Sand Creek CHLORIDE

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ENVIRONMENTAL SERVICES

KEY FINDINGS

Annual median chloride concentrations generally increased from 1999 to 2009 and then generally decreased through 2019.

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

Monthly chloride concentration and monthly chloride load in Sand Creek vary seasonally with higher values occurring in the spring and early summer. This suggests that deicing salt and synthetic fertilizer are likely the primary chloride sources.

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?

During the analysis period of 1999-2019, Scott County, Scott SWCD, and local governments through the Scott Clean Water Education Program (SCWEP), have partnered on education efforts regarding chloride and deicing salt application.[1]

This memo provides data and analyses from Sand 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.[2] 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.[3] Thirty percent of Twin Cities shallow aquifer monitoring wells have chloride concentrations that exceed the Minnesota state water quality standard.[4]

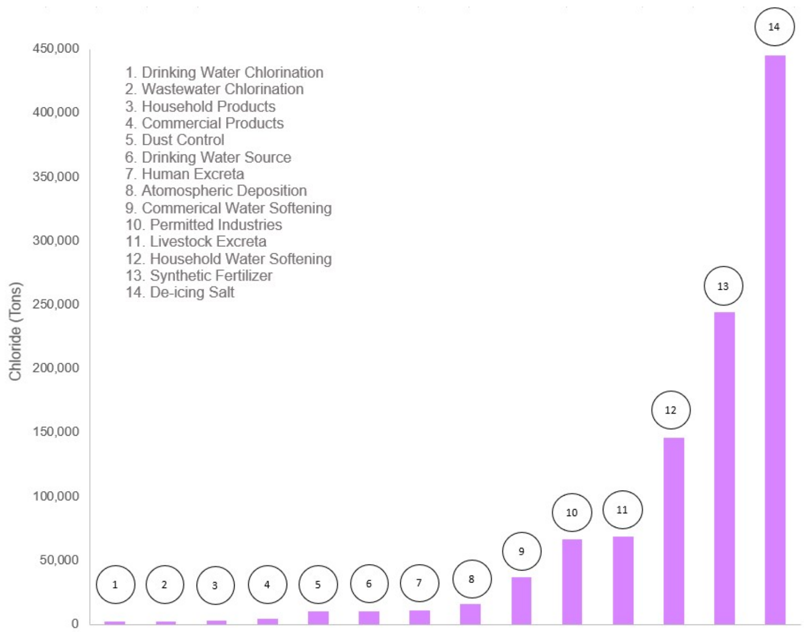

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

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.[5]

Chloride pollution in Minnesota has multiple sources.[6] 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,[7] 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[8] 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 treatment systems.[9]

Synthetic fertilizer: Chloride is associated with macronutrients like potassium. The most common potassium source in Minnesota is potash fertilizer, potassium chloride.[10] 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.[11] 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

Sand Creek receives run off from approximately 274 square miles of mixed agricultural land, open space, bluff land, and urban areas (cities of New Prague, Montgomery, and Jordan) through portions of Le Sueur, Rice, and Scott counties before draining to the Minnesota River in the southern Twin Cities Metropolitan Area. Approximately 66% of the Sand Creek watershed is in agricultural land use, and about 36% of the agricultural land in the watershed is likely drain tiled.[12] About 7% of the watershed is impervious.

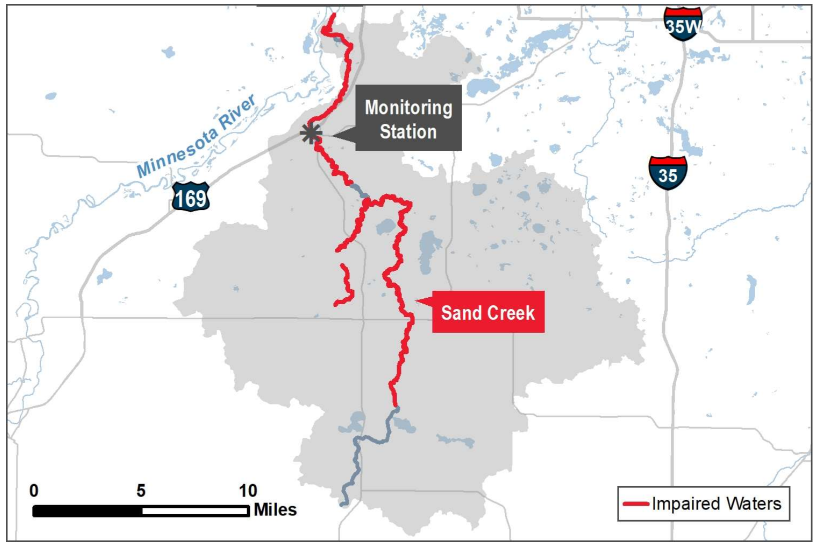

Figure 2: Map of Sand Creek Watershed

The main branch of Sand Creek flows northerly through Le Sueur and Rice counties, the cities of Montgomery, New Prague, and Jordan, and the Louisville Swamp (a floodplain wetland of the Minnesota River) before ultimately discharging to the Minnesota River in Scott County.

The creek has a total channel length of approximately 230 miles and is fed by several tributaries. Porter Creek drains the east section of the watershed; Raven Creek (which is further divided into a West Branch and East Branch/County Ditch 10) drains the west portion of the watershed; and Picha Creek drains a small section of the northeast watershed and enters Sand Creek downstream of the monitoring station.

Approximately 6% of the Sand Creek watershed is roadways, based on an analysis completed by the Minnesota Pollution Control Agency.[13] The MPCA found that watersheds with 18% roadway density or higher are more likely to have chloride concentrations above water quality standards.[14]

Sand Creek from southern Lanesburgh Township in Le Sueur County to the confluence with Raven Stream, the East Branch of Raven Stream, and Raven Stream from the confluence of the East and West Branches to the confluence with Sand Creek were listed for chloride impairment in 2010. Sand Creek from the confluence with Porter Creek to the Minnesota River was listed for chloride impairment in 2014.[15]

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

Livestock Excreta: There are 272 registered feedlots in the monitored area of the Sand Creek watershed with a total of 23,745 animal units (AUs), and an additional 26 feedlots in the unmonitored area with 2,835 AUs.

Household Water Softening: There are three domestic wastewater treatment plants, New Prague, Montgomery and Riverbend Mobile Home Park that discharge to Sand Creek. One wastewater treatment plant, Jordan, is outside of the monitored area. Much of the domestic wastewater in the watershed is treated by household subsurface sewage treatment systems. The chloride waste from the water softening process enters surface and groundwater through wastewater treatment plants or residential subsurface treatment systems.[16]

Synthetic Fertilizer: Chloride may come from agricultural and urban application of potash fertilizer.[17] 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 1999-2019

Chloride Concentration

MCES collected 636 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.

Ambient chloride concentrations show a great deal of variability over the analysis period. Annual median chloride concentrations generally increased from 1999 and 2009 and decreased from 2009 through 2019. There is significant year-to-year variability within these periods.

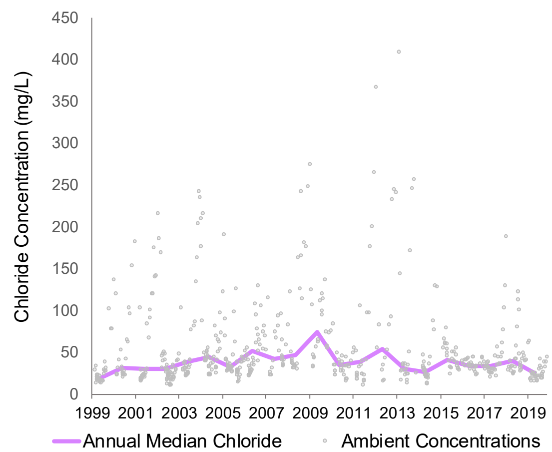

Figure 3: Annual Median and Ambient Chloride Concentrations of Sand Creek

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.

Precipitation and Streamflow

Ambient concentrations are often closely tied to rainfall and resulting flow conditions in the stream. Figure 4 shows annual total precipitation and the 1981-2010 National Weather Service Climate Normal precipitation at Minneapolis-St. Paul airport[18] with Sand Creek annual mean flows. Flow is usually higher in years with greater rainfall. Flow in Sand Creek varied dynamically during the assessment period, though has generally been higher in the period from 2010-2019 than in the years prior.

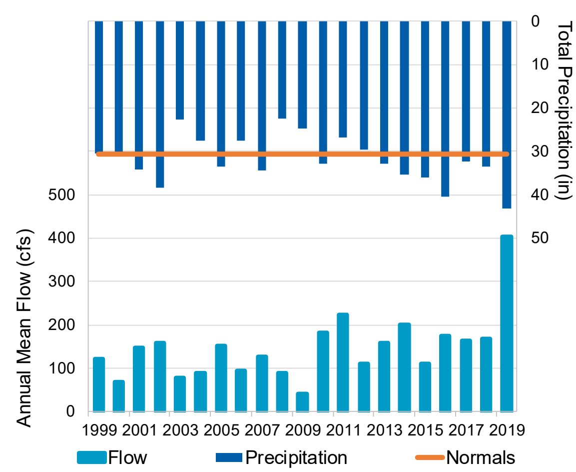

Figure 4: Annual Mean Flow and Precipitation for Sand Creek

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

Streamflow and Chloride Concentration

Figure 5 shows 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 generally been high.

However, there is variability in concentration that does not directly correlate 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.

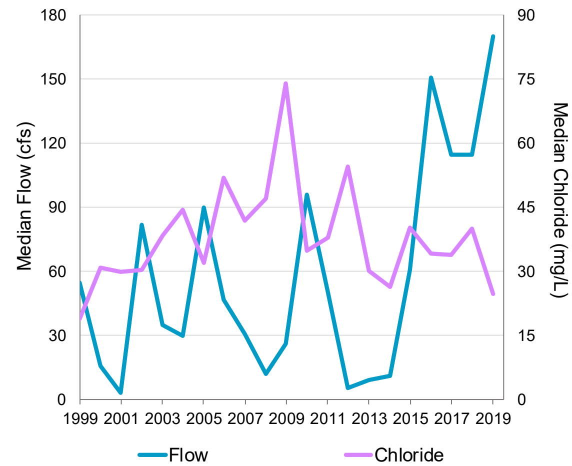

Figure 5: Annual Median Flow and Chloride Concentration in Sand Creek

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 that changes of the flow-adjusted chloride concentration in Sand Creek can be best represented by a statistically significant one-trend model (p = 7.5x10-7) over the 1999 to 2019 period (Table 1 and Figure 6). The results show that the flow-adjusted chloride concentration increased gradually by about 37% overall the entire assessment period.

Table 1: Statistical Trend for Chloride Concentration in Sand Creek

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
1999 – 2019	46.2 - 63.5	37%	0.824	0.00008	⬆

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.

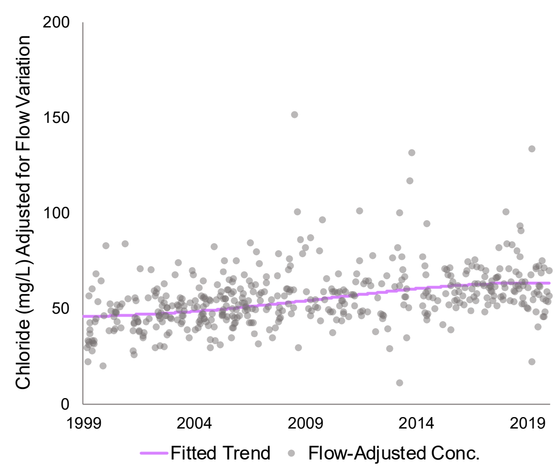

Figure 6: Flow-Adjusted Trends for Chloride Concentration in Sand Creek

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 2009 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 stream, so ambient concentrations have been going down. The stream is vulnerable to increases in ambient chloride concentration if flows decrease.

Chloride Load

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

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

Annual chloride load variability in Sand Creek is also likely due to the quantity and timing of winter storm events and de-icing response to those storm events, as well as the quantity and timing of synthetic fertilizer application and spring and summer runoff events.

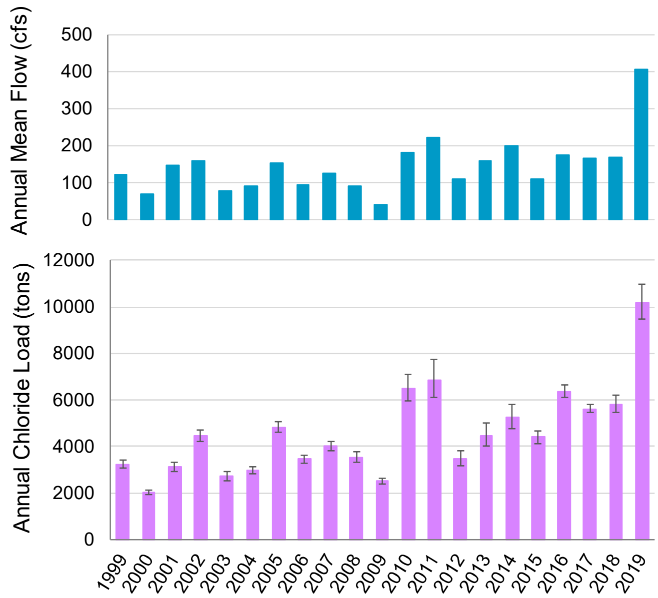

Figure 7: Mean Annual Flows and Annual Chloride Loads in Sand Creek (Error bars = 95% Confidence Interval)

> **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

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. The higher concentrations were in the winter while the lower concentrations occurred in the summer.

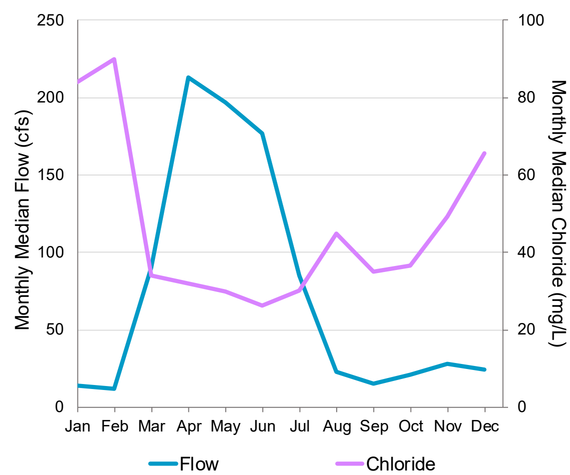

Figure 8: Monthly Median Flow and Median Ambient Chloride Concentrations in Sand Creek

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.

From 1999-2019, the higher monthly chloride loads occurred from March through June, possibly due to de-icing salt and synthetic fertilizer runoff coupled with the higher flows occurring during that period. Loads then declined in July and remained fairly low from August through February.

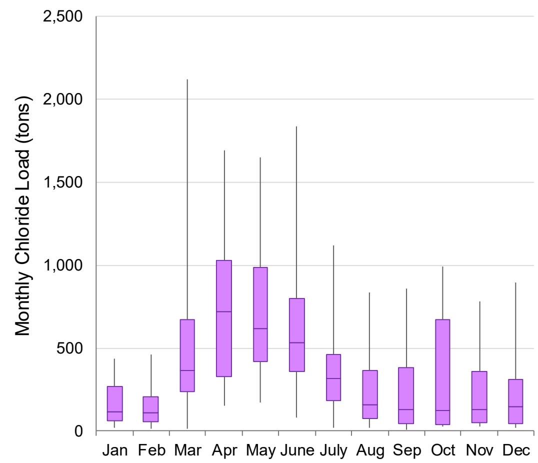

Figure 9: Sand Creek Monthly Chloride Loads

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 de-icing salt application, fertilizer use, livestock waste management, household water softening and wastewater treatment plant discharge.
- 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 and is very useful in understanding drivers of impairment.
- Investigate the potential for stormwater runoff and agricultural drainage to enter shallow groundwater and how that affects chloride pollution timing and concentration.
- Investigate chloride and flow upstream of the monitoring station to better identify chloride sources to Sand Creek.
- Continue to identify and implement chloride mitigation and management BMPs including trainings to minimize de-icing salt use.

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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