Cannon River CHLORIDE

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ENVIRONMENTAL SERVICES

KEY FINDINGS

Annual median chloride concentrations are low and possibly decreasing, likely due to increasing flow.

However, trend analysis, which removes the influence of flow, indicates there are continued increases in chloride inputs and/or chloride mobilization in the watershed.

Livestock excreta, household water softening, synthetic fertilizer, and de-icing salt are all likely sources of chloride in the Cannon River.

INTRODUCTION

The Metropolitan Council Environmental Services (MCES) is committed to stewardship of Twin Cities streams and tributary rivers and works with its partners to maintain and improve waterbody health and function. These efforts are supported by the collection and analysis of high-quality, long-term data.

In 2014, *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams* described statistical water quality trends for streams and tributary rivers in the Twin Cities. At that time, data were insufficient to analyze chloride trends. By 2019, our monitoring work provided sufficient data for statistical trend analysis. Meanwhile, concern about chloride pollution has increased for watershed managers and the general public. This memo includes information about chloride sources and timing of chloride runoff and addresses the following questions:

- How has in-stream chloride changed over time?
- How have upland watershed activities impacted in-stream chloride over time?
- What can monitoring data tell us about chloride sources and pathways in the watershed?

This memo provides data and analyses from Cannon River with state and regional context about chloride pollution. This information has prompted questions from MCES staff and will likely prompt questions from readers. This memo is intended to initiate a dialog about regional chloride dynamics and inspire action to alleviate chloride pollution. Please contact us to discuss potential future partnerships if you are interested in continuing this work.

CHLORIDE POLLUTION IN TWIN CITIES WATERS

Chloride concentrations have been rapidly rising in many Twin Cities waterbodies over the past two decades. In the Twin Cities, 40 lakes and streams are impaired for aquatic life due to chloride contamination and an additional 41 waterbodies are high risk for chloride impairment.[1] A recent study by MCES indicated an increasing trend for chloride concentrations in the Mississippi, Minnesota, and St. Croix Rivers during the recent 30 years.[2] Thirty percent of Twin Cities shallow aquifer monitoring wells have chloride concentrations that exceed the Minnesota state water quality standard.[3]

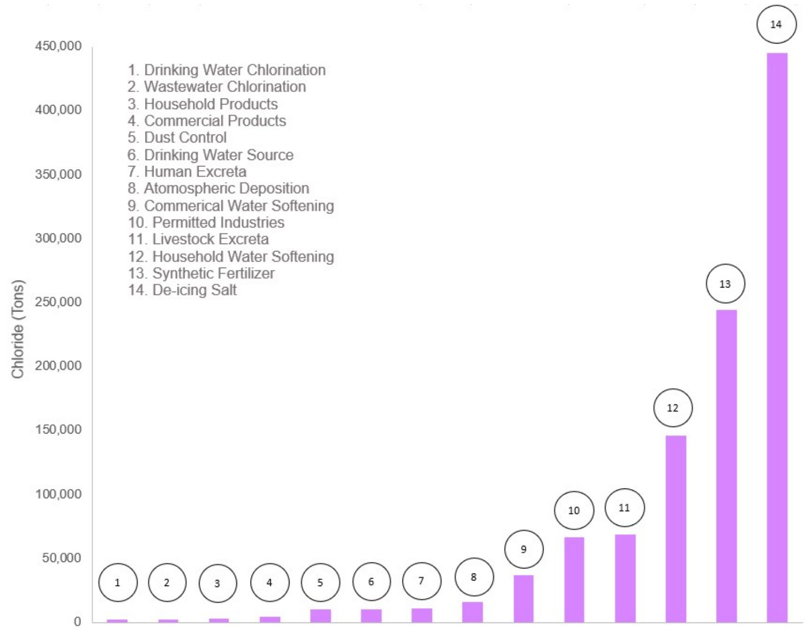

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

Chloride is a permanent water pollutant, there is no easy way to remove it with existing technology. It is toxic to fish, aquatic bugs, and amphibians. Chronic toxicity is indicated by samples above 230 mg/L, acute toxicity by samples above 860 mg/L.[4]

Chloride pollution in Minnesota has multiple sources.[5] The four largest are livestock excreta, household water softening, synthetic fertilizer and de-icing salt (Figure 1).

Livestock Excreta: Research found elevated chloride in seepage from earthen-lined manure storage and high chloride levels in groundwater downgradient of manure storage,[6] but there is little research investigating effects of livestock feedlots or manure application practices on chloride levels in water.

Household water softening: More than 70% of the drinking water used in the Twin Cities comes from groundwater[7] and many groundwater users soften their water with chloride salts. The chloride waste from the water softening process enters surface and groundwater through wastewater treatment plants or residential subsurface sewage treatment systems.[8]

Synthetic fertilizer: Chloride is associated with macronutrients like potassium. The most common potassium source in Minnesota is potash fertilizer, potassium chloride.[9] Plants consume the potassium and release the chloride into surface and groundwater.

De-icing salt: Approximately 402,000 tons of de-icing salt is annually applied in the Twin Cities.[10] De-icing salt is carried by melting ice and snow into surface and groundwater.

Climate change is creating a warmer, wetter climate in Minnesota and the effects are most significant during the coldest months. An altered winter freeze-thaw cycle will have unpredictable effects on chloride use and pollution dynamics.

STREAM AND WATERSHED DESCRIPTION

The Cannon River is located south of the metropolitan area and is a tributary to the Mississippi River, below the Mississippi's confluence with the Minnesota River. It 118 miles long and drains approximately 1,470 square miles of agricultural land, grasses, forest, and urban areas (cities of Waseca, Owatonna, Faribault, Northfield, and Red Wing) through portions of Freeborn, Steele, Waseca, Blue Earth, Le Sueur, Rice, Dakota, and Goodhue Counties.[11]

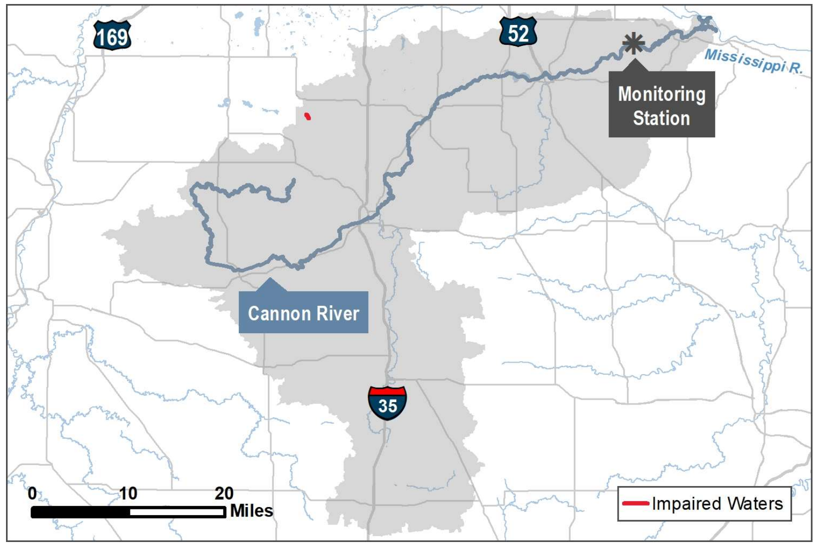

Figure 2: Map of the Cannon River Watershed

Approximately 6% of the Cannon River watershed is roadways, based on an analysis completed by the Minnesota Pollution Control Agency (MPCA). [12] The MPCA found that watersheds with 18% roadway density or higher are more likely to have chloride concentrations above water quality standards.[13]

Since 2018, an unnamed ditch in Rice County in the northwest portion of the watershed has been listed by MPCA as impaired for aquatic life use due to excess chloride (Figure 2).[14]

Cannon River chloride pollution sources likely include livestock excreta, household water softening, synthetic fertilizer, and de-icing salt.

Livestock Excreta: There are 1,639 registered feedlots in its monitored area with a total of 190,221 animal units (AUs), and an additional 159 feedlots in the unmonitored area with 23,881 AUs.

Household Water Softening: There are 19 domestic wastewater treatment plants, including three Class A facilities - the Northfield, Faribault, and Owatonna WWTPs - which together have a design flow of 17.2 MGD (26.6 cfs). In addition, many households are served by subsurface sewage treatment systems. The chloride waste from the water softening process has the potential to enter surface and groundwater through wastewater treatment plants or residential subsurface sewage treatment systems.[15]

Synthetic Fertilizer: Chloride may come from agricultural and urban application of potash fertilizer.[16] This source of chloride is not well understood in the watershed.

De-icing Salt: De-icing salt is primarily applied between December and March and would likely runoff during melt events from February through April.

FINDINGS

Annual Chloride Dynamics 2001-2019

Chloride Concentration

MCES and the Dakota County Soil and Water Conservation District collected 463 chloride samples between 2001 and 2019. The ambient concentrations are plotted with the annual median concentration (Figure 3). Ambient concentration describes the conditions experienced by aquatic organisms in the river. These values are affected by precipitation, flow, and watershed factors, including those caused by human activity.

Annual median concentrations were generally low and very slightly decreasing.

> **Ambient concentration:** The mass of chloride divided by the total volume of water in a stream at a specific time. This value represents the instantaneous amount of chloride in the stream water.

Precipitation and Streamflow

Ambient concentrations are often closely tied to rainfall and resulting flow conditions in the river. Higher streamflow can lower pollutant levels through dilution, and lower streamflow can increase pollutant levels through concentration.

Figure 4 shows annual total precipitation and the 1981-2010 National Weather Service Climate Normal precipitation at Minneapolis-St. Paul airport[17] with Cannon River annual mean flows. Flow is usually higher in years with greater rainfall. Annual mean flow in Cannon River varied dynamically during the assessment period.

> **Annual Mean Flow:** The average of all daily flows for the year.

Streamflow and Chloride Concentration

Figure 5 shows annual median chloride concentration and annual median flow values, representing typical conditions for each year. There is a general relationship between flow and concentration: when flow has been high, concentration has generally been low due to dilution, and when flow has been low, concentration has increased. However, there is variability in concentration that does not vary perfectly with flow. This means that factors other than flow impact chloride conditions in the river.

In order to see how non-flow factors such as watershed practices may have affected chloride concentrations, we used the R-QWTREND model.

Chloride Trends

R-QWTREND is a statistical model specifically designed to investigate pollutant trends, which tests potential trends (increase or decrease in concentration) against a no-trend model (no increase or decrease in concentrations). This model removes the variability of annual flow and seasonality from the statistical analysis. If the model does not show a

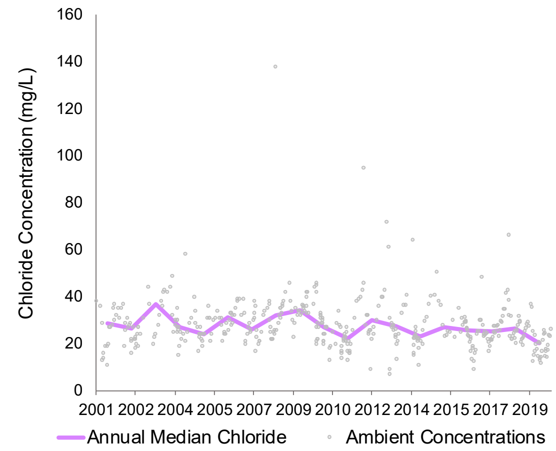

Figure 3: Ambient and Annual Median Chloride Concentrations in the Cannon River

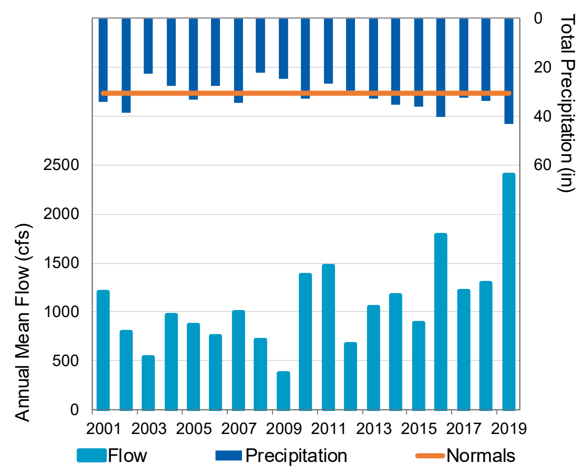

Figure 4: Annual Mean Flow and Precipitation for the Cannon River

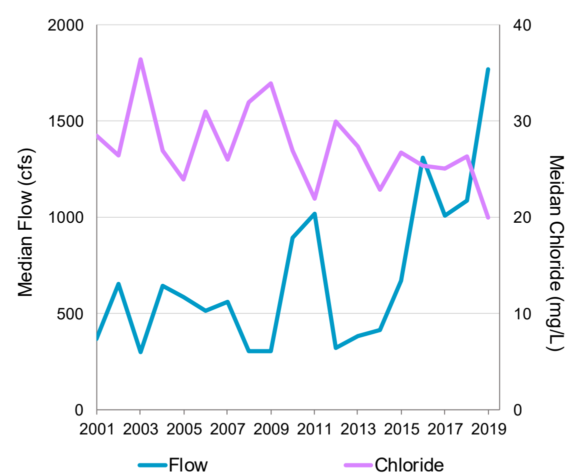

Figure 5: Annual Median Flow and Chloride Concentration in the Cannon River

statistically significant trend for a given time period, there is not sufficient evidence to claim that concentrations are increasing or decreasing. If increasing or decreasing concentrations cannot be described, then concentrations are assumed to be stable.

R-QWTREND analysis shows that changes of the flow-adjusted chloride concentration in Cannon River can be best represented by a statistically significant one-trend model over the assessment period (2001 to 2019). Overall, the chloride concentration increased by 13%.

Table 1: Statistical Trend for Chloride Concentration in the Cannon River

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
2001 – 2019	26.5 - 29.9	13%	0.177	0.0014	⬆

Pollutant trend: An analysis that shows the direction of change (improving vs. declining water quality) in a pollutant over time. This study examined changes in flow-adjusted chloride concentration from 2001 – 2019, allowing us to look at human-caused influences in chloride concentrations.

Flow-adjusted concentration: An adjustment to ambient concentration that removes variability of annual flow and seasonality mathematically, for use in statistical analysis.

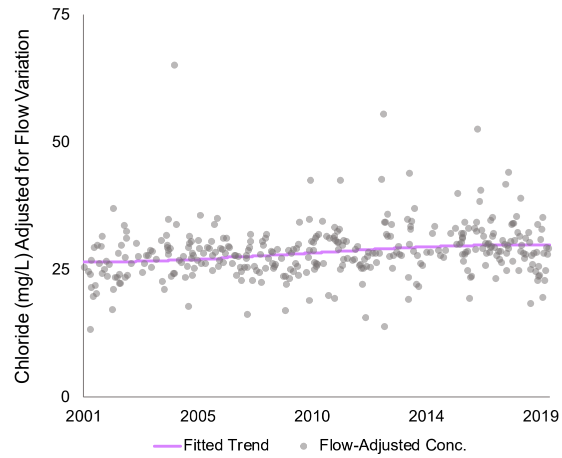

Figure 6: Flow-Adjusted Trends for Chloride Concentration in the Cannon River

Additional data from 2020 and into the future has the potential to impact the significance and the direction of the recent trend period.

The continued upward flow-adjusted trend over the period from 2001 to 2019 is different from the generally downward direction in annual ambient median concentration observed in Figure 3. The trend analysis likely indicates continued increases in chloride inputs and/or chloride mobilization in the watershed. Currently these chloride increases appear to be offset by increasing flows in the river, so ambient concentrations have been going down. The river is vulnerable to increases in ambient chloride concentration if flows decrease.

Chloride Loads

Figures 7 illustrates annual loads and annual mean flow. The annual loads for chloride exhibited significant year-to-year variation indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the river.

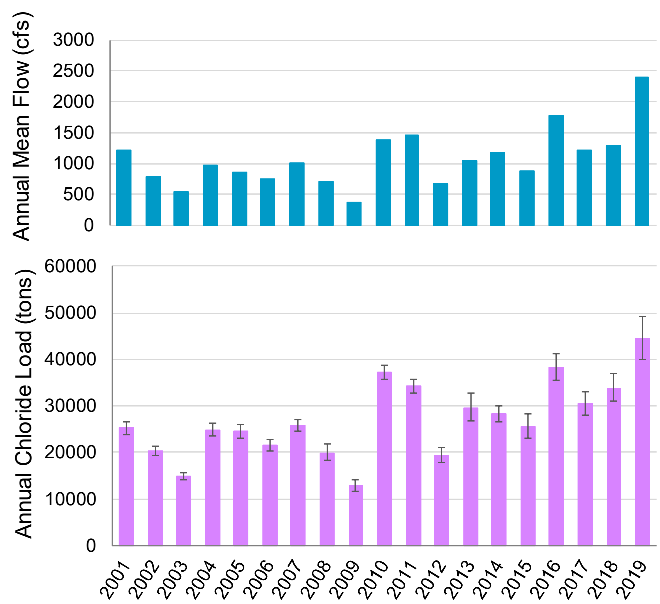

Figure 7: Annual Chloride Loads in the Cannon River

The increase in chloride loads in years of higher flow could be due to the increased flushing of salt that had built up in watershed lakes and groundwater during drier years, when pollutants are less likely to be mobilized.

Pollutant load: The total mass of a pollutant exported from a stream over a period of time. MCES uses Flux32 software to estimate pollutant loads.

Seasonal Chloride Dynamics 2001 – 2019

Chloride Concentration and Streamflow

Figure 8 shows monthly median chloride concentration and monthly median flow values, representing typical conditions in each month. Seasonal changes can influence monthly median flow and monthly median chloride concentration. Higher flows occurred during the spring while higher chloride concentrations occurred in the winter.

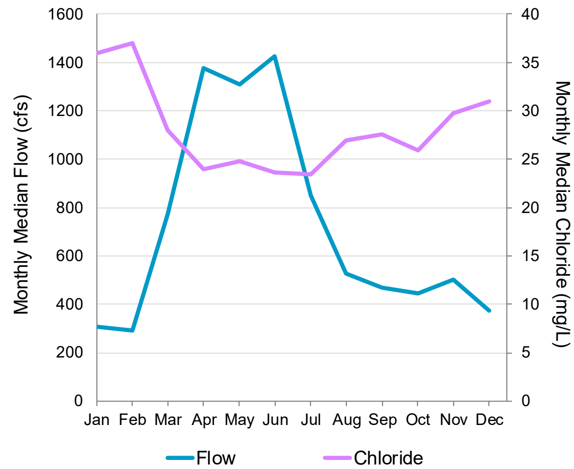

Figure 8: Monthly Median Flow and Median Ambient Chloride Concentrations in the Cannon

Chloride Load

Chloride load is seasonally dynamic. The highest chloride load occurs from March through June. Chloride loads calculated with Flux32 were compiled as monthly averages for 2001-2019, Figure 9 uses a line to indicate maximum and minimum values for each month. The bottom of each box represents the first quartile, the top represents the third quartile, and the line in the middle of the box represents the median monthly chloride load.

From 2001-2019, higher monthly loads occur in the spring and early summer, possibly due to de-icing salt and synthetic fertilizer runoff coupled with the higher flows occurring during that period.

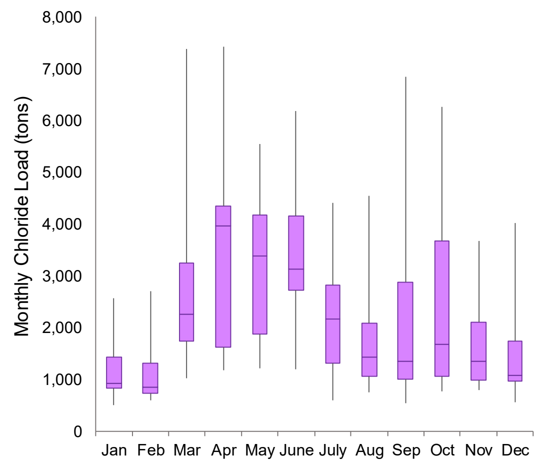

Figure 9: Monthly Chloride Loads in the Cannon River

LIMITATIONS

The analyses described in this memo identify changes in chloride concentrations in the river, but they do not identify the cause of those changes. MCES has suggested hypotheses about causes of changing chloride dynamics but additional information or research is needed to identify specific changes in watershed management, climactic changes, or any other factors which may have affected concentration in the river.

During some winter months in from 2001 – 2019, hazardous ice conditions precluded sample collection. This data gap possibly biases our understanding of seasonal and annual chloride dynamics. The Flux load calculation method changed in 2016.

RECOMMENDATIONS & NEXT STEPS

Chloride pollution reduction projects and initiatives are most effective when guided by data collection and analysis. In order to support the Dakota County SWCD, Cannon River Joint Powers Board, and other partners to prioritize resources to understand chloride dynamics and mitigate chloride pollution, MCES provides the following recommendations:

- Calculate or compile the watershed water and chloride budgets including but not limited to livestock excreta, fertilizer use, household water softening and de-icing salt application.
- Include chloride monitoring in upstream water quality monitoring. Work with MPCA and other Cannon River Joint Powers Board members to assess upstream water quality data.
- Pursue a home water softener upgrade incentive program or centralized water softening.
- Implement chloride mitigation and management BMPs including trainings to minimize de-icing salt use and synthetic fertilizer runoff.

We are aware that not all watershed organizations have the time, capacity, or resources to take these or other future next steps. MCES may have the ability to assist with future data collection, data analysis or other technical advice. Please contact us to discuss the potential of future partnerships if you are interested in continuing this work. Please contact us for additional technical information or information on field, laboratory and data analysis methods. Method documentation is also available as part of the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams* report, *Introduction and Methodologies* section, available on the Council website at https://metrocouncil.org/streams.

CLEAN WATER LAND & LEGACY AMENDMENT

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[1] Minnesota Pollution Control Agency. 2021. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>
[2] Metropolitan Council Environmental Services, 2018. Regional Assessment of River Quality in the Twin Cities Metropolitan Area. <https://metrocouncil.org/Wastewater-Water/Services/Water-Quality-Management/River-Monitoring-Analysis/Regional-Assessment-of-River-Quality-(2).aspx>
[3]I Minnesota Pollution Control Agency. 2021. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>
[4] Minnesota Administrative Rules. *Minnesota Water Quality Standards for Protection of Waters of the State*. Minn. Rules 7050.0218 and Minn. Rules7050.0222. < https://www.revisor.mn.gov/rules/7050/>
[5] Overbo and Heger, n.d. *Estimating annual chloride use in Minnesota.* Water Resources Center. <wrc.umn.edu/chloride>
[6] Minnesota Pollution Control Agency. 2001. Effects of Liquid Manure Storage Systems on Groundwater Quality. <https://www.pca.state.mn.us/sites/default/files/rpt-liquidmanurestorage.pdf>
[7] Metropolitan Council, 2013. Municipal Water Use in the Seven-County Twin Cities Metro Area. <https://metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning.aspx>
[8] Minnesota Pollution Control Agency. 2021. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>
[9] Rehm, G. and M. Schmitt. 1997. Potassium for crop production. Minnesota Extension Service. Minneapolis: University of Minnesota.
[10] Minnesota Pollution Control Agency. 2021. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>
[11] Metropolitan Council. 2014. Cannon River. In Comprehensive water quality assessment of select metropolitan area streams. St. Paul: Metropolitan Council.
[12] Minnesota Pollution Control Agency. 2020. Draft Statewide Chloride Management Plan <https://www.pca.state.mn.us/water/draft-statewide-chloride-management-plan>
[13] Minnesota Pollution Control Agency. 2016. Twin Cities Metropolitan Area Chloride Management Plan. <https://www.pca.state.mn.us/sites/default/files/wq-iw11-06ff.pdf>
[14] Minnesota Pollution Control Agency. 2021. *Minnesota's Impaired Waters List.* <https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list>
[15] Minnesota Pollution Control Agency. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>
[16] USGS. 2015. Methods for Evaluation Potential Sources of Chloride in Surface Waters and Groundwaters of the Conterminous United States.
[17] Minnesota Department of Natural Resources. 2020. *Minneapolis/St. Paul Climate Data Normals and Averages.* *https://www.dnr.state.mn.us/climate/twin_cities/normals.html*