Nine Mile Creek CHLORIDE

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ENVIRONMENTAL SERVICES

KEY FINDINGS

In general, chloride concentrations have steadily increased over the past 20 years.

Chloride concentration varies seasonally and chloride exports are highest between March and May, indicating that de-icing salt is likely the primary chloride source. However, chloride export remains elevated through the summer and fall. Further investigation is needed to understand seasonal chloride dynamics in the watershed, including an examination of chloride cycling in lakes and transport of chloride in shallow groundwater.

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 those analyses, 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?

The Nine Mile Creek Watershed District has implemented extensive outreach, education, and incentive efforts to promote reduction of chloride use during the analysis period. These efforts are on-going, and the District is committed to reducing chloride use throughout the watershed.

This memo provides data and analyses from Nine Mile Creek 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]

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 three largest are household water softening, synthetic fertilizer and de-icing salt (Figure 1).

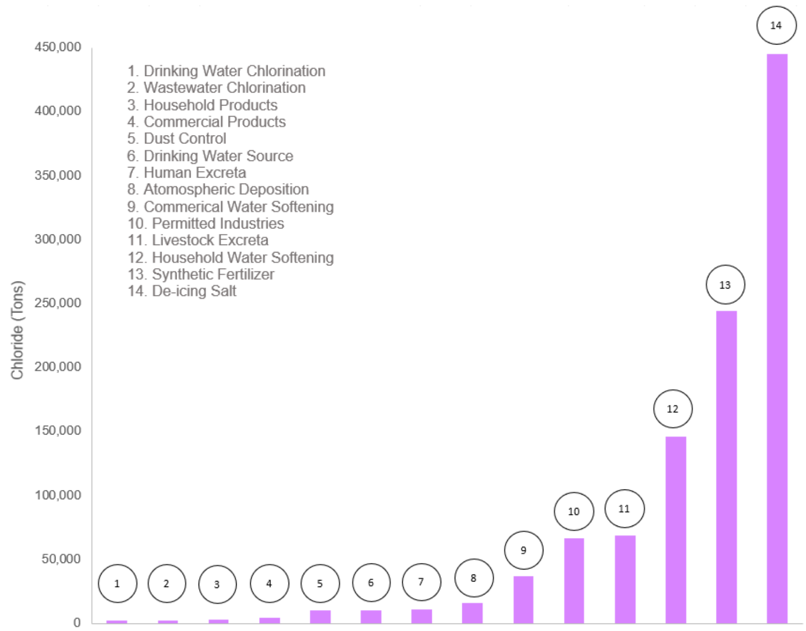

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

Household water softening: More than 70% of the drinking water used in the Twin Cities comes from groundwater[6] 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.[7]

Synthetic fertilizer: Chloride is associated with macronutrients like potassium. The most common potassium source in Minnesota is potash fertilizer, potassium chloride.[8] 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.[9] 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 mainstem (north branch) of Nine Mile Creek is about 15-miles long with headwaters in the city of Hopkins. The south branch is about 8.5 miles long and originates in the city of Minnetonka. The two branches join directly upstream of Normandale Lake in Bloomington. Together they drain approximately 50 square miles of urban and suburban land and open space in Hennepin County, including portions of the cities of Hopkins, Minnetonka, Eden Prairie, Edina, Richfield, and Bloomington, and discharge to the Minnesota River in Bloomington, MN (Figure 2).

Nine Mile Creek watershed is about 31,555 acres, with 28,784 acres (91.2%) of the watershed upstream of the monitoring station. About 20,308 acres/64.4% (18,637 acres/64.7% within the monitored area) is developed urban land, with the remainder being wooded, grassland, wetland and open water.[10]

Approximately 28% of the Nine Mile Creek watershed is roadways, based on an analysis completed by the Minnesota Pollution Control Agency (MPCA)[11]. This includes portions of a number of major highways: Interstates 494 and 35W, US 212, US 169, TH 62 and TH 100. An MPCA analysis found that waterbodies having watersheds with 18% roadway density or higher are more likely to have chloride concentrations above water quality standards.[12]

The lower portion of Nine Mile Creek, from an unnamed wetland to the creek's confluence with the Minnesota River, was originally listed for chloride impairment in 2004. A Total Maximum Daily Load study for Nine Mile Creek was approved in 2010[13]. A 62% reduction in chloride is estimated to be required to eliminate the impairment.

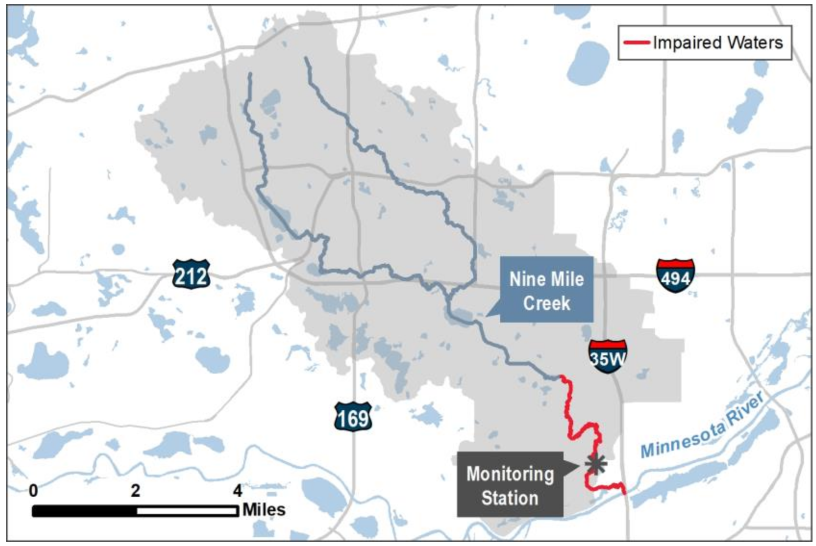

Figure 2: Map of Nine Mile Creek Watershed

Household water softening is not likely to be a major chloride source in Nine Mile Creek watershed. Chloride from household water softening enters surface and groundwater through wastewater treatment plants or residential subsurface sewage treatment systems. All wastewater in Nine Mile Creek watershed is treated through the MCES Metropolitan Wastewater Treatment Plant and discharged to the Mississippi River in St. Paul.

Synthetic fertilizer is a possible chloride source in Nine Mile Creek watershed. Chloride may come from urban and suburban turf management application of potash fertilizer.[14] This source of chloride is not well understood in the watershed.

De-icing salt is likely the primary source of chloride pollution in Nine Mile Creek watershed. 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 collected 609 chloride samples between 1999 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 stream. These values show a great deal of variation and are affected by precipitation, flow, and watershed factors, including those caused by human activity.

Annual median chloride concentration has generally increased over the assessment period, except when it dropped significantly in 2016.

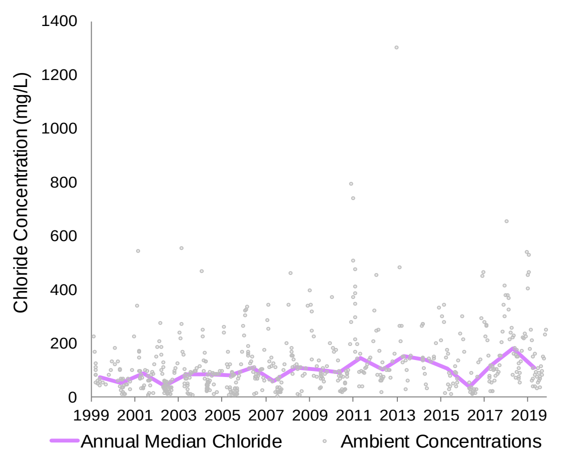

Figure 3: Ambient chloride concentrations on Nine Mile Creek, with the annual median chloride concentration

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.

Annual Median Concentration: This is the 'typical' concentration observed in the stream during the year. It is the center of our observed data and is not affected by extreme high or low concentrations.

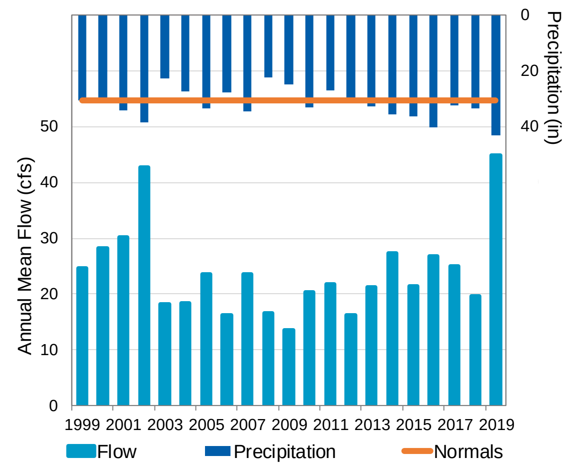

Figure 4: Annual Mean Flow and Precipitation for Nine Mile Creek

Precipitation and Streamflow

Ambient concentrations are often closely tied to rainfall and resulting flow conditions in the stream. Figure 4 shows Nine Mile Creek yearly rainfall, the 1981-2010 National Weather Service Climate Normal precipitation at Minneapolis-St. Paul airport[15], and annual median flows. Flow is usually higher in years with greater rainfall. Flow in Nine Mile Creek varied dynamically during the assessment period. Flows were high from 1999 through 2002, then decreased before increasing slightly from 2014 through 2017 and significantly in 2019.

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

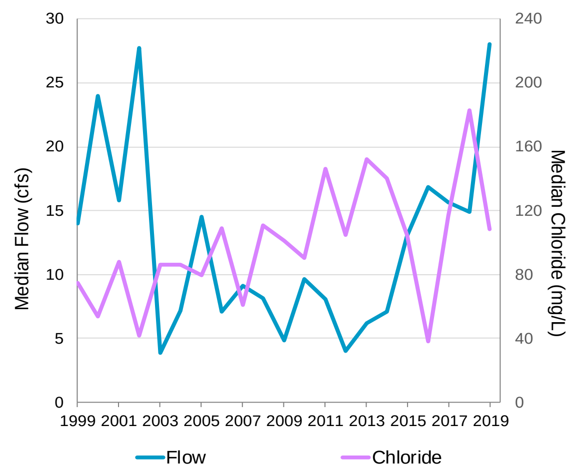

Figure 5: Annual Median Flow and Chloride Concentration in Nine Mile Creek

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 stream.

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 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 in chloride concentration in Nine Mile Creek can be best represented by a statistically significant one-trend model (*p* = 6.7×10^{-12}) over the assessment period of 1999 to 2019 (Table 1 and Figure 6). The model shows an increasing trend for chloride concentration in Nine Mile Creek from 1999 to 2019, indicating a decline in water quality as it relates to chloride. The chloride concentration increased by 110.9% over the assessment period.

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

Table 1: Statistical Trend for Chloride Concentration in Nine Mile Creek

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
1999 – 2019	77.1 - 162.6	110.9%	4.07	0.00000	↑

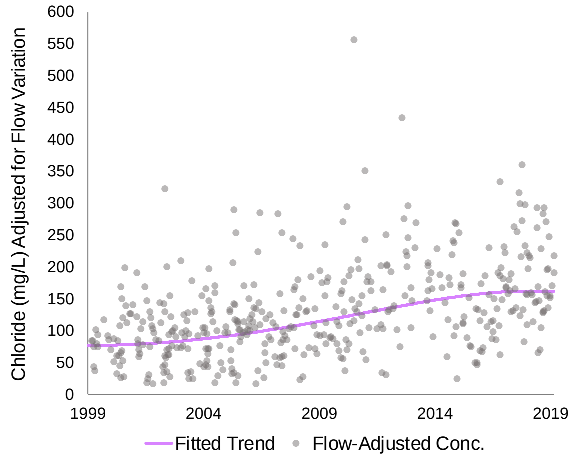

Figure 6: Flow-Adjusted Trends for Chloride Concentration in Nine Mile Creek

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.

Chloride Load

Figure 7 illustrates annual chloride loads expressed as tons and monthly mean flow. The annual loads for chloride calculated with Flux32 exhibited significant year-to-year variation closely corresponding to yearly variations in flow, indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream.

The increase in Cl loads in years of higher flow could be due to flushing of salt that had built up in watershed lakes and groundwater during drier years, when pollutants are less likely to be mobilized. Annual chloride load variability in Nine Mile Creek is also likely due to quantity and timing of winter storm events and de-icing response to those storm events.

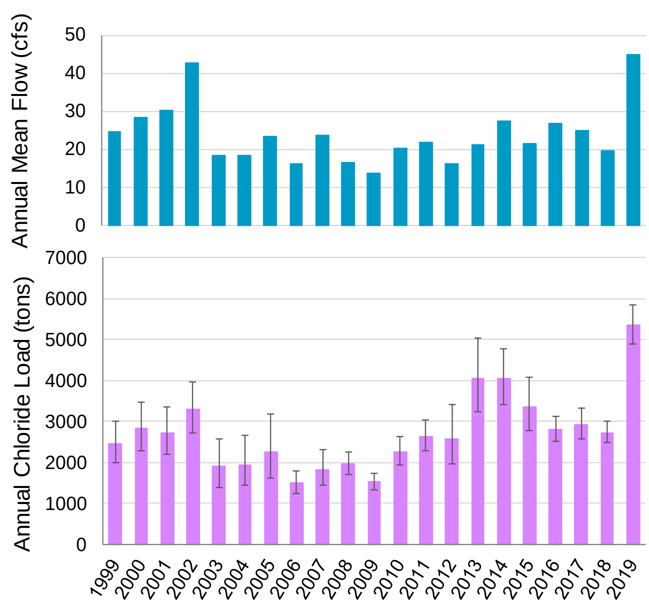

Figure 7: Mean Annual Flows and Annual Chloride Loads in Nine Mile Creek (Error bars = 95% Confidence Interval)

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 1999 – 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. De-icing salt is likely the primary source of chloride in the watershed. De-icing salt is primarily applied between December and March and would likely runoff during melt events from February through April. Peak flow was observed during the spring, while peak chloride concentration occurred in winter.

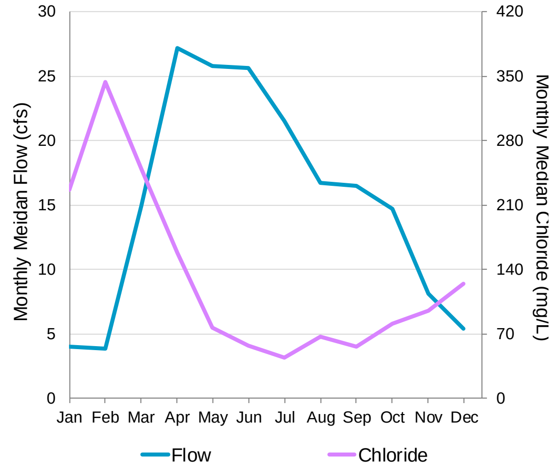

Figure 8: Monthly Median Flow and Median Ambient Chloride Concentrations in Nine Mile Creek

Chloride Load

Chloride load is seasonally dynamic. Chloride loads calculated with Flux32 were compiled as monthly averages for 1999-2019. 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.

During the 1999-2019 period, the highest monthly loads occurred from March through May, likely due to snow melt and spring precipitation. Monthly loads then gradually declined from June through October but remained fairly high. Chloride dynamics are likely affected by chloride cycling in upstream lakes with high chloride, shallow groundwater storage and additional, unknown factors.

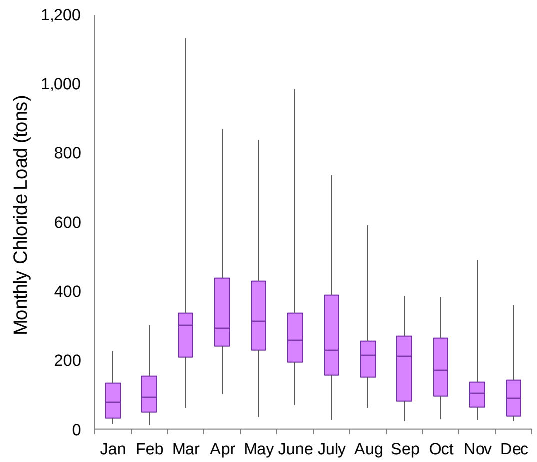

Figure 9: Monthly Chloride Loads in Nine Mile Creek

LIMITATIONS

The analyses described in this memo identify changes in chloride concentrations in the stream, 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 stream.

During some winter months in 1999 – 2019, hazardous ice conditions precluded sample collection. This data gap possibly biases our understanding of seasonal and annual chloride dynamics.

RECOMMENDATIONS & NEXT STEPS

Chloride pollution reduction projects and initiatives are most effective when guided by data collection and analysis. In order to support prioritizing 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 fertilizer use and de-icing salt application.
- Investigate the potential for stormwater runoff to enter shallow groundwater and how that affects chloride pollution timing and concentration.
- Investigate chloride concentrations and cycling in lakes to understand how lakes affect in-stream chloride.
- Update flow and load duration curves from 2014 *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams.* This analysis calculates the likelihood of a chloride standard exceedance for a particular flow.
- Determine whether milder winters exacerbate seasonal chloride pollution by investigating winter chloride trends during thaw events. A thaw is two or more days with air temperature lows above 32°F.
- Investigate relationship between continuous conductivity and chloride to understand chloride dynamics at a higher resolution.
- Compile a timeline of land use changes, chloride best management practices and stormwater management installations in the watershed.
- Continue to implement chloride mitigation and management BMPs including trainings to minimize salt use on roads, parking lots, sidewalks and other impervious surfaces.

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.

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[1] Minnesota Pollution Control Agency. *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] Minnesota Pollution Control Agency. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>

[4] Minnesota Water Quality Standards. Minn. Rules 7050.0218 and Minn. Rules7050.0222.
< https://www.revisor.mn.gov/rules/7050/>

[5] Overbo and Heger, n.d. *Major chloride sources and their annual chloride contributions to the environment in Minnesota.* Water Resources Center. <wrc.umn.edu/chloride>

[6] Metropolitan Council, 2013. Municipal Water Use in the Seven-County Twin Cities Metro Area. <https://metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning.aspx>

[7] Minnesota Pollution Control Agency. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>

[8] Rehm, G. and M. Schmitt. 1997. Potassium for crop production. Minnesota Extension Service. Minneapolis: University of Minnesota.

[9] Minnesota Pollution Control Agency. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>

[10] Metropolitan Council Environmental Services. 2014. *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams*. St. Paul: MCES.

[11] Minnesota Pollution Control Agency. 2020. Draft Statewide Chloride Management Plan <https://www.pca.state.mn.us/water/draft-statewide-chloride-management-plan>

12 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>

13 Nine Mile Creek – Turbidity, Impaired Biota and Chloride: TMDL Project. <https://www.pca.state.mn.us/water/tmdl/nine-mile-creek-turbidity-impaired-biota-and-chloride-tmdl-project>

14 Granato, G.E., DeSimone, L.A., Barbaro, J.R., and Jeznach, L.C., 2015, Methods for evaluating potential sources of chloride in surface waters and groundwaters of the conterminous United States: U.S. Geological Survey Open-File Report 2015–1080, 89 p., http://dx.doi.org/10.3133/ofr20151080.

15 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>*