Bevens Creek CHLORIDE

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ENVIRONMENTAL SERVICES

KEY FINDINGS

Chloride in Bevens Creek has decreased since 2016, coinciding with a period of high flow. The decreasing trend since 2016 is moderate, however, and Bevens Creek appears to remain at high risk of chloride impairment.

Bevens Creek has a complicated chloride trend over the period of record that is not closely tied to flow. Subsurface sewage treatment systems, road salt, and fertilizer sources of chloride need to be investigated further to understand chloride dynamics in the watershed.

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, Carver County implemented a direct discharge incentive program in Bevens Creek watershed. The goal of this program was to remove all direct discharges in the watershed by 2019.

This memo provides data and analyses from Bevens 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]

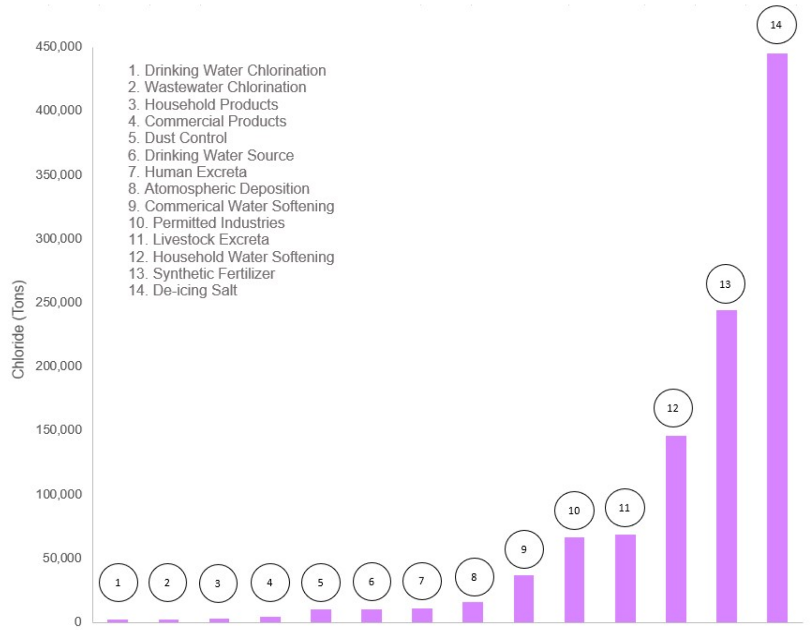

Figure 1: Major chloride sources and their annual chloride contributions to the environment in Minnesota.

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 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

Bevens Creek is 39 miles long and drains approximately 133 square miles of mixed agricultural land, open space, bluff land, and urban areas in Sibley and Carver Counties. The headwaters is in Green Isle Township in Sibley County, outside of the Twin Cities Metropolitan Area, and it discharges to the Minnesota River near Jordan, MN (Figure 2).

Bevens Creek watershed is about 85,361 acres. 66% of the land use is agricultural land use and approximately 36% of the agricultural land in the watershed is likely drain tiled[11,12]. About 7% is impervious.

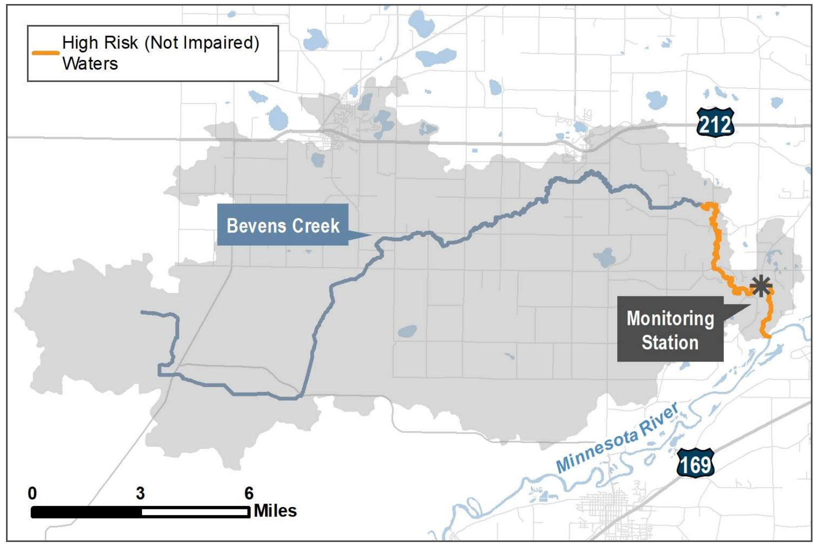

Figure 2: Map of Bevens Creek Watershed

Approximately 5% of the Bevens Creek watershed is roadways, based on an analysis completed by the Minnesota Pollution Control Agency (MPCA) [13]. The MPCA found that watersheds with 18% roadway density or higher are more likely to have chloride concentrations above water quality standards.[14]

Bevens Creek was originally listed for chloride impairment in 2002 but was de-listed for chloride impairment in 2014 after MPCA determined the water quality standard is being met[15]. MPCA continues to classify Bevens Creek from near County Road 41 to the mouth of the Minnesota River as high risk for chloride impairment.

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

Livestock Excreta: There are more than 56 feedlots with 100 animal units (AUs) or more.

Household Water Softening: There are 2 domestic wastewater treatment plants, Norwood Young America and Hamburg. Many residential developments 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 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 508 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 was fairly stable over the period of record.

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.

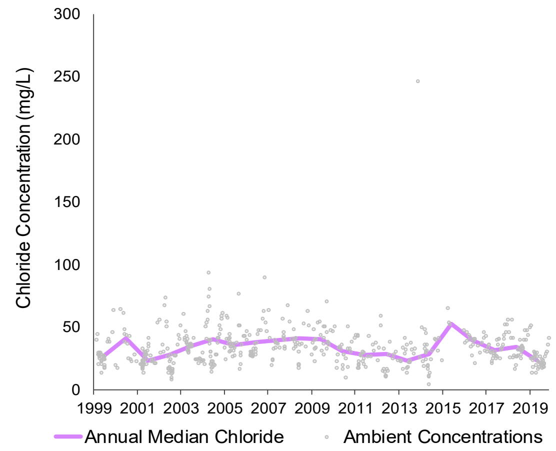

Figure 3: Annual Median and Ambient Chloride Concentrations of Bevens Creek

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[18] with Bevens Creek annual mean flows. Flow is usually higher in years with greater rainfall. Flow in Bevens Creek varied dynamically during the assessment period.

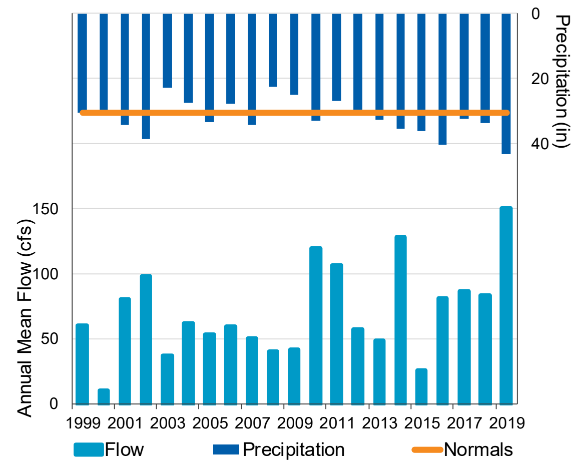

Figure 4: Annual Mean Flow and Precipitation for Bevens Creek

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

Streamflow and Chloride Concentration

Figure 5 shows that concentration and flow are not well correlated. Factors other than flow impact chloride conditions in the stream.

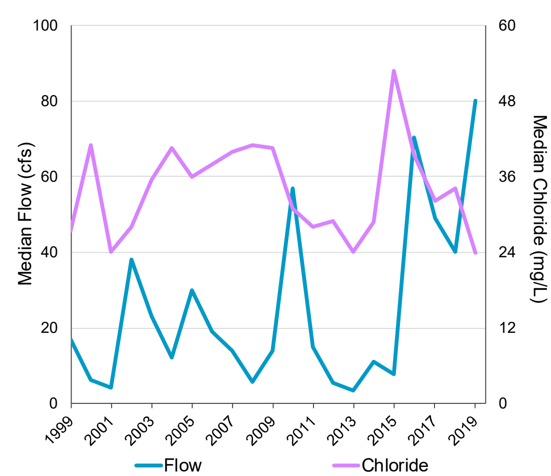

Figure 5: Annual Median Flow and Chloride Concentration in Bevens Creek

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 Bevens Creek can be best represented by a statistically significant four-trend model ($p = 2.9 \times 10^{-10}$) over the assessment period of 1999 to 2019 (Table 1 and Figure 6). This model has four significant periods; the flow-adjusted chloride concentration in the stream increased from 1999 to 2002, decreased from 2002 to 2012, increased from 2012 to 2016 and decreased from 2016 to 2019.

Table 1: Statistical Trend for Chloride Concentration in Bevens Creek

Trend Period	Concentration range (mg/L)	Change in Conc (%)	Change Rate (mg/L/yr)	*p*	Trend
1999 – 2002	34.3 – 43.6	27%	2.32	0.0025	↑
2003 – 2012	43.6 – 34.5	-21%	-0.904	0.0039	↓
2013 – 2016	34.5 – 42.7	24%	2.04	0.0067	↑
2017 – 2019	42.7 – 36.3	-15%	-2.12	0.058	↓

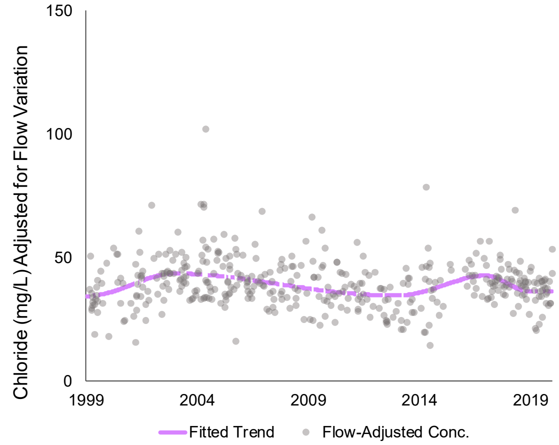

Figure 6: Flow-Adjusted Trends for Chloride Concentration in Bevens Creek

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 significant year-to-year variation 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 chloride that had built up in watershed lakes and groundwater during drier years, when pollutants are less likely to be mobilized.

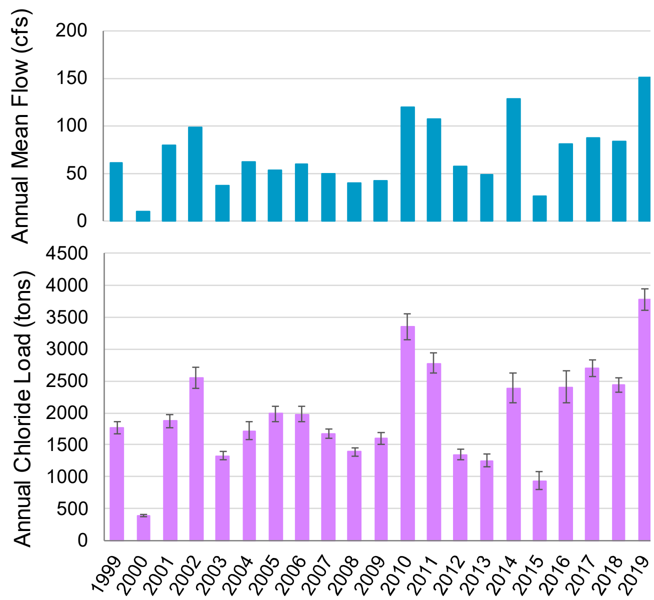

Figure 7: Mean Annual Flows and Annual Chloride Loads in Bevens Creek (Error bars = 95% Confidence Interval)

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. Higher flows occurred during the spring while higher chloride concentrations occurred in the winter.

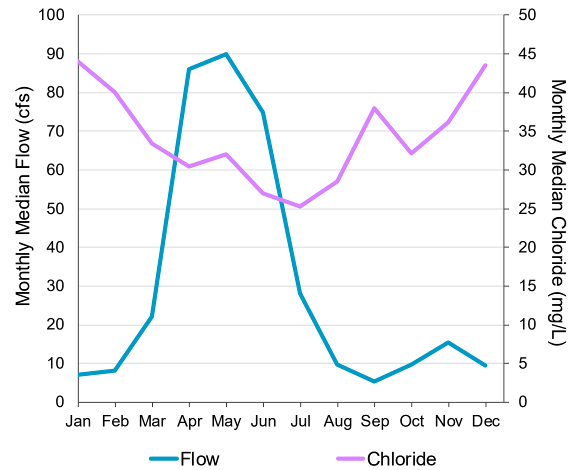

Figure 8: Monthly Median Flow and Median Ambient Chloride Concentrations in Bevens Creek

Chloride Load

Chloride load is seasonally dynamic. The highest chloride load occurs 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.

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.

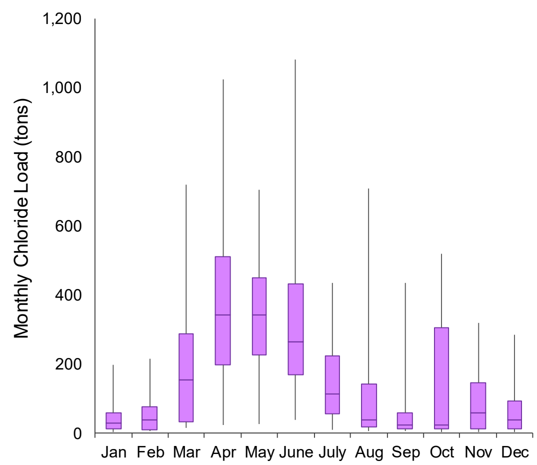

Figure 9: Monthly Chloride Loads in Bevens Creek

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 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, synthetic fertilizer use, livestock waste management, household water softening, wastewater treatment plant discharge, and de-icing salt application.
- Compare this analysis to upstream water quality and flow data (including at the previous MCES monitoring site at mile 5) to better identify chloride sources to Bevens Creek.

- Compile a timeline of land use changes, chloride best management practices and stormwater management installations in the watershed.
- 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.
- 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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