Carver Creek CHLORIDE

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ENVIRONMENTAL SERVICES

KEY FINDINGS

No statistically significant chloride trend was identified in Carver Creek over the assessment period, indicating chloride concentration in the stream stayed relatively stable from 2001 - 2019.

Monthly chloride concentration and monthly chloride load in Carver Creek vary seasonally with higher values occurring in the spring and early summer.

Flow in Carver Creek varied dynamically during the assessment period. The highest flow years were 2011, 2014 and 2019.

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, MCES prepared the *Comprehensive Water Quality Assessment of Select Metropolitan Area Streams* report. This report 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?

During the analysis period of 1999-2019, the county and cities in the watershed have been actively working to address chloride pollution through monitoring investigations and outreach and education efforts. Carver County implemented a direct discharge incentive program in the Carver Creek watershed. The goal of this program was to remove all direct discharges in the watershed by 2019. Carver County also implemented a water resources management plan, including chloride management actions to address the increased concern of chloride in the stream.

This memo provides data and analyses from Carver 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 four largest are livestock excreta, household water softening, synthetic fertilizer and de-icing salt (Figure 1).

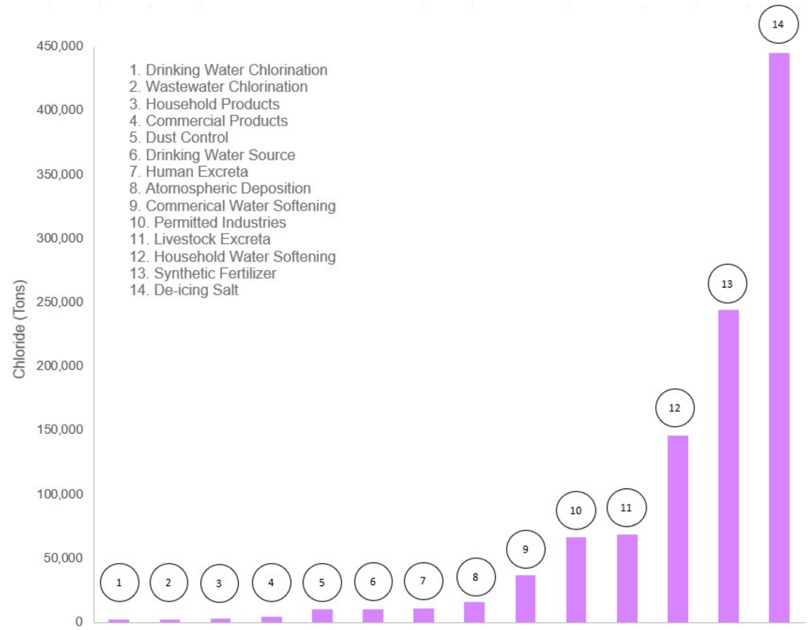

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

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

Carver Creek is 31-miles long and drains approximately 83 square miles of mixed agricultural land, open space, bluff land, and urban areas in the western metropolitan area. In 2014, 47% of the land was in agricultural use. Approximately 17% of the agricultural land is likely drain tiled.[11] About 13% was developed urban land and about 18% is impervious surface.

Approximately 6% of the Carver Creek 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]

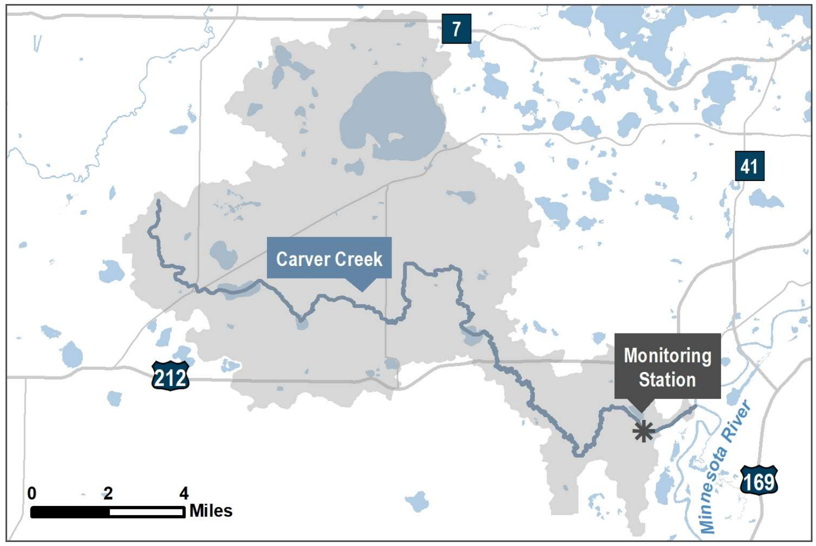

Figure 2: Map of Carver Creek Watershed

The creek runs through lakes, wetlands and the Minnesota Valley National Wildlife Refuge before discharging into the Minnesota River. (Figure 2).

Carver Creek is impaired for bacteria and turbidity but not classified as impaired for chloride or at risk for chloride impairment according to MPCA[14]. Carver Creek chloride pollution sources likely include synthetic fertilizer, livestock waste, discharge from subsurface sewage treatment systems, and de-icing salt applied to roads and other impervious surfaces

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

<u>Livestock Excreta:</u> There are more than 26 feedlots with 100 animal units (AUs) or more.

<u>Household Water Softening</u>: Household wastewater from the Cities of Carver, Waconia, and a portion of Laketown Township is treated at the MCES Blue Lake Wastewater Treatment Plant and discharged to the Minnesota River in Shakopee. Most residents in the watershed are served by subsurface sewage treatment systems. The chloride waste from the water softening process enters surface and groundwater through wastewater treatment plants or residential subsurface sewage treatment systems.[15]

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

<u>De-icing Salt:</u> 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 1999 -2019

Chloride Concentration

MCES collected 516 chloride samples between 1999 and 2019. The ambient concentrations are plotted with the annual median concentration (Figure 3). These values are affected by precipitation, flow, and watershed factors, including those caused by human activity.

Annual median chloride concentration was relatively stable over the assessment period.

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.

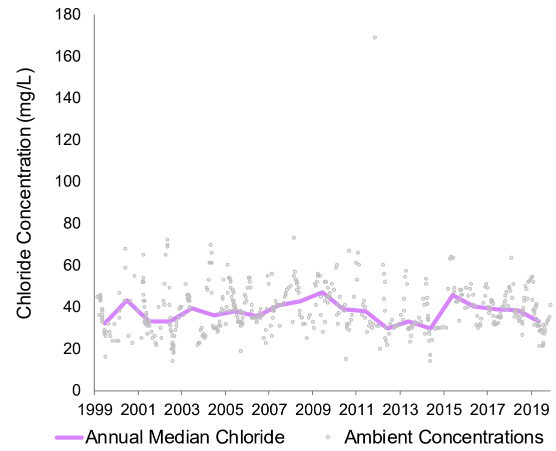

Figure 3: Annual medians and ambient chloride concentrations on Carver Creek

Precipitation and Streamflow

Ambient concentrations are often closely tied to rainfall and resulting flow conditions in the stream. 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 Carver Creek annual mean flow. Flow is usually higher in years with greater rainfall. Flow in Carver Creek varied dynamically during the assessment period. The highest flow years were 2011, 2014 and 2019.

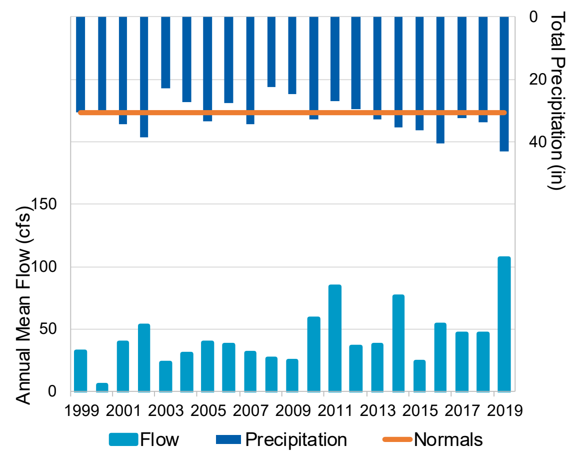

Figure 4: Annual Mean Flow and Precipitation for Carver Creek

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

Streamflow and Chloride Concentration

Figure 5 shows that flow generally increased during the assessment period, with very high flow in 2019. Chloride concentration and flow are not well correlated. 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.

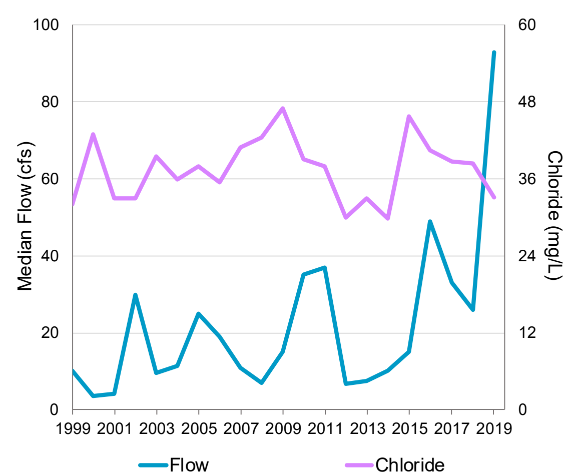

Figure 5: Annual Median Flow and Chloride Concentration in Carver Creek

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 no statistically significant trend for Carver Creek for the assessment period from 1999 to 2019. Figure 6 shows the flow adjusted concentrations which do not increase or decrease over the assessment period. This analysis shows chloride concentrations have been stable since 1999.

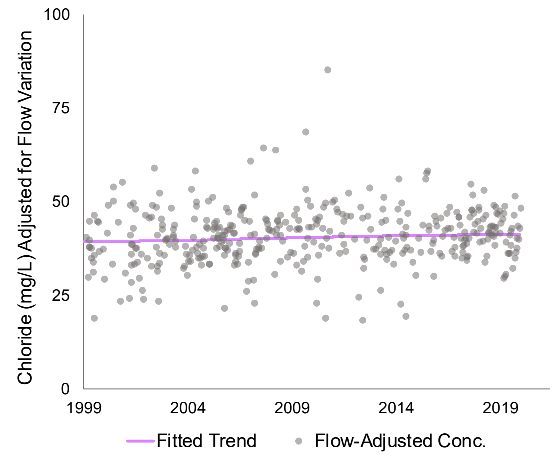

Figure 6: Flow-Adjusted Trends for Chloride Concentration in Carver Creek

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

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 1999 – 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 Loads

Figure 7 illustrates annual chloride loads and annual mean flow. The annual loads for chloride calculated with Flux32 exhibited significant year-to-year variation indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream.

Annual chloride load variability in Carver Creek is likely due to quantity and timing of synthetic fertilizer application and spring and summer runoff events.

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.

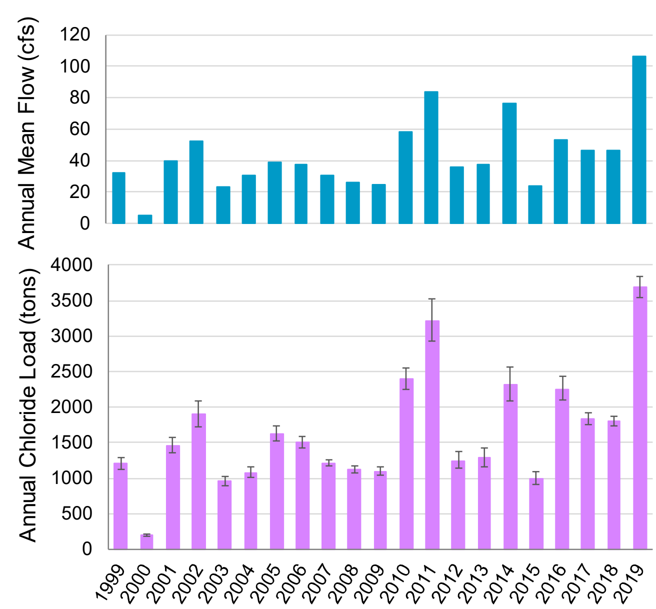

Figure 7: Annual Chloride Loads in Carver Creek (Error bars = 95% Confidence Interval)

Seasonal Chloride Dynamics 1999 – 2019

Chloride Concentration and Streamflow

Seasonal changes can influence monthly median flow and monthly median chloride concentration. Monthly median flow had an apparent seasonal variation (Figure 8). Higher flows were observed during the spring and early summer while lower flows were observed in the fall and winter. Monthly median chloride concentration also had a seasonal change but at a smaller scale. The higher concentrations were observed in the winter and spring while the lower concentrations occurred in the summer and early fall.

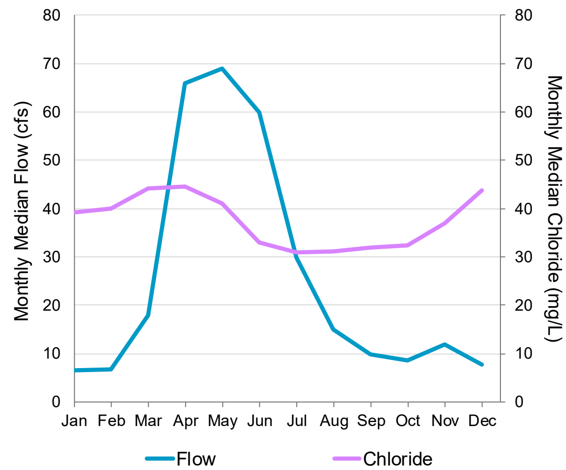

Figure 8: Monthly Median Flow and Ambient Chloride Concentrations in Carver Creek

Chloride Load

Chloride load is seasonally dynamic. The higher chloride loads occur from April through June. 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.

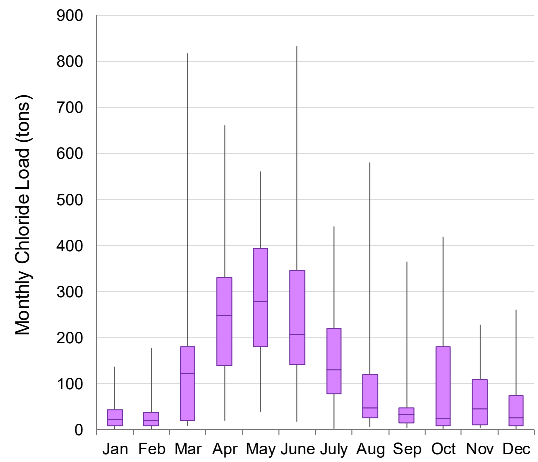

Figure 9: Monthly Chloride Loads in Carver Creek

From 1999-2019, 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. Chloride dynamics may be affected by chloride cycling in lakes, shallow groundwater storage and additional, unknown factors.

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 from 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, livestock waste management, household water softening, wastewater treatment plant discharge, and de-icing salt application.

- Investigate chloride concentrations and cycling in Miller Lake and other watershed 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
- Continue to 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.

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

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[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. *Chloride 101.* <https://www.pca.state.mn.us/water/chloride-101>

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

[11] Metropolitan Council. 2014. Carver Creek. 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>

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[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>*