Southeastern Wisconsin
Regional Planning Commission

Chloride Impact Study for the Southeastern Wisconsin Region

TAC Meeting
November 13, 2024

#275032

Speakers

- Laura Herrick, Chief Environmental Engineer
- Tom Slawski, Chief Biologist
- Aaron Owens, Senior Planner
- Karin Hollister, Principal Engineer
- Nick Neureuther, Specialist-Biologist
- Justin Poinsatte, Principal Specialist-Biologist
- James Mahoney, Engineer

Agenda

- Review of Summary Notes from April 17, 2024, TAC meeting
- Review of preliminary draft chapters of SEWRPC Technical Report No. 63, *Chloride Conditions and Trends in SE WI*
  - *Chapter 1 – Introduction*
  - *Chapter 2 – Study Area Background (part)*
  - *Chapter 5 – Conditions and Trends: Lakes (part)*
- Review of preliminary draft chapters of SEWRPC Technical Report No. 66, *State of the Art in Chloride Management*
  - *Chapter 1 – Introduction*
  - *Chapter 3 – Municipal Water and Wastewater Utilities*
- Next Steps

Chloride Study Reports

- *PR-57 A Chloride Impact Study for Southeastern Wisconsin*
- *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*

Review of Summary Notes from April 17, 2024, Technical Advisory Committee Meeting

Technical Report No. 63
Chloride Conditions and Trends in SE WI

TR-63 Chapters

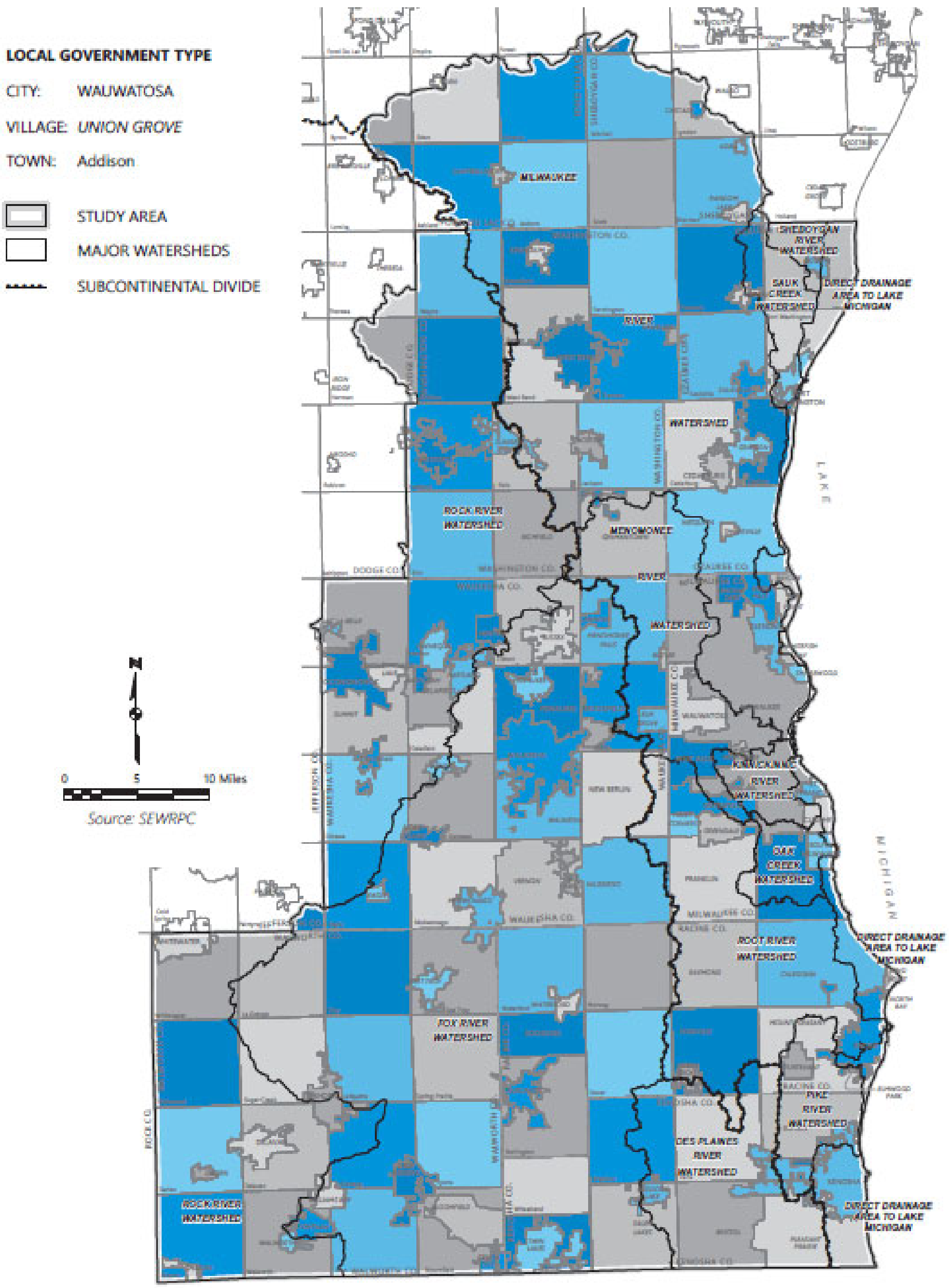
- **Chapter 1 – Introduction**
- **Chapter 2 – Study Area Background (part)**
- Chapter 3 – Analysis of Chloride Impact Study Monitoring Data: 2018-2021
- Chapter 4 – Conditions and Trends: Rivers
- **Chapter 5 – Conditions and Trends: Lakes (part)**
- Chapter 6 – Conditions and Trends: Groundwater
- Chapter 7 – Drivers and Interactions

TR-63 Chapters

- Chapter 1 – Introduction
- Chapter 2 – Study Area Background (part)
- Chapter 3 – Analysis of Chloride Impact Study Monitoring Data: 2018-2021
- Chapter 4 – Conditions and Trends: Rivers
- Chapter 5 – Conditions and Trends: Lakes (part)
- Chapter 6 – Conditions and Trends: Groundwater
- Chapter 7 – Drivers and Interactions

Watersheds of the Study Area

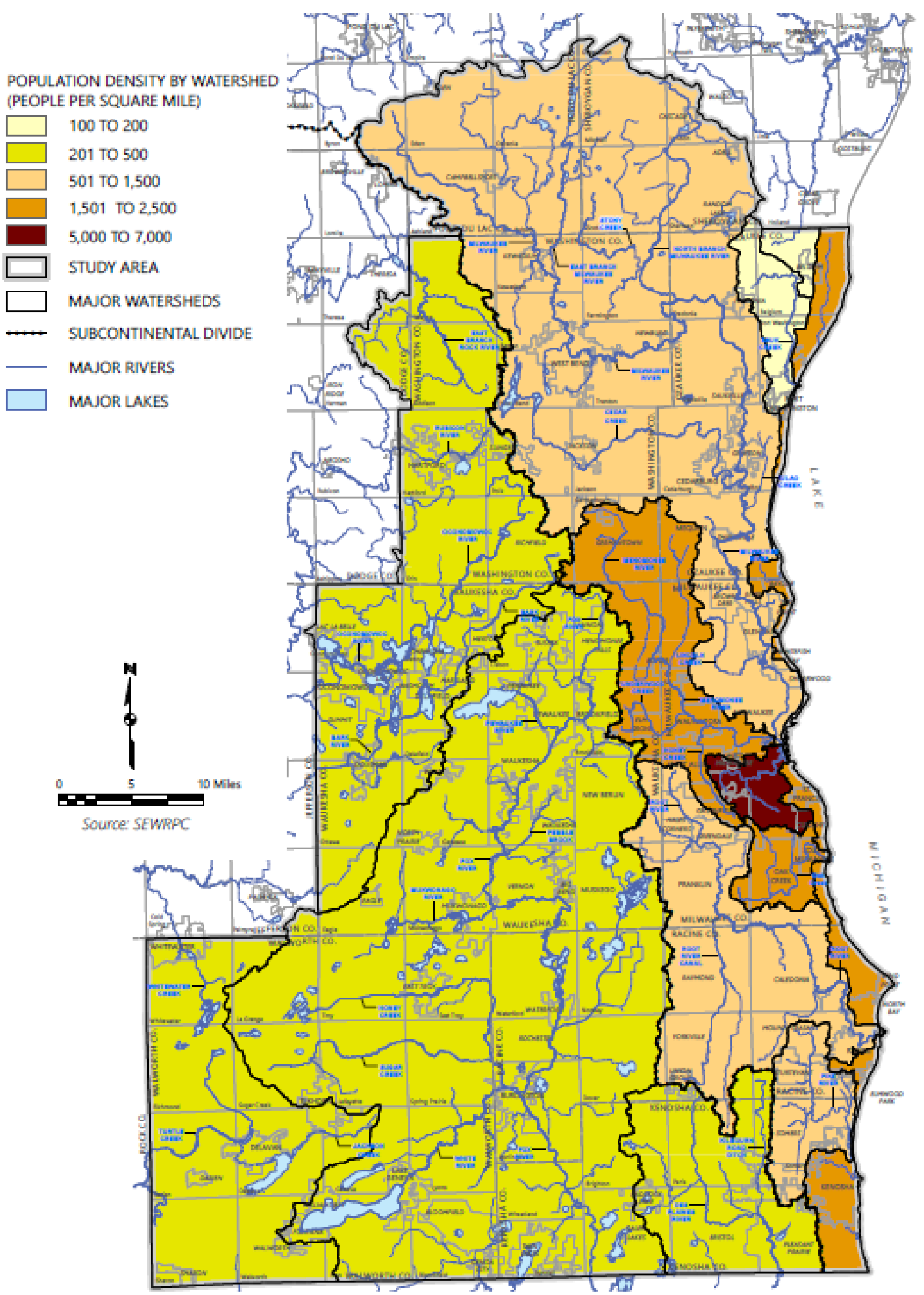
Map 2.1
Major Watersheds and Civil Divisions Within the Study Area



- Study Area includes:
  - 7 County SE WI Region plus areas that drain into the Region including all or portions of the following watersheds:
    - Des Plaines River
    - Kinnickinnic River
    - Menomonee River
    - Milwaukee River
    - Oak Creek
    - Pike River
    - Rock River
    - Root River
    - Sauk Creek
    - Sheboygan River

Population Density

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



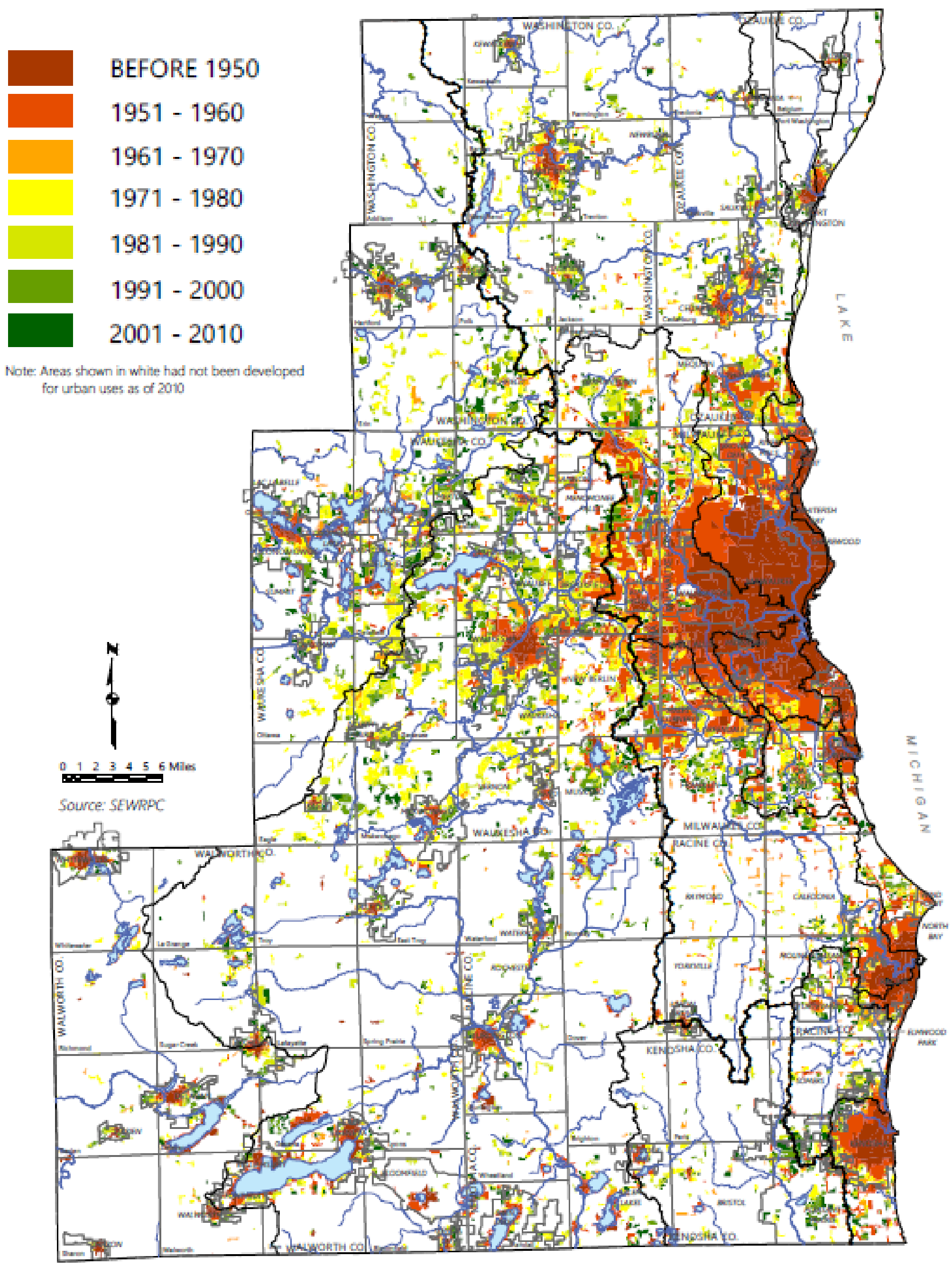
Estimated Population by Watershed

- Kinnickinnic: 156,800 (6,273 people/sq mi)
- Menomonee: 320,800 (2,359 people/sq mi)
- Lake Michigan Direct Drainage: 217,600 (2,315 people/sq mi)
- Oak Creek: 56,600 (2,021 people/sq mi)
- Pike: 51,600 (1,012 people/sq mi)
- Root 179,000 (904 people/sq mi)
- Milwaukee: 493,200 (704 people/sq mi)
- Fox: 365,100 (389 people/sq mi)
- Rock* 155,400 (246 people/sq mi)
- Des Plaines: 31,500 (237 people/sq mi)
- Sheboygan* 1,500 (141 people/sq mi)
- Sauk* 4,000 (113 people/sq mi)

*Only accounts for estimated population in portion of watershed within the study area.

Historical Land Use and Urban Development

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



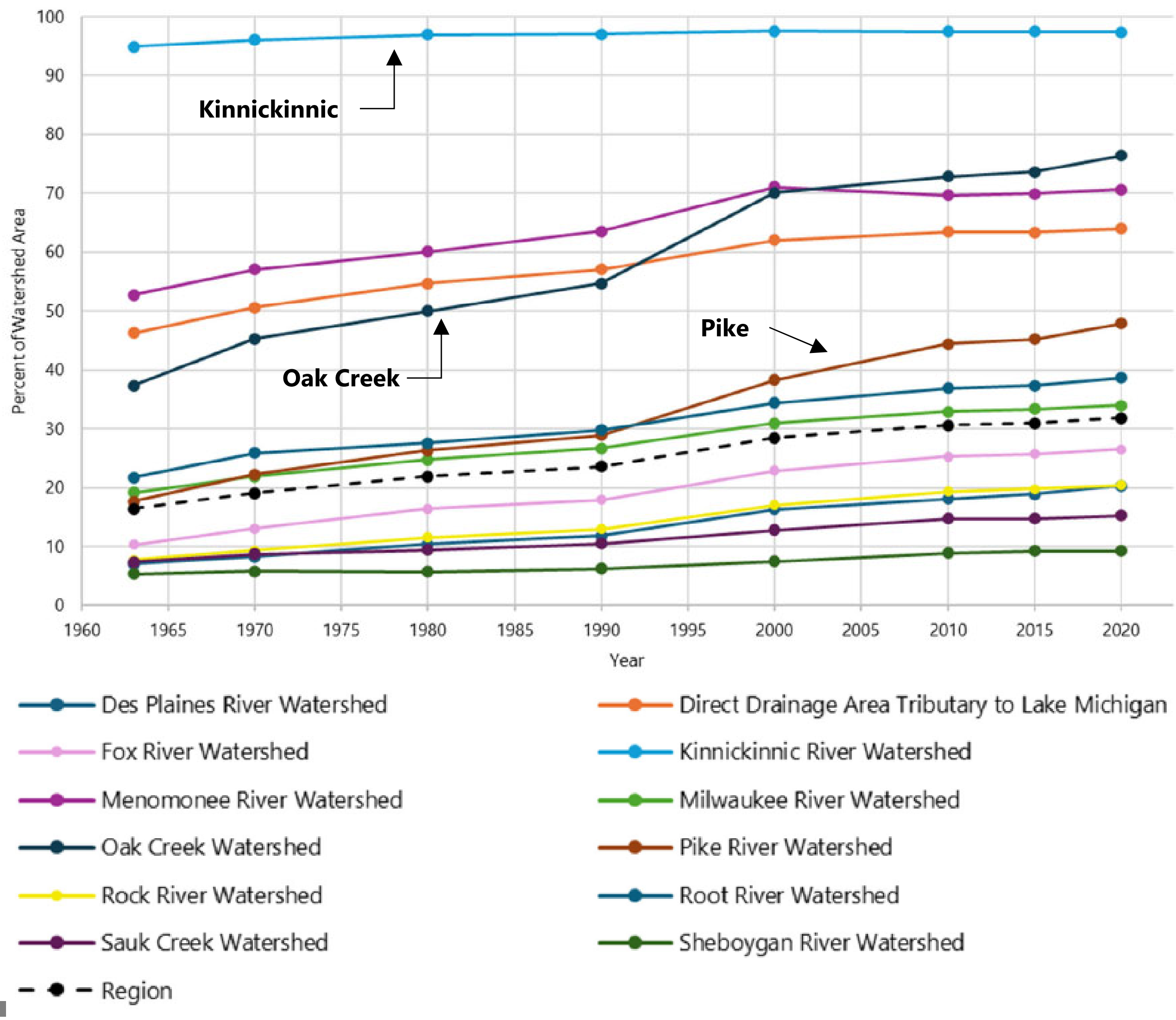
➤ Increases in Urban Development

In mid-1950s about 5% of Region in Urban Land Uses

- 6% Increase 1950-1963
- 2.1% Increase in 1960s
- 3.9% Increase in 1970s
- 2.4% Increase in 1980s
- 2.6% Increase in 1990s
- 2.1% Increase in 2000s

Increases in Urban Land Use

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



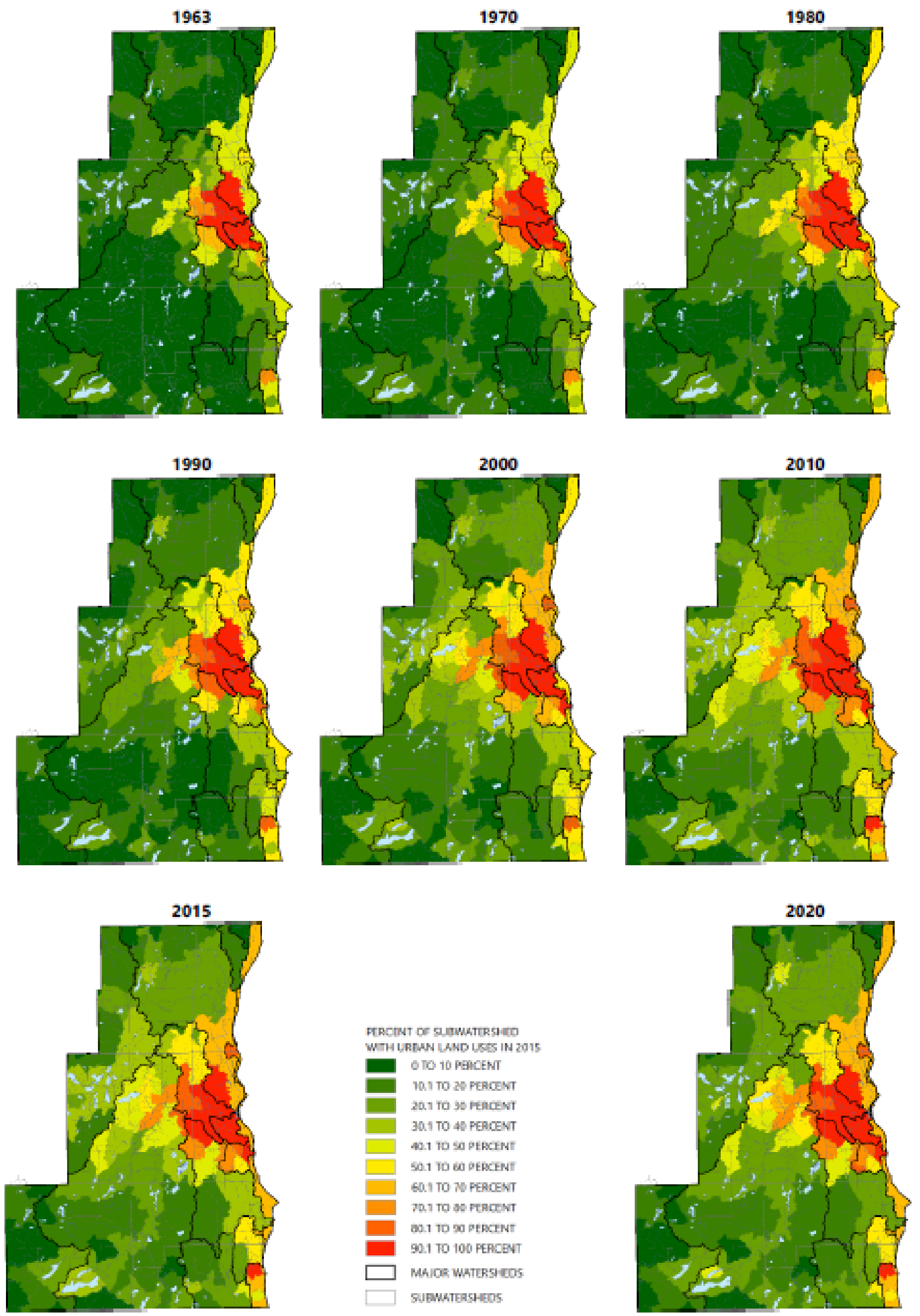
- Urban Land Uses Include:
  Roads and parking lots; lower-, medium-, and high-density residential; commercial; industrial; government and institutional; transportation, communication, and utilities; recreational; unused urban lands

- Increase in Urban Land Uses:

- Kinnickinnic River watershed
  95% (1963) → 97% (2020)
- Oak Creek watershed
  37% (1963) → 76% (2020)
- Pike River watershed
  18% (1963) → 48% (2020)
- Region
  15% (1963) → 32% (2020)

Increases in Urban Land Use

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

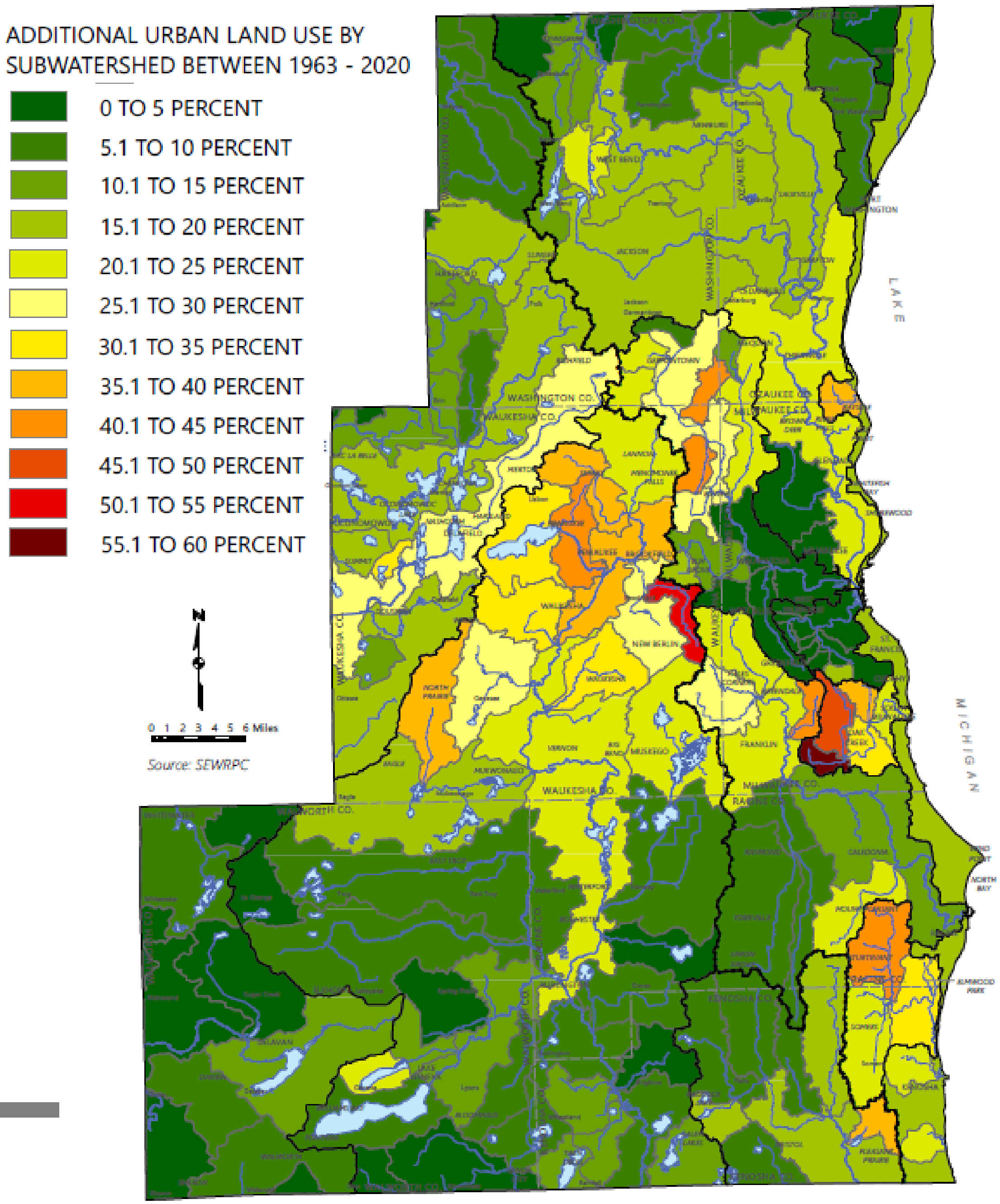


PERCENT OF SUBWATERSHED WITH URBAN LAND USES IN 2015

- 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
- MAJOR WATERSHEDS
- SUBWATERSHEDS

Increases in Urban Land Use

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

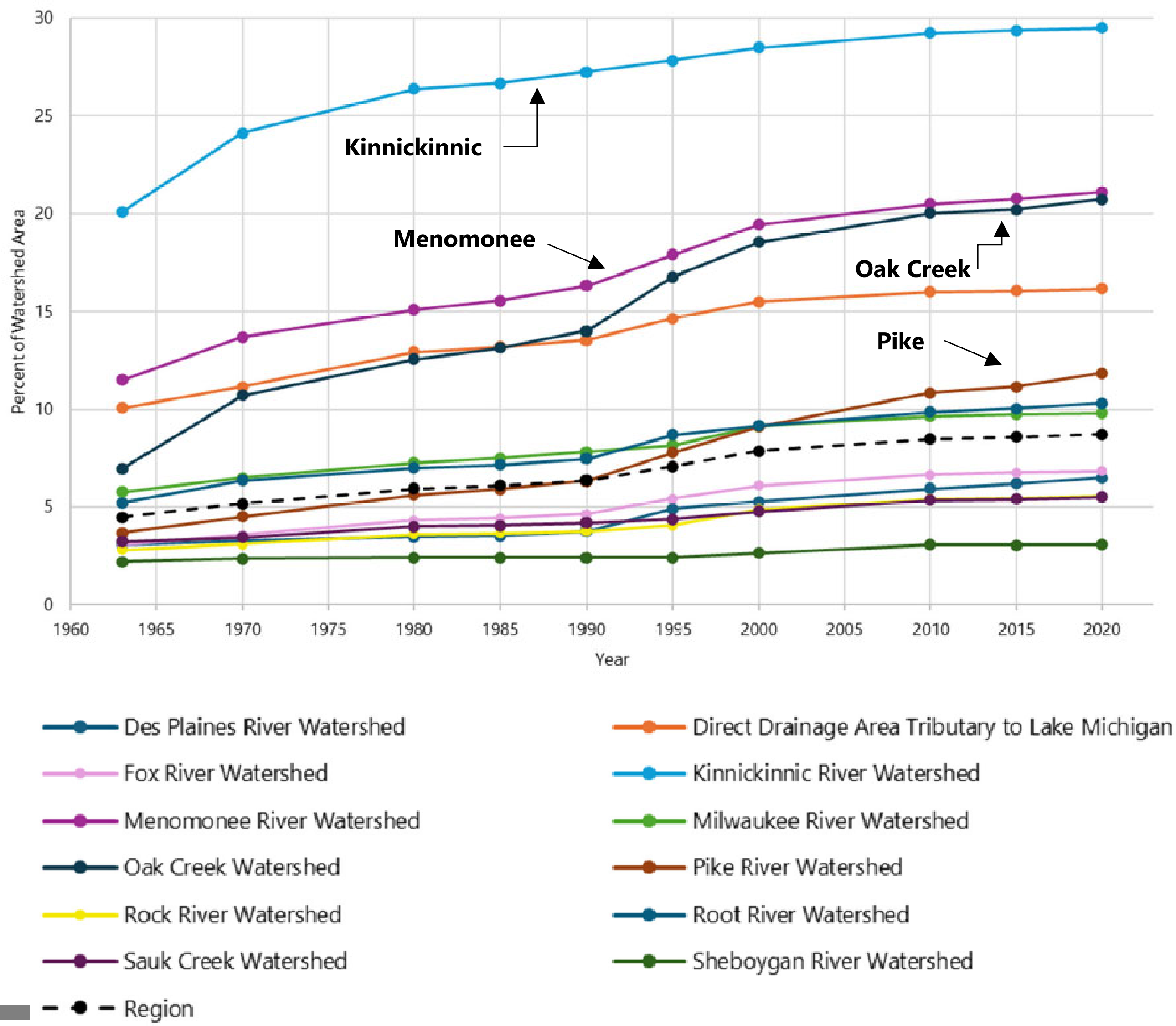


Largest Increases in Urban Land Use:

- Oak Creek watershed +39%
  - Upper Oak Creek subwatershed +57%
  - North Branch Oak Creek subwatershed +45%
- Pike River watershed +30%
  - Upper Pike River subwatershed +40%
- Menomonee River watershed +18%
  - Lilly Creek subwatershed +43%
  - Nor-X-Way Channel subwatershed +41
- Fox River watershed +16
  - Deer Creek subwatershed +51%
  - Pewaukee River subwatershed +43%

Increases in Roads and Parking Lots

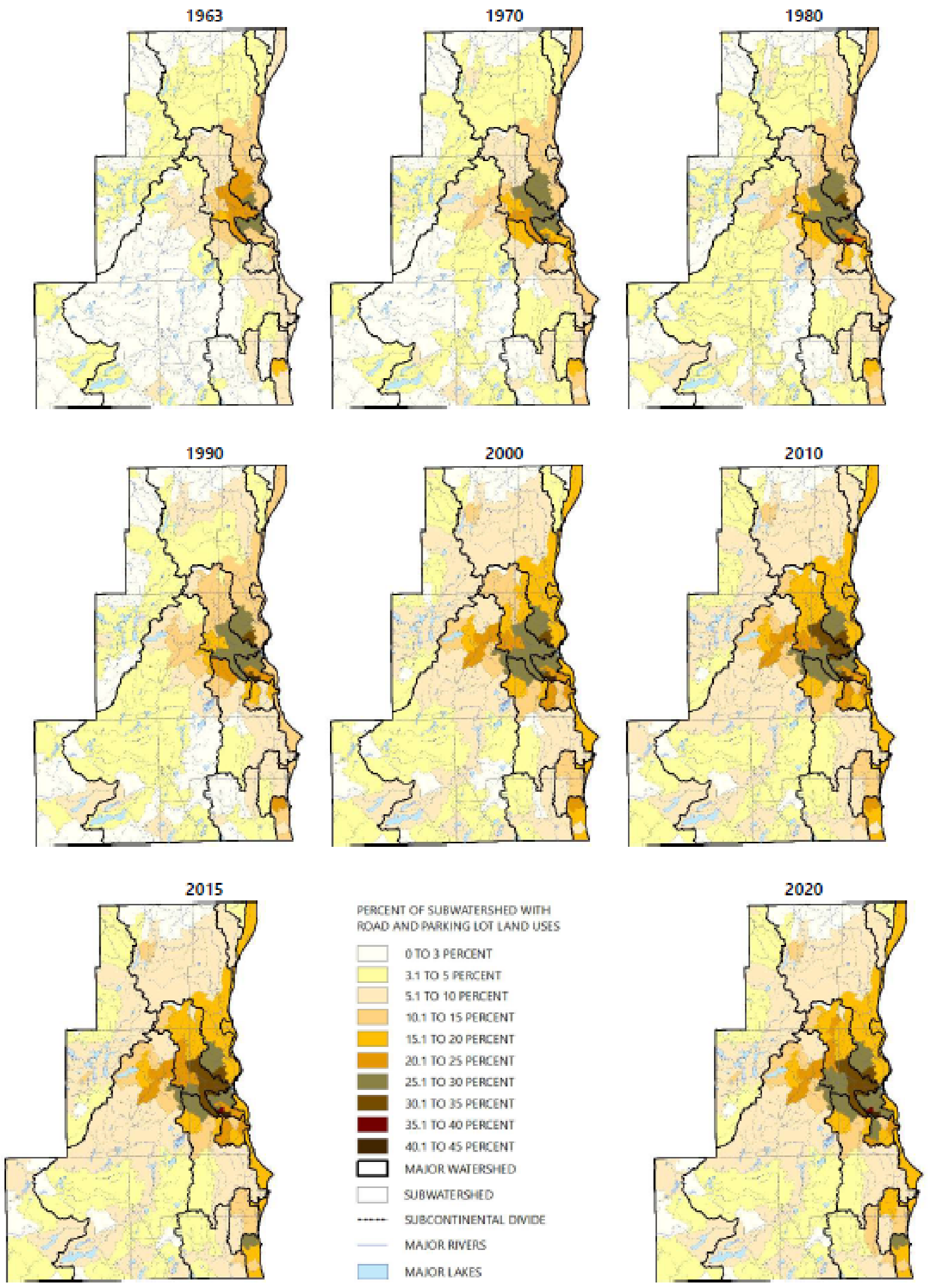
Figure 2.3
Trends in the Density of Roads and Parking Lots
Within the Watersheds of the Region: 1963 to 2020



- Increase in Road and Parking Lot Land Uses:
  - Oak Creek watershed
    7% (1963) → 21% (2020)
  - Menomonee River watershed
    12% (1963) → 21% (2020)
  - Kinnickinnic River watershed
    20% (1963) → 30% (2020)
  - Pike River watershed
    4% (1963) → 12% (2020)
  - Region
    5% (1963) → 9% (2020)

Increases in Roads and Parking Lots

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



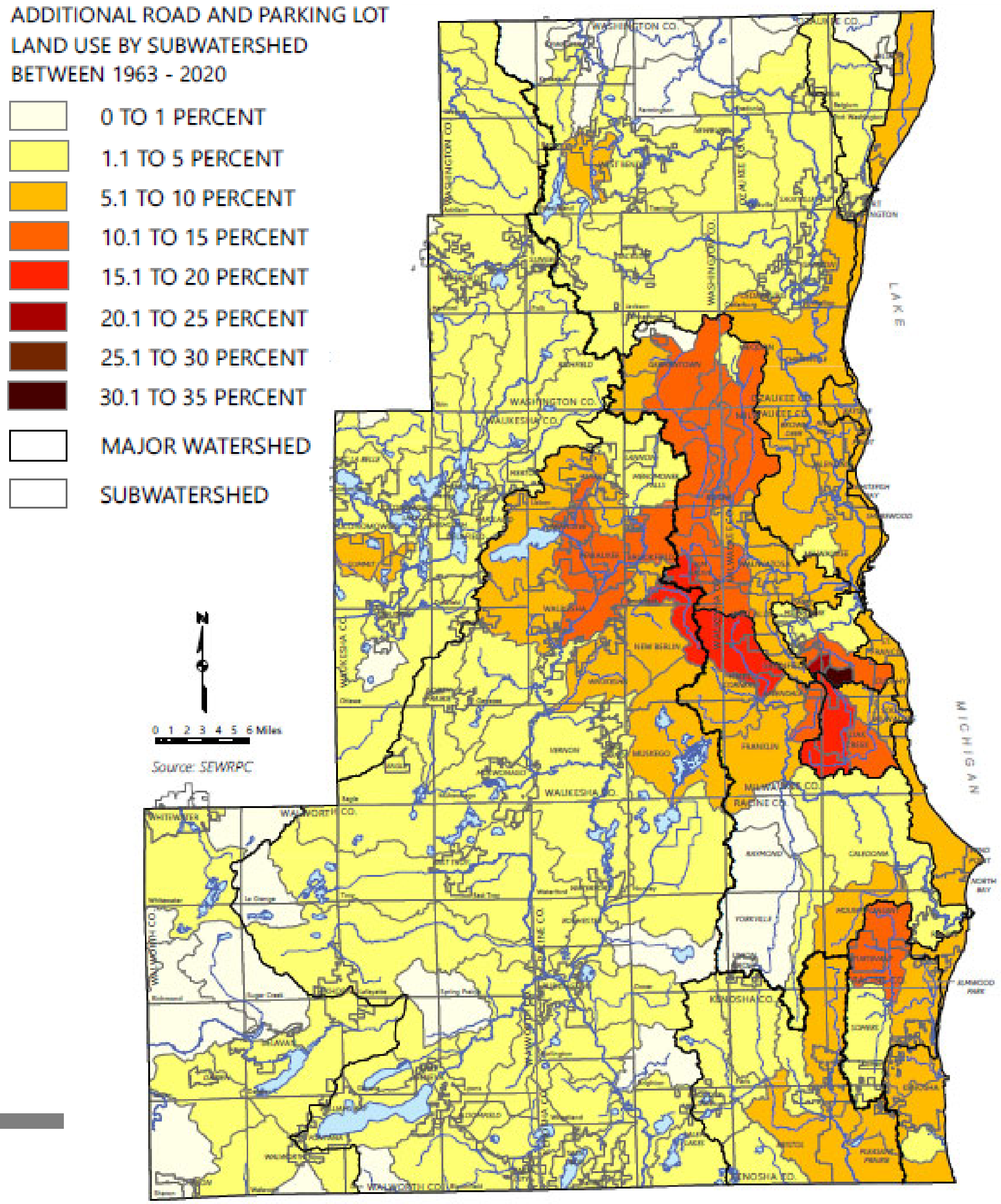
Source: SEWRPC

PERCENT OF SUBWATERSHED WITH ROAD AND PARKING LOT LAND USES

- 0 TO 3 PERCENT
- 3.1 TO 5 PERCENT
- 5.1 TO 10 PERCENT
- 10.1 TO 15 PERCENT
- 15.1 TO 20 PERCENT
- 20.1 TO 25 PERCENT
- 25.1 TO 30 PERCENT
- 30.1 TO 35 PERCENT
- 35.1 TO 40 PERCENT
- 40.1 TO 45 PERCENT
- MAJOR WATERSHED
- SUBWATERSHED

Increases in Roads and Parking Lots

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

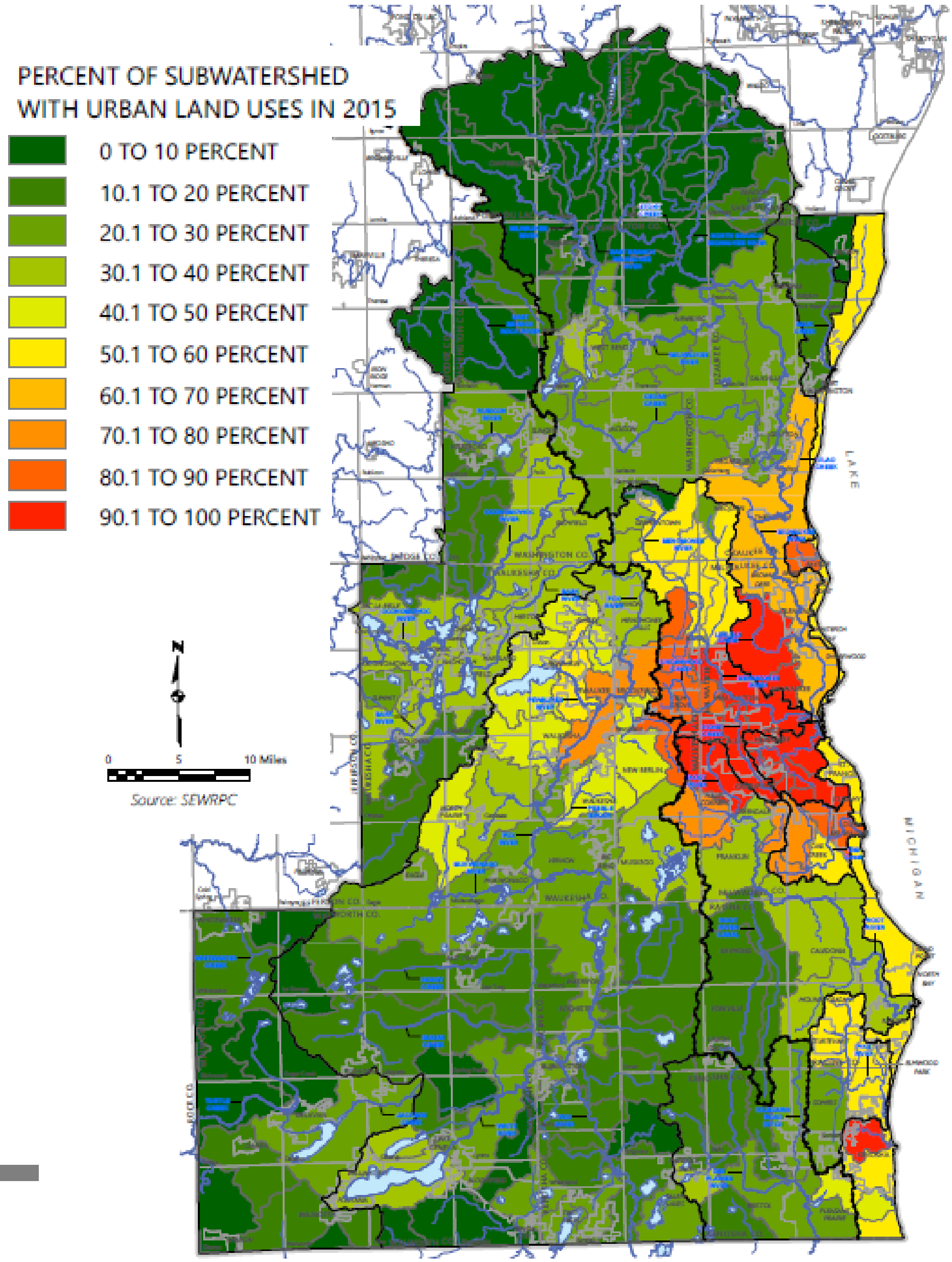


Largest Increases in Road and Parking Lots:

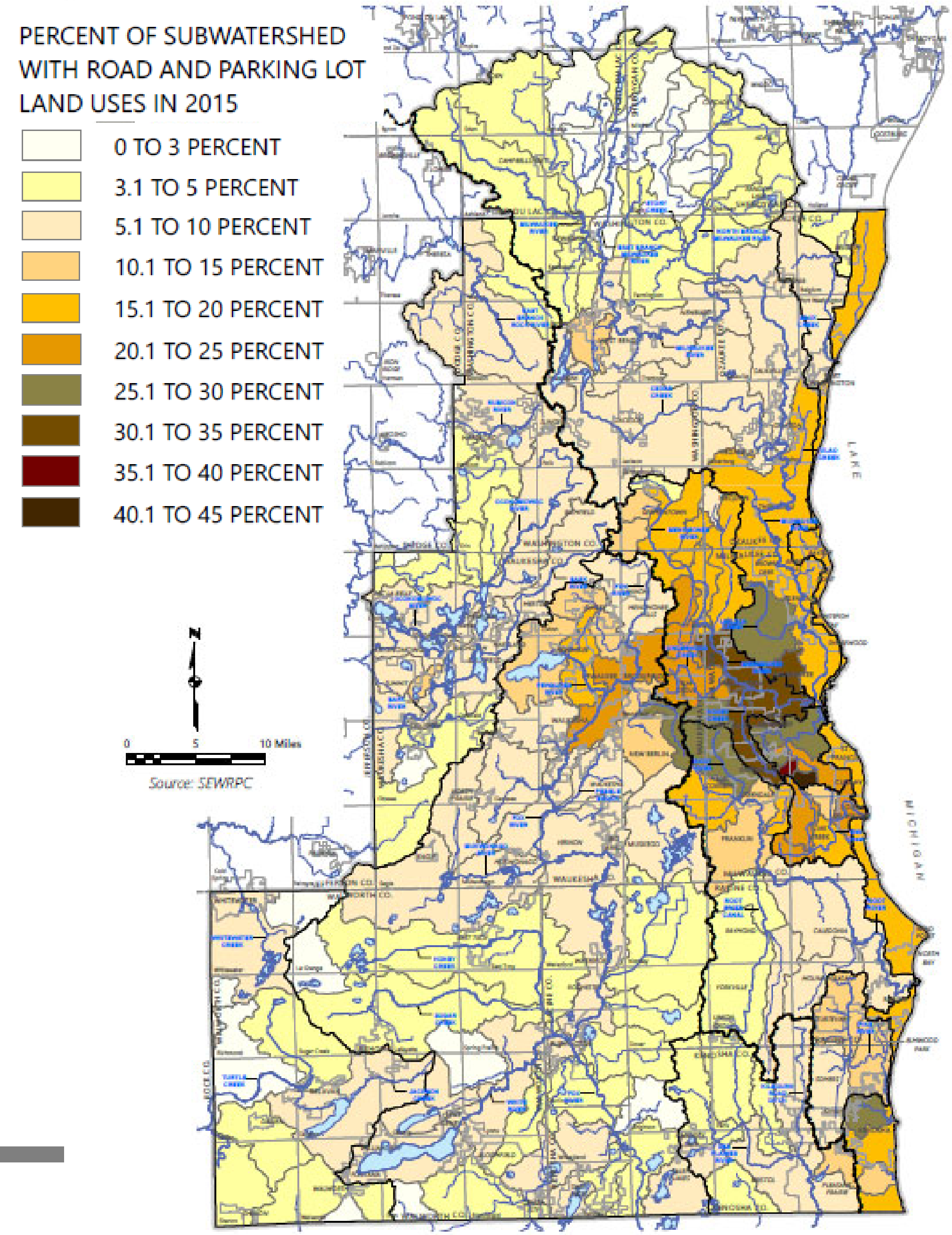
- Oak Creek watershed +14%
  - Upper Oak Creek subwatershed +19%
  - North Branch Oak Creek subwatershed +19%
- Menomonee River watershed +10%
  - Dousman Ditch subwatershed +16%
  - Lilly Creek subwatershed +13%
  - Nor-X-Way Channel subwatershed +14
- Kinnickinnic River watershed +10%
  - Holmes Avenue Creek subwatershed +34%
  - Villa Mann Creek subwatershed +20%
- Pike River watershed +8%
  - Upper Pike River subwatershed +12%
- Fox River watershed +4%
  - Deer Creek subwatershed +19%
  - Upper Fox subwatershed +14%
  - Pewaukee River subwatershed +14%

Percent Urban and Road/Parking Lot Density: Existing Conditions

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



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



Wastewater Treatment Facilities & Sewer Service Areas

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

- EXISTING WASTEWATER TREATMENT FACILITY (DISCHARGES TO SURFACE WATER)
- EXISTING WASTEWATER TREATMENT FACILITY (DISCHARGES TO SOIL)
- ABANDONED WASTEWATER TREATMENT FACILITY (DISCHARGED TO SURFACE WATER)
- MAJOR LAKES

Notes: See Table 2.2 for details on public wastewater treatment facilities.

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

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

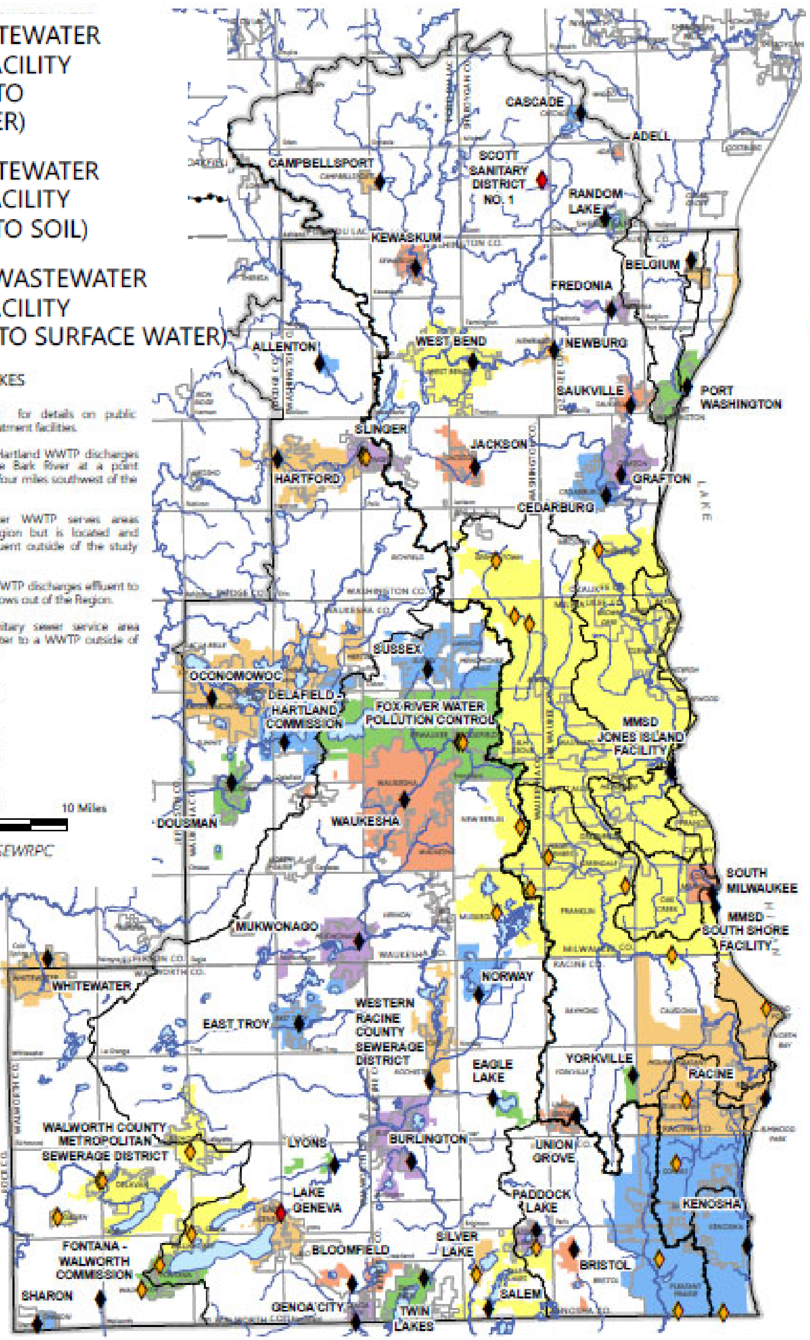
The Belgium WWTP discharges effluent to a stream that flows out of the Region.

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

N

0 5 10 Miles

Source: SEWRPC



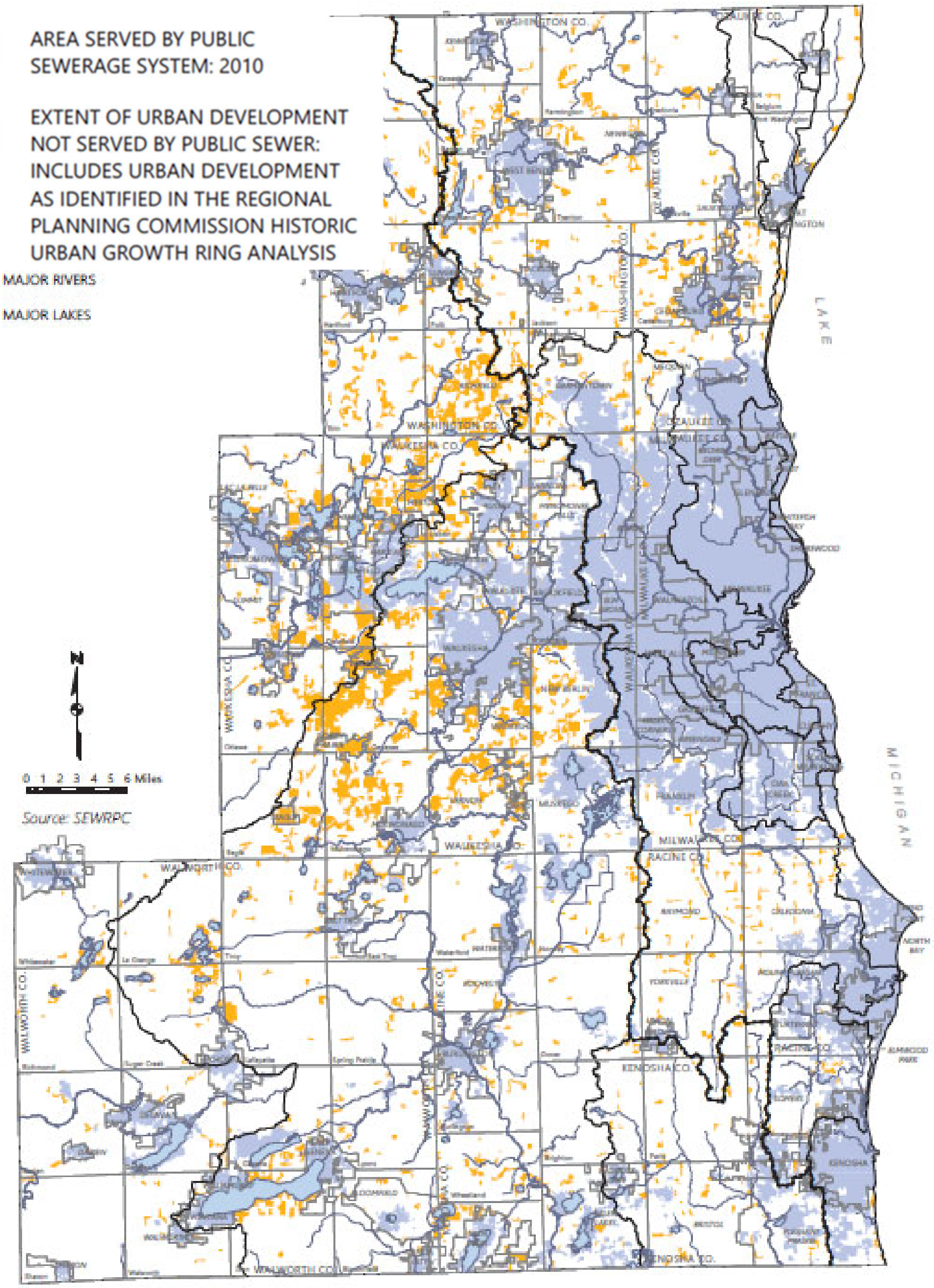
Map 2.11
Areas Served by Public Sanitary Sewerage Systems in the Southeastern Wisconsin Region: 2010

- AREA SERVED BY PUBLIC SEWERAGE SYSTEM: 2010
- EXTENT OF URBAN DEVELOPMENT NOT SERVED BY PUBLIC SEWER: INCLUDES URBAN DEVELOPMENT AS IDENTIFIED IN THE REGIONAL PLANNING COMMISSION HISTORIC URBAN GROWTH RING ANALYSIS
- MAJOR RIVERS
- MAJOR LAKES

N

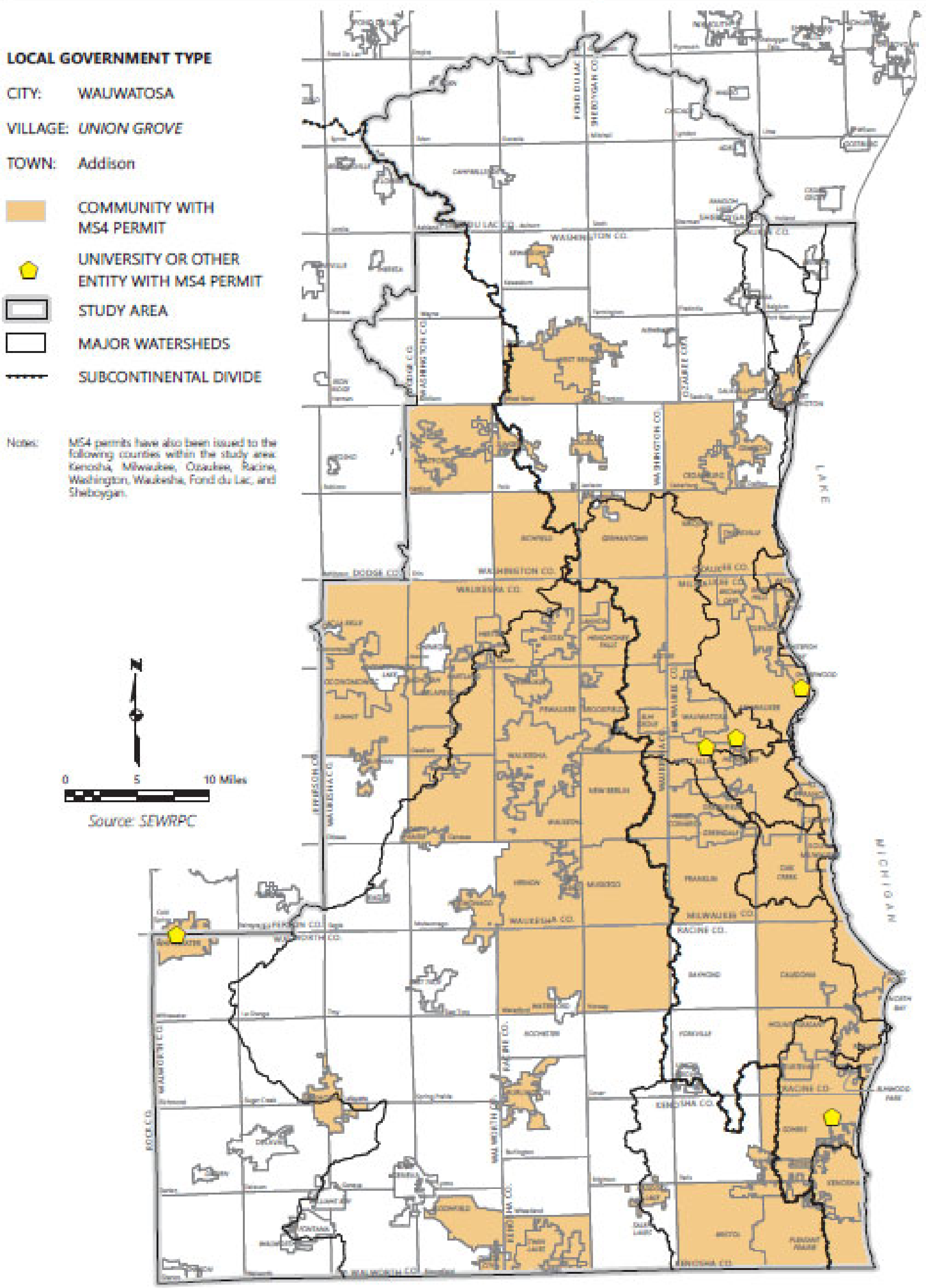
0 1 2 3 4 5 6 Miles

Source: SEWRPC

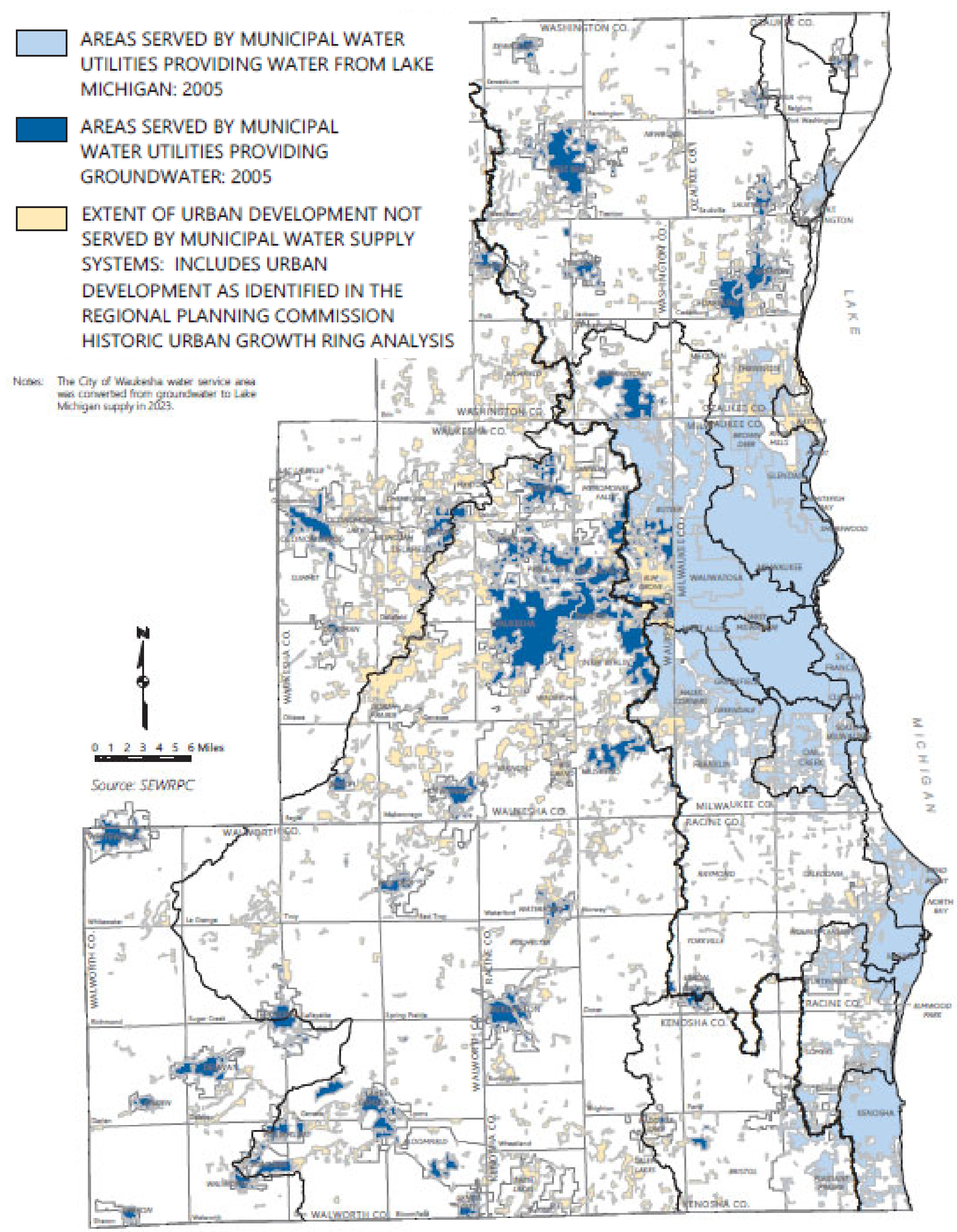


MS4 Permitted Communities and Water Supply

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

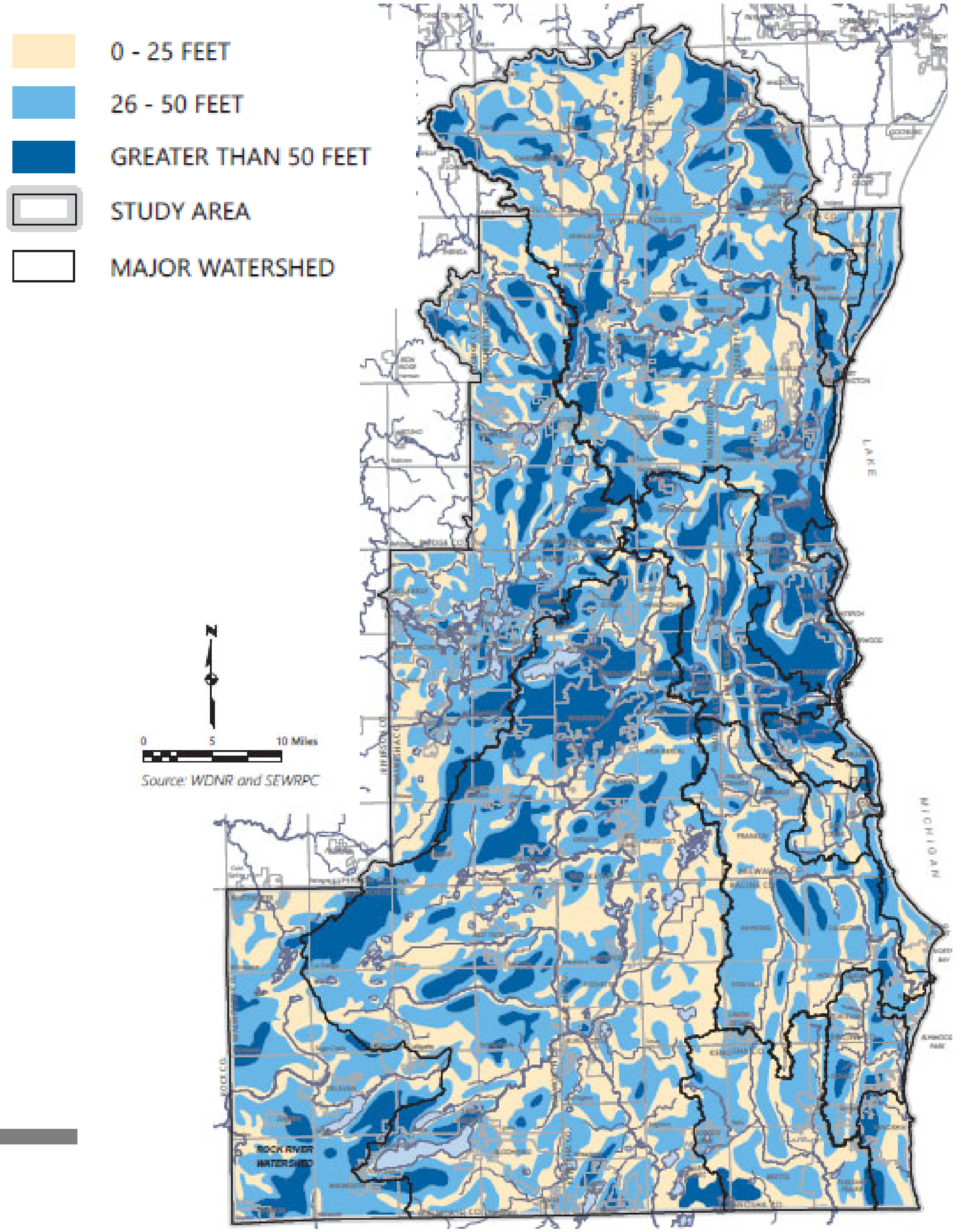


Map 2.13
Municipal Water Supply Service Areas and Sources of Supply in the Southeastern Wisconsin Region: 2005

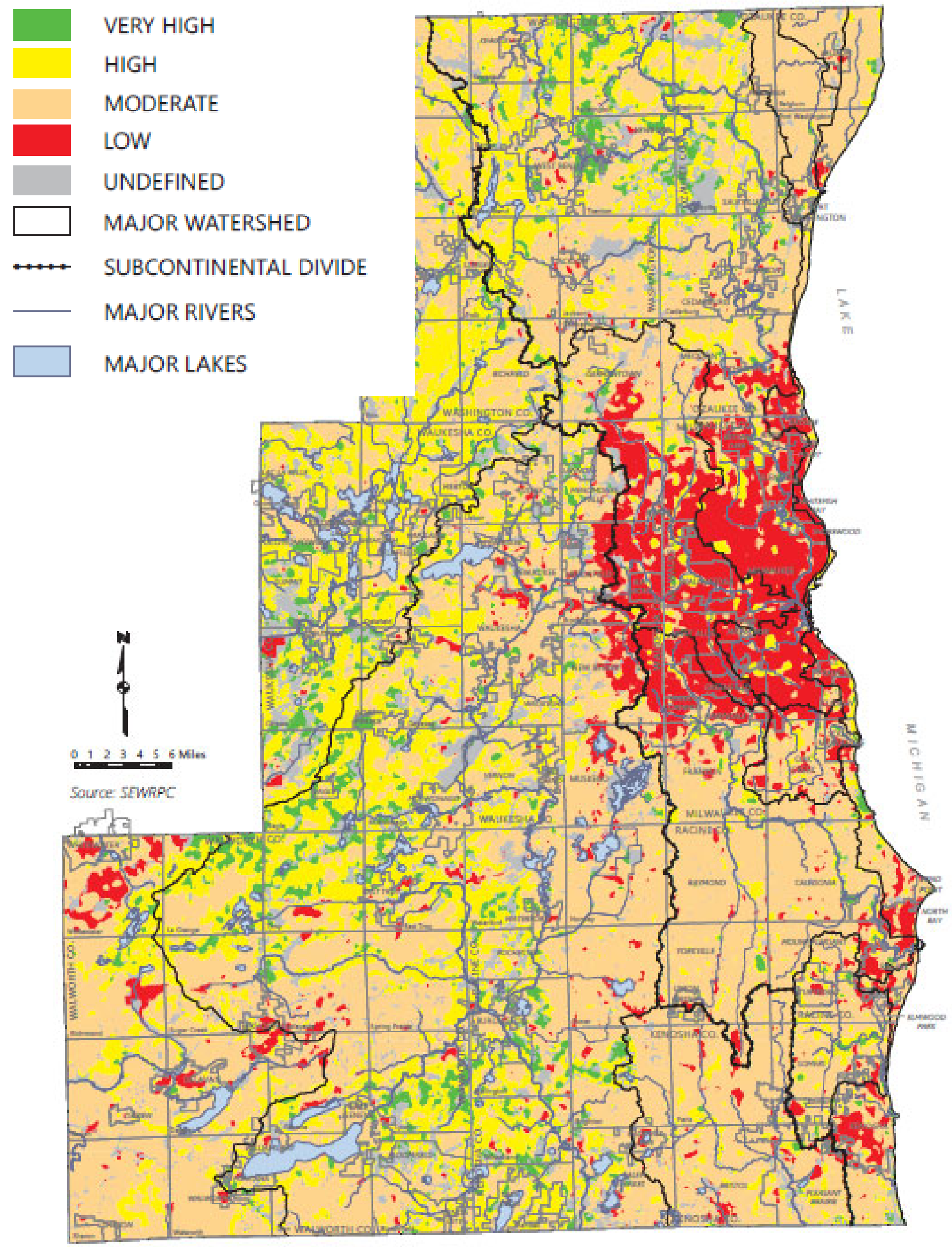


Areas Vulnerable to Groundwater Contamination

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

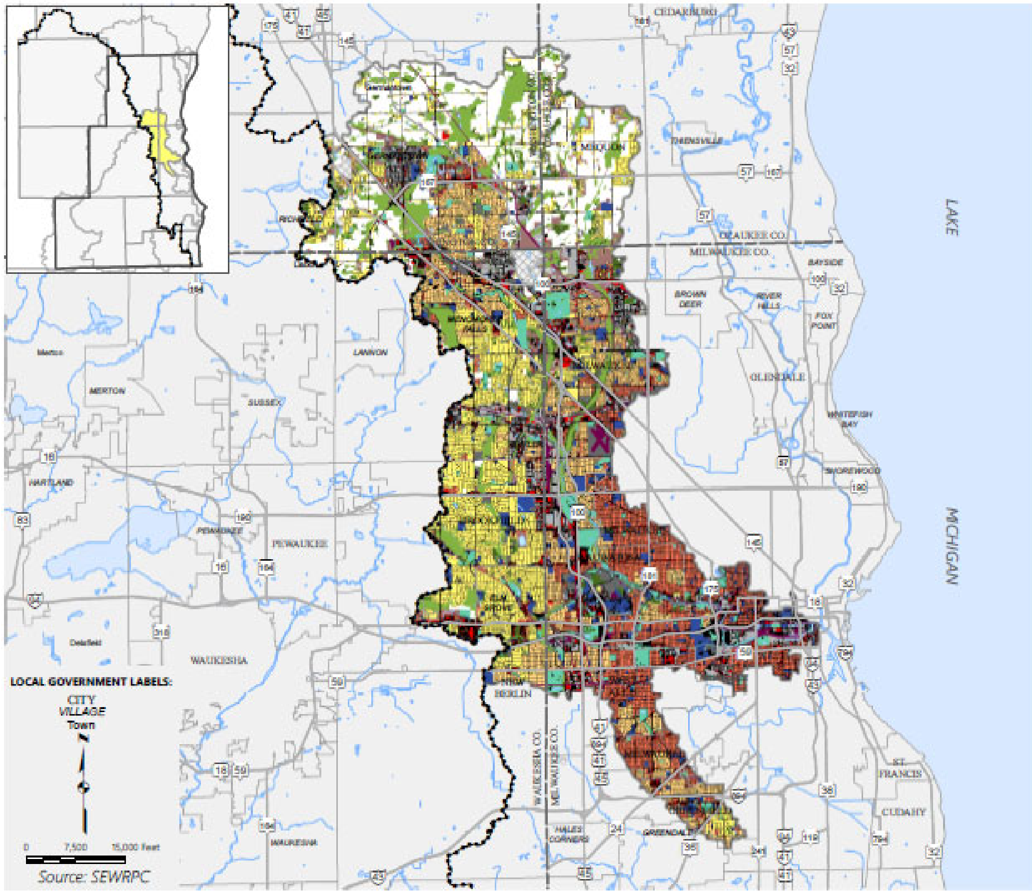


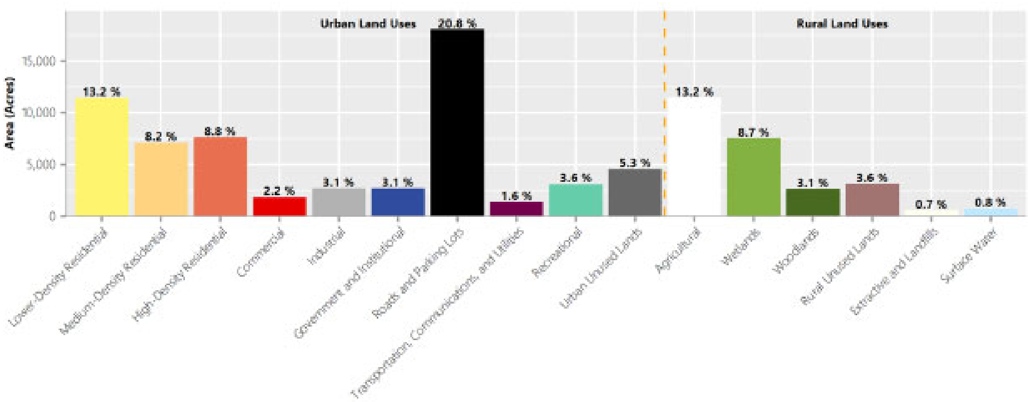
Map 2.15
Estimates of Groundwater Recharge Potential in the Southeastern Wisconsin Region



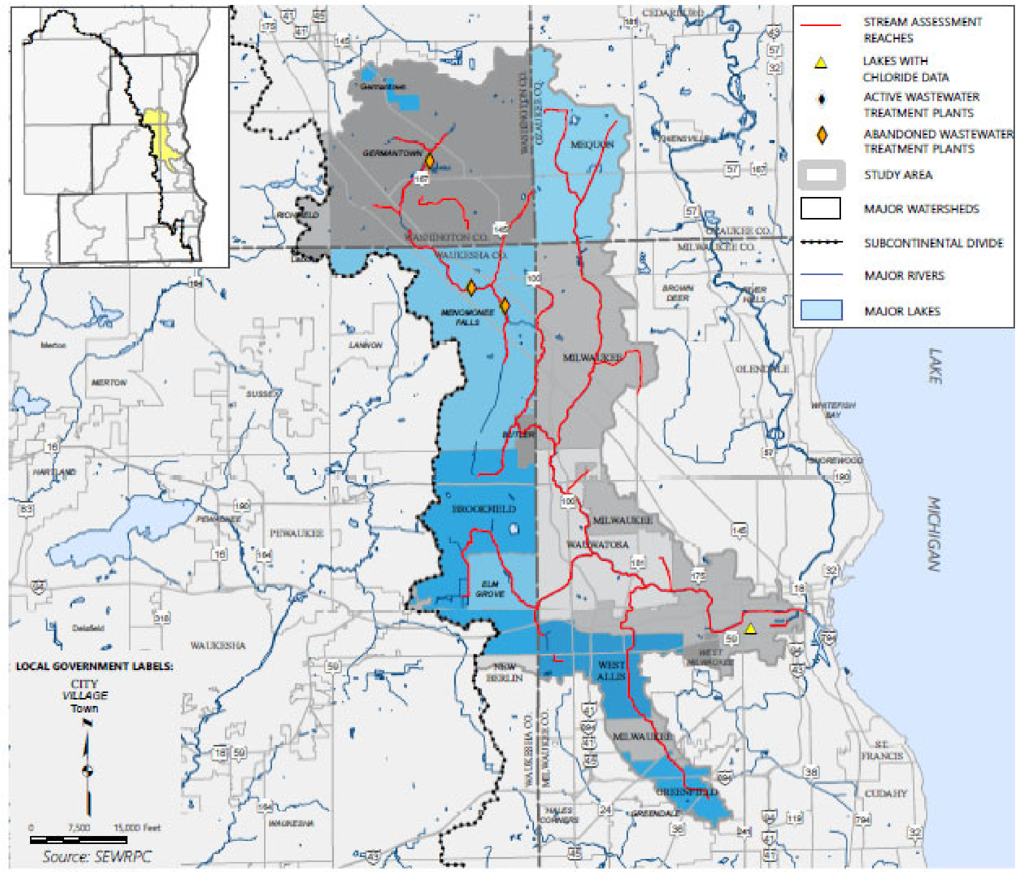
Specific Watershed Characteristics

Map A.7
Existing Land Use in the Menomonee River Watershed





Map A.8
Characteristics of the Menomonee River Watershed



Facts at a Glance

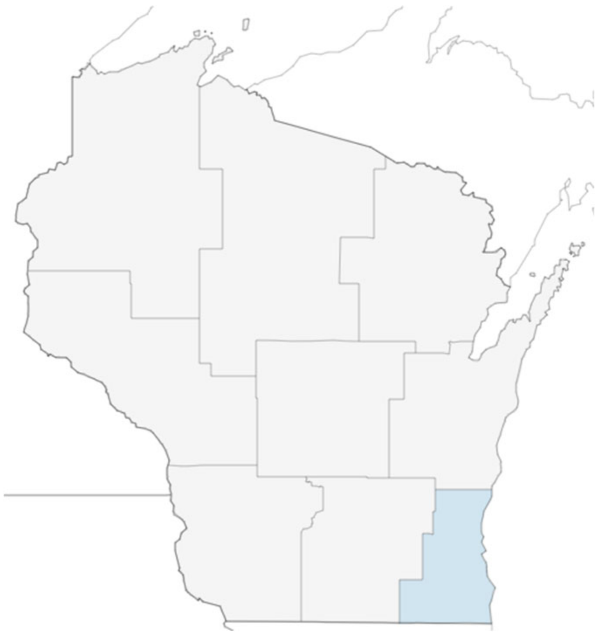
- **Drainage Area Size:** 136 square miles
- **Existing Land Use:** Urban – 69.9%; Rural – 30.1%
- **Urban Land Use Increase Since 1963:** 17.1%
- **Existing Roads and Parking Lots:** 20.8%
- **Increase in Roads and Parking Lots Since 1963:** 9.3%
- **Active Wastewater Treatment Facilities:** None
- **Abandoned Wastewater Treatment Facilities:** Germantown, Menomonee Falls – Lilly Road, and Menomonee Falls – Pilgrim Road
- **Estimated Population in 2010:** 320,850
- **Estimated Population Served by Sewer in 2010:** 315,860 (98%)
- **Estimated Households in 2010:** 131,110
- **Estimated Households Served by Sewer in 2010:** 129,190
- **Water Supply Source:** Lake Michigan

Questions?

Regional Climate Conditions and Trends

- Climate Data Sources
  - NOAA National Centers for Environmental Information (NCEI, formerly the National Climatic Data Center)
  - Wisconsin State Climatology Office
  - Wisconsin Initiative on Climate Change Impacts (WICCI)

- Wisconsin Climate Division 9 – SE WI
  - Temperature Data (1895-present)
  - Precipitation Data (1895-present)
  - Snowfall Data (1950-present)



Climate Normals for the Region

- NOAA U.S. Climate Normals represent average conditions over 30 years, updated every 10 years.

30-Year Climate Normals for Southeastern Wisconsin: 1991-2020

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

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

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

Temperature Conditions: Study Period

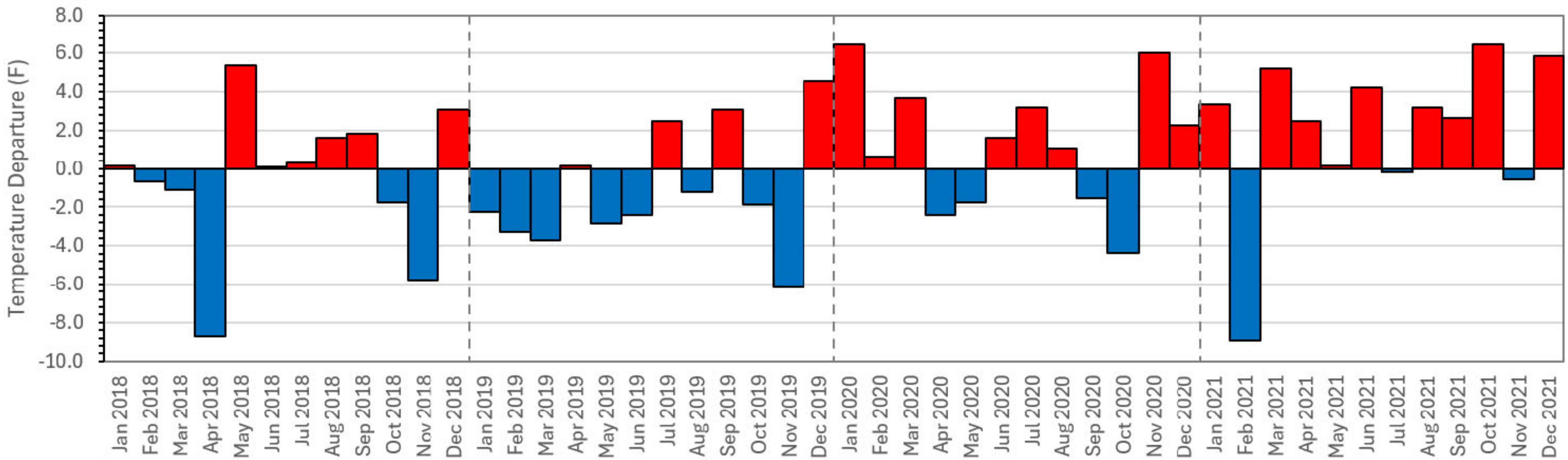
Monthly Mean Temperatures for Southeastern Wisconsin: 2018-2021

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

1991-2020 Normals

Mean Daily Temperature (°F)
20.7
24.2
34.3
45.4
56.7
66.7
71.3
69.6
62.3
50.2
37.5
26.3

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

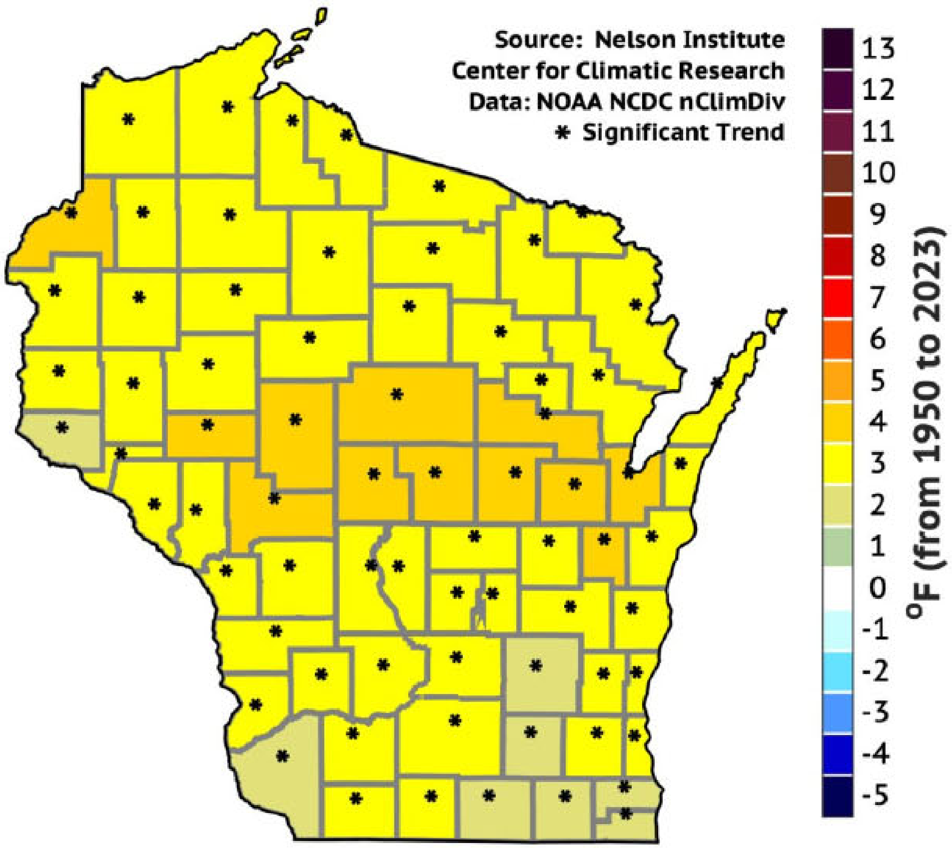


Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

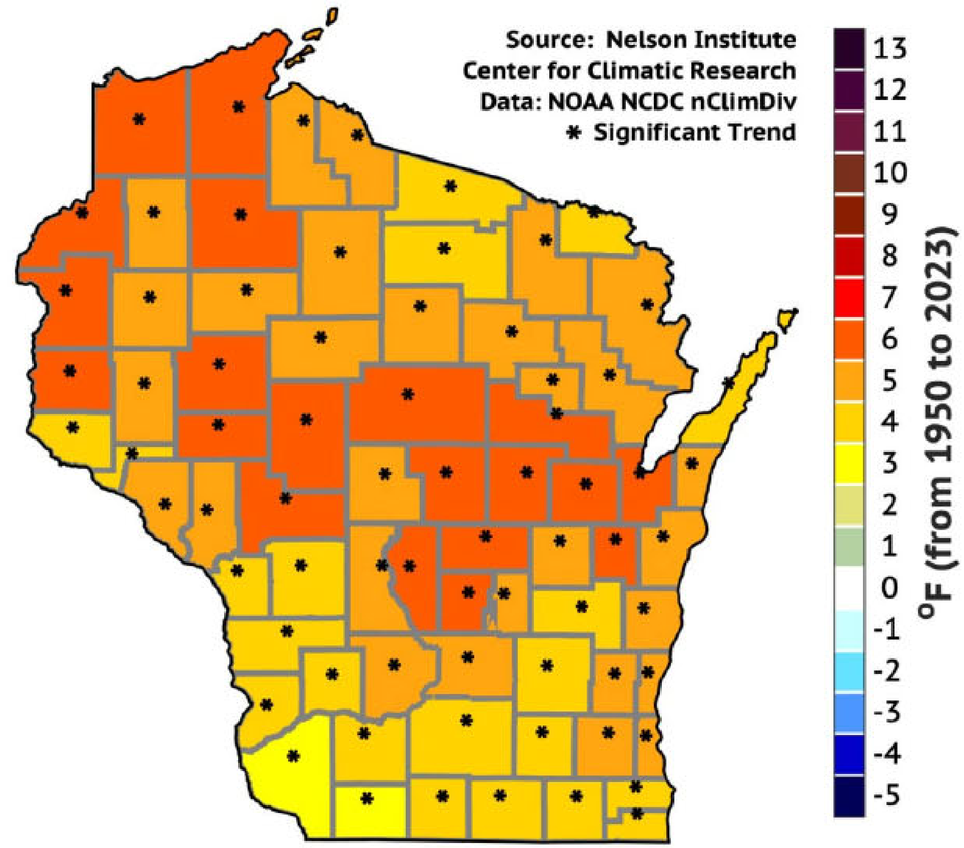
Temperature Trends: 1950 to 2023

Historical Change in Annual Average Temperature and Average Winter Temperature: 1950-2023

Historical Change in Annual TMEAN from 1950 to 2023



Historical Change in DJF TMEAN from 1950 to 2023



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

Precipitation Conditions: Study Period

Monthly Precipitation Totals for Southeastern Wisconsin: 2018-2021

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

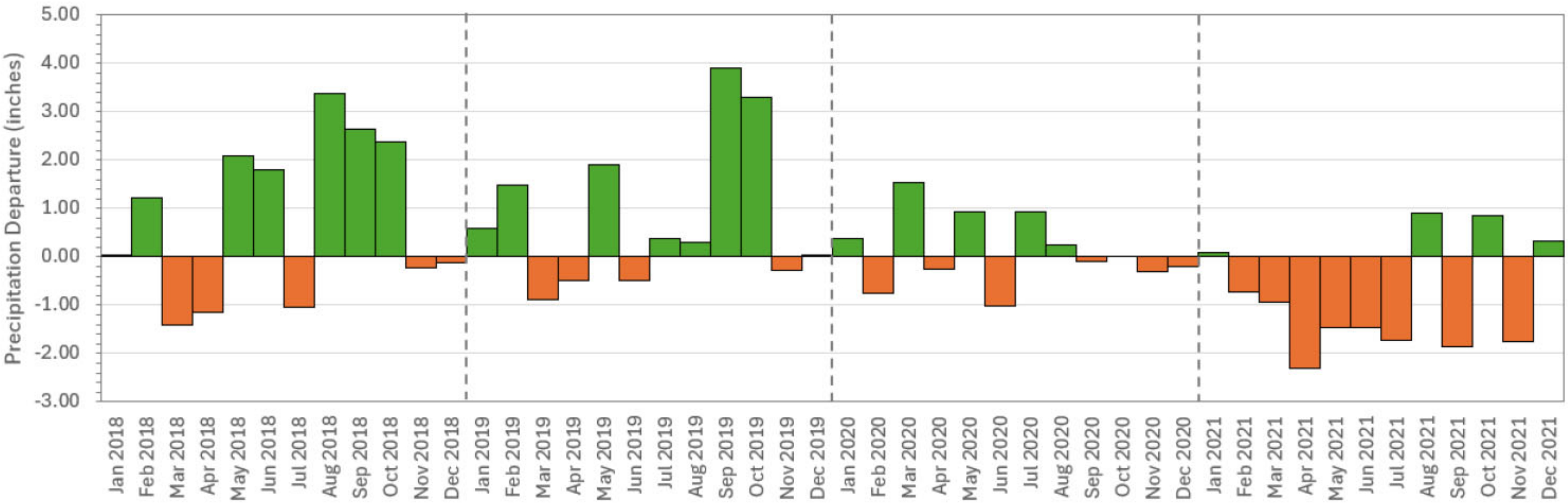
Note: Precipitation totals include the liquid water equivalent of all forms of liquid and frozen precipitation.

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

- Normal (average) annual precipitation = 35.28 inches
- Record wettest years: 2019 (1^{st}) and 2018 (2^{nd})

Precipitation Departures: Study Period

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

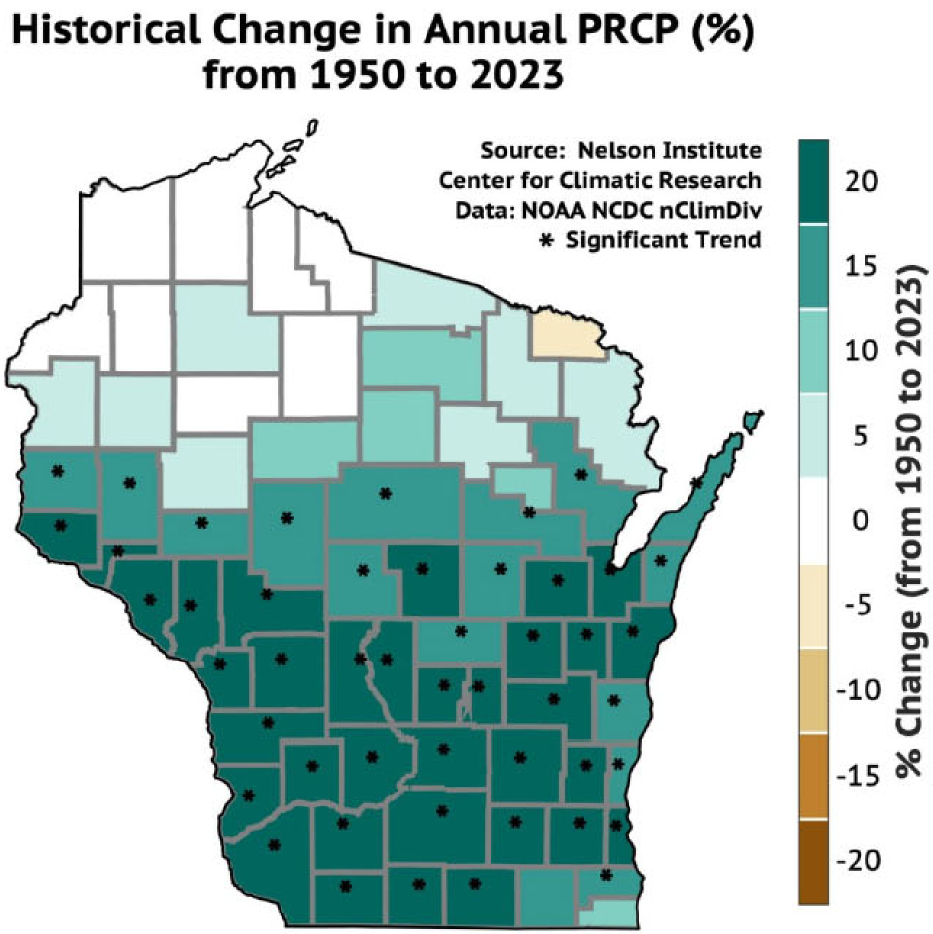


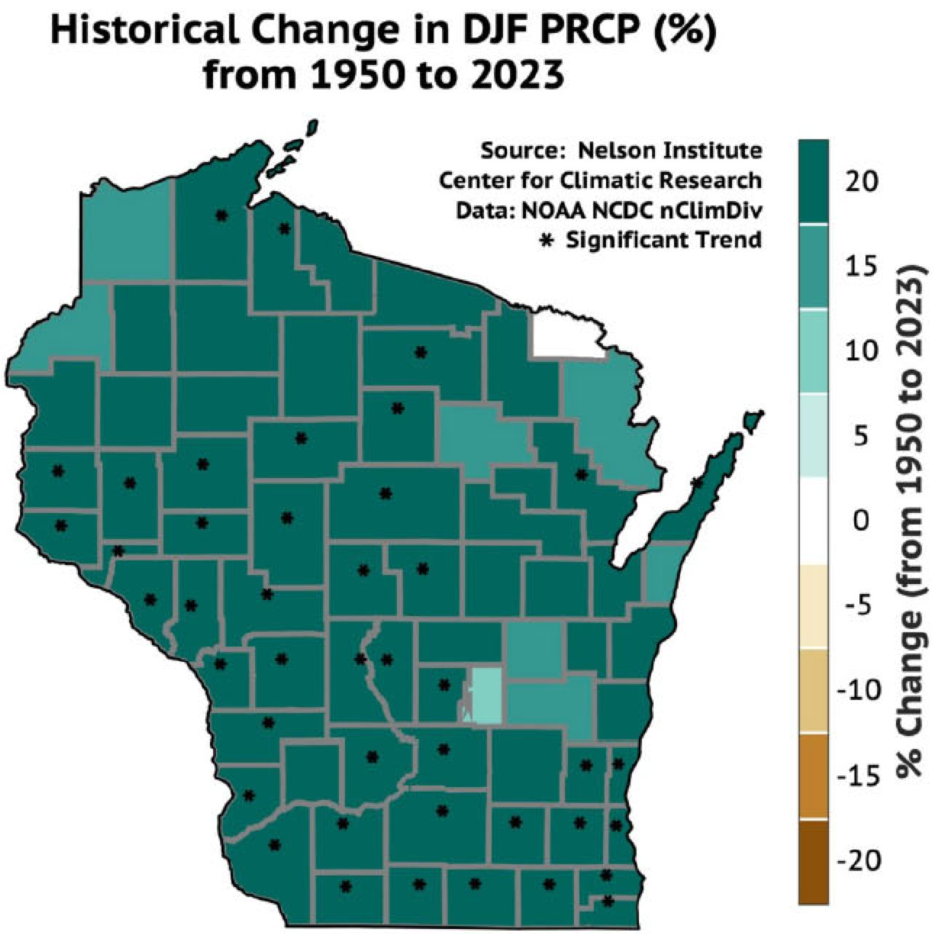
Source: Wisconsin State Climatology Office and NOAA National Centers for Environmental Information

Departure = Observed Precipitation – Normal Precipitation

Precipitation Trends: 1950 to 2023

Historical Change in Annual Precipitation and Winter Season Precipitation: 1950-2023

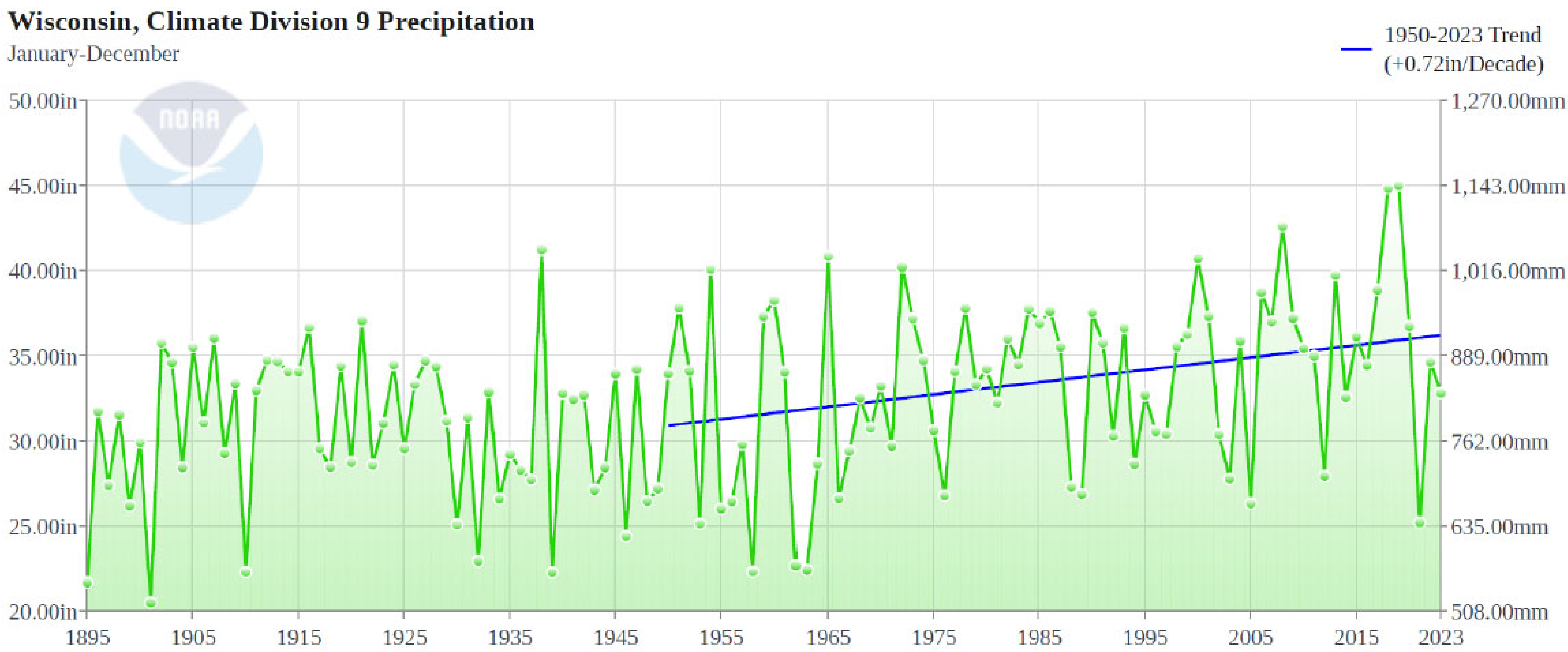




Source: Wisconsin Initiative on Climate Change Impacts, wicci.wisc.edu/wisconsin-climate-trends-and-projections

Long-Term Annual Precipitation

Annual Precipitation for Southeastern Wisconsin: 1895-2023



Source: NOAA National Centers for Environmental Information

Snowfall Conditions: Study Period

Monthly Snowfall Totals for Southeastern Wisconsin: Winter 2018-2019 to Winter 2020-2021

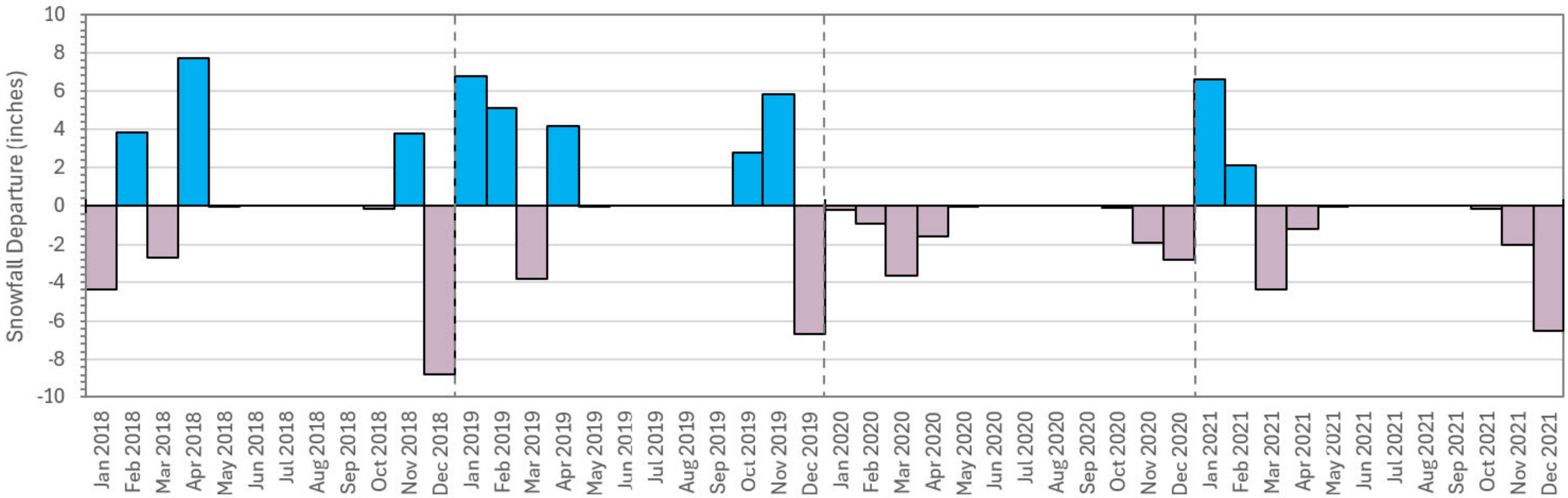
Month	Winter 2018-2019 Snowfall (inches)	Winter 2019-2020 Snowfall (inches)	Winter 2020-2021 Snowfall (inches)
October	0	2.9	0.1
November	5.9	7.9	0.2
December	1.0	3.1	7.0
January	19.3	12.4	19.2
February	15.9	9.8	12.8
March	1.5	1.6	0.9
April	5.8	0.1	0.5
Winter Total	49.4	37.8	40.7

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

- Normal (average) annual snowfall = 42.3 inches

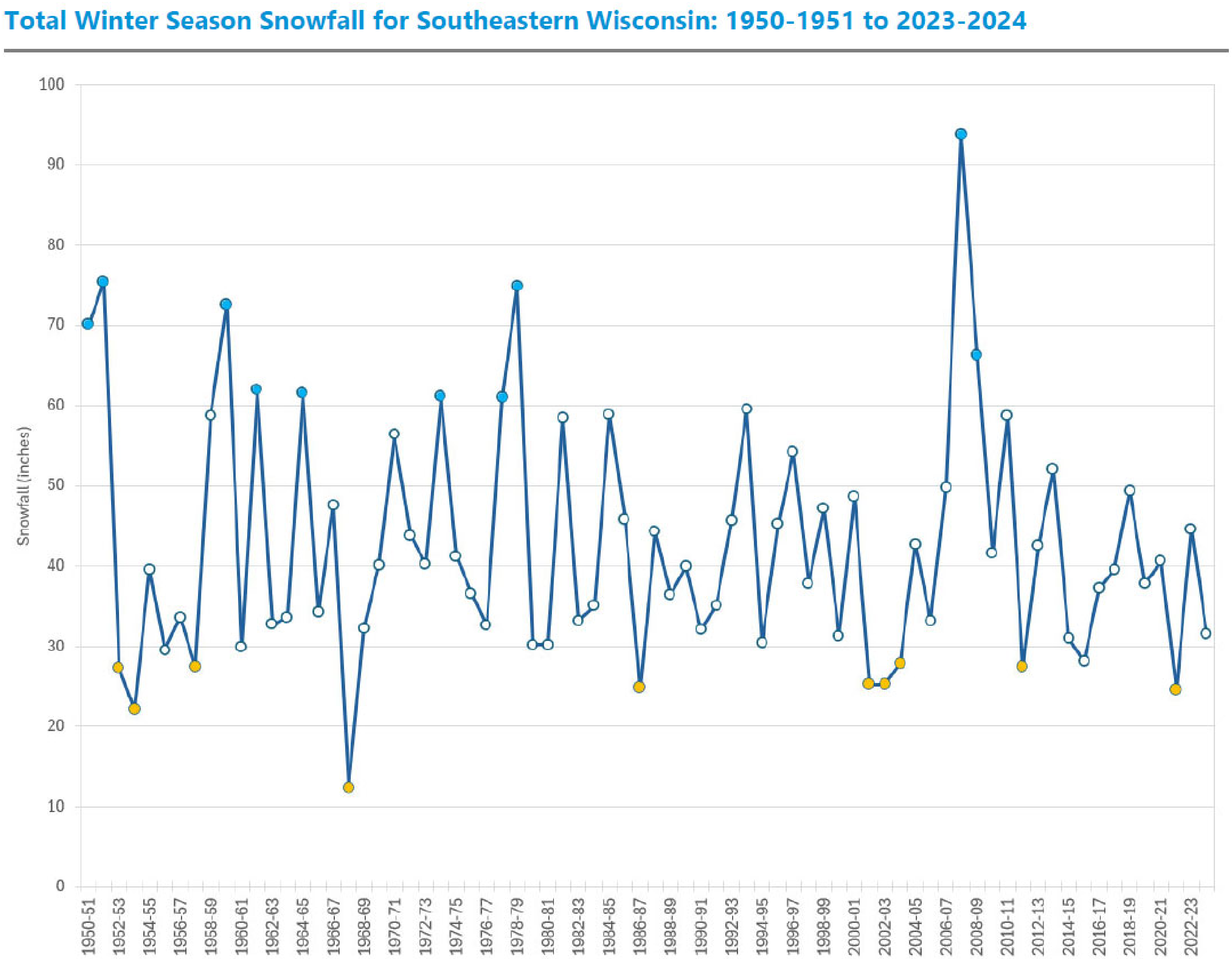
Snowfall Departures: Study Period

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



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

Winter Season Snowfall: 1950-51 to Present

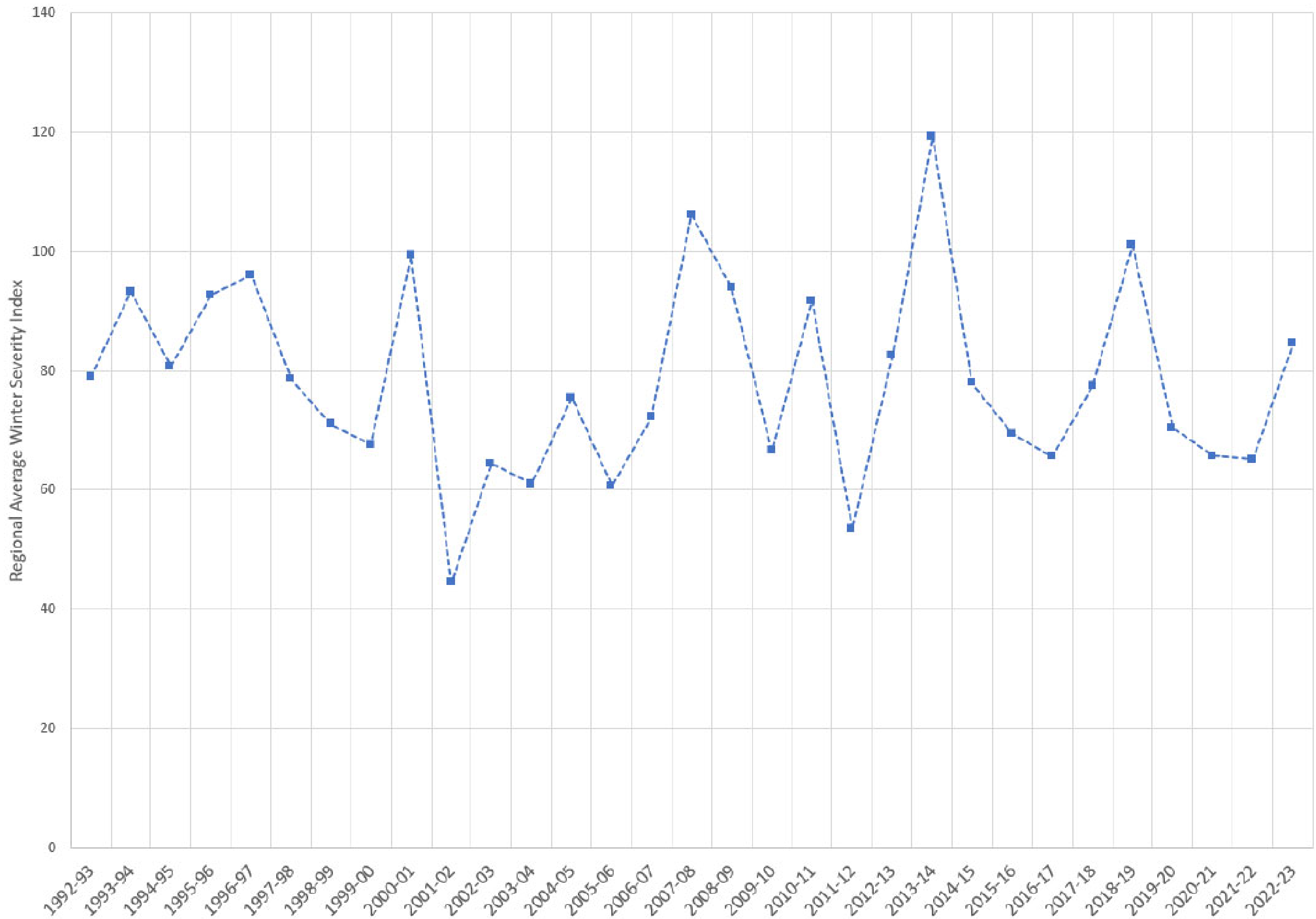


Relative Measures of Winter Severity

- Winter severity indices allow for relative comparison of winter seasons and provide historical context to current conditions
- Winter Severity Index (WSI) – Regional Average
  - Wisconsin Department of Transportation (WisDOT)
  - Includes snow, freezing rain, blowing/drifting snow
  - County WSIs computed from County storm reports, later MDSS
  - Period of Record: 1992-93 to present
- Accumulated Winter Season Severity Index (AWSSI) – Milwaukee, WI
  - Midwestern Regional Climate Center (MRCC)
  - Computed from MMIA precipitation and temperature data
  - Period of Record: 1950-51 to present

Relative Measures of Winter Severity: WSI

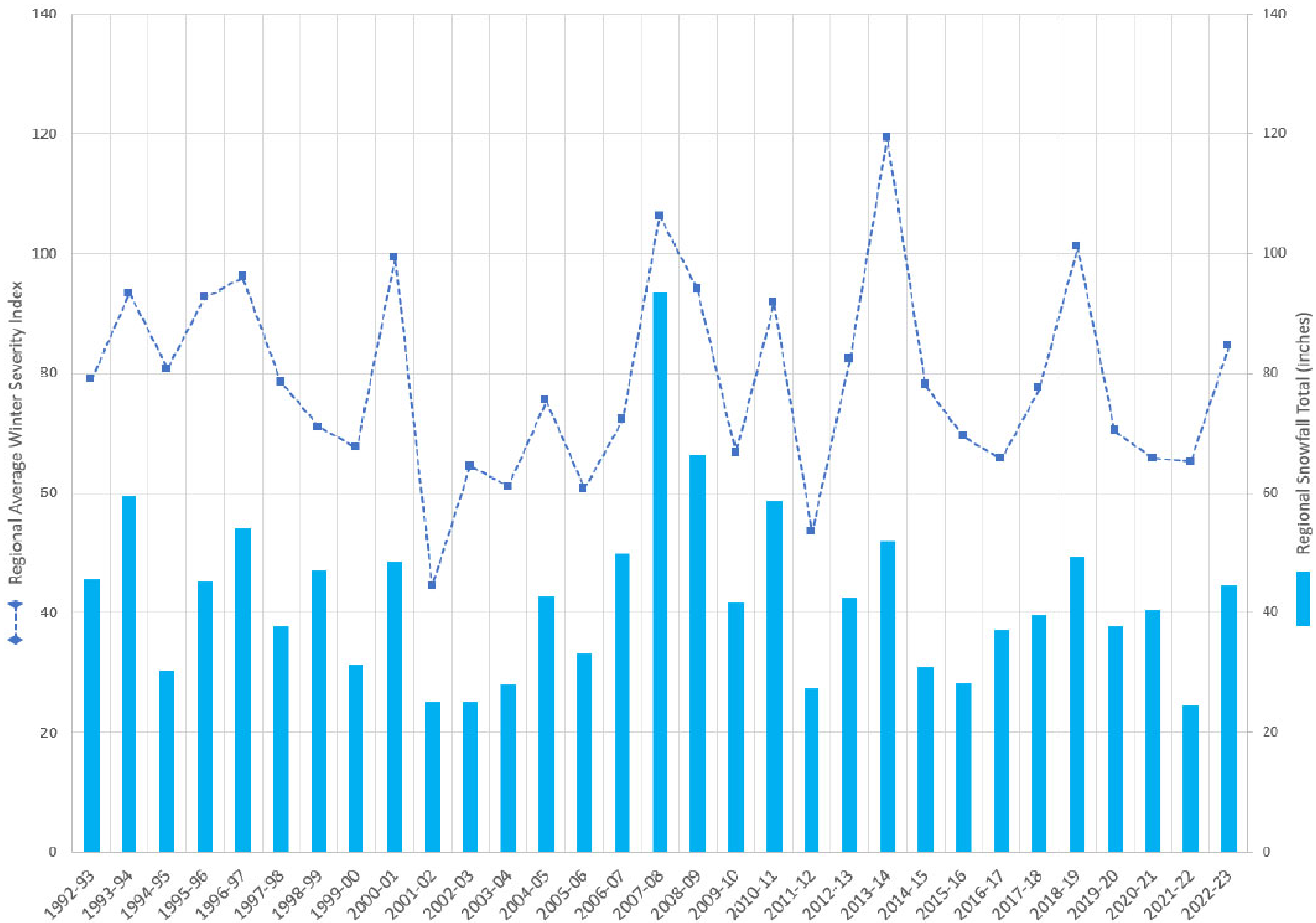
WisDOT Winter Severity Index: Regional Average (1992-1993 to 2022-2023)



Source: Wisconsin Department of Transportation

Regional WSI vs Regional Snowfall Totals

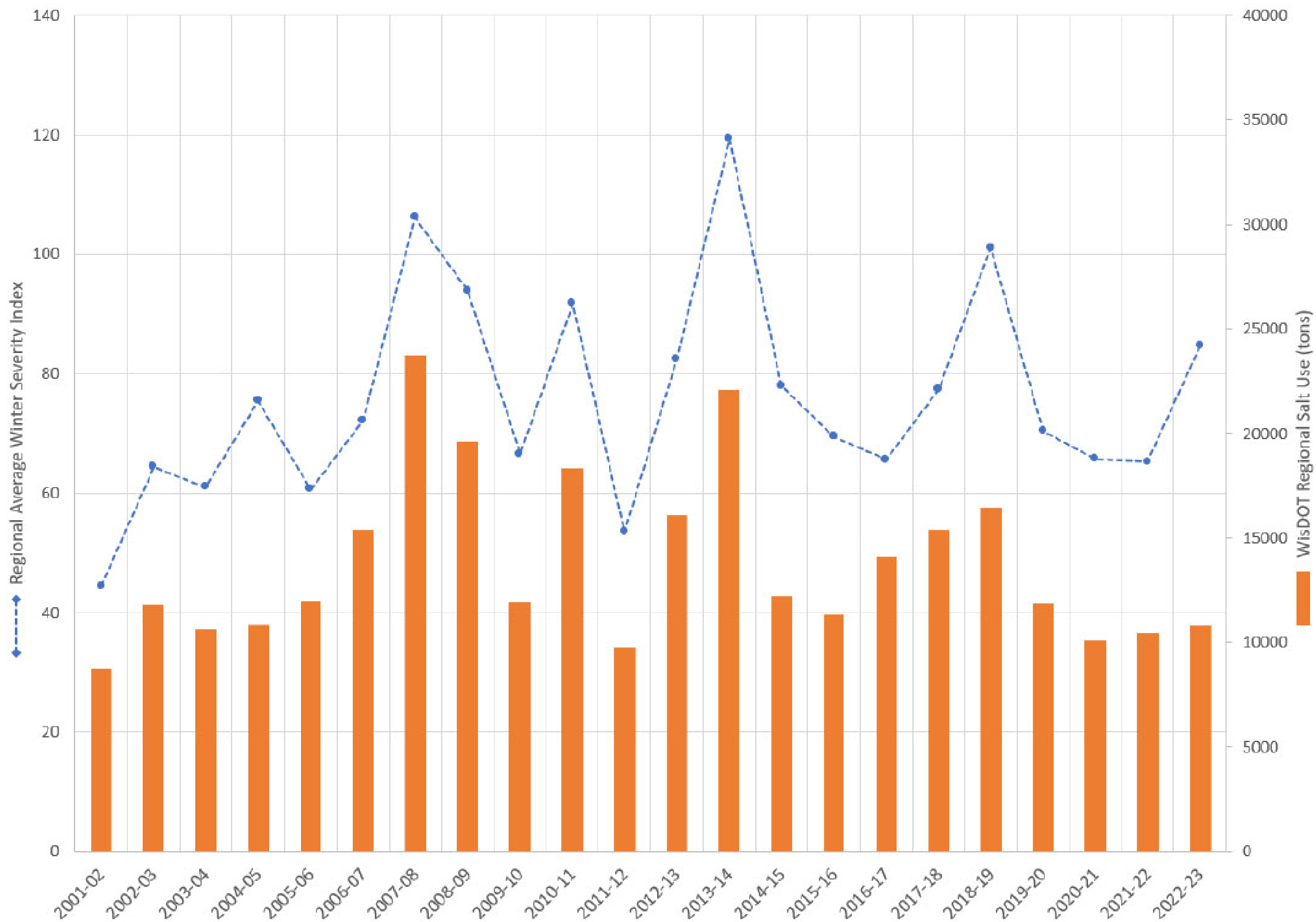
Regional Average WSI and Total Winter Season Snowfall: (1992-1993 to 2022-2023)



Source: Wisconsin Department of Transportation and Wisconsin State Climatology Office

Regional WSI vs Regional WisDOT Salt Usage

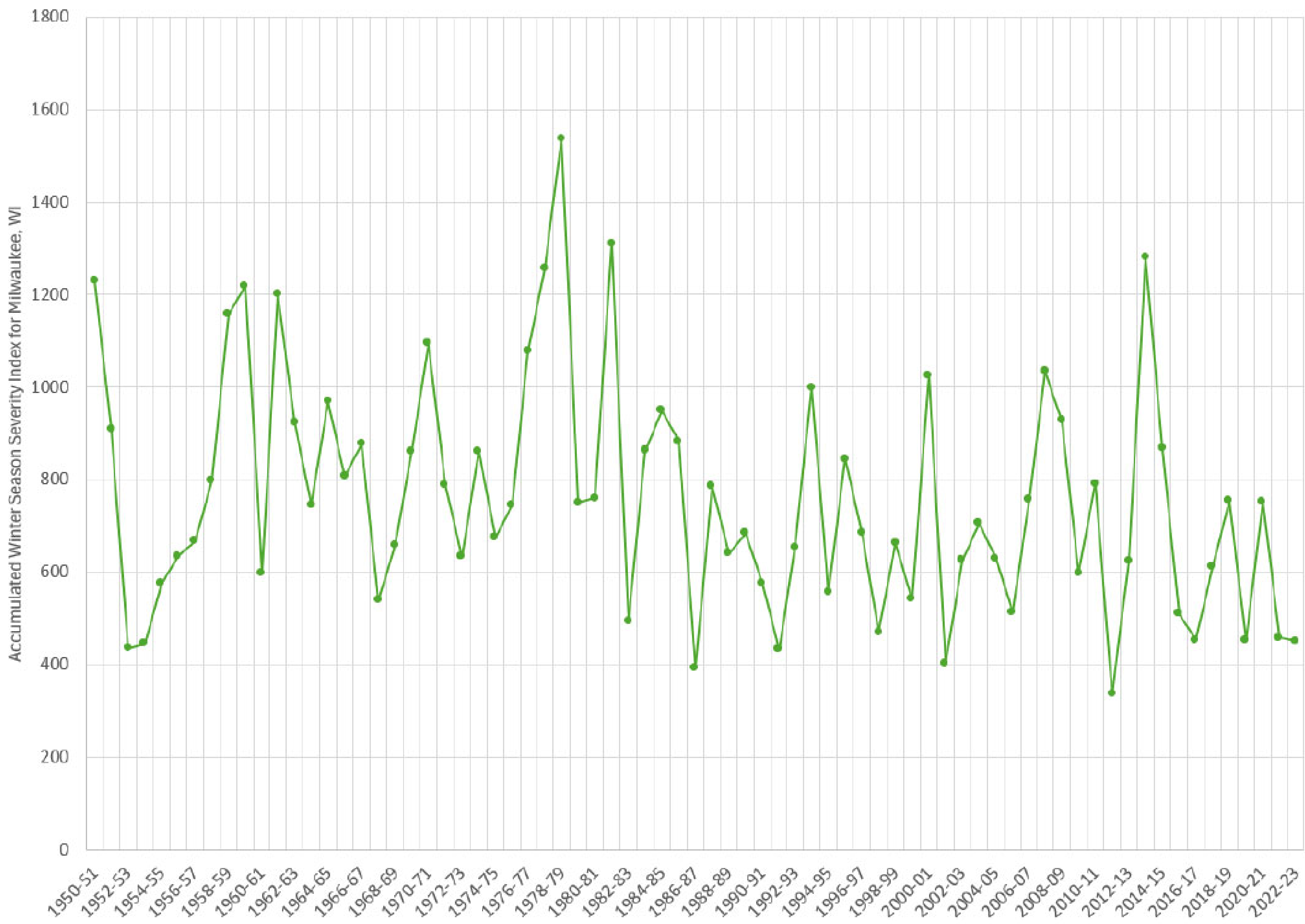
Regional Average WSI and WisDOT Regional Road Salt Use: (2001-2002 to 2022-2023)



Source: Wisconsin Department of Transportation

Relative Measures of Winter Severity: AWSSI

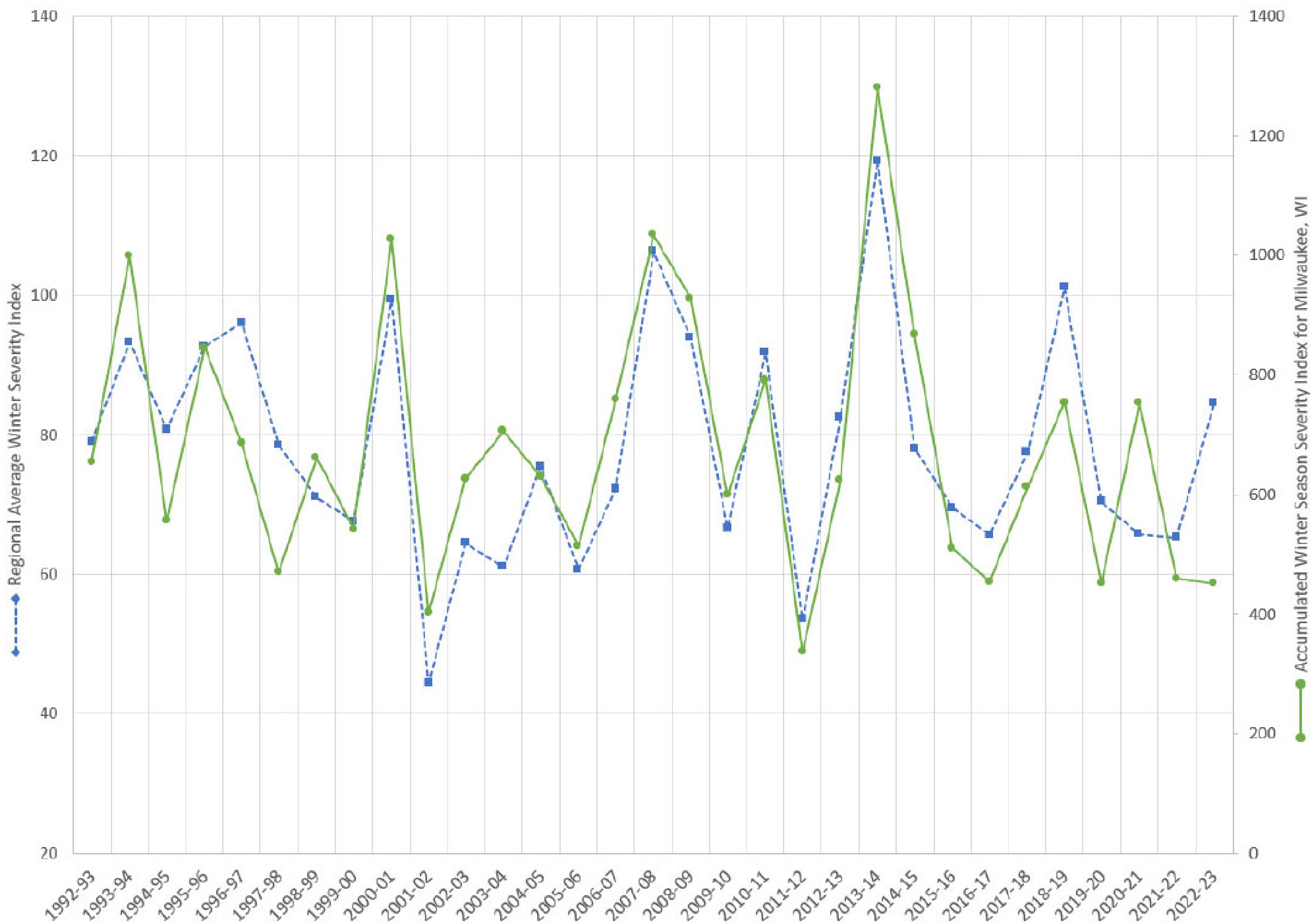
MRCC Accumulated Winter Season Severity Index: Milwaukee (1950-1951 to 2022-2023)



Source: Midwestern Regional Climate Center

Relative Measures of Winter Severity: WSI vs AWSSI

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

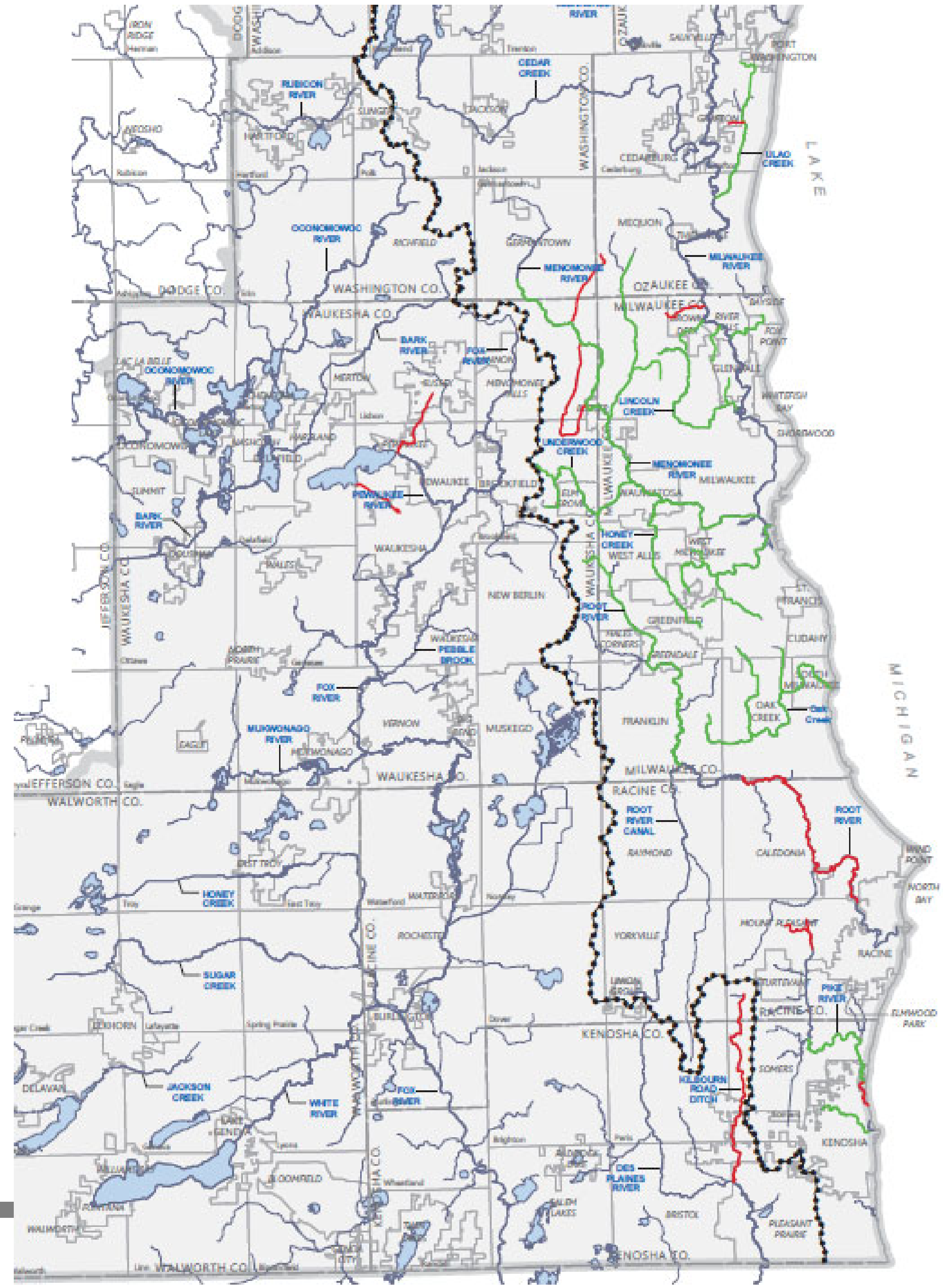


Source: Wisconsin Department of Transportation and Midwestern Regional Climate Center

Questions?

Water Quality Standards

- Chloride Impairments: 2024
  - Most of Milwaukee Co
  - Rest urban locations



Water Quality Standards - Chloride

- Surface Water Standards
  - USEPA same as MN
- Groundwater Standards
  - PAL 125 mg/l
  - Enforcement Standard 250 mg/l
- Secondary Drinking Water Standard
  - MCL 250 mg/l

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

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

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

Note: Iowa and Indiana criteria are based on ambient hardness and sulfate concentrations

Water Quality Standards - Chloride

- Protectiveness of Current Standards

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

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

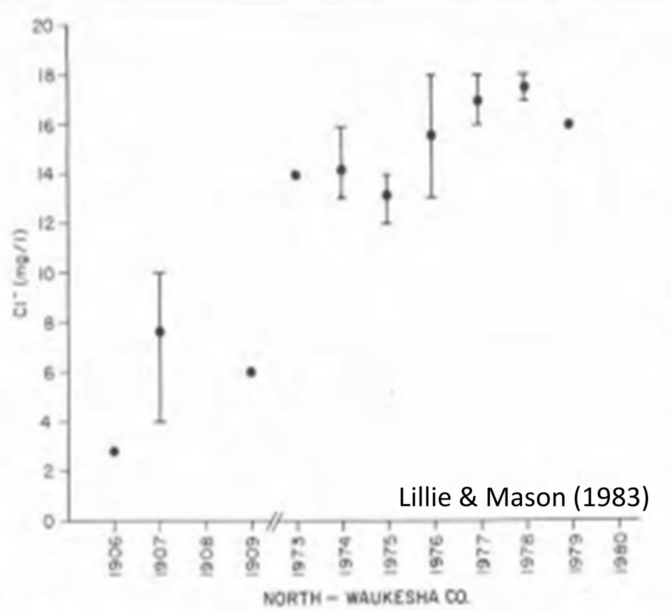
Source: SEWRPC

TR-63 Chapters

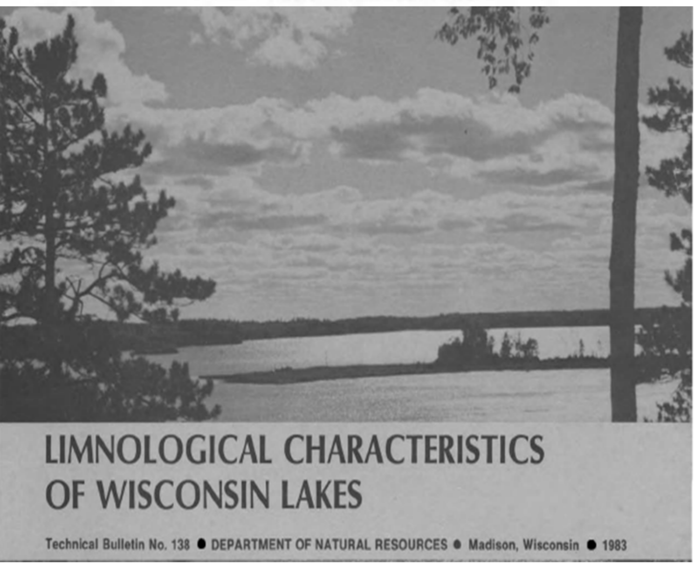
- Chapter 1 – Introduction
- Chapter 2 – Study Area Background (part)
- Chapter 3 – Analysis of Chloride Impact Study Monitoring Data: 2018- 2021
- Chapter 4 – Conditions and Trends: Rivers
- Chapter 5 – Conditions and Trends: Lakes (part)
- Chapter 6 – Conditions and Trends: Groundwater
- Chapter 7 – Drivers and Interactions

- 5.1 INTRODUCTION
- 5.2 REGIONAL LAKE BACKROUND INFORMATION
- 5.3 DATA COLLECTION AND ORGANIZATION
    - Data Sources
    - Data Formatting and Aggregation
    - Defining Recent Conditions and Trends Data
- 5.4 RECENT CHLORIDE CONDITIONS OF REGION
    - Relationships With Chloride
    - Specific Conductance Conditions
- 5.5 CHLORIDE TRENDS IN REGION LAKES

Introduction Chapter 5.1

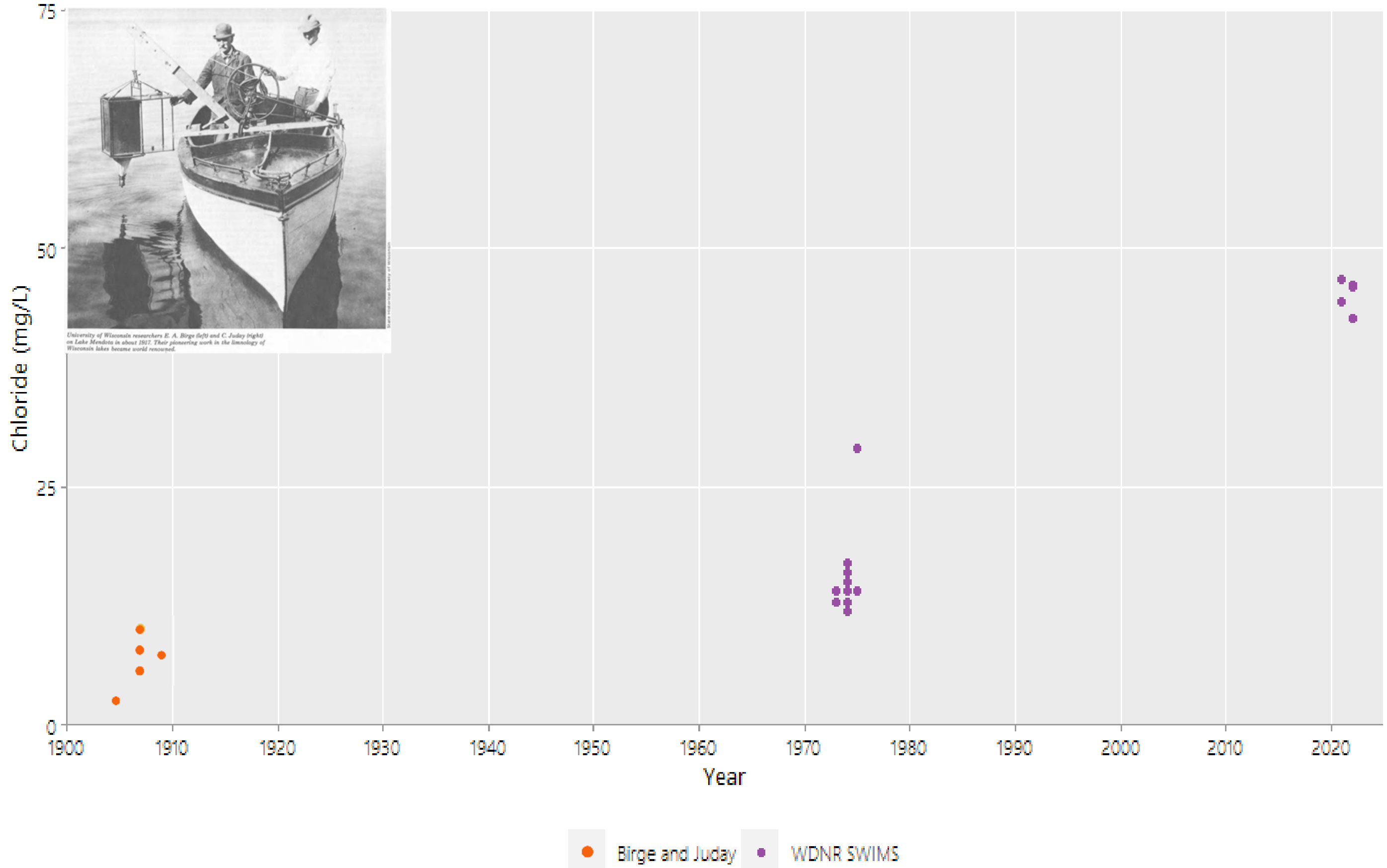


Lillie & Mason (1983)



North Lake (Waukesha County)

Scatterplots of Chloride Concentrations Over Time for North Lake: 1907 to 2022

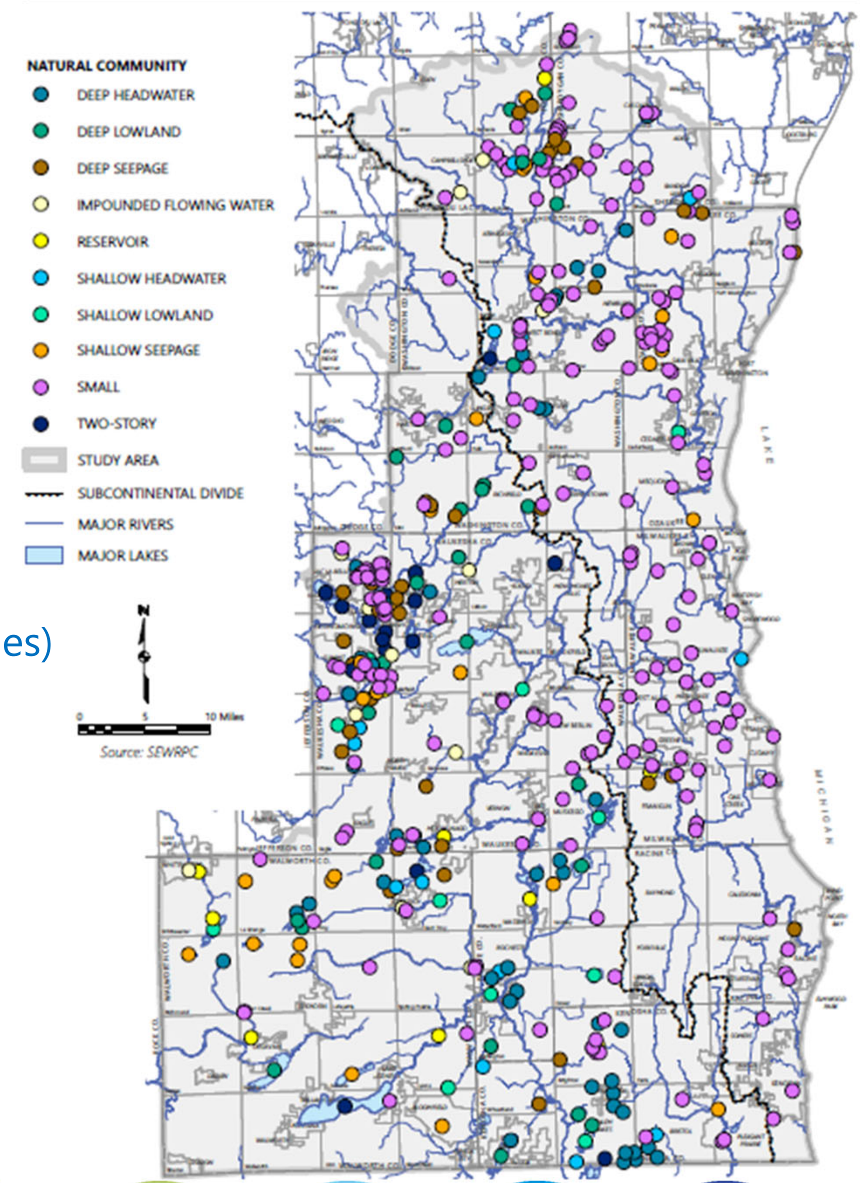


Source: WDNR SWIMS, Birge and Juday

Regional Lake Background Information Chapter 5.2

- Description of Lakes in the Region
- Region: 803 total lakes
  - 482 Lakes acreage: 0.17 to 5403.8 acres
  - 370 Lakes depth: 1 to 135 ft
  - Watershed Size : 0.04 to 282.3(sq.miles)
  - Residence Time
    - Lake Types
    - Natural Communities

Map 5.ClStudyLakes_NatComms
WDNR-Designated Natural Communities of Lakes in Chloride Study Area



Data Collection and Organization Lakes 5.3

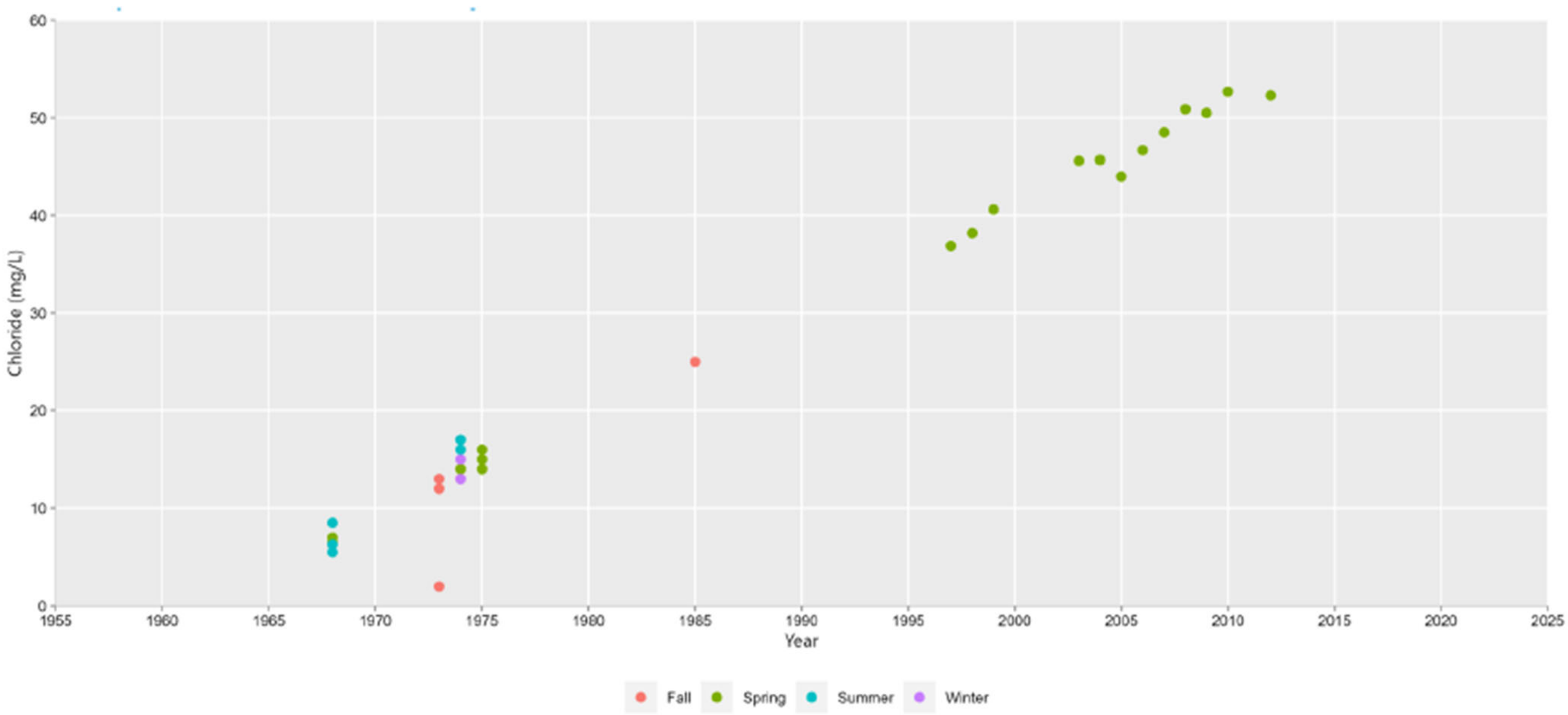
- Compiled chloride and specific conductance data from multiple organizations and databases
  - EPA Water Quality Portal database
  - Wisconsin Department of Natural Resources (58 percent)
  - United States Geologic Survey (27.5 percent)
  - SEWRPC historical records (11 percent)
  - Municipalities and lake organizations (4.5 percent)

- Created comprehensive dataset with formatted data and conducted data quality assurance

Data Collection and Organization Lakes 5.3

- Data formatting
  - Convert units as necessary
    - Chloride in mg/l
    - Specific conductance in µS/cm @ 25^{o}C
    - Water depth in feet
    - Assign coordinates and reproject to NAD83 (2011)
  - Spatially join data to WDNR lake polygons to assign WBIC
- Quality assurance
  - Remove anomalies if conditions warranted
  - Remove duplicates between databases

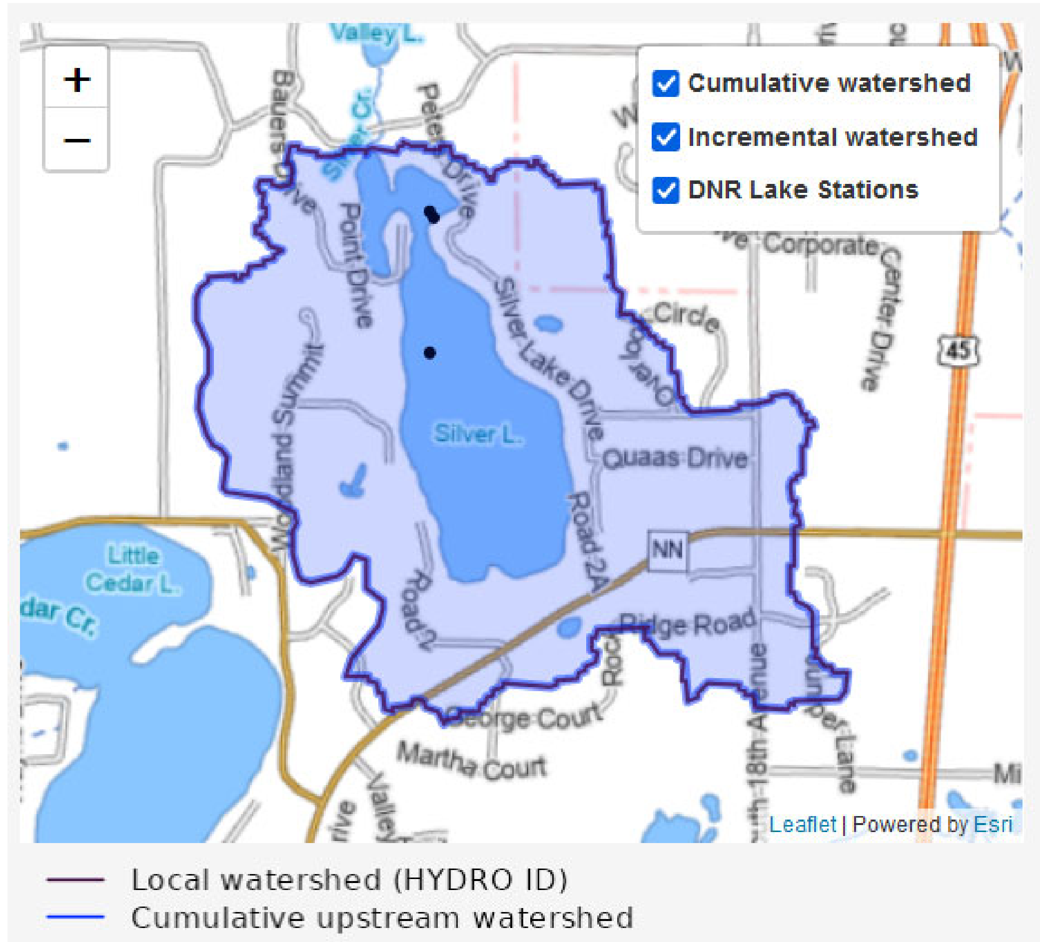
Data Formatting and Aggregation Lakes 5.3



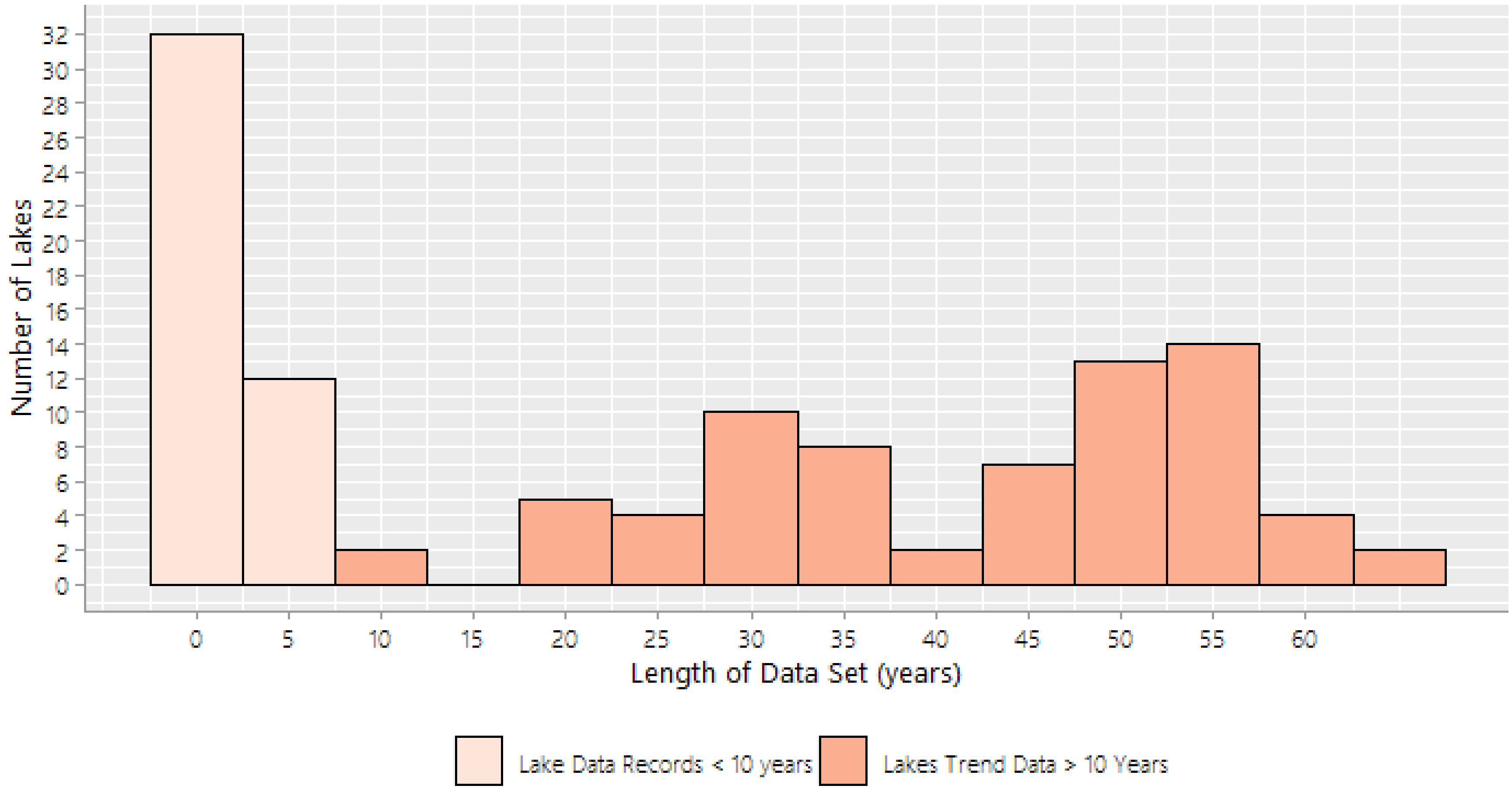
- Define seasons and assign to samples
  - Spring: Mar-May
  - Summer: Jun-Aug
  - Fall: Sep-Nov
  - Winter: Dec-Feb

Data Formatting and Aggregation Lakes 5.3

- Assign lake, watershed, and other attributes for analysis
  - Lake characteristics (hydrology, size, residence time)
  - Watershed characteristics (size, land use)
  - Shoreline land use
- Used WDNR Water Explorer (WEx) tool to delineate watersheds



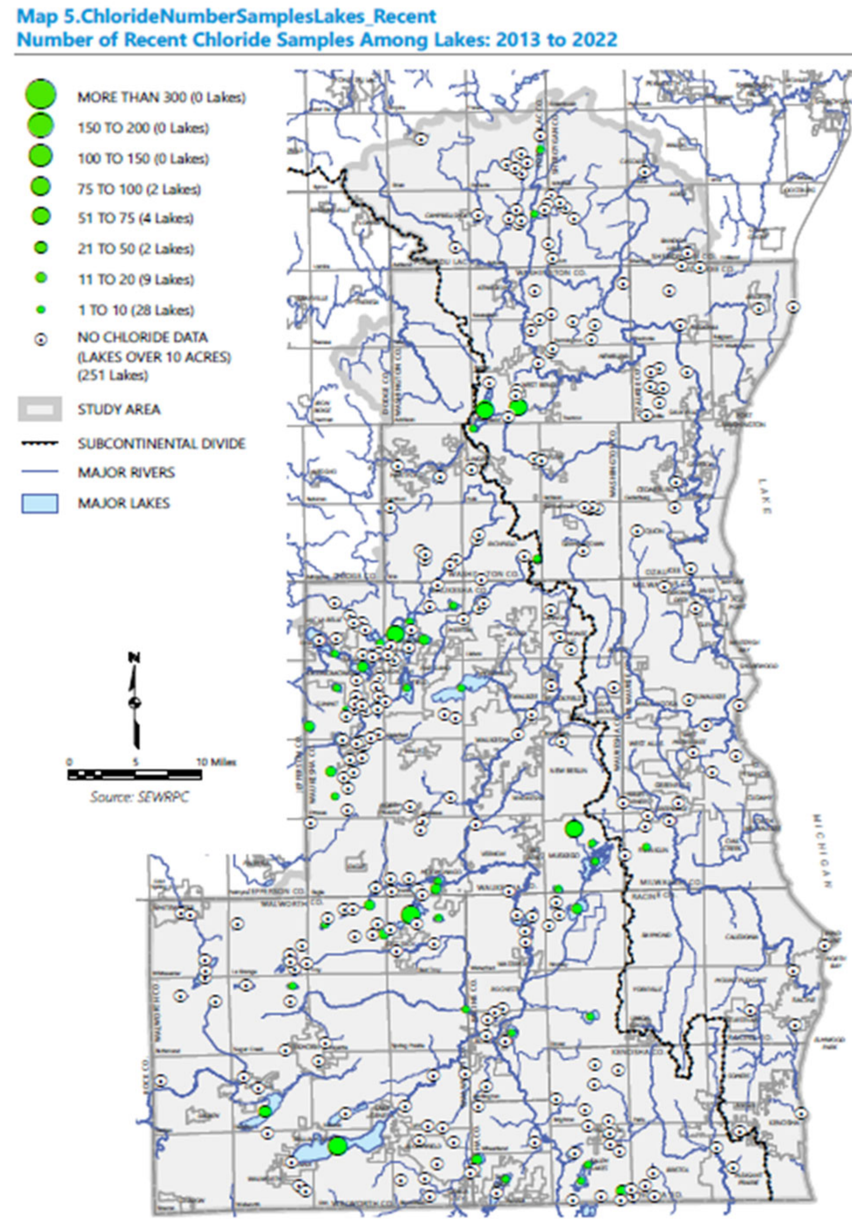
Defining Recent Conditions and Trends 5.3



- Lakes with "Trends" Dataset: at least 10 years and 2 samples
- Recent Conditions: Data collected between 2013 - 2022

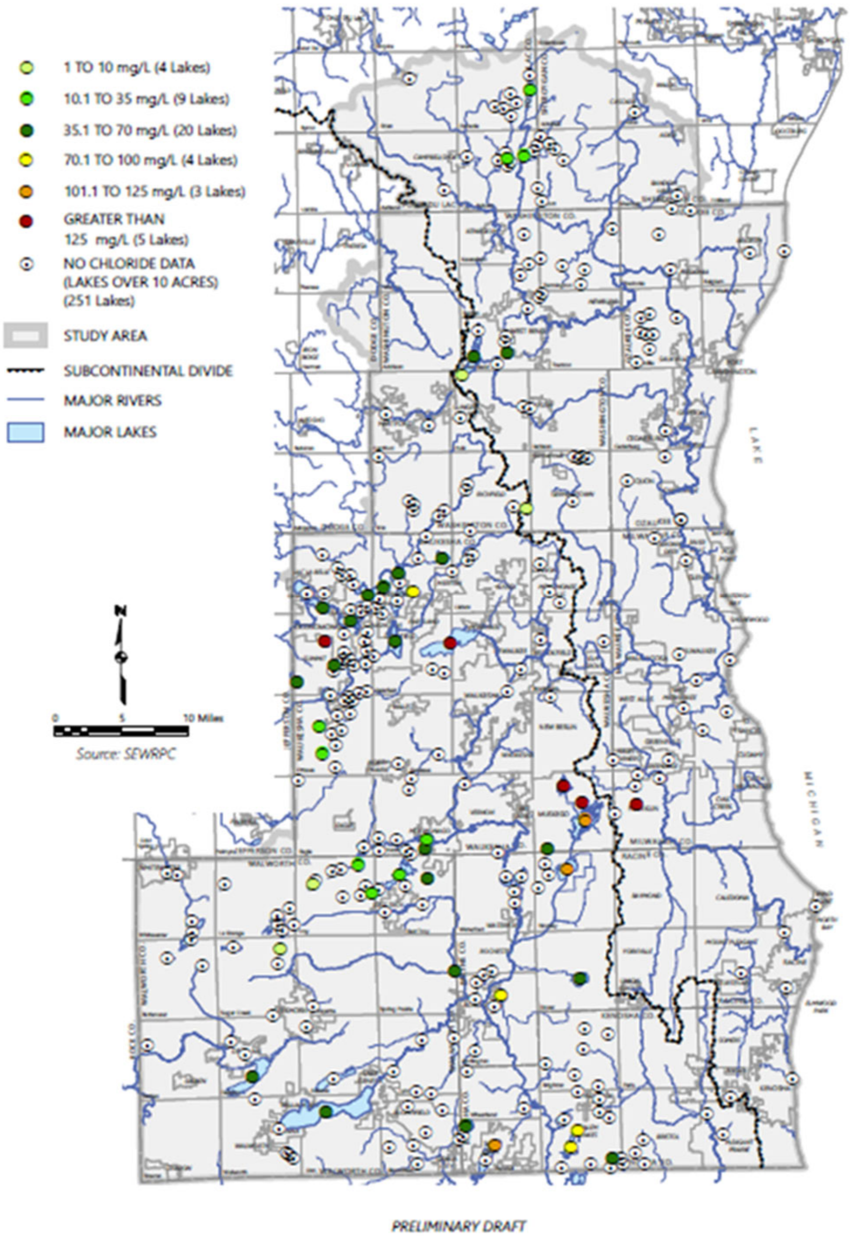
Recent Chloride Conditions Of Region Lakes 5.4

- Recent Chloride Condition Samples
  - 45 Lakes with recent condition data (2013 to 2022)
  - 62 percent 1- 10 samples
  - 20 percent 11- 20 samples
  - 18 percent 21-100 samples



Recent Chloride Conditions Of Region Lakes 5.4

Map 5.ChorideMeanLakes_Recent
Recent Mean Chloride Concentration Among Lakes: 2013 through 2022



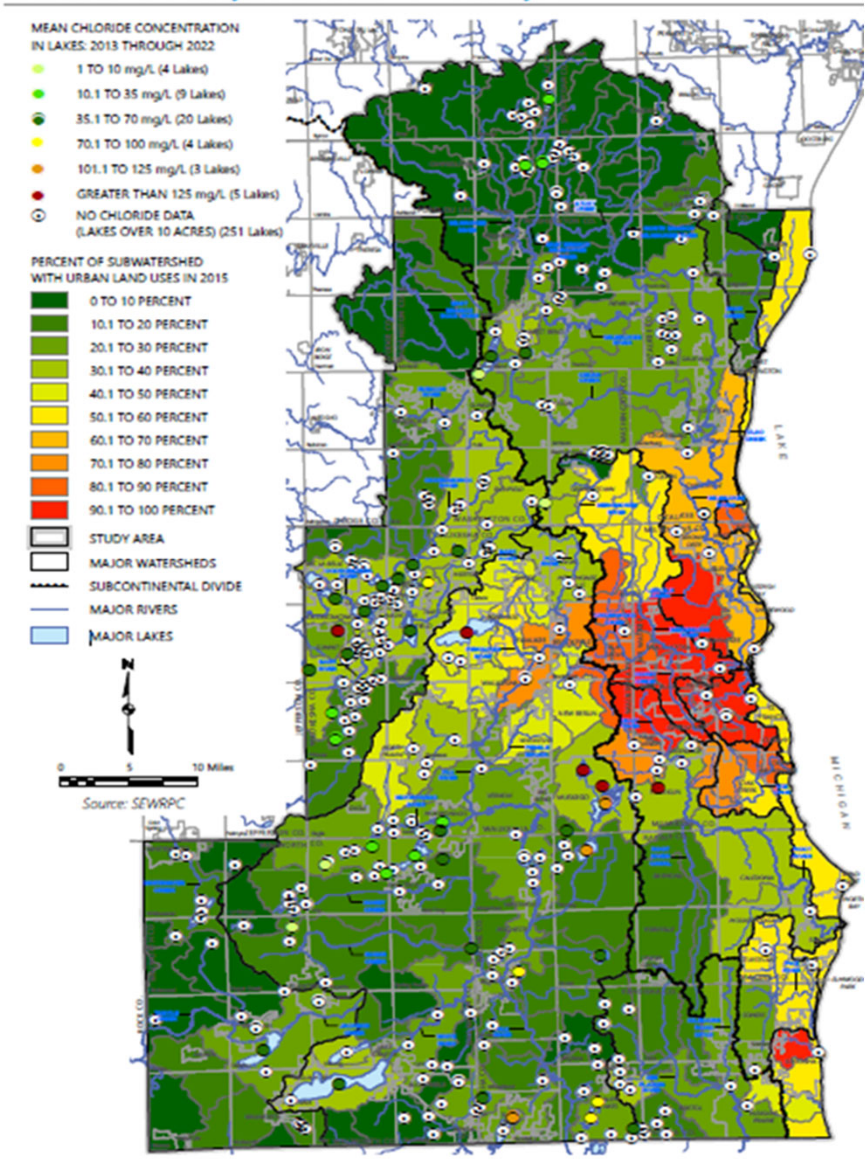
Regional Lake Chloride Descriptive Statistics

- Average Chloride 61.4 mg/l
- Lowest average 3.82 mg/l (Mueller Lake)
- Highest average 218.3 mg/l (Bass Bay Lake)
- This exceeds the Birge and Juday background concentration by over 20 times

Recent Chloride Conditions Of Region Lakes 5.4

- The highest mean chloride concentrations are located where percent urban land use is the greatest

Map 5.ClorideRecentMean_PercentUrban
Recent Mean Chloride Concentrations in Lakes and
Percent Urban Land Use by Subwatersheds Within the Study Area



Recent Chloride Conditions Of Region Lakes 5.4

Table 5.ChlorideLakeThreshholds
Chloride Concentrations of Lakes in Recent Conditions Dataset: 2013 - 2022[a]

Recent Lakes			Chloride Concentrations				
OFFICIAL_NAME	WBIC	COUNTY	35 mg/l: Diatoms	40 mg/l: Daphnia	54 mg/l: Wetland Plant Species	108 mg/l: Fish Diversity	185 mg/l: Plankton
Camp Lake	747100	Kenosha	X	X	X		
Center Lake	747300	Kenosha	X	X	X		
Lake Mary	743000	Kenosha	X	X	X	X	
Powers Lake	744200	Kenosha	X	X			
Voltz Lake	746300	Kenosha	X				
Unnamed	5588789	Milwaukee	X	X	X	X	X
Browns Lake	750300	Racine	X	X	X		
Eagle Lake	759800	Racine	X	X	X		
Wind Lake	761700	Racine	X	X	X	X	
Delavan Lake	793600	Walworth	X	X	X		
Geneva Lake	758300	Walworth	X	X			
Honey Lake (Vienna)	752300	Walworth	X	X			
Potter Lake	753800	Walworth	X	X	X		
Cedar Lake	25300	Washington	X	X	X		
Silver Lake (Paradise Valley)	36200	Washington	X				
Bass Bay Lake	763200	Waukesha	X	X	X	X	X
Beaver Lake	774400	Waukesha	X	X	X		
Big Muskego Lake	762400	Waukesha	X	X	X	X	
Fowler Lake	849400	Waukesha	X	X			
Golden Lake	775900	Waukesha	X				
Lake Denoon	761300	Waukesha	X	X	X		
Lake Keesus	852400	Waukesha	X	X			
Little Muskego Lake	762700	Waukesha	X	X	X	X	X
Middle Genesee Lake	778300	Waukesha	X	X	X		
Moose Lake	778400	Waukesha	X	X	X		
Nagawicka Lake	828000	Waukesha	X	X			
North Lake	850800	Waukesha	X	X			
Oconomowoc Lake	849600	Waukesha	X	X	X		
Okauchee Lake	850300	Waukesha	X	X			
Pewaukee Lake	772000	Waukesha	X	X	X	X	
Silver Lake	779800	Waukesha	X	X	X	X	
Upper Phantom Lake	766000	Waukesha	X	X			

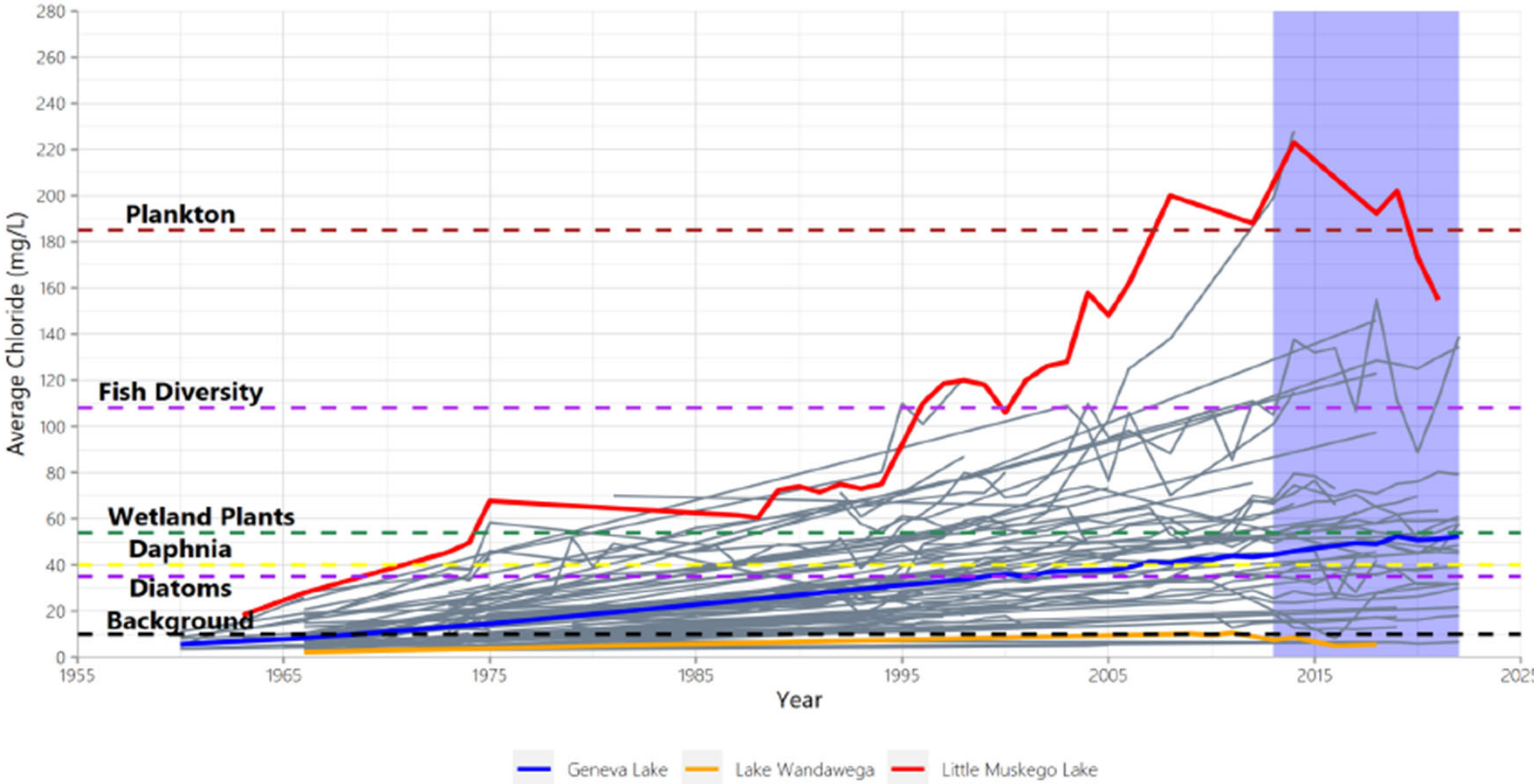
Note: Lakes not listed have no chloride data or have concentrations below the known effect concentrations

[a] SEWRPC Technical Report No. 62, Impacts of Chloride on the Natural and Built Environment, April 2024, Table 3.17

- None of the lakes evaluated exceed the acute (757 mg/l) or chronic (395 mg/l) Wisconsin standards
- Evaluations were derived using thresholds of biological impacts

Recent Chloride Conditions Of Region Lakes 5.4

Figure 5.YearlyAverageChlorideLevelsThresholds
All Chloride Lake Data: 1960 to 2022



Note: The shaded blue area indicates the recent conditions (2013 through 2022) used for this study. The colored dashed lines indicate the natural background concentrations for the Region (background) or the various biological impacts of increasing chloride concentrations (e.g., `Diatoms` indicating altered diatom communities).Each lake is represented by a grey line or a colored line to highlight individual lakes.

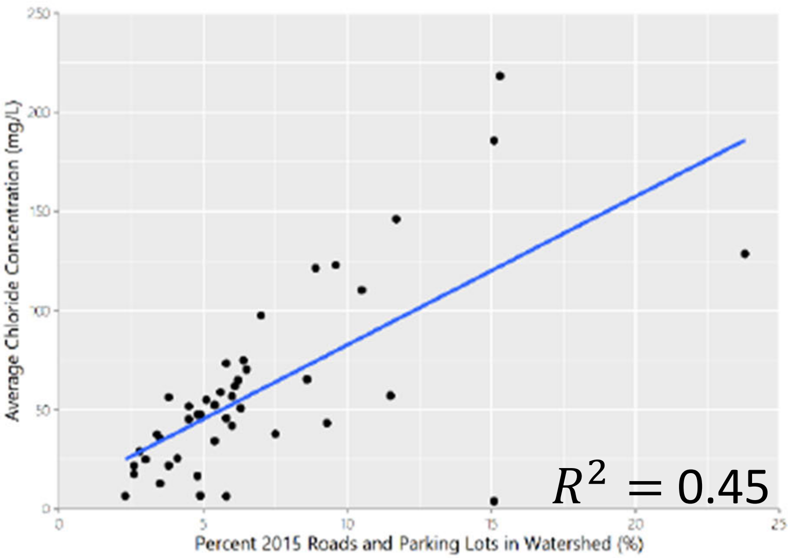
Source: SEWRPC

- Many lakes are approaching or exceeding levels that may negatively impact aquatic organisms
- Currently seeing the highest chloride concentrations in most lakes

Relationships With Chloride Lakes 5.4

Figure 5.ClRelationScatters

Scatterplots of Percent Urban Land Use and Percent Roads and Parking Lots in Watershed by Recent Average Chloride Concentration: 2013-2022



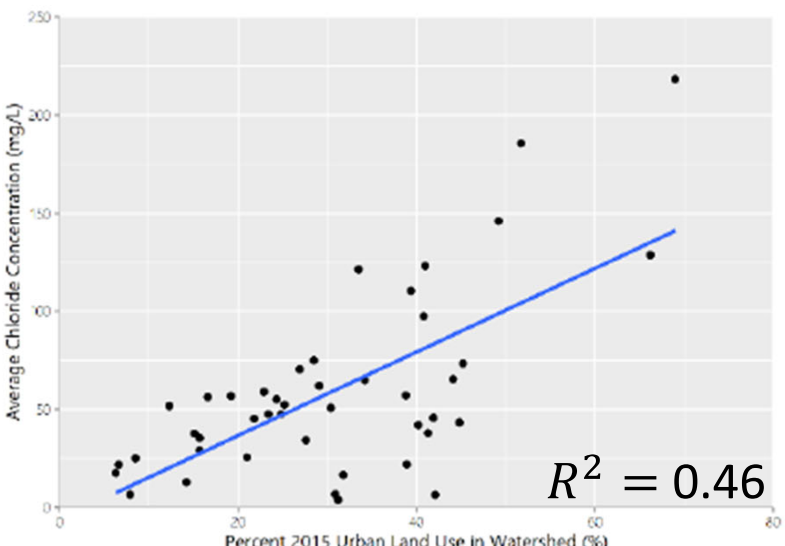
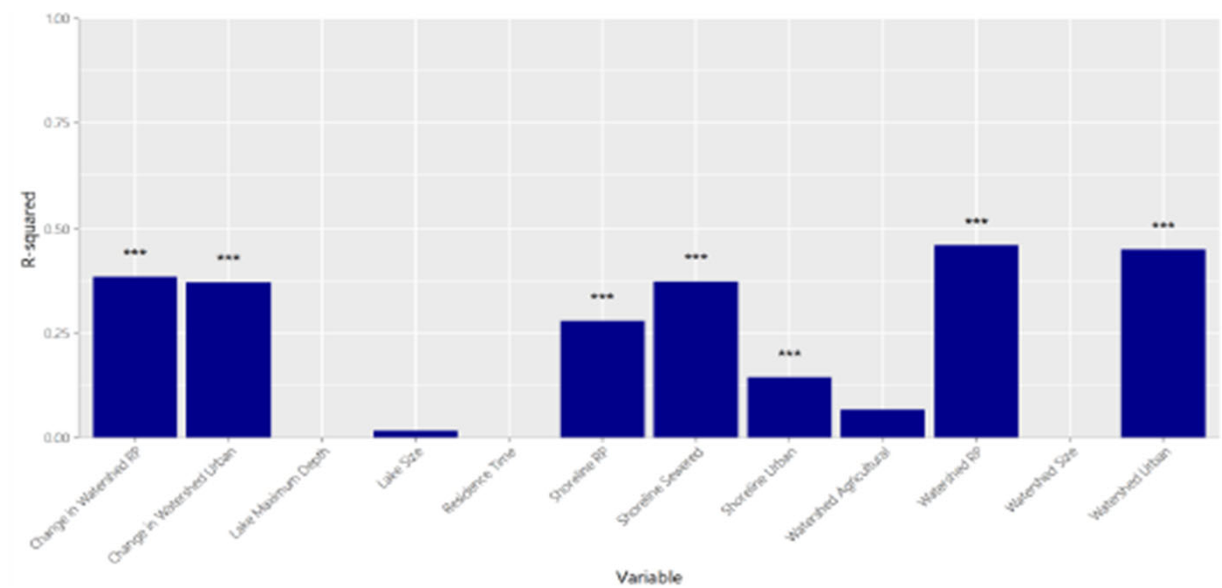


Figure 5.RecentClR2

R-squared Values of Explanatory Variables with Recent Average Lake Chloride : 2013 - 2022



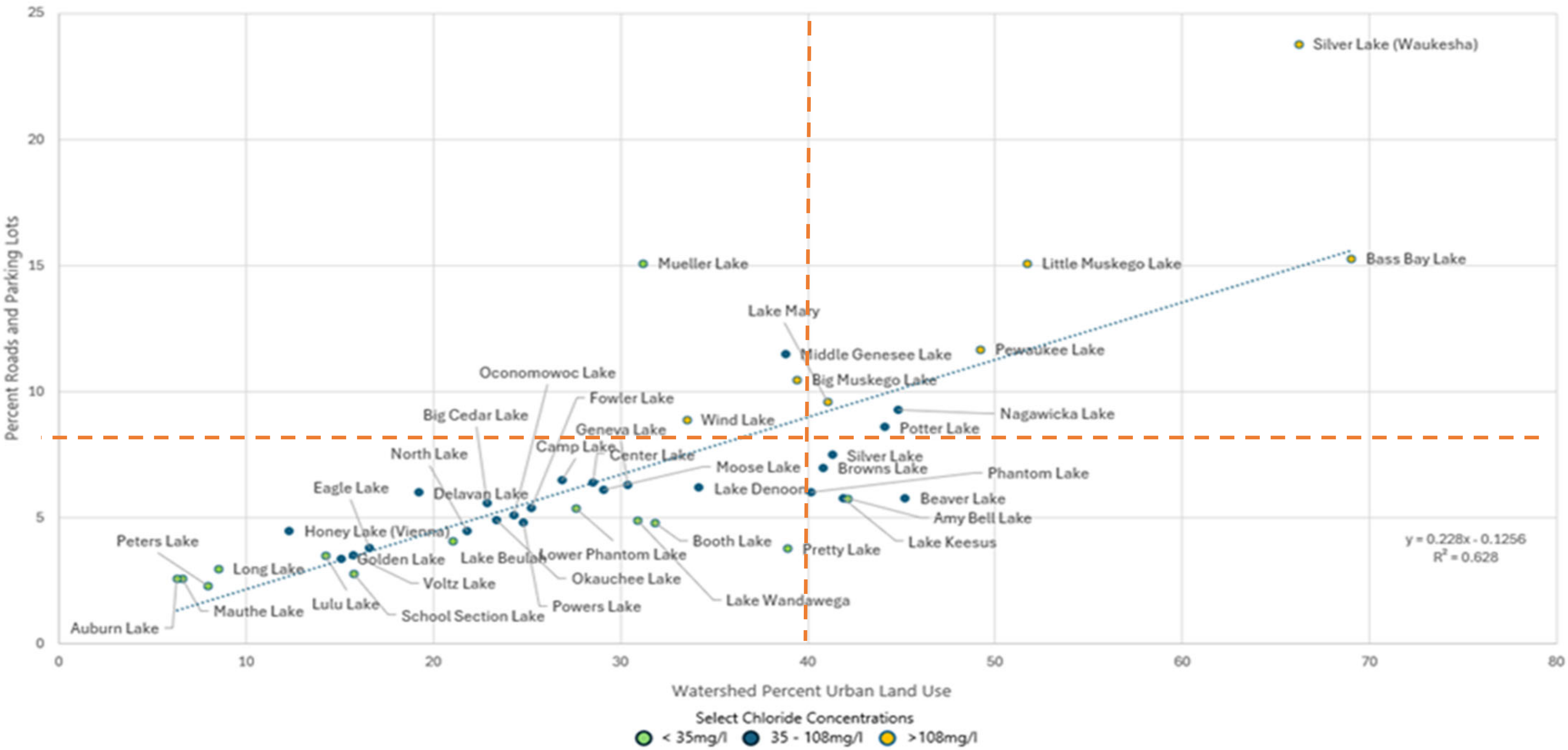
Note: Explanatory variables with a statistically significant relationship to average lake chloride are indicated by the "***" symbols. "Watershed RP" is the percent of the watershed in roads and parking lots while "Watershed Urban" is the percent of the watershed in urban land uses. The "Change in Watershed RP" variable is the difference between the roads and parking lot percent of the watershed in 2015 compared to 1963. "Change in Watershed Urban" is the difference between the urban land use percent of the watershed in 2015 compared to 1963.

Source: SEWRPC

- Statistically significant variables are land use related
- Watershed land use is an important determinant of lake chloride concentrations

Relationships With Chloride Lakes 5.4

Figure 5. Percent Urban Land Use and Percent Roads and Parking Lots Relationship
Relationship of Percent Urban Land use and Percent Roads and Parking Lots Among Select Lake Chloride Concentrations: 2013-2022



- Higher Urban land use reflects higher chloride concentrations and at 40% or more, may cause chloride to increase more rapidly

Questions?

Technical Report No. 66
State of the Art in Chloride Management

- **Chapter 1 – Introduction**
- **Chapter 3 – Municipal Water and Wastewater Utilities**
- **Appendix**

Chapter 1 – Introduction

1.) Purpose of the Report

Present a review of the relevant technical literature regarding best management and state-of-the-art practices for reducing chloride inputs to the environment from:

- Winter Maintenance Practices
- Municipal and Wastewater Utilities
- Private Water Softening and Treatment
- Agricultural and Industrial Processes

2.) Place TR-66 in Context of the Objectives of Chloride Impact Study

Chloride Impact Study Reports:

- *PR-57-A Chloride Impact Study for Southeastern Wisconsin*
- *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*

3.) Organization of the Report

TR-66 Chapters

- Chapter 1 – Introduction
- Chapter 2 – Winter Maintenance Practices
- Chapter 3 – Municipal Water and Wastewater Utilities
- Chapter 4 – Private Water Softening and Treatment
- Chapter 5 – Other Chloride Sources (Agricultural & Industrial)

Questions?

Chapter 3 – Chloride Management at Municipal Water and Wastewater Utilities

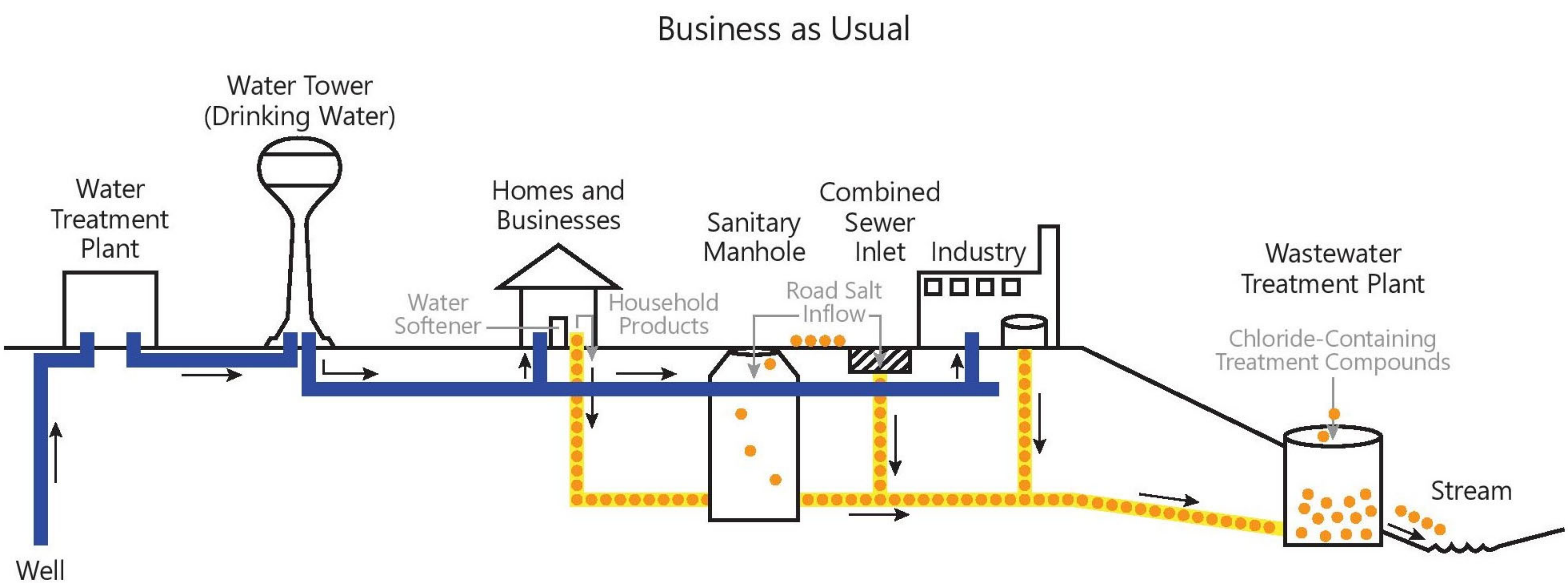
- Chapter Overview
  - Introduction
  - Sources of Chloride to WWTPs
  - Chloride Removal at WWTPs
  - Centralized Softening at WTFs
  - Other Municipal Chloride Reduction Alternatives

Introduction

- WWTP effluent can be a major source of chlorides to the environment
- Primary source of chloride to WWTPs is waste from ion-exchange water softeners
  - Homes connected to municipal sanitary sewer discharge to WWTPs
  - Homes with septic systems discharge to soil
- Traditional wastewater treatment processes do not remove chloride
  - Cl removal at WWTP
  - Source reduction

Chloride Sources to WWTPs

Figure 3.3
Chloride Sources to Wastewater Treatment Plants



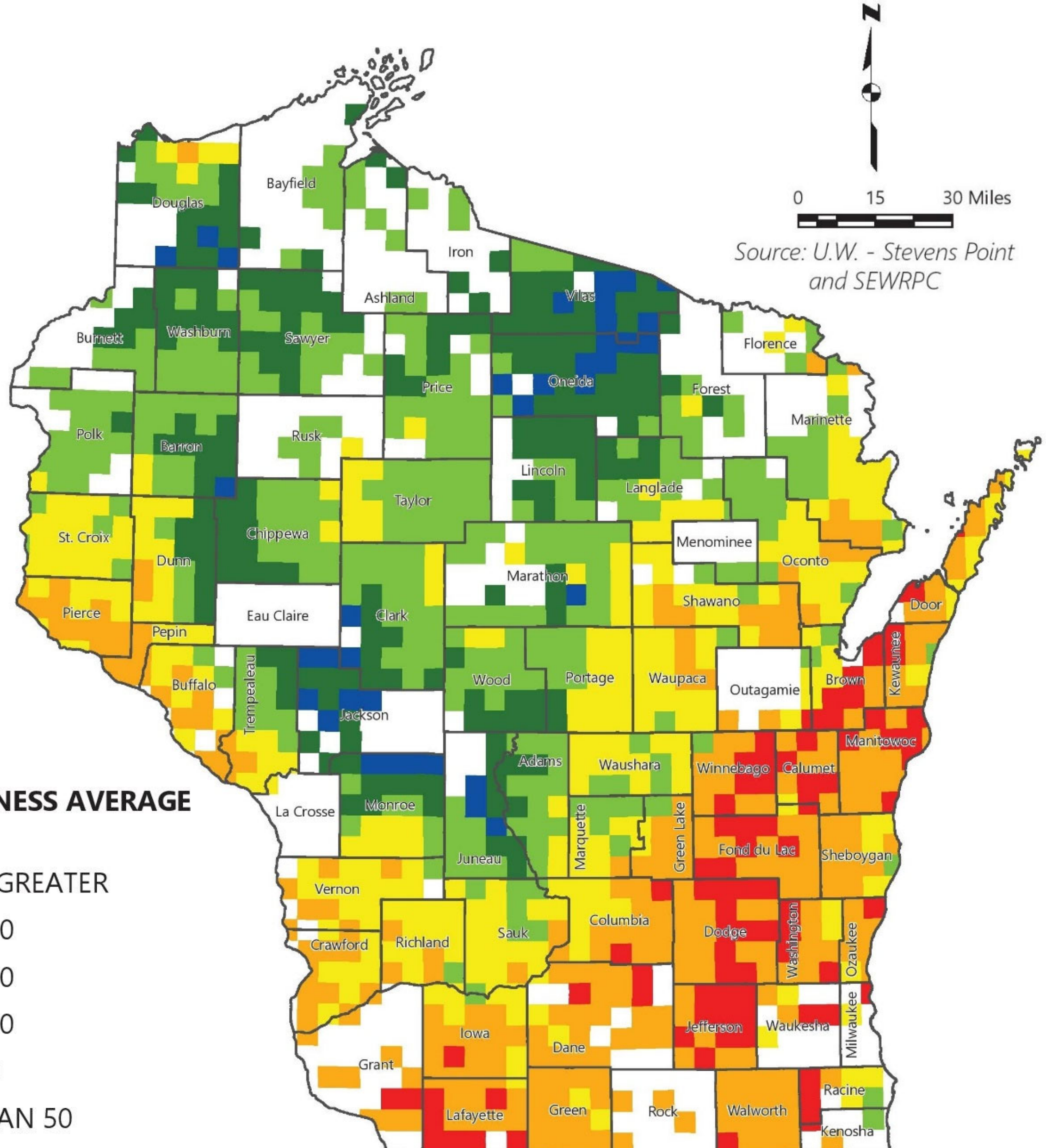
Note: The chloride represented in the diagram is not drawn to scale with respect to comparing the magnitude of chloride produced from one source to another. However, the density of chloride dots is intended to depict changes in chloride production between the two scenarios.

The diagram represents a community with a combined sewer. For communities with separate storm and sanitary sewers, road salt inflow into the sanitary sewer system occurs via infiltration and inflow through defects at manholes and in the pipes.

Source: SEWRPC

Groundwater Hardness

- Areas with naturally hard groundwater used as drinking water often have a high prevalence of water softening
- WI generally has hard groundwater (>120 mg/l as $CaCO_3$)



TOTAL HARDNESS AVERAGE
mg/l as $CaCO_3$

- 401 OR GREATER
- 301 - 400
- 201 - 300
- 101 - 200
- 50 - 100
- LESS THAN 50
- UNDETERMINED

Hardness

- Hardness in water is primarily determined by the amount of Ca^{2+} and Mg^{2+} ions

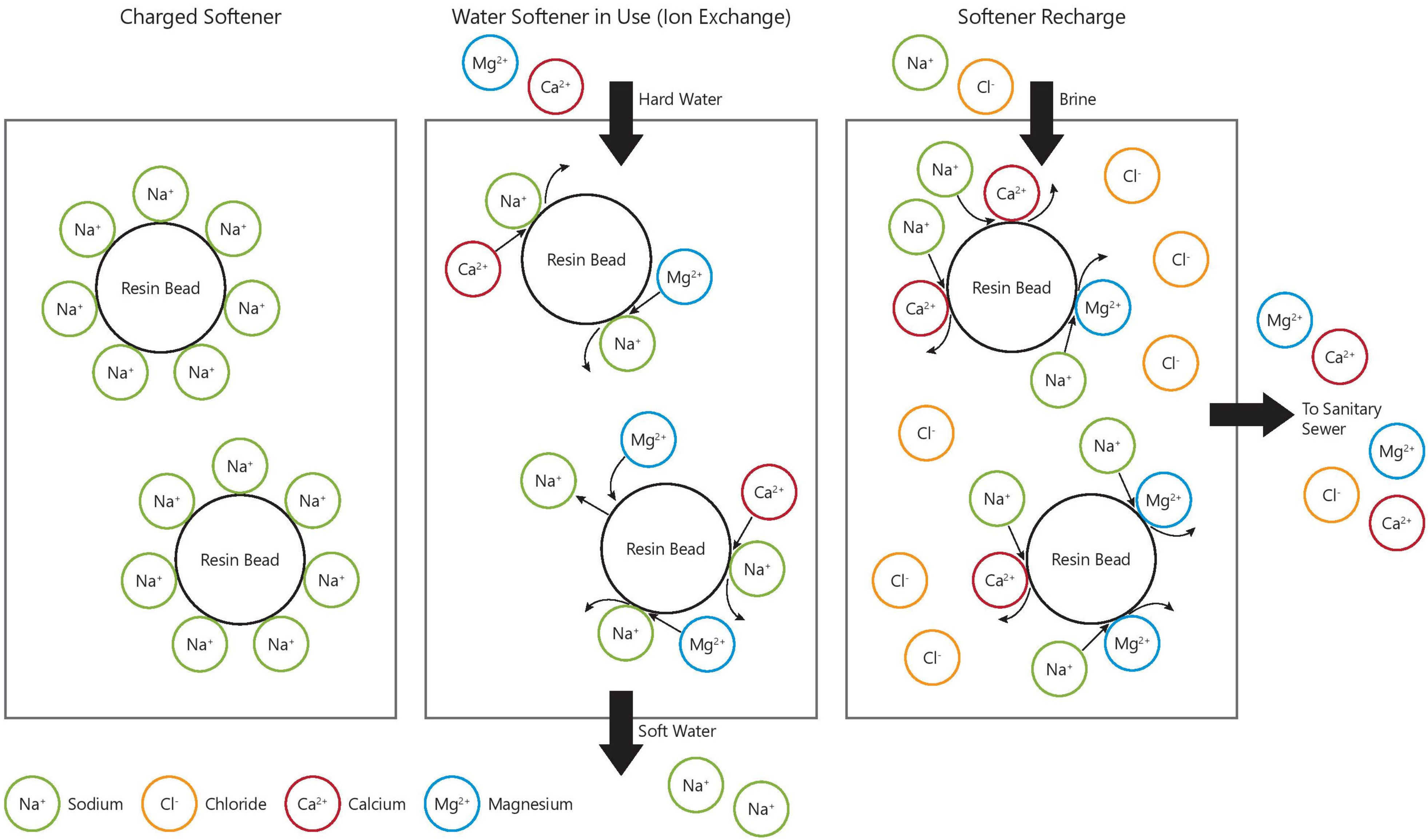
- Effects of excess hardness
  - No negative health impacts
  - Buildup of scale in plumbing and appliances
    - Decreases performance and efficiency
    - Can decrease usable lifespan
  - Inhibit lathering of soaps and other cleaning agents, decreasing their effectiveness

- Hardness is commonly removed by water softening

Water Softening

- Ion-exchange technology
  - Located at the point of entry of water service in a building
- Softening cycle
  - Ca^{2+} and Mg^{2+} ions in the water exchange with cations from an exchange resin
  - The exchange ion is typically Na^{+}
- Regeneration cycle
  - Flushes the system with a salt brine solution (sodium chloride ($NaCl$))
  - Na^{+} displaces Ca^{2+} and Mg^{2+} from resin, and the Cl^{-}, Ca^{2+}, and Mg^{2+} ions are discharges as wastewater

Water Softening



Source: SEWRPC

Chloride Effluent Limits

- Water quality-based effluent limitations (WQBELs) set by the DNR for pollutant levels in wastewater effluent

- Increasingly stringent limits for chloride require WWTPs to reduce chloride in effluent
  - Cl removal at WWTP
  - Source reduction

WWTPs in Region with Chloride Variances

Table 3.1
Facilities in Southeastern Wisconsin with Individual Chloride Variances: January 2024

Facility Name	Permit Number	County
City of Brookfield	0023469-09	Waukesha
East Troy Wastewater Treatment Facility	0020397-10	Walworth
Fontana-Walworth Water Pollution Control Commission	0036021-07	Walworth
Hartford Water Pollution Control Facility	0020192-09	Washington
Norway Sanitary District No. 1	0031470-08	Racine
Oconomowoc Wastewater Treatment Plant	0021181-09	Waukesha
Paddock Lake Wastewater Treatment Facility	0025062-10	Kenosha
Slinger Wastewater Treatment Facility	0020290-10	Washington
Sussex Wastewater Treatment Facility	0020559-08	Waukesha
Twin Lakes Wastewater Treatment Facility	0021695-10	Kenosha
Village of Union Grove	0028291-10	Racine
City of Waukesha	0029971-09	Waukesha
City of West Bend	0025763-11	Washington
Yorkville Sewer Utility District No. 1	0029831-09	Racine

Source: Wisconsin Department of Natural Resources

Chloride Removal at WWTPs

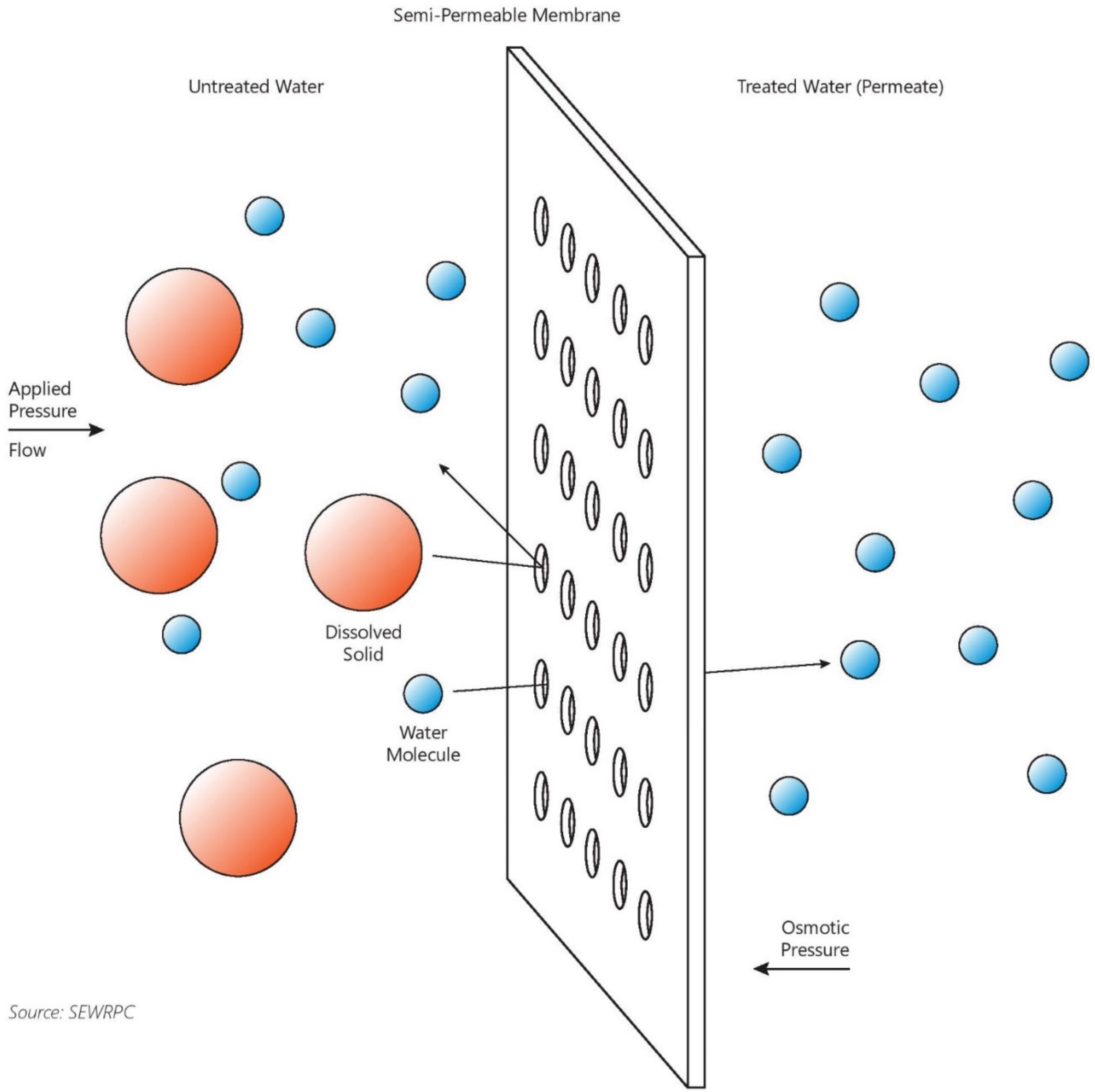
- Requires implementation of additional treatment processes at WWTP
  - Removal of chloride
  - Handling of the waste stream from the chloride removal process

- Chloride can be removed by either membrane filtration or ion-exchange
  - Reverse osmosis and electrodialysis reversal are the main membrane filtration alternatives
  - Ion-exchange would target removal of Cl^-, not Ca^{2+} and Mg^{2+}

Reverse Osmosis (RO)

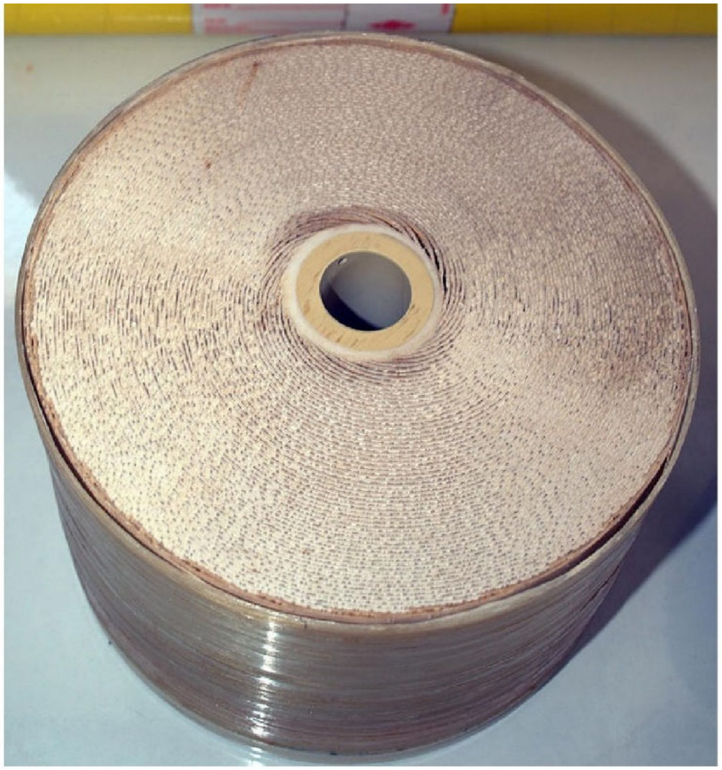
- Forces water through semipermeable membrane under high pressure
- Recovery rate can be up to 80%
- Removal efficiency of over 98%
- Removal efficiency can be impacted by membrane fouling
  - Occurs when membrane pores get clogged
  - Pretreatment to remove organic matter and suspended solids and backwashing can reduce fouling
- Can remove dissolved solids including chloride, phosphorus, nitrogen, mercury, sulfate, organic compounds, and other substances

Reverse Osmosis

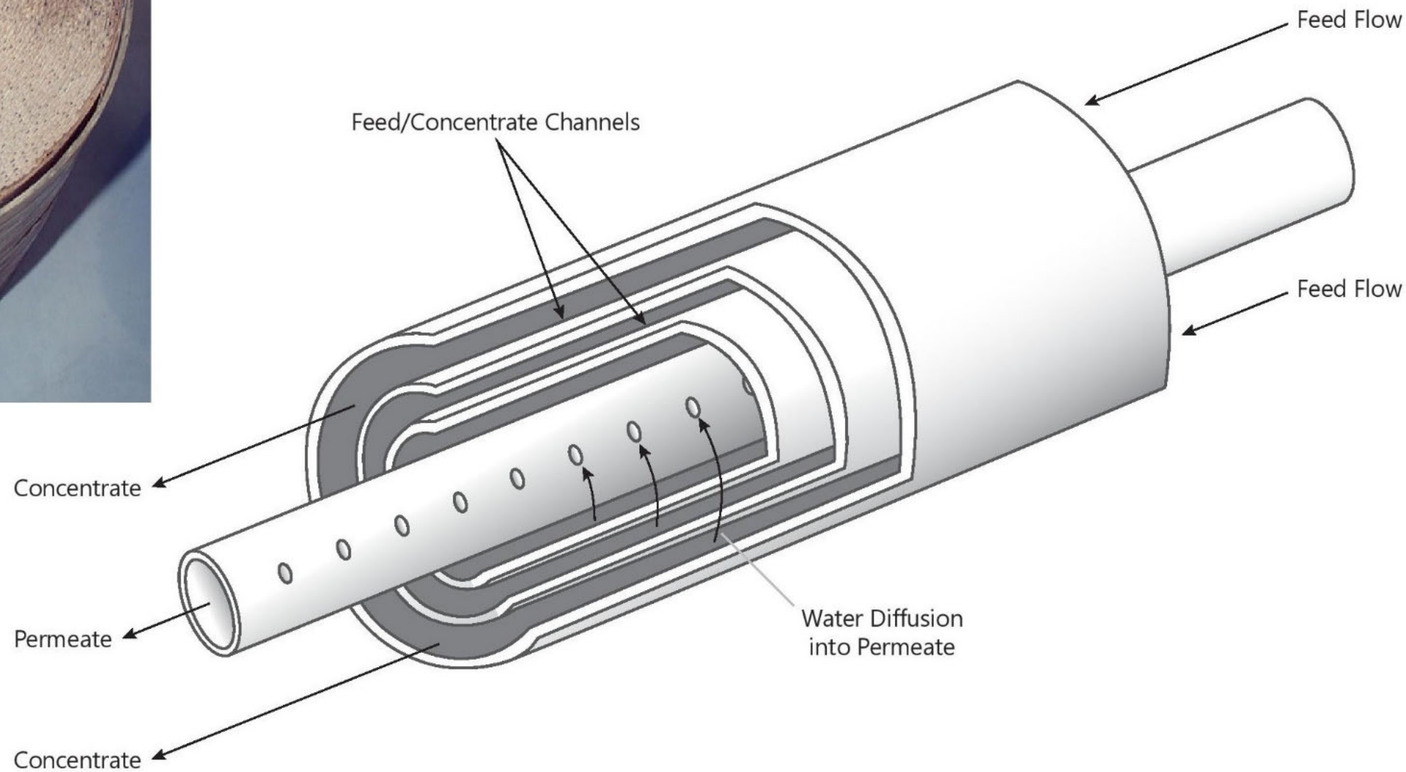


Source: SEWRPC

Reverse Osmosis – Spiral Wound



Source: Wikimedia User David Shankbone

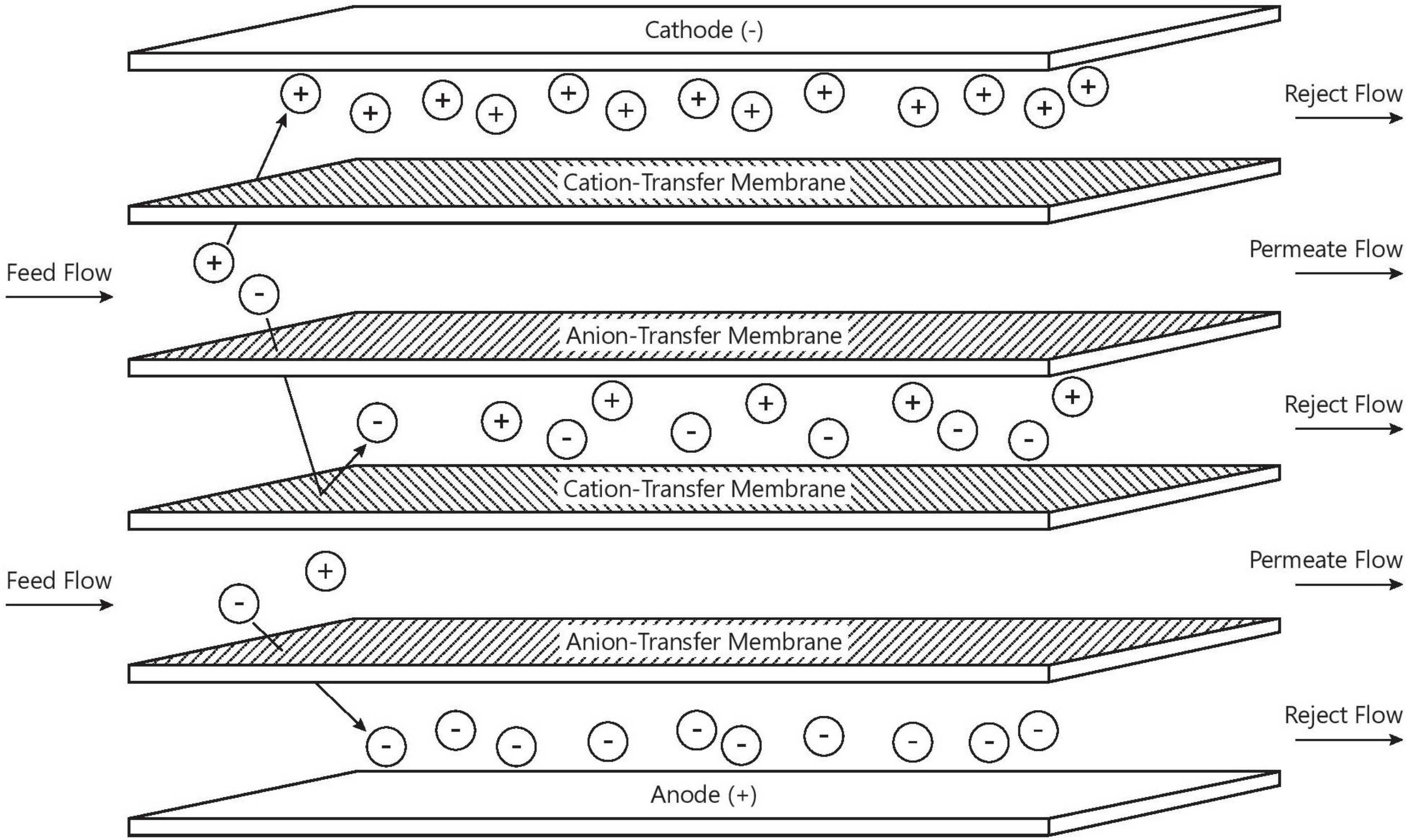


Source: SEWRPC

Electrodialysis Reversal (EDR)

- Uses electrical charge to draw charged dissolved solids into semipermeable membranes
- Recovery rate can be 80%
- Removal efficiency of 95%
- Pretreatment is needed to remove organic matter and suspended solids
- Less prone to fouling than RO because electrically neutral particles are not pulled into the membrane but rather remain suspended in the reject flow
- Periodic reversal of electrode charge can dislodge buildup of ionic materials
- Can remove dissolved solids including chloride, phosphorus, nitrogen, sulfate, and other charged constituents

Electrodialysis Reversal



Source: SEWRPC

Ion Exchange

- Similar to ion exchange used for water softening
  - A resin with an affinity of chloride must be used
  - Need to know which other constituents are present in the wastewater to understand other possible interactions with the resin

- Regeneration process uses a brine that does not contain chloride

- Pretreatment is needed to remove suspended solids and organic compounds

Brine Minimization

- All chloride removal technologies generate a waste stream that has a high chloride concentration
  - Can be up to 20% volume of initial flow for RO and EDR
  - Additional processing and disposal is needed
  - High cost
- Waste brine volume can be reduced by evaporation and crystallization
  - Evaporation uses heat to boil away excess water
  - Crystallization uses a seeded slurry to aggregate solid salt crystals
  - Can yield a water recovery rate of up to 99%, with the brine containing 17% solids
  - Highly energy intensive

Brine Disposal

- Disposal of waste brine is generally limited to:
  - Industrial waste facilities
  - Landfills
    - Best suited for solid waste or sludge
    - Ultimate fate is groundwater chloride contamination
  - Deep well injection
    - Best suited for liquid brine, however liquid brine is more costly to transport
    - Strictly regulated to protect groundwater drinking water
    - Prohibited in WI
- Brine would need to be characterized to assure it complies with requirements of the disposal facility

Brine Beneficial Reuse

- Winter roadway deicing and anti-icing products
  - Solid salt crystals
  - Liquid brine for pretreatment
- Must be analyzed to assure that no harmful substances are in the final product
- Space would be needed to store the product prior to shipment
  - Storage requirements may be larger during non-winter months
    - No demand for deicing products
    - Brine continues to be produced

Costs for Chloride Removal

- Reviewed costs for RO chloride removal at WWTPs
  - Based on data from the literature
  - For RO systems paired with evaporation and crystallization

Table 3.3
Summary of Costs for Chloride Removal by Reverse Osmosis at Municipal Wastewater Treatment Plants

	Capital Costs[a] (Millions of dollars/MGD[b])	O&M Annual Costs[a] (Millions of dollars/MGD)
Minimum	7.0	1.0
Maximum	17.0	5.0
Arithmetic Mean	12.8	3.0
n-Value	5	4

Note: Costs presented in this table are for reverse osmosis systems paired with evaporation and crystallization brine reduction systems. Additional information can be found in Appendix X.

[a] *All costs are expressed in year 2023 dollars.*

[b] *Million gallons per day.*

Sources: AECOM, Minnesota Pollution Control Agency, and SEWRPC

Conclusions for WWTP Chloride Removal

- Likely to result in overall increase in fees for rate payers

- Generally considered to be significantly more expensive than centralized water softening
  - Due to brine reduction and disposal costs
  - Costs very substantially based on factors specific to each WWTP
    - Amount of chloride removal required
    - Brine minimization and disposal method
    - Constituents present in the wastewater

Source Reduction – Centralized Softening

- Softens water at a central plant prior to distribution to homes
- Reduces the need for water softening in homes, reducing the amount of chloride sent to WWTP
- Requires construction and operation of a central plant
- Central softening technologies include:
  - Lime softening
  - Reverse osmosis (RO)
  - Electrodialysis reversal (EDR)
  - Ion-exchange
  - Distillation

Lime – Centralized Softening

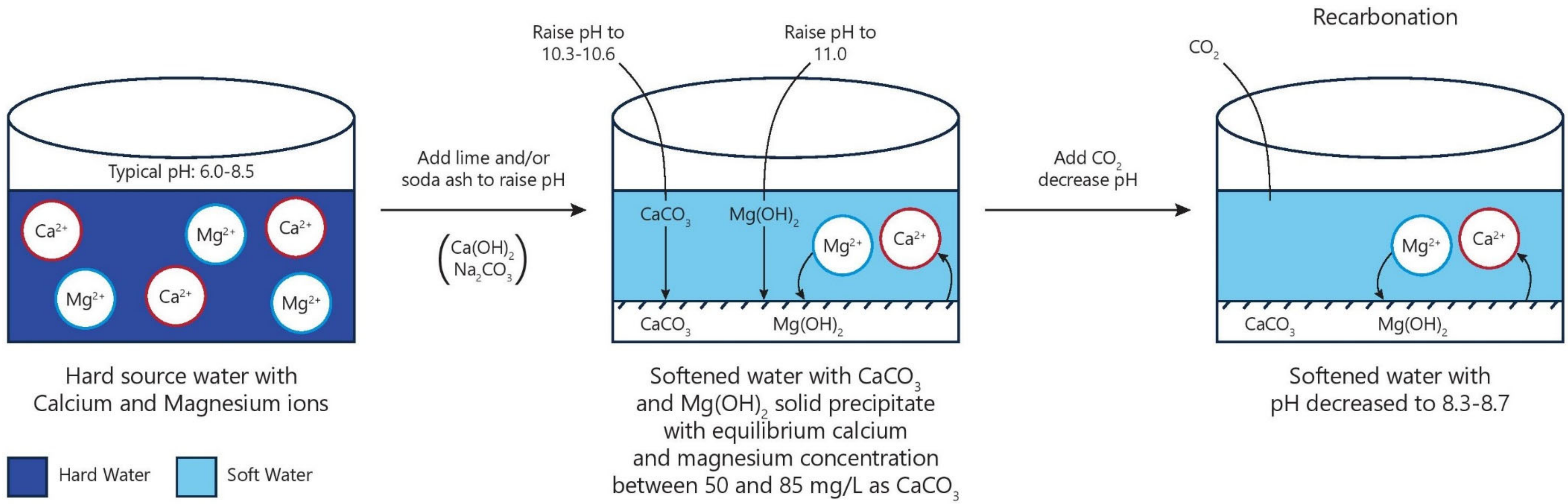
- Uses hydrated lime and soda ash to precipitate out Ca^{2+} and Mg^{2+}
  - Lime (calcium hydroxide, $Ca(OH)_2$) removes carbonate hardness
  - Soda ash (sodium carbonate, Na_2CO_3) removes non-carbonate hardness

- Addition of lime and soda ash increases the pH of the water
  - Calcium precipitates out at a pH of 10.3 to 10.6
  - Magnesium precipitates out at a pH of 11

- After precipitation of hardness, the settled solids are removed, leaving remaining clear water at a pH of 10.3 to 11

Lime – Centralized Softening

- Recarbonation adds CO_2 to the water to reduce the pH to 8.3 to 8.7
  - Higher pH is too saturated with calcium carbonate and will precipitate out in pipes and equipment
  - Lower pH is under-saturated with calcium carbonate and will remove existing scale in pipes and equipment



Source: SEWRPC

Lime Sludge Disposal

- Lime sludge needs to be processed for disposal or beneficial reuse
- Commonly piped to a lagoon where excess moisture is evaporated away
- Once reduced it can be disposed of in a landfill or reused beneficially
- Beneficial reuse options include:
  - Application to agricultural fields as a source of calcium for crops and to neutralize soil acidity
  - Uses in construction
  - Cement manufacturing
  - Coal combustion sulfur oxides control

RO and EDR– Centralized Softening

- Systems function as described for chloride removal at WWTPs
  - Dissolved solids are either pushed (RO) or drawn (EDR) into semipermeable membranes
  - Water passes through membrane but dissolved solids are rejected
- Reject flow can be routed to WWTP
  - Contains high concentrations of calcium and magnesium
  - Does not contain any chloride
  - Conveyance to WWTP can be problematic due to the high level of hardness

Scale Corrosion Prevention

- The high removal efficiency produces very pure water
- Can corrode scale in drinking water distribution system piping
- To prevent against scale corrosion, a degree of hardness must be added back into the finished water

Bypass and Blending

- Bypassing a portion of flow around the treatment system
- Amount of blending depends on several factors
  - Raw source water hardness
  - Desired hardness of finished water
  - Other constituents in the source water
- Presence of other constituents in the source water can make blending difficult

Increased Hydraulic Loads

- Reject flow can be up to 20% of feed flow

- Puts additional demand on groundwater supply
  - Maintain existing municipal water demand
  - Additional groundwater pumping needed

- Hydraulic loading to WWTP also increases
  - Could require costly capacity upgrades

EDR Differences from RO

- Less prone to fouling than RO
  - EDR *draws* ions into membranes where RO *forces* them, resulting in less fouling from constituents with neutral charge
  - EDR membranes can last up to ten years compared to two years for RO
    - Less fouling
    - Reversal step to clean membrane
- Not being implemented in new plants
  - Does not remove as many other contaminants as RO
  - Has not technologically improved since early development
  - Not widely offered by suppliers

Ion Exchange – Centralized Softening

- Similar to ion-exchange water softeners in homes
  - Exchange resin captures Ca^{2+} and Mg^{2+} and releases Na^{+}
  - Regeneration cycle using NaCl
    - Recharges resin with Na^{+} ions
    - Creates waste stream of Cl^{-} and dislodged Ca^{2+} and Mg^{2+}
- Does produce chloride
  - Can still reduce amount of chloride produced compared to business as usual
  - Waste brine is produced centrally and can be contained
  - Bypass and blending can be used at a central plant
  - This hardness can protect scale in distribution system

Waste Brine – Ion Exchange

- Needs to be contained, processed, and disposed of similar to Cl removal at WWTPs
  - Evaporation and crystallization
  - Disposal options are landfill (solid waste) or deep well injection (liquid)
  - Beneficial reuse as winter deicing
    - Rock salt or brine

Distillation – Centralized Softening

- Boil source water and capture and condense the steam
- Can remove most impurities with up to 99.5% removal efficiency
- Some volatile organic compounds (VOCs) are not removed
  - Volatilize with the water into the steam
  - Can add activated carbon filters, gas vents, and use separate condensation chambers to remove VOCs
- Concentrate can be disposed of at WWTP
  - Similar conveyance considerations as RO and EDR due to excessive hardness
- Very energy intensive and cost prohibitive

Table 3.6
Summary of Considerations for Central Softening Technologies

Consideration	Lime	Reverse Osmosis	Electrodialysis Reversal	Ion-Exchange	Distillation
Produces chloride in waste flow				X	
Feasible on smaller scales		X	X	X	X
Feasible at individual wellheads		X	X		X
Effective at removing chloride		X	X	X	X
Waste is suitable for disposal at WWTP[a]		X	X		X
May require construction of conveyance system for waste flow to WWTP		X	X		X
May require WWTP hydraulic capacity to be increased		X	X		X
Pretreatment required[b]	X	X	X		
Waste may have beneficial reuse	X			X	
Requires waste volume reduction	X			X	
Increases amount of source water pumped		X	X		
Source water quality and level of hardness impact efficiency[c]	X	X	X	X	

[a] *Assuming only hardness removal and no presence of any substances prohibited by the WWTP in the source water.*

[b] *Pretreatment would be needed to achieve optimal removal efficiency if organic materials or other solids are sufficiently present in the raw source water.*

[c] *Presence of other constituents in the source water or higher levels of hardness can either reduce efficiency or increase operation cost to achieve the desired efficiency.*

Source: SEWRPC

Costs for Centralized Softening

- Reviewed cost data from literature, projects, and supplier estimates

- Standardized by per capita basis

- Capital costs only
  - Reverse osmosis
  - Lime

Costs for Centralized Softening

Table 3.4
Summary of Capital Costs for Centralized Lime Softening

	Capital Costs (Dollars per Capita)[a]
Minimum	$220
Maximum	$29,300
Median	$640
Arithmetic Mean	$3,380
n-Value	25

[a] *All costs are expressed in year 2023 dollars.*

Source: Barr Engineering Co.; Bolton and Menk, Inc.; Minnesota Pollution Control Agency; Snyder & Associates; and SEWRPC

Table 3.5
Summary of Capital Costs for Centralized Reverse Osmosis Softening

	Capital Costs (Dollars per Capita)[a]
Minimum	$70
Maximum	$7,810
Median	$2,020
Arithmetic Mean	$2,310
n-Value	20

[a] *All costs are expressed in year 2023 dollars.*

Source: AECOM; Bolton and Menk, Inc.; The Messenger; Minnesota Pollution Control Agency; Newterra Corporation; Snyder & Associates; and SEWRPC

Costs for Centralized Softening

- Varied greatly
  - Many factors can impact costs
    - Source water quality
      - High levels of other constituents may require higher level of treatment
      - Suspended solids may require pretreatment
    - Higher initial hardness may require a larger facility (lime)
    - Larger population size benefits from economies of scale

Costs for Centralized Softening

Table 3.7
Cost Comparison of Water Treatment Technologies

Technology	Capital Cost	Operating Cost	Limitations
Lime Softening	$$$$$	$$$	Storage of lime; Lime sludge waste; Large footprint
Reverse Osmosis	$$$	$$$	15 to 25 percent loss to concentrate stream
Electrodialysis Reversal	$$$	$$$	15 to 25 percent loss to concentrate stream
Ion-Exchange	$$	$$	Chloride disposal
Distillation	$$$$$	$$$$$	High energy use; Residual disposal

Source: Snyder & Associates and SEWRPC

Final Considerations for Centralized Softening

- Reduction in at-home softening must occur for centralized softening to reduce chloride
- Public outreach program may be needed
  - Softener recalibration for the pre-softened water
  - Free softener pickup and disposal services
- Some at home softening may still be needed
- Homeowners may be hesitant to reduce amount of softening or to remove softener
- Homeowners may need to adjust their expectations for acceptable levels of hardness
  - Likely accustomed to fully softened water

Additional Source Reduction Alternatives

- Softening at individual wellheads
- Improve efficiency of point-of-entry softening
- Water quality trading

Softening at Wellheads

- Provides softened water to distribution system
- Uses same technologies as centralized softening, operated on a smaller and more distributed scale
  - Many of the same considerations for each technology previously discussed apply
- Challenges with operating multiple, spread-out systems
  - Automation would be very important
    - Ion-exchange requires monitoring for amount of remaining resin exchange capacity and addition of regeneration salt
    - Lime requires monitoring of pH and type of hardness
    - RO and EDR would require waste flow pipelines from each wellhead to WWTP

Improve Efficiency of at Home Softening

- Older softeners run on a timer
  - Regenerate based on time interval, not amount of flow
  - Less efficient
- Newer systems run on a demand-based cycle
  - Regenerate based on flow
  - More efficient, especially during periods of lower water use
- Regardless of softener type, calibration is essential to optimizing salt use and reducing chloride production
  - Source water hardness
  - Softener capacity
  - Water use per person (70 gpdc) – timer systems only

Improve Efficiency of at Home Softening

- Bypass valves can reduce amount of salt used
  - Allows a portion of untreated source water to bypass softener
  - Blends with softened water to provide a certain level of hardness

- Policy methods can make efficient softeners easier to obtain
  - Rebate programs to offset cost of upgrading
  - Softener calibration at no or low cost

Water Quality Trading Programs

- Market-based approach to reducing pollution, where a point source discharger can purchase credits from a credit generator
- Currently in WI only phosphorus and total suspended solids are eligible for trading
- Should trading become available for chloride in the future, it could be an option for chloride reduction via trading between WWTP and a municipality
  - Switching from rock salt to brine
  - Work with homeowners to optimize or upgrade softeners

Questions?

Chloride Impact Study – Next Steps

- Comments on TR-63 Draft Chapters can be sent to Tom (tslawski@sewrpc.org)
- Comments on TR-66 Draft Chapters can be sent to Aaron (aowens@sewrpc.org)
- Comments are due by December 6, 2024

Chloride Impact Study – Next Steps

- Anticipate next TAC meeting in spring 2025 to review draft chapters from TR-65 (Mass Balance Analysis for Chloride)
- Meeting agendas, presentations, and summary notes along with draft text are posted on project website

  www.sewrpc.org/chloride-study

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