# Hinkson Creek CAM Science Team Statement on Chlorides

## Executive Summary

Chloride is a known stressor of aquatic life and concentrations exceeding water quality standards have been documented in Hinkson Creek. While chloride is an apparent cause of impairment in Hinkson Creek, there are likely other physical, chemical, and/or hydrological issues that contribute to aquatic life impairment. Studies on Hinkson Creek have shown that chloride concentrations are about four-times higher than those in reference/control streams. Chloride concentrations in Hinkson Creek tend to be lower in upstream sites where the watershed is more rural, and increase downstream as the watershed becomes more urbanized. Some of the chloride values that have been measured exceeded water quality criteria levels, indicating toxic chloride events have occurred in Hinkson Creek. Conductivity can fluctuate greatly in Hinkson Creek during the winter months, indicating water quality is dynamic. Studies show that while elevated chloride levels are most likely to occur during winter months, high concentrations can occur during non-winter periods.

## Introduction

There have been significant research and data collection efforts since 2001 to identify pollutants that cause impairment in Hinkson Creek. While the sources of impairment in Hinkson Creek are likely multiple stressors, chloride levels have been high enough to contribute to the impairment of aquatic life in the stream. Impairments relating to chlorides are a common problem for urban streams, due to the use of various salt compounds applied to roadways, parking lots, and sidewalks within their watersheds during winter.

Many different sites along Hinkson Creek have been monitored as part of the various studies over time. In the past, these sites were divided into those that are located upstream of Interstate-70 (I-70) and those found downstream to allow for comparisons. Upstream sites are located in the rural portion of Hinkson Creek's watershed, while downstream sites are influenced by a highly urbanized portion of the watershed.

Missouri's water quality standards list two chloride concentrations as being a concern to aquatic life in Missouri's streams. The first value is the chronic toxicity level of 230 mg/L, a concentration that can harm aquatic life if maintained for a period of four days or more. The second value is the acute toxicity concentration of 860 mg/L. This extreme level of chloride can be detrimental to aquatic life if maintained for more than an hour.

## Study Results

Missouri Department of Natural Resources 2001 - 2006

Water samples were collected from Hinkson Creek, tributaries to Hinkson Creek, and reference/control streams within central Missouri between late 2001 through the spring of 2006. Most of the samples were collected in conjunction with the invertebrate monitoring that occurred during the spring and fall seasons, or during periods of normal stream flow.

A total of 123 chloride samples were collected from 14 sites on Hinkson Creek and another 43 samples collected from nine different tributary and reference/control streams. Individual chloride measurements in the upper Hinkson Creek (28 samples from two sites) averaged 36 mg/L with a range of 8 to 217 mg/L (Figure 1). At downstream sites (95 samples from 12 sites) chloride concentrations ranged 11 to 333 mg/L, with an average of 42 mg/L. The 333 mg/L chloride reading occurred at Forum Boulevard in December 2005. This was the only value measured in Hinkson Creek that exceeded the chronic toxicity level of 230 mg/L. The chloride concentrations in the 19 samples collected from six tributaries ranged from 21 to 122 mg/L, with an average of 44 mg/L. The three highest values came from Flat Branch Creek. The three reference/control streams had chloride values that ranged from 1 to 24 mg/L with an average of 12 mg/L (n=20).

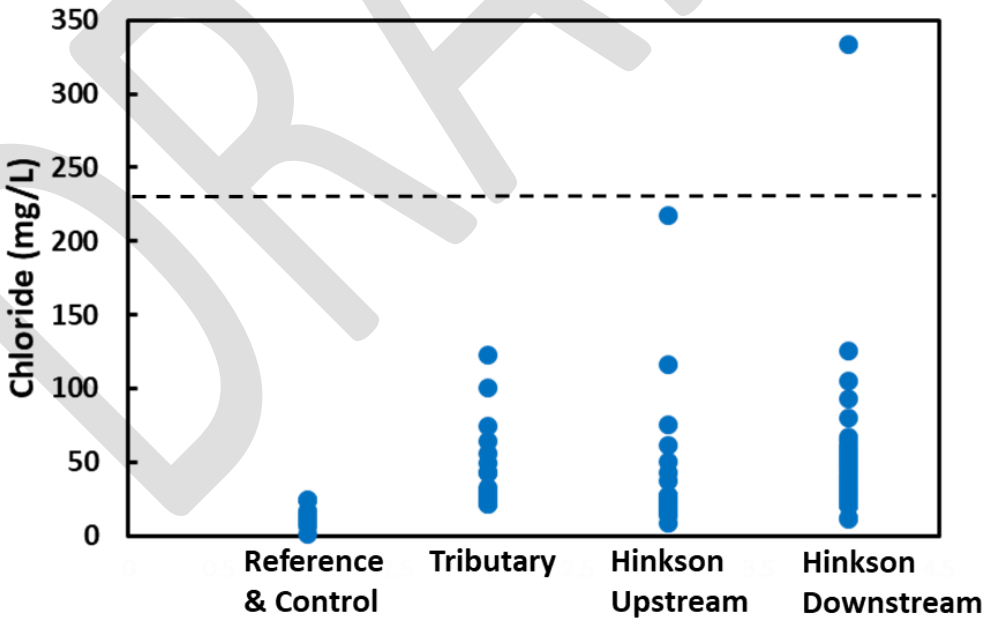


Figure 1. Chloride values measured during 2001-06 in three mid-Missouri reference/control streams, six tributaries to Hinkson Creek, two upstream sites in Hinkson Creek, and 12 downstream sites in Hinkson Creek. Symbols represent individual chloride measurements and the horizontal dashed line represent the chronic criteria level of 230 mg/L.

There were nine samples collected during 2004 from storm/snowmelt runoff. These samples came from storm water drainage sites located near the Broadway Market Place shopping complex, southwest of the I-70-Highway 63 intersection. Chloride concentrations ranged from 48 to 22,800 mg/L, with an average of 3,317 mg/L.

Missouri Department of Natural Resources 2012 - 2017

Water sample collections occurred during this period, again in conjunction with the spring and fall invertebrate monitoring. There were 111 chloride measurements made in Hinkson Creek between spring 2012 and fall 2017, along with 12 samples collected from Bonne Femme Creek. At the two upstream Hinkson Creek sites, chloride ranged 7 to 21 mg/L, with an average of 14 mg/L (Figure 2). Downstream sites averaged 46 mg/L with a range of 14 to 144 mg/L. In contrast, values in Bonne Femme Creek ranged from 7 to 36 mg/L, with an average of 17 mg/L. None of the chloride measures exceeded the chronic toxicity level of 230 mg/L.

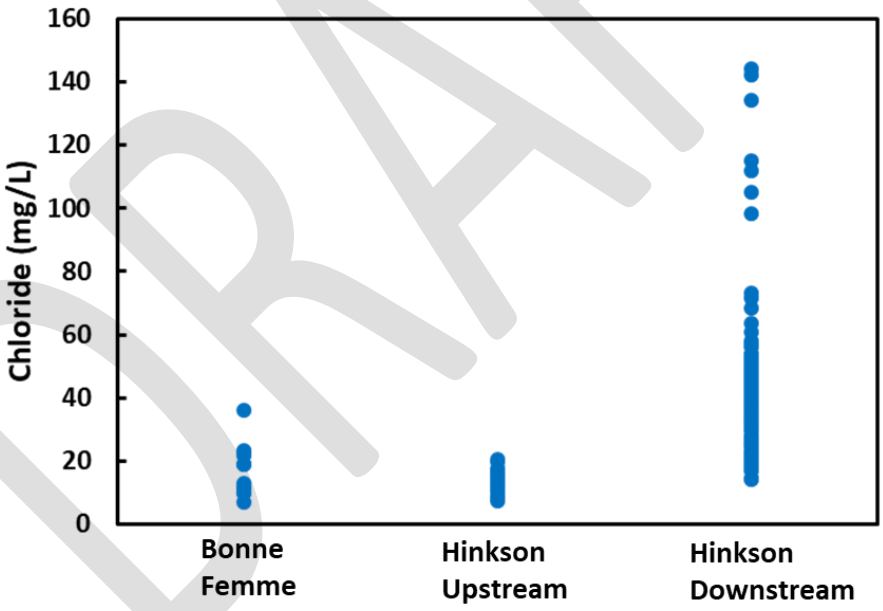


Figure 2. Chloride values measured during 2012-17 in a control stream (Bonne Femme), two upstream sites in Hinkson Creek, and nine downstream sites in Hinkson Creek. Symbols represent individual chloride measurements.

U.S. Geological Survey 2011

A study conducted during a snow event in early 2011 looked at the potential toxicity of chloride in Hinkson Creek. Seven sites (five in Hinkson, one in Grindstone Creek and one in Flat Branch) were monitored 1 to 5 times each, with the water being used in a lab experiment looking at survival and reproductive success of *Ceriodaphnia dubia* (a species of water flea often used in aquatic toxicity test). Site 1, located upstream of I-70, averaged 21 mg/L of chloride. In comparison, the other four sites in Hinkson Creek, located at and downstream from I-70, averaged between 90 and 158 mg/L chloride. The average level in Grindstone was 301 mg/L and 1,252 mg/L in Flat Branch. The 301 mg/L value from Grindstone exceeded the chronic criteria (230 mg/L), while the average value from Flat Branch exceeded the acute criteria level (860 mg/L). Survival and reproductive success of the water flea in water from Flat Branch Creek were significantly lower, compared to the results from the upstream Hinkson Creek site.

Hubbart et al. 2017

Five sites in Hinkson Creek were monitored four times a week, October 2009 through May 2014. Two of the sites, Rodgers Road and Mexico Gravel Road, were upstream sites and they had maximum chloride concentrations during the study of 248 and 351 mg/L, respectively. In contrast, the three downstream sites (Broadway, Providence Road, and Scott Blvd.) had maximum chloride values that ranged between 941 – 1911 mg/L. Chronic chloride concentrations ($\geq$230 mg/L) were measured at four of the five sites, with acute chloride levels ($\geq$860 mg/L) being measured at the three downstream sites (Table 1). Figure 3 shows how chloride concentrations varied over the four and a half year study. While there is an obvious seasonal pattern of higher levels of chloride occurring during winter months, there were some chloride values that exceeded the chronic toxicity level in non-winter months.

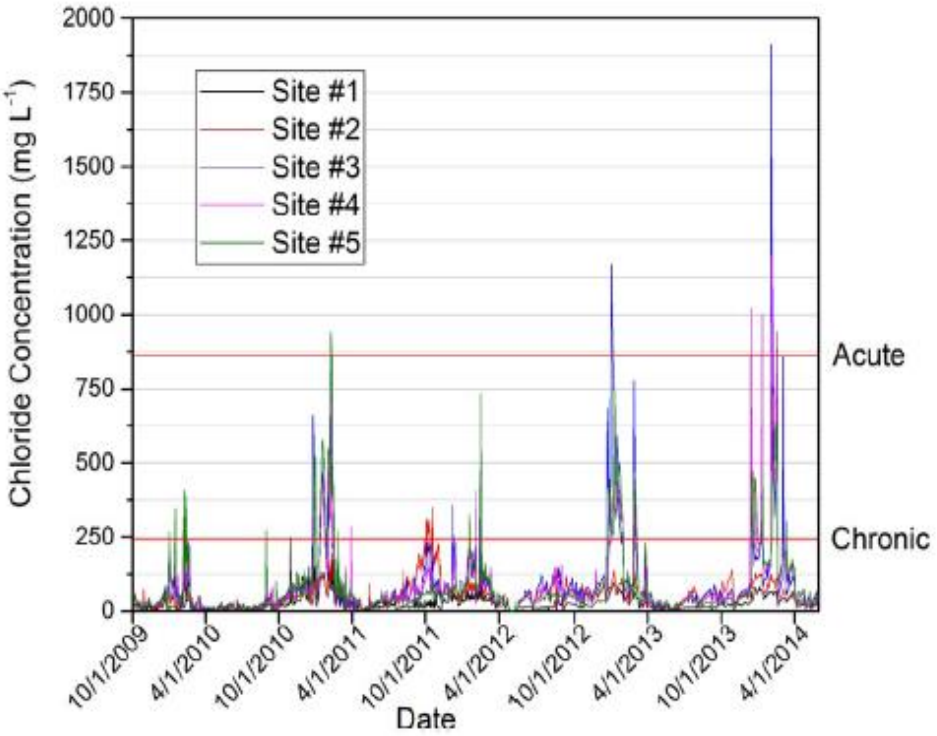


Figure 3. Observed chloride concentrations at five sites during Oct. 2009 – May 2014 in Hinkson Creek. Horizontal red lines indicate the acute (230 mg/L) and chronic (860 mg/L) toxicity levels. (Figure 3 in Hubbart *et al*. 2017.)

Table 1. Number of times in which chloride measurements met or exceeded chronic and acute conditions at five Hinkson Creek sites during the study.

| Criteria | Rodgers Road (Site 1) | Mexico Gravel (Site 2) | Broadway (Site 3) | Providence (Site 4) | Scott Blvd. (Site 5) |
|---|---|---|---|---|---|
| Chronic (230 mg/L) | 1 | 8 | 106 | 115 | 121 |
| Acute (860 mg/L) | 0 | 0 | 12 | 4 | 2 |

*The Rodgers Road site had a maximum chloride reading of 248 mg/L. While this value exceeds the chronic criteria, it was only elevated for a single day and thus did not constitute a toxic event.

<u>Geosyntec Conductivity Monitoring</u>

During the winter of 2019-20, Geosyntec collected conductivity data from five sites on Hinkson Creek at 30 minute intervals. Conductivity is a measure of a water's ability to conduct

an electric current, and it relates to the amount of dissolved salts within the water. While conductivity is not a direct measure of chloride, the two show a strong relationship, with higher conductivity readings occurring when chloride levels increase. Conductivity was chosen to monitor because it does show this positive relation to chloride and because conductivity sensors can be deployed long-term in the stream and set to collect frequent readings.

Results from the monitoring are shown in Table 2. There is a trend for lower conductivity readings at the two upstream sites (HC8 and HC7) compared to the three downstream sites (HC 5.5, HC3.5, and HC1). There were also great ranges of conductivity measured at all sites, with upstream sites ranging by 6 or 7 fold and downstream sites showing maximum values that were anywhere from 16 to 27 times higher than the minimum values. These results suggest that the levels of dissolved salts (including chloride) can fluctuate greatly during the winter months. Results also indicate that elevated conductivity values persisted for a week after a snow event (Figure 4).

Table 2. Conductivity results from Geosyntec's five month study conducted during winter 2019-20.

| | Site | Location | Number of Measurements | Range (µS/cm) | Average (µS/cm) |
|---|---|---|---|---|---|
| Upstream | HC 8 | Rodgers Road | 6,187 | 100 to 623 | 301 |
| | HC 7 | Hinkson Creek Road | 5,445 | 92 to 685 | 391 |
| Downstream | HC 5.5 | Green Valley Drive | 5,484 | 122 to 3,323 | 604 |
| | HC 3.5 | Recreation Drive | 7,252 | 134 to 2,149 | 562 |
| | HC 1 | Scott Boulevard | 6,659 | 146 to 2,604 | 598 |

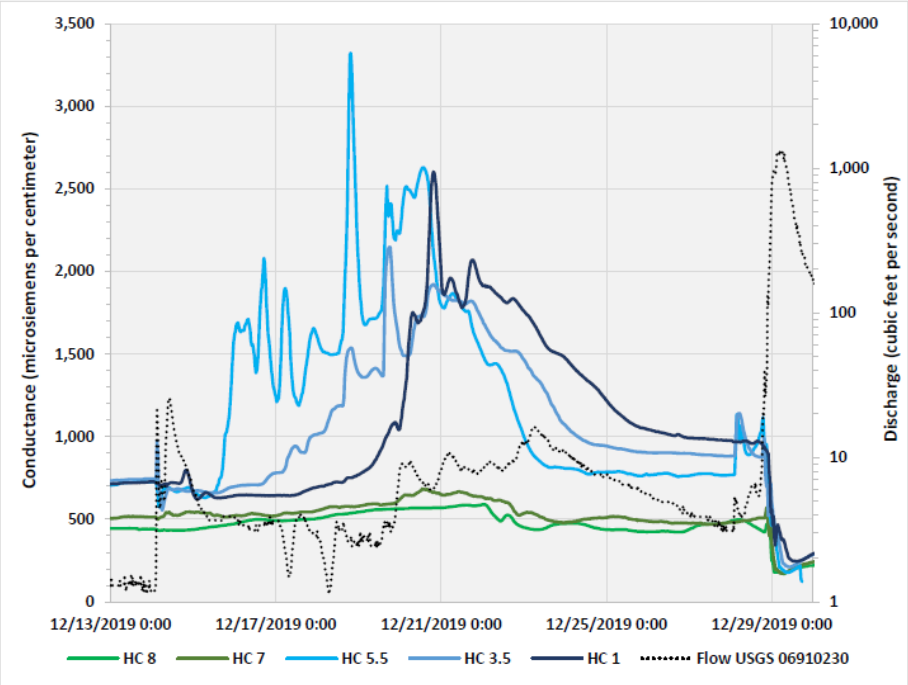


Figure 4. Hinkson Creek conductivity (left vertical axis) and discharge data (right vertical axis) over a 17-day period (horizontal axis). (Figure 6 from Geosyntec report Aquatic Macroinvertebrate Data Mining Report, 2020).



MU Hinkson Synoptic Sampling

The University of Missouri's Limnology Laboratory initiated a stream-wide monitoring project in June of 2018. Since that initial sampling, the lab has conducted eight more monitoring events. Each sampling event involves the collection of water samples and data from 29 to 45 sites on the Hinkson and its tributaries. Altogether, there have been 288 chloride measures made from 34 sites on Hinkson Creek. Individual values have ranged from 4 to 295 mg/L, with an average of 36 mg/L. One sample, collected in February 2019, exceeded the chronic toxicity level of 230 mg/L. Ten tributaries have been sampled 80 times in total, with a chloride range of 5 to 435 mg/L and an average of 52 mg/L. None of the samples had chloride levels that reached the acute criteria of 860 mg/L, and three samples exceeded the chronic criteria of 230 mg/L. Out of the ten tributaries, Flat Branch appears to be the largest chloride contributor.

The longitudinal pattern of median chloride concentrations across the stream is shown in Figure 5. The lowest levels are consistently found at sites located upstream from the landfill.

As site location approaches I-70, chloride levels begin to increase, and remain consistent from East Broadway to the confluence with Perche Creek.

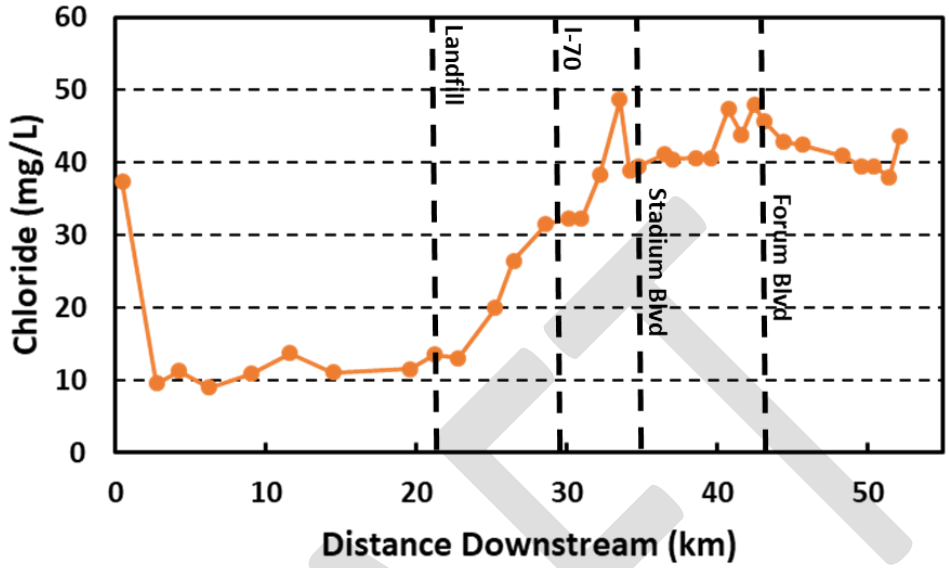


Figure 5. The median or middle chloride concentration (vertical axis) from each of the 34 sites along Hinkson Creek (horizontal axis).

Individual chloride values from all 34 Hinkson Creek sites during the nine monitoring events are shown in Figure 6. There can be a fair amount of variation in chloride concentrations at a given site depending on time of year and stream flow. Most sites (24 out of 27) had their maximum chloride level in June 2018, a non-winter sampling. Discharge on this date was 0.29 cubic feet ($ft^3$), by far the lowest flow of any of the sampling dates (range 0.29 – 718 $ft^3$, median = 19.5 $ft^3$).

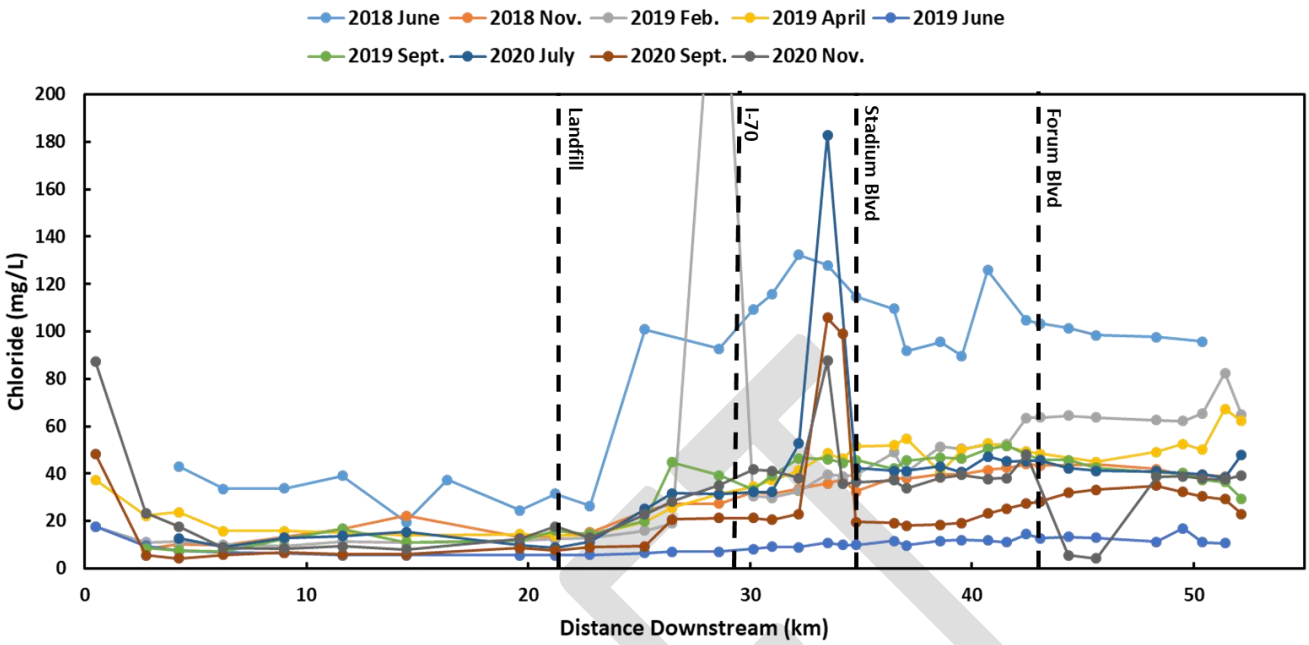


Figure 6. Chloride concentrations (vertical axis) at 34 sites along Hinkson Creek (horizontal axis) during nine monitoring events.

Along with chloride, conductivity was also measured on these samples. The relationship between these two parameters in the samples collected via the MU synoptic sampling is shown in Figure 7. Chloride concentrations are shown on the horizontal axis and conductivity on the vertical axis. Logarithmic scale is used for both parameters, in order to compress the wide-ranging data (chloride ranged 4 to 435 mg/L; conductivity ranged 136 to 2,140 µS/cm). There is an obvious positive relationship between these two parameters, with higher conductivity readings occurring when chloride concentrations are elevated.

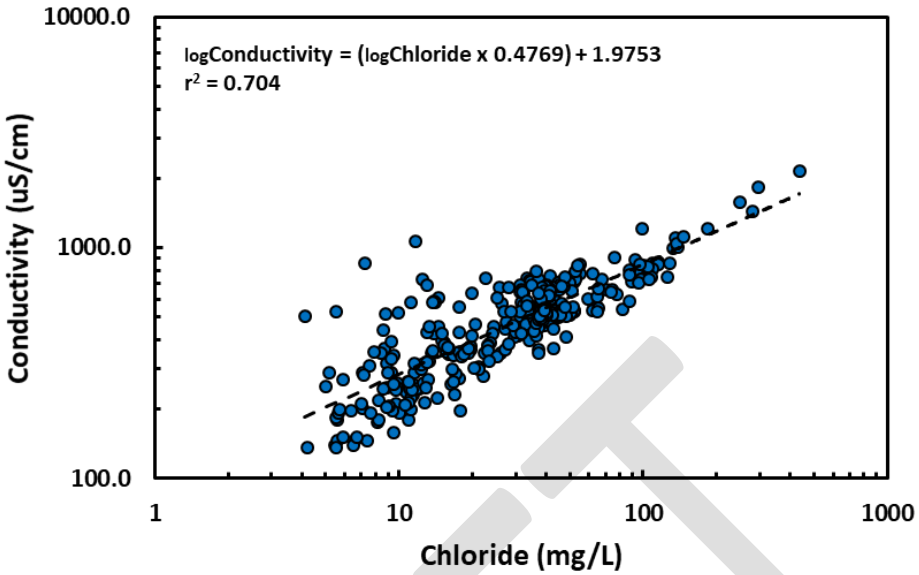


Figure 7. The relationship between conductivity measures and chloride concentrations in Hinkson Creek and its tributaries. Both scales are logarithmic, to help compress the wide-ranging data. Each symbol represents the chloride and conductivity values from individual samples and the dashed line shows the average relationship across the range of values.

**Discussion**

Studies by the Missouri Department of Natural Resources (2001-06 and 2012-17) found only one stream chloride value that exceeded the lower chronic toxicity level of 230 mg/L. It should be noted that these sampling efforts were often in conjunction with invertebrate monitoring or during times of normal flow in the creek, and therefore were not targeting expected periods of high chloride levels.

The nine storm/snowmelt runoff samples showed that inputs into Hinkson Creek could deliver notable amounts of chloride, with four of the samples having chloride concentrations in excess of 1000 mg/L. The sample with the highest chloride level (22,800 mg/L) was collected from the storm water drainage coming off the MoDOT maintenance facility to the north of the Broadway Market Place shopping complex.

One take away from the stream sample results is that chloride levels in the reference and control stream sites were lower, on average, than those measured in Hinkson Creek and its tributaries. Chloride levels at the up- and downstream sites on Hinkson Creek showed inconsistent results, with similar levels, on average, during the 2001-06 period. In contrast, during the 2012-17 period downstream sites averaged more than three times the concentration of chloride than upstream sites. These results are a little surprising given the MoDOT maintenance facility, which was located southwest of the I-70/Highway 63 interchange, was decommissioned during the period between these two studies. This facility stored de-icing

material and was a notable source of chloride to the creek. Again, the timing of sample collections may help explain why large differences in chloride were not found up- and downstream during the initial study.

The 2011 USGS study did target a period when high chloride levels should be expected. Values above both the chronic (230 mg/L) and acute (860 mg/L) toxicity levels were measured in two tributaries. Grindstone and Flat Branch were sampled one and two times, respectively. Due to the low number of samples collected, we do not know if elevated chloride concentrations were maintained long enough to be considered as a toxic event. Results from the laboratory experiment showed the high chloride levels in Flat Branch Creek did affect survival and reproductive success of the water flea being studied.

The Hubbart *et al*. study, which collected water samples four times a week over a four and a half year period found acute toxicity levels were reached on 18 occasions across three sites. Chronic toxicity levels were measured 350 times across four sites (Table 1). The results shown in Figure 3 suggest that chronic chloride levels may have been maintained for at least a four-day period at multiple sites during the winter of 2012-13.

Conductivity data from the Geosyntec study suggest that water quality can fluctuate greatly during the winter months in Hinkson Creek, with downstream sites showing higher maximum and average conductivity values.

The MU synoptic sampling targets many sites on Hinkson and its tributaries, but only on three occasions per year, on average. Only 1% of the samples collected through this effort exceeded the chronic toxicity criteria. The study highlights the spatial and temporal variability in water quality conditions across Hinkson Creek and points to a negative relationship between chloride concentrations and stream discharge, with higher chloride concentrations during low flow conditions.

An important result of this effort is the documentation of the positive relationship between chloride and conductivity. This information, when combined with the Geosyntec conductivity data collection effort during the winter of 2019-20 begin to provides us with a feel for how chloride levels might fluctuate on the short-term during winter. Based on the relationship between the two parameters, a chloride concentration of 230 mg/L would equate to a conductivity value of around 1,264 µS/cm, while 860 mg/L of chloride would equal a conductivity of 2,370 µS/cm. The Geosyntec study found conductivity values in excess of 2,000 µS/cm at the three downstream sites (Table 2).

**What We Know**

- Chloride concentrations in Hinkson Creek tend to be about four times higher than those measured in reference and control stream sites.
- Tributaries to Hinkson Creek have chloride concentrations that generally equal or exceed those in Hinkson Creek.
- While results vary from one study to the next, overall the Hinkson Creek sites located in the more urbanized portion of the watershed tend to have higher chloride concentrations than sites located upstream in the more rural portion of the watershed.
- Measured chloride concentrations in Hinkson Creek have exceeded both the chronic and acute toxicity criteria.
- Chloride concentrations show a strong relation to conductivity measures, which can be easily monitored on a more frequent basis than chloride.
- Frequent measures of conductivity during the winter of 2019-20 indicate high extreme conductivity values that can remain elevated for extended periods of time.

**What We Don't Know**

- How often do chloride concentrations that exceed the chronic criteria (230 mg/L) remain elevated for four or more days, thus constituting a toxic event?
- How often do extreme chloride concentrations that exceed the acute criteria (860 mg/L) remain elevated for longer than one hour, thus constituting a toxic event?
- Do chloride concentrations that are elevated above those found in reference streams, but below the chronic criteria, cause problems if maintained over the long-term?
- Are there other water quality parameters (sulfate, water hardness, temperature, etc.) that interact with chlorides to influence toxicity in Hinkson Creek?
- Chloride levels can be elevated outside of winter months – How big of an issue is this and what are the mechanisms that lead to these higher, non-winter, levels?
- What is the extent of the problem (how far upstream)?
- Should we monitor in an effort to identify "hot spots" for chloride?
- Are there sources other than wintertime salt applications to roadways, parking lots, and sidewalks that contribute to elevated chloride concentrations (fertilizers, dust control on gravel roads, leachate from the landfill)?
- What management practices can be adopted to reduce chloride applications within the watershed during winter while maintain the required level of public safety?
- Are there portions of the watershed where implementing management practices would result in maximum benefits to stream water quality?

- What is the best way to monitor chloride in order to determine the efficiency of management practices?
- What are other municipalities doing to address high chloride levels in urban streams?
- What is the persistence of chlorides in the watershed? How long will it take to see an effect from management practices?

**Potential Studies**

Salt Application Experiment – A study to investigate how various applications of de-icing materials influence chloride transmission into Hinkson Creek. The study would involve identifying areas within the watershed that have similar sizes and densities of impervious surfaces (roads, parking lots, etc.). Some of these areas would receive salt applications that follow the current guidelines, while other areas would receive alternative salt-applications. The alternative applications could include the use of brine instead of solid material, treatment with a non-salt product, or other practices that the state, county, city or university might consider. Alternative treatments would be implemented to a level that ensures that public safety is met. Monitoring of runoff would document the amount of chloride moving from the various treatment groups, with results determining if alternative treatments can aid in the reduction of chloride contamination of Hinkson Creek.