Southeastern Wisconsin

Regional Planning Commission

Chloride Impact Study for the Southeastern Wisconsin Region

Technical Advisory Committee Meeting
Review of TR-65 *Mass Balance Analysis for Chloride in Southeastern Wisconsin*
October 8, 2025

Speakers

- Laura Herrick
  Chief Environmental Engineer

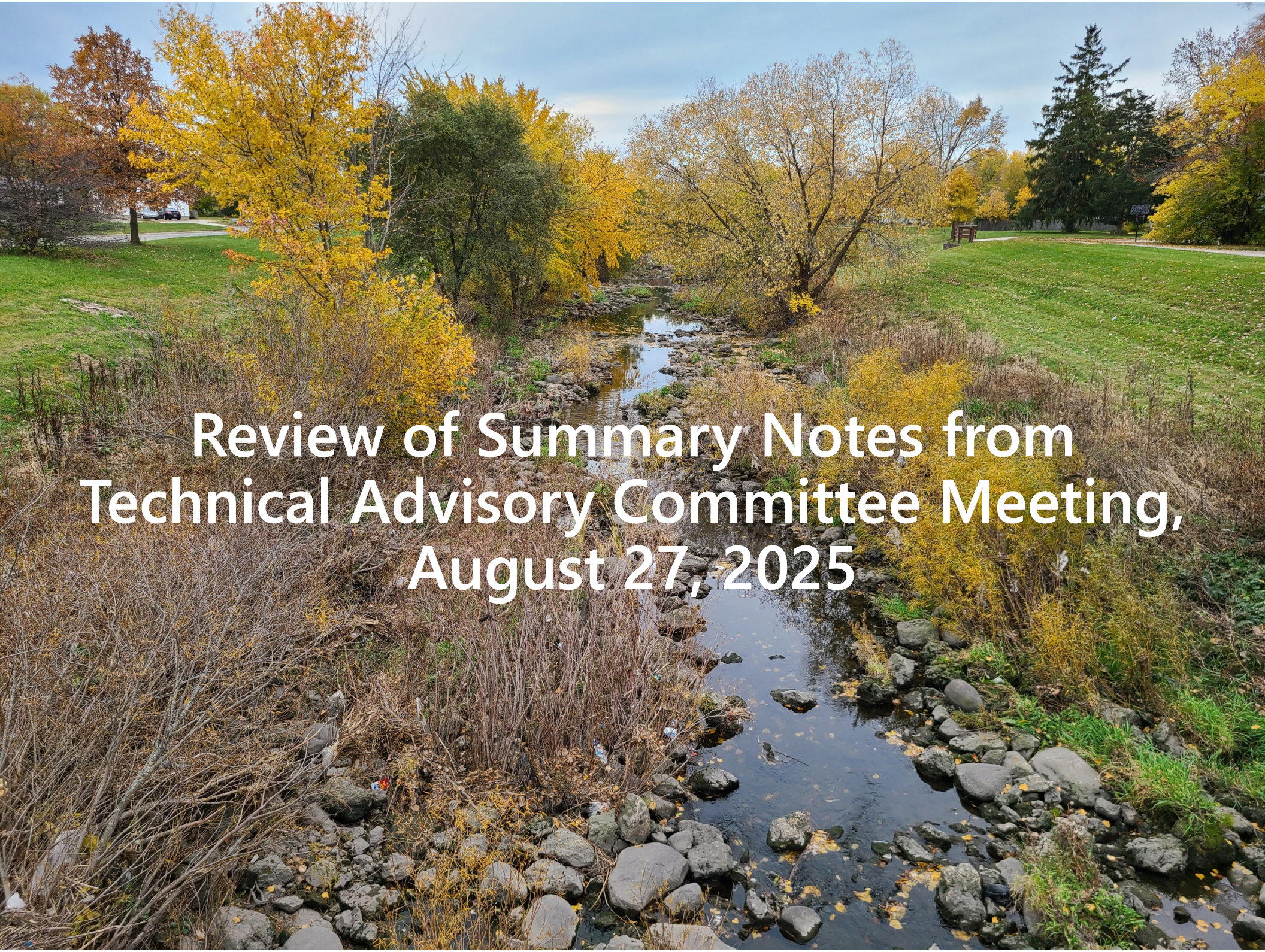
- Karin Hollister
  Principal Engineer

Agenda

- Review of Summary Notes from TAC meeting August 27, 2025
- Review of preliminary draft chapters of SEWRPC Technical Report No. 65, *Mass Balance Analysis for Chloride in Southeastern Wisconsin*
  - Chapter 1: Introduction
  - Chapter 2: Chloride Sources and Data for Chloride Loading and Mass Balance Analysis
  - Chapter 3: Chloride Loading and Mass Balance Analysis Methodology
  - Chapter 4: Chloride Loading and Mass Balance Analysis Results
  - Appendices
- Next Steps

Chloride Impact Study Reports

- TR-61 Field Monitoring and Data Collection for the Chloride Impact Study
- TR-62 Impacts of Chloride on the Natural and Built Environment
- TR-63 Chloride Conditions and Trends in Southeastern Wisconsin
- TR-64 Regression Analysis of Specific Conductance and Chloride Concentrations
- **TR-65 Mass Balance Analysis for Chloride in Southeastern Wisconsin**
- TR-66 State of the Art for Chloride Management
- TR-67 Legal and Policy Considerations for the Management of Chloride
- PR-57 A Chloride Impact Study for Southeastern Wisconsin



Review of Summary Notes from Technical Advisory Committee Meeting, August 27, 2025

Technical Report No. 65

Introduction

TR-65 Outline

- Chapter 1 Introduction
- Chapter 2 Chloride Sources and Data for Chloride Loading and Mass Balance Analysis
- Chapter 3 Chloride Loading and Mass Balance Analysis Methodology
- Chapter 4 Chloride Loading and Mass Balance Analysis Results
- Appendix A Abbreviations and Acronyms
- Appendix B Drainage Area Characteristics for Stream Monitoring Sites
- Appendix C Mass Balance Analysis Results for Stream Monitoring Sites

General Notes on this Report

This report presents the chloride loads developed for the Region and individual stream monitoring sites, along with the results of the chloride mass balance analysis for Southeastern Wisconsin

- Study background and chloride sources
- Data used to develop chloride loads and mass balance analysis
- Methods and assumptions used to develop chloride loads and mass balance analysis
- Evaluation of results and conclusions
  - Regional chloride budget: Regional chloride source loads
  - Chloride source loads at stream monitoring sites
  - Chloride mass balance analysis at select stream monitoring sites

Chloride Mass Load Terms and Definitions

The chloride mass load, or chloride load, refers to the amount of chloride entering the environment over a specific period of time.

- Point Source Chloride Loads

  = *Chloride Concentration x Effluent Flow Rate*

- Nonpoint Source Chloride Loads

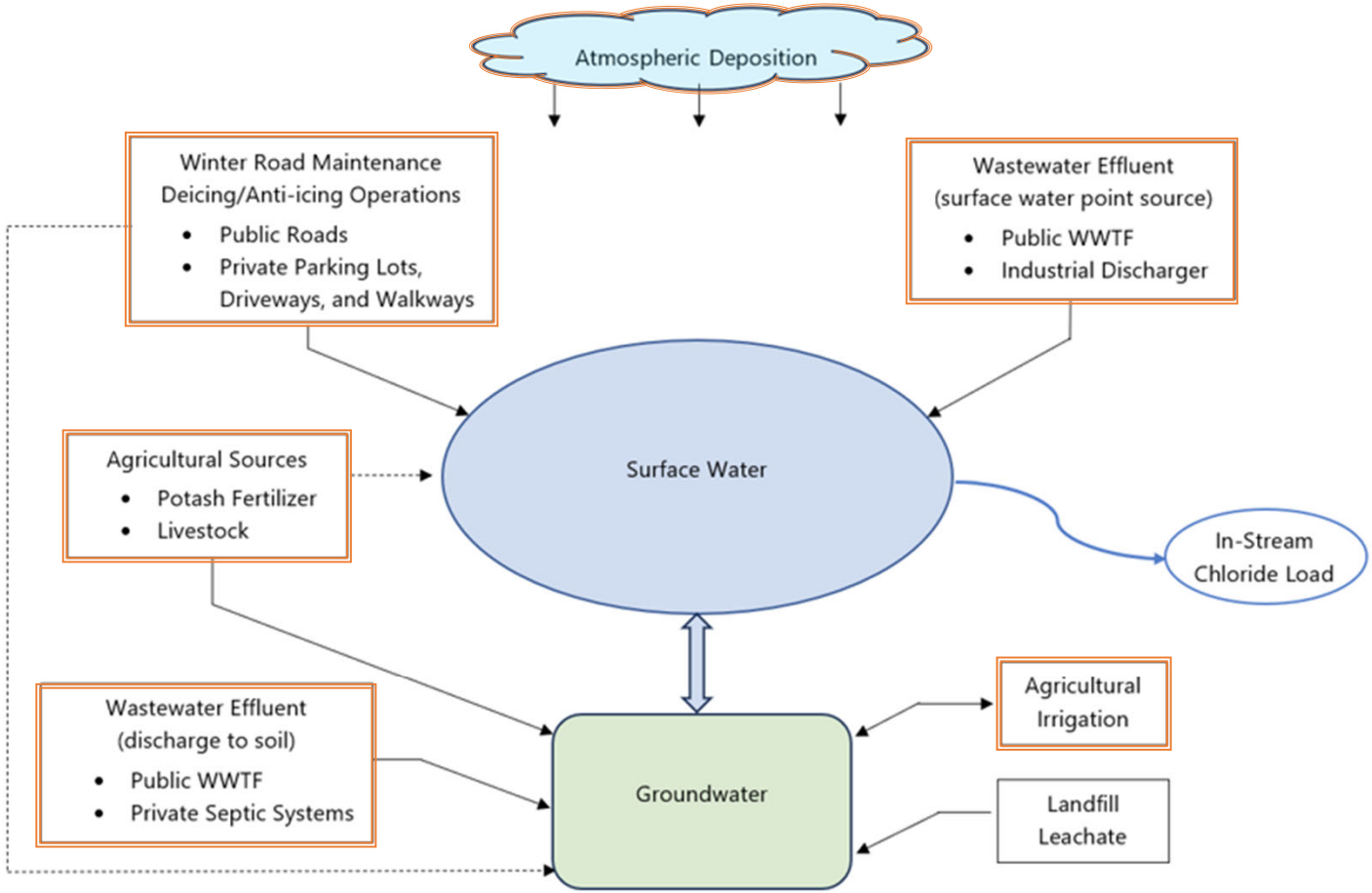
  = *Chloride Application Rate x Area of Application*

- In-Stream Chloride Loads

  = *Chloride Concentration x Streamflow Discharge Rate*

Regional Chloride Budget

Figure 2.9
Regional Chloride Sources and Simplified Transport Schematic

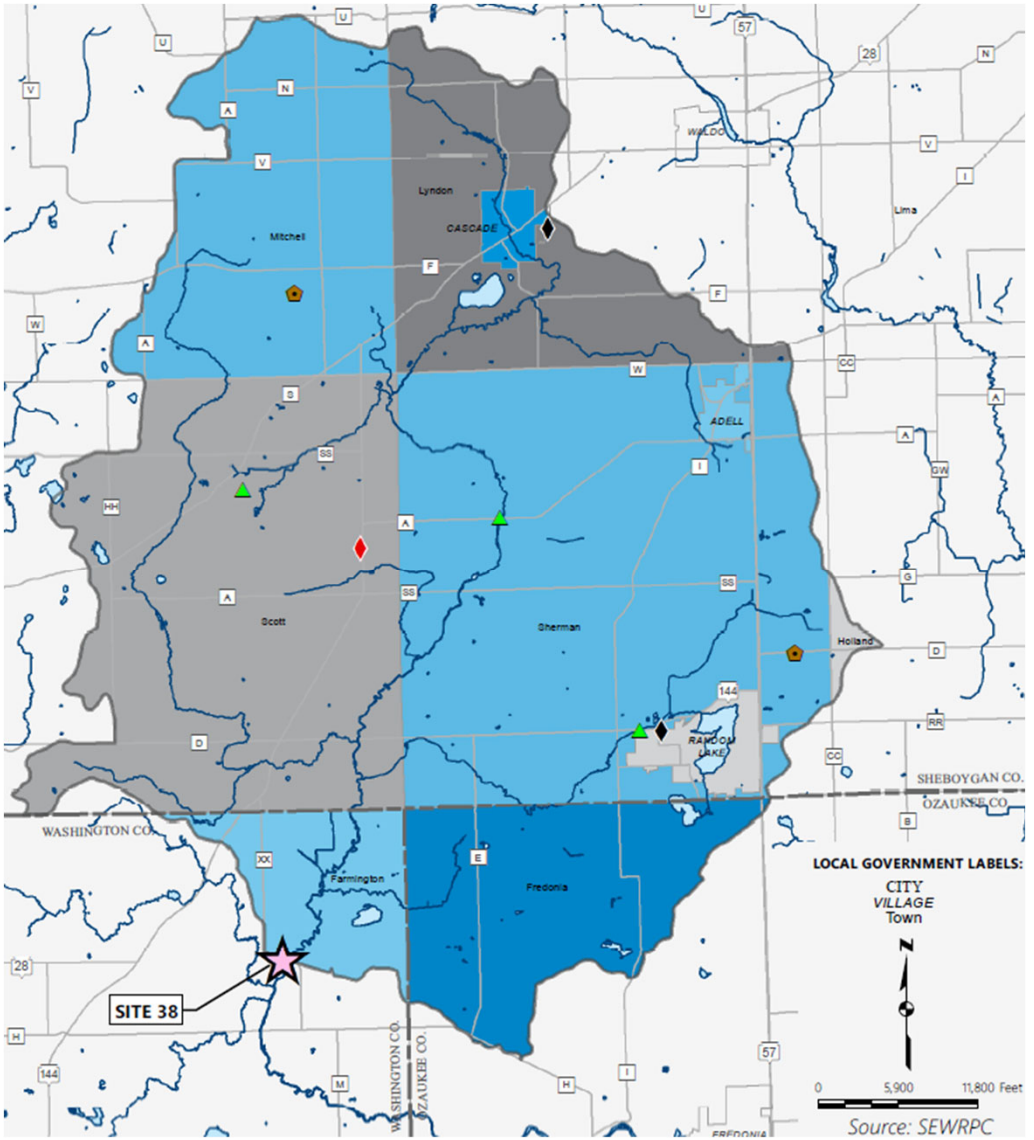


Note: Solid arrows define primary transport pathways and arrows with dashed lines define secondary transport pathways. For agricultural sources, the transport pathway to surface water may be considered primary for agricultural fields underlain by drain tiles.

Source: SEWRPC

Monitoring Site Chloride Source Loads

- Natural Sources
  - Atmospheric deposition
- Winter Maintenance Operations
  - Public roadways
  - Private parking lots
- Wastewater Effluent
  - Public WWTF
  - Industrial dischargers
- Agricultural Sources
  - Potash fertilizer
  - Livestock manure



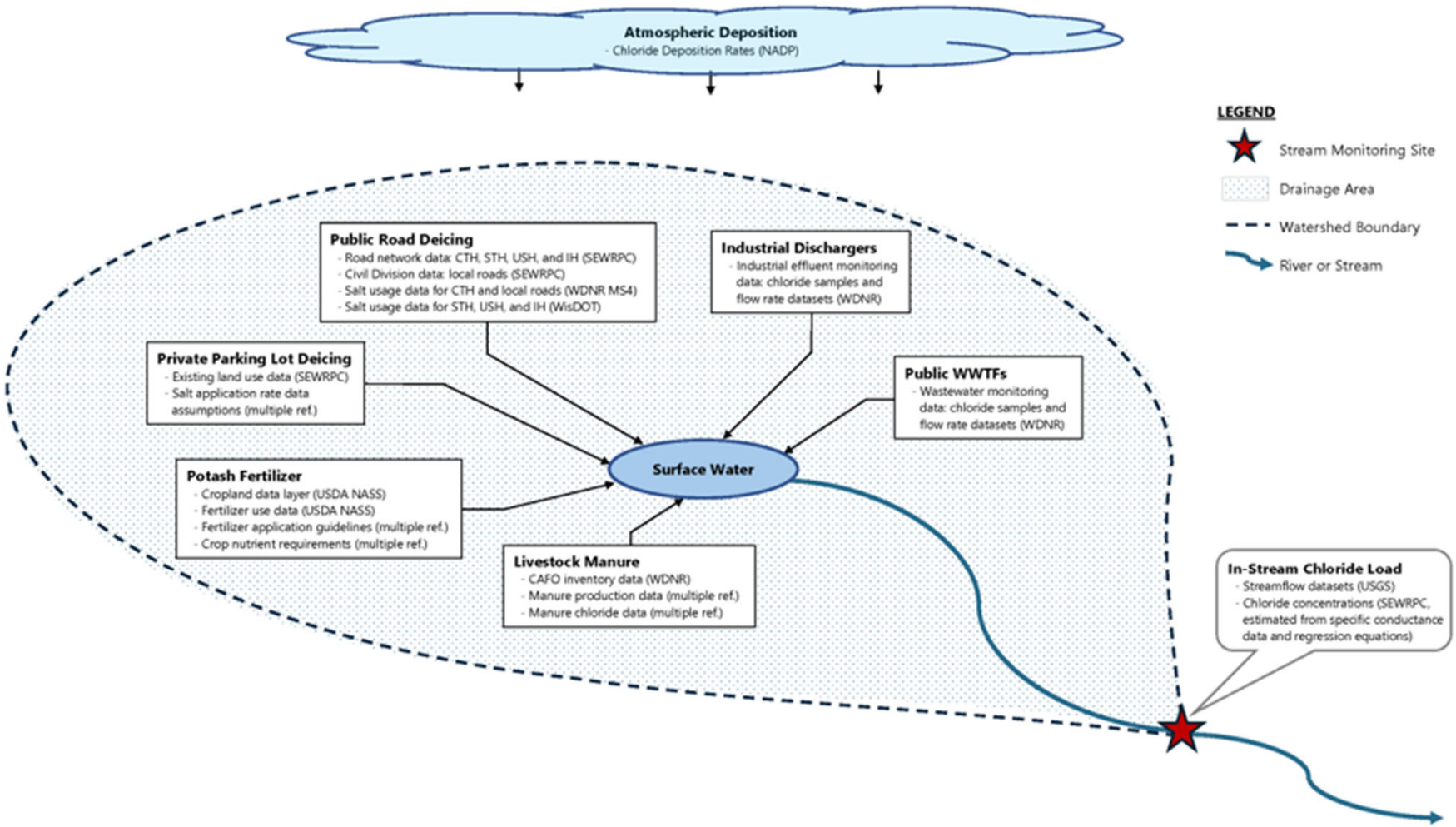
Chloride Mass Balance Analysis

Σ Chloride Inputs – Chloride Output = Δ Chloride Retained in the System

- **Σ Chloride Inputs** = Sum of point and nonpoint source chloride loads
- **Chloride Output** = Estimated in-stream chloride load
- The change in the amount of chloride retained in the mass balance system or watershed is equal to the sum of chloride inputs minus the chloride output, exported out of the system.

Chloride Mass Balance Analysis

Figure 3.1
Chloride Mass Balance Schematic for Stream Monitoring Sites



Note: Interactions between surface water and groundwater were not quantified for the mass balance analysis.

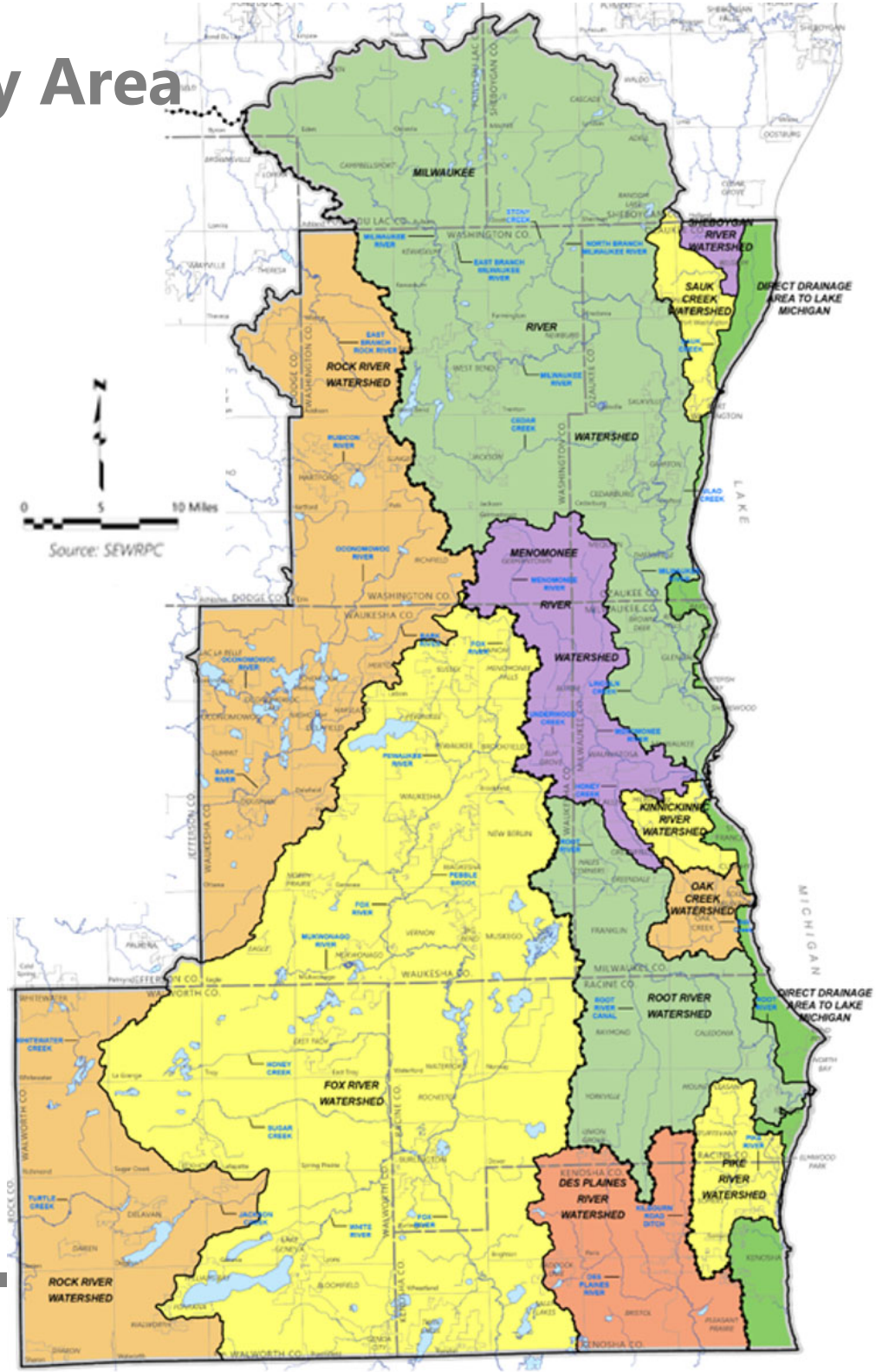
Source: SEWRPC


Study Area Overview

Chloride Impact Study Area

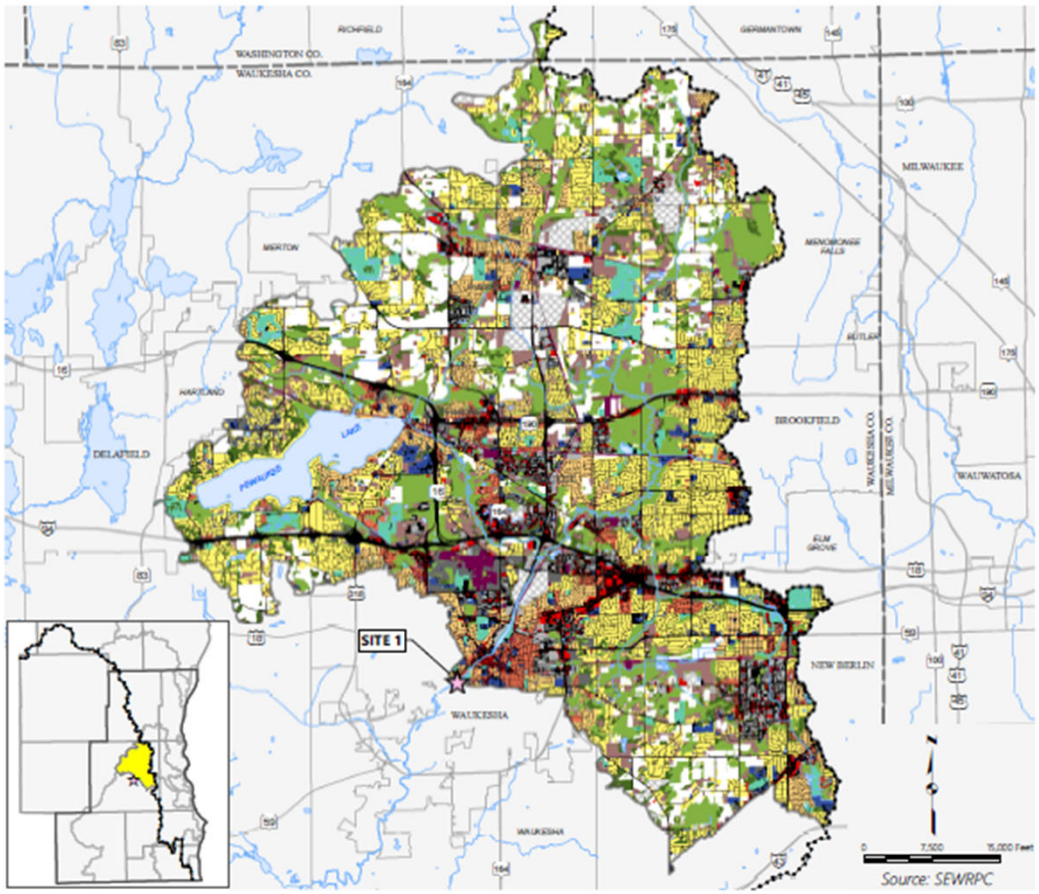
Major Watersheds in the Study Area

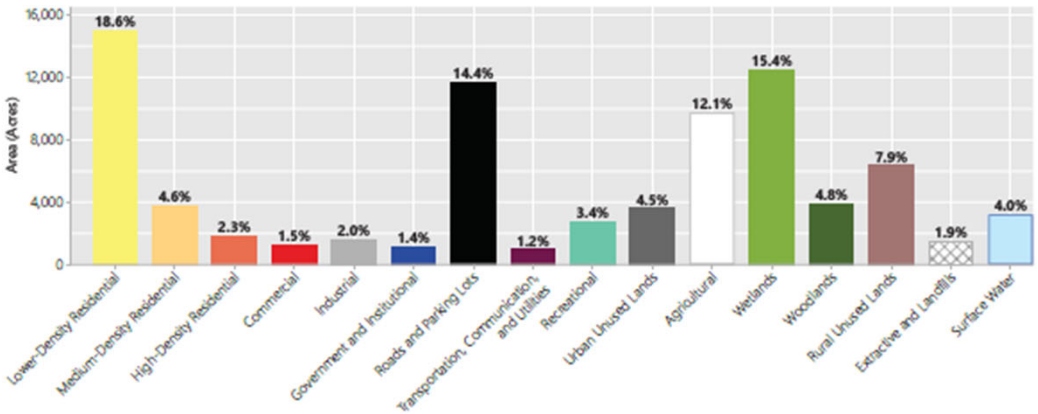
- Des Plaines River
- Fox River
- Kinnickinnic River
- Menomonee River
- Milwaukee River
- Oak Creek
- Pike River
- Rock River
- Root River
- Sauk Creek
- Sheboygan River
- Direct Drainage to Lake Michigan



Study Area Land Use

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





Existing Land Use

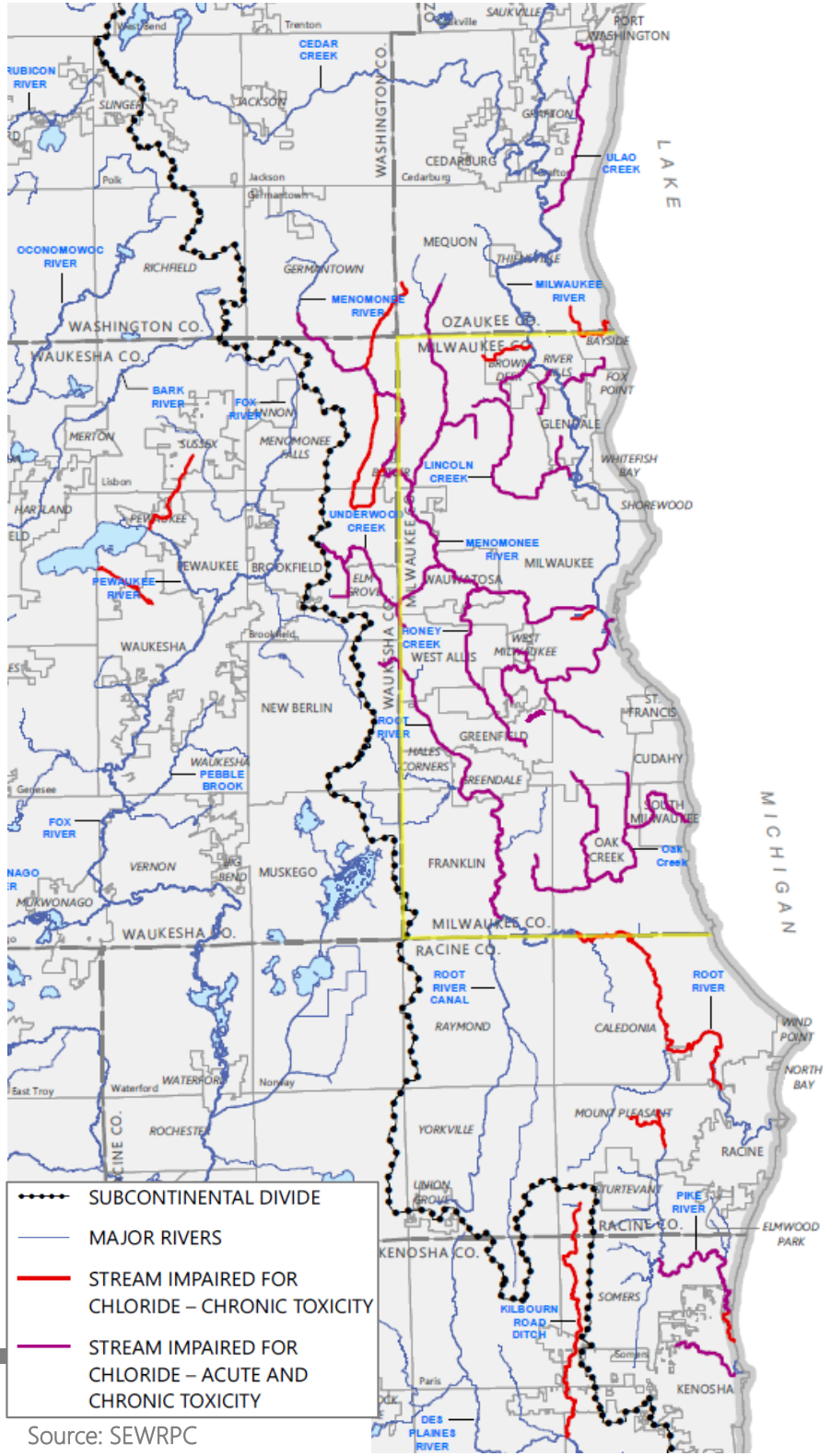
- 2015 SEWRPC Regional Land Use Inventory
- 16 land use groups for Study
  - 10 urban land use groups
  - 6 nonurban land use groups
- Out-of-Region data obtained from neighboring counties
- Appendix B presents land use maps for each stream monitoring site drainage area

Chloride Impairments

- As of 2022, 35 waterbodies in southeastern Wisconsin were listed as impaired due to exceeding chloride toxicity thresholds

- Wisconsin criteria for chloride toxicity
  - Chronic 395 mg/l (10)
  - Acute 757 mg/l (25)

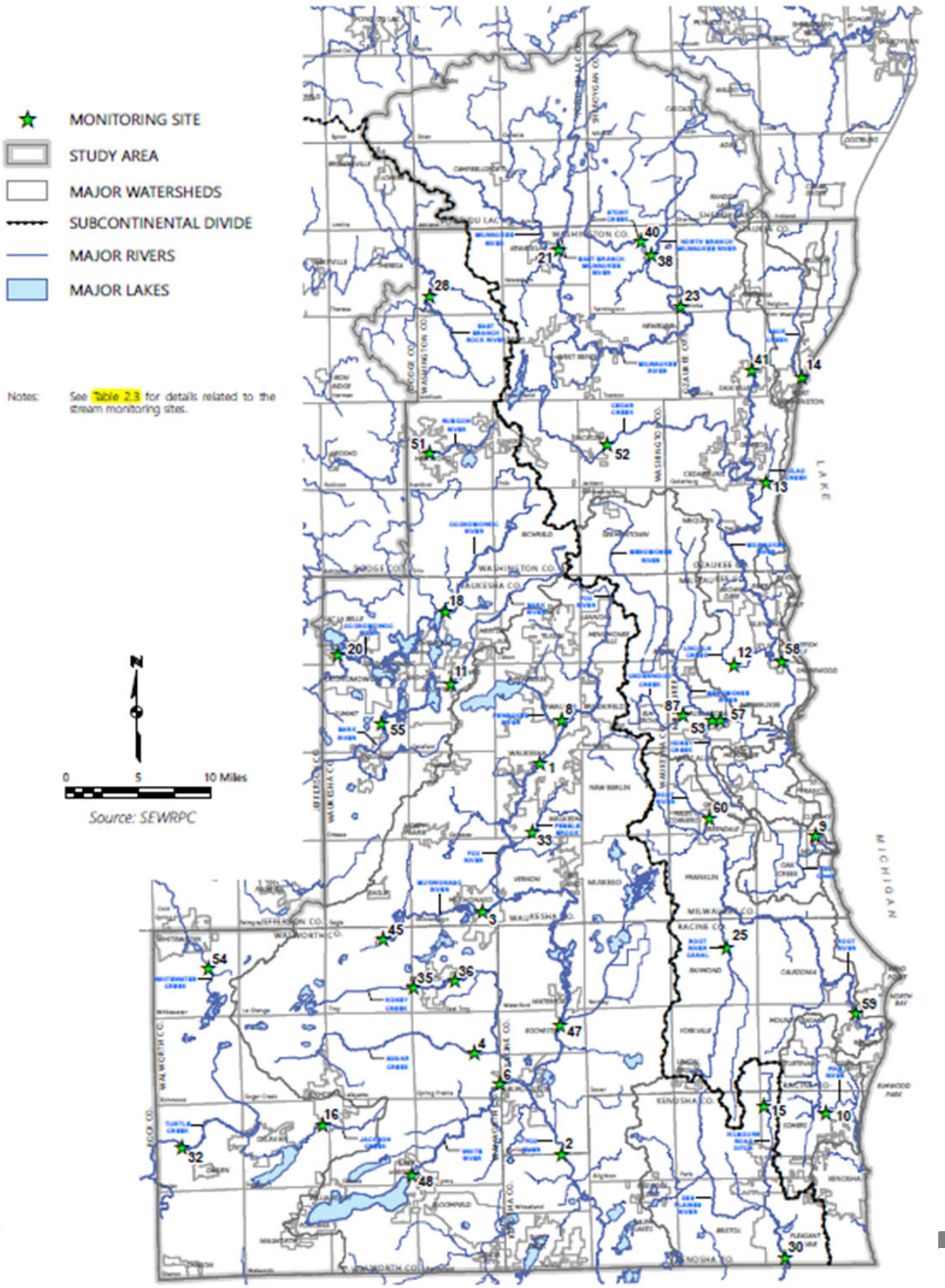
Jurisdiction	Chronic Toxicity Criterion (mg/l)	Acute Toxicity Criterion (mg/l)	General Chloride Criterion (mg/l)
Canada	120	640	--
Illinois	--	--	500
Michigan	150	640	--
Minnesota	230	860	--
Wisconsin	395	757	--



Source: SEWRPC

Stream Monitoring Sites

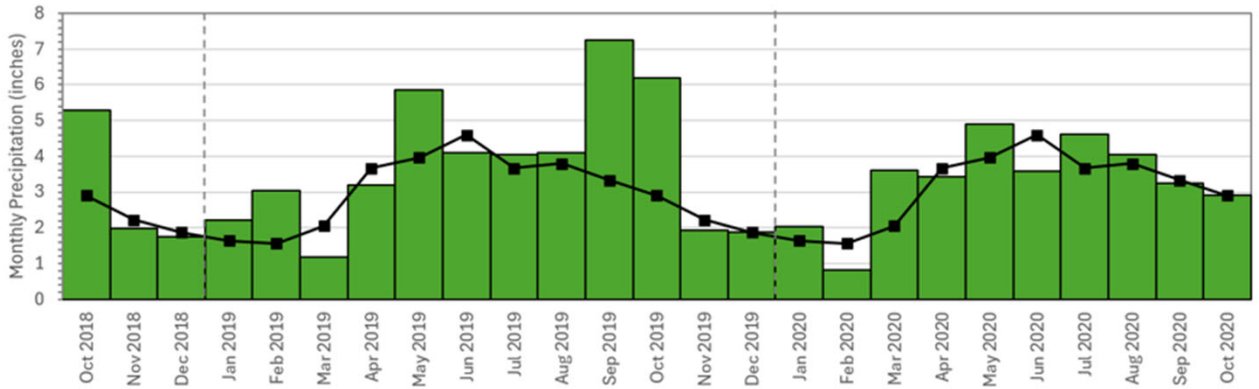
Map 2.3
Stream Monitoring Sites for the Chloride Impact Study



- 41 sites across the Region
- Study period data collection October 2018 – October 2020
- Continuous Monitoring (5-min)
  - Specific Conductance
  - Temperature
  - Depth of water above sensor
- Water quality grab samples
  - Monthly chloride samples
  - Winter event samples

Study Period Weather Conditions

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



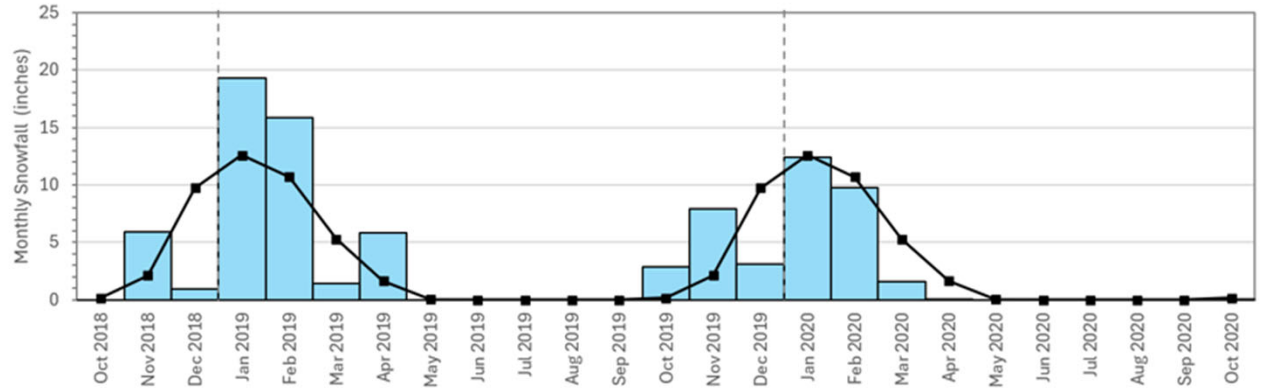
Note: The solid line represents the 30-year normal or average monthly precipitation.

Source: Wisconsin State Climatology Office and NOAA NCEI

Avg. Annual Precip. = 35.28 in

- 2018 = 44.86 in (**#2** wettest)
- 2019 = 45.02 in (**#1** wettest)
- 2020 = 36.76 in

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

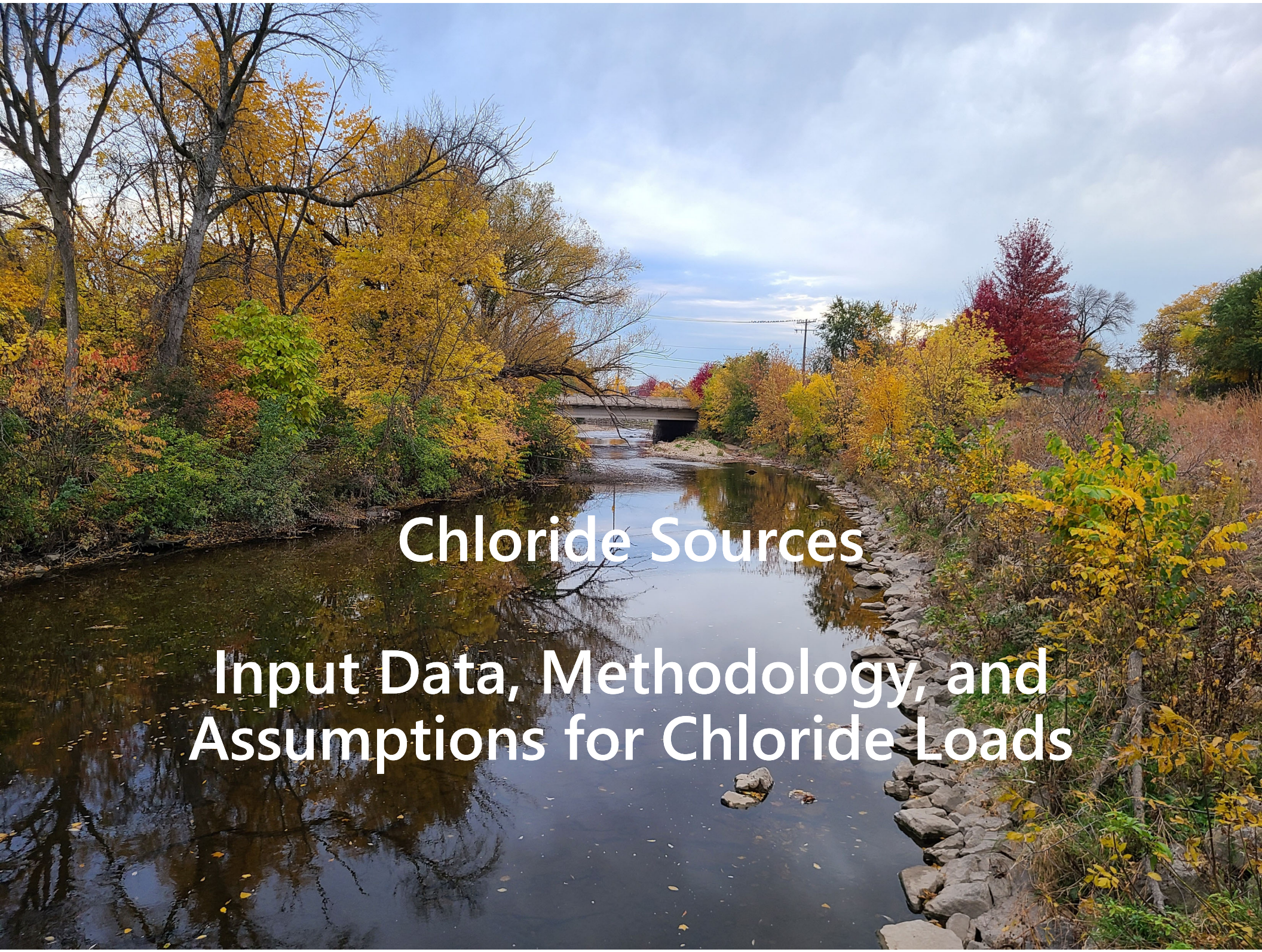


Note: The solid line represents the 30-year normal or average monthly snowfall.

Source: Wisconsin State Climatology Office and NOAA NCEI

Avg. Winter Snowfall = 42.3 in

- Winter 2018-19 = 49.4 in
- Winter 2019-20 = 37.8 in

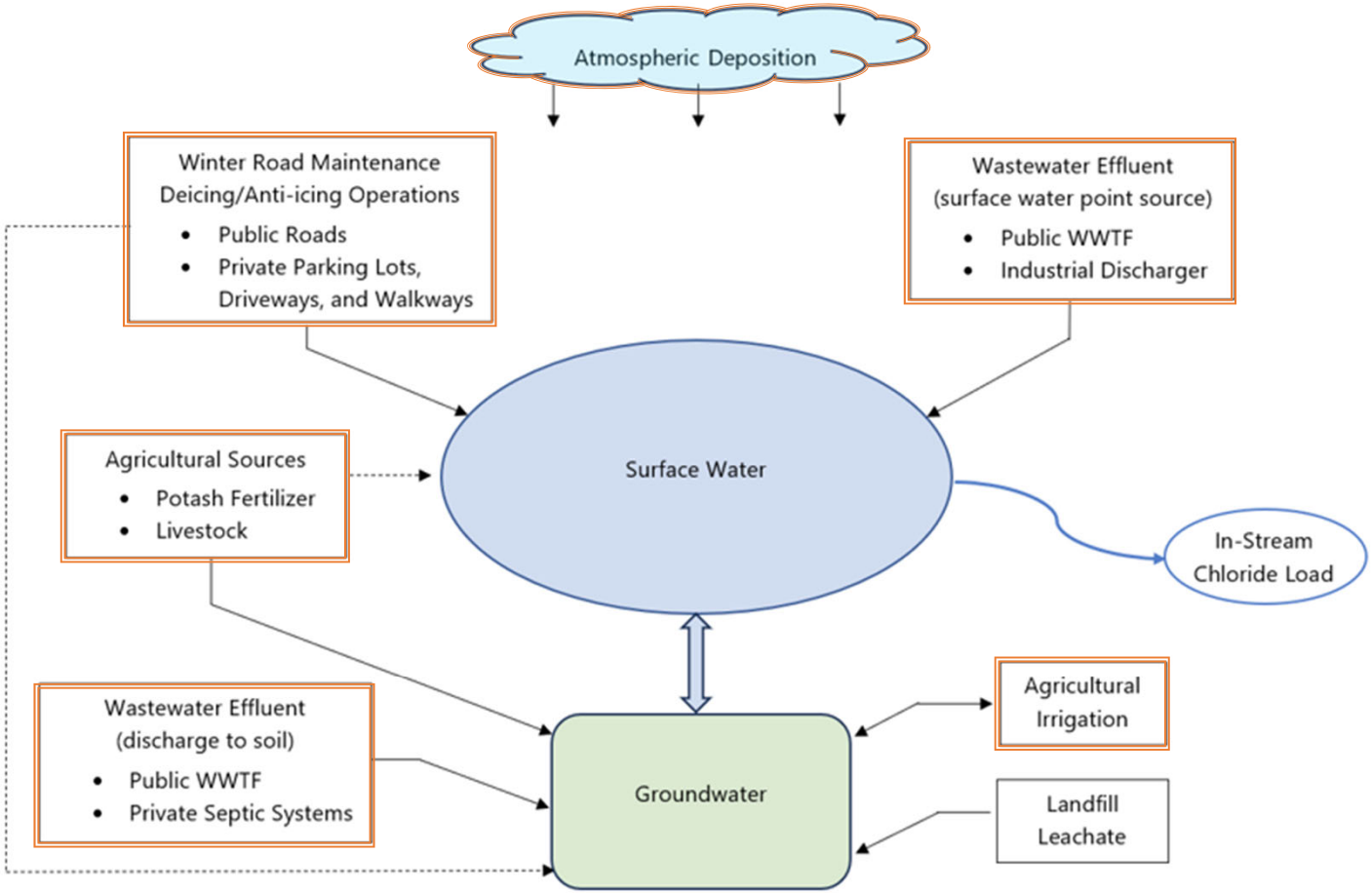


Chloride Sources

Input Data, Methodology, and Assumptions for Chloride Loads

Sources of Chloride

Figure 2.9
Regional Chloride Sources and Simplified Transport Schematic



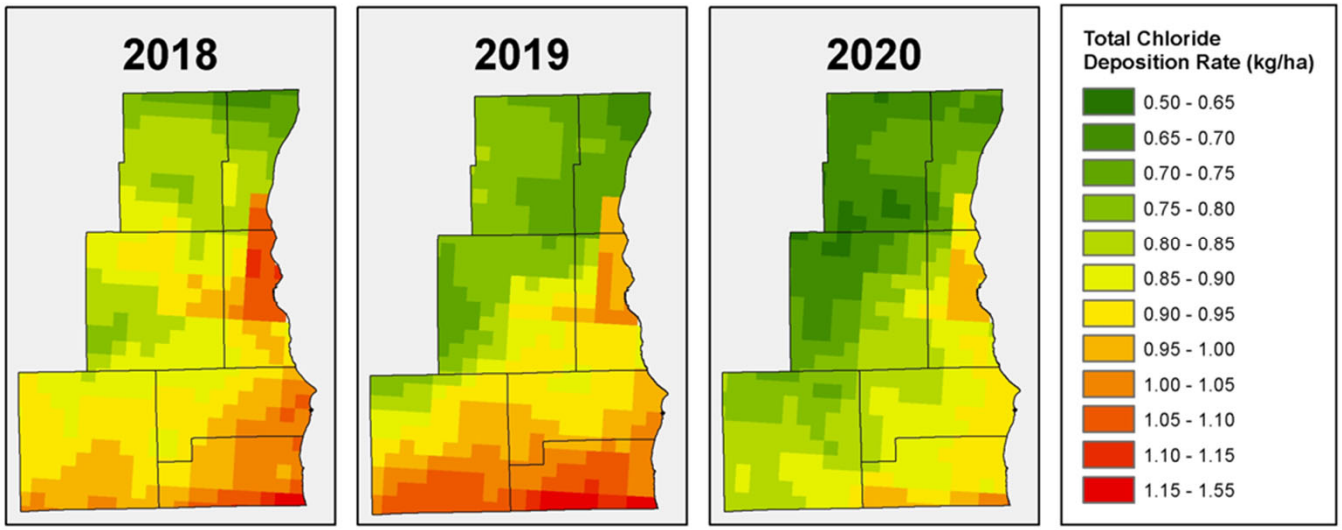
Note: Solid arrows define primary transport pathways and arrows with dashed lines define secondary transport pathways. For agricultural sources, the transport pathway to surface water may be considered primary for agricultural fields underlain by drain tiles.

Source: SEWRPC

Chloride Load from Atmospheric Deposition

- Natural source of chloride
- Total deposition includes wet and dry deposition
- Gridded 4 km x 4 km raster data obtained from the National Atmospheric Deposition Program (NADP)
- Geospatial intersections with Counties and monitoring site drainage areas

Figure 3.4
Atmospheric Deposition of Chloride: Total Deposition Rates for the Region 2018–2020



Source: NADP and SEWPRC

Chloride Load from Atmospheric Deposition

- Average annual chloride contribution over Region = **660 tons/year**
- Relatively stable over the study period and last 10 years
- Baseline for comparison, expressing other sources in terms of equivalent amount of chloride from atmospheric deposition (Cl_{atm})

Table 3.1
Annual Chloride Loads from Atmospheric Deposition: 2018–2020

County	2018 (tons)	2019 (tons)	2020 (tons)
Kenosha	80.7	85.0	72.8
Milwaukee	68.8	65.1	62.5
Ozaukee	54.0	49.9	49.5
Racine	92.7	92.2	84.7
Walworth	152.8	159.0	134.9
Washington	100.7	94.4	84.5
Waukesha	144.2	135.7	123.1
Region	693.9	681.2	612.0

Source: NADP and SEWRPC

Winter Maintenance Operations

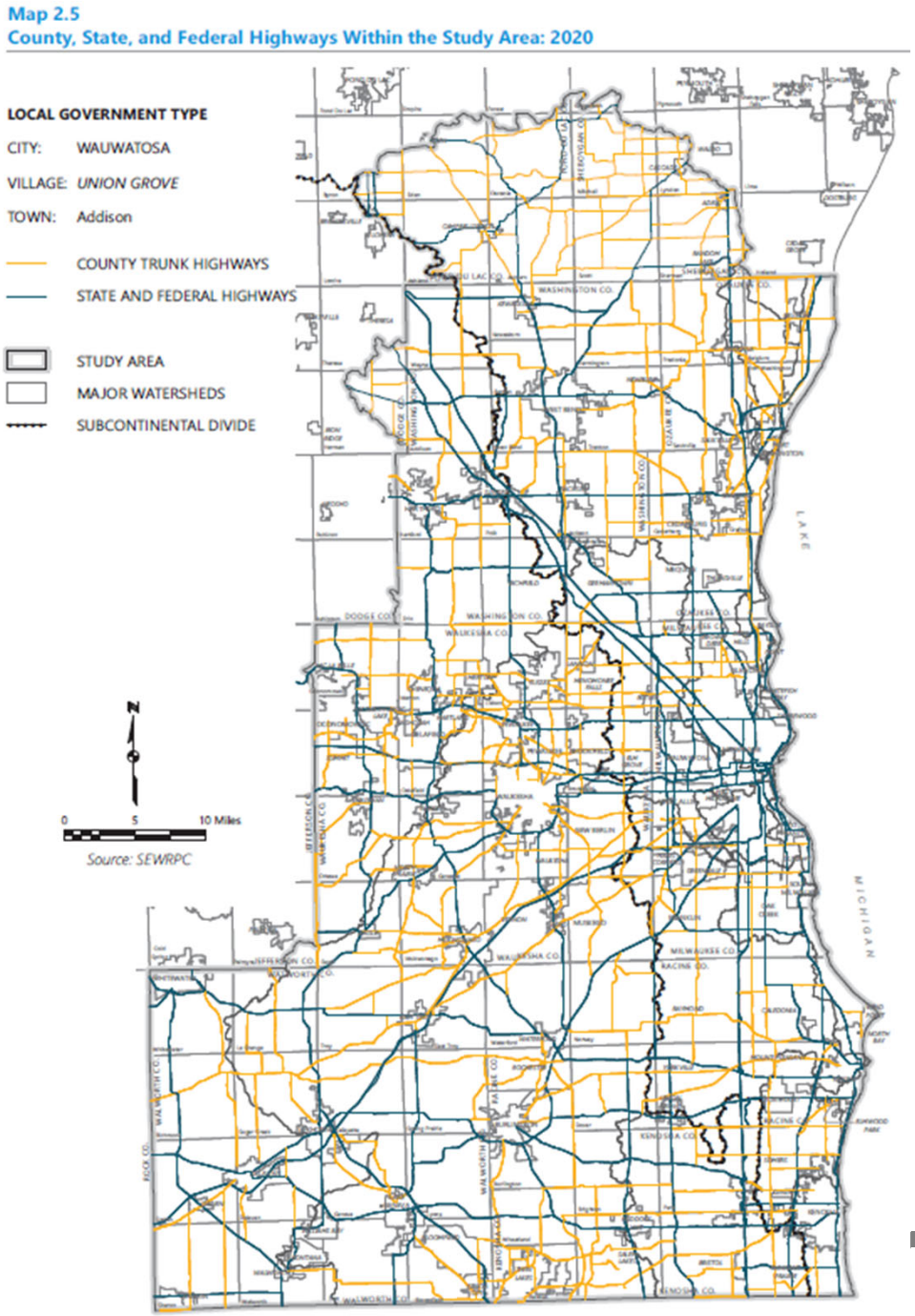
- Chloride-based compounds used to manage snow and ice on impervious surfaces
  - Sodium chloride (NaCl), rock salt or liquid salt brine
  - Calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$)
- Various jurisdictions are responsible for deicing and anti-icing operations on public roads
- Assumed even distribution or consistent application of deicing materials across all of the roadways within a jurisdiction

Source: Henry Jorgenson (via Reflo's Milwaukee Water Stories, by Michael Timm)

- State and Federal Highway Deicing Salt (WisDOT data)
- County and local roadways Deicing Salt (MS4 data)
- Private Parking Lot Deicing Salt

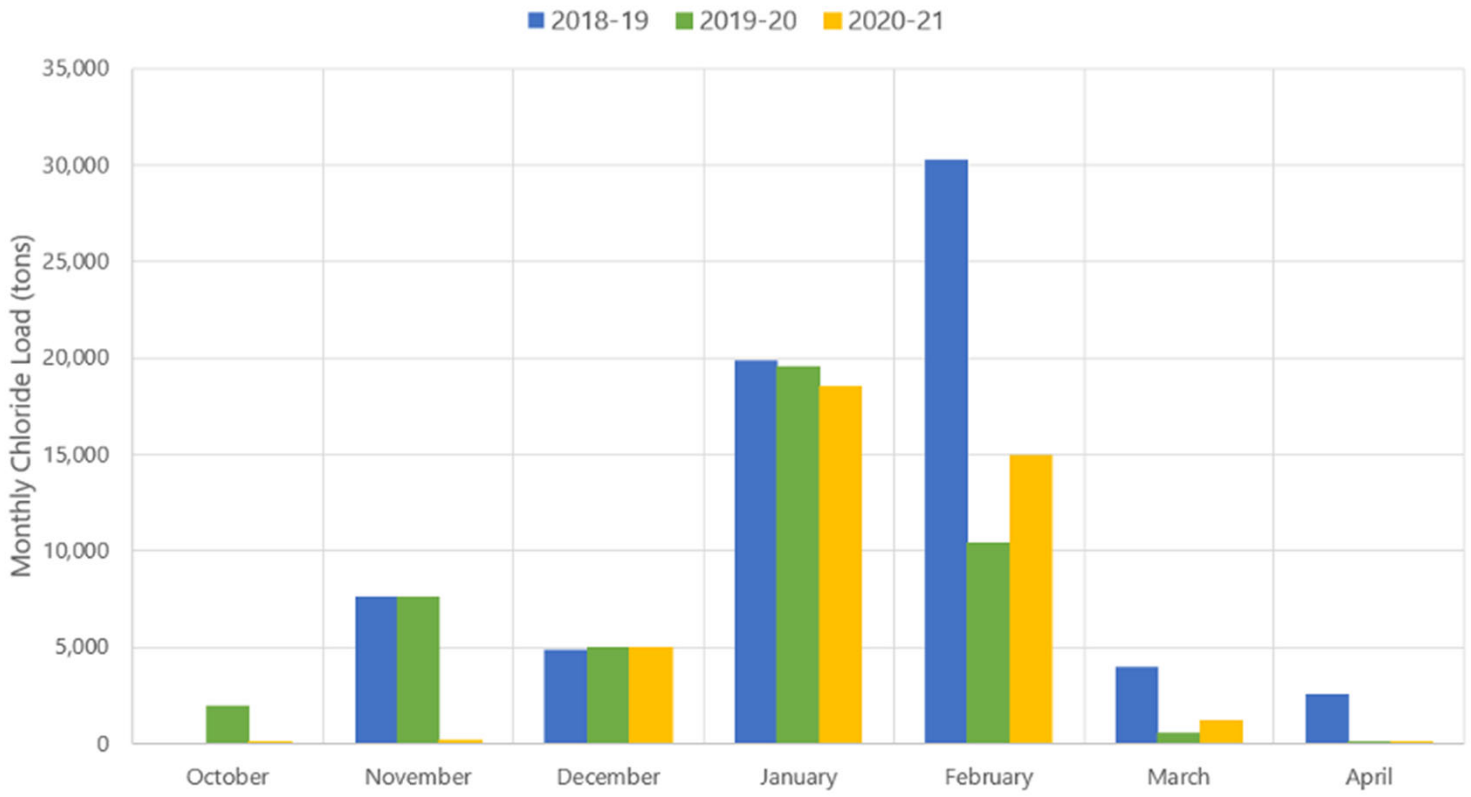
Chloride Load from State and Federal Roads

- Transportation network data from SEWRPC dataset
- Usage data obtained from the storm reports on WisTransPortal
- Geospatial intersection with individual monitoring site drainage areas
  - Lane mile ratio was used to determine the proportion of deicing salt applied to roads within a specific drainage area



Chloride Load from State and Federal Roads

Figure 3.5
Total Monthly Chloride Loads from Deicing State and Federal Highways in Southeastern Wisconsin



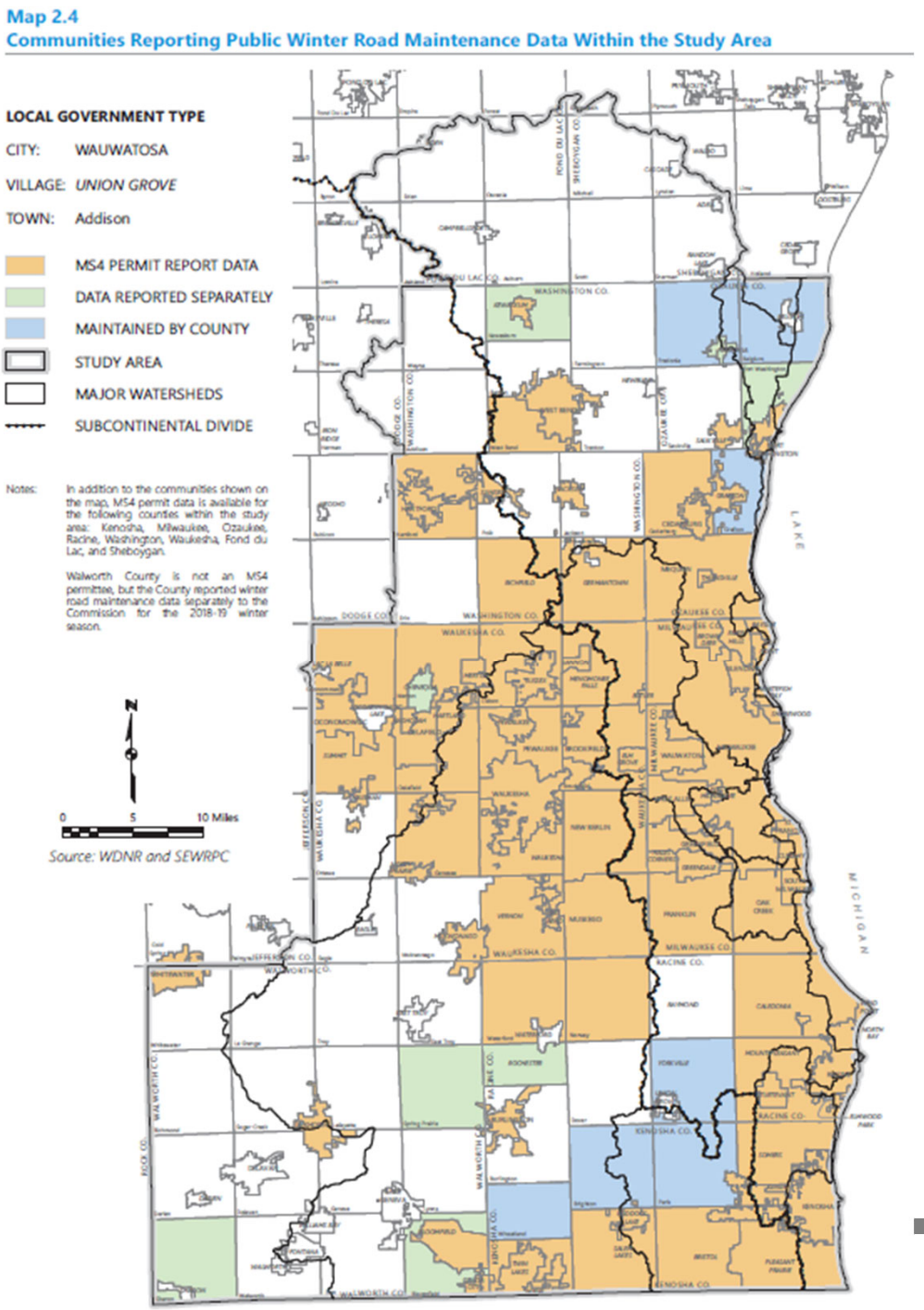
Source: WisDOT and SEWRPC

- Average annual chloride contribution in Region = **51,300 tons/year**

~ 77 x Cl_{atm}

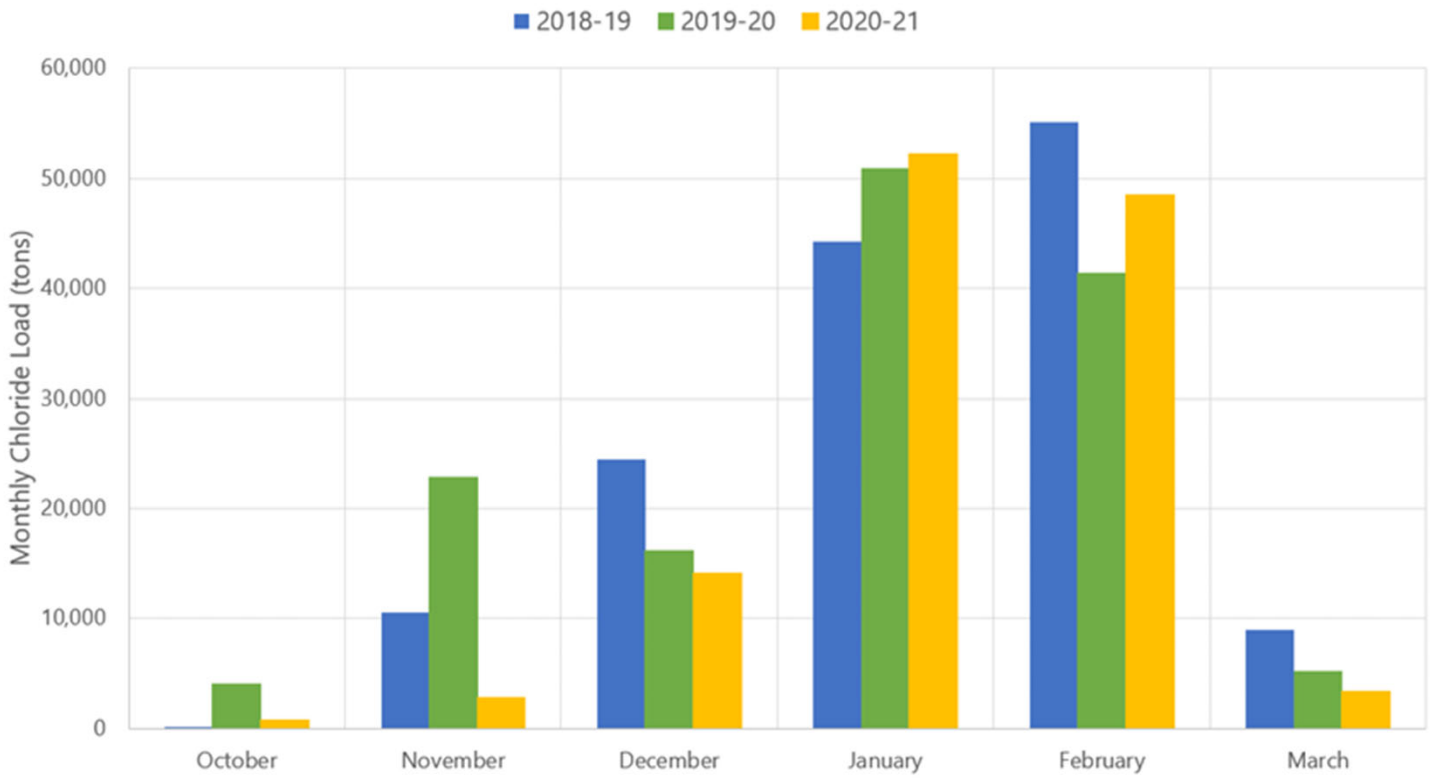
Chloride Load from County and Local Roads

- Deicing Salt on County and local roadways was obtained from MS4 permit annual report data from the WDNR
- County highways used SEWRPC transportation network dataset
- Similar lane mile ratio methodology as the State and Federal highways
- Salt applied to local roadways by municipalities using areal proportioning



Chloride Load from County and Local Roads

Figure 3.6
Total Monthly Chloride Loads from Deicing for MS4 Communities in Southeastern Wisconsin



Note: Data reported separately for communities without MS4 permits were not included in the totals above. Also, approximately 99 percent of the chloride comes from rock salt, the rest is from salt brine and a sand/salt mixture.

Source: WDNR and SEWRPC

- Average annual chloride contribution in Region = **135,141 tons/year**

~ 204 x Cl_{atm}

Chloride Load from Private Parking Lots

- Private Parking Lot Deicing Salt
- Regional existing land use dataset identifies parking areas > 10 spots
  - Over 25,500 acres of off-street parking in the Region
- Assumed an average salt application rate of 0.25 lb/sq ft per winter
  - Private salting data not available, relied on literature review
- Application timing estimated using monthly distribution WisDOT data
- Average annual chloride contribution in Region = **84,430 tons/year**
  - ~ 127 x Cl_{atm}

Source: SEWRPC

Wastewater Effluent

Conventional treatment processes and equipment do not remove chloride from wastewater

Wastewater sources

- Public WWTF
- Industrial Wastewater Discharger
- Residential Septic Systems

Chloride Load from Public WWTF Effluent

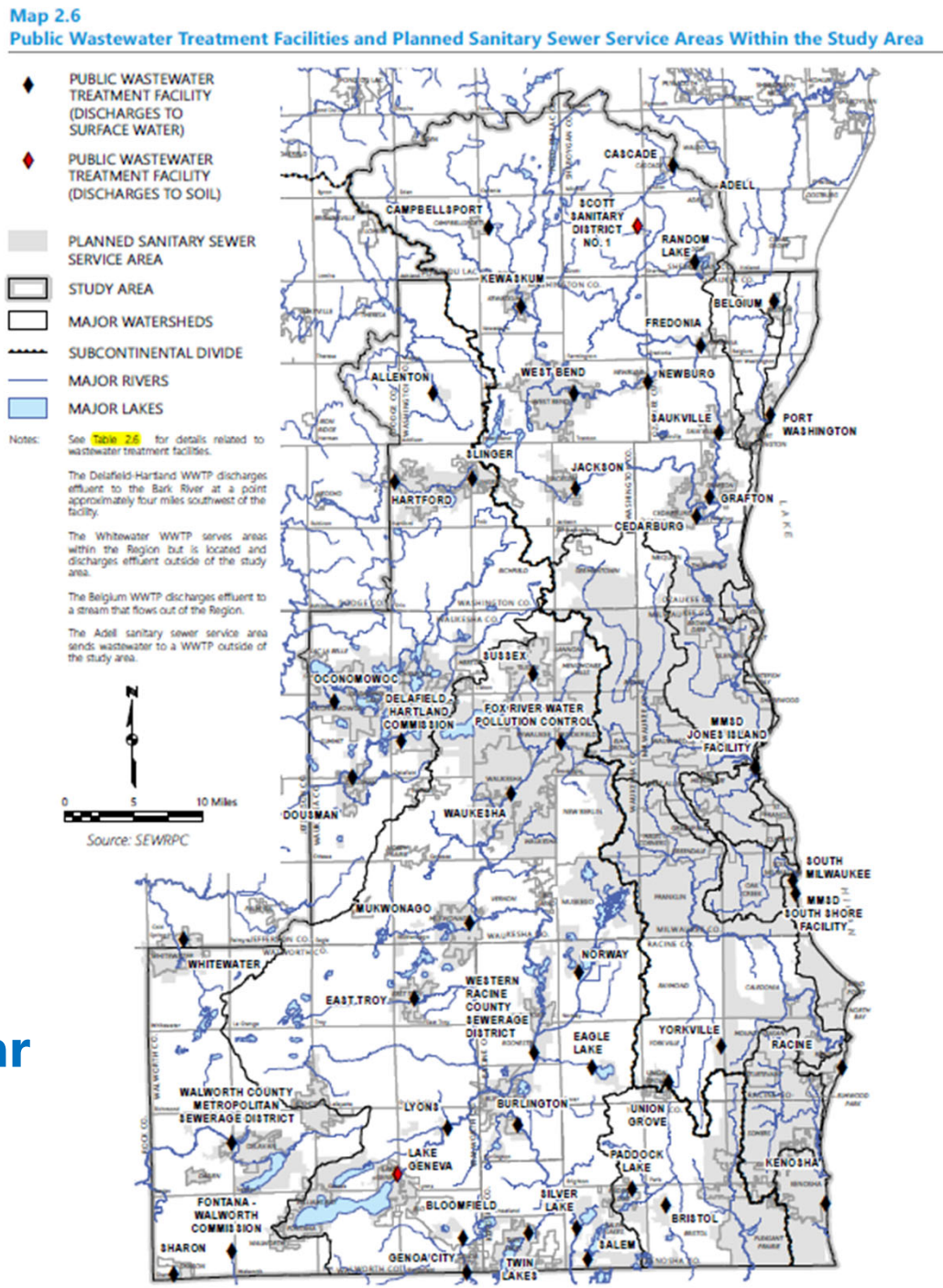
Table 2.6
Active Wastewater Treatment Facilities Within the Study Area: 2018–2020

Facility Name	Receiving Water	County	Ownership	Annual Average Design Flow (MGD)	SEWRPC Sites Downstream (Site No.)
Des Plaines Watershed					
Brighton Dale Links Wastewater Treatment Plant	Unnamed wetland-marsh complex (Brighton Creek Watershed)	Kenosha	Private	0.004	30
Bristol Utility District No.1	Tributary to Des Plaines River	Kenosha	Public	0.87	30
Fonks Home Center Inc, Hickory Haven	Tributary to Des Plaines River	Kenosha	Private	0.031	30
MHC Rainbow Lake, LLC	Diffuse wetland draining to Mud Lake (Dutch Gap Canal Watershed)	Kenosha	Private	0.04	--
Paddock Lake Wastewater Treatment Facility	Tributary to Brighton Creek	Kenosha	Public	0.80	30
Direct Drainage Area Tributary to Lake Michigan					
Kenosha Wastewater Treatment Facility	Lake Michigan	Kenosha	Public	28.6	--
Milwaukee Metropolitan Sewerage District – Jones Island	Milwaukee River Outer Harbor	Milwaukee	Public	123	--
Milwaukee Metropolitan Sewerage District –South Shore	Lake Michigan	Milwaukee	Public	113	--
Port Washington Wastewater Treatment Plant	Lake Michigan	Ozaukee	Public	3.10	--
Racine Wastewater Utility	Lake Michigan	Racine	Public	36.0	--
South Milwaukee Wastewater Treatment Facility	Lake Michigan	Milwaukee	Public	6.00	--
Fox River Watershed					
Village of Bloomfield Utility Department	Tributary to East Branch Nippersink Creek	Walworth	Public	0.46	--
Burlington Water Pollution Control	Fox River	Racine	Public	3.50	2
Eagle Lake Sewer Utility District	Eagle Creek	Racine	Public	0.40	2
East Troy Wastewater Treatment Facility	Honey Creek	Walworth	Public	0.81	36, 2
Fox River Water Pollution Control Center	Fox River	Waukesha	Public	12.5	1, 47, 2

Chloride Load from Public WWTF Effluent

- 49 public WWTFs in the study area during the study period
- 6 WWTFs discharging directly to Lake Michigan were not required to monitor chloride
- Monitoring data obtained from WDNR
  - Effluent chloride concentrations
  - Discharge flow rates

- Average annual chloride contribution
  - Inland Rivers = **46,276 tons/year**
    - ~ 70 x Cl_{atm}
  - Lake Michigan = **107,261 tons/year**
    - ~ 162 x Clatm



Chloride Load from Industrial Wastewater

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

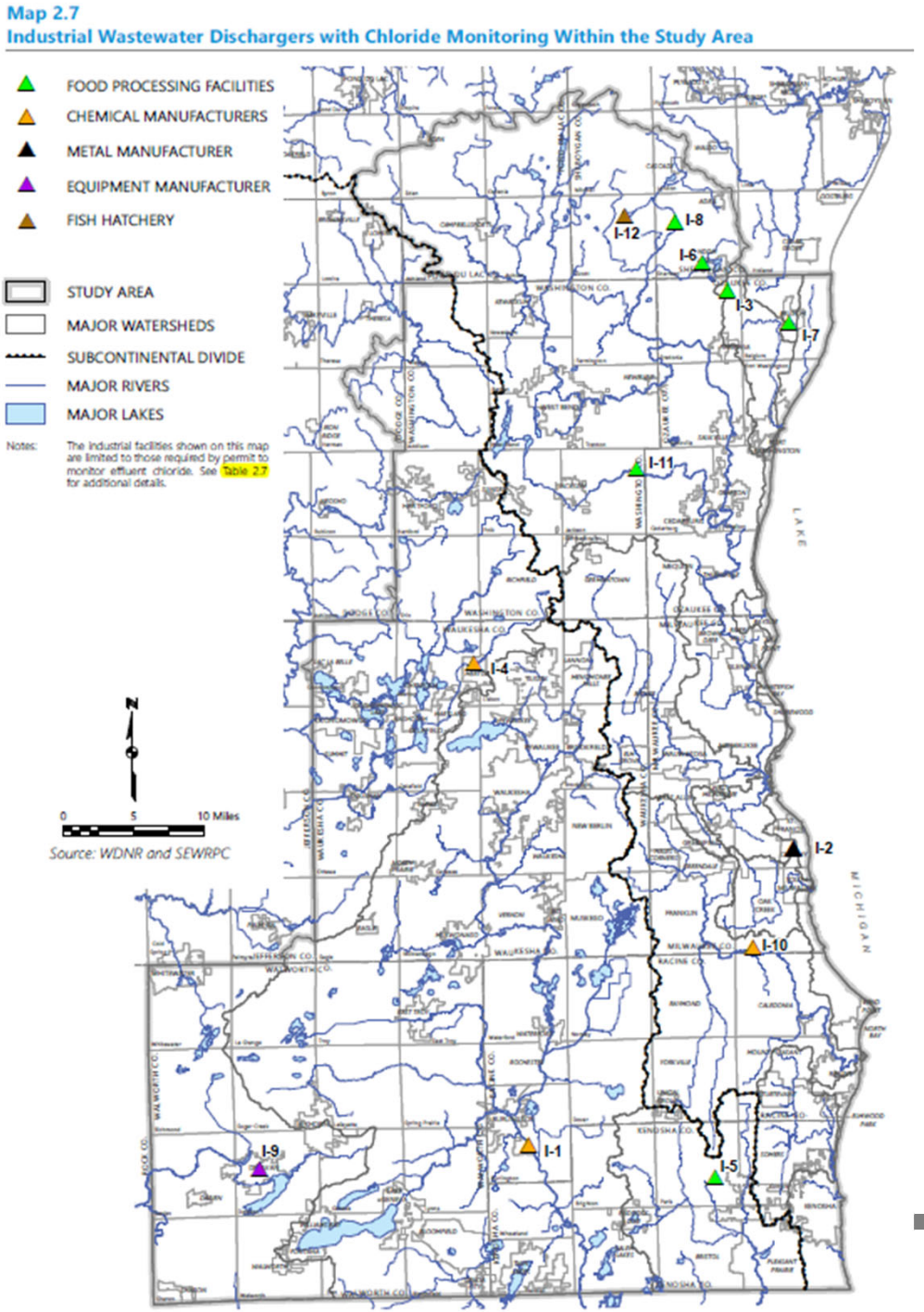
Facility ID	Industrial Facility Type	Receiving Water	Major Watershed	Civil Division	County	SEWRPC Sites Downstream (Site No.)
I-1	Chemical Manufacturer	Fox River	Fox River	Burlington	Racine	2
I-2	Metal Manufacturer/Forge	Edgerton Ditch & Lake Michigan Direct	Lake Michigan	Cudahy	Milwaukee	--
I-3	Food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

Note: See Map 2.7 for the industrial facility locations.

Source: WDNR and SEWRPC

Chloride Load from Industrial Wastewater

- Industrial facilities with surface water discharge and chloride monitoring
- 12 industrial facilities in the study area considered in analysis, identified by facility type on the map
- Monitoring data obtained from WDNR (WPDES permits)
- Average annual chloride contribution = **636 tons/year**
  - ~ 1 x Cl_{atm}



Chloride Load from Private Septic Systems

- Residential Septic Systems – assumed all unsewered households are served by septic systems
  - 81,909 unsewered households (2010 census)
  - 222,942 unsewered population (2010 census)
- Domestic wastewater
  - Water softener salt (assumed 420 lb/household/year)
  - Household products (assumed 25,000 mg/person/day)
  - Human Excreta (assumed 9,000 mg/person/day)
- Compared water softener salt assumption against the methodology presented in the Minnesota statewide chloride budget
- Average annual chloride contribution in Region = **13,478 tons/year**
  - ~ 20 x Cl_{atm}

Agricultural Sources

- Potash fertilizer
- Livestock manure
- Agricultural irrigation

Source: Wikimedia/Michael Dibb

Agricultural Sources – Potash (KCl) Fertilizer

- CropScape crop data layer – geospatial data identifying crops planted each year
- Potash applications computed for
  - Corn
  - Soybeans
  - Alfalfa
- NASS Chemical Use Surveys used to estimate potash for corn and soy beans
- Alfalfa potash application assumptions
  - Nutrient requirements
  - Soil conditions
  - Crop yield expectations

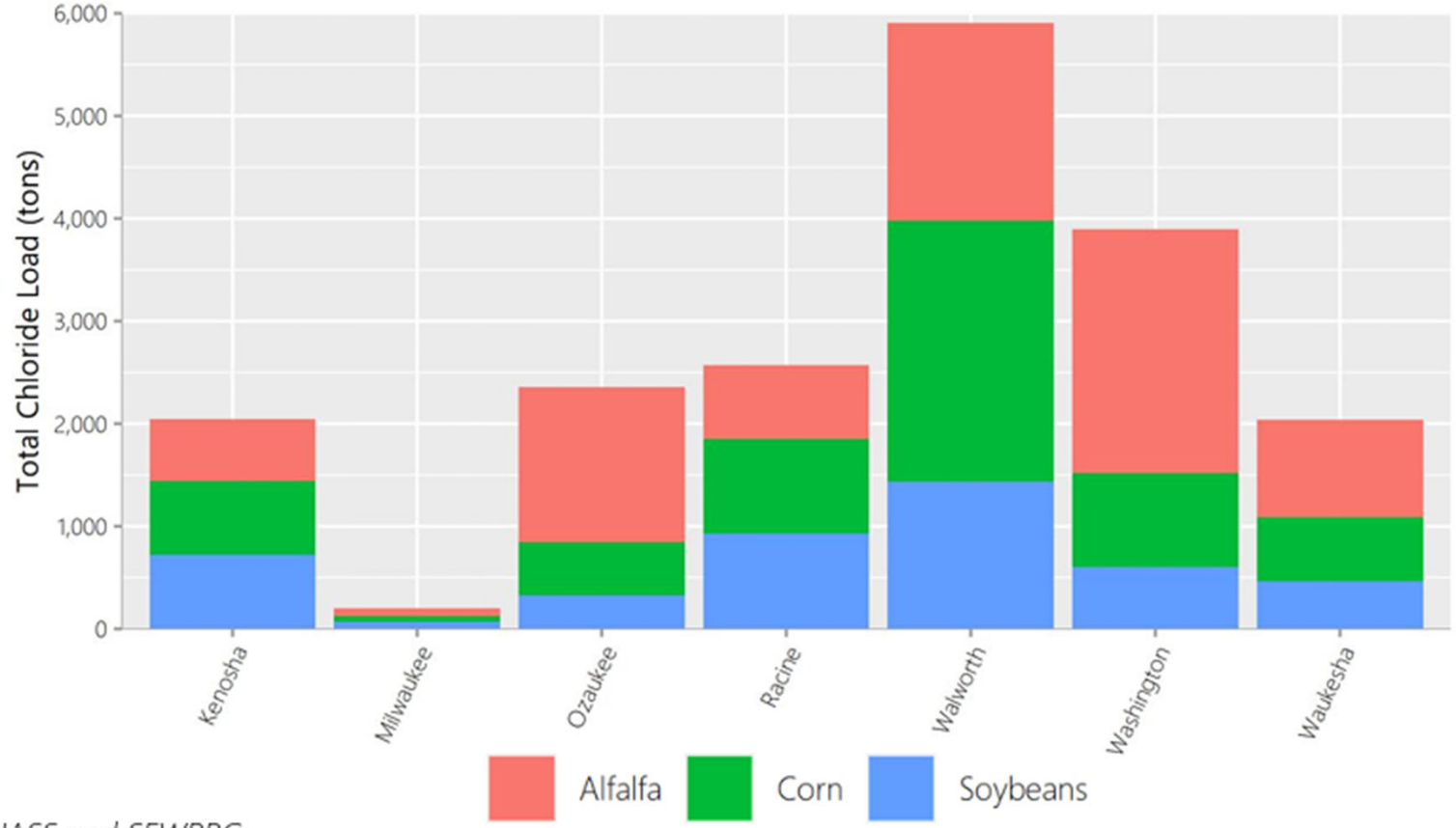
Table 3.5
Selected Crops Grown Within the Region: Cropscape Datasets 2018–2020

Type of Crop	2018 (acres)	2019 (acres)	2020 (acres)
Corn	270,184	210,740	278,215
Soybeans	180,390	149,829	170,664
Pasture/Grasslands	159,507	128,005	123,459
Alfalfa	69,803	82,958	90,378
Winter Wheat	31,440	24,893	17,378
Barley	68	62	193
Potatoes	28	15	54

Source: USDA NASS

Agricultural Sources – Potash Fertilizer

2020:



Source: USDA NASS and SEWRPC

- Average annual chloride contribution in Region = **17,510 tons/year**

  ~ 26 x Cl_{atm}

Agricultural Sources – Livestock Manure

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

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

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

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

Source: USDA NASS

Agricultural Sources – Livestock Manure

Table 3.7
Livestock Manure Characteristics and Data used to Estimate Chloride Loads

Type of Livestock	Daily Chloride Production in Livestock Manure[a] (lb/AU/day)	Typical Live Animal Mass[a] (lb)	Daily Manure Production[b]		Manure Chloride Concentrations	
			Solid (lb/day)	Liquid (gal/day)	Solid[c] (lb/ton)	Liquid[d] (mg/l)
Dairy Cattle	0.13	--	--	--	--	--
Milking and Dry Cows	--	1,400	--	--	--	--
Heifers (800-1200 lbs)	--	1,100[e]	--	--	--	--
Heifers (400-800 lbs)	--	600[e]	--	--	--	--
Calves (under 400 lbs)	--	200[e]	--	--	--	--
Swine	0.26	135	--	--	--	--
Sheep	0.089	60	--	--	--	--
Layers (chickens)	0.56	4	--	--	--	--
Broilers and Pullets	--	2	--	--	--	--
Beef Cattle	--	--	63	--	4.34	--
Turkeys	--	--	0.9	--	2.7	--
Horses	--	--	--	5.98	--	400

[a] *The daily manure chloride production and typical live animal mass data were obtained from ASAE (2003), except as noted in the table. One animal unit (AU) is equivalent to 1,000 pounds of live animal mass.*

[b] *The daily manure production for various livestock was obtained from USDA/NRCS (2016).*

[c] *Manure chloride concentrations for beef were obtained from Wilson (2018) and turkeys from Sherwood (1989), as cited in Overbo et al. (2021).*

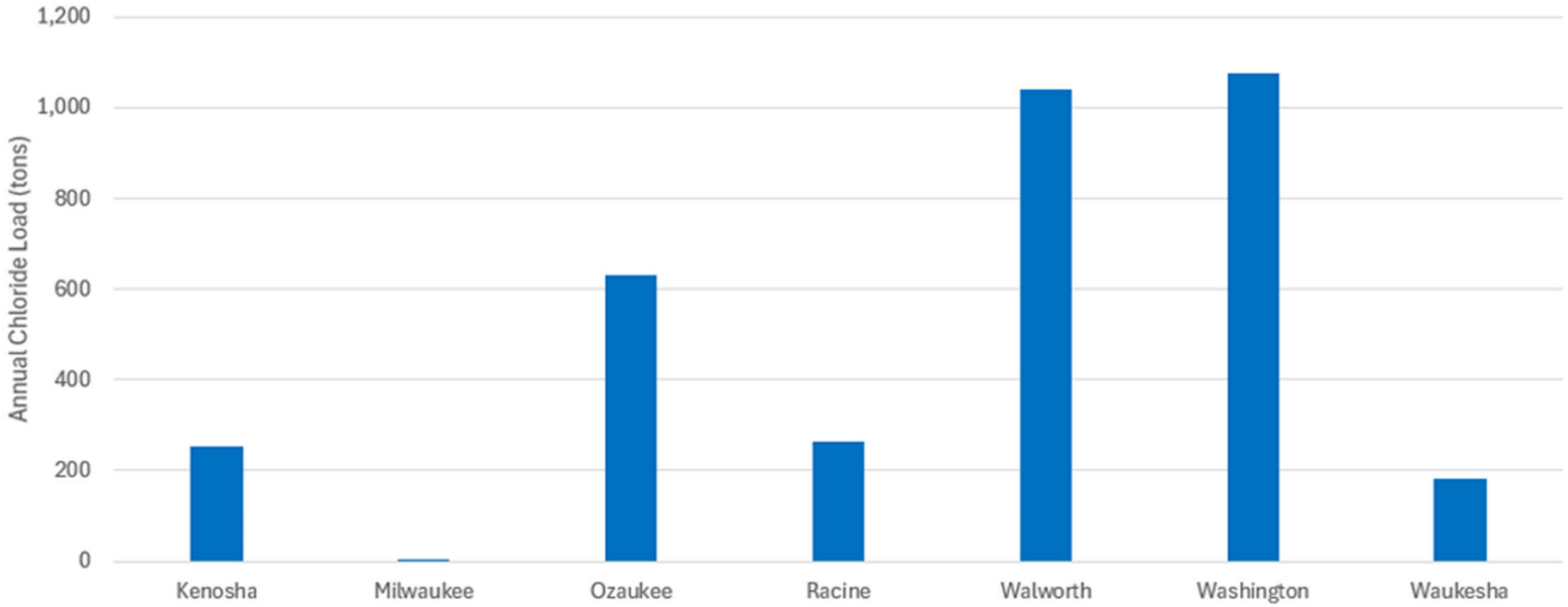
[d] *Manure chloride concentrations for horses were obtained from Panno et al. (2005).*

[e] *Typical live animal mass was estimated using the AU equivalent factors provided in the WDNR Form 3400-025A AU Calculation Worksheets.*

Source: SEWRPC

Agricultural Sources – Livestock Manure

Figure 3.8
Annual Chloride Load Estimated for Livestock Manure Spreading by County: 2017



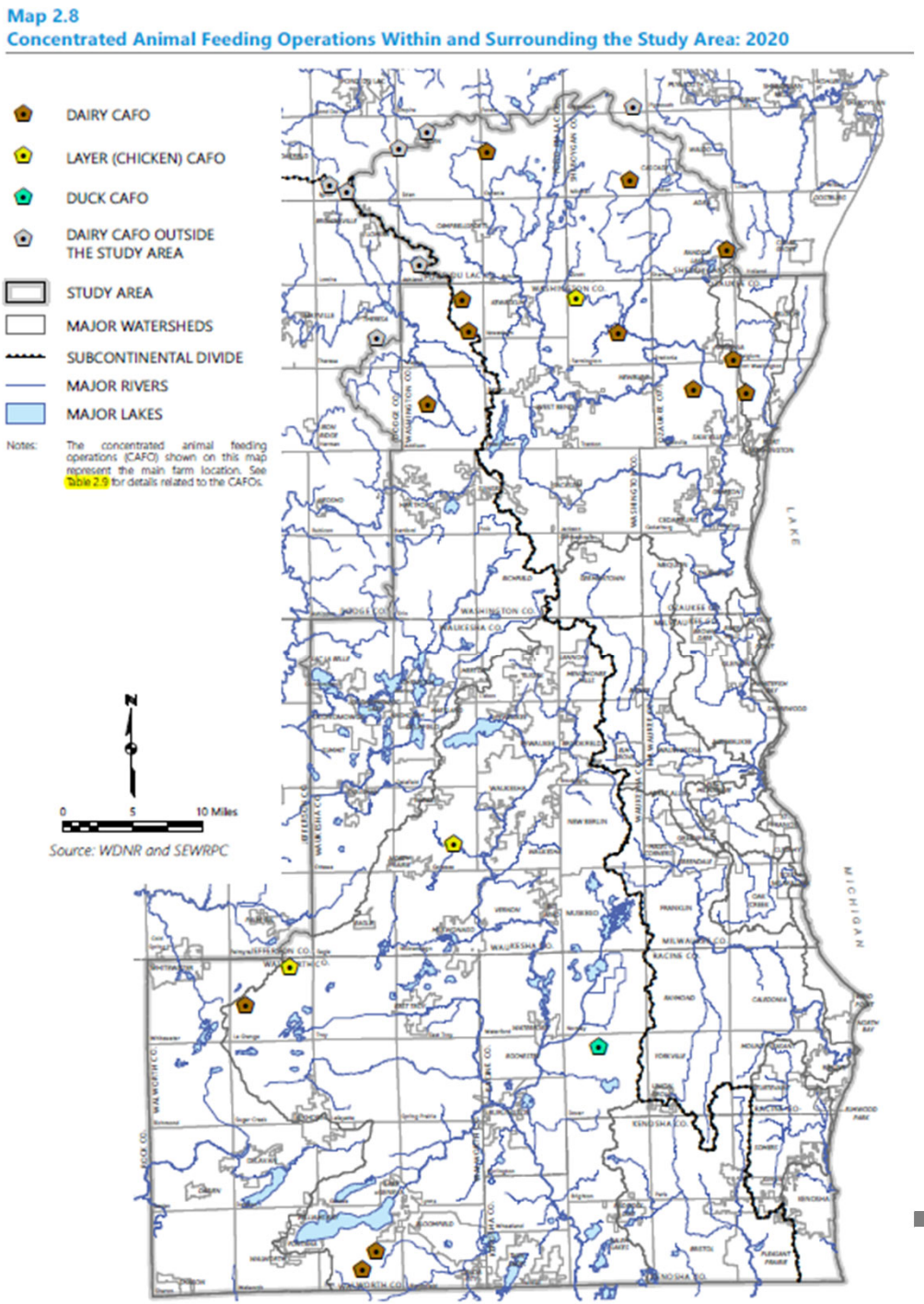
Source: USDA NASS and SEWRPC

- Average annual chloride contribution in Region = **3,439 tons/year**

  ~ 5 x Cl_{atm}

Agricultural Sources – CAFOs

- Concentrated Animal Feeding Operation (CAFO)
  - 1,000 Animal Units
- 17 CAFOs within study area
- Dairy CAFOs
  - Layers (Chicken) CAFOs compost waste and sell as consumer fertilizer
  - Duck CAFO sends process wash water to WWTF
- Average annual chloride contribution = **772 tons/year**
  - ~ 1 x Cl_{atm}



Agricultural Sources – CAFOs

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

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

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

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

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

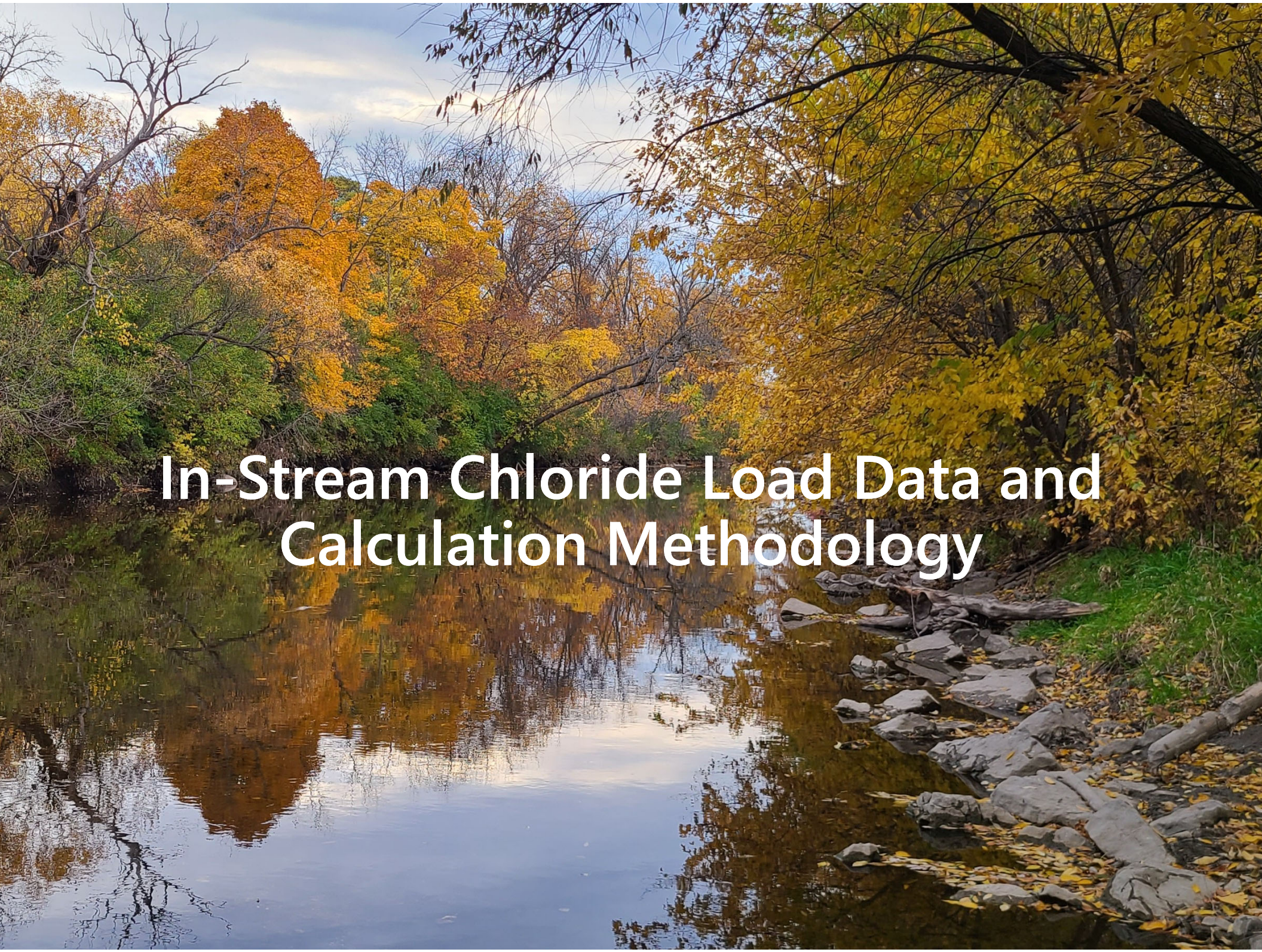
[c] *Layers refers to chickens that are raised to produce eggs.*

Source: WDNR and SEWRPC

Agricultural Sources – Irrigation

- USGS 2015 Water Use Report by County
  - Region used approximately 9.5 million gallons per day
  - 95% sourced from groundwater, mean chloride = 96.7 mg/l
- Average annual chloride contribution = **1,399 tons/year**
  - ~ 2 x Cl_{atm}

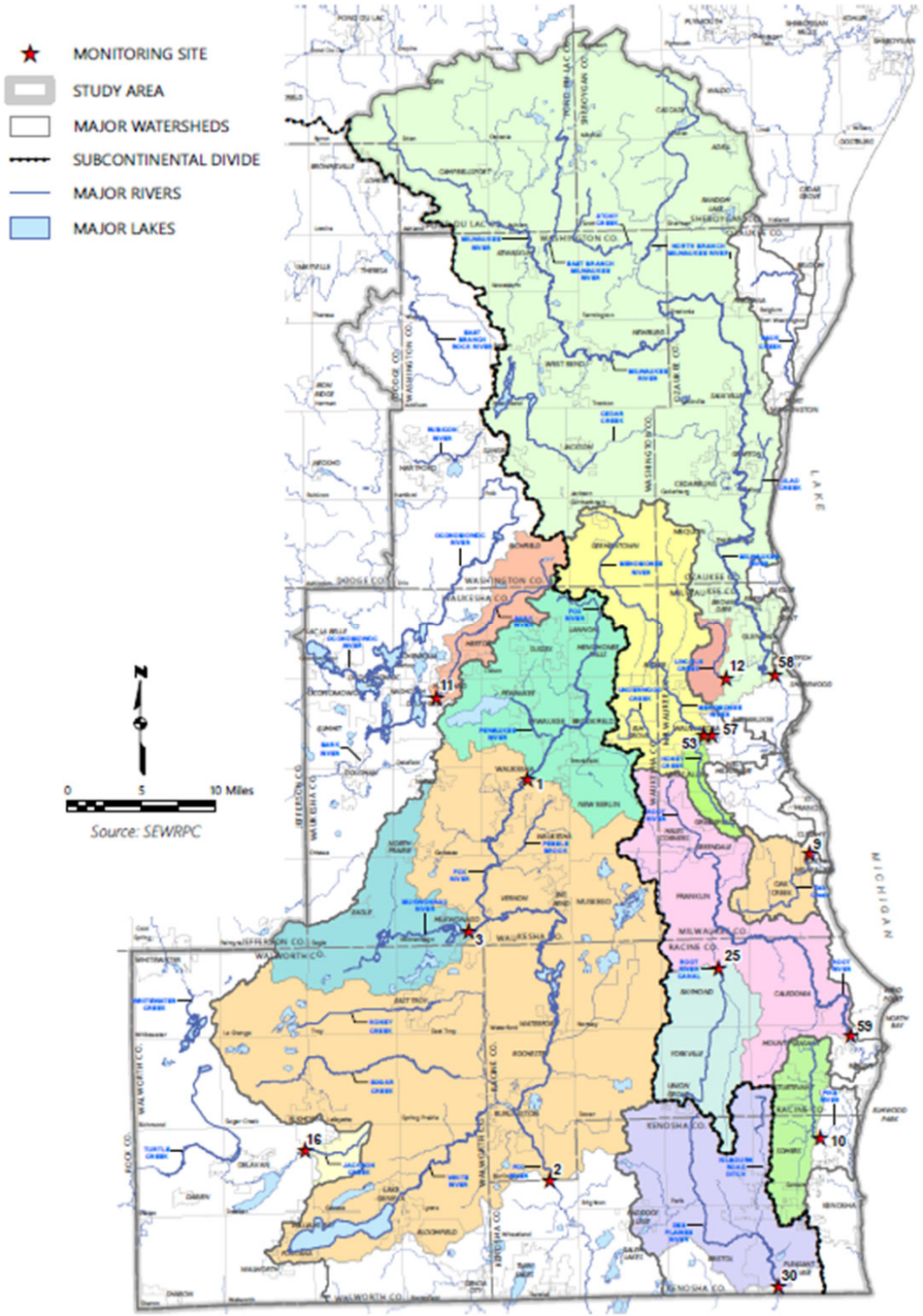
Source: Wikimedia/ N. Chadwick



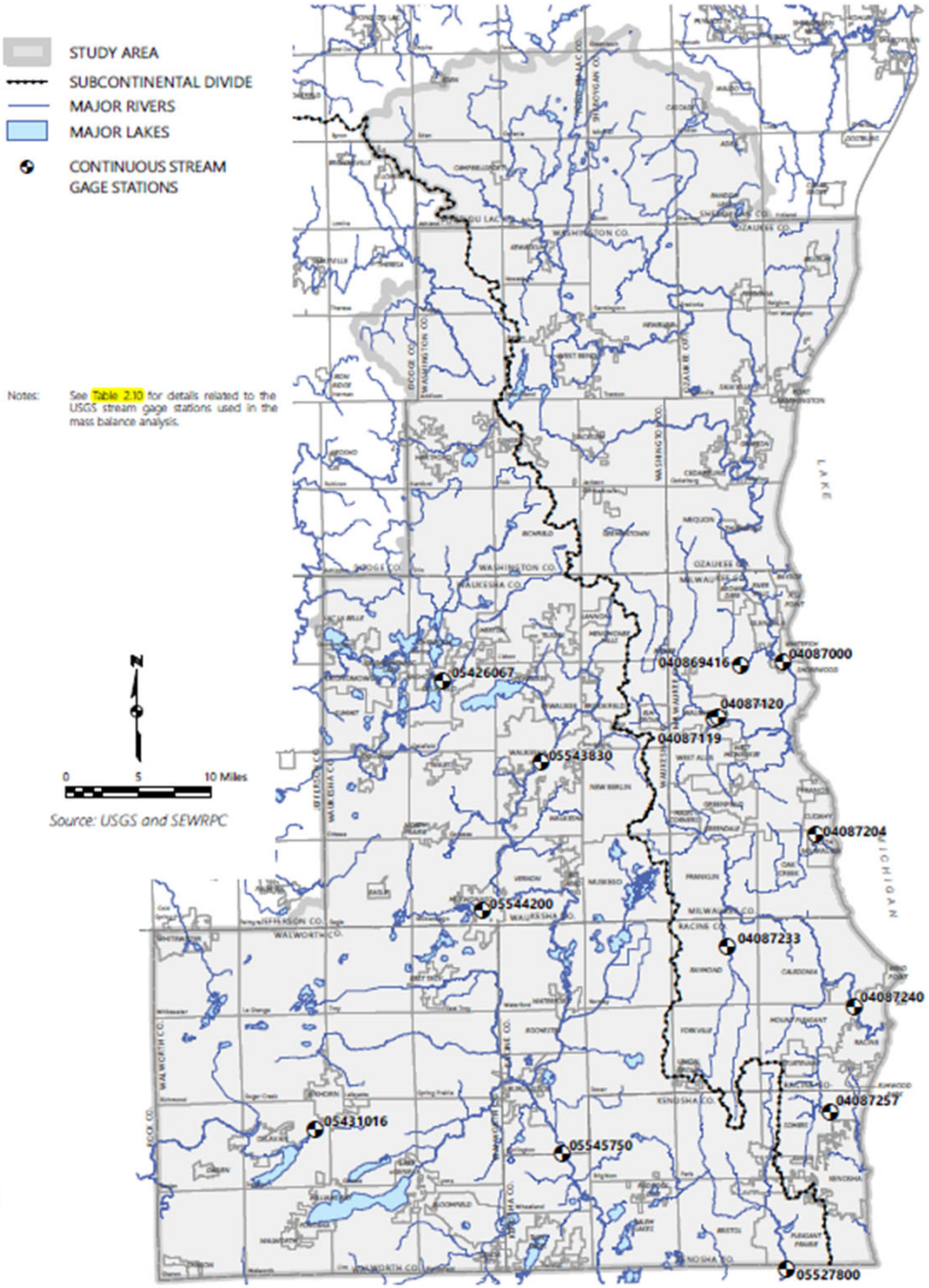
In-Stream Chloride Load Data and Calculation Methodology

In-Stream Chloride Load/Mass Balance Sites

Map 3.1
Stream Monitoring Sites and Upstream Drainage Areas used for the Chloride Mass Balance Analysis



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



In-Stream Chloride Load – Streamflow Data

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

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

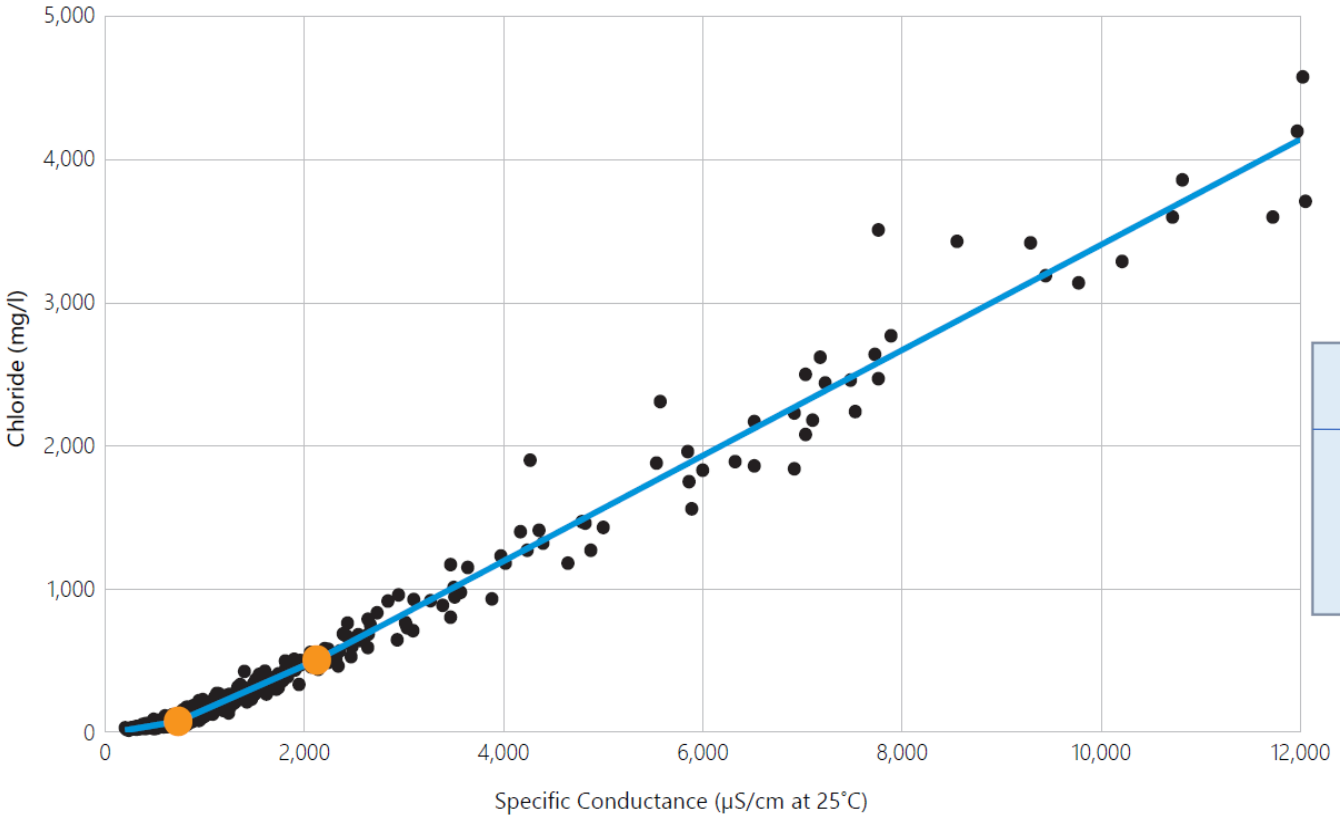
Note: See Map 2.9 for the locations of each stream gage station.

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

Source: USGS and SEWRPC

Estimated In-Stream Chloride Concentrations

- 5-min specific conductance data collected for the study
- Converted to estimated in-stream chloride concentrations using regression equations developed in TR-64



Specific Conductance Range (µS/cm)	Equation to Estimate Chloride (mg/l)
SC ≤ 103	$[Cl^-] = 0$
103 < SC ≤ 732	$[Cl^-] = 0.1171 \times SC - 12.0$
732 < SC ≤ 2,123	$[Cl^-] = 0.3084 \times SC - 151.9$
SC > 2,123	$[Cl^-] = 0.3687 \times SC - 280.0$

In-Stream Chloride Loads

$$In\text{-}Stream\ Chloride\ Load = C * Q * \Delta t * k$$

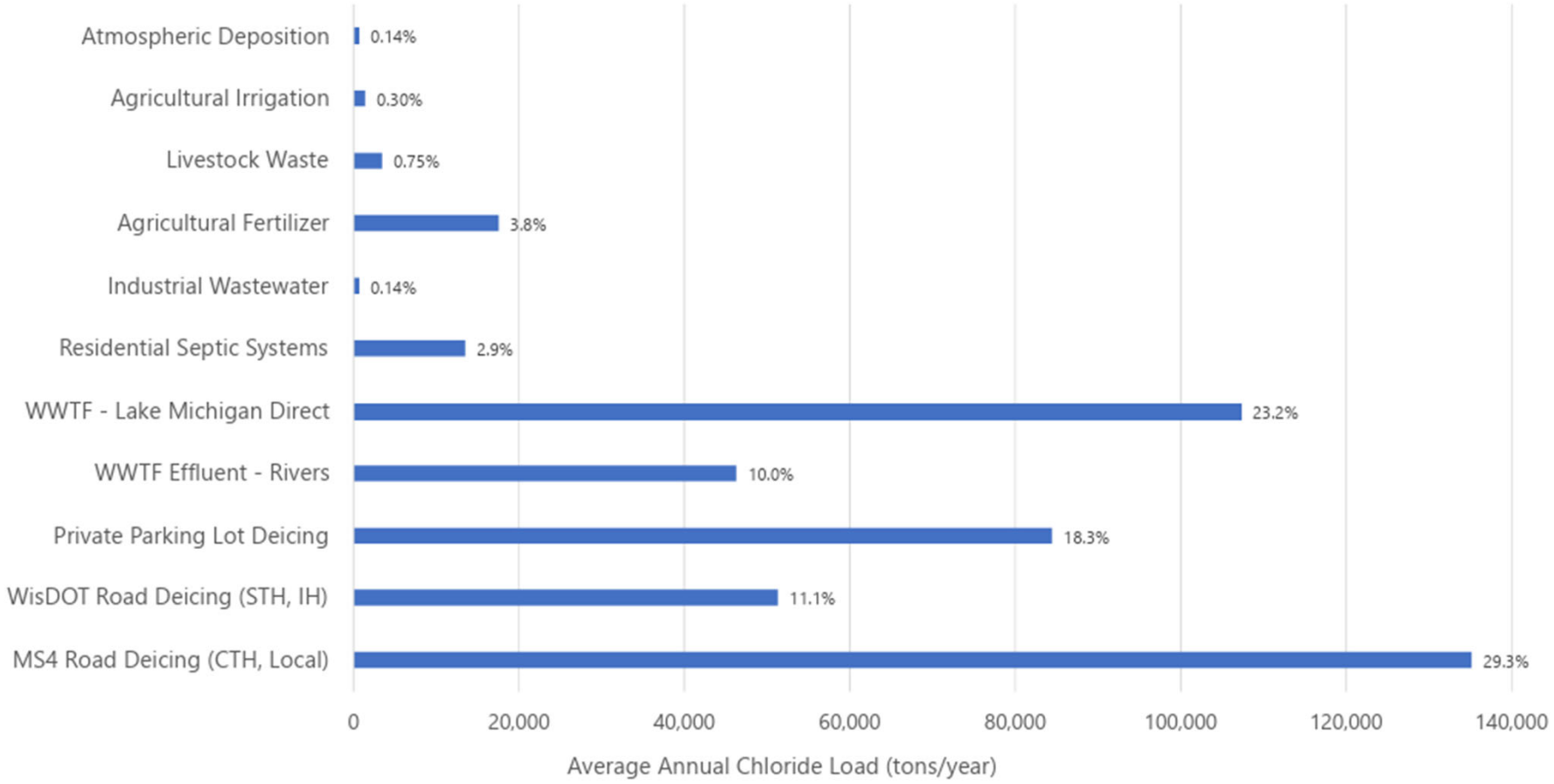
Where:

C	=	chloride concentration expressed in terms of mass per volume, typically mg/l
Q	=	flow rate expressed in terms of volume per time, typically cubic feet per second (cfs)
Δt	=	computational time interval
K	=	unit conversion factor

Chloride Loading and Mass Balance Analysis Results

Regional Chloride Budget

Figure 4.1
Regional Chloride Budget: Average Annual Chloride Source Loads for Southeastern Wisconsin



Note: Average annual chloride source loads were computed for the study period as described in Chapter 3.

Source: SEWRPC

Regional Chloride Budget

Table 4.1
Regional Chloride Budget: Estimated Average Annual Chloride Contributions

Chloride Source	General Source Category	Annual Average Chloride Mass Load (tons/year)[a]	Percent of Total Chloride Mass Load (percent)
MS4 road salt applied to local and county roadways	Winter maintenance	135,140	29.3
WisDOT road salt applied to state and federal roadways	Winter maintenance	51,300	11.1
Private road salt applied to parking lots	Winter maintenance	84,430	18.3
WWTF effluent discharged to rivers and streams	Wastewater	46,280	10.0
WWTF effluent discharged directly to Lake Michigan	Wastewater	107,260	23.2
Private residential septic systems	Wastewater	13,480	2.92
Industrial wastewater effluent	Wastewater	640	0.14
Agricultural potash fertilizer	Agricultural	17,510	3.79
Livestock manure	Agricultural	3,440	0.75
Agricultural irrigation	Agricultural	1,400	0.30
Atmospheric deposition	Natural	660	0.14
	Total	461,540	100[b]

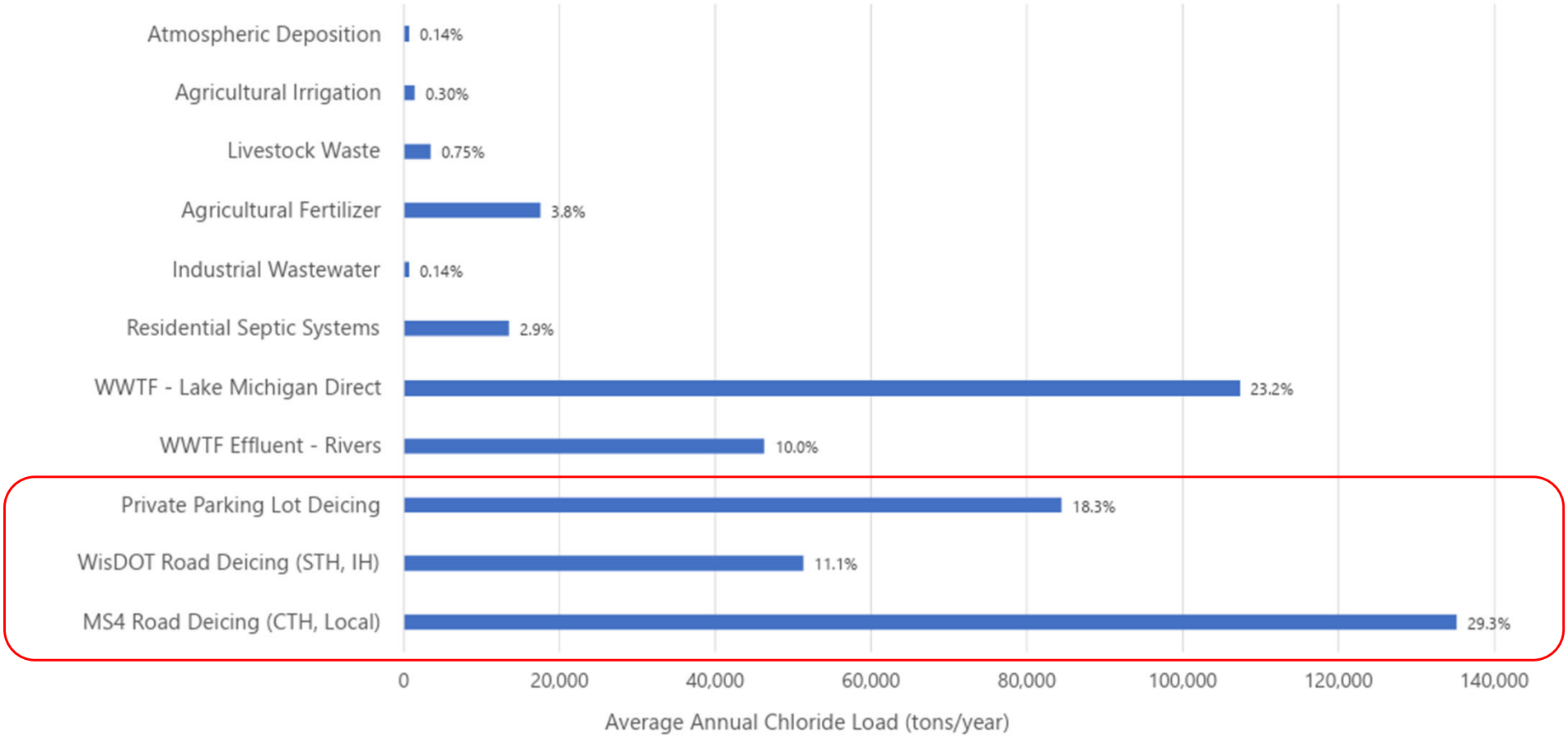
[a] *The average annual chloride mass load computed for each source of chloride during the study period was rounded to the nearest 10 tons.*

[b] *The rounded percentages in the table add up to slightly less than 100 percent.*

Source: SEWRPC

Regional Chloride Budget – Deicing Salt

Figure 4.1
Regional Chloride Budget: Average Annual Chloride Source Loads for Southeastern Wisconsin



Note: Average annual chloride source loads were computed for the study period as described in Chapter 3.

Source: SEWRPC

Regional Chloride Budget – Deicing Salt

Public and private operations were largest source of chloride in Region

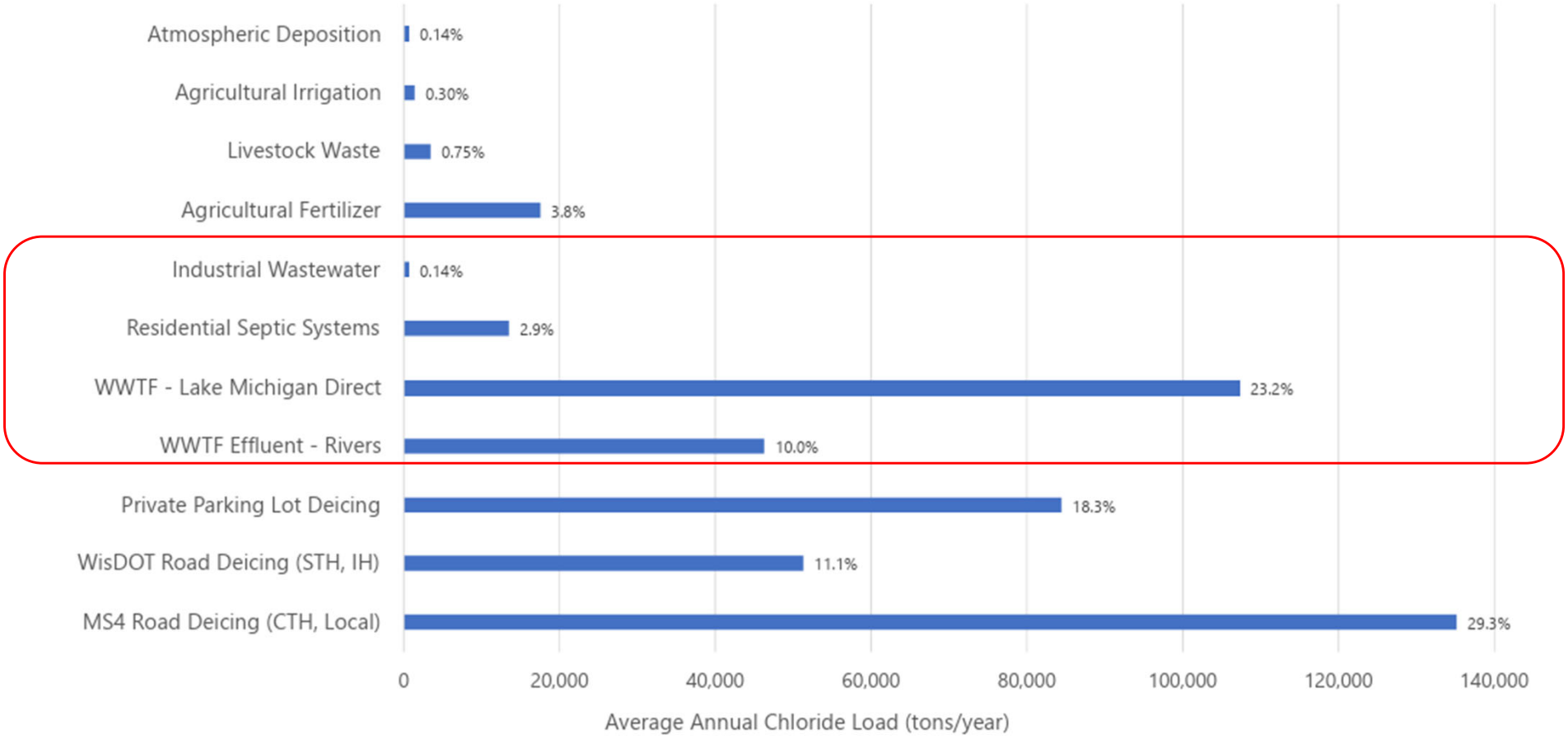
- Total = 270,870 tons/year ~ 59% of the Regional chloride budget
  - State and Federal highways = 19%
  - County highways and local roads = 50%
  - Private parking lots = 31%

Regional public roadway deicing material usage

- Average annual usage (winter 2018-19 through 2020-21)
  - Salt usage ~ 303,500 tons salt/year
  - Salt Brine usage ~ 2,500,000 gallons brine/year
- Public roadway deicing chloride load 96% to 99% from rock salt

Regional Chloride Budget – Wastewater

Figure 4.1
Regional Chloride Budget: Average Annual Chloride Source Loads for Southeastern Wisconsin



Note: Average annual chloride source loads were computed for the study period as described in Chapter 3.

Source: SEWRPC

Regional Chloride Budget – Wastewater

Wastewater effluent was the second largest source of chloride in Region

- Total = 167,660 tons per year ~ 36% of the Regional chloride budget
  - Public WWTFs – Rivers = 27.6%
  - Public WWTFs – Lake Michigan = 64.0%
  - Industrial wastewater dischargers = 0.4%
  - Private residential septic systems = 8.0%

Public wastewater treatment facilities

- Total = 153,540 tons per year ~ 91% of the wastewater chloride load
  - Lake Michigan ~ 117,900 tons per year
  - 6 direct dischargers were not required to regularly monitor chloride

Regional Chloride Budget – Wastewater

Industrial wastewater was the smallest source of chloride in Region

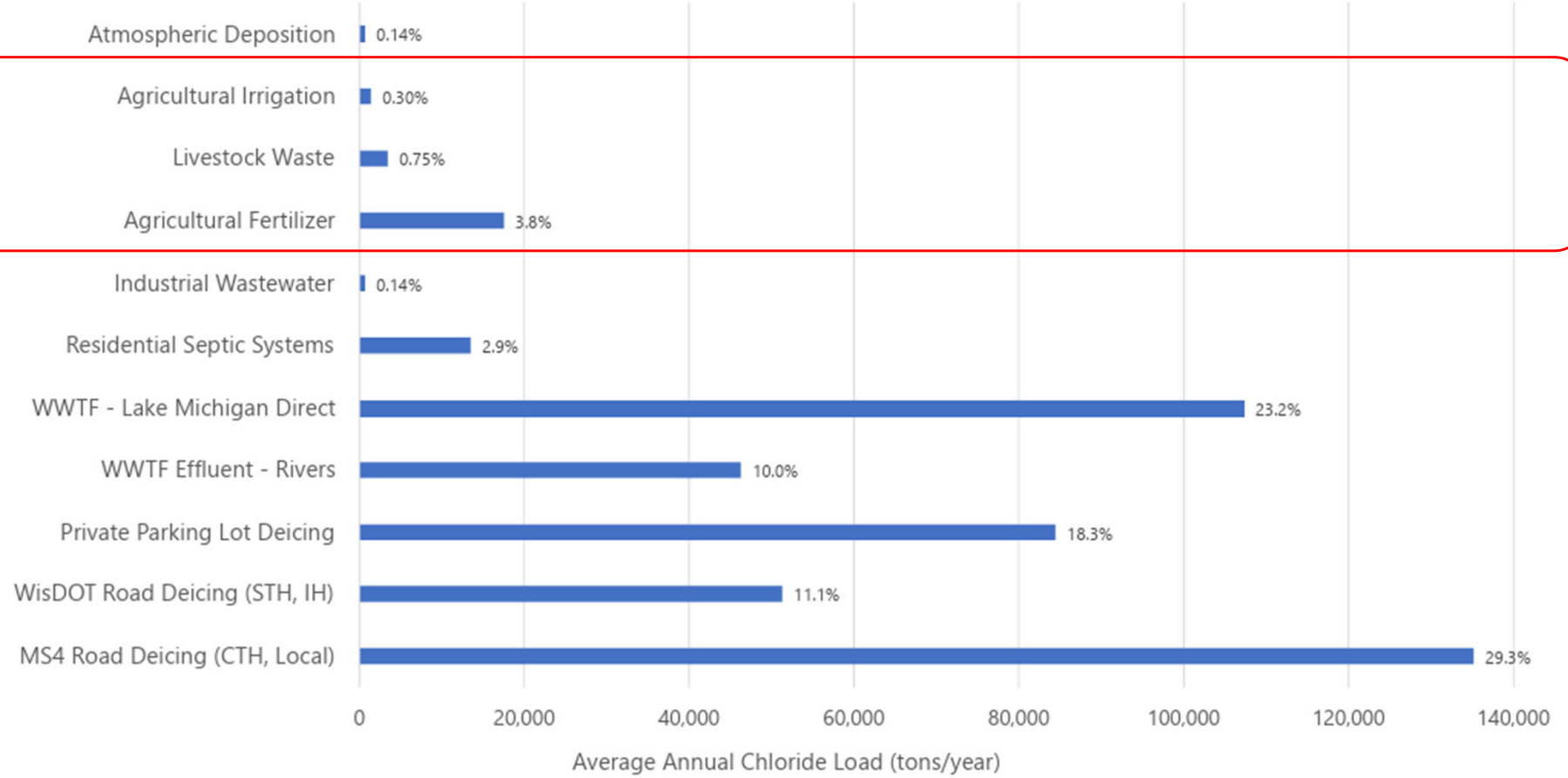
- Total = 640 tons per year ~ 0.14% of the Regional chloride budget
  - Approximately 2/3 from food processing facilities
  - Chloride monitoring data less frequent than public WWTFs

Residential Septic Systems

- Total = 13,480 tons per year ~ 2.9% of the Regional chloride budget
  - Estimated based Regional unsewered households and population
  - Computed chloride for Region but not individual monitoring sites

Regional Chloride Budget – Agricultural

Figure 4.1
Regional Chloride Budget: Average Annual Chloride Source Loads for Southeastern Wisconsin



Note: Average annual chloride source loads were computed for the study period as described in Chapter 3.

Source: SEWRPC

Regional Chloride Budget – Agricultural

Ag sources were a moderately significant source of chloride in Region

- Total = 22,350 tons per year ~ 5% of the Regional chloride budget
  - Potash fertilizer ~ 78%
  - Livestock manure ~ 16%
  - Agricultural irrigation ~ 6%

- Potash (KCl) fertilizer load – corn, soybeans, and alfalfa

- Livestock manure estimated using County inventories from Census of Ag
  - Load for monitoring sites computed from CAFO data (subset)

- Irrigation not included as a source for individual monitoring sites

Regional Chloride Budget – Natural Sources

Atmospheric deposition was one of the smallest chloride sources in Region

- Total = 660 tons per year ~ 0.14% of the Regional chloride budget

- Atmospheric deposition of chloride (Cl_{atm}) as a baseline for comparison
  - Winter maintenance and deicing = 410 x Cl_{atm}
  - Wastewater effluent = 254 x Cl_{atm}
  - Agricultural sources = 34 x Cl_{atm}


Chloride Source Loads
for Stream Monitoring Sites

Monitoring Site Chloride Source Loads

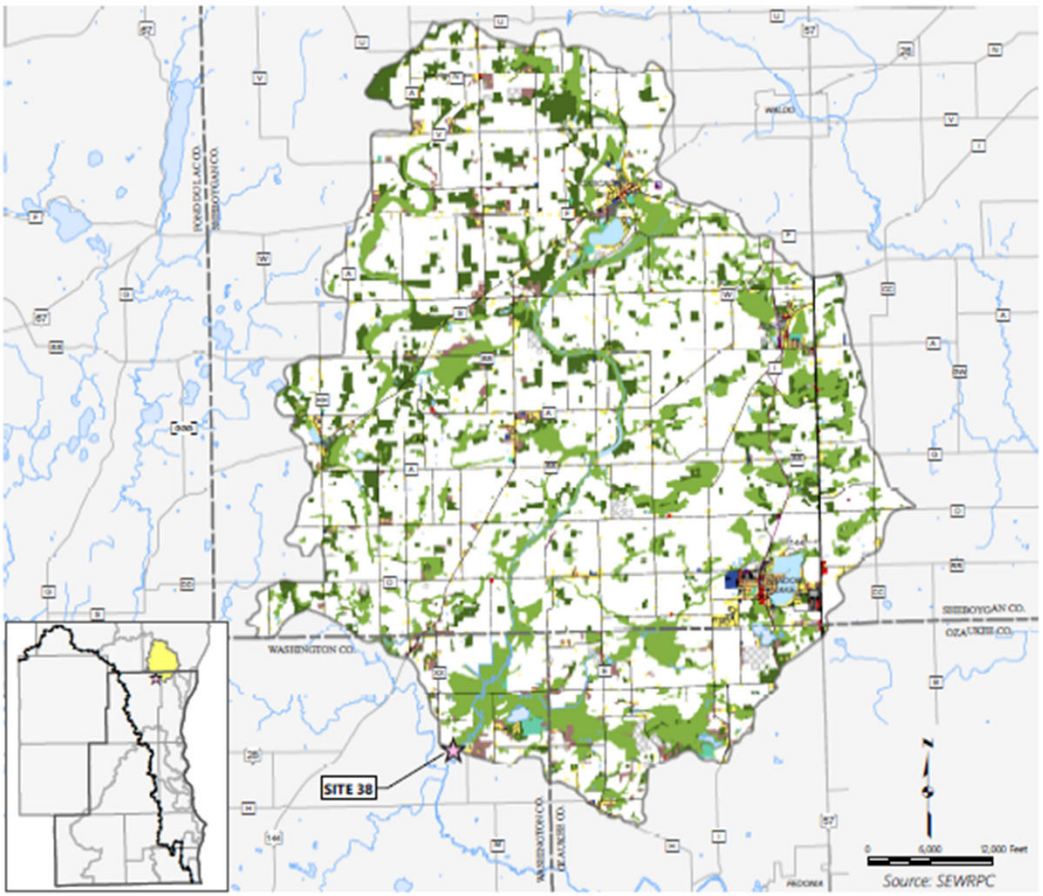
- Natural Sources
  - Atmospheric deposition
- Winter Maintenance Operations
  - Public roadways
  - Private parking lots
- Wastewater Effluent
  - Public WWTF
  - Industrial dischargers
- Agricultural Sources
  - Potash fertilizer
  - Livestock manure

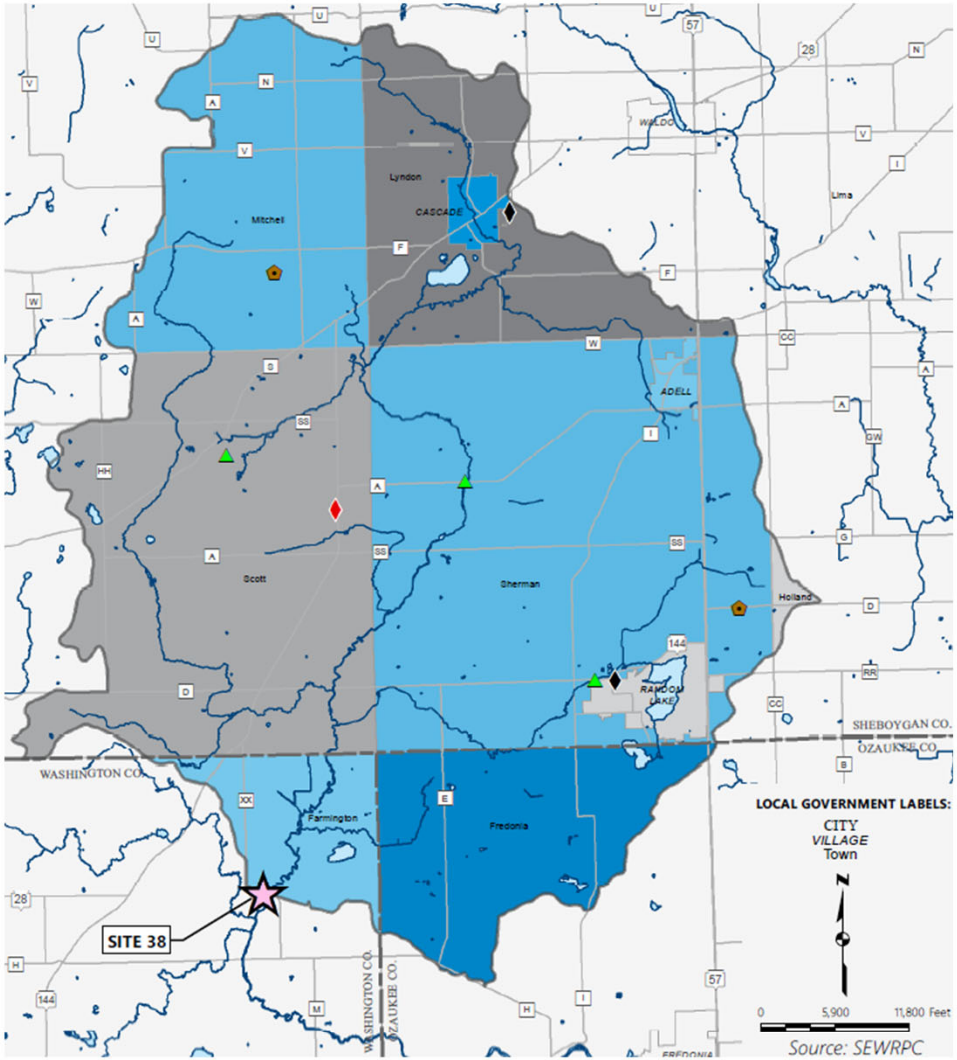
Table 4.2
Chloride Source Loads Estimated for Stream Monitoring Sites: October 2018 – October 2020

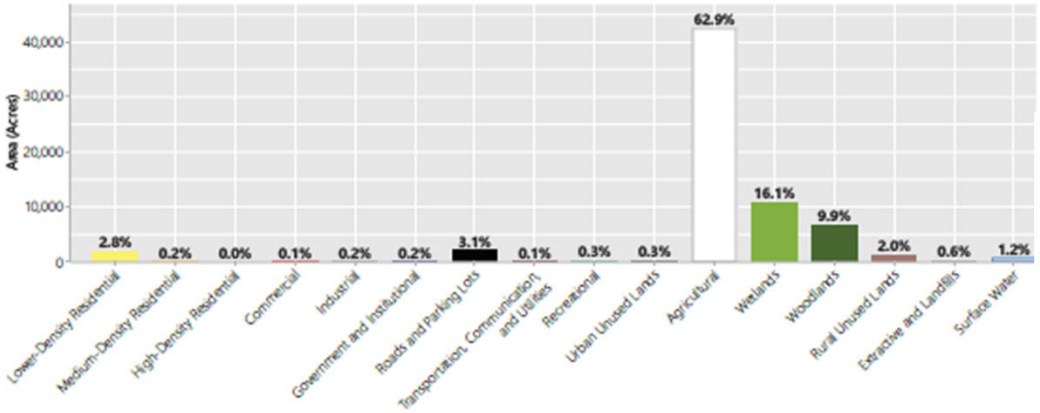
Site No.	Drainage Area (sq mi)	Sources of Chloride (percent)[a]								Total Chloride Source Load (tons/sq mi)
		Natural	Winter Maintenance			Wastewater		Agricultural		
		AtmDep	WisDOT	MS4	Pkg Lot	WWTP	Ind WW	Potash	CAFO	
1	126.3	0.1	8.1	34.7	29.3	27.1	--	0.7	--	558.9
2	807.1	0.2	12.9	35.8	20.1	25.4	<0.1	5.5	0.1	225.6
3	85.4	0.7	19.8	45.0	20.6	--	--	13.9	--[b]	73.1
4	60.5	0.5	23.6	45.3	12.9	--	--	17.7	--	118.3
6	112.2	0.7	41.2	16.0	24.4	1.4	--	16.3	--	86.3
8	38.1	0.1	16.5	50.1	32.1	--	--	1.2	--	367.5
9	25.8	0.1	25.1	41.9	32.6	--	--	0.3	--	649.8
10	36.6	0.1	10.3	56.0	30.9	--	--	2.7	--	457.5
11	35.0	0.2	7.5	64.6	23.9	--	<0.1	3.8	--	200.8
12	11.0	0.1	19.3	53.0	27.6	--	--	<0.1	--	971.9
13	9.2	0.1	23.4	37.0	35.2	--	--	4.3	--	298.2
14	31.7	0.3	16.0	39.4	10.5	--	<0.1	33.8	--	117.3
15	8.5	0.2	40.1	50.7	2.4	--	--	6.6	--	286.3
16	9.8	0.4	19.8	40.9	20.9	--	--	18.0	--	144.9
18	41.3	0.5	15.1	59.3	11.0	--	--	14.1	--	87.0
20	100.4	0.4	21.6	52.5	16.3	--	--	9.2	--	112.7
21	49.4	1.8	25.5	4.4	16.3	--	--	52.0	--	22.9
23	264.6	0.3	11.2	31.4	13.9	27.5	--	15.0	0.7	139.4
25	58.8	0.3	12.4	58.0	5.6	12.3	--	11.4	--	181.5
28	54.7	0.5	37.1	8.3	6.8	3.8	--	40.3	3.2	83.5
30	114.6	0.2	17.9	57.4	16.2	2.7	0.1	5.5	--	314.0
32	94.0	0.3	16.5	22.7	16.8	29.9	1.5	12.3	--	185.5
33	16.0	0.2	17.0	56.6	23.9	--	--	2.3	--	251.9
35	37.7	0.6	33.0	37.7	2.8	--	--	25.9	--	83.7
36	44.6	0.4	31.7	28.9	11.8	11.0	--	16.2	--	121.8
38	105.8	0.5	9.8	36.9	3.6	7.2	6.8	32.5	2.7	84.6
40	17.8	0.8	31.5	16.2	4.6	--	--	46.9	--[b]	53.6
41	448.3	0.4	11.6	31.7	11.3	21.5	1.2	20.3	2.0	115.5
45	24.4	1.5	35.0	7.0	10.2	--	--	46.3	--[b]	32.4
47	455.6	0.2	10.1	35.7	22.3	28.8	--	2.9	--[b]	301.7
48	29.1	0.9	41.7	1.0	45.6	--	--	10.8	--	65.7
51	27.5	0.2	19.2	29.1	21.5	22.0	--	8.0	--	247.5
52	53.6	0.3	32.4	24.0	19.6	15.2	--	8.5	--	178.3
53	10.7	0.1	19.1	49.9	30.9	--	--	<0.1	--	909.1
54	18.8	1.0	7.0	51.3	5.4	--	--	35.3	--	47.3
55	53.2	0.2	11.1	60.1	25.6	--	<0.1	3.0	--	223.2
57	124.5	0.1	19.0	43.8	36.4	--	--	0.7	--	599.7
58	684.7	0.2	14.6	36.9	20.7	15.8	0.7	10.3	0.8	186.7
59	189.7	0.2	17.5	53.1	22.0	2.7	0.2	4.3	--	288.5
60	15.0	0.1	20.9	46.5	32.5	--	--	<0.1	--	796.9
87	19.0	0.1	25.0	34.9	40.0	--	--	<0.1	--	759.2

Chloride Source Loads – Rural Monitoring Site

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







Facts at a Glance

- **Drainage Area Size:** 106 square miles
- **Major Watershed:** Milwaukee River
- **Land Use:** Urban – 7.4%; Rural – 92.6%
- **Roads and Parking Lots (% of drainage area):** 3.1
- **Estimated Population (2010):** 7,910
- **Estimated Households (2010):** 3,080 (37% served by public sanitary sewer)
- **Nearest USGS Streamgage:** None
- **Upstream Wastewater Treatment Facilities (♦):** 2
  WWTF discharge to soil (♦): 1
- **Upstream Industrial Wastewater Dischargers (△):** 3
- **Concentrated Animal Feeding Operations (⬟):** 2
- **Chloride-Impaired Waters:** None
- **Water Supply Source:** Groundwater

Chloride Source Loads – Monitoring Sites

Figure 4.2
General Chloride Source Loads Estimated for Stream Monitoring Sites: October 2018 – October 2020

Note: The x-axes display the stream monitoring site number, with sites ranked from the lowest to the highest chloride source loads. The y-axes display the chloride source loads in tons per square mile and the y-axis range varies for each plot. See Table 4.3 for additional information related to the stream monitoring sites and estimated chloride source loads.

Source: SEWRPC

Chloride Source Loads – Monitoring Sites

Table 4.3
General Chloride Source Loads Estimated for Stream Monitoring Sites Ranked Highest to Lowest: October 2018 – October 2020

Site No.	Site Name	Drainage Area (sq mi)	General Sources of Chloride (ton/sq mi)				Total Chloride Source Load (tons/sq mi)[a]
			Atm. Dep.	Winter Maint.	Wastewater	Agricultural	
12	Lincoln Creek[a]	11.0	0.5	971.0	--	0.4	971.9
53	Honey Creek at Wauwatosa[a]	10.7	0.6	908.3	--	0.2	909.1
60	Root River at Grange Avenue[a]	15.0	0.6	796.1	--	0.2	796.9
87	Underwood Creek[a,b]	19.0	0.5	758.4	--	0.3	759.2
9	Oak Creek[a,b]	25.8	0.6	647.5	--	1.8	649.8
57	Menomonee River at Wauwatosa[a,b]	124.5	0.5	594.7	--	4.4	599.7
1	Fox River at Waukesha[b]	126.3	0.5	403.0	151.5	4.0	558.9
10	Pike River[a,b]	36.6	0.6	444.4	--	12.5	457.5
8	Pewaukee River[b]	38.1	0.5	362.5	--	4.5	367.5
30	Des Plaines River[b]	114.6	0.6	287.4	8.9	17.2	314.0
47	Fox River at Rochester[b]	455.6	0.5	205.6	87.0	8.7	301.7
13	Ulao Creek[a]	9.2	0.5	285.0	--	12.8	298.2
59	Root River near Horlick Dam[b]	189.7	0.5	267.5	8.1	12.4	288.5
15	Kilbourn Road Ditch[a]	8.5	0.6	266.9	--	18.8	286.3
33	Pebble Brook	16.0	0.5	245.6	--	5.8	251.9
51	Rubicon River	27.5	0.4	172.9	54.4	19.7	247.5
2	Fox River at New Munster[b]	807.1	0.5	155.1	57.4	12.6	225.6
55	Bark River Downstream	53.2	0.4	216.0	--	6.7	223.2
11	Bark River Upstream	35.0	0.4	192.7	--	7.7	200.8
58	Milwaukee River at Estabrook Park[b]	684.7	0.4	134.8	30.7	20.7	186.7
32	Turtle Creek	94.0	0.5	104.0	58.1	22.8	185.5
25	Root River Canal	58.8	0.5	137.8	22.4	20.8	181.5
52	Cedar Creek	53.6	0.4	135.7	27.0	15.2	178.3
16	Jackson Creek	9.8	0.6	118.3	--	26.1	144.9
23	Milwaukee River Downstream of Newburg	264.6	0.4	78.8	38.3	21.9	139.4
36	Honey Creek Downstream of East Troy	44.6	0.5	88.1	13.4	19.8	121.8
4	Sugar Creek	60.5	0.5	96.8	--	21.0	118.3
14	Sauk Creek	31.7	0.4	77.3	--	39.6	117.3
41	Milwaukee River near Saukville	448.3	0.4	63.2	26.2	25.7	115.5
20	Oconomowoc River Downstream	100.4	0.4	101.9	--	10.3	112.7
18	Oconomowoc River Upstream	41.3	0.4	74.3	--	12.2	87.0
6	White River near Burlington	112.2	0.6	70.4	1.2	14.1	86.3
38	North Branch Milwaukee River	105.8	0.4	42.5	11.9	29.8	84.6
35	Honey Creek Upstream of East Troy	37.7	0.5	61.5	--	21.6	83.7
28	East Branch Rock River	54.7	0.4	43.6	3.2	36.3	83.5
3	Mukwonago River at Mukwonago	85.4	0.5	62.4	--	10.1	73.1
48	White River at Lake Geneva	29.1	0.6	58.0	--	7.1	65.7
40	Stony Creek	17.8	0.4	28.0	--	25.2	53.6
54	Whitewater Creek	18.8	0.5	30.1	--	16.7	47.3
45	Mukwonago River at Nature Road	24.4	0.5	16.9	--	15.0	32.4
21	East Branch Milwaukee River	49.4	0.4	10.5	--	11.9	22.9

Site Chloride Source Loads – Deicing Salt

Table 4.3 excerpt – 15 sites with the highest total chloride source loads

- Top 6 sites with the highest total chloride source loads
  - Highly urbanized drainage areas
  - Deicing salt accounted for over 99% of the chloride load
- Deicing salt contributed more than 90% of the chloride load at 13 of 15

Site No.	Site Name	Drainage Area (sq mi)	General Sources of Chloride (ton/sq mi)				Total Chloride Source Load (tons/sq mi)[a]
			Atm. Dep.	Winter Maint.	Wastewater	Agricultural	
12	Lincoln Creek[a]	11.0	0.5	971.0	--	0.4	971.9
53	Honey Creek at Wauwatosa[a]	10.7	0.6	908.3	--	0.2	909.1
60	Root River at Grange Avenue[a]	15.0	0.6	796.1	--	0.2	796.9
87	Underwood Creek[a,b]	19.0	0.5	758.4	--	0.3	759.2
9	Oak Creek[a,b]	25.8	0.6	647.5	--	1.8	649.8
57	Menomonee River at Wauwatosa[a,b]	124.5	0.5	594.7	--	4.4	599.7
1	Fox River at Waukesha[b]	126.3	0.5	403.0	151.5	4.0	558.9
10	Pike River[a,b]	36.6	0.6	444.4	--	12.5	457.5
8	Pewaukee River[b]	38.1	0.5	362.5	--	4.5	367.5
30	Des Plaines River[b]	114.6	0.6	287.4	8.9	17.2	314.0
47	Fox River at Rochester[b]	455.6	0.5	205.6	87.0	8.7	301.7
13	Ulao Creek[a]	9.2	0.5	285.0	--	12.8	298.2
59	Root River near Horlick Dam[b]	189.7	0.5	267.5	8.1	12.4	288.5
15	Kilbourn Road Ditch[a]	8.5	0.6	266.9	--	18.8	286.3
33	Pebble Brook	16.0	0.5	245.6	--	5.8	251.9

Site Chloride Source Loads – Wastewater

16 monitoring sites had public WWTFs located upstream (Table 3.3)

- Monitoring sites with highest chloride load from WWTF effluent
  - Site 2 Fox River at New Munster = 46,269 tons (10 WWTFs)
  - Site 47 Fox River at Rochester = 39,638 tons (5 WWTFs)
  - Site 58 Milwaukee River at Estabrook = 20,175 tons (11 WWTFs)
- Monitoring sites with lowest chloride load from WWTF effluent
  - Site 6 White River near Burlington = 135 tons (1 WWTF)
  - Site 28 East Branch Rock River = 175 tons (1 WWTF)
  - Site 36 Honey Creek Downstream of East Troy = 596 tons (1 WWTF)

10 monitoring sites had industrial wastewater dischargers upstream

- Highest: Site 58 = 880 tons (4 industrial facilities)
- Lowest: Sites 11 and 55 Bark River Up/Downstream = 0.36 tons (1 ind.)

Site Chloride Source Loads – Ag and Natural

Majority of agricultural chloride source load was from potash

- Monitoring sites with highest normalized chloride load from potash
  - Site 14 Sauk Creek = 39.6 tons/sq mi
  - Site 28 East Branch Rock River = 33.6 tons/sq mi
  - Site 38 North Branch Milwaukee River = 27.5 tons/sq mi
- 6 monitoring sites had CAFOs upstream
  - Lowest: Site 2 = 126 tons
  - Highest: Sites 41 and 58 Milwaukee River sites = 1,023 tons

Atmospheric deposition of chloride at stream sites: 0.4 to 0.6 tons/sq mi

- Highest: Site 2 Fox River at New Munster = 414 tons
- Lowest: Smallest sites received 4 to 5 tons (Site 13 Ulao Creek and Site 15 Kilbourn Road Ditch)

Site Chloride Source Loads and Land Use

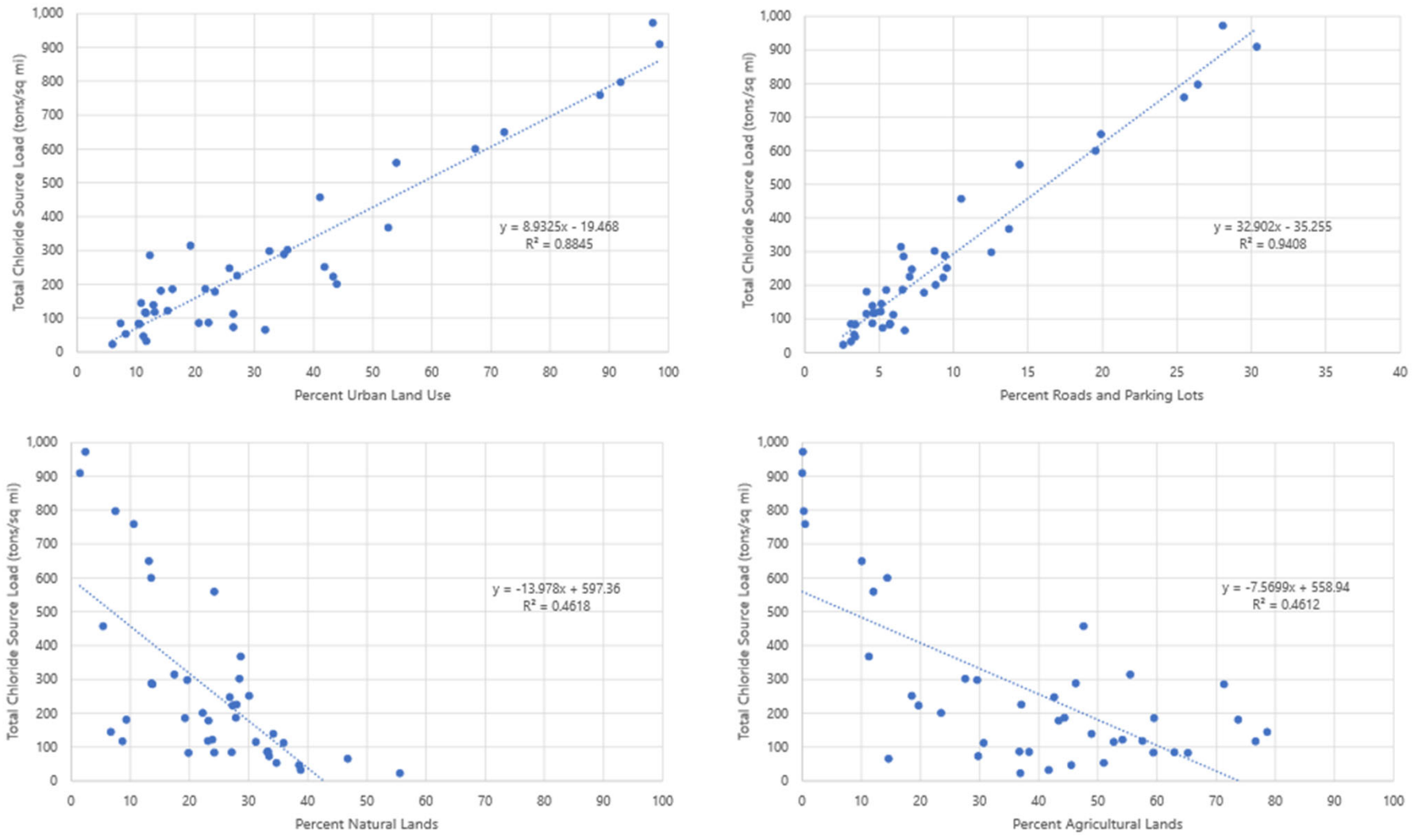
Table 4.4
Total Chloride Source Loads Estimated for the Study Period and Drainage Area Characteristics Ranked for each Stream Monitoring Site

SEWRPC	Total Chloride Source Load		Drainage Area Size		Urban Lands		Roads and Parking Lots		Natural Lands		Agricultural Lands	
Site No.[a]	(tons/sq mi)	(rank)	(sq mi)	(rank)	(percent)	(rank)	(percent)	(rank)	(percent)	(rank)	(percent)	(rank)
1	558.9	7	126.3	7	54.0	7	14.4	7	24.2	20	12.1	35
2	225.6	17	807.1	1	27.1	17	7.0	18	28.0	15	37.1	23
3	73.1	36	85.4	14	26.4	18	5.2	27	33.5	8	29.7	27
4	118.3	27	60.5	15	13.1	29	4.7	30	23.1	24	57.5	9
6	86.3	32	112.2	10	20.6	24	5.7	24	33.2	10	38.4	22
8	367.5	9	38.1	23	52.7	8	13.7	8	28.6	13	11.3	36
9	649.8	5	25.8	30	72.3	5	19.9	5	13.1	33	10.1	37
10	457.5	8	36.6	25	41.1	12	10.5	10	5.4	39	47.6	15
11	200.8	19	35.0	26	43.9	9	8.8	14	22.2	25	23.5	30
12	971.9	1	11.0	37	97.4	2	28.1	2	2.4	40	0.1	40
13	298.2	12	9.2	40	32.5	15	12.5	9	19.6	27	29.6	28
57	599.7	6	124.5	8	67.3	6	19.5	6	13.5	32	14.4	34
58	186.7	20	684.7	2	21.7	23	6.6	21	27.8	16	44.4	18
59	288.5	13	189.7	6	35.0	14	9.4	12	13.6	31	46.3	16
60	796.9	3	15.0	36	91.9	3	26.4	3	7.5	37	0.3	39
87	759.2	4	19.0	32	88.4	4	25.5	4	10.6	34	0.5	38
Spearman's rank correlation coefficient[b]			ρ = -0.120		ρ = 0.806		ρ = 0.885		ρ = -0.690		ρ = -0.502	

Site Chloride Source Loads and Land Use

Figure 4.3

Relationships Between Drainage Area Land Use and Estimated Chloride Source Loads for Stream Monitoring Sites over the Study Period



Source: SEWRPC

Site Cl^- Source Loads and Chloride Impairments

Table 4.3
General Chloride Source Loads Estimated for Stream Monitoring Sites Ranked Highest to Lowest: October 2018 – October 2020

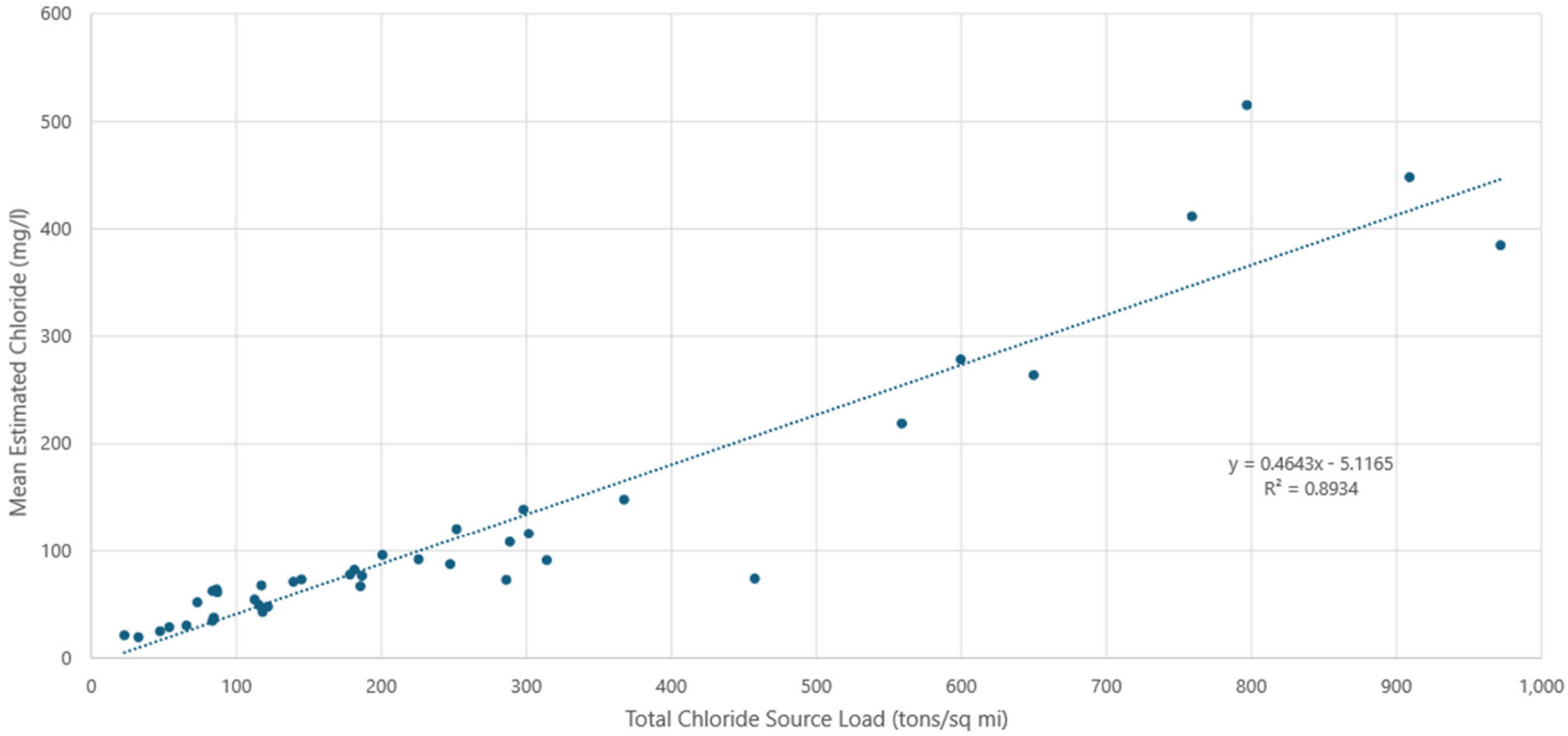
Site No.	Site Name	Drainage Area (sq mi)	General Sources of Chloride (ton/sq mi)				Total Chloride Source Load (tons/sq mi)[a]
			Atm. Dep.	Winter Maint.	Wastewater	Agricultural	
12	Lincoln Creek[a]	11.0	0.5	971.0	--	0.4	971.9
53	Honey Creek at Wauwatosa[a]	10.7	0.6	908.3	--	0.2	909.1
60	Root River at Grange Avenue[a]	15.0	0.6	796.1	--	0.2	796.9
87	Underwood Creek[a,b]	19.0	0.5	758.4	--	0.3	759.2
9	Oak Creek[a,b]	25.8	0.6	647.5	--	1.8	649.8
57	Menomonee River at Wauwatosa[a,b]	124.5	0.5	594.7	--	4.4	599.7
1	Fox River at Waukesha[b]	126.3	0.5	403.0	151.5	4.0	558.9
10	Pike River[a,b]	36.6	0.6	444.4	--	12.5	457.5
8	Pewaukee River[b]	38.1	0.5	362.5	--	4.5	367.5
30	Des Plaines River[b]	114.6	0.6	287.4	8.9	17.2	314.0
47	Fox River at Rochester[b]	455.6	0.5	205.6	87.0	8.7	301.7
13	Ulao Creek[a]	9.2	0.5	285.0	--	12.8	298.2
59	Root River near Horlick Dam[b]	189.7	0.5	267.5	8.1	12.4	288.5
15	Kilbourn Road Ditch[a]	8.5	0.6	266.9	--	18.8	286.3
33	Pebble Brook	16.0	0.5	245.6	--	5.8	251.9
51	Rubicon River	27.5	0.4	172.9	54.4	19.7	247.5
2	Fox River at New Munster[b]	807.1	0.5	155.1	57.4	12.6	225.6
55	Bark River Downstream	53.2	0.4	216.0	--	6.7	223.2
11	Bark River Upstream	35.0	0.4	192.7	--	7.7	200.8
58	Milwaukee River at Estabrook Park[b]	684.7	0.4	134.8	30.7	20.7	186.7

Table 4.3 excerpt of the top 20 sites with the highest chloride source loads

- Red highlight – site located on a chloride-impaired stream segment
- Yellow highlight – site with chloride-impaired waterbody located upstream
- Orange highlight – sites with both

Site Cl^- Source Loads and In-Stream Chloride

Figure 4.4
Chloride Source Loads Versus Mean Estimated Chloride Concentrations for each Monitoring Site

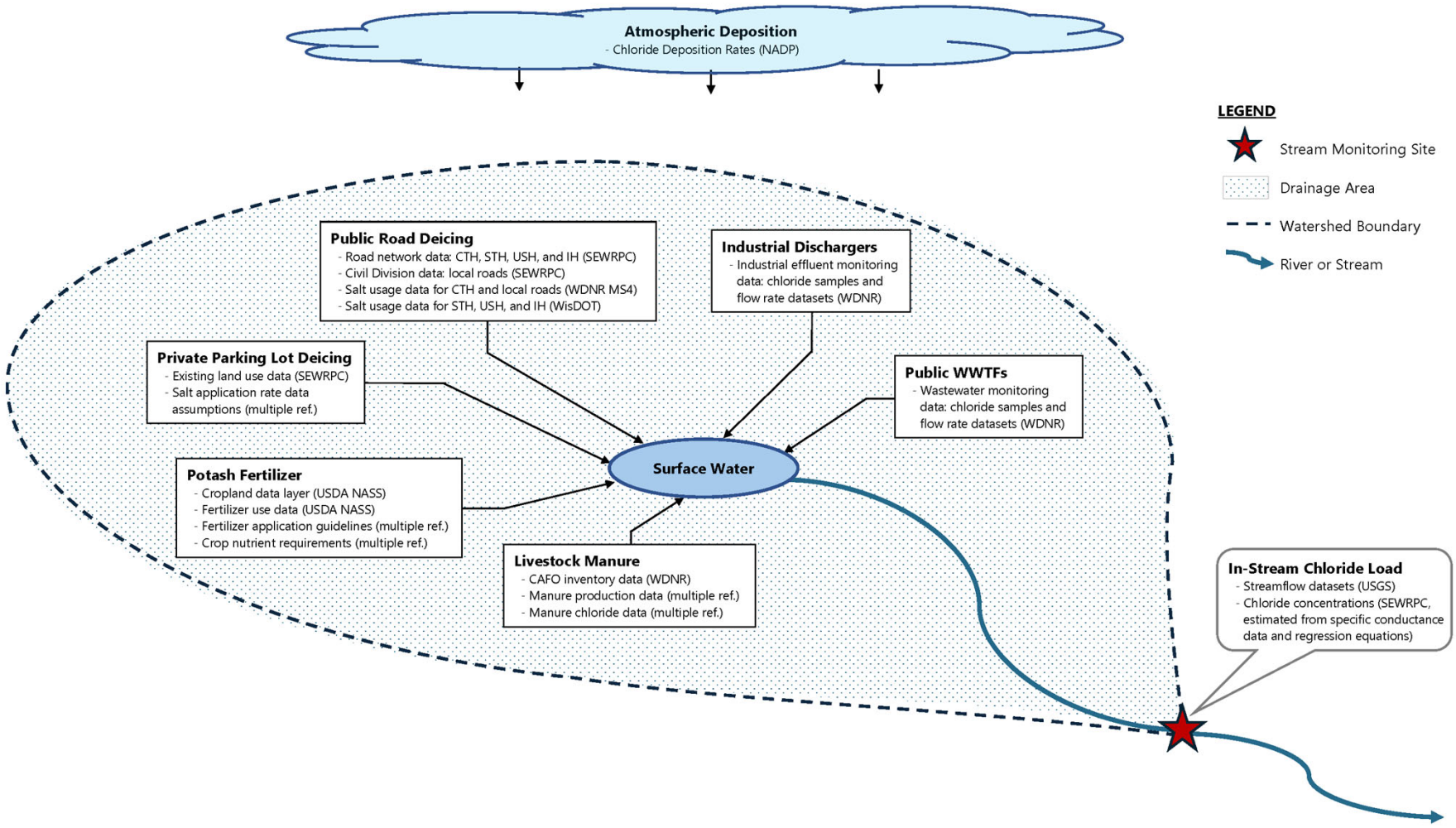


Note: Mean chloride concentrations were estimated for the study period using the regression equations developed in TR-64.

Source: SEWRPC

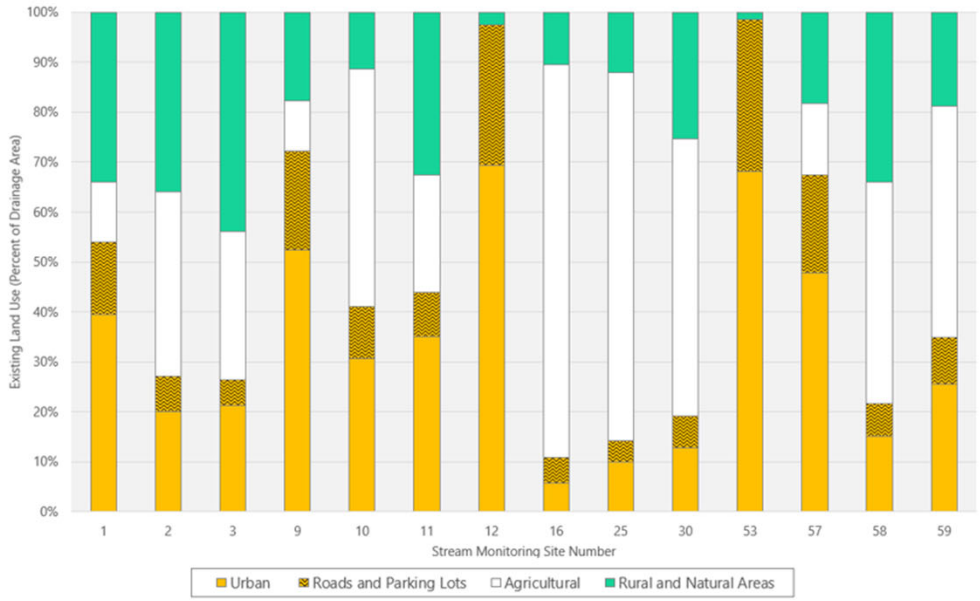
Chloride Mass Balance Analysis

Σ Chloride Inputs – Chloride Output = Δ Chloride Retained in the System



Mass Balance Analysis Sites

Figure 3.3
Existing Generalized Land Use Percentages for Monitoring Sites in the Mass Balance Analysis

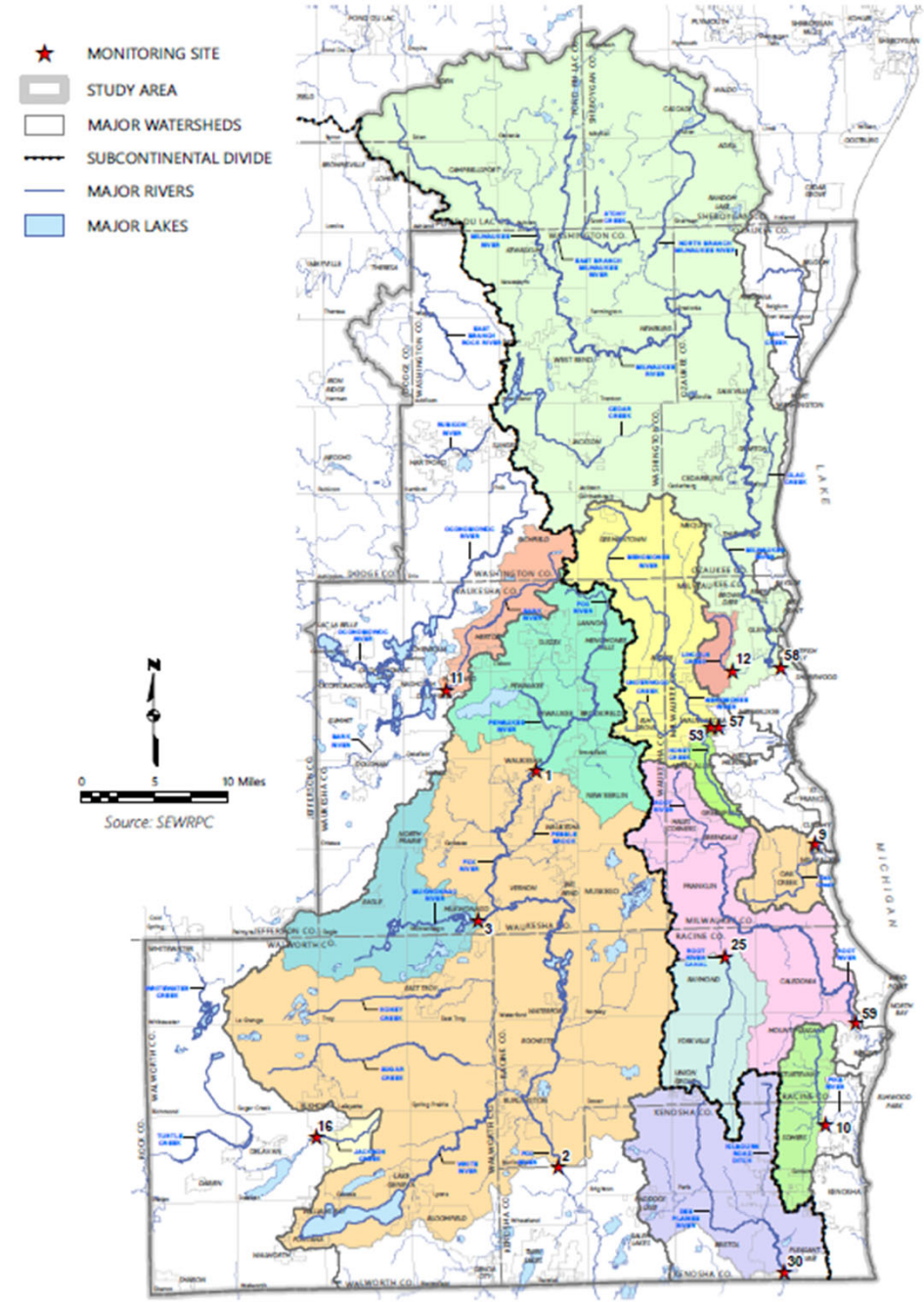


Note: Refer to Table 2.3 for the site drainage area size and other stream monitoring site details. Urban land use includes residential, commercial, industrial, government and institutional, and other urban land uses, while roads and parking lots are represented separately. Rural and natural areas include wetlands, woodlands, surface water, unused rural lands, and extractive lands, while agricultural lands are represented separately.

Source: SEWRPC

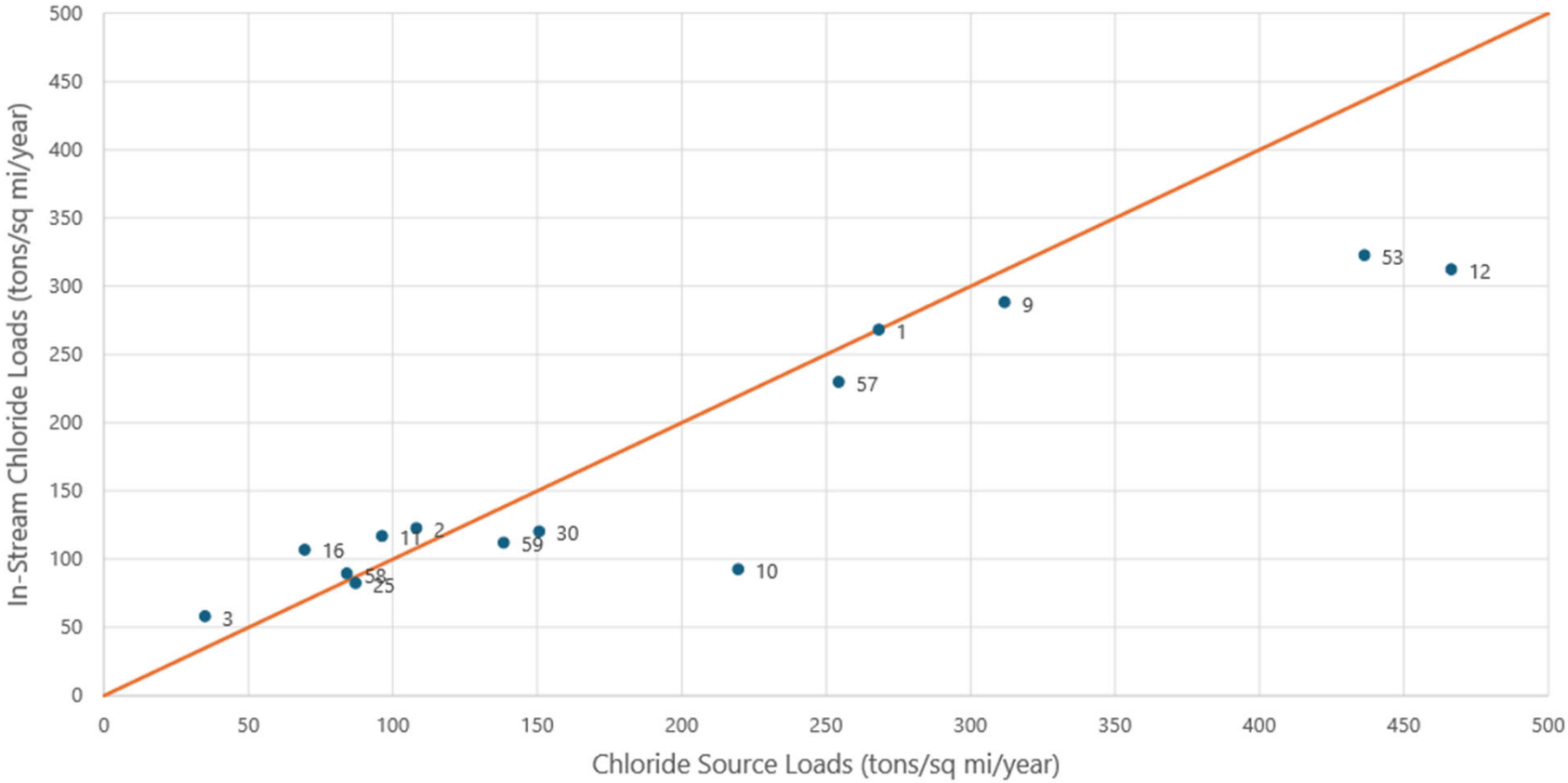
- 14 stream monitoring sites used for the mass balance analysis

Map 3.1
Stream Monitoring Sites and Upstream Drainage Areas used for the Chloride Mass Balance Analysis



Chloride Mass Balance Analysis Results

Figure 4.5
Comparison of Chloride Source Loads with In-Stream Chloride Loads During the Study Period



Note: The chloride source loads and in-stream chloride loads were computed for the study period, annualized, and normalized by drainage area. The orange line on the plot represents the line of parity, for which the x- and y-values are equal.

Source: SEWRPC

Chloride Mass Balance Analysis Results

Table 4.5
Chloride Mass Balance for Stream Monitoring Sites During the Study Period

Site No.	Site Name	Appendix C Figure No.[a]	Drainage Area (sq mi)	Study Period Months	In-Stream Chloride Load (tons)	Chloride Source Load (tons)	Chloride Load Percent Difference[b]
10	Pike River	C.5	36.6	25	7,030	16,751	138.3
12	Lincoln Creek	C.7	11.0	25	7,167	10,713	49.5
53	Honey Creek at Wauwatosa	C.11	10.7	25	7,213	9,763	35.3
30	Des Plaines River	C.10	114.6	25	28,636	35,983	25.7
59	Root River near Horlick Dam	C.14	189.7	25	44,111	54,744	24.1
57	Menomonee River at Wauwatosa	C.12	124.5	11	26,174	29,035	10.9
9	Oak Creek	C.4	25.8	25	15,476	16,765	8.3
25	Root River Canal	C.9	58.8	25	10,067	10,681	6.1
1	Fox River at Waukesha	C.1	126.3	25	70,440	70,587	0.2
58	Milwaukee River at Estabrook Park	C.13	684.7	11	55,937	52,859	-5.5
2	Fox River at New Munster	C.2	807.1	25	205,865	182,076	-11.6
11	Bark River Upstream	C.6	35.0	25	8,483	7,026	-17.2
16	Jackson Creek	C.8	9.8	25	2,181	1,423	-34.7
3	Mukwonago River at Mukwonago	C.3	85.4	25	10,269	6,238	-39.3

[a] *Appendix C presents additional mass balance results organized by stream monitoring site under the figure numbers presented in the table.*

[b] *Percent differences are based on the in-stream chloride load (percent difference = (source – in-stream) / in-stream) and the results presented in the table are positive when source loads are greater than in-stream loads and negative when in-stream loads are greater than source loads.*

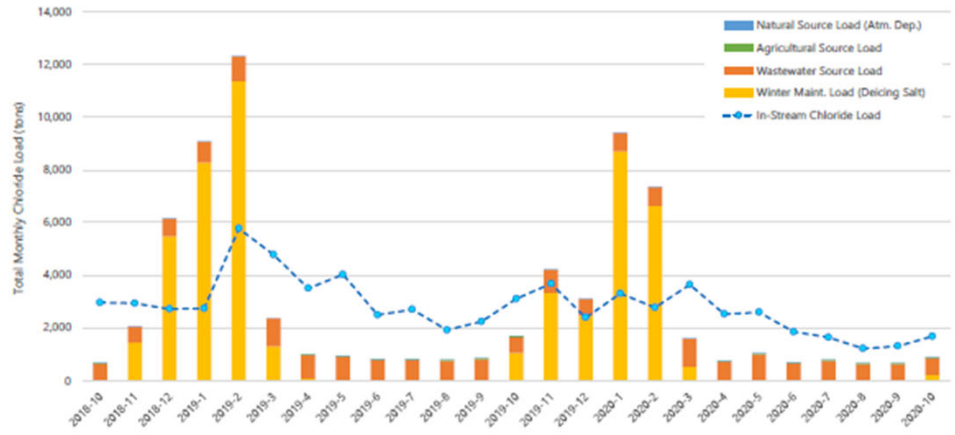
Source: SEWRPC

Appendix C: Chloride Mass Balance Results

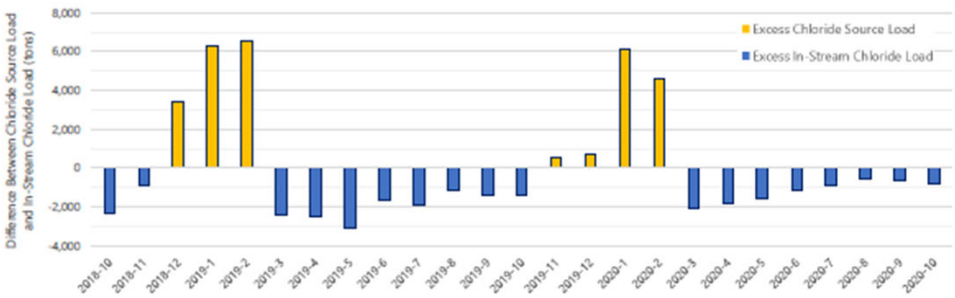
- Figure (a) – monthly chloride loads
  - General chloride source loads
  - In-stream chloride loads
- Figure (b) – excess chloride loads
  - Excess chloride source (yellow)
  - Excess in-stream chloride (blue)
- Figure (c) – seasonal chloride loads
  - 3-month meteorological seasons
  - Load in tons per month
- Additional results
  - Overall balance
  - Excess load balances
  - Flow-weighted chloride conc.

Figure C.1
Chloride Loads and Mass Balance Analysis Results at Site 1 Fox River at Waukesha

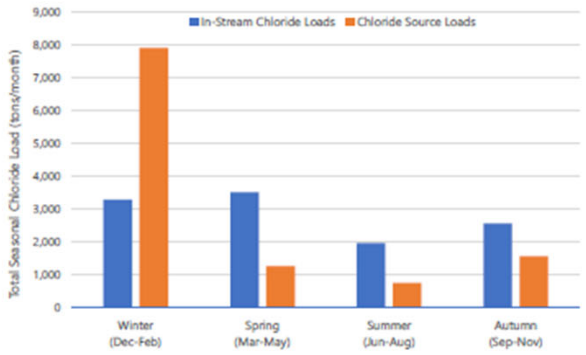
(a) Monthly Chloride Sources Loads Versus In-Stream Chloride Loads



(b) Monthly Excess Chloride Loads



(c) Seasonal Chloride Load Comparison



Site 1 Results Summary

Chloride mass balance over the study period
- **0.21%** (sources > in-stream)

Percent of the winter excess chloride load accounted for by excess in-stream chloride load over the following non-winter months
- Winter 2018-2019 = **95.3%**
- Winter 2019-2020 = **78.6%**

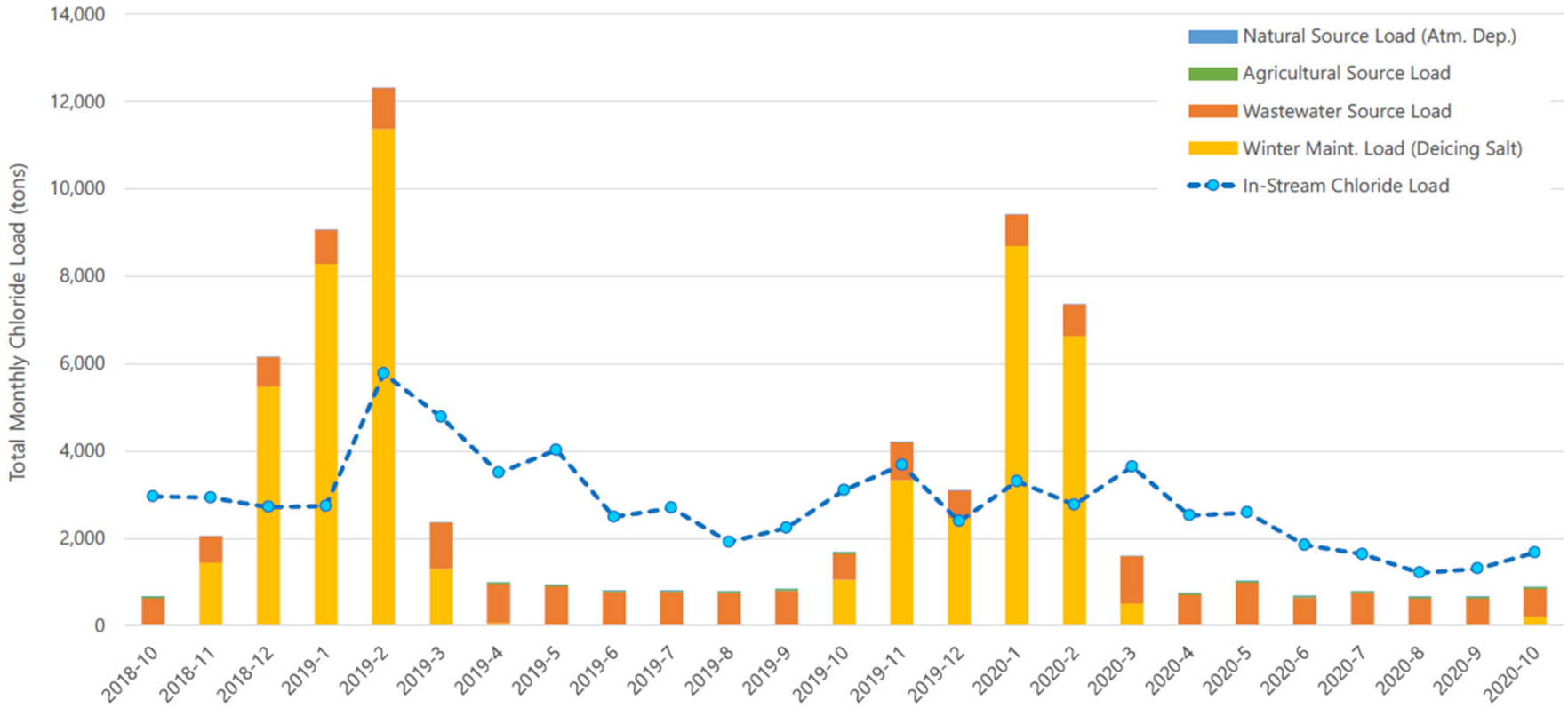
Flow-Weighted Mean Chloride Concentrations
- Study Period = **180.1 mg/l**
- Monthly Maximum = 403.8 mg/l
- Monthly Minimum = 90.1 mg/l

Source: SEWRPC

Site 1: Chloride Mass Balance Results

Figure C.1
Chloride Loads and Mass Balance Analysis Results at Site 1 Fox River at Waukesha

(a) Monthly Chloride Sources Loads Versus In-Stream Chloride Loads



Overall Study Period Difference = **0.2**%

Chloride Mass Balance Analysis Results

Table 4.5
Chloride Mass Balance for Stream Monitoring Sites During the Study Period

Site No.	Site Name	Appendix C Figure No.[a]	Drainage Area (sq mi)	Study Period Months	In-Stream Chloride Load (tons)	Chloride Source Load (tons)	Chloride Load Percent Difference[b]
10	Pike River	C.5	36.6	25	7,030	16,751	138.3
12	Lincoln Creek	C.7	11.0	25	7,167	10,713	49.5
53	Honey Creek at Wauwatosa	C.11	10.7	25	7,213	9,763	35.3
30	Des Plaines River	C.10	114.6	25	28,636	35,983	25.7
59	Root River near Horlick Dam	C.14	189.7	25	44,111	54,744	24.1
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9	Oak Creek	C.4	25.8	25	15,476	16,765	8.3
25	Root River Canal	C.9	58.8	25	10,067	10,681	6.1
1	Fox River at Waukesha	C.1	126.3	25	70,440	70,587	0.2
58	Milwaukee River at Estabrook Park	C.13	684.7	11	55,937	52,859	-5.5
2	Fox River at New Munster	C.2	807.1	25	205,865	182,076	-11.6
11	Bark River Upstream	C.6	35.0	25	8,483	7,026	-17.2
16	Jackson Creek	C.8	9.8	25	2,181	1,423	-34.7
3	Mukwonago River at Mukwonago	C.3	85.4	25	10,269	6,238	-39.3

[a] *Appendix C presents additional mass balance results organized by stream monitoring site under the figure numbers presented in the table.*

[b] *Percent differences are based on the in-stream chloride load (percent difference = (source – in-stream) / in-stream) and the results presented in the table are positive when source loads are greater than in-stream loads and negative when in-stream loads are greater than source loads.*

Source: SEWRPC

Factors Influencing Mass Balance Results

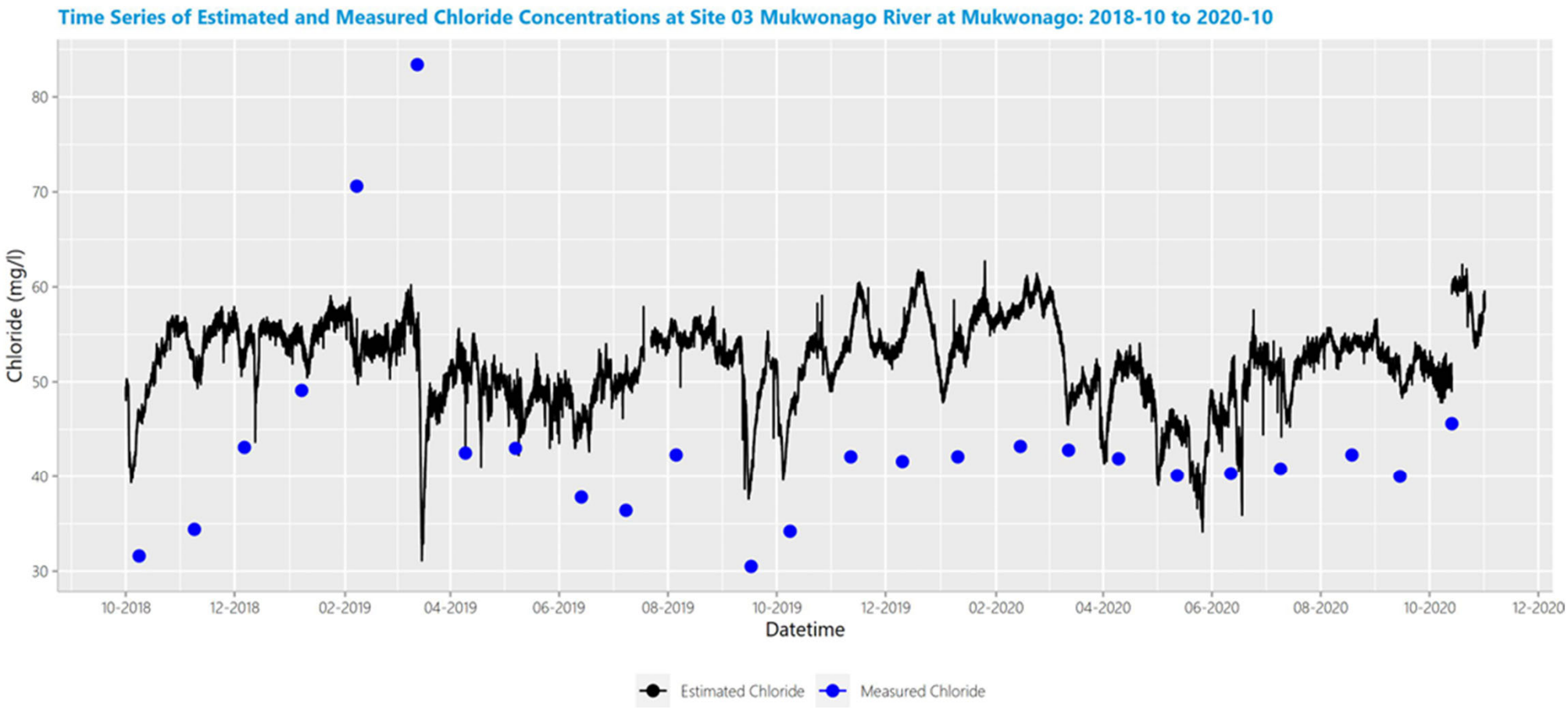
Input dataset issues affecting in-stream chloride load estimates

- Missing data (USGS streamflow or specific conductance)
  - Site 25 missing 85% of specific conductance data in Sept 2020
- Sensor fouling or dampened specific conductance data
  - Site 10 in-stream specific conductance typically lower than sonde

Effects of regression equations on in-stream chloride load estimates

- Regression equation performance varied by monitoring site
  - Underestimated at sites where sources > in-stream by 25% or more
    - Site 10 underestimated by ~ 30% on average
  - Overestimated in-stream chloride at Site 3 (23% on average)
- Carry-over effects on in-stream chloride load estimates

Factors Influencing Mass Balance Results



Source: SEWRPC TR-63 Appendix C

Factors Influencing Mass Balance Results

Input dataset issues affecting chloride source loads

- Missing data or chloride source omission
- Computational methodologies, assumptions, or simplifications
    - Areal proportioning or equal distribution of road salt
    - Fertilizer application rate assumptions

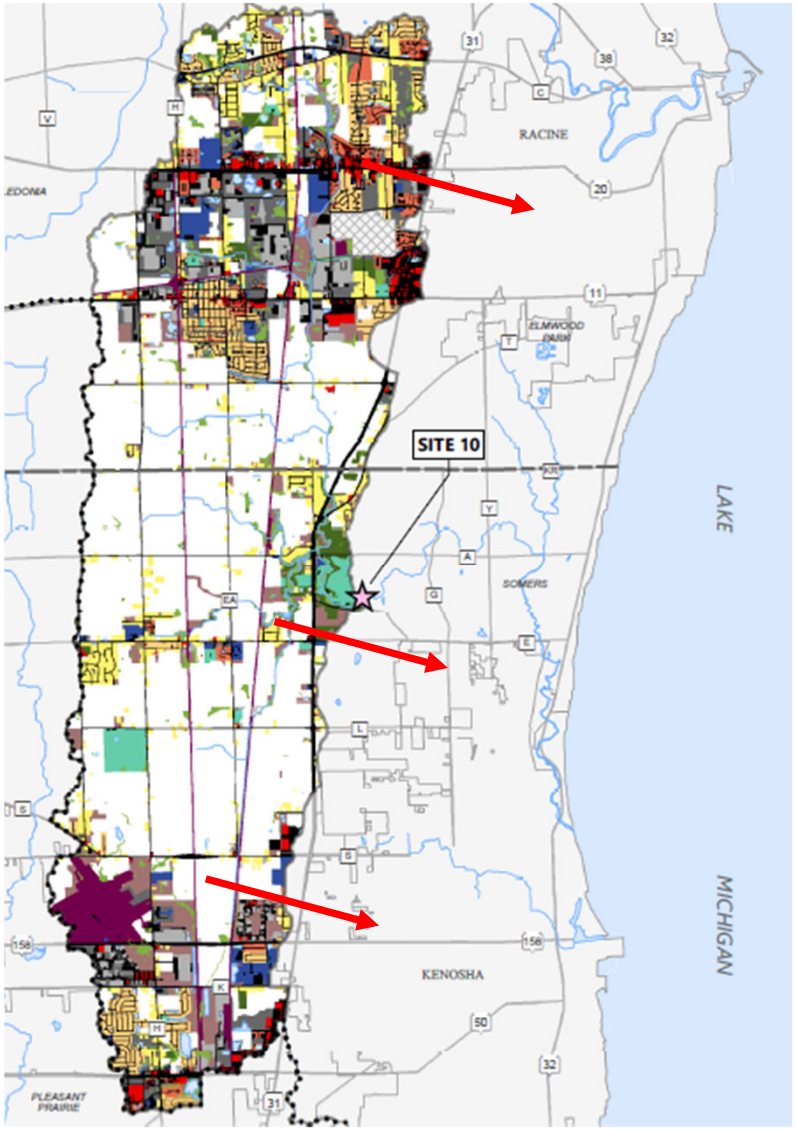
Chloride transport pathways affecting chloride mass balance

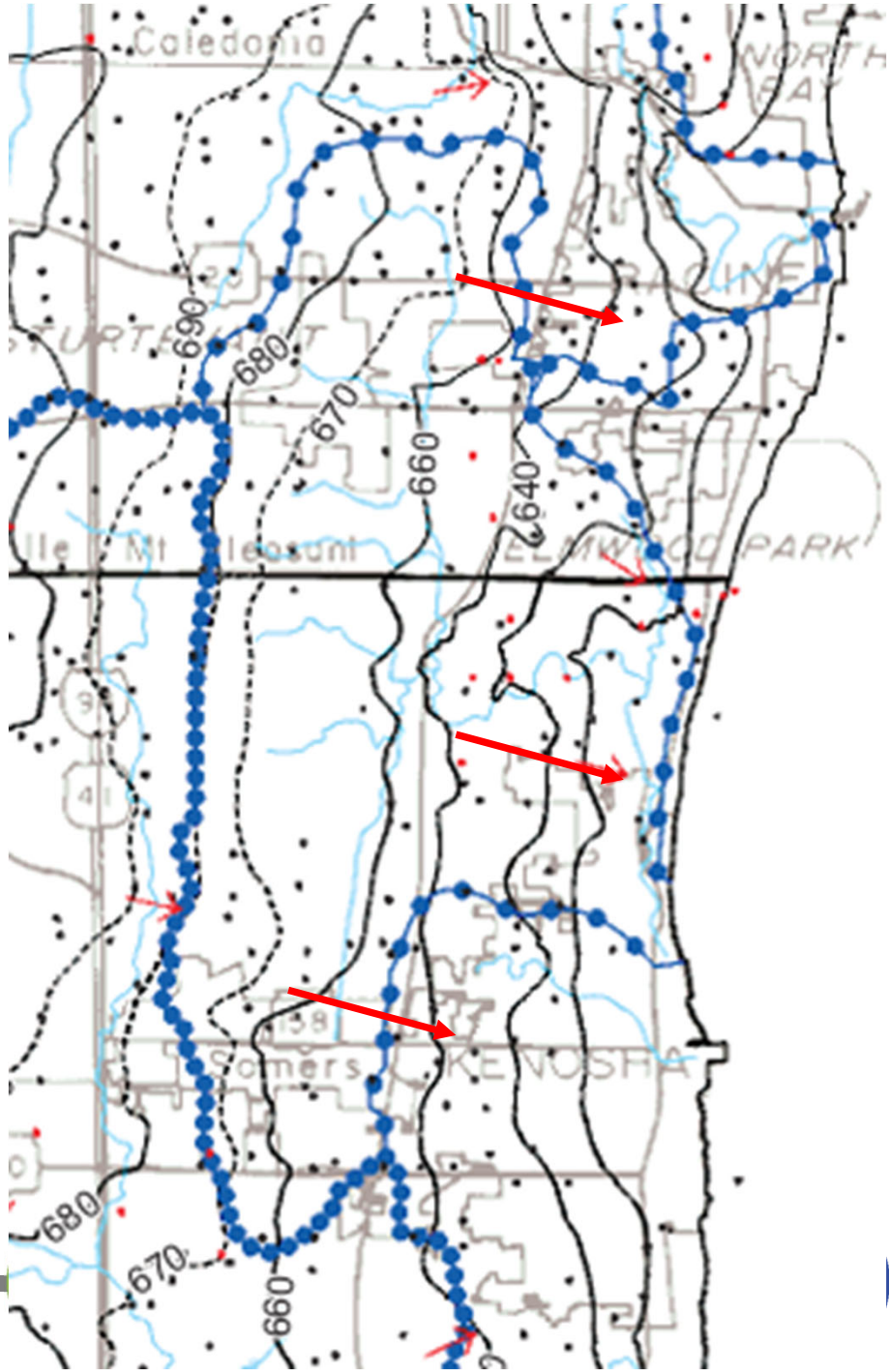
- Groundwater and surface water interactions
- Subsurface pathways exporting chloride out of the watershed
    - Inflow and infiltration into sanitary sewer systems
    - Storm sewer underground pipe networks
- Aerosolization

Factors Influencing Mass Balance Results

Site 10 Pike River Example

- TR-37 Groundwater Resources Map 21



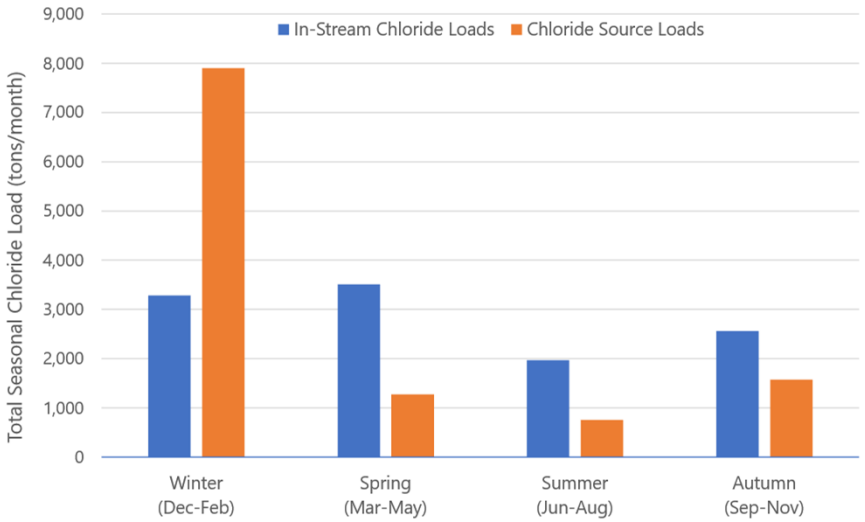


Seasonal Patterns

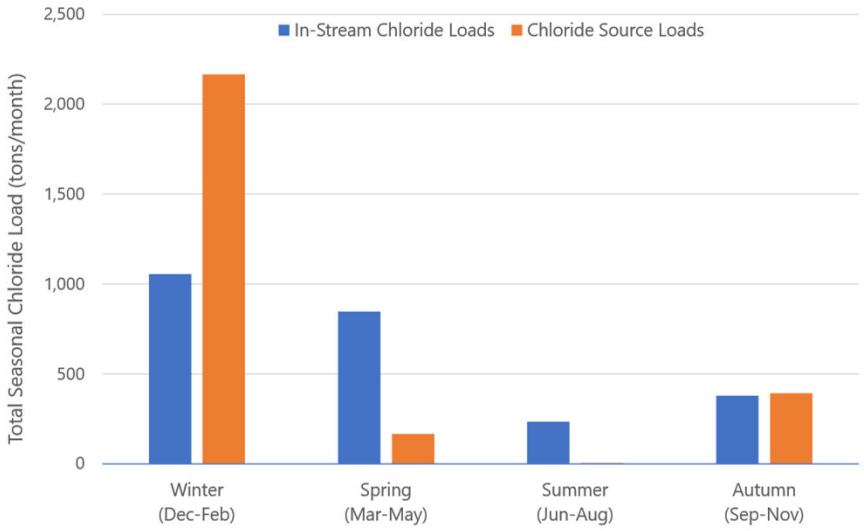
Seasonal patterns typical for every site

- During winter: source loads >> in-stream loads (~175%)
- During spring and summer: in-stream loads> source loads (~75%)
- During fall: typically, in-stream loads> source loads (~26%)
  - More evenly balanced at highly urbanized sites

Site 1: Fox River at Waukesha [Fig C.1 (c)]



Site 9: Oak Creek [Fig C.4 (c)]

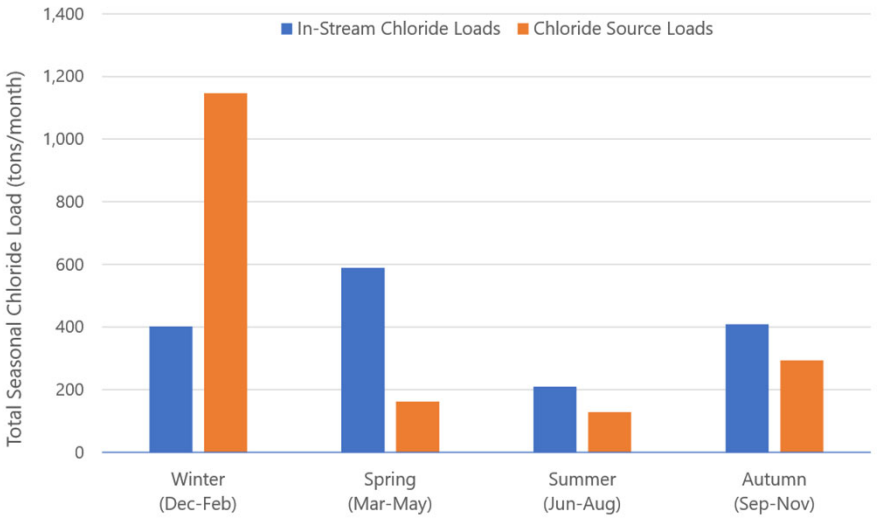


Seasonal Patterns

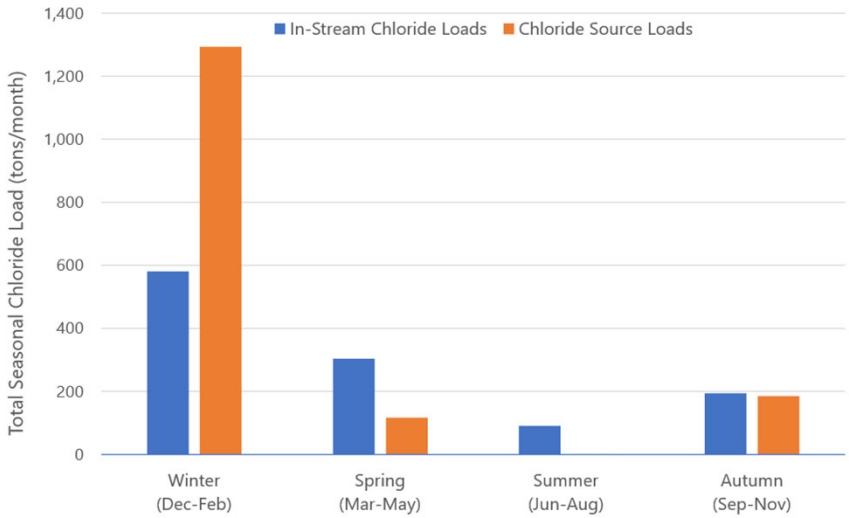
Highest in-stream chloride loads

- During spring at most monitoring sites
- During winter at highly urbanized sites
  - Sites 9, 12, 53, and 57

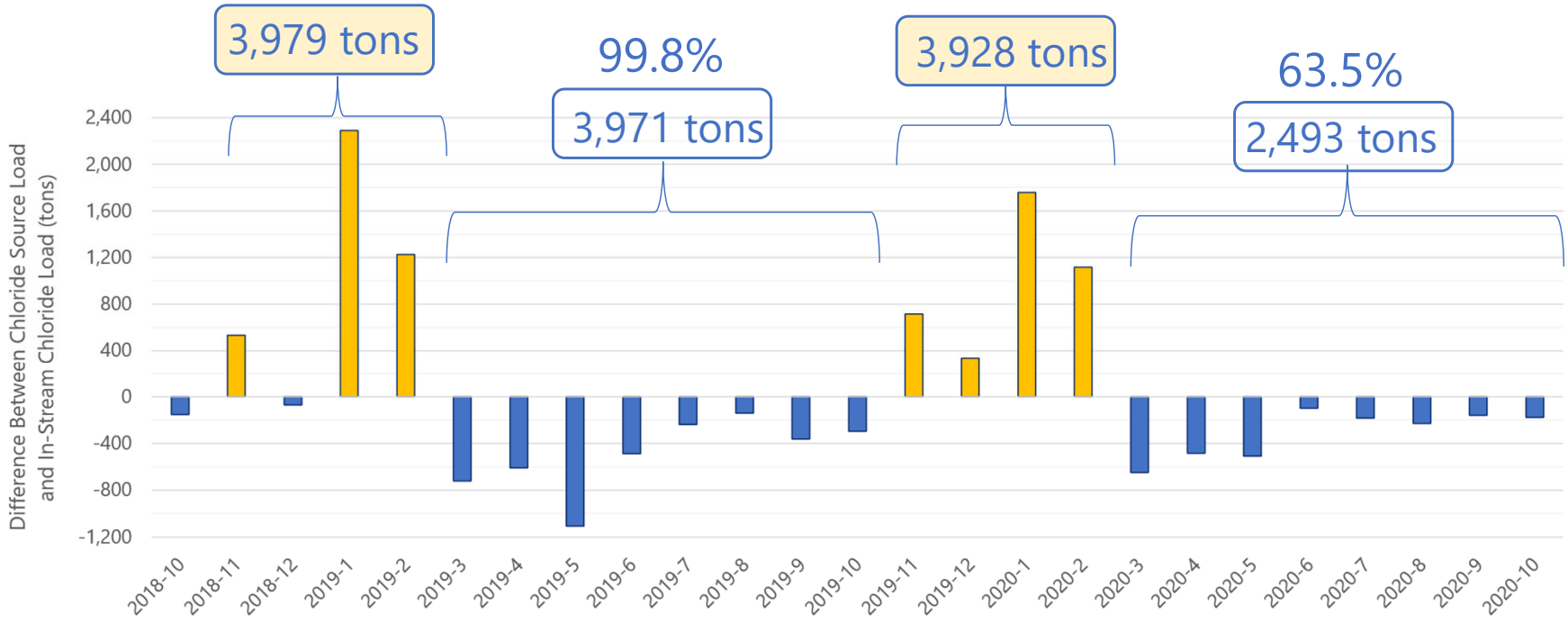
Site 25: Root River Canal [Fig C.9 (c)]



Site 53: Honey Creek at Wauwatosa Fig C.11 (c)]



Seasonal Excess Chloride Loads



Site 9: Oak Creek [Fig C.4 (b)]

- Winter 2018-19 excess chloride source load 99.8% accounted for

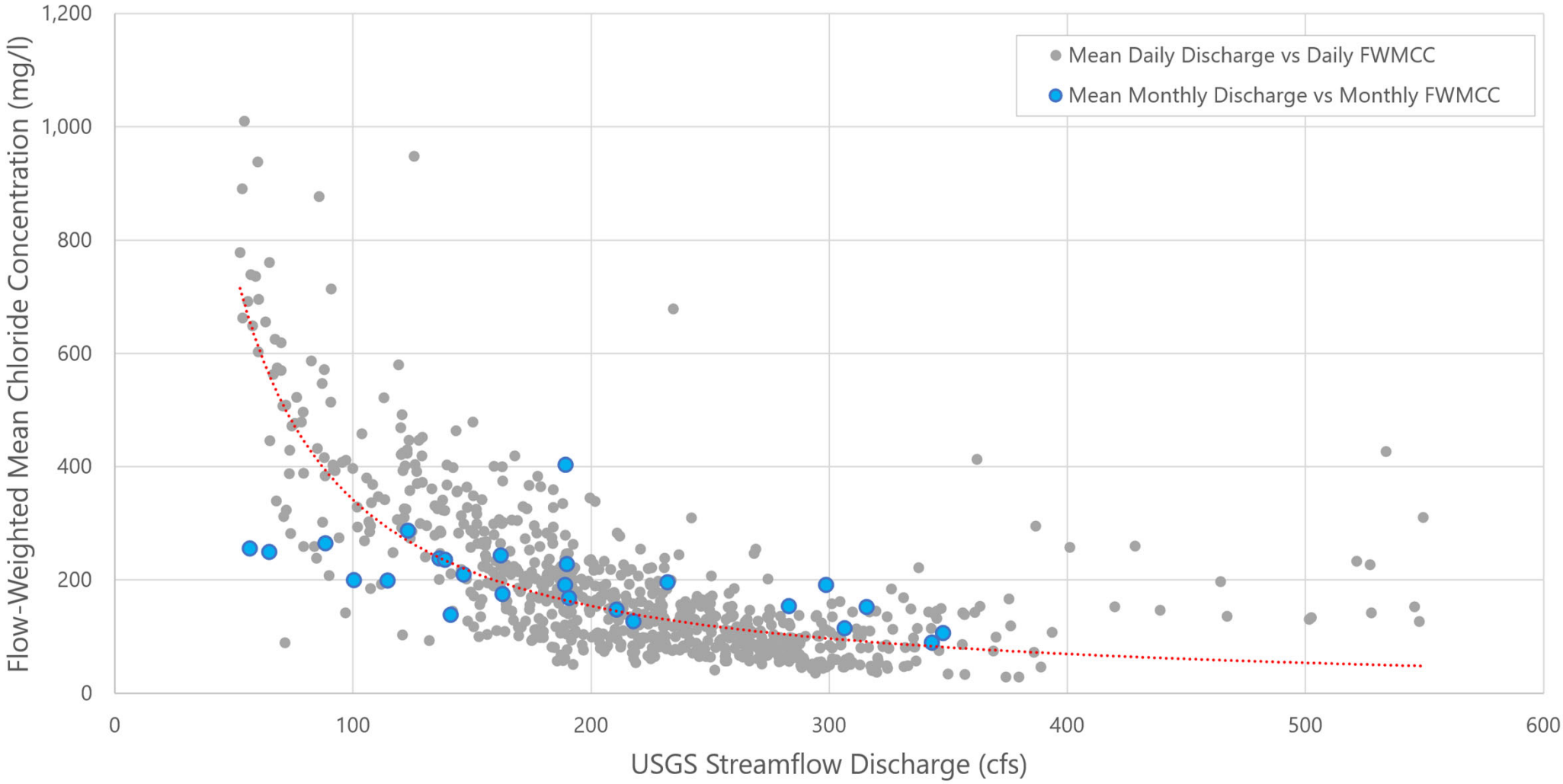
- Winter 2019-20 excess chloride source load 63.5% accounted for

Flow-Weighted Mean Chloride Concentrations

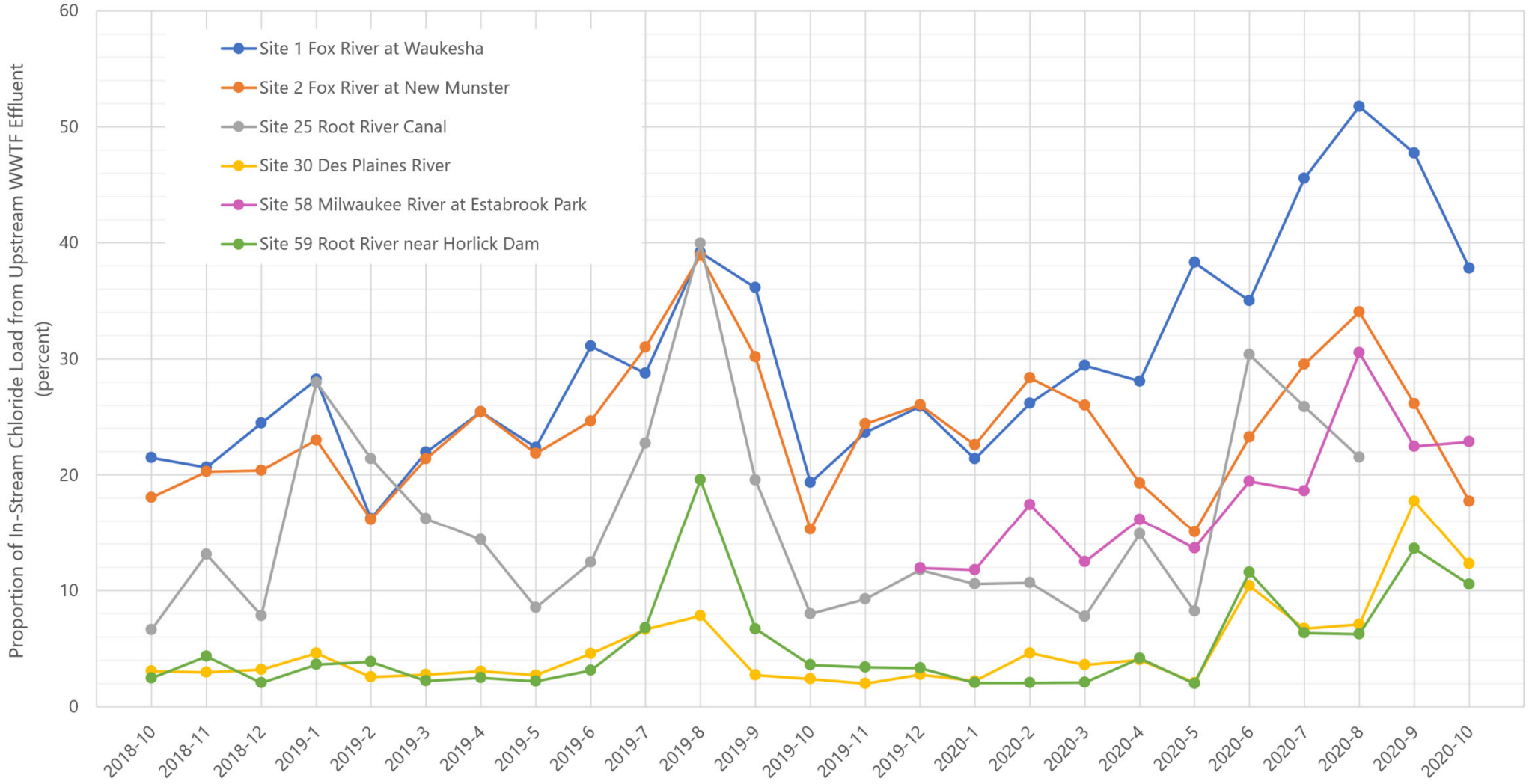
- FWMCC = Total Chloride Load / Total Volume of Streamflow Discharge
  - Computed for each month
  - Computed for full study period
- Sites with highest FWMCC over full study period
  - Site 53 Honey Creek at Wauwatosa = 221.6 mg/l
  - Site 12 Lincoln Creek = 196.3 mg/l
  - Site 1 Fox River at Waukesha = 180.1 mg/l
- Sites with lowest FWMCC over full study period
  - Site 16 Jackson Creek = 49.5 mg/l
  - Site 25 Root River Canal = 50.1 mg/l
  - Site 3 Mukwonago River at Mukwonago = 50.5 mg/l

Streamflow Discharge and Flow-Weighted Mean Chloride Concentrations

Site 1: Fox River at Waukesha



Wastewater Treatment Facility Effluent



Conclusions

- The Regional chloride budget results indicated that winter maintenance activities were the largest source of chloride to the environment during the study period
  - Public roadway deicing ~ 69%
  - Private parking lot salting ~ 31%

- The second largest source of chloride in the Regional chloride budget was wastewater effluent, over 90% from public WWTFs

- Even relatively minor sources of chloride can have a significant effect on a local scale.

Conclusions

- Overall, the computed chloride source loads and estimated in-stream chloride loads matched well for the 14 stream monitoring sites evaluated for the chloride mass balance.
  - 6 sites were within 12 percent over the full study period
  - 9 sites were within 30 percent
  - 1 site was greater than 50 percent

- Monitoring sites with smaller drainage areas were more sensitive to the factors influencing the chloride mass balance results than sites with larger drainage areas

Questions?

Next Steps

Chloride Impact Study – Next Steps

- Comments on Technical Report No. 65 Preliminary Draft
  - Send to Laura Herrick: lherrick@sewrpc.org
  - Comments due by Friday October 31, 2025

Meeting agendas, presentations, and summary notes along with completed reports and preliminary drafts are posted on project website

www.sewrpc.org/chloridestudy

Chloride Impact Study – Next Steps

- Forthcoming TAC meetings for Technical Reports in progress
  - TR 63 – Chloride Conditions and Trends in SE WI (Chapter 5 Lakes)
  - TR 66 – State-of-the-Art of Chloride Management

- Planning Report PR 57
  - Summarizing the technical reports and provide consideration for alterative scenarios, future conditions, and recommendations.

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U.S. Department of Transportation
Federal Highway Administration

MMSD
PARTNERS FOR A CLEANER ENVIRONMENT

SEWRPC
Serving the counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

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Thank You

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Laura Herrick
Chief Environmental Engineer
lherrick@sewrpc.org
262.953.3224

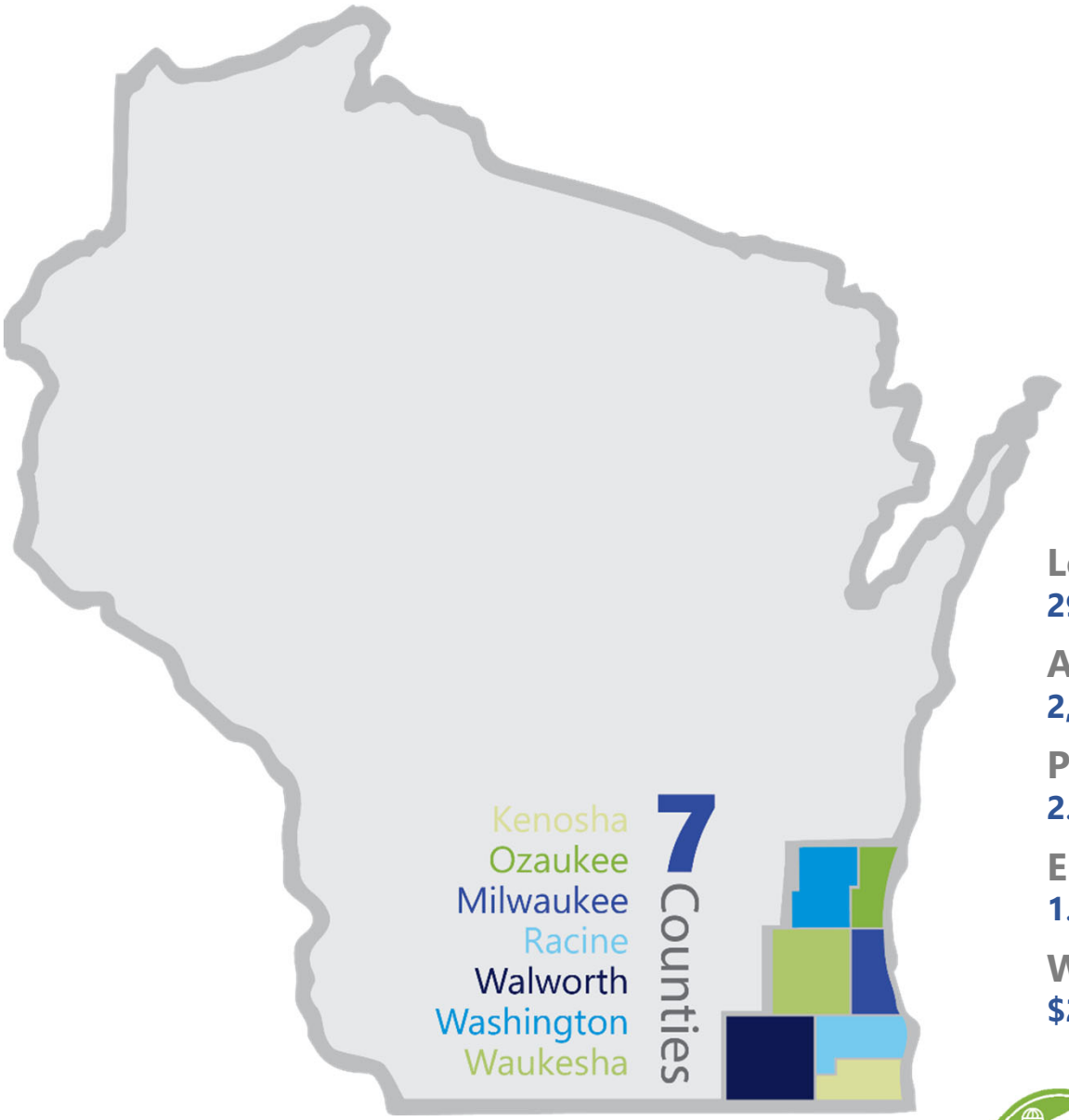
Karin Hollister
Principal Engineer
khollister@sewrpc.org
262.953.3247

SEWRPC.org /SEWRPC @SEW_RPC

Commission Staff Contributors

- Laura Herrick – Chief Env. Engineer
  - Mike Hahn – retired
  - Joe Boxhorn – retired
  - Ron Printz – retired
  - Karin Hollister
  - Aaron Owens
  - Megan Shedivy
  - Nicklaus Neureuther – former staff
  - Alexis McAdams – former staff
  - Julia Orlowski
  - Zijia Li – former staff
  - James Mahoney
  - Collin Klaubauf
  - Emily Porter
  - Kathy Sobottke – retired
  - Kim Walsh – intern
  - Santos Quispe – intern
- Thomas M. Slawski – Chief Biologist
  - Dale Buser – retired
  - Justin Poinsatte
  - Zofia Noe – former staff
  - Mike Borst – retired
  - Emma Weiss-Burns – intern
- Design and Production Support
  - Megan Deau
  - Tim Gorsegner
  - Patti Bouchard
  - Alexa Carzoli – former staff
  - Rick Wazny

Southeastern Wisconsin Regional Planning Commission – SEWRPC



Local Governments
29 Cities | **67** Villages | **50** Towns

Area
2,689 Square Miles | **5%** of State

Population
2.05 Million People | **35%** of State

Employment
1.34 Million Jobs | **35%** of State

Wealth
$295.9 Billion in Equalized Valuation | **35%** of State

Land Use Relationships

Correlations between in-stream chloride loads and land use categories

- Urban Land Use
  - Spearman's ρ = 0.802
  - R-squared = 0.8326
- Natural Lands
  - Spearman's ρ = -0.376
  - R-squared = 0.1965
- Roads and Parking Lots
  - Spearman's ρ = 0.837
  - R-squared = 0.8701
- Agricultural Lands
  - Spearman's ρ = -0.763
  - R-squared = 0.6463

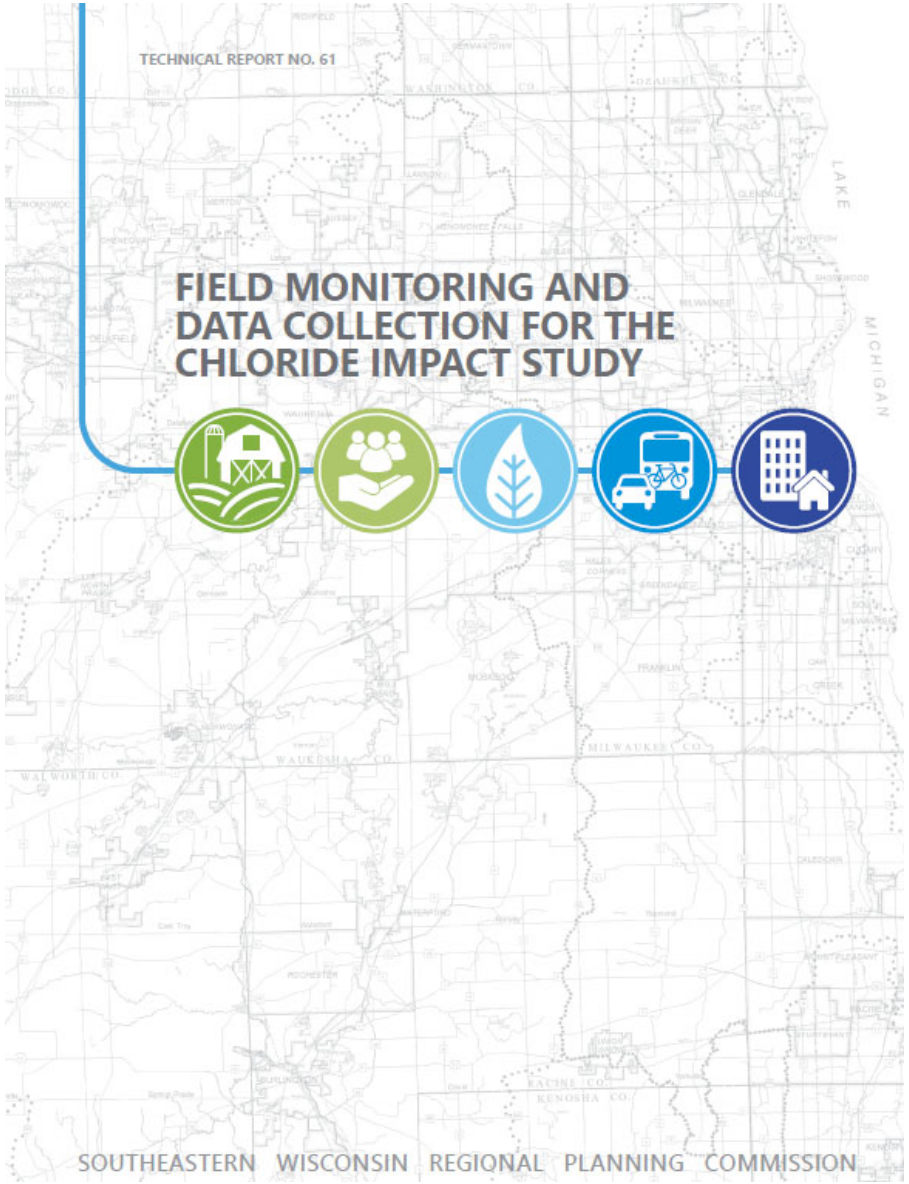
Conclusions

- The highest estimated in-stream chloride loads occurred during spring at most of the stream monitoring sites, except for the sites with the highest percentage of urban land use, where the highest estimated in-stream chloride loads were observed during the winter months.

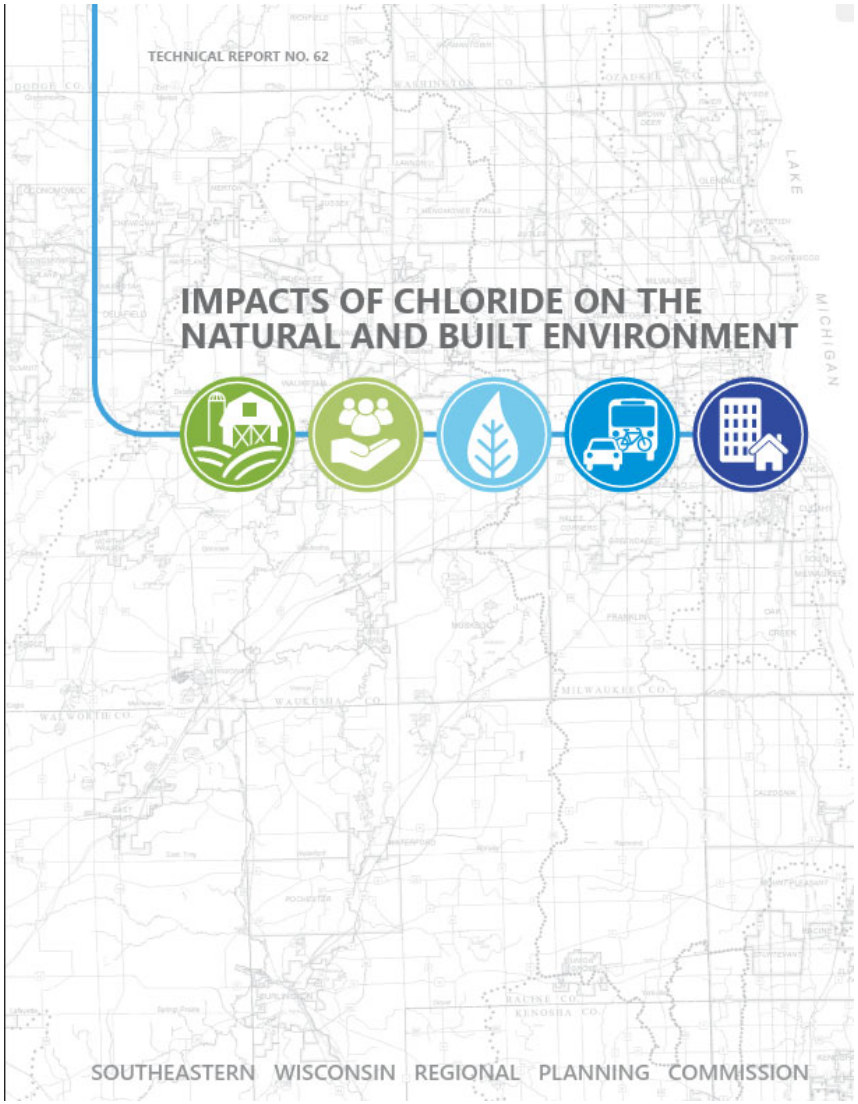
- A comparison of excess chloride sources loads during the winter months with the excess in-stream chloride loads during the subsequent non-winter months suggests that chloride from winter maintenance applications may be retained within a watershed, moving slowly through the surficial soil layers until they are released into the surface water network long after they were introduced into the environment.

Field Monitoring and Data Collection (TR-61)

- Documents approach in selecting stream and lake monitoring sites
- Characterizes the areas draining to the monitoring sites
- Describes equipment and methodology used for continuous monitoring and grab sampling
- Describes how equipment was maintained
- Quality assurance and quality control procedures
- Data management, documentation, and post-processing procedures



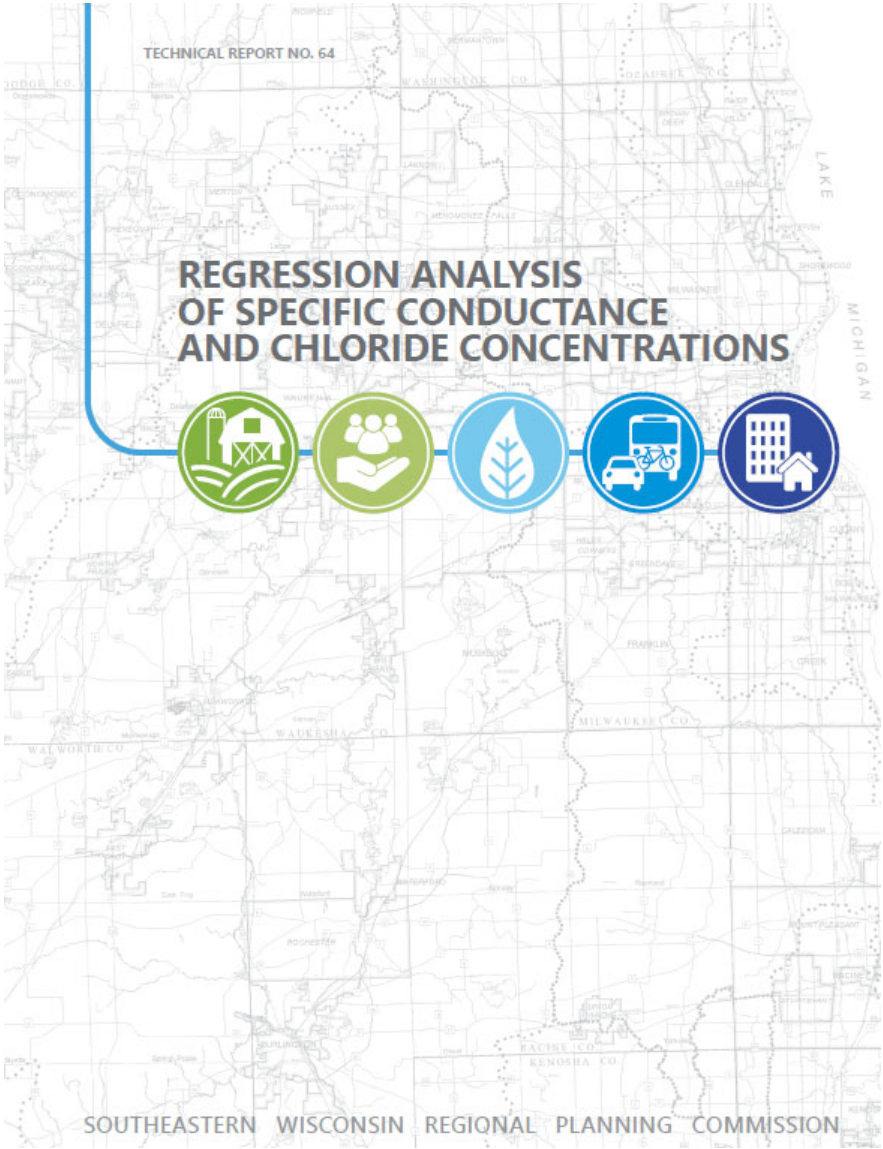
Impacts of Chloride (TR-62)



- Reviews the scientific and technical literature on impacts of chloride and chloride salts on the natural and built environment
  - Physical and chemical interactions with the natural environment
  - Impacts on biological systems
  - Impacts on infrastructure and the built environment
  - Impacts on human health and activities

Regression Analysis (TR-64)

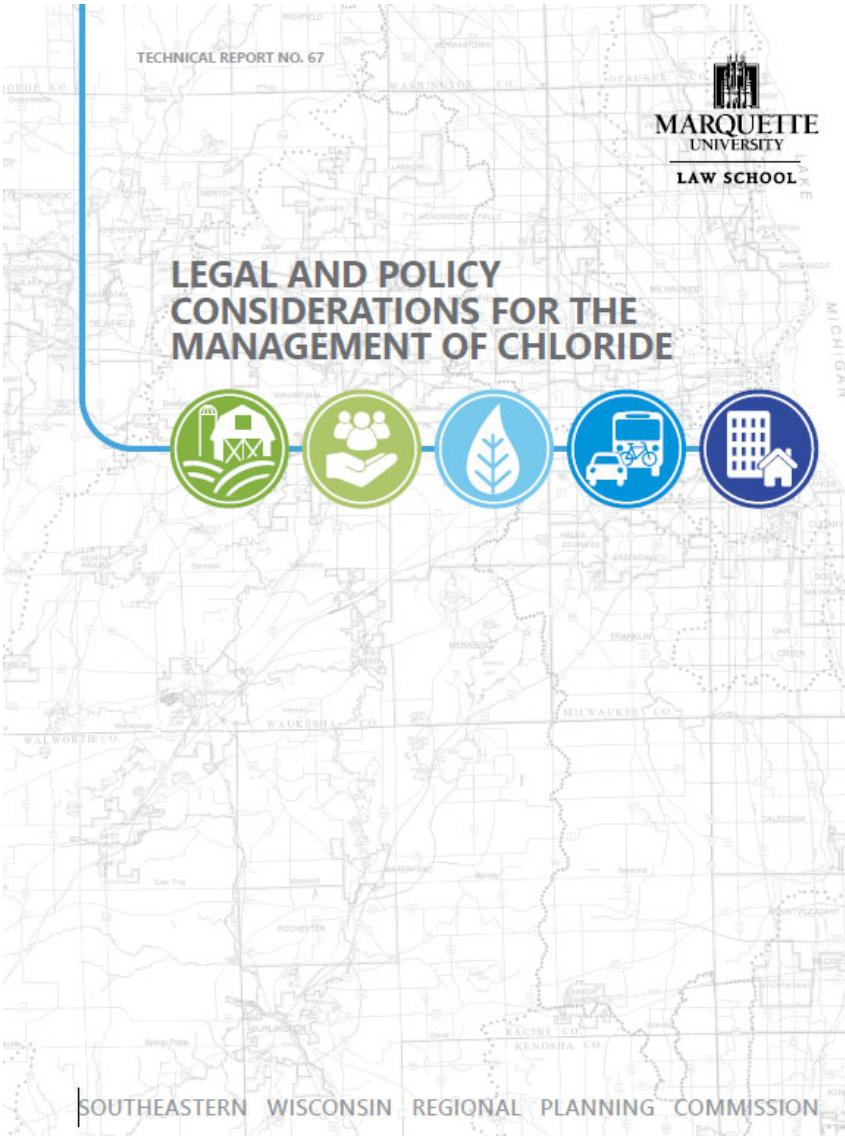
- Documents the data and methods used to develop regression models
- Provides the regression equations used to estimate chloride based on our continuous specific conductance dataset collected in Regional streams
- Provides results of cross validation efforts
- Provides guidance and considerations for the use of the regression models



Legal and Policy Considerations (TR-67)

Examines chloride management options available to decision-makers

- Limiting Liability
- Informational Strategies
- Direct Regulatory Strategies
- Chloride Alternatives
- Water Quality Trading
- Integrated Watershed Management
- Economic Measures and Assistance



Study Area Land Use

Table 2.1
Existing Land Use Within the Study Area

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

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

Source: SEWRPC