Bluff Creek CHLORIDE

KEY FINDINGS

Chloride concentration in Bluff Creek has increased since 1999. The stream is at high risk of chloride impairment.

Flow in Bluff Creek generally increased since 1999 although it has been extremely variable.

Chloride varied seasonally with higher values occurring in the spring and early summer, indicating salt use for winter de-icing is likely the major source for chloride in the stream. Other sources, such as synthetic fertilizer, are not well understood and should be investigated.

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 City of Chanhassen has classified Bluff Creek as a high-risk waterbody for chloride pollution and has specifically identified chloride management as a goal in its stormwater management plan[1]. During the analysis period, state and local authorities have been actively working to improve water quality through TMDL studies and best management practice installation to address turbidity and fish biota impairments. However, chloride pollution steadily increased during the study period. Additional water quality improvement strategies will be needed to address increasing chloride pollution.

This memo provides data and analyses from Bluff 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]

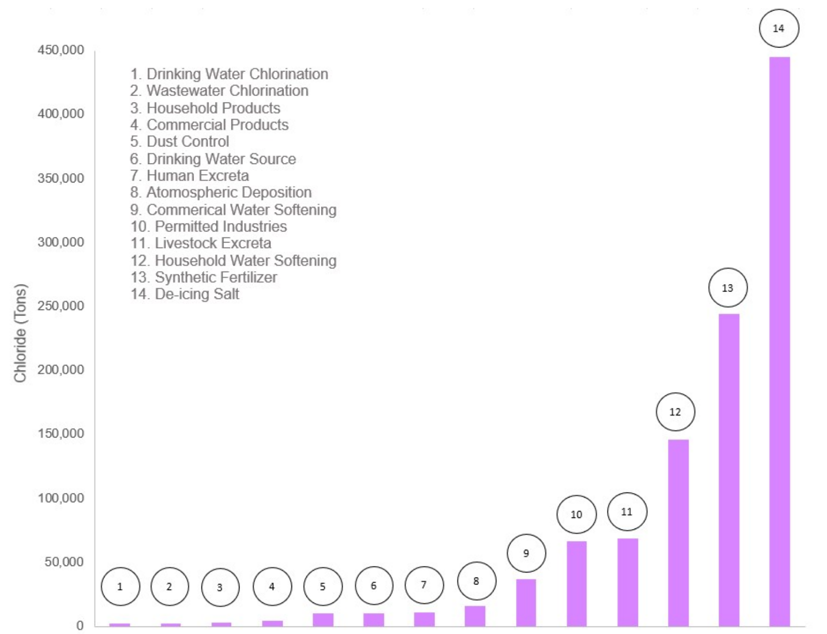

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

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

<u>Household water softening</u>: 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 septic systems.[8]

<u>Synthetic fertilizer</u>: 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.

<u>De-icing salt</u>: 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

Bluff Creek is a 9.5-mile long and mostly urbanized stream located in the southwestern metropolitan area. It begins in Chanhassen and runs through the Minnesota Valley National Wildlife Refuge and Rice Lake before discharging into the Minnesota River, MN (Figure 2).

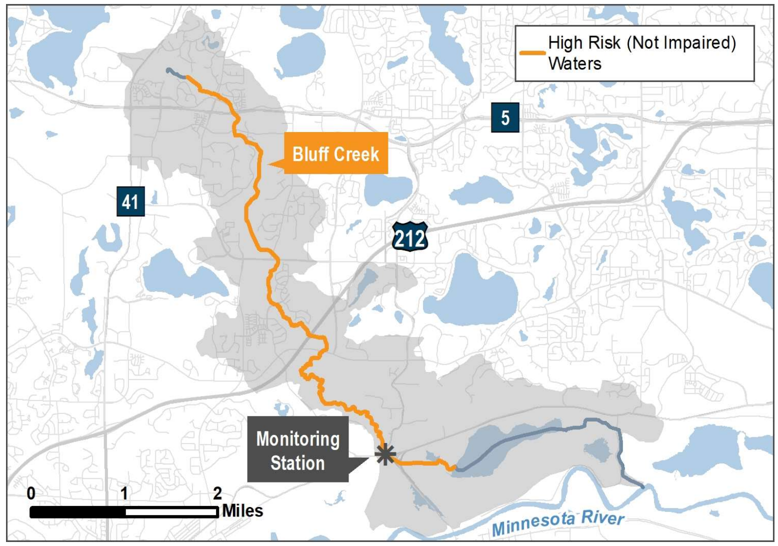

Figure 2: Map of Bluff Creek Watershed

Bluff Creek watershed is about 5,892 acres, with 3,611 acres (61.3%) of the watershed upstream of the monitoring station. The watershed currently is 40% urban (28% residential and 12% commercial) land use, 12% agricultural land use and 44% open space.[11]

Approximately 17% of the Bluff 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]

Bluff Creek is not impaired for chloride. However, as an urbanized watershed, the stream has been classified as a high-risk waterbody. According to a TMDL study by the city of Chanhassen and MPCA[14], chloride concentrations in the stream exceeded the MPCA chronic standard for a Class 2B stream based on the data collected by MCES 1999 - 2008.

Household water softening is a possible chloride source in Bluff Creek watershed. Chloride from household water softening can enter surface and groundwater through wastewater treatment plants or residential subsurface sewage treatment systems. Most wastewater in the Bluff Creek watershed is treated through the MCES Blue Lake Wastewater Treatment Plant and discharged to the Minnesota River in Shakopee; some households use subsurface sewage treatment systems.

Synthetic fertilizer is a possible chloride source in the Bluff Creek watershed. Chloride could result from residential and other urban and suburban turf management applications of potash fertilizer.[15] This source of chloride is not well understood in the watershed.

De-icing salt is likely a major source of chloride pollution in Bluff 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 1999-2019

Chloride Concentration

MCES collected 419 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 are affected by precipitation, flow, and watershed factors, including those caused by human activity.

Annual median chloride concentration generally increased from 1999 to 2011 and remained relatively stable from 2012 through 2019. There are no measurements of chloride available for the period of May 2014 to December 2015 because of nearby road and in-stream construction.

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[16] with Bluff Creek annual mean flows. Flow is usually higher in years with greater rainfall. Flow in Bluff Creek 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 flow has generally increased over the study period and chloride concentration chloride concentration generally increased from 1999 to 2011 and remained relatively stable from 2012 through 2019. This means that factors other than flow appear to 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.

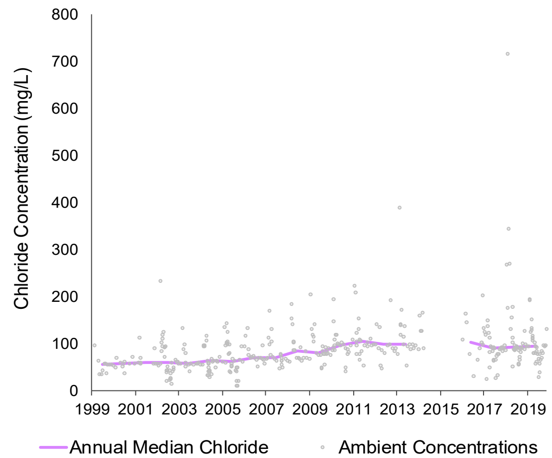

Figure 3: Ambient and Annual Median Chloride Concentrations in Bluff Creek
(Samples were not collected 2014 to 2015)

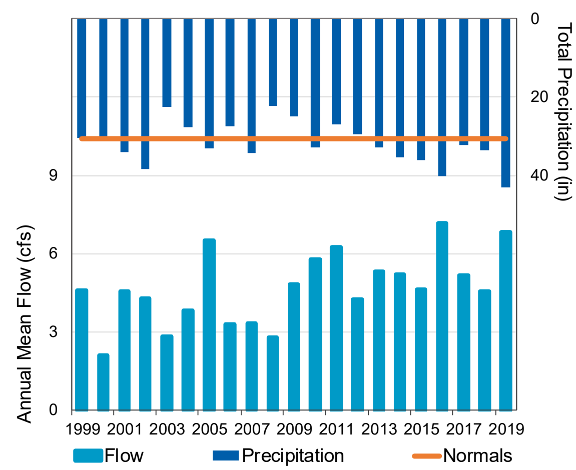

Figure 4: Annual Mean Flow and Precipitation for Bluff Creek

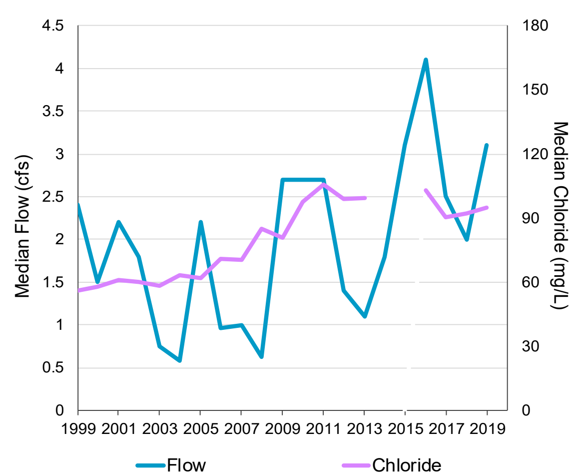

Figure 5: Annual Median Flow and Chloride Concentration in Bluff Creek

R-QWTREND analysis shows that changes in chloride concentration in Bluff Creek can be best represented by a statistically significant one-trend model (p =5.6x10^{-13}) over the assessment period of 1999 to 2019 (Table 1 and Figure 6). The flow-adjusted chloride concentration in the stream increased by 80% from 1999 to 2019, likely due to behaviors in the watershed, including potentially an increase in use of de-icing salt.

Table 1: Statistical Trend for Chloride Concentration in Bluff Creek

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
1999 – 2019	60.5 - 108.9	80%	2.84	0	⬆

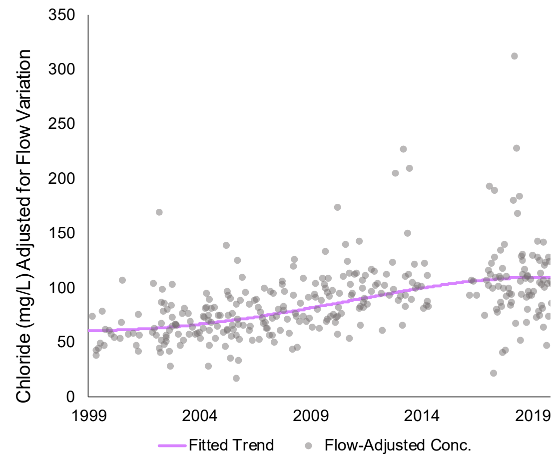

Figure 6: Flow-Adjusted Trends for Chloride Concentration in Bluff Creek

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 Load

Figure 7 illustrates annual loads expressed as tons and annual mean flow. The annual loads for chloride calculated with Flux32 exhibited general increase with significant year-to-year variation indicating the influence of precipitation and flow on the transport of pollutants within the watershed and the stream. Loads from 2009 – 2019 were substantially higher than loads early in the study period despite similar flows, reflecting increased concentrations from 2009 - 2019.

Annual chloride load variability in Bluff Creek is also likely due to quantity and timing of winter storm events and de-icing response to those storm 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.

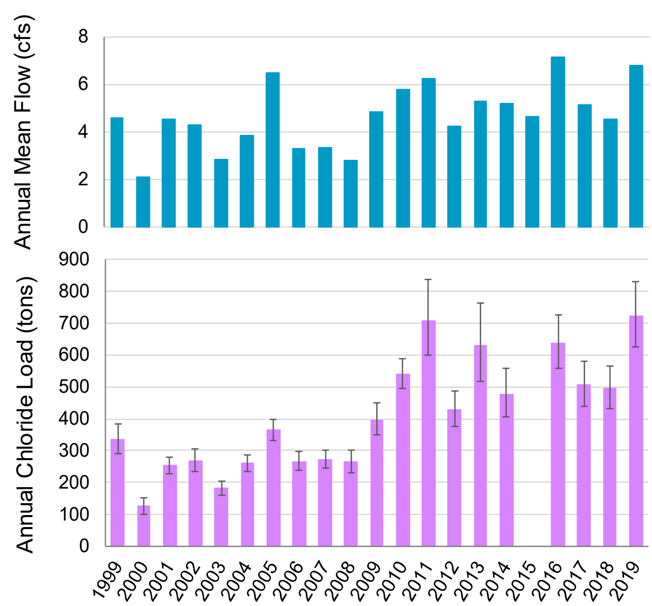

Figure 7: Mean Annual Flows and Annual Chloride Loads in Bluff Creek
(Error bars = 95% Confidence Interval)

Seasonal Chloride Dynamics 1999 – 2019

Chloride Concentration and Streamflow

Seasonal changes can influence monthly median flow and monthly median chloride concentration. Monthly medians of flow and chloride concentration had an apparent seasonal variation (Figure 8). Higher flows were observed during the spring while lower flows were observed in the winter. For chloride, higher monthly median concentrations were in the winter and spring while the lower concentrations occurred in the summer and early fall.

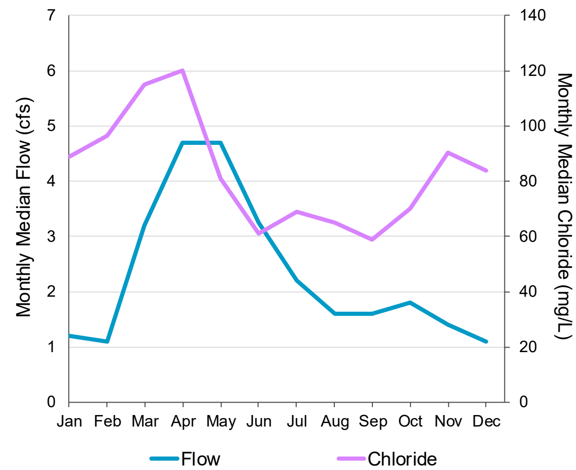

Figure 8: Monthly Median Flow and Median Ambient Chloride Concentrations in Bluff Creek

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 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, 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.

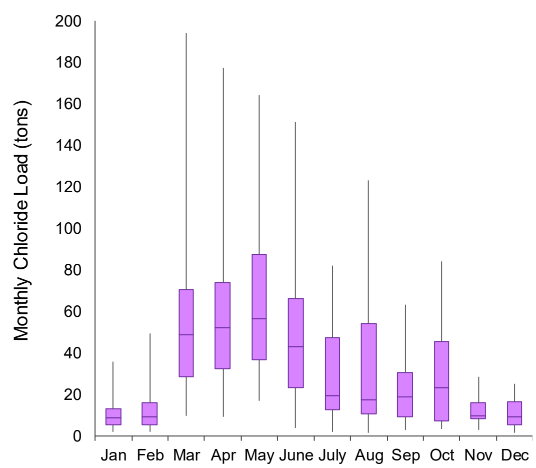

Figure 9: Monthly Chloride Loads in Bluff Creek from years 1999-2014, 2016-2019

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 from 1999 – 2019, hazardous 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, synthetic fertilizer use, household water softening, and de-icing salt application.
- Investigate the potential for stormwater runoff to enter shallow groundwater and how that affects chloride pollution timing and concentration.

- Compile a timeline of land use changes, chloride best management practices and stormwater management installations in the watershed.
- Investigate whether milder winters exacerbate seasonal chloride pollution by investigating winter chloride trends during thaw events, two or more days with air temperature lows above 32°F.
- 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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