

[198] *This 230 mg/l concentration is also the State of Minnesota chronic toxicity threshold.*

associated with biological impacts or established guidelines and regulatory thresholds from outside of Wisconsin, though they remained below the State's regulatory action level.[199]

Based on the available data, the Root River watershed accounts for a modest share of recent chloride toxicity threshold exceedances within the study area as a whole, representing 3.7 percent of chronic toxicity threshold exceedances, 4.5 percent of acute threshold exceedances, and 2.3 percent of extreme impact threshold exceedances while accounting for about 4 percent of the total recent chloride samples in the study area.

As of 2024, only the Root River mainstem was listed as chloride-impaired under Section 303(d) of the Clean Water Act. The lower portion of the mainstem was listed for chronic toxicity, and the upper portion was listed for both chronic and acute toxicity. These impaired stream segments include six of the 23 assessment reaches analyzed in this watershed (see Table 4.68 and Map 4.137). Only a portion of the middle Root River mainstem reach RT04 was included in the 303(d) listed portion of the Root River, however the reach had a recent maximum chloride concentration of 800 mg/l. Hoods Creek reach RT08 had a recent maximum chloride concentration of 531 mg/l, but was not currently included on the 303(d) list, likely due to having only five samples collected during the recent period. Both RT04 and RT08 are identified as "high risk" stream reaches on Map 4.137 and on Figure 4.14 in Section 4.4 of this Report.[200]

Land Use

Map 4.138 and Map 4.139 show median chloride concentrations for the three assessment reaches with balanced recent chloride datasets with percent urban land use and road and parking lot densities superimposed. These maps illustrate that two of the three balanced reaches traverse highly urbanized subbasins with significant road and parking lot densities in the upper and lower portions of the watershed. These land use characteristics at least partially explain the elevated recent median chloride concentrations observed at Root River mainstem reach RT06 (320 mg/l). However, RT02 observed a moderate median concentration of 111 mg/l, potentially indicating a diluting effect on chloride concentrations in this downstream reach due to higher flows. The Root River Canal (RT13) drains highly rural subbasins with low densities of roads and parking lots, likely contributing to the relatively low median chloride concentration observed during the recent period (73 mg/l).

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

[200] For this Report, assessment reaches that were not listed as impaired were considered high risk for impairment if they had a chloride sample within 10 percent of the State's chronic toxicity threshold, or 355 mg/l.

Similarly, Map 4.140 and Map 4.141 show recent maximum chloride concentrations across all assessment reaches in the watershed (balanced and imbalanced) along with the density of urban development and roads and parking lots, respectively. Most Root River assessment reaches observed concerning maximum chloride concentrations during the recent period, except for reaches RT10, RT18, and RT21 which had very limited datasets with no winter chloride samples. All Root River mainstem assessment reaches recorded very high maximum chloride values. Two of these reaches (RT07 and RT06) exhibit maximum concentrations above the 1,400 mg/l extreme impact threshold, and are in extremely urbanized subbasins with a high density of roads and parking lots. Middle Root River mainstem reach RT04 traverses subbasins that have relatively low percentages of urban land use but still exhibited a very high maximum chloride concentration of 800 mg/l, potentially attributable to the IH 94 corridor that transects this reach. Even Root River Canal reach RT13, located in a very rural part of the watershed with very little roads and parking lots, recorded a fairly elevated maximum chloride concentration of 318 mg/l, exceeding the USEPA chronic toxicity threshold.

Temporal Trends

Figure 4.83 displays all recent chloride samples for the three Root River watershed assessment reaches with balanced recent datasets, along with three imbalanced reaches with a significant amount of data, arranged from downstream to upstream. During the recent period, no statistically significant trends (increasing or decreasing) were observed for the assessment reaches in the Root River watershed for either chloride or specific conductance. Despite the lack of statistical significance, several observations can be made:

- Seasonal patterns are evident across all balanced assessment reaches in the watershed.
- More frequent exceedances of the chronic chloride toxicity threshold occurred in upstream portions of the Root River mainstem, with exceedances increasing downstream to upstream. The most frequent exceedances of the acute threshold were observed at the most upstream reaches (RT06 and RT07).
- The recent chloride dataset for Root River Canal reach RT13 data was limited 2018-2021, and remained below the chronic toxicity threshold.

Seasonal Trends

Figure 4.84 again reveals a seasonal pattern of chronic chloride toxicity exceedances in the Root River watershed for the recent period. Exceedance frequencies peaked in January (50 percent) and March (48.5 percent), with high exceedance rates continuing into June (almost 15 percent). Although exceedance rates declined through late summer and early fall to a low in September (3 percent), a spike in exceedances was observed in November (15 percent). A total of 37 chronic toxicity threshold exceedances (3.4 percent of all recent period exceedances in the watershed) were recorded between June and the end of November. This suggests that harmful chloride levels can be delivered via rural sources in these warmer months, such as fertilizer. In addition, chloride may linger in the shallow aquifer, causing elevated concentrations long after road salt has been applied in the colder months. Notably, recent period exceedance frequencies were generally higher than the full period, particularly in January, March, and April.

Other Factors Potentially Influencing Instream Chloride Conditions

Figure 4.80 indicated that the Root River Canal (RT13) was the only stream reach with a balanced full period dataset to display significantly higher chloride concentrations in the fall (September – November) than in the winter. RT13 also observed higher chloride concentrations in summer (June – August) than spring (March – May). Available WWTP information for the watershed was assessed to determine whether effluent from these facilities may be a contributing source (in addition to agricultural fertilizers as was discussed earlier) explaining higher summer and fall chloride concentrations observed in some watershed streams.

The Root River watershed currently has two WWTPs that discharge treated wastewater to watershed streams. An additional four WWTPs previously discharged wastewater in the watershed but are now abandoned. Locations of both active and abandoned WWTPs are shown in A Map A.20, with receiving waters and other facility information provided in Table 2.2 in Chapter 2 of this Report. These WWTPs were not designed to remove chloride ions, meaning that any chloride entering the facility is discharged with the treated wastewater into nearby waterways.

The two active WWTPs in the Root River watershed include the Village of Union Grove facility, that discharges into the West Branch Root River Canal at assessment reach RT16, and the Village of Yorkville plant that discharges into Ives Grove Ditch upstream of its confluence with Hoods Creek at reach RT08. During the study period of the Chloride Impact Study (2018-2021) the average chloride concentrations in WWTP effluent from the Union Grove and Yorkville facilities was 339 mg/l and 577 mg/l, respectively. Notably, the Yorkville WWTP average chloride concentration exceeded the Wisconsin chronic toxicity threshold and the facility currently has a chloride variance permit.[201] Study period average daily discharges from the WWTPs were 1.27 million gallons per day (MGD) for the Union Grove plant and 0.08 MGD for the Yorkville plant.

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[201] *SEWRPC Technical Report No. 66, State of the Art in Chloride Management, in progress.*

USGS flow data from the Root River Canal reach RT13 (gage 04087233-Root River Canal near Franklin) indicated that average spring and fall flow during the period of 2013 and 2022 was about 22 MGD (34 cfs). Treated effluent discharge from the Union Grove WWTP accounted for about 6 percent of the flow at the stream gauge from June through November. This percentage is very small and assumes no loss to groundwater or evaporation. Unfortunately, a similar comparison for the Yorkville facility was not possible as there is not a flow gage on Hoods Creek.

Considering median chloride concentrations in the stream reaches immediately downstream of the treatment plant (RT16 and RT15), it is possible that the elevated discharge concentrations at the Union Grove facility were impacting instream concentrations at RT16 (median chloride concentration for 1961-2022 of 78 mg/l, however there was no recent period chloride data collected). Likewise, the elevated chloride concentrations from the Yorkville WWTP discharge may be impacting the concentrations at Hoods Creek reach RT08 (full period median: 144 mg/l, recent period median: 159 mg/l). However, without sufficient chloride and streamflow data, it is not possible to quantify the WWTP impact on chloride levels in downstream assessment reaches.

Sauk Creek and Sheboygan River Watersheds

Direct Drainage Area to Lake Michigan

4.6 SUMMARY OF CHLORIDE CONDITIONS AND TRENDS IN THE STREAMS AND RIVERS OF THE STUDY AREA

Technical Report No. 63

CHLORIDE CONDITIONS AND TRENDS IN SOUTHEASTERN WISCONSIN

Chapter 4

CHLORIDE CONDITIONS AND TRENDS: RIVERS AND STREAMS

TABLES

Table 4.1
Strahler Stream Order Designations for Streams in the Study Area

Stream Order	Stream Length (miles)	Percent of Streams
First-Order	2,040	52.6
Second-Order	863	22.2
Third-Order	481	12.4
Fourth-Order	316	8.1
Fifth-Order	155	4.0
Sixth-Order	25	0.7

Source: Wisconsin Department of Natural Resources

Table 4.2
Summary of Stream Assessment Reaches for the Chloride Impact Study: 1961-2022

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
Des Plaines Watershed								
DP01	Des Plaines River: 110.6 to 111.9 miles	734000	4	1.3	77	1964 - 2021	88	1964 - 2021
DP02	Des Plaines River: 115.2 to 116.6 miles	734000	4	1.4	183	1961 - 1976	4	1961 - 2009
DP03	Des Plaines River: 116.6 to 116.9 miles	734000	4	0.3	--	--	14	2007 - 2010
DP04	Des Plaines River: 119.6 to 120.8 miles	734000	4	1.1	--	--	16	2010 - 2011
DP05	Des Plaines River: 122.7 to 124.5 miles	734000	4	1.8	62	1964 - 1976	69	1964 - 2015
DP06	Unnamed Tributary to Des Plaines River: 0 to 1.4 miles	736800	1	1.4	7	1998	8	1998
DP07	Kilbourn Road Ditch: 0 to 6.1 miles	736900	3	6.1	7	1998	8	1998
DP08	Kilbourn Road Ditch: 7.3 to 11.4 miles	736900	2	4.1	33	2018 - 2021	33	2018 - 2021
DP09	Center Creek: 1.0 to 3.5 miles	737200	2	2.4	7	1998	8	1998
DP10	Brighton Creek: 0 to 2.9 miles	737400	4	2.9	28	1964 - 1975	3	1964 - 1975
DP11	Brighton Creek: 5.6 to 7.3 miles	737400	3	1.7	--	--	2	2007 - 2015
DP12	Unnamed Tributary to Brighton Creek: 0 to 1.3 miles	738900	1	1.3	--	--	5	2008
Fox River Watershed								
FX01	Fox River: 116.0 to 119.4 miles	742500	6	3.4	271	1961 - 1977	152	1961 - 2009
FX02	Fox River: 126.2 to 130.2 miles	742500	6	4.0	197	1964 - 2022	386	1964 - 2022
FX03	Fox River: 135.9 to 138.8 miles	742500	6	2.9	94	1964 - 1977	102	1964 - 1977
FX04	Fox River: 139.3 to 143.0 miles	742500	6	3.7	26	2018 - 2020	35	2018 - 2022
FX05	Fox River: 146.5 to 148.1 miles	742500	5	1.6	39	1964 - 2019	53	1964 - 2019
FX06	Fox River: 150.3 to 154.4 miles	742500	5	4.1	22	2007 - 2015	--	--
FX07	Fox River: 155.9 to 157.5 miles	742500	5	1.5	44	1964 - 2019	56	1964 - 2019
FX08	Fox River: 160.9 to 162.4 miles	742500	5	1.6	41	1961 - 1975	56	1961 - 2022
FX09	Fox River: 166.9 to 169.5 miles	742500	5	2.6	221	1964 - 2022	392	1964 - 2022
FX10	Fox River: 169.5 to 174.5 miles	742500	5	5.0	49	1964 - 2015	39	1964 - 2018
FX11	Fox River: 174.5 to 176.5 miles	742500	5	2.0	42	1964 - 2021	89	1964 - 2022
FX12	Fox River: 176.5 to 180.3 miles	742500	5	3.8	128	1961 - 2021	290	1961 - 2022
FX13	Fox River: 181.5 to 182.9 miles	742500	4	1.4	46	1964 - 1998	55	1964 - 1998
FX14	Fox River: 182.9 to 183.4 miles	742500	4	0.5	8	1992 - 1998	10	1992 - 1998
FX15	Fox River: 188.4 to 187.1 miles	742500	3	3.7	7	1998	25	1998 - 2009
FX16	Fox River: 189.6 to 191.2 miles	742500	3	1.5	29	1961 - 2015	146	1961 - 2022
FX17	Fox River: 192.5 to 194.4 miles	742500	2	1.9	39	1964 - 1975	46	1964 - 1975
FX18	North Branch Nippersink Creek: 8.7 to 10.5 miles	742700	4	1.8	35	1964 - 1998	44	1964 - 1998
FX19	North Branch Nippersink Creek: 10.5 to 12.0 miles	742700	4	1.6	--	--	1	2009
FX20	North Branch Nippersink Creek: 12.1 to 13.6 miles	742700	3	1.6	7	1998	8	1998

Table continued on next page.

Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
	Fox River Watershed (continued)							
FX21	East Branch North Branch Nippersink Creek: 0 to 1.5 miles	743400	3	1.5	7	1998	8	1998
FX22	Unnamed Tributary to East Branch North Branch Nippersink Creek: 0 to 0.8 miles	743500	2	0.8	--	--	1	2012
FX23	West Branch North Branch Nippersink Creek: 0 to 1.9 miles	744400	3	1.9	7	1998	14	1998 - 2001
FX24	Bassett Creek: 0 to 3.6 miles	748200	2	3.6	56	1964 - 1975	74	1964 - 2001
FX25	Peterson Creek: 1.2 to 5.3 miles	748500	2	4.1	--	--	1	2009
FX26	Unnamed Tributary to New Munster Creek: 0 to 1.6 miles	749000	1	1.6	--	--	1	2007
FX27	Spring Brook (Racine County): 0 to 4.0 miles	750400	2	4.0	--	--	1	2009
FX28	White River: 1.1 to 5.5 miles	751200	4	4.4	97	1961 - 2020	168	1961 - 2022
FX29	White River: 14.1 to 18.9 miles	751200	3	4.9	60	1964 - 2020	68	1964 - 2020
FX30	Honey Creek: 0 to 2.8 miles	751500	4	2.8	30	1964 - 1975	50	1964 - 2016
FX31	Honey Creek: 2.8 to 4.8 miles	751500	4	2.0	16	1961 - 2018	33	1961 - 2022
FX32	Honey Creek: 9.2 to 10.3 miles	751500	4	1.2	--	--	5	1995
FX33	Honey Creek: 10.7 to 12.2 miles	751500	4	1.5	--	--	6	2016
FX34	Honey Creek: 13.7 to 15.3 miles	751500	4	1.6	85	1964 - 2020	96	1964 - 2020
FX35	Honey Creek: 17.1 to 21.5 miles	751500	4	4.4	26	2018 - 2020	39	1995 - 2020
FX36	Honey Creek: 25.0 to 26.2 miles	751500	1	1.2	--	--	5	1995 - 2016
FX37	Sugar Creek: 0 to 3.4 miles	752100	3	3.4	59	1961 - 2020	98	1961 - 2022
FX38	Sugar Creek: 4.1 to 15.4 miles	752100	3	11.2	--	--	18	1981 - 2016
FX39	Sugar Creek: 18.3 to 22.7 miles	752100	3	4.4	28	1964 – 1975	51	1964 - 2016
FX40	Spring Brook (Walworth County): 0 to 2.5 miles	752400	2	2.5	--	--	19	1995 - 2016
FX41	North Branch Spring Brook (Spring Prairie): 0 to 2.1 miles	752500	1	2.1	--	--	1	2016
FX42	Baker Creek: 0 to 5.2 miles	753000	2	5.2	--	--	23	1995 - 2016
FX43	Spring Creek: 0 to 4.4 miles	753900	3	4.4	--	--	15	1995 - 2016
FX44	Unnamed Tributary to Honey Creek: 0.9 to 1.8 miles	754600	2	0.9	--	--	2	2016
FX45	Unnamed Tributary to Honey Creek: 0.5 to 1.8 miles	754800	2	1.3	--	--	2	2016
FX46	Unnamed Tributary to Honey Creek: 0 to 1.9 miles	755100	1	1.9	--	--	2	2016
FX47	Ore Creek: 0 to 0.8 miles	757000	3	0.8	7	1998	9	1998 - 2018
FX48	Ore Creek: 2.8 to 4.0 miles	757000	3	1.2	--	--	6	2001 - 2001
FX49	Second Branch Ore Creek: 0 to 1.9 miles	757100	2	1.9	1	2018	1	2018
FX50	Como Creek: 0 to 3.3 miles	757600	4	3.3	28	1964 - 1975	37	1964 - 2017
FX51	Eagle Creek: 0 to 4.8 miles	759500	2	4.8	--	--	7	2019 - 2020
FX52	Unnamed Tributary to Eagle Creek: 0 to 1.8 miles	759600	1	1.8	--	--	2	2007
FX53	East Eagleast Lake Ditch: 0 to 1.7 miles	760000	1	1.7	--	--	2	2019
FX54	Wind Lake Drainage Canal: 0 to 3.6 miles	760200	5	3.7	28	1964 - 1975	34	1964 - 1975
FX55	Wind Lake Drainage Canal: 6.8 to 7.3 miles	760200	4	0.4	--	--	36	2020 - 2022
FX56	Goose Lake Branch Canal: 2.8 to 3.8 miles	760300	3	1.0	1	1977	5	1977
FX57	Horner Farms Ditch Tributary to Wind Lake Canal: 0 to 1.8 miles	761500	3	1.8	8	1977	20	1967 - 1977
FX58	Muskego Canal: 0 to 1.3 miles	761800	4	1.3	35	1964 - 1975	40	1964 - 1975

Table continued on next page.

Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
Fox River Watershed (continued)								
FX59	Unnamed Tributary to Muskego Canal: 0 to 1.3 miles	762200	3	1.3	--	--	6	1988 - 1989
FX60	Jewel Creek: 0 to 0.7 miles	762500	3	0.7	12	2004 - 2005	21	2004 - 2022
FX61	Unnamed Tributary to Bass Bay: 0 to 2.2 miles	763100	1	2.2	--	--	9	1994 - 1994
FX62	Tichigan Creek: 0 to 1.5 miles	763700	2	1.5	--	--	4	2014 - 2018
FX63	Unnamed Tributary to Tichigan Lake (Fox River): 0.5 to 3.5 miles	763800	1	3.0	--	--	1	2018
FX64	Unnamed Tributary to Tichigan Lake (Fox River): 0 to 3.6 miles	763900	1	3.6	--	--	1	2018
FX65	Unnamed Tributary to Fox River: 0 to 1.0 miles	764000	2	1.0	--	--	1	2018
FX66	Ripple Brook: 0 to 1.1 miles	764800	1	1.1	--	--	1	2018
FX67	Mukwonago River: 1.0 to 2.3 miles	765500	4	1.3	110	1961 - 2022	291	1961 - 2022
FX68	Mukwonago River: 4.1 to 6.4 miles	765500	4	2.2	18	2004 - 2017	39	2004 - 2017
FX69	Mukwonago River: 6.4 to 7.6 miles	765500	3	1.2	18	2004 - 2017	26	2004 - 2017
FX70	Mukwonago River: 9.6 to 11.3 miles	765500	3	1.7	17	2004 - 2017	16	2004 - 2021
FX71	Mukwonago River: 13.6 to 15.9 miles	765500	3	2.3	76	2004 - 2020	67	2004 - 2021
FX72	Pickeral Lake Outlet: 0 to 0.1 mile	766600	2	0.1	4	1973 - 1974	4	1973 - 1974
FX73	Jericho Creek: 0 to 5.7 miles	768300	2	5.7	51	2004 - 2017	51	2004 - 2021
FX74	Unnamed Tributarty to Jericho Creek: 0 to 1.3 miles	768400	1	1.3	--	--	1	2008
FX75	Unnamed tributary to Mukwonago River: 0 to 2.5 miles	768900	2	2.5	40	2004 - 2017	32	2004 - 2021
FX76	Mill Brook: 0 to 3.8 miles	769400	2	3.8	--	--	2	2018
FX77	Pebble Brook: 0 to 7.3 miles	769500	3	7.3	25	2018 - 2020	29	2013 - 2020
FX78	Mill Creek: 0 to 1.0 miles	769700	2	1.0	--	--	1	2009
FX79	Genesee Creek: 0.5 to 1.3 miles	769800	3	0.8	1	2004	1	2018
FX80	Genesee Creek: 1.9 to 4.4 miles	769800	3	2.5	--	--	4	2008 - 2018
FX81	Spring Brook (Waukesha County): 0 to 3.1 miles	770300	2	3.1	--	--	2	2018
FX82	Pebble Creek: 0 to 3.3 miles	771300	4	3.3	2	2004 - 2009	33	2007 - 2015
FX83	Pebble Creek: 3.3 to 4.7 miles	771300	3	1.5	--	--	169	2007 - 2020
FX84	Pebble Creek: 4.7 to 6.6 miles	771300	2	1.8	--	--	1	2015 - 2015
FX85	Brandy Brook: 0 to 4.2 miles	771400	3	4.2	--	--	30	2007 - 2015
FX86	Pewaukee Lake Outlet: 0 to 0.2 miles	771700	4	0.2	--	--	180	2007 - 2020
FX87	Pewaukee River: 0 to 6.3 miles	771700	4	6.3	102	1964 - 2020	652	1964 - 2020
FX88	Pewaukee River: 6.3 to 10.7 miles	771700	2	4.5	7	2014 - 2015	345	2007 - 2020
FX89	Coco Creek: 0 to 0.9 miles	772100	3	0.9	7	2012 - 2014	182	2007 - 2020
FX90	Coco Creek: 0.9 to 3.9 miles	772100	2	3.0	--	--	177	2007 - 2020
FX91	Meadowbrook Creek: 0 to 1.8 miles	772300	3	1.8	5	2015	174	2007 - 2020
FX92	Zion Creek: 0 to 0.8 miles	772400	2	0.8	6	2012 - 2014	184	2007 - 2020
FX93	Poplar Creek: 0 to 3.9 miles	772800	4	3.9	79	1964 - 2004	93	1964 - 2015
FX94	Poplar Creek: 5.5 to 7.8 miles	772800	3	2.3	3	2018 - 2019	5	2015 - 2020
FX95	Deer Creek: 0.5 to 5.5 miles	772900	3	5.0	--	--	8	2009 - 2015
FX96	Sussex Creek: 0.7 to 5.4 miles	773400	2	4.7	49	1964 – 2015	127	1964 - 2020
FX97	North Branch Genesee Creek: 0 to 1.0 miles	3000068	2	1.0	--	--	1	2018

Table continued on next page.

Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
	Fox River Watershed (continued)							
FX98	South Branch Genesee Creek: 0 to 1.9 miles	3000069	2	1.9	--	--	1	2018
FX99	Unnamed Tributary to Pebble Creek: 0 to 1.9 miles	3000119	2	1.9	--	--	1	2015
FX100	Unnamed Tributary to Sussex Creek: 0 to 3.0 miles	3000121	1	3.0	--	--	1	1998
FX101	Unnamed Tributary to Deer Creek: 0 to 1.6 miles	5036064	1	1.6	2	1977	2	1977
FX102	Unnamed Tributary to Lauderdale Lakes: 0 to 0.7 miles	5039050	1	0.7	--	--	4	1994 - 2002
	Kinnickinnic River Watershed							
KK01	Kinnickinnic River: 0 to 2.4 miles	15100	3	2.4	3,695	1975 - 2022	3,691	1975 - 2022
KK02	Kinnickinnic River: 2.4 to 5.2 miles	15100	3	2.8	2,198	1964 - 2022	2,220	1964 - 2022
KK03	Kinnickinnic River: 5.2 to 7.9 miles	15100	2	2.7	336	1975 - 2022	376	1975 - 2022
KK04	Lyons Park Creek 0 to 1.7 miles	15100	1	1.7	--	--	10	2017 - 2018
KK05	Wilson Park Creek: 0 to 3.4 miles	15200	3	3.4	331	1975 - 2022	356	1975 - 2022
KK06	Wilson Park Creek: 3.4 to 4.4 miles	15200	2	1.0	217	1967 - 2022	47	1975 - 2022
KK07	Wilson Park Creek: 4.4 to 5.8 miles	15200	1	1.4	176	1977 - 2022	18	1977 - 2022
KK08	Villa Mann Creek: 0 to 1.4 miles	15300	1	1.4	4	2018 - 2018	13	2017 - 2018
KK09	43rd Street Ditch: 0 to 1.2 miles	15900	1	1.2	318	2006 - 2022	315	2006 - 2022
KK10	Zablocki Park Creek: 0 to 0.9 miles	5036633	1	0.9	4	2018 - 2020	38	2015 - 2020
	Menomonee River Watershed							
MN01	Menomonee River: 0 to 1.8 miles	16000	4	1.8	4,186	1975 - 2022	3,879	1975 - 2022
MN02	Menomonee River: 1.8 to 6.3 miles	16000	4	4.5	2,566	1962 - 2022	1,888	1962 - 2022
MN03	Menomonee River: 6.3 to 8.4 miles	16000	4	2.1	5	2017	26	2016 - 2018
MN04	Menomonee River: 8.4 to 12.6 miles	16000	4	4.2	1,166	1966 - 2022	1,201	1966 - 2022
MN05	Menomonee River: 12.6 to 14.5 miles	16000	4	1.8	979	1975 - 2022	876	1975 - 2022
MN06	Menomonee River: 14.5 to 18.0 miles	16000	4	3.5	147	1964 - 2011	179	1964 - 2018
MN07	Menomonee River: 19.0 to 20.4 miles	16000	4	1.4	27	1964 - 1975	53	1964 - 2018
MN08	Menomonee River: 20.4 to 24.2 miles	16000	4	3.8	1,252	1964 - 2022	1,137	1964 - 2022
MN09	Menomonee River: 24.8 to 27.1 miles	16000	4	2.3	255	1964 - 1978	180	1964 - 2022
MN10	Menomonee River: 27.1 to 27.8 miles	16000	3	0.7	333	1964 - 2022	350	1964 - 2022
MN11	Honey Creek: 0 to 3.1 miles	16300	2	3.1	1,036	1964 - 2022	641	1964 - 2022
MN12	Honey Creek: 3.1 to 4.9 miles	16300	2	1.8	170	2003 - 2022	169	2003 - 2022
MN13	Honey Creek: 4.9 to 9.0 miles	16300	1	4.1	146	2003 - 2011	146	2003 - 2011
MN14	Underwood Creek: 0 to 2.8 miles	16700	3	2.8	824	1964 - 2022	652	1964 - 2022
MN15	Underwood Creek: 2.8 to 7.2 miles	16700	3	4.4	410	2003 - 2022	439	2003 - 2022
MN16	Southbranch Underwood Creek: 0 to 1.0 miles	16800	2	1.0	169	2003 - 2022	168	2003 - 2022
MN17	Southbranch Underwood Creek: 1.7 to 2.2 miles	16800	1	0.4	169	2003 - 2022	168	2003 - 2022
MN18	Dousman Ditch: 0 to 1.6 miles	17100	3	1.6	6	2020	1	2020
MN19	Little Menomonee River: 0 to 7.3 miles	17600	3	7.3	840	1964 - 2022	828	1964 - 2022
MN20	Little Menomonee River: 7.3 to 10.9 miles	17600	2	3.6	591	1975 - 2022	158	1975 - 2022
MN21	Noyes Creek: 0 to 3.0 miles	17700	2	3.0	341	1975 - 2020	141	1975 - 2020
MN22	Little Menomonee Creek: 0 to 3.9 miles	17900	2	3.9	58	2017 - 2022	2	2007

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Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
Menomonee River Watershed (continued)								
MN23	Butler Creek: 0 to 2.5 miles	18100	4	2.5	9	2018 - 2019	38	2013 - 2020
MN24	Dretzka Park Creek: 0 to 2.1 miles	18350	2	2.1	2	2021 - 2022	28	2016 - 2022
MN25	Lily Creek: 0 to 1.4 miles	18400	4	1.4	13	2004 - 2015	46	2004 - 2018
MN26	Nor-X-Way Channel: 0 to 3.3 miles	18450	2	3.3	4	2018	14	2017
MN27	Willow Creek: 0 to 0.9 miles	18800	3	0.9	21	2004 - 2022	76	2001 - 2022
MN28	Goldendale Creek: 0 to 1.2 miles	18900	3	1.2	--	--	25	2017 - 2022
MN29	Burnham Canal: 0.5 to 1.1 miles	3000042	1	0.6	578	1989 - 2022	593	1989 - 2022
MN30	Unnamed Tributary to Menomonee River: 0 to 2.7 miles	5034083	2	2.7	325	1976 - 1978	1	1976
MN31	Grantosa Creek: 0 to 1.0 miles	5035175	1	1.0	--	--	5	2016 - 2018
MN32	Unnamed Tributary to Dousman Ditch: 0 to 0.1 miles	5035840	1	0.1	96	1976 - 1977	3	1977
MN33	Scoonmaker Creek	None	1	1.2	240	1975 - 1977	95	1975 - 1978
Milwaukee River Watershed								
MK01	Milwaukee River: 0 to 0.8 miles	15000	5	0.8	2,270	1964 - 2022	1,766	1964 - 2022
MK02	Milwaukee River: 0.8 to 7.7 miles	15000	5	6.8	3,053	1961 - 2022	2,941	1964 - 2022
MK03	Milwaukee River: 7.7 to 12.8 miles	15000	5	5.1	351	1975 - 2022	370	1975 - 2022
MK04	Milwaukee River: 15.1 to 19.4 miles	15000	5	4.3	574	1961 - 2022	535	1964 - 2022
MK05	Milwaukee River: 19.6 to 20.7 miles	15000	5	1.0	--	--	5	2016
MK06	Milwaukee River: 24.1 to 27.5 miles	15000	5	3.4	518	1964 - 2022	500	1964 - 2022
MK07	Milwaukee River: 27.5 to 29.8 miles	15000	5	2.3	20	1995	32	1993 - 2022
MK08	Milwaukee River: 29.8 to 32.3 miles	15000	5	2.5	29	1964 - 1975	63	1964 - 2018
MK09	Milwaukee River: 32.3 to 35.8 miles	15000	5	3.5	--	--	35	1993 - 2019
MK10	Milwaukee River: 35.8 to 43.7 miles	15000	5	8.0	70	1964 - 2020	117	1964 - 2020
MK11	Milwaukee River: 43.7 to 47.8 miles	15000	5	4.1	73	1976 - 2004	111	1976 - 2020
MK12	Milwaukee River: 47.8 to 53.2 miles	15000	5	5.4	31	2018 - 2020	33	2006 - 2020
MK13	Milwaukee River: 57.3 to 63.9 miles	15000	5	6.6	106	1964 - 2004	77	1964 - 2020
MK14	Milwaukee River: 64.1 to 67.4 miles	15000	5	3.3	--	--	22	1993 - 2022
MK15	Milwaukee River: 67.4 to 68.4 miles	15000	5	1.0	--	--	9	2019 - 2020
MK16	Milwaukee River: 69.9 to 74.7 miles	15000	5	4.8	29	1964 - 1975	38	1964 - 2018
MK17	Milwaukee River: 77.3 to 78.6 miles	15000	4	1.3	86	1976 - 2004	77	1976 - 2020
MK18	Milwaukee River: 79.9 to 83.4 miles	15000	4	3.5	39	1964 - 1975	48	1964 - 2020
MK19	Milwaukee River: 87.4 to 87.8 miles	15000	4	0.4	1	1994	15	2020 - 2021
MK20	Milwaukee River: 91.8 to 95.8 miles	15000	4	4.0	--	--	1	2020
MK21	Lincoln Creek: 0 to 5.0 miles	19400	2	5.0	663	1975 - 2022	435	1975 - 2022
MK22	Lincoln Creek: 5.0 to 10.0 miles	19400	1	5.0	335	1975 - 2022	328	1975 - 2022
MK23	Crestwood Creek: 0 to 1.3 miles	19450	1	1.4	6	2017	19	2016 - 2018
MK24	Indian Creek: 0 to 2.7 miles	19600	2	2.7	250	1975 - 2022	288	2006 - 2022
MK25	Brown Deer Park Creek: 0 to 2.2 miles	19700	2	2.2	14	2016 - 2017	29	2016 - 2020
MK26	Beaver Creek: 0 to 3.3 miles	20000	1	3.3	9	2017	27	2016 - 2018
MK27	Lac du Cours Creek: 0 to 0.3 miles	20200	1	0.3	--	--	34	2017 - 2022

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Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
Milwaukee River Watershed (continued)								
MK28	Trinity Creek: 0 to 3.3 miles	20400	2	3.3	--	--	53	2016 - 2021
MK29	Pigeon Creek: 0 to 2.4 miles	20500	3	2.4	2	2004	125	2001 - 2022
MK30	Mee-Kwon Creek: 0 to 1.4 miles	20700	1	1.4	--	--	18	2016 - 2018
MK31	Unnamed Tributary to Milwaukee River: 0 to 0.3 miles	21100	2	0.3	--	--	3	2019
MK32	Ulao Creek: 0 to 0.7 miles	21200	4	0.7	28	2016 - 2021	46	2016 - 2020
MK33	Ulao Creek: 1.8 to 5.3 miles	21200	3	3.5	148	2011 - 2022	129	2011 - 2021
MK34	Ulao Creek: 5.3 to 6.2 miles	21200	2	0.9	65	2016 - 2021	11	2020 - 2021
MK35	Ulao Creek: 6.6 to 9.2 miles	21200	2	2.6	26	2016 - 2021	--	--
MK36	Cedar Creek: 1.1 to 1.8 miles	21300	4	0.7	196	1990 - 1991	86	1990 - 2019
MK37	Cedar Creek: 1.8 to 14.1 miles	21300	4	12.3	656	1964 - 2022	596	1964 - 2022
MK38	Cedar Creek: 16.0 to 18.3 miles	21300	4	2.3	35	1964 - 1975	91	1964 - 2019
MK39	Cedar Creek: 19.1 to 19.6 miles	21300	4	0.6	1	2000	--	--
MK40	Cedar Creek: 20.7 to 21.2 miles	21300	4	0.5	28	2000 - 2020	27	1995 - 2020
MK41	Cedar Creek: 21.2 to 22.5 miles	21300	4	1.3	1	2000	6	2022
MK42	Cedar Creek: 23.0 to 23.3 miles	21300	3	0.3	--	--	4	2022
MK43	Cedar Creek: 23.6 to 25.7 miles	21300	2	2.1	--	--	42	2016 - 2020
MK44	Cedar Creek: 25.7 to 29.7 miles	21300	2	4.1	2	2001	7	2018 - 2019
MK45	Cedar Creek: 31.3 to 37.8 miles	21300	2	1.4	--	--	66	2017 - 2019
MK46	Mud Creek: 0 to 3.5 miles	22000	2	3.5	--	--	23	2009 - 2019
MK47	North Branch Cedar Creek: 0 to 2.0 miles	22500	3	2.0	4	2018 - 2022	67	2007 - 2022
MK48	Cedarburg Creek: 0 to 6.4 miles	22900	2	6.4	--	--	46	2011 - 2021
MK49	Evergreen Creek: 0 to 3.3 miles	23000	3	3.3	--	--	36	2017 - 2020
MK50	Friedens Creek: 0 to 3.5 miles	23300	2	3.5	1	2019	28	2001 - 2022
MK51	Little Cedar Creek: 0.2 to 1.7 miles	23400	3	1.6	--	--	36	2016 - 2019
MK52	Little Cedar Creek: 1.7 to 3.9 miles	23400	3	2.2	1	2022	64	2017 - 2022
MK53	Little Cedar Creek: 3.9 to 7.8 miles	23400	2	3.9	--	--	6	2020
MK54	Kressin Branch: 0 to 5.1 miles	23500	2	5.1	--	--	24	2017 - 2021
MK55	Unnamed Tributary to Little Cedar Creek: 0 to 0.7 miles	23600	3	0.7	1	2021	21	2020 - 2022
MK56	Polk Springs Creek: 0 to 3.4 miles	23800	2	3.4	--	--	30	2001 - 2019
MK57	Jackson Creek: 0 to 1.3 miles	23900	2	1.3	--	--	21	2017 - 2019
MK58	Lehner Creek: 0 to 2.3 miles	24400	1	2.2	--	--	41	2017 - 2020
MK59	Unnamed Tributary to Gilbert Lake: 0 to 0.6 miles	25500	1	0.6	1	2012	4	2012 - 2013
MK60	Mole Creek: 0 to 7.9 miles	26300	2	7.9	202	1991 - 2022	78	2001 - 2022
MK61	Hawthorne Drive Creek: 0 to 0.7 miles	26500	2	0.7	--	--	1	2020
MK62	Fredonia Creek: 0 to 4.0 miles	26600	2	4.0	--	--	14	2018 - 2020
MK63	Sandhill Creek: 0 to 3.1 miles	26800	1	3.1	--	--	6	2022 - 2022
MK64	North Branch Milwaukee River: 0 to 4.7 miles	27100	4	4.7	110	1964 - 2007	99	1964 - 2020
MK65	North Branch Milwaukee River: 5.0 to 7.1 miles	27100	4	2.2	25	2018 - 2020	27	2008 - 2020
MK66	North Branch Milwaukee River: 10.2 to 12.2 miles	27100	4	1.9	53	1993 - 2001	1	2020

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Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
	Milwaukee River Watershed (continued)							
MK67	North Branch Milwaukee River: 14.3 to 18.1 miles	27100	4	3.8	5	1993 - 2007	1	2020
MK68	North Branch Milwaukee River: 18.1 to 21.5 miles	27100	3	3.4	7	1993 - 2007	--	--
MK69	North Branch Milwaukee River: 23.3 to 27.8 miles	27100	2	4.5	7	1993 - 2022	20	2017 - 2022
MK70	Wallace Creek: 0 to 5.5 miles	27600	3	5.5	--	--	8	2001 - 2020
MK71	Stony Creek: 0 to 10.3 miles	28700	2	10.3	27	2004 - 2020	49	2002 - 2021
MK72	Silver Creek: 0 to 2.0 miles	29900	3	2.0	--	--	8	2019 - 2020
MK73	Mink Creek: 0 to 14.5 miles	30600	2	14.5	--	--	19	2016 - 2020
MK74	Batavia Creek: 0 to 3.9 miles	31400	2	3.9	2	1993 - 1994	21	2015 - 2020
MK75	Gooseville Creek: 0 to 0.9 miles	32000	2	0.9	2	1993 - 1994	--	--
MK76	Melius Creek: 0 to 1.1 miles	32100	3	1.1	2	1993 - 1994	17	2016 - 2018
MK77	Chambers Creek: 0 to 2.9 miles	32200	2	2.9	2	1993 - 1994	--	--
MK78	Unnamed Tributary to North Branch Milwaukee River: 0.1 to 3.7 miles	33000	3	3.6	9	1993 - 2007	--	--
MK79	Riveredge Nature Center Creek: 0 to 1.1 miles	34000	2	1.2	--	--	12	2017 - 2020
MK80	Myra Creek: 0 to 3.7 miles	34400	1	3.7	--	--	1	2012
MK81	Unnamed Tributary to Milwaukee River: 0 to 0.6 miles	34800	2	0.6	--	--	5	2019
MK82	Quas Creek: 0 to 4.3 miles	34900	2	4.3	--	--	19	2019 - 2022
MK83	Silver Creek: 0 to 2.4 miles	35500	2	2.4	--	--	23	2018 - 2022
MK84	Engmon Creek: 0 to 1.1 miles	35700	1	1.1	2	2019 - 2019	19	2018 - 2021
MK85	East Branch Milwaukee River: 0 to 11.0 miles	36900	4	11.0	112	1976 - 2020	75	1976 - 2020
MK86	East Branch Milwaukee River: 11.8 to 17.4 miles	36900	4	5.6	--	--	1	2020
MK87	East Branch Milwaukee River (channelized west): 18.1 to 18.4 miles	36900	3	0.3	--	--	6	2022
MK88	East Branch Milwaukee River (natural meander east): 18.1 to 18.4 miles	36900	3	0.3	--	--	6	2022
MK89	Crooked Lake Creek (Tributary to East Branch Milwaukee River): 0 to 4.8 miles	37300	2	4.8	--	--	3	2008 - 2020
MK90	Parnell Creek: 0 to 2.7 miles	38300	3	2.7	27	1996 - 2007	1	1996
MK91	Watercress Creek (Long Lake Tributary): 0 to 4.7 miles	39000	2	4.7	5	1995 - 2022	11	2019 - 2022
MK92	Kewaskum Creek: 0 to 0.9 miles	39800	3	0.9	--	--	10	2018 - 2020
MK93	Unnamed Tributary 1 to Kewaskum Creek: 0 to 1.0 miles	39900	1	1.0	106	1976 - 1978	--	--
MK94	Unnamed Tributary 2 to Kewaskum Creek: 1.6 to 2.0 miles	40000	1	0.4	69	1976 - 1978	--	--
MK95	Unnamed Tributary to Milwaukee River: 0 to 0.4 miles	40100	2	0.4	--	--	7	2022
MK96	West Branch Milwaukee River: 0 to 2.4 miles	40400	3	2.4	73	1994 - 2015	--	--
MK97	West Branch Milwaukee River: 3.9 to 6.7 miles	40400	3	2.8	--	--	1	2020
MK98	West Branch Milwaukee River: 8.2 to 11.4 miles	40400	3	3.2	--	--	1	2020
MK99	West Branch Milwaukee River: 16.6 to 17.7 miles	40400	3	1.2	303	2011 - 2015	--	--
MK100	West Branch Milwaukee River: 20.4 to 21.3 miles	40400	1	0.9	264	2011 - 2015	--	--
MK101	Stoffel Creek: 1.6 to 7.0 miles	40500	1	5.4	1	2019 - 2019	2	2019 - 2020

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Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
	Milwaukee River Watershed (continued)							
MK102	Unnamed Tributary to West Branch Milwaukee River: 0 to 1.3 miles	40600	2	1.3	--	--	5	2022
MK103	Auburn Lake Creek: 0 to 1.4 miles	41600	3	1.4	--	--	1	2020
MK104	Unnamed Tributary to Milwaukee River: 0 to 4.4 miles	43500	3	4.4	--	--	2	2009 - 2020
MK105	Unnamed Tributary to Milwaukee River: 0 to 2.7 miles	44000	2	2.7	--	--	1	2007
MK106	Unnamed Tributary to Milwaukee River: 1.5 to 3.4 miles	44200	2	1.9	--	--	5	2007 - 2014
MK107	Southbranch Creek: 0 to 2.4 miles	3000073	1	2.4	339	2006 - 2022	347	2006 - 2022
MK108	Unnamed Tributary to Stoffel Creek: 0 to 0.9 miles	5030146	2	0.9	--	--	6	2008 - 2017
MK109	Unnamed Tributary 3 to Kewaskum Creek: 0 to 0.6 miles	5030831	1	0.6	12	1976 - 1977	--	--
MK110	Riverside Drive Creek: 0 to 3.6 miles	5030968	2	3.6	--	--	45	2017 - 2022
MK111	Helm's Creek Tributary to Ulao Creek: 0 to 0.2 miles	5032380	2	0.2	11	2020 - 2021	11	2020 - 2021
MK112	Kaul Creek: 0 to 1.0 miles	5032520	1	1.0	53	2016 - 2021	--	--
MK113	Gateway Drive Tributary to Ulao Creek: 0 to 0.6 miles	5032660	1	0.6	12	2020 - 2021	12	2020 - 2021
MK114	Unnamed Tributary to Pigeon Creek: 0 to 0.7 miles	5032995	3	0.7	7	2011 - 2013	41	2011 - 2018
MK115	Vila Grove Park Creek: 0 to 1.3 miles	5033448	2	1.4	--	--	2	2017
	Oak Creek Watershed							
OC01	Oak Creek: 0 to 5.0 miles	14500	4	5.1	1,864	1964 - 2022	3,029	1964 - 2022
OC02	Oak Creek: 5.0 to 9.5 miles	14500	4	4.5	867	1964 - 2022	1,147	1964 - 2022
OC03	Oak Creek: 9.5 to 12.4 miles	14500	2	2.9	417	1985 - 2022	604	1985 - 2022
OC04	Mitchell Field Drainage Ditch: 0 to 3.2 miles	14800	2	3.2	73	2007 - 2022	221	2012 - 2022
OC05	North Branch Oak Creek: 1.1 to 2.1 miles	14900	4	1.0	16	1990 - 2022	21	1990 - 2022
OC06	North Branch Oak Creek: 2.1 to 3.0 miles	14900	3	0.9	--	--	100	2012 - 2016
OC07	North Branch Oak Creek: 3.0 to 6.8 miles	14900	2	3.8	5	1975 - 2017	95	1975 - 2018
OC08	Drexel Avenue Tributary: 0 to 0.4 miles	5037407	3	0.4	1	2019	64	2015 - 2019
	Pike River Watershed							
PK01	Pike River: 0 to 4.5 miles	1300	4	4.6	475	1964 - 2020	524	1964 - 2021
PK02	Pike River: 5.2 to 9.5 miles	1300	4	4.3	333	1976 - 2021	450	1976 - 2021
PK03	North Branch Pike River: 0 to 1.9 miles	1900	3	1.9	69	1964 - 1996	72	1964 - 1996
PK04	North Branch Pike River: 3.8 to 7.9 miles	1900	2	4.1	54	1996 - 2016	57	1996 - 2016
PK05	Unnamed Tributary to Pike River: 0 to 0.6 miles	2450	1	0.6	13	2011 - 2013	11	2012 - 2013
PK06	South Branch Pike River: 0 to 6.7 miles	2500	3	6.7	76	1964 - 1996	90	1964 - 1996
PK07	Unnamed Tributary to South Branch Pike River: 1.2 to 3.0 miles	2600	1	1.8	--	--	2	2017
PK08	Unnamed Tributary to South Branch Pike River: 1.1 to 2.7 miles	2700	2	1.6	--	--	1	2017
PK09	Unnamed Tributary to Pike River: 0 to 0.3 miles	5040874	2	0.3	--	--	1	2017
PK10	Unnamed Tributary to Pike River 0 to 1.8 miles	None	1	1.8	94	2011 - 2020	100	2012 - 2021
	Rock River Watershed							
RK01	Piscasaw Creek: 29.29 to 29.34 miles	788900	3	0.1	--	--	21	1992 - 1994
RK02	Turtle Creek: 25.6 to 34.7 miles	790300	4	9.1	66	1961 - 2020	70	1961 - 2020

Table continued on next page.

Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
Rock River Watershed (continued)								
RK03	Turtle Creek: 34.7 to 35.5 miles	790300	3	0.6	--	--	6	2017
RK04	Little Turtle Creek: 3.1 to 6.8 miles	791700	4	3.7	--	--	4	2007 - 2017
RK05	Darien Creek: 0.3 to 2.1 miles	791800	3	1.8	--	--	7	2017
RK06	Darien Creek: 2.1 to 7.2 miles	791800	3	5.2	--	--	3	2007 - 2017
RK07	Unnamed Tributary to Little Turtle Creek: 0 to 2.5 miles	792200	2	2.5	--	--	1	2017
RK08	Ladd Creek: 0.5 to 2.3 miles	792400	3	1.8	--	--	1	2017
RK09	West Branch Ladd Creek: 0 to 2.3 miles	792500	2	2.3	--	--	1	2017
RK10	Unnamed Tributary to Turtle Creek: 0 to 3.6 miles	792800	2	3.6	--	--	1	2013
RK11	Delavan Lake Outlet: 0 to 4.6 miles	793100	4	4.6	29	1964 - 1975	37	1964 - 2017
RK12	Delavan Lake Inlet (Jackson Creek): 0.8 to 1.5 miles	793800	3	0.7	--	--	33	1994
RK13	Jackson Creek: 0 to 0.3 miles	793800	3	0.3	30	1964 - 1992	62	1964 - 1993
RK14	Jackson Creek: 0.5 to 3.2 miles	793800	2	2.7	28	1992 - 2020	30	1983 - 2020
RK15	Unnamed Tributary to Jackson Creek: 0 to 1.6 miles	793900	2	1.6	1	1992	5	1983 - 1984
RK16	Unnamed Tributary to Turtle Creek: 0 to 1.9 miles	794300	2	1.9	--	--	1	2017
RK17	Bark River: 35.8 to 38.7 miles	813500	3	3.0	61	1964 - 1978	99	1964 - 2015
RK18	Bark River: 38.7 to 41.2 miles	813500	3	2.4	2	1982 - 1982	10	1982 - 2014
RK19	Bark River: 41.2 to 43.8 miles	813500	3	2.7	34	2000 - 2020	31	1982 - 2020
RK20	Bark River: 46.2 to 48.0 miles	813500	3	1.7	6	1973 - 1975	7	1973 - 2014
RK21	Bark River: 46.7 to 45.8 miles	813500	3	0.2	--	--	6	1994 - 1995
RK22	Bark River: 49.4 to 54.9 miles	813500	3	5.6	38	1973 - 2020	178	1973 - 2020
RK23	Bark River: 58.0 to 67.3 miles	813500	2	9.3	8	2000	1	2011
RK24	Whitewater Creek: 9.8 to 11.7 miles	813900	3	1.9	26	2018 - 2020	74	1978 - 2020
RK25	Spring Brook (Whitewater): 0 to 3.3 miles	815300	3	3.3	--	--	1	2011
RK26	Bluff Creek: 0 to 2.0 miles	816100	2	2.0	15	1999 - 2001	5	1999 - 2000
RK27	Unnamed Tributary to Whitewater Creek 0 to 2.0 miles	816200	3	2.0	1	2018	1	2018
RK28	Scuppernong River: 12.2 to 13.4 miles	817600	3	1.1	49	1976 - 2018	58	1976 - 2018
RK29	Scuppernong River: 15.0 to 15.4 miles	817600	3	0.4	--	--	8	2001 - 2011
RK30	Scuppernong River: 18.4 to 19.4 miles	817600	2	1.0	5	2018 - 2022	39	2009 - 2022
RK31	Unnamed Tributary to Scuppernong River: 0 to 1.3 miles	821200	1	1.3	--	--	1	2008
RK32	Scuppernong Creek: 10.3 to 12.7 miles	825600	1	2.4	--	--	3	2008 - 2014
RK33	Oconomowoc River: 9.6 to 12.2 miles	848200	4	2.6	295	1964 - 2020	83	1964 - 1995
RK34	Oconomowoc River: 12.2 to 13.9 miles	848200	4	1.7	276	1961 - 2020	32	1961 - 2020
RK35	Oconomowoc River (Fowler Lake): 14.9 to 15.8 miles	848200	4	0.9	23	2018 - 2020	--	--
RK36	Oconomowoc River: 15.8 to 17.6 miles	848200	4	1.7	85	1964 - 2020	35	1964 - 1975
RK37	Oconomowoc River: 18.9 to 19.4 miles	848200	4	0.5	38	1973 - 2020	12	1973 - 1975
RK38	Oconomowoc River: 23.1 to 24.9 miles	848200	4	1.8	33	1973 - 2020	10	1973 - 2015
RK39	Oconomowoc River: 26.1 to 27.7 miles	848200	4	1.7	116	1964 - 2020	99	1964 - 2020
RK40	Oconomowoc River: 30.1 to 31.9 miles	848200	4	1.8	24	2014 - 2020	--	--
RK41	Oconomowoc River: 33.4 to 36.5 miles	848200	3	3.0	17	2019 - 2020	--	--

Table continued on next page.

Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
Rock River Watershed (continued)								
RK42	Oconomowoc River: 37.2 to 39.6 miles	848200	3	2.4	22	2014 - 2020	1	2007
RK43	Oconomowoc River: 39.6 to 40.5 miles	848200	2	0.9	15	1967 - 2020	1	1967
RK44	Battle Creek: 2.0 to 5.7 miles	848300	2	3.7	24	2014 - 2020	4	2008 - 2016
RK45	Rosenow Creek: 0 to 1.8 miles	848900	2	1.7	25	2007 - 2020	--	--
RK46	Mason Creek: 0 to 3.6 miles	851100	2	3.6	57	2012 - 2020	139	2009 - 2020
RK47	Little Oconomowoc River: 0 to 6.3 miles	851400	2	6.3	--	--	3	1998 - 2008
RK48	Flynn Creek: 0 to 3.2 miles	852800	3	3.2	20	2019 - 2020	6	2001 - 2009
RK49	Coney River: 0 to 6.6 miles	853400	2	6.6	11	2018 - 2020	2	2007 - 2011
RK50	Ashippun River: 1.8 to 5.0 miles	853800	3	3.1	62	1961 - 1977	64	1961 - 1977
RK51	Ashippun River: 9.1 to 13.0 miles	853800	3	3.9	--	--	2	1982 - 2008
RK52	Ashippun River: 27.0 to 30.9 miles	853800	2	3.8	--	--	2	2008 - 2011
RK53	Rubicon River: 22.8 to 27.7 miles	856500	3	4.8	63	1964 - 2021	65	1964 - 2020
RK54	Rubicon River: 27.7 to 28.6 miles	856500	2	0.9	19	1999	--	--
RK55	Rubicon River: 28.6 to 31.3 miles	856500	2	2.7	41	1967 - 1999	1	1967
RK56	Rubicon River: 31.3 to 32.2 miles	856500	1	1.0	7	1995	3	1995
RK57	Unnamed Tributay to Rubicon River: 0 to 0.4 miles	858400	1	0.4	6	1995	5	1995
RK58	East Branch Rock River: 31.4 to 39.7 miles	861400	4	8.3	69	1964 - 2020	72	1964 - 2020
RK59	East Branch Rock River: 39.7 to 41.4 miles	861400	4	1.7	7	1995	5	1995
RK60	Unnamed Tributary to Lomira Creek: 0.2 to 1.5 miles	864300	3	1.3	--	--	1	2012
RK61	Kohlsville River: 0 to 1.8 miles	865400	4	1.8	33	1964 - 2022	78	1964 - 2022
RK62	Kohlsville River: 5.0 to 6.0 miles	865400	2	1.0	--	--	1	2008
RK63	No Name Creek: 2.9 to 6.5 miles	866200	2	3.5	2	2004 - 2009	1	2009
RK64	Limestone Creek: 0 to 3.5 miles	866800	3	3.5	1	1967	2	1967 - 2007
RK65	Unnamed Tributary to Limestone Creek: 0 to 0.9 miles	866900	2	0.9	--	--	2	2007
RK66	Allenton Creek: 1.7 to 4.0 miles	867100	1	2.3	--	--	1	2008
RK67	Unnamed Tributary to Allenton Creek: 0 to 0.8 miles	867200	1	0.8	--	--	1	2008
RK68	Unnamed Tributary to Limestone Creek: 0 to 1.6 miles	5031359	2	1.6	--	--	1	2012
RK69	Unnamed Tributary to Jackson Creek: 0 to 2.0 miles	5040633	1	2.0	--	--	1	2007
RK70	Unnamed Tributary to Delavan Lake: 0 to 2.4 miles	5041139	1	2.4	--	--	1	1984
RK71	Lower Pine River 0 to 0.3 mile	None	1	0.3	1	1991	--	--
Root River Watershed								
RT01	Root River 0 to 5.2 miles	2900	5	5.2	63	1996 - 2018	20	1996 - 2022
RT02	Root River: 5.2 to 7.4 miles	2900	5	2.2	344	1961 - 2021	245	1961 - 2021
RT03	Root River: 11.5 to 13.7 miles	2900	5	2.3	5	1996	6	1996
RT04	Root River: 17.1 to 25.8 miles	2900	5	8.7	291	1964 - 2022	306	1964 - 2022
RT05	Root River: 25.8 to 34.3 miles	2900	4	8.5	333	1961 - 2022	498	1961 - 2022
RT06	Root River: 35.8 to 41.2 miles	2900	3	5.4	537	1964 - 2022	679	1964 - 2022
RT07	Root River: 41.2 to 43.7 miles	2900	2	2.5	449	1999 - 2022	453	1999 - 2022
RT08	Hoods Creek: 0 to 6.9 miles	3100	2	6.9	15	1996 - 2020	26	1996 - 2020

Table continued on next page.

Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
	Root River Watershed (continued)							
RT09	Hoods Creek: 6.9 to 8.9 miles	3100	2	2.0	--	--	1	2015
RT10	Crawfish Creek: 0.5 to 1.7 miles	3385	2	1.2	2	2020	5	2020 - 2022
RT11	Husher Creek: 0 to 4.2 miles	3500	3	4.2	5	1996	12	1996 - 2011
RT12	Kilbournville Tributary: 0 to 2.8 miles	3600	2	2.8	--	--	1	2007
RT13	Root River Canal: 0.8 to 5.7 miles	4300	4	4.9	150	1964 - 2021	235	1964 - 2021
RT14	West Branch Root River Canal: 0 to 0.6 miles	4500	4	0.6	10	1996	13	1996 - 2012
RT15	West Branch Root River Canal: 0.6 to 3.9 miles	4500	4	3.2	4	1996	4	1996
RT16	West Branch Root River Canal: 7.1 to 9.3 miles	4500	3	2.1	5	1996	6	1996
RT17	Raymond Creek: 0 to 2.1 miles	4600	2	2.1	5	1996	5	1996
RT18	East Branch Root River Canal: 0 to 8.4 miles	4900	2	8.4	1	2019	2	2019 - 2020
RT19	East Branch Root River Canal: 8.4 to 9.5 miles	4900	2	1.2	4	1996	5	1996
RT20	Tess Corners Creek: 0 to 0.4 miles	6200	3	0.4	6	1996	6	1996
RT21	Unnamed Tributary to Crawfish Creek: 1.4 to 2.1 miles	3000341	1	0.6	2	2020	5	2020 - 2022
RT22	Scout Lake Inlet: 0 to 0.4 miles	5036992	1	0.4	--	--	39	1980 - 1981
RT23	Scout Lake Outlet: 0 to 0.4 miles	5036992	1	0.4	1	1981	73	1980 - 1981
	Sauk Creek Watershed							
SK01	Sauk Creek: 0 to 2.6 miles	49500	3	2.6	67	1964 - 2021	88	1964 - 2021
SK02	Sauk Creek: 2.6 to 11.5 miles	49500	3	8.9	28	1964 - 1975	40	1964 - 2014
SK03	Sauk Creek: 11.9 to 13.0 miles	49500	2	1.1	--	--	1	2014
SK04	Unnamed Tributary to Sauk Creek: 0 to 4.6 miles	49700	2	4.6	--	--	6	1994 - 2014
SK05	Unnamed Tributary to Sauk Creek: 0 to 1.2 miles	49900	2	1.2	--	--	1	2014
	Sheboygan River Watershed							
SH01	Unnamed Tributary to Belgium River: 3.4 to 6.0 miles	51400	2	2.7	--	--	1	2011
SH02	Belgium River: 1.6 to 4.6 miles	51500	2	3.0	6	1979	--	--
	Direct Drainage Area to Lake Michigan							
DD01	Barnes Creek: 0 to 1.4	800	3	1.4	32	1964 - 1996	35	1964 - 1996
DD02	Pike Creek: 0 to 2.2 miles	1200	2	2.2	159	1964 - 2020	173	1964 - 2021
DD03	Fish Creek: 0 to 2.7 miles	44700	2	2.7	188	2006 - 2022	188	2006 - 2022
DD04	Sucker Creek: 0 to 1.0 miles	50100	3	1.0	--	--	12	2009 - 2010
DD05	Sucker Creek: 2.0 to 8.2 miles	50100	3	6.2	28	1964 - 1975	33	1964 - 1975
DD06	Parkway Beach Creek: 0 to 0.6 miles	7650	1	0.6	--	--	47	2013
DD07	Unnamed Tributary to Lake Michigan: 0 to 1.1 miles	7670	1	1.1	--	--	66	2013
DD08	Birch Creek: 0 to 1.6 miles	7700	1	1.6	--	--	65	2013
DD09	Klema Ditch: 0 to 1.9 miles	7800	2	1.9	--	--	157	2013
DD10	Rocky Creek: 0 to 0.6 miles	7800	3	0.6	--	--	80	2013
DD11	Cliffside Park Tributary: 0 to 2.0 miles	7825	2	2.0	--	--	73	2013
DD12	Unnamed Tributary to Lake Michigan: 0.4 to 1.6 miles	7840	1	1.2	2	2020	59	2013 - 2022
DD13	Unnamed Tributary to Lake Michigan: 0 to 0.9 miles	3000342	1	0.9	--	--	74	2013

Table continued on next page.

Table 4.2 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
Direct Drainage Area to Lake Michigan (continued)								
DD14	Prairie Stream: 0 to 0.4 miles	3000399	1	0.4	--	--	75	2013
DD15	Dominican Creek: 0 to 0.9 miles	3000518	1	0.9	--	--	69	2013
DD16	Unnamed Tributary to Lake Michigan: 0 to 1.7 miles	5037118	1	1.7	--	--	101	2012 - 2016
DD17	Bender Park Creek: 0 to 1.0 miles	5038010	2	1.0	--	--	48	2013
DD18	Unnamed Tributary to Lake Michigan: 0 to 0.6 miles	5038139	1	0.6	--	--	56	2013
DD19	Unnamed Tributary to Unnamed Tributary to Lake Michigan: 0 to 1.0 miles	5038361	2	1.0	2	2020	69	2013 - 2020
DD20	Crestview Creek - Harvest Rd Branch: 0 to 1.1 miles	5038717	1	1.1	--	--	59	2013
DD21	Crestview Creek: 0 to 1.5 miles	5038767	2	1.5	--	--	53	2013
DD22	Crestview Creek - Matthew Rd Branch: 0 to 1.3 miles	5038767	1	1.3	--	--	80	2013
DD23	Unnamed Tributary to Lake Michigan 0 to 0.7 mile	None	1	0.7	--	--	64	2013

Note: Text in red represents chloride and/or specific conductance datasets that were determined to be "imbalanced." Imbalanced datasets may not fairly represent chloride conditions due to small sample size or uneven sampling throughout all seasons.

Source: City of Oconomowoc, City of Racine Public Health Department, Eagle Spring Lake Management District, USEPA, MMSD, USGS, University of Wisconsin – Milwaukee, WDNR, and SEWRPC

Table 4.3
Chloride Summary Statistics by Watershed for the Full Period of Record: 1961-2022

		Chloride Concentration (mg/l)					
Watershed	**Number of Samples**	Minimum	Mean	Median	Maximum	25th Quartile	75th Quartile
Des Plaines River	404	3	79	46	1,650	30	75
Fox River	2,558	1	79	50	2,112	29	100
Kinnickinnic River	7,279	1	222	96	9,800[a]	53	220
Menomonee River	16,964	0.1	178	111	9,800	65	200
Milwaukee River	11,562	0	102	67	6,630	44	98
Oak Creek	3,243	2	237	180	7,120	126	260
Pike River	1,114	5	137	110	1,255	48	185
Rock River	1,791	0.1	57	51	1,215	26	73
Root River	2,232	0	205	140	4,130	87	230
Sauk Creek	95	20	61	48	365	35	74
Sheboygan River	6	688[b]	784[b]	769[b]	938[b]	707[b]	831[b]
Direct Drainage Area to Lake Michigan	411	0.5	223	108	3,473	96	280

[a] *A maximum chloride concentration of 44,000 mg/l was observed at KK06 (Wilson Park Creek: 3.4 to 4.4 miles) but was considered an outlier.*

[b] *There is not sufficient chloride data in the Sheboygan River watershed to compare summary statistics to other watersheds.*

Source: SEWRPC

Table 4.4
Balanced Assessment Reaches with Statistically Significant Trends in Chloride Concentrations for the Full Period of Record: 1961-2022

Reach ID	Reach Name	Watershed	Trend in Chloride (mg/l per yr)	Sampling Span	R^2
Increasing Chloride Trends					
OC04	Mitchell Field Drainage Ditch: 0 to 3.2 miles	Oak Creek	77.2	2007 to 2022	0.10
KK06	Wilson Park Creek: 3.4 to 4.4 miles	Kinnickinnic River	52.7	1967 to 2022	0.05
KK09	43rd Street Ditch: 0 to 1.2 miles	Kinnickinnic River	25.5	2006 to 2022	0.04
KK07	Wilson Park Creek: 4.4 to 5.8 miles	Kinnickinnic River	12.1	1977 to 2022	0.18
MK107	Southbranch Creek: 0 to 2.4 miles	Milwaukee River	12.0	2006 to 2022	0.11
KK03	Kinnickinnic River: 5.2 to 7.9 miles	Kinnickinnic River	9.3	1975 to 2022	0.11
KK02	Kinnickinnic River: 2.4 to 5.2 miles	Kinnickinnic River	8.4	1964 to 2022	0.08
RT06	Root River: 35.8 to 41.2 miles	Root River	8.0	1964 to 2022	0.05
MK21	Lincoln Creek: 0 to 5.0 miles	Milwaukee River	7.9	1975 to 2022	0.02
DD02[a]	Pike Creek: 0 to 2.2 miles	Direct Drainage	6.8	1964 to 2020	0.11
MN11	Honey Creek (Menomonee River): 0 to 3.1 miles	Menomonee River	6.7	1964 to 2022	0.04
OC03	Oak Creek: 9.5 to 12.4 miles	Oak Creek	6.7	1985 to 2022	0.31
OC01[a]	Oak Creek: 0 to 5.0 miles	Oak Creek	6.4	1964 to 2022	0.20
OC02	Oak Creek: 5.0 to 9.5 miles	Oak Creek	5.5	1964 to 2022	0.18
MN29[a]	Burnham Canal: 0.5 to 1.1 miles	Menomonee River	4.4	1989 to 2022	0.12
PK02	Pike River: 5.2 to 9.5 miles	Pike River	4.2	1976 to 2021	0.13
FX12	Fox River: 176.5 to 180.3 miles	Fox River	4.0	1961 to 2021	0.55
FX09	Fox River: 166.9 to 169.5 miles	Fox River	3.8	1964 to 2022	0.55
FX87	Pewaukee River: 0 to 6.3 miles	Fox River	3.6	1964 to 2020	0.66
MN14	Underwood Creek: 0 to 2.8 miles	Menomonee River	3.3	1964 to 2022	0.01
PK01[a]	Pike River: 0 to 4.5 miles	Pike River	2.8	1964 to 2020	0.10
MN01[a]	Menomonee River: 0 to 1.8 miles	Menomonee River	2.7	1975 to 2022	0.09
RT05	Root River: 25.8 to 34.3 miles	Root River	2.6	1961 to 2022	0.08
MN02	Menomonee River: 1.8 to 6.3 miles	Menomonee River	2.5	1962 to 2022	0.03
RK19	Bark River: 41.2 to 43.8 miles	Rock River	2.5	2000 to 2020	0.90
MN04	Menomonee River: 8.4 to 12.6 miles	Menomonee River	2.1	1966 to 2022	0.09
RK22	Bark River: 49.4 to 54.9 miles	Rock River	1.9	1973 to 2020	0.31
FX07	Fox River: 155.9 to 157.5 miles	Fox River	1.8	1964 to 2019	0.84
RK53	Rubicon River: 22.8 to 27.7 miles	Rock River	1.7	1964 to 2021	0.70
FX11	Fox River: 174.5 to 176.5 miles	Fox River	1.7	1964 to 2021	0.11
MK10	Milwaukee River: 35.8 to 43.7 miles	Milwaukee River	1.6	1964 to 2020	0.14
FX02	Fox River: 126.2 to 130.2 miles	Fox River	1.6	1964 to 2022	0.52
KK01	Kinnickinnic River: 0 to 2.4 miles	Kinnickinnic River	1.4	1975 to 2022	0.07
DP01	Des Plaines River: 110.6 to 111.9 miles	Des Plaines River	1.4	1964 to 2021	0.17
RK33	Oconomowoc River: 9.6 to 12.2 miles	Rock River	1.3	1964 to 2020	0.28
MN05	Menomonee River: 12.6 to 14.5 miles	Menomonee River	1.3	1975 to 2022	0.05
MN08	Menomonee River: 20.4 to 24.2 miles	Menomonee River	1.2	1964 to 2022	0.04
RT02	Root River: 5.2 to 7.4 miles	Root River	1.1	1961 to 2021	0.10
MK04	Milwaukee River: 15.1 to 19.4 miles	Milwaukee River	1.0	1961 to 2022	0.37
MK37	Cedar Creek: 1.8 to 14.1 miles	Milwaukee River	1.0	1964 to 2022	0.49
MK02[a]	Milwaukee River: 0.8 to 7.7 miles	Milwaukee River	0.9	1961 to 2022	0.15
SK01[a]	Sauk Creek: 0 to 2.6 miles	Sauk Creek	0.9	1964 to 2021	0.20
MN06	Menomonee River: 14.5 to 18.0 miles	Menomonee River	0.9	1964 to 2011	0.09
RK36	Oconomowoc River: 15.8 to 17.6 miles	Rock River	0.8	1964 to 2020	0.93
RK58	East Branch Rock River: 31.4 to 39.7 miles	Rock River	0.8	1964 to 2020	0.56

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Table 4.4 (Continued)

Reach ID	Reach Name	Watershed	Trend in Chloride (mg/l per yr)	Sampling Span	R^2
Increasing Chloride Trends (continued)					
RK02	Turtle Creek: 25.6 to 34.7 miles	Rock River	0.7	1961 to 2020	0.82
FX34	Honey Creek: 13.7 to 15.3 miles	Fox River	0.7	1964 to 2020	0.90
RK39	Oconomowoc River: 26.1 to 27.7 miles	Rock River	0.7	1964 to 2020	0.93
FX67	Mukwonago River: 1.0 to 2.3 miles	Fox River	0.7	1961 to 2022	0.84
MK01[a]	Milwaukee River: 0 to 0.8 miles	Milwaukee River	0.7	1964 to 2022	0.02
RK37	Oconomowoc River: 18.9 to 19.4 miles	Rock River	0.7	1973 to 2020	0.73
MK06	Milwaukee River: 24.1 to 27.5 miles	Milwaukee River	0.6	1964 to 2022	0.11
FX28	White River: 1.1 to 5.5 miles	Fox River	0.6	1961 to 2020	0.76
FX37	Sugar Creek: 0 to 3.4 miles	Fox River	0.6	1961 to 2020	0.62
RK38	Oconomowoc River: 23.1 to 24.9 miles	Rock River	0.6	1973 to 2020	0.90
FX71	Mukwonago River: 13.6 to 15.9 miles	Fox River	0.5	2004 to 2020	0.45
MN10	Menomonee River: 27.1 to 27.8 miles	Menomonee River	0.5	1964 to 2022	0.27
FX29	White River: 14.1 to 18.9 miles	Fox River	0.4	1964 to 2020	0.32
MN20	Little Menomonee River: 7.3 to 10.9 miles	Menomonee River	0.3	1975 to 2022	0.11
MK85	East Branch Milwaukee River: 0 to 11.0 miles	Milwaukee River	0.2	1976 to 2020	0.54
Decreasing Chloride Trends					
MN19	Little Menomonee River: 0 to 7.3 miles	Menomonee River	-1.6	1964 to 2022	0.01
RT13	Root River Canal: 0.8 to 5.7 miles	Root River	-0.8	1964 to 2021	0.02

Note: A simple linear regression was performed to analyze trends in chloride concentrations at all assessment reaches for the full period of record. Linear regressions were developed using the year of sample collection as the independent variable (x-axis) rather than the full date of collection. Each individual sample concentration was used as the dependent variable (y-axis). This approach captures the overall linear trend while accounting for the natural variability of the data points within each year. Assessment reaches that had a linear regression relationship with P-values < 0.01 were considered statistically significant trends.

[a] These assessment reaches are likely to be influenced by Lake Michigan water levels. Extreme high and low Lake Michigan levels may influence chloride concentrations observed in these assessment reaches.

Source: SEWRPC

Table 4.5
Chloride Summary Statistics by Watershed for the Recent Period of Record: 2013-2022

		Chloride Concentration (mg/l)					
Watershed	**Number of Samples**	Minimum	Mean	Median	Maximum	25th Quartile	75th Quartile
Des Plaines River	63	18	187	81	1,470	54	154
Fox River	577	11	127	99	991	44	165
Kinnickinnic River	2,523	13	298	130	26,300	71	330
Menomonee River	4,379	13	236	160	6,400	87	260
Milwaukee River	4,856	3	115	76	6,630	52	100
Oak Creek	730	30	422	310	7,120	220	480
Pike River	743	5	169	137	1,255	92	220
Rock River	844	9	62	56	363	42	73
Root River	626	12	291	180	3,600	123	320
Sauk Creek	28	22	80	64	365	51	77
Sheboygan River	--	--	--	--	--	--	--
Direct Drainage Area to Lake Michigan	196	29	305	229	3,473	161	353

Source: SEWRPC

Table 4.6
Linear Regression Statistics for Relationships Between Selected Land Use Categories and Recent Median Chloride Concentration Among Balanced Stream Assessment Reaches

Land Use Groupings	Slope	P-value	Significant	R^2
Urban Land Use[a]	2.6	3.52×10^{-18}	Yes	0.61
Roads and Parking Lots	8.4	1.00×10^{-17}	Yes	0.60
Residential (all categories)[b]	6.0	8.19×10^{-15}	Yes	0.53
Lower-Density Residential	-1.3	0.41	No	0.01
Medium-Density Residential	10.5	2.13×10^{-6}	Yes	0.25
High-Density Residential	6.5	1.94×10^{-12}	Yes	0.46
Commercial	55.3	1.22×10^{-13}	Yes	0.50
Industrial	25.6	1.60×10^{-8}	Yes	0.33
Rural Land Use[c]	-2.6	5.99×10^{-18}	Yes	0.61
Agricultural	-3.1	4.13×10^{-12}	Yes	0.45
Natural Land Use[d]	-5.0	6.86×10^{-10}	Yes	0.38
Wetlands	-7.2	5.98×10^{-6}	Yes	0.23
Woodlands	-9.7	7.77×10^{-8}	Yes	0.30

[a] *Includes lower-density residential; medium-density residential; high-density residential; commercial; industrial; government and institutional; roads and parking lots; transportation, communication, and utility; recreation; and urban unused lands.*

[b] *Includes lower-density residential; medium-density residential; high-density residential.*

[c] *Includes agricultural, wetlands, woodlands, rural unused lands, extractive and landfill, and surface water.*

[d] *Includes wetlands, woodlands, and surface water.*

Source: SEWRPC

Table 4.7
Balanced Assessment Reaches with Statistically Significant Trends in Chloride Concentrations for the Recent Period of Record: 2013-2022

Reach ID	Reach Name	Watershed	Number of Recent Chloride Samples	Trend in Chloride (mg/l per yr)	Sampling Span	R^2
Increasing Chloride Trends						
MN11	Honey Creek: 0 to 3.1 miles	Menomonee River	233	46.9	2013-2022	0.03
Decreasing Chloride Trends						
MK33	Ulao Creek: 1.8 to 5.3 miles	Milwaukee River	139	-61.8	2013-2022	0.13
MN19	Little Menomonee River: 0 to 7.3 miles	Menomonee River	407	-11.9	2013-2022	0.02
PK10	Unnamed Tributary to Pike River 0 to 1.8 miles	Pike River	82	-9.8	2013-2020	0.17
MN08	Menomonee River: 20.4 to 24.2 miles	Menomonee River	204	-6.9	2013-2022	0.06
MN29[a]	Burnham Canal: 0.5 to 1.1 miles	Menomonee River	199	-6.2	2013-2022	0.02
MN01[a]	Menomonee River: 0 to 1.8 miles	Menomonee River	1,396	-5.7	2013-2022	0.01
RK33	Oconomowoc River: 9.6 to 12.2 miles	Rock River	100	-5.4	2013-2020	0.23
RK34	Oconomowoc River: 12.2 to 13.9 miles	Rock River	151	-3.1	2013-2020	0.39
MK01[a]	Milwaukee River: 0 to 0.8 miles	Milwaukee River	1,174	-1.9	2013-2022	0.01
MN10	Menomonee River: 27.1 to 27.8 miles	Menomonee River	184	-1.5	2013-2022	0.11
MK02[a]	Milwaukee River: 0.8 to 7.7 miles	Milwaukee River	1,287	-1.2	2013-2022	0.01

Note: A simple linear regression was performed to analyze trends in chloride concentrations at all assessment reaches for the recent period of record. Linear regressions were developed using the year of sample collection as the independent variable (x-axis) rather than the full date of collection. Each individual sample concentration was used as the dependent variable (y-axis). This approach captures the overall linear trend while accounting for the natural variability of the data points within each year. Assessment reaches that had a linear regression relationship with P-values < 0.01 were considered statistically significant trends.

[a] *These assessment reaches are likely to be influenced by Lake Michigan water levels. During the recent period of record (2013 through 2022), Lake Michigan experienced near record low water levels in 2013. By 2015, water levels had risen above the long-term average annual water level and to near record levels in 2019 and 2020 before receding back to near average levels in 2022. Extreme high Lake Michigan water levels may cause dilution of chloride concentrations.*

Source: SEWRPC

Table 4.8
Summary of Stream Assessment Reaches Within the Des Plaines River Watershed:[a] 1961-2022

Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
DP01	Des Plaines River: 110.6 to 111.9 miles	734000	4	1.3	77	1964 - 2021	88	1964 - 2021
DP02	Des Plaines River: 115.2 to 116.6 miles	734000	4	1.4	183	1961 - 1976	4	1961 - 2009
DP03	Des Plaines River: 116.6 to 116.9 miles	734000	4	0.3	--	--	14	2007 - 2010
DP04	Des Plaines River: 119.6 to 120.8 miles	734000	4	1.1	--	--	16	2010 - 2011
DP05	Des Plaines River: 122.7 to 124.5 miles	734000	4	1.8	62	1964 - 1976	69	1964 - 2015
DP06	Unnamed Tributary to Des Plaines River: 0 to 1.4 miles	736800	1	1.4	7	1998	8	1998
DP07	Kilbourn Road Ditch: 0 to 6.1 miles	736900	3	6.1	7	1998	8	1998
DP08	Kilbourn Road Ditch: 7.3 to 11.4 miles	736900	2	4.1	33	2018 - 2021	33	2018 - 2021
DP09	Center Creek: 1.0 to 3.5 miles	737200	2	2.4	7	1998	8	1998
DP10	Brighton Creek: 0 to 2.9 miles	737400	4	2.9	28	1964 - 1975	3	1964 - 1975
DP11	Brighton Creek: 5.6 to 7.3 miles	737400	3	1.7	--	--	2	2007 - 2015
DP12	Unnamed Tributary to Brighton Creek: 0 to 1.3 miles	738900	1	1.3	--	--	5	2008

Note: Chloride and specific conductance datasets shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

[a] *This table represents the portion of the watershed that is within the study area. River miles for the Des Plaines River are measured from its mouth at the Illinois River.*

Source: WDNR, USGS, and SEWRPC

Table 4.9

Percent of Measured Chloride and Specific Conductance Samples by Season at Assessment Reaches Within the Des Plaines River Watershed:[a] 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
DP01	Des Plaines River: 110.6 to 111.9 miles	77	20.8	18.2	44.2	16.9	88	22.7	15.9	46.6	14.8
DP02	Des Plaines River: 115.2 to 116.6 miles	183	20.8	25.7	26.8	26.8	4	0.0	0.0	0.0	100
DP03	Des Plaines River: 116.6 to 116.9 miles	--	--	--	--	--	14	0.0	42.9	35.7	21.4
DP04	Des Plaines River: 119.6 to 120.8 miles	--	--	--	--	--	16	0.0	31.3	37.5	31.3
DP05	Des Plaines River: 122.7 to 124.5 miles	62	0.0	6.5	35.5	58.1	69	0.0	5.8	42.0	52.2
DP06	Unnamed Tributary to Des Plaines River: 0 to 1.4 miles	7	0.0	28.6	42.9	28.6	8	12.5	25.0	37.5	25.0
DP07	Kilbourn Road Ditch: 0 to 6.1 miles	7	0.0	28.6	42.9	28.6	8	12.5	25.0	37.5	25.0
DP08	Kilbourn Road Ditch: 7.3 to 11.4 miles	33	42.4	18.2	18.2	21.2	33	42.4	18.2	18.2	21.2
DP09	Center Creek: 1.0 to 3.5 miles	7	0.0	28.6	42.9	28.6	8	12.5	25.0	37.5	25.0
DP10	Brighton Creek: 0 to 2.9 miles	28	0.0	14.3	78.6	7.1	34	0.0	11.8	82.4	5.9
DP11	Brighton Creek: 5.6 to 7.3 miles	--	--	--	--	--	2	0.0	0.0	0.0	100
DP12	Unnamed Tributary to Brighton Creek: 0 to 1.3 miles	--	--	--	--	--	5	0.0	0.0	60.0	40.0

Note: Seasons are defined as Winter (December through February), Spring (March through May), Summer (June through August), and Fall (September through November). Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps during the period of 1961 through 2022. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance. Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter.

[a] *This table represents the portion of the watershed that is within the study area. River miles for the Des Plaines River are measured from its mouth at the Illinois River.*

Source: WDNR, USGS, and SEWRPC

Table 4.10
Summary Statistics for Measured Chloride and Specific Conductance at Assessment Reaches within the Des Plaines River Watershed:[a] 1961-2022

Reach ID	Assessment Reach	Number of Chloride Concentration (mg/l)					Measured Specific Conductance (μS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
DP01	Des Plaines River: 110.6 to 111.9 miles	77	20	84	60	517	88	329	901	899	2,347
DP02	Des Plaines River: 115.2 to 116.6 miles	183	3	56	41	1,650	4	652	770	766	898
DP03	Des Plaines River: 116.6 to 116.9 miles	--	--	--	--	--	14	667	815	784	992
DP04	Des Plaines River: 119.6 to 120.8 miles	--	--	--	--	--	16	189	858	878	1,220
DP05	Des Plaines River: 122.7 to 124.5 miles	62	7	83	45	273	69	630	943	910	1,478
DP06	Unnamed Tributary to Des Plaines River: 0 to 1.4 miles	7	38	80	83	120	8	535	844	901	1,028
DP07	Kilbourn Road Ditch: 0 to 6.1 miles	7	61	127	90	208	8	638	868	898	1,119
DP08	Kilbourn Road Ditch: 7.3 to 11.4 miles	33	18	243	73	1,470	33	232	1,215	685	5,645
DP09	Center Creek: 1.0 to 3.5 miles	7	32	45	45	71	8	544	747	754	865
DP10	Brighton Creek: 0 to 2.9 miles	28	5	19	15	38	34	553	675	660	875
DP11	Brighton Creek: 5.6 to 7.3 miles	--	--	--	--	--	2	785	875	875	966
DP12	Unnamed Tributary to Brighton Creek: 0 to 1.3 miles	--	--	--	--	--	5	308	825	890	1,120

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

[a] *This table represents the portion of the watershed that is within the study area. River miles for the Des Plaines River are measured from its mouth at the Illinois River.*

Source: WDNR, USGS, and SEWRPC

00273578.DOCX
200-1100
LKH/AWO/mid
6/6/25, 6/19/24, 05/29/2025

Table 4.11
Percentage of Measurements in Which Chloride Concentrations Exceeded Various Water Quality Thresholds in the Des Plaines River Watershed Full Record: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
DP01	Des Plaines River: 110.6 to 111.9 miles	77	100.0	84.4	9.1	6.9	2.6	0.0	0.0
DP02	Des Plaines River: 115.2 to 116.6 miles	183	97.8	57.4	3.3	0.6	0.5	0.5	0.5
DP03	Des Plaines River: 116.6 to 116.9 miles	--	--	--	--	--	--	--	--
DP04	Des Plaines River: 119.6 to 120.8 miles	--	--	--	--	--	--	--	--
DP05	Des Plaines River: 122.7 to 124.5 miles	62	98.4	74.2	19.4	12.9	0.0	0.0	0.0
DP06	Unnamed Tributary to Des Plaines River: 0 to 1.4 miles	7	100.0	100.0	0.0	0.0	0.0	0.0	0.0
DP07	Kilbourn Road Ditch: 0 to 6.1 miles	7	100.0	100.0	42.9	0.0	0.0	0.0	0.0
DP08	Kilbourn Road Ditch: 7.3 to 11.4 miles	33	100.0	81.8	39.4	27.3	21.2	12.1	3.0
DP09	Center Creek: 1.0 to 3.5 miles	7	100.0	85.7	0.0	0.0	0.0	0.0	0.0
DP10	Brighton Creek: 0 to 2.9 miles	28	60.7	7.1	0.0	0.0	0.0	0.0	0.0
DP11	Brighton Creek: 5.6 to 7.3 miles	--	--	--	--	--	--	--	--
DP12	Unnamed Tributary to Brighton Creek: 0 to 1.3 miles	--	--	--	--	--	--	--	--

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps during the period of 1961 through 2022. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: SEWRPC

Table 4.12
Summary Statistics for Recent Measured Chloride and Specific Conductance at Assessment Reaches Within the Des Plaines River Watershed:[a] 2013-2022

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)[b]					Measured Specific Conductance (µS/cm)[b]				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
DP01	Des Plaines River: 110.6 to 111.9 miles	30	24	125	83	517	33	329	877	756	2,347
DP02	Des Plaines River: 115.2 to 116.6 miles	--	--	--	--	--	--	--	--	--	--
DP03	Des Plaines River: 116.6 to 116.9 miles	--	--	--	--	--	--	--	--	--	--
DP04	Des Plaines River: 119.6 to 120.8 miles	--	--	--	--	--	--	--	--	--	--
DP05	Des Plaines River: 122.7 to 124.5 miles	--	--	--	--	--	1	874	874	874	874
DP06	Unnamed Tributary to Des Plaines River: 0 to 1.4 miles	--	--	--	--	--	--	--	--	--	--
DP07	Kilbourn Road Ditch: 0 to 6.1 miles	--	--	--	--	--	--	--	--	--	--
DP08	Kilbourn Road Ditch: 7.3 to 11.4 miles	33	18	243	73	1,470	33	232	1,215	685	5,645
DP09	Center Creek: 1.0 to 3.5 miles	--	--	--	--	--	--	--	--	--	--
DP10	Brighton Creek: 0 to 2.9 miles	--	--	--	--	--	--	--	--	--	--
DP11	Brighton Creek: 5.6 to 7.3 miles	--	--	--	--	--	1	966	966	966	966
DP12	Unnamed Tributary to Brighton Creek: 0 to 1.3 miles	--	--	--	--	--	--	--	--	--	--

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

[a] *This table represents the portion of the watershed that is within the study area. River miles for the Des Plaines River are measured from its mouth at the Illinois River.*

[b] *The recent period of record for the Des Plaines River watershed includes samples from October 2018 through February 2021.*

Source: SEWRPC

Table 4.13
Percentage of Recent Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Des Plaines River Watershed: 2013-2022

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
DP01	Des Plaines River: 110.6 to 111.9 miles	30	100	86.7	23.3	16.7	6.7	0.0	0.0
DP02	Des Plaines River: 115.2 to 116.6 miles	--	--	--	--	--	--	--	--
DP03	Des Plaines River: 116.6 to 116.9 miles	--	--	--	--	--	--	--	--
DP04	Des Plaines River: 119.6 to 120.8 miles	--	--	--	--	--	--	--	--
DP05	Des Plaines River: 122.7 to 124.5 miles	--	--	--	--	--	--	--	--
DP06	Unnamed Tributary to Des Plaines River: 0 to 1.4 miles	--	--	--	--	--	--	--	--
DP07	Kilbourn Road Ditch: 0 to 6.1 miles	--	--	--	--	--	--	--	--
DP08	Kilbourn Road Ditch: 7.3 to 11.4 miles	33	100	81.8	39.4	27.3	21.2	12.1	3.0
DP09	Center Creek: 1.0 to 3.5 miles	--	--	--	--	--	--	--	--
DP10	Brighton Creek: 0 to 2.9 miles	--	--	--	--	--	--	--	--
DP11	Brighton Creek: 5.6 to 7.3 miles	--	--	--	--	--	--	--	--
DP12	Unnamed Tributary to Brighton Creek: 0 to 1.3 miles	--	--	--	--	--	--	--	--

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the recent period of record are included in this table to indicate sampling gaps during the recent period of record. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: SEWRPC

#277504
200-1100
AWO/MAS/mid
6/10/25

Table 4.14
Summary of Stream Assessment Reaches Within the Fox River Watershed: 1961-2022

Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
FX01	Fox River: 116.0 to 119.4 miles	742500	6	3.4	271	1961 - 1977	152	1961 - 2009
FX02	Fox River: 126.2 to 130.2 miles	742500	6	4.0	197	1964 - 2022	386	1964 - 2022
FX03	Fox River: 135.9 to 138.8 miles	742500	6	2.9	94	1964 - 1977	102	1964 - 1977
FX04	Fox River: 139.3 to 143.0 miles	742500	6	3.7	26	2018 - 2020	35	2018 - 2022
FX05	Fox River: 146.5 to 148.1 miles	742500	5	1.6	39	1964 - 2019	53	1964 - 2019
FX06	Fox River: 150.3 to 154.4 miles	742500	5	4.1	22	2007 - 2015	--	--
FX07	Fox River: 155.9 to 157.5 miles	742500	5	1.5	44	1964 - 2019	56	1964 - 2019
FX08	Fox River: 160.9 to 162.4 miles	742500	5	1.6	41	1961 - 1975	56	1961 - 2022
FX09	Fox River: 166.9 to 169.5 miles	742500	5	2.6	221	1964 - 2022	392	1964 - 2022
FX10	Fox River: 169.5 to 174.5 miles	742500	5	5.0	49	1964 - 2015	39	1964 - 2018
FX11	Fox River: 174.5 to 176.5 miles	742500	5	2.0	42	1964 - 2021	89	1964 - 2022
FX12	Fox River: 176.5 to 180.3 miles	742500	5	3.8	128	1961 - 2021	290	1961 - 2022
FX13	Fox River: 181.5 to 182.9 miles	742500	4	1.4	46	1964 - 1998	55	1964 - 1998
FX14	Fox River: 182.9 to 183.4 miles	742500	4	0.5	8	1992 - 1998	10	1992 - 1998
FX15	Fox River: 188.4 to 187.1 miles	742500	3	3.7	7	1998	25	1998 - 2009
FX16	Fox River: 189.6 to 191.2 miles	742500	3	1.5	29	1961 - 2015	146	1961 - 2022
FX17	Fox River: 192.5 to 194.4 miles	742500	2	1.9	39	1964 - 1975	46	1964 - 1975
FX18	North Branch Nippersink Creek: 8.7 to 10.5 miles	742700	4	1.8	35	1964 - 1998	44	1964 - 1998
FX19	North Branch Nippersink Creek: 10.5 to 12.0 miles	742700	4	1.6	--	--	1	2009
FX20	North Branch Nippersink Creek: 12.1 to 13.6 miles	742700	3	1.6	7	1998	8	1998
FX21	East Branch North Branch Nippersink Creek: 0 to 1.5 miles	743400	3	1.5	7	1998	8	1998
FX22	Unnamed Tributary to East Branch North Branch Nippersink Creek: 0 to 0.8 miles	743500	2	0.8	--	--	1	2012
FX23	West Branch North Branch Nippersink Creek: 0 to 1.9 miles	744400	3	1.9	7	1998	14	1998 - 2001
FX24	Bassett Creek: 0 to 3.6 miles	748200	2	3.6	56	1964 - 1975	74	1964 - 2001
FX25	Peterson Creek: 1.2 to 5.3 miles	748500	2	4.1	--	--	1	2009
FX26	Unnamed Tributary to New Munster Creek: 0 to 1.6 miles	749000	1	1.6	--	--	1	2007
FX27	Spring Brook (Racine County): 0 to 4.0 miles	750400	2	4.0	--	--	1	2009
FX28	White River: 1.1 to 5.5 miles	751200	4	4.4	97	1961 - 2020	168	1961 - 2022
FX29	White River: 14.1 to 18.9 miles	751200	3	4.9	60	1964 - 2020	68	1964 - 2020
FX30	Honey Creek: 0 to 2.8 miles	751500	4	2.8	30	1964 - 1975	50	1964 - 2016
FX31	Honey Creek: 2.8 to 4.8 miles	751500	4	2.0	16	1961 - 2018	33	1961 - 2022
FX32	Honey Creek: 9.2 to 10.3 miles	751500	4	1.2	--	--	5	1995

Table 4.14 (Continued)

Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
FX33	Honey Creek: 10.7 to 12.2 miles	751500	4	1.5	--	--	6	2016
FX34	Honey Creek: 13.7 to 15.3 miles	751500	4	1.6	85	1964 - 2020	96	1964 - 2020
FX35	Honey Creek: 17.1 to 21.5 miles	751500	4	4.4	26	2018 - 2020	39	1995 - 2020
FX36	Honey Creek: 25.0 to 26.2 miles	751500	1	1.2	--	--	5	1995 - 2016
FX37	Sugar Creek: 0 to 3.4 miles	752100	3	3.4	59	1961 - 2020	98	1961 - 2022
FX38	Sugar Creek: 4.1 to 15.4 miles	752100	3	11.2	--	--	18	1981 - 2016
FX39	Sugar Creek: 18.3 to 22.7 miles	752100	3	4.4	28	1964 – 1975	51	1964 - 2016
FX40	Spring Brook (Walworth County): 0 to 2.5 miles	752400	2	2.5	--	--	19	1995 - 2016
FX41	North Branch Spring Brook (Spring Prairie): 0 to 2.1 miles	752500	1	2.1	--	--	1	2016
FX42	Baker Creek: 0 to 5.2 miles	753000	2	5.2	--	--	23	1995 - 2016
FX43	Spring Creek: 0 to 4.4 miles	753900	3	4.4	--	--	15	1995 - 2016
FX44	Unnamed Tributary to Honey Creek: 0.9 to 1.8 miles	754600	2	0.9	--	--	2	2016
FX45	Unnamed Tributary to Honey Creek: 0.5 to 1.8 miles	754800	2	1.3	--	--	2	2016
FX46	Unnamed Tributary to Honey Creek: 0 to 1.9 miles	755100	1	1.9	--	--	2	2016
FX47	Ore Creek: 0 to 0.8 miles	757000	3	0.8	7	1998	9	1998 - 2018
FX48	Ore Creek: 2.8 to 4.0 miles	757000	3	1.2	--	--	6	2001 - 2001
FX49	Second Branch Ore Creek: 0 to 1.9 miles	757100	2	1.9	1	2018	1	2018
FX50	Como Creek: 0 to 3.3 miles	757600	4	3.3	28	1964 - 1975	37	1964 - 2017
FX51	Eagle Creek: 0 to 4.8 miles	759500	2	4.8	--	--	7	2019 - 2020
FX52	Unnamed Tributary to Eagle Creek: 0 to 1.8 miles	759600	1	1.8	--	--	2	2007
FX53	East Eagleast Lake Ditch: 0 to 1.7 miles	760000	1	1.7	--	--	2	2019
FX54	Wind Lake Drainage Canal: 0 to 3.6 miles	760200	5	3.7	28	1964 - 1975	34	1964 - 1975
FX55	Wind Lake Drainage Canal: 6.8 to 7.3 miles	760200	4	0.4	--	--	36	2020 - 2022
FX56	Goose Lake Branch Canal: 2.8 to 3.8 miles	760300	3	1.0	1	1977	5	1977
FX57	Horner Farms Ditch Tributary to Wind Lake Canal: 0 to 1.8 miles	761500	3	1.8	8	1977	20	1967 - 1977
FX58	Muskego Canal: 0 to 1.3 miles	761800	4	1.3	35	1964 - 1975	40	1964 - 1975
FX59	Unnamed Tributary to Muskego Canal: 0 to 1.3 miles	762200	3	1.3	--	--	6	1988 - 1989
FX60	Jewel Creek: 0 to 0.7 miles	762500	3	0.7	12	2004 - 2005	21	2004 - 2022
FX61	Unnamed Tributary to Bass Bay: 0 to 2.2 miles	763100	1	2.2	--	--	9	1994 - 1994
FX62	Tichigan Creek: 0 to 1.5 miles	763700	2	1.5	--	--	4	2014 - 2018
FX63	Unnamed Tributary to Tichigan Lake (Fox River): 0.5 to 3.5 miles	763800	1	3.0	--	--	1	2018
FX64	Unnamed Tributary to Tichigan Lake (Fox River): 0 to 3.6 miles	763900	1	3.6	--	--	1	2018
FX65	Unnamed Tributary to Fox River: 0 to 1.0 miles	764000	2	1.0	--	--	1	2018
FX66	Ripple Brook: 0 to 1.1 miles	764800	1	1.1	--	--	1	2018
FX67	Mukwonago River: 1.0 to 2.3 miles	765500	4	1.3	110	1961 - 2022	291	1961 - 2022
FX68	Mukwonago River: 4.1 to 6.4 miles	765500	4	2.2	18	2004 - 2017	39	2004 - 2017
FX69	Mukwonago River: 6.4 to 7.6 miles	765500	3	1.2	18	2004 - 2017	26	2004 - 2017
FX70	Mukwonago River: 9.6 to 11.3 miles	765500	3	1.7	17	2004 - 2017	16	2004 - 2021
FX71	Mukwonago River: 13.6 to 15.9 miles	765500	3	2.3	76	2004 - 2020	67	2004 - 2021
FX72	Pickeral Lake Outlet: 0 to 0.1 mile	766600	2	0.1	4	1973 - 1974	4	1973 - 1974

Table 4.14 (Continued)

Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
FX73	Jericho Creek: 0 to 5.7 miles	768300	2	5.7	51	2004 - 2017	51	2004 - 2021
FX74	Unnamed Tributarty to Jericho Creek: 0 to 1.3 miles	768400	1	1.3	--	--	1	2008
FX75	Unnamed tributary to Mukwonago River: 0 to 2.5 miles	768900	2	2.5	40	2004 - 2017	32	2004 - 2021
FX76	Mill Brook: 0 to 3.8 miles	769400	2	3.8	--	--	2	2018
FX77	Pebble Brook: 0 to 7.3 miles	769500	3	7.3	25	2018 - 2020	29	2013 - 2020
FX78	Mill Creek: 0 to 1.0 miles	769700	2	1.0	--	--	1	2009
FX79	Genesee Creek: 0.5 to 1.3 miles	769800	3	0.8	1	2004	1	2018
FX80	Genesee Creek: 1.9 to 4.4 miles	769800	3	2.5	--	--	4	2008 - 2018
FX81	Spring Brook (Waukesha County): 0 to 3.1 miles	770300	2	3.1	--	--	2	2018
FX82	Pebble Creek: 0 to 3.3 miles	771300	4	3.3	2	2004 - 2009	33	2007 - 2015
FX83	Pebble Creek: 3.3 to 4.7 miles	771300	3	1.5	--	--	169	2007 - 2020
FX84	Pebble Creek: 4.7 to 6.6 miles	771300	2	1.8	--	--	1	2015 - 2015
FX85	Brandy Brook: 0 to 4.2 miles	771400	3	4.2	--	--	30	2007 - 2015
FX86	Pewaukee Lake Outlet: 0 to 0.2 miles	771700	4	0.2	--	--	180	2007 - 2020
FX87	Pewaukee River: 0 to 6.3 miles	771700	4	6.3	102	1964 - 2020	652	1964 - 2020
FX88	Pewaukee River: 6.3 to 10.7 miles	771700	2	4.5	7	2014 - 2015	345	2007 - 2020
FX89	Coco Creek: 0 to 0.9 miles	772100	3	0.9	7	2012 - 2014	182	2007 - 2020
FX90	Coco Creek: 0.9 to 3.9 miles	772100	2	3.0	--	--	177	2007 - 2020
FX91	Meadowbrook Creek: 0 to 1.8 miles	772300	3	1.8	5	2015	174	2007 - 2020
FX92	Zion Creek: 0 to 0.8 miles	772400	2	0.8	6	2012 - 2014	184	2007 - 2020
FX93	Poplar Creek: 0 to 3.9 miles	772800	4	3.9	79	1964 - 2004	93	1964 - 2015
FX94	Poplar Creek: 5.5 to 7.8 miles	772800	3	2.3	3	2018 - 2019	5	2015 - 2020
FX95	Deer Creek: 0.5 to 5.5 miles	772900	3	5.0	--	--	8	2009 - 2015
FX96	Sussex Creek: 0.7 to 5.4 miles	773400	2	4.7	49	1964 – 2015	127	1964 - 2020
FX97	North Branch Genesee Creek: 0 to 1.0 miles	3000068	2	1.0	--	--	1	2018
FX98	South Branch Genesee Creek: 0 to 1.9 miles	3000069	2	1.9	--	--	1	2018
FX99	Unnamed Tributary to Pebble Creek: 0 to 1.9 miles	3000119	2	1.9	--	--	1	2015
FX100	Unnamed Tributary to Sussex Creek: 0 to 3.0 miles	3000121	1	3.0	--	--	1	1998
FX101	Unnamed Tributary to Deer Creek: 0 to 1.6 miles	5036064	1	1.6	2	1977	2	1977
FX102	Unnamed Tributary to Lauderdale Lakes: 0 to 0.7 miles	5039050	1	0.7	--	--	4	1994 - 2002

Note: Chloride and specific conductance datasets shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: WDNR, USGS, USEPA, Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.15
Percent of Measured Chloride and Specific Conductance Samples by Season at Assessment Reaches Within the Fox River Watershed: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
FX01	Fox River: 116.0 to 119.4 miles	271	18.8	22.1	27.3	31.7	152	11.2	22.4	31.6	34.9
FX02	Fox River: 126.2 to 130.2 miles	197	18.3	24.9	33.5	23.4	386	17.6	23.8	32.9	25.6
FX03	Fox River: 135.9 to 138.8 miles	94	5.3	13.8	25.5	55.3	102	4.9	12.7	31.4	51.0
FX04	Fox River: 139.3 to 143.0 miles	26	26.9	23.1	23.1	26.9	35	34.3	20.0	20.0	25.7
FX05	Fox River: 146.5 to 148.1 miles	39	5.1	12.8	66.7	15.4	53	3.8	11.3	69.8	15.1
FX06	Fox River: 150.3 to 154.4 miles	22	4.5	27.3	27.3	40.9	--	--	--	--	--
FX07	Fox River: 155.9 to 157.5 miles	44	11.4	11.4	63.6	13.6	56	8.9	12.5	64.3	14.3
FX08	Fox River: 160.9 to 162.4.4 miles	41	12.2	14.6	61.0	12.2	56	14.3	12.5	60.7	12.5
FX09	Fox River: 166.9 to 169.5 miles	221	19.5	23.5	32.1	24.9	392	19.1	23.5	31.4	26.0
FX10	Fox River: 169.5 to 174.5 miles	49	2.0	18.4	57.1	22.4	39	0.0	7.7	82.1	10.3
FX11	Fox River: 174.5 to 176.5 miles	42	14.3	16.7	59.5	9.5	89	15.7	19.1	47.2	18.0
FX12	Fox River: 176.5 to 180.3 miles	128	14.8	20.3	28.1	36.7	290	17.9	21.7	30.0	30.3
FX13	Fox River: 181.5 to 182.9 miles	46	8.7	17.4	60.9	13.0	55	9.1	14.5	63.6	12.7
FX14	Fox River: 182.9 to 183.4 miles	8	0.0	25.0	37.5	37.5	10	10.0	20.0	30.0	40.0
FX15	Fox River: 188.4 to 187.1 miles	7	0.0	28.6	42.9	28.6	25	12.0	32.0	28.0	28.0
FX16	Fox River: 189.6 to 191.2 miles	29	17.2	34.5	20.7	27.6	146	28.1	26.0	24.7	21.2
FX17	Fox River: 192.5 to 194.4 miles	39	12.8	12.8	64.1	10.3	46	10.9	13.0	67.4	8.7
FX18	North Branch Nippersink Creek: 8.7 to 10.5 miles	35	0.0	17.1	71.4	11.4	44	2.3	13.6	75.0	9.1
FX19	North Branch Nippersink Creek: 10.5 to 12.0 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX20	North Branch Nippersink Creek: 12.1 to 13.6 miles	7	0.0	28.6	42.9	28.6	8	12.5	25.0	37.5	25.0
FX21	East Branch North Branch Nippersink Creek: 0 to 1.5 miles	7	0.0	28.6	42.9	28.6	8	12.5	25.0	37.5	25.0
FX22	Unnamed Tributary to East Branch North Branch Nippersink Creek: 0 to 0.8 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX23	West Branch North Branch Nippersink Creek: 0 to 1.9 miles	7	0.0	28.6	42.9	28.6	14	7.1	21.4	42.9	28.6
FX24	Bassett Creek: 0 to 3.6 miles	56	0.0	14.3	78.6	7.1	74	0.0	12.2	79.7	8.1
FX25	Peterson Creek: 1.2 to 5.3 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX26	Unnamed Tributary to New Munster Creek: 0 to 1.6 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX27	Spring Brook (Racine County): 0 to 4.0 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX28	White River: 1.1 to 5.5 miles	97	7.2	13.4	32.0	47.4	168	17.3	15.5	33.3	33.9
FX29	White River: 14.1 to 18.9 miles	60	10.0	20.0	51.7	18.3	68	10.3	17.6	55.9	16.2
FX30	Honey Creek: 0 to 2.8 miles	30	3.3	16.7	73.3	6.7	50	2.0	14.0	72.0	12.0
FX31	Honey Creek: 2.8 to 4.8 miles	16	0.0	18.8	75.0	6.3	33	12.1	15.2	54.5	18.2

Table 4.15 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
FX32	Honey Creek: 9.2 to 10.3 miles	--	--	--	--	--	5	0.0	0.0	60.0	40.0
FX33	Honey Creek: 10.7 to 12.2 miles	--	--	--	--	--	6	0.0	0.0	50.0	50.0
FX34	Honey Creek: 13.7 to 15.3 miles	85	7.1	20.0	32.9	40.0	96	6.3	16.7	38.5	38.5
FX35	Honey Creek: 17.1 to 21.5 miles	26	23.1	26.9	23.1	26.9	39	15.4	20.5	30.8	33.3
FX36	Honey Creek: 25.0 to 26.2 miles	--	--	--	--	--	7	0.0	0.0	57.1	42.9
FX37	Sugar Creek: 0 to 3.4 miles	59	11.9	22.0	10.2	55.9	98	16.3	21.4	17.3	44.9
FX38	Sugar Creek: 4.1 to 15.4 miles	--	--	--	--	--	18	0.0	0.0	55.6	44.4
FX39	Sugar Creek: 18.3 to 22.7 miles	28	0.0	14.3	78.6	7.1	51	0.0	7.8	74.5	17.6
FX40	Spring Brook (Walworth County): 0 to 2.5 miles	--	--	--	--	--	19	0.0	10.5	47.4	42.1
FX41	North Branch Spring Brook (Spring Prairie): 0 to 2.1 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
FX42	Baker Creek: 0 to 5.2 miles	--	--	--	--	--	23	0.0	8.7	47.8	43.5
FX43	Spring Creek: 0 to 4.4 miles	--	--	--	--	--	15	0.0	6.7	53.3	40.0
FX44	Unnamed Tributary to Honey Creek: 0.9 to 1.8 miles	--	--	--	--	--	2	0.0	0.0	50.0	50.0
FX45	Unnamed Tributary to Honey Creek: 0.5 to 1.8 miles	--	--	--	--	--	2	0.0	0.0	50.0	50.0
FX46	Unnamed Tributary to Honey Creek: 0 to 1.9 miles	--	--	--	--	--	2	0.0	0.0	50.0	50.0
FX47	Ore Creek: 0 to 0.8 miles	7	0.0	28.6	42.9	28.6	9	11.1	22.2	44.4	22.2
FX48	Ore Creek: 2.8 to 4.0 miles	--	--	--	--	--	6	0.0	16.7	50.0	33.3
FX49	Second Branch Ore Creek: 0 to 1.9 miles	1	0.0	0.0	100	0.0	1	0.0	0.0	100	0.0
FX50	Como Creek: 0 to 3.3 miles	28	0.0	14.3	78.6	7.1	37	0.0	10.8	81.1	8.1
FX51	Eagle Creek: 0 to 4.8 miles	--	--	--	--	--	7	0.0	14.3	28.6	57.1
FX52	Unnamed Tributary to Eagle Creek: 0 to 1.8 miles	--	--	--	--	--	2	0.0	0.0	100	0.0
FX53	East Eagleast Lake Ditch: 0 to 1.7 miles	--	--	--	--	--	2	0.0	0.0	50.0	50.0
FX54	Wind Lake Drainage Canal: 0 to 3.6 miles	28	0.0	14.3	78.6	7.1	34	0.0	11.8	82.4	5.9
FX55	Wind Lake Drainage Canal: 6.8 to 7.3 miles	--	--	--	--	--	36	19.4	27.8	27.8	25.0
FX56	Goose Lake Branch Canal: 2.8 to 3.8 miles	1	0.0	100	0.0	0.0	5	0.0	20.0	60.0	20.0
FX57	Horner Farms Ditch Tributary to Wind Lake Canal: 0 to 1.8 miles	8	0.0	100	0.0	0.0	20	0.0	40.0	50.0	10.0
FX58	Muskego Canal: 0 to 1.3 miles	35	5.7	14.3	65.7	14.3	40	5.0	12.5	70.0	12.5
FX59	Unnamed Tributary to Muskego Canal: 0 to 1.3 miles	--	--	--	--	--	6	16.7	83.3	0.0	0.0
FX60	Jewel Creek: 0 to 0.7 miles	12	16.7	33.3	41.7	8.3	21	9.5	23.8	42.9	23.8
FX61	Unnamed Tributary to Bass Bay: 0 to 2.2 miles	--	--	--	--	--	9	0.0	33.3	66.7	0.0
FX62	Tichigan Creek: 0 to 1.5 miles	--	--	--	--	--	4	0.0	25.0	50.0	25.0
FX63	Unnamed Tributary to Tichigan Lake (Fox River): 0.5 to 3.5 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX64	Unnamed Tributary to Tichigan Lake (Fox River): 0 to 3.6 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX65	Unnamed Tributary to Fox River: 0 to 1.0 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX66	Ripple Brook: 0 to 1.1 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX67	Mukwonago River: 1.0 to 2.3 miles	110	10.0	20.0	32.7	37.3	291	15.5	22.0	32.3	30.2
FX68	Mukwonago River: 4.1 to 6.4 miles	18	0.0	33.3	33.3	33.3	39	15.4	28.2	28.2	28.2
FX69	Mukwonago River: 6.4 to 7.6 miles	18	0.0	33.3	38.9	27.8	26	0.0	23.1	42.3	34.6
FX70	Mukwonago River: 9.6 to 11.3 miles	17	0.0	35.3	35.3	29.4	16	0.0	31.3	31.3	37.5

Table 4.15 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
FX71	Mukwonago River: 13.6 to 15.9 miles	76	7.9	28.9	31.6	31.6	67	9.0	29.9	23.9	37.3
FX72	Pickeral Lake Outlet: 0 to 0.1 mile	4	0.0	25.0	25.0	50.0	4	0.0	25.0	25.0	50.0
FX73	Jericho Creek: 0 to 5.7 miles	51	0.0	35.3	35.3	29.4	51	0.0	29.4	35.3	35.3
FX74	Unnamed Tributarty to Jericho Creek: 0 to 1.3 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX75	Unnamed tributary to Mukwonago River: 0 to 2.5 miles	40	0.0	30.0	37.5	32.5	32	0.0	31.3	34.4	34.4
FX76	Mill Brook: 0 to 3.8 miles	--	--	--	--	--	2	0.0	0.0	100	0.0
FX77	Pebble Brook: 0 to 7.3 miles	25	24.0	24.0	24.0	28.0	29	20.7	20.7	34.5	24.1
FX78	Mill Creek: 0 to 1.0 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
FX79	Genesee Creek: 0.5 to 1.3 miles	1	0.0	0.0	0.0	100	1	0.0	0.0	100	0.0
FX80	Genesee Creek: 1.9 to 4.4 miles	--	--	--	--	--	4	0.0	0.0	100	0.0
FX81	Spring Brook (Waukesha County): 0 to 3.1 miles	--	--	--	--	--	2	0.0	0.0	100	0.0
FX82	Pebble Creek: 0 to 3.3 miles	2	0.0	0.0	100	0.0	33	0.0	21.2	30.3	48.5
FX83	Pebble Creek: 3.3 to 4.7 miles	--	--	--	--	--	169	24.9	25.4	23.7	26.0
FX84	Pebble Creek: 4.7 to 6.6 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
FX85	Brandy Brook: 0 to 4.2 miles	--	--	--	--	--	30	0.0	20.0	23.3	56.7
FX86	Pewaukee Lake Outlet: 0 to 0.2 miles	--	--	--	--	--	180	25.6	26.7	24.4	23.3
FX87	Pewaukee River: 0 to 6.3 miles	102	17.6	16.7	52.9	12.7	652	22.9	23.3	31.3	22.5
FX88	Pewaukee River: 6.3 to 10.7 miles	7	100	0.0	0.0	0.0	345	25.2	27.2	24.1	23.5
FX89	Coco Creek: 0 to 0.9 miles	7	57.1	28.6	14.3	0.0	182	25.8	26.9	23.6	23.6
FX90	Coco Creek: 0.9 to 3.9 miles	--	--	--	--	--	177	24.9	25.4	25.4	24.3
FX91	Meadowbrook Creek: 0 to 1.8 miles	5	100	0.0	0.0	0.0	174	25.3	25.3	25.3	24.1
FX92	Zion Creek: 0 to 0.8 miles	6	66.7	16.7	16.7	0.0	184	25.5	25.5	25.5	23.4
FX93	Poplar Creek: 0 to 3.9 miles	79	3.8	19.0	40.5	36.7	93	4.3	15.1	46.2	34.4
FX94	Poplar Creek: 5.5 to 7.8 miles	3	0.0	0.0	100	0.0	5	0.0	0.0	60.0	40.0
FX95	Deer Creek: 0.5 to 5.5 miles	--	--	--	--	--	8	0.0	0.0	50.0	50.0
FX96	Sussex Creek: 0.7 to 5.4 miles	49	8.2	18.4	51.0	22.4	127	18.9	20.5	42.5	18.1
FX97	North Branch Genesee Creek: 0 to 1.0 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX98	South Branch Genesee Creek: 0 to 1.9 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX99	Unnamed Tributary to Pebble Creek: 0 to 1.9 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
FX100	Unnamed Tributary to Sussex Creek: 0 to 3.0 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
FX101	Unnamed Tributary to Deer Creek: 0 to 1.6 miles	2	0.0	100	0.0	0.0	2	0.0	100	0.0	0.0
FX102	Unnamed Tributary to Lauderdale Lakes: 0 to 0.7 miles	--	--	--	--	--	4	50.0	0.0	50.0	0.0

Note: Seasons are defined as Winter (December through February), Spring (March through May), Summer (June through August), and Fall (September through November). Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance. Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter.

Table 4.15 (Continued)

Source: WDNR, USGS, USEPA, Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.16
Summary Statistics for Measured Chloride and Specific Conductance at Assessment Reaches Within the Fox River Watershed: 1961-2022

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (μS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
FX01	Fox River: 116.0 to 119.4 miles	271	3	34	31	140	152	380	696	668	999
FX02	Fox River: 126.2 to 130.2 miles	197	15	98	96	234	386	13	935	877	9,552
FX03	Fox River: 135.9 to 138.8 miles	94	20	59	62	111	102	500	696	682	990
FX04	Fox River: 139.3 to 143.0 miles	26	81	140	138	257	35	648	1,040	972	2,060
FX05	Fox River: 146.5 to 148.1 miles	39	30	64	58	169	53	564	789	736	1,536
FX06	Fox River: 150.3 to 154.4 miles	22	93	164	160	243	--	--	--	--	--
FX07	Fox River: 155.9 to 157.5 miles	44	29	63	55	168	56	504	791	750	1,551
FX08	Fox River: 160.9 to 162.4.4 miles	41	14	70	67	145	56	524	912	843	1,854
FX09	Fox River: 166.9 to 169.5 miles	221	42	163	150	540	392	11	1,155	1,100	2,313
FX10	Fox River: 169.5 to 174.5 miles	49	46	173	115	384	39	585	969	915	1,643
FX11	Fox River: 174.5 to 176.5 miles	42	35	102	100	320	89	560	1,312	1,100	2,661
FX12	Fox River: 176.5 to 180.3 miles	128	18	170	129	669	290	327	1,058	987	3,000
FX13	Fox River: 181.5 to 182.9 miles	46	30	113	112	270	55	743	1,053	1,033	1,500
FX14	Fox River: 182.9 to 183.4 miles	8	61	108	122	137	10	449	843	873	1,051
FX15	Fox River: 188.4 to 187.1 miles	7	63	79	81	93	25	668	981	989	1,290
FX16	Fox River: 189.6 to 191.2 miles	29	7	117	121	165	146	389	958	1,011	1,340
FX17	Fox River: 192.5 to 194.4 miles	39	5	38	44	62	46	528	755	751	1,080
FX18	North Branch Nippersink Creek:8.7 to 10.5 miles	35	11	23	20	44	44	553	679	684	795
FX19	North Branch Nippersink Creek: 10.5 to 12.0 miles	--	--	--	--	--	1	748	748	748	748
FX20	North Branch Nippersink Creek: 12.1 to 13.6 miles	7	31	35	36	38	8	692	753	766	773
FX21	East Branch North Branch Nippersink Creek: 0 to 1.5 miles	7	37	43	42	54	8	590	642	646	702
FX22	Unnamed Tributary to East Branch North Branch Nippersink Creek: 0 to 0.8 miles	--	--	--	--	--	1	1,468	1,468	1,468	1,468
FX23	West Branch North Branch Nippersink Creek: 0 to 1.9 miles	7	30	34	34	38	14	679	742	748	780
FX24	Bassett Creek: 0 to 3.6 miles	56	20	70	58	245	74	530	897	835	1,860
FX25	Peterson Creek: 1.2 to 5.3 miles	--	--	--	--	--	1	751	751	751	751
FX26	Unnamed Tributary to New Munster Creek: 0 to 1.6 miles	--	--	--	--	--	1	723	723	723	723
FX27	Spring Brook (Racine County): 0 to 4.0 miles	--	--	--	--	--	1	709	709	709	709
FX28	White River: 1.1 to 5.5 miles	97	7	35	31	73	168	328	658	641	1,232
FX29	White River: 14.1 to 18.9 miles	60	5	46	50	93	68	422	594	552	842
FX30	Honey Creek: 0 to 2.8 miles	30	5	14	15	18	50	531	660	652	804
FX31	Honey Creek: 2.8 to 4.8 miles	16	6	34	37	41	33	506	735	718	1,103
FX32	Honey Creek: 9.2 to 10.3 miles	--	--	--	--	--	5	559	663	661	749
FX33	Honey Creek: 10.7 to 12.2 miles	--	--	--	--	--	6	748	799	790	852

Table 4.16 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
FX34	Honey Creek: 13.7 to 15.3 miles	85	5	23	15	57	96	500	652	640	848
FX35	Honey Creek: 17.1 to 21.5 miles	26	13	32	33	37	39	246	672	680	791
FX36	Honey Creek: 25.0 to 26.2 miles	--	--	--	--	--	7	447	539	526	645
FX37	Sugar Creek: 0 to 3.4 miles	59	6	29	33	62	98	419	706	702	1,132
FX38	Sugar Creek: 4.1 to 15.4 miles	--	--	--	--	--	18	439	672	711	862
FX39	Sugar Creek: 18.3 to 22.7 miles	28	5	21	20	34	51	465	710	728	918
FX40	Spring Brook (Walworth County): 0 to 2.5 miles	--	--	--	--	--	19	526	700	701	830
FX41	North Branch Spring Brook (Spring Prairie): 0 to 2.1 miles	--	--	--	--	--	1	839	839	839	839
FX42	Baker Creek: 0 to 5.2 miles	--	--	--	--	--	23	396	880	849	1,415
FX43	Spring Creek: 0 to 4.4 miles	--	--	--	--	--	15	637	855	834	1,026
FX44	Unnamed Tributary to Honey Creek: 0.9 to 1.8 miles	--	--	--	--	--	2	892	996	996	1,100
FX45	Unnamed Tributary to Honey Creek: 0.5 to 1.8 miles	--	--	--	--	--	2	875	1,008	1,008	1,141
FX46	Unnamed Tributary to Honey Creek: 0 to 1.9 miles	--	--	--	--	--	2	564	596	596	628
FX47	Ore Creek: 0 to 0.8 miles	7	33	38	40	43	9	614	720	732	780
FX48	Ore Creek: 2.8 to 4.0 miles	--	--	--	--	--	6	678	728	719	781
FX49	Second Branch Ore Creek: 0 to 1.9 miles	1	44	44	44	44	1	778	778	778	778
FX50	Como Creek: 0 to 3.3 miles	28	5	19	17	37	37	440	783	540	7,912
FX51	Eagle Creek: 0 to 4.8 miles	--	--	--	--	--	7	538	950	922	1,682
FX52	Unnamed Tributary to Eagle Creek: 0 to 1.8 miles	--	--	--	--	--	2	484	487	487	491
FX53	East Eagleast Lake Ditch: 0 to 1.7 miles	--	--	--	--	--	2	705	787	787	869
FX54	Wind Lake Drainage Canal: 0 to 3.6 miles	28	14	37	35	54	34	119	714	705	1,120
FX55	Wind Lake Drainage Canal: 6.8 to 7.3 miles	--	--	--	--	--	36	634	870	825	1,377
FX56	Goose Lake Branch Canal: 2.8 to 3.8 miles	1	36	36	36	36	5	1,173	1,603	1,700	1,800
FX57	Horner Farms Ditch Tributary to Wind Lake Canal: 0 to 1.8 miles	8	39	71	64	122	20	1,100	1,594	1,635	1,900
FX58	Muskego Canal: 0 to 1.3 miles	35	17	34	33	75	40	446	624	583	1,560
FX59	Unnamed Tributary to Muskego Canal: 0 to 1.3 miles	--	--	--	--	--	6	585	653	620	740
FX60	Jewel Creek: 0 to 0.7 miles	12	80	154	136	310	21	259	1,026	1,040	1,410
FX61	Unnamed Tributary to Bass Bay: 0 to 2.2 miles	--	--	--	--	--	9	446	734	820	888
FX62	Tichigan Creek: 0 to 1.5 miles	--	--	--	--	--	4	717	815	842	860
FX63	Unnamed Tributary to Tichigan Lake (Fox River): 0.5 to 3.5 miles	--	--	--	--	--	1	954	954	954	954
FX64	Unnamed Tributary to Tichigan Lake (Fox River): 0 to 3.6 miles	--	--	--	--	--	1	855	855	855	855
FX65	Unnamed Tributary to Fox River: 0 to 1.0 miles	--	--	--	--	--	1	965	965	965	965
FX66	Ripple Brook: 0 to 1.1 miles	--	--	--	--	--	1	891	891	891	891
FX67	Mukwonago River: 1.0 to 2.3 miles	110	5	20	14	83	291	46	543	505	5,744
FX68	Mukwonago River: 4.1 to 6.4 miles	18	15	24	24	36	39	294	547	575	648
FX69	Mukwonago River: 6.4 to 7.6 miles	18	14	26	26	39	26	332	578	606	668
FX70	Mukwonago River: 9.6 to 11.3 miles	17	17	29	29	55	16	390	588	575	868
FX71	Mukwonago River: 13.6 to 15.9 miles	76	7	14	14	26	67	292	559	572	821
FX72	Pickeral Lake Outlet: 0 to 0.1 mile	4	6	8	8	9	4	449	475	476	500
FX73	Jericho Creek: 0 to 5.7 miles	51	12	44	44	81	51	326	719	721	1,108

Table 4.16 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
FX74	Unnamed Tributarty to Jericho Creek: 0 to 1.3 miles	--	--	--	--	--	1	672	672	672	672
FX75	Unnamed tributary to Mukwonago River: 0 to 2.5 miles	40	3	21	21	40	32	202	541	544	778
FX76	Mill Brook: 0 to 3.8 miles	--	--	--	--	--	2	964	1,028	1,028	1,092
FX77	Pebble Brook: 0 to 7.3 miles	25	76	108	108	178	29	714	982	960	1,418
FX78	Mill Creek: 0 to 1.0 miles	--	--	--	--	--	1	638	638	638	638
FX79	Genesee Creek: 0.5 to 1.3 miles	1	1,821	1,821	1,821	1,821	1	856	856	856	856
FX80	Genesee Creek: 1.9 to 4.4 miles	--	--	--	--	--	4	787	916	860	1,157
FX81	Spring Brook (Waukesha County): 0 to 3.1 miles	--	--	--	--	--	2	643	727	727	812
FX82	Pebble Creek: 0 to 3.3 miles	2	87	1,099	1,099	2,112	33	587	814	807	1,020
FX83	Pebble Creek: 3.3 to 4.7 miles	--	--	--	--	--	169	450	1,180	1,240	1,950
FX84	Pebble Creek: 4.7 to 6.6 miles	--	--	--	--	--	1	1,650	1,650	1,650	1,650
FX85	Brandy Brook: 0 to 4.2 miles	--	--	--	--	--	30	524	727	697	960
FX86	Pewaukee Lake Outlet: 0 to 0.2 miles	--	--	--	--	--	180	424	785	820	1,170
FX87	Pewaukee River: 0 to 6.3 miles	102	14	115	66	568	652	131	1,009	971	2,210
FX88	Pewaukee River: 6.3 to 10.7 miles	7	336	508	447	991	345	338	1,287	1,290	3,800
FX89	Coco Creek: 0 to 0.9 miles	7	70	132	120	264	182	424	982	1,061	1,570
FX90	Coco Creek: 0.9 to 3.9 miles	--	--	--	--	--	177	66	964	1,060	1,580
FX91	Meadowbrook Creek: 0 to 1.8 miles	5	450	479	464	529	174	150	1,537	1,535	3,100
FX92	Zion Creek: 0 to 0.8 miles	6	52	160	145	314	184	60	1,066	1,144	1,660
FX93	Poplar Creek: 0 to 3.9 miles	79	1	73	70	171	93	53	918	888	1,756
FX94	Poplar Creek: 5.5 to 7.8 miles	3	49	112	144	144	5	292	1,234	1,070	2,015
FX95	Deer Creek: 0.5 to 5.5 miles	--	--	--	--	--	8	818	1,437	1,375	2,128
FX96	Sussex Creek: 0.7 to 5.4 miles	49	37	118	84	526	127	360	1,273	1,200	11,750
FX97	North Branch Genesee Creek: 0 to 1.0 miles	--	--	--	--	--	1	1,120	1,120	1,120	1,120
FX98	South Branch Genesee Creek: 0 to 1.9 miles	--	--	--	--	--	1	740	740	740	740
FX99	Unnamed Tributary to Pebble Creek: 0 to 1.9 miles	--	--	--	--	--	1	688	688	688	688
FX100	Unnamed Tributary to Sussex Creek: 0 to 3.0 miles	--	--	--	--	--	1	863	863	863	863
FX101	Unnamed Tributary to Deer Creek: 0 to 1.6 miles	2	34	36	36	38	2	650	660	660	670
FX102	Unnamed Tributary to Lauderdale Lakes: 0 to 0.7 miles	--	--	--	--	--	4	195	245	243	297

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: WDNR, USGS, USEPA, Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.17
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Fox River Watershed Full Record: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
FX01	Fox River: 116.0 to 119.4 miles	271	96.7	35.1	1.1	0.0	0.0	0.0	0.0
FX02	Fox River: 126.2 to 130.2 miles	197	100.0	88.8	26.9	1	0.0	0.0	0.0
FX03	Fox River: 135.9 to 138.8 miles	94	100.0	90.4	0.0	0.0	0.0	0.0	0.0
FX04	Fox River: 139.3 to 143.0 miles	26	100.0	100.0	80.8	3.8	0.0	0.0	0.0
FX05	Fox River: 146.5 to 148.1 miles	39	100.0	87.2	10.3	0.0	0.0	0.0	0.0
FX06	Fox River: 150.3 to 154.4 miles	22	100.0	100.0	95.5	4.5	0.0	0.0	0.0
FX07	Fox River: 155.9 to 157.5 miles	44	100.0	86.4	11.4	0.0	0.0	0.0	0.0
FX08	Fox River: 160.9 to 162.4.4 miles	41	100.0	90.2	4.9	0.0	0.0	0.0	0.0
FX09	Fox River: 166.9 to 169.5 miles	221	100.0	100.0	61.1	19.9	1.8	0.0	0.0
FX10	Fox River: 169.5 to 174.5 miles	49	100.0	100.0	46.9	38.8	0.0	0.0	0.0
FX11	Fox River: 174.5 to 176.5 miles	42	100.0	97.6	21.4	2.4	0.0	0.0	0.0
FX12	Fox River: 176.5 to 180.3 miles	128	100.0	96.9	53.1	29.7	3.9	0.0	0.0
FX13	Fox River: 181.5 to 182.9 miles	46	100.0	97.8	37	6.5	0.0	0.0	0.0
FX14	Fox River: 182.9 to 183.4 miles	8	100.0	100.0	62.5	0.0	0.0	0.0	0.0
FX15	Fox River: 188.4 to 187.1 miles	7	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX16	Fox River: 189.6 to 191.2 miles	29	96.6	93.1	51.7	0.0	0.0	0.0	0.0
FX17	Fox River: 192.5 to 194.4 miles	39	92.3	61.5	0.0	0.0	0.0	0.0	0.0
FX18	North Branch Nippersink Creek: 8.7 to 10.5 miles	35	100.0	17.1	0.0	0.0	0.0	0.0	0.0
FX19	North Branch Nippersink Creek: 10.5 to 12.0 miles	--	--	--	--	--	--	--	--
FX20	North Branch Nippersink Creek: 12.1 to 13.6 miles	7	100.0	57.1	0.0	0.0	0.0	0.0	0.0
FX21	East Branch North Branch Nippersink Creek: 0 to 1.5 miles	7	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX22	Unnamed Tributary to East Branch North Branch Nippersink Creek: 0 to 0.8 miles	--	--	--	--	--	--	--	--
FX23	West Branch North Branch Nippersink Creek: 0 to 1.9 miles	7	100.0	42.9	0.0	0.0	0.0	0.0	0.0
FX24	Bassett Creek: 0 to 3.6 miles	56	100.0	85.7	10.7	1.8	0.0	0.0	0.0
FX25	Peterson Creek: 1.2 to 5.3 miles	--	--	--	--	--	--	--	--
FX26	Unnamed Tributary to New Munster Creek: 0 to 1.6 miles	--	--	--	--	--	--	--	--
FX27	Spring Brook (Racine County): 0 to 4.0 miles	--	--	--	--	--	--	--	--
FX28	White River: 1.1 to 5.5 miles	97	99	36.1	0.0	0.0	0.0	0.0	0.0
FX29	White River: 14.1 to 18.9 miles	60	96.7	80	0.0	0.0	0.0	0.0	0.0
FX30	Honey Creek: 0 to 2.8 miles	30	93.3	0.0	0.0	0.0	0.0	0.0	0.0
FX31	Honey Creek: 2.8 to 4.8 miles	16	93.8	75	0.0	0.0	0.0	0.0	0.0

Table 4.17 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
FX32	Honey Creek: 9.2 to 10.3 miles	--	--	--	--	--	--	--	--
FX33	Honey Creek: 10.7 to 12.2 miles	--	--	--	--	--	--	--	--
FX34	Honey Creek: 13.7 to 15.3 miles	85	88.2	27.1	0.0	0.0	0.0	0.0	0.0
FX35	Honey Creek: 17.1 to 21.5 miles	26	100.0	26.9	0.0	0.0	0.0	0.0	0.0
FX36	Honey Creek: 25.0 to 26.2 miles	--	--	--	--	--	--	--	--
FX37	Sugar Creek: 0 to 3.4 miles	59	96.6	42.4	0.0	0.0	0.0	0.0	0.0
FX38	Sugar Creek: 4.1 to 15.4 miles	--	--	--	--	--	--	--	--
FX39	Sugar Creek: 18.3 to 22.7 miles	28	96.4	0.0	0.0	0.0	0.0	0.0	0.0
FX40	Spring Brook (Walworth County): 0 to 2.5 miles	--	--	--	--	--	--	--	--
FX41	North Branch Spring Brook (Spring Prairie): 0 to 2.1 miles	--	--	--	--	--	--	--	--
FX42	Baker Creek: 0 to 5.2 miles	--	--	--	--	--	--	--	--
FX43	Spring Creek: 0 to 4.4 miles	--	--	--	--	--	--	--	--
FX44	Unnamed Tributary to Honey Creek: 0.9 to 1.8 miles	--	--	--	--	--	--	--	--
FX45	Unnamed Tributary to Honey Creek: 0.5 to 1.8 miles	--	--	--	--	--	--	--	--
FX46	Unnamed Tributary to Honey Creek: 0 to 1.9 miles	--	--	--	--	--	--	--	--
FX47	Ore Creek: 0 to 0.8 miles	7	100.0	71.4	0.0	0.0	0.0	0.0	0.0
FX48	Ore Creek: 2.8 to 4.0 miles	--	--	--	--	--	--	--	--
FX49	Second Branch Ore Creek: 0 to 1.9 miles	1	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX50	Como Creek: 0 to 3.3 miles	28	96.4	7.1	0.0	0.0	0.0	0.0	0.0
FX51	Eagle Creek: 0 to 4.8 miles	--	--	--	--	--	--	--	--
FX52	Unnamed Tributary to Eagle Creek: 0 to 1.8 miles	--	--	--	--	--	--	--	--
FX53	East Eagleast Lake Ditch: 0 to 1.7 miles	--	--	--	--	--	--	--	--
FX54	Wind Lake Drainage Canal: 0 to 3.6 miles	28	100.0	42.9	0.0	0.0	0.0	0.0	0.0
FX55	Wind Lake Drainage Canal: 6.8 to 7.3 miles	--	--	--	--	--	--	--	--
FX56	Goose Lake Branch Canal: 2.8 to 3.8 miles	1	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX57	Horner Farms Ditch Tributary to Wind Lake Canal: 0 to 1.8 miles	8	100.0	100.0	12.5	0.0	0.0	0.0	0.0
FX58	Mukego Canal: 0 to 1.3 miles	35	100.0	28.6	0.0	0.0	0.0	0.0	0.0
FX59	Unnamed Tributary to Muskego Canal: 0 to 1.3 miles	--	--	--	--	--	--	--	--
FX60	Jewel Creek: 0 to 0.7 miles	12	100.0	100.0	66.7	8.3	0.0	0.0	0.0
FX61	Unnamed Tributary to Bass Bay: 0 to 2.2 miles	--	--	--	--	--	--	--	--
FX62	Tichigan Creek: 0 to 1.5 miles	--	--	--	--	--	--	--	--
FX63	Unnamed Tributary to Tichigan Lake (Fox River): 0.5 to 3.5 miles	--	--	--	--	--	--	--	--
FX64	Unnamed Tributary to Tichigan Lake (Fox River): 0 to 3.6 miles	--	--	--	--	--	--	--	--
FX65	Unnamed Tributary to Fox River: 0 to 1.0 miles	--	--	--	--	--	--	--	--
FX66	Ripple Brook: 0 to 1.1 miles	--	--	--	--	--	--	--	--
FX67	Mukwonago River: 1.0 to 2.3 miles	110	68.2	22.7	0.0	0.0	0.0	0.0	0.0
FX68	Mukwonago River: 4.1 to 6.4 miles	18	100.0	11.1	0.0	0.0	0.0	0.0	0.0
FX69	Mukwonago River: 6.4 to 7.6 miles	18	100.0	11.1	0.0	0.0	0.0	0.0	0.0
FX70	Mukwonago River: 9.6 to 11.3 miles	17	100.0	5.9	0.0	0.0	0.0	0.0	0.0
FX71	Mukwonago River: 13.6 to 15.9 miles	76	76.3	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.17 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
FX72	Pickeral Lake Outlet: 0 to 0.1 mile	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FX73	Jericho Creek: 0 to 5.7 miles	51	100.0	70.6	0.0	0.0	0.0	0.0	0.0
FX74	Unnamed Tributarty to Jericho Creek: 0 to 1.3 miles	--	--	--	--	--	--	--	--
FX75	Unnamed tributary to Mukwonago River: 0 to 2.5 miles	40	82.5	12.5	0.0	0.0	0.0	0.0	0.0
FX76	Mill Brook: 0 to 3.8 miles	--	--	--	--	--	--	--	--
FX77	Pebble Brook: 0 to 7.3 miles	25	100.0	100.0	16	0.0	0.0	0.0	0.0
FX78	Mill Creek: 0 to 1.0 miles	--	--	--	--	--	--	--	--
FX79	Genesee Creek: 0.5 to 1.3 miles	1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
FX80	Genesee Creek: 1.9 to 4.4 miles	--	--	--	--	--	--	--	--
FX81	Spring Brook (Waukesha County): 0 to 3.1 miles	--	--	--	--	--	--	--	--
FX82	Pebble Creek: 0 to 3.3 miles	2	100.0	100.0	50	50	50	50	50
FX83	Pebble Creek: 3.3 to 4.7 miles	--	--	--	--	--	--	--	--
FX84	Pebble Creek: 4.7 to 6.6 miles	--	--	--	--	--	--	--	--
FX85	Brandy Brook: 0 to 4.2 miles	--	--	--	--	--	--	--	--
FX86	Pewaukee Lake Outlet: 0 to 0.2 miles	--	--	--	--	--	--	--	--
FX87	Pewaukee River: 0 to 6.3 miles	102	100.0	82.4	34.3	12.7	2	0.0	0.0
FX88	Pewaukee River: 6.3 to 10.7 miles	7	100.0	100.0	100.0	100.0	85.7	14.3	0.0
FX89	Coco Creek: 0 to 0.9 miles	7	100.0	100.0	42.9	14.3	0.0	0.0	0.0
FX90	Coco Creek: 0.9 to 3.9 miles	--	--	--	--	--	--	--	--
FX91	Meadowbrook Creek: 0 to 1.8 miles	5	100.0	100.0	100.0	100.0	100.0	0.0	0.0
FX92	Zion Creek: 0 to 0.8 miles	6	100.0	100.0	66.7	16.7	0.0	0.0	0.0
FX93	Poplar Creek: 0 to 3.9 miles	79	92.4	87.3	12.7	0.0	0.0	0.0	0.0
FX94	Poplar Creek: 5.5 to 7.8 miles	3	100.0	100.0	66.7	0.0	0.0	0.0	0.0
FX95	Deer Creek: 0.5 to 5.5 miles	--	--	--	--	--	--	--	--
FX96	Sussex Creek: 0.7 to 5.4 miles	49	100.0	100.0	32.7	6.1	2	0.0	0.0
FX97	North Branch Genesee Creek: 0 to 1.0 miles	--	--	--	--	--	--	--	--
FX98	South Branch Genesee Creek: 0 to 1.9 miles	--	--	--	--	--	--	--	--
FX99	Unnamed Tributary to Pebble Creek: 0 to 1.9 miles	--	--	--	--	--	--	--	--
FX100	Unnamed Tributary to Sussex Creek: 0 to 3.0 miles	--	--	--	--	--	--	--	--
FX101	Unnamed Tributary to Deer Creek: 0 to 1.6 miles	2	100.0	50	0.0	0.0	0.0	0.0	0.0
FX102	Unnamed Tributary to Lauderdale Lakes: 0 to 0.7 miles	--	--	--	--	--	--	--	--

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: WDNR, USGS, USEPA, Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.18
Summary Statistics for Recent Measured Chloride and Specific Conductance at Assessment Reaches Within the Fox River Watershed: 2013-2022

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
FX01	Fox River: 116.0 to 119.4 miles	--	--	--	--	--	--	--	--	--	--
FX02	Fox River: 126.2 to 130.2 miles	110	56	115	111	234	209	13	963	930	9,552
FX03	Fox River: 135.9 to 138.8 miles	--	--	--	--	--	--	--	--	--	--
FX04	Fox River: 139.3 to 143.0 miles	26	81	140	138	257	35	648	1,040	972	2,060
FX05	Fox River: 146.5 to 148.1 miles	5	115	140	135	169	11	880	1,074	1,042	1,536
FX06	Fox River: 150.3 to 154.4 miles	8	146	166	163	208	--	--	--	--	--
FX07	Fox River: 155.9 to 157.5 miles	5	133	142	136	168	11	903	1,090	1,080	1,551
FX08	Fox River: 160.9 to 162.4.4 miles	--	--	--	--	--	8	1,124	1,455	1,419	1,854
FX09	Fox River: 166.9 to 169.5 miles	44	92	242	247	406	104	758	1,382	1,365	2,313
FX10	Fox River: 169.5 to 174.5 miles	8	263	293	289	330	5	1,347	1,477	1,396	1,643
FX11	Fox River: 174.5 to 176.5 miles	1	193	193	193	193	39	841	1,786	1,766	2,661
FX12	Fox River: 176.5 to 180.3 miles	37	105	281	258	669	47	867	1,456	1,380	2,404
FX13	Fox River: 181.5 to 182.9 miles	--	--	--	--	--	--	--	--	--	--
FX14	Fox River: 182.9 to 183.4 miles	--	--	--	--	--	--	--	--	--	--
FX15	Fox River: 188.4 to 187.1 miles	--	--	--	--	--	--	--	--	--	--
FX16	Fox River: 189.6 to 191.2 miles	11	28	121	124	165	128	425	964	1,010	1,340
FX17	Fox River: 192.5 to 194.4 miles	--	--	--	--	--	--	--	--	--	--
FX18	North Branch Nippersink Creek:8.7 to 10.5 miles	--	--	--	--	--	--	--	--	--	--
FX19	North Branch Nippersink Creek: 10.5 to 12.0 miles	--	--	--	--	--	--	--	--	--	--
FX20	North Branch Nippersink Creek: 12.1 to 13.6 miles	--	--	--	--	--	--	--	--	--	--
FX21	East Branch North Branch Nippersink Creek: 0 to 1.5 miles	--	--	--	--	--	--	--	--	--	--
FX22	Unnamed Tributary to East Branch North Branch Nippersink Creek: 0 to 0.8 miles	--	--	--	--	--	--	--	--	--	--
FX23	West Branch North Branch Nippersink Creek: 0 to 1.9 miles	--	--	--	--	--	--	--	--	--	--
FX24	Bassett Creek: 0 to 3.6 miles	--	--	--	--	--	--	--	--	--	--
FX25	Peterson Creek: 1.2 to 5.3 miles	--	--	--	--	--	--	--	--	--	--
FX26	Unnamed Tributary to New Munster Creek: 0 to 1.6 miles	--	--	--	--	--	--	--	--	--	--
FX27	Spring Brook (Racine County): 0 to 4.0 miles	--	--	--	--	--	--	--	--	--	--
FX28	White River: 1.1 to 5.5 miles	25	28	53	54	73	30	328	688	673	1,232
FX29	White River: 14.1 to 18.9 miles	25	49	54	53	93	25	508	545	541	682
FX30	Honey Creek: 0 to 2.8 miles	--	--	--	--	--	6	734	761	758	804
FX31	Honey Creek: 2.8 to 4.8 miles	15	19	36	37	41	27	507	752	724	1,103
FX32	Honey Creek: 9.2 to 10.3 miles	--	--	--	--	--	--	--	--	--	--
FX33	Honey Creek: 10.7 to 12.2 miles	--	--	--	--	--	6	748	799	790	852

Table 4.18 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
FX34	Honey Creek: 13.7 to 15.3 miles	25	26	46	46	57	27	562	712	720	846
FX35	Honey Creek: 17.1 to 21.5 miles	26	13	32	33	37	34	246	673	681	791
FX36	Honey Creek: 25.0 to 26.2 miles	--	--	--	--	--	2	577	579	579	581
FX37	Sugar Creek: 0 to 3.4 miles	25	34	44	41	62	37	500	758	738	1,132
FX38	Sugar Creek: 4.1 to 15.4 miles	--	--	--	--	--	5	446	713	744	862
FX39	Sugar Creek: 18.3 to 22.7 miles	--	--	--	--	--	6	758	822	828	891
FX40	Spring Brook (Walworth County): 0 to 2.5 miles	--	--	--	--	--	8	696	752	751	830
FX41	North Branch Spring Brook (Spring Prairie): 0 to 2.1 miles	--	--	--	--	--	1	839	839	839	839
FX42	Baker Creek: 0 to 5.2 miles	--	--	--	--	--	12	775	1,054	1,091	1,415
FX43	Spring Creek: 0 to 4.4 miles	--	--	--	--	--	5	814	907	842	1,026
FX44	Unnamed Tributary to Honey Creek: 0.9 to 1.8 miles	--	--	--	--	--	2	892	996	996	1,100
FX45	Unnamed Tributary to Honey Creek: 0.5 to 1.8 miles	--	--	--	--	--	2	875	1,008	1,008	1,141
FX46	Unnamed Tributary to Honey Creek: 0 to 1.9 miles	--	--	--	--	--	2	564	596	596	628
FX47	Ore Creek: 0 to 0.8 miles	--	--	--	--	--	1	780	780	780	780
FX48	Ore Creek: 2.8 to 4.0 miles	--	--	--	--	--	--	--	--	--	--
FX49	Second Branch Ore Creek: 0 to 1.9 miles	1	44	44	44	44	1	778	778	778	778
FX50	Como Creek: 0 to 3.3 miles	--	--	--	--	--	2	775	4,343	4,343	7,912
FX51	Eagle Creek: 0 to 4.8 miles	--	--	--	--	--	7	538	950	922	1,682
FX52	Unnamed Tributary to Eagle Creek: 0 to 1.8 miles	--	--	--	--	--	--	--	--	--	--
FX53	East Eagleast Lake Ditch: 0 to 1.7 miles	--	--	--	--	--	2	705	787	787	869
FX54	Wind Lake Drainage Canal: 0 to 3.6 miles	--	--	--	--	--	--	--	--	--	--
FX55	Wind Lake Drainage Canal: 6.8 to 7.3 miles	--	--	--	--	--	36	634	870	825	1,377
FX56	Goose Lake Branch Canal: 2.8 to 3.8 miles	--	--	--	--	--	--	--	--	--	--
FX57	Horner Farms Ditch Tributary to Wind Lake Canal: 0 to 1.8 miles	--	--	--	--	--	--	--	--	--	--
FX58	Muskego Canal: 0 to 1.3 miles	--	--	--	--	--	--	--	--	--	--
FX59	Unnamed Tributary to Muskego Canal: 0 to 1.3 miles	--	--	--	--	--	--	--	--	--	--
FX60	Jewel Creek: 0 to 0.7 miles	--	--	--	--	--	7	259	1,025	1,130	1,260
FX61	Unnamed Tributary to Bass Bay: 0 to 2.2 miles	--	--	--	--	--	--	--	--	--	--
FX62	Tichigan Creek: 0 to 1.5 miles	--	--	--	--	--	4	717	815	842	860
FX63	Unnamed Tributary to Tichigan Lake (Fox River): 0.5 to 3.5 miles	--	--	--	--	--	1	954	954	954	954
FX64	Unnamed Tributary to Tichigan Lake (Fox River): 0 to 3.6 miles	--	--	--	--	--	1	855	855	855	855
FX65	Unnamed Tributary to Fox River: 0 to 1.0 miles	--	--	--	--	--	1	965	965	965	965
FX66	Ripple Brook: 0 to 1.1 miles	--	--	--	--	--	1	891	891	891	891
FX67	Mukwonago River: 1.0 to 2.3 miles	30	31	43	42	83	65	464	721	606	5,744
FX68	Mukwonago River: 4.1 to 6.4 miles	1	36	36	36	36	1	606	606	606	606
FX69	Mukwonago River: 6.4 to 7.6 miles	1	39	39	39	39	3	384	542	590	651
FX70	Mukwonago River: 9.6 to 11.3 miles	1	55	55	55	55	2	765	817	817	868
FX71	Mukwonago River: 13.6 to 15.9 miles	44	11	17	17	26	39	394	586	585	821
FX72	Pickeral Lake Outlet: 0 to 0.1 mile	--	--	--	--	--	--	--	--	--	--
FX73	Jericho Creek: 0 to 5.7 miles	3	56	65	59	81	7	790	892	809	1,108

Table 4.18 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
FX74	Unnamed Tributarty to Jericho Creek: 0 to 1.3 miles	--	--	--	--	--	--	--	--	--	--
FX75	Unnamed tributary to Mukwonago River: 0 to 2.5 miles	8	15	28	26	40	3	668	711	686	778
FX76	Mill Brook: 0 to 3.8 miles	--	--	--	--	--	2	964	1,028	1,028	1,092
FX77	Pebble Brook: 0 to 7.3 miles	25	76	108	108	178	29	714	982	960	1,418
FX78	Mill Creek: 0 to 1.0 miles	--	--	--	--	--	--	--	--	--	--
FX79	Genesee Creek: 0.5 to 1.3 miles	--	--	--	--	--	1	856	856	856	856
FX80	Genesee Creek: 1.9 to 4.4 miles	--	--	--	--	--	1	844	844	844	844
FX81	Spring Brook (Waukesha County): 0 to 3.1 miles	--	--	--	--	--	2	643	727	727	812
FX82	Pebble Creek: 0 to 3.3 miles	--	--	--	--	--	8	970	993	989	1,020
FX83	Pebble Creek: 3.3 to 4.7 miles	--	--	--	--	--	142	450	1,220	1,270	1,950
FX84	Pebble Creek: 4.7 to 6.6 miles	--	--	--	--	--	1	1,650	1,650	1,650	1,650
FX85	Brandy Brook: 0 to 4.2 miles	--	--	--	--	--	9	613	877	901	960
FX86	Pewaukee Lake Outlet: 0 to 0.2 miles	--	--	--	--	--	131	493	843	850	1,170
FX87	Pewaukee River: 0 to 6.3 miles	33	133	236	211	568	404	131	1,110	1,080	2,210
FX88	Pewaukee River: 6.3 to 10.7 miles	7	336	508	447	991	247	338	1,405	1,410	3,800
FX89	Coco Creek: 0 to 0.9 miles	6	70	142	132	264	132	424	1,053	1,093	1,570
FX90	Coco Creek: 0.9 to 3.9 miles	--	--	--	--	--	127	66	1,037	1,100	1,580
FX91	Meadowbrook Creek: 0 to 1.8 miles	5	450	479	464	529	124	150	1,648	1,658	3,100
FX92	Zion Creek: 0 to 0.8 miles	5	103	182	149	314	130	60	1,137	1,181	1,660
FX93	Poplar Creek: 0 to 3.9 miles	--	--	--	--	--	7	1,227	1,550	1,649	1,756
FX94	Poplar Creek: 5.5 to 7.8 miles	3	49	112	144	144	5	292	1,234	1,070	2,015
FX95	Deer Creek: 0.5 to 5.5 miles	--	--	--	--	--	3	1,140	1,620	1,704	2,015
FX96	Sussex Creek: 0.7 to 5.4 miles	8	128	227	192	526	80	844	1,465	1,290	11,750
FX97	North Branch Genesee Creek: 0 to 1.0 miles	--	--	--	--	--	1	1,120	1,120	1,120	1,120
FX98	South Branch Genesee Creek: 0 to 1.9 miles	--	--	--	--	--	1	740	740	740	740
FX99	Unnamed Tributary to Pebble Creek: 0 to 1.9 miles	--	--	--	--	--	1	688	688	688	688
FX100	Unnamed Tributary to Sussex Creek: 0 to 3.0 miles	--	--	--	--	--	--	--	--	--	--
FX101	Unnamed Tributary to Deer Creek: 0 to 1.6 miles	--	--	--	--	--	--	--	--	--	--
FX102	Unnamed Tributary to Lauderdale Lakes: 0 to 0.7 miles	--	--	--	--	--	--	--	--	--	--

Note: Summary statistics shown in red text represent reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment reaches with no chloride samples during the recent period of record are included in this table to indicate sampling gaps during the period of 2013 through 2022. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: WDNR, USGS, USEPA, Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.19
Percentage of Measurements in Which Chloride Concentrations Exceeded Various Water Quality Thresholds in the Fox River Watershed[a] Recent Record: 2013-2022

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
FX01	Fox River: 116.0 to 119.4 miles	--	--	--	--	--	--	--	--
FX02	Fox River: 126.2 to 130.2 miles	110	100.0	100.0	38.2	1.8	0.0	0.0	0.0
FX03	Fox River: 135.9 to 138.8 miles	--	--	--	--	--	--	--	--
FX04	Fox River: 139.3 to 143.0 miles	26	100.0	100.0	80.8	3.8	0.0	0.0	0.0
FX05	Fox River: 146.5 to 148.1 miles	5	100.0	100.0	80	0.0	0.0	0.0	0.0
FX06	Fox River: 150.3 to 154.4 miles	8	100.0	100.0	100.0	0.0	0.0	0.0	0.0
FX07	Fox River: 155.9 to 157.5 miles	5	100.0	100.0	100.0	0.0	0.0	0.0	0.0
FX08	Fox River: 160.9 to 162.4.4 miles	--	--	--	--	--	--	--	--
FX09	Fox River: 166.9 to 169.5 miles	44	100.0	100.0	97.7	56.8	2.3	0.0	0.0
FX10	Fox River: 169.5 to 174.5 miles	8	100.0	100.0	100.0	100.0	0.0	0.0	0.0
FX11	Fox River: 174.5 to 176.5 miles	1	100.0	100.0	100.0	0.0	0.0	0.0	0.0
FX12	Fox River: 176.5 to 180.3 miles	37	100.0	100.0	97.3	67.6	10.8	0.0	0.0
FX13	Fox River: 181.5 to 182.9 miles	--	--	--	--	--	--	--	--
FX14	Fox River: 182.9 to 183.4 miles	--	--	--	--	--	--	--	--
FX15	Fox River: 188.4 to 187.1 miles	--	--	--	--	--	--	--	--
FX16	Fox River: 189.6 to 191.2 miles	11	100.0	90.9	63.6	0.0	0.0	0.0	0.0
FX17	Fox River: 192.5 to 194.4 miles	--	--	--	--	--	--	--	--
FX18	North Branch Nippersink Creek: 8.7 to 10.5 miles	--	--	--	--	--	--	--	--
FX19	North Branch Nippersink Creek: 10.5 to 12.0 miles	--	--	--	--	--	--	--	--
FX20	North Branch Nippersink Creek: 12.1 to 13.6 miles	--	--	--	--	--	--	--	--
FX21	East Branch North Branch Nippersink Creek: 0 to 1.5 miles	--	--	--	--	--	--	--	--
FX22	Unnamed Tributary to East Branch North Branch Nippersink Creek: 0 to 0.8 miles	--	--	--	--	--	--	--	--
FX23	West Branch North Branch Nippersink Creek: 0 to 1.9 miles	--	--	--	--	--	--	--	--
FX24	Bassett Creek: 0 to 3.6 miles	--	--	--	--	--	--	--	--
FX25	Peterson Creek: 1.2 to 5.3 miles	--	--	--	--	--	--	--	--
FX26	Unnamed Tributary to New Munster Creek: 0 to 1.6 miles	--	--	--	--	--	--	--	--
FX27	Spring Brook (Racine County): 0 to 4.0 miles	--	--	--	--	--	--	--	--
FX28	White River: 1.1 to 5.5 miles	25	100.0	96	0.0	0.0	0.0	0.0	0.0
FX29	White River: 14.1 to 18.9 miles	25	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX30	Honey Creek: 0 to 2.8 miles	--	--	--	--	--	--	--	--
FX31	Honey Creek: 2.8 to 4.8 miles	15	100.0	80	0.0	0.0	0.0	0.0	0.0

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
FX32	Honey Creek: 9.2 to 10.3 miles	--	--	--	--	--	--	--	--
FX33	Honey Creek: 10.7 to 12.2 miles	--	--	--	--	--	--	--	--
FX34	Honey Creek: 13.7 to 15.3 miles	25	100.0	92	0.0	0.0	0.0	0.0	0.0
FX35	Honey Creek: 17.1 to 21.5 miles	26	100.0	26.9	0.0	0.0	0.0	0.0	0.0
FX36	Honey Creek: 25.0 to 26.2 miles	--	--	--	--	--	--	--	--
FX37	Sugar Creek: 0 to 3.4 miles	25	100.0	88	0.0	0.0	0.0	0.0	0.0
FX38	Sugar Creek: 4.1 to 15.4 miles	--	--	--	--	--	--	--	--
FX39	Sugar Creek: 18.3 to 22.7 miles	--	--	--	--	--	--	--	--
FX40	Spring Brook (Walworth County): 0 to 2.5 miles	--	--	--	--	--	--	--	--
FX41	North Branch Spring Brook (Spring Prairie): 0 to 2.1 miles	--	--	--	--	--	--	--	--
FX42	Baker Creek: 0 to 5.2 miles	--	--	--	--	--	--	--	--
FX43	Spring Creek: 0 to 4.4 miles	--	--	--	--	--	--	--	--
FX44	Unnamed Tributary to Honey Creek: 0.9 to 1.8 miles	--	--	--	--	--	--	--	--
FX45	Unnamed Tributary to Honey Creek: 0.5 to 1.8 miles	--	--	--	--	--	--	--	--
FX46	Unnamed Tributary to Honey Creek: 0 to 1.9 miles	--	--	--	--	--	--	--	--
FX47	Ore Creek: 0 to 0.8 miles	--	--	--	--	--	--	--	--
FX48	Ore Creek: 2.8 to 4.0 miles	--	--	--	--	--	--	--	--
FX49	Second Branch Ore Creek: 0 to 1.9 miles	1	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX50	Como Creek: 0 to 3.3 miles	--	--	--	--	--	--	--	--
FX51	Eagle Creek: 0 to 4.8 miles	--	--	--	--	--	--	--	--
FX52	Unnamed Tributary to Eagle Creek: 0 to 1.8 miles	--	--	--	--	--	--	--	--
FX53	East Eagleast Lake Ditch: 0 to 1.7 miles	--	--	--	--	--	--	--	--
FX54	Wind Lake Drainage Canal: 0 to 3.6 miles	--	--	--	--	--	--	--	--
FX55	Wind Lake Drainage Canal: 6.8 to 7.3 miles	--	--	--	--	--	--	--	--
FX56	Goose Lake Branch Canal: 2.8 to 3.8 miles	--	--	--	--	--	--	--	--
FX57	Horner Farms Ditch Tributary to Wind Lake Canal: 0 to 1.8 miles	--	--	--	--	--	--	--	--
FX58	Mukego Canal: 0 to 1.3 miles	--	--	--	--	--	--	--	--
FX59	Unnamed Tributary to Muskego Canal: 0 to 1.3 miles	--	--	--	--	--	--	--	--
FX60	Jewel Creek: 0 to 0.7 miles	--	--	--	--	--	--	--	--
FX61	Unnamed Tributary to Bass Bay: 0 to 2.2 miles	--	--	--	--	--	--	--	--
FX62	Tichigan Creek: 0 to 1.5 miles	--	--	--	--	--	--	--	--
FX63	Unnamed Tributary to Tichigan Lake (Fox River): 0.5 to 3.5 miles	--	--	--	--	--	--	--	--
FX64	Unnamed Tributary to Tichigan Lake (Fox River): 0 to 3.6 miles	--	--	--	--	--	--	--	--
FX65	Unnamed Tributary to Fox River: 0 to 1.0 miles	--	--	--	--	--	--	--	--
FX66	Ripple Brook: 0 to 1.1 miles	--	--	--	--	--	--	--	--
FX67	Mukwonago River: 1.0 to 2.3 miles	30	100.0	83.3	0.0	0.0	0.0	0.0	0.0
FX68	Mukwonago River: 4.1 to 6.4 miles	1	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX69	Mukwonago River: 6.4 to 7.6 miles	1	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX70	Mukwonago River: 9.6 to 11.3 miles	1	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX71	Mukwonago River: 13.6 to 15.9 miles	44	100.0	0.0	0.0	0.0	0.0	0.0	0.0

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
FX72	Pickeral Lake Outlet: 0 to 0.1 mile	--	--	--	--	--	--	--	--
FX73	Jericho Creek: 0 to 5.7 miles	3	100.0	100.0	0.0	0.0	0.0	0.0	0.0
FX74	Unnamed Tributarty to Jericho Creek: 0 to 1.3 miles	--	--	--	--	--	--	--	--
FX75	Unnamed tributary to Mukwonago River: 0 to 2.5 miles	8	100.0	25	0.0	0.0	0.0	0.0	0.0
FX76	Mill Brook: 0 to 3.8 miles	--	--	--	--	--	--	--	--
FX77	Pebble Brook: 0 to 7.3 miles	25	100.0	100.0	16	0.0	0.0	0.0	0.0
FX78	Mill Creek: 0 to 1.0 miles	--	--	--	--	--	--	--	--
FX79	Genesee Creek: 0.5 to 1.3 miles	--	--	--	--	--	--	--	--
FX80	Genesee Creek: 1.9 to 4.4 miles	--	--	--	--	--	--	--	--
FX81	Spring Brook (Waukesha County): 0 to 3.1 miles	--	--	--	--	--	--	--	--
FX82	Pebble Creek: 0 to 3.3 miles	--	--	--	--	--	--	--	--
FX83	Pebble Creek: 3.3 to 4.7 miles	--	--	--	--	--	--	--	--
FX84	Pebble Creek: 4.7 to 6.6 miles	--	--	--	--	--	--	--	--
FX85	Brandy Brook: 0 to 4.2 miles	--	--	--	--	--	--	--	--
FX86	Pewaukee Lake Outlet: 0 to 0.2 miles	--	--	--	--	--	--	--	--
FX87	Pewaukee River: 0 to 6.3 miles	33	100.0	100.0	100.0	39.4	6.1	0.0	0.0
FX88	Pewaukee River: 6.3 to 10.7 miles	7	100.0	100.0	100.0	100.0	85.7	14.3	0.0
FX89	Coco Creek: 0 to 0.9 miles	6	100.0	100.0	50	16.7	0.0	0.0	0.0
FX90	Coco Creek: 0.9 to 3.9 miles	--	--	--	--	--	--	--	--
FX91	Meadowbrook Creek: 0 to 1.8 miles	5	100.0	100.0	100.0	100.0	100.0	0.0	0.0
FX92	Zion Creek: 0 to 0.8 miles	5	100.0	100.0	80	20	0.0	0.0	0.0
FX93	Poplar Creek: 0 to 3.9 miles	--	--	--	--	--	--	--	--
FX94	Poplar Creek: 5.5 to 7.8 miles	3	100.0	100.0	66.7	0.0	0.0	0.0	0.0
FX95	Deer Creek: 0.5 to 5.5 miles	--	--	--	--	--	--	--	--
FX96	Sussex Creek: 0.7 to 5.4 miles	8	100.0	100.0	100.0	12.5	12.5	0.0	0.0
FX97	North Branch Genesee Creek: 0 to 1.0 miles	--	--	--	--	--	--	--	--
FX98	South Branch Genesee Creek: 0 to 1.9 miles	--	--	--	--	--	--	--	--
FX99	Unnamed Tributary to Pebble Creek: 0 to 1.9 miles	--	--	--	--	--	--	--	--
FX100	Unnamed Tributary to Sussex Creek: 0 to 3.0 miles	--	--	--	--	--	--	--	--
FX101	Unnamed Tributary to Deer Creek: 0 to 1.6 miles	--	--	--	--	--	--	--	--
FX102	Unnamed Tributary to Lauderdale Lakes: 0 to 0.7 miles	--	--	--	--	--	--	--	--

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the recent period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

[a] *This table represents the portion of the watershed that is within the study area.*

Source: Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, U.S. EPA, USGS, WDNR, and SEWRPC

Table 4.20
Waterbodies Listed as Impaired Due to Chloride in the Fox River Watershed: 2024

Stream Name	Chloride Assessment Reaches Included in Impairment	Extent (River mile)[a]	Impairment		Listing Date	Max Recent Chloride Observed (Reach, Concentration, Date)
			Acute Toxicity	Chronic Toxicity		
Meadowbrook Creek	FX91	0.00-3.14	--	X	2018	FX91, 529 mg/l, 1/20/2015
Pewaukee River above Pewaukee Lake	FX88	0.00-4.45	--	X	2020	FX88, 991 mg/l, 2/20/2014

[a] *River mile is measured upstream from the confluence with whatever the waterbody drains into.*

Source: WDNR and SEWRPC

#277505 – TR-63 Table 4.21
200-1100
AWO/MAS/mid
6/10/25

Table 4.21
Summary of Stream Assessment Reaches Within the Kinnickinnic River Watershed: 1961-2022

Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
KK01	Kinnickinnic River: 0 to 2.4 miles	15100	3	2.4	3,695	1975 - 2022	3,691	1975 - 2022
KK02	Kinnickinnic River: 2.4 to 5.2 miles	15100	3	2.8	2,198	1964 - 2022	2,220	1964 - 2022
KK03	Kinnickinnic River: 5.2 to 7.9 miles	15100	2	2.7	336	1975 - 2022	376	1975 - 2022
KK04	Lyons Park Creek 0 to 1.7 miles	15100	1	1.7	--	--	10	2017 - 2018
KK05	Wilson Park Creek: 0 to 3.4 miles	15200	3	3.4	331	1975 - 2022	356	1975 - 2022
KK06	Wilson Park Creek: 3.4 to 4.4 miles	15200	2	1.0	217	1967 - 2022	47	1975 - 2022
KK07	Wilson Park Creek: 4.4 to 5.8 miles	15200	1	1.4	176	1977 - 2022	18	1977 - 2022
KK08	Villa Mann Creek: 0 to 1.4 miles	15300	1	1.4	4	2018 - 2018	13	2017 - 2018
KK09	43rd Street Ditch: 0 to 1.2 miles	15900	1	1.2	318	2006 - 2022	315	2006 - 2022
KK10	Zablocki Park Creek: 0 to 0.9 miles	5036633	1	0.9	4	2018 - 2020	38	2015 - 2020

Note: Chloride and specific conductance datasets shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, Milwaukee Riverkeeper, USGS, WDNR, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.22
Percent of Measured Chloride and Specific Conductance Samples by Season at Assessment Reaches Within the Kinnickinnic River Watershed: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
KK01	Kinnickinnic River: 0 to 2.4 miles	3,695	5.2	26.7	36.9	31.3	3,691	5.2	26.0	37.1	31.7
KK02	Kinnickinnic River: 2.4 to 5.2 miles	2,198	11.1	24.2	34.6	30.1	2,220	11.5	24.6	33.4	30.5
KK03	Kinnickinnic River: 5.2 to 7.9 miles	336	9.2	25.6	28.3	36.9	376	8.0	23.1	32.4	36.4
KK04	Lyons Park Creek 0 to 1.7 miles	--	--	--	--	--	10	0.0	20.0	50.0	30.0
KK05	Wilson Park Creek: 0 to 3.4 miles	331	14.5	28.7	29.0	27.8	356	13.5	28.1	31.2	27.2
KK06	Wilson Park Creek: 3.4 to 4.4 miles	217	36.9	19.4	24.9	18.9	47	21.3	27.7	40.4	10.6
KK07	Wilson Park Creek: 4.4 to 5.8 miles	176	38.1	23.9	25.6	12.5	18	5.6	5.6	72.2	16.7
KK08	Villa Mann Creek: 0 to 1.4 miles	4	100	0.0	0.0	0.0	15	33.3	33.3	20.0	13.3
KK09	43rd Street Ditch: 0 to 1.2 miles	318	13.8	28.6	29.9	27.7	315	13.7	27.6	30.2	28.6
KK10	Zablocki Park Creek: 0 to 0.9 miles	4	100	0.0	0.0	0.0	38	65.8	10.5	13.2	10.5

Note: Seasons are defined as Winter (December through February), Spring (March through May), Summer (June through August), and Fall (September through November). Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance. Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter.

Source: MMSD, Milwaukee Riverkeeper, USGS, WDNR, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.23
Summary Statistics for Measured Chloride and Specific Conductance at Assessment Reaches Within the Kinnickinnic River Watershed: 1961-2022

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
KK01	Kinnickinnic River: 0 to 2.4 miles	3,695	6	83	64	870	3,691	0	637	586	3,000
KK02	Kinnickinnic River: 2.4 to 5.2 miles	2,198	2	257	160	6,200	2,220	14	1,316	1,060	15,100
KK03	Kinnickinnic River: 5.2 to 7.9 miles	336	2	329	260	3,200	376	127	1,461	1,342	9,770
KK04	Lyons Park Creek 0 to 1.7 miles	--	--	--	--	--	10	700	1,687	1,755	2,400
KK05	Wilson Park Creek: 0 to 3.4 miles	331	30	408	260	8,630	356	174	1,699	1,465	15,600
KK06	Wilson Park Creek: 3.4 to 4.4 miles	217	1	1,303	170	44,000	47	116	1,989	1,010	17,900
KK07	Wilson Park Creek: 4.4 to 5.8 miles	176	4	348	200	2,930	18	110	380	246	1,470
KK08	Villa Mann Creek: 0 to 1.4 miles	4	669	2,342	1,239	6,220	15	1,020	4,832	2,700	19,800
KK09	43rd Street Ditch: 0 to 1.2 miles	318	18	441	300	7,800	315	130	1,833	1,530	16,900
KK10	Zablocki Park Creek: 0 to 0.9 miles	4	694	1,594	1,720	2,240	38	970	2,274	1,907	7,900

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, Milwaukee Riverkeeper, USGS, WDNR, University of Wisconsin-Milwaukee, and SEWRPC.

Table 4.24
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Kinnickinnic River Watershed Full Record: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
KK01	Kinnickinnic River: 0 to 2.4 miles	3,695	99.9	80.6	15.4	4.4	0.6	0.1	0.0
KK02	Kinnickinnic River: 2.4 to 5.2 miles	2,198	99.5	95.5	62.7	33.9	13.6	4.4	1.8
KK03	Kinnickinnic River: 5.2 to 7.9 miles	336	98.8	88.4	78.3	56.3	26.2	6.3	1.8
KK04	Lyons Park Creek 0 to 1.7 miles	--	--	--	--	--	--	--	--
KK05	Wilson Park Creek: 0 to 3.4 miles	331	100	98.5	87.9	58	22.4	10.0	4.5
KK06	Wilson Park Creek: 3.4 to 4.4 miles	217	78.3	62.7	53.9	45.2	39.6	29.0	16.6
KK07	Wilson Park Creek: 4.4 to 5.8 miles	176	94.3	77.8	60.8	45.5	31.3	15.3	3.4
KK08	Villa Mann Creek: 0 to 1.4 miles	4	100	100	100	100	100	75.0	50.0
KK09	43rd Street Ditch: 0 to 1.2 miles	318	100	98.7	89.6	64.8	35.5	10.7	2.8
KK10	Zablocki Park Creek: 0 to 0.9 miles	4	100	100	100	100	100	75.0	50.0

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, Milwaukee Riverkeeper, USGS, WDNR, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.25
Summary Statistics for Recent Measured Chloride and Specific Conductance at Assessment Reaches Within the Kinnickinnic River Watershed: 2013-2022

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (μS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
KK01	Kinnickinnic River: 0 to 2.4 miles	1,448	13	106	81	870	1,454	113	710	660	3,000
KK02	Kinnickinnic River: 2.4 to 5.2 miles	393	25	488	350	6,200	420	195	1,954	1,650	15,100
KK03	Kinnickinnic River: 5.2 to 7.9 miles	184	18	429	330	3,200	226	127	1,662	1,520	9,770
KK04	Lyons Park Creek 0 to 1.7 miles	--	--	--	--	--	10	700	1,687	1,755	2,400
KK05	Wilson Park Creek: 0 to 3.4 miles	187	30	378	300	2,400	210	174	1,661	1,530	7,480
KK06	Wilson Park Creek: 3.4 to 4.4 miles	58	15	1,885	673	26,300	7	738	2,898	1,610	11,100
KK07	Wilson Park Creek: 4.4 to 5.8 miles	54	27	540	408	2,930	2	779	1,125	1,125	1,470
KK08	Villa Mann Creek: 0 to 1.4 miles	4	669	2,342	1,239	6,220	15	1,020	4,832	2,700	19,800
KK09	43rd Street Ditch: 0 to 1.2 miles	191	18	542	370	7,800	189	130	2,039	1,680	16,900
KK10	Zablocki Park Creek: 0 to 0.9 miles	4	694	1,594	1,720	2,240	38	970	2,274	1,907	7,900

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, Milwaukee Riverkeeper, USGS, WDNR, and SEWRPC

Table 4.26
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Kinnickinnic River Watershed Recent Record: 2013-2022

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
KK01	Kinnickinnic River: 0 to 2.4 miles	1,448	100	90	25.1	7.7	1	0.1	0.0
KK02	Kinnickinnic River: 2.4 to 5.2 miles	393	100	99	87.3	76.1	37.7	12.5	5.1
KK03	Kinnickinnic River: 5.2 to 7.9 miles	184	100	97.3	87	69	38.6	10.9	3.3
KK04	Lyons Park Creek 0 to 1.7 miles	--	--	--	--	--	--	--	--
KK05	Wilson Park Creek: 0 to 3.4 miles	187	100	97.3	87.2	66.8	24.1	9.6	3.2
KK06	Wilson Park Creek: 3.4 to 4.4 miles	58	100	93.1	82.8	70.7	65.5	44.8	24.1
KK07	Wilson Park Creek: 4.4 to 5.8 miles	54	100	96.3	87	75.9	51.9	20.4	7.4
KK08	Villa Mann Creek: 0 to 1.4 miles	4	100	100	100	100	100	75	50
KK09	43rd Street Ditch: 0 to 1.2 miles	191	100	97.9	91.1	76.4	46.1	14.1	4.2
KK10	Zablocki Park Creek: 0 to 0.9 miles	4	100	100	100	100	100	75	50

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the recent period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, Milwaukee Riverkeeper, USGS, University of Wisconsin-Milwaukee, WDNR, and SEWRPC

Table 4.27
Waterbodies Listed as Impaired Due to Chloride in the Kinnickinnic River Watershed: 2024

Stream Name	Chloride Assessment Reaches Included in Impairment	Extent (River mile)[a]	Impairment		Listing Date	Max Recent Chloride Observed (Reach, Concentration, Date)
			Acute Toxicity	Chronic Toxicity		
Kinnickinnic River[b]	KK03, KK04	5.49-9.93	X	X	2018	KK03, 3,200 mg/l, 2/21/2019
Kinnickinnic River	KK02	3.16-5.49	X	X	2014	KK02, 6,200, mg/l, 2/19/2014
Kinnickinnic River	KK01	0.00-3.16	X	X	2018	KK01, 870 mg/l, 2/11/2013
South 43rd Street Ditch	KK09	0.00-1.16	X	X	2022	KK09 7,800 mg/l, 2/19/2014
Wilson Park Creek	KK05	0.0-3.5	X	X	2018	KK05, 2,400 mg/l, 12/21/2019
Zablocki Park Creek	KK10	0.0-0.9	X	X	2022	KK10, 2,240 mg/l, 2/13/2019

[a] *River mile is measured upstream from the confluence with whatever the waterbody drains into.*

[b] *For the Chloride Impact Study, the segment from 7.9 miles to 9.93 miles that is sometimes considered part of the Kinnickinnic River is referred to as Lyons Park Creek.*

Source: WDNR and SEWRPC

#2761654 – TR-63 Table 4.28
200-1100
AWO/LKH
2/12/2025, 5/8/25

Table 4.28
Summary of Stream Assessment Reaches Within the Menomonee River Watershed: 1961-2022

Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
MN01	Menomonee River: 0 to 1.8 miles	16000	4	1.8	4,186	1975 - 2022	3,879	1975 - 2022
MN02	Menomonee River: 1.8 to 6.3 miles	16000	4	4.5	2,566	1962 - 2022	1,888	1962 - 2022
MN03	Menomonee River: 6.3 to 8.4 miles	16000	4	2.1	5	2017	26	2016 - 2018
MN04	Menomonee River: 8.4 to 12.6 miles	16000	4	4.2	1,166	1966 - 2022	1,201	1966 - 2022
MN05	Menomonee River: 12.6 to 14.5 miles	16000	4	1.8	979	1975 - 2022	876	1975 - 2022
MN06	Menomonee River: 14.5 to 18.0 miles	16000	4	3.5	147	1964 - 2011	179	1964 - 2018
MN07	Menomonee River: 19.0 to 20.4 miles	16000	4	1.4	27	1964 - 1975	53	1964 - 2018
MN08	Menomonee River: 20.4 to 24.2 miles	16000	4	3.8	1,252	1964 - 2022	1,137	1964 - 2022
MN09	Menomonee River: 24.8 to 27.1 miles	16000	4	2.3	255	1964 - 1978	180	1964 - 2022
MN10	Menomonee River: 27.1 to 27.8 miles	16000	3	0.7	333	1964 - 2022	350	1964 - 2022
MN11	Honey Creek: 0 to 3.1 miles	16300	2	3.1	1,036	1964 - 2022	641	1964 - 2022
MN12	Honey Creek: 3.1 to 4.9 miles	16300	2	1.8	170	2003 - 2022	169	2003 - 2022
MN13	Honey Creek: 4.9 to 9.0 miles	16300	1	4.1	146	2003 - 2011	146	2003 - 2011
MN14	Underwood Creek: 0 to 2.8 miles	16700	3	2.8	824	1964 - 2022	652	1964 - 2022
MN15	Underwood Creek: 2.8 to 7.2 miles	16700	3	4.4	410	2003 - 2022	439	2003 - 2022
MN16	Southbranch Underwood Creek: 0 to 1.0 miles	16800	2	1.0	169	2003 - 2022	168	2003 - 2022
MN17	Southbranch Underwood Creek: 1.7 to 2.2 miles	16800	1	0.4	169	2003 - 2022	168	2003 - 2022
MN18	Dousman Ditch: 0 to 1.6 miles	17100	3	1.6	6	2020	1	2020
MN19	Little Menomonee River: 0 to 7.3 miles	17600	3	7.3	840	1964 - 2022	828	1964 - 2022
MN20	Little Menomonee River: 7.3 to 10.9 miles	17600	2	3.6	591	1975 - 2022	158	1975 - 2022
MN21	Noyes Creek: 0 to 3.0 miles	17700	2	3.0	341	1975 - 2020	141	1975 - 2020
MN22	Little Menomonee Creek: 0 to 3.9 miles	17900	2	3.9	58	2017 - 2022	2	2007
MN23	Butler Creek: 0 to 2.5 miles	18100	4	2.5	9	2018 - 2019	38	2013 - 2020
MN24	Dretzka Park Creek: 0 to 2.1 miles	18350	2	2.1	2	2021 - 2022	28	2016 - 2022
MN25	Lily Creek: 0 to 1.4 miles	18400	4	1.4	13	2004 - 2015	46	2004 - 2018
MN26	Nor-X-Way Channel: 0 to 3.3 miles	18450	2	3.3	4	2018	14	2017
MN27	Willow Creek: 0 to 0.9 miles	18800	3	0.9	21	2004 - 2022	76	2001 - 2022
MN28	Goldendale Creek: 0 to 1.2 miles	18900	3	1.2	--	--	25	2017 - 2022
MN29	Burnham Canal: 0.5 to 1.1 miles	3000042	1	0.6	578	1989 - 2022	593	1989 - 2022
MN30	Unnamed Tributary to Menomonee River: 0 to 2.7 miles	5034083	2	2.7	325	1976 - 1978	1	1976
MN31	Grantosa Creek: 0 to 1.0 miles	5035175	1	1.0	--	--	5	2016 - 2018
MN32	Unnamed Tributary to Dousman Ditch: 0 to 0.1 miles	5035840	1	0.1	96	1976 - 1977	3	1977
MN33	Schoonmaker Creek	None	1	1.2	240	1975 - 1977	95	1975 - 1978

Table 4.28 (Continued)

Note: Chloride and specific conductance datasets shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, USEPA, USGS, University of Wisconsin – Milwaukee, WDNR, and SEWRPC

Table 4.29
Percent of Measured Chloride and Specific Conductance Samples by Season at Assessment Reaches Within the Menomonee River Watershed: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
MN01	Menomonee River: 0 to 1.8 miles	4,186	12.1	27.5	32.3	28.0	3,879	11.8	26.6	32.7	29.0
MN02	Menomonee River: 1.8 to 6.3 miles	2,566	13.2	28.7	35.7	22.5	1,888	13.5	25.3	34.6	26.5
MN03	Menomonee River: 6.3 to 8.4 miles	5	80.0	20.0	0.0	0.0	26	38.5	19.2	30.8	11.5
MN04	Menomonee River: 8.4 to 12.6 miles	1,166	9.3	25.6	35.7	29.3	1,201	9.1	24.9	36.7	29.3
MN05	Menomonee River: 12.6 to 14.5 miles	979	7.6	28.3	37.8	26.4	876	7.9	26.3	36.8	29.1
MN06	Menomonee River: 14.5 to 18.0 miles	147	6.1	25.2	45.6	23.1	179	5.0	22.9	50.3	21.8
MN07	Menomonee River: 19.0 to 20.4 miles	27	0.0	18.5	77.8	3.7	53	0.0	17.0	71.7	11.3
MN08	Menomonee River: 20.4 to 24.2 miles	1,252	11.1	28.0	35.9	25.0	1,137	11.2	24.4	37.0	27.4
MN09	Menomonee River: 24.8 to 27.1 miles	255	12.5	34.5	42.4	10.6	180	24.4	24.4	38.3	12.8
MN10	Menomonee River: 27.1 to 27.8 miles	333	12.3	27.6	33.6	26.4	350	11.7	27.4	35.1	25.7
MN11	Honey Creek: 0 to 3.1 miles	1,036	9.1	30.6	39.0	21.3	641	8.9	25.9	39.8	25.4
MN12	Honey Creek: 3.1 to 4.9 miles	170	0.6	27.1	38.2	34.1	169	0.6	27.2	38.5	33.7
MN13	Honey Creek: 4.9 to 9.0 miles	146	0.0	23.3	43.8	32.9	146	0.0	23.3	43.8	32.9
MN14	Underwood Creek: 0 to 2.8 miles	824	8.5	30.0	39.1	22.5	652	8.6	26.4	38.8	26.2
MN15	Underwood Creek: 2.8 to 7.2 miles	410	0.5	27.1	38.0	34.4	439	0.5	26.9	39.0	33.7
MN16	Southbranch Underwood Creek: 0 to 1.0 miles	169	0.6	27.8	37.3	34.3	168	0.6	28.0	36.9	34.5
MN17	Southbranch Underwood Creek: 1.7 to 2.2 miles	169	0.6	27.8	37.3	34.3	168	0.6	28.0	36.9	34.5
MN18	Dousman Ditch: 0 to 1.6 miles	6	100	0.0	0.0	0.0	1	100	0.0	0.0	0.0
MN19	Little Menomonee River: 0 to 7.3 miles	840	13.7	30.2	30.8	25.2	828	14.7	27.2	32.7	25.4
MN20	Little Menomonee River: 7.3 to 10.9 miles	591	11.0	32.1	35.7	21.2	158	16.5	34.2	31.0	18.4
MN21	Noyes Creek: 0 to 3.0 miles	341	15.2	36.4	34.3	14.1	141	22.7	30.5	29.1	17.7
MN22	Little Menomonee Creek: 0 to 3.9 miles	58	0.0	17.2	44.8	37.9	2	0.0	0.0	0.0	100
MN23	Butler Creek: 0 to 2.5 miles	9	100	0.0	0.0	0.0	38	44.7	13.2	21.1	21.1
MN24	Dretzka Park Creek: 0 to 2.1 miles	2	100	0.0	0.0	0.0	28	46.4	17.9	28.6	7.1
MN25	Lily Creek: 0 to 1.4 miles	13	46.2	30.8	23.1	0.0	46	21.7	26.1	32.6	19.6
MN26	Nor-X-Way Channel: 0 to 3.3 miles	4	100	0.0	0.0	0.0	14	64.3	7.1	21.4	7.1
MN27	Willow Creek: 0 to 0.9 miles	21	33.3	33.3	28.6	4.8	76	21.1	21.1	36.8	21.1
MN28	Goldendale Creek: 0 to 1.2 miles	--	--	--	--	--	25	64.0	20.0	8.0	8.0
MN29	Burnham Canal: 0.5 to 1.1 miles	578	9.0	27.0	34.4	29.6	593	9.8	27.0	33.9	29.3
MN30	Unnamed Tributary to Menomonee River: 0 to 2.7 miles	325	0.9	32.6	42.5	24.0	1	0.0	100	0.0	0.0
MN31	Grantosa Creek: 0 to 1.0 miles	--	--	--	--	--	5	0.0	20.0	60.0	20.0

Table 4.29 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
MN32	Unnamed Tributary to Dousman Ditch: 0 to 0.1 miles	96	11.5	25.0	56.3	7.3	3	0.0	0.0	100	0.0
MN33	Schoonmaker Creek	240	18.3	29.2	37.5	15.0	95	7.4	35.8	42.1	14.7

Note: Seasons are defined as Winter (December through February), Spring (March through May), Summer (June through August), and Fall (September through November). Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps during the period. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance. Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter.

Source: MMSD, Milwaukee Riverkeeper, USGS, University of Wisconsin-Milwaukee, WDNR, and SEWRPC

Table 4.30
Summary Statistics for Measured Chloride and Specific Conductance at Assessment Reaches Within the Menomonee River Watershed: 1961-2022

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (μS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MN01	Menomonee River: 0 to 1.8 miles	4,186	11	143	101	1,700	3,879	0	907	818	6,320
MN02	Menomonee River: 1.8 to 6.3 miles	2,566	0	180	126	2,940	1,888	4	1,025	973	10,400
MN03	Menomonee River: 6.3 to 8.4 miles	5	443	634	679	864	26	750	1,585	1,360	3,300
MN04	Menomonee River: 8.4 to 12.6 miles	1,166	1	159	140	1,500	1,201	258	995	984	7,000
MN05	Menomonee River: 12.6 to 14.5 miles	979	3	151	131	1,100	876	220	958	957	3,390
MN06	Menomonee River: 14.5 to 18.0 miles	147	30	151	155	340	179	360	1,072	1,084	1,820
MN07	Menomonee River: 19.0 to 20.4 miles	27	26	94	104	264	53	510	1,013	1,030	1,566
MN08	Menomonee River: 20.4 to 24.2 miles	1,252	1	116	100	1,600	1,137	180	886	895	2,379
MN09	Menomonee River: 24.8 to 27.1 miles	255	1	74	55	1,080	180	79	768	720	2,355
MN10	Menomonee River: 27.1 to 27.8 miles	333	13	47	48	93	350	228	758	771	1,350
MN11	Honey Creek: 0 to 3.1 miles	1,036	3	339	196	6,470	641	135	1,605	1,350	19,200
MN12	Honey Creek: 3.1 to 4.9 miles	170	16	404	330	1,900	169	158	1,738	1,630	6,320
MN13	Honey Creek: 4.9 to 9.0 miles	146	12	252	215	1,200	146	113	1,373	1,280	3,266
MN14	Underwood Creek: 0 to 2.8 miles	824	15	315	230	6,400	652	208	1,504	1,390	16,100
MN15	Underwood Creek: 2.8 to 7.2 miles	410	59	275	250	1,300	439	138	1,508	1,477	4,530
MN16	Southbranch Underwood Creek: 0 to 1.0 miles	169	42	277	250	1,100	168	283	1,424	1,437	4,250
MN17	Southbranch Underwood Creek: 1.7 to 2.2 miles	169	24	375	350	1,800	168	167	1,834	1,946	5,670
MN18	Dousman Ditch: 0 to 1.6 miles	6	714	1,400	1,205	3,020	1	10	10	10	10
MN19	Little Menomonee River: 0 to 7.3 miles	840	8	121	69	4,190	828	132	918	839	13,100
MN20	Little Menomonee River: 7.3 to 10.9 miles	591	4	48	45	200	158	220	676	680	1,148
MN21	Noyes Creek: 0 to 3.0 miles	341	8	303	115	9,800	141	180	1,453	1,040	10,400
MN22	Little Menomonee Creek: 0 to 3.9 miles	58	44	59	60	71	2	777	781	781	785
MN23	Butler Creek: 0 to 2.5 miles	9	402	574	501	1,050	38	1,060	1,639	1,555	3,400
MN24	Dretzka Park Creek: 0 to 2.1 miles	2	1,050	2,170	2,170	3,290	28	570	2,049	1,505	14,020
MN25	Lily Creek: 0 to 1.4 miles	13	102	383	353	739	46	780	1,559	1,330	3,300
MN26	Nor-X-Way Channel: 0 to 3.3 miles	4	563	649	618	795	14	540	1,637	1,670	2,300
MN27	Willow Creek: 0 to 0.9 miles	21	76	165	113	844	76	283	1,102	1,035	3,400
MN28	Goldendale Creek: 0 to 1.2 miles	--	--	--	--	--	25	790	1,121	1,095	1,830
MN29	Burnham Canal: 0.5 to 1.1 miles	578	3	144	110	830	593	80	935	847	3,000
MN30	Unnamed Tributary to Menomonee River: 0 to 2.7 miles	325	1	37	14	1,925	1	59	59	59	59
MN31	Grantosa Creek: 0 to 1.0 miles	--	--	--	--	--	5	460	1,364	1,310	2,600
MN32	Unnamed Tributary to Dousman Ditch: 0 to 0.1 miles	96	1	352	19	3,250	3	84	139	147	185

Table 4.30 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MN33	Schoonmaker Creek	240	1	313	112	4,800	95	91	1,046	1,020	6,500

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, Milwaukee Riverkeeper, USGS, University of Wisconsin-Milwaukee, WDNR, and SEWRPC

Table 4.31
Percentage of Measurements in Which Chloride Concentrations Exceeded Various Water Quality Thresholds in the Menomonee River Watershed Full Record: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MN01	Menomonee River: 0 to 1.8 miles	4,186	100	96.4	40.0	14.7	3.9	0.9	0.0
MN02	Menomonee River: 1.8 to 6.3 miles	2,566	99.0	94.3	52.5	18.0	7.1	2.2	0.9
MN03	Menomonee River: 6.3 to 8.4 miles	5	100	100	100	100	100	20.0	0.0
MN04	Menomonee River: 8.4 to 12.6 miles	1,166	99.8	98.2	58.8	12.4	2.7	0.5	0.1
MN05	Menomonee River: 12.6 to 14.5 miles	979	99.9	98.6	55.3	11.3	2.2	0.3	0.0
MN06	Menomonee River: 14.5 to 18.0 miles	147	100	99.3	66.7	6.8	0.0	0.0	0.0
MN07	Menomonee River: 19.0 to 20.4 miles	27	100	88.9	22.2	3.7	0.0	0.0	0.0
MN08	Menomonee River: 20.4 to 24.2 miles	1,252	99.8	97	32.3	3.3	1.4	0.5	0.1
MN09	Menomonee River: 24.8 to 27.1 miles	255	82.7	69.4	11.0	2.0	2.0	2.0	0.0
MN10	Menomonee River: 27.1 to 27.8 miles	333	100	79.6	0.0	0.0	0.0	0.0	0.0
MN11	Honey Creek: 0 to 3.1 miles	1,036	97.9	84.2	61.6	44.8	22.0	8.3	4.0
MN12	Honey Creek: 3.1 to 4.9 miles	170	100	98.8	81.8	72.4	41.2	8.8	1.8
MN13	Honey Creek: 4.9 to 9.0 miles	146	100	96.6	73.3	44.5	16.4	2.1	0.0
MN14	Underwood Creek: 0 to 2.8 miles	824	100	96.8	76.7	49.3	18.3	5.3	2.3
MN15	Underwood Creek: 2.8 to 7.2 miles	410	100	100	94.4	59.5	10.2	1.5	0.0
MN16	Southbranch Underwood Creek: 0 to 1.0 miles	169	100	100	81.1	53.8	17.8	3.0	0.0
MN17	Southbranch Underwood Creek: 1.7 to 2.2 miles	169	100	98.2	86.4	73.4	40.8	4.7	0.6
MN18	Dousman Ditch: 0 to 1.6 miles	6	100	100	100	100	100	83.3	16.7
MN19	Little Menomonee River: 0 to 7.3 miles	840	99.8	96.1	18.8	6.5	3.7	1.7	0.8
MN20	Little Menomonee River: 7.3 to 10.9 miles	591	99.5	73.9	0.8	0.0	0.0	0.0	0.0
MN21	Noyes Creek: 0 to 3.0 miles	341	99.7	84.5	48.4	29.6	15.5	7.3	5.0
MN22	Little Menomonee Creek: 0 to 3.9 miles	58	100	100	0.0	0.0	0.0	0.0	0.0
MN23	Butler Creek: 0 to 2.5 miles	9	100	100	100	100	100	22.2	0.0
MN24	Dretzka Park Creek: 0 to 2.1 miles	2	100	100	100	100	100	100	50.0
MN25	Lily Creek: 0 to 1.4 miles	13	100	100	92.3	69.2	54.5	0.0	0.0
MN26	Nor-X-Way Channel: 0 to 3.3 miles	4	100	100	100	100	100	25.0	0.0
MN27	Willow Creek: 0 to 0.9 miles	21	100	100	47.6	4.8	4.8	4.8	0.0
MN28	Goldendale Creek: 0 to 1.2 miles	--	--	--	--	--	--	--	--
MN29	Burnham Ca0.0l: 0.5 to 1.1 miles	578	99.8	99.3	38.4	14.7	4.2	0.3	0.0
MN30	Unamed Tributary to Menomonee River: 0 to 2.7 miles	325	54.8	24.9	2.2	1.2	0.9	0.6	0.6
MN31	Grantosa Creek: 0 to 1.0 miles	--	--	--	--	--	--	--	--
MN32	Unamed Tributary to Dousman Ditch: 0 to 0.1 miles	96	65.6	43.8	25.0	19.8	16.7	11.5	11.5

Table 4.31 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MN33	Schoonmaker Creek	240	77.9	60.4	47.9	30.0	20.0	10.8	4.6

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: SEWRPC

Table 4.32
Summary Statistics for Recent Measured Chloride and Specific Conductance at Assessment Reaches Within the Menomonee River Watershed: 2013-2022

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	**Assessment Reach**	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MN01	Menomonee River: 0 to 1.8 miles	1,396	24	188	150	1,300	1,386	204	1,055	979	6,320
MN02	Menomonee River: 1.8 to 6.3 miles	231	38	296	230	2,240	234	120	1,309	1,265	7,530
MN03	Menomonee River: 6.3 to 8.4 miles	5	443	634	679	864	26	750	1,585	1,360	3,300
MN04	Menomonee River: 8.4 to 12.6 miles	359	31	209	180	1,500	375	267	1,135	1,100	7,000
MN05	Menomonee River: 12.6 to 14.5 miles	191	32	209	180	940	199	286	1,132	1,100	3,390
MN06	Menomonee River: 14.5 to 18.0 miles	--	--	--	--	--	15	360	1,074	1,102	1,360
MN07	Menomonee River: 19.0 to 20.4 miles	--	--	--	--	--	16	510	1,078	1,135	1,372
MN08	Menomonee River: 20.4 to 24.2 miles	204	47	147	140	890	216	315	988	1,000	1,950
MN09	Menomonee River: 24.8 to 27.1 miles	--	--	--	--	--	28	630	1,190	1,255	1,598
MN10	Menomonee River: 27.1 to 27.8 miles	184	13	50	50	87	191	228	739	771	1,070
MN11	Honey Creek: 0 to 3.1 miles	233	20	655	400	4,580	237	153	2,178	1,770	13,492
MN12	Honey Creek: 3.1 to 4.9 miles	86	16	504	445	1,900	85	158	2,038	1,970	6,320
MN13	Honey Creek: 4.9 to 9.0 miles	--	--	--	--	--	--	--	--	--	--
MN14	Underwood Creek: 0 to 2.8 miles	202	33	467	360	6,400	199	348	1,811	1,748	16,100
MN15	Underwood Creek: 2.8 to 7.2 miles	174	67	317	260	1,300	203	138	1,562	1,490	4,530
MN16	Southbranch Underwood Creek: 0 to 1.0 miles	87	42	335	290	1,100	87	323	1,568	1,560	4,250
MN17	Southbranch Underwood Creek: 1.7 to 2.2 miles	87	24	462	480	1,800	87	167	2,026	2,200	5,670
MN18	Dousman Ditch: 0 to 1.6 miles	6	714	1,400	1,205	3,020	1	10	10	10	10
MN19	Little Menomonee River: 0 to 7.3 miles	407	15	105	66	4,190	404	132	920	849	13,100
MN20	Little Menomonee River: 7.3 to 10.9 miles	239	28	54	54	113	3	671	919	937	1,148
MN21	Noyes Creek: 0 to 3.0 miles	8	587	1,332	832	3,080	16	670	3,214	2,700	10,400
MN22	Little Menomonee Creek: 0 to 3.9 miles	58	44	59	60	71	--	--	--	--	--
MN23	Butler Creek: 0 to 2.5 miles	9	402	574	501	1,050	38	1,060	1,639	1,555	3,400
MN24	Dretzka Park Creek: 0 to 2.1 miles	2	1,050	2,170	2,170	3,290	28	570	2,049	1,505	14,020
MN25	Lily Creek: 0 to 1.4 miles	5	323	543	555	739	25	780	1,579	1,340	3,000
MN26	Nor-X-Way Channel: 0 to 3.3 miles	4	563	649	618	795	14	540	1,637	1,670	2,300
MN27	Willow Creek: 0 to 0.9 miles	3	212	424	217	*844*	40	283	1,132	1,050	3,400
MN28	Goldendale Creek: 0 to 1.2 miles	--	--	--	--	--	25	790	1,121	1,095	1,830
MN29	Burnham Canal: 0.5 to 1.1 miles	199	48	186	150	830	205	434	1,063	986	3,000
MN30	Unnamed Tributary to Menomonee River: 0 to 2.7 miles	--	--	--	--	--	--	--	--	--	--
MN31	Grantosa Creek: 0 to 1.0 miles	--	--	--	--	--	5	460	1,364	1,310	2,600

Table 4.32 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MN32	Unnamed Tributary to Dousman Ditch: 0 to 0.1 miles	--	--	--	--	--	--	--	--	--	--
MN33	Schoonmaker Creek	--	--	--	--	--	--	--	--	--	--

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with chloride samples during the full period of record are included in this table to indicate sampling gaps during the period. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, Milwaukee Riverkeeper, USGS, University of Wisconsin-Milwaukee, WDNR, and SEWRPC

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Table 4.33

Percentage of Recent Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Menomonee River Watershed Recent Record: 2013-2022

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MN01	Menomonee River: 0 to 1.8 miles	1,396	100	99.3	62.8	23.5	6.2	1.4	0.0
MN02	Menomonee River: 1.8 to 6.3 miles	231	100	100	87.9	47.2	15.6	6.1	1.3
MN03	Menomonee River: 6.3 to 8.4 miles	5	100	100	100	100	100	20.0	0.0
MN04	Menomonee River: 8.4 to 12.6 miles	359	100	99.4	84.1	25.1	5.8	1.4	0.3
MN05	Menomonee River: 12.6 to 14.5 miles	191	100	99.5	85.3	26.2	5.2	1.0	0.0
MN06	Menomonee River: 14.5 to 18.0 miles	--	--	--	--	--	--	--	--
MN07	Menomonee River: 19.0 to 20.4 miles	--	--	--	--	--	--	--	--
MN08	Menomonee River: 20.4 to 24.2 miles	204	100	100	67.2	3.4	1.0	0.5	0.0
MN09	Menomonee River: 24.8 to 27.1 miles	--	--	--	--	--	--	--	--
MN10	Menomonee River: 27.1 to 27.8 miles	184	100	89.1	0.0	0.0	0.0	0.0	0.0
MN11	Honey Creek: 0 to 3.1 miles	233	100	97	91.0	80.7	51.5	21.0	9.9
MN12	Honey Creek: 3.1 to 4.9 miles	86	100	97.7	84.9	80.2	57.0	15.1	3.5
MN13	Honey Creek: 4.9 to 9.0 miles	--	--	--	--	--	--	--	--
MN14	Underwood Creek: 0 to 2.8 miles	202	100	99.5	93.6	81.2	40.6	9.4	3.0
MN15	Underwood Creek: 2.8 to 7.2 miles	174	100	100	93.7	65.5	20.7	3.4	0.0
MN16	Southbranch Underwood Creek: 0 to 1.0 miles	87	100	100	88.5	64.4	28.7	5.7	0.0
MN17	Southbranch Underwood Creek: 1.7 to 2.2 miles	87	100	96.6	87.4	80.5	64.4	9.2	1.1
MN18	Dousman Ditch: 0 to 1.6 miles	6	100	100	100	100	100	83.3	16.7
MN19	Little Menomonee River: 0 to 7.3 miles	407	100	96.3	16.0	3.9	1.7	0.7	0.5
MN20	Little Menomonee River: 7.3 to 10.9 miles	239	100	97.1	0.0	0.0	0.0	0.0	0.0
MN21	Noyes Creek: 0 to 3.0 miles	8	100	100	100	100	100	50.0	25.0
MN22	Little Menomonee Creek: 0 to 3.9 miles	58	100	100	0.0	0.0	0.0	0.0	0.0
MN23	Butler Creek: 0 to 2.5 miles	9	100	100	100	100	100	22.2	0.0
MN24	Dretzka Park Creek: 0 to 2.1 miles	2	100	100	100	100	100	100	50.0
MN25	Lily Creek: 0 to 1.4 miles	5	100	100	100	100	80.0	0.0	0.0
MN26	Nor-X-Way Channel: 0 to 3.3 miles	4	100	100	100	100	100	25.0	0.0
MN27	Willow Creek: 0 to 0.9 miles	3	100	100	100	33.3	33.3	33.3	0.0
MN28	Goldendale Creek: 0 to 1.2 miles	--	--	--	--	--	--	--	--
MN29	Burnham Ca0.0l: 0.5 to 1.1 miles	199	100	100	58.8	23.6	6.5	0.5	0.0

Table 4.33 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MN30	Unnamed Tributary to Menomonee River: 0 to 2.7 miles	--	--	--	--	--	--	--	--
MN31	Grantosa Creek: 0 to 1.0 miles	--	--	--	--	--	--	--	--
MN32	Unamed Tributary to Dousman Ditch: 0 to 0.1 miles	--	--	--	--	--	--	--	--
MN33	Schoonmaker Creek	--	--	--	--	--	--	--	--

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with chloride samples during the recent period of record are included in this table to indicate sampling gaps during the period. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, Milwaukee Riverkeeper, USGS, University of Wisconsin-Milwaukee, WDNR, and SEWRPC

Table 4.34
Waterbodies Listed as Impaired Due to Chloride in the Menomonee River Watershed: 2024

Stream Name	Chloride Assessment Reaches Included in Impairment	Extent (River mile)[a]	Impairment		Listing Date	Max Recent Chloride Observed (Reach, Concentration, Date)
			Acute Toxicity	Chronic Toxicity		
Butler Ditch	MN23	0.00-2.85	--	X	2020	MN23, 1,050 mg/l, 1/20/2018
Dousman Ditch	MN18	0.00-2.50	X	X	2022	MN18, 3,020, mg/l, 2/3/2020
Honey Creek	MN11, MN12, MN13	0.00-8.96	X	X	2018	MN11, 4,580 mg/l, 2/22/2021
Lilly Creek	MN25	0.00-4.70	--	X	2016	MN25, 739 mg/l, 2/22/2014
Little Menomonee River	MN19, MN20 *(partial)*	0.0-9.0	X	X	2016	MN19, 4,190 mg/l, 1/28/2013
Menomonee River	MN01, MN02, MN03, MN04, MN05, MN06, MN07, MN08	0.00-24.81	X	X	2018	MN02, 2,240 mg/l, 1/24/2020
Nor-X-Way Channel	MN26	0.0-4.9	--	X	2020	MN26, 795 mg/l, 2/19/2018
Noyes Creek	MN21	0.00-3.54	X	X	2020	MN21, 3,080 mg/l, 1/31/2017
South Branch of Underwood Creek	MN16	0.00-1.11	X	X	2018	MN16, 1,100 mg/l, 3/25/2014
Underwood Creek	MN14, MN15	0.00-8.54	X	X	2018	MN14, 6,400 mg/l, 2/18/2014

[a] *River mile is measured upstream from the confluence with whatever the waterbody drains into.*

Source: WDNR and SEWRPC

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Table 4.35
Summary of Stream Assessment Reaches Within the Milwaukee River Watershed: 1961-2022

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
MK01	Milwaukee River: 0 to 0.8 miles	15000	5	0.8	2,270	1964 - 2022	1,766	1964 - 2022
MK02	Milwaukee River: 0.8 to 7.7 miles	15000	5	6.8	3,053	1961 - 2022	2,941	1964 - 2022
MK03	Milwaukee River: 7.7 to 12.8 miles	15000	5	5.1	351	1975 - 2022	370	1975 - 2022
MK04	Milwaukee River: 15.1 to 19.4 miles	15000	5	4.3	574	1961 - 2022	535	1964 - 2022
MK05	Milwaukee River: 19.6 to 20.7 miles	15000	5	1.0	--	--	5	2016
MK06	Milwaukee River: 24.1 to 27.5 miles	15000	5	3.4	518	1964 - 2022	500	1964 - 2022
MK07	Milwaukee River: 27.5 to 29.8 miles	15000	5	2.3	20	1995	32	1993 - 2022
MK08	Milwaukee River: 29.8 to 32.3 miles	15000	5	2.5	29	1964 - 1975	63	1964 - 2018
MK09	Milwaukee River: 32.3 to 35.8 miles	15000	5	3.5	--	--	35	1993 - 2019
MK10	Milwaukee River: 35.8 to 43.7 miles	15000	5	8.0	70	1964 - 2020	117	1964 - 2020
MK11	Milwaukee River: 43.7 to 47.8 miles	15000	5	4.1	73	1976 - 2004	111	1976 - 2020
MK12	Milwaukee River: 47.8 to 53.2 miles	15000	5	5.4	31	2018 - 2020	33	2006 - 2020
MK13	Milwaukee River: 57.3 to 63.9 miles	15000	5	6.6	106	1964 - 2004	77	1964 - 2020
MK14	Milwaukee River: 64.1 to 67.4 miles	15000	5	3.3	--	--	22	1993 - 2022
MK15	Milwaukee River: 67.4 to 68.4 miles	15000	5	1.0	--	--	9	2019 - 2020
MK16	Milwaukee River: 69.9 to 74.7 miles	15000	5	4.8	29	1964 - 1975	38	1964 - 2018
MK17	Milwaukee River: 77.3 to 78.6 miles	15000	4	1.3	86	1976 - 2004	77	1976 - 2020
MK18	Milwaukee River: 79.9 to 83.4 miles	15000	4	3.5	39	1964 - 1975	48	1964 - 2020
MK19	Milwaukee River: 87.4 to 87.8 miles	15000	4	0.4	1	1994	15	2020 - 2021
MK20	Milwaukee River: 91.8 to 95.8 miles	15000	4	4.0	--	--	1	2020
MK21	Lincoln Creek: 0 to 5.0 miles	19400	2	5.0	663	1975 - 2022	435	1975 - 2022
MK22	Lincoln Creek: 5.0 to 10.0 miles	19400	1	5.0	335	1975 - 2022	328	1975 - 2022
MK23	Crestwood Creek: 0 to 1.3 miles	19450	1	1.4	6	2017	19	2016 - 2018
MK24	Indian Creek: 0 to 2.7 miles	19600	2	2.7	250	1975 - 2022	288	2006 - 2022
MK25	Brown Deer Park Creek: 0 to 2.2 miles	19700	2	2.2	14	2016 - 2017	29	2016 - 2020
MK26	Beaver Creek: 0 to 3.3 miles	20000	1	3.3	9	2017	27	2016 - 2018
MK27	Lac du Cours Creek: 0 to 0.3 miles	20200	1	0.3	--	--	34	2017 - 2022
MK28	Trinity Creek: 0 to 3.3 miles	20400	2	3.3	--	--	53	2016 - 2021
MK29	Pigeon Creek: 0 to 2.4 miles	20500	3	2.4	2	2004	125	2001 - 2022
MK30	Mee-Kwon Creek: 0 to 1.4 miles	20700	1	1.4	--	--	18	2016 - 2018
MK31	Unnamed Tributary to Milwaukee River: 0 to 0.3 miles	21100	2	0.3	--	--	3	2019
MK32	Ulao Creek: 0 to 0.7 miles	21200	4	0.7	28	2016 - 2021	46	2016 - 2020
MK33	Ulao Creek: 1.8 to 5.3 miles	21200	3	3.5	148	2011 - 2022	129	2011 - 2021
MK34	Ulao Creek: 5.3 to 6.2 miles	21200	2	0.9	65	2016 - 2021	11	2020 - 2021
MK35	Ulao Creek: 6.6 to 9.2 miles	21200	2	2.6	26	2016 - 2021	--	--
MK36	Cedar Creek: 1.1 to 1.8 miles	21300	4	0.7	196	1990 - 1991	86	1990 - 2019

Table 4.35 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
MK37	Cedar Creek: 1.8 to 14.1 miles	21300	4	12.3	656	1964 - 2022	596	1964 - 2022
MK38	Cedar Creek: 16.0 to 18.3 miles	21300	4	2.3	35	1964 - 1975	91	1964 - 2019
MK39	Cedar Creek: 19.1 to 19.6 miles	21300	4	0.6	1	2000	--	--
MK40	Cedar Creek: 20.7 to 21.2 miles	21300	4	0.5	28	2000 - 2020	27	1995 - 2020
MK41	Cedar Creek: 21.2 to 22.5 miles	21300	4	1.3	1	2000	6	2022
MK42	Cedar Creek: 23.0 to 23.3 miles	21300	3	0.3	--	--	4	2022
MK43	Cedar Creek: 23.6 to 25.7 miles	21300	2	2.1	--	--	42	2016 - 2020
MK44	Cedar Creek: 25.7 to 29.7 miles	21300	2	4.1	2	2001	7	2018 - 2019
MK45	Cedar Creek: 31.3 to 37.8 miles	21300	2	1.4	--	--	66	2017 - 2019
MK46	Mud Creek: 0 to 3.5 miles	22000	2	3.5	--	--	23	2009 - 2019
MK47	North Branch Cedar Creek: 0 to 2.0 miles	22500	3	2.0	4	2018 - 2022	67	2007 - 2022
MK48	Cedarburg Creek: 0 to 6.4 miles	22900	2	6.4	--	--	46	2011 - 2021
MK49	Evergreen Creek: 0 to 3.3 miles	23000	3	3.3	--	--	36	2017 - 2020
MK50	Friedens Creek: 0 to 3.5 miles	23300	2	3.5	1	2019	28	2001 - 2022
MK51	Little Cedar Creek: 0.2 to 1.7 miles	23400	3	1.6	--	--	36	2016 - 2019
MK52	Little Cedar Creek: 1.7 to 3.9 miles	23400	3	2.2	1	2022	64	2017 - 2022
MK53	Little Cedar Creek: 3.9 to 7.8 miles	23400	2	3.9	--	--	6	2020
MK54	Kressin Branch: 0 to 5.1 miles	23500	2	5.1	--	--	24	2017 - 2021
MK55	Unnamed Tributary to Little Cedar Creek: 0 to 0.7 miles	23600	3	0.7	1	2021	21	2020 - 2022
MK56	Polk Springs Creek: 0 to 3.4 miles	23800	2	3.4	--	--	30	2001 - 2019
MK57	Jackson Creek: 0 to 1.3 miles	23900	2	1.3	--	--	21	2017 - 2019
MK58	Lehner Creek: 0 to 2.3 miles	24400	1	2.2	--	--	41	2017 - 2020
MK59	Unnamed Tributary to Gilbert Lake: 0 to 0.6 miles	25500	1	0.6	1	2012	4	2012 - 2013
MK60	Mole Creek: 0 to 7.9 miles	26300	2	7.9	202	1991 - 2022	78	2001 - 2022
MK61	Hawthorne Drive Creek: 0 to 0.7 miles	26500	2	0.7	--	--	1	2020
MK62	Fredonia Creek: 0 to 4.0 miles	26600	2	4.0	--	--	14	2018 - 2020
MK63	Sandhill Creek: 0 to 3.1 miles	26800	1	3.1	--	--	6	2022 - 2022
MK64	North Branch Milwaukee River: 0 to 4.7 miles	27100	4	4.7	110	1964 - 2007	99	1964 - 2020
MK65	North Branch Milwaukee River: 5.0 to 7.1 miles	27100	4	2.2	25	2018 - 2020	27	2008 - 2020
MK66	North Branch Milwaukee River: 10.2 to 12.2 miles	27100	4	1.9	53	1993 - 2001	1	2020
MK67	North Branch Milwaukee River: 14.3 to 18.1 miles	27100	4	3.8	5	1993 - 2007	1	2020
MK68	North Branch Milwaukee River: 18.1 to 21.5 miles	27100	3	3.4	7	1993 - 2007	--	--
MK69	North Branch Milwaukee River: 23.3 to 27.8 miles	27100	2	4.5	7	1993 - 2022	20	2017 - 2022
MK70	Wallace Creek: 0 to 5.5 miles	27600	3	5.5	--	--	8	2001 - 2020
MK71	Stony Creek: 0 to 10.3 miles	28700	2	10.3	27	2004 - 2020	49	2002 - 2021
MK72	Silver Creek: 0 to 2.0 miles	29900	3	2.0	--	--	8	2019 - 2020
MK73	Mink Creek: 0 to 14.5 miles	30600	2	14.5	--	--	19	2016 - 2020
MK74	Batavia Creek: 0 to 3.9 miles	31400	2	3.9	2	1993 - 1994	21	2015 - 2020
MK75	Gooseville Creek: 0 to 0.9 miles	32000	2	0.9	2	1993 - 1994	--	--
MK76	Melius Creek: 0 to 1.1 miles	32100	3	1.1	2	1993 - 1994	17	2016 - 2018
MK77	Chambers Creek: 0 to 2.9 miles	32200	2	2.9	2	1993 - 1994	--	--

Table 4.35 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
MK78	Unnamed Tributary to North Branch Milwaukee River: 0.1 to 3.7 miles	33000	3	3.6	9	1993 - 2007	--	--
MK79	Riveredge Nature Center Creek: 0 to 1.1 miles	34000	2	1.2	--	--	12	2017 - 2020
MK80	Myra Creek: 0 to 3.7 miles	34400	1	3.7	--	--	1	2012
MK81	Unnamed Tributary to Milwaukee River: 0 to 0.6 miles	34800	2	0.6	--	--	5	2019
MK82	Quas Creek: 0 to 4.3 miles	34900	2	4.3	--	--	19	2019 - 2022
MK83	Silver Creek: 0 to 2.4 miles	35500	2	2.4	--	--	23	2018 - 2022
MK84	Engmon Creek: 0 to 1.1 miles	35700	1	1.1	2	2019 - 2019	19	2018 - 2021
MK85	East Branch Milwaukee River: 0 to 11.0 miles	36900	4	11.0	112	1976 - 2020	75	1976 - 2020
MK86	East Branch Milwaukee River: 11.8 to 17.4 miles	36900	4	5.6	--	--	1	2020
MK87	East Branch Milwaukee River (channelized west): 18.1 to 18.4 miles	36900	3	0.3	--	--	6	2022
MK88	East Branch Milwaukee River (natural meander east): 18.1 to 18.4 miles	36900	3	0.3	--	--	6	2022
MK89	Crooked Lake Creek (Tributary to East Branch Milwaukee River): 0 to 4.8 miles	37300	2	4.8	--	--	3	2008 - 2020
MK90	Parnell Creek: 0 to 2.7 miles	38300	3	2.7	27	1996 - 2007	1	1996
MK91	Watercress Creek (Long Lake Tributary): 0 to 4.7 miles	39000	2	4.7	5	1995 - 2022	11	2019 - 2022
MK92	Kewaskum Creek: 0 to 0.9 miles	39800	3	0.9	--	--	10	2018 - 2020
MK93	Unnamed Tributary 1 to Kewaskum Creek: 0 to 1.0 miles	39900	1	1.0	106	1976 - 1978	--	--
MK94	Unnamed Tributary 2 to Kewaskum Creek: 1.6 to 2.0 miles	40000	1	0.4	69	1976 - 1978	--	--
MK95	Unnamed Tributary to Milwaukee River: 0 to 0.4 miles	40100	2	0.4	--	--	7	2022
MK96	West Branch Milwaukee River: 0 to 2.4 miles	40400	3	2.4	73	1994 - 2015	--	--
MK97	West Branch Milwaukee River: 3.9 to 6.7 miles	40400	3	2.8	--	--	1	2020
MK98	West Branch Milwaukee River: 8.2 to 11.4 miles	40400	3	3.2	--	--	1	2020
MK99	West Branch Milwaukee River: 16.6 to 17.7 miles	40400	3	1.2	303	2011 - 2015	--	--
MK100	West Branch Milwaukee River: 20.4 to 21.3 miles	40400	1	0.9	264	2011 - 2015	--	--
MK101	Stoffel Creek: 1.6 to 7.0 miles	40500	1	5.4	1	2019 - 2019	2	2019 - 2020
MK102	Unnamed Tributary to West Branch Milwaukee River: 0 to 1.3 miles	40600	2	1.3	--	--	5	2022
MK103	Auburn Lake Creek: 0 to 1.4 miles	41600	3	1.4	--	--	1	2020
MK104	Unnamed Tributary to Milwaukee River: 0 to 4.4 miles	43500	3	4.4	--	--	2	2009 - 2020
MK105	Unnamed Tributary to Milwaukee River: 0 to 2.7 miles	44000	2	2.7	--	--	1	2007
MK106	Unnamed Tributary to Milwaukee River: 1.5 to 3.4 miles	44200	2	1.9	--	--	5	2007 - 2014
MK107	Southbranch Creek: 0 to 2.4 miles	3000073	1	2.4	339	2006 - 2022	347	2006 - 2022
MK108	Unnamed Tributary to Stoffel Creek: 0 to 0.9 miles	5030146	2	0.9	--	--	6	2008 - 2017
MK109	Unnamed Tributary 3 to Kewaskum Creek: 0 to 0.6 miles	5030831	1	0.6	12	1976 - 1977	--	--
MK110	Riverside Drive Creek: 0 to 3.6 miles	5030968	2	3.6	--	--	45	2017 - 2022
MK111	Helm's Creek Tributary to Ulao Creek: 0 to 0.2 miles	5032380	2	0.2	11	2020 - 2021	11	2020 - 2021
MK112	Kaul Creek: 0 to 1.0 miles	5032520	1	1.0	53	2016 - 2021	--	--
MK113	Gateway Drive Tributary to Ulao Creek: 0 to 0.6 miles	5032660	1	0.6	12	2020 - 2021	12	2020 - 2021

Table 4.35 (Continued)

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
MK114	Unnamed Tributary to Pigeon Creek: 0 to 0.7 miles	5032995	3	0.7	7	2011 - 2013	41	2011 - 2018
MK115	Vila Grove Park Creek: 0 to 1.3 miles	5033448	2	1.4	--	--	2	2017

Note: Chloride and specific conductance datasets shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.36
Percent of Measured Chloride and Specific Conductance Samples by Season at Assessment Reaches within the Milwaukee River Watershed: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
MK01	Milwaukee River: 0 to 0.8 miles	2,270	10.5	30.4	32.8	26.3	1,766	10.3	27.3	34.9	27.5
MK02	Milwaukee River: 0.8 to 7.7 miles	3,053	11.9	26.5	33.6	28.0	2,941	12.1	27.2	33.4	27.4
MK03	Milwaukee River: 7.7 to 12.8 miles	351	13.7	27.1	31.9	27.4	370	12.7	26.2	33.8	27.3
MK04	Milwaukee River: 15.1 to 19.4 miles	574	13.9	26.7	34.0	25.4	535	7.5	20.7	45.4	26.4
MK05	Milwaukee River: 19.6 to 20.7 miles	--	--	--	--	--	5	0.0	20.0	60.0	20.0
MK06	Milwaukee River: 24.1 to 27.5 miles	518	9.7	26.6	36.3	27.4	500	10.8	24.2	36.0	29.0
MK07	Milwaukee River: 27.5 to 29.8 miles	20	0.0	40.0	60.0	0.0	32	9.4	25.0	34.4	31.3
MK08	Milwaukee River: 29.8 to 32.3 miles	29	3.4	13.8	75.9	6.9	63	1.6	15.9	63.5	19.0
MK09	Milwaukee River: 32.3 to 35.8 miles	--	--	--	--	--	35	0.0	28.6	31.4	40.0
MK10	Milwaukee River: 35.8 to 43.7 miles	70	21.4	15.7	47.1	15.7	117	23.9	17.1	39.3	19.7
MK11	Milwaukee River: 43.7 to 47.8 miles	73	2.7	12.3	16.4	68.5	111	18.0	22.5	22.5	36.9
MK12	Milwaukee River: 47.8 to 53.2 miles	31	29.0	25.8	19.4	25.8	33	27.3	21.2	21.2	30.3
MK13	Milwaukee River: 57.3 to 63.9 miles	106	1.9	11.3	34.0	52.8	77	13.0	20.8	36.4	29.9
MK14	Milwaukee River: 64.1 to 67.4 miles	--	--	--	--	--	22	63.6	22.7	0.0	13.6
MK15	Milwaukee River: 67.4 to 68.4 miles	--	--	--	--	--	9	88.9	11.1	0.0	0.0
MK16	Milwaukee River: 69.9 to 74.7 miles	29	3.4	13.8	75.9	6.9	38	2.6	15.8	76.3	5.3
MK17	Milwaukee River: 77.3 to 78.6 miles	86	1.2	10.5	22.1	66.3	77	19.5	24.7	14.3	41.6
MK18	Milwaukee River: 79.9 to 83.4 miles	39	12.8	15.4	61.5	10.3	48	10.4	12.5	66.7	10.4
MK19	Milwaukee River: 87.4 to 87.8 miles	1	0.0	0.0	0.0	100	15	80.0	20.0	0.0	0.0
MK20	Milwaukee River: 91.8 to 95.8 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
MK21	Lincoln Creek: 0 to 5.0 miles	653	11.0	26.3	35.2	27.4	435	9.0	27.6	33.1	30.3
MK22	Lincoln Creek: 5.0 to 10.0 miles	335	2.7	29.6	37.3	30.4	328	2.4	29.0	37.5	31.1
MK23	Crestwood Creek: 0 to 1.3 miles	6	83.3	16.7	0.0	0.0	19	31.6	15.8	26.3	26.3
MK24	Indian Creek: 0 to 2.7 miles	250	3.2	29.2	34.0	33.6	288	6.3	28.8	33.7	31.3
MK25	Brown Deer Park Creek: 0 to 2.2 miles	14	100	0.0	0.0	0.0	29	55.2	6.9	20.7	17.2
MK26	Beaver Creek: 0 to 3.3 miles	9	88.9	11.1	0.0	0.0	27	44.4	14.8	25.9	14.8

Table 4.36 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
MK27	Lac du Cours Creek: 0 to 0.3 miles	--	--	--	--	--	34	55.9	14.7	17.6	11.8
MK28	Trinity Creek: 0 to 3.3 miles	--	--	--	--	--	53	56.6	13.2	17.0	13.2
MK29	Pigeon Creek: 0 to 2.4 miles	2	0.0	0.0	100	0.0	125	37.6	16.0	24.8	21.6
MK30	Mee-Kwon Creek: 0 to 1.4 miles	--	--	--	--	--	18	0.0	11.1	50.0	38.9
MK31	Unnamed Tributary to Milwaukee River: 0 to 0.3 miles	--	--	--	--	--	3	100	0.0	0.0	0.0
MK32	Ulao Creek: 0 to 0.7 miles	28	0.0	10.7	35.7	53.6	46	8.7	19.6	39.1	32.6
MK33	Ulao Creek: 1.8 to 5.3 miles	148	12.8	18.9	27.7	40.5	129	22.5	31.0	22.5	24.0
MK34	Ulao Creek: 5.3 to 6.2 miles	65	6.2	13.8	32.3	47.7	11	36.4	27.3	27.3	9.1
MK35	Ulao Creek: 6.6 to 9.2 miles	26	0.0	11.5	30.8	57.7	--	--	--	--	--
MK36	Cedar Creek: 1.1 to 1.8 miles	196	1.0	46.4	26.0	26.5	86	4.7	46.5	36.0	12.8
MK37	Cedar Creek: 1.8 to 14.1 miles	656	6.6	26.8	35.4	31.3	596	13.6	27.0	31.9	27.5
MK38	Cedar Creek: 16.0 to 18.3 miles	35	2.9	17.1	65.7	14.3	91	1.1	23.1	47.3	28.6
MK39	Cedar Creek: 19.1 to 19.6 miles	1	0.0	0.0	0.0	100	--	--	--	--	--
MK40	Cedar Creek: 20.7 to 21.2 miles	28	25.0	21.4	21.4	32.1	27	25.9	22.2	25.9	25.9
MK41	Cedar Creek: 21.2 to 22.5 miles	1	0.0	0.0	0.0	100	6	100	0.0	0.0	0.0
MK42	Cedar Creek: 23.0 to 23.3 miles	--	--	--	--	--	4	100	0.0	0.0	0.0
MK43	Cedar Creek: 23.6 to 25.7 miles	--	--	--	--	--	42	21.4	26.2	19.0	33.3
MK44	Cedar Creek: 25.7 to 29.7 miles	2	0.0	100	0.0	0.0	7	0.0	0.0	42.9	57.1
MK45	Cedar Creek: 31.3 to 37.8 miles	--	--	--	--	--	22	0.0	27.3	27.3	45.5
MK46	Mud Creek: 0 to 3.5 miles	--	--	--	--	--	23	0.0	26.1	26.1	47.8
MK47	North Branch Cedar Creek: 0 to 2.0 miles	4	0.0	0.0	50.0	50.0	67	0.0	14.9	43.3	41.8
MK48	Cedarburg Creek: 0 to 6.4 miles	--	--	--	--	--	46	28.3	26.1	21.7	23.9
MK49	Evergreen Creek: 0 to 3.3 miles	--	--	--	--	--	36	25.0	25.0	22.2	27.8
MK50	Friedens Creek: 0 to 3.5 miles	1	100	0.0	0.0	0.0	28	71.4	10.7	7.1	10.7
MK51	Little Cedar Creek: 0.2 to 1.7 miles	--	--	--	--	--	36	8.3	30.6	22.2	38.9
MK52	Little Cedar Creek: 1.7 to 3.9 miles	1	100	0.0	0.0	0.0	64	56.3	20.3	9.4	14.1
MK53	Little Cedar Creek: 3.9 to 7.8 miles	--	--	--	--	--	6	100	0.0	0.0	0.0
MK54	Kressin Branch: 0 to 5.1 miles	--	--	--	--	--	24	8.3	29.2	25.0	37.5
MK55	Unnamed Tributary to Little Cedar Creek: 0 to 0.7 miles	1	100	0.0	0.0	0.0	21	85.7	14.3	0.0	0.0
MK56	Polk Springs Creek: 0 to 3.4 miles	--	--	--	--	--	30	0.0	23.3	30.0	46.7
MK57	Jackson Creek: 0 to 1.3 miles	--	--	--	--	--	21	0.0	28.6	28.6	42.9
MK58	Lehner Creek: 0 to 2.3 miles	--	--	--	--	--	41	22.0	22.0	26.8	29.3
MK59	Unnamed Tributary to Gilbert Lake: 0 to 0.6 miles	1	0.0	100	0.0	0.0	4	0.0	50.0	25.0	25.0
MK60	Mole Creek: 0 to 7.9 miles	202	1.5	13.4	33.2	52.0	78	20.5	23.1	30.8	25.6

Table 4.36 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
MK61	Hawthorne Drive Creek: 0 to 0.7 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
MK62	Fredonia Creek: 0 to 4.0 miles	--	--	--	--	--	14	50.0	7.1	28.6	14.3
MK63	Sandhill Creek: 0 to 3.1 miles	--	--	--	--	--	6	83.3	16.7	0.0	0.0
MK64	North Branch Milwaukee River: 0 to 4.7 miles	110	0.9	11.8	36.4	50.9	99	7.1	20.2	40.4	32.3
MK65	North Branch Milwaukee River: 5.0 to 7.1 miles	25	24.0	24.0	24.0	28.0	27	22.2	22.2	25.9	29.6
MK66	North Branch Milwaukee River: 10.2 to 12.2 miles	53	5.7	32.1	43.4	18.9	1	0.0	0.0	0.0	100
MK67	North Branch Milwaukee River: 14.3 to 18.1 miles	5	0.0	0.0	100	0.0	1	0.0	0.0	0.0	100
MK68	North Branch Milwaukee River: 18.1 to 21.5 miles	7	0.0	0.0	100	0.0	--	--	--	--	--
MK69	North Branch Milwaukee River: 23.3 to 27.8 miles	7	0.0	14.3	57.1	28.6	20	5.0	5.0	55.0	35.0
MK70	Wallace Creek: 0 to 5.5 miles	--	--	--	--	--	8	0.0	12.5	50.0	37.5
MK71	Stony Creek: 0 to 10.3 miles	27	22.2	22.2	25.9	29.6	49	14.3	20.4	34.7	30.6
MK72	Silver Creek: 0 to 2.0 miles	--	--	--	--	--	8	75.0	12.5	0.0	12.5
MK73	Mink Creek: 0 to 14.5 miles	--	--	--	--	--	19	5.3	10.5	47.4	36.8
MK74	Batavia Creek: 0 to 3.9 miles	2	0.0	0.0	100	0.0	21	9.5	4.8	57.1	28.6
MK75	Gooseville Creek: 0 to 0.9 miles	2	0.0	0.0	100	0.0	--	--	--	--	--
MK76	Melius Creek: 0 to 1.1 miles	2	0.0	0.0	100	0.0	17	5.9	11.8	47.1	35.3
MK77	Chambers Creek: 0 to 2.9 miles	2	0.0	0.0	100	0.0	--	--	--	--	--
MK78	Unnamed Tributary to North Branch Milwaukee River: 0.1 to 3.7 miles	9	0.0	0.0	100	0.0	--	--	--	--	--
MK79	Riveredge Nature Center Creek: 0 to 1.1 miles	--	--	--	--	--	12	66.7	0.0	33.3	0.0
MK80	Myra Creek: 0 to 3.7 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
MK81	Unnamed Tributary to Milwaukee River: 0 to 0.6 miles	--	--	--	--	--	5	80.0	20.0	0.0	0.0
MK82	Quas Creek: 0 to 4.3 miles	--	--	--	--	--	19	78.9	15.8	0.0	5.3
MK83	Silver Creek: 0 to 2.4 miles	--	--	--	--	--	23	65.2	21.7	13.0	0.0
MK84	Engmon Creek: 0 to 1.1 miles	2	100	0.0	0.0	0.0	19	68.4	5.3	15.8	10.5
MK85	East Branch Milwaukee River: 0 to 11.0 miles	112	5.4	14.3	17.9	62.5	75	8.0	26.7	20.0	45.3
MK86	East Branch Milwaukee River: 11.8 to 17.4 miles	--	--	--	--	--	1	0.0	0.0	0.0	100

Table 4.36 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
MK87	East Branch Milwaukee River (channelized west): 18.1 to 18.4 miles	--	--	--	--	--	6	100	0.0	0.0	0.0
MK88	East Branch Milwaukee River (natural meander east): 18.1 to 18.4 miles	--	--	--	--	--	6	100	0.0	0.0	0.0
MK89	Crooked Lake Creek (Tributary to East Branch Milwaukee River): 0 to 4.8 miles	--	--	--	--	--	3	0.0	0.0	66.7	33.3
MK90	Parnell Creek: 0 to 2.7 miles	27	11.1	48.1	22.2	18.5	1	0.0	0.0	0.0	100
MK91	Watercress Creek (Long Lake Tributary): 0 to 4.7 miles	5	0.0	20.0	40.0	40.0	11	0.0	9.1	45.5	45.5
MK92	Kewaskum Creek: 0 to 0.9 miles	--	--	--	--	--	10	70.0	30.0	0.0	0.0
MK93	Unnamed Tributary 1 to Kewaskum Creek: 0 to 1.0 miles	106	3.8	67.9	16.0	12.3	--	--	--	--	--
MK94	Unnamed Tributary 2 to Kewaskum Creek: 1.6 to 2.0 miles	69	1.4	30.4	55.1	13.0	--	--	--	--	--
MK95	Unnamed Tributary to Milwaukee River: 0 to 0.4 miles	--	--	--	--	--	7	100	0.0	0.0	0.0
MK96	West Branch Milwaukee River: 0 to 2.4 miles	73	23.3	26.0	24.7	26.0	--	--	--	--	--
MK97	West Branch Milwaukee River: 3.9 to 6.7 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
MK98	West Branch Milwaukee River: 8.2 to 11.4 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
MK99	West Branch Milwaukee River: 16.6 to 17.7 miles	303	10.2	53.5	18.8	17.5	--	--	--	--	--
MK100	West Branch Milwaukee River: 20.4 to 21.3 miles	264	9.8	64.0	17.8	8.3	--	--	--	--	--
MK101	Stoffel Creek: 1.6 to 7.0 miles	1	0.0	0.0	100	0.0	2	0.0	0.0	50.0	50.0
MK102	Unnamed Tributary to West Branch Milwaukee River: 0 to 1.3 miles	--	--	--	--	--	5	100	0.0	0.0	0.0
MK103	Auburn Lake Creek: 0 to 1.4 miles	--	--	--	--	--	1	0.0	0.0	0.0	100
MK104	Unnamed Tributary to Milwaukee River: 0 to 4.4 miles	--	--	--	--	--	2	0.0	0.0	50.0	50.0
MK105	Unnamed Tributary to Milwaukee River: 0 to 2.7 miles	--	--	--	--	--	1	0.0	0.0	100	0.0
MK106	Unnamed Tributary to Milwaukee River: 1.5 to 3.4 miles	--	--	--	--	--	5	0.0	0.0	60.0	40.0

Table 4.36 (Continued)

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
MK107	Southbranch Creek: 0 to 2.4 miles	339	2.9	23.3	51.0	22.7	347	2.9	23.1	51.3	22.8
MK108	Unnamed Tributary to Stoffel Creek: 0 to 0.9 miles	--	--	--	--	--	6	0.0	0.0	100	0.0
MK109	Unnamed Tributary 3 to Kewaskum Creek: 0 to 0.6 miles	12	0.0	50.0	50.0	0.0	--	--	--	--	--
MK110	Riverside Drive Creek: 0 to 3.6 miles	--	--	--	--	--	45	44.4	20.0	13.3	22.2
MK111	Helm's Creek Tributary to Ulao Creek: 0 to 0.2 miles	11	36.4	27.3	27.3	9.1	11	36.4	27.3	27.3	9.1
MK112	Kaul Creek: 0 to 1.0 miles	53	0.0	9.4	34.0	56.6	--	--	--	--	--
MK113	Gateway Drive Tributary to Ulao Creek: 0 to 0.6 miles	12	41.7	25.0	25.0	8.3	12	41.7	25.0	25.0	8.3
MK114	Unnamed Tributary to Pigeon Creek: 0 to 0.7 miles	7	42.9	28.6	14.3	14.3	41	17.1	31.7	24.4	26.8
MK115	Vila Grove Park Creek: 0 to 1.3 miles	--	--	--	--	--	2	50.0	50.0	0.0	0.0

Note: Seasons are defined as Winter (December through February), Spring (March through May), Summer (June through August), and Fall (September through November). Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps during the period of 1961 through 2022. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance. Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC.

Table 4.37
Summary Statistics for Measured Chloride and Specific Conductance at Assessment Reaches within the Milwaukee River Watershed: 1961-2022

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	Assessment Reach	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK01	Milwaukee River: 0 to 0.8 miles	2,270	4	84	76	810	1,766	160	711	701	3,050
MK02	Milwaukee River: 0.8 to 7.7 miles	3,053	0	76	73	590	2,941	69	757	755	7,710
MK03	Milwaukee River: 7.7 to 12.8 miles	351	25	83	80	260	370	366	792	807	1,400
MK04	Milwaukee River: 15.1 to 19.4 miles	574	0	63	61	310	535	340	710	720	1,520
MK05	Milwaukee River: 19.6 to 20.7 miles	- -	- -	- -	- -	- -	5	750	800	800	870
MK06	Milwaukee River: 24.1 to 27.5 miles	518	15	67	62	190	500	277	748	754	1,130
MK07	Milwaukee River: 27.5 to 29.8 miles	20	41	65	47	101	32	540	802	794	1,333
MK08	Milwaukee River: 29.8 to 32.3 miles	29	5	33	35	44	63	82	694	670	940
MK09	Milwaukee River: 32.3 to 35.8 miles	- -	- -	- -	- -	- -	35	407	722	747	920
MK10	Milwaukee River: 35.8 to 43.7 miles	70	5	66	39	535	117	360	792	697	2,600
MK11	Milwaukee River: 43.7 to 47.8 miles	73	26	54	55	178	111	240	698	700	1,263
MK12	Milwaukee River: 47.8 to 53.2 miles	31	27	82	55	308	33	494	775	696	1,581
MK13	Milwaukee River: 57.3 to 63.9 miles	106	11	60	59	149	77	300	734	725	1,215
MK14	Milwaukee River: 64.1 to 67.4 miles	- -	- -	- -	- -	- -	22	541	868	888	1,540
MK15	Milwaukee River: 67.4 to 68.4 miles	- -	- -	- -	- -	- -	9	845	1,319	1,130	2,020
MK16	Milwaukee River: 69.9 to 74.7 miles	29	5	27	27	50	38	425	599	617	696
MK17	Milwaukee River: 77.3 to 78.6 miles	86	24	43	40	129	77	420	720	720	1,072
MK18	Milwaukee River: 79.9 to 83.4 miles	39	5	47	45	131	48	436	695	696	896
MK19	Milwaukee River: 87.4 to 87.8 miles	1	59	59	59	59	15	590	798	830	895
MK20	Milwaukee River: 91.8 to 95.8 miles	- -	- -	- -	- -	- -	1	762	762	762	762
MK21	Lincoln Creek: 0 to 5.0 miles	653	5	356	210	4,770	435	113	1,624	1,271	15,400
MK22	Lincoln Creek: 5.0 to 10.0 miles	335	12	195	150	2,100	328	169	1,020	838	6,847
MK23	Crestwood Creek: 0 to 1.3 miles	6	594	765	677	1,130	19	590	1,814	1,560	4,200
MK24	Indian Creek: 0 to 2.7 miles	250	19	260	205	3,340	288	241	1,464	1,185	10,800
MK25	Brown Deer Park Creek: 0 to 2.2 miles	14	402	741	611	1,290	29	340	2,132	2,200	4,600
MK26	Beaver Creek: 0 to 3.3 miles	9	495	649	644	794	27	540	1,819	1,570	3,700
MK27	Lac du Cours Creek: 0 to 0.3 miles	- -	- -	- -	- -	- -	34	410	697	675	1,010
MK28	Trinity Creek: 0 to 3.3 miles	- -	- -	- -	- -	- -	53	380	1,107	1,080	1,860
MK29	Pigeon Creek: 0 to 2.4 miles	2	53	57	57	61	125	620	879	880	1,140
MK30	Mee-Kwon Creek: 0 to 1.4 miles	- -	- -	- -	- -	- -	18	710	868	885	1,000
MK31	Unnamed Tributary to Milwaukee River: 0 to 0.3 miles	- -	- -	- -	- -	- -	3	770	937	950	1,090

Table 4.37 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (μS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK32	Ulao Creek: 0 to 0.7 miles	28	44	166	151	309	46	527	1,108	1,060	1,735
MK33	Ulao Creek: 1.8 to 5.3 miles	148	24	268	140	3,030	129	250	1,775	1,070	11,700
MK34	Ulao Creek: 5.3 to 6.2 miles	65	23	58	56	254	11	451	613	597	728
MK35	Ulao Creek: 6.6 to 9.2 miles	26	35	75	77	99	- -	- -	- -	- -	- -
MK36	Cedar Creek: 1.1 to 1.8 miles	196	28	52	48	84	86	462	705	684	934
MK37	Cedar Creek: 1.8 to 14.1 miles	656	12	51	52	160	596	54	707	700	1,550
MK38	Cedar Creek: 16.0 to 18.3 miles	35	1	36	26	324	91	275	712	719	1,550
MK39	Cedar Creek: 19.1 to 19.6 miles	1	64	64	64	64	- -	- -	- -	- -	- -
MK40	Cedar Creek: 20.7 to 21.2 miles	28	56	86	81	213	27	102	799	788	1,487
MK41	Cedar Creek: 21.2 to 22.5 miles	1	55	55	55	55	6	800	1,058	970	1,630
MK42	Cedar Creek: 23.0 to 23.3 miles	- -	- -	- -	- -	- -	4	760	895	920	980
MK43	Cedar Creek: 23.6 to 25.7 miles	- -	- -	- -	- -	- -	42	373	679	689	871
MK44	Cedar Creek: 25.7 to 29.7 miles	2	35	36	36	37	7	540	589	580	650
MK45	Cedar Creek: 31.3 to 37.8 miles	- -	- -	- -	- -	- -	22	408	539	553	585
MK46	Mud Creek: 0 to 3.5 miles	- -	- -	- -	- -	- -	23	259	346	317	776
MK47	North Branch Cedar Creek: 0 to 2.0 miles	4	38	43	43	46	67	516	759	747	1,178
MK48	Cedarburg Creek: 0 to 6.4 miles	- -	- -	- -	- -	- -	46	560	833	825	1,081
MK49	Evergreen Creek: 0 to 3.3 miles	- -	- -	- -	- -	- -	36	360	1,267	778	10,000
MK50	Friedens Creek: 0 to 3.5 miles	1	448	448	448	448	28	647	1,029	921	2,200
MK51	Little Cedar Creek: 0.2 to 1.7 miles	- -	- -	- -	- -	- -	36	217	792	841	1,270
MK52	Little Cedar Creek: 1.7 to 3.9 miles	1	985	985	985	985	64	629	1,122	1,013	4,160
MK53	Little Cedar Creek: 3.9 to 7.8 miles	- -	- -	- -	- -	- -	6	813	914	899	1,032
MK54	Kressin Branch: 0 to 5.1 miles	- -	- -	- -	- -	- -	24	472	757	759	955
MK55	Unnamed Tributary to Little Cedar Creek: 0 to 0.7 miles	1	869	869	869	869	21	1,010	1,514	1,324	3,600
MK56	Polk Springs Creek: 0 to 3.4 miles	- -	- -	- -	- -	- -	30	714	817	822	896
MK57	Jackson Creek: 0 to 1.3 miles	- -	- -	- -	- -	- -	21	211	831	846	1,116
MK58	Lehner Creek: 0 to 2.3 miles	- -	- -	- -	- -	- -	41	560	886	890	1,030
MK59	Unnamed Tributary to Gilbert Lake: 0 to 0.6 miles	1	70	70	70	70	4	625	788	813	900
MK60	Mole Creek: 0 to 7.9 miles	202	25	46	46	94	78	314	801	815	1,081
MK61	Hawthorne Drive Creek: 0 to 0.7 miles	- -	- -	- -	- -	- -	1	1,116	1,116	1,116	1,116
MK62	Fredonia Creek: 0 to 4.0 miles	- -	- -	- -	- -	- -	14	640	901	890	1,160
MK63	Sandhill Creek: 0 to 3.1 miles	- -	- -	- -	- -	- -	6	830	1,327	1,430	1,640
MK64	North Branch Milwaukee River: 0 to 4.7 miles	110	5	32	35	67	99	518	659	650	1,238
MK65	North Branch Milwaukee River: 5.0 to 7.1 miles	25	21	34	35	46	27	489	699	688	1,278
MK66	North Branch Milwaukee River: 10.2 to 12.2 miles	53	13	29	31	41	1	834	834	834	834

Table 4.37 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK67	North Branch Milwaukee River: 14.3 to 18.1 miles	5	30	37	36	50	1	1,243	1,243	1,243	1,243
MK68	North Branch Milwaukee River: 18.1 to 21.5 miles	7	40	48	47	57	- -	- -	- -	- -	- -
MK69	North Branch Milwaukee River: 23.3 to 27.8 miles	7	27	29	28	32	20	500	785	770	1,223
MK70	Wallace Creek: 0 to 5.5 miles	- -	- -	- -	- -	- -	8	525	724	655	1,239
MK71	Stony Creek: 0 to 10.3 miles	27	19	32	32	46	49	461	692	662	1,270
MK72	Silver Creek: 0 to 2.0 miles	- -	- -	- -	- -	- -	8	330	852	890	1,120
MK73	Mink Creek: 0 to 14.5 miles	- -	- -	- -	- -	- -	19	630	737	740	820
MK74	Batavia Creek: 0 to 3.9 miles	2	36	36	36	36	21	530	722	740	820
MK75	Gooseville Creek: 0 to 0.9 miles	2	24	24	24	24	- -	- -	- -	- -	- -
MK76	Melius Creek: 0 to 1.1 miles	2	19	19	19	19	17	620	750	770	880
MK77	Chambers Creek: 0 to 2.9 miles	2	21	22	22	22	- -	- -	- -	- -	- -
MK78	Unnamed Tributary to North Branch Milwaukee River: 0.1 to 3.7 miles	9	48	82	76	143	- -	- -	- -	- -	- -
MK79	Riveredge Nature Center Creek: 0 to 1.1 miles	- -	- -	- -	- -	- -	12	610	703	690	830
MK80	Myra Creek: 0 to 3.7 miles	- -	- -	- -	- -	- -	1	575	575	575	575
MK81	Unnamed Tributary to Milwaukee River: 0 to 0.6 miles	- -	- -	- -	- -	- -	5	190	966	960	1,440
MK82	Quas Creek: 0 to 4.3 miles	- -	- -	- -	- -	- -	19	990	1,184	1,170	1,748
MK83	Silver Creek: 0 to 2.4 miles	- -	- -	- -	- -	- -	23	600	1,072	980	1,850
MK84	Engmon Creek: 0 to 1.1 miles	2	272	582	582	892	19	983	1,491	1,160	4,300
MK85	East Branch Milwaukee River: 0 to 11.0 miles	112	8	17	19	25	75	378	506	503	646
MK86	East Branch Milwaukee River: 11.8 to 17.4 miles	- -	- -	- -	- -	- -	1	621	621	621	621
MK87	East Branch Milwaukee River (channelized west): 18.1 to 18.4 miles	- -	- -	- -	- -	- -	6	585	625	624	671
MK88	East Branch Milwaukee River (natural meander east): 18.1 to 18.4 miles	- -	- -	- -	- -	- -	6	572	619	621	656
MK89	Crooked Lake Creek (Tributary to East Branch Milwaukee River): 0 to 4.8 miles	- -	- -	- -	- -	- -	3	508	572	583	625
MK90	Parnell Creek: 0 to 2.7 miles	27	4	12	10	23	1	641	641	641	641
MK91	Watercress Creek (Long Lake Tributary): 0 to 4.7 miles	5	23	36	40	44	11	604	740	709	1,105
MK92	Kewaskum Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	10	760	921	919	1,200
MK93	Unnamed Tributary 1 to Kewaskum Creek: 0 to 1.0 miles	106	1	26	16	190	- -	- -	- -	- -	- -

Table 4.37 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (μS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK94	Unnamed Tributary 2 to Kewaskum Creek: 1.6 to 2.0 miles	69	1	19	20	38	- -	- -	- -	- -	- -
MK95	Unnamed Tributary to Milwaukee River: 0 to 0.4 miles	- -	- -	- -	- -	- -	7	877	1,213	1,227	1,435
MK96	West Branch Milwaukee River: 0 to 2.4 miles	73	18	42	43	55	- -	- -	- -	- -	- -
MK97	West Branch Milwaukee River: 3.9 to 6.7 miles	- -	- -	- -	- -	- -	1	788	788	788	788
MK98	West Branch Milwaukee River: 8.2 to 11.4 miles	- -	- -	- -	- -	- -	1	826	826	826	826
MK99	West Branch Milwaukee River: 16.6 to 17.7 miles	303	18	46	46	127	- -	- -	- -	- -	- -
MK100	West Branch Milwaukee River: 20.4 to 21.3 miles	264	3	22	22	54	- -	- -	- -	- -	- -
MK101	Stoffel Creek: 1.6 to 7.0 miles	1	30	30	30	30	2	741	895	895	1,049
MK102	Unnamed Tributary to West Branch Milwaukee River: 0 to 1.3 miles	- -	- -	- -	- -	- -	5	1,030	1,080	1,100	1,110
MK103	Auburn Lake Creek: 0 to 1.4 miles	- -	- -	- -	- -	- -	1	564	564	564	564
MK104	Unnamed Tributary to Milwaukee River: 0 to 4.4 miles	- -	- -	- -	- -	- -	2	489	542	542	595
MK105	Unnamed Tributary to Milwaukee River: 0 to 2.7 miles	- -	- -	- -	- -	- -	1	820	820	820	820
MK106	Unnamed Tributary to Milwaukee River: 1.5 to 3.4 miles	- -	- -	- -	- -	- -	5	547	802	787	975
MK107	Southbranch Creek: 0 to 2.4 miles	339	26	210	170	1,200	347	245	1,063	943	4,270
MK108	Unnamed Tributary to Stoffel Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	6	680	768	784	810
MK109	Unnamed Tributary 3 to Kewaskum Creek: 0 to 0.6 miles	12	1	9	4	50	- -	- -	- -	- -	- -
MK110	Riverside Drive Creek: 0 to 3.6 miles	- -	- -	- -	- -	- -	45	350	955	930	1,948
MK111	Helm's Creek Tributary to Ulao Creek: 0 to 0.2 miles	11	138	321	243	1,180	11	874	1,579	1,351	4,267
MK112	Kaul Creek: 0 to 1.0 miles	53	10	43	41	92	- -	- -	- -	- -	- -
MK113	Gateway Drive Tributary to Ulao Creek: 0 to 0.6 miles	12	99	1,152	546	6,630	12	541	3,894	2,038	20,645
MK114	Unnamed Tributary to Pigeon Creek: 0 to 0.7 miles	7	61	92	91	144	41	600	819	820	1,060
MK115	Vila Grove Park Creek: 0 to 1.3 miles	- -	- -	- -	- -	- -	2	720	765	765	810

Table 4.37 (Continued)

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.38
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Milwaukee River Watershed Full Record: 1961-2022

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MK01	Milwaukee River: 0 to 0.8 miles	2,270	99.9	90.3	11.2	2.1	0.4	0	0.0
MK02	Milwaukee River: 0.8 to 7.7 miles	3,053	99.9	91.6	6.1	0.8	0.1	0.0	0.0
MK03	Milwaukee River: 7.7 to 12.8 miles	351	100	98.9	7.4	0.3	0.0	0.0	0.0
MK04	Milwaukee River: 15.1 to 19.4 miles	574	98.6	76.8	4.2	0.3	0.0	0.0	0.0
MK05	Milwaukee River: 19.6 to 20.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK06	Milwaukee River: 24.1 to 27.5 miles	518	100	90.9	2.9	0.0	0.0	0.0	0.0
MK07	Milwaukee River: 27.5 to 29.8 miles	20	100	100	0.0	0.0	0.0	0.0	0.0
MK08	Milwaukee River: 29.8 to 32.3 miles	29	96.6	48.3	0.0	0.0	0.0	0.0	0.0
MK09	Milwaukee River: 32.3 to 35.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK10	Milwaukee River: 35.8 to 43.7 miles	70	97.1	62.9	5.7	5.7	5.7	0.0	0.0
MK11	Milwaukee River: 43.7 to 47.8 miles	73	100	90.4	1.4	0.0	0.0	0.0	0.0
MK12	Milwaukee River: 47.8 to 53.2 miles	31	100	93.5	12.9	6.5	0.0	0.0	0.0
MK13	Milwaukee River: 57.3 to 63.9 miles	106	100	89.6	1.9	0.0	0.0	0.0	0.0
MK14	Milwaukee River: 64.1 to 67.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK15	Milwaukee River: 67.4 to 68.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK16	Milwaukee River: 69.9 to 74.7 miles	29	93.1	6.9	0.0	0.0	0.0	0.0	0.0
MK17	Milwaukee River: 77.3 to 78.6 miles	86	100	67.4	1.2	0.0	0.0	0.0	0.0
MK18	Milwaukee River: 79.9 to 83.4 miles	39	89.7	53.8	2.6	0.0	0.0	0.0	0.0
MK19	Milwaukee River: 87.4 to 87.8 miles	1	100	100	0.0	0.0	0.0	0.0	0.0
MK20	Milwaukee River: 91.8 to 95.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK21	Lincoln Creek: 0 to 5.0 miles	653	99.2	90.8	70.8	46.4	19.1	7.7	4.9
MK22	Lincoln Creek: 5.0 to 10.0 miles	335	100	94.3	58.2	26	8.1	1.8	0.3
MK23	Crestwood Creek: 0 to 1.3 miles	6	100	100	100	100	100	33.3	0.0
MK24	Indian Creek: 0 to 2.7 miles	250	100	98.4	73.6	40	12	3.2	0.8
MK25	Brown Deer Park Creek: 0 to 2.2 miles	14	100	100	100	100	100	35.7	0.0
MK26	Beaver Creek: 0 to 3.3 miles	9	100	100	100	100	100	33.3	0.0
MK27	Lac du Cours Creek: 0 to 0.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK28	Trinity Creek: 0 to 3.3 miles	- -	- -	- -	- -	- -	- -	- -	- -

Table 4.38 (Continued)

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MK29	Pigeon Creek: 0 to 2.4 miles	2	100	100	0.0	0.0	0.0	0.0	0.0
MK30	Mee-Kwon Creek: 0 to 1.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK31	Unnamed Tributary to Milwaukee River: 0 to 0.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK32	Ulao Creek: 0 to 0.7 miles	28	100	100	82.1	14.3	0.0	0.0	0.0
MK33	Ulao Creek: 1.8 to 5.3 miles	148	100	98.6	66.2	28.4	14.2	6.8	2.7
MK34	Ulao Creek: 5.3 to 6.2 miles	65	100	93.8	3.1	1.5	0.0	0.0	0.0
MK35	Ulao Creek: 6.6 to 9.2 miles	26	100	96.2	0.0	0.0	0.0	0.0	0.0
MK36	Cedar Creek: 1.1 to 1.8 miles	196	100	98	0.0	0.0	0.0	0.0	0.0
MK37	Cedar Creek: 1.8 to 14.1 miles	656	100	75	0.3	0.0	0.0	0.0	0.0
MK38	Cedar Creek: 16.0 to 18.3 miles	35	94.3	25.7	2.9	2.9	0.0	0.0	0.0
MK39	Cedar Creek: 19.1 to 19.6 miles	1	100	100	0.0	0.0	0.0	0.0	0.0
MK40	Cedar Creek: 20.7 to 21.2 miles	28	100	100	7.1	0.0	0.0	0.0	0.0
MK41	Cedar Creek: 21.2 to 22.5 miles	1	100	100	0.0	0.0	0.0	0.0	0.0
MK42	Cedar Creek: 23.0 to 23.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK43	Cedar Creek: 23.6 to 25.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK44	Cedar Creek: 25.7 to 29.7 miles	2	100	100	0.0	0.0	0.0	0.0	0.0
MK45	Cedar Creek: 31.3 to 37.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK46	Mud Creek: 0 to 3.5 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK47	North Branch Cedar Creek: 0 to 2.0 miles	4	100	100	0.0	0.0	0.0	0.0	0.0
MK48	Cedarburg Creek: 0 to 6.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK49	Evergreen Creek: 0 to 3.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK50	Friedens Creek: 0 to 3.5 miles	1	100	100	100	100	100	0.0	0.0
MK51	Little Cedar Creek: 0.2 to 1.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK52	Little Cedar Creek: 1.7 to 3.9 miles	1	100	100	100	100	100	100	0.0
MK53	Little Cedar Creek: 3.9 to 7.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK54	Kressin Branch: 0 to 5.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK55	Unnamed Tributary to Little Cedar Creek: 0 to 0.7 miles	1	100	100	100	100	100	100	0.0
MK56	Polk Springs Creek: 0 to 3.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK57	Jackson Creek: 0 to 1.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK58	Lehner Creek: 0 to 2.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK59	Unnamed Tributary to Gilbert Lake: 0 to 0.6 miles	1	100	100	0.0	0.0	0.0	0.0	0.0
MK60	Mole Creek: 0 to 7.9 miles	202	100	94.1	0.0	0.0	0.0	0.0	0.0
MK61	Hawthorne Drive Creek: 0 to 0.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK62	Fredonia Creek: 0 to 4.0 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK63	Sandhill Creek: 0 to 3.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK64	North Branch Milwaukee River: 0 to 4.7 miles	110	96.4	48.2	0.0	0.0	0.0	0.0	0.0
MK65	North Branch Milwaukee River: 5.0 to 7.1 miles	25	100	52	0.0	0.0	0.0	0.0	0.0
MK66	North Branch Milwaukee River: 10.2 to 12.2 miles	53	100	13.2	0.0	0.0	0.0	0.0	0.0
MK67	North Branch Milwaukee River: 14.3 to 18.1 miles	5	100	60	0.0	0.0	0.0	0.0	0.0
MK68	North Branch Milwaukee River: 18.1 to 21.5 miles	7	100	100	0.0	0.0	0.0	0.0	0.0
MK69	North Branch Milwaukee River: 23.3 to 27.8 miles	7	100	0.0	0.0	0.0	0.0	0.0	0.0
MK70	Wallace Creek: 0 to 5.5 miles	- -	- -	- -	- -	- -	- -	- -	- -

Table 4.38 (Continued)

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MK71	Stony Creek: 0 to 10.3 miles	27	100	25.9	0.0	0.0	0.0	0.0	0.0
MK72	Silver Creek: 0 to 2.0 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK73	Mink Creek: 0 to 14.5 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK74	Batavia Creek: 0 to 3.9 miles	2	100	100	0.0	0.0	0.0	0.0	0.0
MK75	Gooseville Creek: 0 to 0.9 miles	2	100	0.0	0.0	0.0	0.0	0.0	0.0
MK76	Melius Creek: 0 to 1.1 miles	2	100	0.0	0.0	0.0	0.0	0.0	0.0
MK77	Chambers Creek: 0 to 2.9 miles	2	100	0.0	0.0	0.0	0.0	0.0	0.0
MK78	Unnamed Tributary to North Branch Milwaukee River: 0.1 to 3.7 miles	9	100	100	11.1	0.0	0.0	0.0	0.0
MK79	Riveredge Nature Center Creek: 0 to 1.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK80	Myra Creek: 0 to 3.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK81	Unnamed Tributary to Milwaukee River: 0 to 0.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK82	Quas Creek: 0 to 4.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK83	Silver Creek: 0 to 2.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK84	Engmon Creek: 0 to 1.1 miles	2	100	100	100	100	50	50	0.0
MK85	East Branch Milwaukee River: 0 to 11.0 miles	112	87.5	0.0	0.0	0.0	0.0	0.0	0.0
MK86	East Branch Milwaukee River: 11.8 to 17.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK87	East Branch Milwaukee River (channelized west): 18.1 to 18.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK88	East Branch Milwaukee River (natural meander east): 18.1 to 18.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK89	Crooked Lake Creek (Tributary to East Branch Milwaukee River): 0 to 4.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK90	Parnell Creek: 0 to 2.7 miles	27	51.9	0.0	0.0	0.0	0.0	0.0	0.0
MK91	Watercress Creek (Long Lake Tributary): 0 to 4.7 miles	5	100	60	0.0	0.0	0.0	0.0	0.0
MK92	Kewaskum Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK93	Unnamed Tributary 1 to Kewaskum Creek: 0 to 1.0 miles	106	67	26.4	1.9	0.0	0.0	0.0	0.0
MK94	Unnamed Tributary 2 to Kewaskum Creek: 1.6 to 2.0 miles	69	75.4	2.9	0.0	0.0	0.0	0.0	0.0
MK95	Unnamed Tributary to Milwaukee River: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK96	West Branch Milwaukee River: 0 to 2.4 miles	73	100	82.2	0.0	0.0	0.0	0.0	0.0
MK97	West Branch Milwaukee River: 3.9 to 6.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK98	West Branch Milwaukee River: 8.2 to 11.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK99	West Branch Milwaukee River: 16.6 to 17.7 miles	303	100	85.5	0.3	0.0	0.0	0.0	0.0
MK100	West Branch Milwaukee River: 20.4 to 21.3 miles	264	89.8	8	0.0	0.0	0.0	0.0	0.0
MK101	Stoffel Creek: 1.6 to 7.0 miles	1	100	0.0	0.0	0.0	0.0	0.0	0.0
MK102	Unnamed Tributary to West Branch Milwaukee River: 0 to 1.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK103	Auburn Lake Creek: 0 to 1.4 miles	- -	- -	- -	- -	- -	- -	- -	- -

Table 4.38 (Continued)

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent) 10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MK104	Unnamed Tributary to Milwaukee River: 0 to 4.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK105	Unnamed Tributary to Milwaukee River: 0 to 2.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK106	Unnamed Tributary to Milwaukee River: 1.5 to 3.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK107	Southbranch Creek: 0 to 2.4 miles	339	100	98.2	69.9	29.8	8.3	2.1	0.0
MK108	Unnamed Tributary to Stoffel Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK109	Unnamed Tributary 3 to Kewaskum Creek: 0 to 0.6 miles	12	16.7	8.3	0.0	0.0	0.0	0.0	0.0
MK110	Riverside Drive Creek: 0 to 3.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK111	Helm's Creek Tributary to Ulao Creek: 0 to 0.2 miles	11	100	100	100	54.5	9.1	9.1	0.0
MK112	Kaul Creek: 0 to 1.0 miles	53	100	60.4	0.0	0.0	0.0	0.0	0.0
MK113	Gateway Drive Tributary to Ulao Creek: 0 to 0.6 miles	12	100	100	91.7	91.7	66.7	33.3	16.7
MK114	Unnamed Tributary to Pigeon Creek: 0 to 0.7 miles	7	100	100	14.3	0.0	0.0	0.0	0.0
MK115	Vila Grove Park Creek: 0 to 1.3 miles	- -	- -	- -	- -	- -	- -	- -	- -

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.39
Summary Statistics for Recent Measured Chloride and Specific Conductance at Assessment Reaches within the Milwaukee River Watershed: 2013-2022

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	Assessment Reach	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK01	Milwaukee River: 0 to 0.8 miles	1,174	15	91	82	810	1,050	244	734	725	3,050
MK02	Milwaukee River: 0.8 to 7.7 miles	1,287	25	83	80	590	1,357	245	772	780	7,710
MK03	Milwaukee River: 7.7 to 12.8 miles	192	33	80	75	260	210	411	775	790	1,400
MK04	Milwaukee River: 15.1 to 19.4 miles	191	32	77	73	310	224	340	756	772	1,520
MK05	Milwaukee River: 19.6 to 20.7 miles	- -	- -	- -	- -	- -	5	750	800	800	870
MK06	Milwaukee River: 24.1 to 27.5 miles	189	22	68	65	190	206	277	740	760	1,130
MK07	Milwaukee River: 27.5 to 29.8 miles	- -	- -	- -	- -	- -	29	540	818	825	1,333
MK08	Milwaukee River: 29.8 to 32.3 miles	- -	- -	- -	- -	- -	30	82	765	810	940
MK09	Milwaukee River: 32.3 to 35.8 miles	- -	- -	- -	- -	- -	32	407	730	755	920
MK10	Milwaukee River: 35.8 to 43.7 miles	31	27	112	52	535	75	360	883	750	2,600
MK11	Milwaukee River: 43.7 to 47.8 miles	- -	- -	- -	- -	- -	16	470	776	765	1,263
MK12	Milwaukee River: 47.8 to 53.2 miles	31	27	82	55	308	28	494	761	691	1,581
MK13	Milwaukee River: 57.3 to 63.9 miles	- -	- -	- -	- -	- -	14	300	829	868	1,215
MK14	Milwaukee River: 64.1 to 67.4 miles	- -	- -	- -	- -	- -	18	600	920	900	1,540
MK15	Milwaukee River: 67.4 to 68.4 miles	- -	- -	- -	- -	- -	9	845	1,319	1,130	2,020
MK16	Milwaukee River: 69.9 to 74.7 miles	- -	- -	- -	- -	- -	3	527	614	626	690
MK17	Milwaukee River: 77.3 to 78.6 miles	- -	- -	- -	- -	- -	10	707	834	830	1,000
MK18	Milwaukee River: 79.9 to 83.4 miles	- -	- -	- -	- -	- -	2	696	765	765	834
MK19	Milwaukee River: 87.4 to 87.8 miles	- -	- -	- -	- -	- -	15	590	798	830	895
MK20	Milwaukee River: 91.8 to 95.8 miles	- -	- -	- -	- -	- -	1	762	762	762	762
MK21	Lincoln Creek: 0 to 5.0 miles	201	10	445	280	4,010	233	113	1,825	1,397	15,400
MK22	Lincoln Creek: 5.0 to 10.0 miles	114	29	231	160	1,200	114	272	1,060	854	3,650
MK23	Crestwood Creek: 0 to 1.3 miles	6	594	765	677	1,130	19	590	1,814	1,560	4,200
MK24	Indian Creek: 0 to 2.7 miles	88	22	294	170	3,340	128	374	1,675	1,075	10,800
MK25	Brown Deer Park Creek: 0 to 2.2 miles	14	402	741	611	1,290	29	340	2,132	2,200	4,600
MK26	Beaver Creek: 0 to 3.3 miles	9	495	649	644	794	27	540	1,819	1,570	3,700
MK27	Lac du Cours Creek: 0 to 0.3 miles	- -	- -	- -	- -	- -	34	410	697	675	1,010
MK28	Trinity Creek: 0 to 3.3 miles	- -	- -	- -	- -	- -	53	380	1,107	1,080	1,860

Table 4.39 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (μS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK29	Pigeon Creek: 0 to 2.4 miles	- -	- -	- -	- -	- -	116	620	888	881	1,140
MK30	Mee-Kwon Creek: 0 to 1.4 miles	- -	- -	- -	- -	- -	18	710	868	885	1,000
MK31	Unnamed Tributary to Milwaukee River: 0 to 0.3 miles	- -	- -	- -	- -	- -	3	770	937	950	1,090
MK32	Ulao Creek: 0 to 0.7 miles	28	44	166	151	309	46	527	1,108	1,060	1,735
MK33	Ulao Creek: 1.8 to 5.3 miles	139	24	242	137	3,030	100	482	1,694	1,063	9,800
MK34	Ulao Creek: 5.3 to 6.2 miles	65	23	58	56	254	11	451	613	597	728
MK35	Ulao Creek: 6.6 to 9.2 miles	26	35	75	77	99	- -	- -	- -	- -	- -
MK36	Cedar Creek: 1.1 to 1.8 miles	- -	- -	- -	- -	- -	5	681	796	758	934
MK37	Cedar Creek: 1.8 to 14.1 miles	131	12	70	69	110	227	193	768	772	1,348
MK38	Cedar Creek: 16.0 to 18.3 miles	- -	- -	- -	- -	- -	49	275	769	793	1,032
MK39	Cedar Creek: 19.1 to 19.6 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK40	Cedar Creek: 20.7 to 21.2 miles	27	56	86	82	213	26	657	826	796	1,487
MK41	Cedar Creek: 21.2 to 22.5 miles	- -	- -	- -	- -	- -	6	800	1,058	970	1,630
MK42	Cedar Creek: 23.0 to 23.3 miles	- -	- -	- -	- -	- -	4	760	895	920	980
MK43	Cedar Creek: 23.6 to 25.7 miles	- -	- -	- -	- -	- -	42	373	679	689	871
MK44	Cedar Creek: 25.7 to 29.7 miles	- -	- -	- -	- -	- -	7	540	589	580	650
MK45	Cedar Creek: 31.3 to 37.8 miles	- -	- -	- -	- -	- -	22	408	539	553	585
MK46	Mud Creek: 0 to 3.5 miles	- -	- -	- -	- -	- -	22	259	345	314	776
MK47	North Branch Cedar Creek: 0 to 2.0 miles	4	38	43	43	46	57	516	766	751	1,178
MK48	Cedarburg Creek: 0 to 6.4 miles	- -	- -	- -	- -	- -	44	560	823	825	1,070
MK49	Evergreen Creek: 0 to 3.3 miles	- -	- -	- -	- -	- -	36	360	1,267	778	10,000
MK50	Friedens Creek: 0 to 3.5 miles	1	448	448	448	448	23	798	1,081	970	2,200
MK51	Little Cedar Creek: 0.2 to 1.7 miles	- -	- -	- -	- -	- -	36	217	792	841	1,270
MK52	Little Cedar Creek: 1.7 to 3.9 miles	1	985	985	985	985	64	629	1,122	1,013	4,160
MK53	Little Cedar Creek: 3.9 to 7.8 miles	- -	- -	- -	- -	- -	6	813	914	899	1,032
MK54	Kressin Branch: 0 to 5.1 miles	- -	- -	- -	- -	- -	24	472	757	759	955
MK55	Unnamed Tributary to Little Cedar Creek: 0 to 0.7 miles	1	869	869	869	869	21	1,010	1,514	1,324	3,600
MK56	Polk Springs Creek: 0 to 3.4 miles	- -	- -	- -	- -	- -	25	714	816	823	896
MK57	Jackson Creek: 0 to 1.3 miles	- -	- -	- -	- -	- -	21	211	831	846	1,116
MK58	Lehner Creek: 0 to 2.3 miles	- -	- -	- -	- -	- -	41	560	886	890	1,030
MK59	Unnamed Tributary to Gilbert Lake: 0 to 0.6 miles	- -	- -	- -	- -	- -	1	625	625	625	625
MK60	Mole Creek: 0 to 7.9 miles	195	25	46	46	66	60	314	795	820	1,081
MK61	Hawthorne Drive Creek: 0 to 0.7 miles	- -	- -	- -	- -	- -	1	1,116	1,116	1,116	1,116
MK62	Fredonia Creek: 0 to 4.0 miles	- -	- -	- -	- -	- -	14	640	901	890	1,160
MK63	Sandhill Creek: 0 to 3.1 miles	- -	- -	- -	- -	- -	6	830	1,327	1,430	1,640

Table 4.39 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK64	North Branch Milwaukee River: 0 to 4.7 miles	- -	- -	- -	- -	- -	1	1,238	1,238	1,238	1,238
MK65	North Branch Milwaukee River: 5.0 to 7.1 miles	25	21	34	35	46	26	489	697	682	1,278
MK66	North Branch Milwaukee River: 10.2 to 12.2 miles	- -	- -	- -	- -	- -	1	834	834	834	834
MK67	North Branch Milwaukee River: 14.3 to 18.1 miles	- -	- -	- -	- -	- -	1	1,243	1,243	1,243	1,243
MK68	North Branch Milwaukee River: 18.1 to 21.5 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK69	North Branch Milwaukee River: 23.3 to 27.8 miles	4	28	29	28	31	20	500	785	770	1,223
MK70	Wallace Creek: 0 to 5.5 miles	- -	- -	- -	- -	- -	1	1,239	1,239	1,239	1,239
MK71	Stony Creek: 0 to 10.3 miles	26	19	32	32	46	42	461	698	661	1,270
MK72	Silver Creek: 0 to 2.0 miles	- -	- -	- -	- -	- -	8	330	852	890	1,120
MK73	Mink Creek: 0 to 14.5 miles	- -	- -	- -	- -	- -	19	630	737	740	820
MK74	Batavia Creek: 0 to 3.9 miles	- -	- -	- -	- -	- -	21	530	722	740	820
MK75	Gooseville Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK76	Melius Creek: 0 to 1.1 miles	- -	- -	- -	- -	- -	17	620	750	770	880
MK77	Chambers Creek: 0 to 2.9 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK78	Unnamed Tributary to North Branch Milwaukee River: 0.1 to 3.7 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK79	Riveredge Nature Center Creek: 0 to 1.1 miles	- -	- -	- -	- -	- -	12	610	703	690	830
MK80	Myra Creek: 0 to 3.7 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK81	Unnamed Tributary to Milwaukee River: 0 to 0.6 miles	- -	- -	- -	- -	- -	5	190	966	960	1,440
MK82	Quas Creek: 0 to 4.3 miles	- -	- -	- -	- -	- -	19	990	1,184	1,170	1,748
MK83	Silver Creek: 0 to 2.4 miles	- -	- -	- -	- -	- -	23	600	1,072	980	1,850
MK84	Engmon Creek: 0 to 1.1 miles	2	272	582	582	892	19	983	1,491	1,160	4,300
MK85	East Branch Milwaukee River: 0 to 11.0 miles	25	14	19	19	25	44	382	537	545	620
MK86	East Branch Milwaukee River: 11.8 to 17.4 miles	- -	- -	- -	- -	- -	1	621	621	621	621
MK87	East Branch Milwaukee River (channelized west): 18.1 to 18.4 miles	- -	- -	- -	- -	- -	6	585	625	624	671
MK88	East Branch Milwaukee River (natural meander east): 18.1 to 18.4 miles	- -	- -	- -	- -	- -	6	572	619	621	656
MK89	Crooked Lake Creek (Tributary to East Branch Milwaukee River): 0 to 4.8 miles	- -	- -	- -	- -	- -	1	583	583	583	583
MK90	Parnell Creek: 0 to 2.7 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 4.39 (Continued)

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (μS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK91	Watercress Creek (Long Lake Tributary): 0 to 4.7 miles	4	30	39	41	44	11	604	740	709	1,105
MK92	Kewaskum Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	10	760	921	919	1,200
MK93	Unnamed Tributary 1 to Kewaskum Creek: 0 to 1.0 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK94	Unnamed Tributary 2 to Kewaskum Creek: 1.6 to 2.0 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK95	Unnamed Tributary to Milwaukee River: 0 to 0.4 miles	- -	- -	- -	- -	- -	7	877	1,213	1,227	1,435
MK96	West Branch Milwaukee River: 0 to 2.4 miles	46	18	41	42	55	- -	- -	- -	- -	- -
MK97	West Branch Milwaukee River: 3.9 to 6.7 miles	- -	- -	- -	- -	- -	1	788	788	788	788
MK98	West Branch Milwaukee River: 8.2 to 11.4 miles	- -	- -	- -	- -	- -	1	826	826	826	826
MK99	West Branch Milwaukee River: 16.6 to 17.7 miles	214	18	46	46	127	- -	- -	- -	- -	- -
MK100	West Branch Milwaukee River: 20.4 to 21.3 miles	193	3	21	20	49	- -	- -	- -	- -	- -
MK101	Stoffel Creek: 1.6 to 7.0 miles	1	30	30	30	30	2	741	895	895	1,049
MK102	Unnamed Tributary to West Branch Milwaukee River: 0 to 1.3 miles	- -	- -	- -	- -	- -	5	1,030	1,080	1,100	1,110
MK103	Auburn Lake Creek: 0 to 1.4 miles	- -	- -	- -	- -	- -	1	564	564	564	564
MK104	Unnamed Tributary to Milwaukee River: 0 to 4.4 miles	- -	- -	- -	- -	- -	1	595	595	595	595
MK105	Unnamed Tributary to Milwaukee River: 0 to 2.7 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK106	Unnamed Tributary to Milwaukee River: 1.5 to 3.4 miles	- -	- -	- -	- -	- -	4	547	759	787	916
MK107	Southbranch Creek: 0 to 2.4 miles	94	36	312	205	1,200	102	245	1,370	1,055	4,270
MK108	Unnamed Tributary to Stoffel Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	4	680	760	775	810
MK109	Unnamed Tributary 3 to Kewaskum Creek: 0 to 0.6 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MK110	Riverside Drive Creek: 0 to 3.6 miles	- -	- -	- -	- -	- -	45	350	955	930	1,948
MK111	Helm's Creek Tributary to Ulao Creek: 0 to 0.2 miles	11	138	321	243	1,180	11	874	1,579	1,351	4,267
MK112	Kaul Creek: 0 to 1.0 miles	53	10	43	41	92	- -	- -	- -	- -	- -
MK113	Gateway Drive Tributary to Ulao Creek: 0 to 0.6 miles	12	99	1,152	546	6,630	12	541	3,894	2,038	20,645

Table 4.39 (Continued)

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	Assessment Reach	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
MK114	Unnamed Tributary to Pigeon Creek: 0 to 0.7 miles	1	91	91	91	91	28	600	808	830	980
MK115	Vila Grove Park Creek: 0 to 1.3 miles	- -	- -	- -	- -	- -	2	720	765	765	810

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.40
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Milwaukee River Watershed Recent Record: 2013-2022

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MK01	Milwaukee River: 0 to 0.8 miles	1,174	100	94.2	12.9	2.5	0.7	0.1	0.0
MK02	Milwaukee River: 0.8 to 7.7 miles	1,287	100	99.2	5.1	0.5	0.2	0.0	0.0
MK03	Milwaukee River: 7.7 to 12.8 miles	192	100	99.5	3.6	0.5	0.0	0.0	0.0
MK04	Milwaukee River: 15.1 to 19.4 miles	191	100	99	2.6	0.5	0.0	0.0	0.0
MK05	Milwaukee River: 19.6 to 20.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK06	Milwaukee River: 24.1 to 27.5 miles	189	100	96.8	0.5	0.0	0.0	0.0	0.0
MK07	Milwaukee River: 27.5 to 29.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK08	Milwaukee River: 29.8 to 32.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK09	Milwaukee River: 32.3 to 35.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK10	Milwaukee River: 35.8 to 43.7 miles	31	100	93.5	12.9	12.9	12.9	0.0	0.0
MK11	Milwaukee River: 43.7 to 47.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK12	Milwaukee River: 47.8 to 53.2 miles	31	100	93.5	12.9	6.5	0.0	0.0	0.0
MK13	Milwaukee River: 57.3 to 63.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK14	Milwaukee River: 64.1 to 67.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK15	Milwaukee River: 67.4 to 68.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK16	Milwaukee River: 69.9 to 74.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK17	Milwaukee River: 77.3 to 78.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK18	Milwaukee River: 79.9 to 83.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK19	Milwaukee River: 87.4 to 87.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK20	Milwaukee River: 91.8 to 95.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK21	Lincoln Creek: 0 to 5.0 miles	201	99	98.5	89.1	64.7	29.4	10.4	5
MK22	Lincoln Creek: 5.0 to 10.0 miles	114	100	98.2	63.2	25.4	13.2	3.5	0.0
MK23	Crestwood Creek: 0 to 1.3 miles	6	100	100	100	100	100	33.3	0.0
MK24	Indian Creek: 0 to 2.7 miles	88	100	98.9	64.8	29.5	13.6	6.8	2.3
MK25	Brown Deer Park Creek: 0 to 2.2 miles	14	100	100	100	100	100	35.7	0.0
MK26	Beaver Creek: 0 to 3.3 miles	9	100	100	100	100	100	33.3	0.0
MK27	Lac du Cours Creek: 0 to 0.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK28	Trinity Creek: 0 to 3.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK29	Pigeon Creek: 0 to 2.4 miles	- -	- -	- -	- -	- -	- -	- -	- -

Table 4.40 (Continued)

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MK30	Mee-Kwon Creek: 0 to 1.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK31	Unnamed Tributary to Milwaukee River: 0 to 0.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK32	Ulao Creek: 0 to 0.7 miles	28	100	100	82.1	14.3	0.0	0.0	0.0
MK33	Ulao Creek: 1.8 to 5.3 miles	139	100	98.6	64	25.9	12.2	5.8	1.4
MK34	Ulao Creek: 5.3 to 6.2 miles	65	100	93.8	3.1	1.5	0.0	0.0	0.0
MK35	Ulao Creek: 6.6 to 9.2 miles	26	100	96.2	0.0	0.0	0.0	0.0	0.0
MK36	Cedar Creek: 1.1 to 1.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK37	Cedar Creek: 1.8 to 14.1 miles	131	100	95.4	0.0	0.0	0.0	0.0	0.0
MK38	Cedar Creek: 16.0 to 18.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK39	Cedar Creek: 19.1 to 19.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK40	Cedar Creek: 20.7 to 21.2 miles	27	100	100	7.4	0.0	0.0	0.0	0.0
MK41	Cedar Creek: 21.2 to 22.5 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK42	Cedar Creek: 23.0 to 23.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK43	Cedar Creek: 23.6 to 25.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK44	Cedar Creek: 25.7 to 29.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK45	Cedar Creek: 31.3 to 37.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK46	Mud Creek: 0 to 3.5 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK47	North Branch Cedar Creek: 0 to 2.0 miles	4	100	100	0.0	0.0	0.0	0.0	0.0
MK48	Cedarburg Creek: 0 to 6.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK49	Evergreen Creek: 0 to 3.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK50	Friedens Creek: 0 to 3.5 miles	1	100	100	100	100	100	0.0	0.0
MK51	Little Cedar Creek: 0.2 to 1.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK52	Little Cedar Creek: 1.7 to 3.9 miles	1	100	100	100	100	100	100	0.0
MK53	Little Cedar Creek: 3.9 to 7.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK54	Kressin Branch: 0 to 5.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK55	Unnamed Tributary to Little Cedar Creek: 0 to 0.7 miles	1	100	100	100	100	100	100	0.0
MK56	Polk Springs Creek: 0 to 3.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK57	Jackson Creek: 0 to 1.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK58	Lehner Creek: 0 to 2.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK59	Unnamed Tributary to Gilbert Lake: 0 to 0.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK60	Mole Creek: 0 to 7.9 miles	195	100	93.8	0.0	0.0	0.0	0.0	0.0
MK61	Hawthorne Drive Creek: 0 to 0.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK62	Fredonia Creek: 0 to 4.0 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK63	Sandhill Creek: 0 to 3.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK64	North Branch Milwaukee River: 0 to 4.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK65	North Branch Milwaukee River: 5.0 to 7.1 miles	25	100	52	0.0	0.0	0.0	0.0	0.0
MK66	North Branch Milwaukee River: 10.2 to 12.2 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK67	North Branch Milwaukee River: 14.3 to 18.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK68	North Branch Milwaukee River: 18.1 to 21.5 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK69	North Branch Milwaukee River: 23.3 to 27.8 miles	4	100	0.0	0.0	0.0	0.0	0.0	0.0
MK70	Wallace Creek: 0 to 5.5 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK71	Stony Creek: 0 to 10.3 miles	26	100	26.9	0.0	0.0	0.0	0.0	0.0

Table 4.40 (Continued)

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MK72	Silver Creek: 0 to 2.0 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK73	Mink Creek: 0 to 14.5 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK74	Batavia Creek: 0 to 3.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK75	Gooseville Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK76	Melius Creek: 0 to 1.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK77	Chambers Creek: 0 to 2.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK78	Unnamed Tributary to North Branch Milwaukee River: 0.1 to 3.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK79	Riveredge Nature Center Creek: 0 to 1.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK80	Myra Creek: 0 to 3.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK81	Unnamed Tributary to Milwaukee River: 0 to 0.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK82	Quas Creek: 0 to 4.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK83	Silver Creek: 0 to 2.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK84	Engmon Creek: 0 to 1.1 miles	2	100	100	100	100	50	50	0.0
MK85	East Branch Milwaukee River: 0 to 11.0 miles	25	100	0.0	0.0	0.0	0.0	0.0	0.0
MK86	East Branch Milwaukee River: 11.8 to 17.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK87	East Branch Milwaukee River (channelized west): 18.1 to 18.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK88	East Branch Milwaukee River (natural meander east): 18.1 to 18.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK89	Crooked Lake Creek (Tributary to East Branch Milwaukee River): 0 to 4.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK90	Parnell Creek: 0 to 2.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK91	Watercress Creek (Long Lake Tributary): 0 to 4.7 miles	4	100	75	0.0	0.0	0.0	0.0	0.0
MK92	Kewaskum Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK93	Unnamed Tributary 1 to Kewaskum Creek: 0 to 1.0 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK94	Unnamed Tributary 2 to Kewaskum Creek: 1.6 to 2.0 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK95	Unnamed Tributary to Milwaukee River: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK96	West Branch Milwaukee River: 0 to 2.4 miles	46	100	78.3	0.0	0.0	0.0	0.0	0.0
MK97	West Branch Milwaukee River: 3.9 to 6.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK98	West Branch Milwaukee River: 8.2 to 11.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK99	West Branch Milwaukee River: 16.6 to 17.7 miles	214	100	82.7	0.5	0.0	0.0	0.0	0.0
MK100	West Branch Milwaukee River: 20.4 to 21.3 miles	193	86	5.2	0.0	0.0	0.0	0.0	0.0
MK101	Stoffel Creek: 1.6 to 7.0 miles	1	100	0.0	0.0	0.0	0.0	0.0	0.0
MK102	Unnamed Tributary to West Branch Milwaukee River: 0 to 1.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK103	Auburn Lake Creek: 0 to 1.4 miles	- -	- -	- -	- -	- -	- -	- -	- -

Table 4.40 (Continued)

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent) 10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
MK104	Unnamed Tributary to Milwaukee River: 0 to 4.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK105	Unnamed Tributary to Milwaukee River: 0 to 2.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK106	Unnamed Tributary to Milwaukee River: 1.5 to 3.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK107	Southbranch Creek: 0 to 2.4 miles	94	100	100	87.2	44.7	26.6	6.4	0.0
MK108	Unnamed Tributary to Stoffel Creek: 0 to 0.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK109	Unnamed Tributary 3 to Kewaskum Creek: 0 to 0.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK110	Riverside Drive Creek: 0 to 3.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
MK111	Helm's Creek Tributary to Ulao Creek: 0 to 0.2 miles	11	100	100	100	54.5	9.1	9.1	0.0
MK112	Kaul Creek: 0 to 1.0 miles	53	100	60.4	0.0	0.0	0.0	0.0	0.0
MK113	Gateway Drive Tributary to Ulao Creek: 0 to 0.6 miles	12	100	100	91.7	91.7	66.7	33.3	16.7
MK114	Unnamed Tributary to Pigeon Creek: 0 to 0.7 miles	1	100	100	0.0	0.0	0.0	0.0	0.0
MK115	Vila Grove Park Creek: 0 to 1.3 miles	- -	- -	- -	- -	- -	- -	- -	- -

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the recent period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.41
Waterbodies Listed as Impaired Due to Chloride in the Milwaukee River Watershed: 2024

Stream Name	Chloride Assessment Reaches Included in Impairment	Extent (River mile)[a]	Impairment		Listing Date	Max Recent Chloride Observed (Reach, Concentration, Date)
			Acute Toxicity	Chronic Toxicity		
Beaver Creek	MK26	0.00-2.65	--	X	2020	MK26, 794 mg/l, 1/31/2017
Brown Deer Park Creek	MK25	0.00-2.30	X	X	2018	MK25, 1,290 mg/l, 2/1/2017
Crestwood Creek	MK23	0.00-1.35	X	X	2020	MK23, 1,130 mg/l, 3/14/2017
Gateway Tributary to Ulao Creek	MK113	0.00-0.85	--	X	2024	MK113, 6,630 mg/l, 2/23/2021
Indian Creek	MK24	0.00-2.63	X	X	2018	MK24, 3,340 mg/l, 1/16/2017
Lincoln Creek	MK21, MK22	0.0-9.7	X	X	2014	MK21, 4,770 mg/l, 2/26/2007
Southbranch Creek	MK107	0.00-2.36	X	X	2018	MK107, 1,200 mg/l, 3/9/2022
Ulao Creek	MK32, MK33, MK34, MK35	0.0-8.6	X	X	2016	MK33, 3,030 mg/l, 1/28/2013

[a] *River mile is measured upstream from the confluence with whatever the waterbody drains into.*

Source: WDNR and SEWRPC

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Table 4.42
Summary of Stream Assessment Reaches Within the Oak Creek Watershed: 1961-2022

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
OC01	Oak Creek: 0 to 5.0 miles	14500	4	5.1	1,864	1964 - 2022	2,996	1964 - 2022
OC02	Oak Creek: 5.0 to 9.5 miles	14500	4	4.5	867	1964 - 2022	1,147	1964 - 2022
OC03	Oak Creek: 9.5 to 12.4 miles	14500	2	2.9	417	1985 - 2022	604	1985 - 2022
OC04	Mitchell Field Drainage Ditch: 0 to 3.2 miles	14800	2	3.2	73	2007 - 2022	221	2012 - 2022
OC05	North Branch Oak Creek: 1.1 to 2.1 miles	14900	4	1.0	16	1990 - 2022	21	1990 - 2022
OC06	North Branch Oak Creek: 2.1 to 3.0 miles	14900	3	0.9	--	--	100	2012 - 2016
OC07	North Branch Oak Creek: 3.0 to 6.8 miles	14900	2	3.8	5	1975 - 2017	95	1975 - 2018
OC08	Drexel Avenue Tributary: 0 to 0.4 miles	5037407	3	0.4	1	2019	64	2015 - 2019

Note: Chloride and specific conductance datasets shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, USGS, WDNR, City of Racine Public Health Department, and SEWRPC

Table 4.43
Percent of Measured Chloride and Specific Conductance Samples by Season at Assessment Reaches within the Oak Creek Watershed: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
OC01	Oak Creek: 0 to 5.0 miles	1,864	4.1	25.2	38.4	32.3	2,996	8.1	23.8	42.9	25.2
OC02	Oak Creek: 5.0 to 9.5 miles	867	1.3	24.9	41.2	32.6	1,147	3.4	21.7	46.8	28.1
OC03	Oak Creek: 9.5 to 12.4 miles	417	1.2	25.9	39.3	33.6	604	4.3	21.7	45.9	28.1
OC04	Mitchell Field Drainage Ditch: 0 to 3.2 miles	73	50.7	28.8	5.5	15.1	221	23.1	18.6	44.3	14.0
OC05	North Branch Oak Creek: 1.1 to 2.1 miles	16	0.0	18.8	43.8	37.5	21	0.0	19.0	47.6	33.3
OC06	North Branch Oak Creek: 2.1 to 3.0 miles	- -	- -	- -	- -	- -	100	11.0	11.0	65.0	13.0
OC07	North Branch Oak Creek: 3.0 to 6.8 miles	5	60.0	0.0	20.0	20.0	95	16.8	15.8	52.6	14.7
OC08	Drexel Avenue Tributary: 0 to 0.4 miles	1	100	0.0	0.0	0.0	64	20.3	21.9	37.5	20.3

Note: Seasons are defined as Winter (December through February), Spring (March through May), Summer (June through August), and Fall (September through November). Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance. Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter.

Source: MMSD, WDNR, USGS, City of Racine Public Health Department, and SEWRPC

Table 4.44
Summary Statistics for Measured Chloride and Specific Conductance at Assessment Reaches within the Oak Creek Watershed: 1961-2022

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	Assessment Reach	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
OC01	Oak Creek: 0 to 5.0 miles	1,864	2	212	168	2,080	2,996	191	1,353	1,260	7,227
OC02	Oak Creek: 5.0 to 9.5 miles	867	6	230	192	1,600	1,147	120	1,331	1,270	5,100
OC03	Oak Creek: 9.5 to 12.4 miles	417	4	229	200	960	604	216	1,411	1,390	3,571
OC04	Mitchell Field Drainage Ditch: 0 to 3.2 miles	73	71	924	663	7,120	221	240	2,366	1,986	20,000
OC05	North Branch Oak Creek: 1.1 to 2.1 miles	16	52	366	245	2,600	21	454	1,562	1,483	7,840
OC06	North Branch Oak Creek: 2.1 to 3.0 miles	- -	- -	- -	- -	- -	100	449	1,682	1,543	3,983
OC07	North Branch Oak Creek: 3.0 to 6.8 miles	5	62	641	625	1,610	95	573	2,148	1,846	6,300
OC08	Drexel Avenue Tributary: 0 to 0.4 miles	1	1,940	1,940	1,940	1,940	64	580	2,000	1,852	6,500

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, WDNR, USGS, City of Racine Public Health Department, and SEWRPC

Table 4.45
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Oak Creek Watershed Full Record: 1961-2022

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
OC01	Oak Creek: 0 to 5.0 miles	1,864	99.5	98.7	72.5	25.6	8.6	2.2	0.4
OC02	Oak Creek: 5.0 to 9.5 miles	867	99.5	98.4	80.6	35.6	10.3	1.8	0.1
OC03	Oak Creek: 9.5 to 12.4 miles	417	99.5	98.6	83.7	34.1	11.0	1.2	0.0
OC04	Mitchell Field Drainage Ditch: 0 to 3.2 miles	73	100	100	95.9	83.6	67.1	42.5	21.9
OC05	North Branch Oak Creek: 1.1 to 2.1 miles	16	100	100	68.8	50	12.5	6.3	6.3
OC06	North Branch Oak Creek: 2.1 to 3.0 miles	--	--	--	--	--	--	--	--
OC07	North Branch Oak Creek: 3.0 to 6.8 miles	5	100	100	60.0	60.0	60.0	40.0	20.0
OC08	Drexel Avenue Tributary: 0 to 0.4 miles	1	100	100	100	100	100	100	100

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps during the period. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, WDNR, USGS, and SEWRPC

Table 4.46
Summary Statistics for Recent Measured Chloride and Specific Conductance at Assessment Reaches within the Oak Creek Watershed: 2013-2022

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	Assessment Reach	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
OC01	Oak Creek: 0 to 5.0 miles	401	44	349	270	2,080	1,253	274	1,575	1,500	7,227
OC02	Oak Creek: 5.0 to 9.5 miles	173	40	367	320	1,600	410	256	1,588	1,543	5,100
OC03	Oak Creek: 9.5 to 12.4 miles	86	30	396	370	940	256	216	1,498	1,447	3,460
OC04	Mitchell Field Drainage Ditch: 0 to 3.2 miles	58	120	1,062	716	7,120	199	240	2,433	2,023	20,000
OC05	North Branch Oak Creek: 1.1 to 2.1 miles	9	85	517	260	2,600	13	456	1,901	1,560	7,840
OC06	North Branch Oak Creek: 2.1 to 3.0 miles	- -	- -	- -	- -	- -	82	449	1,815	1,627	3,983
OC07	North Branch Oak Creek: 3.0 to 6.8 miles	2	833	1,222	1,222	1,610	94	593	2,165	1,850	6,300
OC08	Drexel Avenue Tributary: 0 to 0.4 miles	1	1,940	1,940	1,940	1,940	64	580	2,000	1,852	6,500

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, WDNR, USGS, City of Racine Public Health Department, and SEWRPC

Table 4.47
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Oak Creek Watershed Recent Record: 2013-2022

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
OC01	Oak Creek: 0 to 5.0 miles	401	100	100	93.3	64.1	28.2	4.5	1.5
OC02	Oak Creek: 5.0 to 9.5 miles	173	100	100	94.8	75.1	31.8	5.8	0.6
OC03	Oak Creek: 9.5 to 12.4 miles	86	100	98.8	98.8	83.7	45.3	4.7	0.0
OC04	Mitchell Field Drainage Ditch: 0 to 3.2 miles	58	100	100	98.3	89.7	74.1	48.3	27.6
OC05	North Branch Oak Creek: 1.1 to 2.1 miles	9	100	100	88.9	55.6	22.2	11.1	11.1
OC06	North Branch Oak Creek: 2.1 to 3.0 miles	--	--	--	--	--	--	--	--
OC07	North Branch Oak Creek: 3.0 to 6.8 miles	2	100	100	100	100	100	100	50.0
OC08	Drexel Avenue Tributary: 0 to 0.4 miles	1	100	100	100	100	100	100	100

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the recent period of record are included in this table to indicate sampling gaps during the period. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, WDNR, USGS, and SEWRPC

Table 4.48
Waterbodies Listed as Impaired Due to Chloride in the Oak Creek Watershed: 2024

Stream Name	Chloride Assessment Reaches Included in Impairment	Extent (River mile)[a]	Impairment		Listing Date	Max Recent Chloride Observed (Reach, Concentration, Date)
			Acute Toxicity	Chronic Toxicity		
Oak Creek	OC01, OC02, OC03	0.00-13.32	X	X	2014	OC01, 2,080 mg/l, 2/25/2021
Michell Field Drainage Ditch	OC04	0.00-2.3	X	X	2020	OC04, 7,120 mg/l, 2/1/2021
North Branch Oak Creek	OC05, OC06[b], OC07	0.0-5.7	X	X	2018	OC05, 2,600 mg/l, 3/1/2022

[a] *River mile is measured upstream from the confluence with whatever the waterbody drains into.*

[b] *No chloride samples were collected in the OC06 assessment reach during the recent period of record (2013-2022).*

Source: WDNR and SEWRPC

Table 4.49
Summary of Stream Assessment Reaches Within the Pike River Watershed: 1961-2022

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
PK01	Pike River: 0 to 4.5 miles	1300	4	4.5	475	1964 - 2020	524	1964 - 2021
PK02	Pike River: 5.2 to 9.5 miles	1300	4	4.3	333	1976 - 2021	450	1976 - 2021
PK03	North Branch Pike River: 0 to 1.9 miles	1900	3	1.9	69	1964 - 1996	72	1964 - 1996
PK04	North Branch Pike River: 3.8 to 7.9 miles	1900	2	4.1	54	1996 - 2016	57	1996 - 2016
PK05	Unnamed Tributary to Pike River: 0 to 0.6 miles	2450	1	0.6	13	2011 - 2013	11	2012 - 2013
PK06	South Branch Pike River: 0 to 6.7 miles	2500	3	6.7	76	1964 - 1996	90	1964 - 1996
PK07	Unnamed Tributary to South Branch Pike River: 1.2 to 3.0 miles	2600	1	1.8	--	--	2	2017
PK08	Unnamed Tributary to South Branch Pike River: 1.1 to 2.7 miles	2700	2	1.6	--	--	1	2017
PK09	Unnamed Tributary to Pike River: 0 to 0.3 miles	5040874	2	0.3	--	--	1	2017
PK10	Unnamed Tributary to Pike River 0 to 1.8 miles	None	1	1.8	94	2011 - 2020	100	2012 - 2021

Note: Chloride and specific conductance datasets shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: USGS, WDNR, and SEWRPC

Table 4.50
Percent of Measured Chloride and Specific Conductance Samples by Season at Assessment Reaches within the Pike River Watershed: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
PK01	Pike River: 0 to 4.5 miles	475	13.3	45.1	10.5	31.2	524	13.7	42.6	12.2	31.5
PK02	Pike River: 5.2 to 9.5 miles	333	16.8	41.1	4.8	37.2	450	18.0	37.3	10.2	34.4
PK03	North Branch Pike River: 0 to 1.9 miles	69	1.4	4.3	39.1	55.1	72	1.4	4.2	43.1	51.4
PK04	North Branch Pike River: 3.8 to 7.9 miles	54	5.6	50.0	14.8	29.6	57	5.3	47.4	19.3	28.1
PK05	Unnamed Tributary to Pike River: 0 to 0.6 miles	13	7.7	76.9	0.0	15.4	11	9.1	90.9	0.0	0.0
PK06	South Branch Pike River: 0 to 6.7 miles	76	5.3	10.5	75.0	9.2	90	4.4	8.9	78.9	7.8
PK07	Unnamed Tributary to South Branch Pike River: 1.2 to 3.0 miles	- -	- -	- -	- -	- -	2	0.0	0.0	50.0	50.0
PK08	Unnamed Tributary to South Branch Pike River: 1.1 to 2.7 miles	- -	- -	- -	- -	- -	1	0.0	0.0	0.0	100.0
PK09	Unnamed Tributary to Pike River: 0 to 0.3 miles	- -	- -	- -	- -	- -	1	0.0	0.0	0.0	100.0
PK10	Unnamed Tributary to Pike River 0 to 1.8 miles	94	14.9	52.1	3.2	29.8	100	17.0	48.0	3.0	32.0

Note: Seasons are defined as Winter (December through February), Spring (March through May), Summer (June through August), and Fall (September through November). Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps during the period of 1961 through 2022. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance. Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter.

Source: WDNR, USGS, and SEWRPC

Table 4.51
Summary Statistics for Measured Chloride and Specific Conductance at Assessment Reaches within the Pike River Watershed: 1961-2022

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	Assessment Reach	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
PK01	Pike River: 0 to 4.5 miles	475	22	161	132	1,255	524	72	909	862	2,600
PK02	Pike River: 5.2 to 9.5 miles	333	12	157	126	1,016	450	92	841	773	3,450
PK03	North Branch Pike River: 0 to 1.9 miles	69	8	23	19	85	72	283	488	419	1,070
PK04	North Branch Pike River: 3.8 to 7.9 miles	54	23	198	185	572	57	337	1,043	1,055	1,663
PK05	Unnamed Tributary to Pike River: 0 to 0.6 miles	13	74	210	174	427	11	740	1,200	1,110	1,745
PK06	South Branch Pike River: 0 to 6.7 miles	76	22	49	51	93	90	308	881	932	1,455
PK07	Unnamed Tributary to South Branch Pike River: 1.2 to 3.0 miles	- -	- -	- -	- -	- -	2	1,101	1,148	1,148	1,195
PK08	Unnamed Tributary to South Branch Pike River: 1.1 to 2.7 miles	- -	- -	- -	- -	- -	1	1,078	1,078	1,078	1,078
PK09	Unnamed Tributary to Pike River: 0 to 0.3 miles	- -	- -	- -	- -	- -	1	1,032	1,032	1,032	1,032
PK10	Unnamed Tributary to Pike River 0 to 1.8 miles	94	5	47	13	313	100	60	746	735	1,455

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: WDNR, USGS, and SEWRPC

Table 4.52
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Pike River Watershed Full Record: 1961-2022

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
PK01	Pike River: 0 to 4.5 miles	475	100	94.7	57.1	18.5	4.2	0.4	0.0
PK02	Pike River: 5.2 to 9.5 miles	333	100	81.1	52.6	19.2	4.8	0.9	0.0
PK03	North Branch Pike River: 0 to 1.9 miles	69	98.6	14.5	0.0	0.0	0.0	0.0	0.0
PK04	North Branch Pike River: 3.8 to 7.9 miles	54	100	90.7	81.5	33.3	5.6	0.0	0.0
PK05	Unnamed Tributary to Pike River: 0 to 0.6 miles	13	100	100	76.9	30.8	15.4	0.0	0.0
PK06	South Branch Pike River: 0 to 6.7 miles	76	100	69.7	0.0	0.0	0.0	0.0	0.0
PK07	Unnamed Tributary to South Branch Pike River: 1.2 to 3.0 miles	--	--	--	--	--	--	--	--
PK08	Unnamed Tributary to South Branch Pike River: 1.1 to 2.7 miles	--	--	--	--	--	--	--	--
PK09	Unnamed Tributary to Pike River: 0 to 0.3 miles	--	--	--	--	--	--	--	--
PK10	Unnamed Tributary to Pike River 0 to 1.8 miles	94	86.2	21.3	16	5.3	0.0	0.0	0.0

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: WDNR, USGS, and SEWRPC

Table 4.53
Summary Statistics for Recent Measured Chloride and Specific Conductance at Assessment Reaches within the Pike River Watershed: 2013-2022

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	Assessment Reach	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
PK01	Pike River: 0 to 4.5 miles	365	22	182	145	1,255	388	72	957	899	2,600
PK02	Pike River: 5.2 to 9.5 miles	250	12	189	146	1,016	261	92	981	890	3,450
PK03	North Branch Pike River: 0 to 1.9 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
PK04	North Branch Pike River: 3.8 to 7.9 miles	38	81	225	202	572	38	540	1,161	1,163	1,663
PK05	Unnamed Tributary to Pike River: 0 to 0.6 miles	8	74	145	136	235	8	740	1,018	1,013	1,345
PK06	South Branch Pike River: 0 to 6.7 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
PK07	Unnamed Tributary to South Branch Pike River: 1.2 to 3.0 miles	- -	- -	- -	- -	- -	2	1,101	1,148	1,148	1,195
PK08	Unnamed Tributary to South Branch Pike River: 1.1 to 2.7 miles	- -	- -	- -	- -	- -	1	1,078	1,078	1,078	1,078
PK09	Unnamed Tributary to Pike River: 0 to 0.3 miles	- -	- -	- -	- -	- -	1	1,032	1,032	1,032	1,032
PK10	Unnamed Tributary to Pike River 0 to 1.8 miles	82	5	27	13	290	93	60	718	732	1,095

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: WDNR, USGS, and SEWRPC

Table 4.54
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Pike River Watershed Recent Record: 2013-2022

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
PK01	Pike River: 0 to 4.5 miles	365	100	99.5	66.8	23	5.5	0.5	0.0
PK02	Pike River: 5.2 to 9.5 miles	250	100	94.4	64.4	25.2	6.4	1.2	0.0
PK03	North Branch Pike River: 0 to 1.9 miles	--	--	--	--	--	--	--	--
PK04	North Branch Pike River: 3.8 to 7.9 miles	38	100	100	89.5	42.1	7.9	0.0	0.0
PK05	Unnamed Tributary to Pike River: 0 to 0.6 miles	8	100	100	62.5	12.5	0.0	0.0	0.0
PK06	South Branch Pike River: 0 to 6.7 miles	--	--	--	--	--	--	--	--
PK07	Unnamed Tributary to South Branch Pike River: 1.2 to 3.0 miles	--	--	--	--	--	--	--	--
PK08	Unnamed Tributary to South Branch Pike River: 1.1 to 2.7 miles	--	--	--	--	--	--	--	--
PK09	Unnamed Tributary to Pike River: 0 to 0.3 miles	--	--	--	--	--	--	--	--
PK10	Unnamed Tributary to Pike River 0 to 1.8 miles	82	84.1	11.0	6.1	1.2	0.0	0.0	0.0

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the recent period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: WDNR, USGS, and SEWRPC

Table 4.55
Waterbodies Listed as Impaired Due to Chloride in the Pike River Watershed: 2024

Stream Name	Chloride Assessment Reaches Included in Impairment	Extent (River mile)[a]	Impairment		Listing Date	Max Recent Chloride Observed (Reach, Concentration, Date)
			Acute Toxicity	Chronic Toxicity		
Pike River	PK01, PK02	0.00-9.50	X	X	2016	PK01, 1,255 mg/l, 5/1/2018
North Branch Pike River	PK04	5.23-7.87	--	X	2018	PK04, 572 mg/l, 3/24/2015
Unnamed Tributary to North Branch Pike River	PK05	0.0-0.58	--	X	2016	PK05, 234 mg/l, 4/10/2013[b]

[a] *River mile is measured upstream from the confluence with whatever the waterbody drains into.*

[b] *No chloride sample from the recent period of record has exceeded the chronic toxicity threshold. However, two samples in 2012 (427 mg/l and 411 mg/l) exceeded it.*

Source: WDNR and SEWRPC

Table 4.62
Summary of Stream Assessment Reaches Within the Root River Watershed: 1961-2022

Assessment Reach ID	Assessment Reaches	WBIC	Stream Order	Reach Length (miles)	Number of Chloride Samples	Date Range of Chloride Samples	Number of Conductance Samples	Date Range of Conductance Samples
RT01	Root River 0 to 5.2 miles	2900	5	5.2	63	1996 - 2018	20	1996 - 2022
RT02	Root River: 5.2 to 7.4 miles	2900	5	2.2	344	1961 - 2021	245	1961 - 2021
RT03	Root River: 11.5 to 13.7 miles	2900	5	2.3	5	1996	6	1996
RT04	Root River: 17.1 to 25.8 miles	2900	5	8.7	291	1964 - 2022	306	1964 - 2022
RT05	Root River: 25.8 to 34.3 miles	2900	4	8.5	333	1961 - 2022	498	1961 - 2022
RT06	Root River: 35.8 to 41.2 miles	2900	3	5.4	537	1964 - 2022	679	1964 - 2022
RT07	Root River: 41.2 to 43.7 miles	2900	2	2.5	449	1999 - 2022	453	1999 - 2022
RT08	Hoods Creek: 0 to 6.9 miles	3100	2	6.9	15	1996 - 2020	26	1996 - 2020
RT09	Hoods Creek: 6.9 to 8.9 miles	3100	2	2.0	--	--	1	2015
RT10	Crawfish Creek: 0.5 to 1.7 miles	3385	2	1.2	2	2020	5	2020 - 2022
RT11	Husher Creek: 0 to 4.2 miles	3500	3	4.2	5	1996	12	1996 - 2011
RT12	Kilbournville Tributary: 0 to 2.8 miles	3600	2	2.8	--	--	1	2007
RT13	Root River Canal: 0.8 to 5.7 miles	4300	4	4.9	150	1964 - 2021	235	1964 - 2021
RT14	West Branch Root River Canal: 0 to 0.6 miles	4500	4	0.6	10	1996	13	1996 - 2012
RT15	West Branch Root River Canal: 0.6 to 3.9 miles	4500	4	3.2	4	1996	4	1996
RT16	West Branch Root River Canal: 7.1 to 9.3 miles	4500	3	2.1	5	1996	6	1996
RT17	Raymond Creek: 0 to 2.1 miles	4600	2	2.1	5	1996	5	1996
RT18	East Branch Root River Canal: 0 to 8.4 miles	4900	2	8.4	1	2019	2	2019 - 2020
RT19	East Branch Root River Canal: 8.4 to 9.5 miles	4900	2	1.2	4	1996	5	1996
RT20	Tess Corners Creek: 0 to 0.4 miles	6200	3	0.4	6	1996	6	1996
RT21	Unnamed Tributary to Crawfish Creek: 1.4 to 2.1 miles	3000341	1	0.6	2	2020	5	2020 - 2022
RT22	Scout Lake Inlet: 0 to 0.4 miles	5036992	1	0.4	--	--	39	1980 - 1981
RT23	Scout Lake Outlet: 0 to 0.4 miles	5036992	1	0.4	1	1981	73	1980 - 1981

Note: Chloride and specific conductance datasets shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: USEPA, MMSD, USGS, WDNR, and SEWRPC

Table 4.63
Percent of Measured Chloride and Specific Conductance Samples by Season at Assessment Reaches within the Root River Watershed: 1961-2022

Reach ID	Assessment Reach	Total Chloride Samples	Percent of Chloride Samples by Season				Total Specific Conductance Samples	Percent of Specific Conductance Samples by Season			
			Winter	Spring	Summer	Fall		Winter	Spring	Summer	Fall
RT01	Root River 0 to 5.2 miles	63	1.6	0.0	81.0	17.5	20	0.0	15.0	55.0	30.0
RT02	Root River: 5.2 to 7.4 miles	344	18.6	19.2	32.3	29.9	245	17.6	21.6	30.2	30.6
RT03	Root River: 11.5 to 13.7 miles	5	0.0	0.0	80.0	20.0	6	0.0	0.0	83.3	16.7
RT04	Root River: 17.1 to 25.8 miles	291	1.4	23.7	50.5	24.4	306	1.3	22.5	52.9	23.2
RT05	Root River: 25.8 to 34.3 miles	333	2.7	22.8	40.8	33.6	498	9.6	23.3	39.2	27.9
RT06	Root River: 35.8 to 41.2 miles	537	3.9	25.1	45.1	25.9	679	8.0	24.6	42.3	25.2
RT07	Root River: 41.2 to 43.7 miles	449	0.0	26.3	45.0	28.7	453	0.0	26.0	45.5	28.5
RT08	Hoods Creek: 0 to 6.9 miles	15	13.3	26.7	46.7	13.3	26	15.4	26.9	46.2	11.5
RT09	Hoods Creek: 6.9 to 8.9 miles	- -	- -	- -	- -	- -	1	0.0	0.0	0.0	100.0
RT10	Crawfish Creek: 0.5 to 1.7 miles	2	0.0	0.0	50.0	50.0	5	20.0	0.0	60.0	20.0
RT11	Husher Creek: 0 to 4.2 miles	5	0.0	0.0	80.0	20.0	12	0.0	8.3	66.7	25.0
RT12	Kilbournville Tributary: 0 to 2.8 miles	- -	- -	- -	- -	- -	1	0.0	0.0	100.0	0.0
RT13	Root River Canal: 0.8 to 5.7 miles	150	7.3	7.3	50.0	35.3	235	17.4	20.9	32.8	28.9
RT14	West Branch Root River Canal: 0 to 0.6 miles	10	0.0	0.0	80.0	20.0	13	0.0	0.0	84.6	15.4
RT15	West Branch Root River Canal: 0.6 to 3.9 miles	4	0.0	0.0	75.0	25.0	4	0.0	0.0	75.0	25.0
RT16	West Branch Root River Canal: 7.1 to 9.3 miles	5	0.0	0.0	80.0	20.0	6	0.0	0.0	83.3	16.7
RT17	Raymond Creek: 0 to 2.1 miles	5	0.0	0.0	80.0	20.0	5	0.0	0.0	80.0	20.0
RT18	East Branch Root River Canal: 0 to 8.4 miles	1	0.0	0.0	100.0	0.0	2	0.0	0.0	50.0	50.0
RT19	East Branch Root River Canal: 8.4 to 9.5 miles	4	0.0	0.0	100.0	0.0	5	0.0	0.0	100.0	0.0
RT20	Tess Corners Creek: 0 to 0.4 miles	6	0.0	0.0	66.7	33.3	6	0.0	0.0	66.7	33.3
RT21	Unnamed Tributary to Crawfish Creek: 1.4 to 2.1 miles	2	0.0	0.0	50.0	50.0	5	20.0	0.0	60.0	20.0
RT22	Scout Lake Inlet: 0 to 0.4 miles	- -	- -	- -	- -	- -	39	33.3	28.2	28.2	10.3
RT23	Scout Lake Outlet: 0 to 0.4 miles	1	100.0	0.0	0.0	0.0	73	31.5	19.2	24.7	24.7

Note: Seasons are defined as Winter (December through February), Spring (March through May), Summer (June through August), and Fall (September through November). Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps during the period of 1961 through 2022. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance. Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter.

Source: MMSD, WDNR, University of Wisconsin-Milwaukee, USGS, and SEWRPC

Table 4.64
Summary Statistics for Measured Chloride and Specific Conductance at Assessment Reaches within the Root River Watershed: 1961-2022

Reach ID	Assessment Reach	Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
		Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
RT01	Root River 0 to 5.2 miles	63	48	84	82	269	20	544	855	798	1,248
RT02	Root River: 5.2 to 7.4 miles	344	0	86	74	686	245	312	931	918	2,630
RT03	Root River: 11.5 to 13.7 miles	5	96	101	100	109	6	677	842	867	936
RT04	Root River: 17.1 to 25.8 miles	291	21	126	120	800	306	303	985	1,001	2,770
RT05	Root River: 25.8 to 34.3 miles	333	30	184	150	1,380	498	18	1,151	1,085	5,700
RT06	Root River: 35.8 to 41.2 miles	537	18	345	260	4,130	679	78	1,765	1,494	12,700
RT07	Root River: 41.2 to 43.7 miles	449	10	251	170	1,900	453	105	1,372	1,150	5,840
RT08	Hoods Creek: 0 to 6.9 miles	15	55	165	144	531	26	559	989	906	2,300
RT09	Hoods Creek: 6.9 to 8.9 miles	- -	- -	- -	- -	- -	1	1,692	1,692	1,692	1,692
RT10	Crawfish Creek: 0.5 to 1.7 miles	2	29	59	59	88	5	744	904	792	1,170
RT11	Husher Creek: 0 to 4.2 miles	5	87	99	92	133	12	641	878	879	1,100
RT12	Kilbournville Tributary: 0 to 2.8 miles	- -	- -	- -	- -	- -	1	719	719	719	719
RT13	Root River Canal: 0.8 to 5.7 miles	150	12	118	99	318	235	80	1,007	992	2,150
RT14	West Branch Root River Canal: 0 to 0.6 miles	10	57	111	103	181	13	718	1,070	1,031	1,774
RT15	West Branch Root River Canal: 0.6 to 3.9 miles	4	100	164	164	230	4	734	1,103	1,179	1,321
RT16	West Branch Root River Canal: 7.1 to 9.3 miles	5	61	80	78	99	6	669	828	873	943
RT17	Raymond Creek: 0 to 2.1 miles	5	74	103	92	149	5	683	801	808	890
RT18	East Branch Root River Canal: 0 to 8.4 miles	1	97	97	97	97	2	969	1,235	1,235	1,500
RT19	East Branch Root River Canal: 8.4 to 9.5 miles	4	42	44	43	45	5	892	947	940	1,014
RT20	Tess Corners Creek: 0 to 0.4 miles	6	78	102	97	149	6	605	709	703	841
RT21	Unnamed Tributary to Crawfish Creek:1.4 to 2.1 miles	2	59	110	110	160	5	1,170	2,348	2,540	3,610
RT22	Scout Lake Inlet: 0 to 0.4 miles	- -	- -	- -	- -	- -	39	79	470	440	2,000
RT23	Scout Lake Outlet: 0 to 0.4 miles	1	738	738	738	738	73	100	1,155	848	5,200

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, WDNR, University of Wisconsin-Milwaukee, USGS, and SEWRPC

Table 4.65
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Root River Watershed Full Record: 1961-2022

Reach ID	Assessment Reach	Total Cl Samples	Chloride Measurements Exceeding Concentration Thresholds (percent)						
			10 mg/l	35 mg/l	120 mg/l	230 mg/l	395 mg/l	757 mg/l	1,400 mg/l
RT01	Root River 0 to 5.2 miles	63	100	100	3.2	1.6	0.0	0.0	0.0
RT02	Root River: 5.2 to 7.4 miles	344	97.4	86	14.2	1.7	0.6	0.0	0.0
RT03	Root River: 11.5 to 13.7 miles	5	100	100	0.0	0.0	0.0	0.0	0.0
RT04	Root River: 17.1 to 25.8 miles	291	100	99.3	43.3	2.4	0.3	0.3	0.0
RT05	Root River: 25.8 to 34.3 miles	333	100	99.7	69.1	16.8	6	1.5	0.0
RT06	Root River: 35.8 to 41.2 miles	537	100	99.3	83.4	56.8	19.2	6.9	2.6
RT07	Root River: 41.2 to 43.7 miles	449	99.8	97.8	70.4	37.6	17.4	4	0.2
RT08	Hoods Creek: 0 to 6.9 miles	15	100	100	73.3	6.7	6.7	0.0	0.0
RT09	Hoods Creek: 6.9 to 8.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT10	Crawfish Creek: 0.5 to 1.7 miles	2	100	50	0.0	0.0	0.0	0.0	0.0
RT11	Husher Creek: 0 to 4.2 miles	5	100	100	20	0.0	0.0	0.0	0.0
RT12	Kilbournville Tributary: 0 to 2.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT13	Root River Canal: 0.8 to 5.7 miles	150	100	97.3	40.7	3.3	0.0	0.0	0.0
RT14	West Branch Root River Canal: 0 to 0.6 miles	10	100	100	40	0.0	0.0	0.0	0.0
RT15	West Branch Root River Canal: 0.6 to 3.9 miles	4	100	100	75	0.0	0.0	0.0	0.0
RT16	West Branch Root River Canal: 7.1 to 9.3 miles	5	100	100	0.0	0.0	0.0	0.0	0.0
RT17	Raymond Creek: 0 to 2.1 miles	5	100	100	20	0.0	0.0	0.0	0.0
RT18	East Branch Root River Canal: 0 to 8.4 miles	1	100	100	0.0	0.0	0.0	0.0	0.0
RT19	East Branch Root River Canal: 8.4 to 9.5 miles	4	100	100	0.0	0.0	0.0	0.0	0.0
RT20	Tess Corners Creek: 0 to 0.4 miles	6	100	100	16.7	0.0	0.0	0.0	0.0
RT21	Unnamed Tributary to Crawfish Creek: 1.4 to 2.1 miles	2	100	100	50	0.0	0.0	0.0	0.0
RT22	Scout Lake Inlet: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT23	Scout Lake Outlet: 0 to 0.4 miles	1	100	100	100	100	100	0.0	0.0

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the full period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, WDNR, University of Wisconsin-Milwaukee, USGS, and SEWRPC

Table 4.66
Summary Statistics for Recent Measured Chloride and Specific Conductance at Assessment Reaches within the Root River Watershed: 2013-2022

		Measured Chloride Concentration (mg/l)					Measured Specific Conductance (µS/cm)				
Reach ID	Assessment Reach	Samples	Minimum	Mean	Median	Maximum	Samples	Minimum	Mean	Median	Maximum
RT01	Root River 0 to 5.2 miles	2	124	197	197	269	12	557	938	1,000	1,248
RT02	Root River: 5.2 to 7.4 miles	37	21	134	111	686	36	312	900	868	2,630
RT03	Root River: 11.5 to 13.7 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT04	Root River: 17.1 to 25.8 miles	86	48	158	155	800	86	407	1,035	1,050	2,770
RT05	Root River: 25.8 to 34.3 miles	95	50	228	180	1,300	106	304	1,283	1,185	4,700
RT06	Root River: 35.8 to 41.2 miles	193	18	449	320	3,600	246	78	2,106	1,630	12,300
RT07	Root River: 41.2 to 43.7 miles	175	18	291	180	1,900	175	178	1,438	1,120	5,840
RT08	Hoods Creek: 0 to 6.9 miles	5	55	205	159	531	9	770	1,121	890	2,300
RT09	Hoods Creek: 6.9 to 8.9 miles	- -	- -	- -	- -	- -	1	1,692	1,692	1,692	1,692
RT10	Crawfish Creek: 0.5 to 1.7 miles	2	29	59	59	88	5	744	904	792	1,170
RT11	Husher Creek: 0 to 4.2 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT12	Kilbournville Tributary: 0 to 2.8 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT13	Root River Canal: 0.8 to 5.7 miles	28	12	90	73	318	28	240	788	809	1,686
RT14	West Branch Root River Canal: 0 to 0.6 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT15	West Branch Root River Canal: 0.6 to 3.9 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT16	West Branch Root River Canal: 7.1 to 9.3 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT17	Raymond Creek: 0 to 2.1 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT18	East Branch Root River Canal: 0 to 8.4 miles	1	97	97	97	97	2	969	1,235	1,235	1,500
RT19	East Branch Root River Canal: 8.4 to 9.5 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT20	Tess Corners Creek: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT21	Unnamed Tributary to Crawfish Creek: 1.4 to 2.1 miles	2	59	110	110	160	5	1,170	2,348	2,540	3,610
RT22	Scout Lake Inlet: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
RT23	Scout Lake Outlet: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Note: Summary statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, WDNR, University of Wisconsin-Milwaukee, and SEWRPC

Table 4.67
Percentage of Measurements in Which Chloride Concentration Exceeded Various Water Quality Thresholds in the Root River Watershed Recent Record: 2013-2022

			Chloride Measurements Exceeding Concentration Thresholds (percent)							
Reach ID	**Assessment Reach**	**Total Cl Samples**	**10 mg/l**	**35 mg/l**	**120 mg/l**	**230 mg/l**	**395 mg/l**	**757 mg/l**	**1,400 mg/l**
RT01	Root River 0 to 5.2 miles	2	100	100	100	50	0.0	0.0	0.0
RT02	Root River: 5.2 to 7.4 miles	37	100	91.9	37.8	8.1	2.7	0.0	0.0
RT03	Root River: 11.5 to 13.7 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT04	Root River: 17.1 to 25.8 miles	86	100	100	68.6	7	1.2	1.2	0.0
RT05	Root River: 25.8 to 34.3 miles	95	100	100	85.3	31.6	10.5	1.1	0.0
RT06	Root River: 35.8 to 41.2 miles	193	100	99.5	91.7	68.9	32.1	13	3.6
RT07	Root River: 41.2 to 43.7 miles	175	100	98.3	73.1	38.9	20.6	8.6	0.6
RT08	Hoods Creek: 0 to 6.9 miles	5	100	100	60	20	20	0.0	0.0
RT09	Hoods Creek: 6.9 to 8.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT10	Crawfish Creek: 0.5 to 1.7 miles	2	100	50	0.0	0.0	0.0	0.0	0.0
RT11	Husher Creek: 0 to 4.2 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT12	Kilbournville Tributary: 0 to 2.8 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT13	Root River Canal: 0.8 to 5.7 miles	28	100	89.3	17.9	3.6	0.0	0.0	0.0
RT14	West Branch Root River Canal: 0 to 0.6 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT15	West Branch Root River Canal: 0.6 to 3.9 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT16	West Branch Root River Canal: 7.1 to 9.3 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT17	Raymond Creek: 0 to 2.1 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT18	East Branch Root River Canal: 0 to 8.4 miles	1	100	100	0.0	0.0	0.0	0.0	0.0
RT19	East Branch Root River Canal: 8.4 to 9.5 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT20	Tess Corners Creek: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT21	Unnamed Tributary to Crawfish Creek: 1.4 to 2.1 miles	2	100	100	50	0.0	0.0	0.0	0.0
RT22	Scout Lake Inlet: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -
RT23	Scout Lake Outlet: 0 to 0.4 miles	- -	- -	- -	- -	- -	- -	- -	- -

Note: Statistics shown in red text represent assessment reaches that have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in that specific reach due to a small sample size or uneven distribution of samples throughout the seasons. Criteria for determining balanced and imbalanced datasets are detailed in the "Assessing Robustness and Balance of Assessment Reach Datasets" section, earlier in this Chapter. Assessment Reaches with no chloride samples during the recent period of record are included in this table to indicate sampling gaps. For assessment reaches with limited or no chloride data, specific conductance measurements may be used as a general indicator of chloride conditions. The remaining stream miles present in the watershed that do not appear in this table have not been sampled for chloride or specific conductance.

Source: MMSD, WDNR, University of Wisconsin-Milwaukee, and SEWRPC

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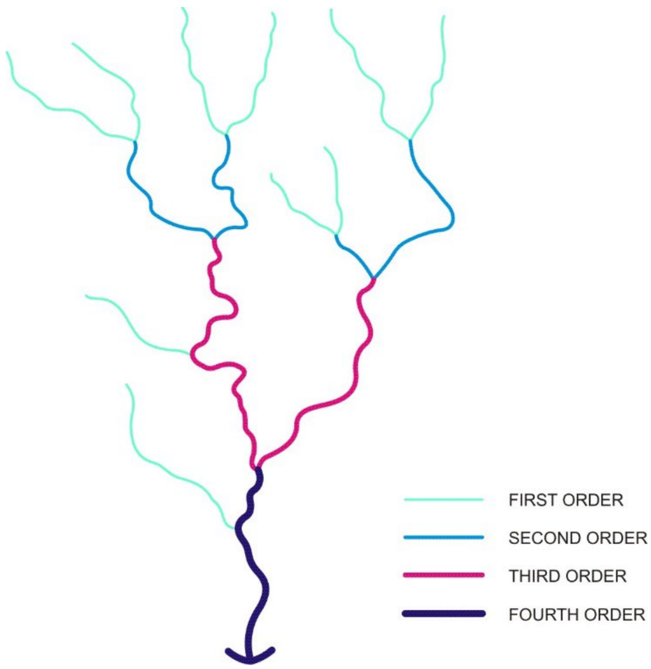
CHLORIDE CONDITIONS AND TRENDS IN SOUTHEASTERN WISCONSIN

Chapter 4

CHLORIDE CONDITIONS AND TRENDS: RIVERS AND STREAMS

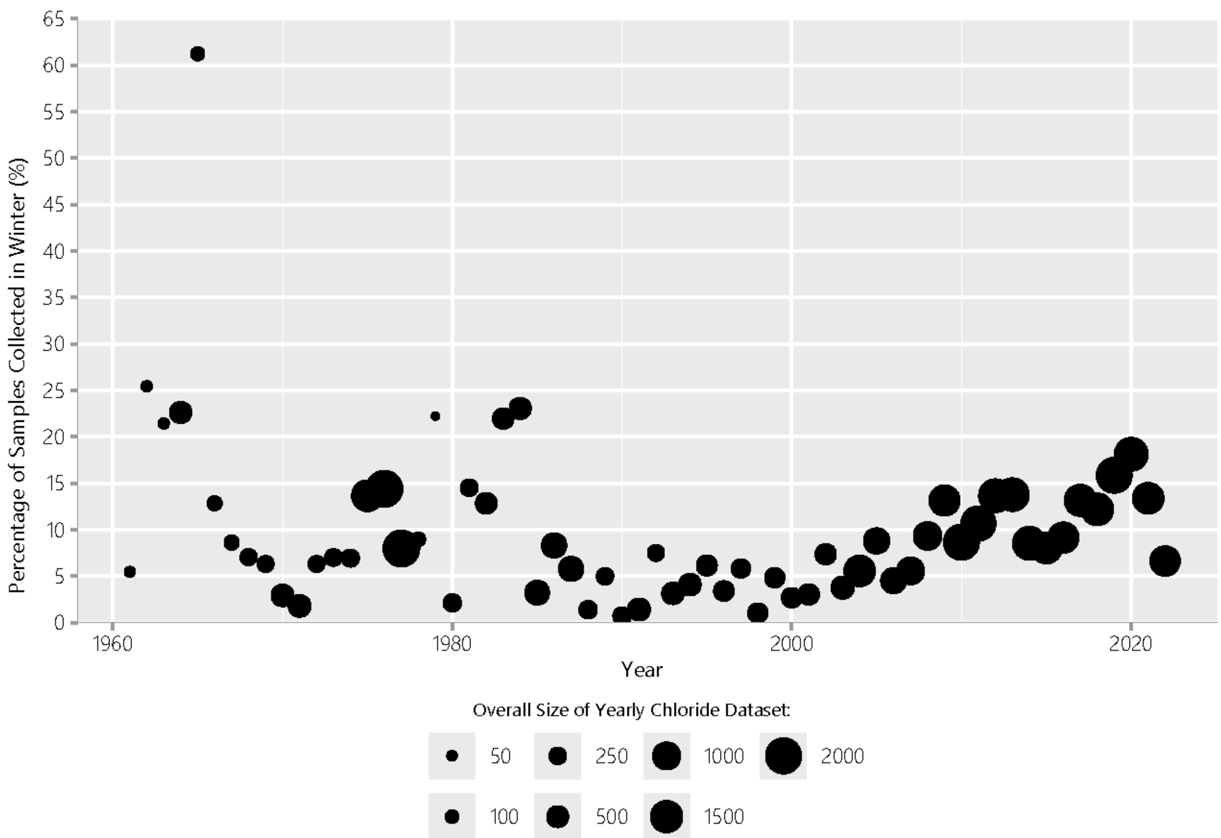
FIGURES

Figure 4.1
Typical Stream Network Patterns Based on Strahler's Stream Order Classification System



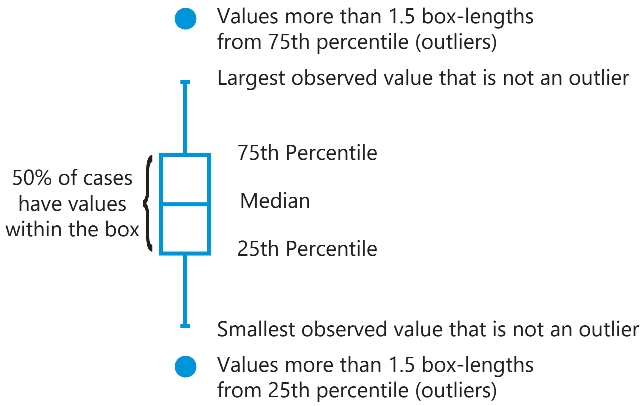
Source: SEWRPC

Figure 4.2
Percentage of Annual Chloride Samples that Were Collected in Winter: 1961-2022



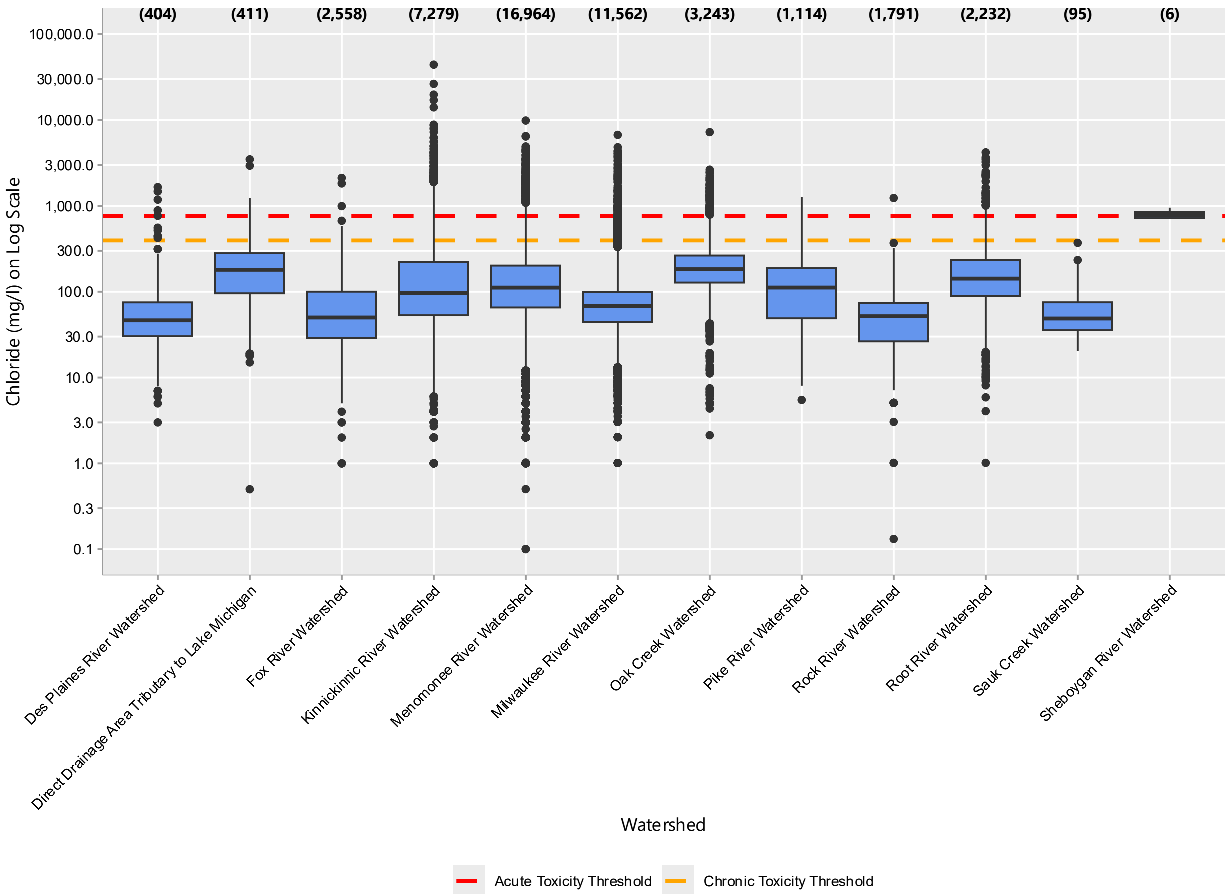
Source: SEWRPC.

Figure 4.3
Explanation of Symbols in Box Plot Figures



Source: SEWRPC

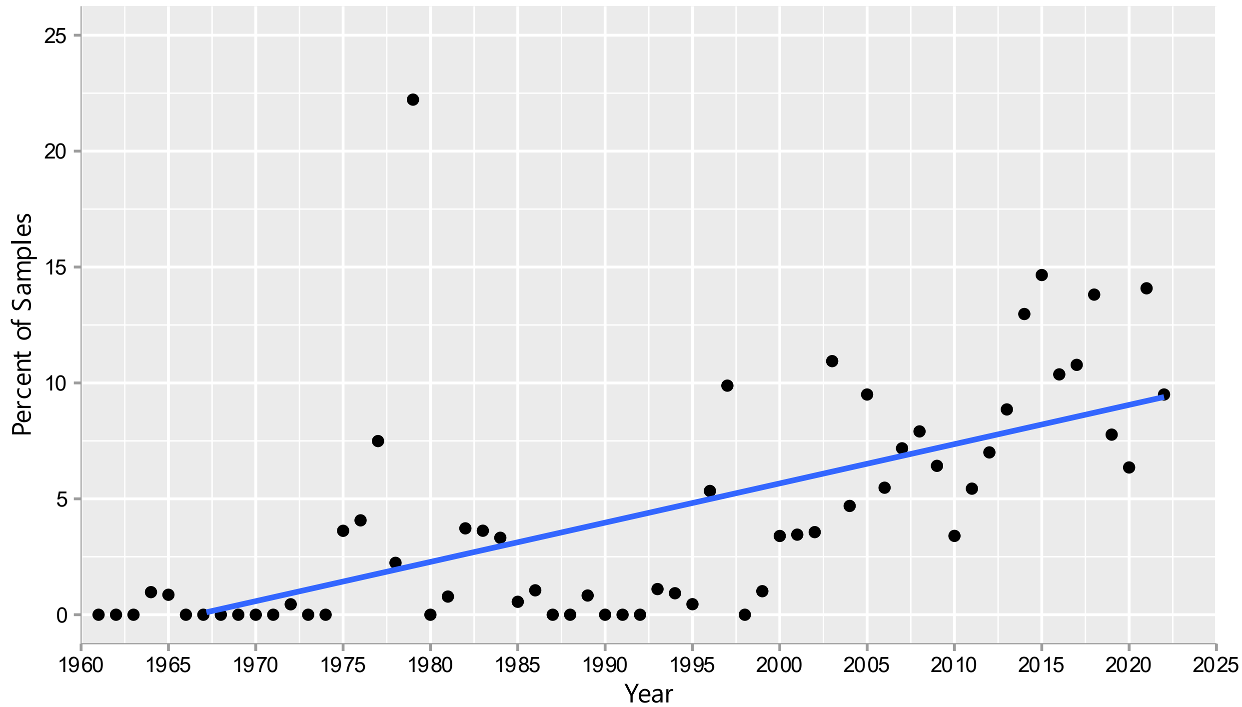
Figure 4.4
Distribution of Chloride Concentrations Among All Samples by Watershed: 1961-2022



Note: This figure includes all chloride samples collected during the full period of record. The numbers in parentheses above each box plot represents the number of chloride samples collected in each watershed.

Source: SEWRPC.

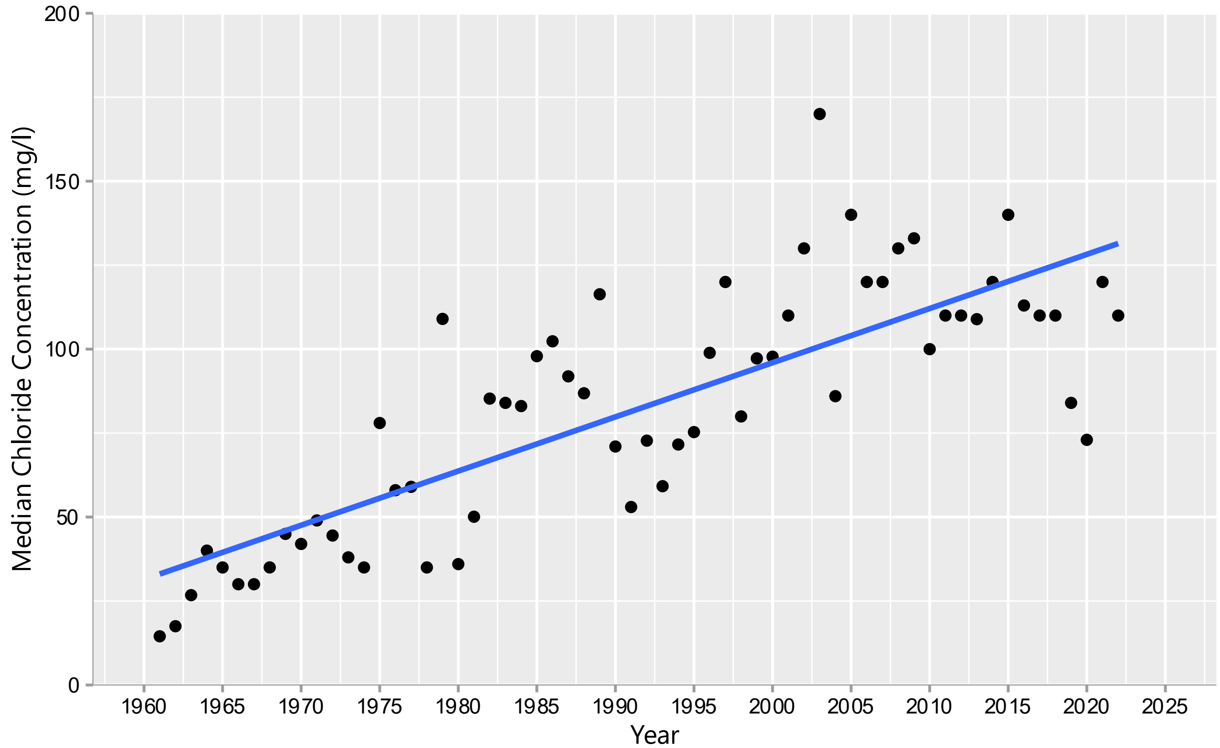
Figure 4.5
Percent of All Samples with Chloride Concentrations Exceeding the Chronic Toxicity Standard: 1961-2022



Note: This figure represents all chloride samples collected during the full period of record.

Source: SEWRPC.

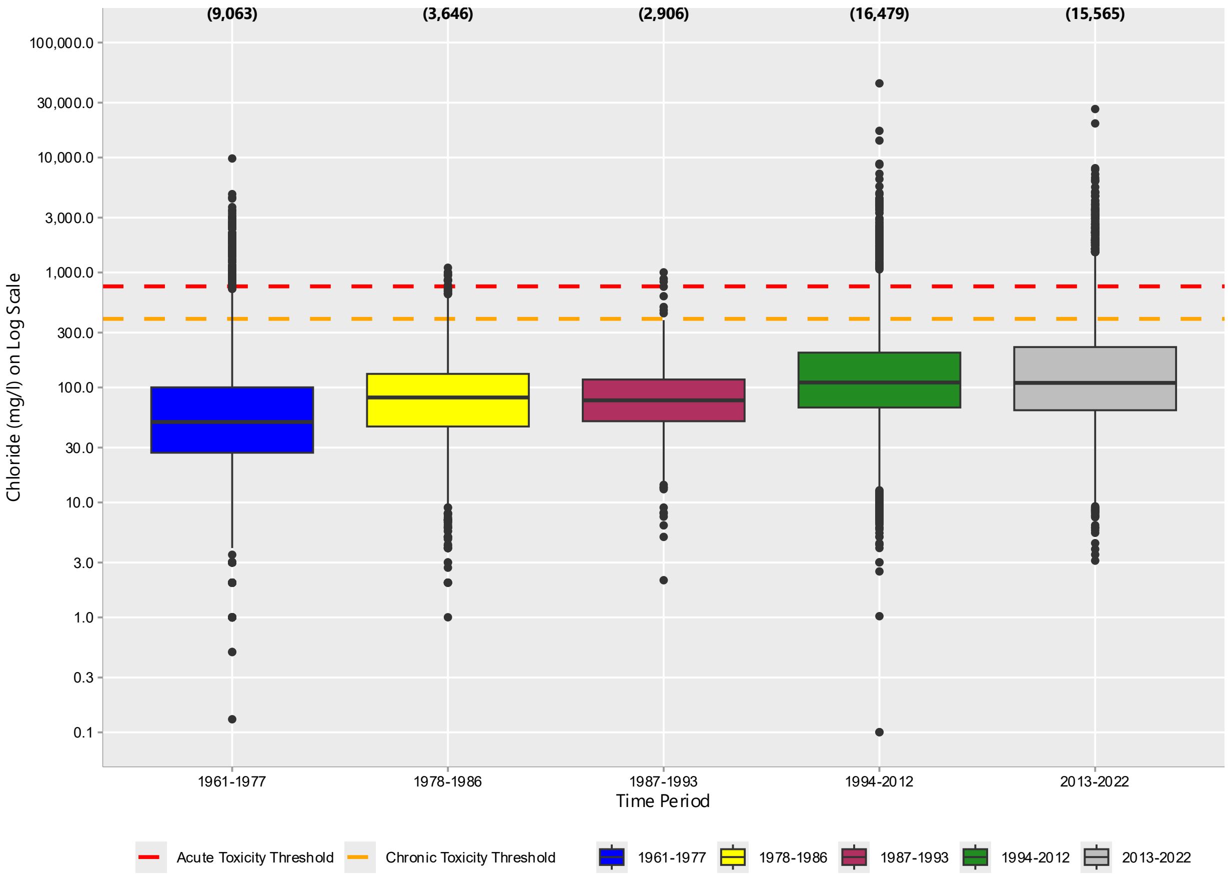
Figure 4.6
Trend in Yearly Median Chloride Concentrations in the Study Area for the Full Period of Record: 1961-2022



Note: This figure represents all chloride samples collected during the full period of record.

Source: SEWRPC.

Figure 4.7
Distribution of All Chloride Samples by Time Period for the Study Area: 1961-2022



Note: This figure represents all chloride samples collected during the full period of record. The number in parentheses above each box plot represents the number of chloride samples collected in the study area during that time period.

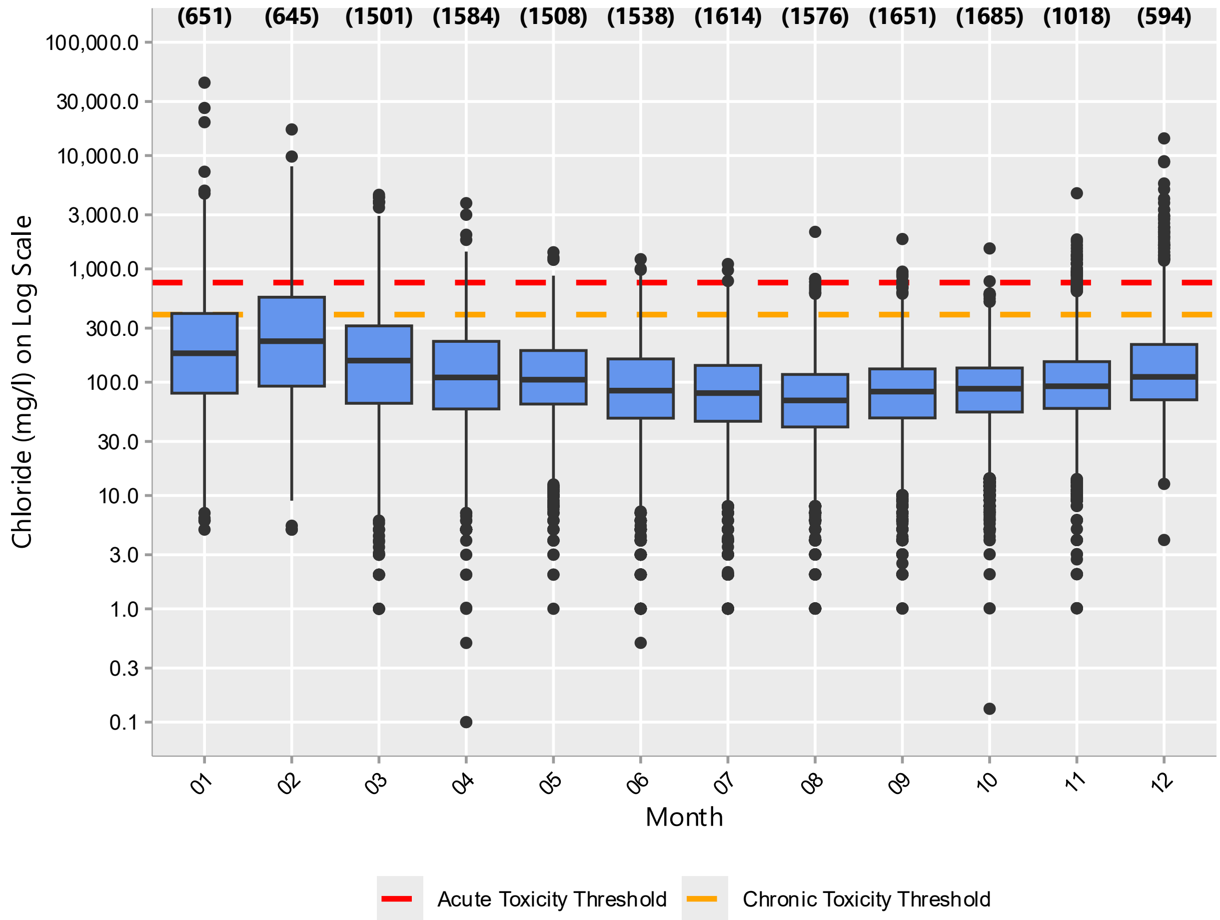
Source: SEWRPC.

Figure 4.8
Trends in Chloride Concentration by Season Among All Samples Collected During the Full Period of Record: 1961-2022

Note: This figure represents all chloride samples collected during the full period of record.

Source: SEWRPC.

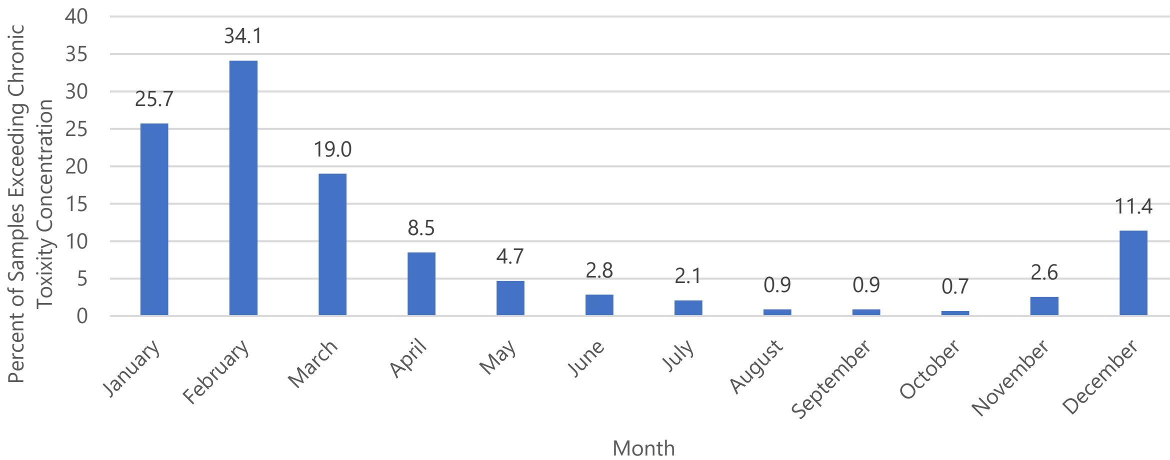
Figure 4.9
Distribution of Chloride Concentrations by Month for All Samples Collected During the Full Period of Record: 1961-2022



Note: This figure represents all chloride samples collected during the full period of record. The number in parentheses above each box plot represents the number of samples collected for each respective month.

Source: SEWRPC.

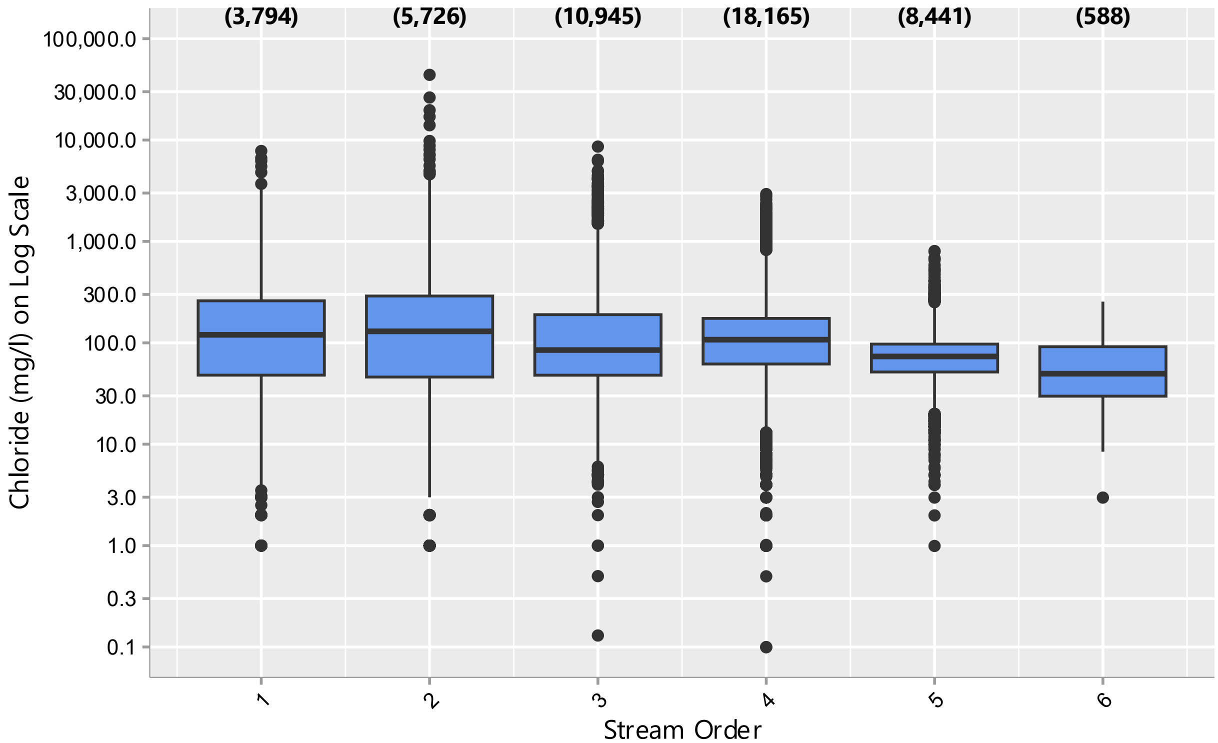
Figure 4.10
Percent of Chloride Samples Exceeding Chronic Toxicity Concentration Among All Samples Collected During the Full Period of Record: 1961-2022



Note: This dataset represents all chloride samples collected during the full period of record. Many of the samples represented in this figure that exceeded the State chronic toxicity threshold were collected prior to the establishment of the chloride toxicity criterion.

Source: SEWRPC.

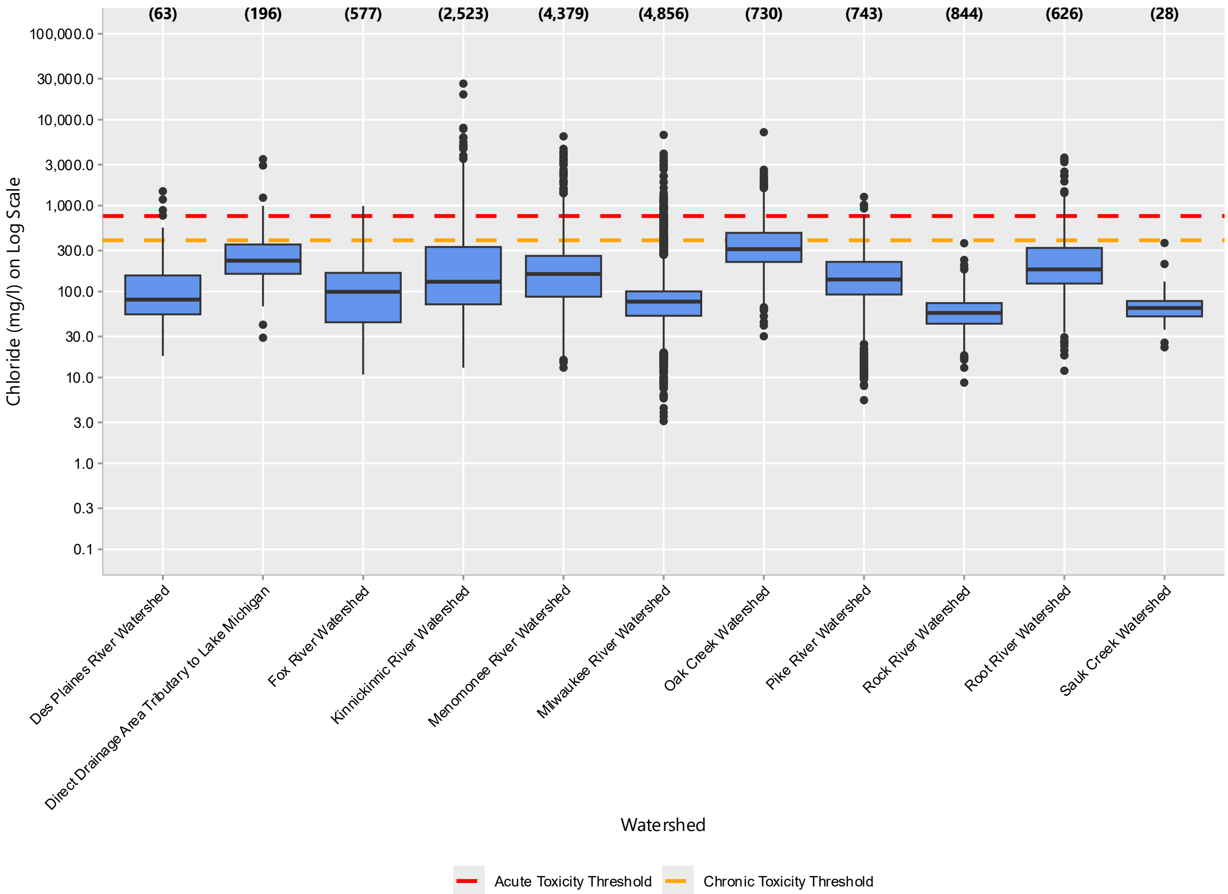
Figure 4.11
Distribution of Chloride Concentration by Stream Order for All Samples Collected During the Full Period of Record: 1961-2022



Note: This figure represents all chloride samples collected during the full period of record. The number in parentheses above each box plot represents the number of chloride samples collected in streams of that order.

Source: SEWRPC.

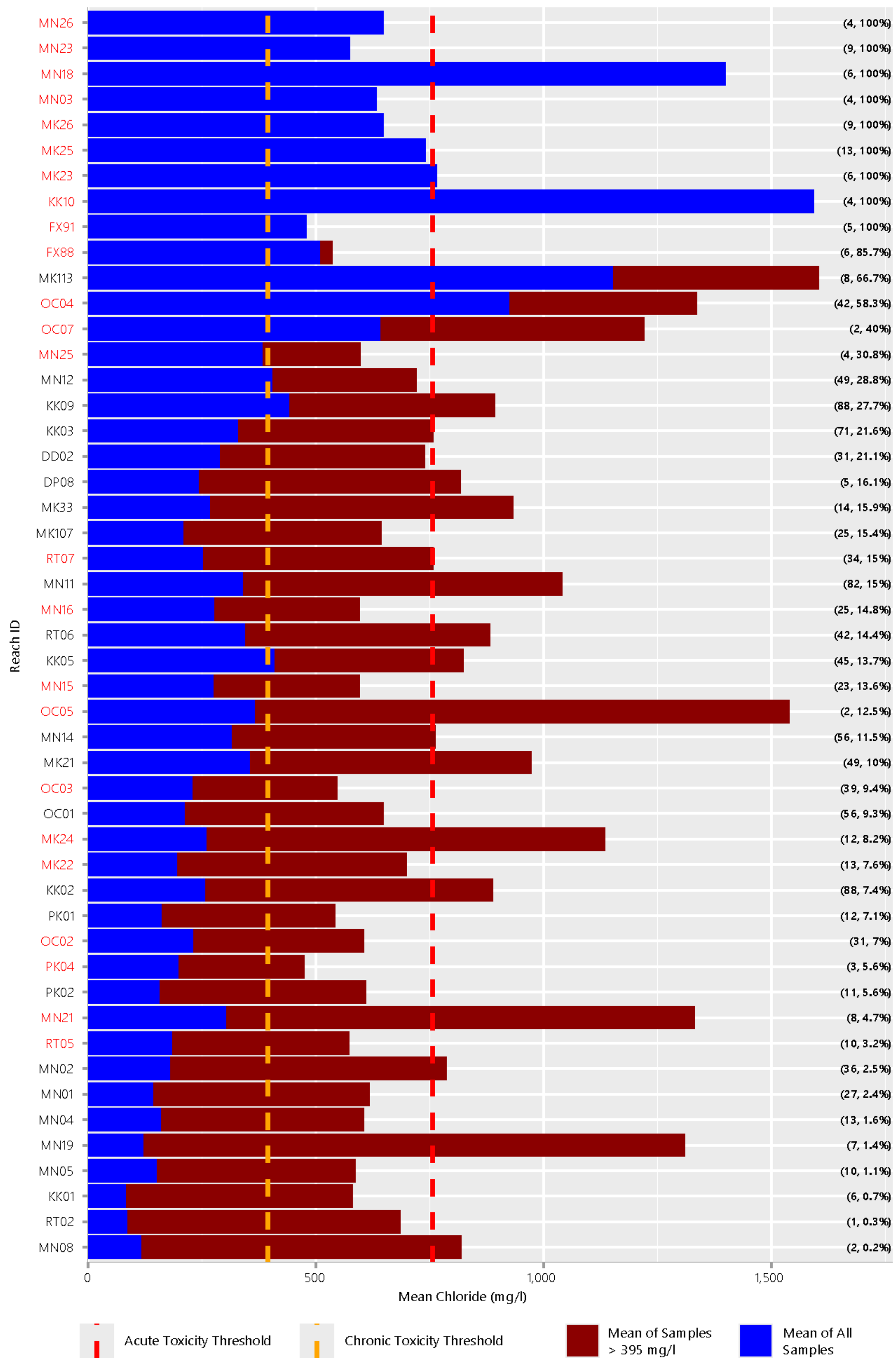
Figure 4.12
Distribution of Chloride Concentration by Watershed for All Samples Collected During the Recent Period of Record: 2013-2022



Note: This figure represents all chloride samples collected during the recent period of record. The number in parentheses above each box plot represents the number of chloride samples collected within each watershed during the recent period of record. The Sheboygan River watershed did not have any recent chloride samples collected and therefore does not appear on this figure.

Source: SEWRPC.

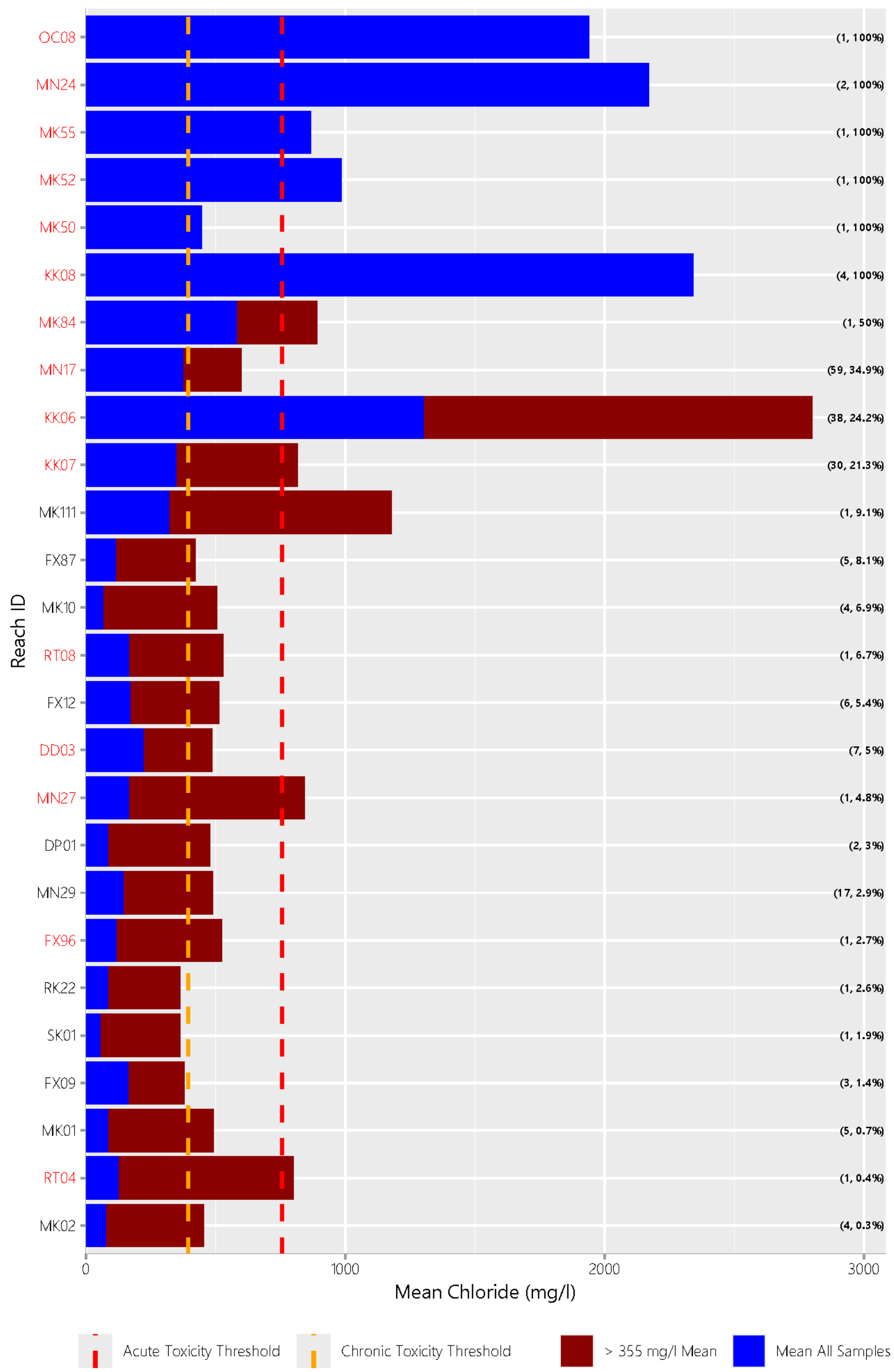
Figure 4.13
Recent Mean Chloride Concentrations for Assessment Reaches Within Streams Listed as Impaired for Chronic Toxicity



Note: Values in parentheses on the right side of the figure indicate the number of days with samples above the chronic threshold during the recent period of record and the percent of sampled days with measurements above the chronic threshold. This figure includes assessment reaches with both balanced and imbalanced datasets. Assessment reaches with imbalanced datasets are shown in red text.

Source: SEWRPC.

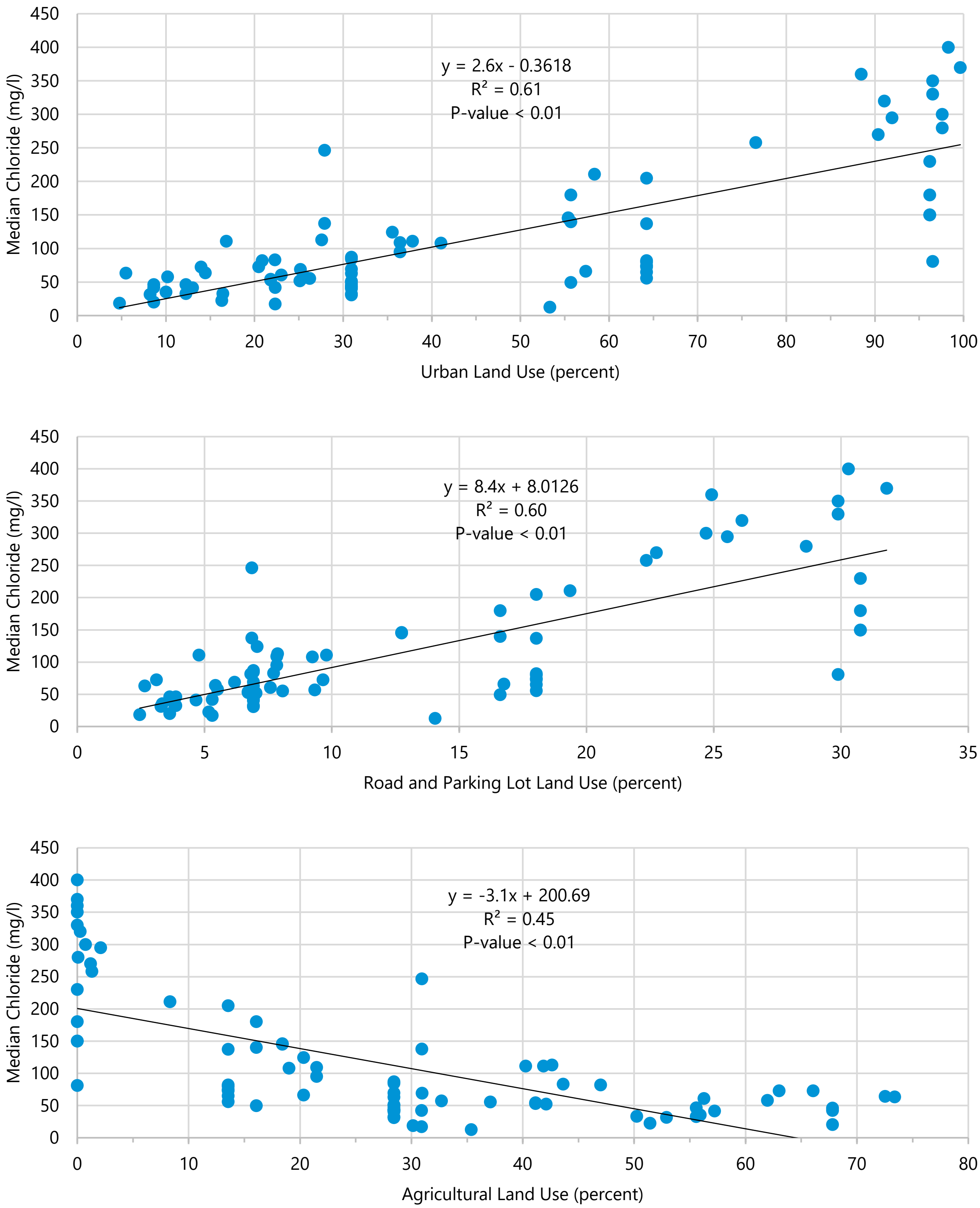
Figure 4.14
Recent Mean Chloride Concentrations for Assessment Reaches Within Streams Considered to be High Risk for Chronic Impairments



Note: Values in parentheses on the right side of the figure indicate the number of days with samples within 10 percent of the chronic toxicity threshold (355 mg/l) during the recent period of record and the percent of sampled days with measurements above 355 mg/l. This figure includes assessment reaches with both balanced and imbalanced datasets. Assessment reaches with imbalanced datasets are shown in red text.

Source: SEWRPC.

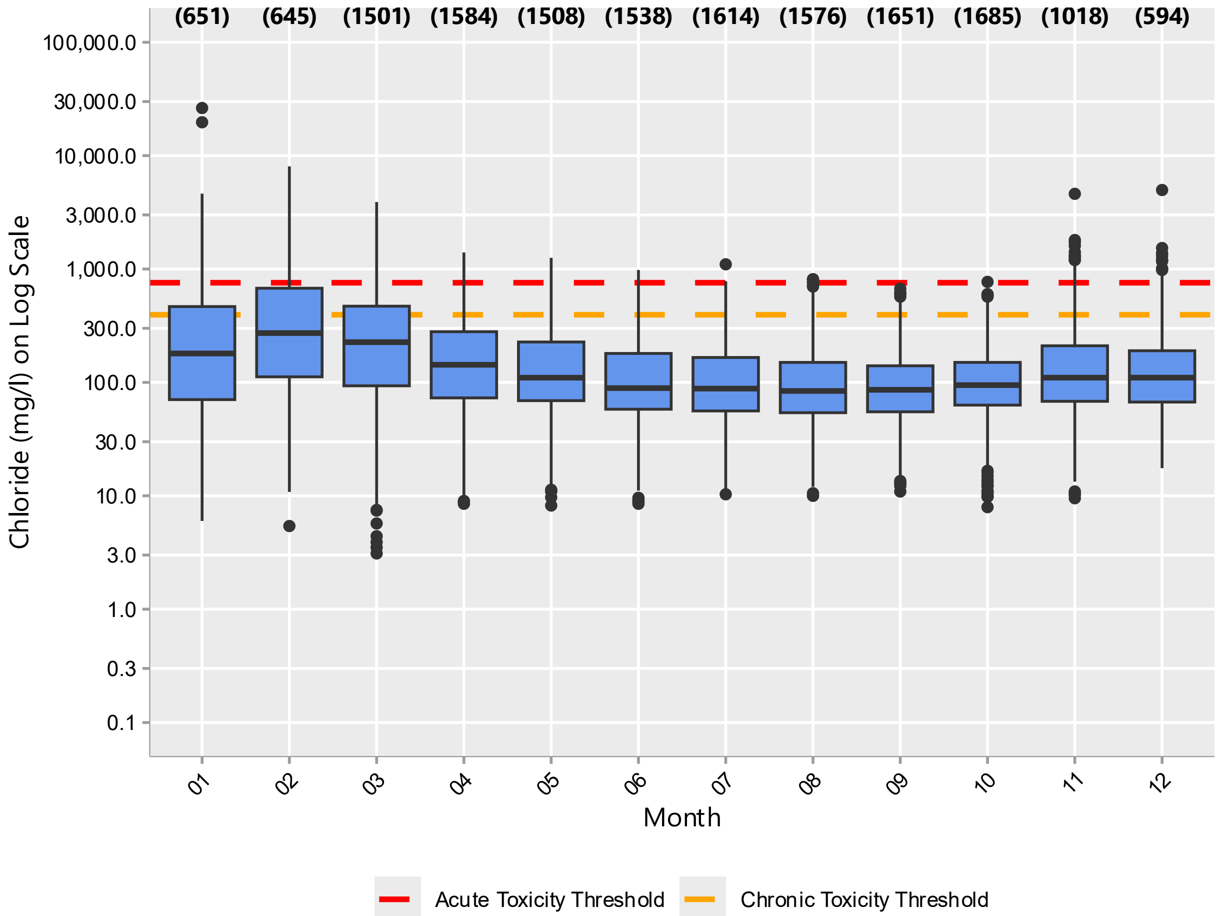
Figure 4.15
Relationships Between Subwatershed Land Use and Median Chloride Concentration at Balanced Assessment Reaches During the Recent Period of Record: 2013 through 2022



Note: All three plots have different x-axis scales to better fit the maximum amounts of land use observed within the subwatersheds for each category. Data points represent assessment reaches determined to have balanced datasets for the recent period of record (2013 through 2022). The amount of each land use category represents 2015 conditions based on the subwatershed for each assessment reach.

Source: SEWRPC

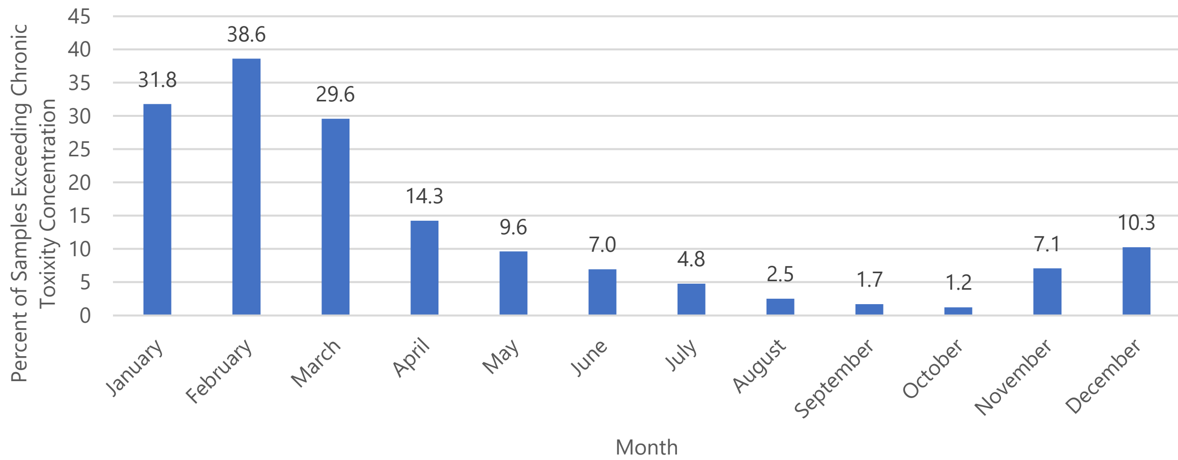
Figure 4.16
Distribution of Chloride Concentrations by Month for All Samples Collected During the Recent Period of Record: 2013-2022



Note: This figure represents all chloride samples collected during the recent period of record. The number in parentheses above each box plot represents the number of samples collected for each respective month.

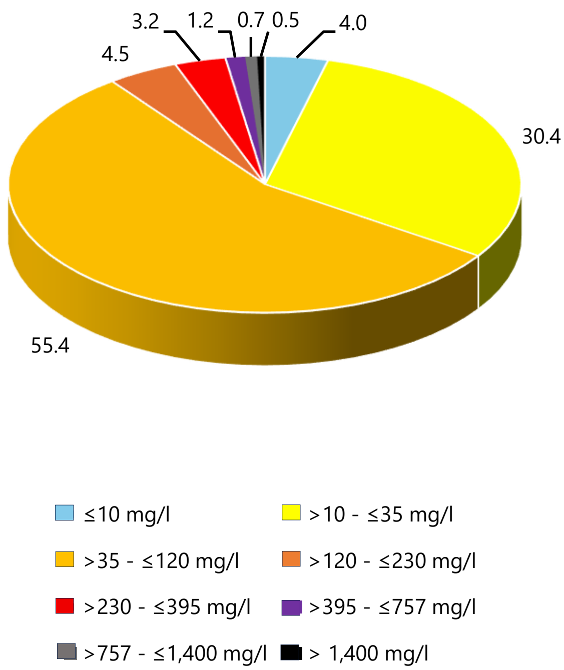
Source: SEWRPC.

Figure 4.17
Percent of All Recent Chloride Samples Exceeding Chronic Toxicity Concentration: 2013 through 2022



Source: SEWRPC

Figure 4.18
Percent of Chloride Samples Collected in the Des Plaines River Watershed Within Various Thresholds of Water Quality: 1961-2022

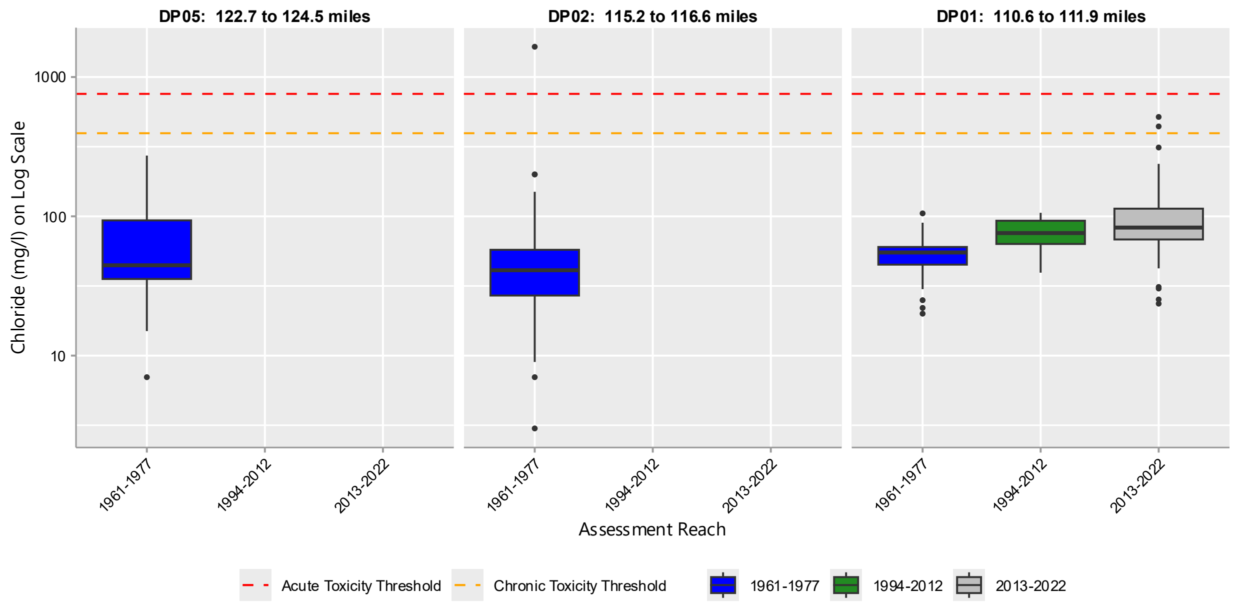


Note: There were 404 chloride samples collected in the Des Plaines River watershed during the full period of record. For descriptions of thresholds, see Table 2.Tresholds in Chapter 2 of this Report.

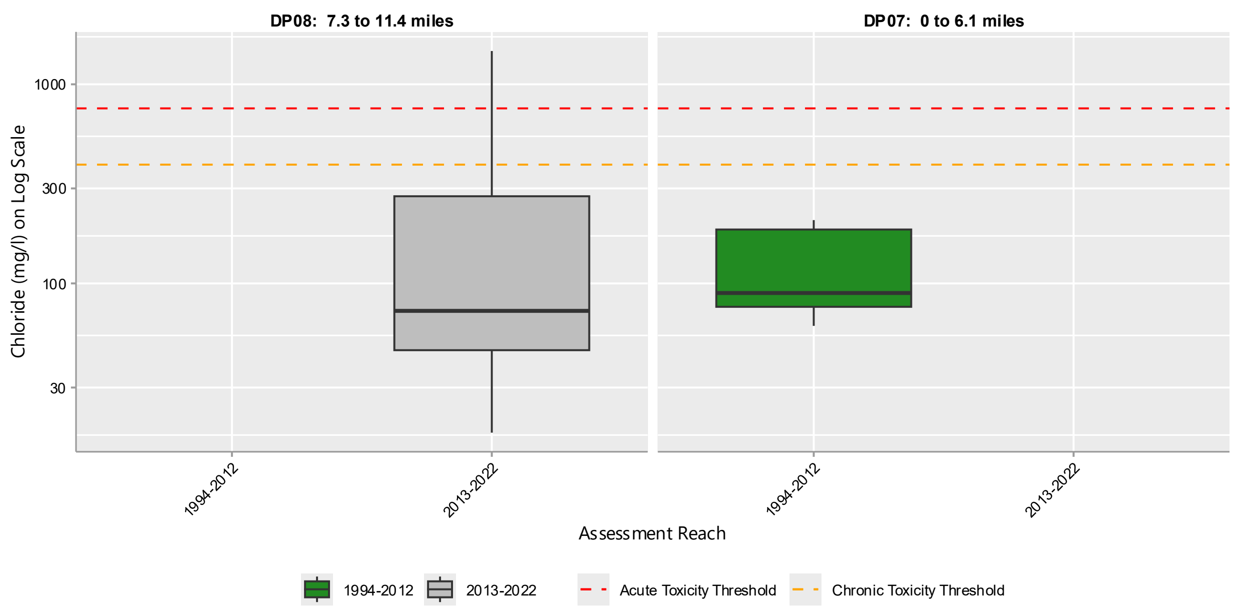
Source: SEWRPC

Figure 4.19
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches on the Des Plaines River and Kilbourn Road Ditch: 1961-2022

Des Plaines River (mainstem)



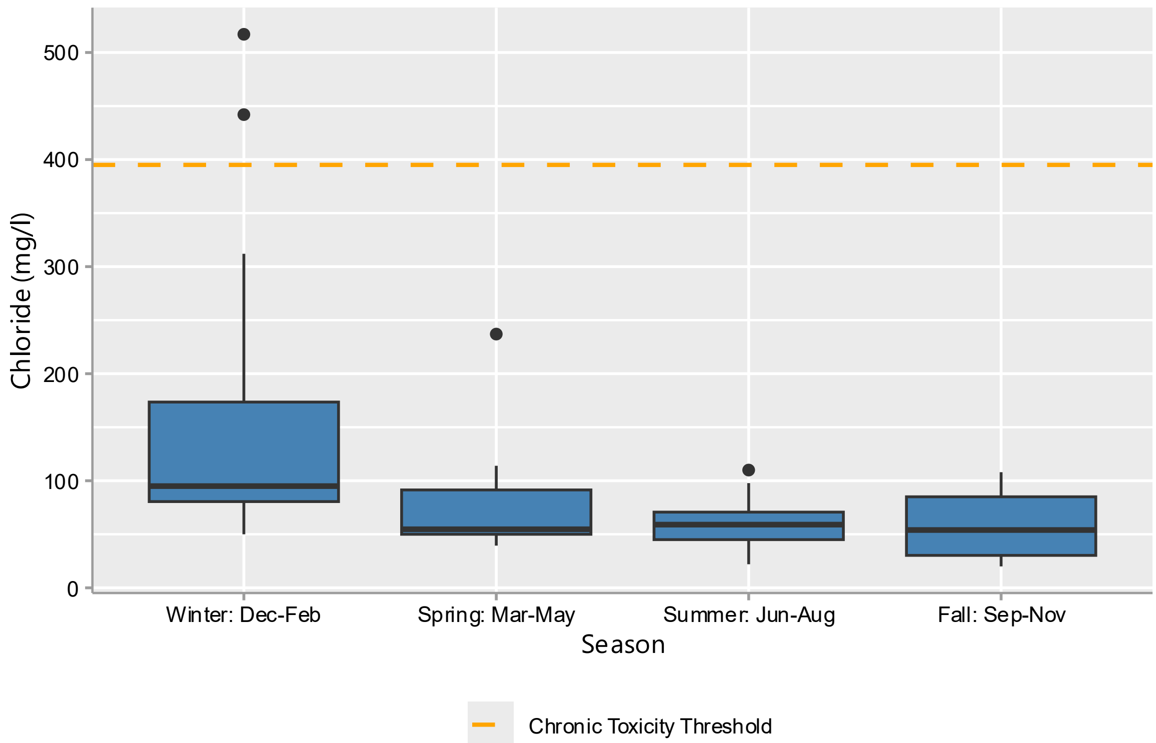
Kilbourn Road Ditch



Note: This figure represents all chloride data collected from the Des Plaines River and Kilbourn Road Ditch in the Des Plaines River watershed. Assessment reaches appear from upstream to downstream (left to right). The following assessment reaches have imbalanced datasets: Des Plaines River reaches DP05 and DP02; Kilbourn Road Ditch reaches DP08 and DP07. Imbalanced datasets may not fairly represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons. Datasets for reaches DP05 and DP07 do not contain any chloride samples collected in winter.

Source: WDNR, USGS, and SEWRPC

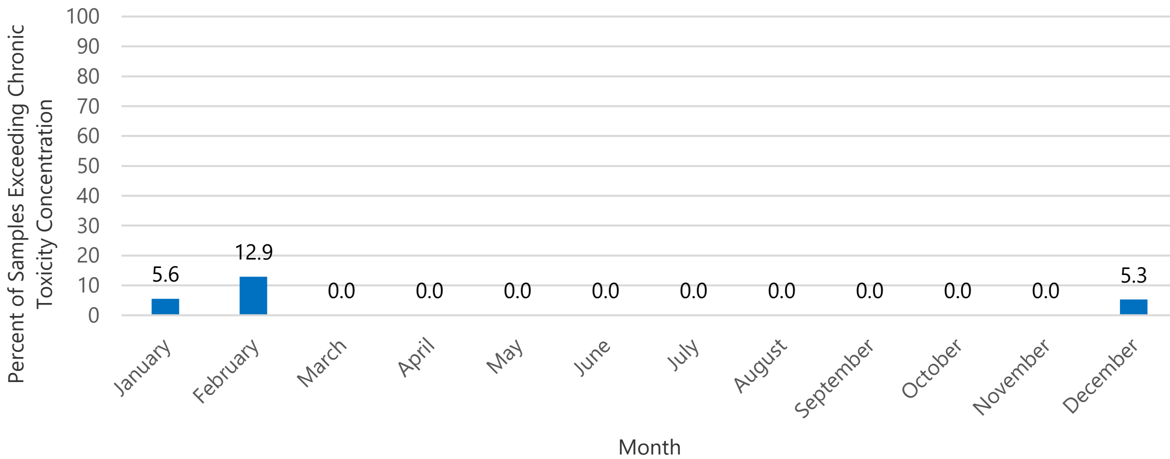
Figure 4.20
Chloride Concentrations by Season for Des Plaines River Mainstem Assessment Reach DP01: 1961-2022



Note: This figure includes all chloride data over the full period of record for mainstem Des Plaines River assessment reach DPO1, which is the only reach with a balanced full-period dataset in the watershed. Seasons include winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

Source: WDNR and SEWRPC.

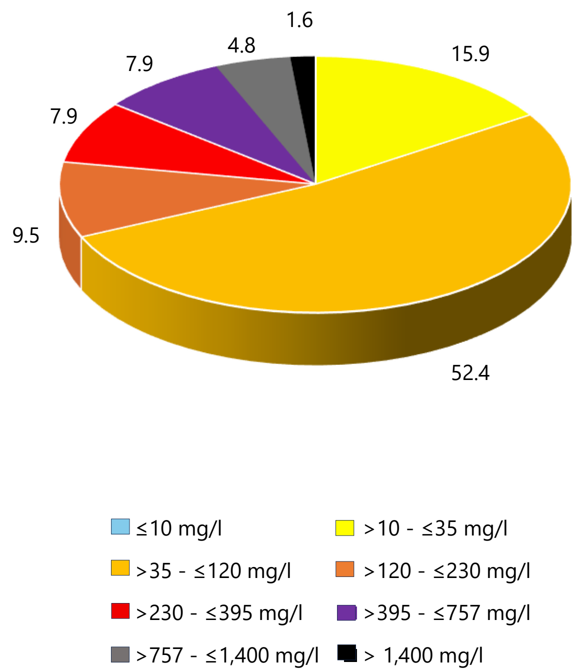
Figure 4.21
Percent of Chloride Samples Exceeding the Chronic Toxicity Threshold in the Des Plaines River Watershed: 1961-2022



Note: This dataset represents all 404 chloride samples collected in the Des Plaines River watershed during the full period of record. One of the samples represented in this figure that exceeded the State chronic toxicity concentration (395 mg/l) was collected prior to the establishment of the chloride toxicity criterion.

Source: SEWRPC

Figure 4.22
Percent of Recent Chloride Samples Collected in the Des Plaines River Watershed Within Various Thresholds of Water Quality: 2013-2022

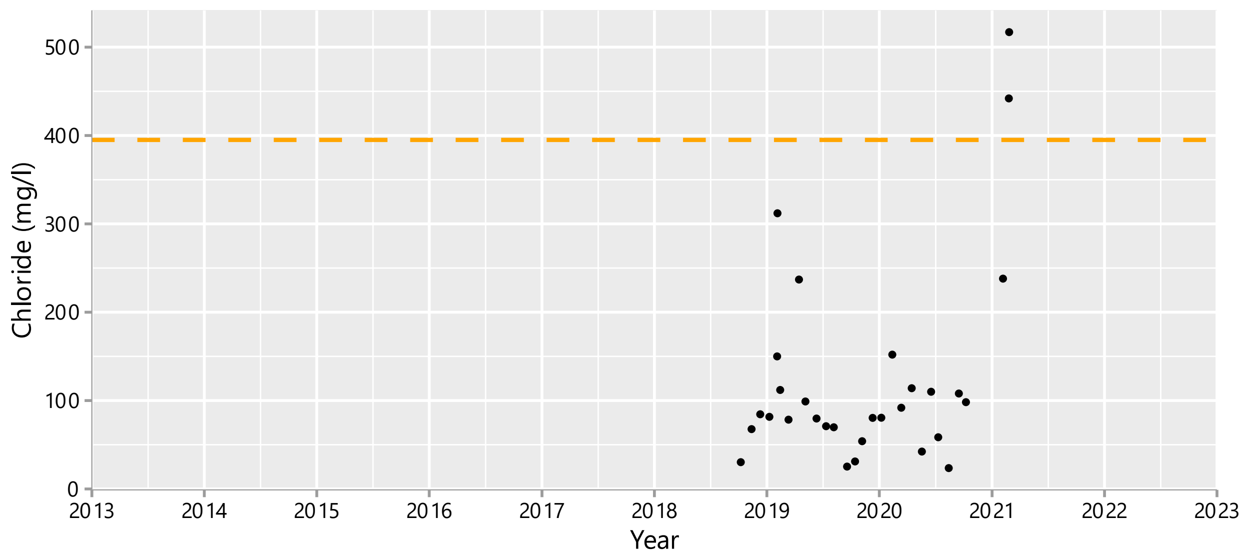


Note There were 63 chloride samples collected in the Des Plaines River watershed during the recent period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

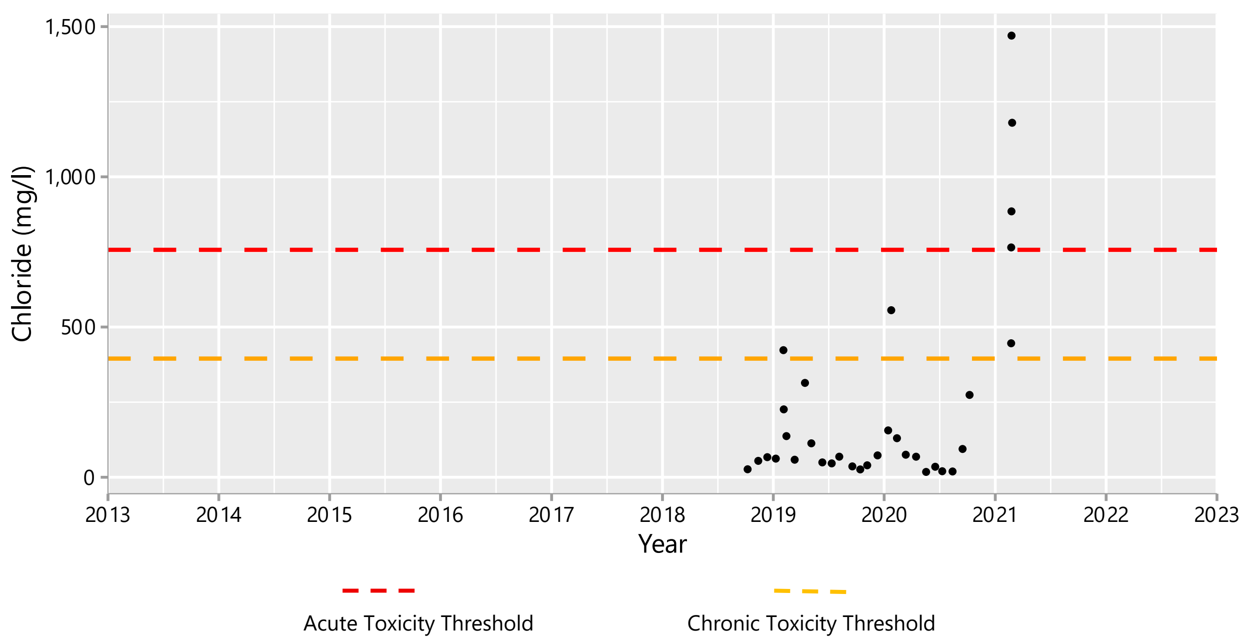
Source: SEWRPC.

Figure 4.23
Trends in Recent Chloride Concentrations for Des Plaines River and Kilbourn Road Ditch Assessment Reaches with Balanced Datasets: 2013-2022

DP01 (Des Plaines River: 110.6 to 111.9 miles)



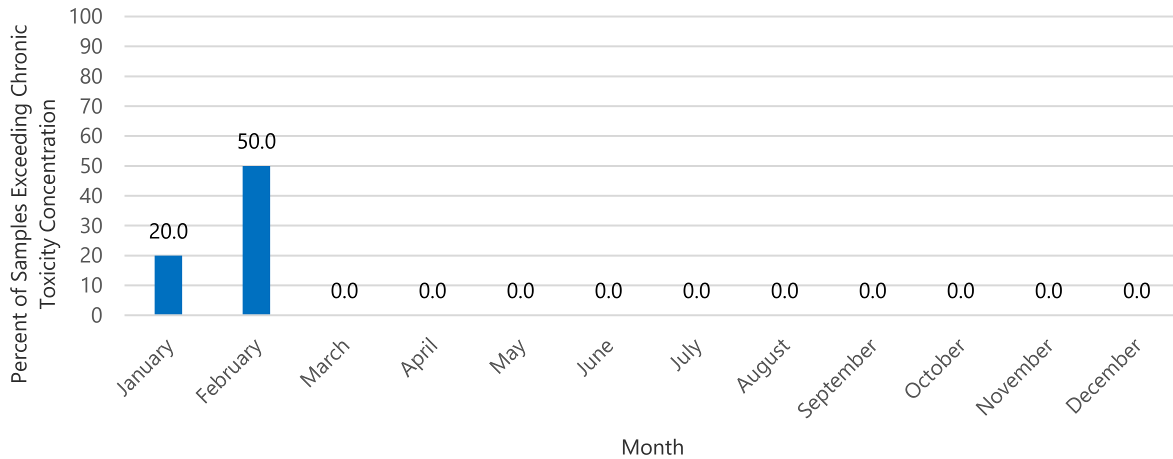
DP08 (Kilbourn Road Ditch: 7.3 to 11.4 miles)



Note: This figure includes all chloride data over the recent period of record for assessment reaches that have balanced datasets in the Des Plaines River watershed. Scales are unique for each assessment reach to best fit the observed data. There were no statistically significant trends found in Des Plaines River watershed assessment reaches over the recent period of record.

Source: SEWRPC.

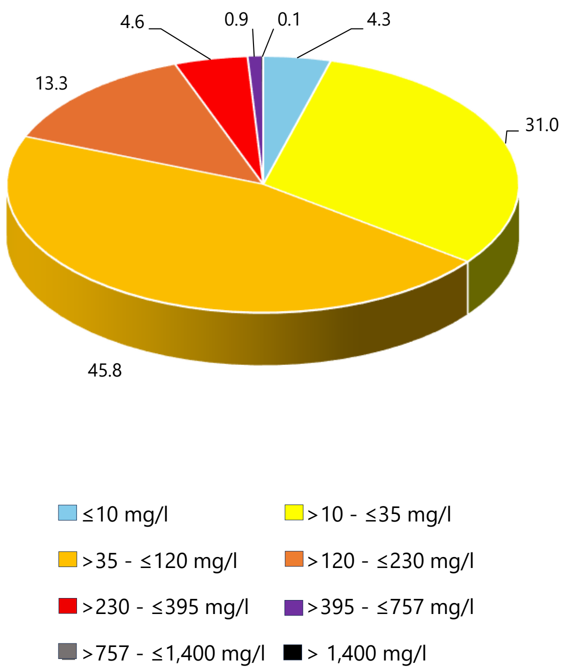
Figure 4.24
Percent of Recent Chloride Samples Exceeding the Chronic Toxicity Threshold in the Des Plaines River Watershed: 2013-2022



Note: This dataset represents all 63 chloride samples collected in the Des Plaines River watershed during the recent period of record.

Source: SEWRPC

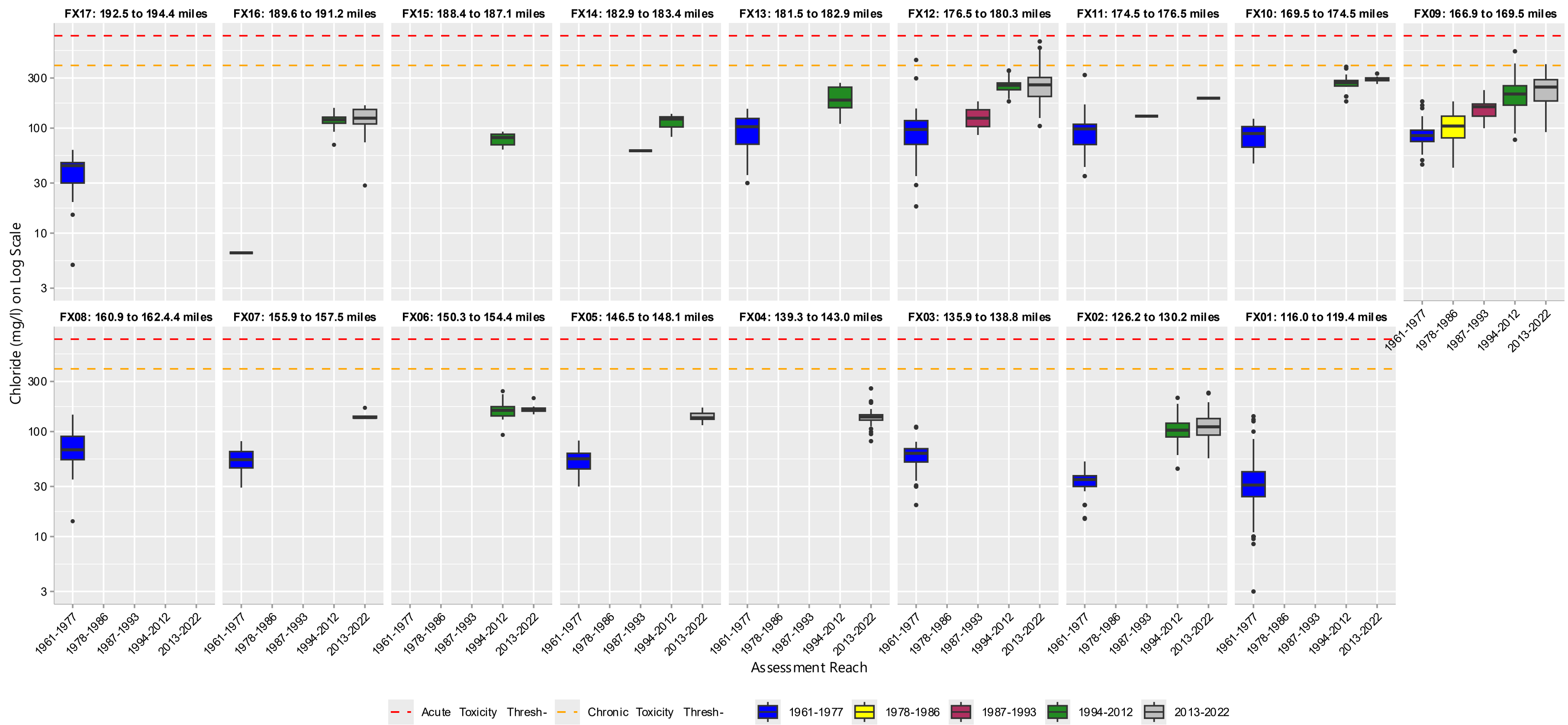
Figure 4.25
Percent of Chloride Samples Collected in the Fox River Watershed Within Various Thresholds of Water Quality: 1961-2022



Note: There were 2,558 chloride samples collected in the Fox River watershed during the full period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC.

Figure 4.26
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches Along the Mainstem of the Fox River: 1961-2022



Note: This figure represents all chloride data collected from the Fox River mainstem. Assessment reaches appear from upstream to downstream (left to right top, then left to right bottom). Fox River reaches FX01, FX03, FX04, FX05, FX06, FX08, FX10, FX13, FX14, FX15, and FX17 have imbalanced datasets that may not fairly represent chloride conditions in those reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

Source: WDNR, USGS, USEPA, Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, and SEWRPC

Figure 4.27
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches on Major Tributaries to the Fox River: 1961-2022

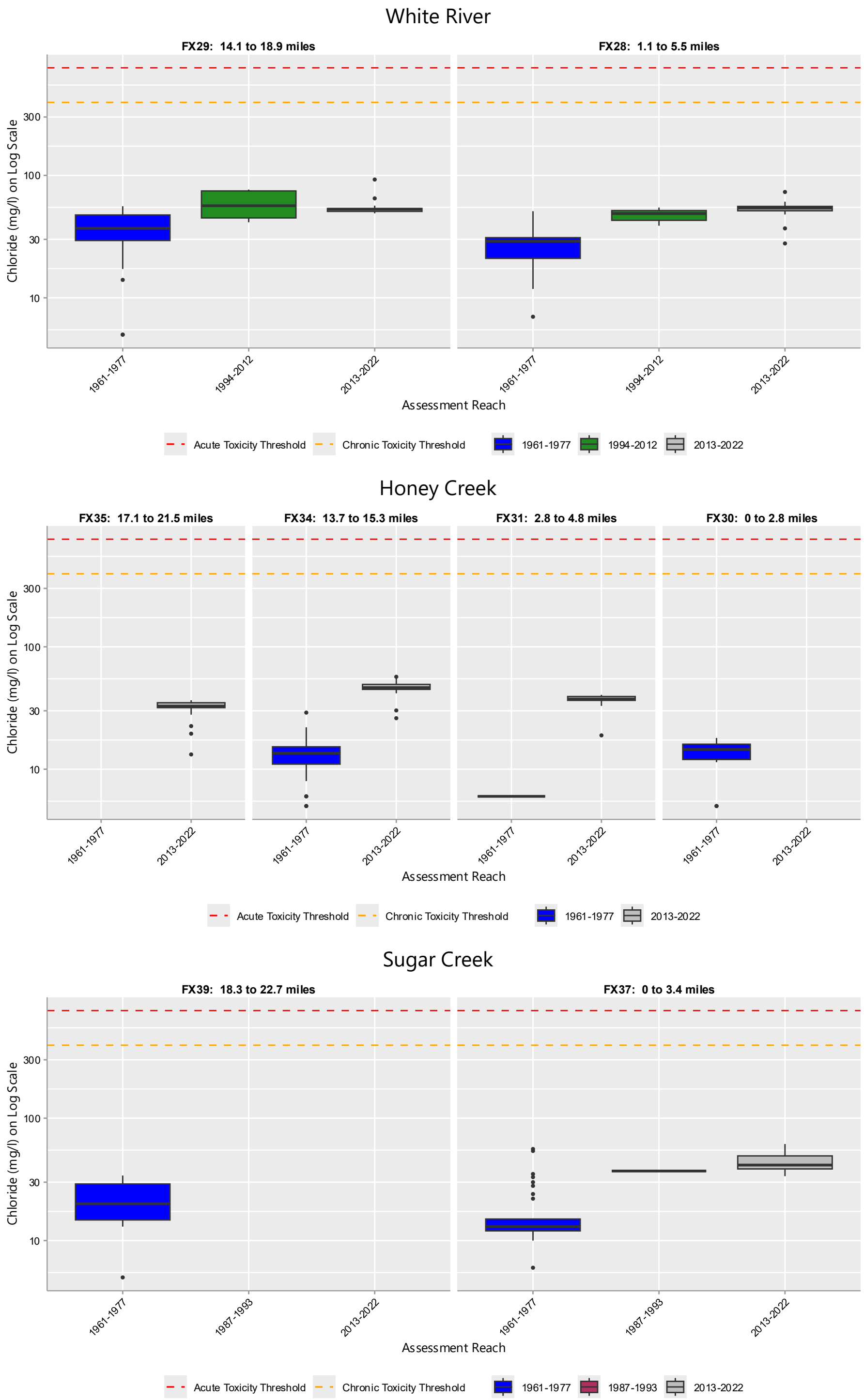
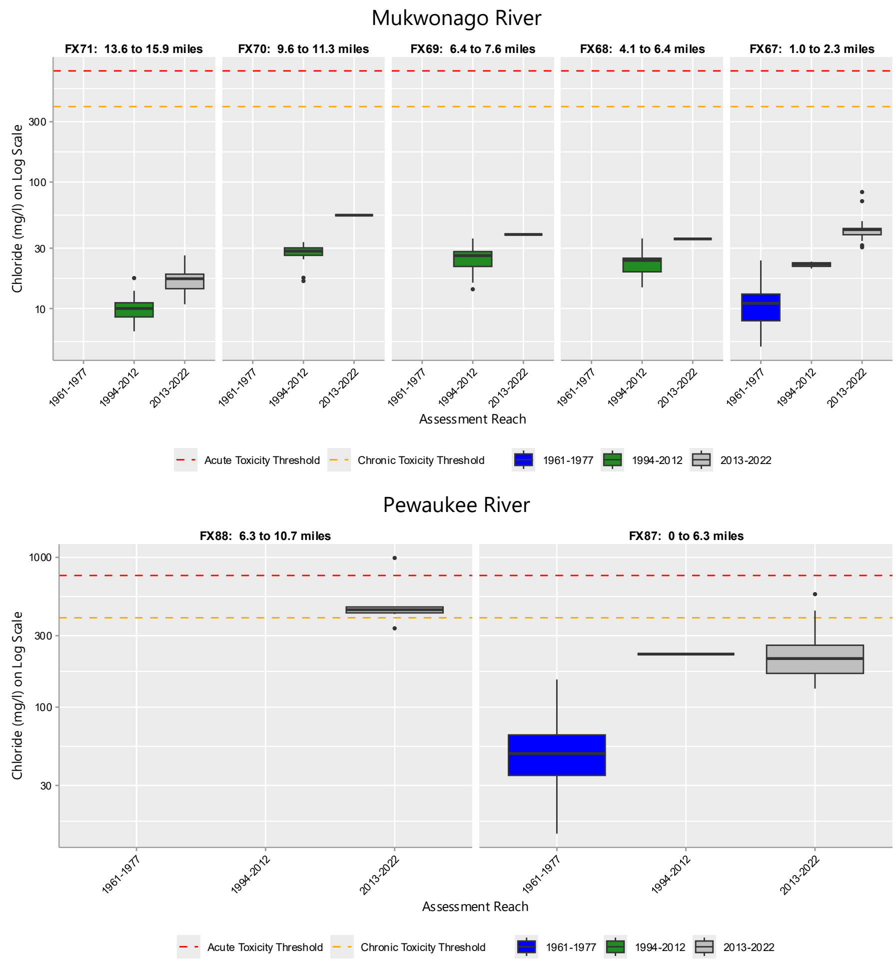


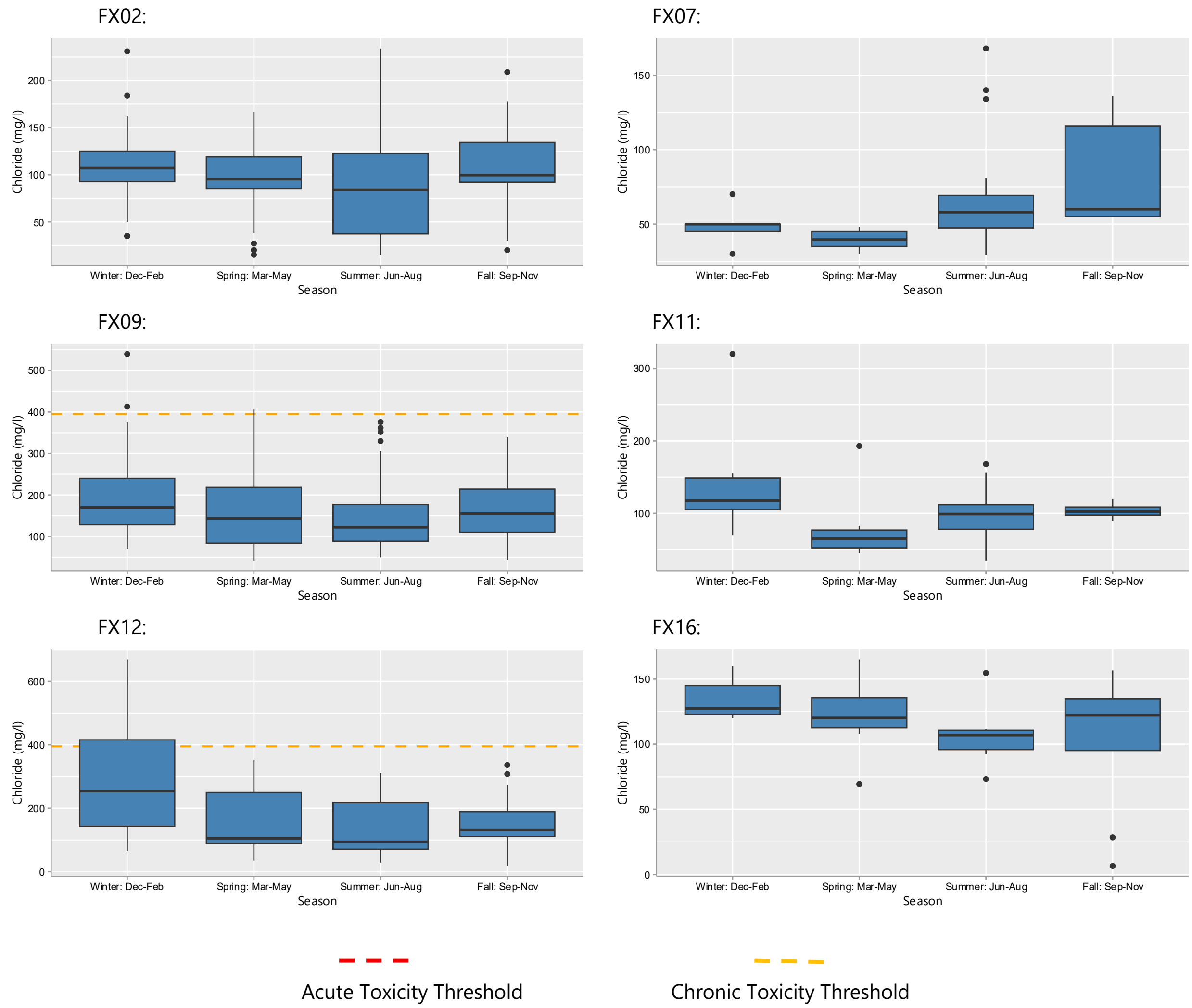
Figure 4.27 (continued)



Note: This figure represents all chloride data collected from the White River, Honey Creek, Sugar Creek, Mukwonago River, and Pewaukee River in the Fox River watershed. Assessment reaches appear from upstream to downstream (left to right). The following assessment reaches have imbalanced datasets: Honey Creek reaches FX30, FX31, and FX35; Sugar Creek reach FX39; Mukwonago River reaches FX68, FX69, and FX70; and Pewaukee River reach FX88. Imbalanced datasets may not fairly represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

Source: WDNR, USGS, Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, and SEWRPC.

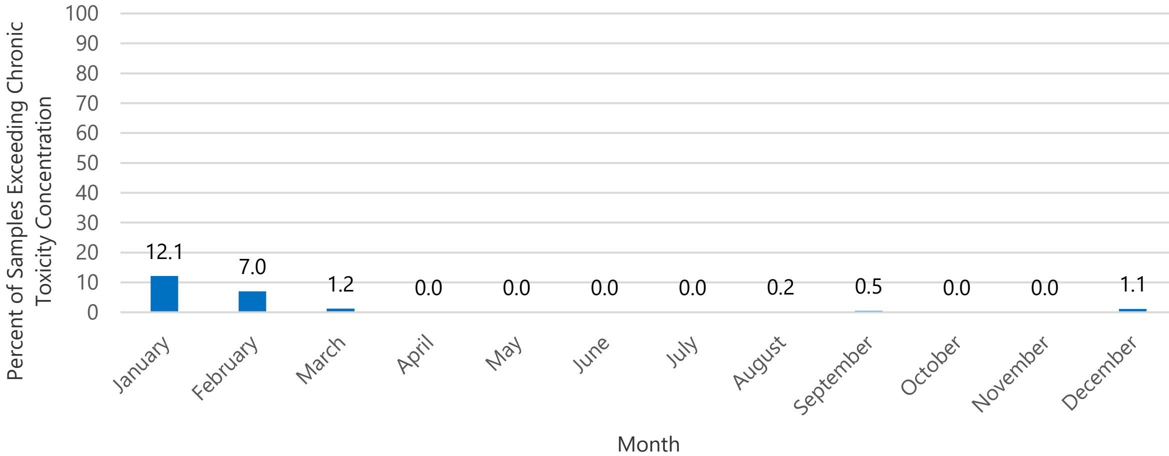
Figure 4.28
Chloride Concentrations by Season for Balanced Fox River Mainstem Assessment Reaches: 1961-2022



Note: This figure represents all chloride data over the full period of record for Fox River mainstem assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. Seasons include winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

Source: WDNR, USGS, USEPA, Eagle Spring Lake Management District, University of Wisconsin-Milwaukee, and SEWRPC

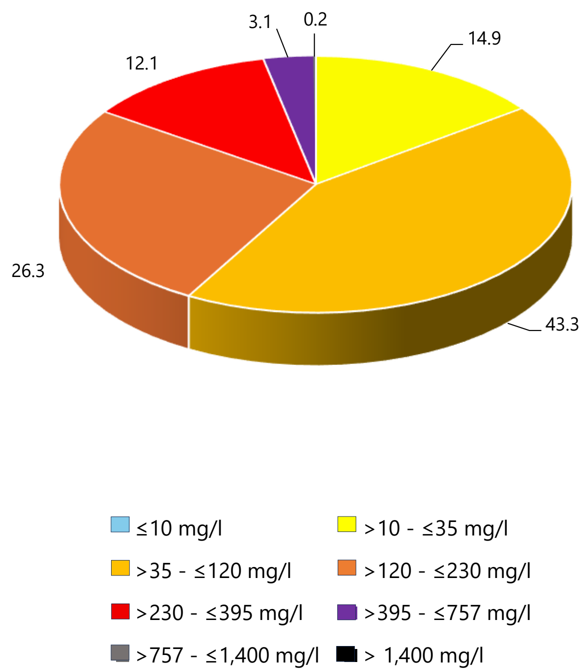
Figure 4.29
Percent of Chloride Samples Exceeding Chronic Toxicity Threshold in the Fox River Watershed: 1961-2022



Note: This dataset represents all 2,558 chloride samples collected in the Fox River watershed during the full period of record. Some of the samples represented in this figure that exceeded the State chronic toxicity concentration (395 mg/l) were collected prior to the establishment of the chloride toxicity criterion.

Source: SEWRPC

Figure 4.30
Percent of Recent Chloride Samples Collected in the Fox River Watershed Within Various Thresholds of Water Quality: 2013-2022



Note: There were 577 chloride samples collected in the Fox River watershed during the recent period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC.

Figure 4.31
Trends in Recent Chloride Concentrations for Fox River Mainstem Assessment Reaches with Balanced Datasets: 2013-2022

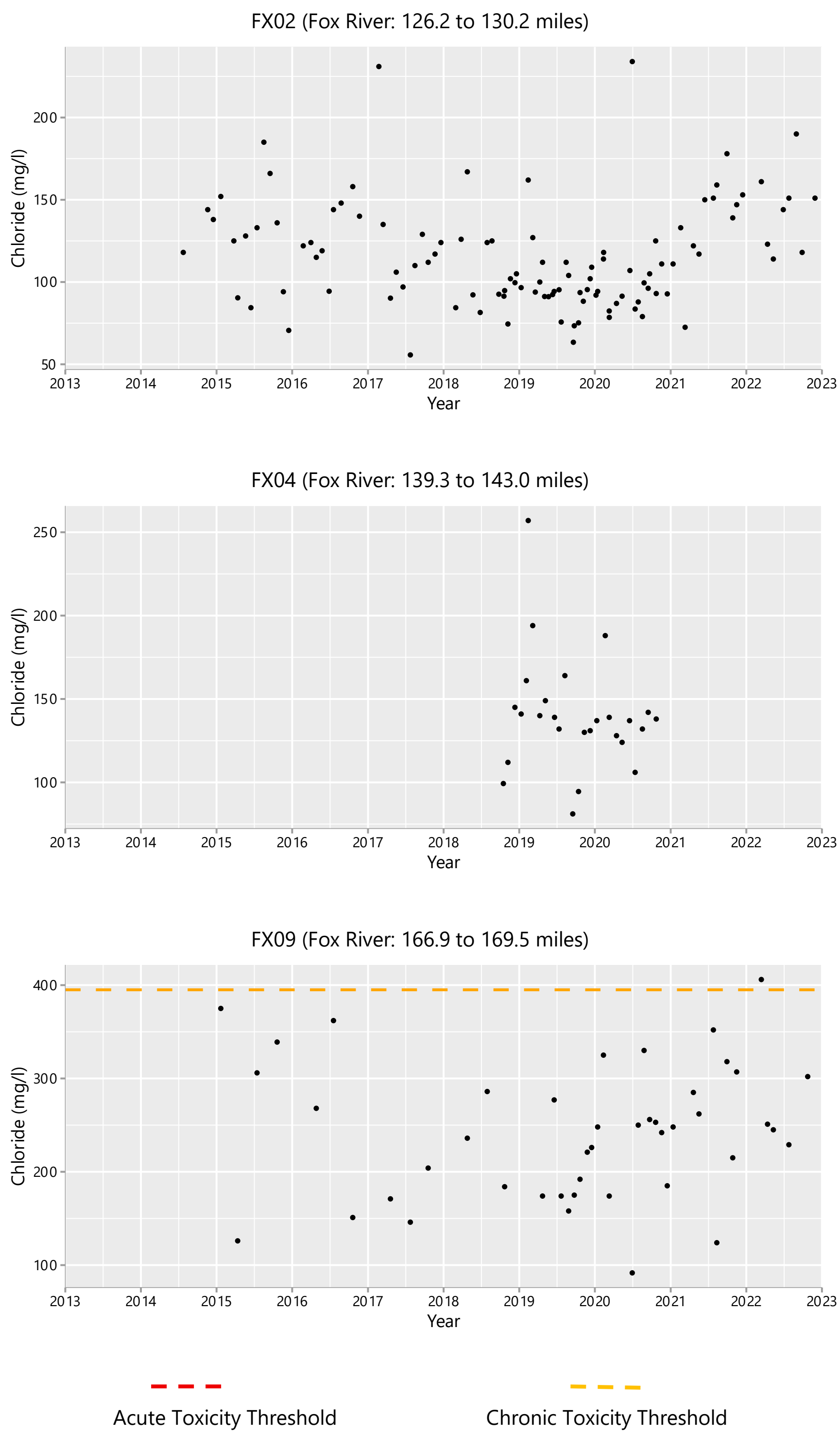
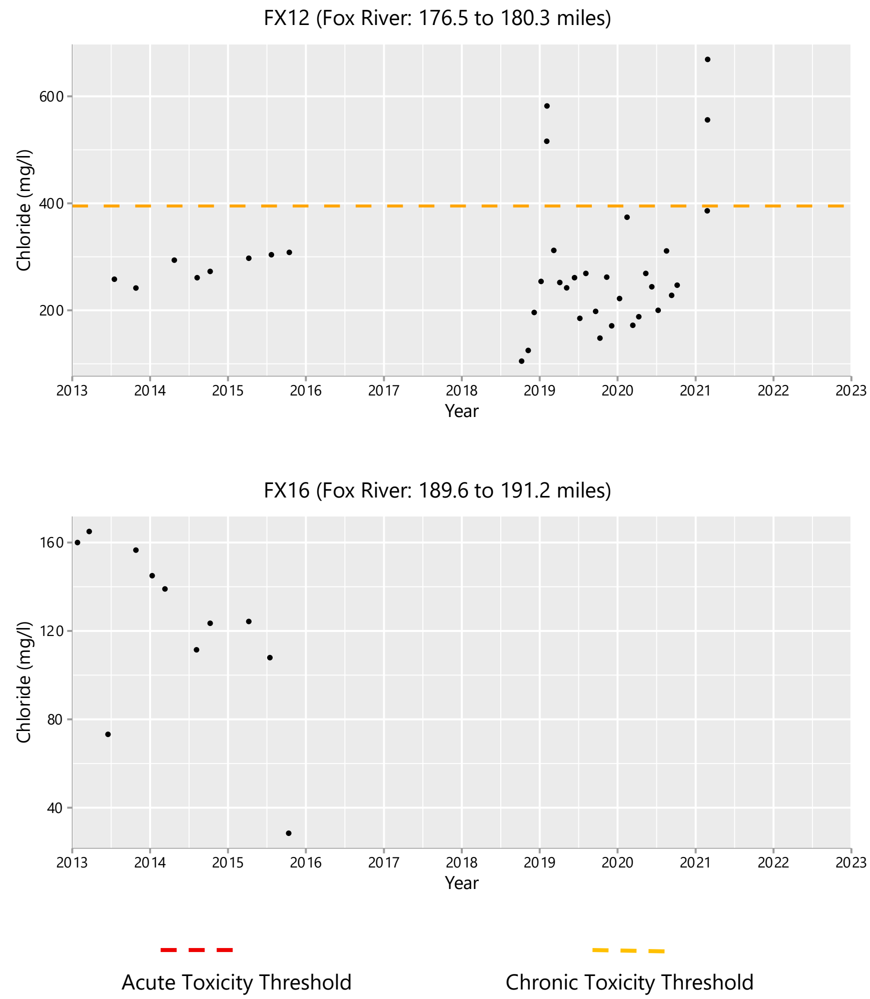


Figure 4.31 (continued)



Note: This figure includes all chloride data collected over the recent period of record for Fox River mainstem assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. There were no statistically significant chloride trends found in Fox River mainstem assessment reaches over the recent period of record.

Source: WDNR, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 4.32
Trends in Recent Chloride Concentrations for Balanced Assessment Reaches in Major Tributaries to the Fox River: 2013-2022

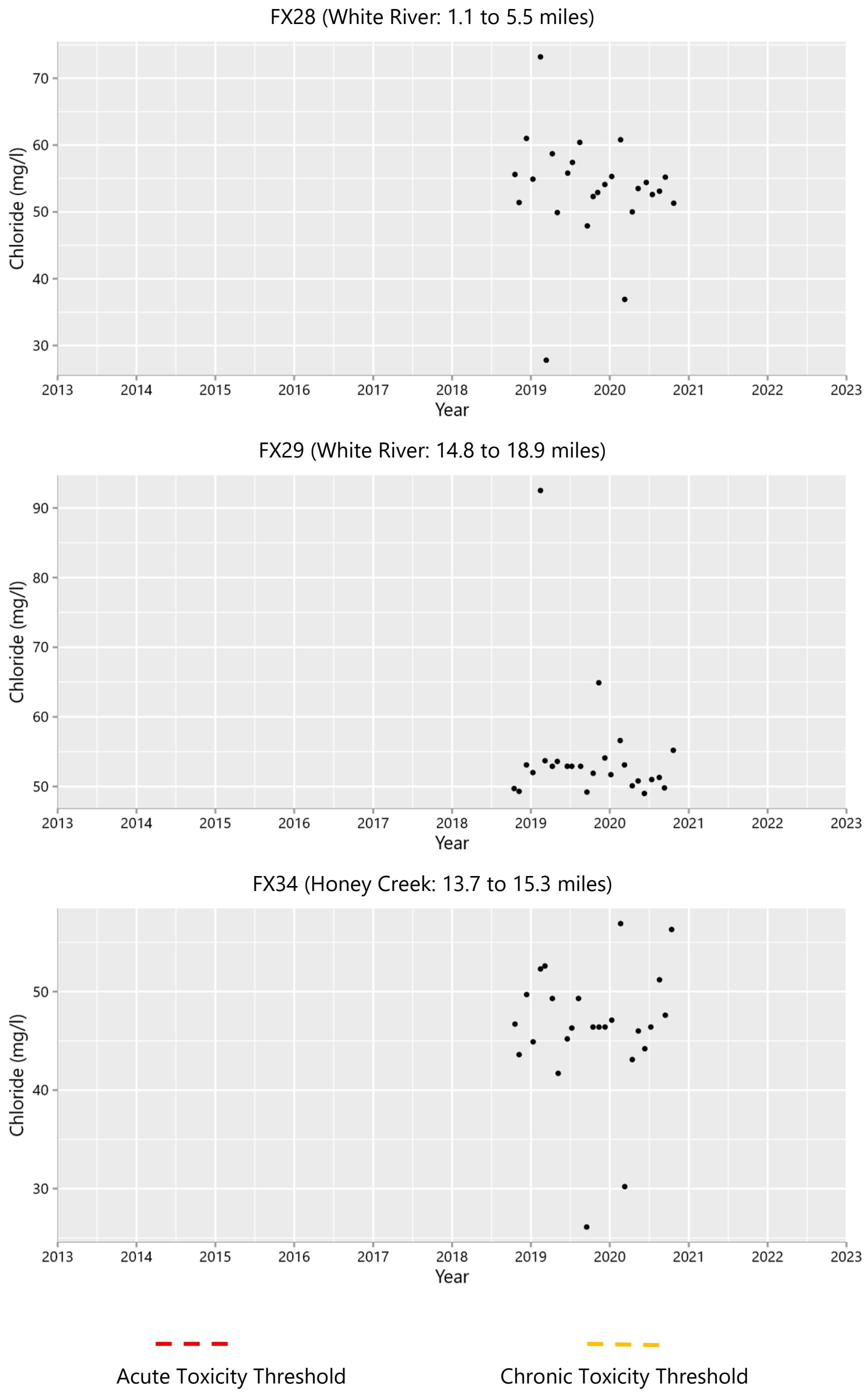


Figure 4.32 (continued)

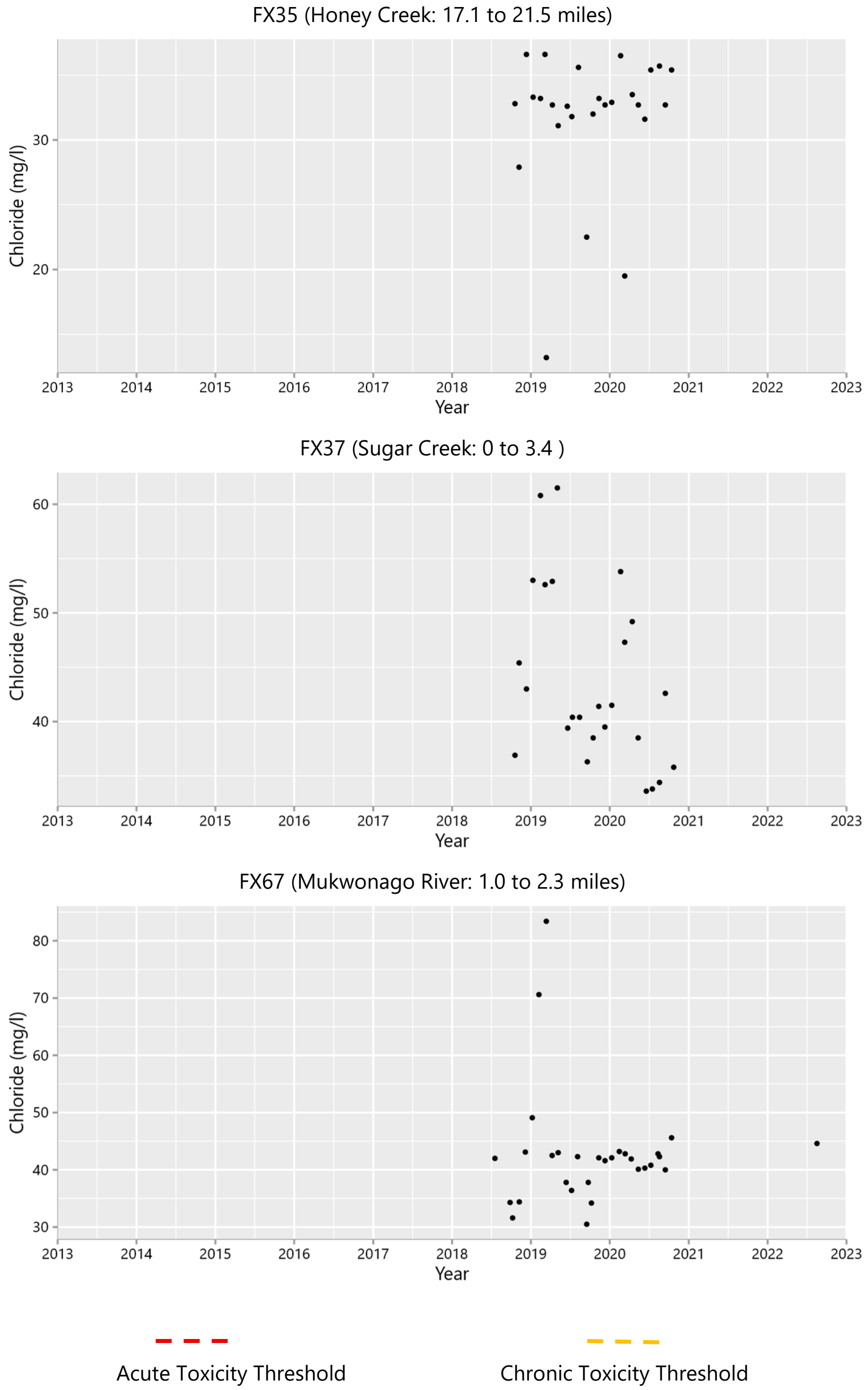
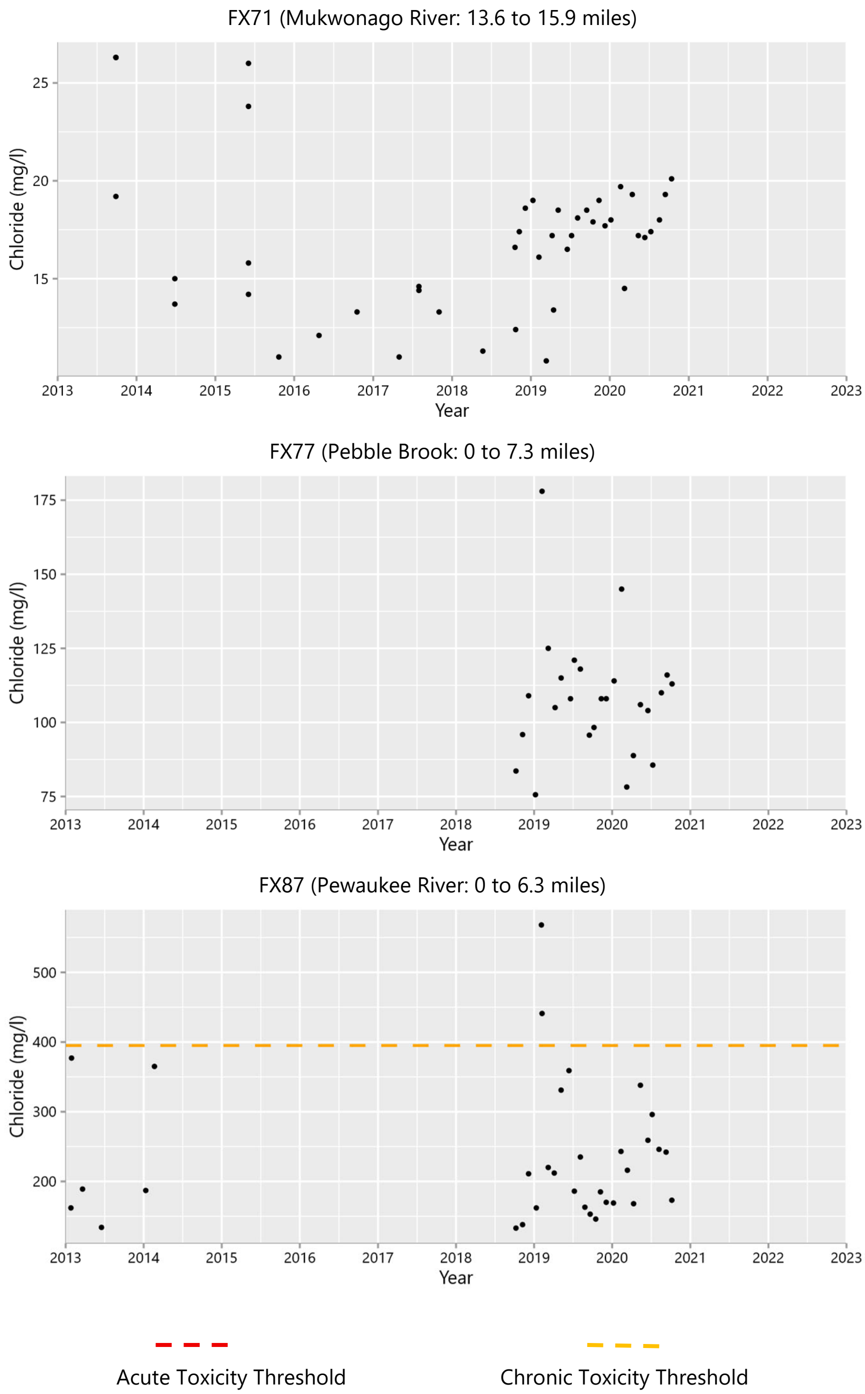


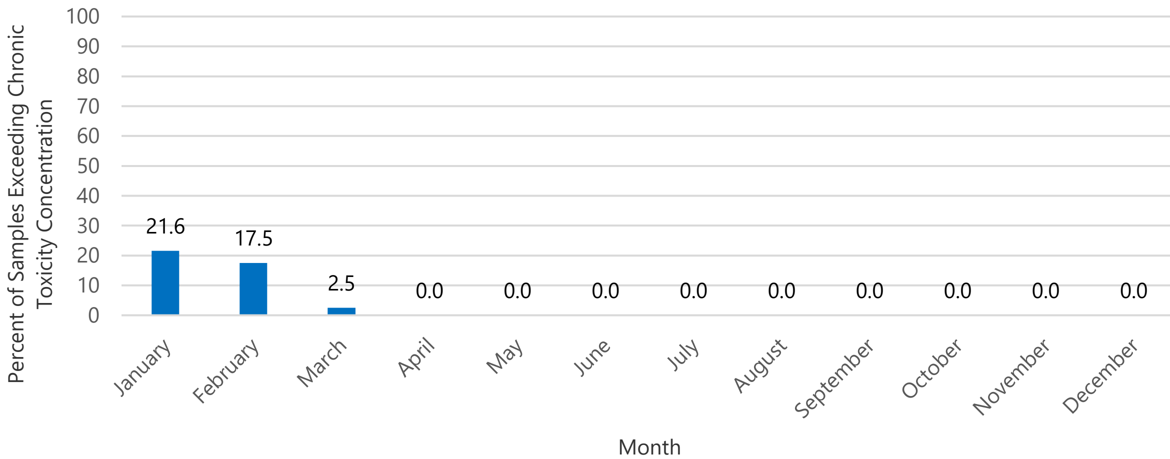
Figure 4.32 (continued)



Note: This figure includes all chloride data collected over the recent period of record for assessment reaches within major tributaries to the Fox River that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. There were no statistically significant trends found in Fox River watershed assessment reaches over the recent period of record.

Source: WDNR, Eagle Spring Lake Management District, and SEWRPC.

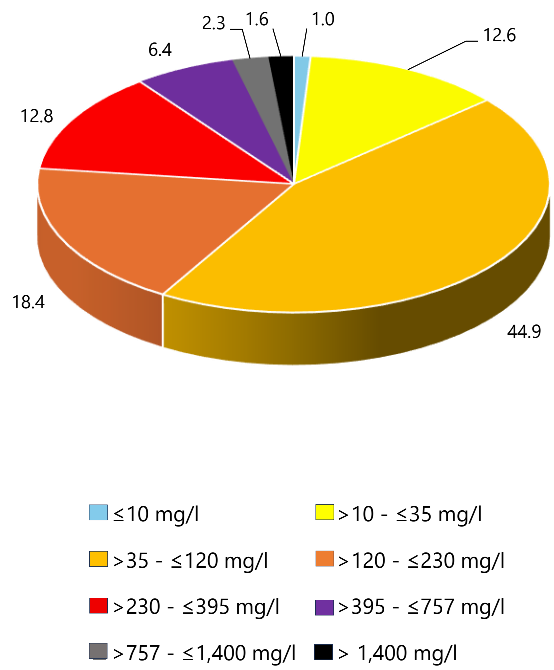
Figure 4.33
Percent of Recent Chloride Samples Exceeding Chronic Toxicity Concentration in the Fox River Watershed: 2013-2022



Note: This dataset represents all 577 chloride samples collected in the Fox River watershed during the recent period of record.

Source: SEWRPC

Figure 4.34
Percent of Chloride Samples Collected in the Kinnickinnic River Watershed Within Various Thresholds of Water Quality: 1961-2022

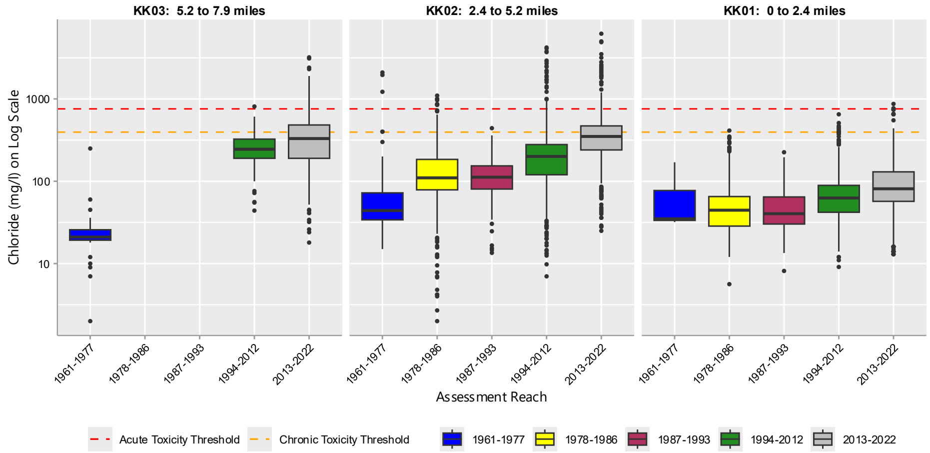


Note: There were 7,279 chloride samples collected in the Kinnickinnic River watershed during the full period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

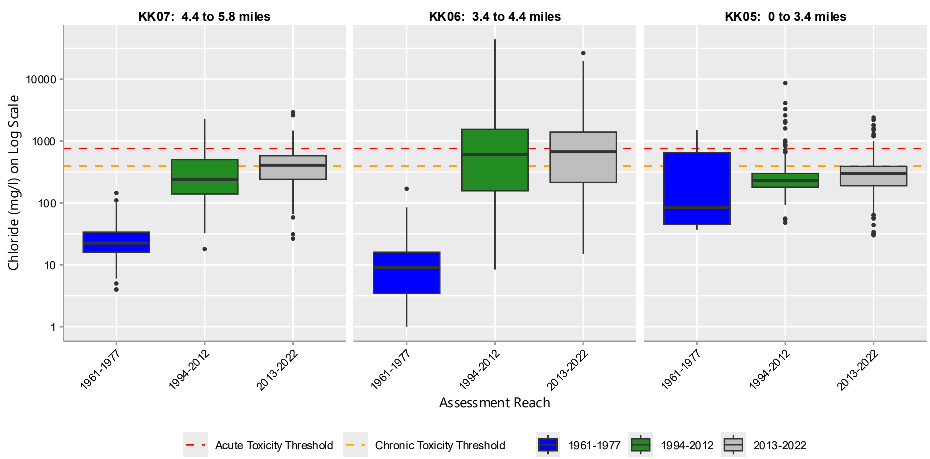
Source: SEWRPC.

Figure 4.35
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches on the Kinnickinnic River Mainstem, Wilson Park Creek, and 43rd Street Ditch: 1961-2022

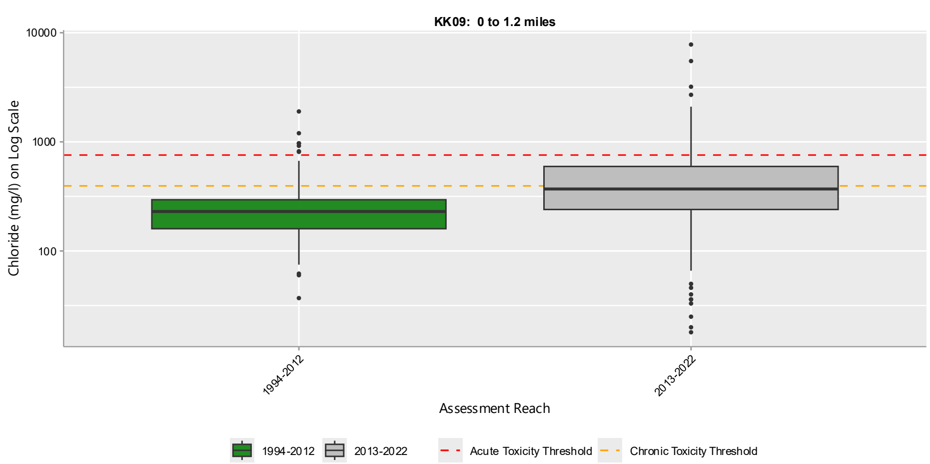
Kinnickinnic River Mainstem



Wilson Park Creek



43rd Street Ditch



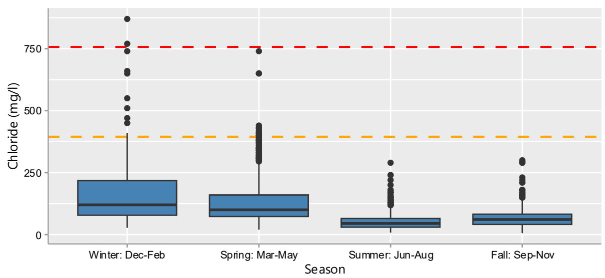
Note: This figure represents all chloride data collected from the Kinnickinnic River mainstem, Wilson Park Creek, and 43rd Street Ditch. Assessment reaches appear from upstream to downstream (left to right). All assessment reaches shown in this figure meet the criteria to be considered a balanced chloride dataset for the full period of record.

Source: MMSD, WDNR, USGS, Milwaukee River Keeper, and SEWRPC.

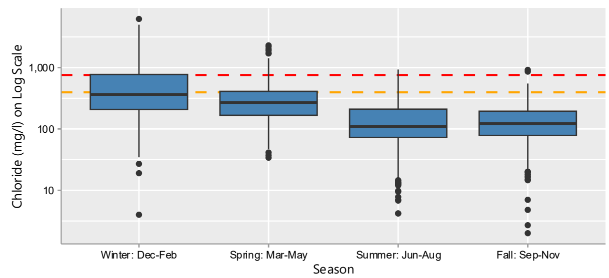
Figure 4.36
Chloride Concentrations by Season for Balanced Kinnickinnic River Watershed Assessment Reaches: 1961-2022

Kinnickinnic River Mainstem:

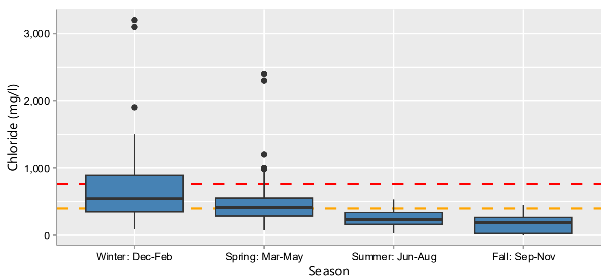
KK01:



KK02:

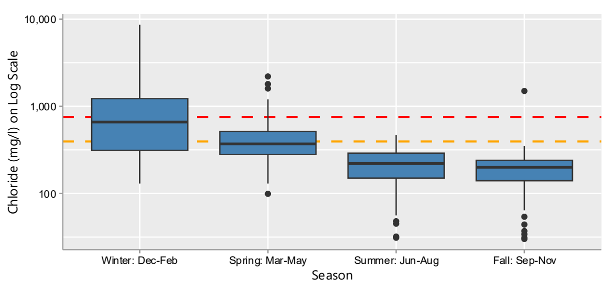


KK03:

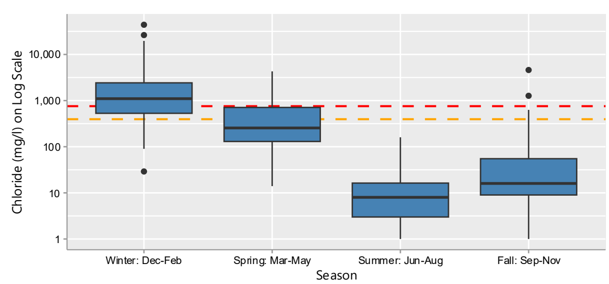


Wilson Park Creek:

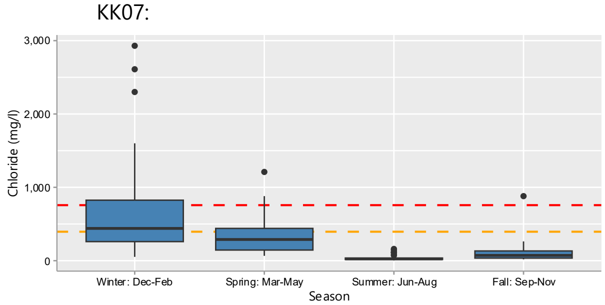
KK05:



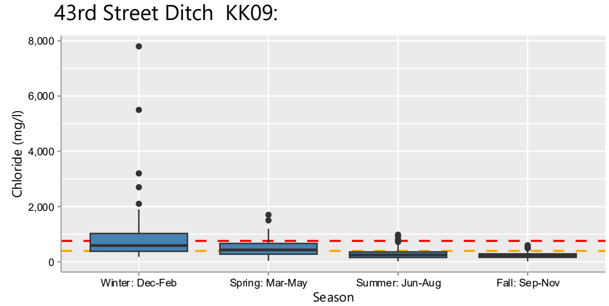
KK06



KK07:



43rd Street Ditch KK09:



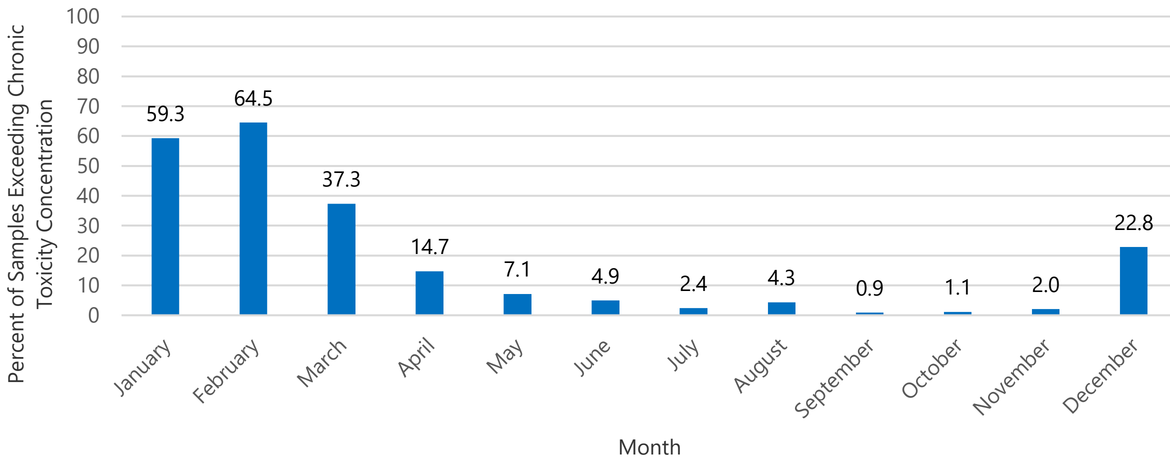
Acute Toxicity Threshold

Chronic Toxicity Threshold

Note: This figure represents all chloride data over the full period of record for Kinnickinnic River watershed assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. Seasons include winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

Source: MMSD, WDNR, USGS, Milwaukee River Keeper, and SEWRPC.

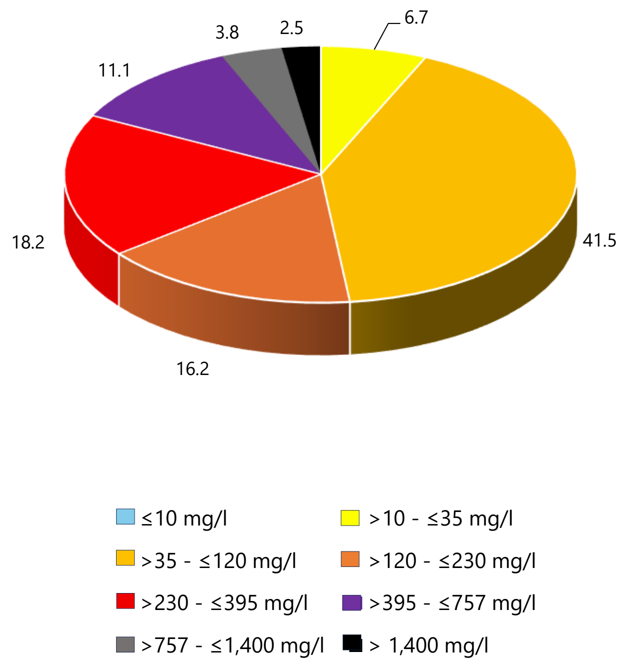
Figure 4.37
Percent of Chloride Samples Exceeding Chronic Toxicity Concentration in the Kinnickinnic River Watershed: 1961-2022



Note: This dataset represents all 7,279 chloride samples collected within the Kinnickinnic River watershed during the full period of record.

Source: SEWRPC

Figure 4.38
Percent of Recent Chloride Samples Collected in the Kinnickinnic River Watershed Within Various Thresholds of Water Quality: 2013-2022



Note There were 2,523 chloride samples collected in the Kinnickinnic River watershed during the recent period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC.

Figure 4.39
Trends in Recent Chloride Concentrations for Balanced Kinnickinnic River Watershed Assessment Reaches: 2013-2022

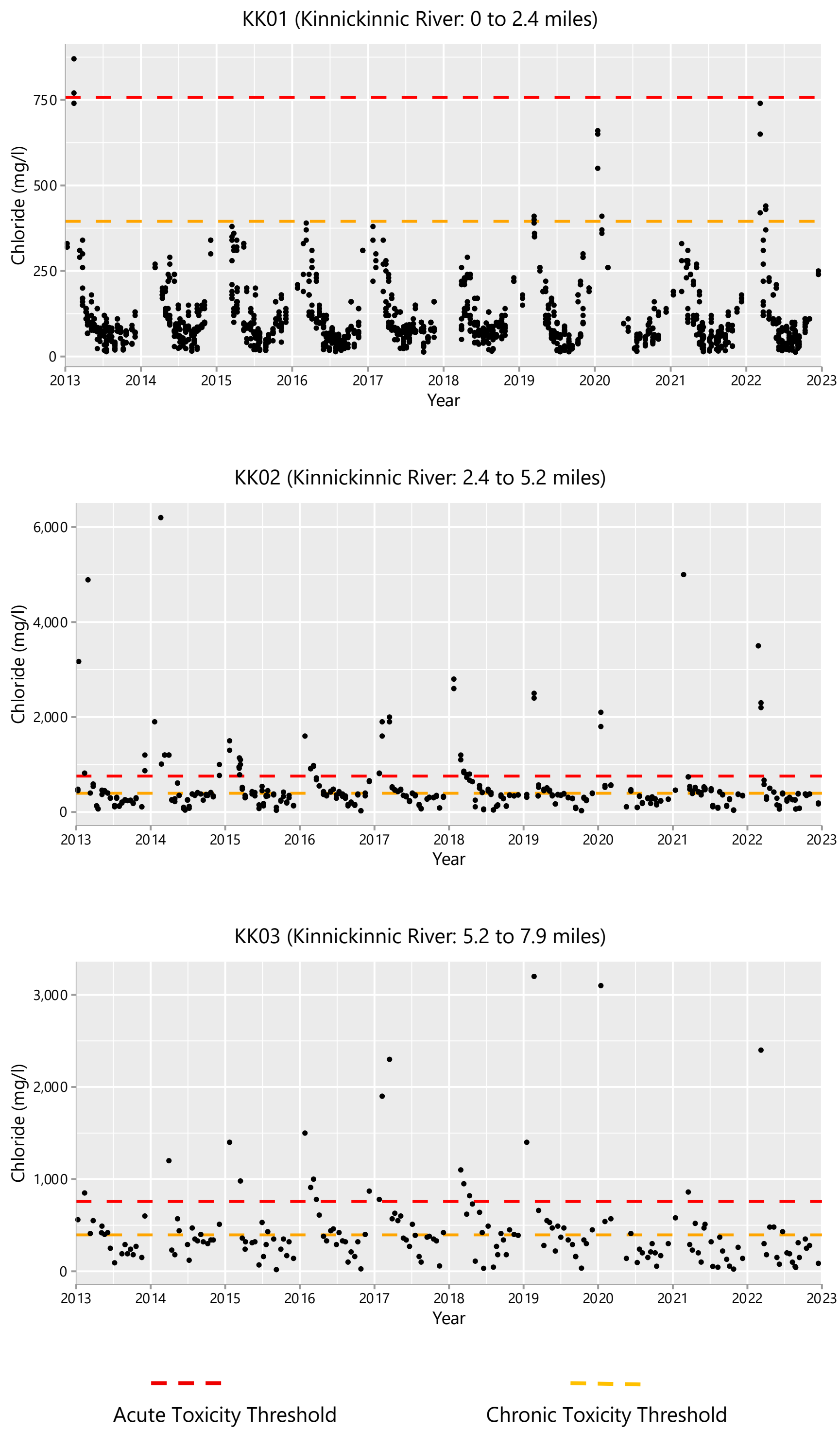
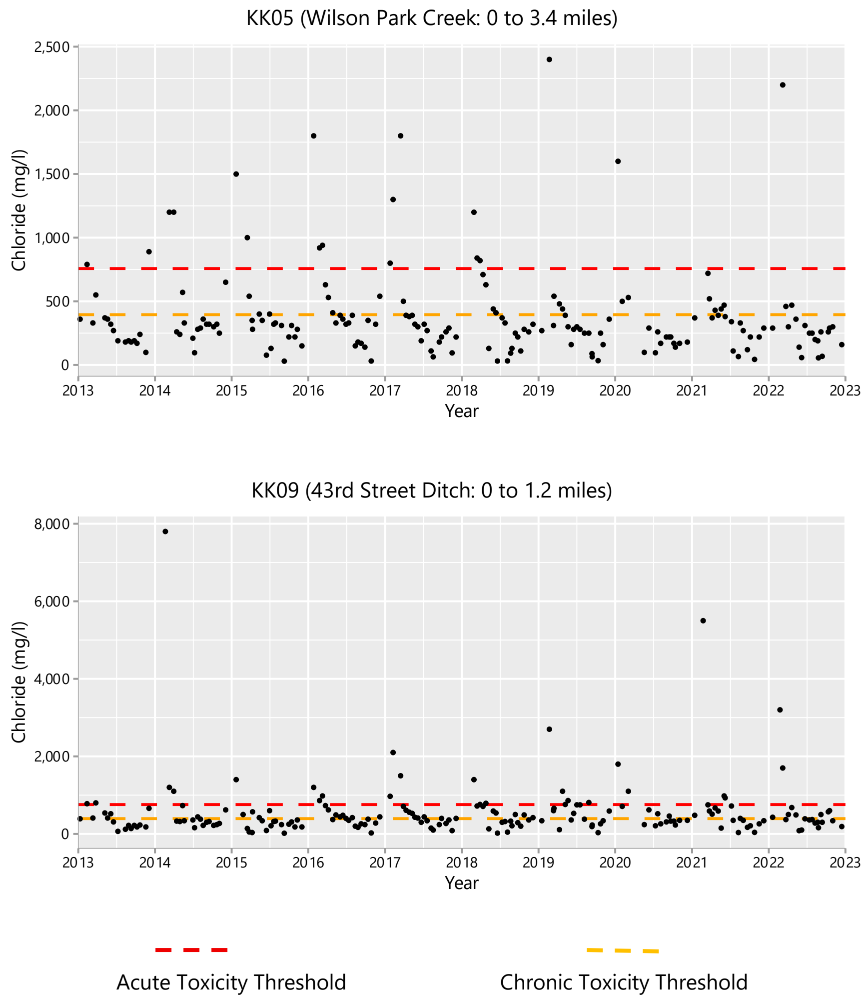


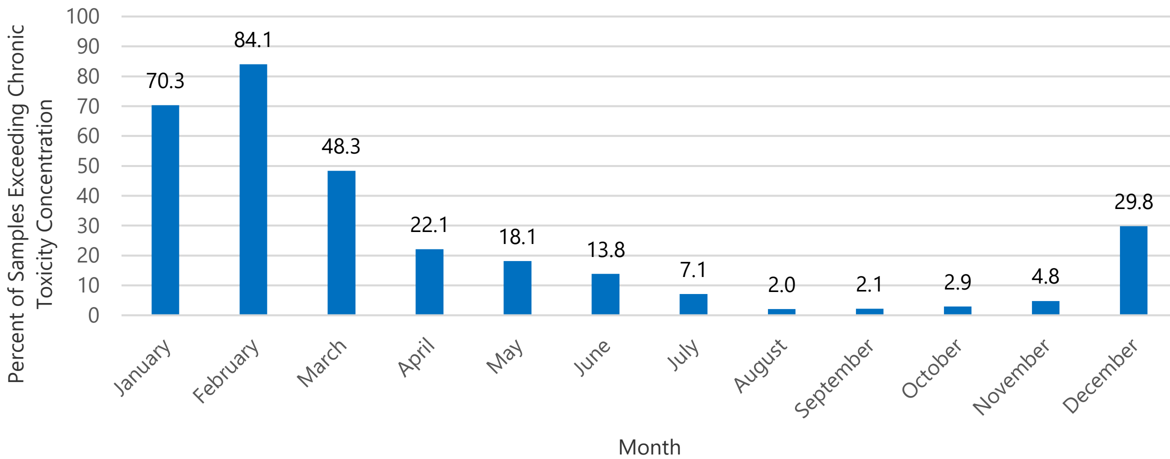
Figure 4.39 (continued)



Note: This figure includes all chloride data collected over the recent period of record for Kinnickinnic River watershed assessment reaches that have balanced recent datasets. Scales are unique for each assessment reach to best fit the observed data. There were no statistically significant chloride trends found in Kinnickinnic River watershed assessment reaches over the recent period of record.

Source: MMSD, WDNR, USGS, Milwaukee River Keeper, and SEWRPC.

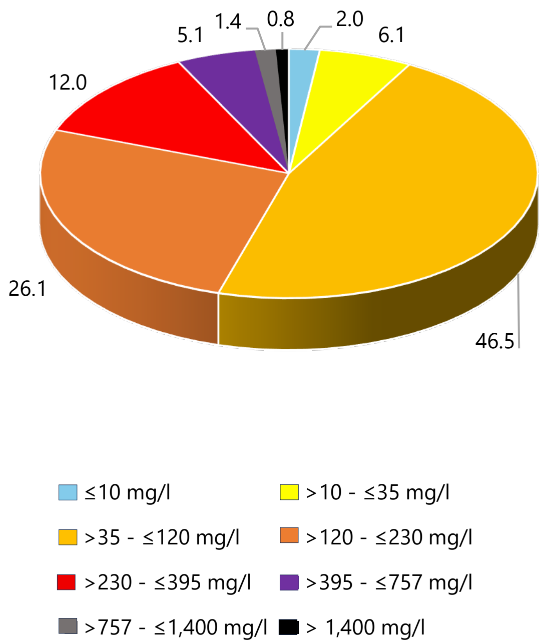
Figure 4.40
Percent of Recent Chloride Samples Exceeding Chronic Toxicity Concentration in the Kinnickinnic River Watershed: 2013-2022



Note: This dataset represents all 2,523 chloride samples collected within the Kinnickinnic River watershed during the recent period of record.

Source: SEWRPC

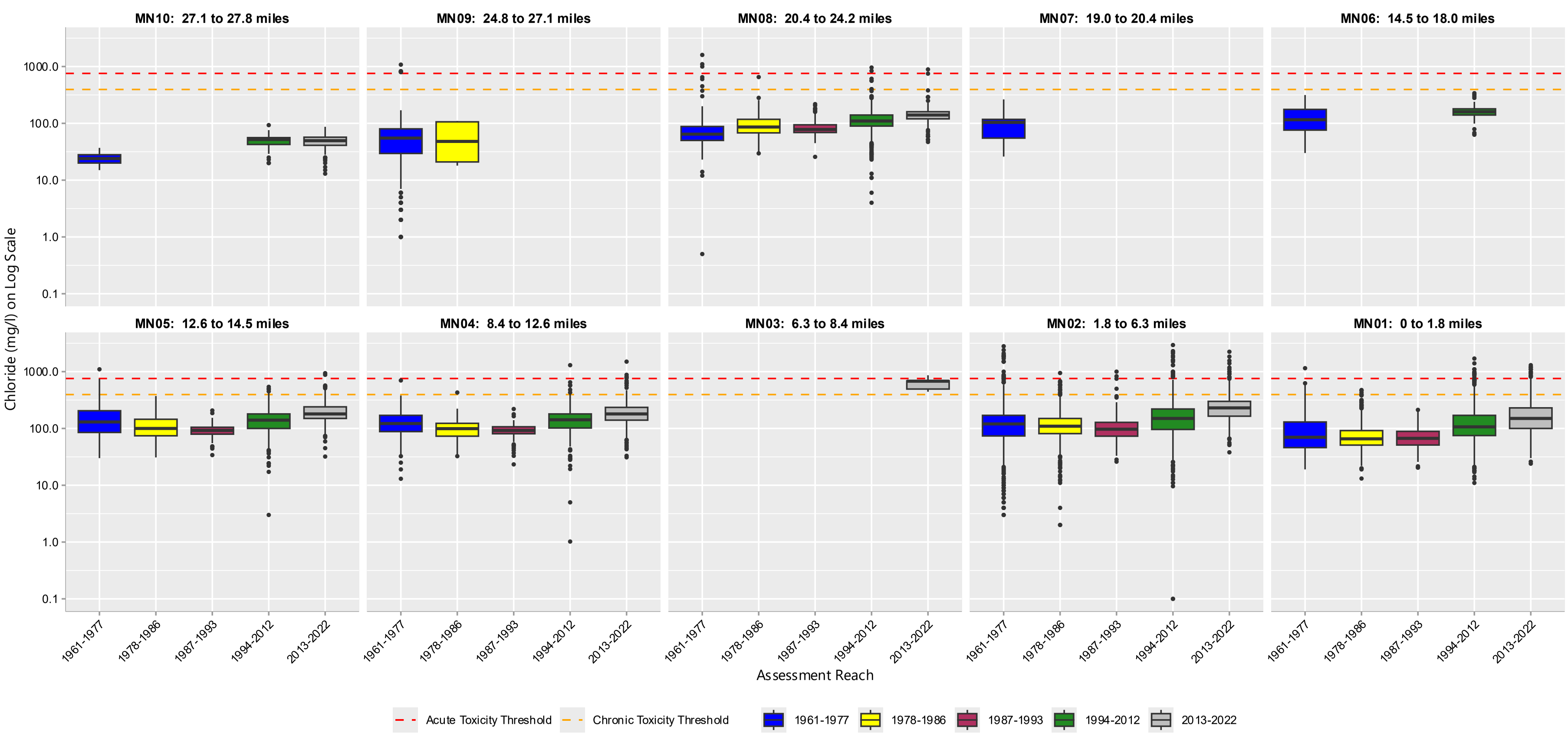
Figure 4.41
Percent of Chloride Samples Collected in the Menomonee River Watershed Within Various Thresholds of Water Quality: 1961-2022



Note: There were 16,964 chloride samples collected in the Menomonee River watershed during the full period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC

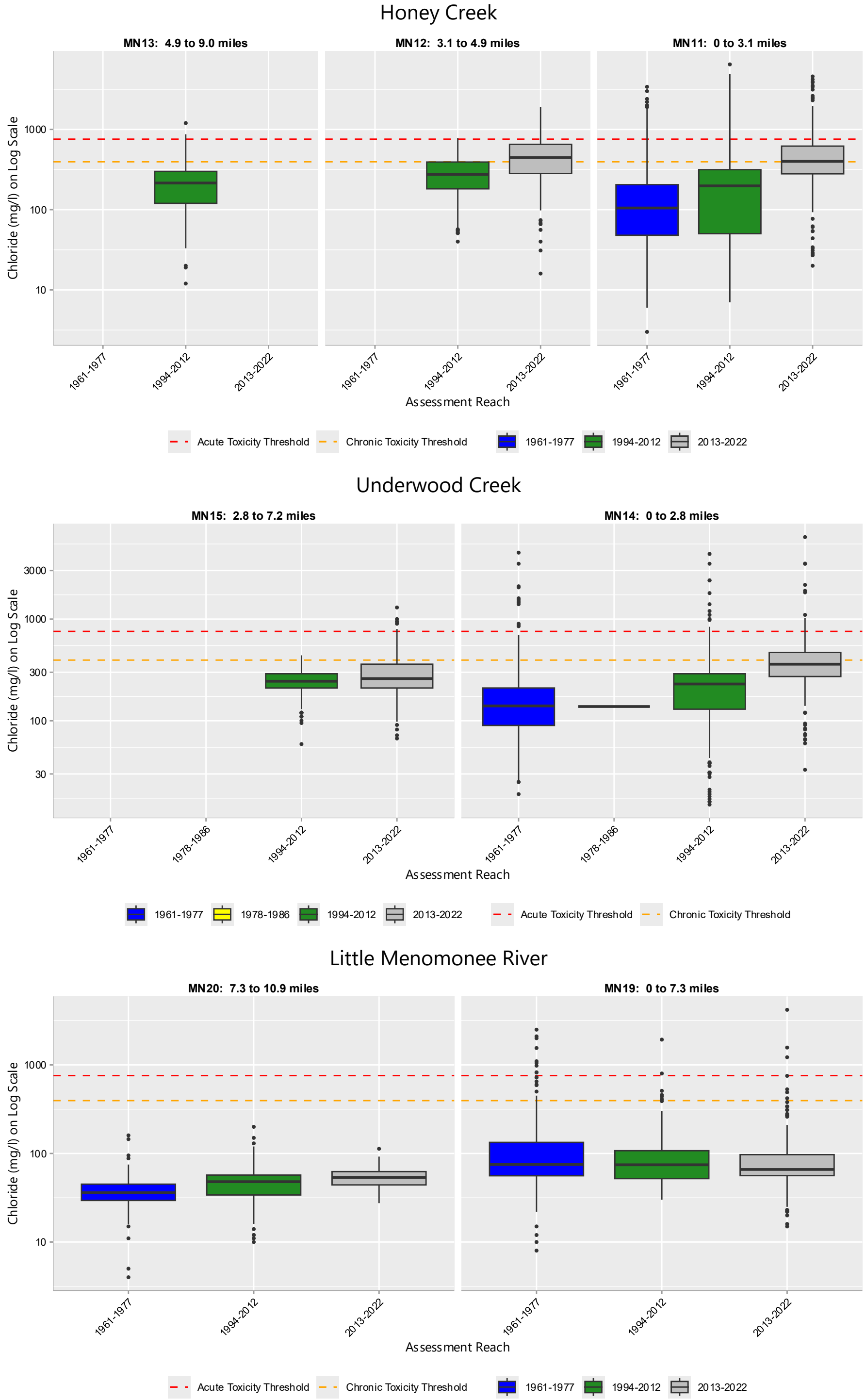
Figure 4.42
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches Along the Mainstem of the Menomonee River: 1961-2022



Note: This figure represents all chloride data collected from the Menomonee River mainstem. Assessment reaches appear from upstream to downstream (left to right top, then left to right bottom). Menomonee River reaches MN03, MN07, and MN09 have imbalanced datasets that may not fairly represent chloride conditions in those reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

Source: MMSD, WDNR, USGS, USEPA, University of Wisconsin-Milwaukee, Milwaukee Riverkeeper, and SEWRPC

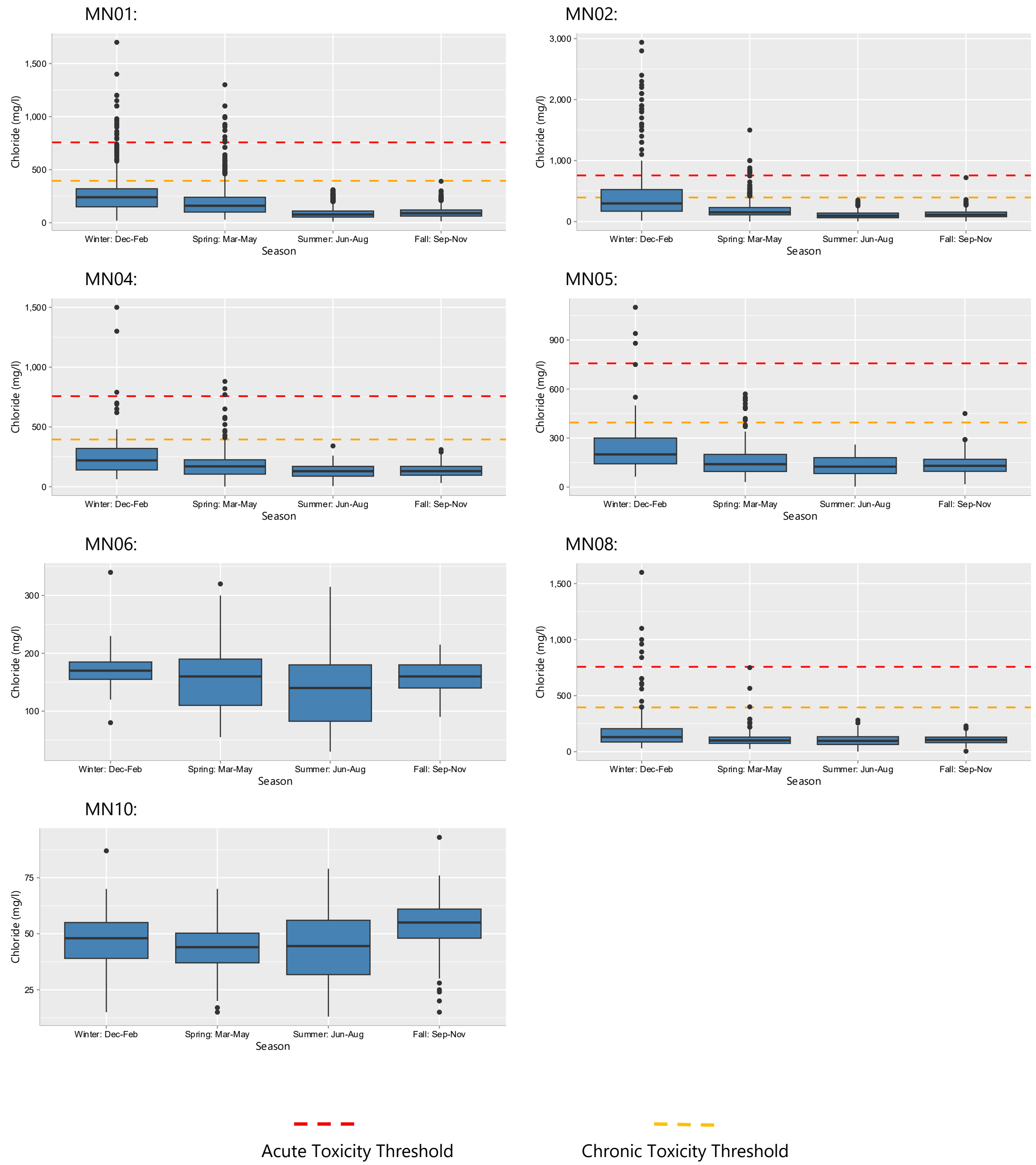
Figure 4.43
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches on Major Tributaries to the Menomonee River: 1961-2022



Note: This figure represents all chloride data collected from Honey Creek, Underwood Creek, and Little Menomonee River in the Menomonee River watershed. Assessment reaches appear from upstream to downstream (left to right). The following assessment reaches have imbalanced datasets: Honey Creek reaches MN13 and MN12; Underwood Creek reach MN15. Imbalanced datasets may not fairly represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

Source: MMSD, WDNR, USGS, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

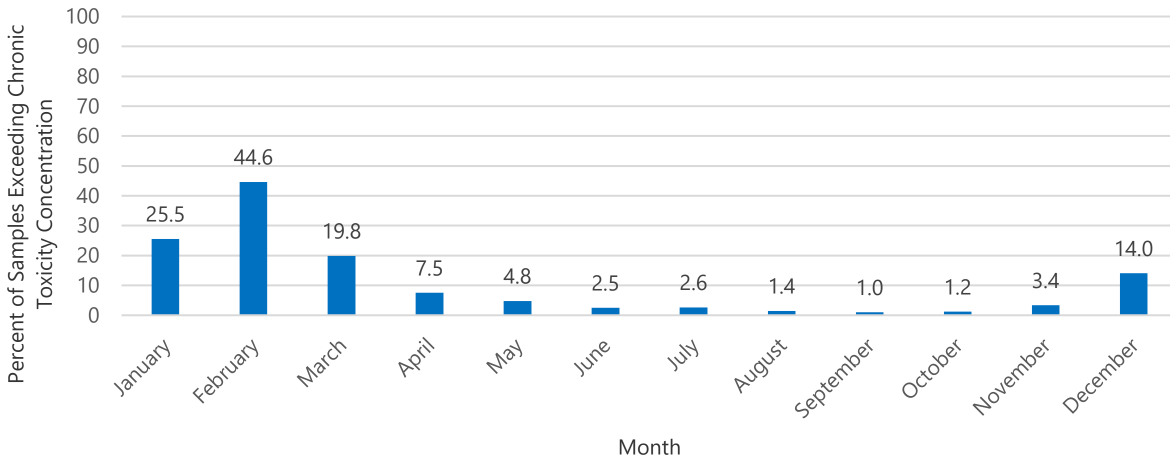
Figure 4.44
Chloride Concentrations by Season for Balanced Menomonee River Mainstem Assessment Reaches: 1961-2022



Note: This figure represents all chloride data over the full period of record for Menomonee River mainstem assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. Seasons include winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

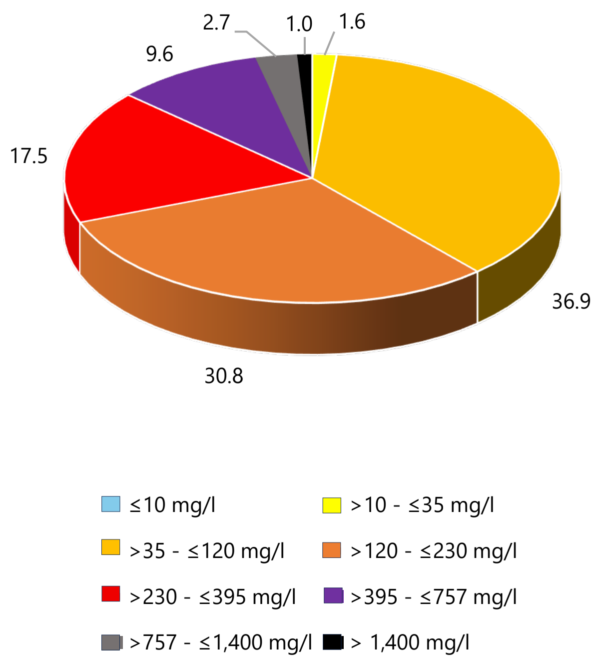
Figure 4.45
Percent of Chloride Samples Exceeding the Chronic Toxicity Threshold in the Menomonee River Watershed: 1961-2022



Note: This dataset represents all 16,964 chloride samples collected in the Menomonee River watershed during the full period of record. Many of the samples represented in this figure that exceeded the State chronic toxicity concentration (395 mg/l) were collected prior to the establishment of the chloride toxicity criterion.

Source: SEWRPC

Figure 4.46
Percent of Recent Chloride Samples Collected in the Menomonee River Watershed Within Various Thresholds of Water Quality: 2013-2022



Note There were 4,379 chloride samples collected in the Menomonee River watershed during the recent period of record.For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC.

Figure 4.47
Trends in Recent Chloride Concentrations for Menomonee River Mainstem Assessment Reaches with Balanced Datasets: 2013-2022

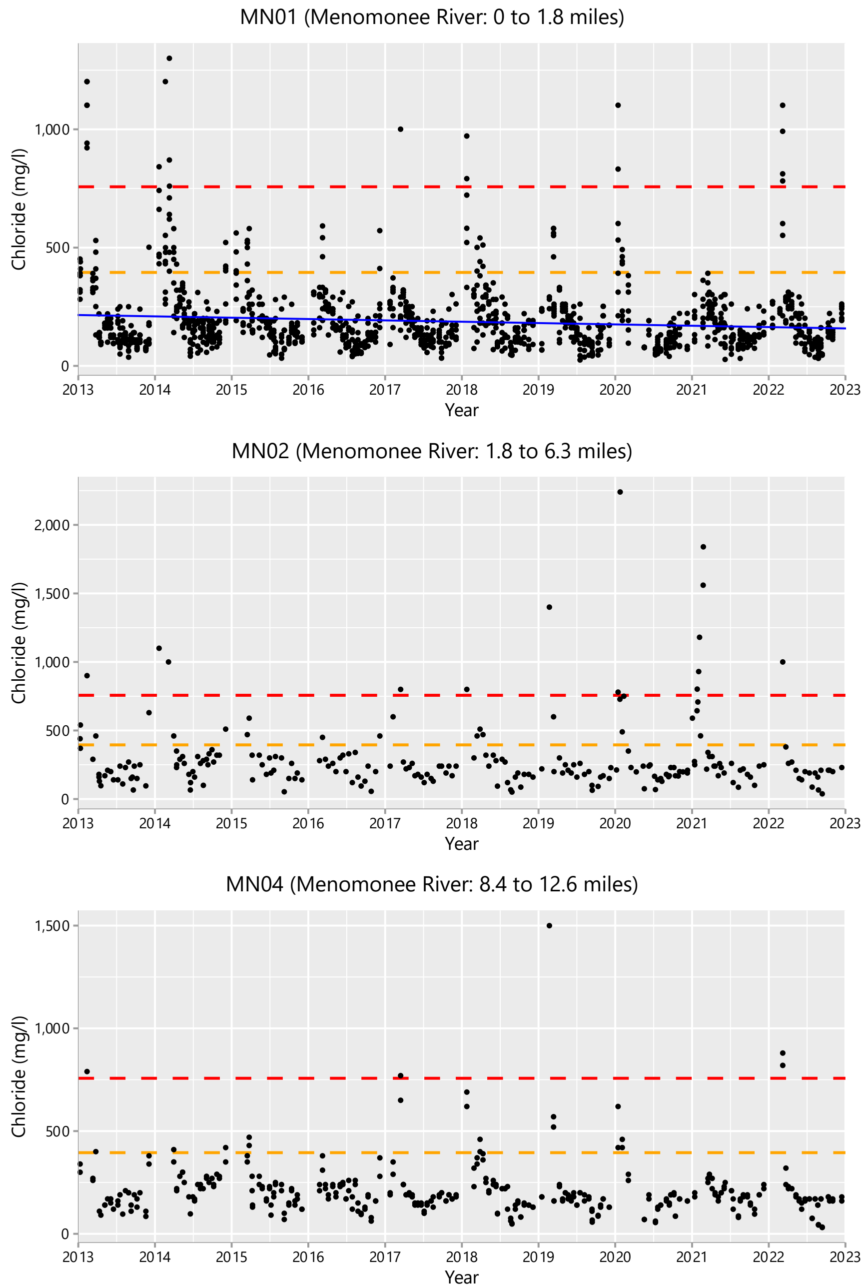
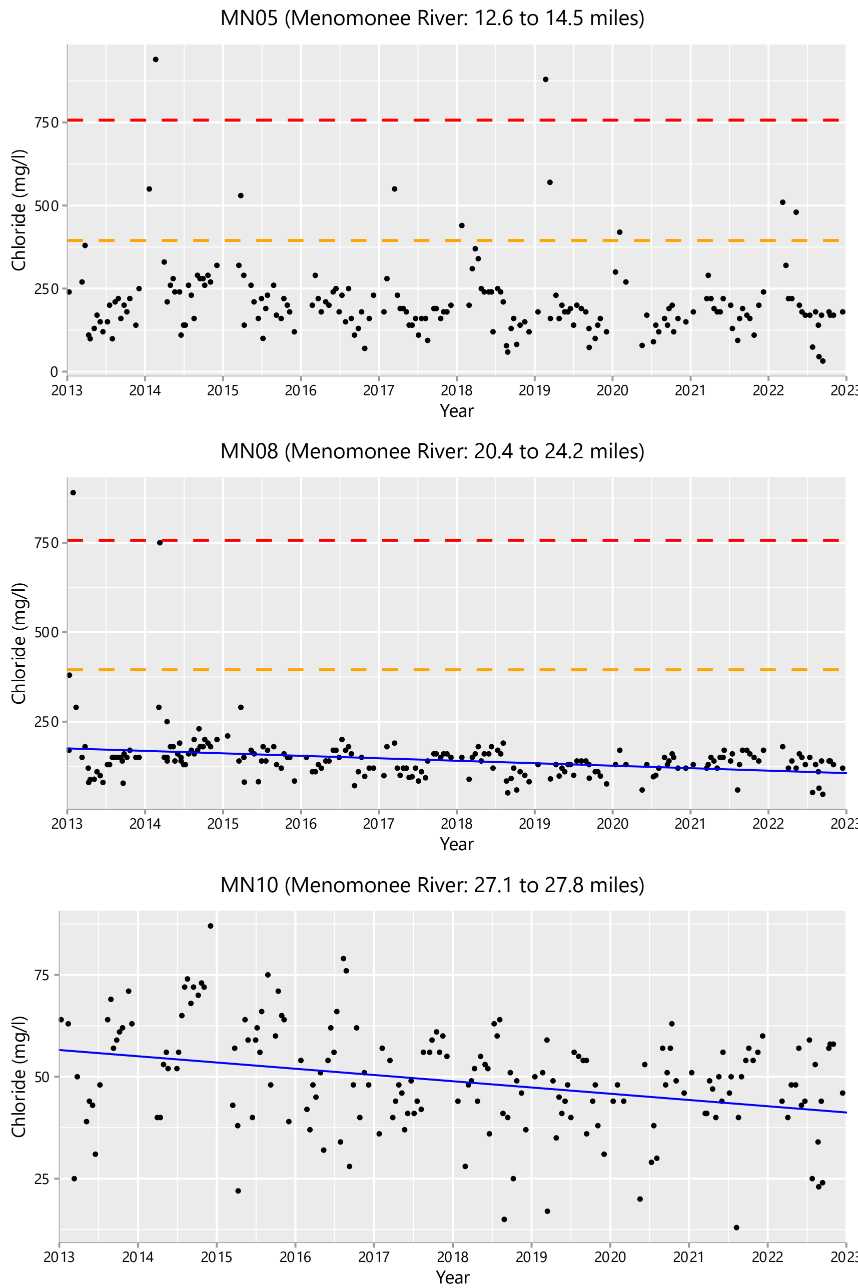


Figure 4.47 (continued)



Note: This figure includes all chloride data collected over the recent period of record for Menomonee River mainstem assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. A simple linear regression was performed to analyze the trends in chloride concentrations for the recent period of record (2013-2022). Trendlines are shown only for assessment reaches that demonstrated a statistically significant trend in chloride (p-value < 0.01). While this figure shows all chloride samples displayed by specific collection date, the trendlines displayed on MN01 and MN10 were developed using the year of collection as the independent variable (x-axis) rather than the full date of collection. Each individual sample concentration was used as the dependent variable (y-axis). This approach captures the overall linear trend while accounting for the natural variability of the data points within each year.

Source: MMSD, WDNR, USGS, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

Figure 4.48
Trends in Recent Chloride Concentrations for Balanced Assessment Reaches in Major Tributaries to the Menomonee River: 2013-2022

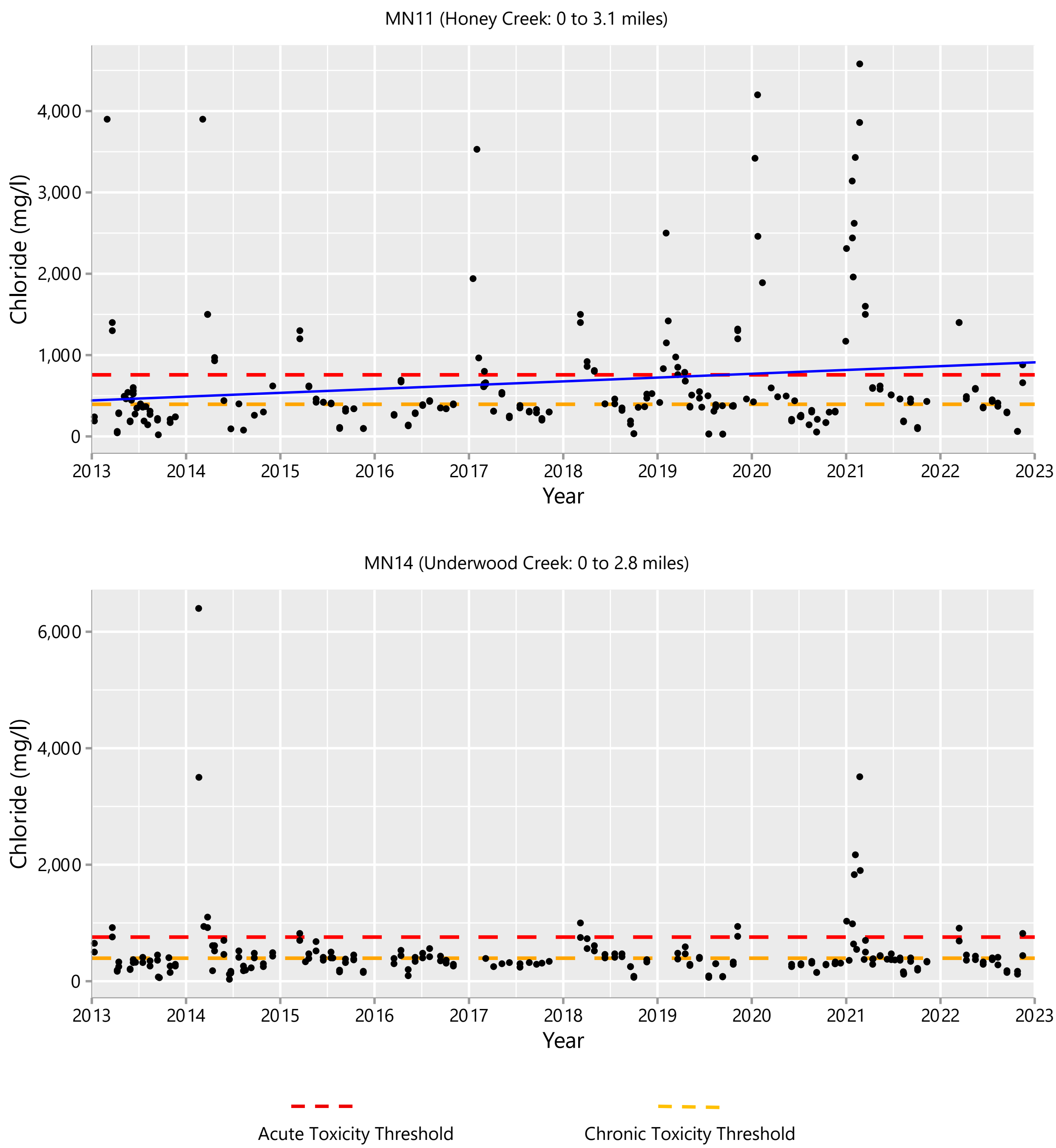
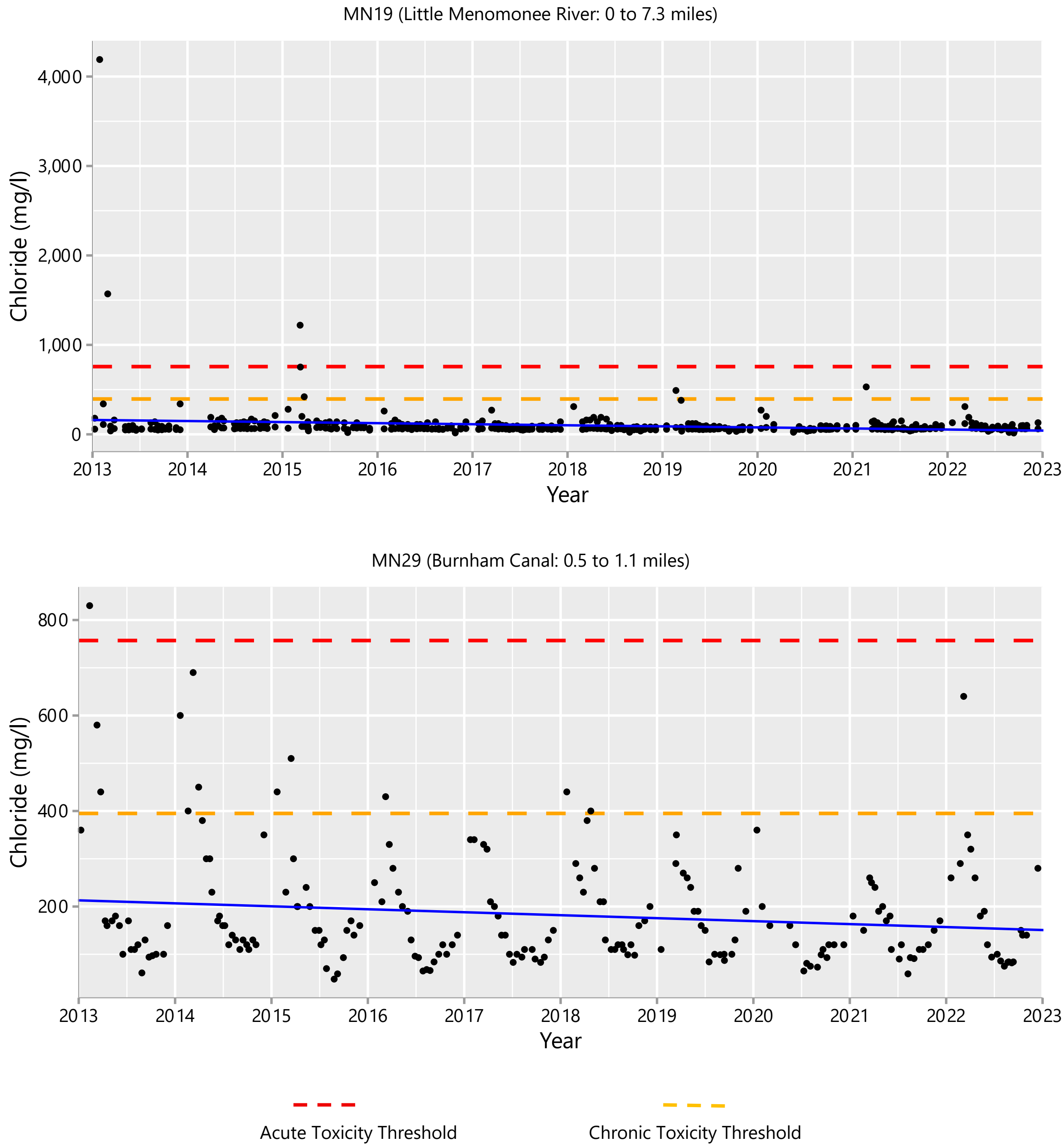


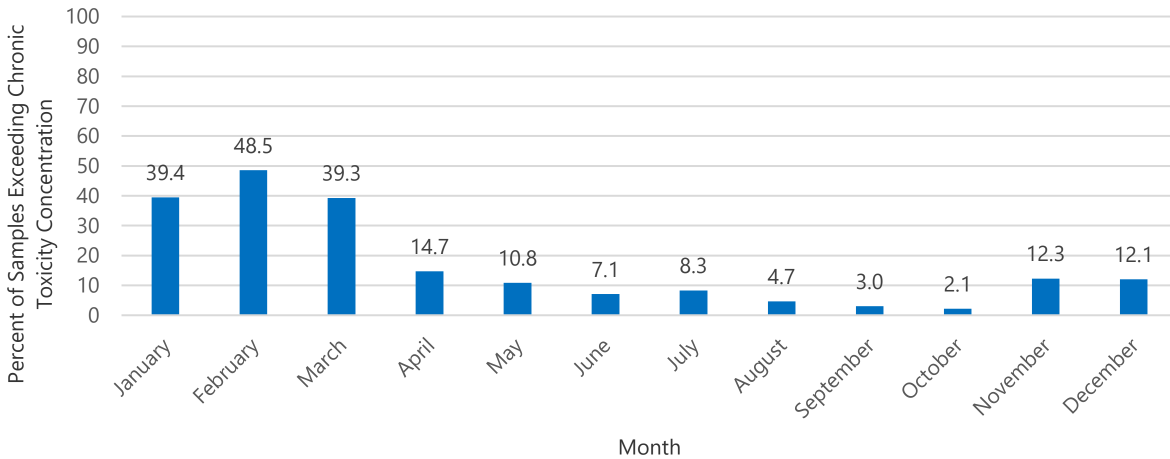
Figure 4.48 (continued)



Note: This figure includes all chloride data collected over the recent period of record for major Menomonee River tributary assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. A simple linear regression was performed to analyze the trends in chloride concentrations for the recent period of record (2013-2022). Trendlines are shown only for assessment reaches that demonstrated a statistically significant trend in chloride (p-value < 0.01). While this figure shows all chloride samples displayed by specific collection date, the trendlines displayed on MN11, MN19, and MN29 were developed using the year of collection as the independent variable (x-axis) rather than the full date of collection. Each individual sample concentration was used as the dependent variable (y-axis). This approach captures the overall linear trend while accounting for the natural variability of the data points within each year.

Source: MMSD, WDNR, USGS, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC

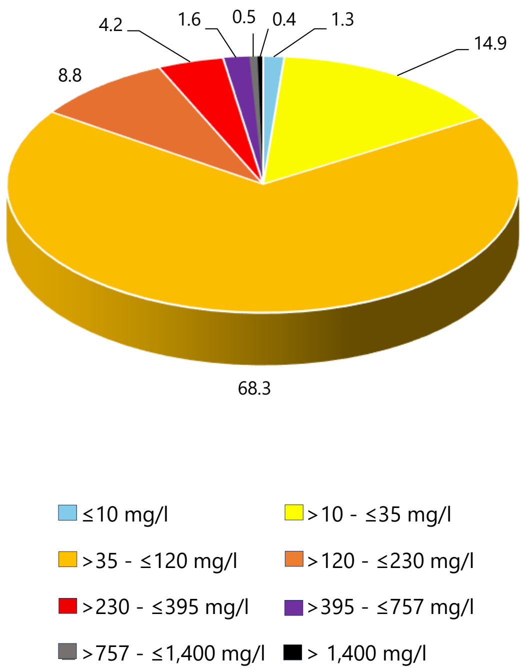
Figure 4.49
Percent of Recent Chloride Samples Exceeding Chronic Toxicity Concentration in the Menomonee River Watershed: 2013-2022



Note: This dataset represents all 4,379 chloride samples collected in the Menomonee River watershed during the recent period of record.

Source: SEWRPC

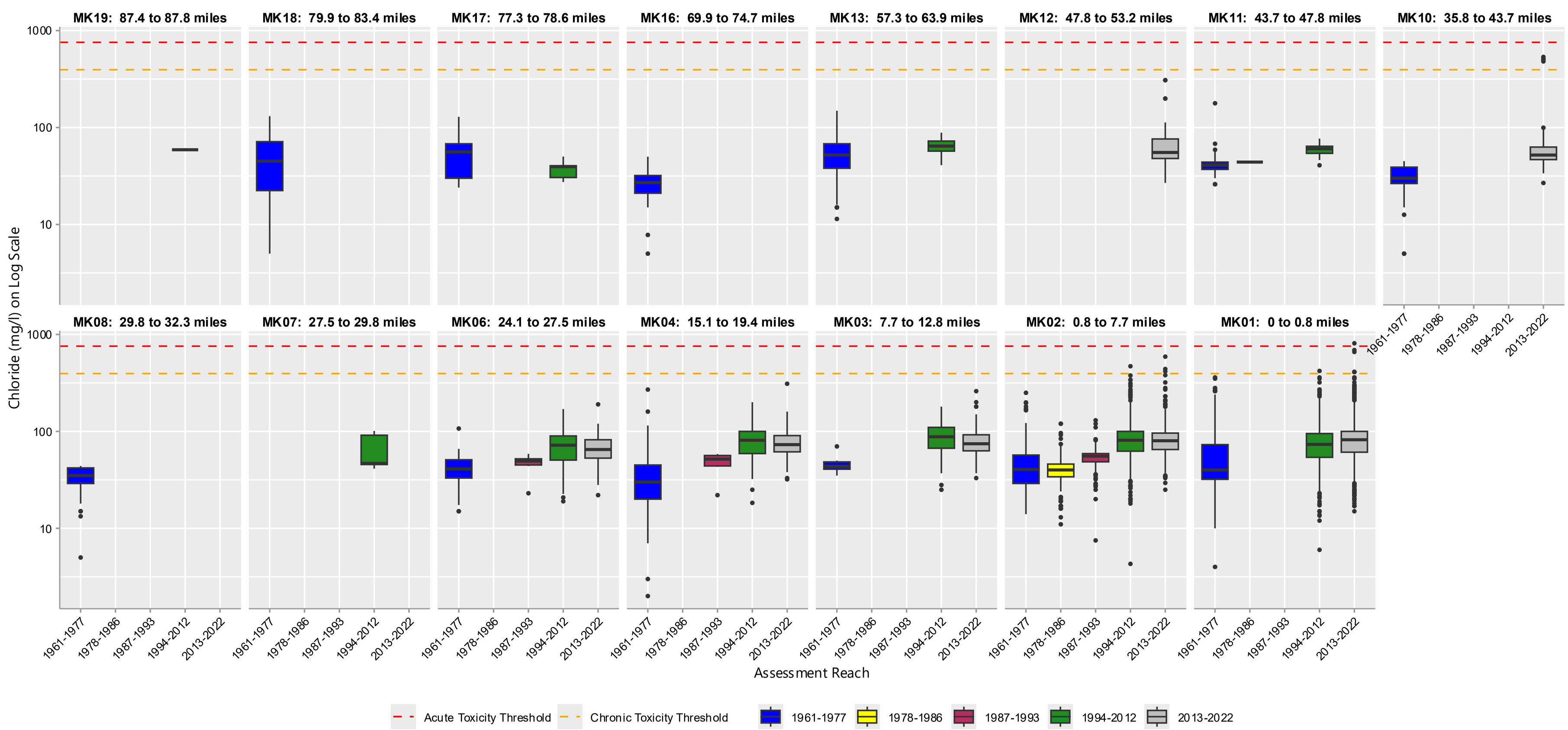
Figure 4.50
Percent of Chloride Samples Collected in the Milwaukee River Watershed Within Various Thresholds of Water Quality: 1961-2022



Note: There were 11,562 chloride samples collected in the Milwaukee River watershed during the full period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC.

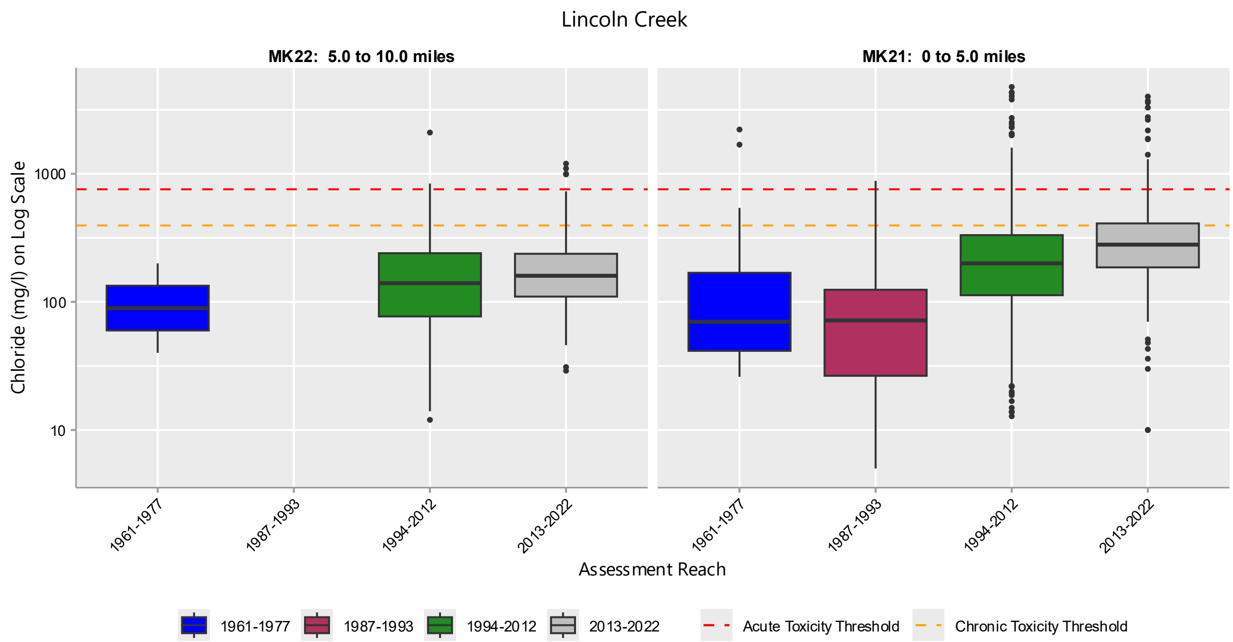
Figure 4.51
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches Along the Mainstem of the Milwaukee River: 1961-2022



Note: This figure represents all chloride data collected from the Milwaukee River mainstem. Assessment reaches appear from upstream to downstream (left to right top, then left to right bottom). Milwaukee River reaches MK07, MK08, MK11, MK12, MK13, MK16, MK17, MK18, and MK19 have imbalanced datasets that may not fairly represent chloride conditions in those reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 4.52
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches on Selected Major Tributaries to the Milwaukee River: 1961-2022



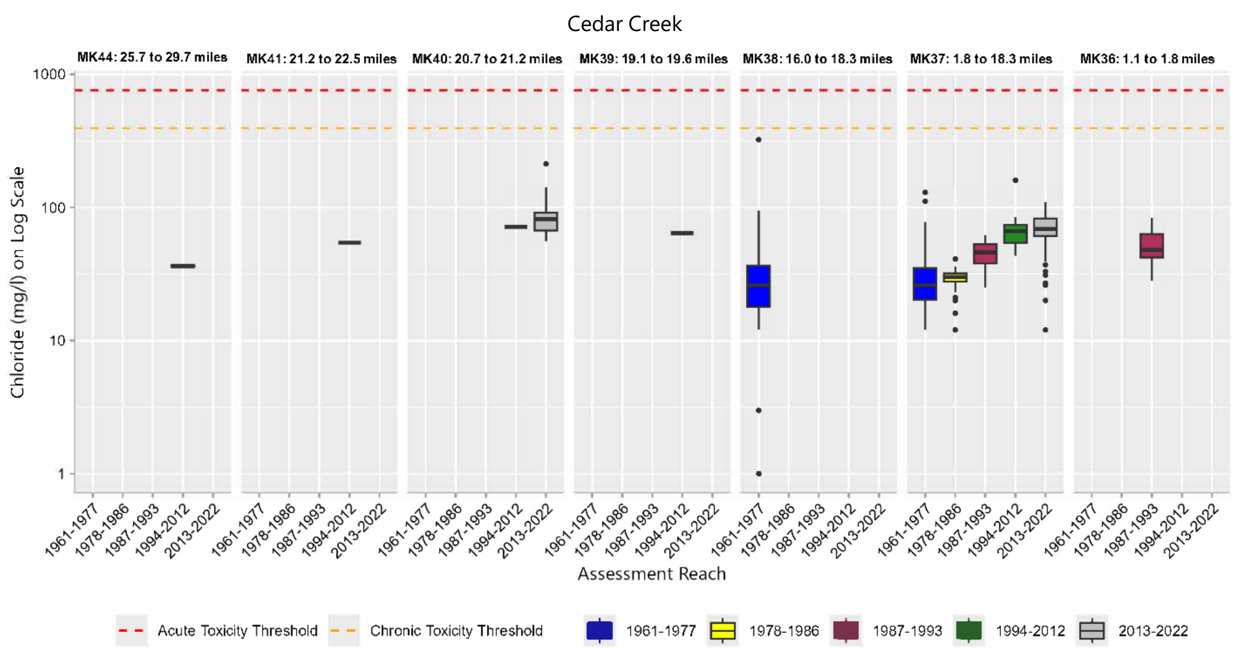
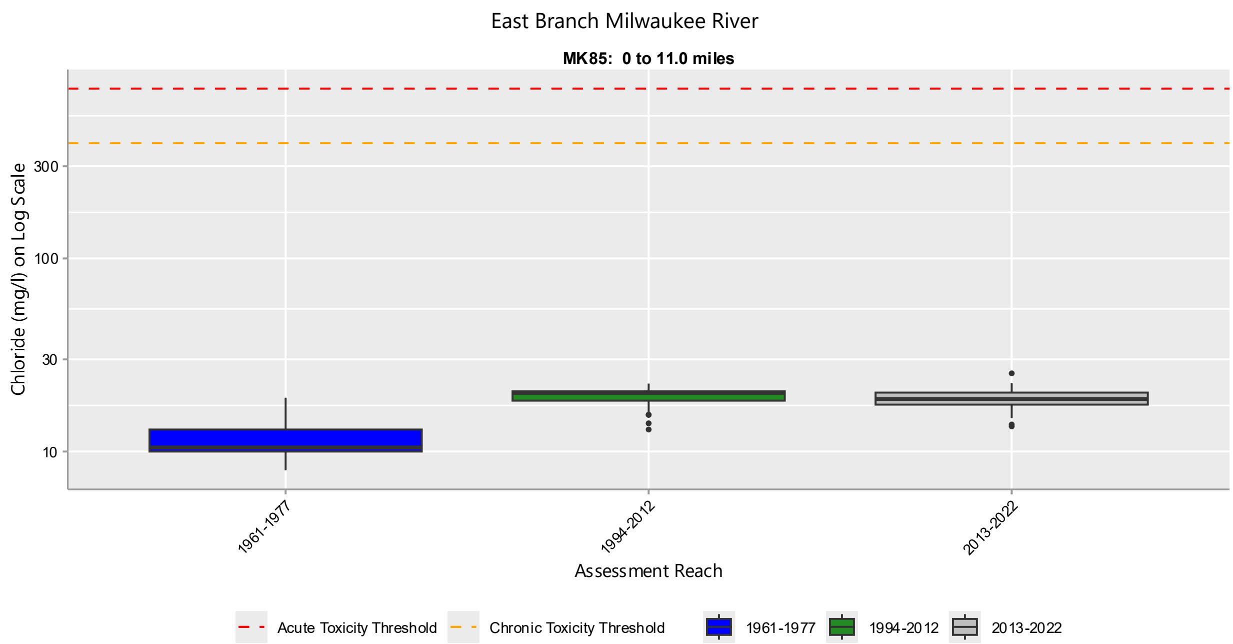
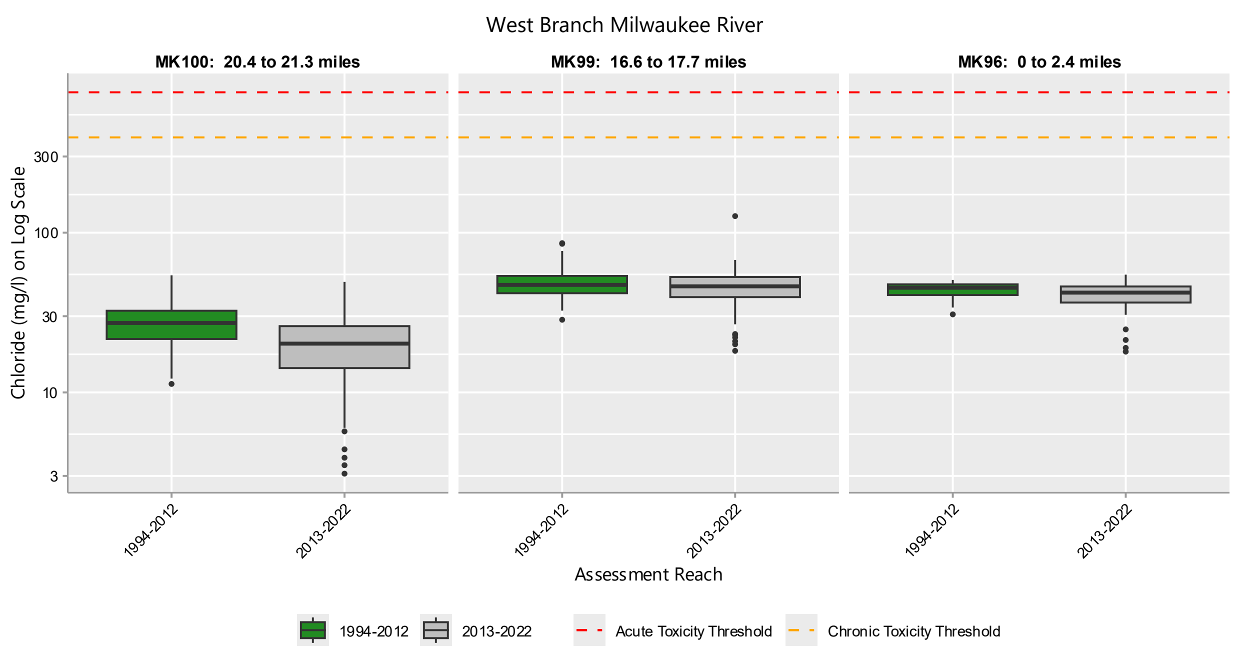


Figure 4.52 (continued)

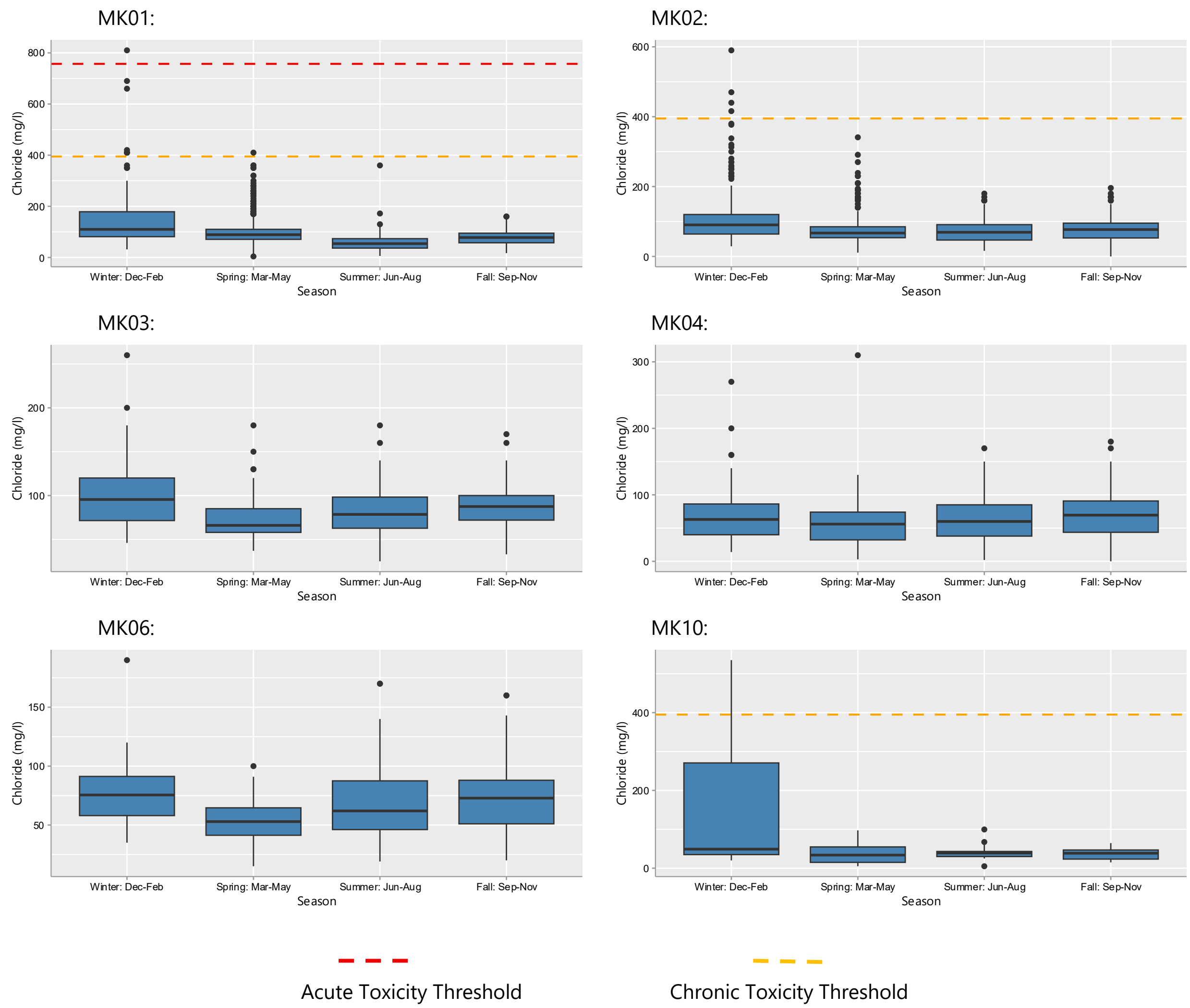




Note: This figure represents all chloride data collected from Lincoln Creek, Cedar Creek, East Branch Milwaukee River, and West Branch Milwaukee River, in the Milwaukee River watershed. Assessment reaches appear from upstream to downstream (left to right). The following assessment reaches have imbalanced datasets: Cedar Creek reaches MK36, MK38, MK39, MK41 and MK44; and West Branch Milwaukee River reaches MK99 and MK100. Imbalanced datasets may not fairly represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC.

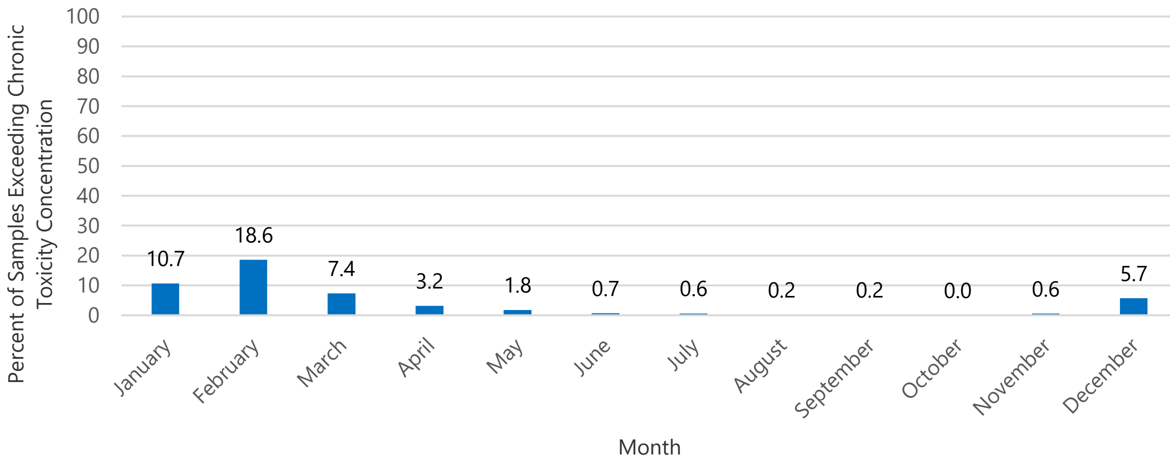
Figure 4.53
Chloride Concentrations by Season for Balanced Milwaukee River Mainstem Assessment Reaches: 1961-2022



Note: This figure represents all chloride data over the full period of record for Milwaukee River mainstem assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. Seasons include winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC.

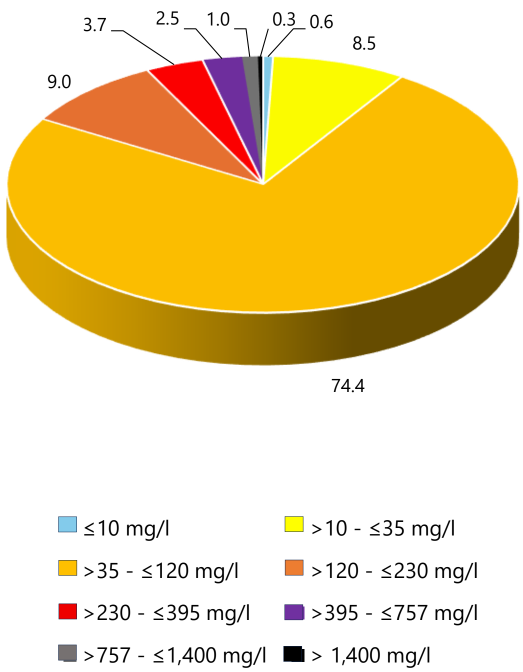
Figure 4.54
Percent of Chloride Samples Exceeding Chronic Toxicity Threshold in the Milwaukee River Watershed: 1961-2022



Note: This dataset represents all 11,562 chloride samples collected in the Milwaukee River watershed during the full period of record. Some of the samples represented in this figure that exceeded the State chronic toxicity concentration (395 mg/l) were collected prior to the establishment of the chloride toxicity criterion.

Source: SEWRPC

Figure 4.55
Percent of Recent Chloride Samples Collected in the Milwaukee River Watershed Within Various Thresholds of Water Quality: 2013-2022



Note: There were 4,856 chloride samples collected in the Milwaukee River watershed during the recent period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC.

Figure 4.56
Trends in Recent Chloride Concentrations for Milwaukee River Mainstem Assessment Reaches with Balanced Datasets: 2013-2022

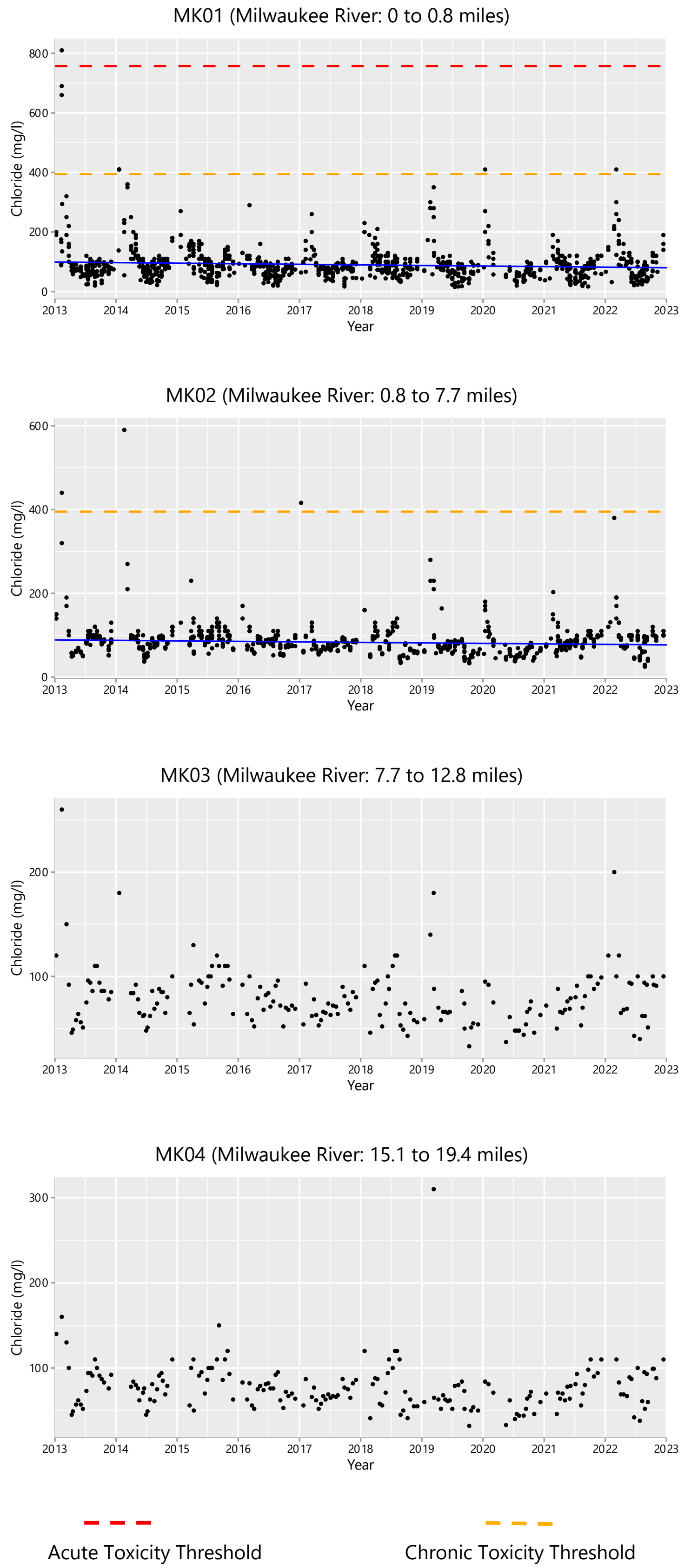
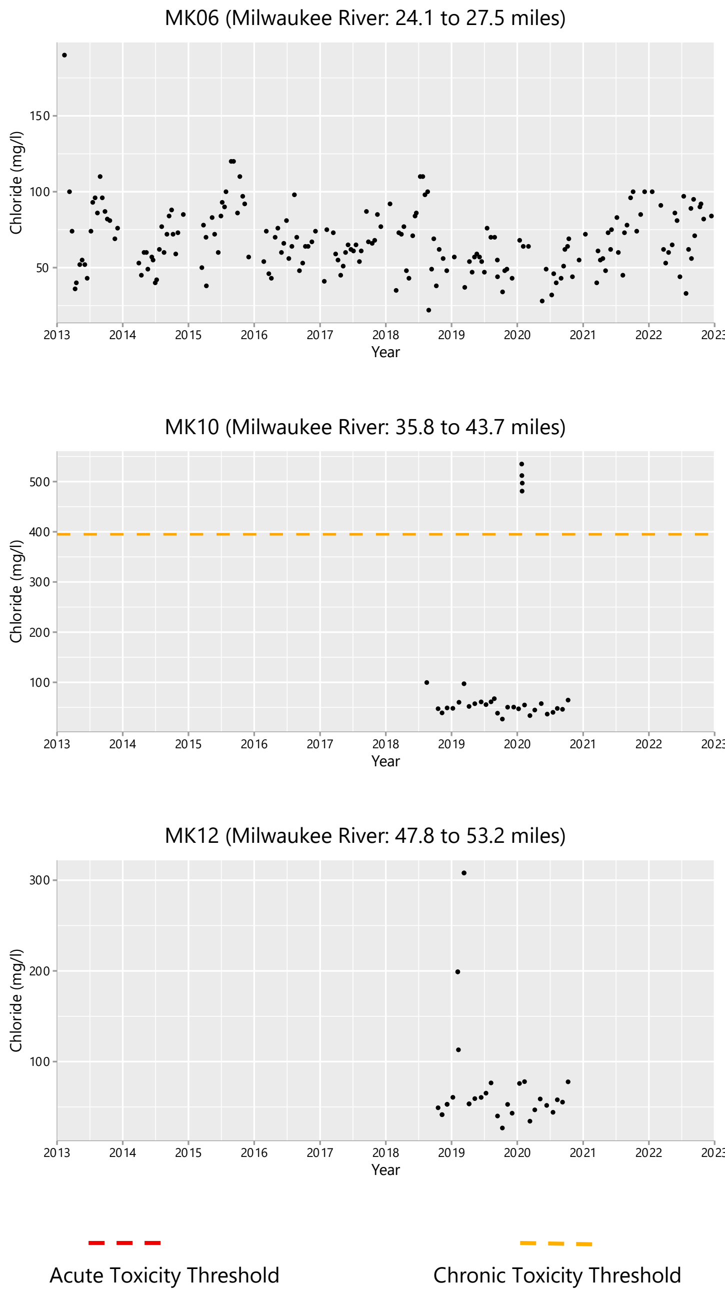


Figure 4.56 (continued)



Note: This figure includes all chloride data collected over the recent period of record for Milwaukee River mainstem assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. A simple linear regression was performed to analyze the trends in chloride concentrations for the recent period of record (2013-2022). Trendlines are shown only for assessment reaches that demonstrated a statistically significant trend in chloride (p-value < 0.01). While this figure shows all chloride samples displayed by specific collection date, the trendlines displayed on MK01 and MK02 were developed using the year of collection as the independent variable (x-axis) rather than the full date of collection. Each individual sample concentration was used as the dependent variable (y-axis). This approach captures the overall linear trend while accounting for the natural variability of the data points within each year.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 4.57
Trends in Recent Chloride Concentrations for Balanced Assessment Reaches in Selected Major Tributaries to the Milwaukee River: 2013-2022

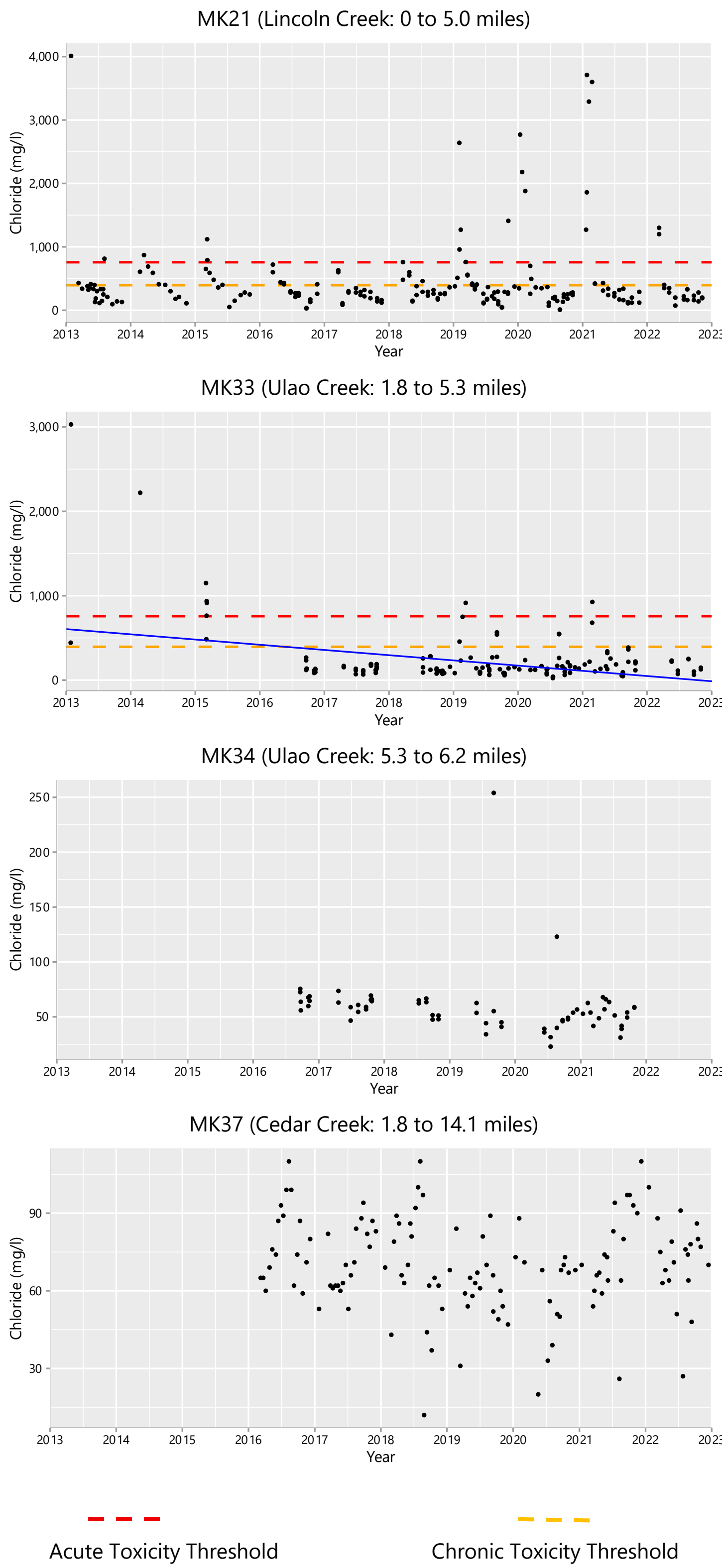


Figure 4.57 (continued)

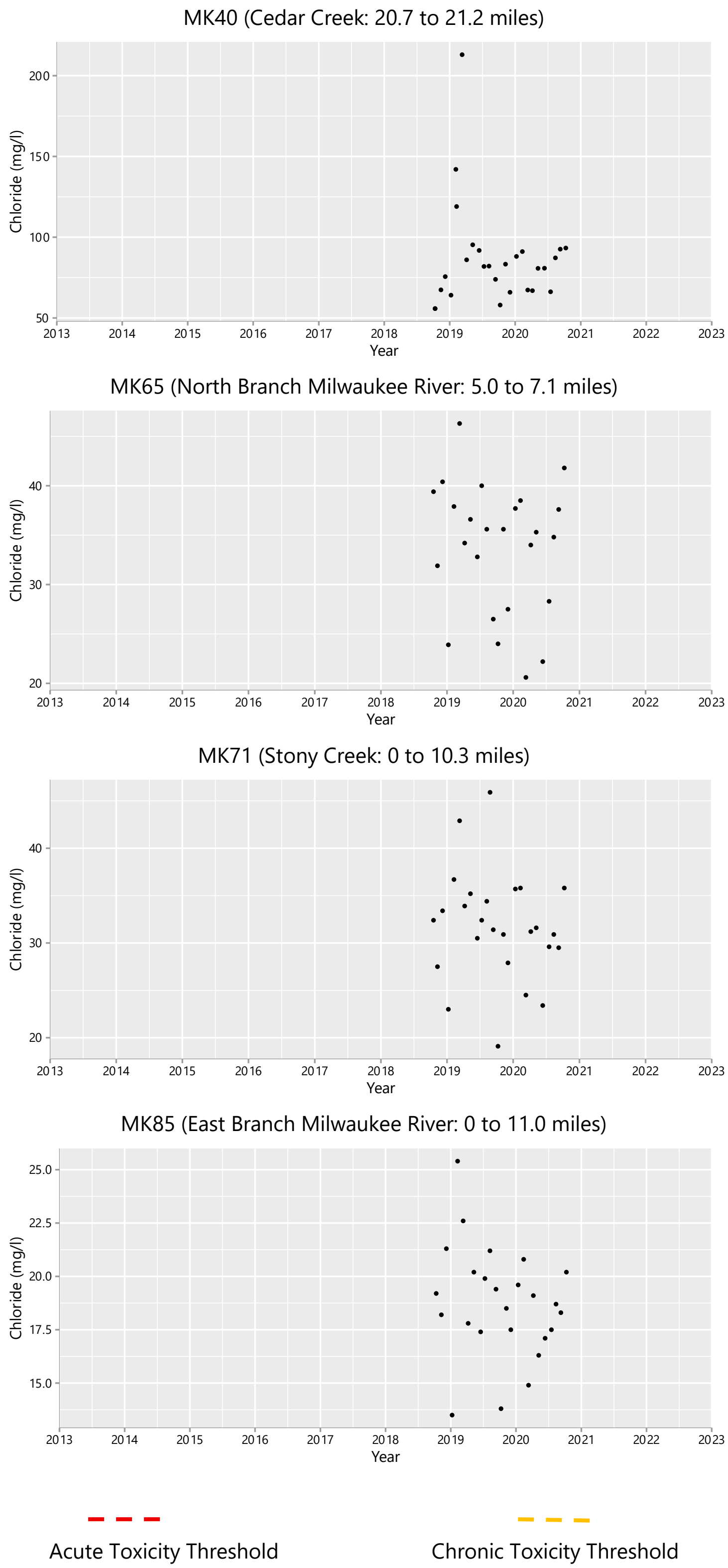
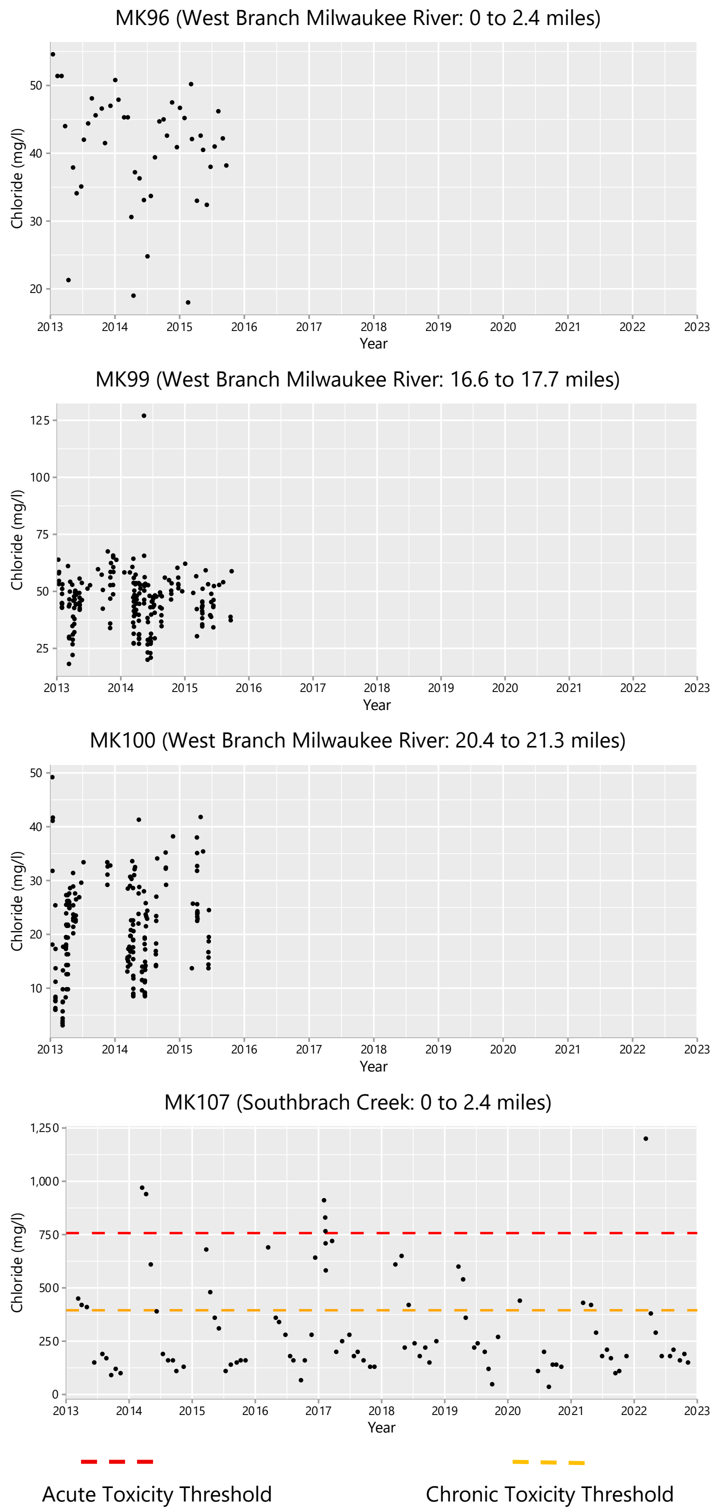


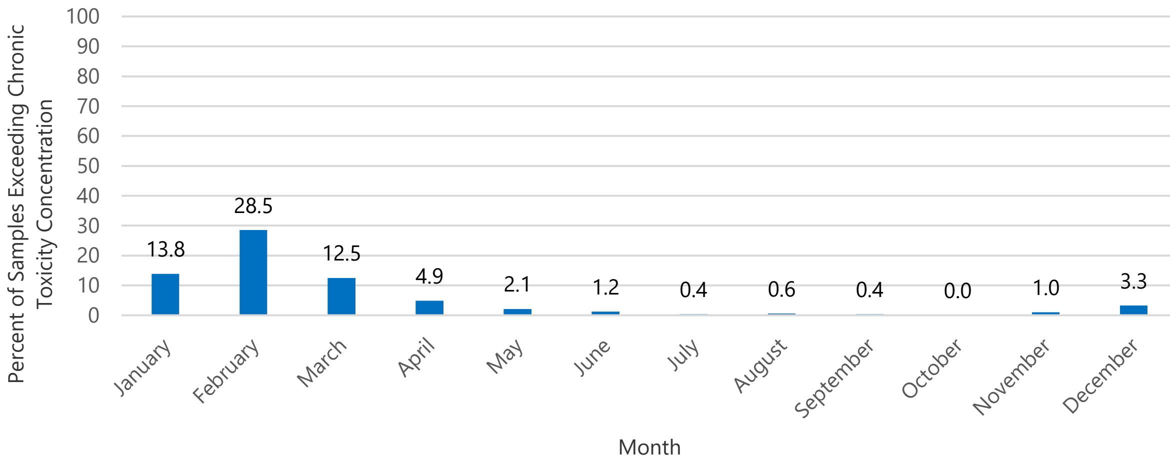
Figure 4.57 (continued)



Note: This figure includes all chloride data collected over the recent period of record for assessment reaches within selected tributaries to the Milwaukee River that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. A simple linear regression was performed to analyze the trends in chloride concentrations for the recent period of record (2013-2022). Trendlines are shown only for assessment reaches that demonstrated a statistically significant trend in chloride (p-value < 0.05). While this figure shows all chloride samples displayed by specific collection date, the trendline displayed on MK33 was developed using the year of collection as the independent variable (x-axis) rather than the full date of collection. Each individual sample concentration was used as the dependent variable (y-axis). This approach captures the overall linear trend while accounting for the natural variability of the data points within each year.

Source: MMSD, USEPA, USGS, WDNR, Milwaukee Riverkeeper, University of Wisconsin-Milwaukee, and SEWRPC.

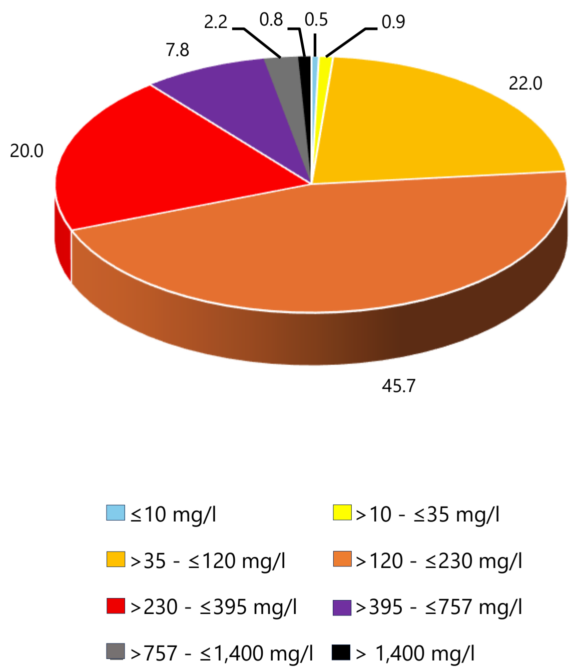
Figure 4.58
Percent of Recent Chloride Samples Exceeding Chronic Toxicity Concentration in the Milwaukee River Watershed: 2013-2022



Note: This dataset represents all 4,856 chloride samples collected in the Milwaukee River watershed during the recent period of record.

Source: SEWRPC

Figure 4.59
Percent of Chloride Samples Collected in the Oak Creek Watershed Within Various Thresholds of Water Quality: 1961-2022

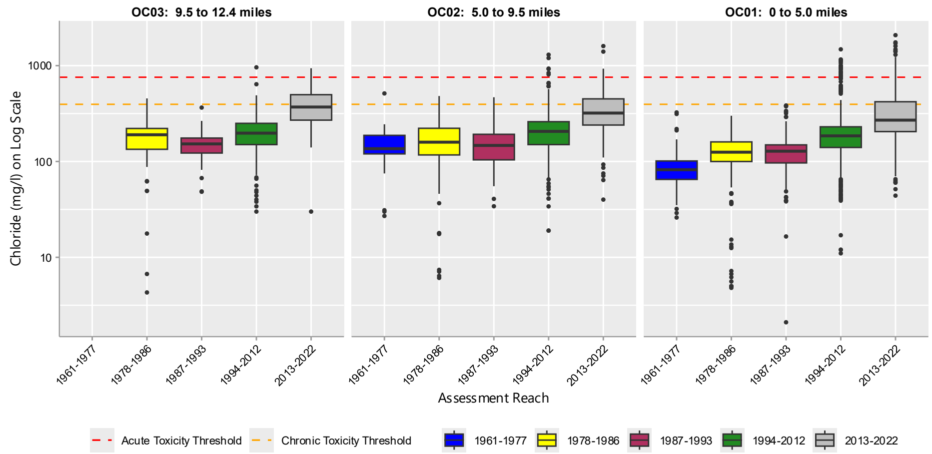


Note: There were 3,243 chloride samples collected in the Oak Creek watershed during the full period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

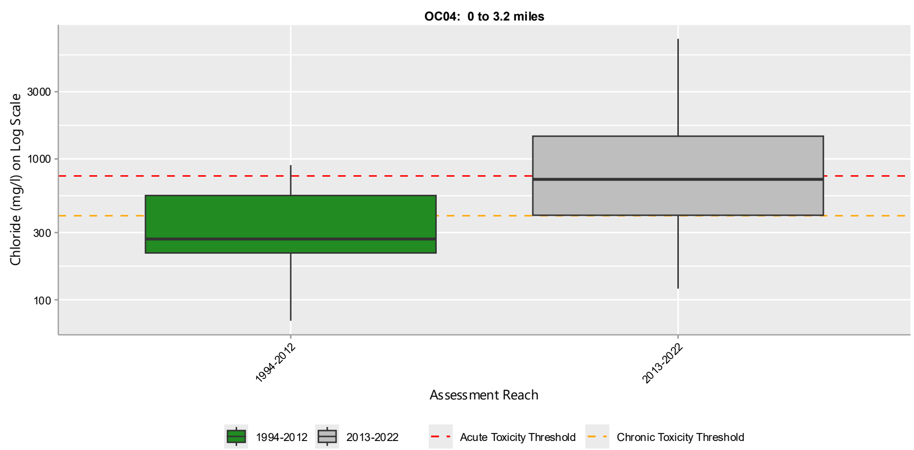
Source: SEWRPC.

Figure 4.60
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches on the Oak Creek Mainstem, Mitchell Field Drainage Ditch, and North Branch Oak Creek: 1961-2022

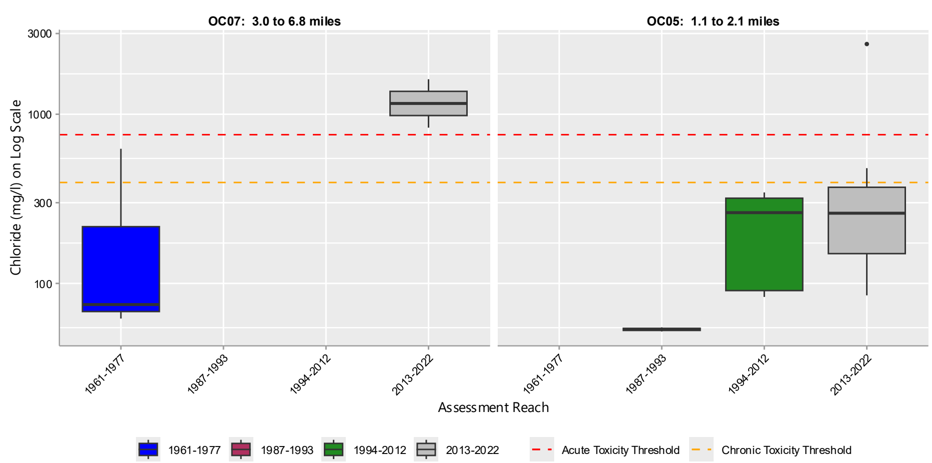
Oak Creek Mainstem



Mitchell Field Drainage Ditch



North Branch Oak Creek

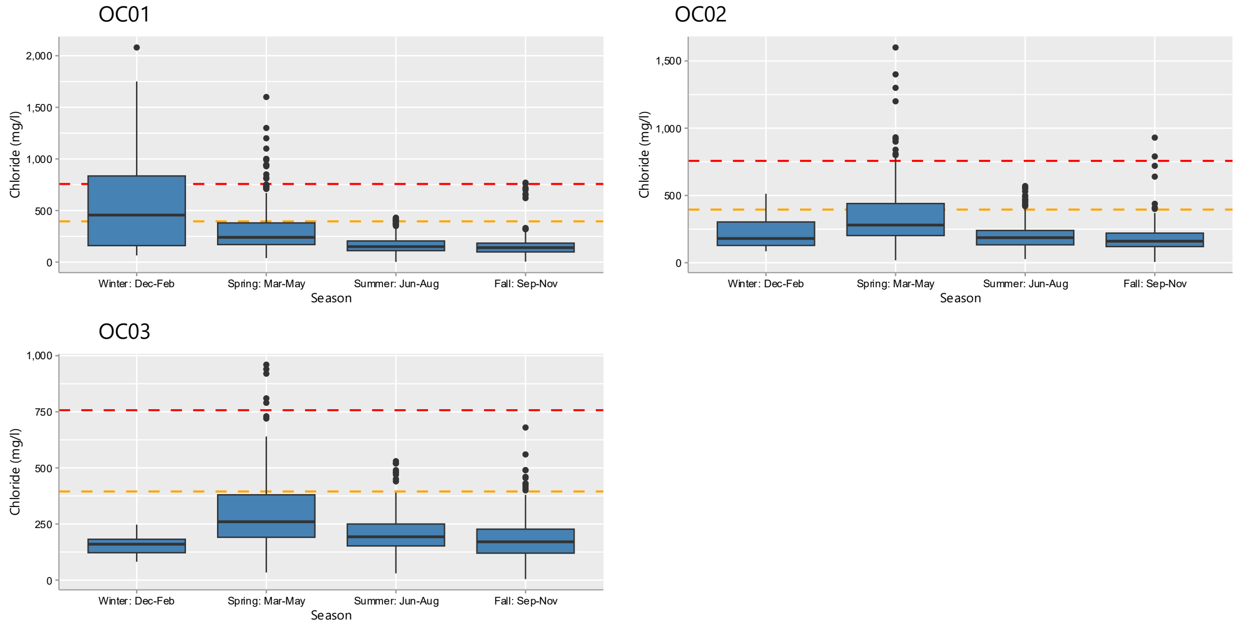


Note: This figure represents all chloride data collected from the Oak Creek mainstem, North Branch Oak Creek, and Mitchell Filed Drainage Ditch. Assessment reaches appear from upstream to downstream (left to right). Both North Branch Oak Creek assessment reaches (OC07 and OC05) have imbalanced chloride datasets. Imbalanced datasets may not fairly represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

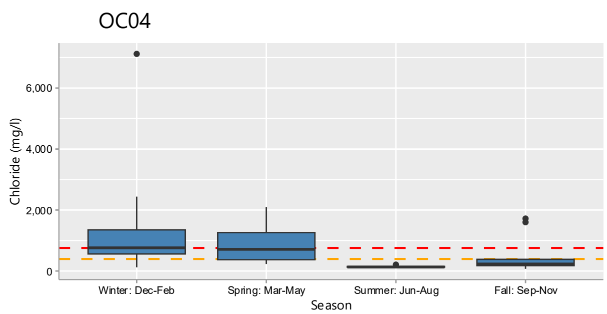
Source: MMSD, WDNR, USGS, and SEWRPC

Figure 4.61
Chloride Concentrations by Season for Balanced Oak Creek Watershed Assessment Reaches: 1961-2022

Oak Creek Mainstem



Mitchell Field Drainage Ditch



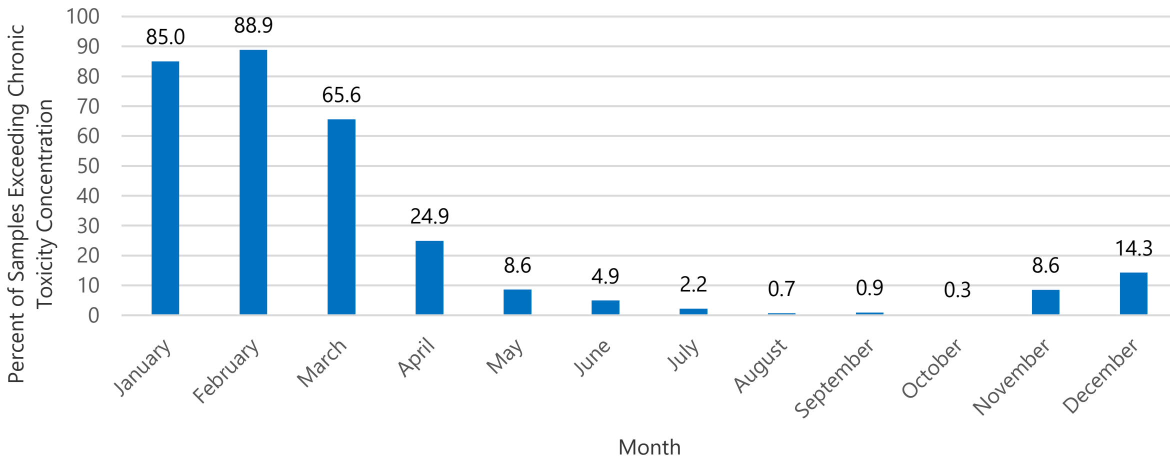
Acute Toxicity Threshold

Chronic Toxicity Threshold

Note: This figure represents all chloride data over the full period of record for Oak Creek watershed assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. Seasons include winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

Source: MMSD, WDNR, USGS, and SEWRPC

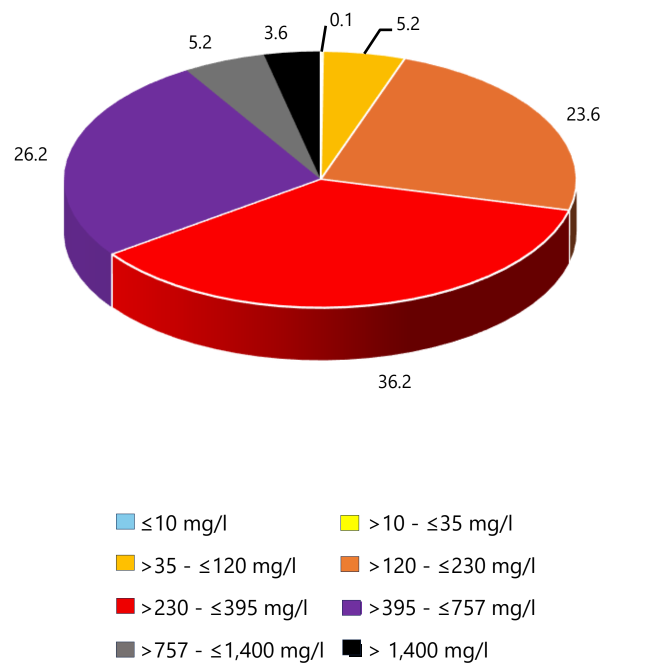
Figure 4.62
Percent of Chloride Samples Exceeding Chronic Toxicity Concentration in the Oak Creek Watershed: 1961-2022



Note: This dataset represents all 3,243 chloride samples collected within the Oak Creek watershed during the full period of record.

Source: SEWRPC

Figure 4.63
Percent of Recent Chloride Samples Collected in the Oak Creek Watershed Within Various Thresholds of Water Quality: 2013-2022

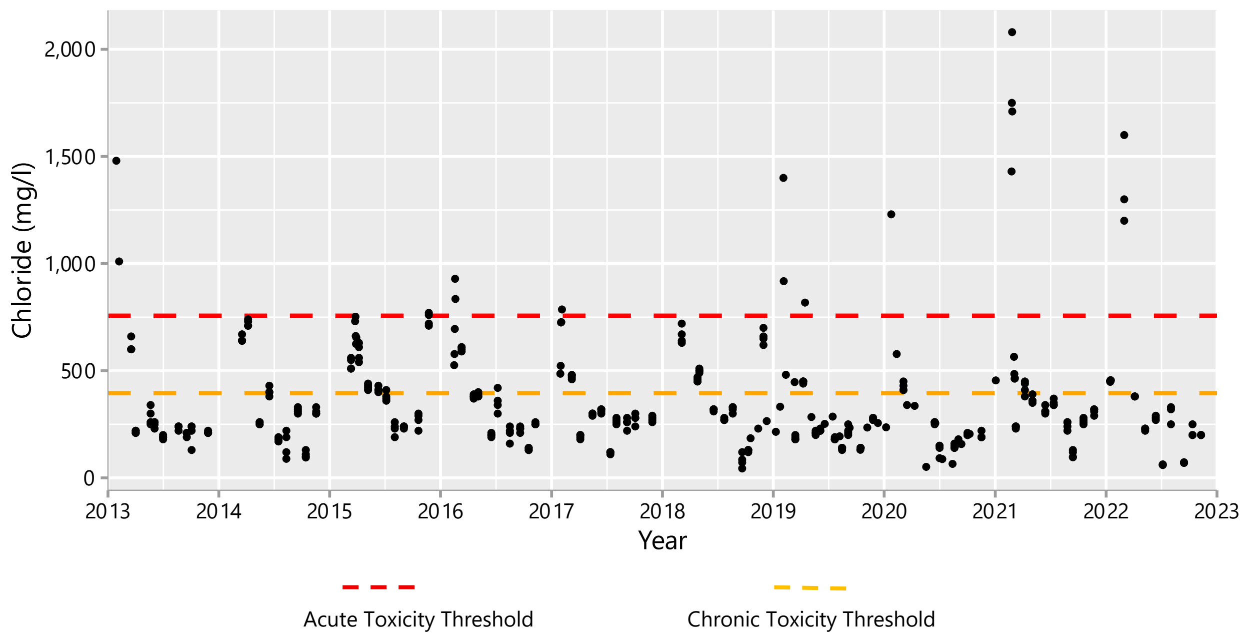


Note There were 730 chloride samples collected in the Oak Creek watershed during the recent period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC.

Figure 4.64
Trends in Recent Chloride Concentrations for Oak Creek Watershed Assessment Reaches with Balanced Datasets: 2013-2022

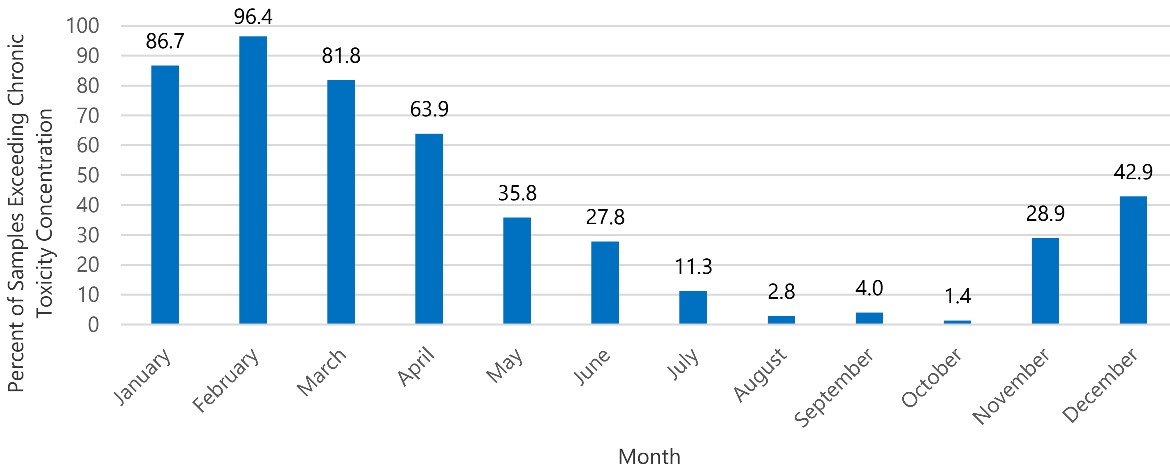
OC01 (Oak Creek: 0 to 5.0 miles)



Note: This figure includes all chloride data over the recent period of record for the one assessment reach that had a balanced dataset in the Oak Creek watershed. Scales are unique for each assessment reach to best fit the observed data. There were no statistically significant chloride trends found in Oak Creek watershed assessment reaches over the recent period of record.

Source: MMSD, WDNR, and SEWRPC.

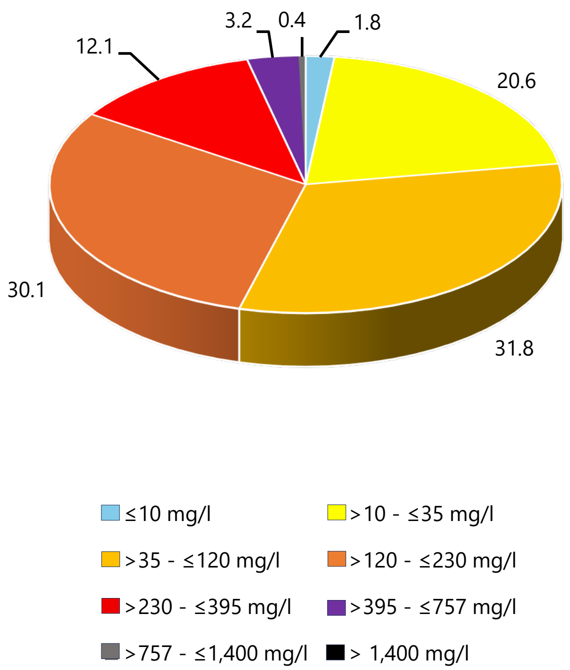
Figure 4.65
Percent of Recent Chloride Samples Exceeding Chronic Toxicity Concentration in the Oak Creek Watershed: 2013-2022



Note: This dataset represents all 730 chloride samples collected within the Oak Creek watershed during the recent period of record.

Source: SEWRPC

Figure 4.66
Percent of Chloride Samples Collected in the Pike River Watershed Within Various Thresholds of Water Quality: 1961-2022

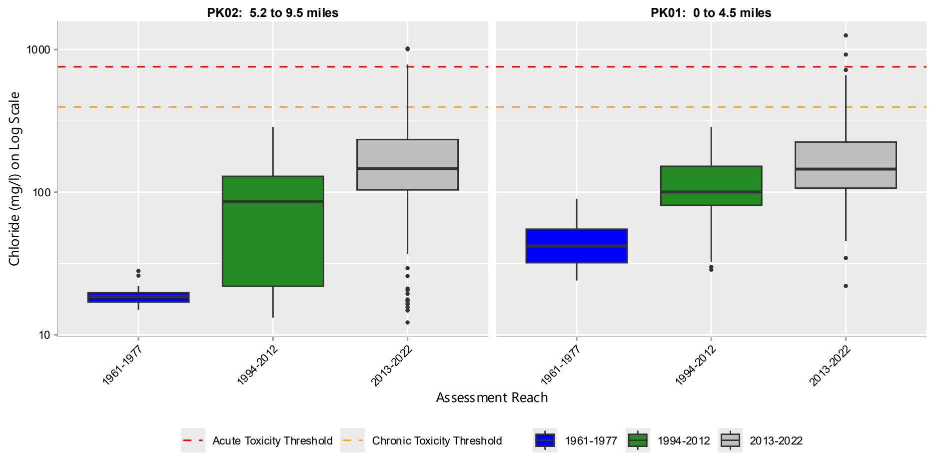


Note: There were 1,114 chloride samples collected in the Pike River watershed during the full period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

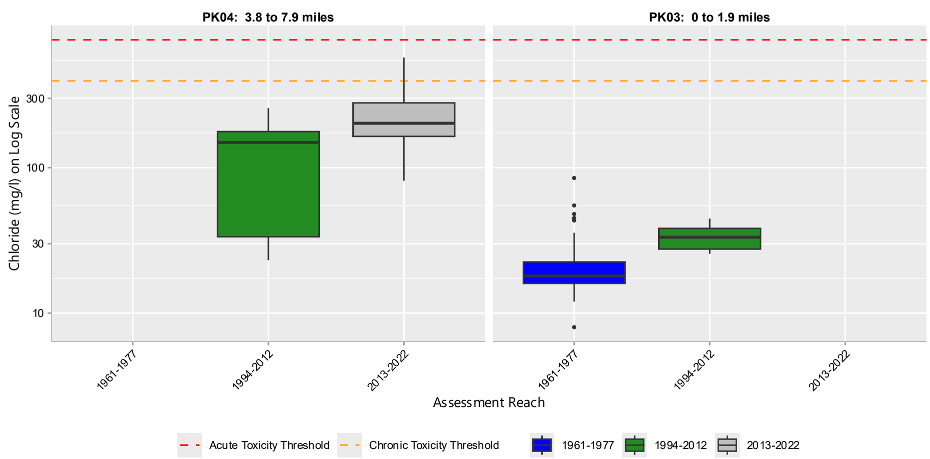
Source: SEWRPC

Figure 4.67
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches on the Pike River mainstem, North Branch Pike River, and South Branch Pike River: 1961-2022

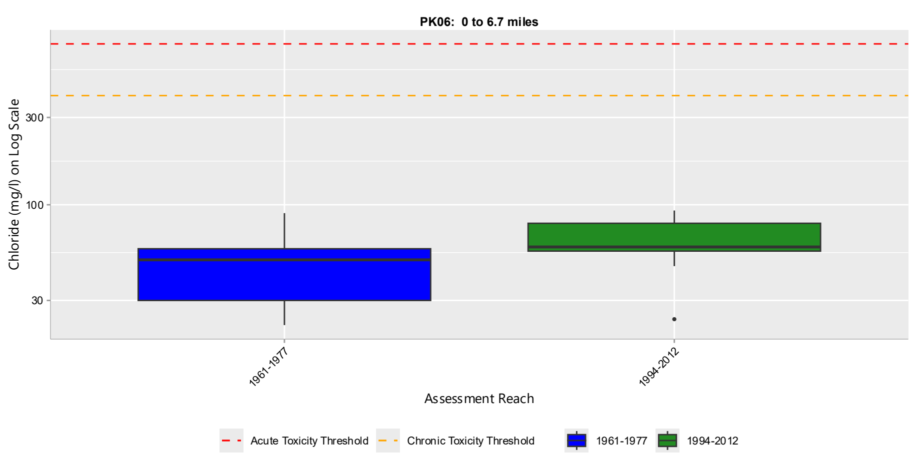
Pike River Mainstem



North Branch Pike River



South Branch Pike River

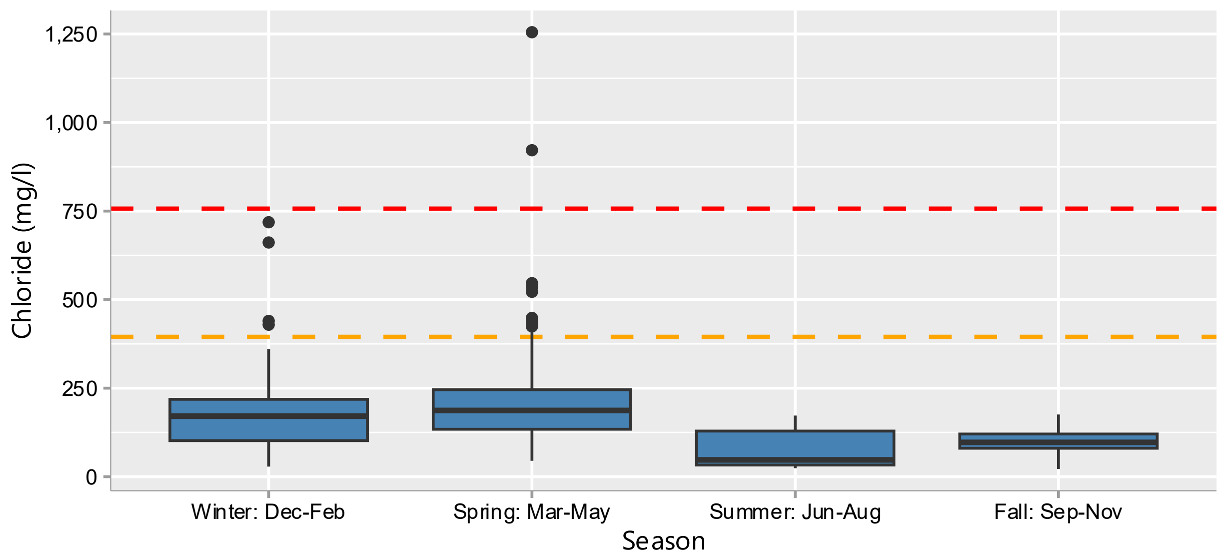


Note: This figure represents all chloride data collected from the Pike River mainstem and the North Branch Pike River and South Branch Pike River tributaries. Assessment reaches appear from upstream to downstream (left to right). Both North Branch Pike River assessment reaches (PK04 and PK03) and South Branch Pike River reach PK06 have imbalanced datasets. Imbalanced datasets may not fairly represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

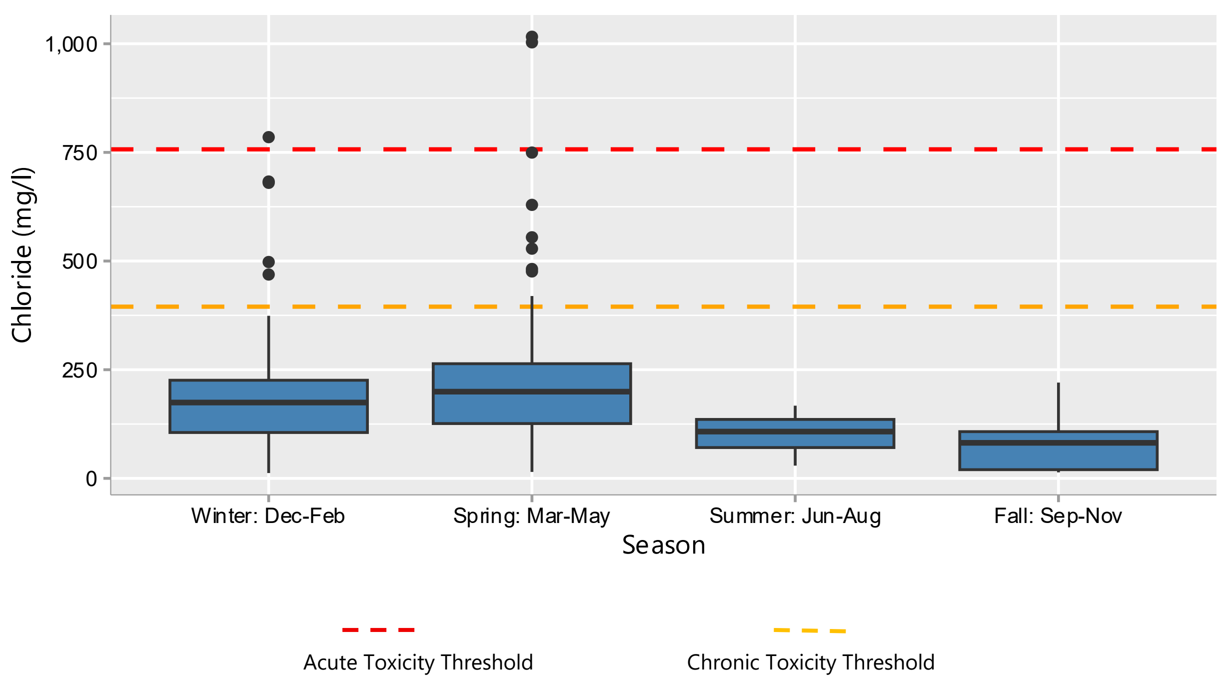
Source: WDNR, USGS, and SEWRPC

Figure 4.68
Chloride Concentrations by Season for Balanced Pike River Mainstem Assessment Reaches: 1961-2022

PK01



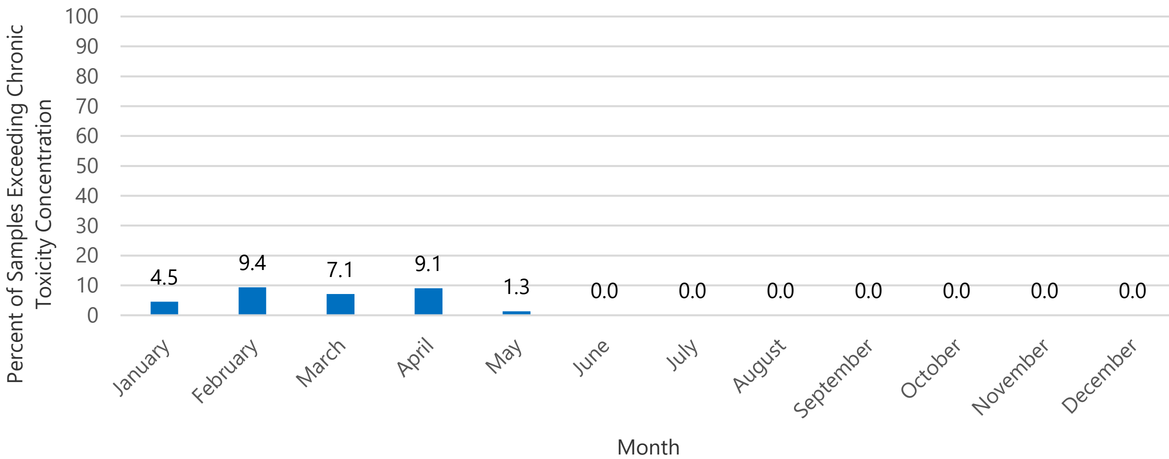
PK02



Note: This figure includes all chloride data over the full period of record for Pike River mainstem assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. Seasons include winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

Source: WDNR, USGS, and SEWRPC

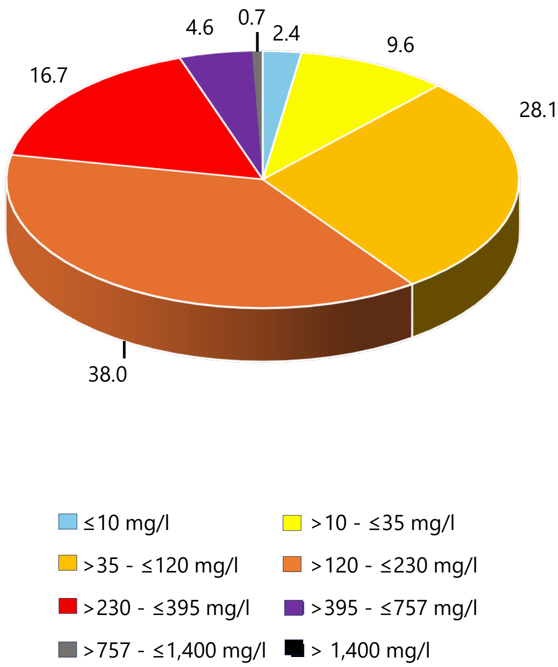
Figure 4.69
Percent of Chloride Samples Exceeding Chronic Toxicity Concentration in the Pike River Watershed: 1961-2022



Note: There were 1,114 chloride samples collected within the Pike River watershed during the full period of record.

Source: SEWRPC

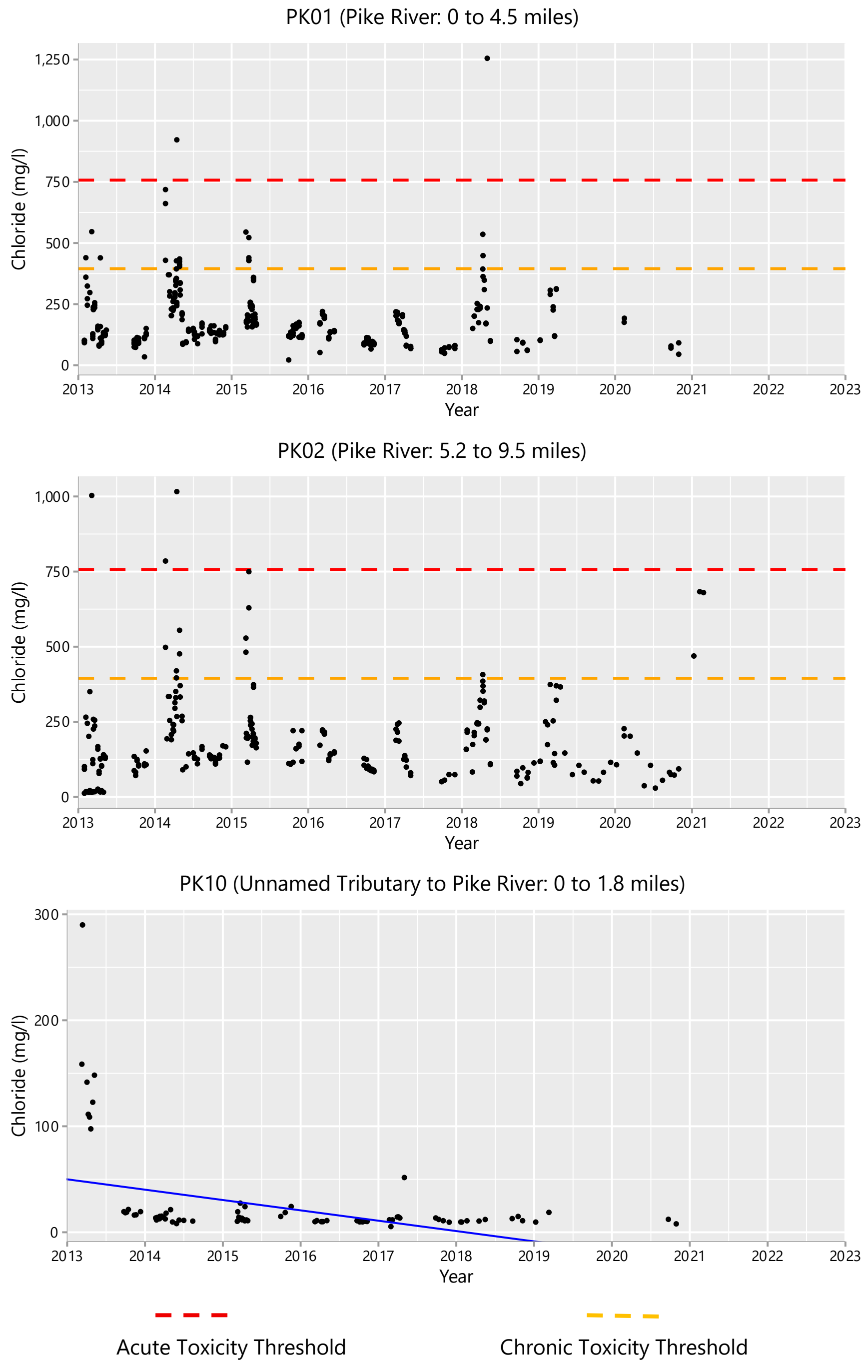
Figure 4.70
Percent of Recent Chloride Samples Collected in the Pike River Watershed Within Various Thresholds of Water Quality: 2013-2022



Note There were 743 chloride samples collected in the Pike River watershed during the recent period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC

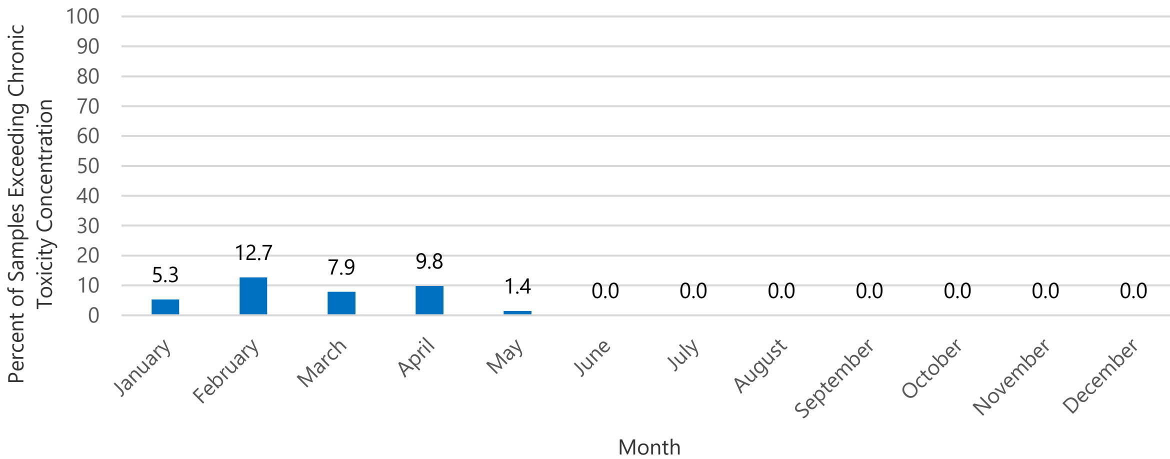
Figure 4.71
Trends in Recent Chloride Concentrations for Pike River Watershed Assessment Reaches with Balanced Datasets: 2013-2022



Note: This figure includes all chloride data collected over the recent period of record for Pike River watershed assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. A simple linear regression was performed to analyze the trends in chloride concentrations for the recent period of record (2013-2022). Trendlines are shown only for assessment reaches that demonstrated a statistically significant trend in chloride (p-value < 0.01). While this figure shows all chloride samples displayed by specific collection date, the trendlines displayed on PK10 were developed using the year of collection as the independent variable (x-axis) rather than the full date of collection. Each individual sample concentration was used as the dependent variable (y-axis). This approach captures the overall linear trend while accounting for the natural variability of the data points within each year.

Source: WDNR, USGS, and SEWRPC

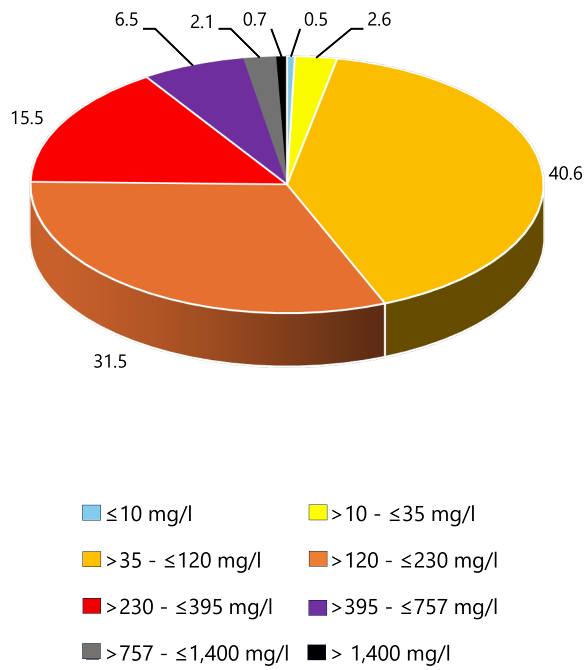
Figure 4.72
Percent of Recent Chloride Samples Exceeding Chronic Toxicity Concentration in the Pike River Watershed: 2013-2022



Note: There were 743 chloride samples collected within the Pike River watershed during the recent period of record.

Source: SEWRPC

Figure 4.78
Percent of Chloride Samples Collected in the Root River Watershed Within Various Thresholds of Water Quality: 1961-2022

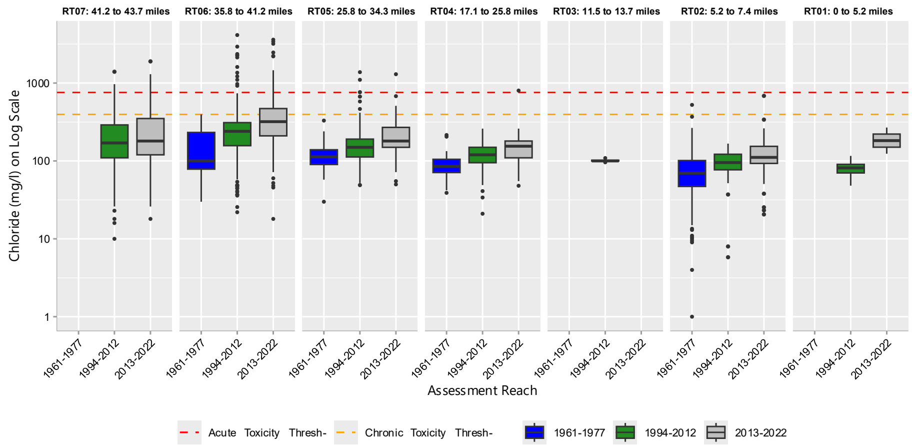


Note: There were 2,232 chloride samples collected in the Root River watershed during the full period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

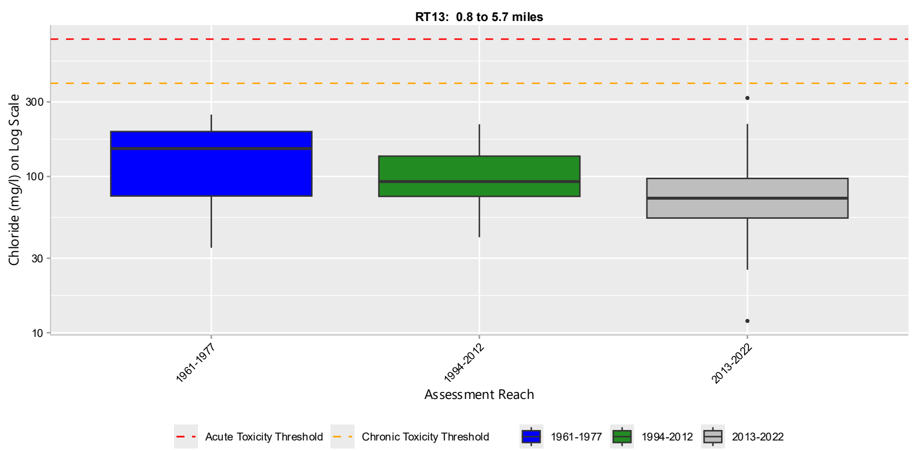
Source: SEWRPC.

Figure 4.79
Distribution of Chloride Concentrations for All Samples Collected at Assessment Reaches on the Root River Mainstem, Root River Canal, and Hoods Creek: 1961-2022

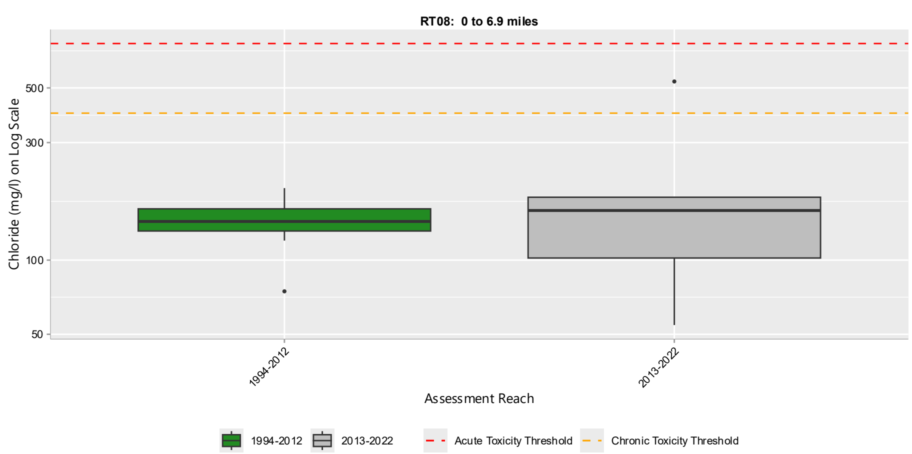
Root River Mainstem



Root River Canal



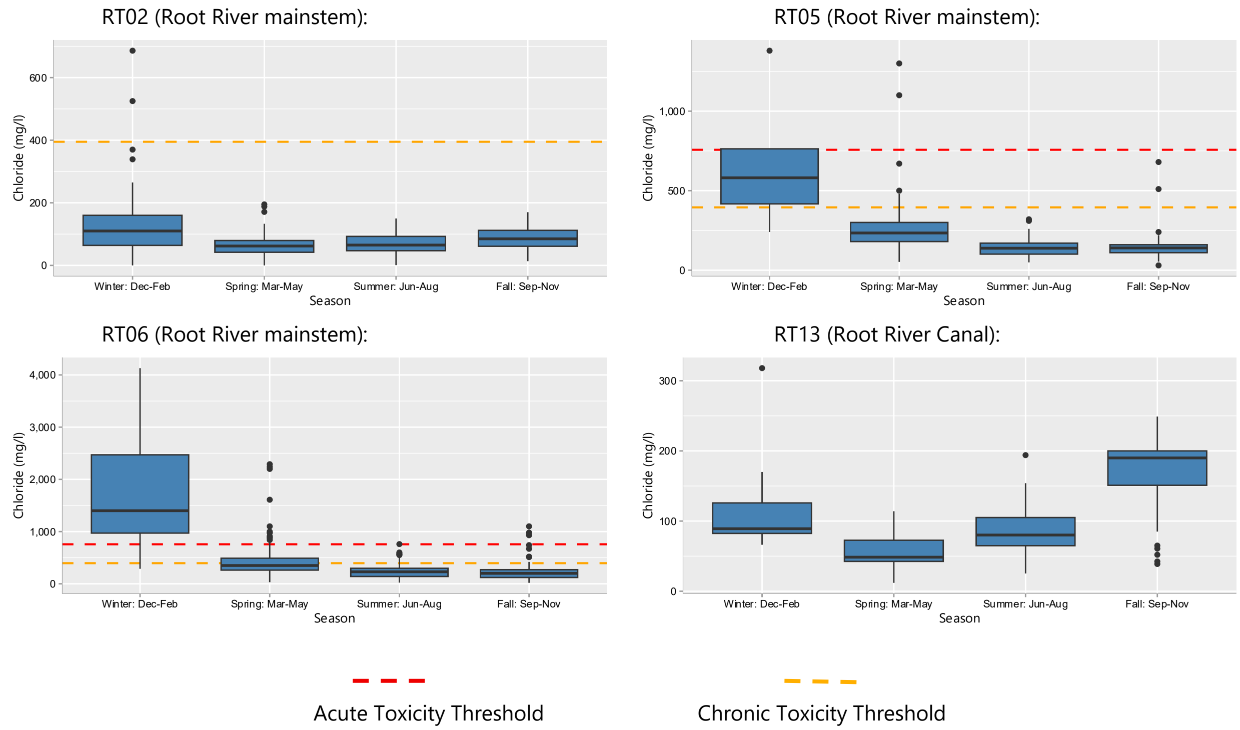
Hoods Creek



Note: This figure represents all chloride data collected from the Root River mainstem, Root River Canal, and Hoods Creek. Assessment reaches appear from upstream to downstream (left to right). The following assessment reaches have imbalanced datasets: Root River reaches RT01, RT03, RT04, and RT07; and Hoods Creek reach RT08. Imbalanced datasets may not fairly represent chloride conditions in these reaches due to a small sample size or uneven distribution of samples throughout the years or throughout all seasons.

Source: MMSD, WDNR, USGS, University of Wisconsin-Milwaukee, and SEWRPC.

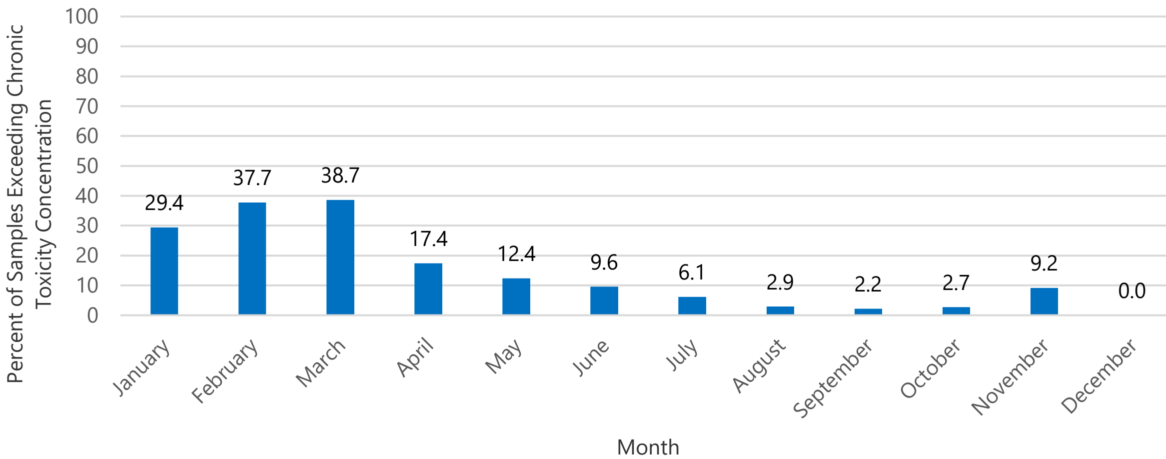
Figure 4.80
Chloride Concentrations by Season for Balanced Root River Watershed Assessment Reaches: 1961-2022



Note: This figure represents all chloride data over the full period of record for Root River watershed assessment reaches that have balanced datasets. Scales are unique for each assessment reach to best fit the observed data. Seasons include winter (December through February), spring (March through May), summer (June through August), and fall (September through November).

Source: MMSD, WDNR, USGS, University of Wisconsin-Milwaukee, and SEWRPC.

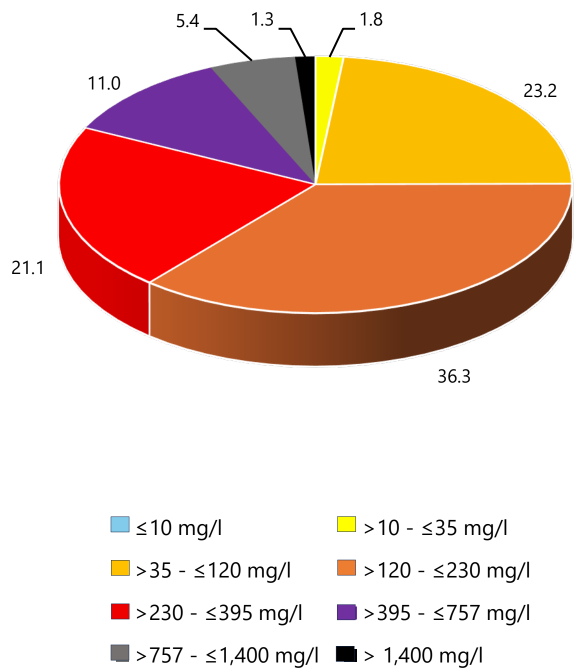
Figure 4.81
Percent of Chloride Samples Exceeding the Chronic Toxicity Threshold in the Root River Watershed: 1961-2022



Note: This dataset represents all 2,232 chloride samples collected in the Root River watershed during the full period of record. Some of the samples represented in this figure that exceeded the State chronic toxicity concentration (395 mg/l) were collected prior to the establishment of the chloride toxicity criterion.

Source: SEWRPC

Figure 4.82
Percent of Recent Chloride Samples Collected in the Root River Watershed Within Various Thresholds of Water Quality: 2013-2022



Note: There were 626 chloride samples collected in the Root River watershed during the recent period of record. For descriptions of thresholds, see Table 2.Thresholds in Chapter 2 of this Report.

Source: SEWRPC.

Figure 4.83
Trends in Recent Chloride Concentrations for Selected Root River Watershed Assessment Reaches: 2013-2022

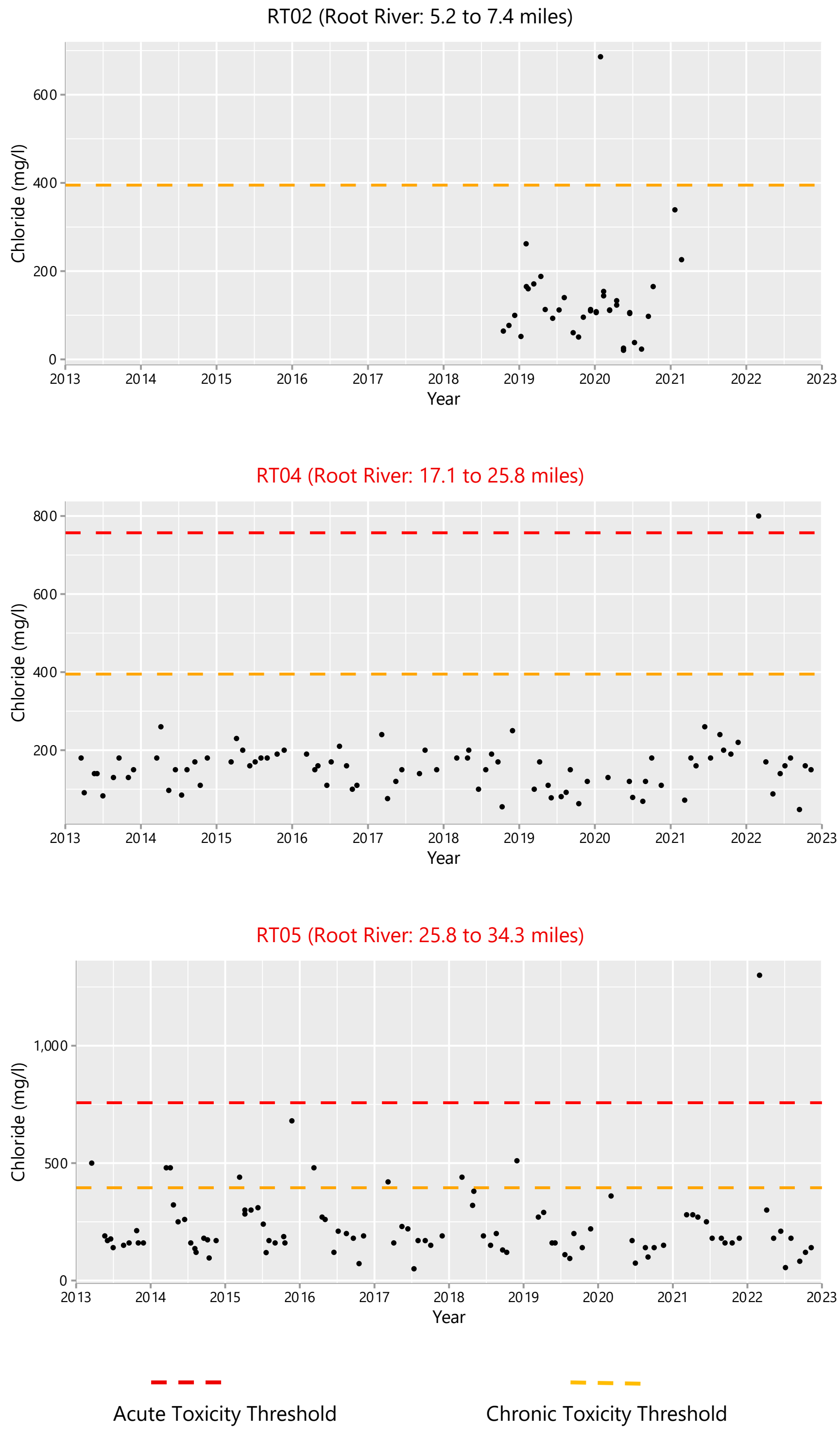
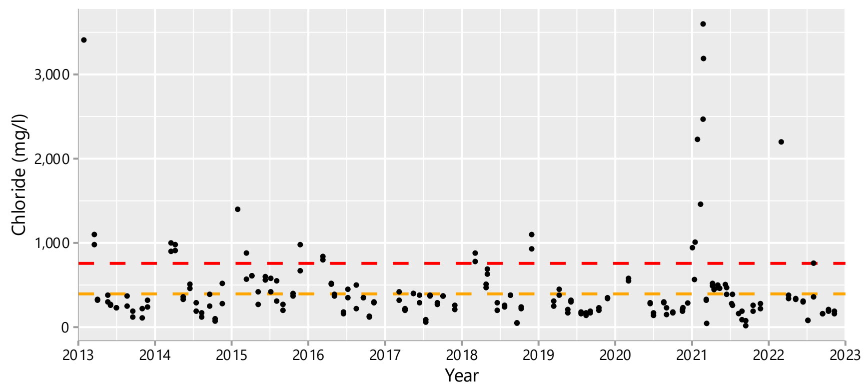
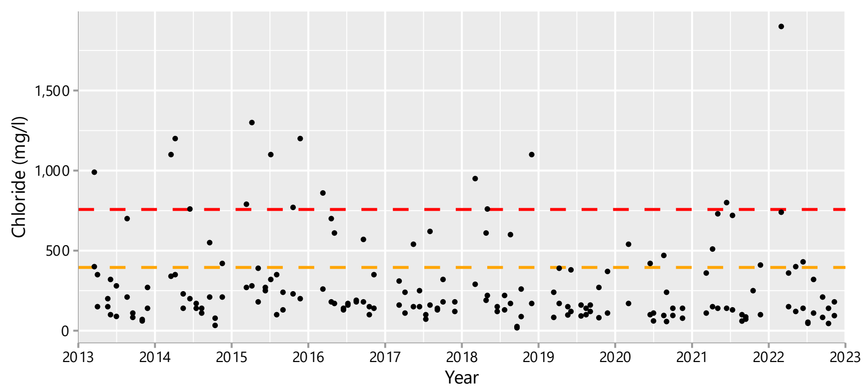


Figure 4.83 (continued)

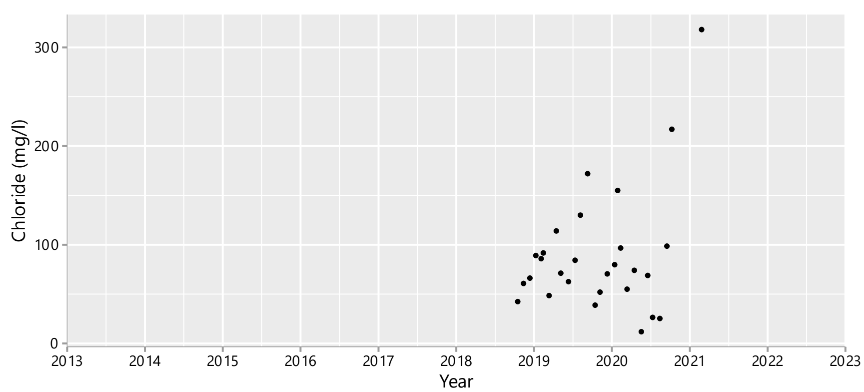
RT06 (Root River: 35.8 to 41.2 miles)



RT07 (Root River: 41.2 to 43.7 miles):



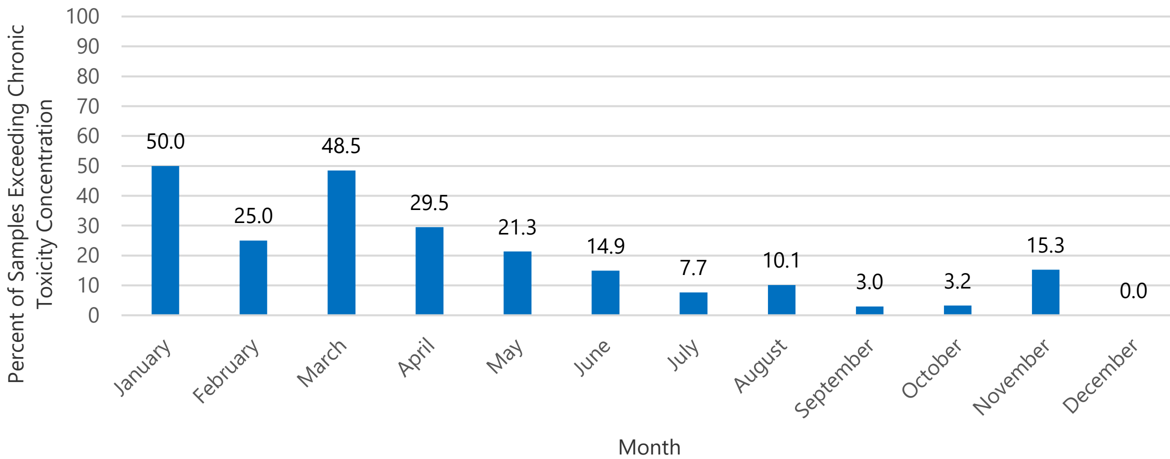
RT13 (Root River Canal: 0.8 to 5.7 miles)



Note: This figure includes all chloride data collected over the recent period of record for selected Root River watershed assessment reaches. The following assessment reaches shown in red text had imbalanced recent period datasets: Root River mainstem reaches RT04, RT05, and RT07. These assessment reaches are included in this figure because they have large datasets, however it is important to consider that the datasets for these reaches do not include any winter chloride samples and therefore likely underrepresent actual maximum chloride concentrations occurring in these reaches during the winter seasons. Scales are unique for each assessment reach to best fit the observed data. There were no statistically significant chloride trends found in Root River watershed assessment reaches over the recent period of record.

Source: MMSD, WDNR, USGS, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 4.84
Percent of Recent Chloride Samples Exceeding Chronic Toxicity Concentration in the Root River Watershed: 2013-2022



Note: This dataset represents all 626 chloride samples collected in the Root River watershed during the recent period of record.

Source: SEWRPC

Technical Report No. 63

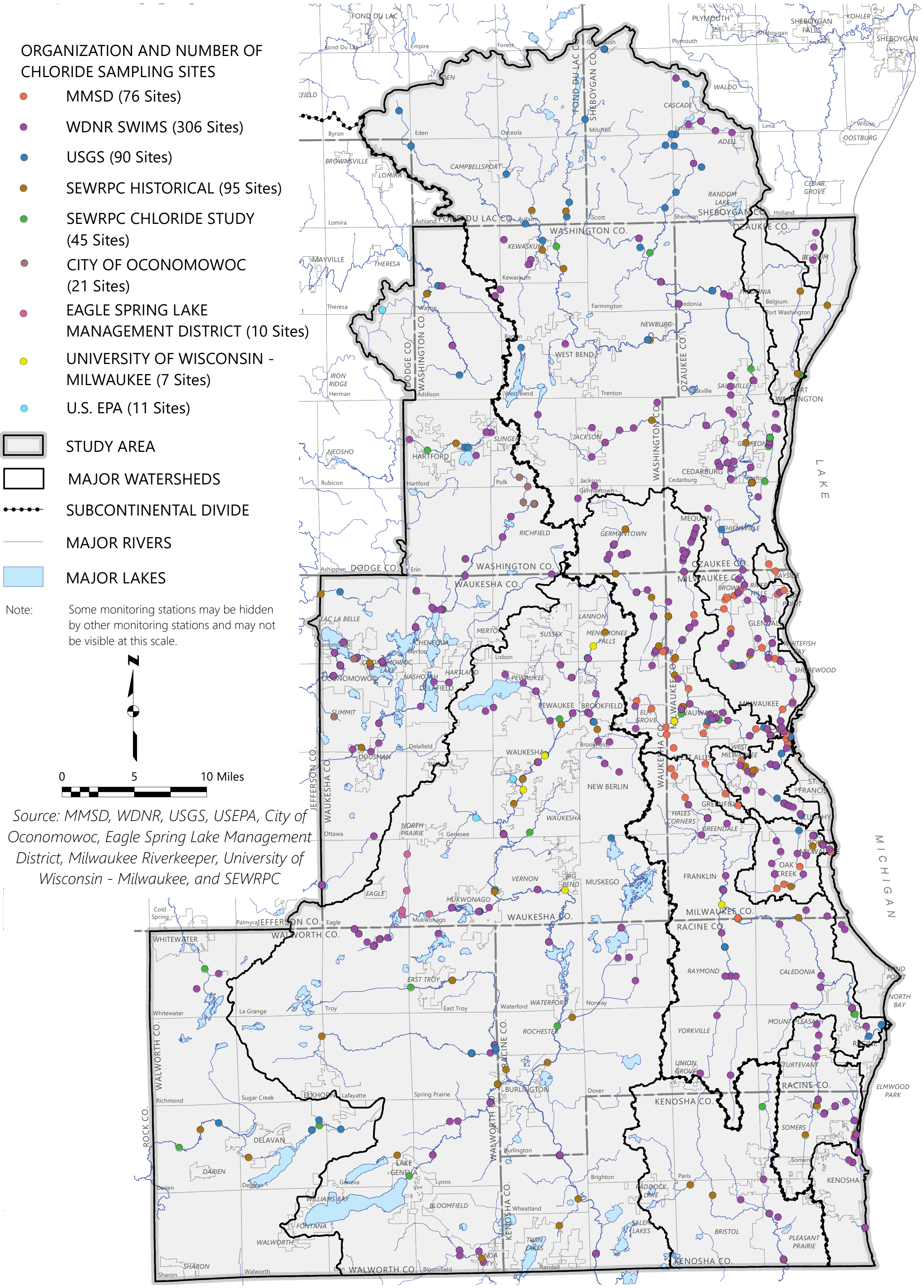
CHLORIDE CONDITIONS AND TRENDS IN SOUTHEASTERN WISCONSIN

Chapter 4

CHLORIDE CONDITIONS AND TRENDS: RIVERS AND STREAMS

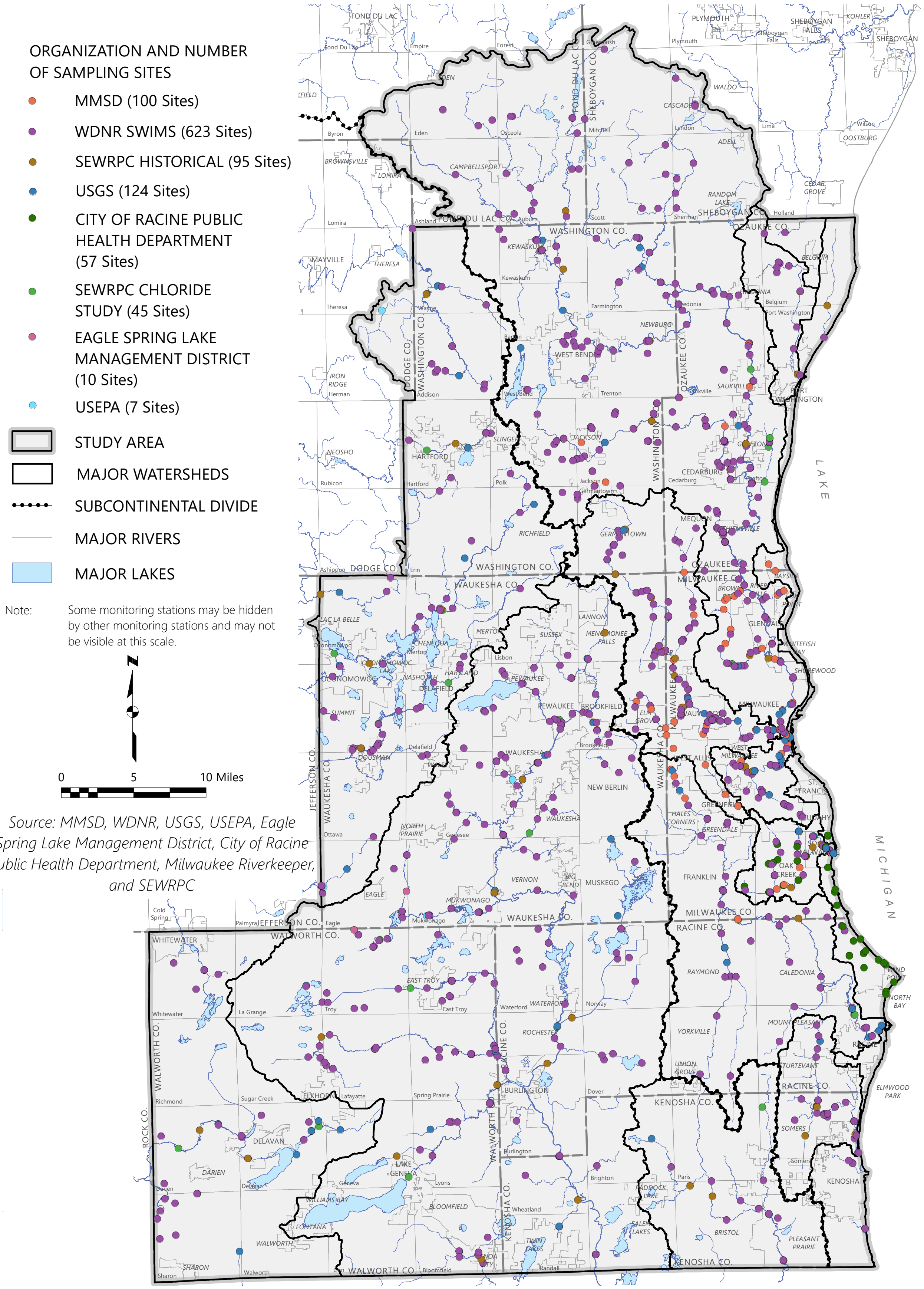
MAPS

Map 4.1
Stream Monitoring Stations with Chloride Samples



Source: MMSD, WDNR, USGS, USEPA, City of Oconomowoc, Eagle Spring Lake Management District, Milwaukee Riverkeeper, University of Wisconsin - Milwaukee, and SEWRPC

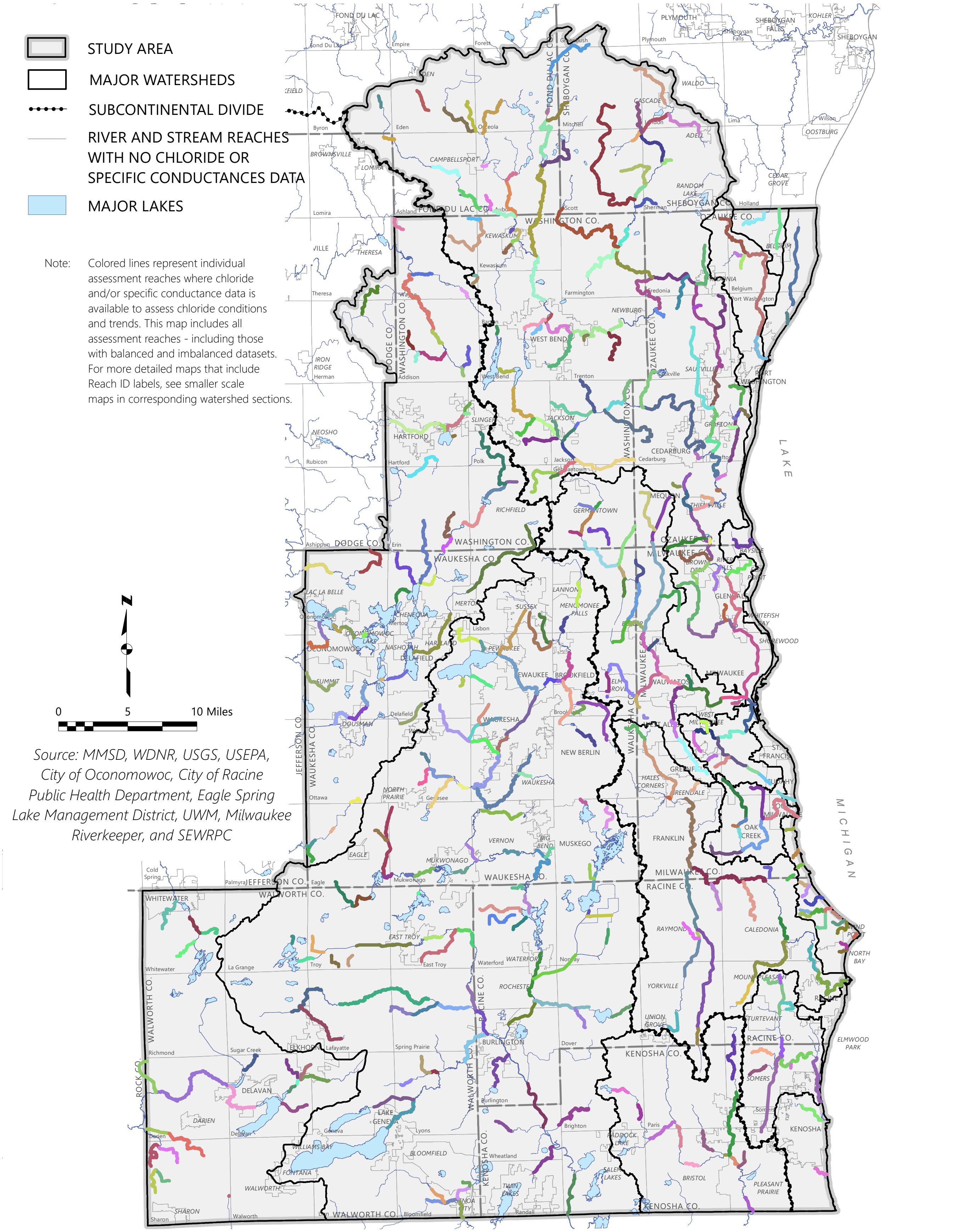
Map 4.2
Stream Monitoring Stations with Specific Conductance Samples



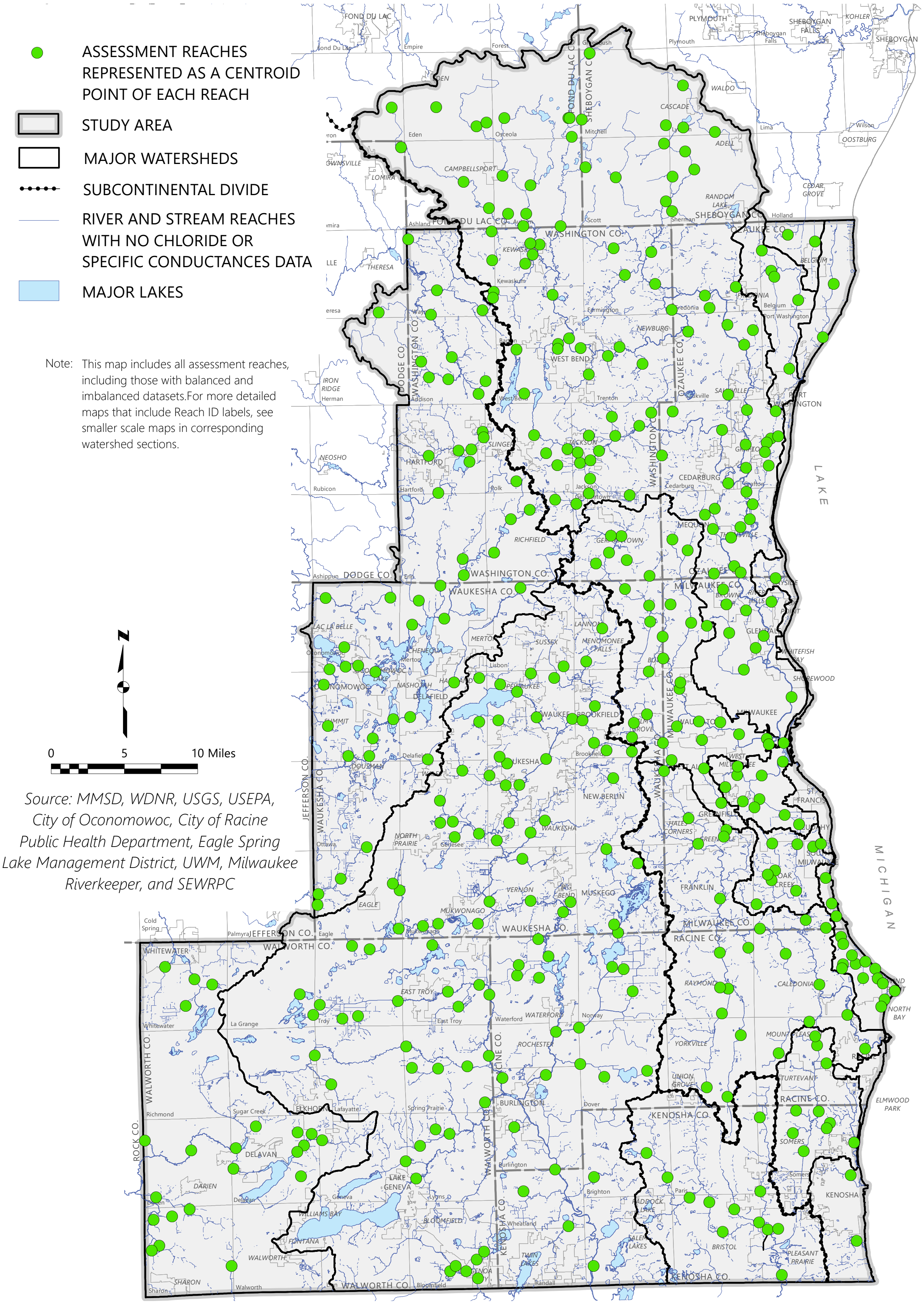
Note: Some monitoring stations may be hidden by other monitoring stations and may not be visible at this scale.

Source: MMSD, WDNR, USGS, USEPA, Eagle Spring Lake Management District, City of Racine Public Health Department, Milwaukee Riverkeeper, and SEWRPC

Map 4.3
Assessment Reaches for the Chloride Impact Study



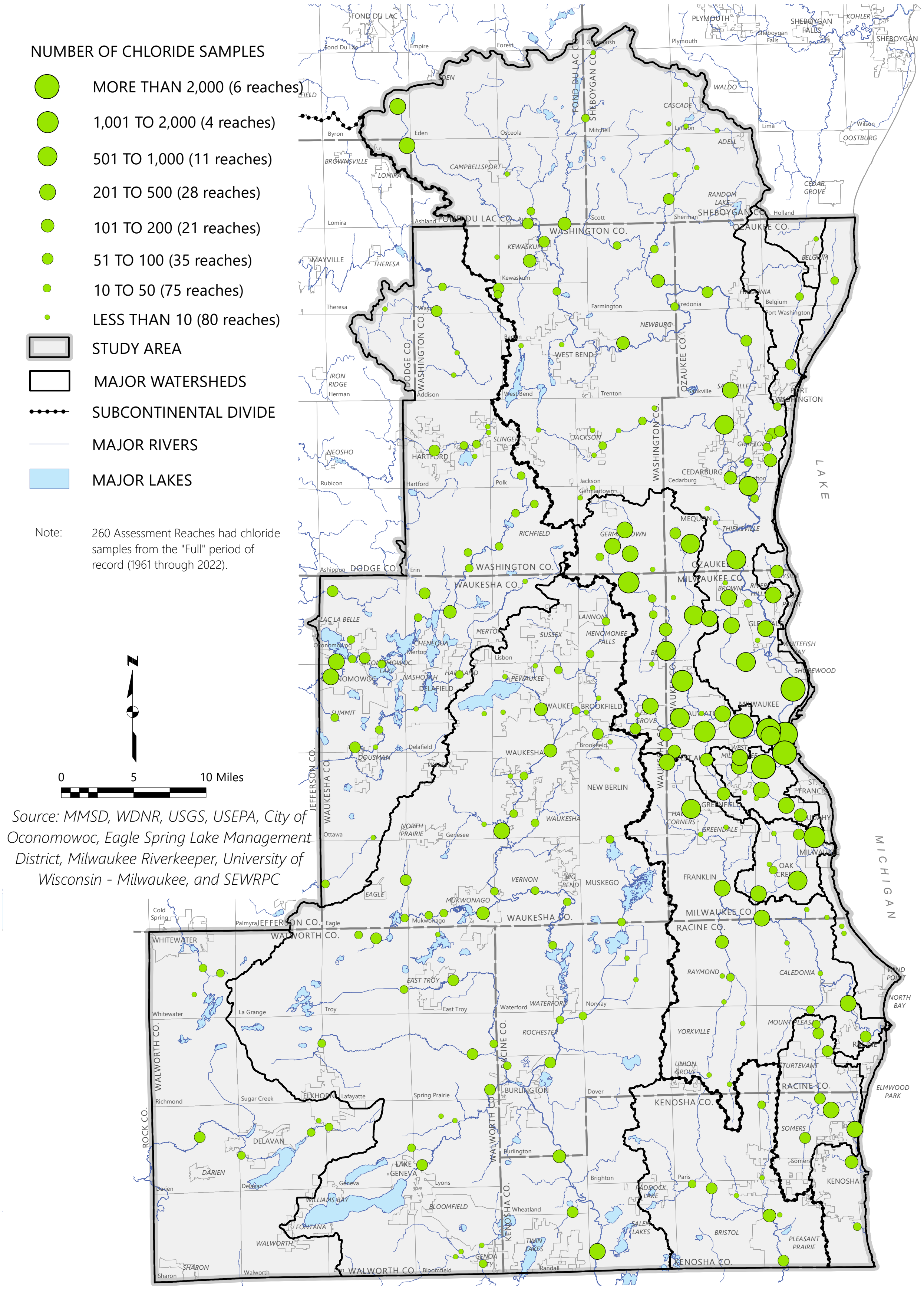
Map 4.4
Assessment Reaches Represented as the Midway Point of Each Assessment Reach Length



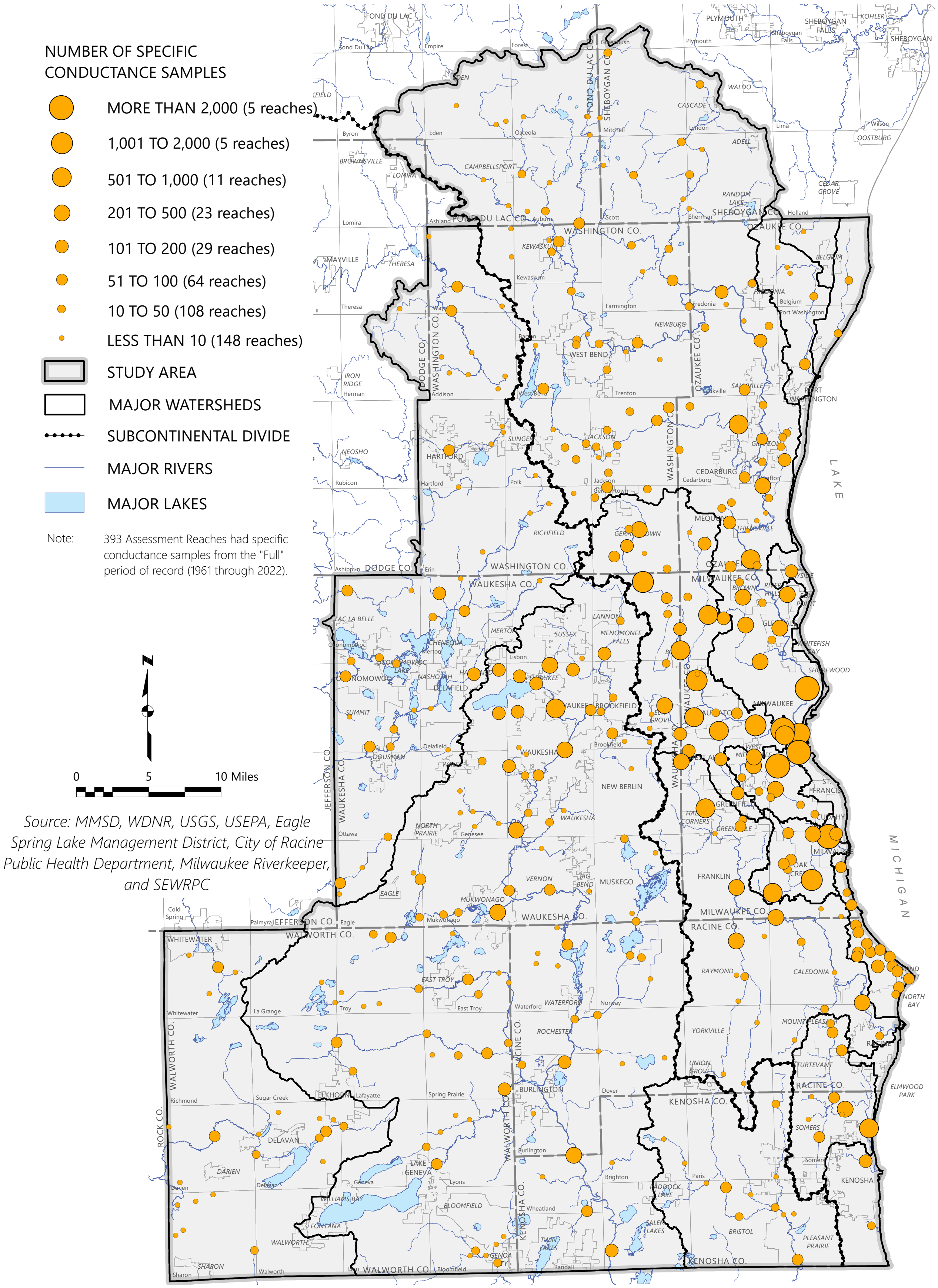
Note: This map includes all assessment reaches, including those with balanced and imbalanced datasets.For more detailed maps that include Reach ID labels, see smaller scale maps in corresponding watershed sections.

Source: MMSD, WDNR, USGS, USEPA, City of Oconomowoc, City of Racine Public Health Department, Eagle Spring Lake Management District, UWM, Milwaukee Riverkeeper, and SEWRPC

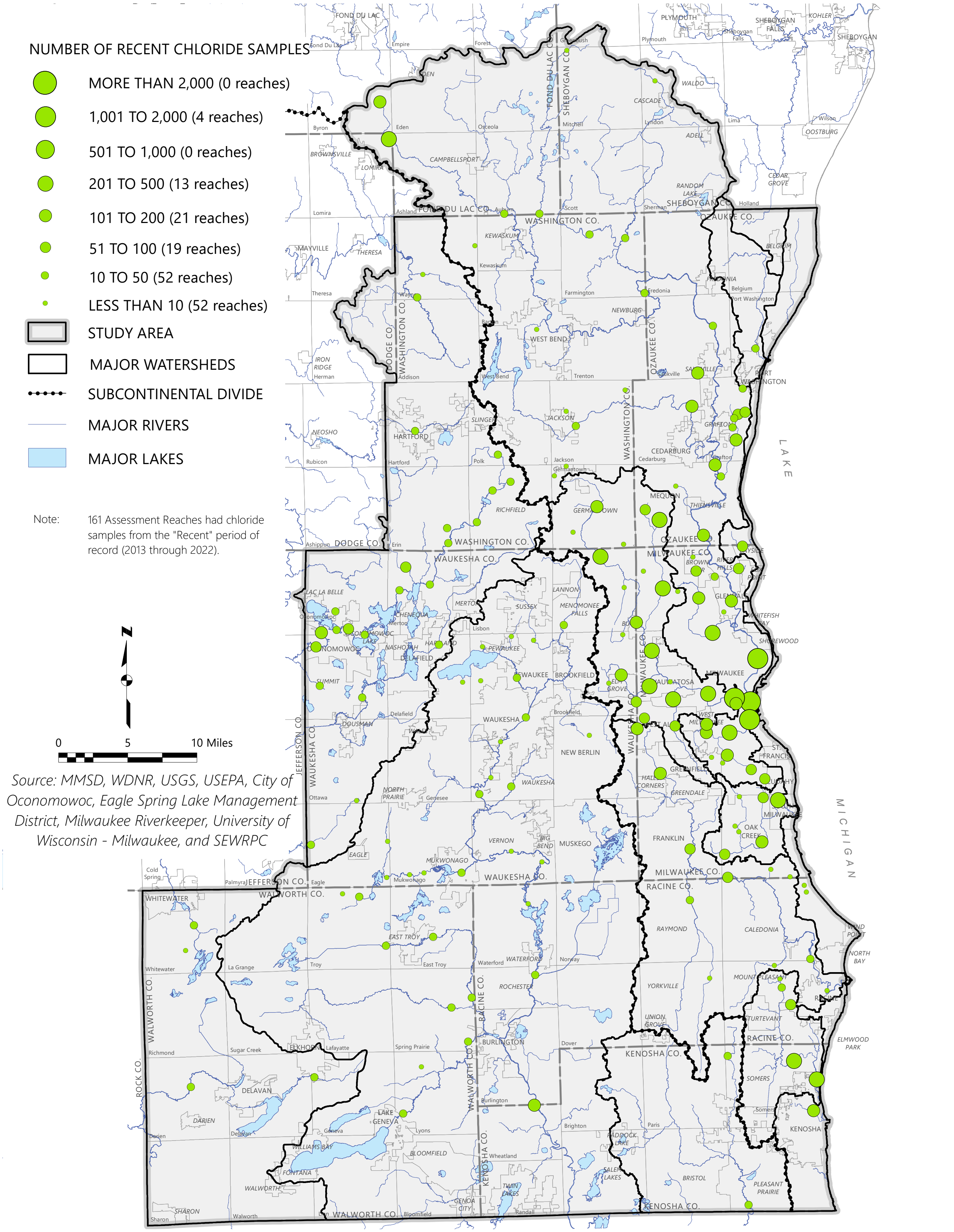
Map 4.5
Total Chloride Samples by Assessment Reach for the Full Record: 1961-2022



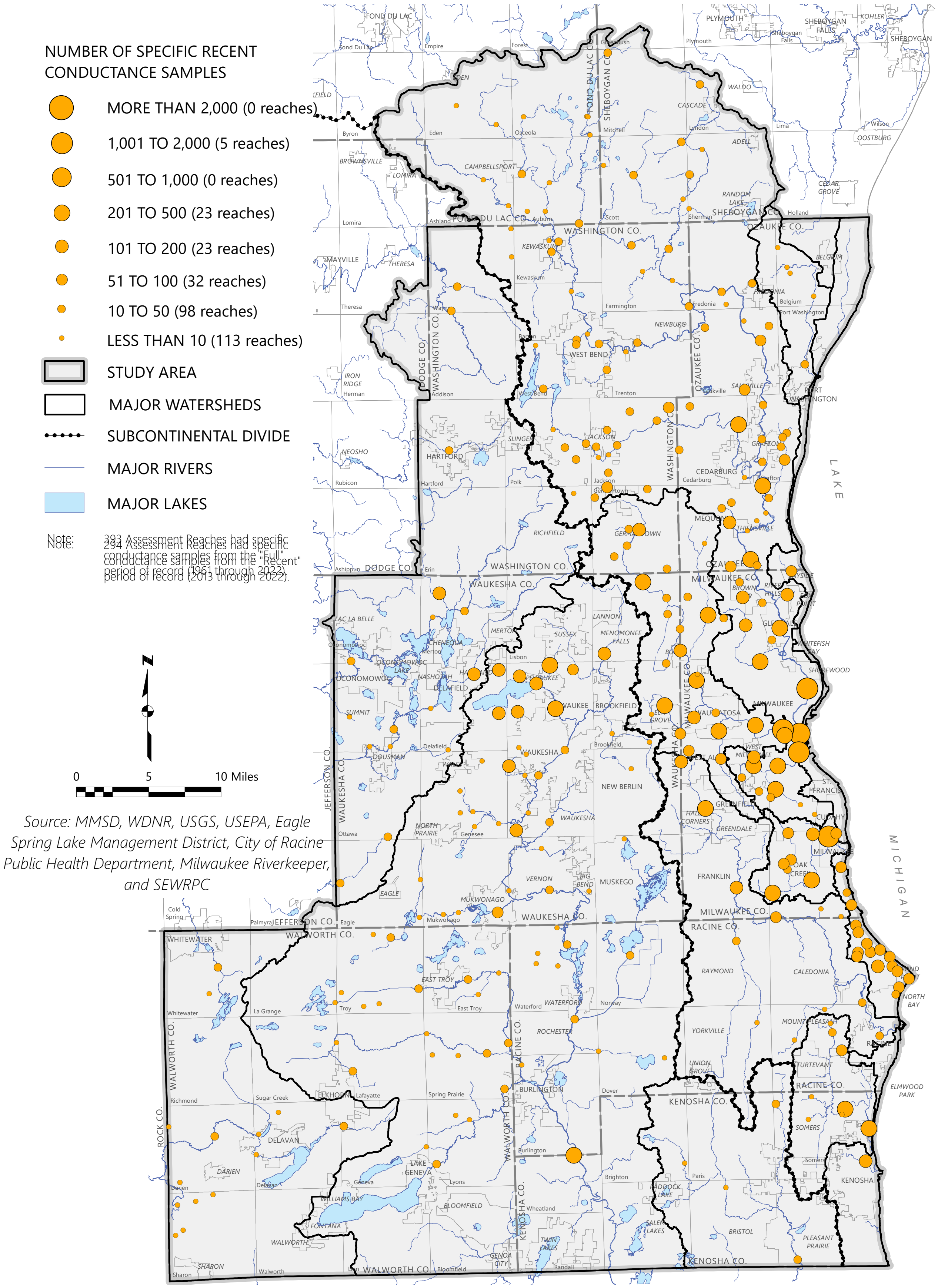
Map 4.6
Total Specific Conductance Samples by Assessment Reach for the Full Record: 1961-2022



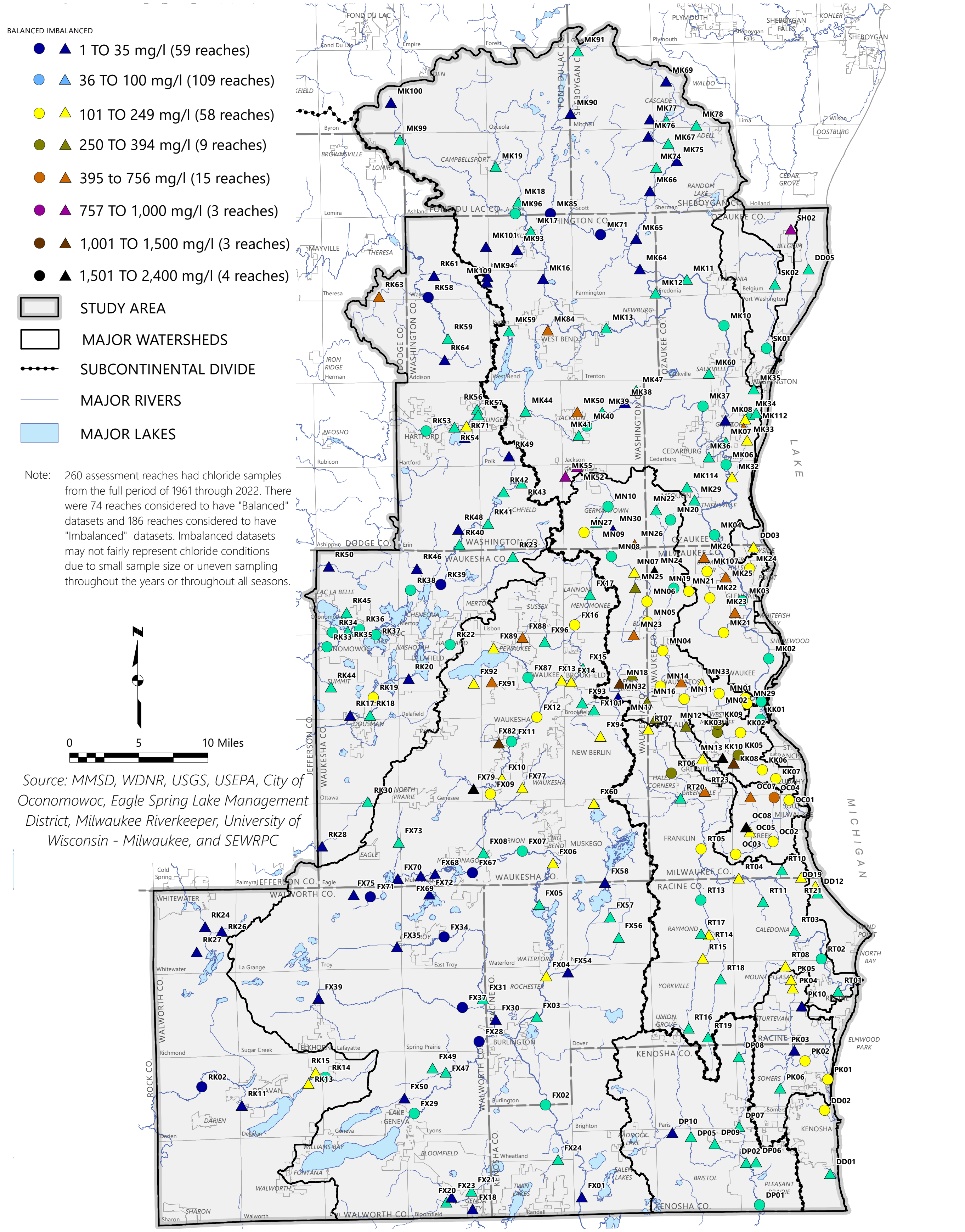
Map 4.7
Total Chloride Samples by Assessment Reach for the Recent Period of Record: 2013-2022



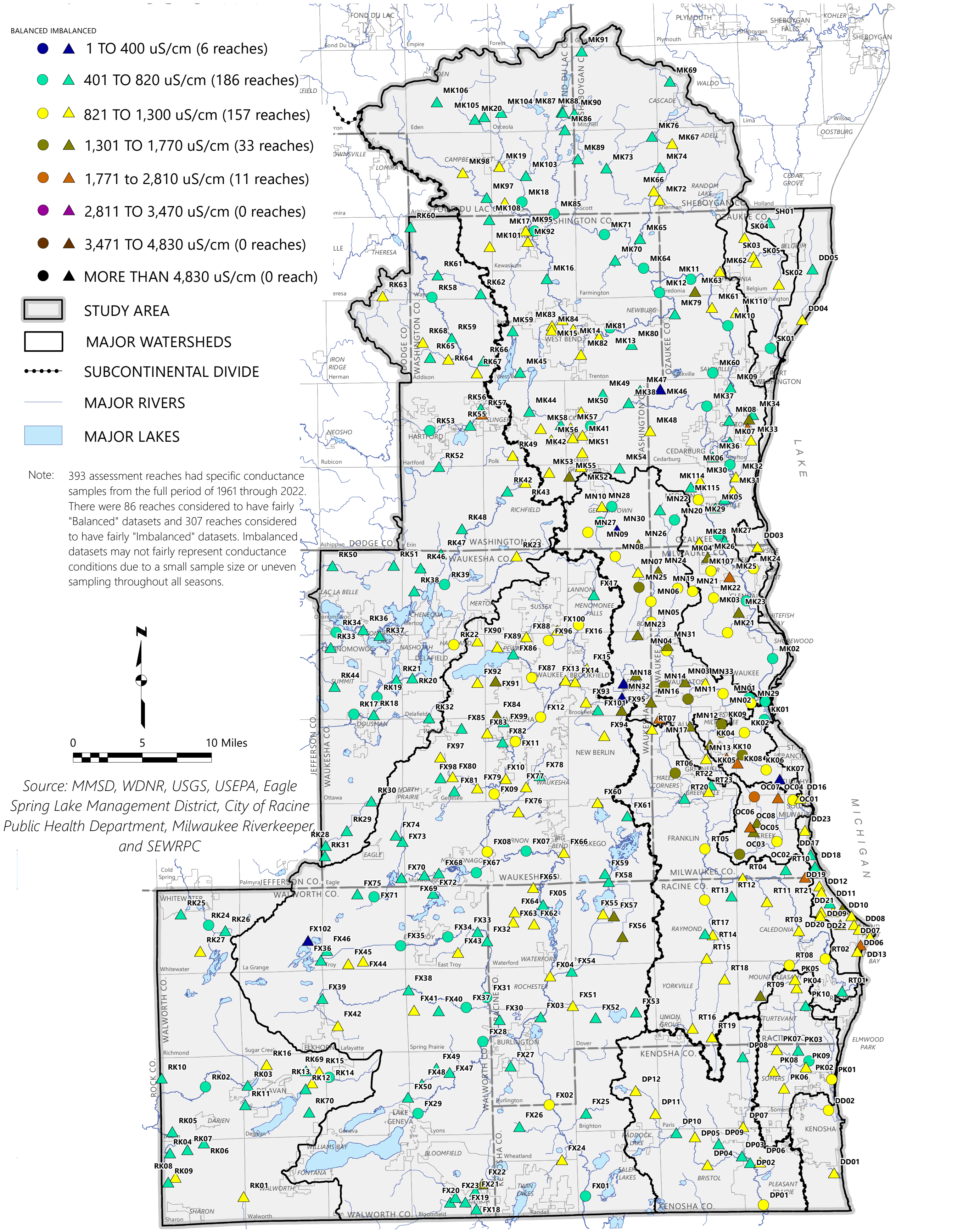
Map 4.8
Total Specific Conductance Samples by Assessment Reach for the Recent Period of Record: 2013-2022



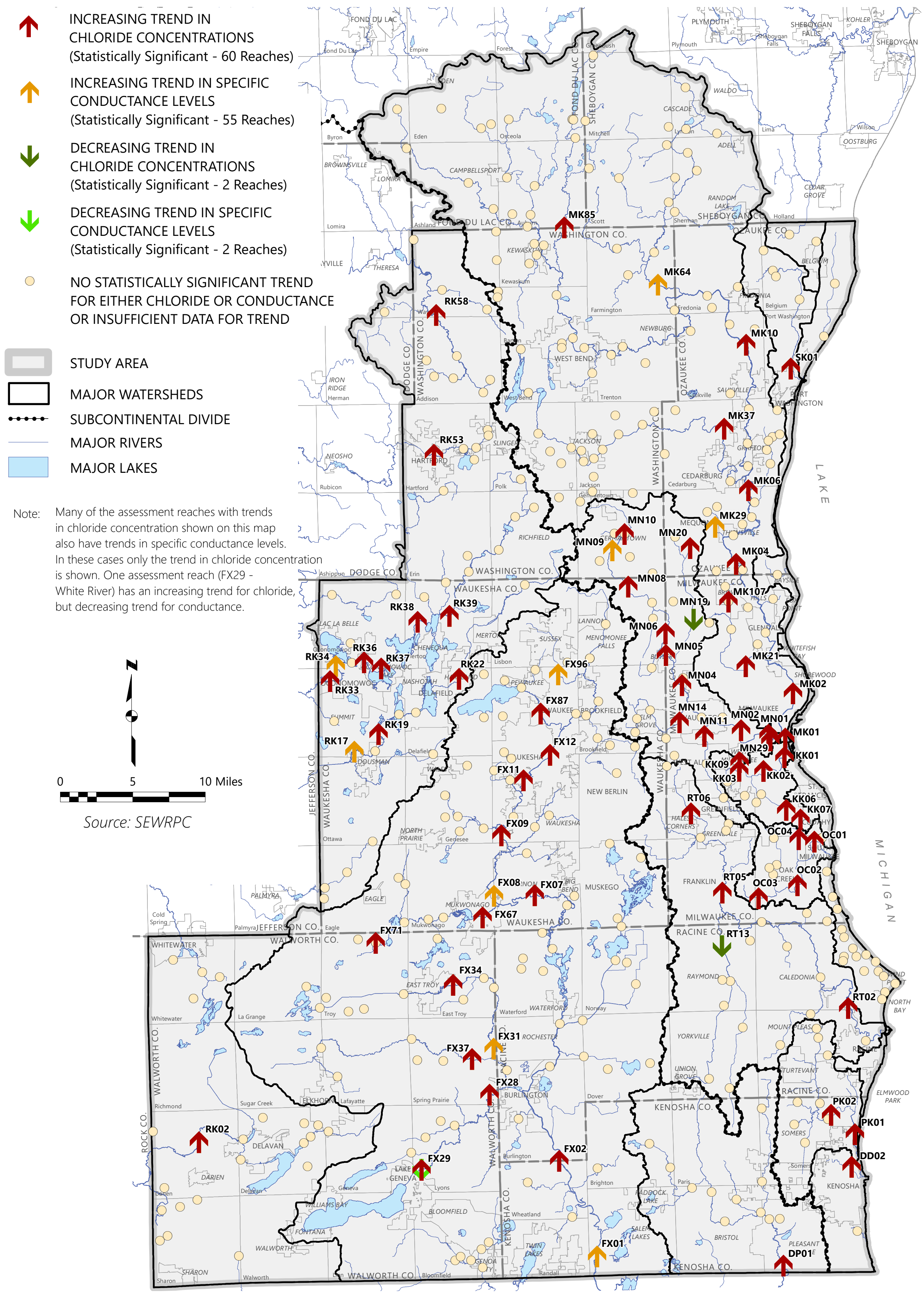
Map 4.9
Median Chloride Concentration Among Assessment Reaches for the Full Record: 1961-2022



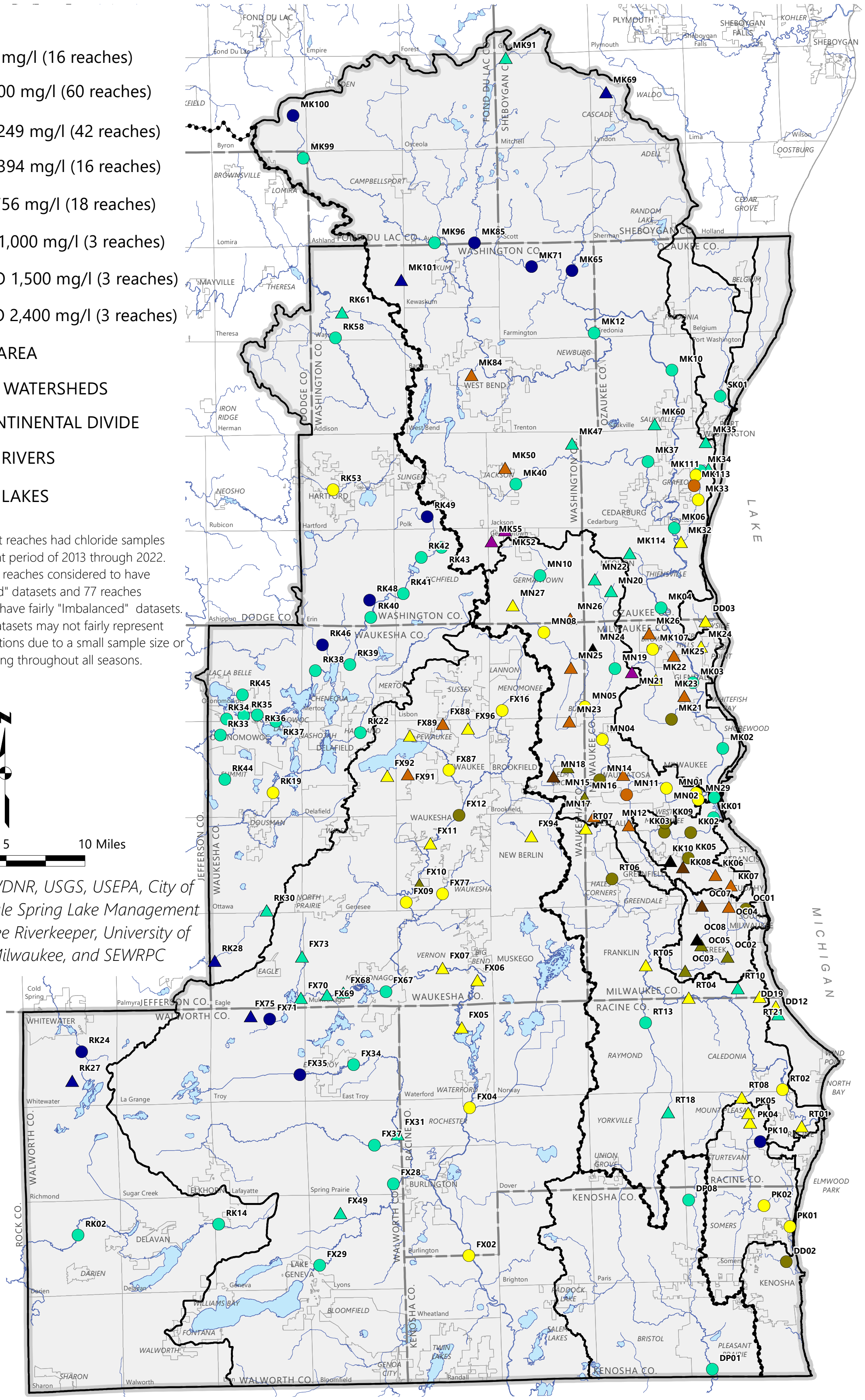
Map 4.10
Median Specific Conductance Levels Among Assessment Reaches for the Full Record: 1961-2022



Map 4.11
Statistically Significant Trends in Chloride and Specific Conductance Among Balanced Stream Assessment Reaches over the Full Period of Record: 1961-2022



Map 4.12
Recent Median Chloride Concentration Among All Assessment Reaches: 2013 Through 2022



BALANCED IMBALANCED

- 1 TO 35 mg/l (16 reaches)
- 36 TO 100 mg/l (60 reaches)
- 101 TO 249 mg/l (42 reaches)
- 250 TO 394 mg/l (16 reaches)
- 395 to 756 mg/l (18 reaches)
- 757 TO 1,000 mg/l (3 reaches)
- 1,001 TO 1,500 mg/l (3 reaches)
- 1,501 TO 2,400 mg/l (3 reaches)

STUDY AREA

MAJOR WATERSHEDS

SUBCONTINENTAL DIVIDE

MAJOR RIVERS

MAJOR LAKES

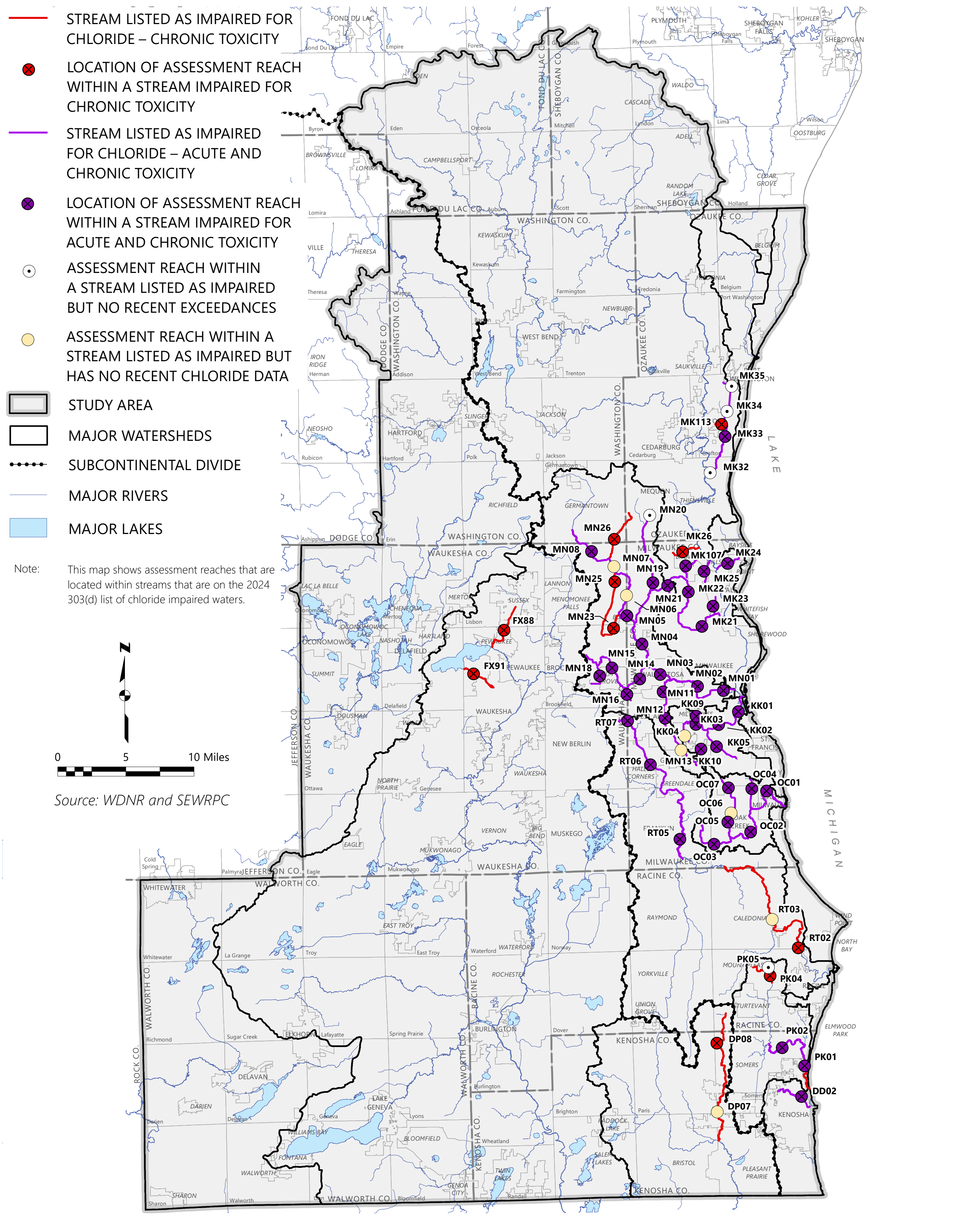
Note: 161 assessment reaches had chloride samples from the recent period of 2013 through 2022. There were 84 reaches considered to have fairly "Balanced" datasets and 77 reaches considered to have fairly "Imbalanced" datasets. Imbalanced datasets may not fairly represent chloride conditions due to a small sample size or uneven sampling throughout all seasons.

N

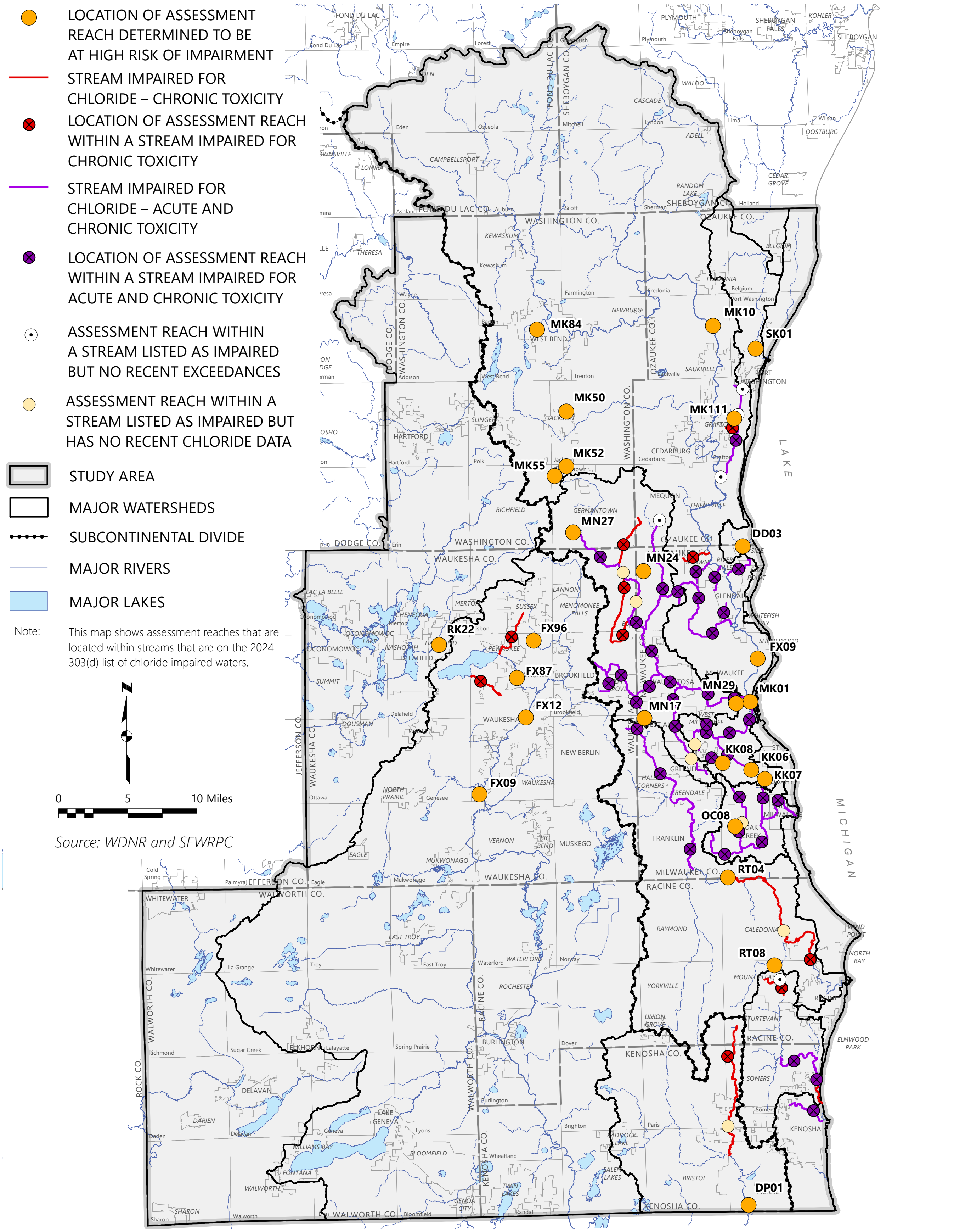
0 5 10 Miles

Source: MMSD, WDNR, USGS, USEPA, City of Oconomowoc, Eagle Spring Lake Management District, Milwaukee Riverkeeper, University of Wisconsin - Milwaukee, and SEWRPC

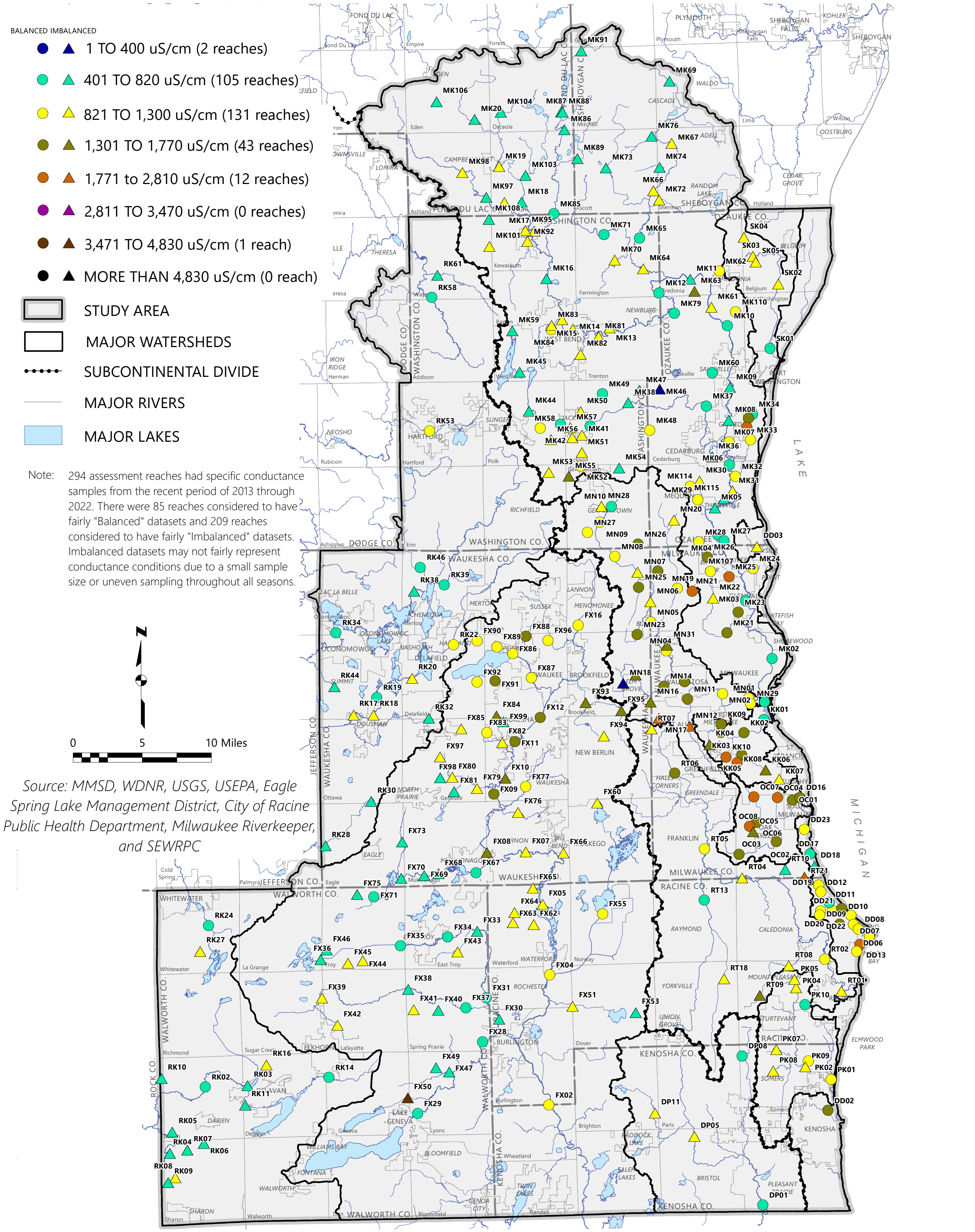
Map 4.13
Assessment Reaches Within Streams that are Impaired for Chloride Toxicity (Recent Period of Record)



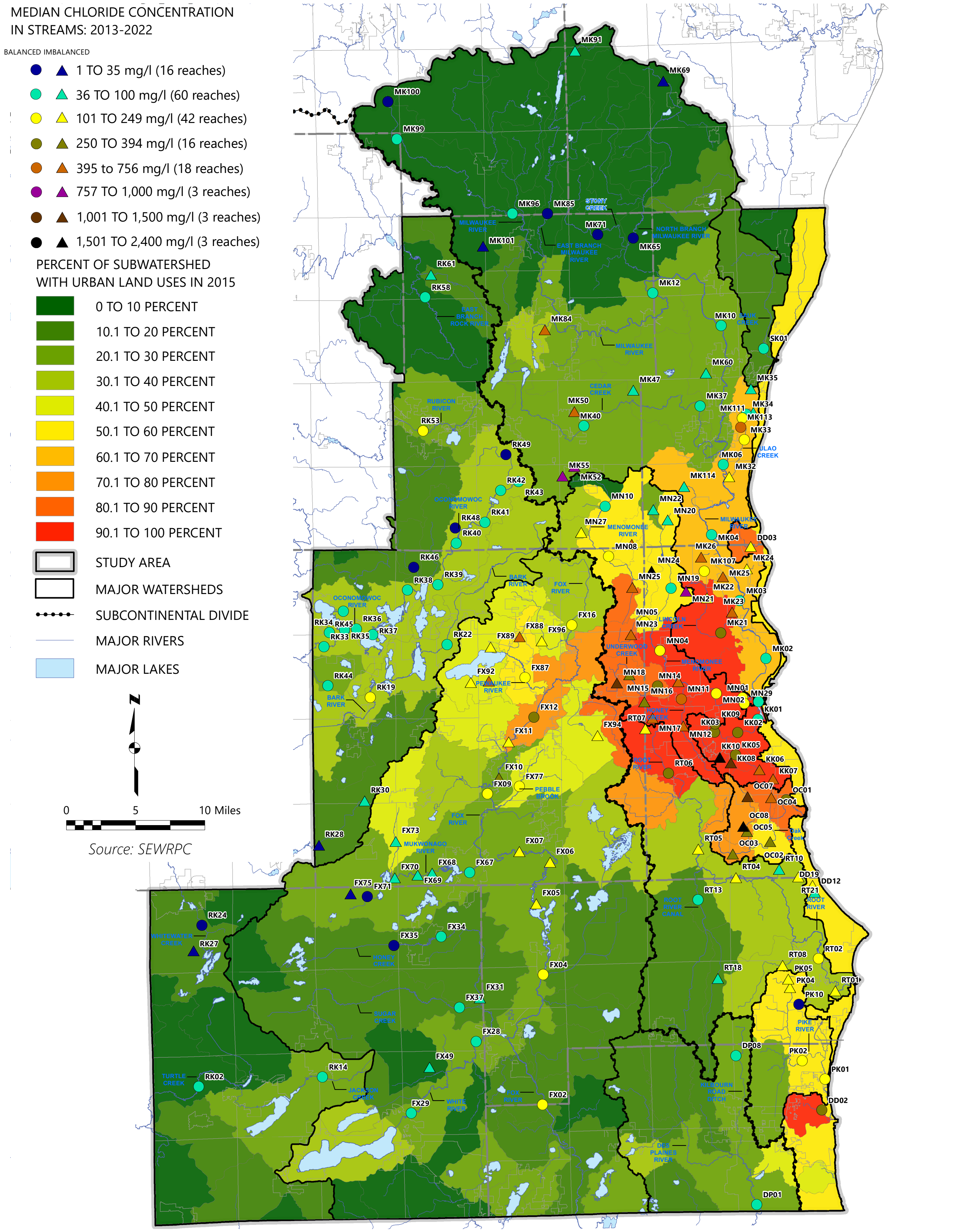
Map 4.14
Stream Assessment Reaches Determined to be High Risk for Impairment and Assessement Reaches Within Streams that are Impaired for Chloride Toxicity (Recent Period of Record)



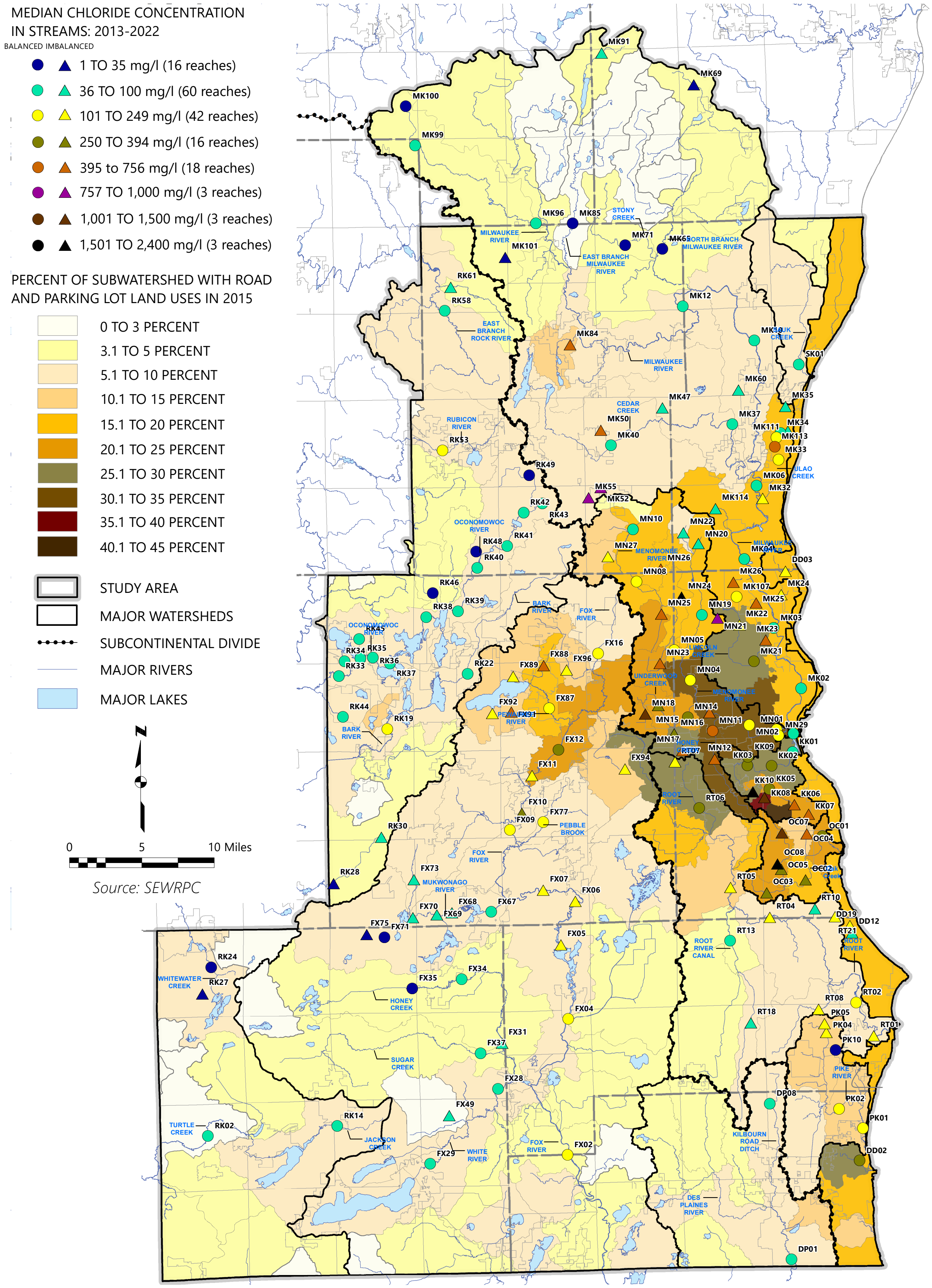
Map 4.15
Median Specific Conductance Among All Assessment Reaches for the Recent Record: 2013-2022



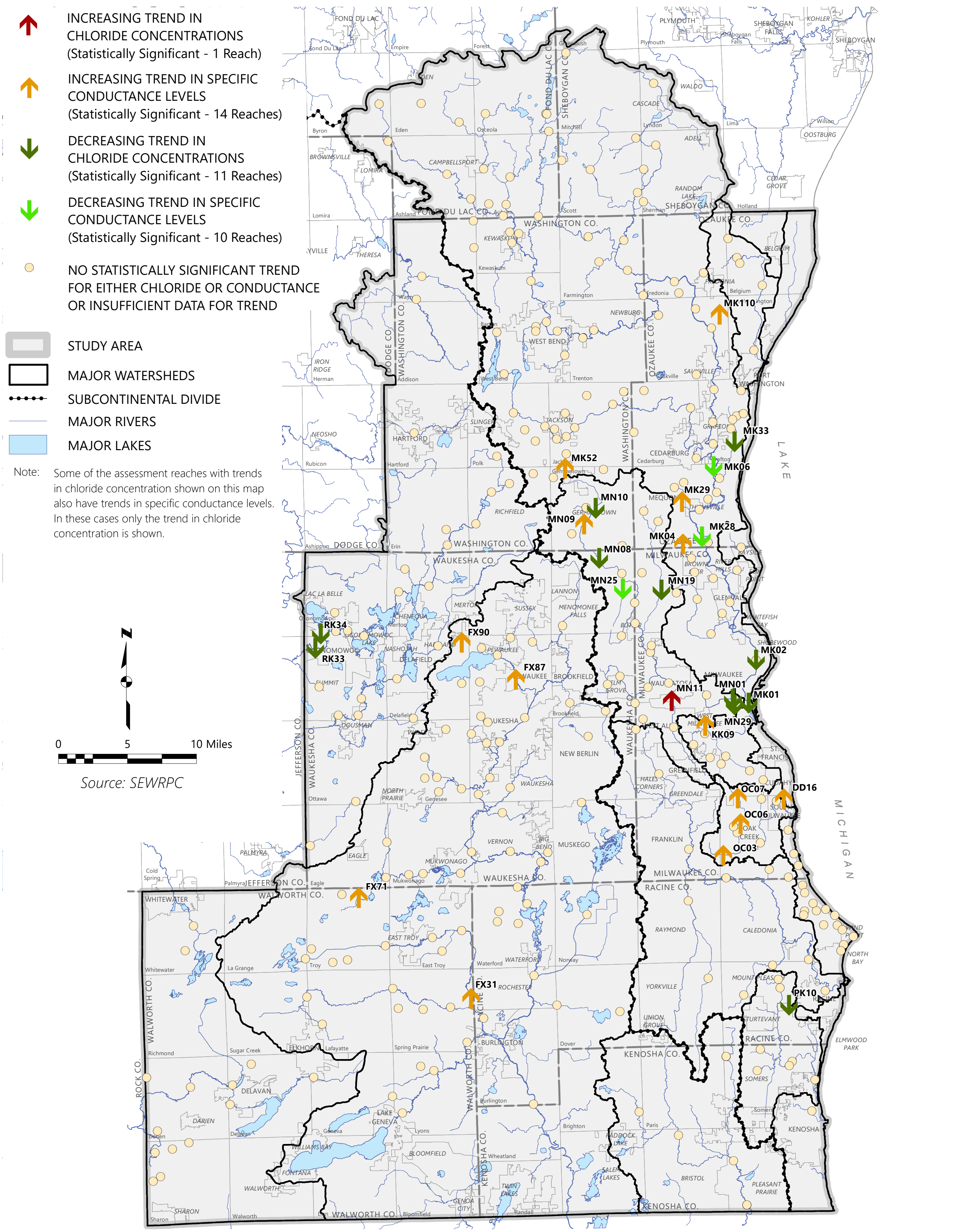
Map 4.16
Recent Median Chloride Concentrations in All Stream Assessment Reaches and Percent Urban Land Use by Subwatershed



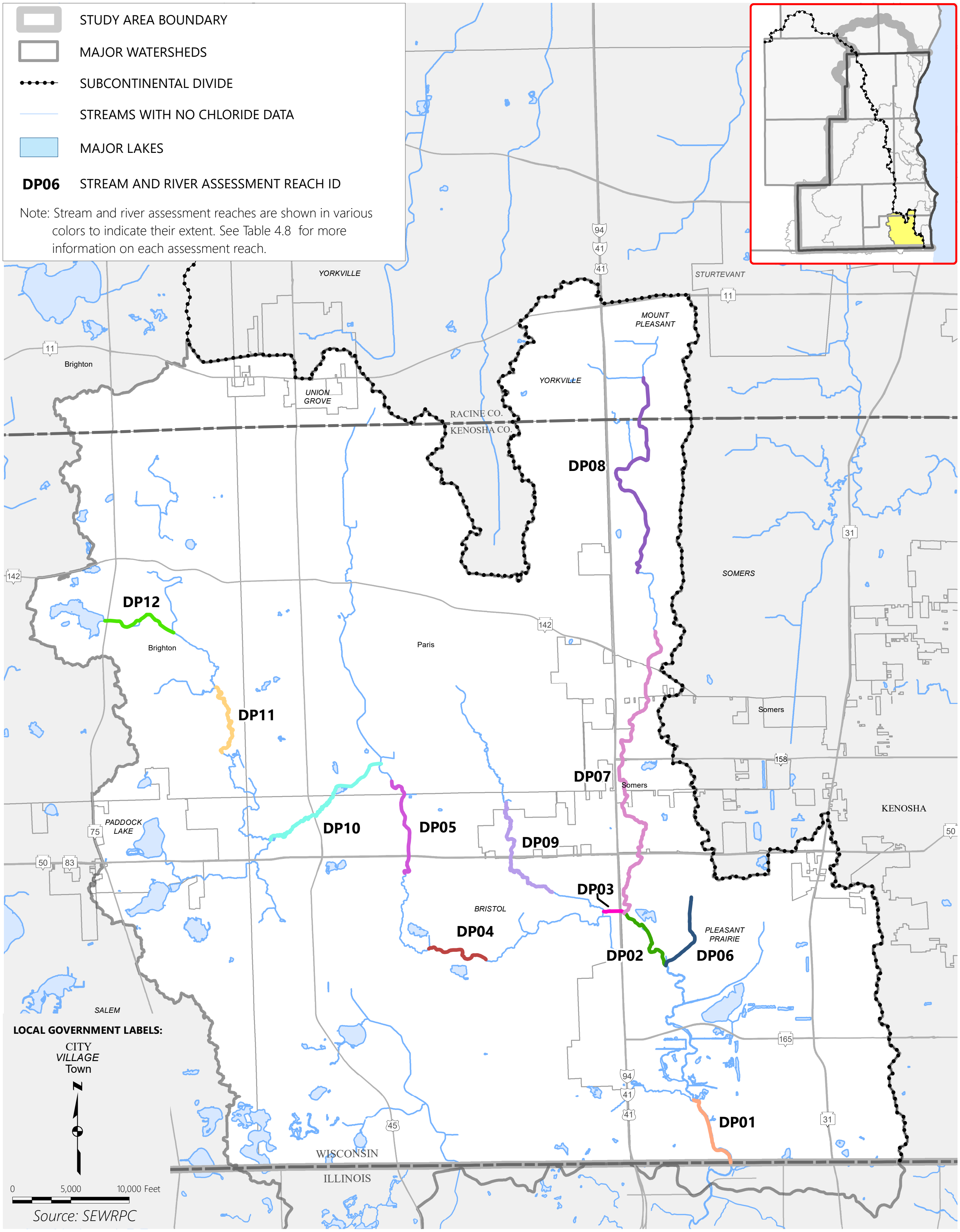
Map 4.17
Recent Median Chloride Concentrations in All Stream Assessment Reaches and Density of Roads and Parking Lots by Subwatershed



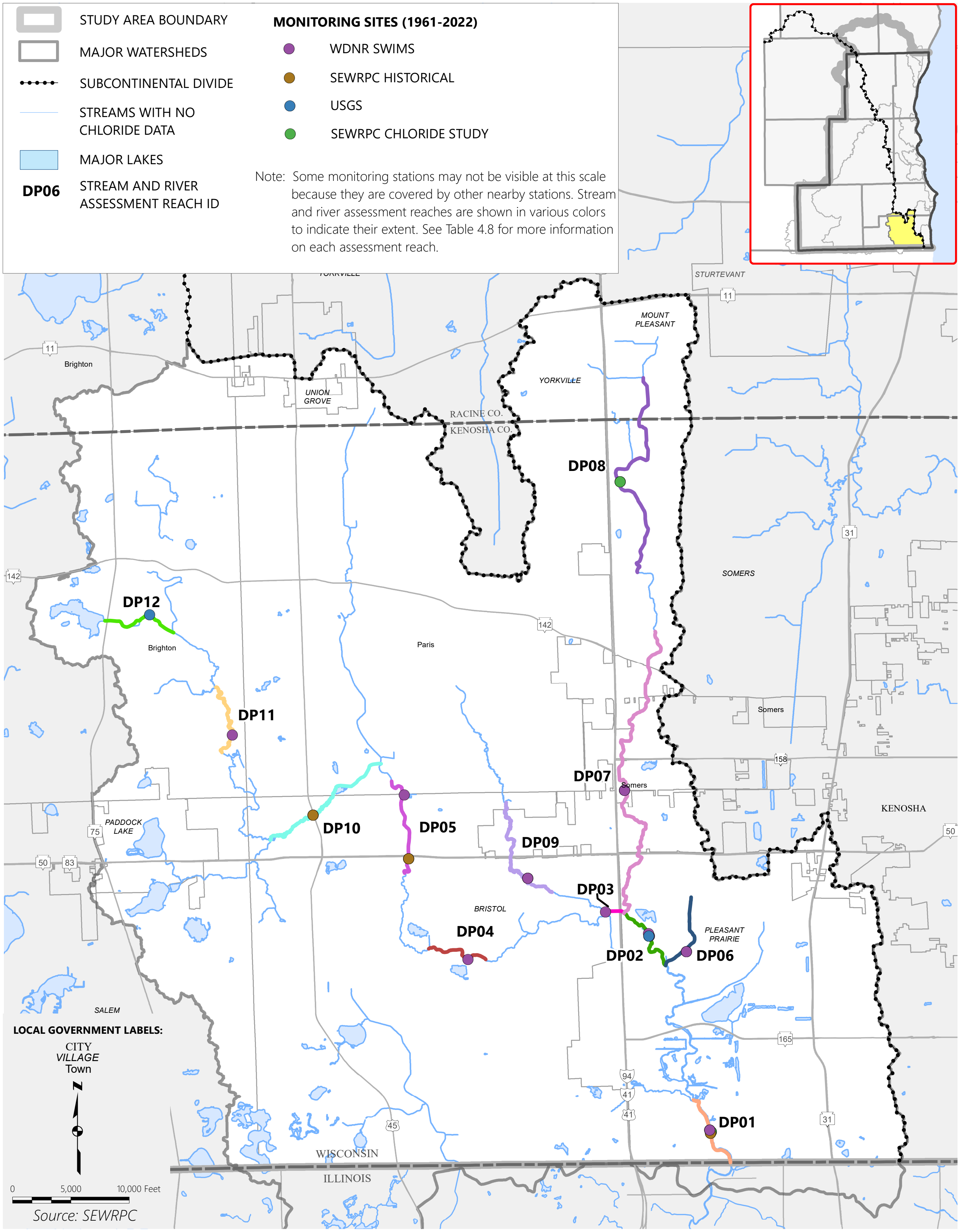
Map 4.Cl_SC_Trends_Recent
Trends in Chloride and Specific Conductance Among Balanced Stream Assessment Reaches over the Recent Period of Record: 2013-2022



Map 4.19
Assessment Reaches for Streams Within the Des Plaines River Watershed

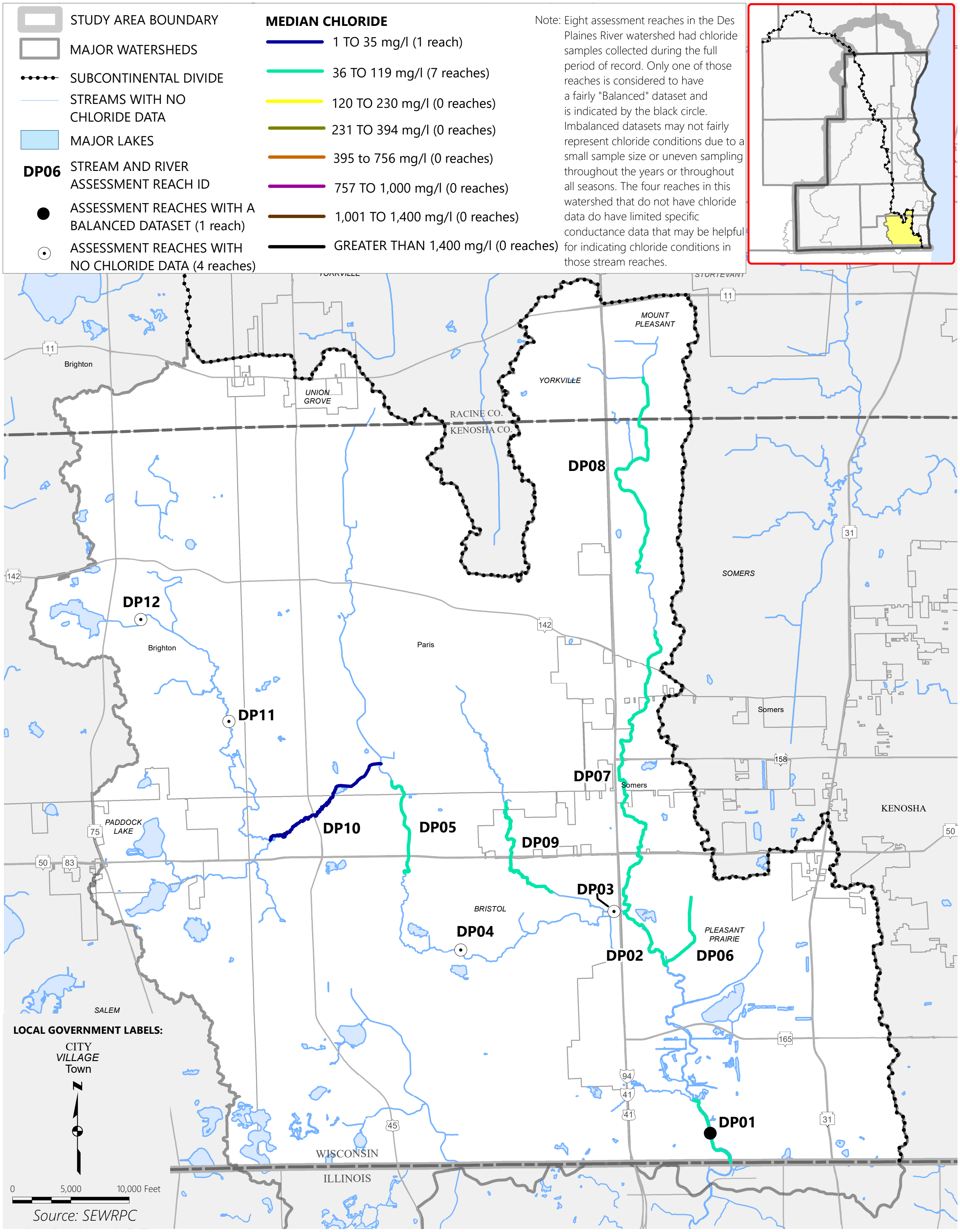


Map 4.20
Monitoring Sites and Assessment Reaches for Streams Within the Des Plaines River Watershed

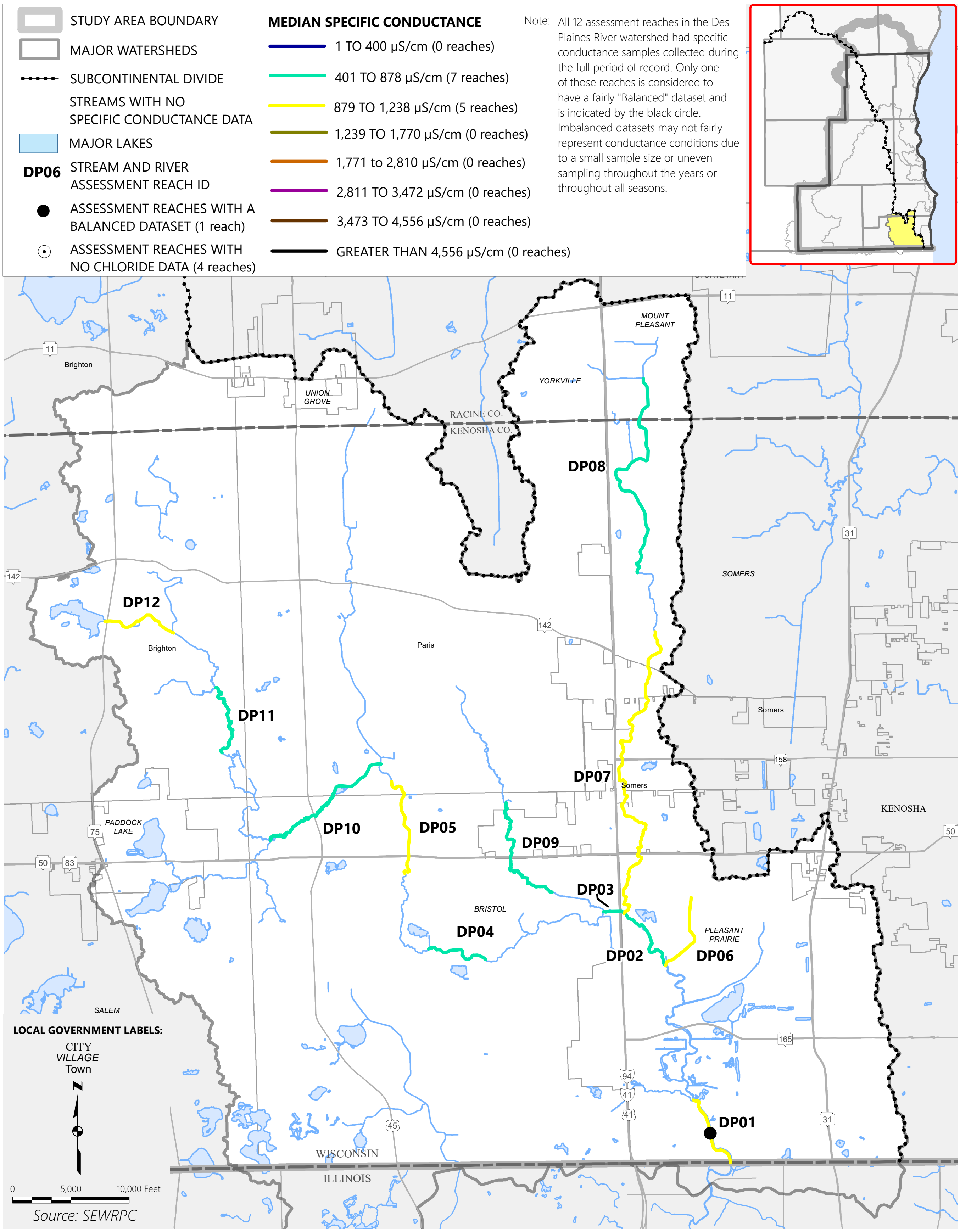


Source: SEWRPC

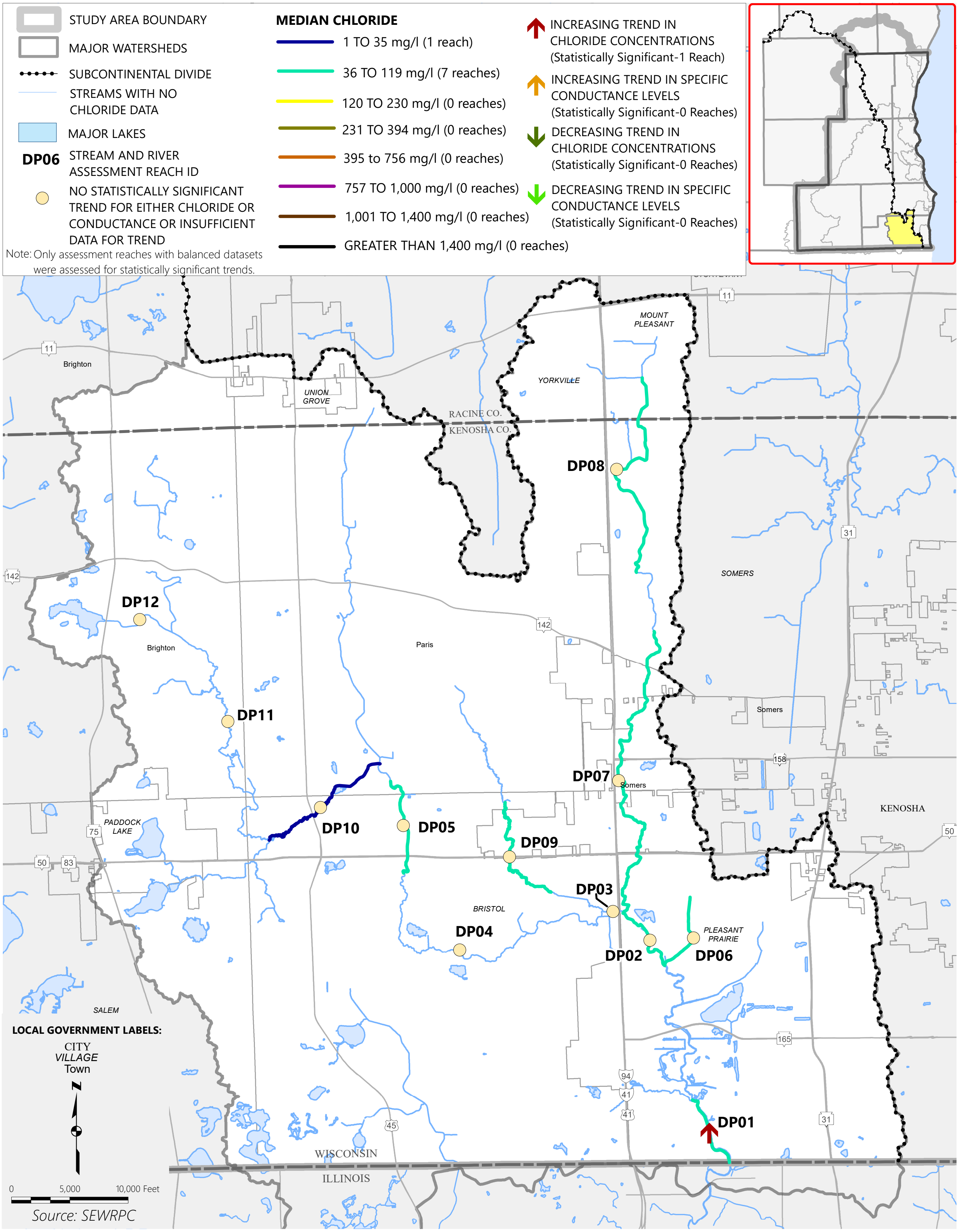
Map 4.21
Median Chloride Concentrations Within the Des Plaines River Watershed for the Full Period of Record: 1961-2022



Map 4.22
Median Specific Conductance Within the Des Plaines River Watershed for the Full Period of Record: 1961-2022

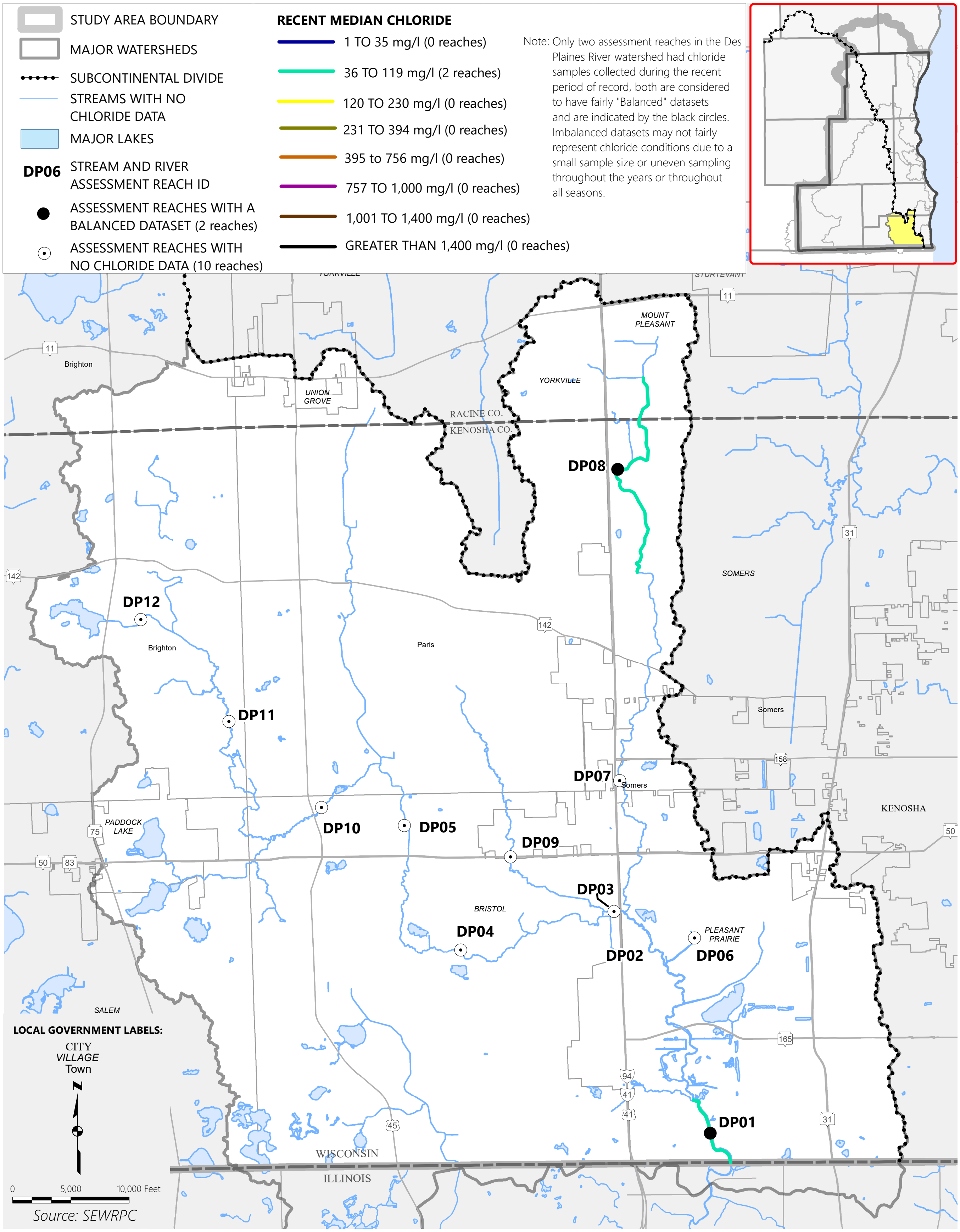


Map 4.23
Trends in Chloride and Specific Conductance Among Assessment Reaches Within the Des Plaines River Watershed over the Full Period of Record: 1961-2022

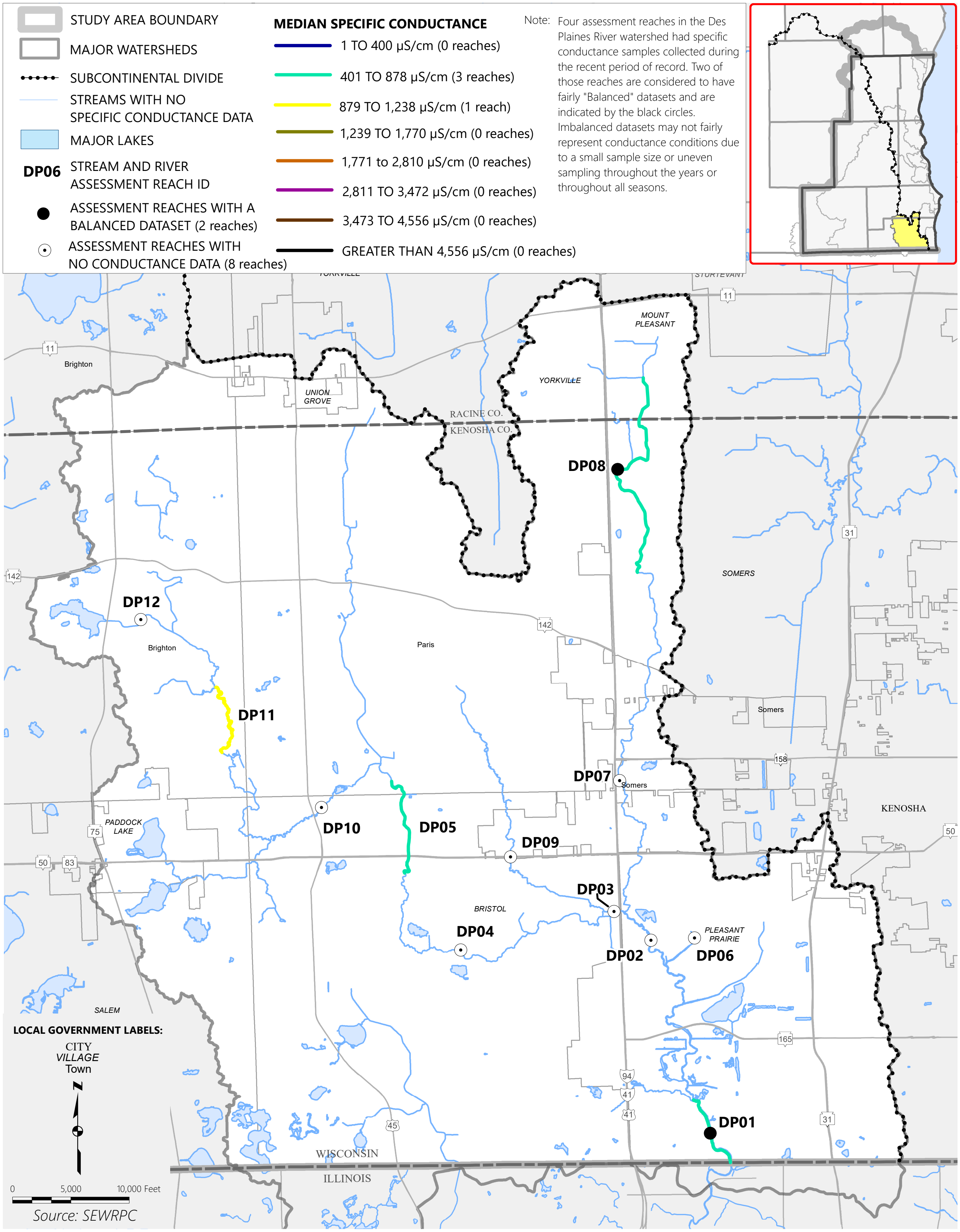


Source: SEWRPC

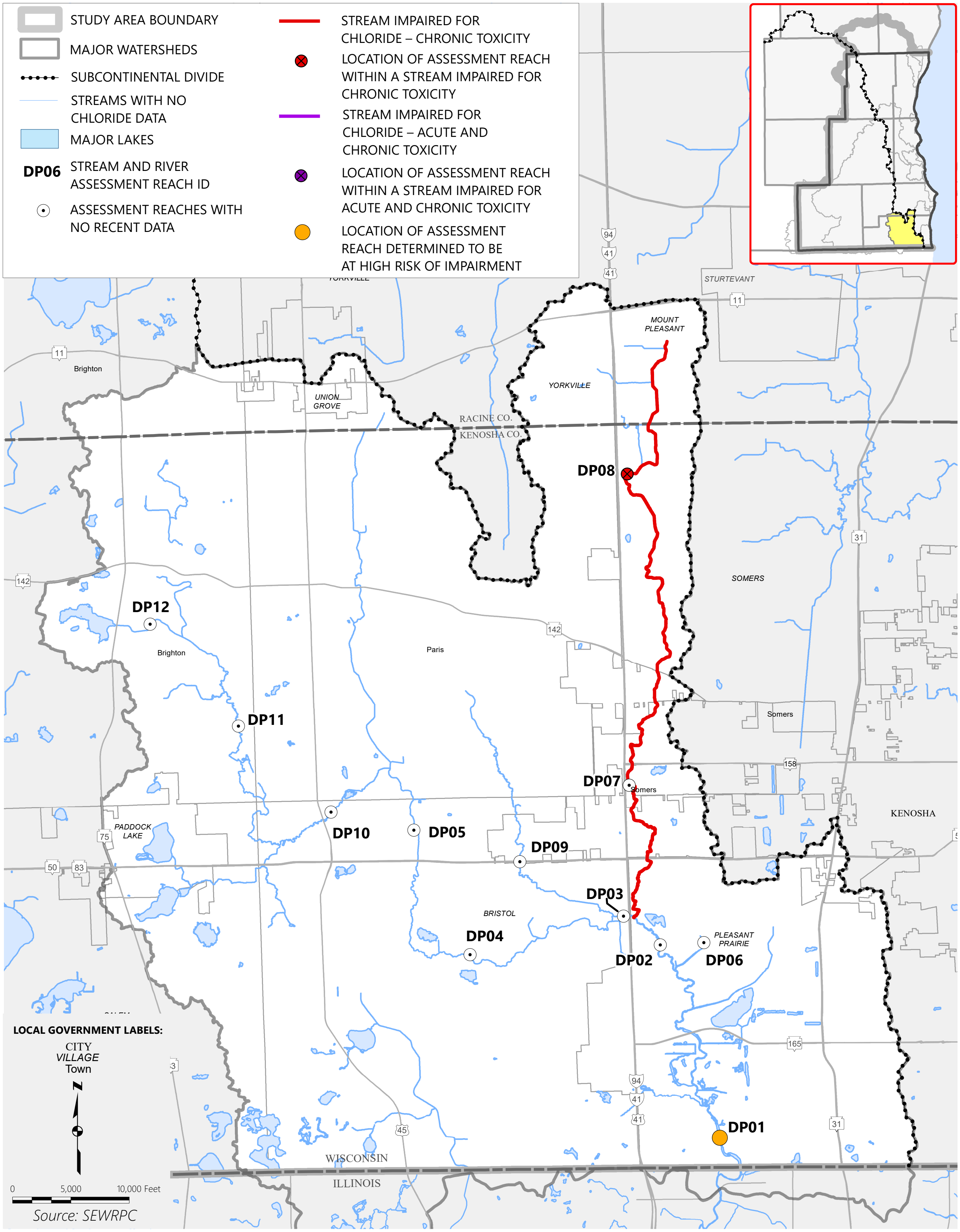
Map 4.24
Recent Median Chloride Concentrations Within the Des Plaines River Watershed for the Recent Period of Record: 2013-2022



Map 4.25
Recent Median Specific Conductance Within the Des Plaines River Watershed: 2013-2022

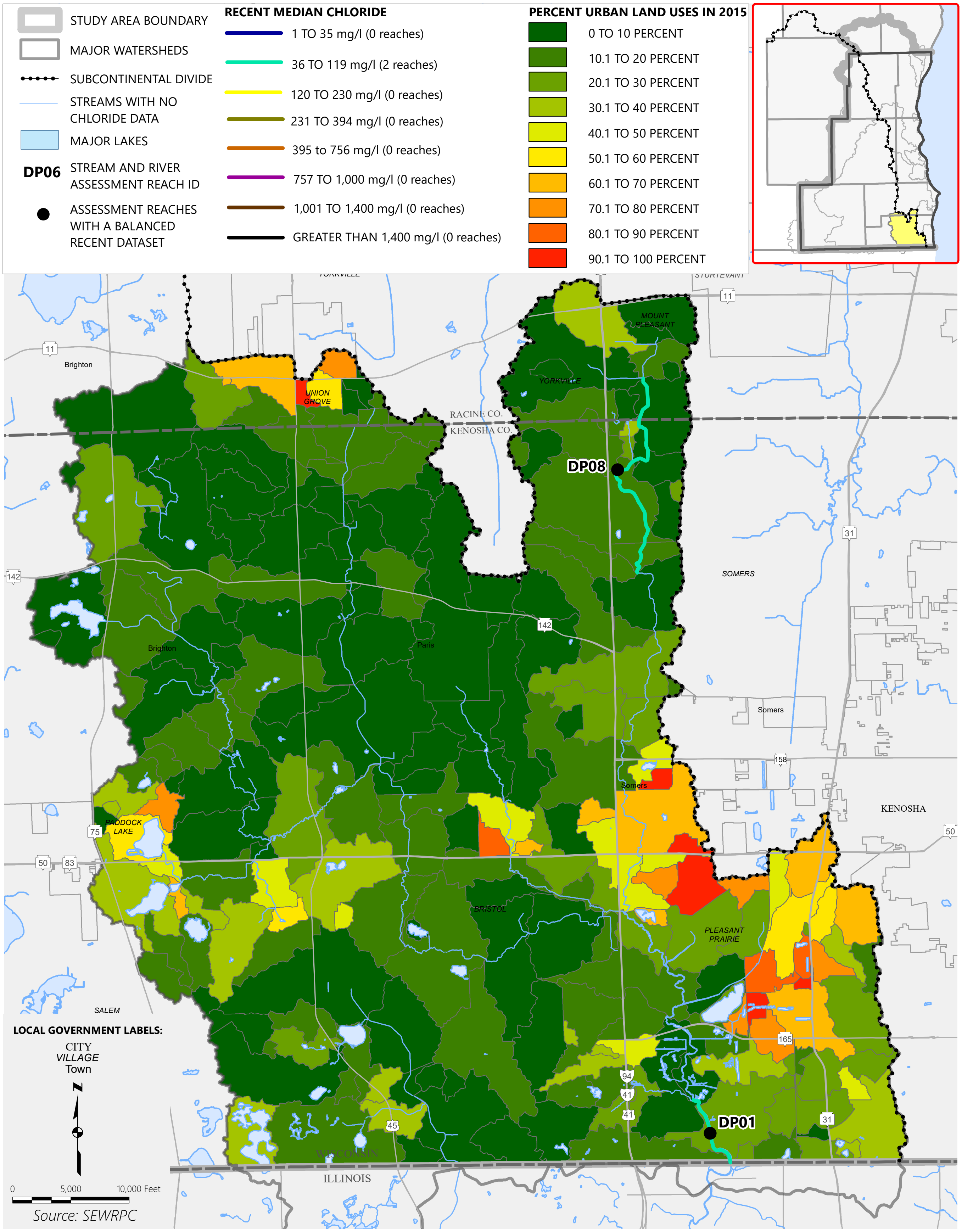


Map 4.26
Streams Impaired for Chloride Within the Des Plaines River Watershed: 2024

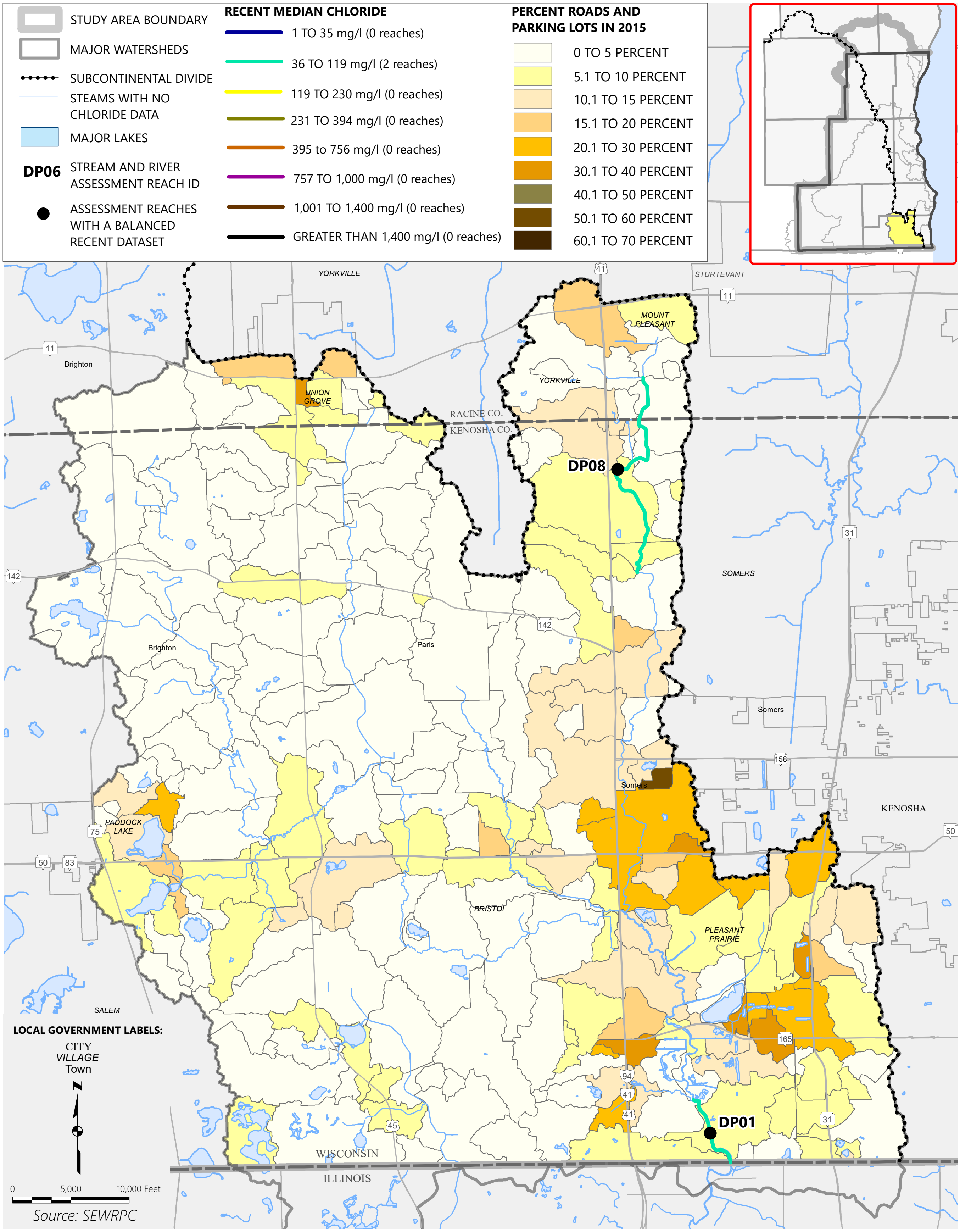


Source: SEWRPC

Map 4.DP_ClRecMedian_PercentUrban
Recent Median Chloride Concentrations in Balanced Assessment Reaches Within the Des Plaines River Watershed and Percent Urban Land Use in Subbasins

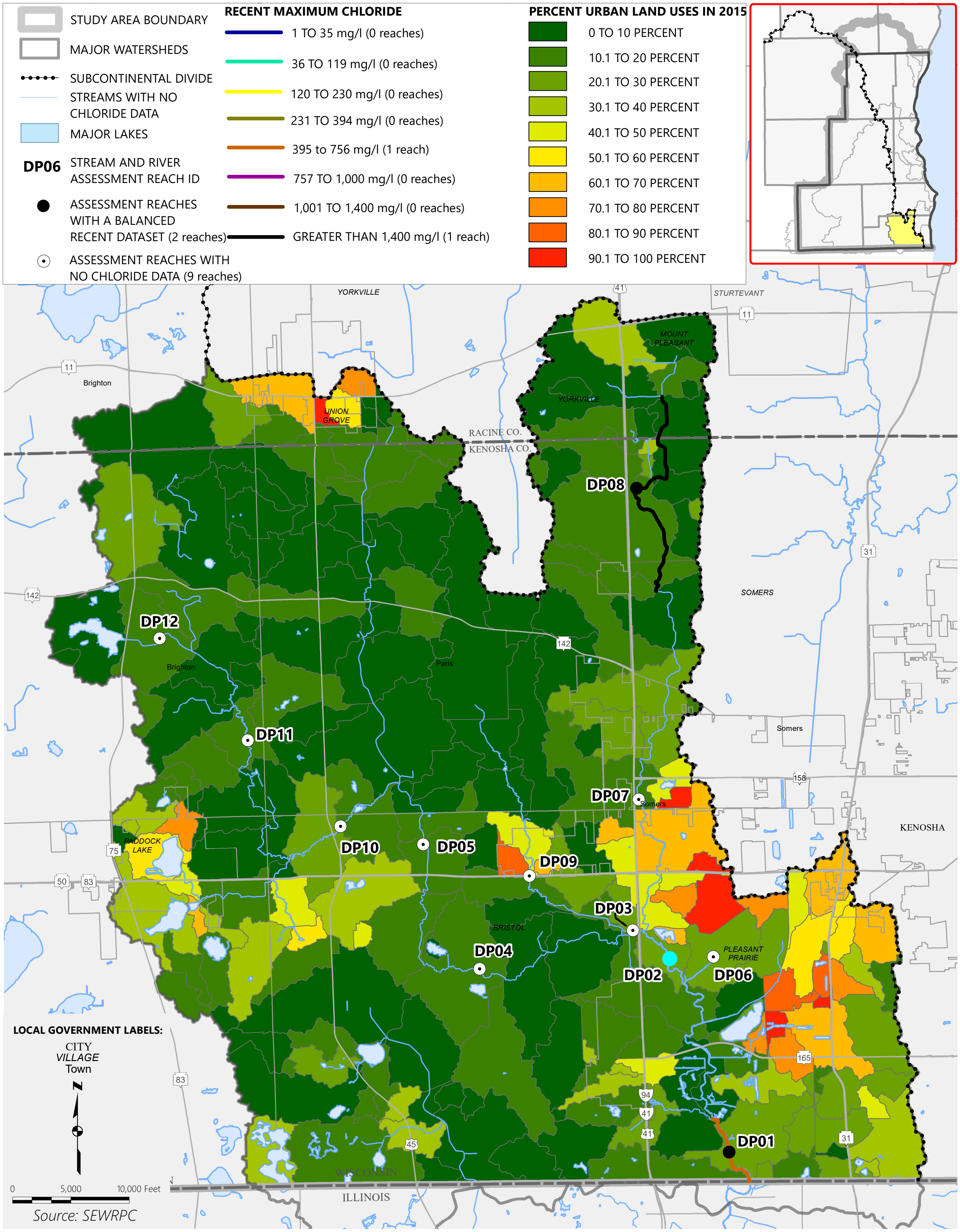


Map 4.28
Recent Median Chloride Concentrations in Balanced Assessment Reaches Within the Des Plaines River Watershed and Road and Parking Lot Density in Subbasins

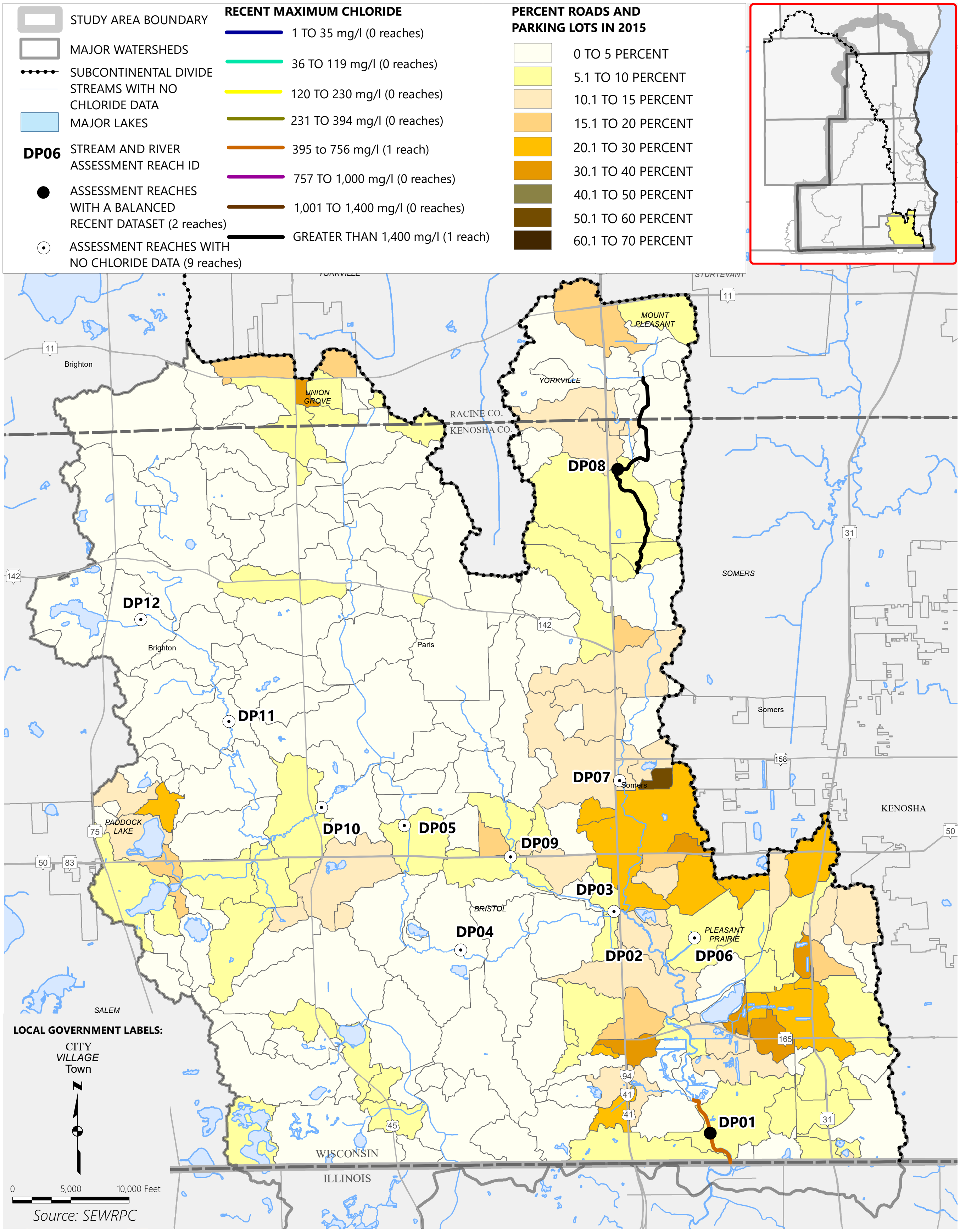


Source: SEWRPC

Map 4.29
Recent Maximum Chloride Concentrations in Assessment Reaches Within the Des Plaines River Watershed and Percent Urban Land Use in Subbasins

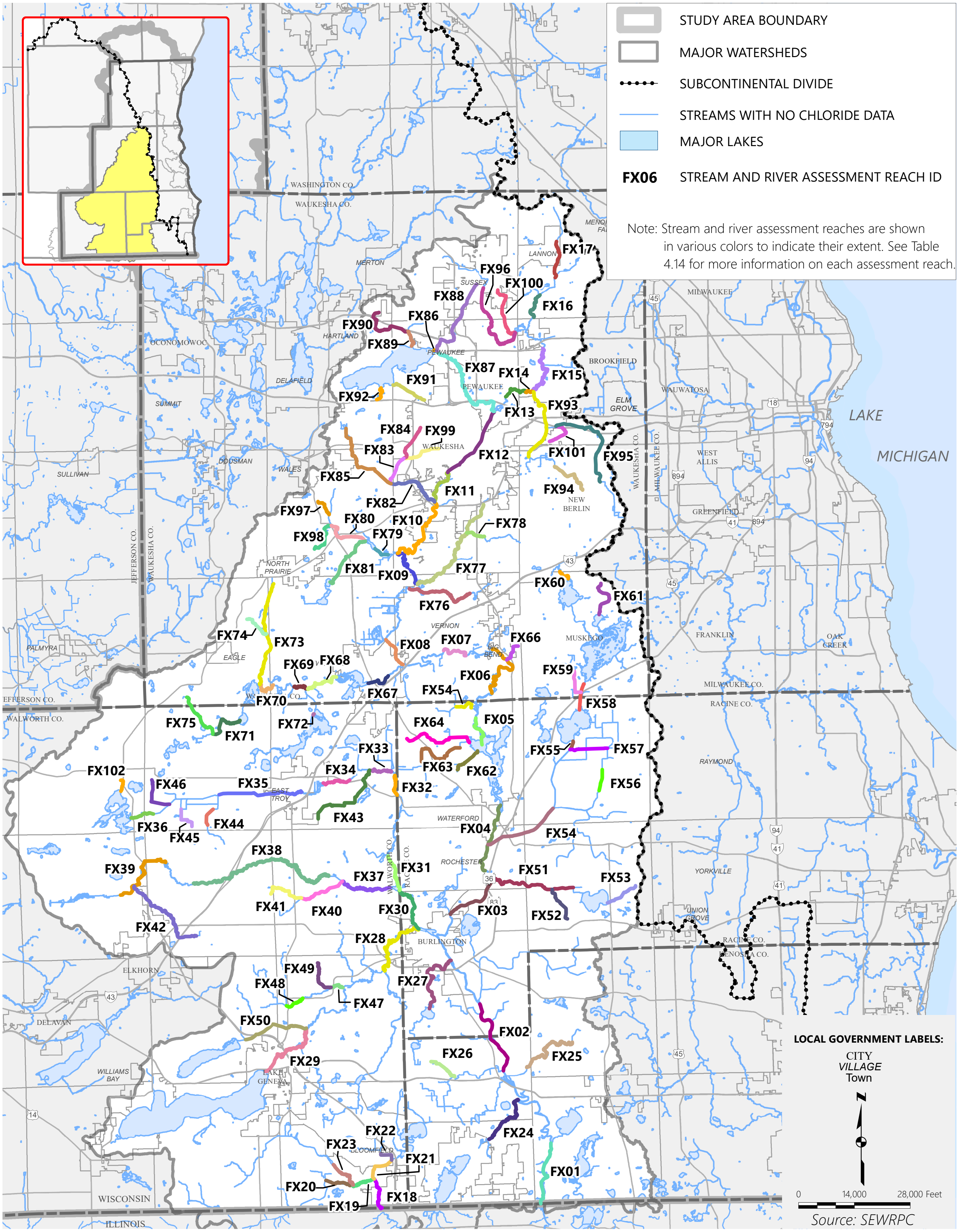


Map 4.30
Recent Maximum Chloride Concentrations in Assessment Reaches Within the Des Plaines River Watershed and Road and Parking Lot Density in Subbasins

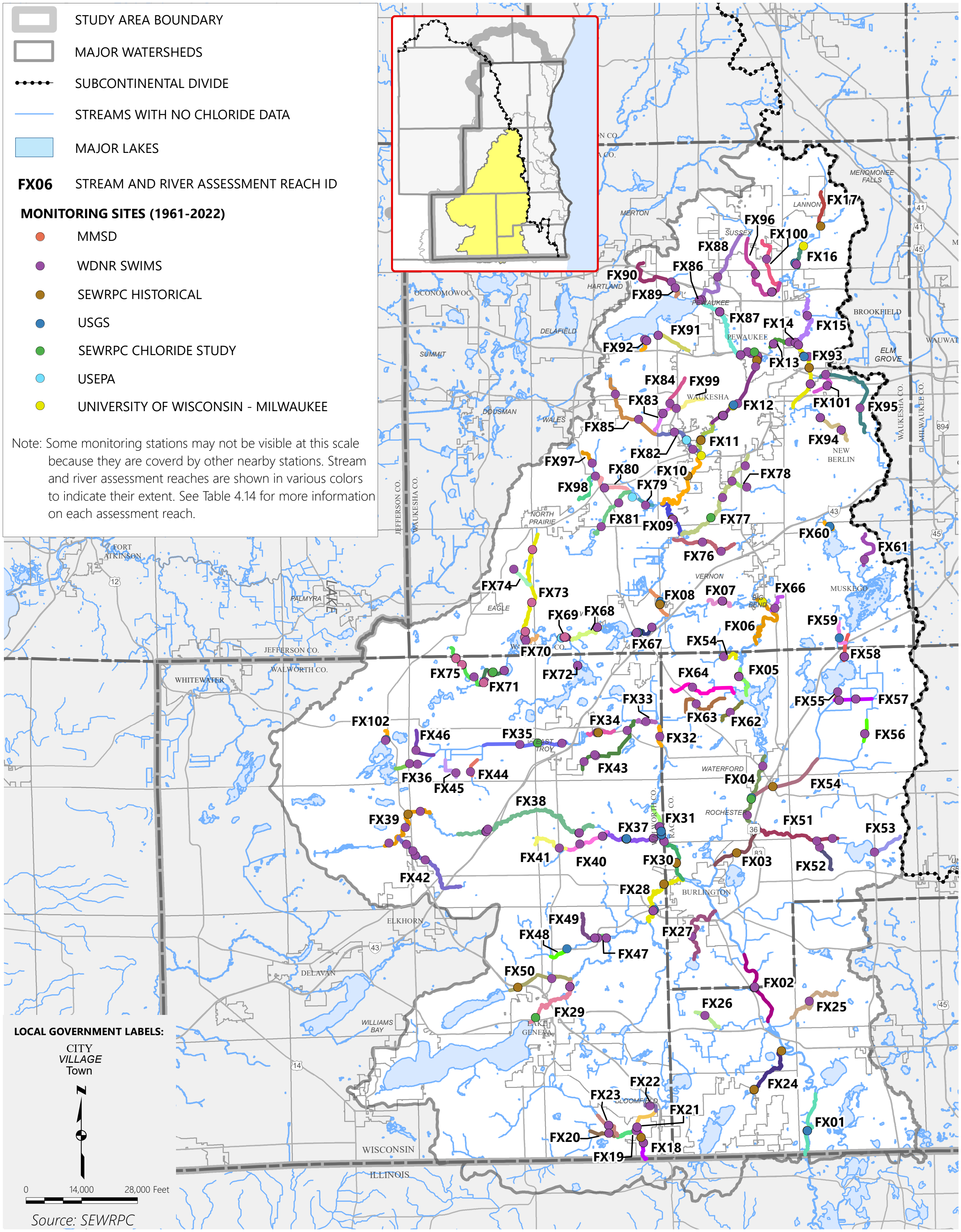


Source: SEWRPC

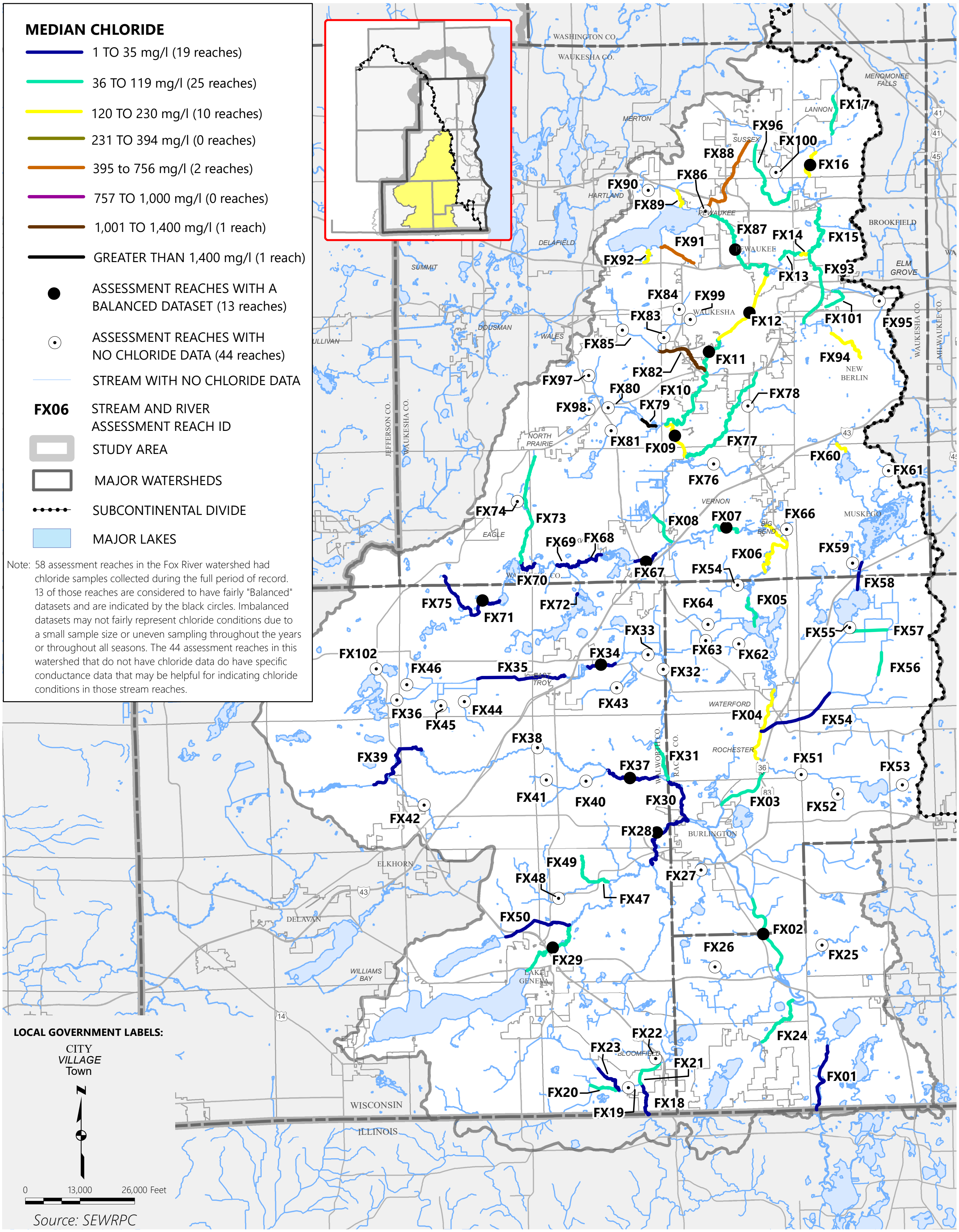
Map 4.31
Assessment Reaches for Streams Within the Fox River Watershed



Map 4.32
Monitoring Sites and Assessment Reaches Within the Fox River Watershed

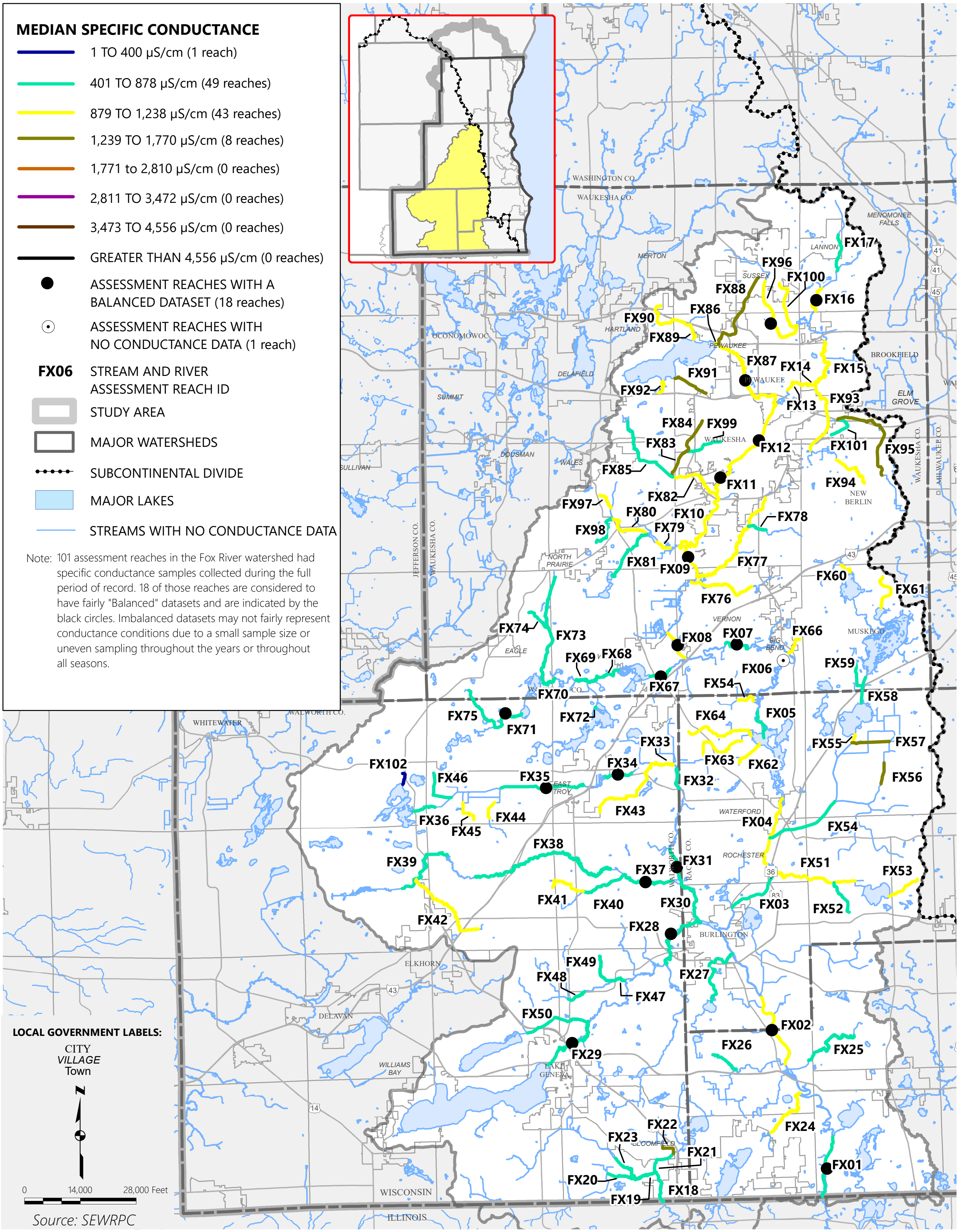


Map 4.33
Median Chloride Concentrations Within the Fox River Watershed for the Full Period of Record: 1961-2022

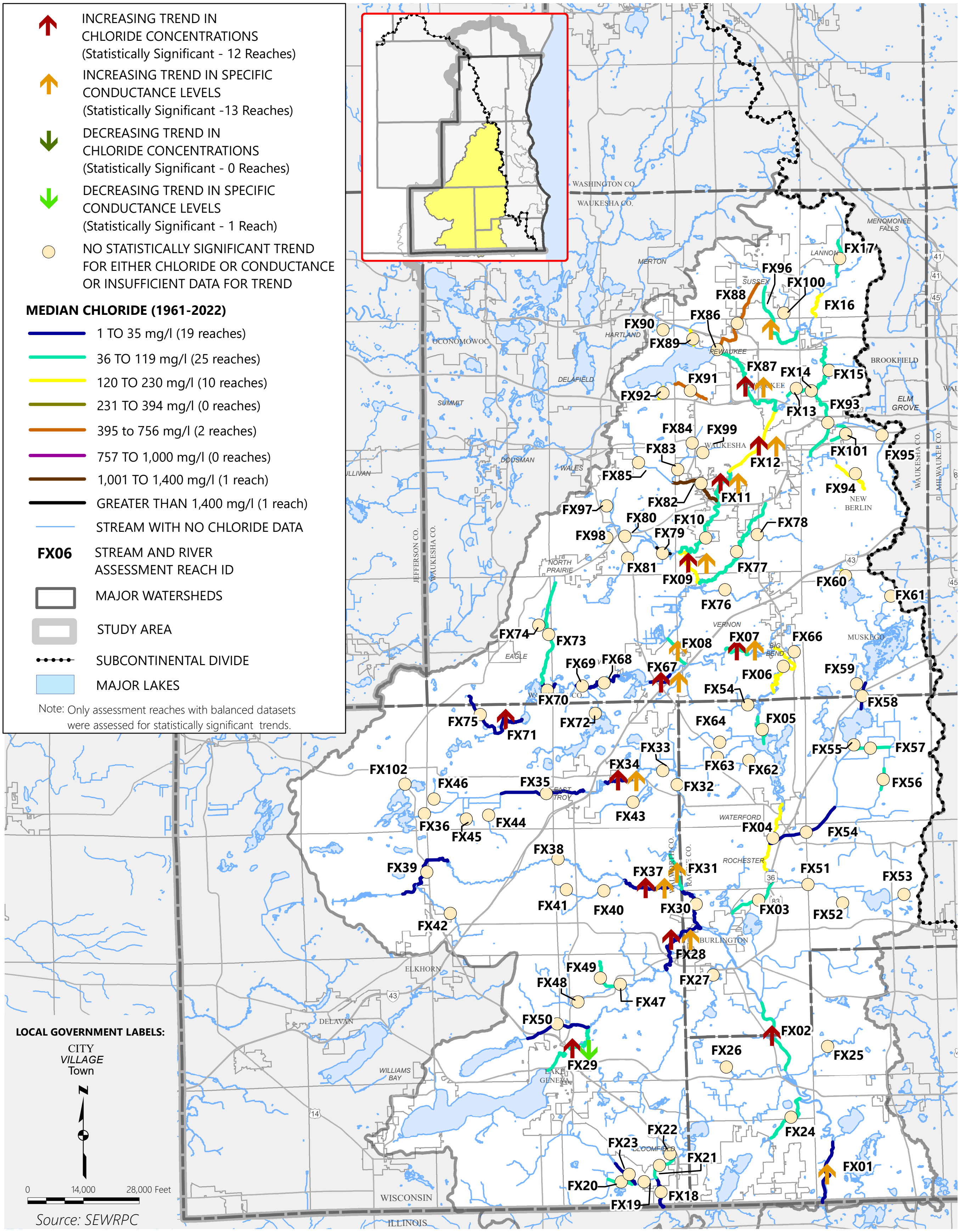


Source: SEWRPC

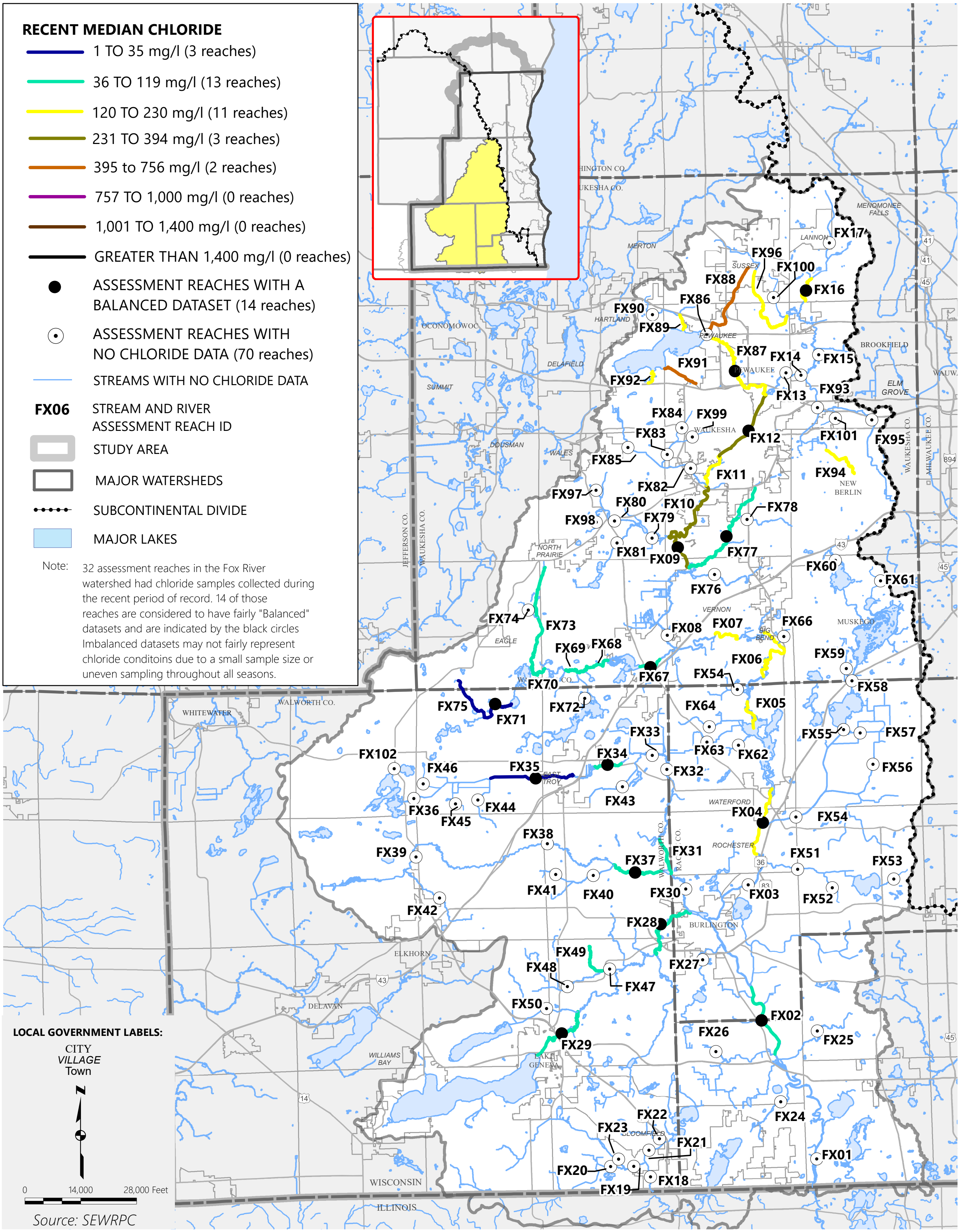
Map 4.34
Median Specific Conductance Within the Fox River Watershed for the Full Period of Record: 1961-2022



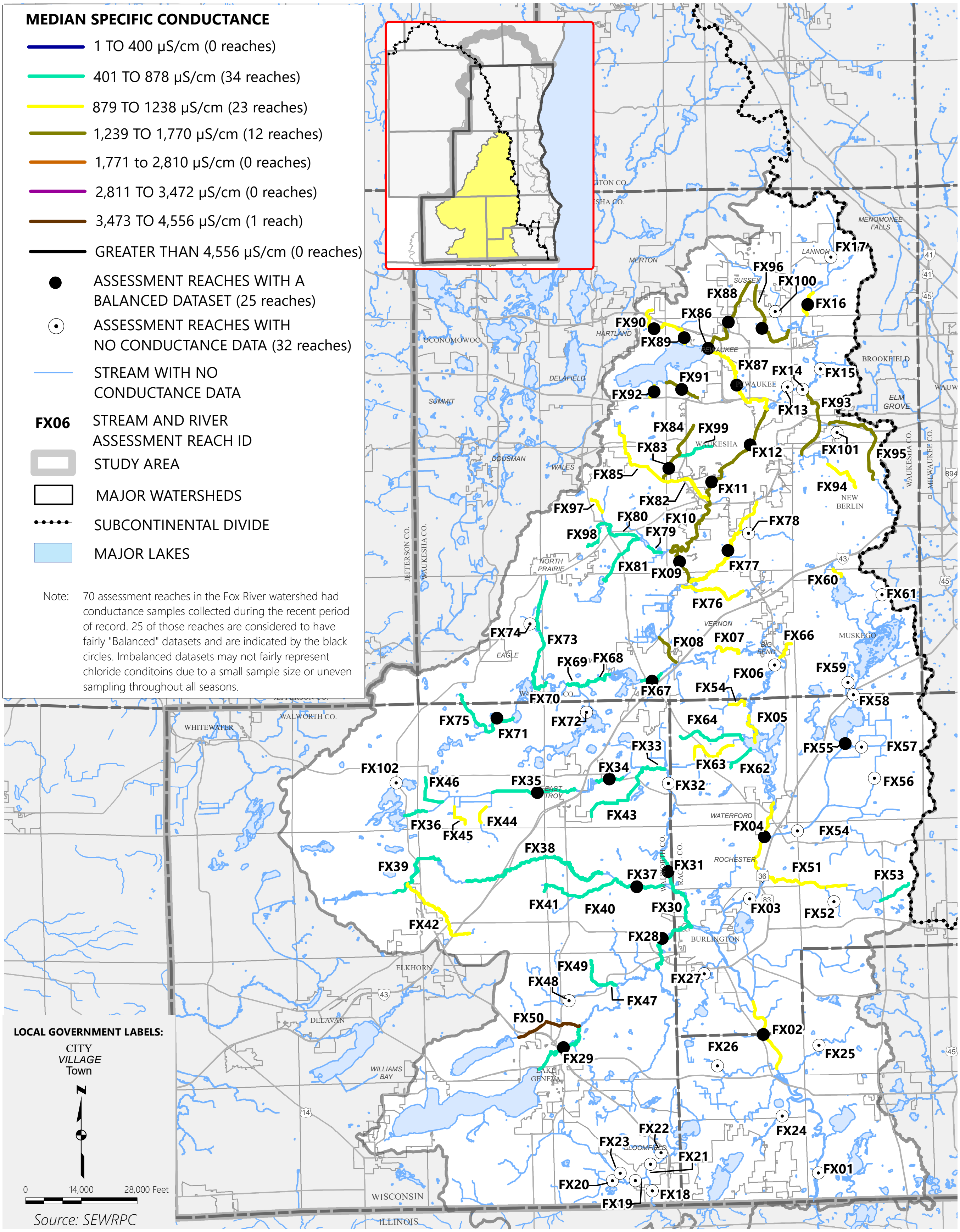
Map 4.35
Trends in Chloride and Specific Conductance Among Assessment Reaches Within the Fox River Watershed over the Full Period of Record: 1961-2022



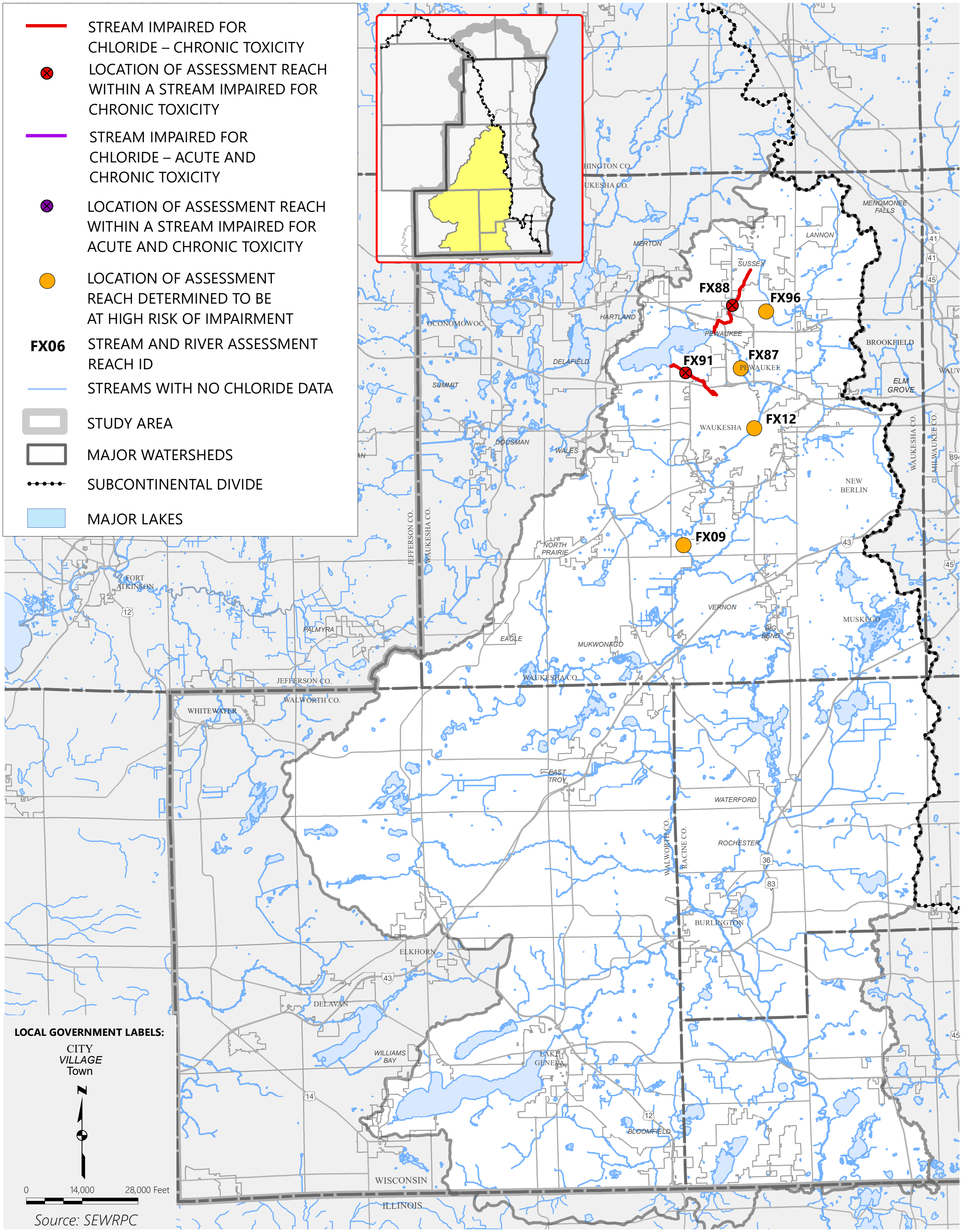
Map 4.36
Recent Median Chloride Concentrations Within the Fox River Watershed: 2013-2022



Map 4.37
Recent Median Specific Conductance Within the Fox River Watershed: 2013-2022

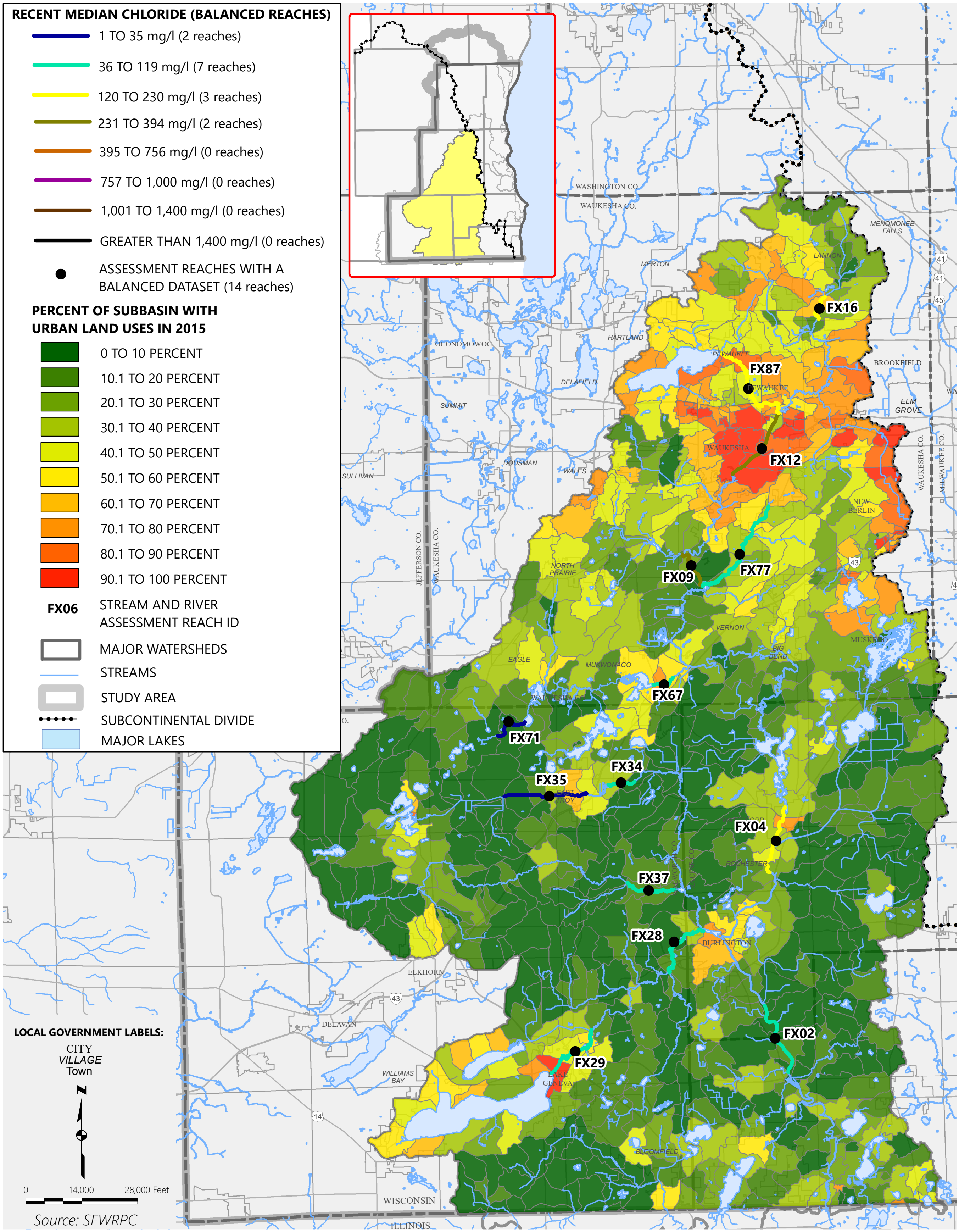


Map 4.38
Streams Impaired for Chloride Within the Fox River Watershed: 2024



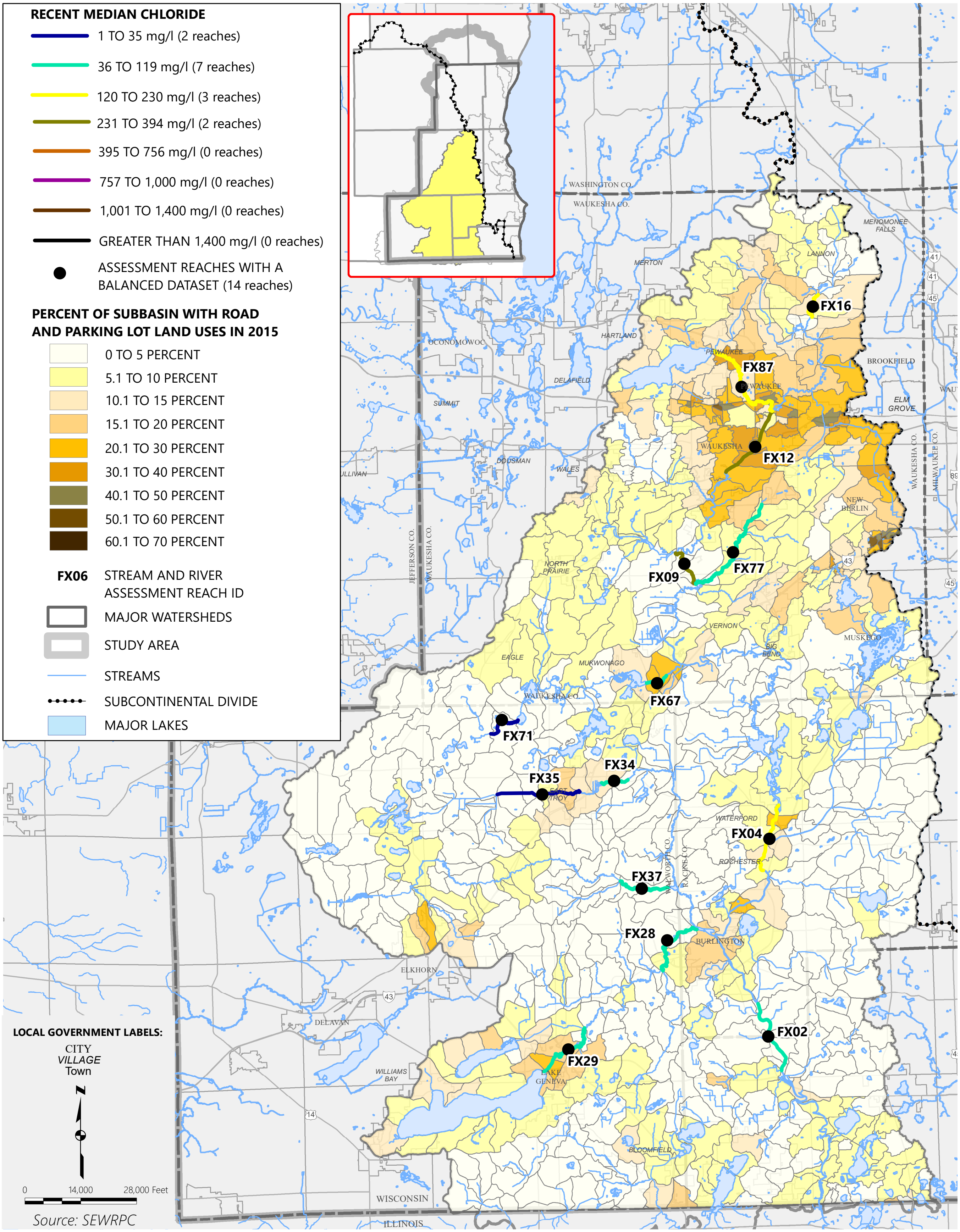
Source: SEWRPC

Map 4.38
Recent Median Chloride Concentration in Balanced Assessment Reaches Within the Fox River Watershed and Percent Urban Land Use in Subbasins

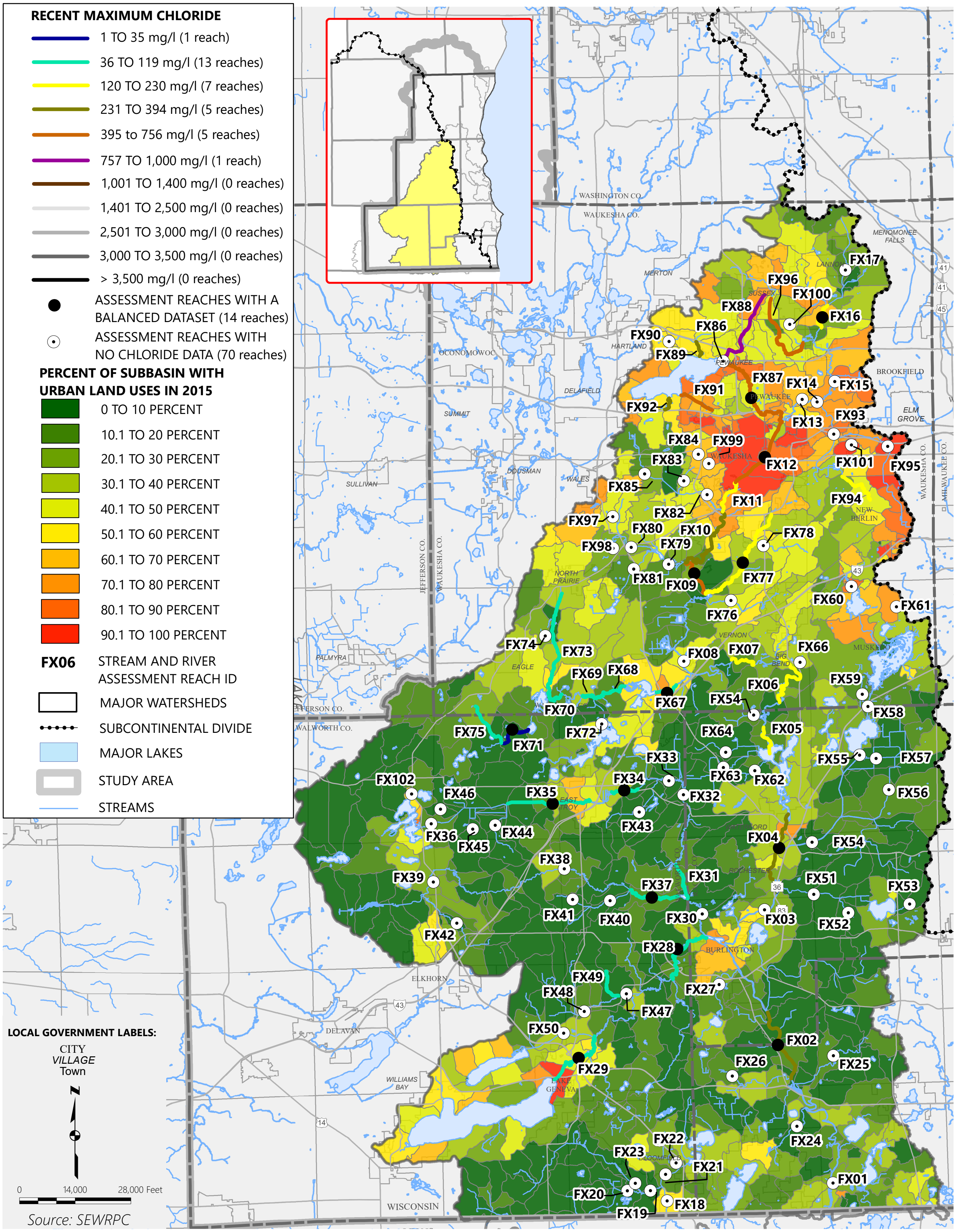


Source: SEWRPC

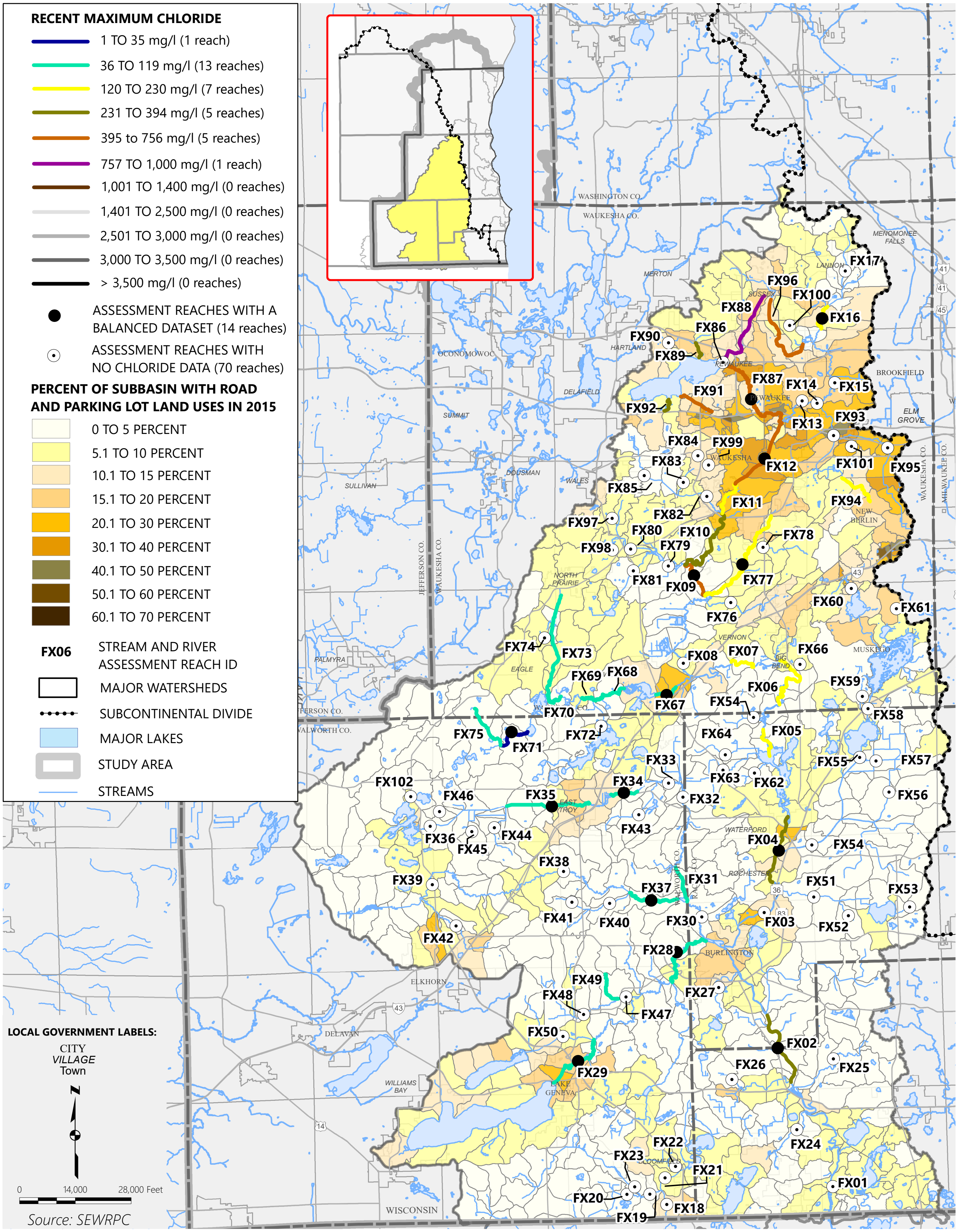
Map 4.40
Recent Median Chloride Concentration in Balanced Assessment Reaches Within the Fox River Watershed and Road and Parking Lot Density in Subbasins



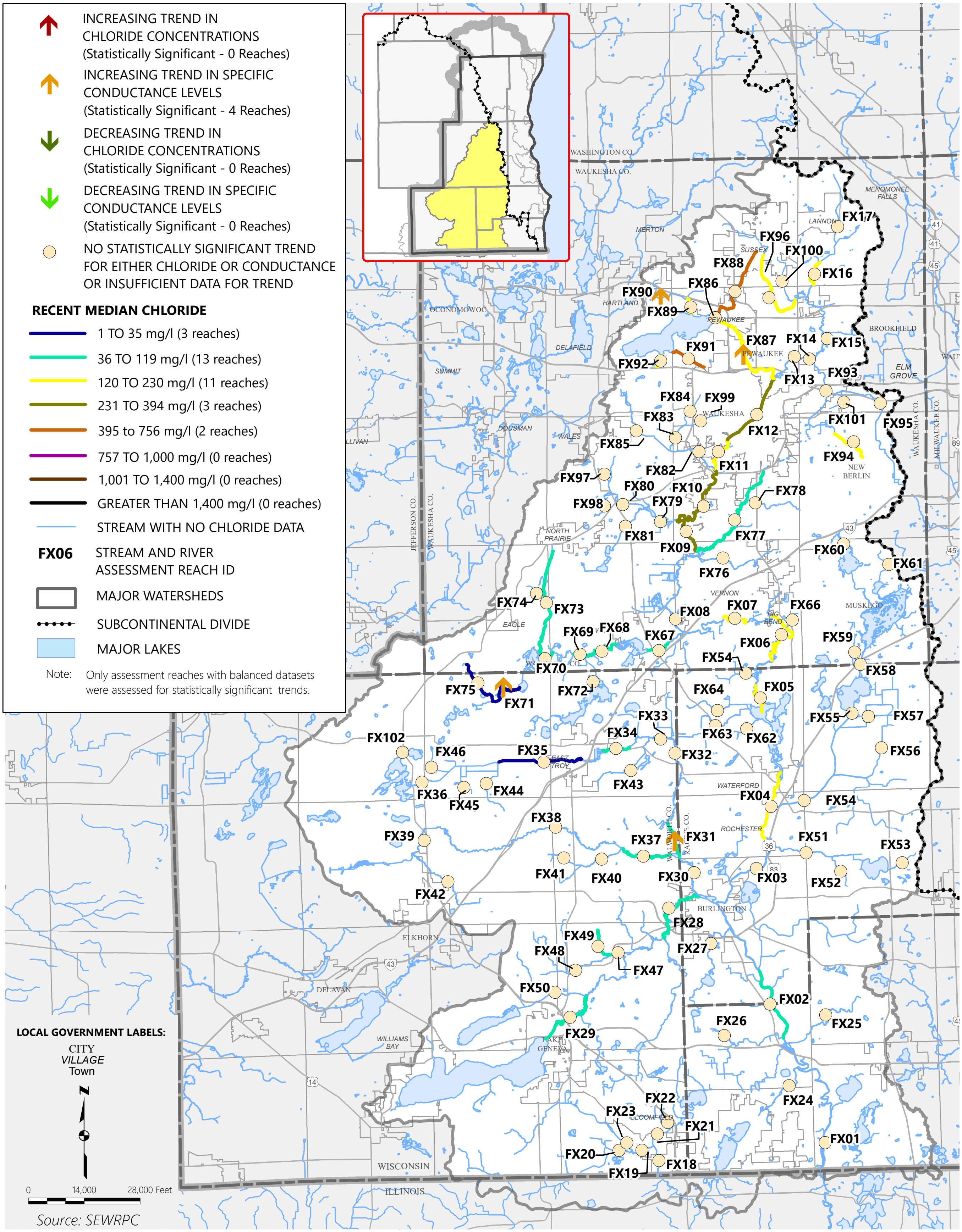
Map 4.41
Recent Maximum Chloride Concentrations in Stream Assessment Reaches Within the Fox River Watershed and Percent Urban Land Use by Subbasin



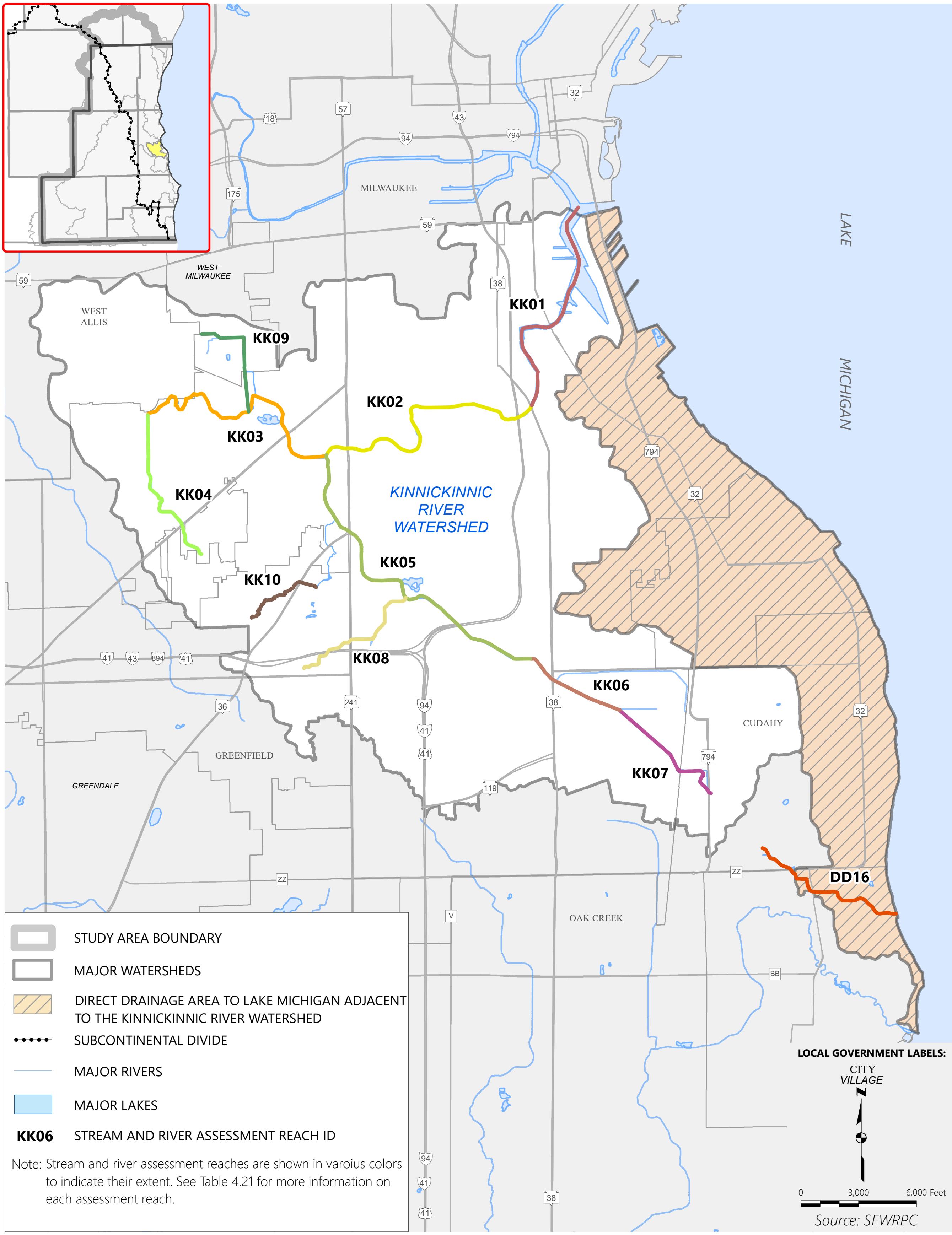
Map 4.42
Recent Maximum Chloride Concentrations in Stream Assessment Reaches Within the Fox River Watershed and Road and Parking Lot Density by Subbasin



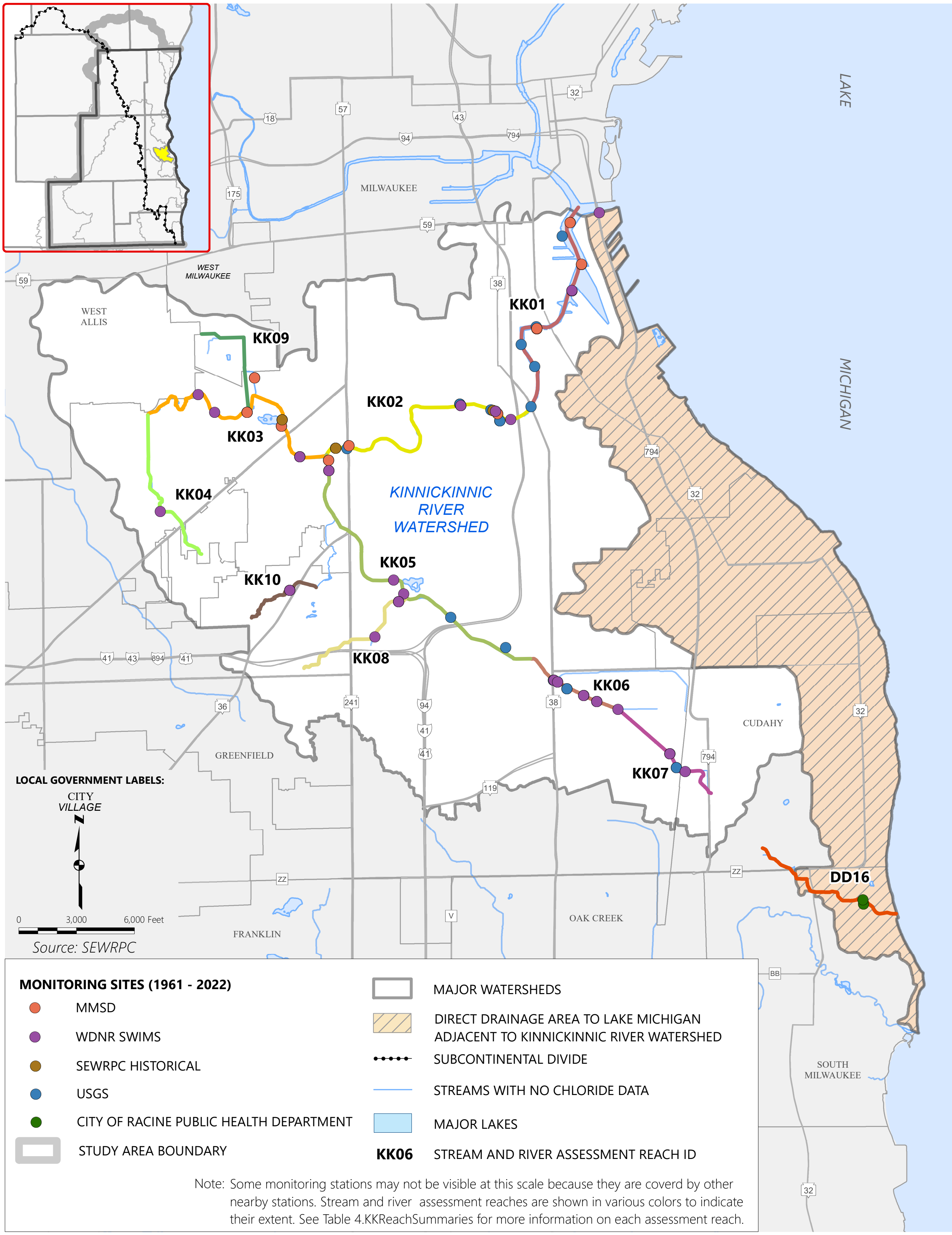
Map 4.43
Trends in Chloride and Specific Conductance Among Assessment Reaches Within the Fox River Watershed over the Recent Period of Record: 2013-2022



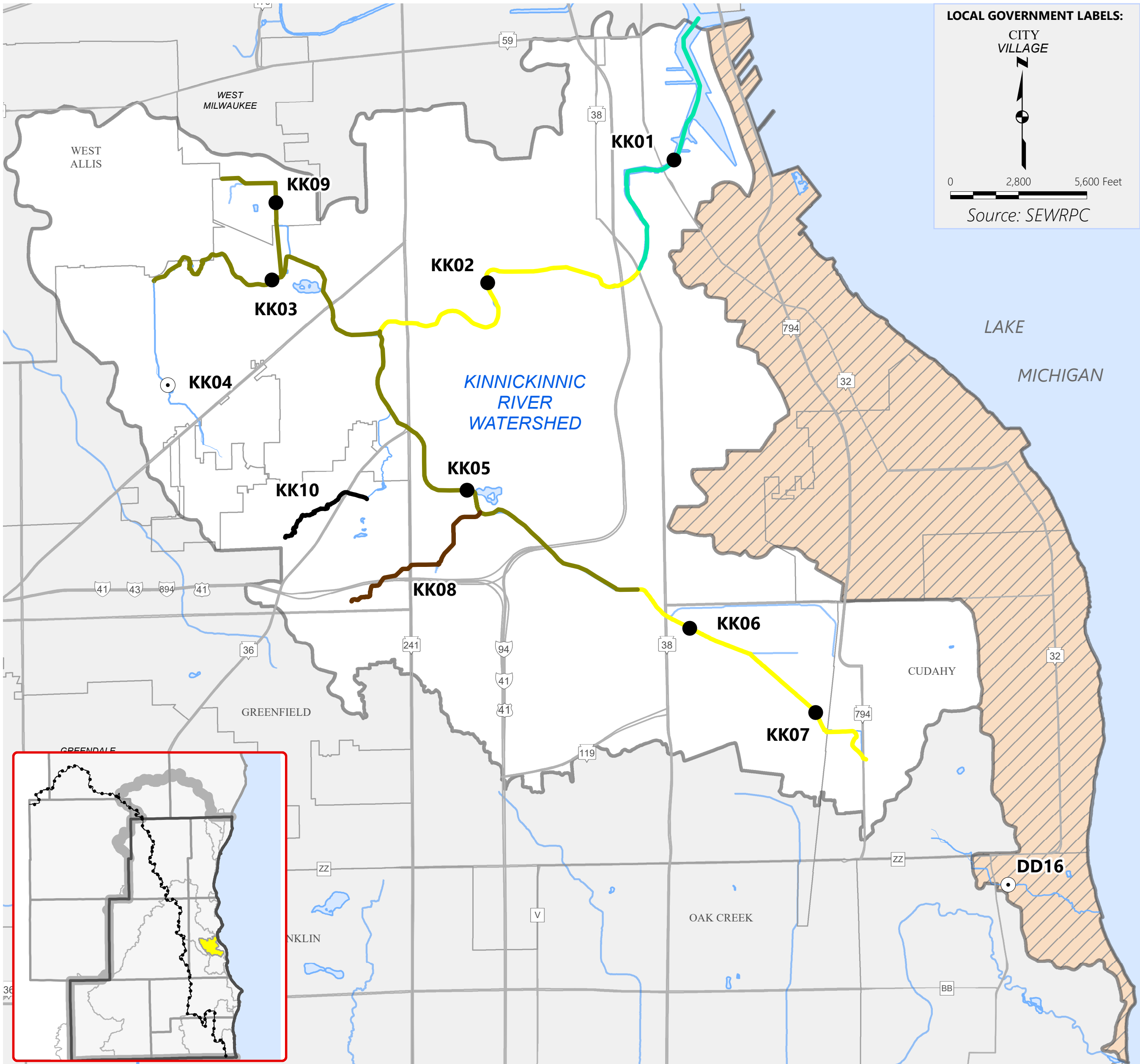
Map 4.44
Assessment Reaches Within the Kinnickinnic River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan



Map 4.45
Monitoring Sites and Assessment Reaches Within the Kinnickinnic River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan



Map 4.46
Median Chloride Concentration Within the Kinnickinnic River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan for the Full Period of Record: 1961-2022



MEDIAN CHLORIDE

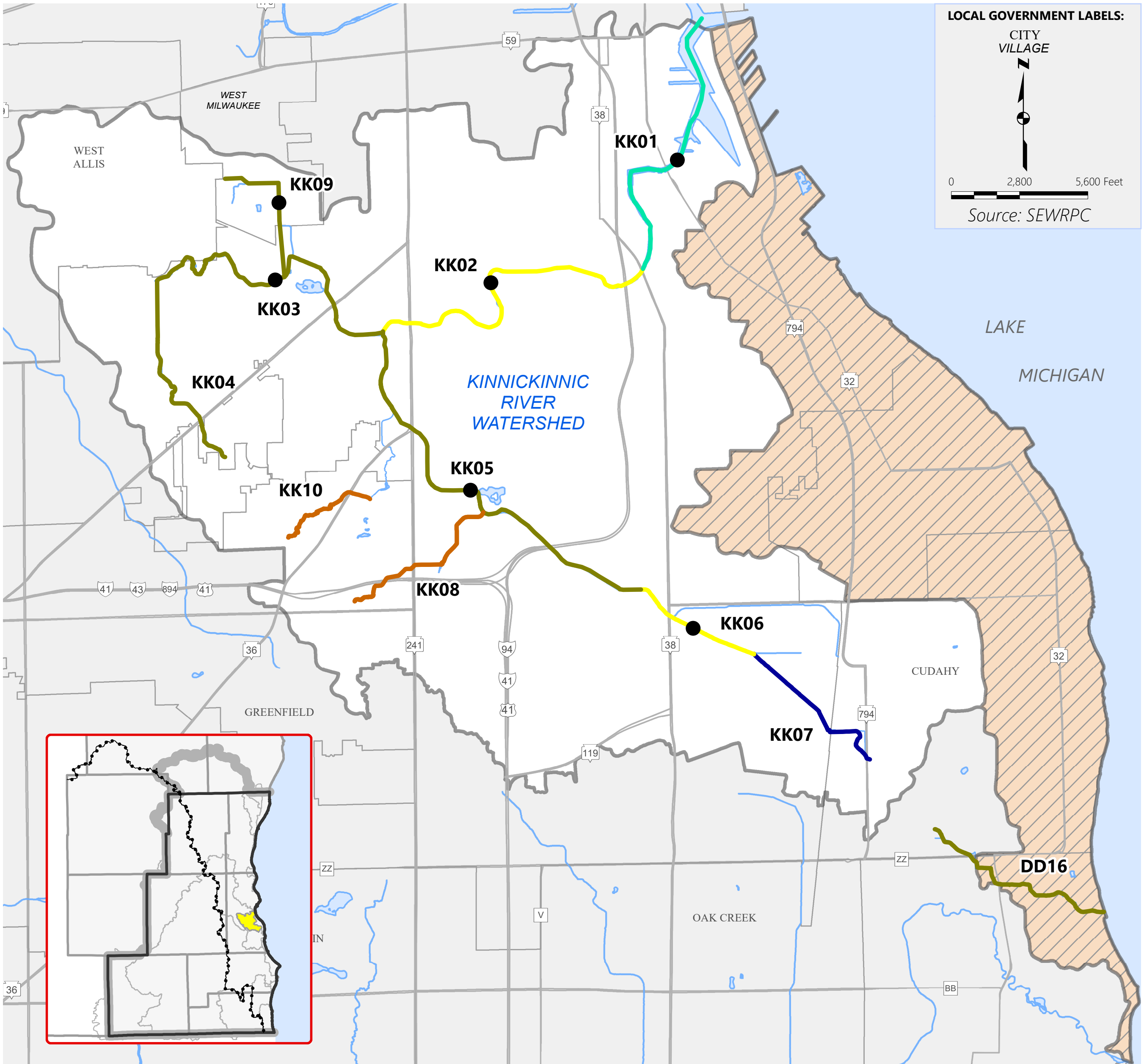
1 TO 35 mg/l (0 reaches)
36 TO 119 mg/l (1 reach)
120 TO 230 mg/l (3 reaches)
231 TO 394 mg/l (2 reaches)
395 to 756 mg/l (0 reaches)
757 TO 1,000 mg/l (0 reaches)
1,001 TO 1,400 mg/l (1 reach)
GREATER THAN 1,400 mg/l (1 reach)

ASSESSMENT REACHES WITH A BALANCED DATASET (7 reaches)
ASSESSMENT REACHES WITH NO CHLORIDE DATA (1 reach + 1 DD reach)
STUDY AREA BOUNDARY
MAJOR WATERSHEDS

DIRECT DRAINAGE AREA TO LAKE MICHIGAN ADJACENT TO KINNICKINNIC RIVER WATERSHED
SUBCONTINENTAL DIVIDE
STREAMS WITH NO CHLORIDE DATA
MAJOR LAKES
KK06 STREAM AND RIVER ASSESSMENT REACH ID

Note: Nine assessment reaches in the Kinnickinnic River watershed had chloride samples collected during the full period of record. Seven of those reaches are considered to have fairly "Balanced" datasets and are indicated by the black circles. Imbalanced datasets may not fairly represent chloride conditions due to a small sample size or uneven sampling throughout the years or throughout all seasons. The one assessment reach in this watershed that does not have chloride data did have specific conductance data that may be helpful for indicating chloride conditions in those stream reaches.

Map 4.47
Median Specific Conductance Within the Kinnickinnic River Watershed and Adjacent Direct Drainage Area to Lake Michigan for the Full Period of Record: 1961-2022



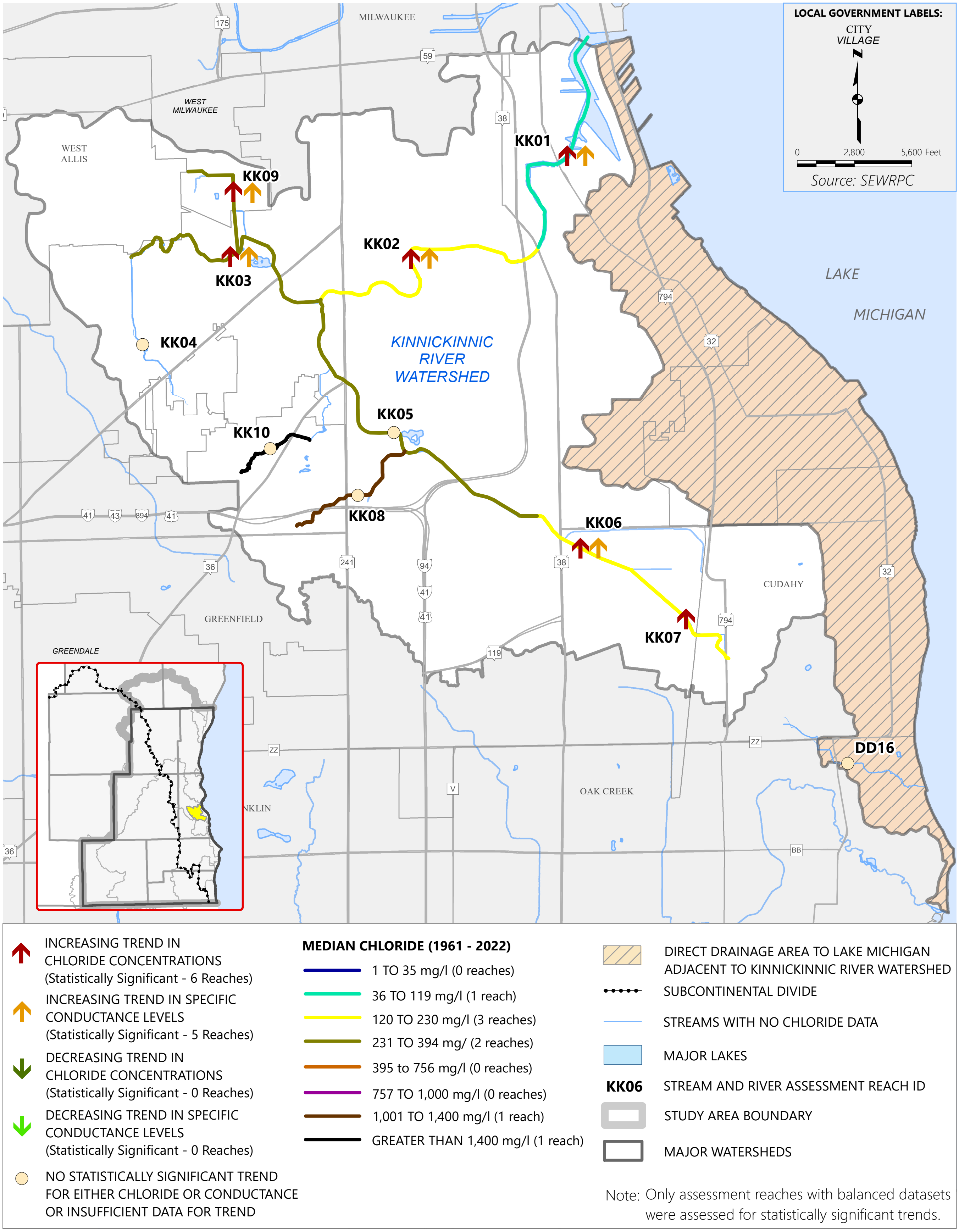
MEDIAN SPECIFIC CONDUCTANCE

- 1 TO 400 µS/cm (1 reach)
- 401 TO 878 µS/cm (1 reach)
- 879 TO 1,238 µS/cm (2 reaches)
- 1,239 TO 1,770 µS/cm (4 reaches + 1 DD reach)
- 1,771 to 2,810 µS/cm (2 reaches)
- 2,811 TO 3,472 µS/cm (0 reaches)
- 3,473 TO 4,556 µS/cm (0 reaches)
- GREATER THAN 4,556 µS/cm (0 reaches)

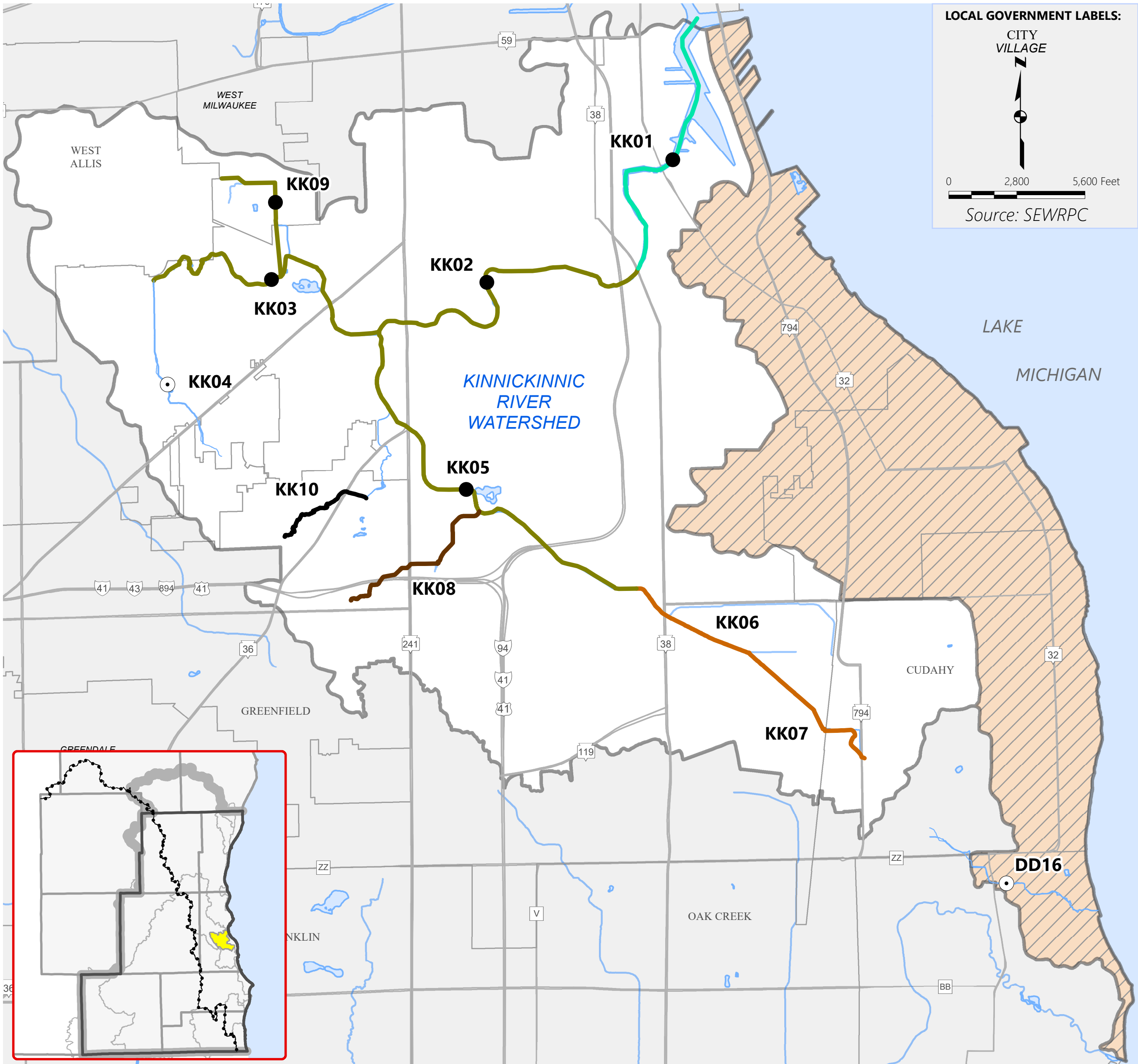
- ASSESSMENT REACHES WITH A BALANCED DATASET (7 reaches)
- ASSESSMENT REACHES WITH NO CONDUCTANCE DATA (0 reaches)
- STUDY AREA BOUNDARY
- MAJOR WATERSHEDS
- DIRECT DRAINAGE AREA TO LAKE MICHIGAN ADJACENT TO KINNICKINNIC RIVER WATERSHED
- SUBCONTINENTAL DIVIDE
- STREAMS WITH NO CHLORIDE DATA
- MAJOR LAKES
- KK06 STREAM AND RIVER ASSESSMENT REACH ID

Note: Ten assessment reaches in the Kinnickinnic River watershed had specific conductance samples collected during the full period of record. Seven of those reaches are considered to have fairly "Balanced" datasets and are indicated by the black circles. Imbalanced datasets may not fairly represent chloride conditions due to a small sample size or uneven sampling throughout the years or throughout all seasons.

Map 4.48
Trends in Chloride and Specific Conductance for Assessment Reaches Within the Kinnickinnic River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan: 1961-2022



Map 4.49
Median Chloride Concentration Within the Kinnickinnic River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan for the Recent Period of Record: 2013-2022



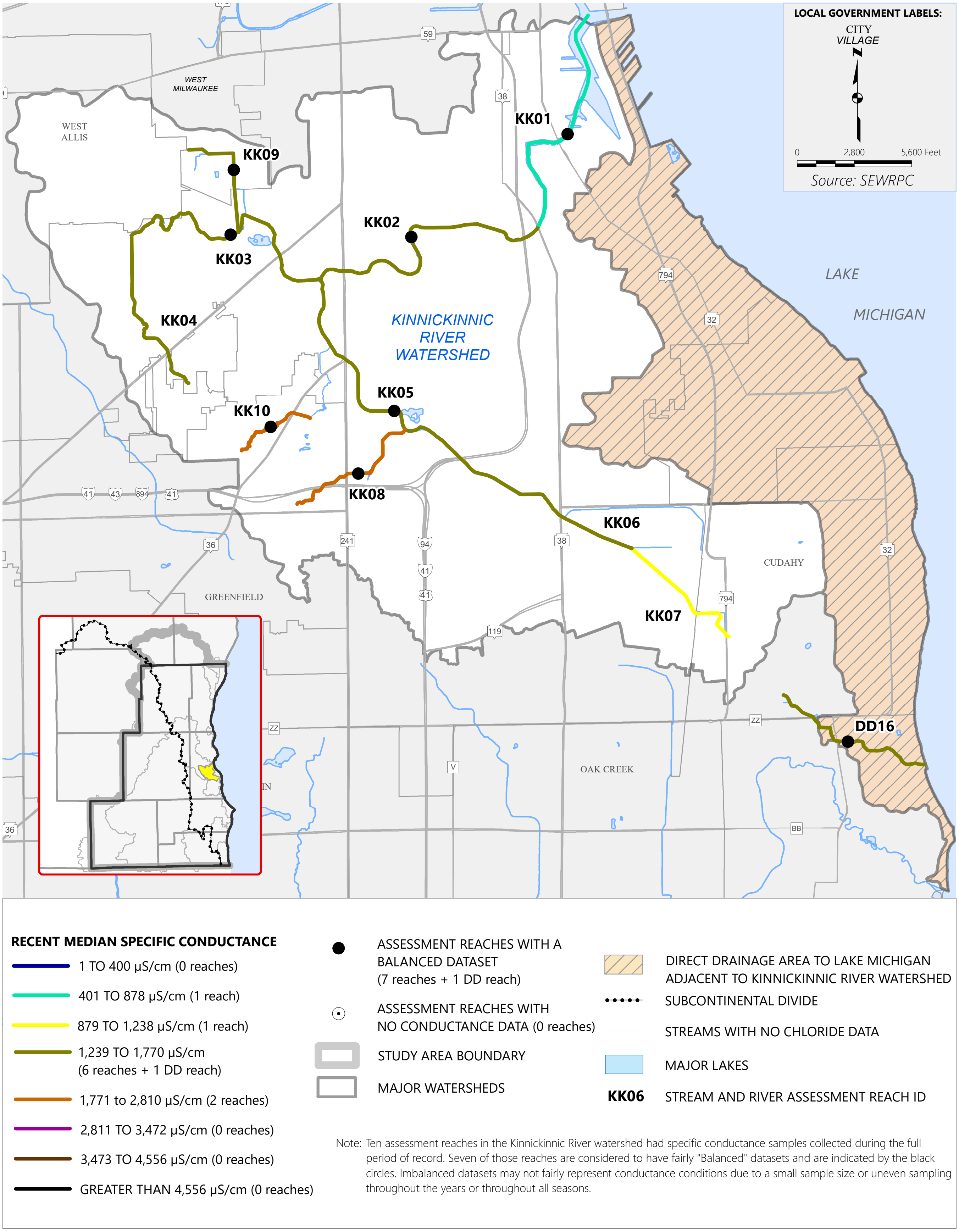
RECENT MEDIAN CHLORIDE

- 1 TO 35 mg/l (0 reaches)
- 36 TO 119 mg/l (1 reach)
- 120 TO 230 mg/l (0 reaches)
- 231 TO 394 mg/l (4 reaches)
- 395 to 756 mg/l (2 reaches)
- 757 TO 1,000 mg/l (0 reaches)
- 1,001 TO 1,400 mg/l (1 reach)
- GREATER THAN 1,400 mg/l (1 reach)

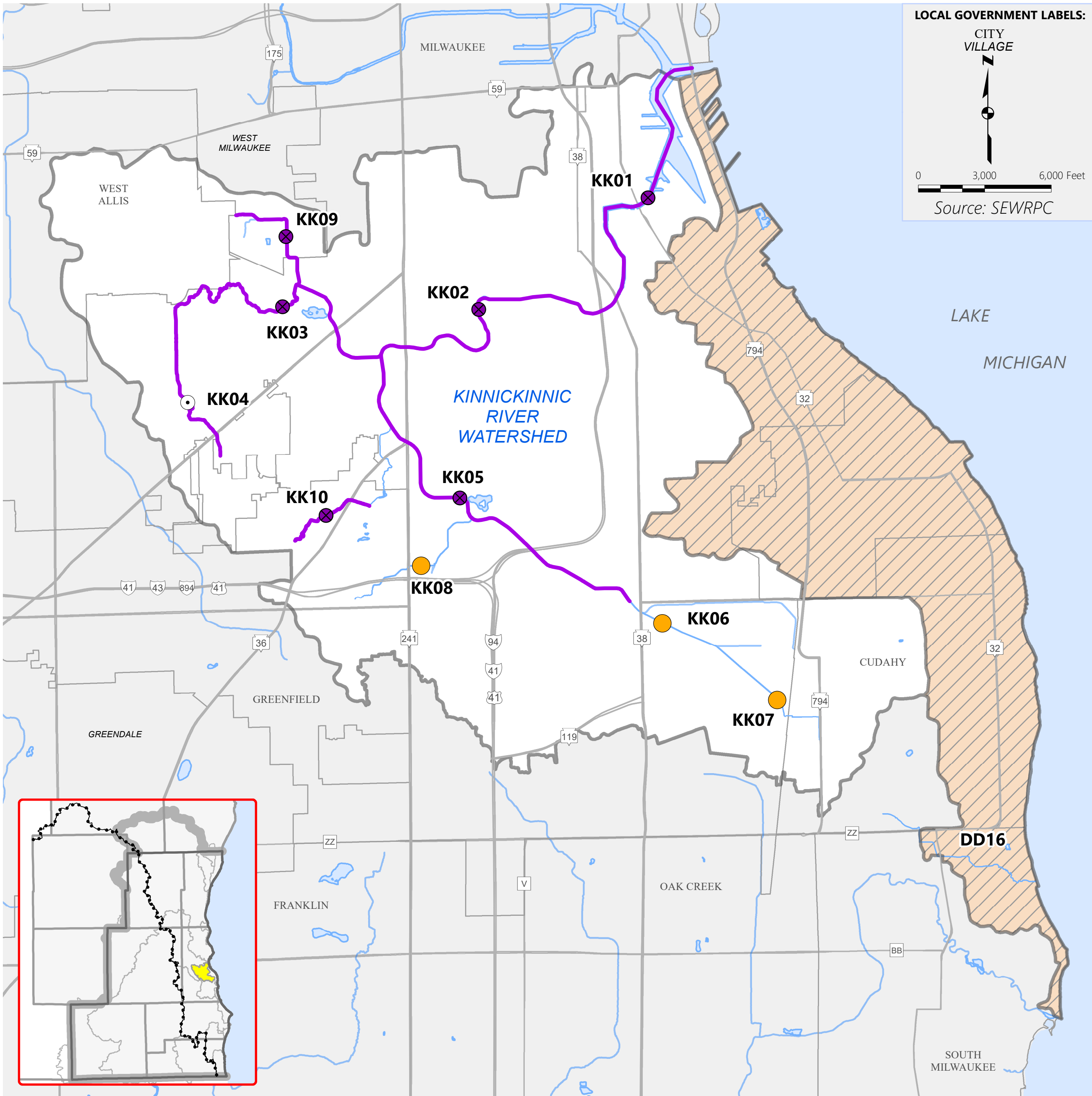
- ASSESSMENT REACHES WITH A BALANCED DATASET (5 reaches)
- ASSESSMENT REACHES WITH NO CHLORIDE DATA (1 reach + 1 DD reach)
- STUDY AREA BOUNDARY
- MAJOR WATERSHEDS
- DIRECT DRAINAGE AREA TO LAKE MICHIGAN ADJACENT TO KINNICKINNIC RIVER WATERSHED
- SUBCONTINENTAL DIVIDE
- STREAMS WITH NO CHLORIDE DATA
- MAJOR LAKES
- **KK06** STREAM AND RIVER ASSESSMENT REACH ID

Note: Nine assessment reaches in the Kinnickinnic River watershed had chloride samples collected during the recent period of record. Five of those reaches are considered to have fairly "Balanced" datasets and are indicated by the black circles. Imbalanced datasets may not fairly represent chloride conditions due to a small sample size or uneven sampling throughout the years or throughout all seasons. One assessment reach in the watershed and one reach in the adjacent Direct Drainage to Lake Michigan did not have any chloride data in the recent period, but both did have conductance data that may be helpful for indicating chloride conditions in those stream reaches.

Map 4.50
Median Specific Conductance Within the Kinnickinnic River Watershed and Adjacent Direct Drainage Area to Lake Michigan for the Recent Period of Record: 2013- 2022



Map 4.51
Streams Impaired for Chloride within the Kinnickinic Creek Watershed: 2024



STREAM IMPAIRED FOR CHLORIDE – CHRONIC TOXICITY

LOCATION OF ASSESSMENT REACH WITHIN A STREAM IMPAIRED FOR CHRONIC TOXICITY

STREAM IMPAIRED FOR CHLORIDE – ACUTE AND CHRONIC TOXICITY

LOCATION OF ASSESSMENT REACH WITHIN A STREAM IMPAIRED FOR ACUTE AND CHRONIC TOXICITY

LOCATION OF ASSESSMENT REACH DETERMINED TO BE AT HIGH RISK OF IMPAIRMENT

ASSESSMENT REACH WITHIN A STREAM LISTED AS IMPAIRED BUT NO RECENT EXCEEDANCES

ASSESSMENT REACH WITH NO RECENT CHLORIDE DATA

DIRECT DRAINAGE AREA TO LAKE MICHIGAN ADJACENT TO KINNICKINNIC RIVER WATERSHED

SUBCONTINENTAL DIVIDE

STREAM WITH NO CHLORIDE DATA

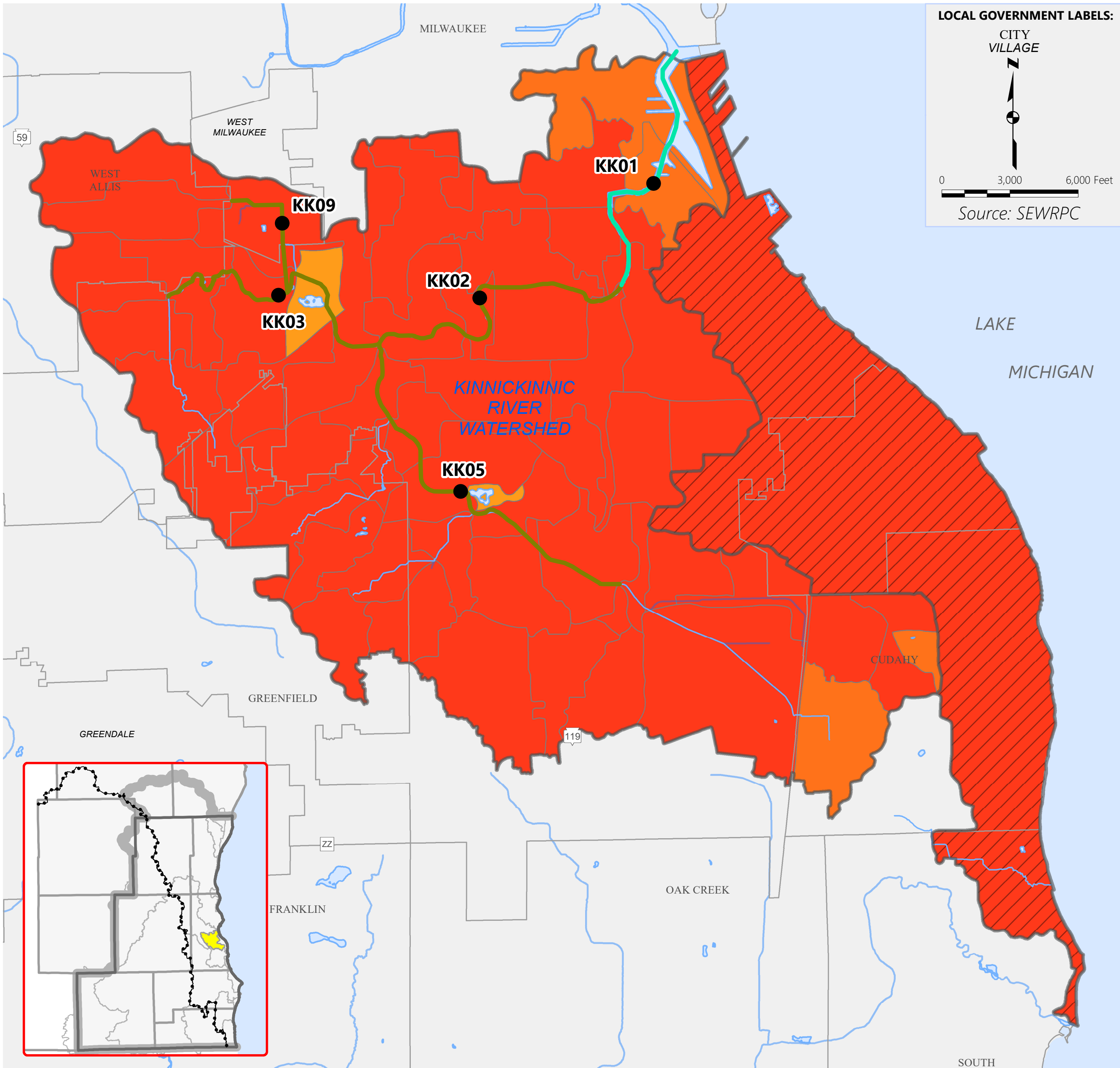
MAJOR LAKES

KK06 STREAM AND RIVER ASSESSMENT REACH ID

STUDY AREA BOUNDARY

MAJOR WATERSHEDS

Map 4.52
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Kinnickinnic River Watershed and Direct Drainage Area to Lake Michigan and Percent Urban Land Use by Subbasin



PERCENT OF SUBBASIN WITH URBAN LAND USES IN 2015

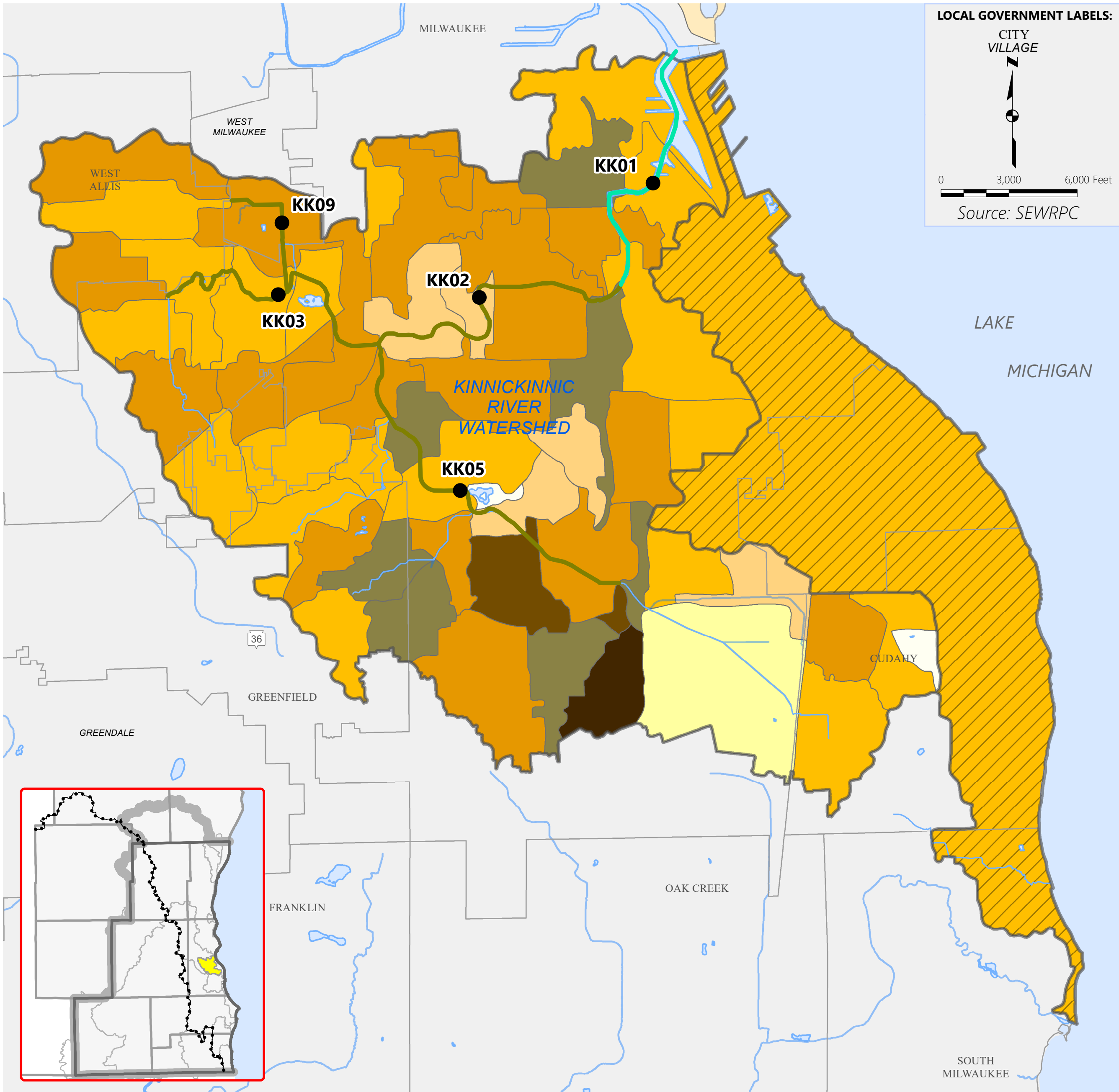
- 0 TO 10 PERCENT
- 10.1 TO 20 PERCENT
- 20.1 TO 30 PERCENT
- 30.1 TO 40 PERCENT
- 40.1 TO 50 PERCENT
- 50.1 TO 60 PERCENT
- 60.1 TO 70 PERCENT
- 70.1 TO 80 PERCENT
- 80.1 TO 90 PERCENT
- 90.1 TO 100 PERCENT

RECENT MEDIAN CHLORIDE

- 1 TO 35 mg/l (0 reaches)
- 36 TO 119 mg/l (1 reach)
- 120 TO 230 mg/l (0 reaches)
- 231 TO 394 mg/l (4 reaches)
- 395 to 756 mg/l (0 reaches)
- 757 TO 1,000 mg/l (0 reaches)
- 1,001 TO 1,400 mg/l (0 reaches)
- GREATER THAN 1,400 mg/l (0 reaches)

- ASSESSMENT REACHES WITH A BALANCED DATASET (5 reaches)
- STUDY AREA BOUNDARY
- MAJOR WATERSHEDS
- DIRECT DRAINAGE AREA TO LAKE MICHIGAN ADJACENT TO KINNICKINNIC RIVER WATERSHED
- SUBCONTINENTAL DIVIDE
- STEAMS WITH NO CHLORIDE DATA
- MAJOR LAKES
- KK06 STREAM AND RIVER ASSESSMENT REACH ID

Map 4.KK_ClRecMedianBalanced_PercentRoadsLots
Recent Median Chloride Concentrations in Balanced Assessment Reaches Within the Kinnickinnic River Watershed and Direct Drainage Area to Lake Michigan and Road and Parking Lot Density in Subbasins



PERCENT OF SUBBASIN WITH ROAD AND PARKING LOT LAND USES IN 2015

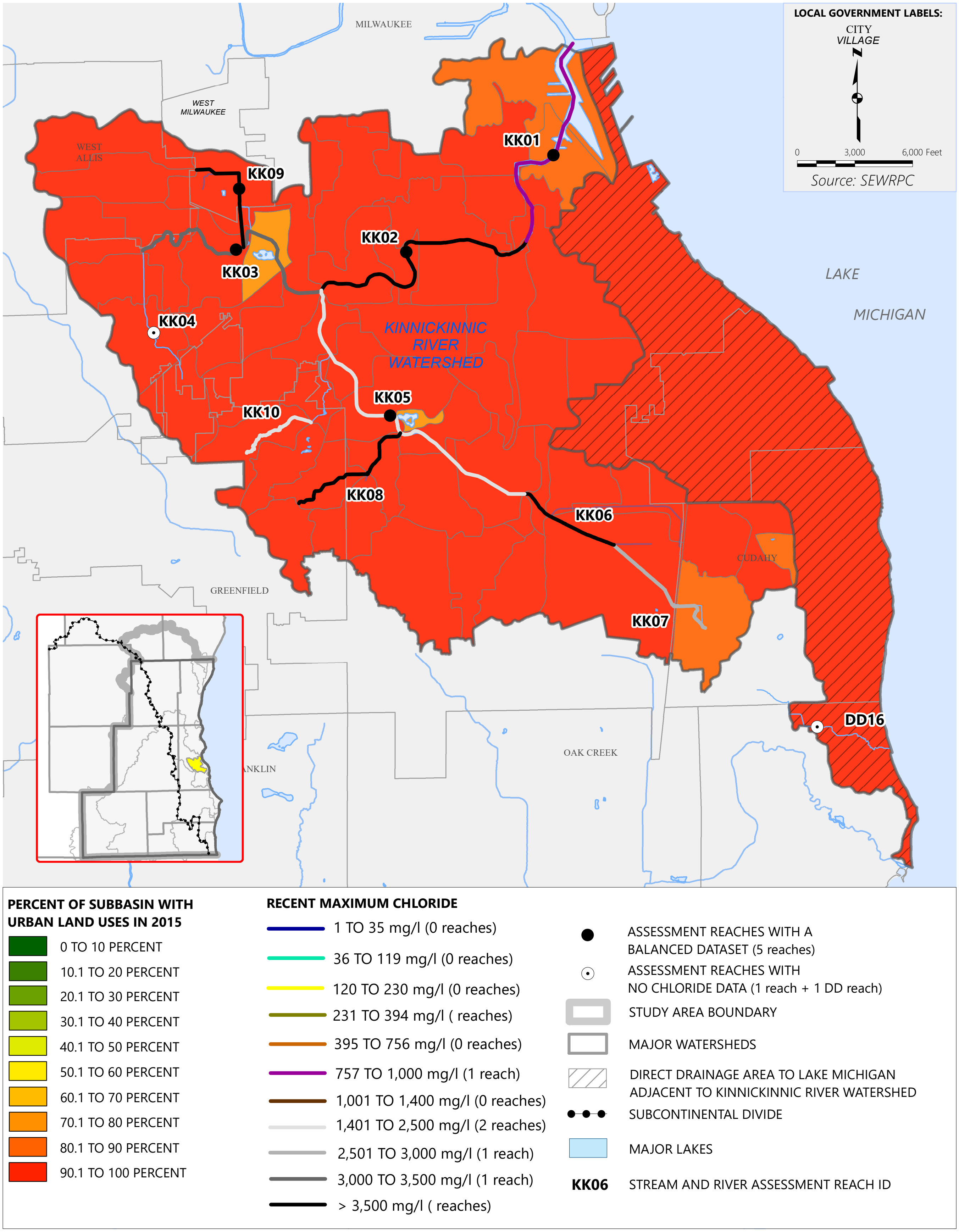
- 0 TO 5 PERCENT
- 5.1 TO 10 PERCENT
- 10.1 TO 15 PERCENT
- 15.1 TO 20 PERCENT
- 20.1 TO 30 PERCENT
- 30.1 TO 40 PERCENT
- 40.1 TO 50 PERCENT
- 50.1 TO 60 PERCENT
- 60.1 TO 70 PERCENT

RECENT MEDIAN CHLORIDE

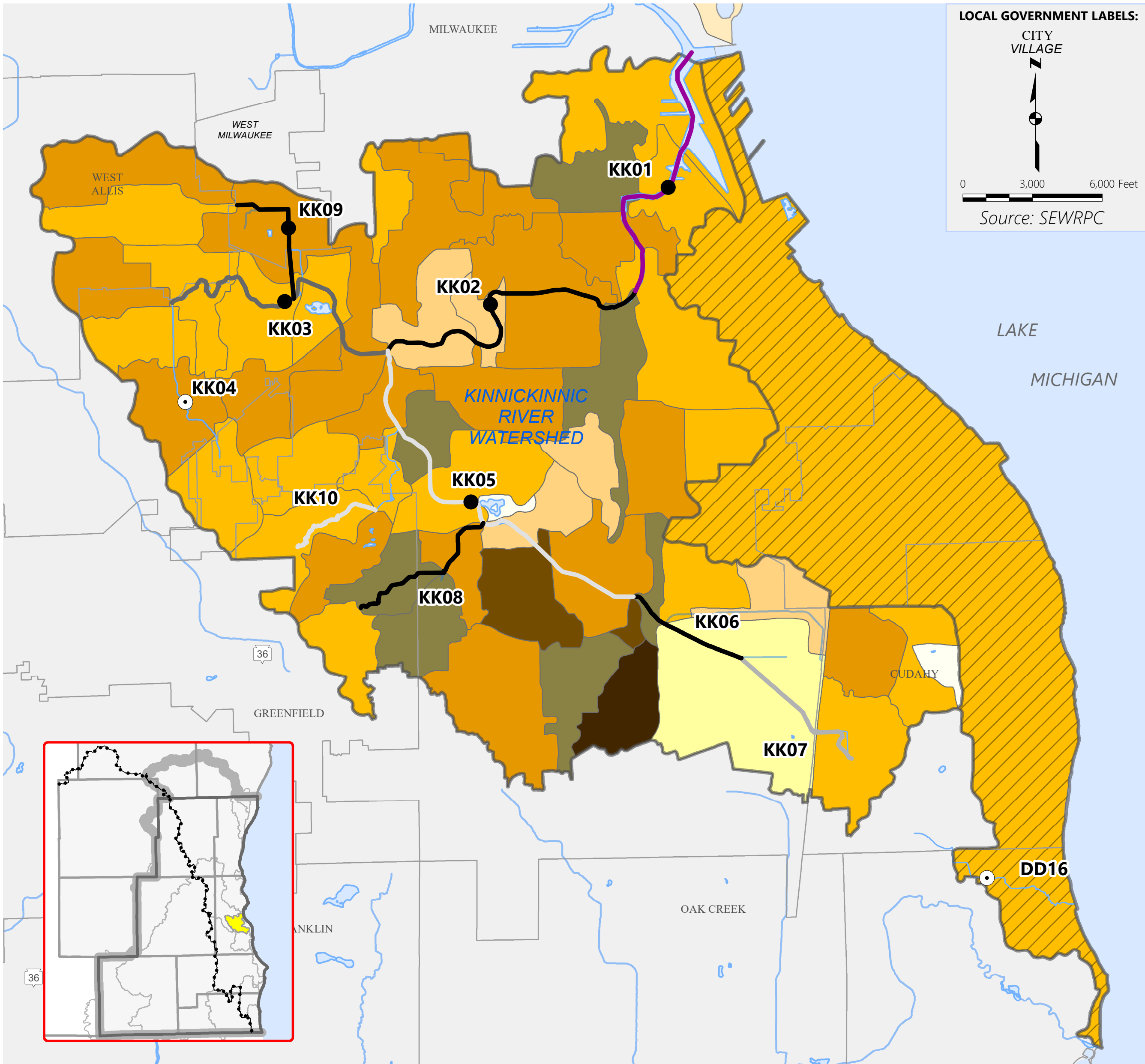
- 1 TO 35 mg/l (0 reaches)
- 36 TO 119 mg/l (1 reach)
- 120 TO 230 mg/l (0 reaches)
- 231 TO 394 mg/l (4 reaches)
- 395 to 756 mg/l (0 reaches)
- 757 TO 1,000 mg/l (0 reaches)
- 1,001 TO 1,400 mg/l (0 reaches)
- GREATER THAN 1,400 mg/l (0 reaches)

- ASSESSMENT REACHES WITH A BALANCED DATASET (5 reaches)
- STUDY AREA BOUNDARY
- MAJOR WATERSHEDS
- DIRECT DRAINAGE AREA TO LAKE MICHIGAN ADJACENT TO KINNICKINNIC RIVER WATERSHED
- SUBCONTINENTAL DIVIDE
- MAJOR LAKES
- KK06 STREAM AND RIVER ASSESSMENT REACH ID

Map 4.54
Recent Maximum Chloride Concentrations in Assessment Reaches Within the Kinnickinnic River Watershed and Direct Drainage Area to Lake Michigan and Percent Urban Land Use by Subbasin



Map 4.55
Recent Maximum Chloride Concentrations in Assessment Reaches Within the Kinnickinnic River Watershed and Direct Drainage Area to Lake Michigan and Road and Parking Lot Density in Subbasins



PERCENT OF SUBBASIN WITH ROAD AND PARKING LOT LAND USES IN 2015

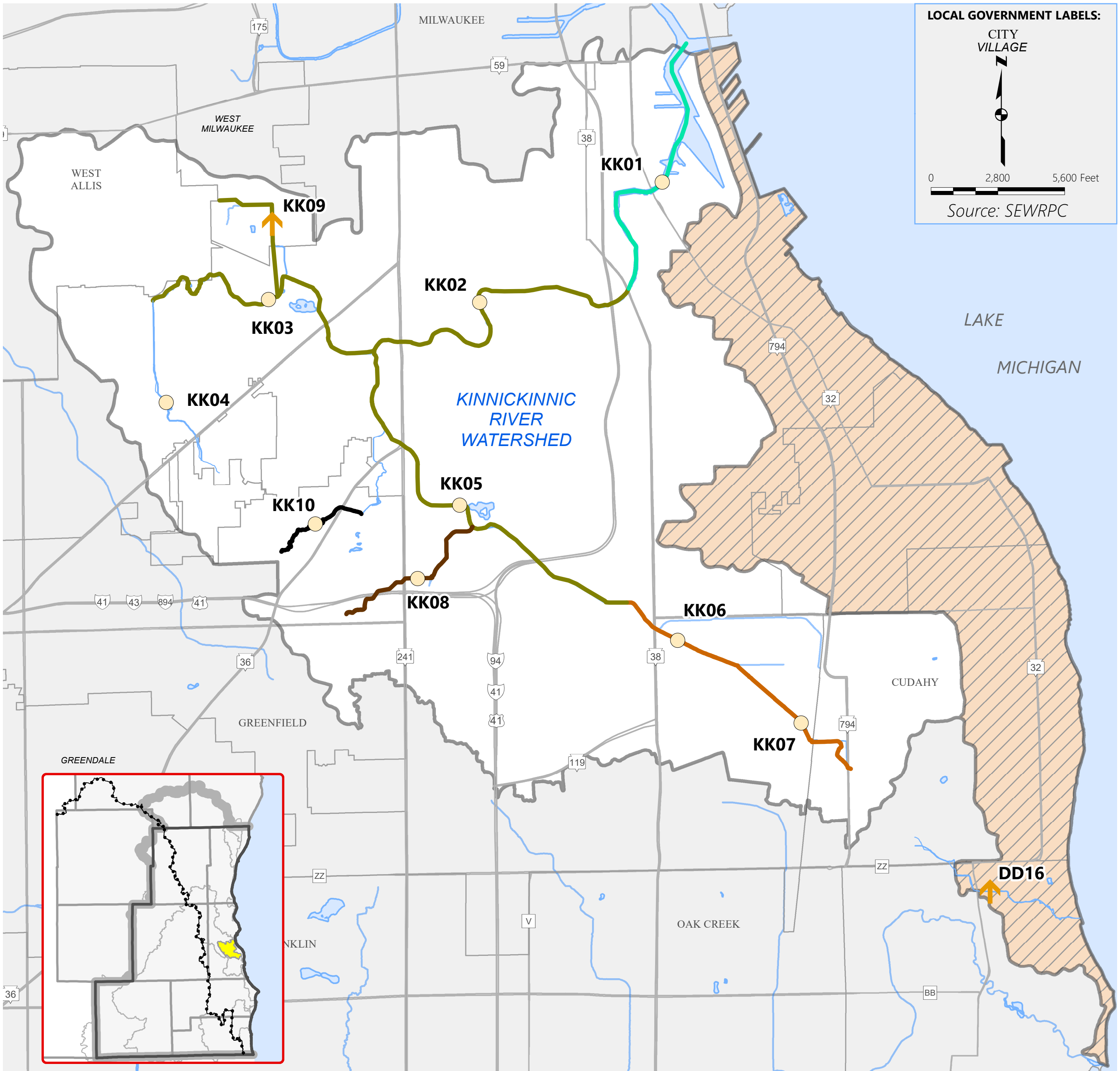
- 0 TO 5 PERCENT
- 5.1 TO 10 PERCENT
- 10.1 TO 15 PERCENT
- 15.1 TO 20 PERCENT
- 20.1 TO 30 PERCENT
- 30.1 TO 40 PERCENT
- 40.1 TO 50 PERCENT
- 50.1 TO 60 PERCENT
- 60.1 TO 70 PERCENT

RECENT MAXIMUM CHLORIDE

- 1 TO 35 mg/l (0 reaches)
- 36 TO 119 mg/l (0 reaches)
- 120 TO 230 mg/l (0 reaches)
- 231 TO 394 mg/l (reaches)
- 395 TO 756 mg/l (0 reaches)
- 757 TO 1,000 mg/l (1 reach)
- 1,001 TO 1,400 mg/l (0 reaches)
- 1,401 TO 2,500 mg/l (2 reaches)
- 2,501 TO 3,000 mg/l (1 reach)
- 3,000 TO 3,500 mg/l (1 reach)
- > 3,500 mg/l (reaches)

- ASSESSMENT REACHES WITH A BALANCED DATASET (5 reaches)
- ASSESSMENT REACHES WITH NO CHLORIDE DATA (1 reach + 1 DD reach)
- STUDY AREA BOUNDARY
- MAJOR WATERSHEDS
- DIRECT DRAINAGE AREA TO LAKE MICHIGAN ADJACENT TO KINNICKINNIC RIVER WATERSHED
- SUBCONTINENTAL DIVIDE
- MAJOR LAKES
- KK06 STREAM AND RIVER ASSESSMENT REACH ID

Map 4.56
Trends in Recent Chloride and Specific Conductance for Assessment Reaches Within the Kinnickinnic River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan: 2013-2022



INCREASING TREND IN CHLORIDE CONCENTRATIONS (Statistically Significant - 0 Reaches)

INCREASING TREND IN SPECIFIC CONDUCTANCE LEVELS (Statistically Significant - 1 Reach + 1 DD Reach)

DECREASING TREND IN CHLORIDE CONCENTRATIONS (Statistically Significant - 0 Reaches)

DECREASING TREND IN SPECIFIC CONDUCTANCE LEVELS (Statistically Significant - 0 Reaches)

NO STATISTICALLY SIGNIFICANT TREND FOR EITHER CHLORIDE OR CONDUCTANCE OR INSUFFICIENT DATA FOR TREND

RECENT MEDIAN CHLORIDE (2013 - 2022)

1 TO 35 mg/l (0 reaches)

36 TO 119 mg/l (1 reach)

120 TO 230 mg/l (0 reaches)

231 TO 394 mg/ (4 reaches)

395 to 756 mg/l (2 reaches)

757 TO 1,000 mg/l (0 reaches)

1,001 TO 1,400 mg/l (1 reach)

GREATER THAN 1,400 mg/l (1 reach)

DIRECT DRAINAGE AREA TO LAKE MICHIGAN ADJACENT TO KINNICKINNIC RIVER WATERSHED

SUBCONTINENTAL DIVIDE

STREAMS WITH NO CHLORIDE DATA

MAJOR LAKES

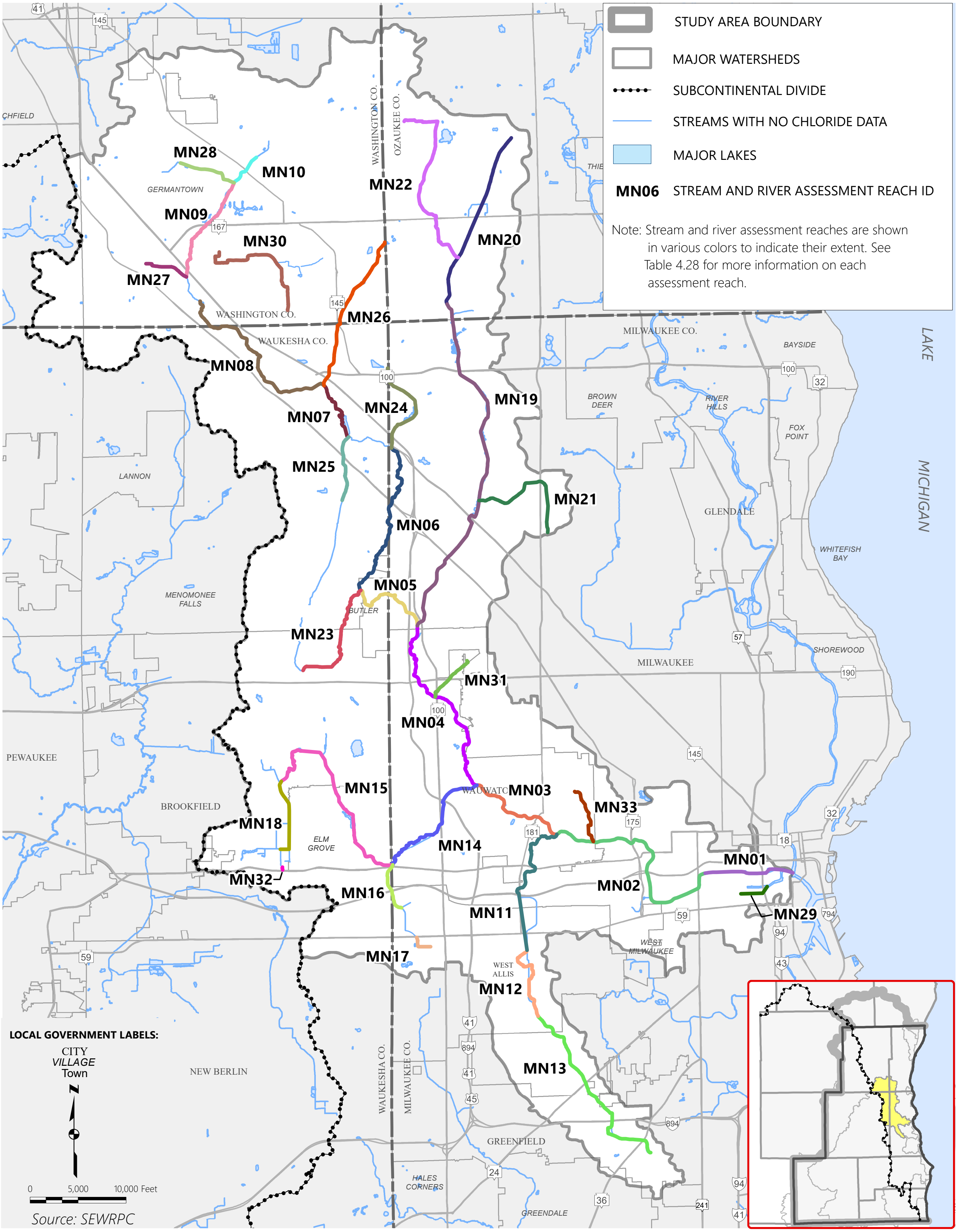
KK06 STREAM AND RIVER ASSESSMENT REACH ID

STUDY AREA BOUNDARY

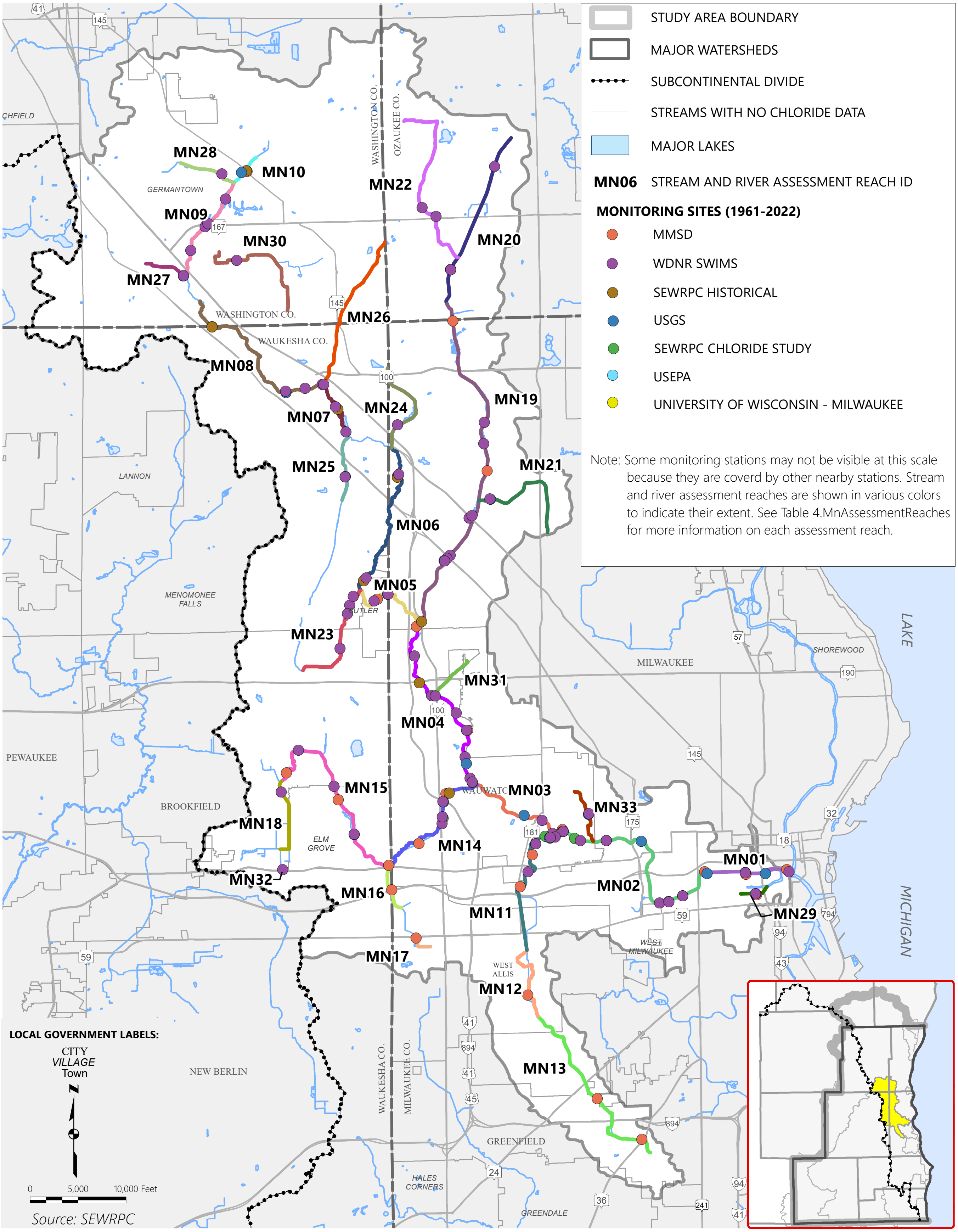
MAJOR WATERSHEDS

Note: Only assessment reaches with balanced datasets were assessed for statistically significant trends.

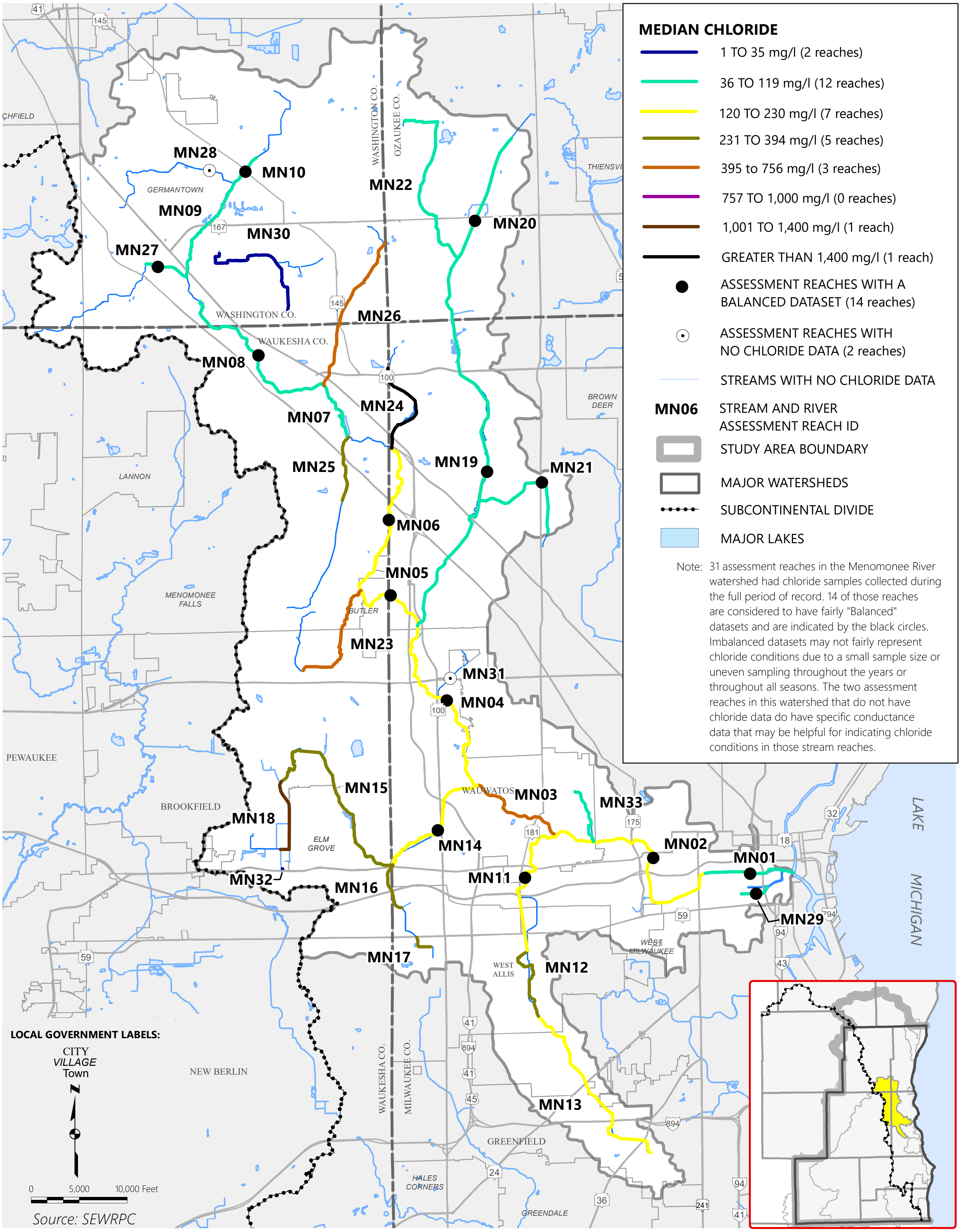
Map 4.57
Assessment Reaches for Streams Within the Menomonee River Watershed



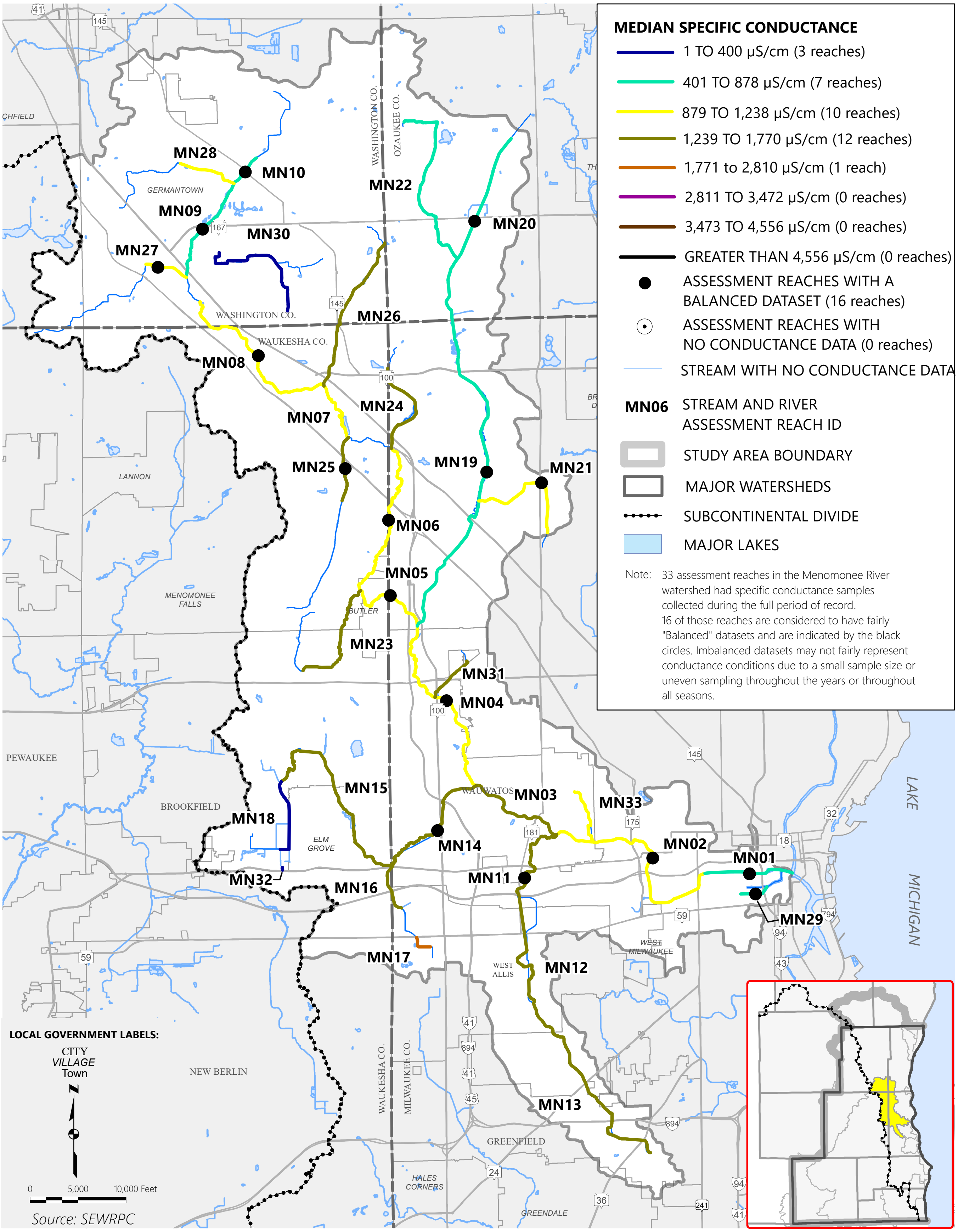
Map 4.58
Monitoring Sites and Assessment Reaches for Streams Within the Menomonee River Watershed



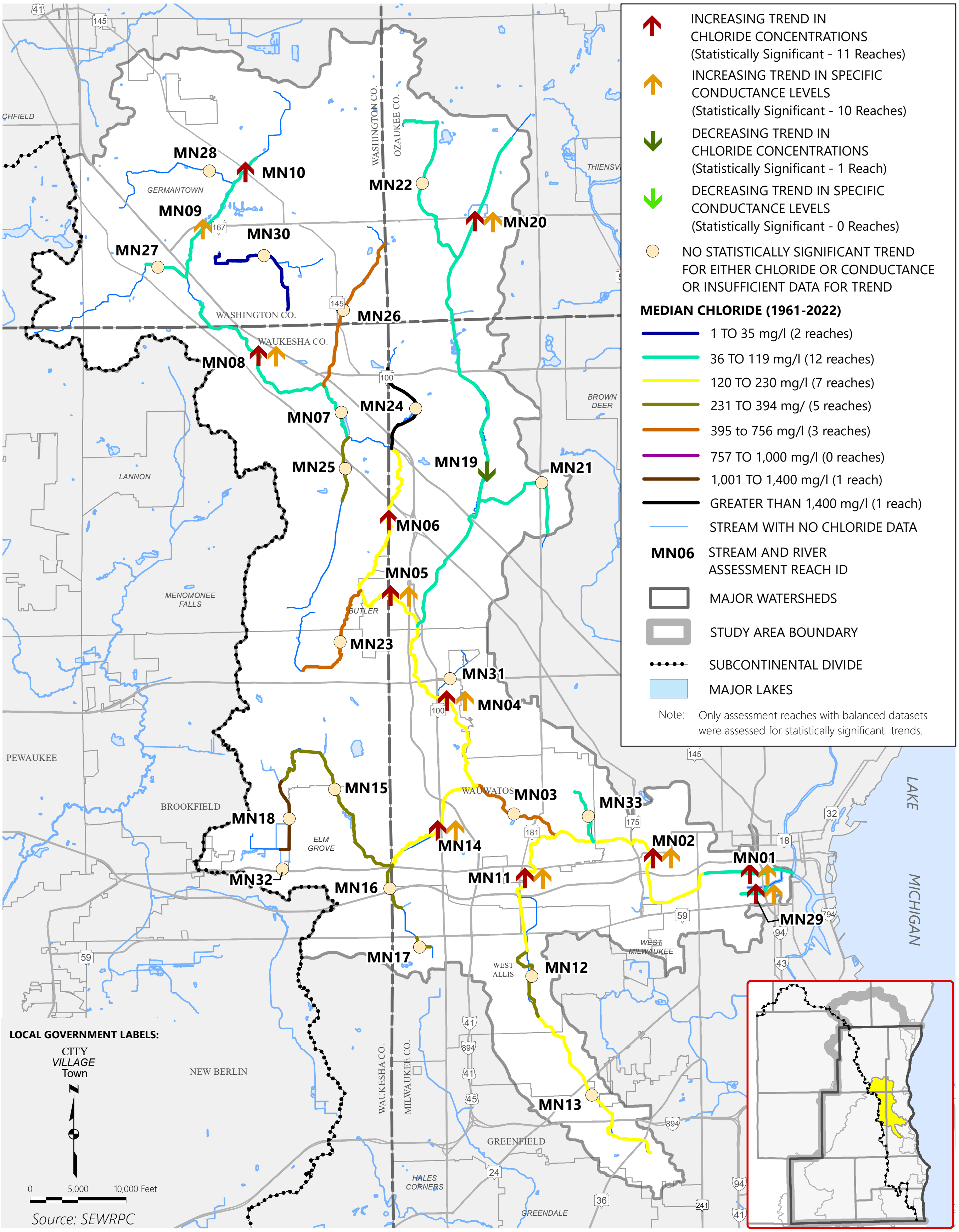
Map 4.59
Median Chloride Concentrations Within the Menomonee River Watershed for the Full Period of Record: 1961-2022



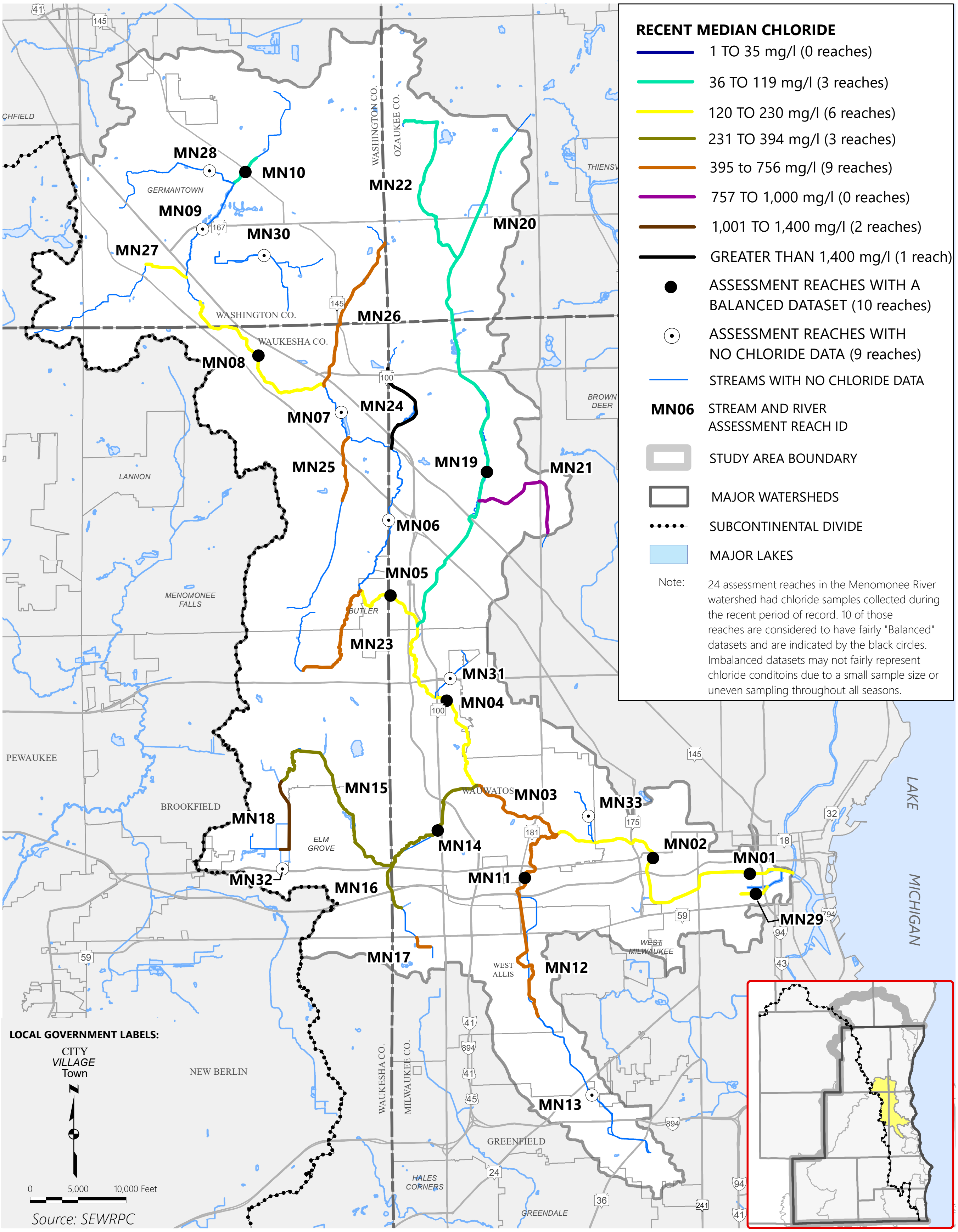
Map 4.60
Median Specific Conductance Within the Menomonee River Watershed for the Full Period of Record: 1961-2022



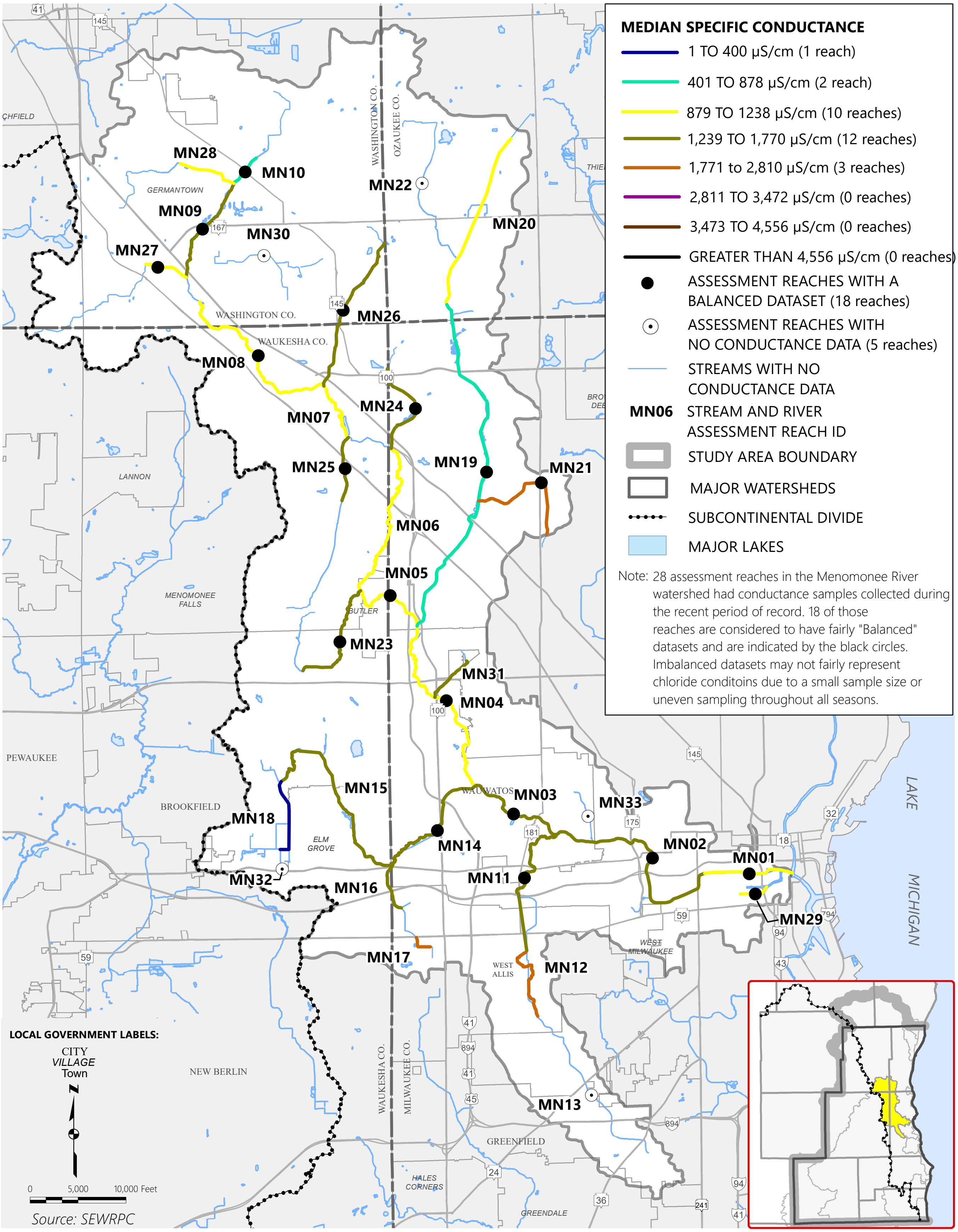
Map 4.61
Trends in Chloride and Specific Conductance Among Assessment Reaches Within the Menomonee River Watershed over the Full Period of Record: 1961-2022



Map 4.62
Recent Median Chloride Concentrations Within the Menomonee River Watershed: 2013-2022

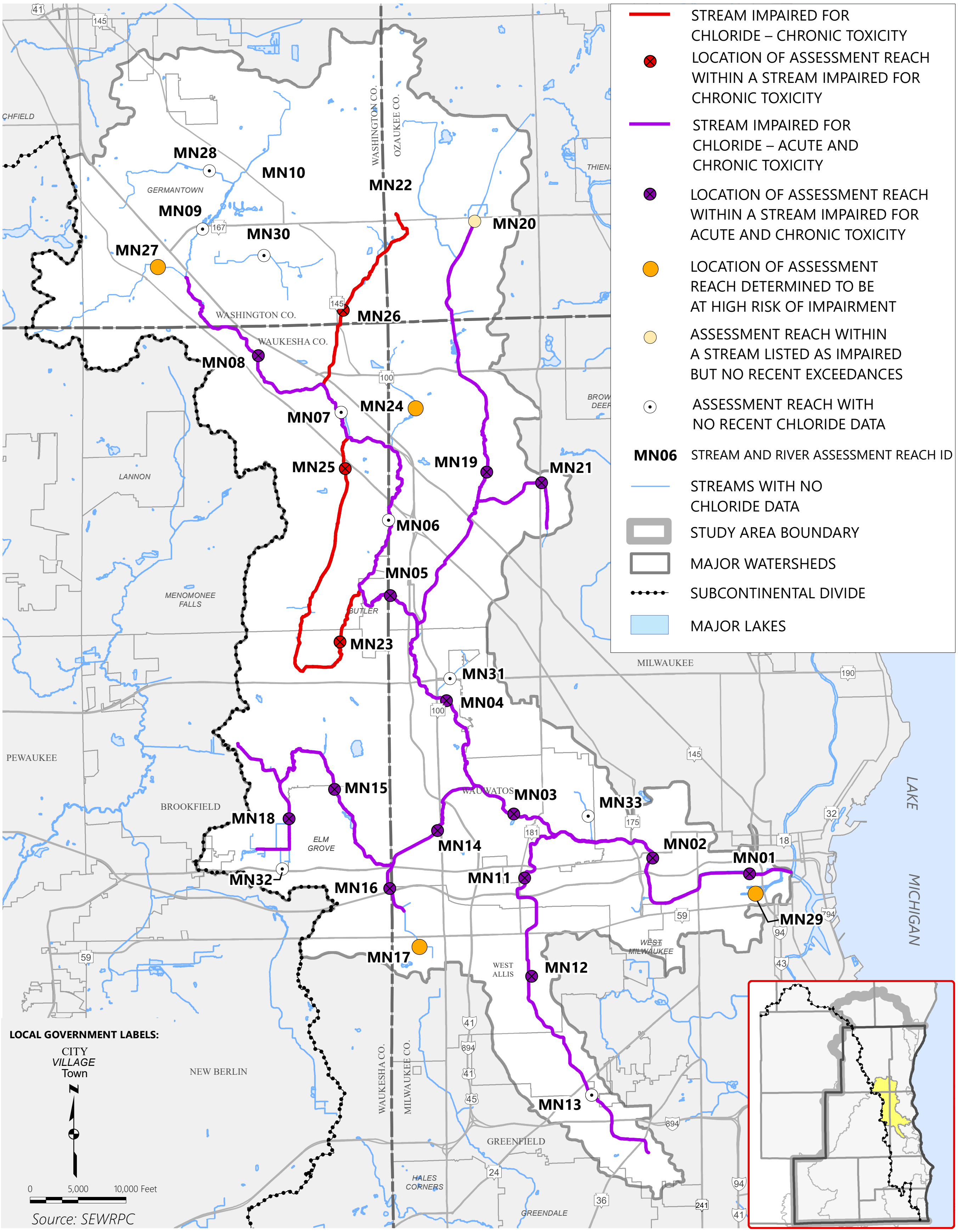


Map 4.63
Recent Median Specific Conductance Within the Menomonee River Watershed: 2013-2022

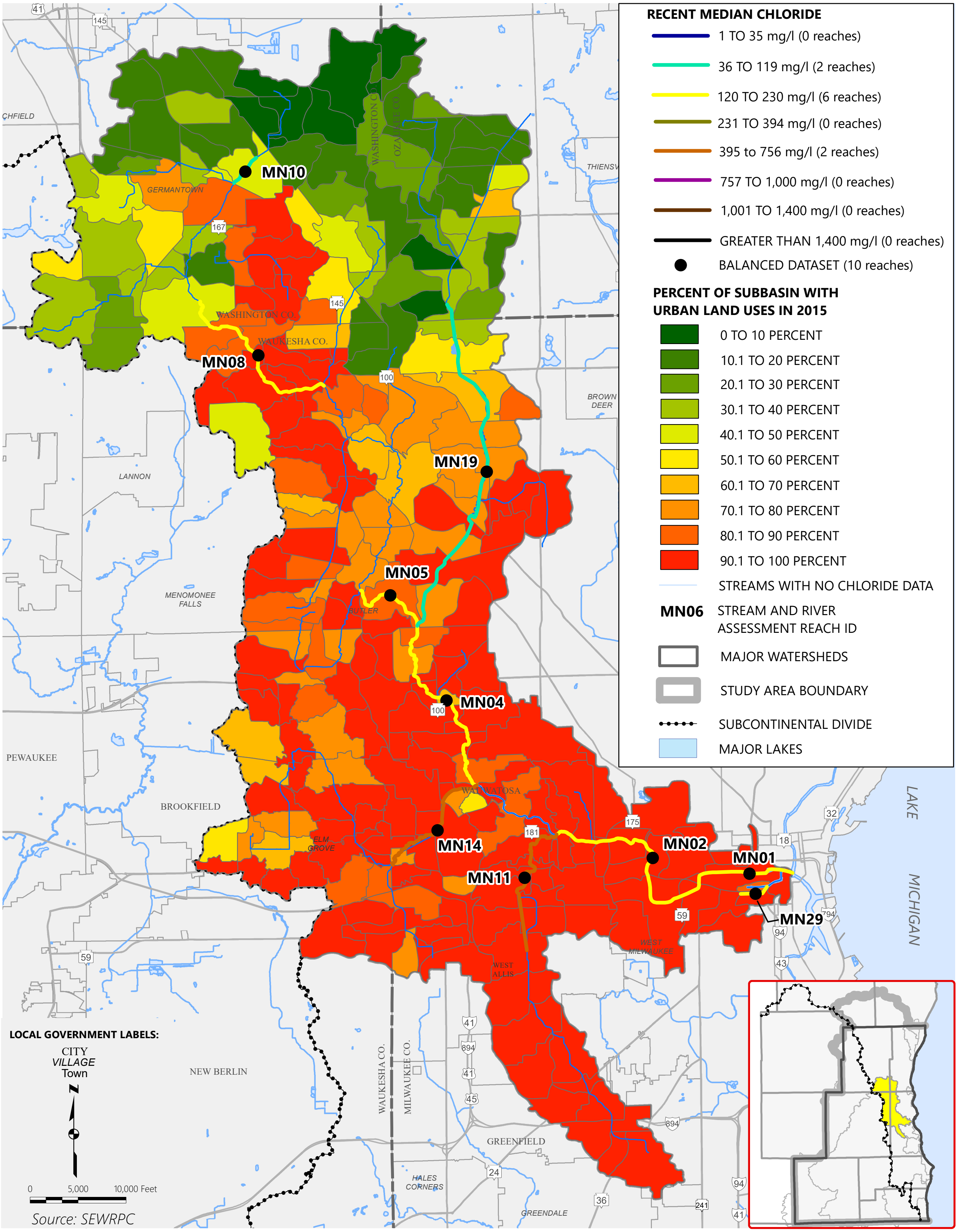


Source: SEWRPC

Map 4.64
Streams Impaired for Chloride Within the Menomonee River Watershed: 2024

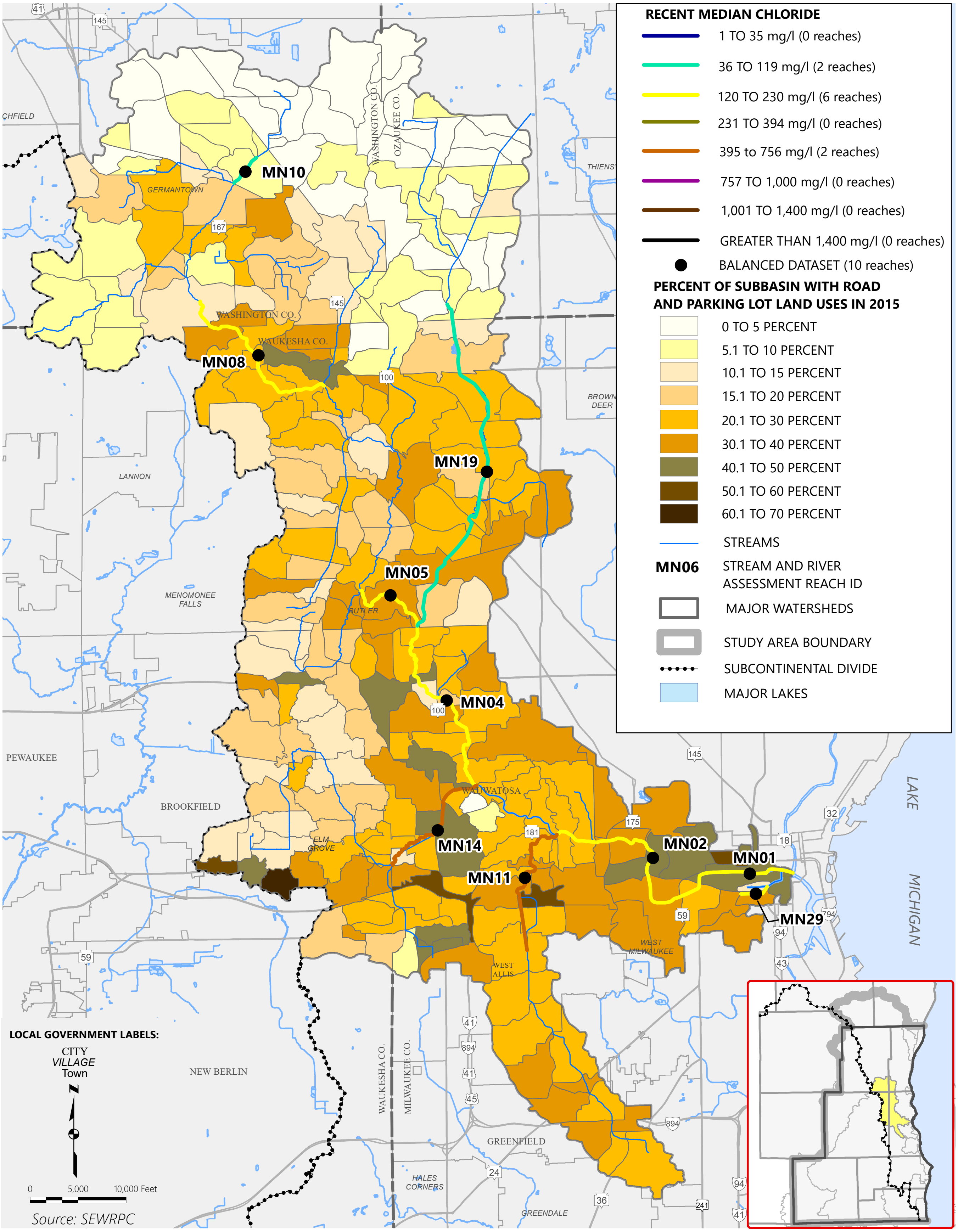


Map 4.65
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Menomonee River Watershed and Percent Urban Land Use by Subbasin

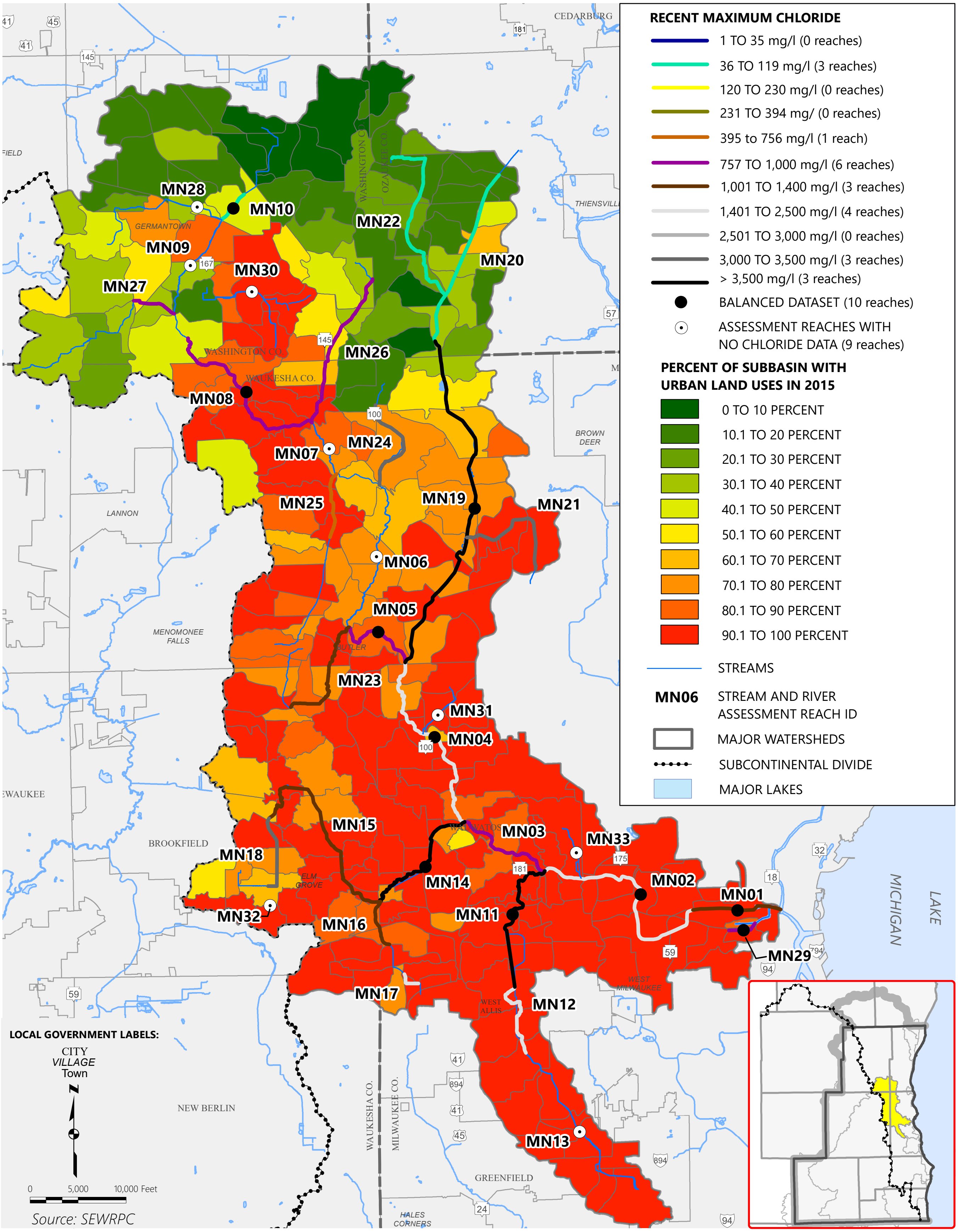


Source: SEWRPC

Map 4.66
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Menomonee River Watershed and Road and Parking Lot Density in Subbasins

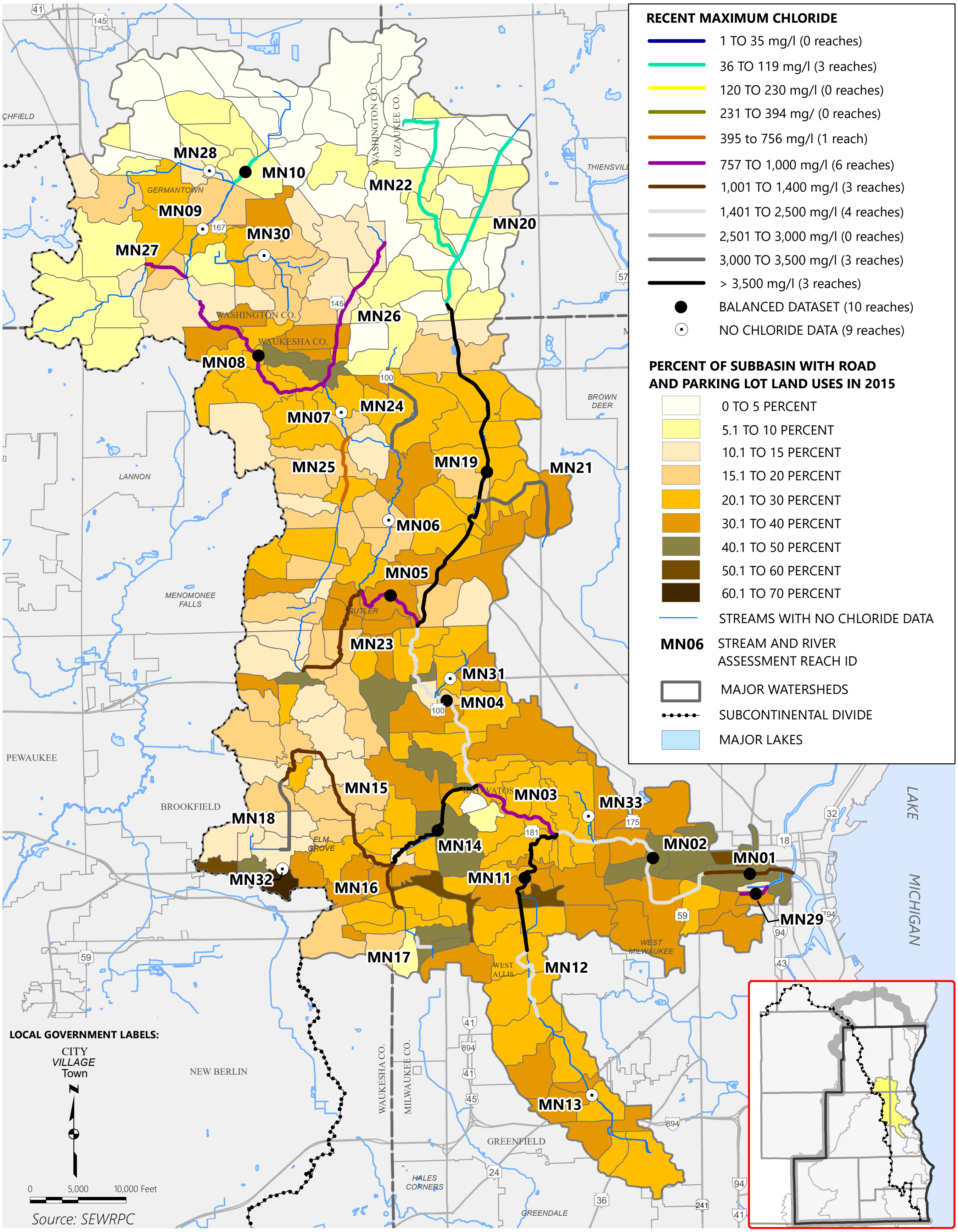


Map 4.67
Recent Maximum Chloride Concentrations in Stream Assessment Reaches Within the Menomonee River Watershed and Percent Urban Land Use by Subbasin



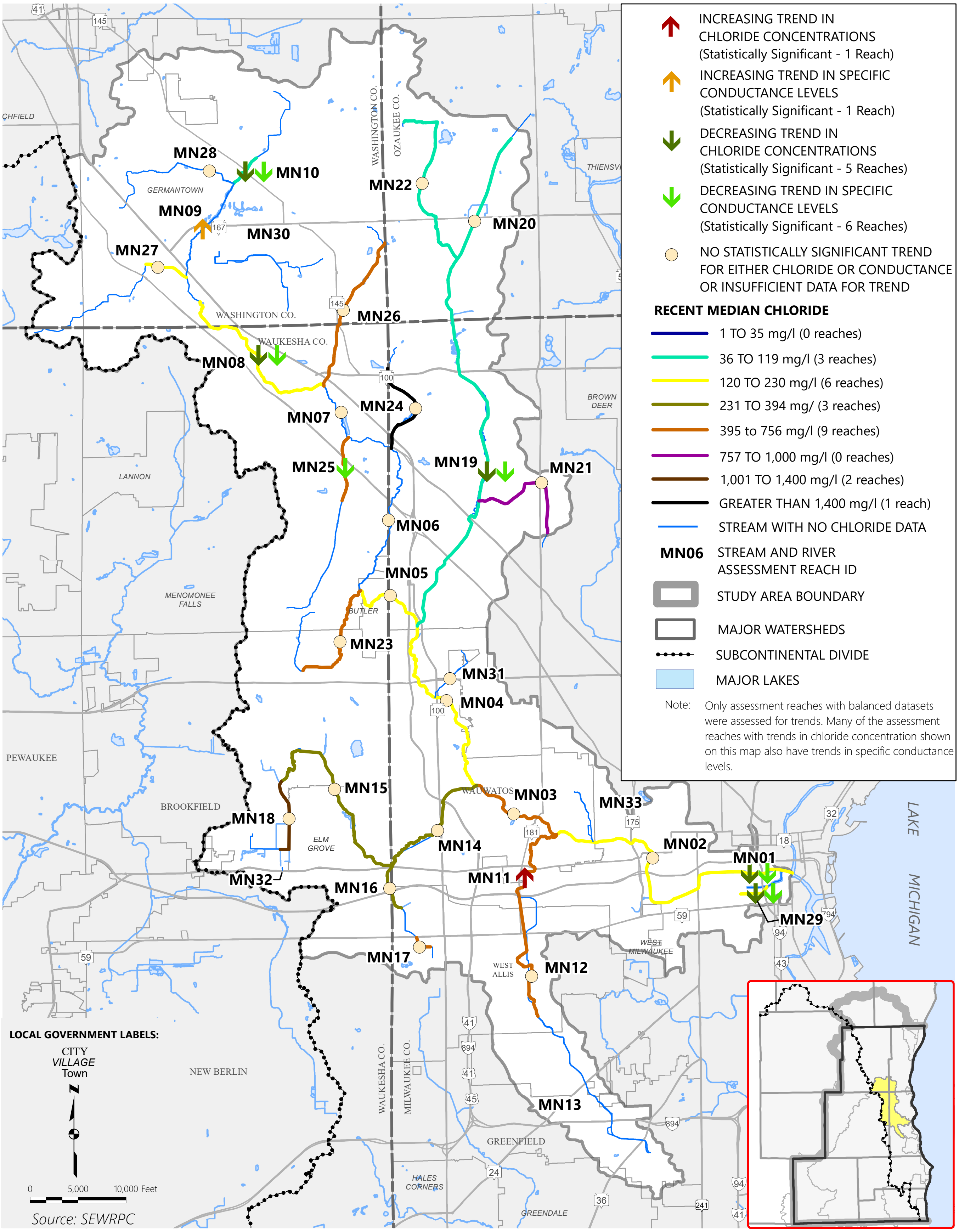
Source: SEWRPC

Map 4.68
Recent Maximum Chloride Concentrations in Stream Assessment Reaches Within the Menomonee River Watershed and Road and Parking Lot Density in Subbasins

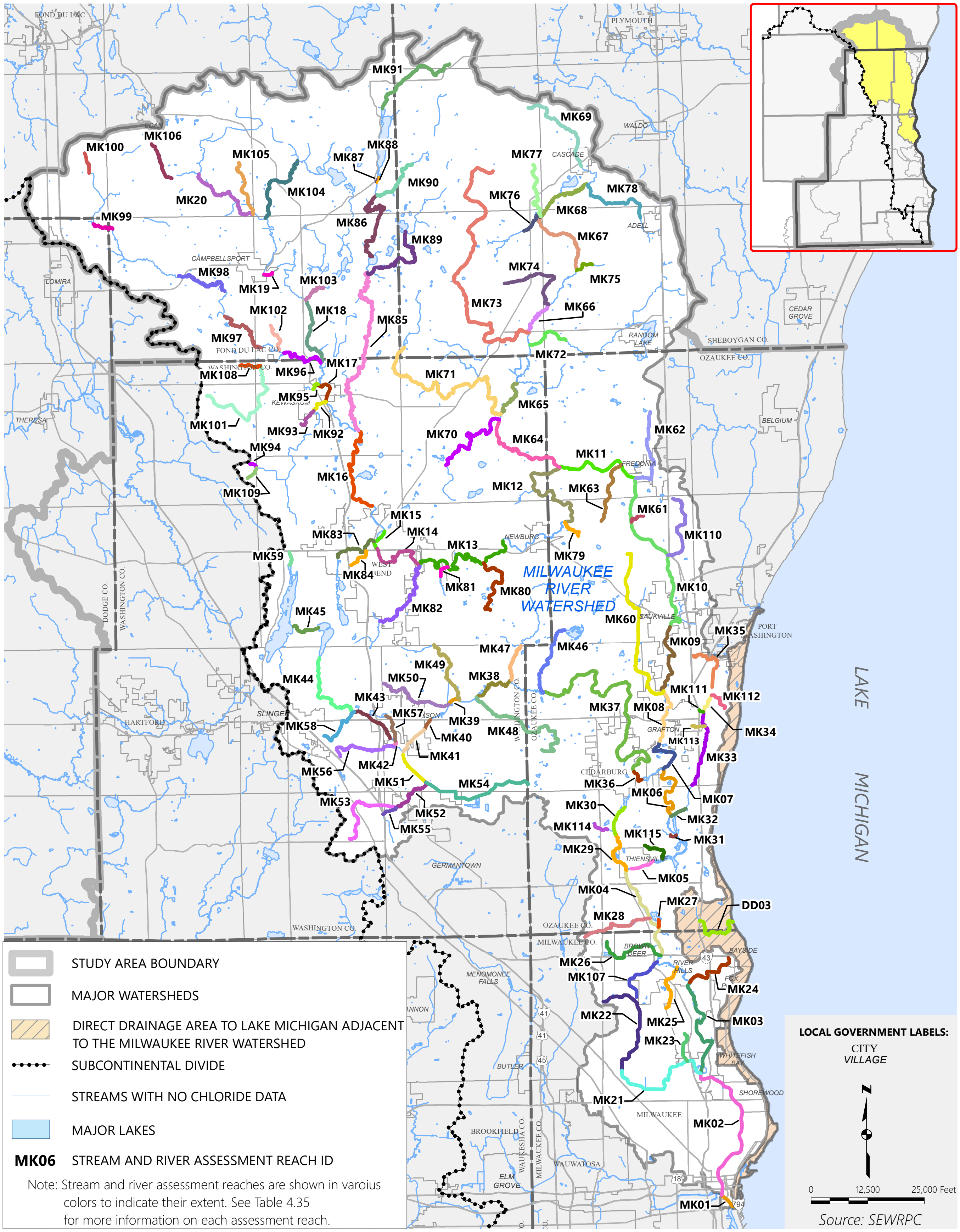


Source: SEWRPC

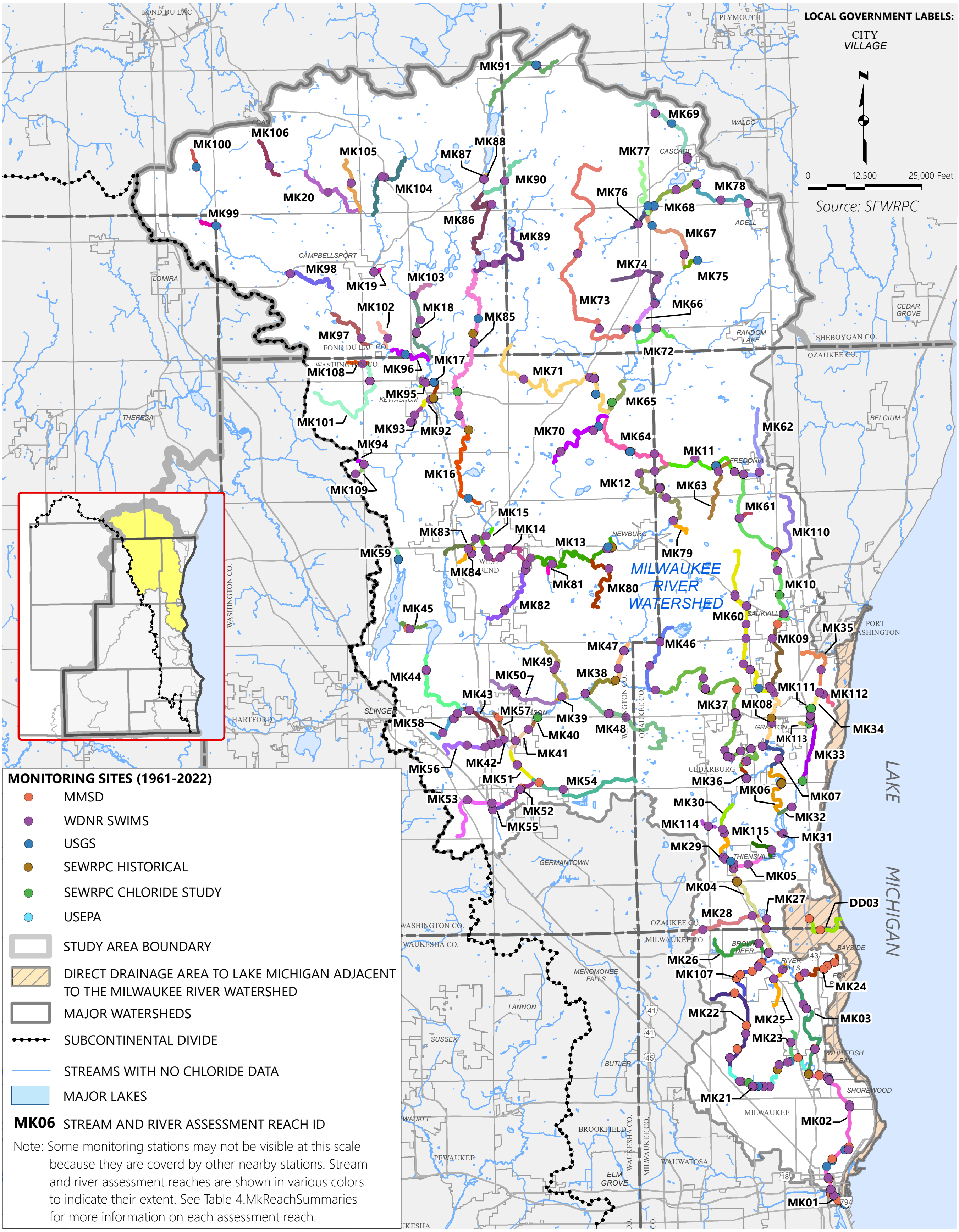
Map 4.69
Trends in Chloride and Specific Conductance Among Balanced Assessment Reaches Within the Menomonee River Watershed over the Recent Period of Record: 2013-2022



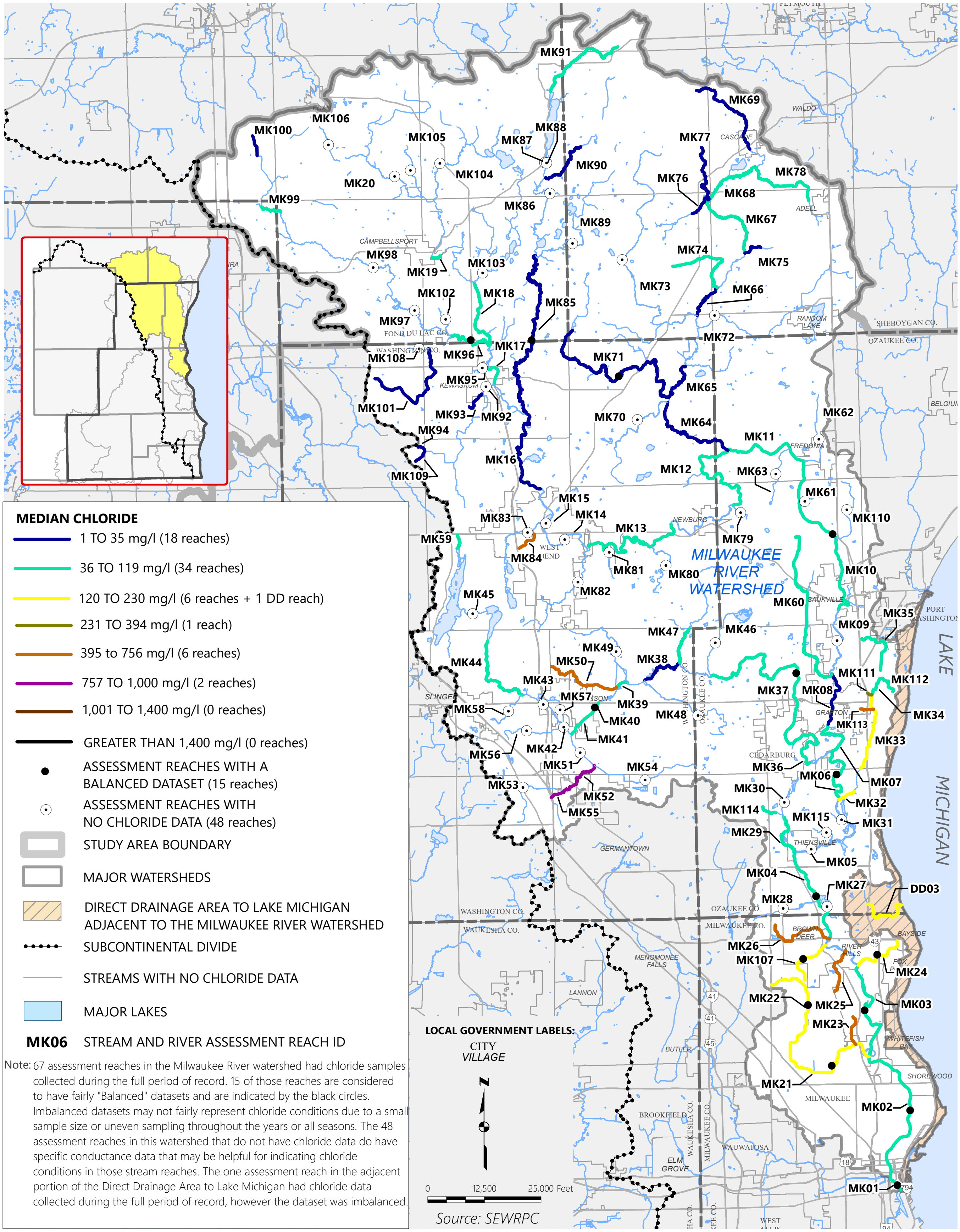
Map 4.70
Assessment Reaches for Streams Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan



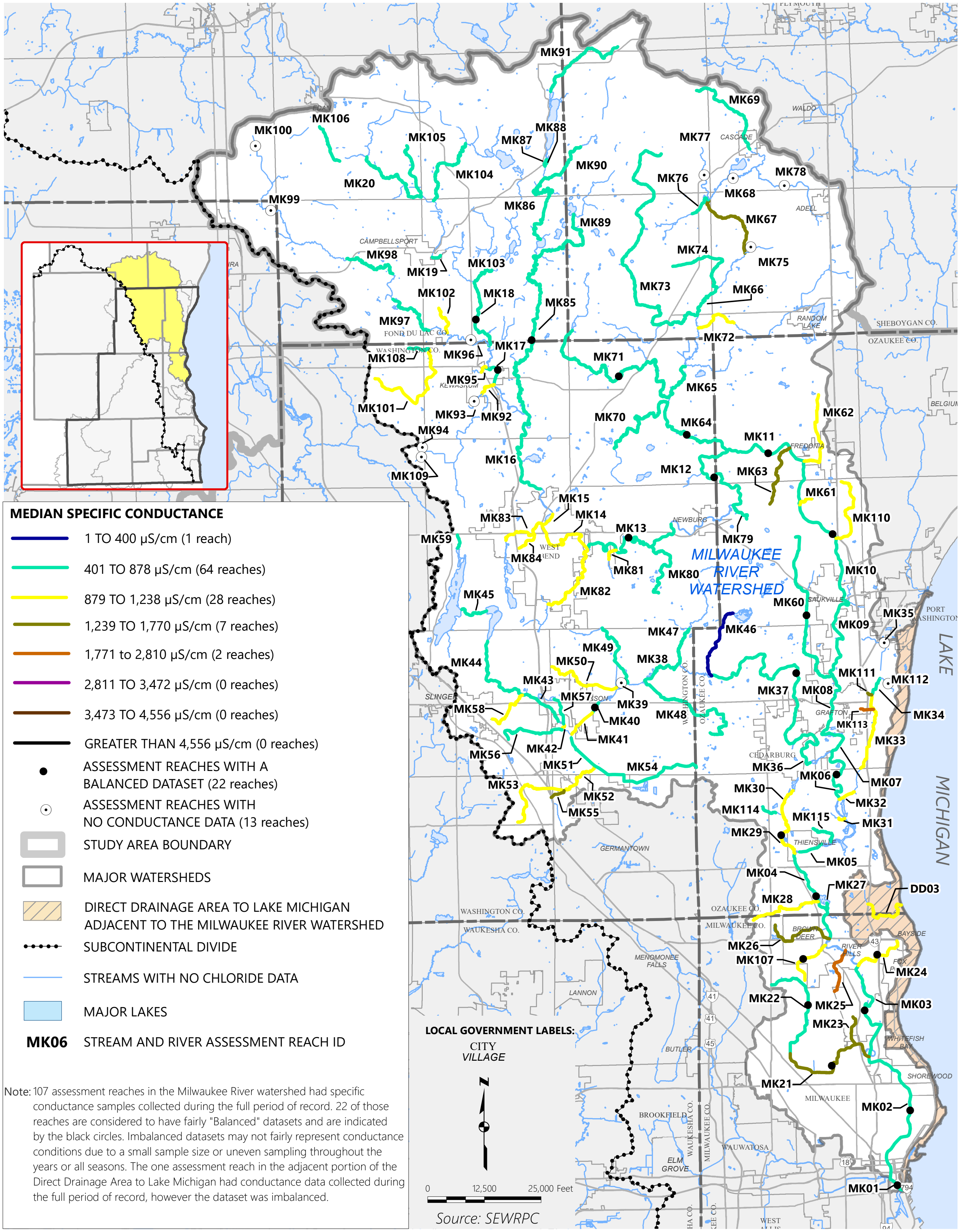
Map 4.71
Monitoring Sites and Assessment Reaches for Streams Within the Milwaukee River and Adjacent Direct Drainage Area to Lake Michigan Watersheds



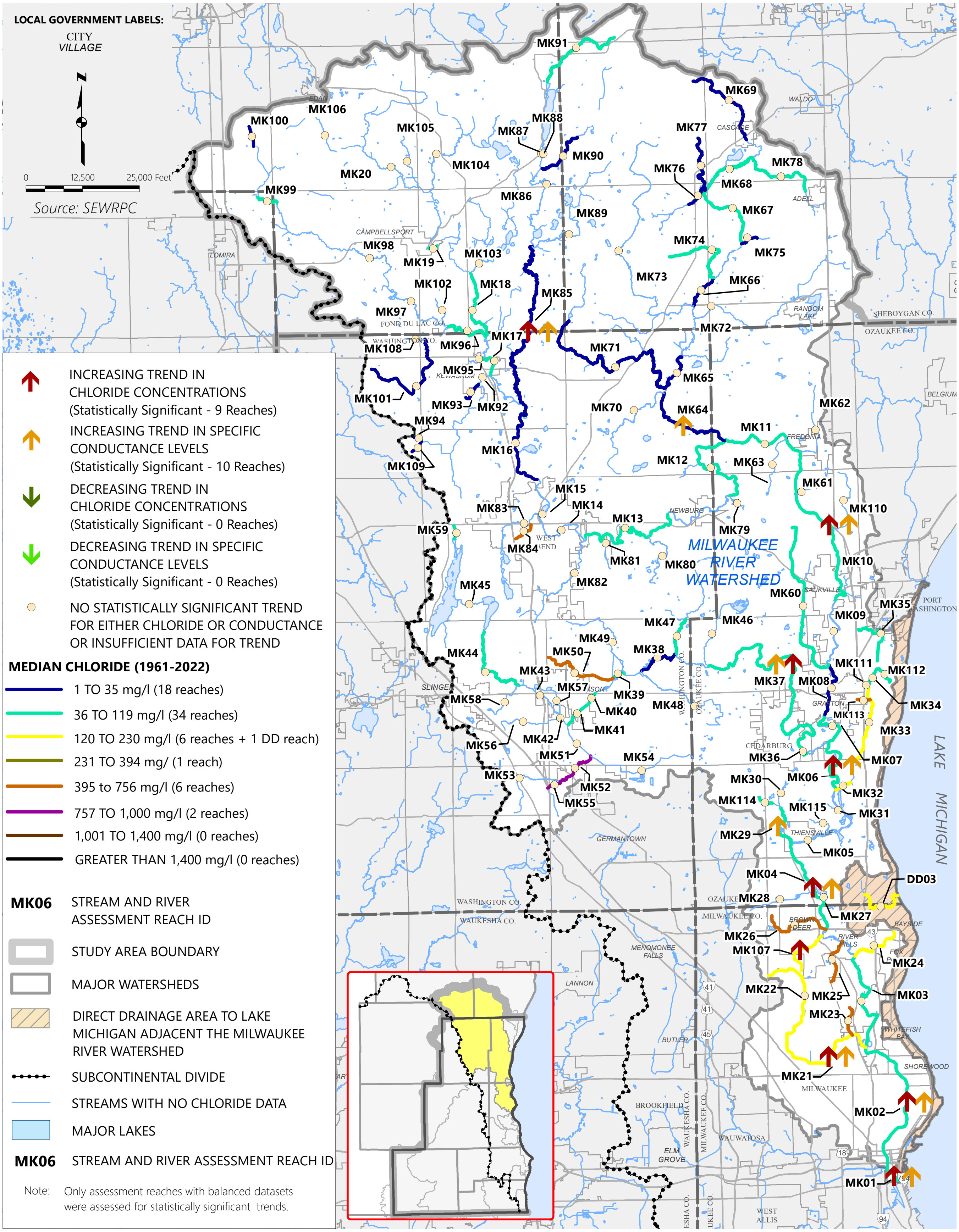
Map 4.72
Median Chloride Concentrations Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan for the Full Period of Record: 1961-2022



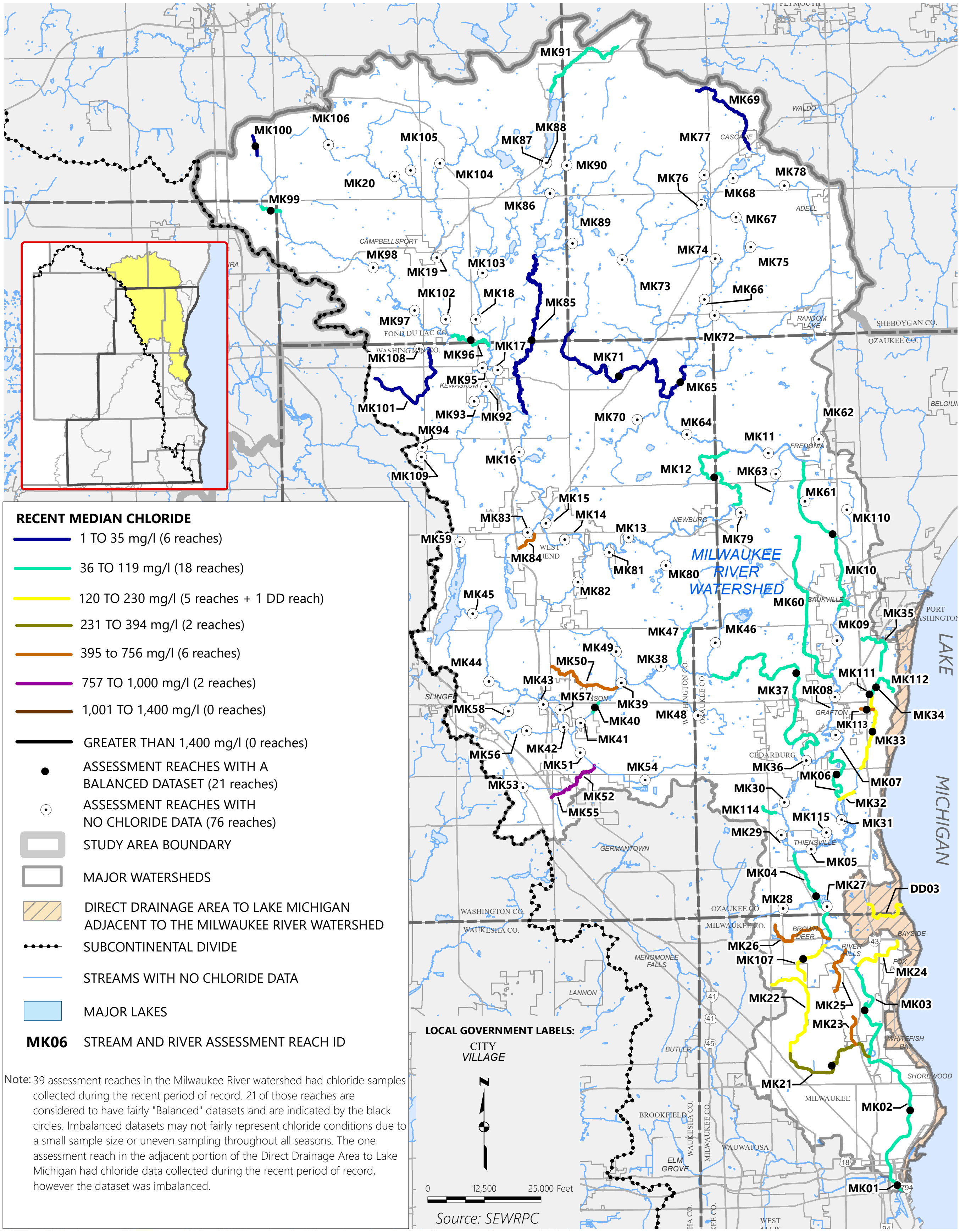
Map 4.73
Median Specific Conductance Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan for the Full Period of Record: 1961-2022



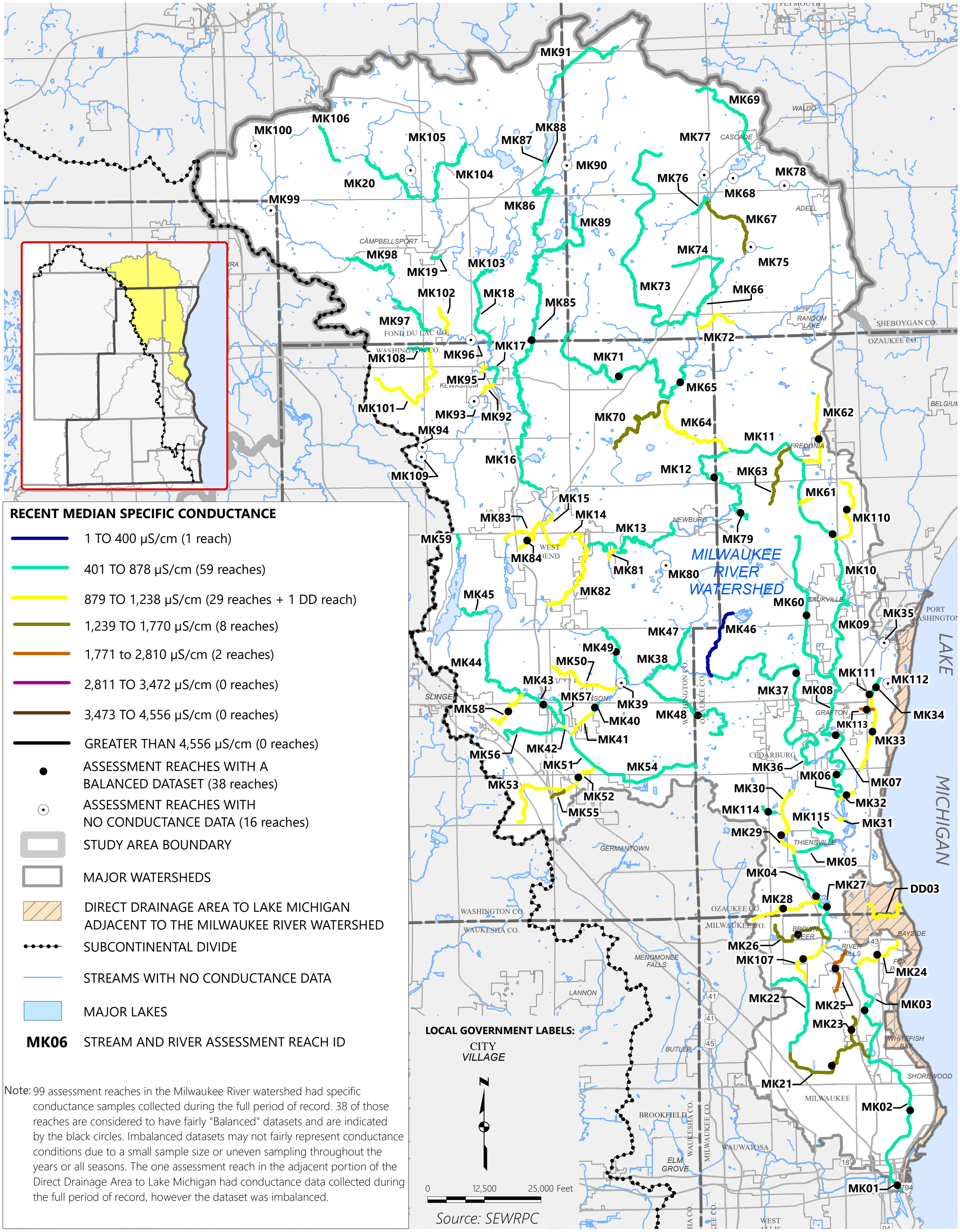
Map 4.74
Trends in Chloride and Specific Conductance Among Assessment Reaches Within the Milwaukee River Watershed and Adjacent Direct Drainage to Lake Michigan over the Full Period of Record: 1961-2022



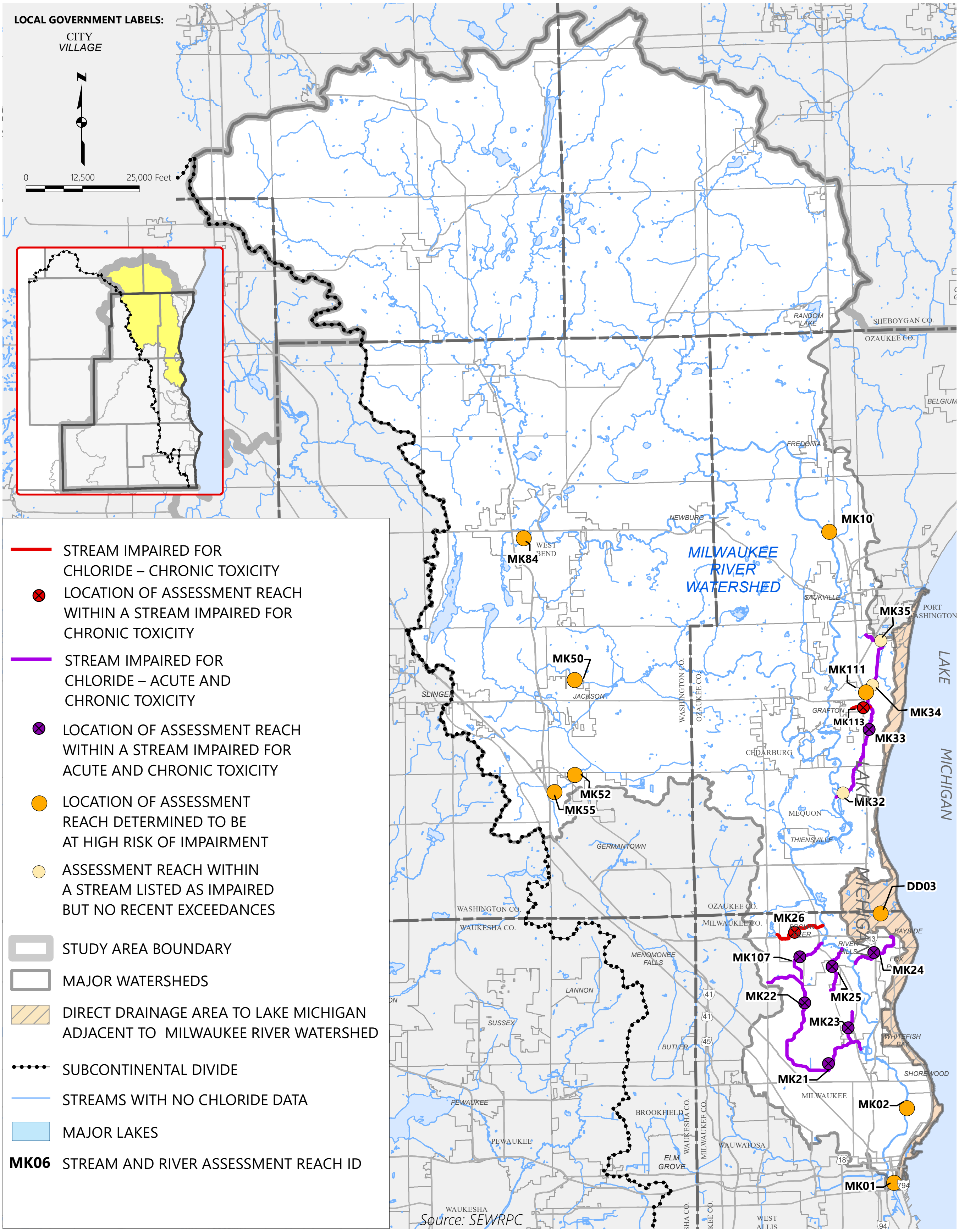
Map 4.75
Recent Median Chloride Concentrations Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan: 2013-2022



Map 4.76
Recent Median Specific Conductance Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan: 1961-2022

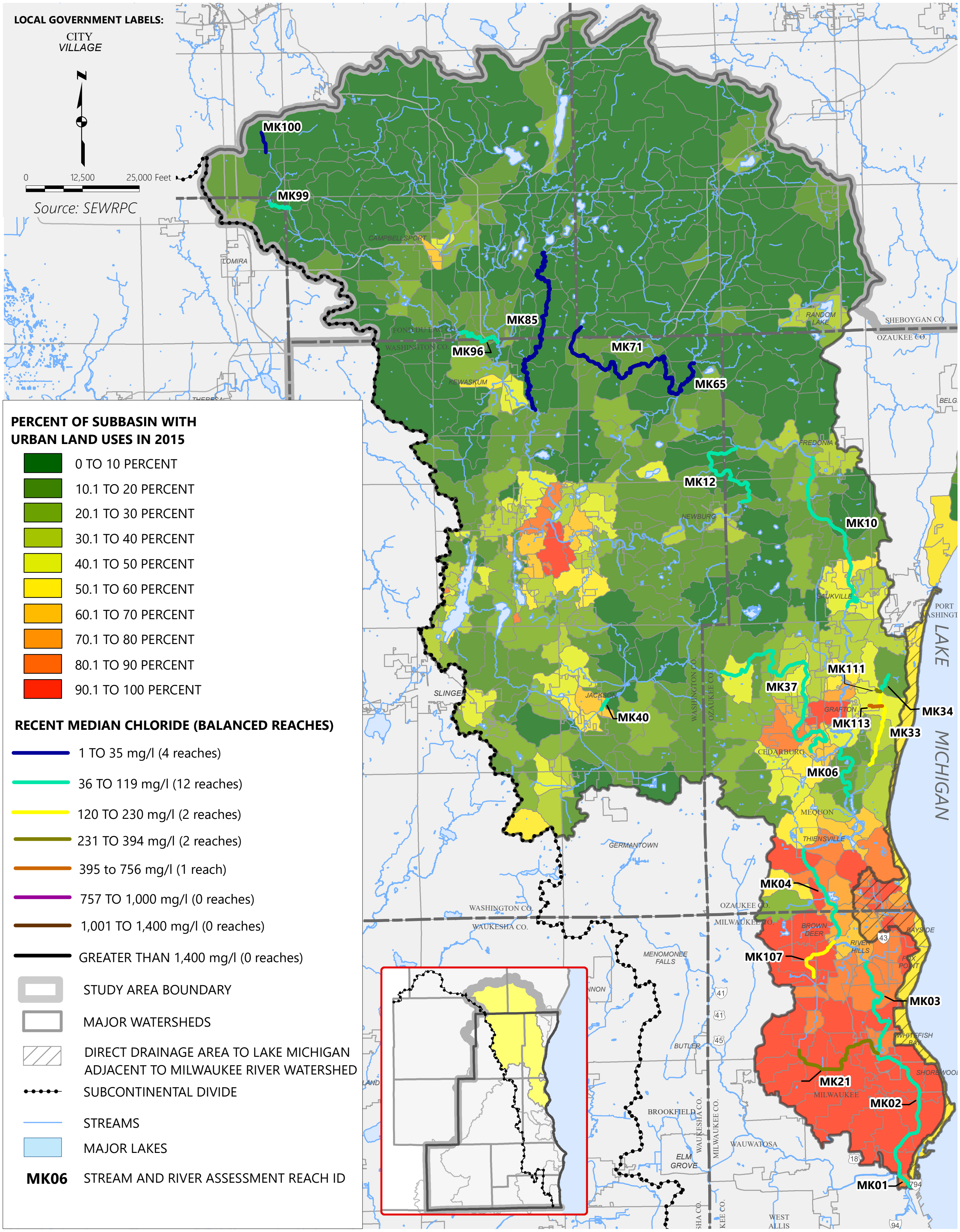


Map 4.77
Streams Impaired for Chloride Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan: 2024

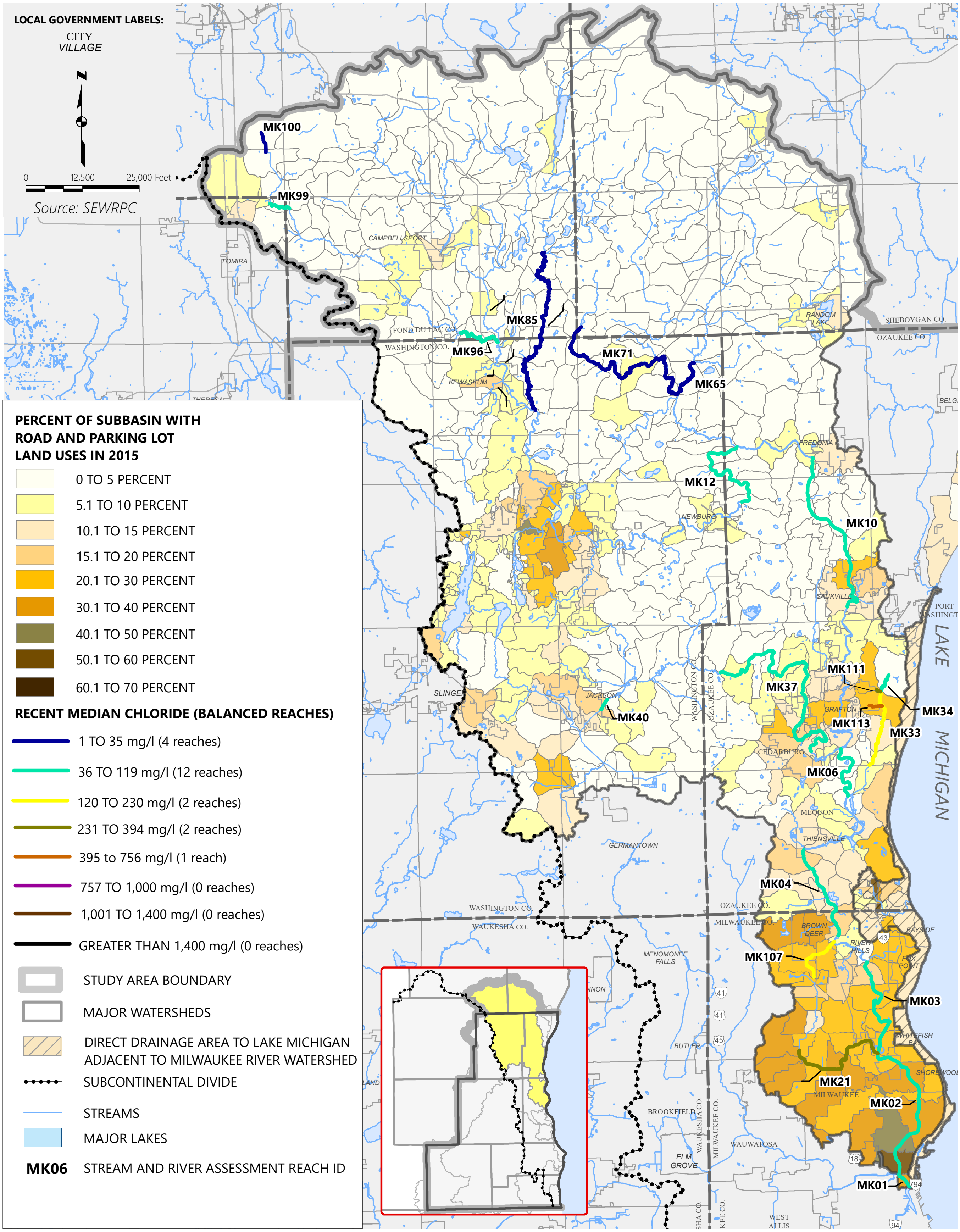


Map 4.78

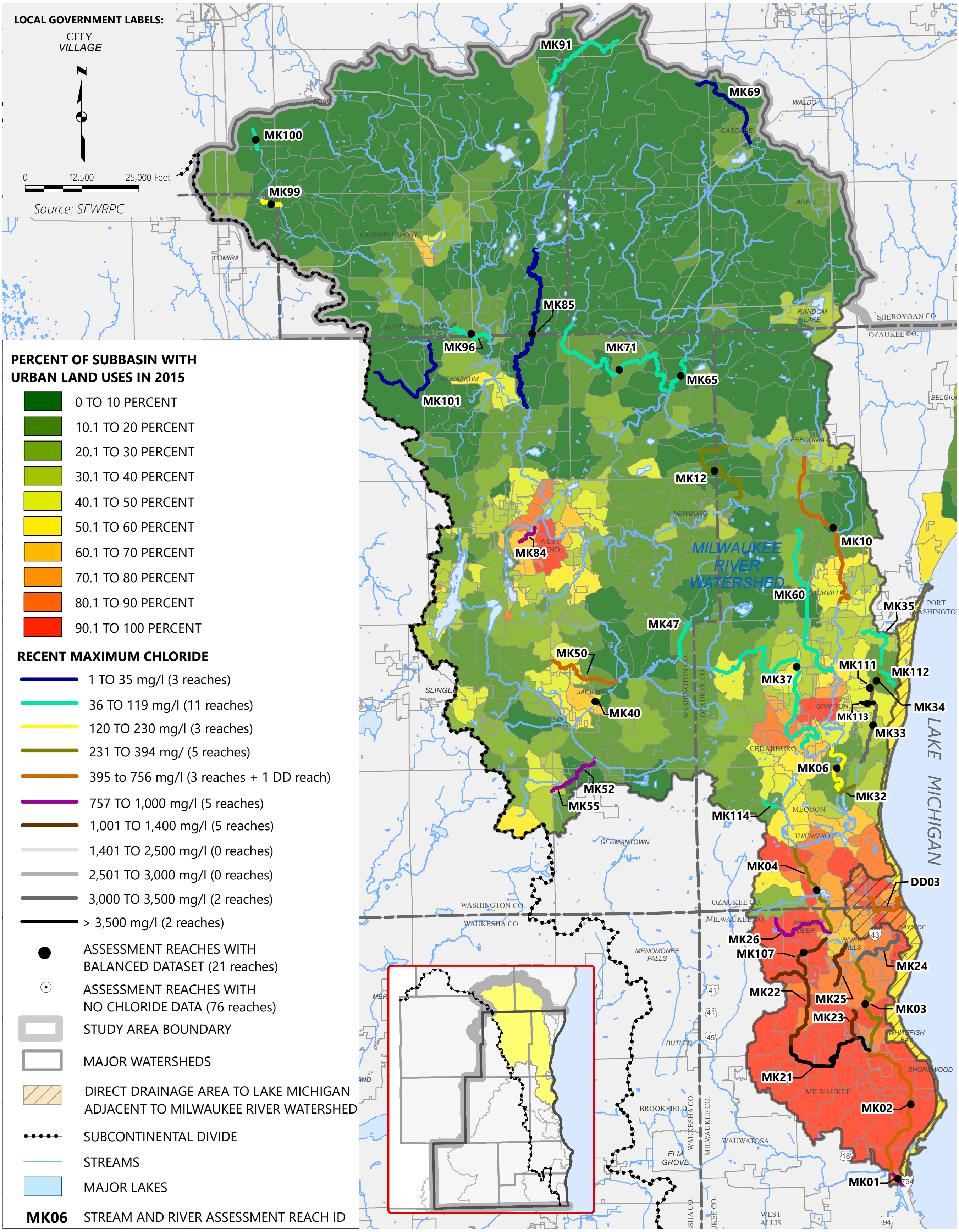
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan and Percent Urban Land Use in Subbasins



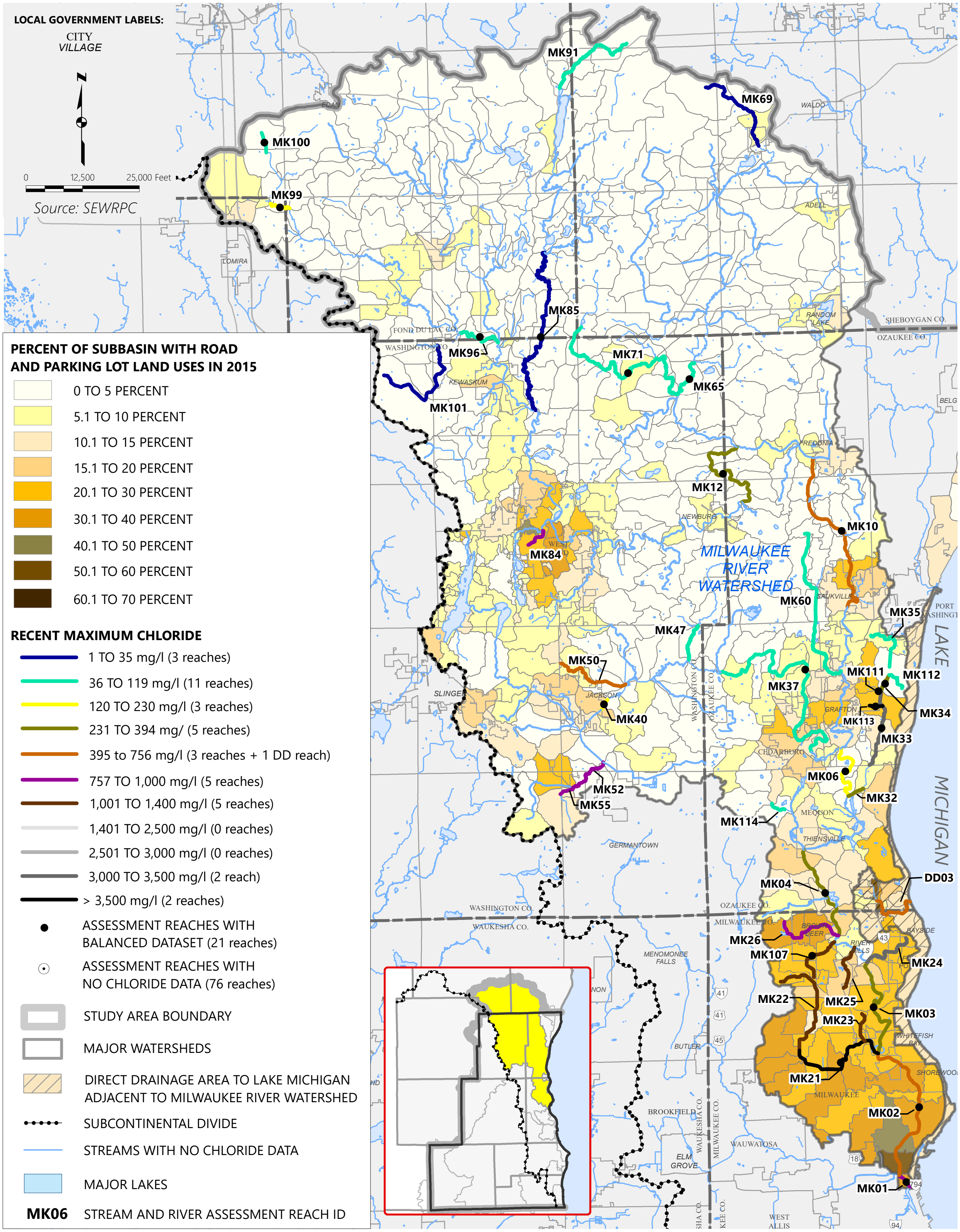
Map 4.79
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan and Road and Parking Lot Density in Subbasins



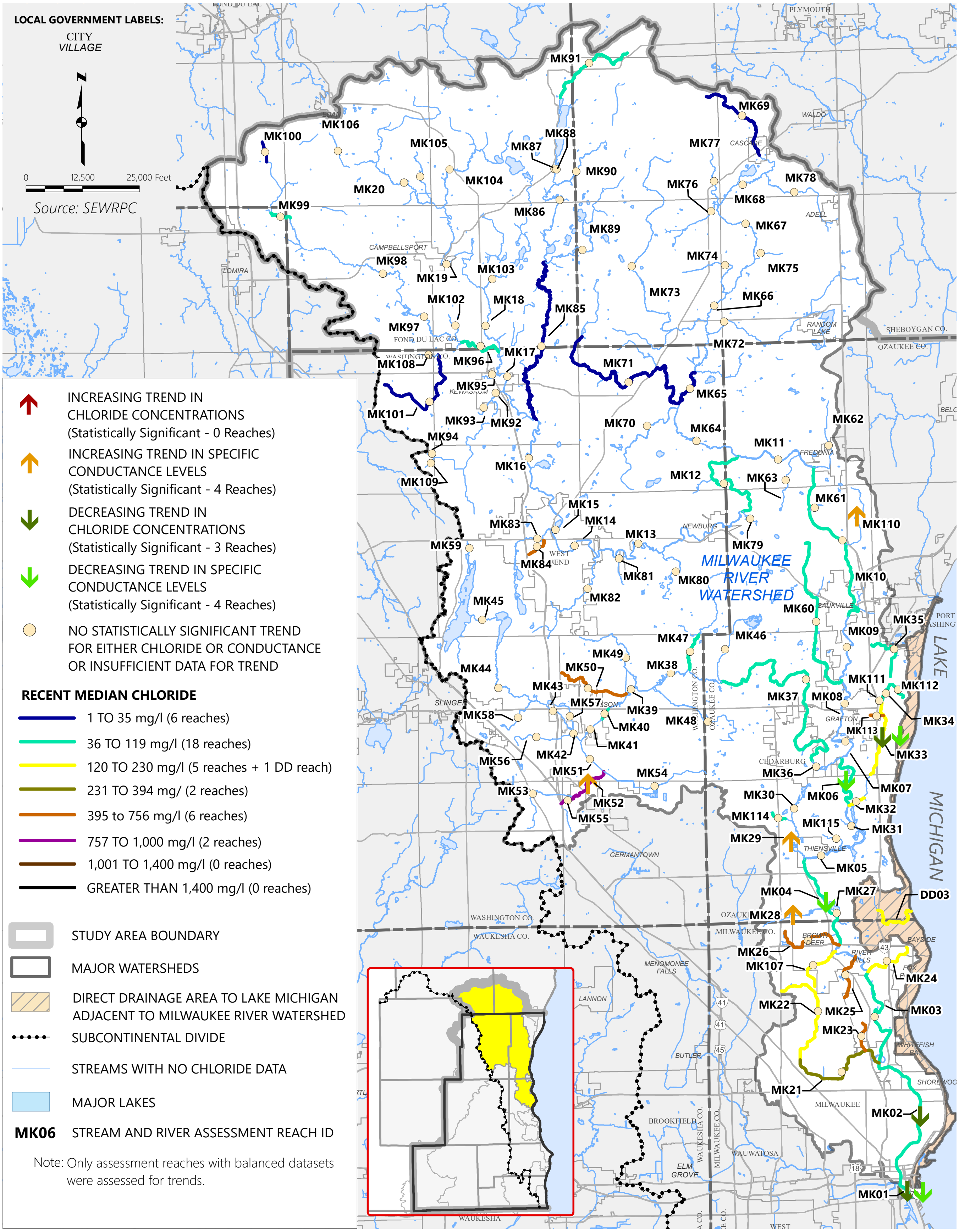
Map 4.80
Recent Maximum Chloride Concentrations in Stream Assessment Reaches Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan and Percent Urban Land Use by Subbasin



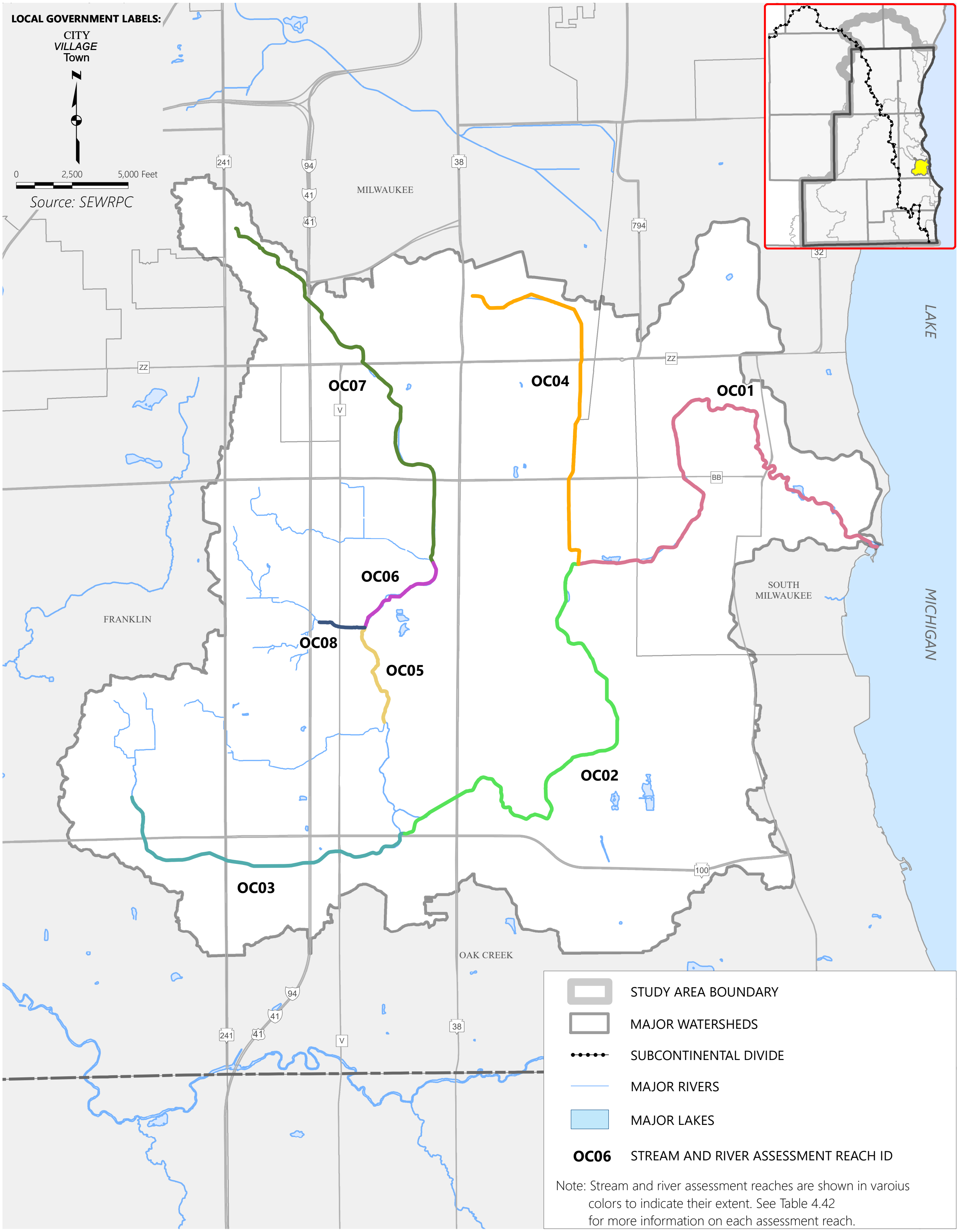
Map 4.81
Recent Maximum Chloride Concentrations in Stream Assessment Reaches Within the Milwaukee River Watershed and Adjacent Direct Drainage Area to Lake Michigan and Road and Parking Lot Density in Subbasins



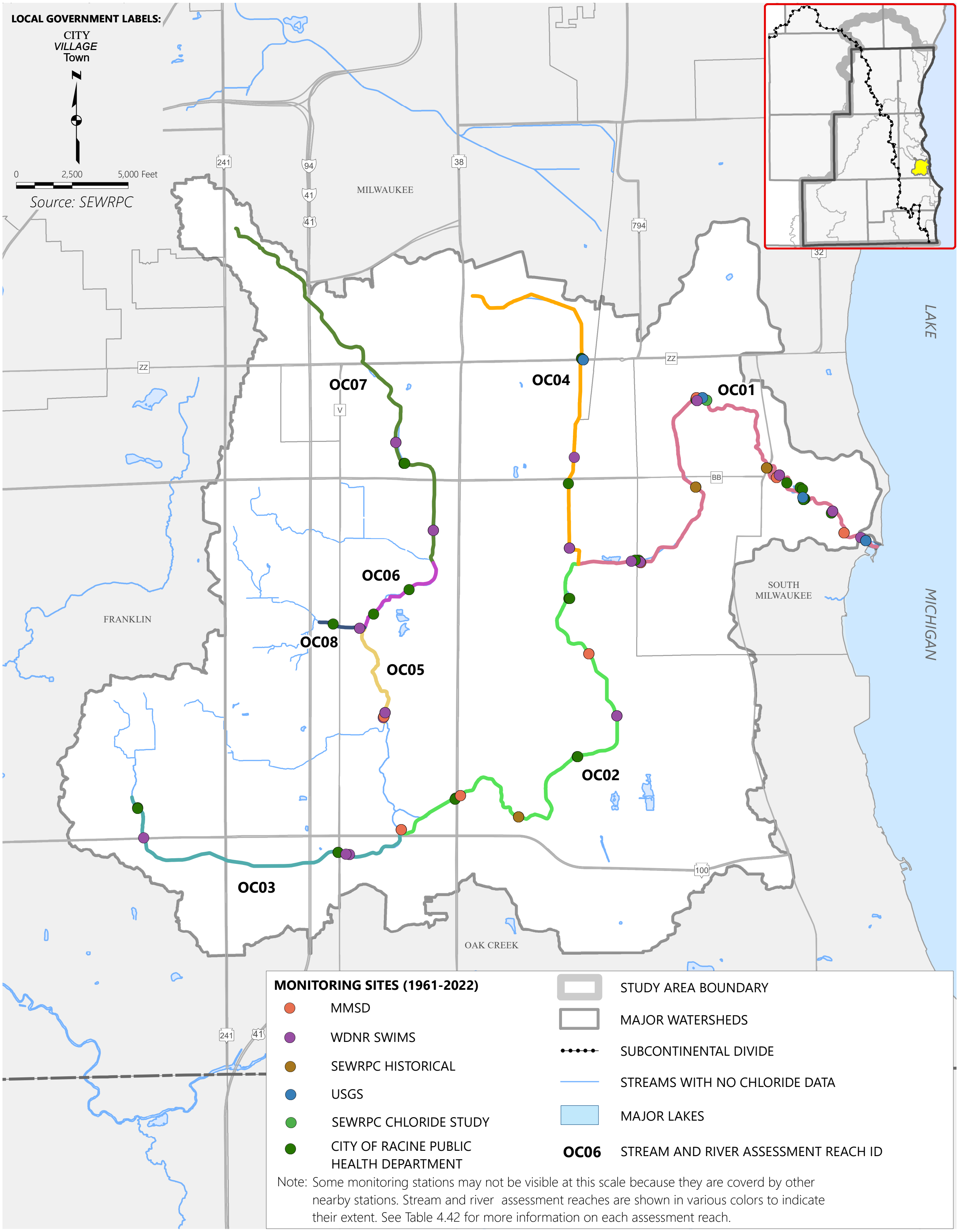
Map 4.82
Trends in Chloride and Specific Conductance Among Balanced Assessment Reaches Within the Milwaukee River and Direct Drainage Area to Lake Michigan Watersheds over the Recent Period of Record: 2013-2022



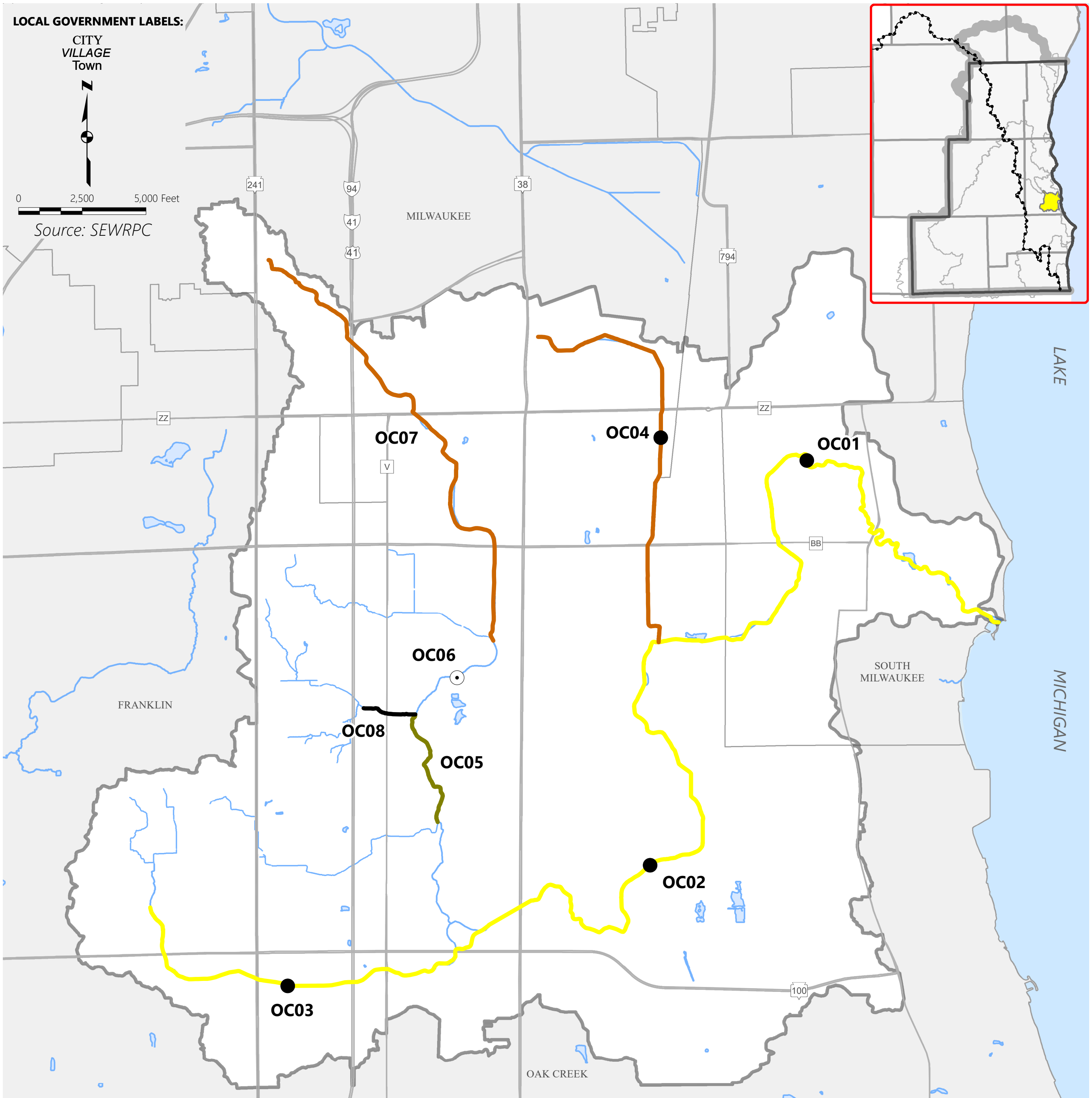
Map 4.83
Assessment Reaches for Streams Within the Oak Creek Watershed



Map 4.84
Assessment Reaches for Streams Within the Oak Creek Watershed



Map 4.85
Median Chloride Concentrations Within the Oak Creek Watershed for the Full Period of Record: 1961-2022



MEDIAN CHLORIDE

- 1 TO 35 mg/l (0 reaches)
- 36 TO 119 mg/l (0 reaches)
- 120 TO 230 mg/l (3 reaches)
- 231 TO 394 mg/l (1 reach)
- 395 to 756 mg/l (2 reaches)
- 757 TO 1,000 mg/l (0 reaches)
- 1,001 TO 1,400 mg/l (0 reaches)
- GREATER THAN 1,400 mg/l (1 reach)

ASSESSMENT REACHES WITH A BALANCED DATASET (4 reaches)

ASSESSMENT REACHES WITH NO CHLORIDE DATA (1 reach)

OC06 STREAM AND RIVER ASSESSMENT REACH ID

STUDY AREA BOUNDARY

MAJOR WATERSHEDS

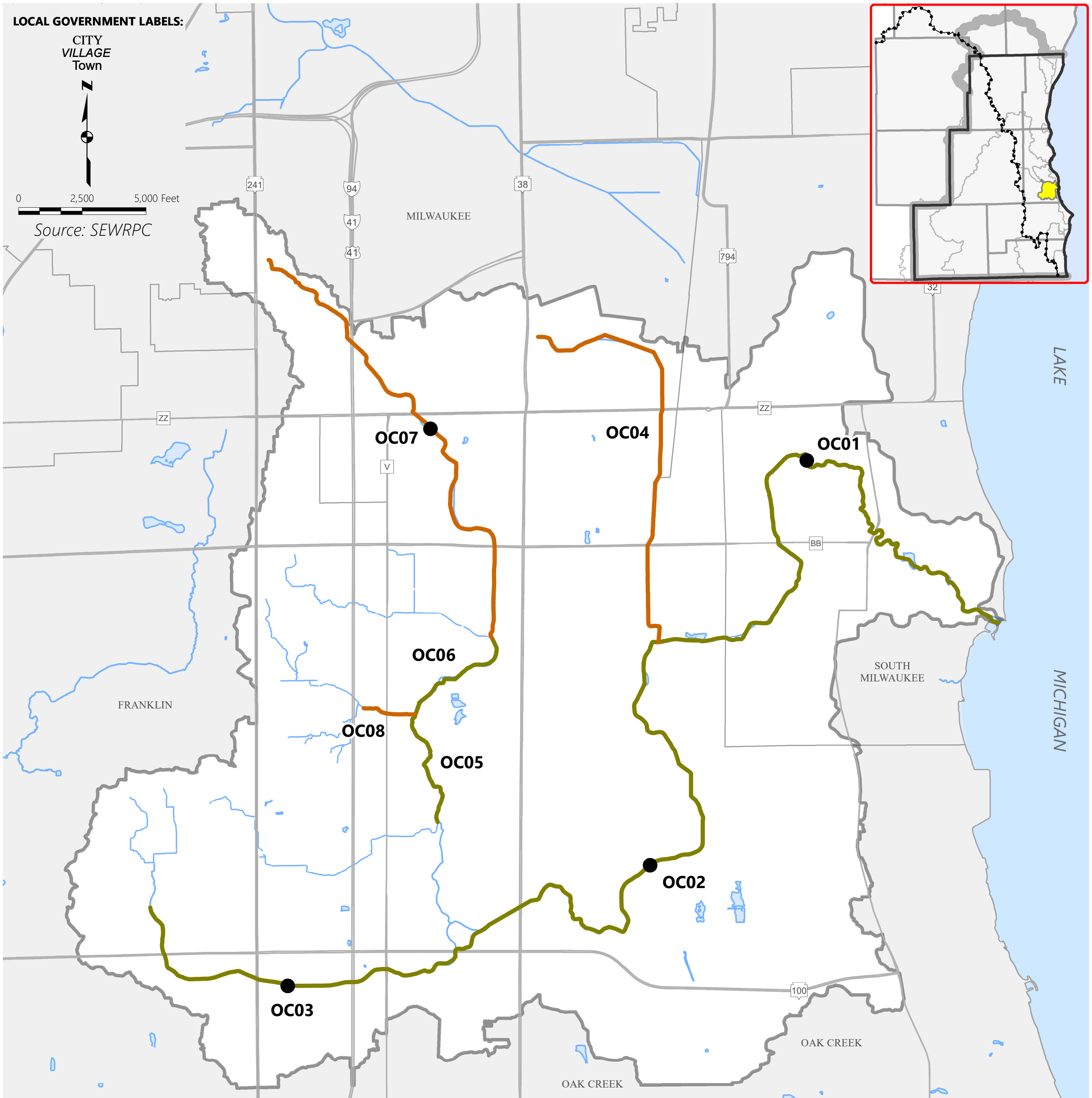
SUBCONTINENTAL DIVIDE

STREAMS WITH NO CHLORIDE DATA

MAJOR LAKES

Note: Seven assessment reaches in the Oak Creek watershed had chloride samples collected during the full period of record. Four of those reaches are considered to have fairly "Balanced" datasets and are indicated by the black circles. Imbalanced datasets may not fairly represent chloride conditions due to a small sample size or uneven sampling throughout the years or throughout all seasons. Reach OC06 did not have chloride data but did have limited specific conductance data that may be helpful for indicating chloride conditions in that stream reach.

Map 4.85
Median Specific Conductance Within the Oak Creek Watershed for the Full Period of Record: 1961-2022



MEDIAN SPECIFIC CONDUCTANCE

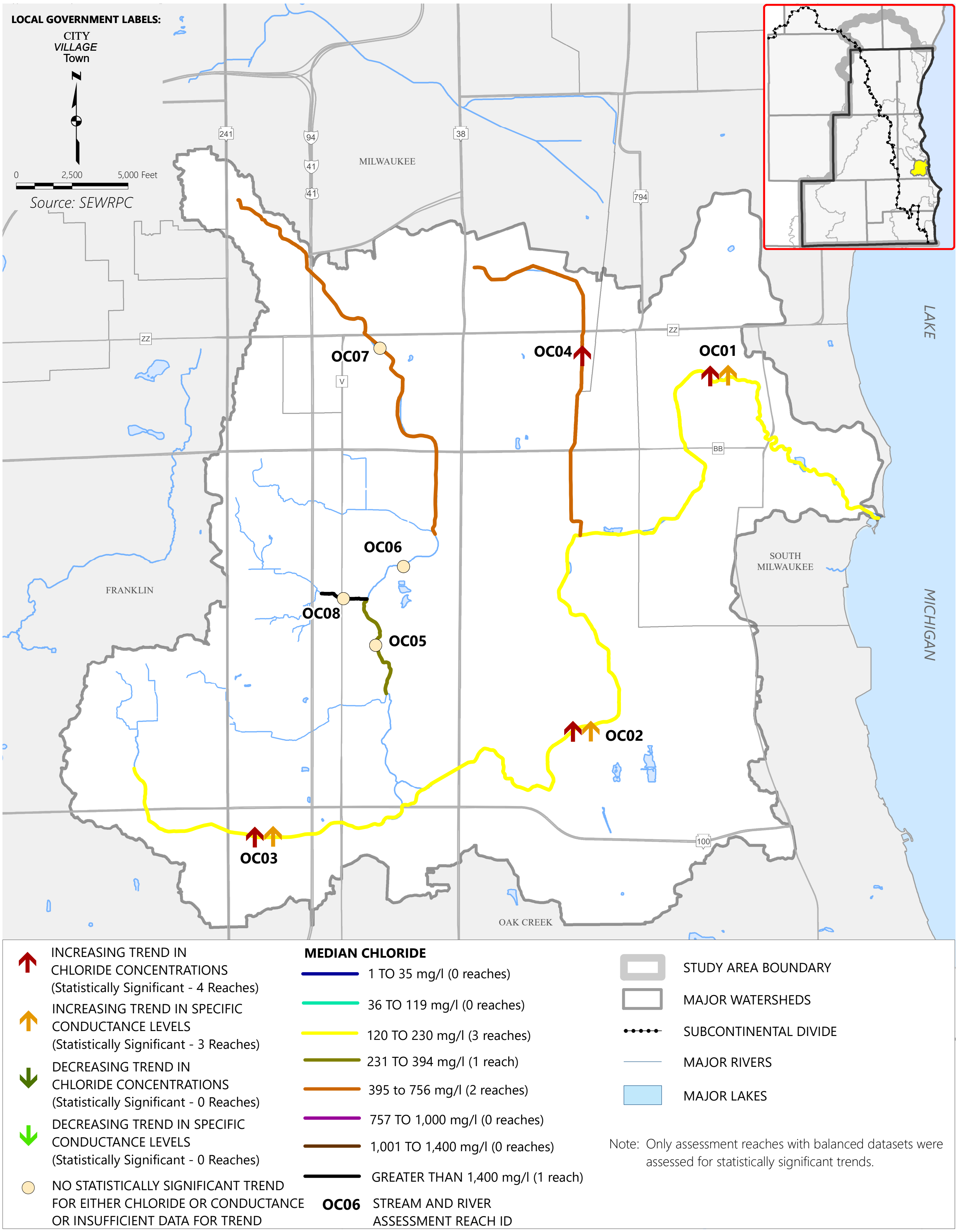
- 1 TO 400 µS/cm (0 reaches)
- 401 TO 878 µS/cm (0 reaches)
- 879 TO 1,238 µS/cm (0 reaches)
- 1,239 TO 1,770 µS/cm (5 reaches)
- 1,771 to 2,810 µS/cm (3 reaches)
- 2,811 TO 3,472 µS/cm (0 reaches)
- 3,473 TO 4,556 µS/cm (0 reaches)
- GREATER THAN 4,556 µS/cm (0 reaches)

- ASSESSMENT REACHES WITH A BALANCED DATASET (4 reaches)
- ASSESSMENT REACHES WITH NO CONDUCTANCE DATA (0 reaches)
- OC06 STREAM AND RIVER ASSESSMENT REACH ID

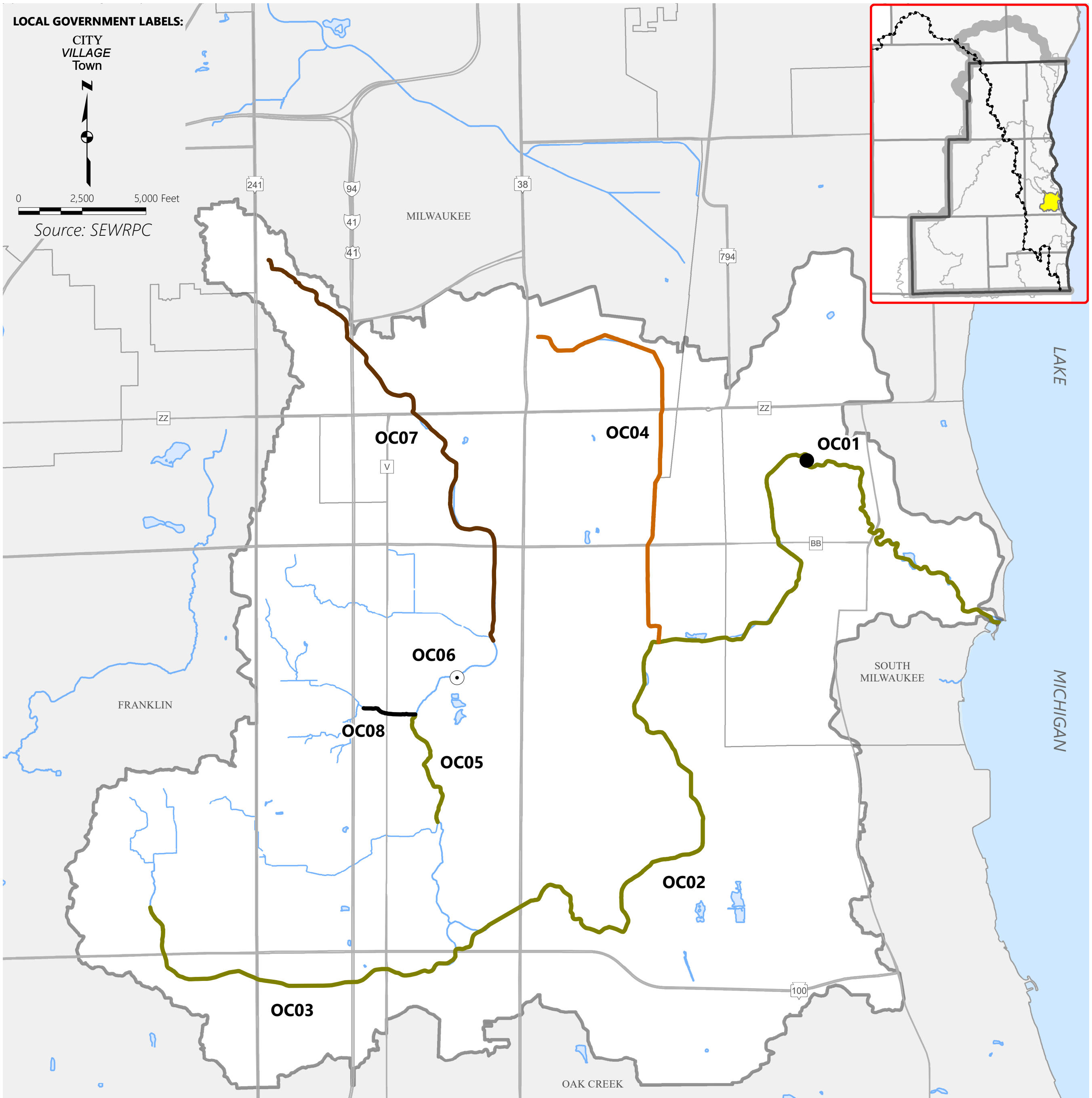
- STUDY AREA BOUNDARY
- MAJOR WATERSHEDS
- SUBCONTINENTAL DIVIDE
- STREAM WITH NO CONDUCTANCE DATA
- MAJOR LAKES

Note: Eight assessment reaches in the Oak Creek watershed had specific conductance samples collected during the recent period of record. Four of those reaches are considered to have fairly "Balanced" datasets and are indicated by the black circles. Imbalanced datasets may not fairly represent conductance conditions due to a small sample size or uneven sampling throughout the years or throughout all seasons.

Map 4.87
Trends in Chloride and Specific Conductance Among Assessment Reaches Within the Oak Creek Watershed for the Full Period of Record: 1961-2022



Map 4.88
Median Chloride Concentrations Within the Oak Creek Watershed for the Recent Period of Record: 2013-2022



RECENT MEDIAN CHLORIDE

- 1 TO 35 mg/l (0 reaches)
- 36 TO 119 mg/l (0 reaches)
- 120 TO 230 mg/l (0 reaches)
- 231 TO 394 mg/l (4 reaches)
- 395 to 756 mg/l (1 reach)
- 757 TO 1,000 mg/l (0 reaches)
- 1,001 TO 1,400 mg/l (1 reach)
- GREATER THAN 1,400 mg/l (1 reach)

ASSESSMENT REACHES WITH A BALANCED DATASET (1 reach)

ASSESSMENT REACHES WITH NO CHLORIDE DATA (1 reach)

OC06 STREAM AND RIVER ASSESSMENT REACH ID

STUDY AREA BOUNDARY

MAJOR WATERSHEDS

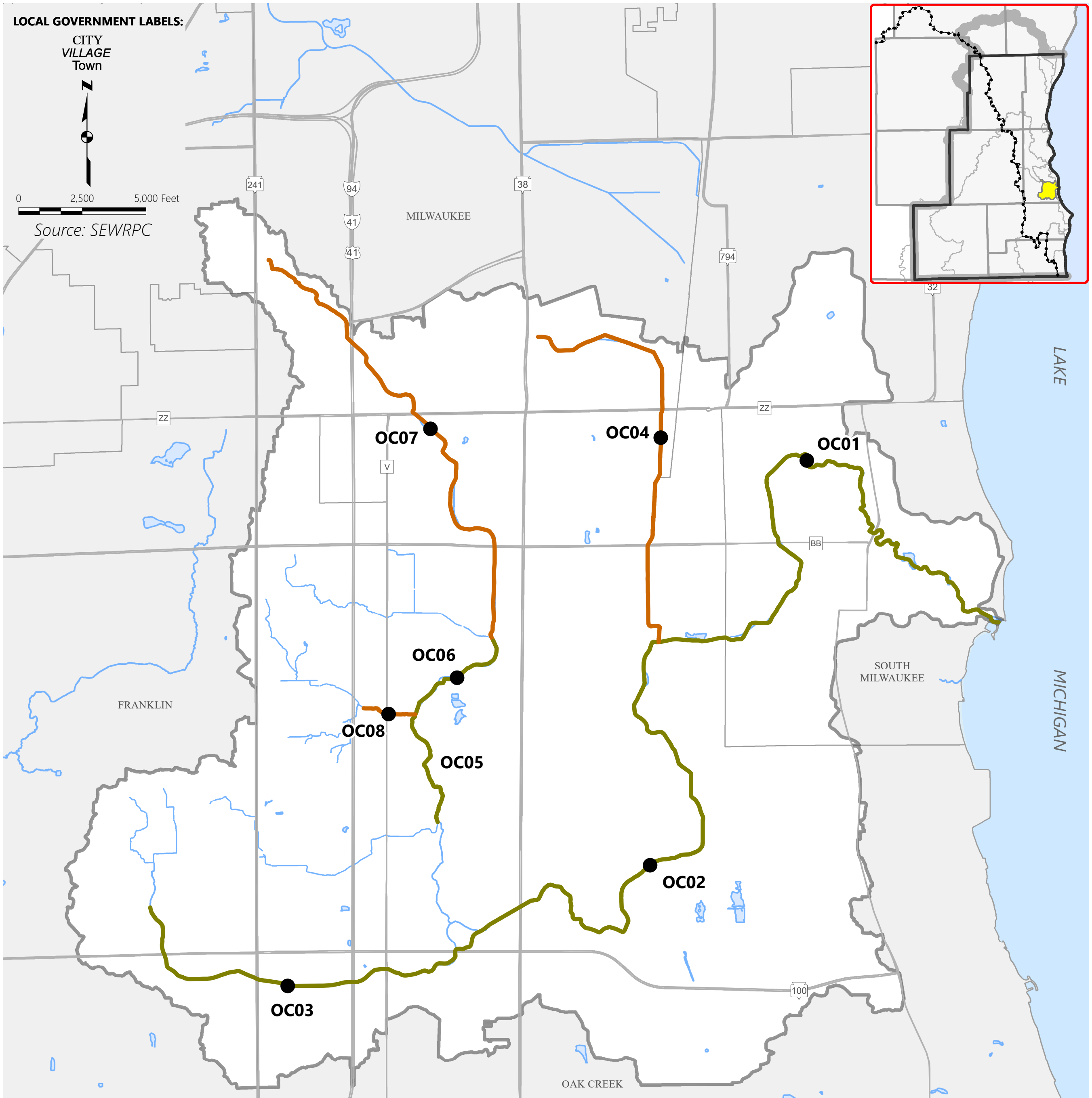
SUBCONTINENTAL DIVIDE

MAJOR RIVERS

MAJOR LAKES

Note: Seven assessment reaches in the Oak Creek watershed had chloride samples collected during the recent period of record. One of those reaches was considered to have a fairly "Balanced" dataset and is indicated by the black circle. Imbalanced datasets may not fairly represent chloride conditions due to a small sample size or uneven sampling throughout all seasons. Reach OC06 did not have recent chloride data but did have specific conductance data that may be helpful for indicating chloride conditions in that stream reach.

Map 4.89
Median Specific Conductance Within the Oak Creek Watershed for the Recent Period of Record: 2013-2022



MEDIAN SPECIFIC CONDUCTANCE

- 1 TO 400 μS/cm (0 reaches)
- 401 TO 878 μS/cm (0 reaches)
- 879 TO 1,238 μS/cm (0 reaches)
- 1,239 TO 1,770 μS/cm (5 reaches)
- 1,771 to 2,810 μS/cm (3 reaches)
- 2,811 TO 3,472 μS/cm (0 reaches)
- 3,473 TO 4,556 μS/cm (0 reaches)
- GREATER THAN 4,556 μS/cm (0 reaches)

ASSESSMENT REACHES WITH A BALANCED DATASET (7 reaches)

ASSESSMENT REACHES WITH NO CONDUCTANCE DATA (0 reaches)

OC06 STREAM AND RIVER ASSESSMENT REACH ID

STUDY AREA BOUNDARY

MAJOR WATERSHEDS

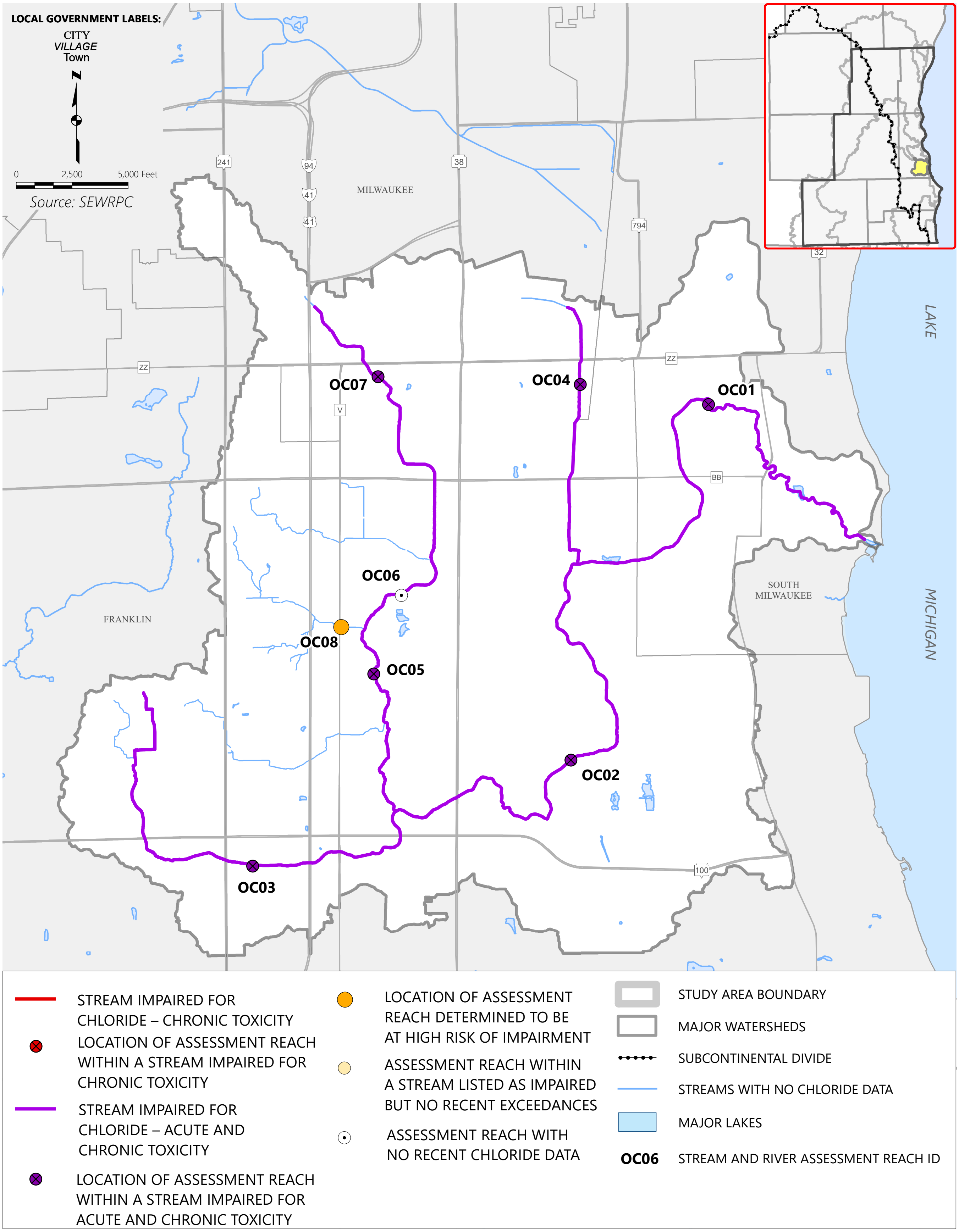
SUBCONTINENTAL DIVIDE

STREAMS WITH NO CONDUCTANCE DATA

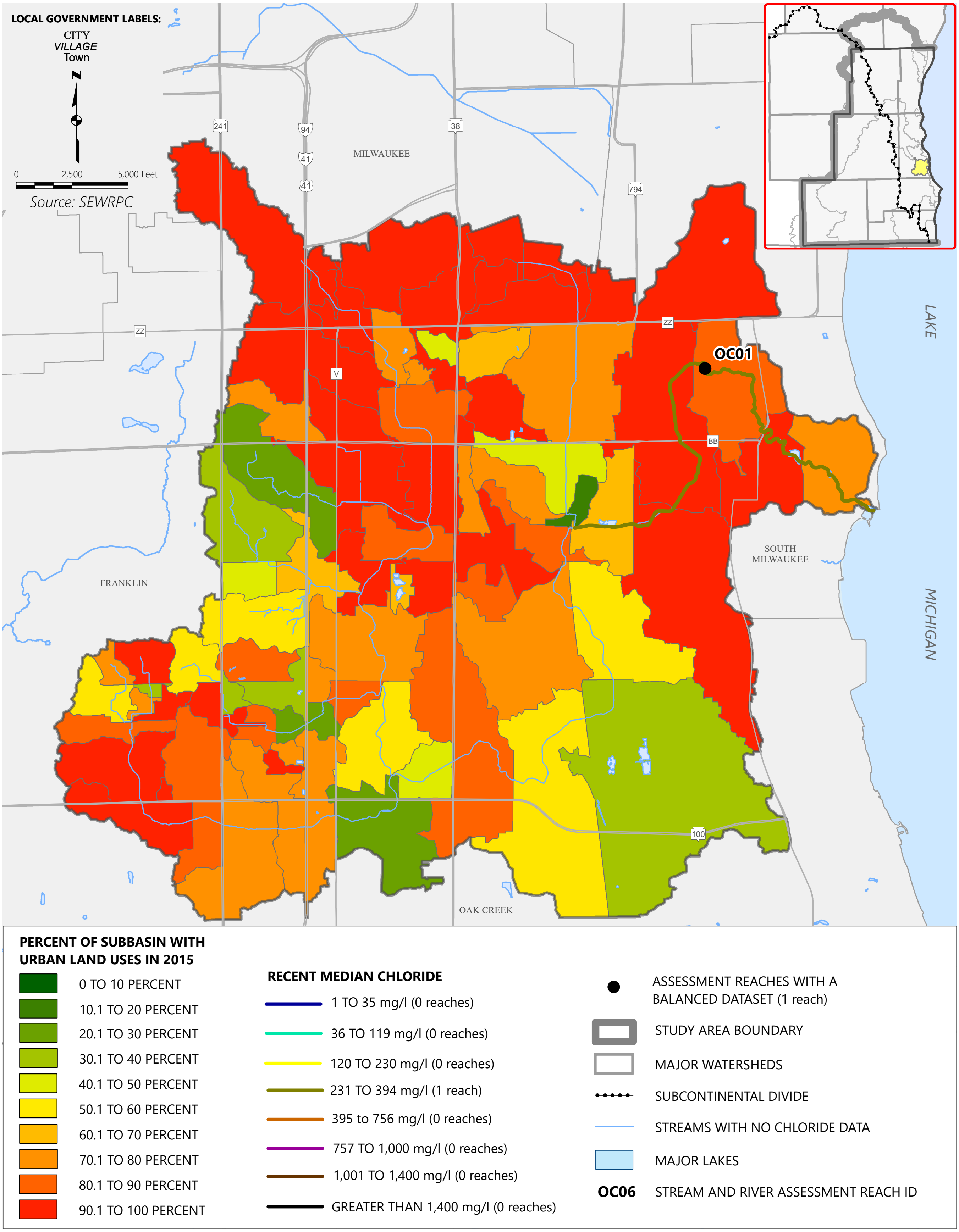
MAJOR LAKES

Note: Eight assessment reaches in the Oak Creek watershed had specific conductance samples collected during the recent period of record. Seven of those reaches are considered to have fairly "Balanced" datasets and are indicated by the black circles. Imbalanced datasets may not fairly represent conductance conditions due to a small sample size or uneven sampling throughout the years or throughout all seasons.

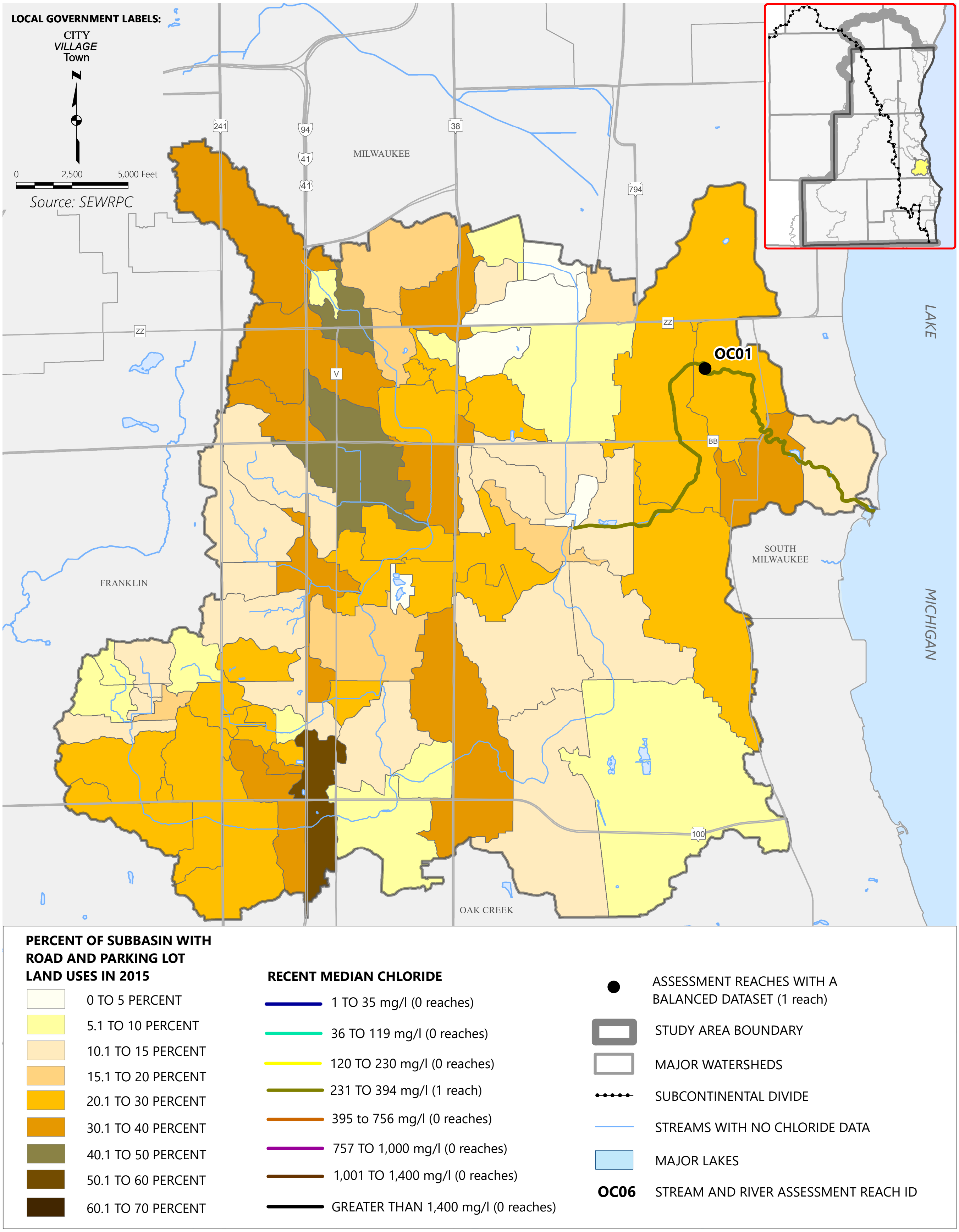
Map 4.90
Streams Impaired for Chloride Within the Oak Creek Watershed: 2024



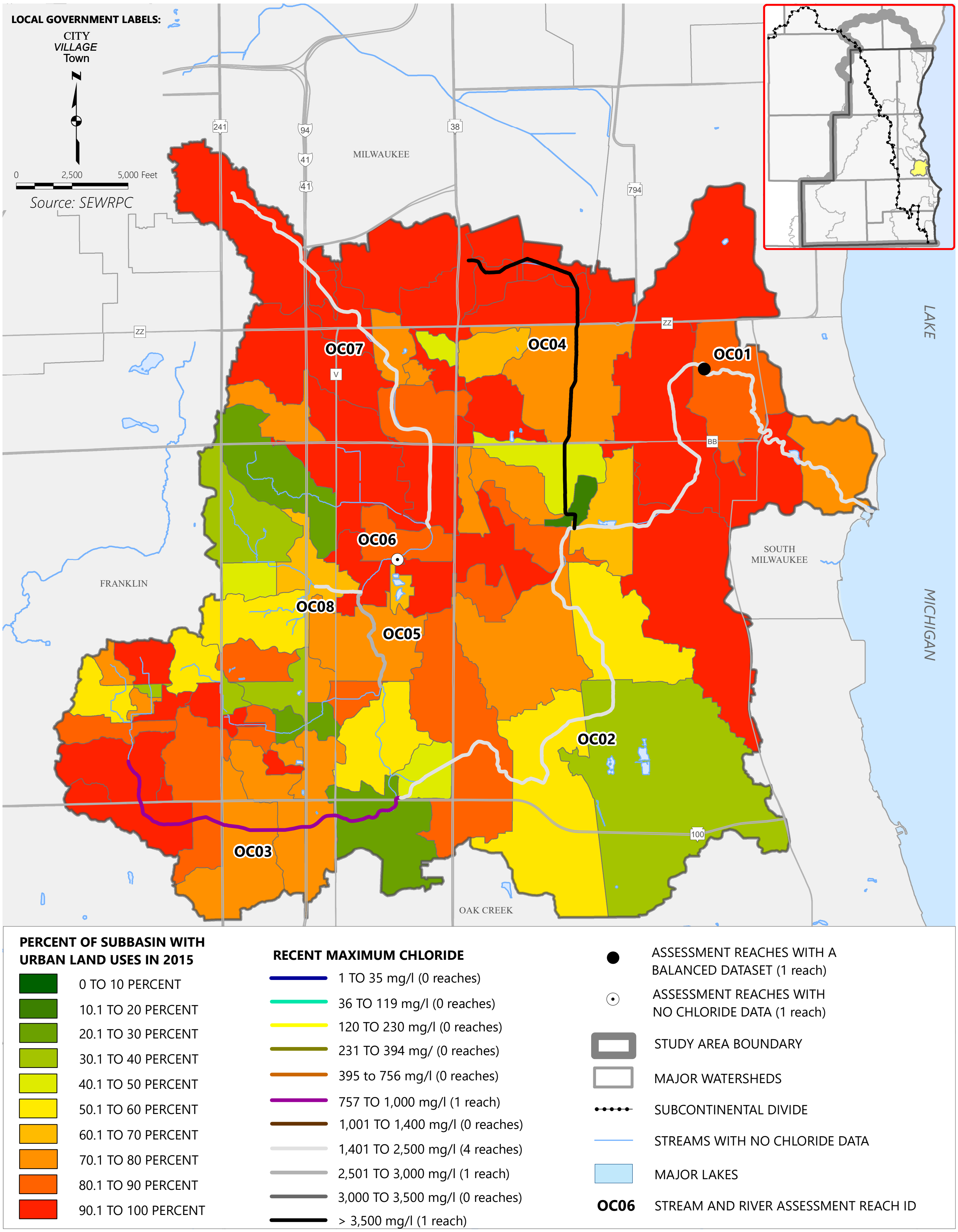
Map 4.91
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Oak Creek River Watershed and Percent Urban Land Use by Subbasin



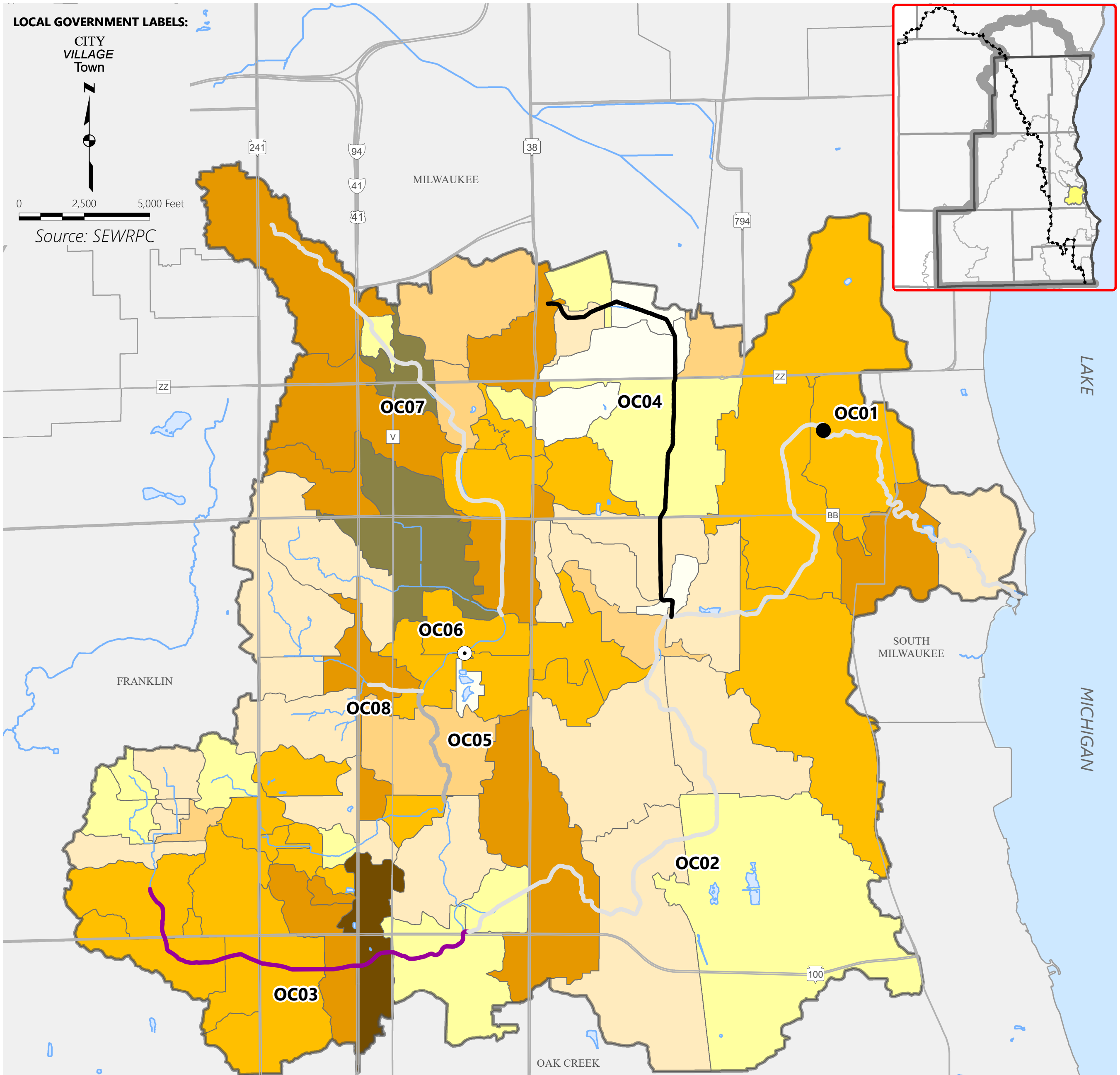
Map 4.92
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Oak Creek River Watershed and Road and Parking Lot Density by Subbasin



Map 4.93
Recent Maximum Chloride Concentrations in Assessment Reaches Within the Oak Creek River Watershed and Percent Urban Land Use by Subbasin



Map 4.94
Recent Maximum Chloride Concentrations in Assessment Reaches Within the Oak Creek River Watershed and Road and Parking Lot Density by Subbasin



PERCENT OF SUBBASIN WITH ROAD AND PARKING LOT LAND USES IN 2015

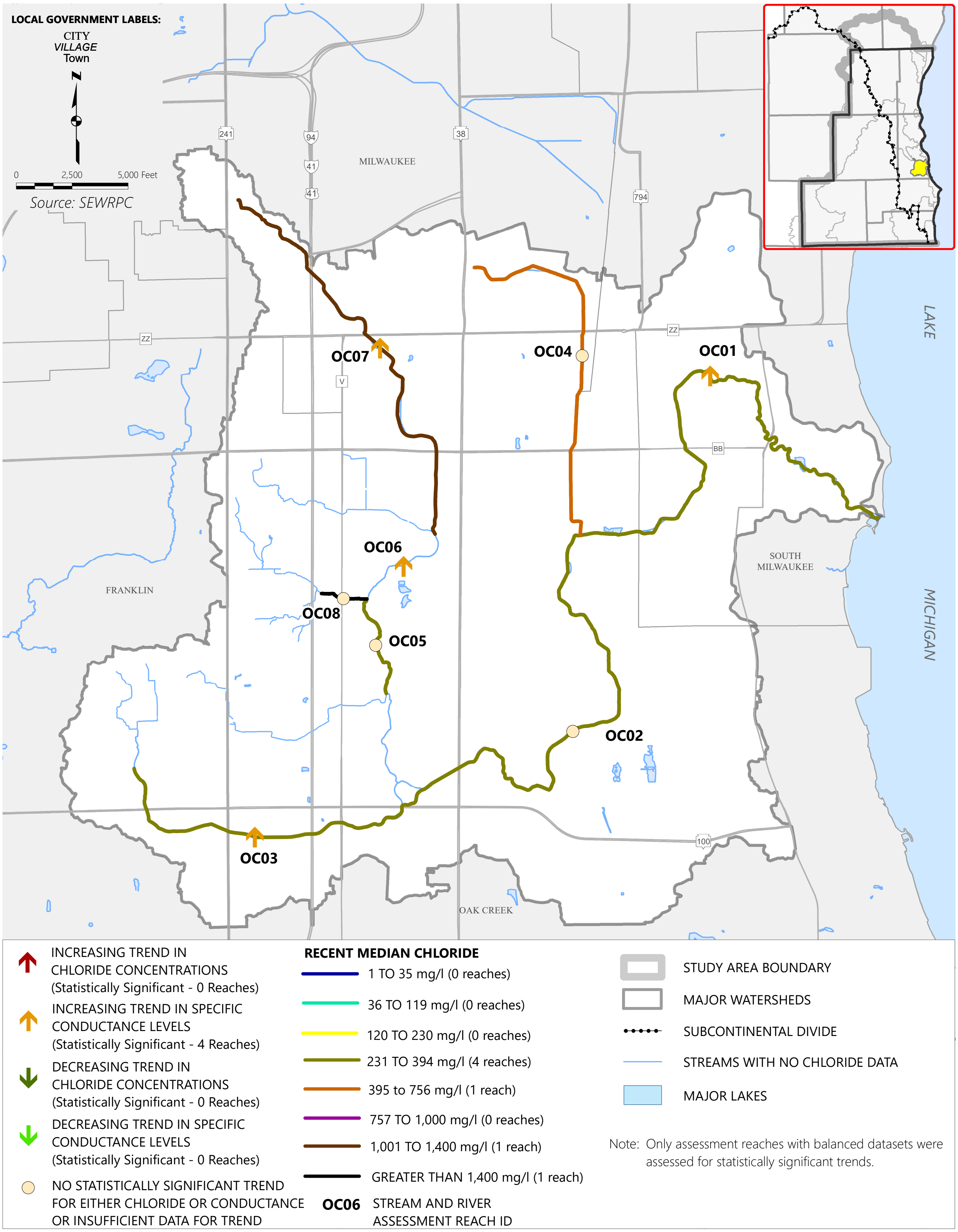
- 0 TO 5 PERCENT
- 5.1 TO 10 PERCENT
- 10.1 TO 15 PERCENT
- 15.1 TO 20 PERCENT
- 20.1 TO 30 PERCENT
- 30.1 TO 40 PERCENT
- 40.1 TO 50 PERCENT
- 50.1 TO 60 PERCENT
- 60.1 TO 70 PERCENT

RECENT MAXIMUM CHLORIDE

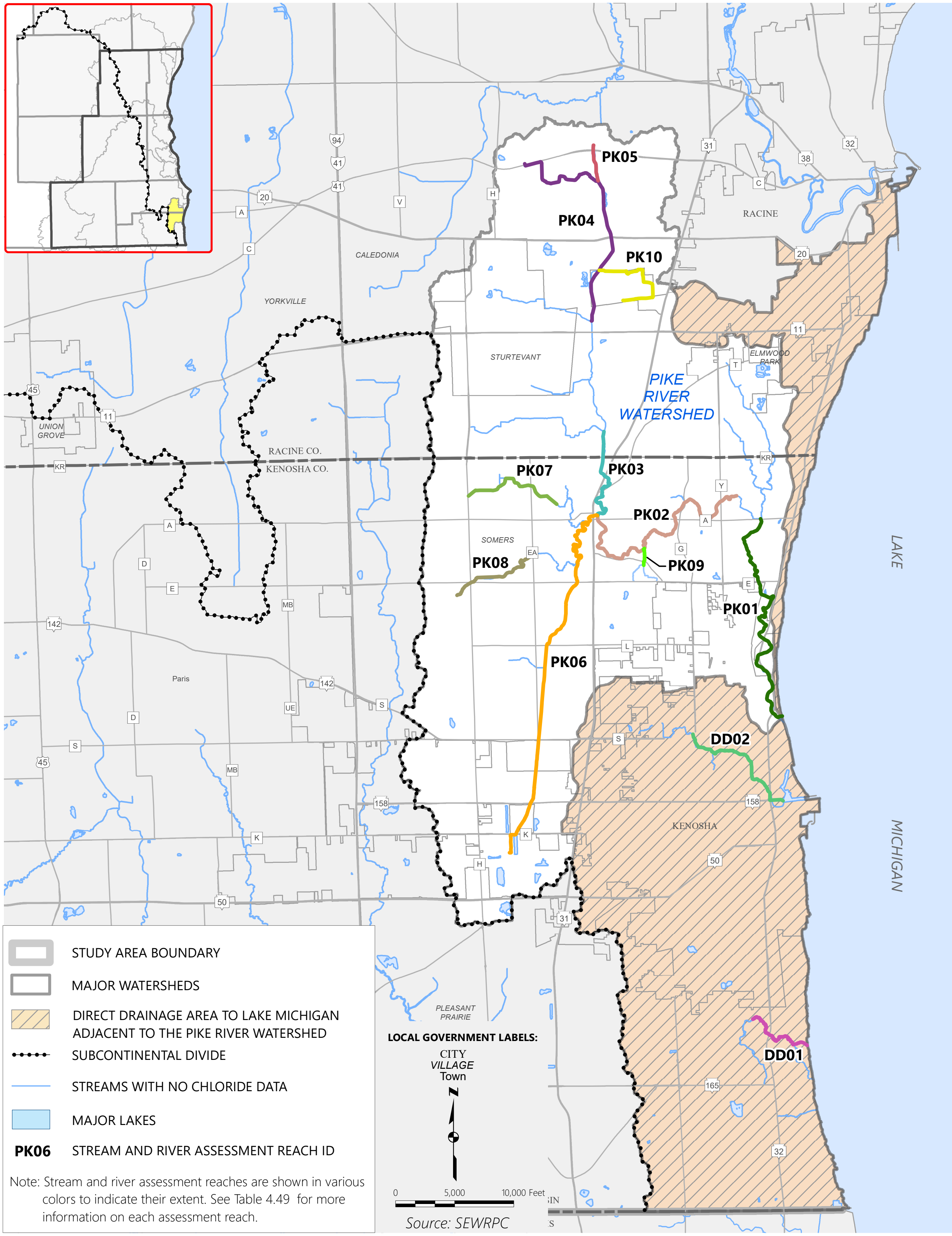
- 1 TO 35 mg/l (0 reaches)
- 36 TO 119 mg/l (0 reaches)
- 120 TO 230 mg/l (0 reaches)
- 231 TO 394 mg/ (0 reaches)
- 395 to 756 mg/l (0 reaches)
- 757 TO 1,000 mg/l (1 reach)
- 1,001 TO 1,400 mg/l (0 reaches)
- 1,401 TO 2,500 mg/l (4 reaches)
- 2,501 TO 3,000 mg/l (1 reach)
- 3,000 TO 3,500 mg/l (0 reaches)
- > 3,500 mg/l (1 reach)

- ASSESSMENT REACHES WITH A BALANCED DATASET (1 reach)
- ASSESSMENT REACHES WITH NO CHLORIDE DATA (1 reach)
- STUDY AREA BOUNDARY
- MAJOR WATERSHEDS
- SUBCONTINENTAL DIVIDE
- STREAMS WITH NO CHLORIDE DATA
- MAJOR LAKES
- **OC06** STREAM AND RIVER ASSESSMENT REACH ID

Map 4.95
Trends in Recent Chloride and Specific Conductance Among Assessment Reaches Within the Oak Creek Watershed: 2013-2022



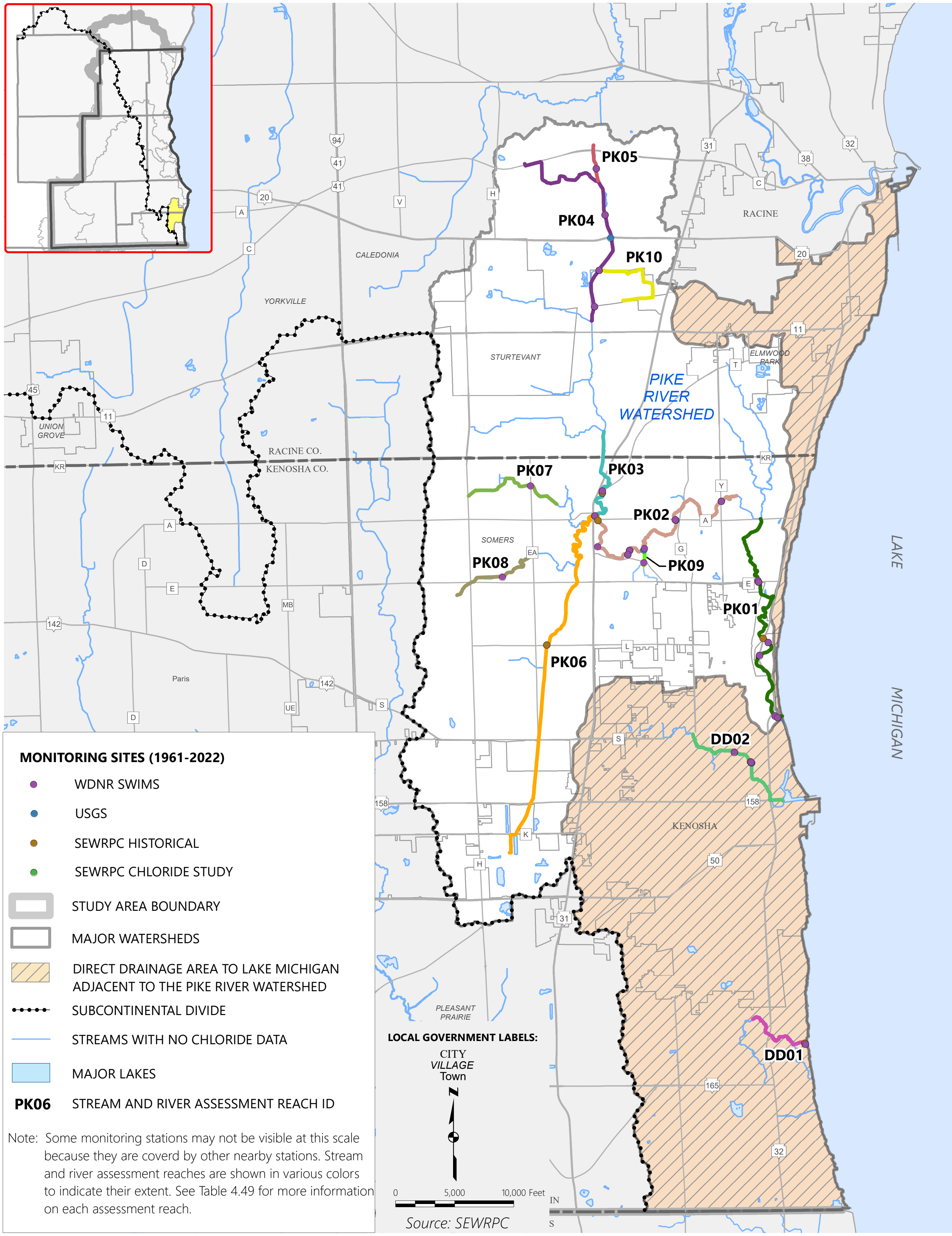
Map 4.96
Assessment Reaches Within the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan



Note: Stream and river assessment reaches are shown in various colors to indicate their extent. See Table 4.49 for more information on each assessment reach.

Source: SEWRPC

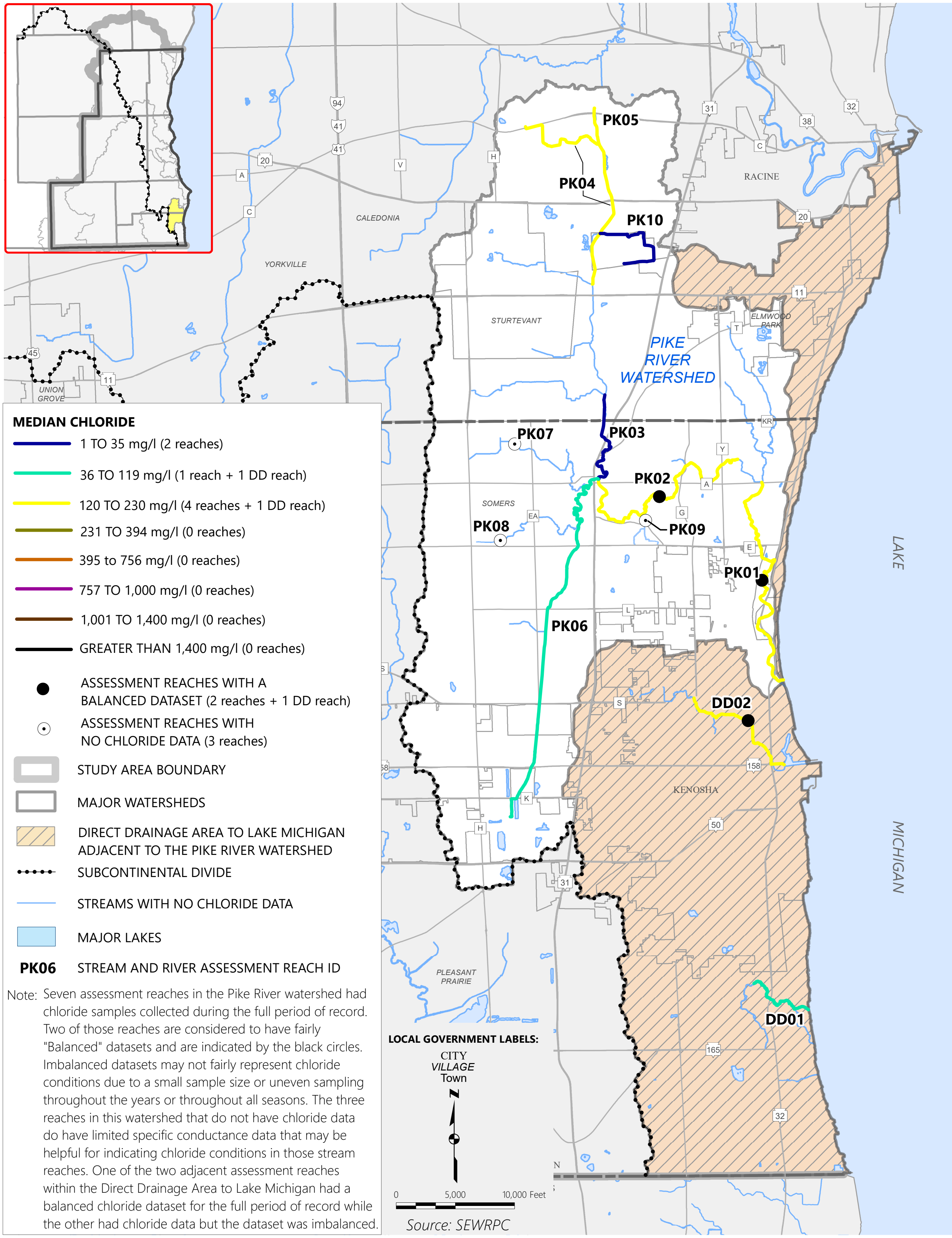
Map 4.97
Monitoring Sites and Assessment Reaches for Streams Within the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan



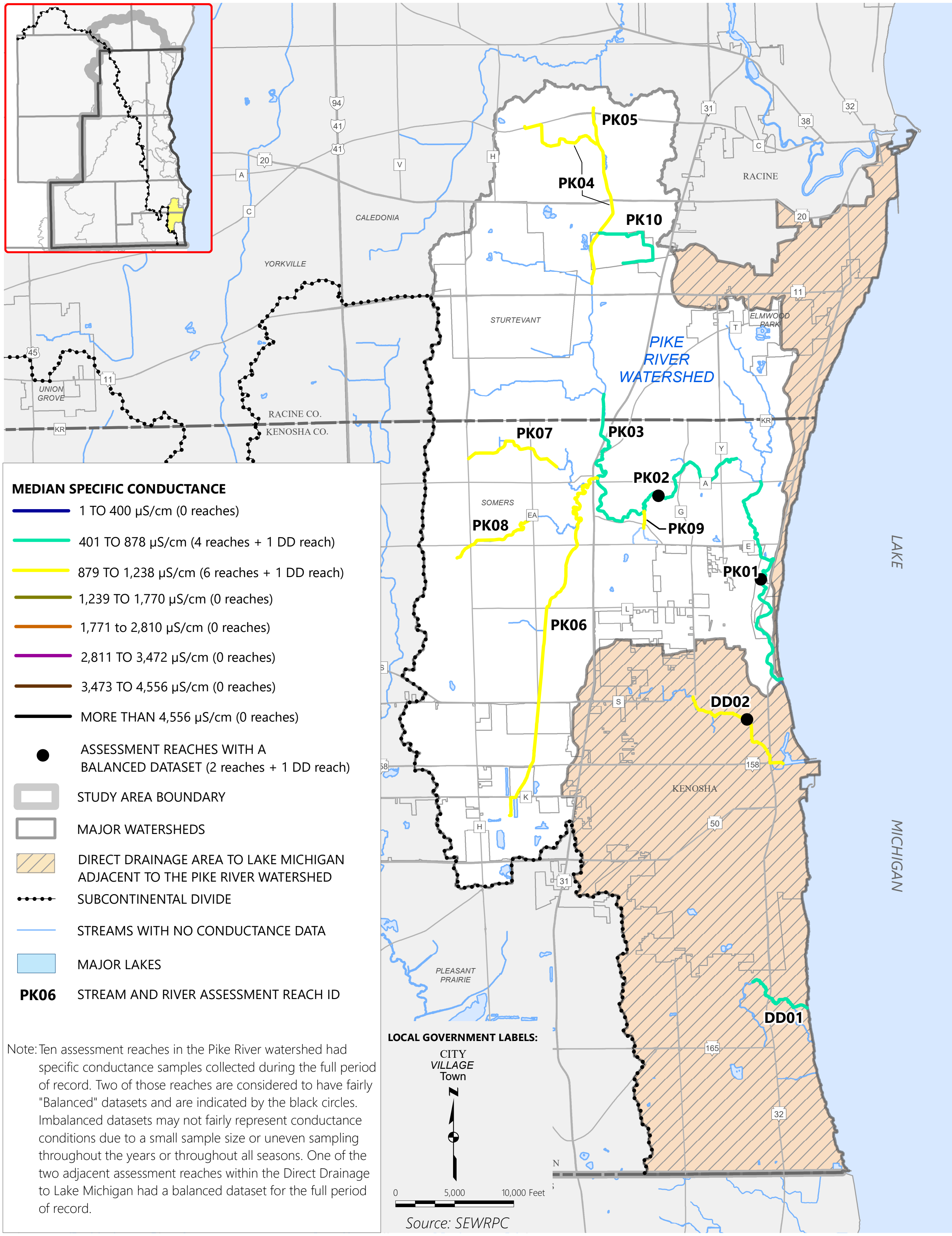
Note: Some monitoring stations may not be visible at this scale because they are coverd by other nearby stations. Stream and river assessment reaches are shown in various colors to indicate their extent. See Table 4.49 for more information on each assessment reach.

Source: SEWRPC

Map 4.98
Median Chloride Concentration Within the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan for the Full Period of Record: 1961-2022



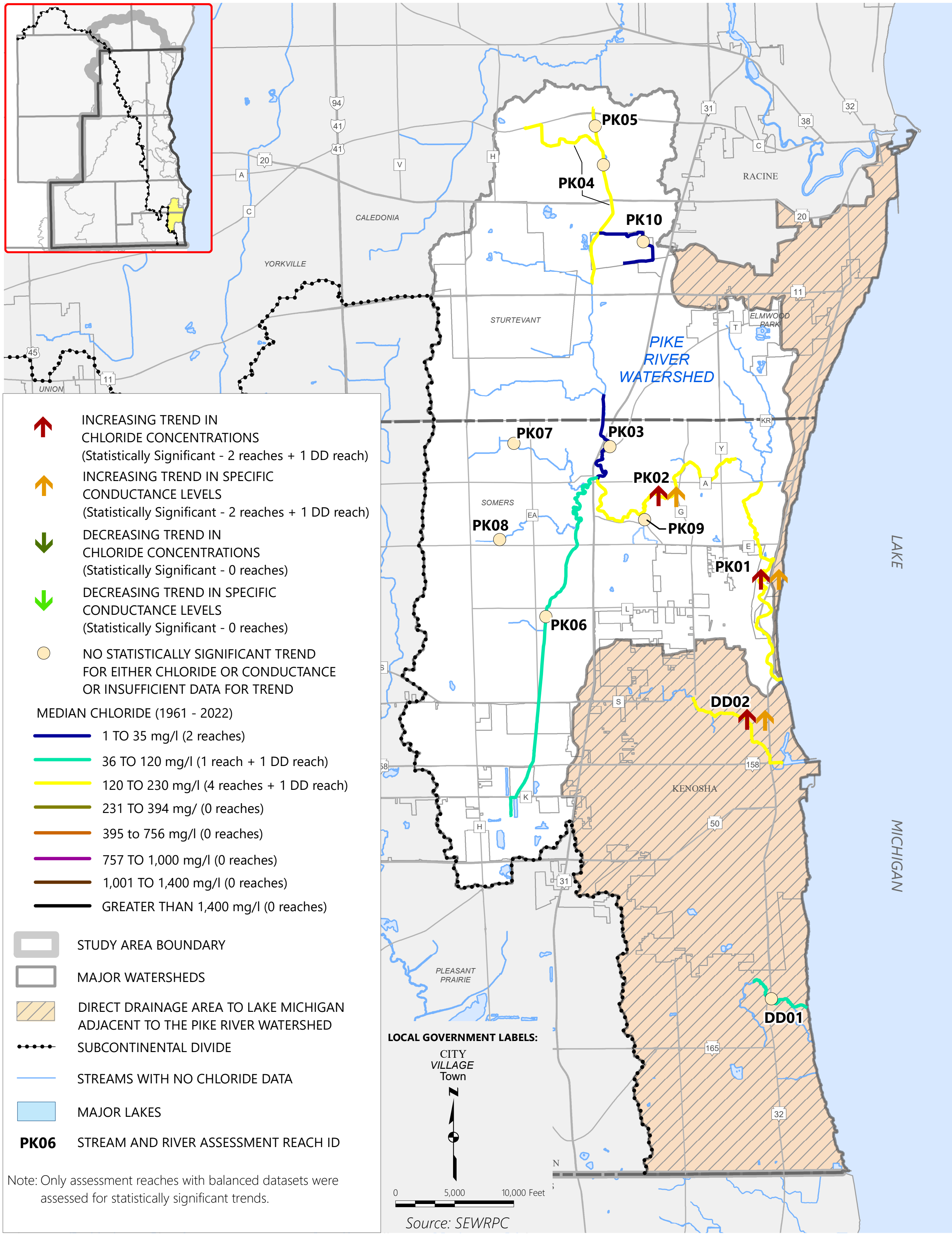
Map 4.99
Median Specific Conductances Within the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan for the Full Period of Record: 1961-2022



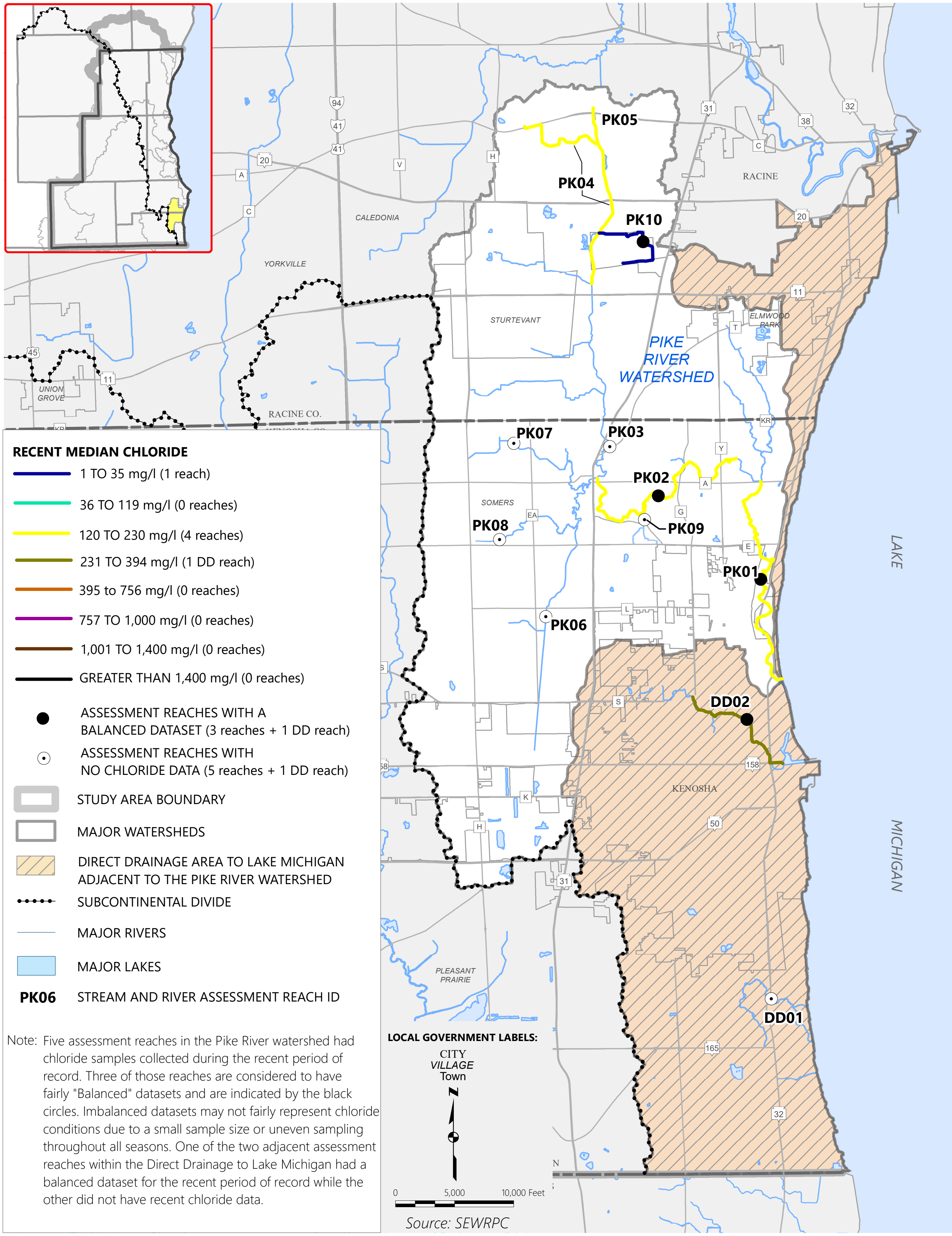
Note: Ten assessment reaches in the Pike River watershed had specific conductance samples collected during the full period of record. Two of those reaches are considered to have fairly "Balanced" datasets and are indicated by the black circles. Imbalanced datasets may not fairly represent conductance conditions due to a small sample size or uneven sampling throughout the years or throughout all seasons. One of the two adjacent assessment reaches within the Direct Drainage to Lake Michigan had a balanced dataset for the full period of record.

Source: SEWRPC

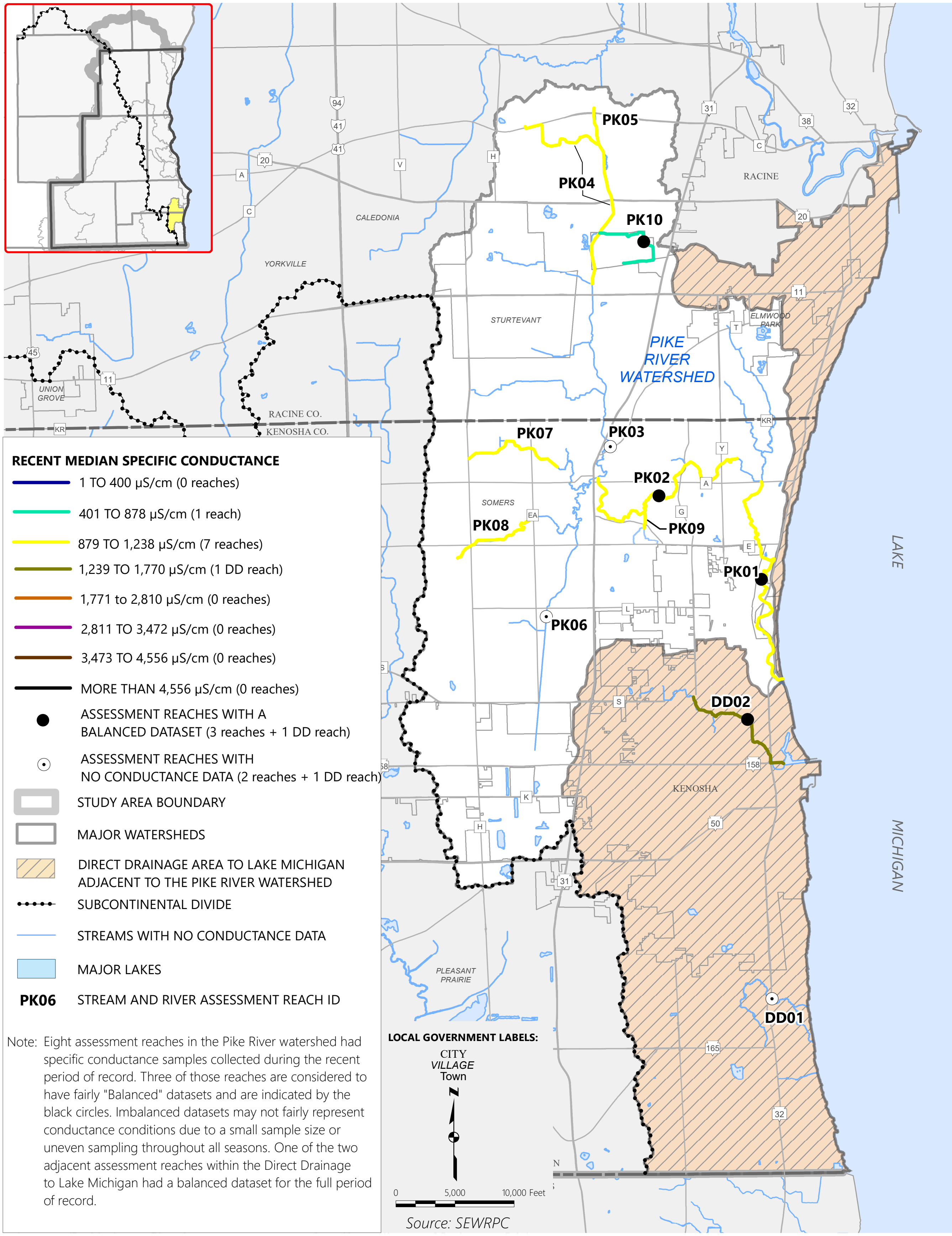
Map 4.100
Trends in Chloride and Specific Conductance for Assessment Reaches in the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan: 1961-2022



Map 4.101
Median Chloride Concentrations Within the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan for the Recent Period of Record: 2013-2022

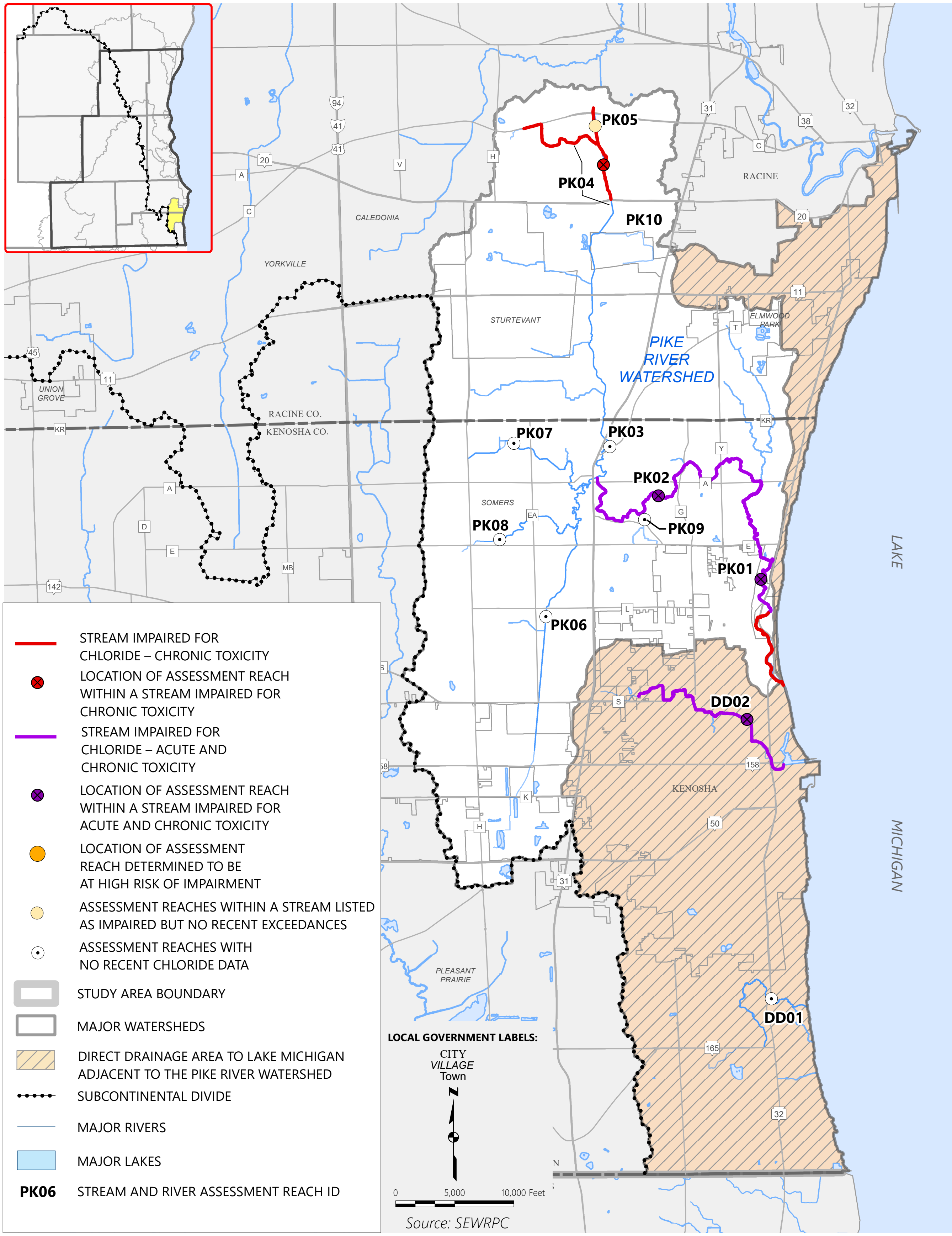


Map 4.102
Median Specific Conductances Within the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan for the Recent Period of Record: 2013-2022

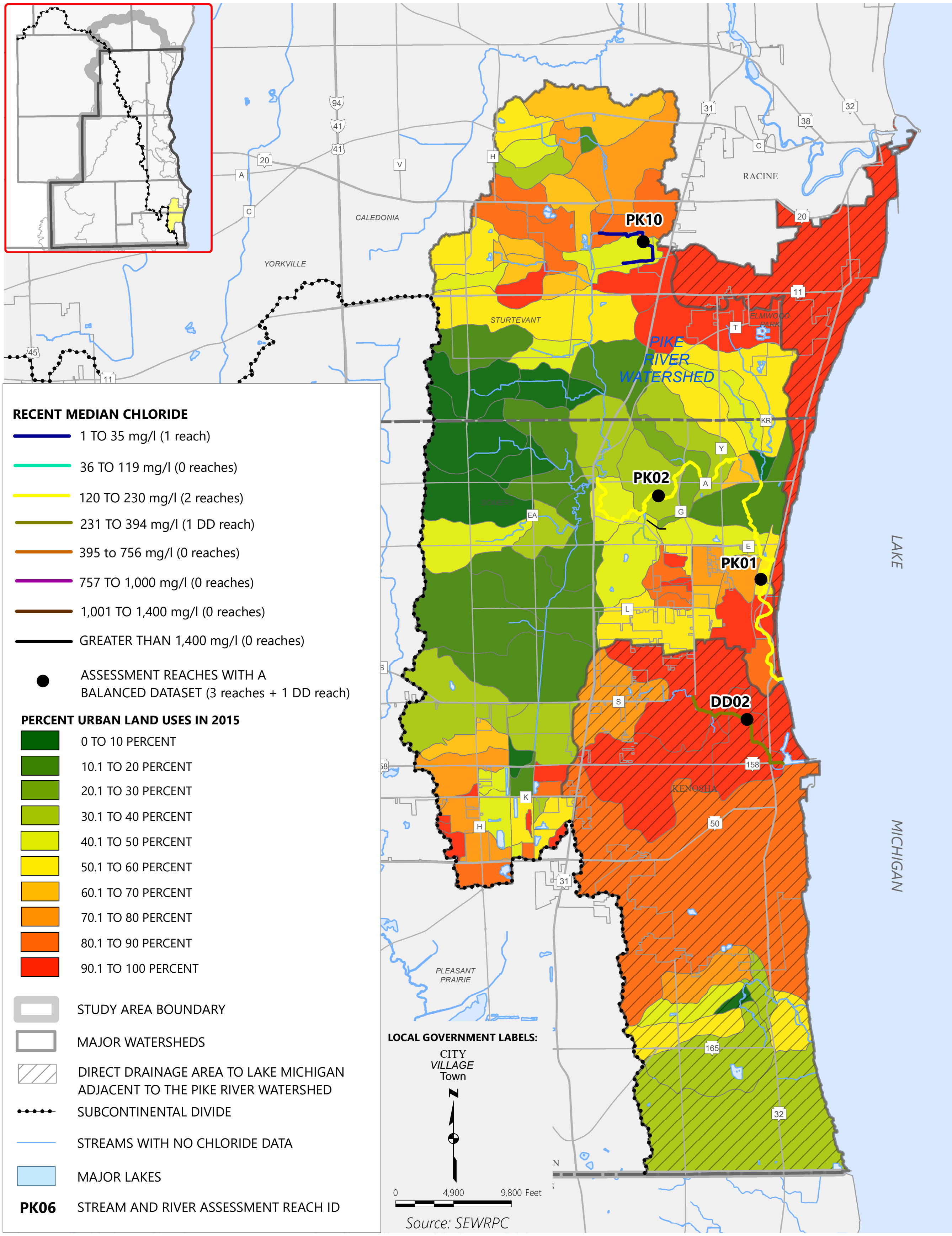


Note: Eight assessment reaches in the Pike River watershed had specific conductance samples collected during the recent period of record. Three of those reaches are considered to have fairly "Balanced" datasets and are indicated by the black circles. Imbalanced datasets may not fairly represent conductance conditions due to a small sample size or uneven sampling throughout all seasons. One of the two adjacent assessment reaches within the Direct Drainage to Lake Michigan had a balanced dataset for the full period of record.

Map 4.103
Streams Impaired for Chloride Within the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan: 2024

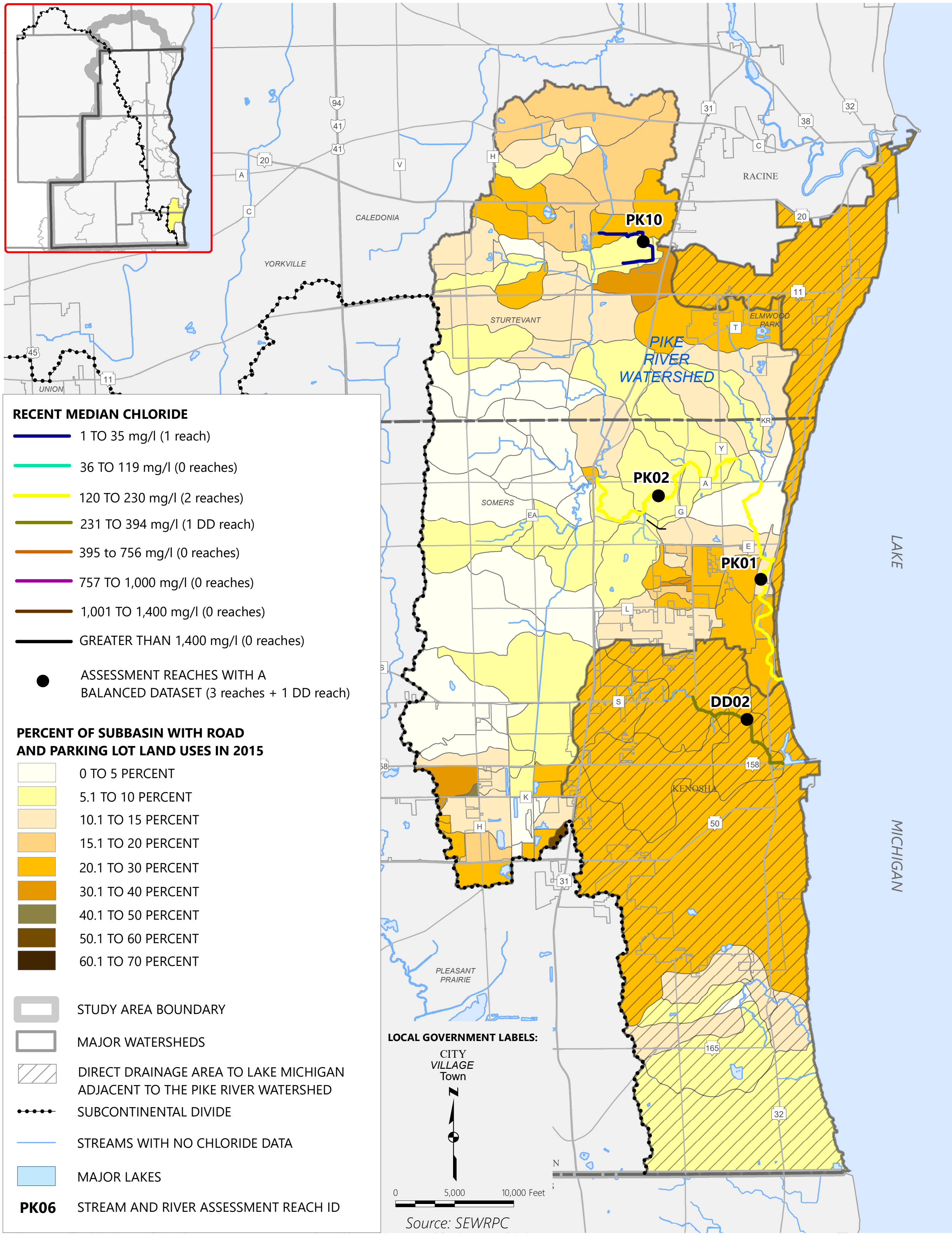


Map 4.104
Recent Median Chloride Concentration in Balanced Assessment Reaches Within the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan and Percent Urban Land Use in Subbasins



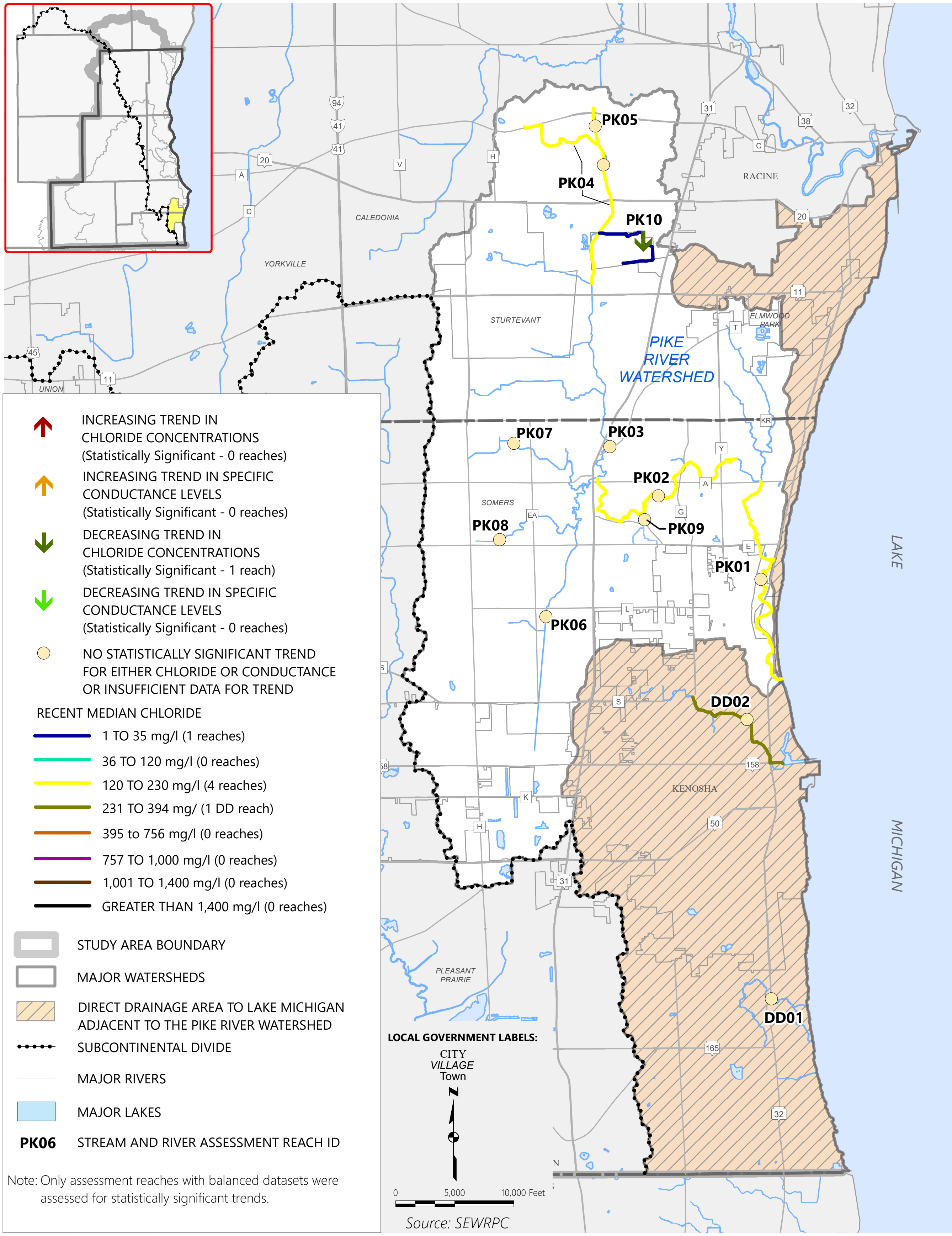
Source: SEWRPC

Map 4.105
Recent Median Chloride Concentration in Balanced Assessment Reaches in the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan and Road and Parking Lot Density in Subbasins

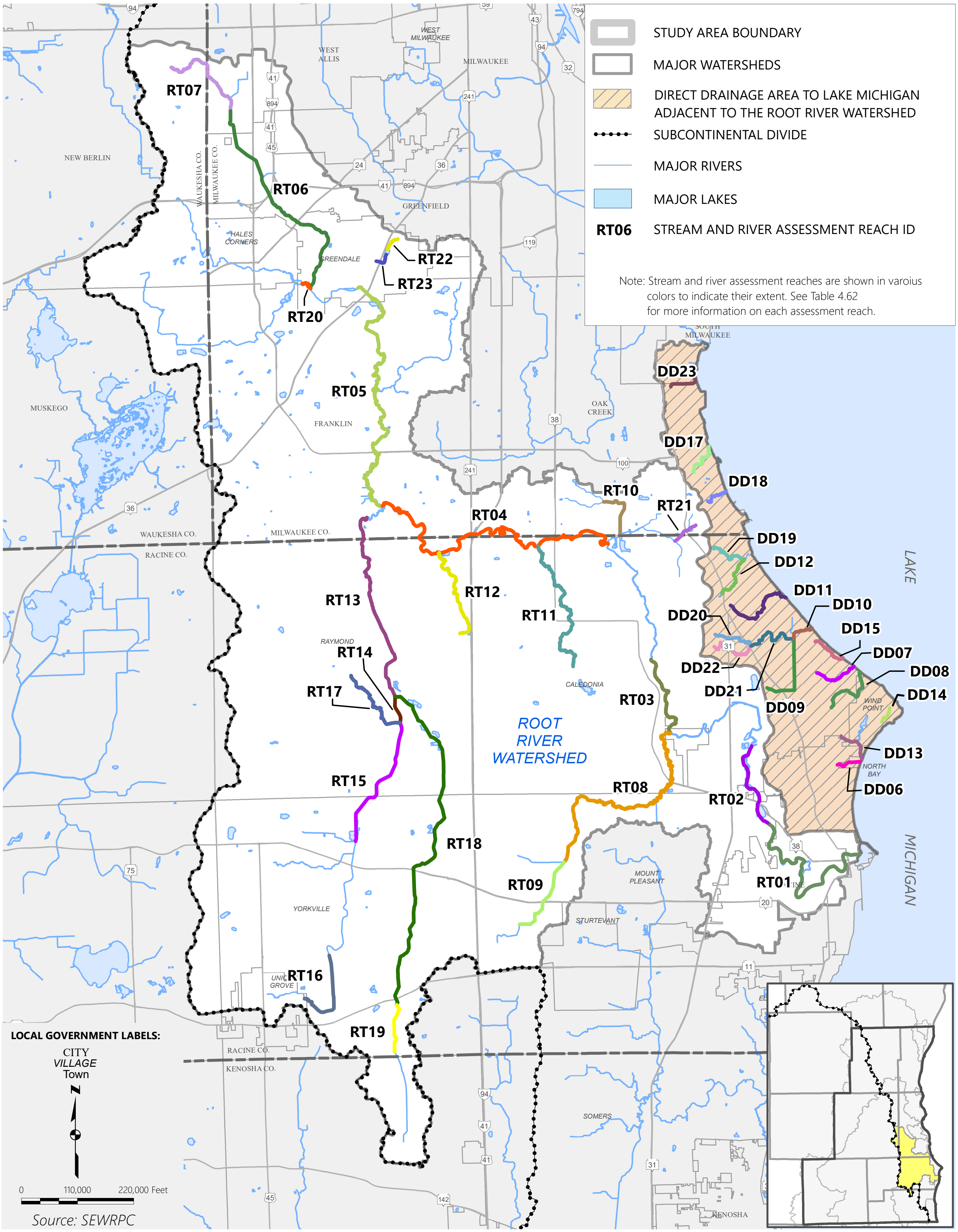


Source: SEWRPC

Map 4.106
Trends in Recent Chloride and Specific Conductance for Assessment Reaches in the Pike River Watershed and Adjacent Portion of the Direct Drainage Area to Lake Michigan: 2013-2022

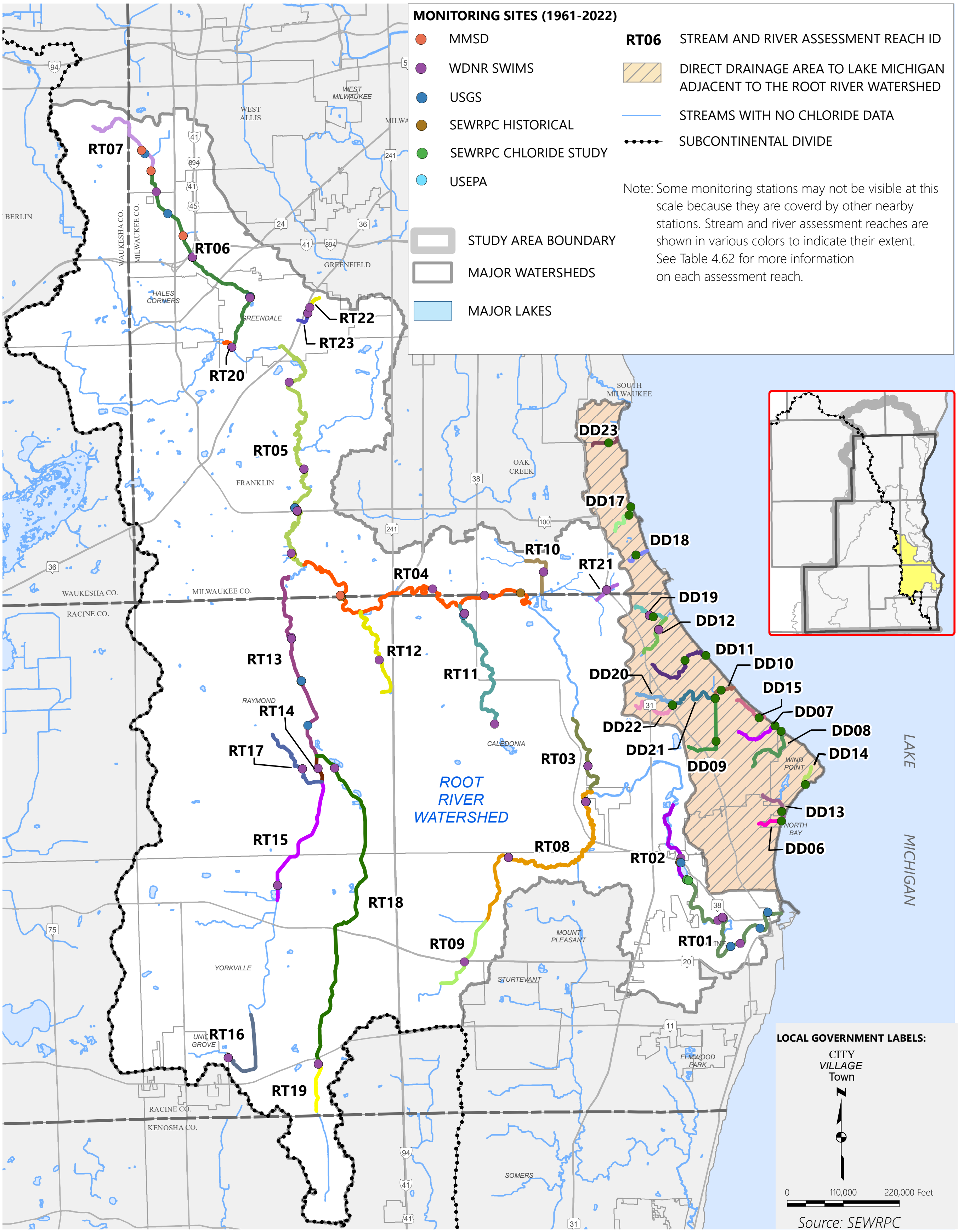


Map 4.130
Assessment Reaches Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan

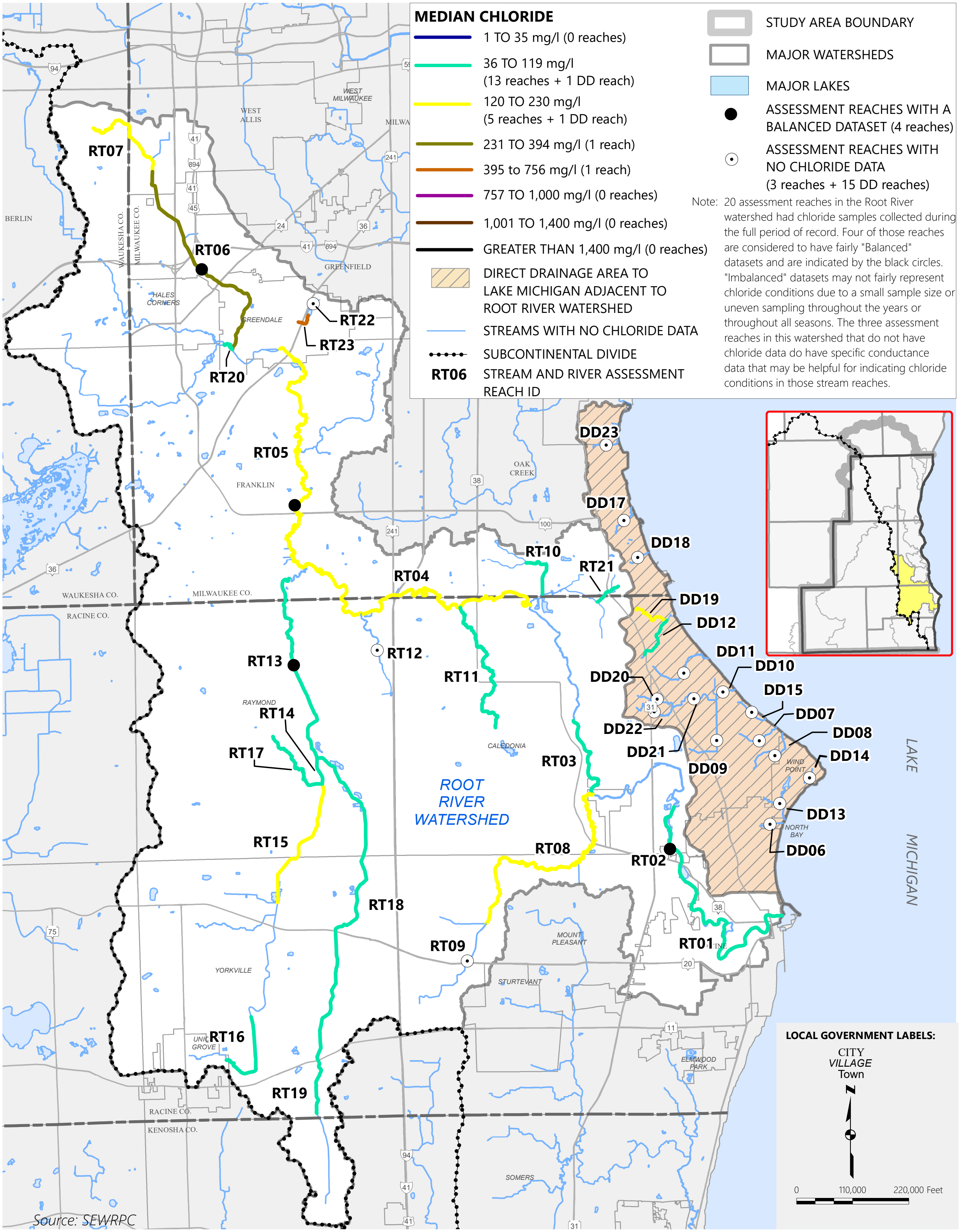


Source: SEWRPC

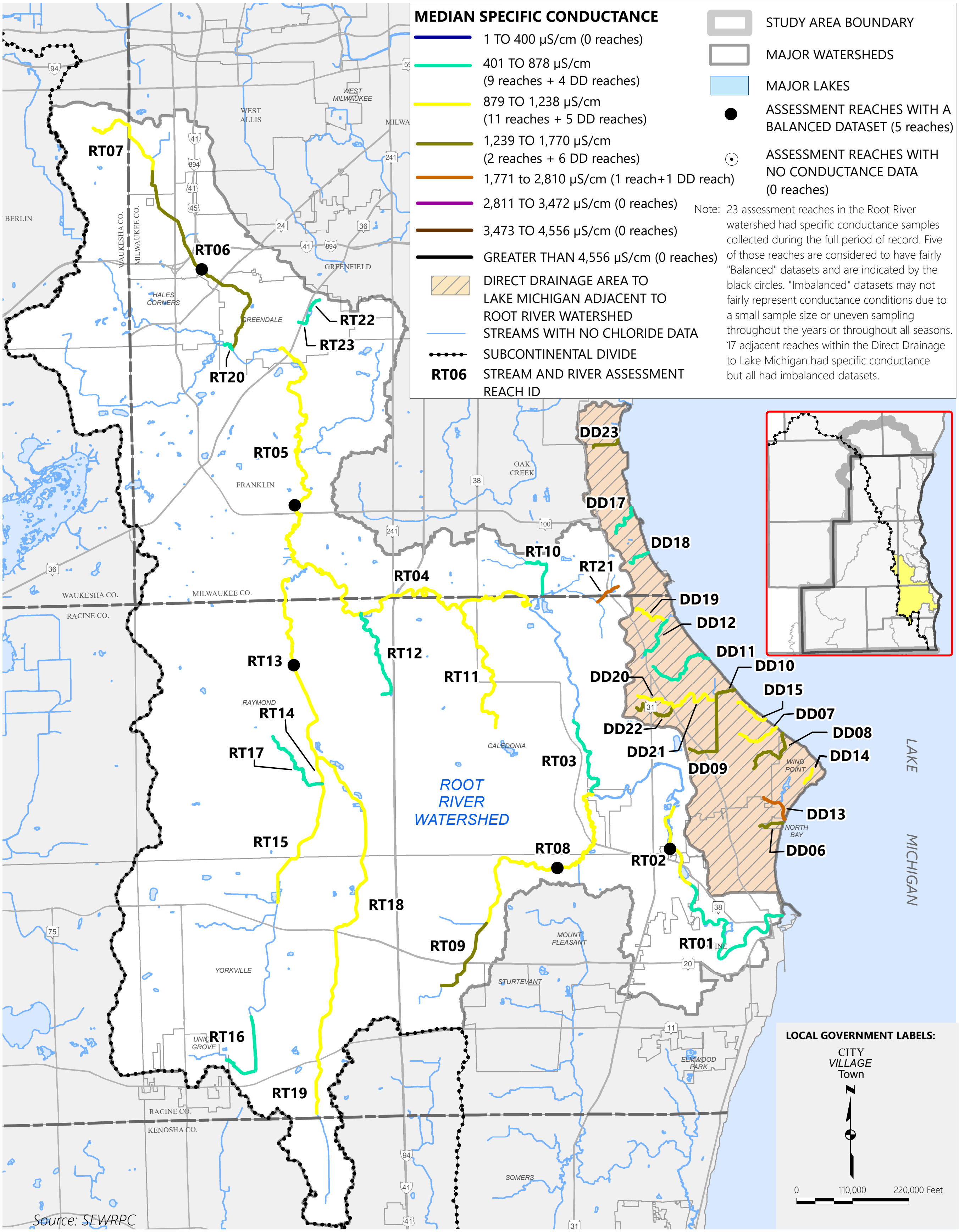
Map 4.131
Monitoring Sites and Assessment Reaches for Streams Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan



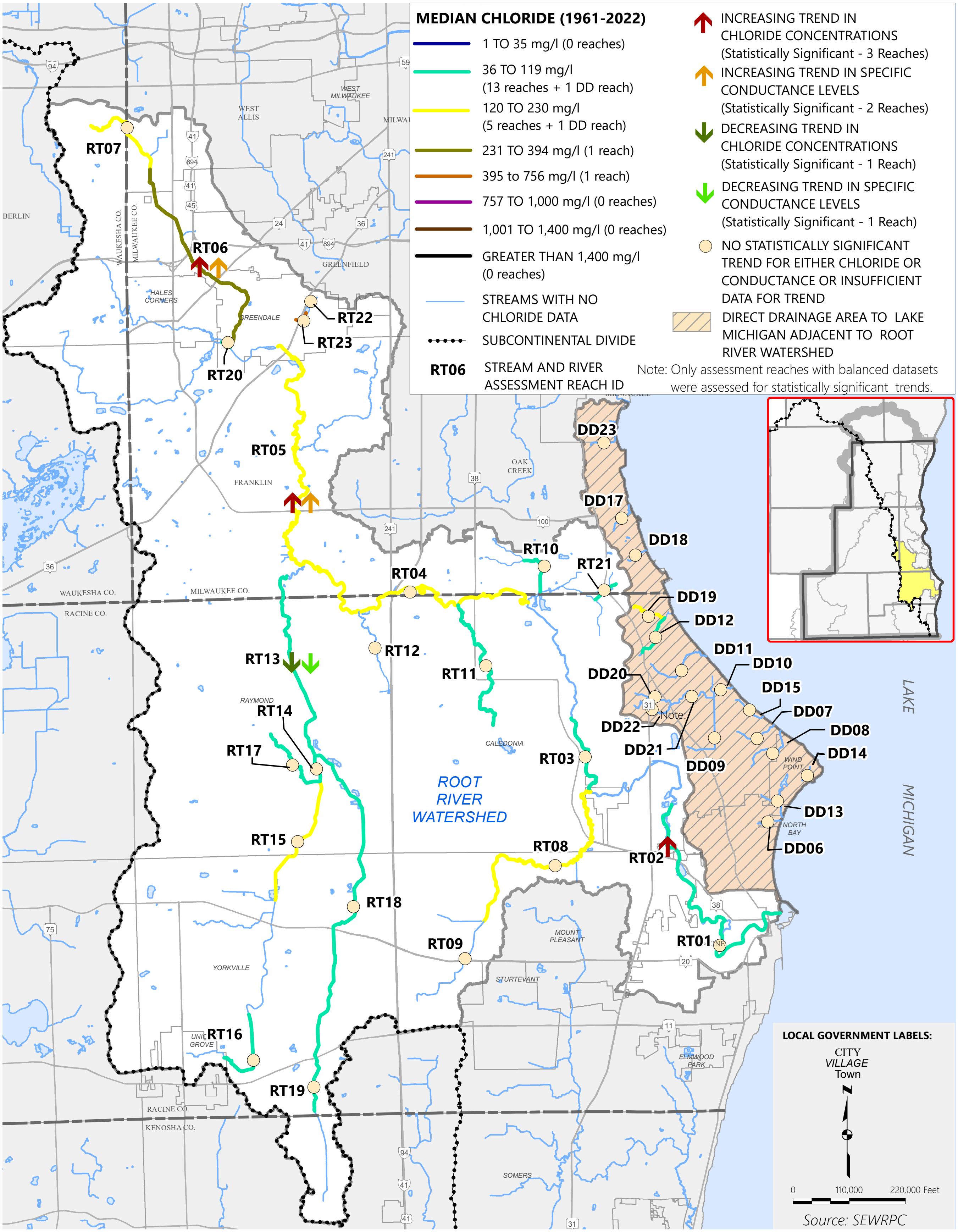
Map 4.132
Median Chloride Concentrations Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan for the Full Period of Record: 1961-2022



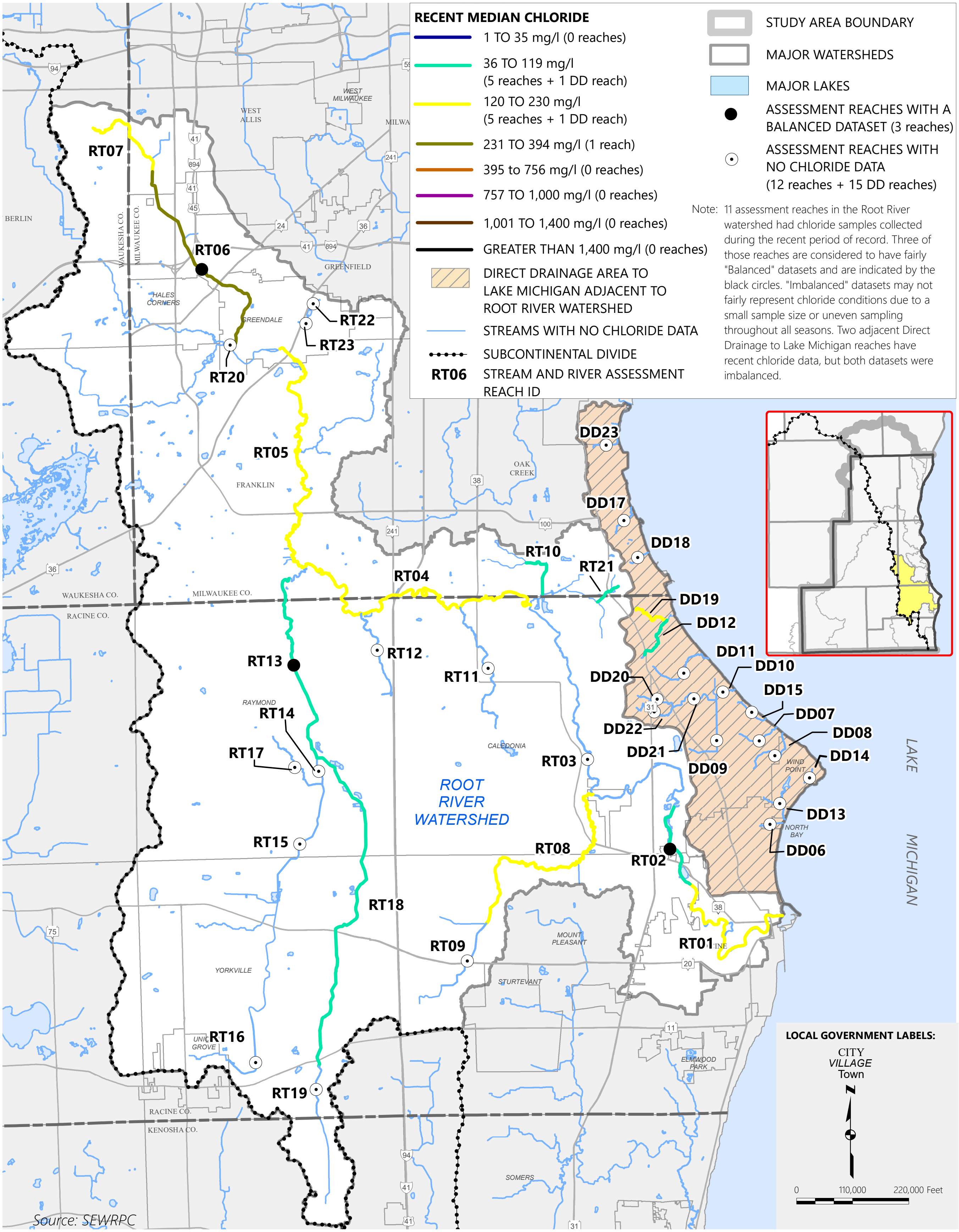
Map 4.133
Median Specific Conductance Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan for the Full Period of Record: 1961-2022



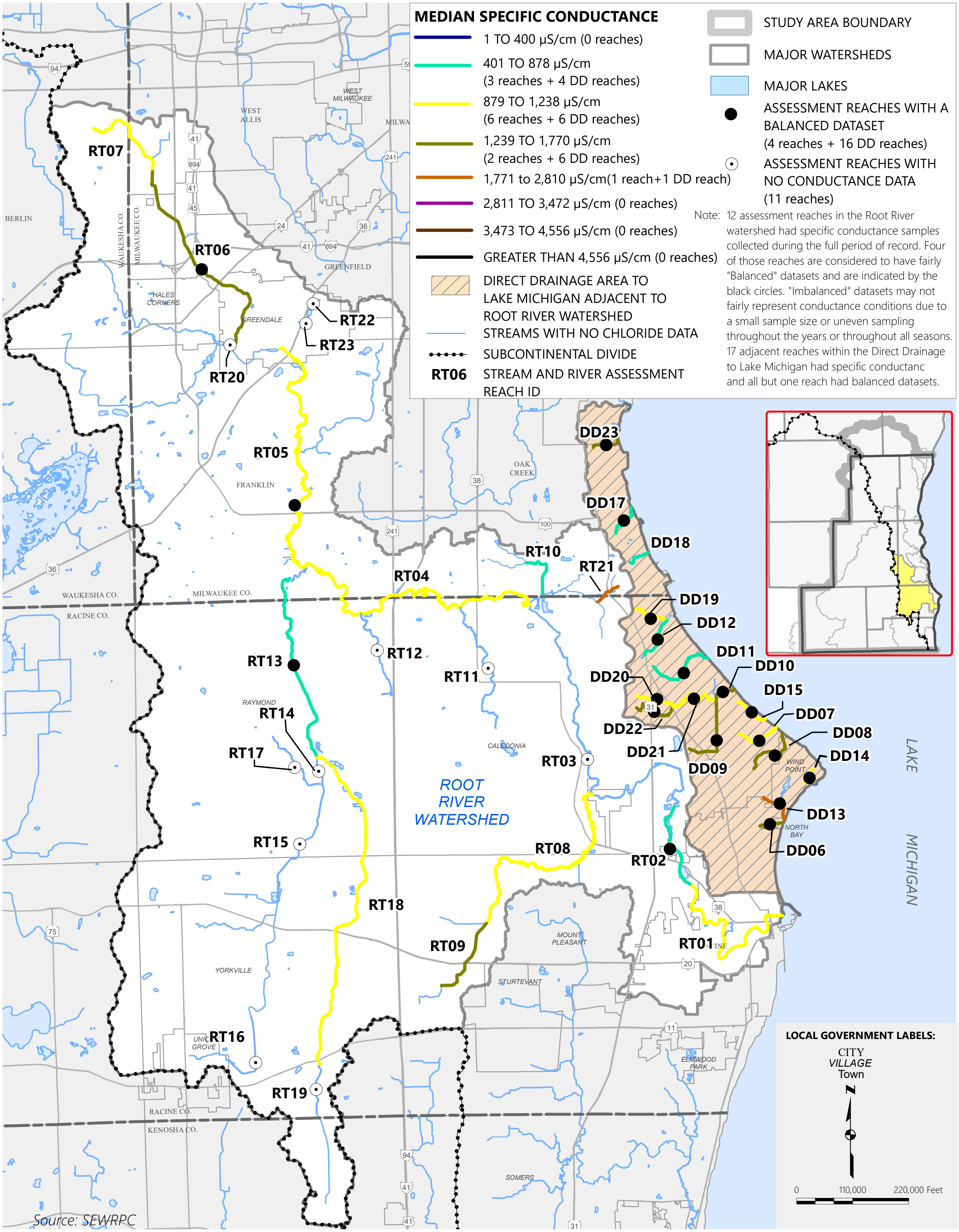
Map 4.134
Trends in Chloride and Specific Conductance Among Assessment Reaches Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan: 1961-2022



Map 4.135
Recent Median Chloride Concentrations Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan: 2013-2022

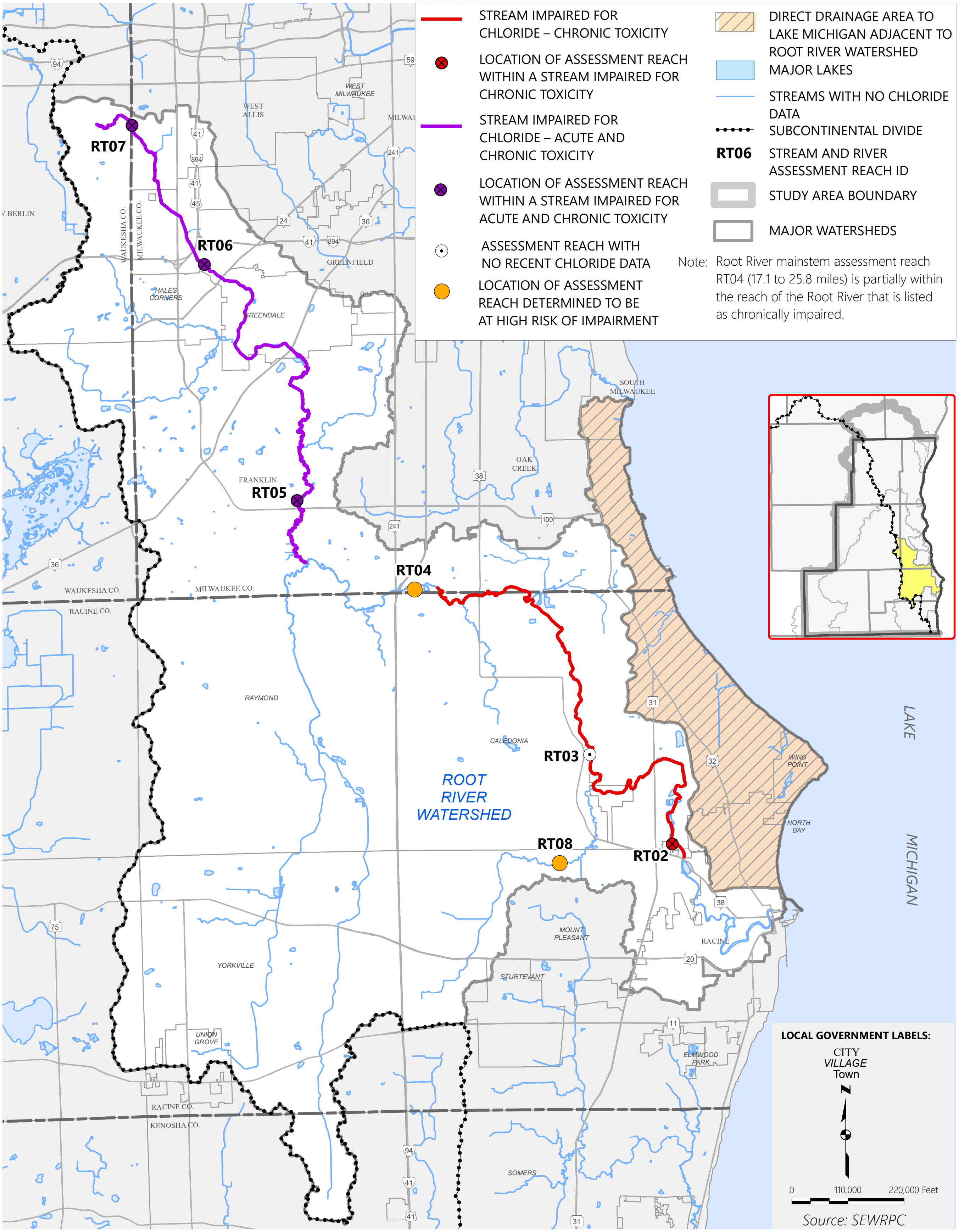


Map 4.136
Recent Median Specific Conductance Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan: 2013-2022

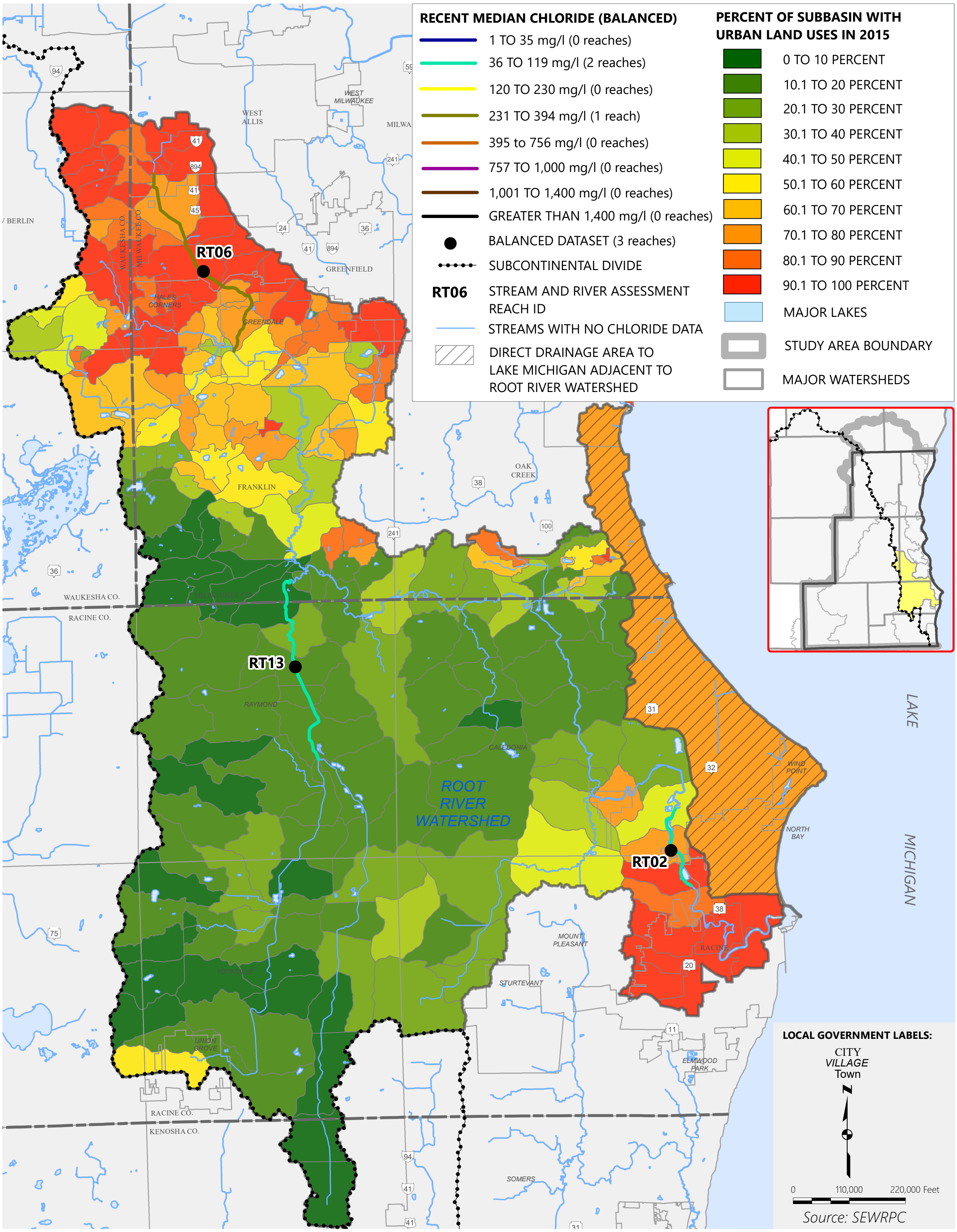


Source: SEWRPC

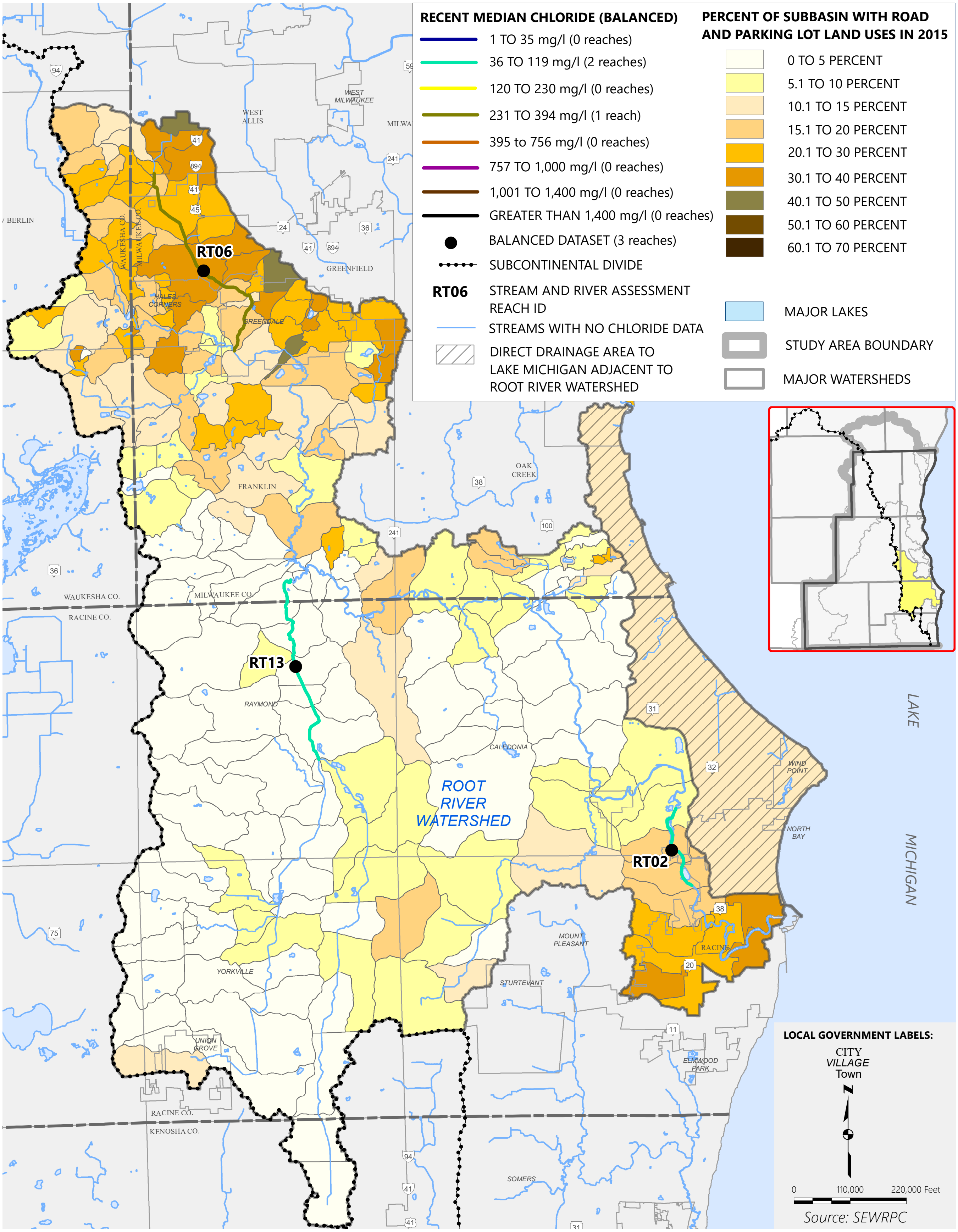
Map 4.137
Streams Impaired for Chloride Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan



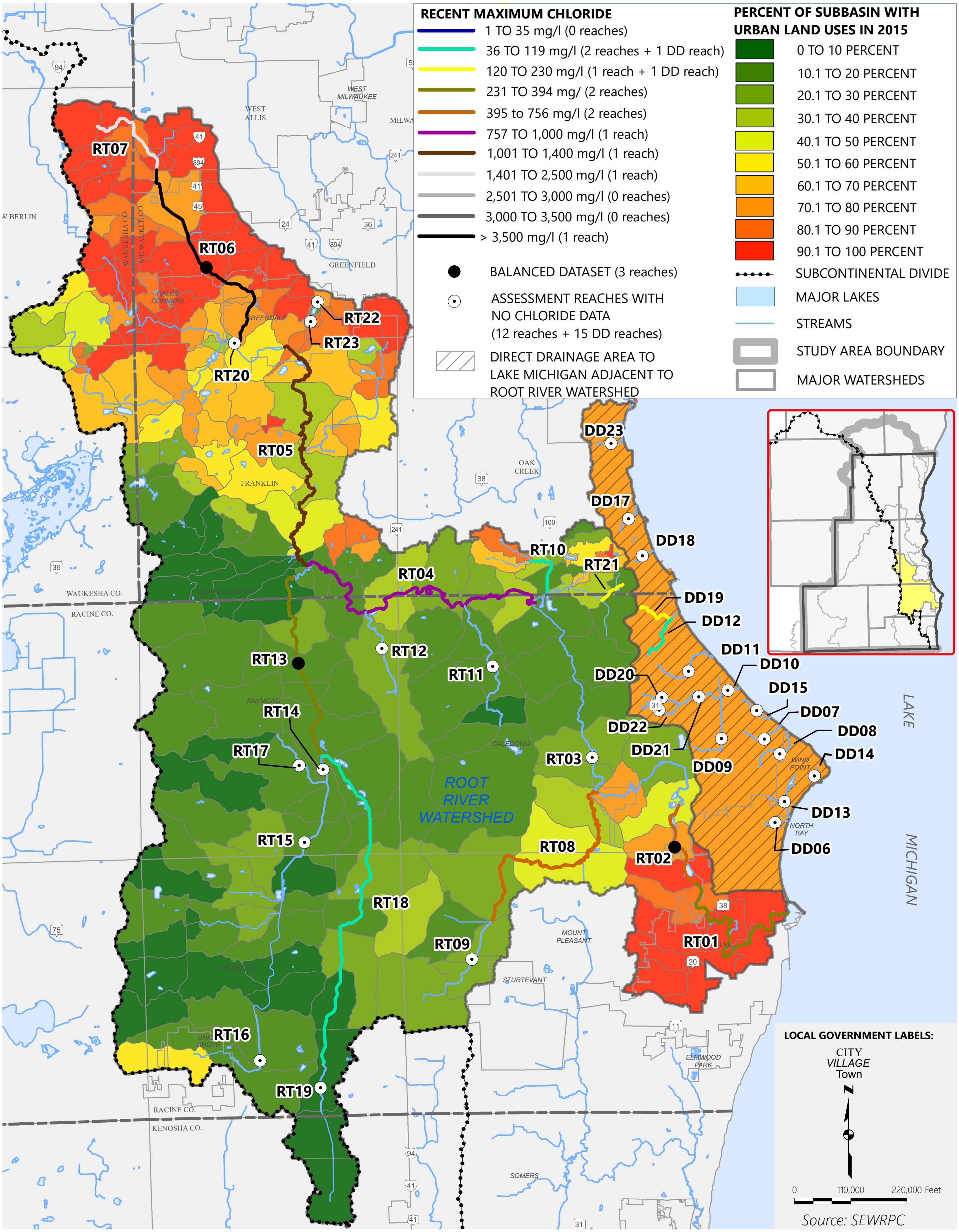
Map 4.138
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan and Percent Urban Land Use by Subbasin



Map 4.139
Recent Median Chloride Concentrations in Balanced Stream Assessment Reaches Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan and Road and Parking Lot Density by Subbasin



Map 4.140
Recent Maximum Chloride Concentrations in Stream Assessment Reaches Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan and Percent Urban Land Use by Subbasin



Map 4.141
Recent Maximum Chloride Concentrations in Stream Assessment Reaches Within the Root River Watershed and Adjacent Direct Drainage Area to Lake Michigan and Road and Parking Lot Density by Subbasin