Appendix C: ORD Specific Conductance Memo

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Center for Environmental Measurement & Modeling
Watershed and Ecosystem Characterization Division
26 W Martin Luther King Drive • Cincinnati, OH 45268

OFFICE OF
RESEARCH AND DEVELOPMENT

March 15, 2022

MEMORANDUM

SUBJECT: Assessment of effects of increased ion concentrations in the St. Louis River Watershed with special attention to potential mining influence and the jurisdiction of the Fond du Lac Band of Lake Superior Chippewa

FROM: Susan Cormier, Senior Scientist
Office of Research and Development, Center for Environmental Measurement and Modeling,
Watershed and Ecosystem Characterization Division

THROUGH: Kevin Oshima, Director
Office of Research and Development, Center for Environmental Measurement and Modeling,
Watershed and Ecosystem Characterization Division

TO: Tera Fong, Director
Region 5, Water Division

In response to a request for scientific support to evaluate potential downstream impacts of the NorthMet Mine, USEPA Office of Research and Development is providing, for USEPA Region 5's use, a characterization of stream specific conductivity (SC) levels, least disturbed background SC, and SC levels that may exceed the Band's WQ criterion and adversely affect aquatic life, including brook trout (*Salvelinus fontinalis*), lake sturgeon (*Acipenser fulvescens*), and benthic macroinvertebrates.

cc: Dave Pfeifer

1. HIGHLIGHTS

1. An increase of the St. Louis River's annual average specific conductivity (SC) levels by 3.4 µS/cm upstream from the reservation is expected to cause the Band's WQ criterion of 300 µS/cm to be violated more frequently with concomitant impacts to aquatic life.
2. There is a 50% decrease in the probability of observing brook trout at 158 µS/cm SC in Minnesota which appear to be due to altered food resources. This level is already higher in much of the St. Louis River. Any additional loadings will further reduce brook trout occurrence.
3. Lake sturgeon have been reported in Minnesota streams and lakes at SC $\leq$ 310 µS/cm. Early life history requirements are not well known and like brook trout, reduced food resources may be the limiting factor for young sturgeon and survival may require SC well below the maximum reported SC for lake sturgeon.
4. Even if the proposed controls required by the wastewater discharge permit issued by Minnesota under section 402 of the Clean Water Act perform exactly as expected, the added dissolved ions will contribute to violations of the water quality criterion of 300 µS/cm within the boundaries of the Fond du Lac Reservation because as described in the NorthMet Mining Project and Land Exchange Final Environmental Impact Statement (EIS, 2015), the ionic inputs overall will increase with the establishment and operation of the mine.
5. To ensure that the Band's water quality criterion is not violated, explicit expectations of total loadings to the Embarrass and Partridge Rivers are needed that are less that what is described in the EIS.

2. EXECUTIVE SUMMARY

PolyMet Mining Corporation, Toronto, Canada has proposed an open pit mine to extract copper, nickel, and other metals. The proposed site is part of the Superior National Forest between Babbitt and Hoyt Lakes, Minnesota in the Northern Lakes and Forests Level III Ecoregion 50 (Omernik, 1987). The proposed NorthMet mining operation would join an existing inactive taconite mine/processing/tailings site (old plant site) with a new open pit mine site (proposed mine site) to be excavated within unmined national forest. Both areas are in the headwaters of the St. Louis River and its tributaries which flow into Lake Superior at Duluth, MN and Superior, WI. The old plant site would be converted to an operational ore processing plant and tailing-disposal site (proposed plant site) and transportation routes would be built or altered.

Section 401(a)(2) of the Clean Water Act (CWA) creates a process whereby states and tribes that may be affected by a federally permitted action in a different state or tribe requiring a water quality certification under Section 401 of the CWA may object to the permit if they determine that the certified discharge “will affect the quality of its waters so as to violate any of [its] water quality requirements.” In the case of PolyMet’s NorthMet project, the Fond du Lac Band of Lake Superior Chippewa (the Band) objected to the CWA Section 404 permit for the construction of the mine and requested a hearing before the Army Corps of Engineers (the Corps). At the hearing, the U.S. Environmental Protection Agency (USEPA) must present an evaluation of the objection and submit recommendations to the Corps on conditions to the CWA Section 404 permit (e.g., best management practices (BMP), monitoring and benchmarks, and mitigation techniques) that are necessary to ensure compliance with the applicable water quality (WQ) requirements of the Band, including those for total ions measured as specific conductivity (SC). Wastewater and stormwater discharges resulting from the construction and operation of the mine are covered by separate wastewater discharge permits issued by the State of Minnesota.

USEPA Office of Research and Development (ORD) is providing, for USEPA Region 5’s use, a characterization of stream SC levels, least disturbed background SC, and SC levels that may exceed the Band’s WQ criterion and adversely affect aquatic life, including brook trout (*Salvelinus fontinalis*), lake sturgeon (*Acipenser fulvescens*), and benthic macroinvertebrates. The results of analyses provided by ORD relate to an assessment area that includes the proposed mine site and proposed plant site and areas downstream along the St. Louis River to Lake Superior, including reservation lands of the Band. In response to the concerns of the Band, the analyses focus on water quality from river mile (RM) 99, through the reservation and to the outskirts of Duluth, MN.

Multiple pieces of evidence indicate that low background SC levels occur in the area. Our review confirmed that least disturbed background SC levels (55 µS/cm) measured between 1975-1977 still occur in the area studied by the Minnesota Environmental Quality Board (MEQB, 1979). Results from data between 1996 and 2021 from the Water Quality Portal (WQP) (USEPA and USGS, 2021) were similar. In the St. Louis River watershed, we estimated the median least disturbed background at 76 µS/cm with an interquartile range of 56 to 102 µS/cm. Other independent data sets and methods were considered, including a legacy USEPA probability data set (Griffith, 2014) and data from the Minnesota Pollution Control Agency (MPCA). Effluent and run-off from the proposed operation will be greater than current background levels in the area of the NorthMet project.

For the purposes of these analyses, it is assumed that all current sources that contribute dissolved mineral loading that are not within the proposed mine complex would continue to contribute with no net change in SC loadings. At the plant site and at the proposed mine site, the plan is to capture and treat the high SC discharges by reverse osmosis (RO) or similar technology during mine development and operation. If successfully implemented, loadings from the proposed plant site could be less than at present after a few years of operation, a potential net decrease.

However, at the proposed mine site, loadings are expected to be greater because, although treated water may be maintained below MPCA benchmarks to protect aquatic life (329 µS/cm annual average) (MPCA, 2020), this SC level is greater than current water quality in parts of the Partridge River and Embarrass Rivers by about 260 µS/cm. To maintain the status quo, if the RO treatment standard of operation is to attain effluent not to exceed 329 µS/cm on average, then additional reductions in loadings from the plant site would be needed to compensate for the increases from the transportation corridors and from the proposed mine site's treated effluent. Also, it is unclear what the effluent will contain and the mine operator's expectations for a SC limit may be much greater. The NorthMet Mining Project and Land Exchange Final Environmental Impact Statement (EIS, 2015) lists limits of 500 and 700 mg/L total dissolved solids (TDS). Depending on the exact ionic mixture, these TDS limits are approximately 800 µS/cm and 1200 µS/cm, far in excess of the newer MPCA recommended benchmarks of 329 µS/cm. The EIS also includes estimates of sulfate and chloride ground water evaluation criteria (250 mg/L) that are about 50-times greater than background concentrations in the Partridge River. To ensure that SC meets the Band's WQC, the SC effluent from the proposed mine site and transportation corridor needs to be at current SC levels and/or there needs to be greater mitigation at the plant site.

With additional loadings and less dilution from the upper St. Louis River Watershed that will result from the mine's development, the elevated SC loads from mining-influenced watersheds in the Mesabi Range will have a greater influence and will further raise the SC of the St. Louis River below its confluence with the Partridge River. SC already exceeds 300 µS/cm as an annual average during some years in the St. Louis River near and within the Reservation. In sum, even if the proposed controls required by the CWA Section 402 permit perform exactly as expected, the dissolved ions concentration will be higher in the St. Louis River than current conditions. The St. Louis River is likely to violate the water quality criterion of 300 µS/cm at the Fond du Lac Reservation. Therefore, these facts indicate that the Band's assertion that the mine will cause violations of their SC water quality criterion is reasonable.

The water quality standard adopted for the protection of aquatic life by the Band is well supported by many independent studies and if maintained would protect 95% of aquatic macroinvertebrate species from extirpation. However, declines in abundance would occur at SC levels lower than 300 µS/cm (USEPA, 2011). If highly salt-intolerant species of local or cultural interest are to be protected, a threshold lower than 300 µS/cm may be required. For example, macroinvertebrates serve as food sources for brook trout and lake sturgeon and are otherwise essential aquatic-ecosystem components. The Band's concern that increases in SC will affect aquatic life is reasonable.

Both lake sturgeon and brook trout, as well as the benthic invertebrates upon which they feed, require low conductivity water for naturally sustained populations. Among the most adverse effects is extirpation; the loss of a taxon where it is expected to occur or has occurred in the past. In this memo, extirpation is operationally defined as the point above which only 5% of the observations of a genus or species occurs. A less adverse effect is a 50% probability of observing a species. Based on MPCA data in Minnesota, the probability of observing brook trout decreases to 50% at 158 µS/cm SC. Extirpation of brook trout is estimated to occur at ≥ 492 µS/cm. Among the 20 stations where lake sturgeon are reported in the MPCA (1996-2013) data set, the maximum observed SC was 310 µS/cm. Like brook trout, lake sturgeon are likely to be less stressed in water less than their maximum tolerance level, i.e., substantially less than 310 µS/cm. If the St. Louis River ionic levels increase, the downstream tributaries may not be able to dilute the water to sustain these fisheries in St. Louis River watershed or the newly restored lake sturgeon spawning area below the Fond du Lac Dam (RM 21.3) in the St. Louis River freshwater estuary.

If mining activity increases the St. Louis River annual average SC levels by an additional 37.9 µS/cm or 71.2 µS/cm upstream from the reservation, we estimated from a quantile linear regression model that 50% or 100%, respectively, of the St. Louis River within the reservation's jurisdiction would exceed the 300 µS/cm as an annual average criterion during some years with concomitant impacts to aquatic life. However, even if the facility is in compliance with the water quality conditions contained in the NPDES permits, the disturbance of vegetation and increased exposure of soil and unweathered waste rock due to the activities authorized by the CWA 404 permit to construct the mine will also raise the ionic concentration. Consequently, loadings will increase and the capacity to dilute the dissolved mineral loading of the St. Louis River would be lessened resulting in increased violations of the Band's water quality criteria.

The potential for the watershed to dilute the ionic loading without exceeding 300 µS/cm in the St. Louis River at the Reservation Boundary needs a more precise estimates of loadings and dilution capacity. Also, current and future ionic loadings in the Embarrass and Partridge River watersheds need to be explicitly described. Additional water quality surveys and monitoring would be needed to augment data collected as part of the EIS (2015). A subwatershed total maximum daily load assessment may suggest engineering controls to balance changes in loadings due to the development of the proposed mine. Timing and rate of releases that coincide with highest flows may be needed to achieve a plan that does not violate the Band's water quality criterion. Daily monitoring would be needed to ensure that mine related loads to the St. Louis River do not raise the SC level and cause violations of SC criteria on the Reservation.

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3. INTRODUCTION

PolyMet Mining Corporation, Toronto, Canada has proposed the NorthMet Project, an open pit mine to extract copper, nickel, and other metals (Figures 1 and 2). The proposed mine site is part of the Superior National Forest between Babbitt and Hoyt Lakes, Minnesota in the Northern Lakes and Forests Level III Ecoregion 50 (Omernik, 1987). The proposed mining operation would join an existing inactive taconite mine/processing/tailings site (old plant site) and a new proposed open pit mine site (proposed mine site) in what is currently unmined national forest in the headwaters of the St. Louis River and its tributaries which flow into Lake Superior at Duluth, MN and Superior, WI (Figure 2, Figure A-1). The old plant site would be converted to an operational ore processing plant and tailing-disposal site (proposed plant site).

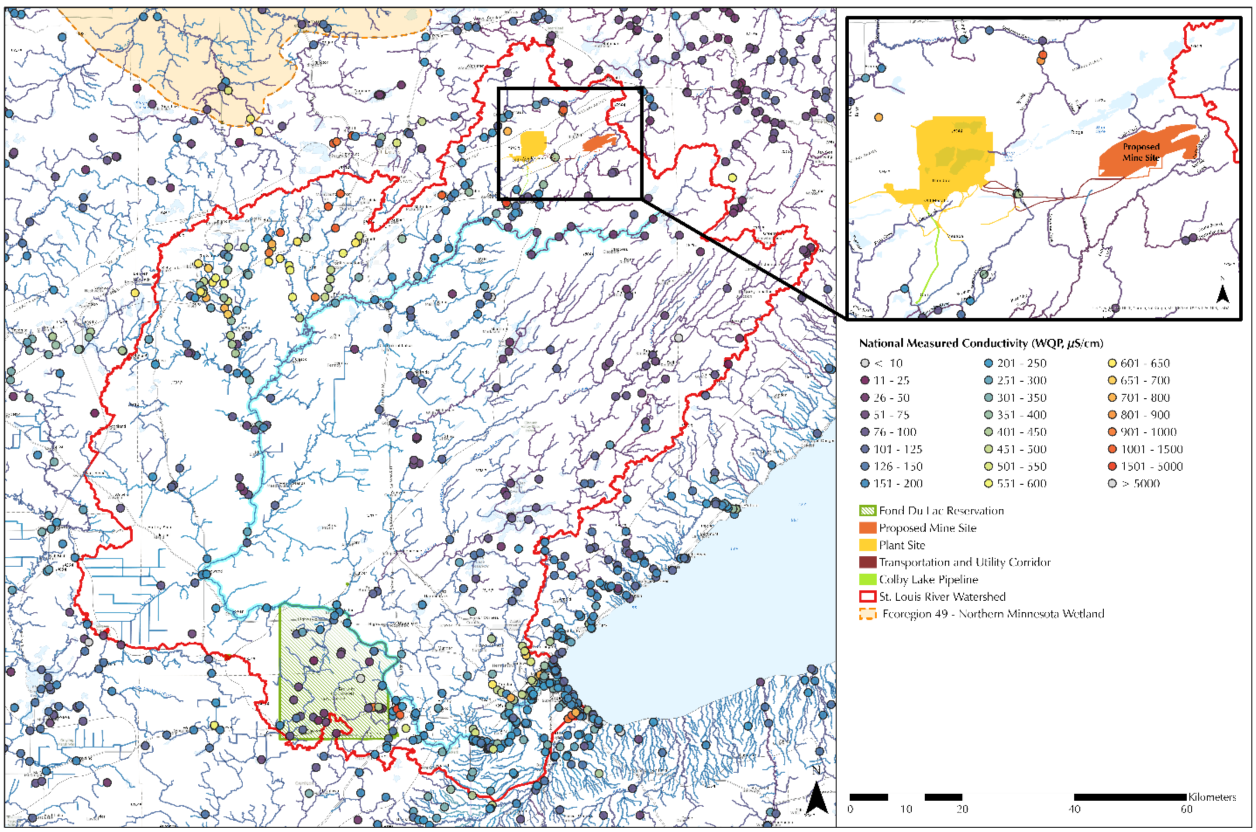

Figure 1. Proposed area of NorthMet Project relative to the Fond du Lac Reservation within the St. Louis River watershed. Median measured specific conductivity (SC) shown on stream network in Ecoregion 50 Minnesota. Station circles: violet (11-100 µS/cm), blue to green (101-300 µS/cm), green (300-550 µS/cm), yellow to orange (550-1500 µS/cm), red (>1500 µS/cm). Mining region forms a red-yellow cluster of higher SC stations toward the center of the map which includes the NorthMet Project area in the northern portion of the watershed. NorthMet project (upper black rectangle and enlarged inset) is located in the northern part of the St. Louis River (aqua line) watershed (central area outlined in red). The reservation is highlighted in green in the south. *Source:* ***Freshwater Explorer***

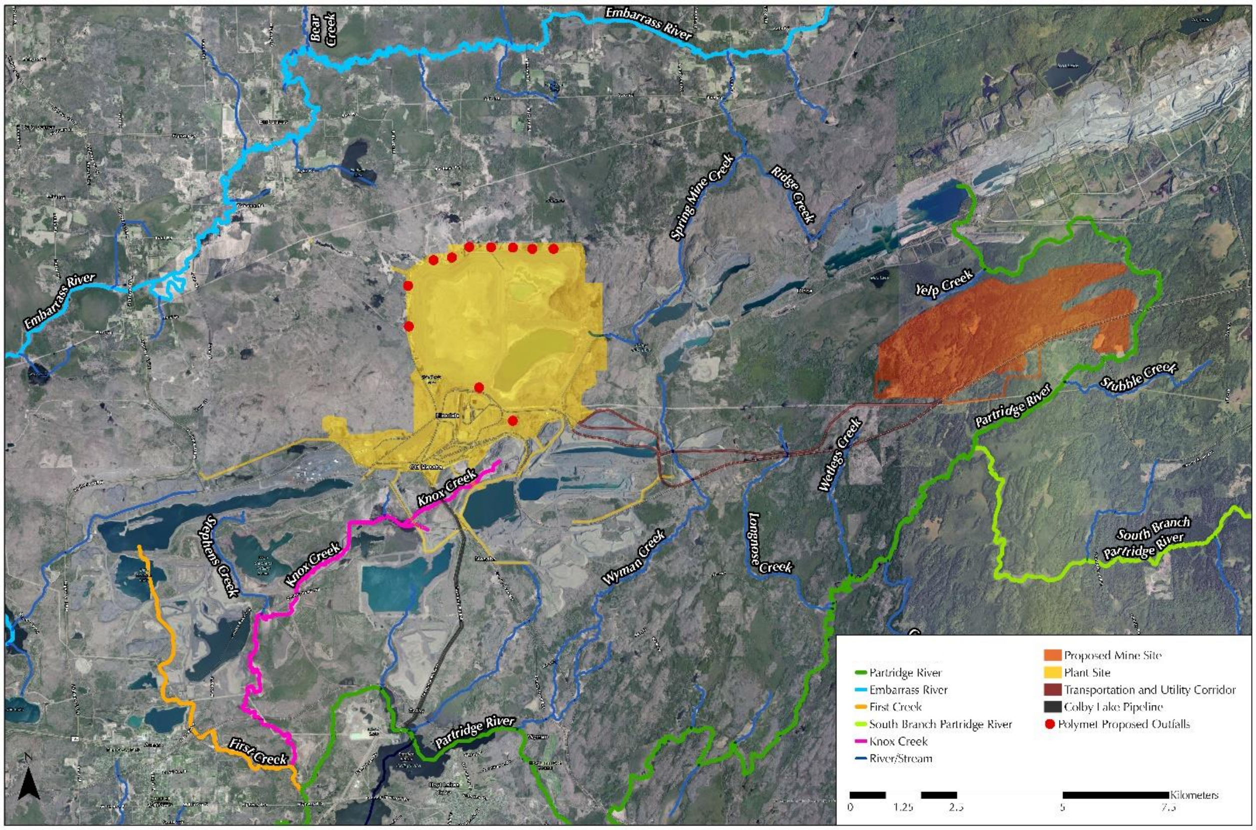

Figure 2. NorthMet project. Ore would be removed from an open pit mine at the proposed mine site in the east (reddish polygon). The ore would be processed in the plant site and tailings would be deposited in the existing old plant site (abandoned taconite mine, ore processing and disposal site) (yellow polygon). Transportation route is shown as brown line. The green hydro line around the proposed mine site is a low conductivity section of the Partridge River. The pink and orange hydro lines are high conductivity draining southwest from the old plant site are a tributary to First Creek and the Partridge River.

Section 401(a)(2) of the Clean Water Act (CWA) creates a process whereby states and tribes affected by a federally permitted action in another state requiring a water quality certification under Section 401 of the CWA may object to the permit if they determine that the certified discharge "will affect the quality of its waters so as to violate any of [its] water quality requirements." In the case of PolyMet's NorthMet project, the Fond du Lac Band of Lake Superior Chippewa (the Band) objected to the CWA Section 404 permit for the construction of the mine and requested a hearing before the Army Corps of Engineers (the Corps). At the hearing, the U.S. Environmental Protection Agency (USEPA) must present an evaluation of the objection and submit recommendations to the Corps on conditions to the CWA Section 404 permit (e.g., best management practices (BMP), monitoring and benchmarks, and mitigation techniques) that are necessary to ensure compliance with the applicable water quality (WQ) requirements of the Band, including those for total ions measured as specific conductivity (SC). USEPA Office of Research and Development (ORD) is providing, for USEPA Region 5's use, estimates of background SC, stream SC levels relative to the Band's SC WQ criterion, and SC levels causing biological effects. The results of analyses provided by ORD relate to an assessment area that includes the proposed mine site, old and proposed plant sites (i.e., processing and disposal site) and downstream via the St. Louis River to Duluth, MN, including reservation lands of the Band.

This assessment is primarily focused on potential impacts to the Band where the St. Louis River flows within the jurisdiction of its reservation at the southeastern drainage of the St. Louis River (Figure 1).

4. STUDY AREA AND DATA SETS

4.1. STUDY AREA

The proposed mine site and surface drainage lie within the Northern Lakes and Forests Level III Ecoregion 50, North America Level III Ecoregion 5.2.1 *(https://www.epa.gov/eco-research/ecoregions*), which includes parts of the Mesabi Range (50m), Glacial Lakes Upham and Aitken (50o), and Toimi Drumlins (50p). The southern portion of the St. Louis River then crosses into the Minnesota/Wisconsin Upland Till Plain (50b) and Lake Superior Clay Plain (50a) where it flows into a freshwater estuary of Lake Superior between Duluth, MN and Superior, WI. The Fond du Lac Reservation lies south on the St. Louis River between river miles (RM) 39 and 62 (Figure 1). A restored spawning area for lake sturgeon is located below the Fond du Lac Dam at RM 21.3 on the St. Louis River. Wild rice resources occur throughout the watershed, which are also of economic and cultural significance to the Band. The Minnesota Pollution Control Agency (MPCA) describes the Northern Lakes and Forests Ecoregion as being heavily forested with steep, rolling hills interspersed with wetlands, bogs, lakes, and ponds. Abundant gamefish reside in the deep, clear lakes (MPCA, 2022).

4.2. DATA SETS

Data for the analyses described in this memo, were obtained from the Water Quality Portal (WQP), the Minnesota Pollution control Agency (MPCA), the Freshwater Explorer (Cormier et al., 2021), and published works. Data were collected for a variety of objectives including targeted sampling and statistically designed surveys. Because sampling designs differ, reported values are not proportional to the number or length of streams in the watershed and represent summary statistics of the available data. To reduce bias from unequal repeat sampling within and across years, station means were calculated using all measurements from stations at the same geographical location (same common identifier of an NHD Flowline, COMID). Note that SC is determined by major ions but the ionic mixture from the proposed mine site and from other mine sites would include other, more toxic ions, such as the product metals. Characterizations in this report are best-case scenarios based on SC alone; a more complete assessment is recommended that considers other significant contaminants that contribute to cumulative toxicity.

4.2.1. Thingvold et al. (1975-1977)

Data were considered from *The Minnesota Regional Copper-Nickel Study* (MEQB, 1979, Thingvold et al., 1979). Thingvold et al., (1979) sampled 32 stream stations (N = 463) and 35 lake stations (N = 141) in the upper St. Louis River basin between 1975-1977. The intent of their report was to set a baseline prior to development in the copper-nickel study area which is co-located with the proposed NorthMet Project mine area. We used these data to make comparisons with more recent data to determine if the SC regime had changed in the last 50 years. We also used the information to characterize SC levels and ionic composition in the upper St. Louis River watershed.

4.2.2. Griffith (1998-2009)

Ecoregional data were considered from secondary sources. Griffith (2014) reported summary statistics from surveys that used probability sampling designs between 1985 and 2009 throughout the United States. Griffith's intent was to characterize ion concentrations for the contiguous 48 states. Data from this report were obtained from Michael Griffith of the USEPA, reanalyzed, and reported in Cormier et al. (2018b). Data for Ecoregion 50, which includes the St. Louis River watershed, were used as an independent estimate for least disturbed background SC and ionic composition. Data is available from the USEPA Environmental Dataset Gateway from this link.

4.2.3. Water Quality Portal (1996-2021)

Data were downloaded from the WQP website (https://www.waterqualitydata.us/) using the following query criteria: Country - United States, Sample Media – Water, Characteristics - Conductivity, Specific Conductivity, Specific Conductance, Calculated/Measured Ratio, Date range - 1 January 2000 to 20 July 2021. Data were processed to remove SC values ≤ 0 and SC values reported with units different from Siemens or mho because these were considered ambiguous (e.g., SC reported as nephelometric turbidity units, degrees, etc.). To enable direct comparisons, all relevant values were converted to µS/cm. Although values < 10 µS/cm have been reliably reported for the St. Louis River (see MEQB, 1979, Thingvold et al., 1979), outlier values < 10 µS/cm were removed to reduce potential influence of potential data management errors. Data extraction and clean-up procedures are described in the metadata of the Freshwater Explorer and data can be downloaded from the application metadata (Wharton, 2021). WQP (1996-2021) data were used to characterize observed SC of streams in Ecoregion 50 within Minnesota and in parts of the St. Louis River watershed. Station distribution is shown in Figure 1.

4.2.4. Water Quality Portal Least disturbed (1996-2021)

Using StreamCat derived watershed and catchment scale landscape metrics (Hill et al., 2016), 169 least disturbed stations in Ecoregion 50 in Minnesota were identified from the WQP (1996-2021) (Figure 3). The Ecoregion 50 spatial coverage was constrained to avoid areas affected by mining in the Mesabi Range. Least disturbed stations were identified using the following selection criteria: WQP least disturbed: Percent Natural Cover Catchment > 95%, Road Density Catchment and Watershed < 0.5 km/km2, Canal/Ditch Density Catchment and Watershed < 0.1 km/km^2, Percent Impervious Surface Catchment and Watershed < 1%, and Distance from Mesabi Range > 500m (Data set: Table A-1). This filtered data set was used to characterize least disturbed SC of Ecoregion 50 within Minnesota and the St. Louis River watershed and mainstem. This land-use screen without additional ground-truthing may include streams with ionic inputs that do not represent least disturbed background. Nonetheless, the data provide a consistent characterization of least disturbed SC levels and a useful visualization of the patterns of least disturbed background across the region.

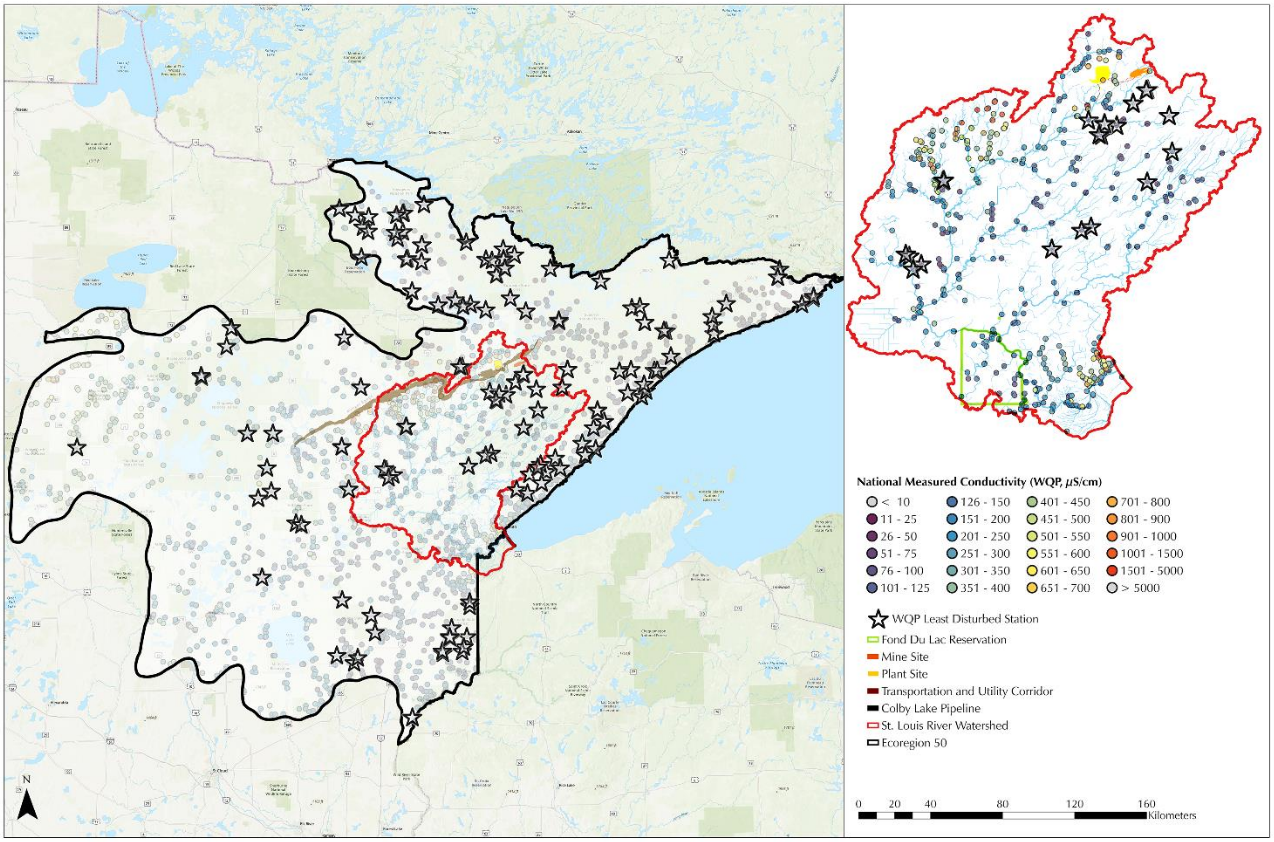

Figure 3. Water Quality Portal (WQP) 1996-2021 stations. Sampling locations in Ecoregion 50 (black outline) and within the St. Louis watershed (red outline) in eastern portion of the ecoregion (gray dots). Least disturbed stations are shown as stars. Mesabi range shown as oblique line in northwest portion of watershed. WQP least disturbed selection criteria: Percent Natural Cover Catchment > 95%, Road Density Catchment and Watershed < 0.5 km/km2, Canal/Ditch Density Catchment and Watershed < 0.1 km/km2, Percent Impervious Surface Catchment and Watershed < 1%, Distance from Mesabi Range > 500m. (*Source: WQP (1996-2021)).*

4.2.5. Minnesota Pollution Control Agency (MPCA) (1996-2013)

MPCA provided data between 1996-2013 collected in all regions of Minnesota. These data were used to characterize ionic composition and to estimate the levels of SC that would either reduce the probability of observing brook trout or are likely to extirpate brook trout from a stream. Analyses and results with these data are referred to as MPCA 1996-2013. For water chemistry characterization, a total of 560 stations and 12667 samples were used as a final statewide dataset (Figure 4). The data set was unfiltered and used as received from the MPCA. MPCA data were also used in previous reports to characterize extirpation of aquatic benthic invertebrates (Cormier et al., 2018b, Cormier et al., 2020).

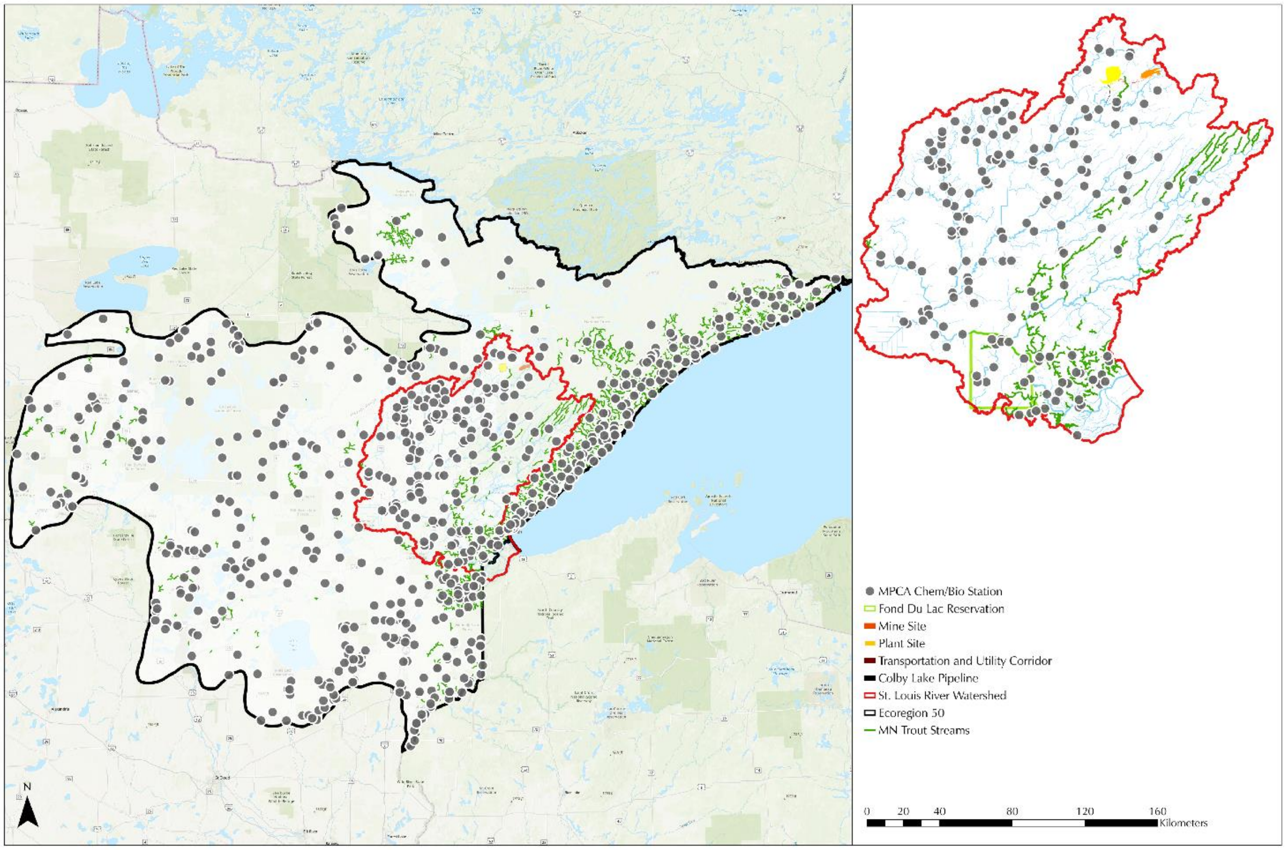

Figure 4. Minnesota Pollution Control Agency (MPCA) (1996-2013). These data contain both biological and chemical data and were used to estimate brook trout SC XC95 values.

4.2.6. Mid-Atlantic Highlands (1990 to 2014)

The Mid-Atlantic Highlands (1990-2014) data set includes four contiguous mid-Atlantic Highlands Level III ecoregions: 67 (Ridge and Valley), 68 (Southwestern Appalachians), 69 (Central Appalachians), and 70 (Western Allegheny Plateau) (Omernik 1987). Water chemistry data included a total of 3277 stations (6.0 > pH < 9.5) (Griffith, 2014). As a validation of the MPCA estimate, these data along with brook trout occurrences were used to estimate effects of increasing levels of SC on brook trout (Griffith et al., 2018).

5. ANALYSES AND RESULTS

5.1. MAJOR ION CHARACTERIZATION

For streams in Ecoregion 50, the ionic mixtures in the MPCA data set are dominated by bicarbonate and sulfate anions and calcium and magnesium cations (Table 1). Chloride did not exceed bicarbonate plus sulfate on a mass basis at any station, that is, for all stations ($[HCO_3^-]$ +

[SO_4^{2-}])/[Cl^-] > 1. For 9.3% of the stations, the concentration of sodium ions exceeded calcium plus magnesium concentrations on a mass basis ([Ca^{2+}] + [Mg^{2+}])/[Na^+] < 1). This finding is consistent with dominant ions reported by Griffith (2014) for Ecoregion 50 (including Minnesota, Wisconsin, and Michigan) (Table 2) and by Hem (1985) for the entire country.

The Minnesota Regional Copper-Nickel Study included the Partridge River and St. Louis River and other rivers in the vicinity (MEQB, 1979, Thingvold et al., 1979). Thingvold et al. (1979 also reported an ionic mixture dominated by calcium and bicarbonate for low SC streams and calcium and sulfate for high SC streams (Thingvold et al., 1979, Table 58, p 91-92). However, in Table 49 on page 73 of Thingvold et al. (1979), the Dunka mine site effluent appeared to be dominated by $CaCl_2$. In deeper wells, sodium was often greater than calcium cations in ground water with higher conductivity, but anions were not reported for most wells (Table 45 page 68). In the EIS (2015), higher NaCl is also related to depth and is believed to be due to evaporation of seawater rather than any particular rock strata (Bottomley, 1996 and Morton and Ameel, 1985 as cited in EIS, 2015) Additional data should be obtained to evaluate the ionic composition of likely effluent mixtures of major ions predicted to result from the PolyMet mine because these mixtures may be more toxic than other ionic mixtures that are common in the region (Mount et al., 2016; Erickson et al., 2017). Also, heavy metal ions are likely to be present and are more toxic than the major ions.

Table 1. Summary statistics of annual mean water chemistry parameters for Ecoregion 50 from the MPCA data set (MPCA 1996-2013)

Parameter	*N* station	*N* sample	Geo mean	Min	10th centile	25th centile	50th centile	75th centile	95th centile	Max
Specific conductivity (µS/cm, 25ºC)	560	560	198	23	78	124	212	317	572	1458
Dissolved oxygen (mg/L)	537	537	7.8	0.1	5.3	7.1	8.7	10.0	11.4	15.3
pH (SU)	549	549	7.5	5.6	6.9	7.2	7.6	7. 9	8.2	8.6
Temperature, water (ºC)	664	664	14.1	1.2	10.0	12.3	14.7	17.8	21.4	25
Chloride (mg/L)	262	262	5.26	0.63	1.43	2.22	4.14	9.98	72.85	204.18
Sulfate (mg/L)	200	200	9.58	1.09	2.28	3.23	5.93	24.10	118.47	1100
Alkalinity (mg/L)	147	147	71.83	8.86	26.40	47.00	72.33	125.46	226.78	363.33
Bicarbonate (mg/L)	147	147	87.73	10.81	32.21	57.34	88.26	153.06	276.74	443.27
Calcium (mg/L)	100	100	21.15	4.40	7.97	14.61	22.14	32.70	48.49	270
Magnesium (mg/L)	98	98	10.02	2.06	3.08	4.92	10.26	16.45	44.96	530
Sodium (mg/L)	45	45	7.09	1.12	1.42	2.16	5.33	19.13	52.00	156
Iron (mg/L) (dissolved)	4	4	5.97	2.44	3.18	4.29	7.39	10.10	10.63	10.76
Mercury (ng/L) (total)	27	27	2.1	0.5	0.8	1.1	1.9	4.2	6.9	8.3
Copper (µg/L) (dissolved)	21	21	0.63	0.12	0.17	0.33	0.89	1.26	2.24	2.81
Aluminum (µg/L) (dissolved)	9	9	194.8	9.93	22.84	63.0	395.3	495.0	915.4	943
($[HCO_3^-]$ + $[SO_4^{2-}]$)/$[Cl^-]$	60	60	15.70	1.14	5.16	11.08	17.61	25.81	68.52	151.55
($[Ca^{2+}]$ + $[Mg^{2+}]$) /$[Na^+]$.	43	43	4.04	0.26	1.71	2.65	4.35	6.25	12.20	12.95

[a]HCO_3^- converted from alkalinity by multiplying by 1.22. Where pH was also measured HCO_3^- was estimated using USGS (2012). SU = standard units. (*Source: MPCA 1996-2013)*.

Table 2. Summary statistics for anion and cation ratios for Ecoregion 50 in Minnesota, Wisconsin, and Michigan from a probability sampling design (Griffith, 2014).

N	**mean**	**min**	**10^{th} centile**	**25^{th} centile**	**50^{th} centile**	**75^{th} centile**	**max**	**Proportion of samples > 1**
Anion Ratios ($[HCO_3^-] + [SO_4^{2-}]$) / $[Cl^-]$								
27	127.34	26.07	36.11	66.06	116.97	177.23	279.23	1.00
Cation Ratios ($[Ca^{2+}] + [Mg^{2+}]$) / $[Na^+]$.								
64	7.84	1.23	2.58	4.77	6.65	9.42	36.08	1.00

Source: Griffith, 2014

Elevated ionic mixtures are known to be toxic to freshwater fish and benthic invertebrates (Griffith, 2017, Cormier et al., 2011). Characterization of the ion mixtures may suggest means to reduce toxicity and may guide permit levels or control technologies. Furthermore, Thingvold et al. (1979, p. 74) recommended causal/source assessments stating: “If future mining operations are located in watersheds affected by existing sources, then more detailed source monitoring should be performed to adequately separate potential impacts due to existing sources from impacts attributed to new sources.” This recommendation from 40 years ago remains relevant to this day.

5.2. BACKGROUND SPECIFIC CONDUCTIVITY

Background was estimated from measured data available from several sources. Conventionally, the 75^{th} centile of measurements from least disturbed stations or the 10^{th} or 25^{th} centile of regional measurements are often used as the upper bound to estimate least disturbed background from measured data (USEPA, 2000a, Herlihy and Sifneos, 2008, Stoddard et al., 2007). However, background may vary substantially from headwaters to downstream areas, from more pristine to least disturbed sites, and over broad spatial areas such as an ecoregions or large watersheds. Therefore, a single value or threshold-type value for background is not used here. Instead, we provide the median and upper and lower quartiles of each dataset distribution.

5.2.1. MPCA (1996-2013)

The MPCA data set consists of 12,667 daily SC samples and 1,409 annual SC samples from 560 stations (Figure). To reduce bias from repeat sampling within and across years at some stations, means were calculated using all measurements from stations with the same geographical location (same COMID). For this mixed data set in Ecoregion 50, the 50^{th} centile SC was 212 µS/cm with an interquartile range of 124 to 317 µS/cm (Table 3). The St. Louis River watershed’s

50th and 75th centile SC values are greater than in the ecoregion, possibly indicative of anthropogenic alteration in the watershed in the Mesabi Range (Figures 1 and 3). The St. Louis River mainstem's 50th centile SC is less than in the ecoregion or watershed, which possibly reflects the substantial dilution by lower SC tributaries in the eastern portion of the watershed (Table 3).

Table 3. Summary statistics of specific conductivity site annual means for Ecoregion 50 and St. Louis River watershed and mainstem (*Source: WQP and WQP least disturbed 1996-2021; MPCA 1996-2013).*

Type	**Min**	**10th centile**	**25th centile**	**50th centile**	**75th centile**	**95th centile**	**Max**	**Mean of means**	**Geo Mean**	***N* Station**
Ecoregion 50										
MPCA	23	78.	124	212	317	572	1458	250	198	560
WQP	12	63	105	177	292	558	4375	228	172	2472
WQP Least disturbed[a]	20	33	49	75	144	245	333	101	80	169
St. Louis River watershed										
MPCA	41	98	135	242	460	738	1458	321	245	184
WQP	28	78	116	211	390	827	1673	300	217	537
WQP Least disturbed	39	46	56	76	102	123	137	79	74	29
St. Louis River mainstem										
MPCA	126	135	140	182	221	336	360	198	189	20
WQP	46	54	138	193	243	377	548	198	166	80
WQP Least disturbed	44	46	51	59	63	70	75	58	57	11

[a]WQP least disturbed: Percent Natural Cover Catchment > 95%, Road Density Catchment and Watershed < 0.5 km/km^2, Canal/Ditch Density Catchment and Watershed < 0.1 km/km^2, Percent Impervious Surface Catchment and Watershed < 1%, Distance from Mesabi Range > 500m.

5.2.2. WQP (1996-2021)

The WQP data set consists of 32,921 daily SC samples and 5,536 annual SC samples from 2,472 stations (Figure Table 3), therefore, bias from repeat sampling was reduced by using the mean for a station. For this mixed data set in Ecoregion 50, the 50th centile SC was 177 µS/cm with an interquartile range of 105 to 292 µS/cm. Within the St. Louis River watershed, the 50th centile SC was 211 µS/cm with an interquartile range of 116 to 390 µS/cm. The St. Louis River watershed's 50th centile SC is greater than in the ecoregion, indicative of anthropogenic alteration in the watershed from the Mesabi mining district (Figures 1 and 3). The St. Louis River mainstem's 50^{th} centile SC is also greater than in the ecoregion but less than in the watershed.

After 1997 in the St. Louis River, the maximum one-time SC measurement upstream of the reservation was 632 µS/cm. The St. Louis River watershed one-time maximum of 2,462 µS/cm was reported in the Partridge River, a tributary to the St. Louis River watershed.

5.2.3. WQP Least disturbed (1996-2021)

The WQP least disturbed data set consists of 853 SC samples from 169 stations in multiple station (**Error! Reference source not found.**, Table 3). For this least disturbed sub-data set in E coregion 50, the 50^{th} centile SC is 75 µS/cm with an interquartile range of 49 to 144 µS/cm (N = 169). In the least disturbed St. Louis River watershed, the 50^{th} centile SC is 76 µS/cm with an interquartile range of 56 to 102 µS/cm (N = 29). The St. Louis River watershed's 50^{th} centile SC least disturbed background is less than in the ecoregion indicative of natural variation in background SC for the ecoregion with more and lower SC least disturbed stations in the north and eastern part of the ecoregion. In the St. Louis River mainstem, the 50^{th} centile is 59 µS/cm with a range interquartile range of 51 to 63 µS/cm (N = 11). The median least disturbed background SC were within 17 µS/cm in Ecoregion 50, the St. Louis River watershed, and the St. Louis River mainstem with 50^{th} centiles of 75, 76, and 59, respectively.

5.2.4. Griffith (1998-2009)

Water chemistry analyses were published in 2014 by Griffith for the entire Ecoregion 50 extending from northeastern Minnesota through Wisconsin and into northern Michigan. These published results were generated from data sets compiled from several USEPA surveys that used probability-based sampling designs (Griffith, 2014). The 25^{th} centile SC for that data set in Level III Ecoregion 50 was 111 µS/cm (N = 151) which is close to the 25^{th} centile of WQP mixed data set (105 µS/cm) that includes data from MPCA and probability-based USEPA National Rivers and Stream Assessment data.

5.2.5. Thingvold (1975-1977)

For comparison, **Error! Reference source not found.** contains values from the MEQB (1979), which were collected between 1975 and 1977 (Thingvold et al., 1979). This earlier sampling effort was confined to an area of interest consisting of 14 watersheds, including the Partridge and Embarrass Rivers near the proposed NorthMet project area and mine site. "Group C stations are considered to be representative of relatively undisturbed watersheds for this area of northeastern Minnesota and can be considered indicative of background levels" (Thingvold et al., 1979). The median stream SC for Group C is reported as 55 µS/cm (Table 2). Johnson and Johnson (2015) report a median of 68 µS/cm for all 463 Copper-Nickel Study samples (including impacted streams) using data collected during the same time-period. These values are consistent with samples in the St. Louis River and Partridge River 1st and 2nd order streams (

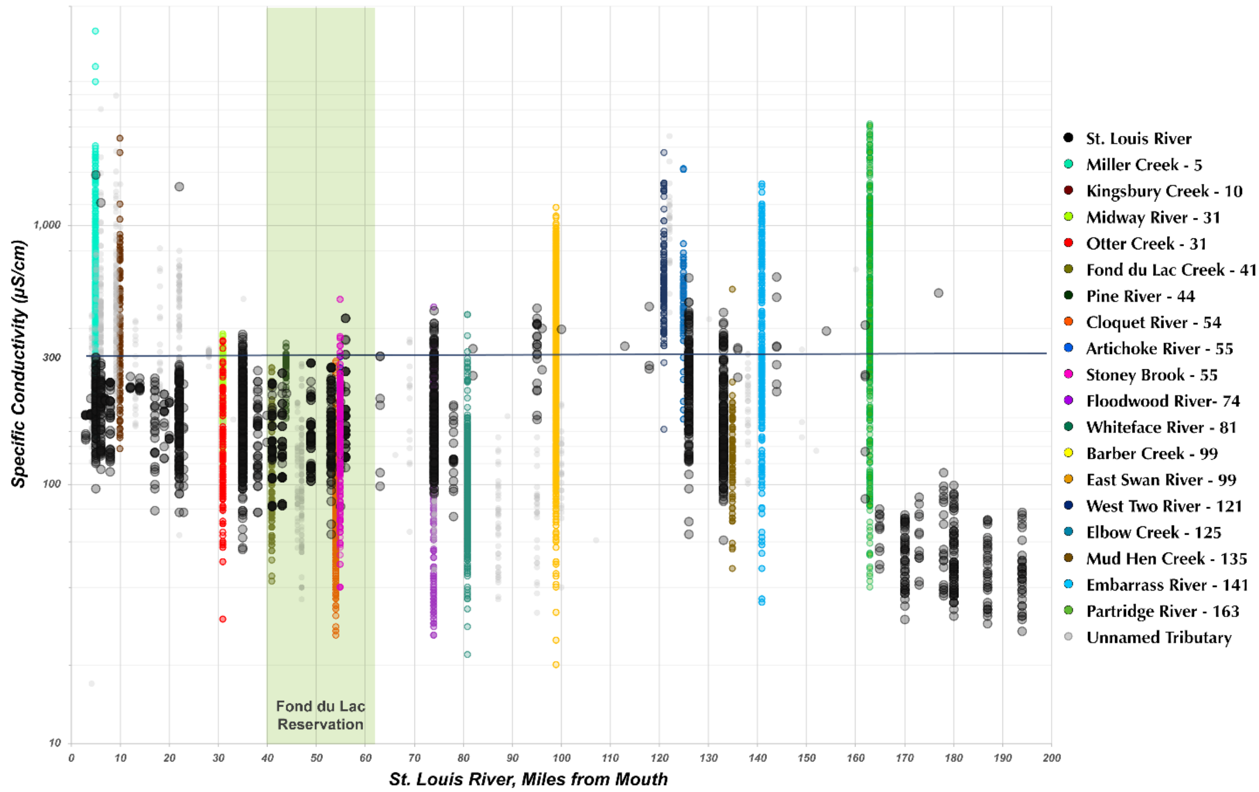

Figure). The median SC (49.5 µS/cm) of 18 MPCA stations in the St. Louis River mainstem above the confluence with the Partridge River is spatially comparable to Group C stations (Thingvold et al., 1979). The median of the St. Louis River mainstem WQP least disturbed mainstem is 59 µS/cm.

Table 4. Data collected between 1975 and 1977, Group C stations were identified as least disturbed streams. Group A (Partridge and St. Louis Rivers) and Group B streams (Embarrass and Dunka Rivers) are downstream from mining areas. (Thingvold et al., 1979).

		Group A			Group B			Group C		
Parameter	units	range	median	N	range	median	N	range	median	N
Calcium	mg/L	4.5-80	29	33	3.8	15	50	1.8-40	6.0	250
Chloride	mg/L	2.8-38	9.1	55	2.9-88	17	65	0.08-41	1.6	342
Magnesium	mg/L	3-40	15	33	3-26	8	50	1-23	3	250
Potassium	mg/L	1.0-8.4	2.3	33	0.3-5.2	1.6	36	0.2-6.2	0.6	241
Silica	mg/L	4.6-24	14	56	4.0-29	9.5	65	0.1-34	63	344
Sodium	mg/L	1.1-45	6.5	33	0.5-35	8.1	36	0.2-19	1.6	235
Specific Conductivity	µS/cm at 25°C	61-1198	323	55	12-655	181	65	24-524	55	343
Hardness	mg/L ($CaCO_3$)	81-310	152	20	5.3-238	81.5	22	12-99	27.1	164

Alkalinity	mg/L (CaCO3)	11-140	71	56	13-160	45	65	1.0-190	19	336
Bicarbonate	mg/L	14-148	54	29	16-134	65	24	6-151	22	204
Sulfate	mg/L	13-630	70	56	3.5-110	14	51	0.8-31	6.6	327
pH	-log10[H+]	6.3-8.2	56	56	6.1-8.1	7.0	65	4.7-8.4	6.9	337

(Source: Thingvold et al., 1979). Appendix 2, p 242, https://www.lrl.mn.gov/docs/pre2004/other/CN153.pdf)

5.2.6. WQP (1996-2021) Relative SC in Ecoregion 50 and along the St. Louis Mainstem

Multiple measured SC values from the WQP data sets were plotted for the mainstem of the St. Louis River (Figure). The SC values in the St. Louis River mainstem above the confluence with the Partridge River (*N* samples = 234, *N* stations = 18) has a median of 49.5 µS/cm and an interquartile range of 40 to 64 µS/cm which are similar to the reference median (55 µS/cm) reported by MEQB (1979) and Thingvold et al., (1979). Some tributaries from the Minnesota Copper Nickel study area (e.g., First Creek via Partridge River) and the Mesabi Range have higher SC (e.g., West Two River, West Swan River), and often raise the St. Louis River mainstem from background to levels > 300 µS/cm. Other tributaries have lower SC ranges that dilute high SC loads delivered by other mined tributaries (Figures 1 and 5). For example, more often than not, the Whiteface River is less than 300 µS/cm for its entire length and dilutes the St. Louis River. In contrast, West Two River has high SC that remains above 300 µS/cm to its confluence with the St. Louis River (Figures 1, 5). The Partridge River has very low SC in its headwaters with many SC values well below 300 µS/cm (Figure 1, 5, and 6), but it fails to dilute inputs from First Creek which drains the plant site with many SC values > 300 µS/cm (Figure 5 and 6).

In the section of the St. Louis River within the jurisdiction of the Fond du Lac Reservation, SC is elevated north of Brookton, MN. Satellite imagery from Google maps suggested 2 potential sources, a railyard with what appear to be exposed salt piles and a closed landfill near Stony Brook. The SC in the St. Louis River occasionally > 300 µS/cm near the railyard, but not downstream from Stony Brook and the landfill. Inspection of data in Stony Brook between 1955 and 1996 showed that SC declined after closure of the landfill (data not shown) and is therefore an unlikely active influence on the St. Louis River.

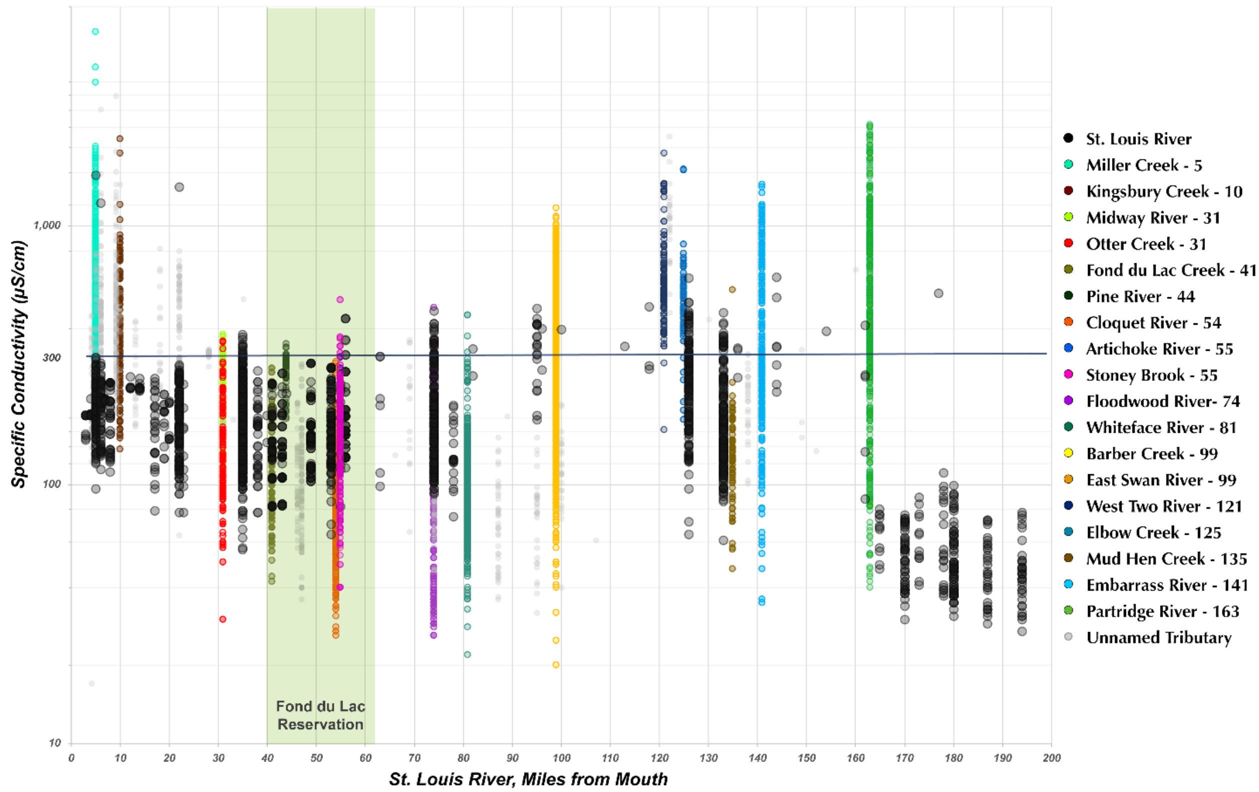

Figure 5. Geographic-order scatterplot used to assess SC range in tributaries and their influence on the St. Louis River (SLR) mainstem (*N* = 8,048, WQP 1996 – 2021). River flows from right to left. Green shaded area bounds Fond du Lac Reservation. Transparent dark gray circles track the SLR by river mile (RM) from upper reaches to mouth. Tributaries are plotted at their confluence with SLR RM. RM confluence is shown to right of tributary name in legend on right of plot. SC ranges often include multiple sites at different locations within a tributary. SLR has exceeded 300 µS/cm (gray horizontal line) at times before and after entry to the Fond du Lac Reservation. The maximum SC in St. Louis River upstream of the reservation is 632 µS/cm. The St. Louis River watershed maximum of 2462 µS/cm occurred in the Partridge River, a tributary to the St. Louis River watershed. (*Source: WQP (1996-2021)).*

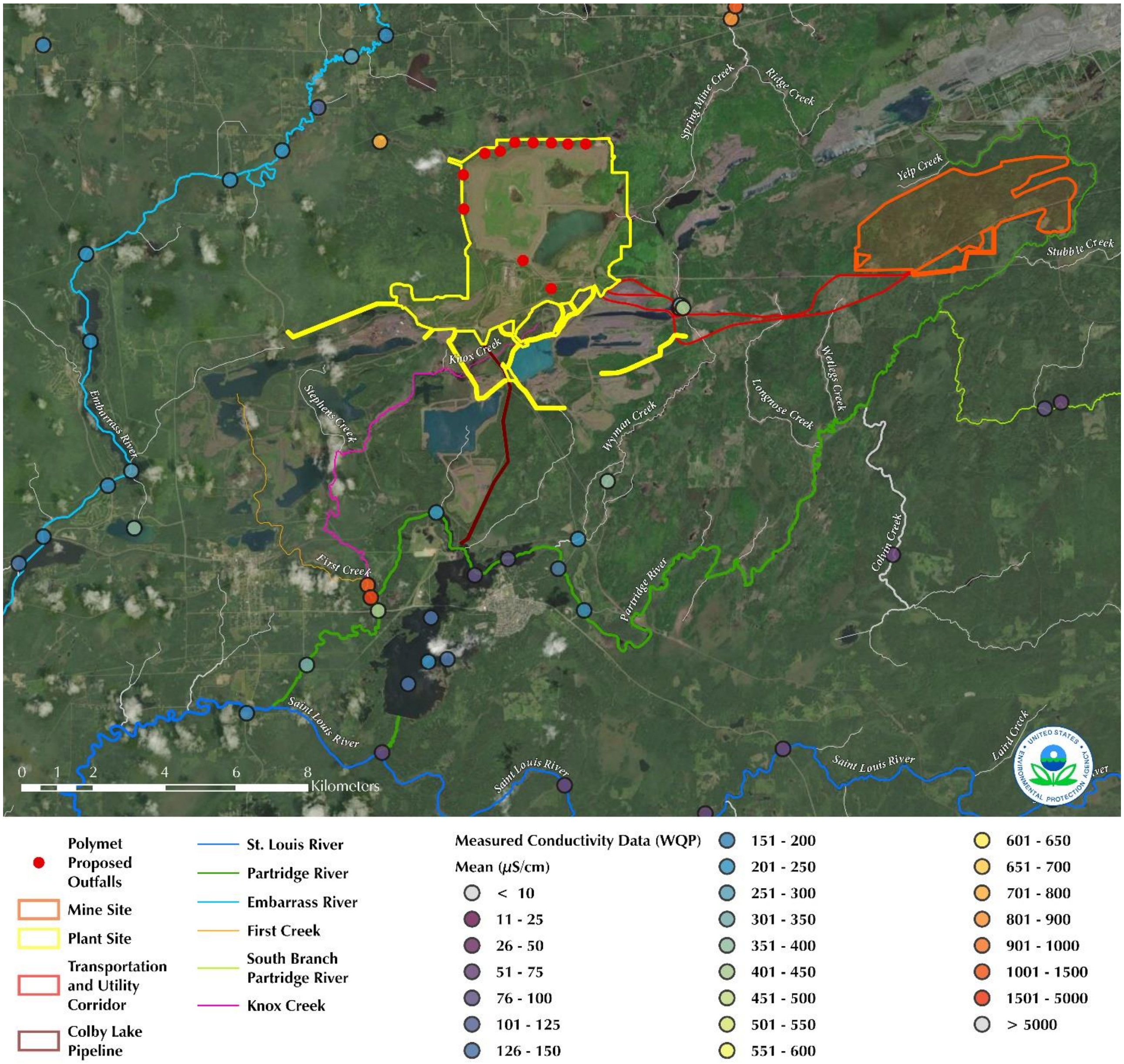

Figure 6. The proposed mine site is located in the Partridge River watershed that currently has low specific conductivity (SC) (purple and blue circles). The plant site is located in the Partridge and Embarrass River watersheds) (Figure A-1). SC is greater than 1000 µS/cm (orange and red circles) at the confluence of First Creek and Partridge River, Spring Mine Creek and northwest of the plant site in the Embarrass River drainage area. After the confluence of the Partridge River, the SC of the St. Louis River increases to a median of 374 µS/cm with a maximum of 1433 µS/cm. The St. Louis River increases from a median of 68 µS/cm to 412 µS/cm below its confluence with the Partridge River. (*Source: Freshwater Explorer*)

The potential to violate the water quality SC criterion in the St. Louis River was explored near the Fond du Lac Reservation using 2 metrics, the annual mean SC at a station and the maximum SC at a station. We compared these values to the Band's criterion continuous concentration (CCC) of 300 µS/cm as an annual average and an example acute criterion or criterion maximum exposure concentration (CMEC) of 520 µS/cm with a duration of one-day.

The CCC of 300 µS/cm is the water quality criterion for the Fond du Lac Reservation. The CMEC is a brief exposure greater than the CCC that may occur without causing the annual average to be greater than the CCC (Cormier et al., 2018c). The CMEC is interpreted as a maximum exposure that 95% of organisms may tolerate without extirpation where SC remains less than the annual CCC. Calculating a CMEC requires a criterion deviation from a data set of stations having multiple measurements within a year with an average annual SC equal to the CCC, in this case 300 µS/cm. Such a data set was not readily available, so for comparison, we used the CMEC (520 µS/cm) estimated for Ecoregion 69 which has a CCC of 310 µS/cm (Cormier et al., 2018c) slightly greater than the Fond du Lac Reservation criterion of 300 µS/cm.

The current SC regime for the St. Louis River upstream and through the reservation was characterized using quantile regression analysis. Quantile regression is similar to linear least squares regression but models the relationship between a set of predictor variables. The predictor variables to model an annual average SC were RM and the 90th centile of mean SC measurements. The predictor variables to model an annual maximum SC were RM and the 90th centile of all available SC measurements. The 90th centile was selected because SC excursions greater than 300 or 520 µS/cm are of interest not average SC regimes across years. Nine MPCA sampling stations were included in the analysis, two stations immediately upstream from the Reservation boundary (RM 65 and RM 75) and 7 stations within the Fond du Lac Reservation boundary (RMs 40 to 62). The 90th quantile least squares regression models were fitted in Figure 7 to the annual averages and in Figure 8 to all the observations. In Figure and 8, the solid blue line is the 90th quantile regression from the confluence with Floodwood River (RM 74) to the downstream border of Fond du Lac Reservation (RM 40).

Next, we estimated how much of an increase in the SC at RM 74 would result in violation of the CCC or the example CMEC. We shifted the quantile regression lines upwards so that the left terminus intercepted the CCC (300 µS/cm) or example CMEC (520 µS/cm) line at the upstream reservation border (gray-dashed), at the mid-point of the St. Louis River (violet) within the reservation, and at the downstream boundary (red) of the Fond du Lac Reservation. The SC at the intercept of the observed 90th quantile regression at RM 74 (the right terminus of the solid blue line) was subtracted from the SC at the intercept of the 90th quantile regression that would result in violation of either the CCC (Figure 7) or example CMEC (Figure 8) at the upper boundary (RM 62), mid-point (RM 51), and lower reservation boundary (RM 40).

With a SC annual average increase of 3.4 µS/cm, SC is estimated to exceed the CCC at the reservation border. Note that for Figure 7, the gray quantile regression line nearly overlaps with the baseline SC quantile regression line. With an annual average increase of 71.2 µS/cm of the elevated background at RM 74, the entire length of the St. Louis River within the reservation boundary is estimated to violate the Fond Du Lac water quality criterion of 300 µS/cm annual average. With an annual average SC increase of 33.9 µS/cm, half of the St. Louis River within the reservation boundary is estimated to violate the Fond Du Lac water quality criterion.

SC greater than the example CMEC for one day predicts that the annual average SC will be greater than the Band's criterion of 300 µS/cm. Based on the example CMEC analysis, with an increase of SC of 560 µS/cm at RM 74, 101 µS/cm/day greater than the recorded maxima, the CMEC is likely to be violated at the reservation border. With a one-day exposure of 597 µS/cm and 633 µS/cm at RM 74, the example CMEC on the reservation is likely to be exceeded to the mid-point and the entire portion of the St. Louis River within the reservation, respectively (Figure 8).

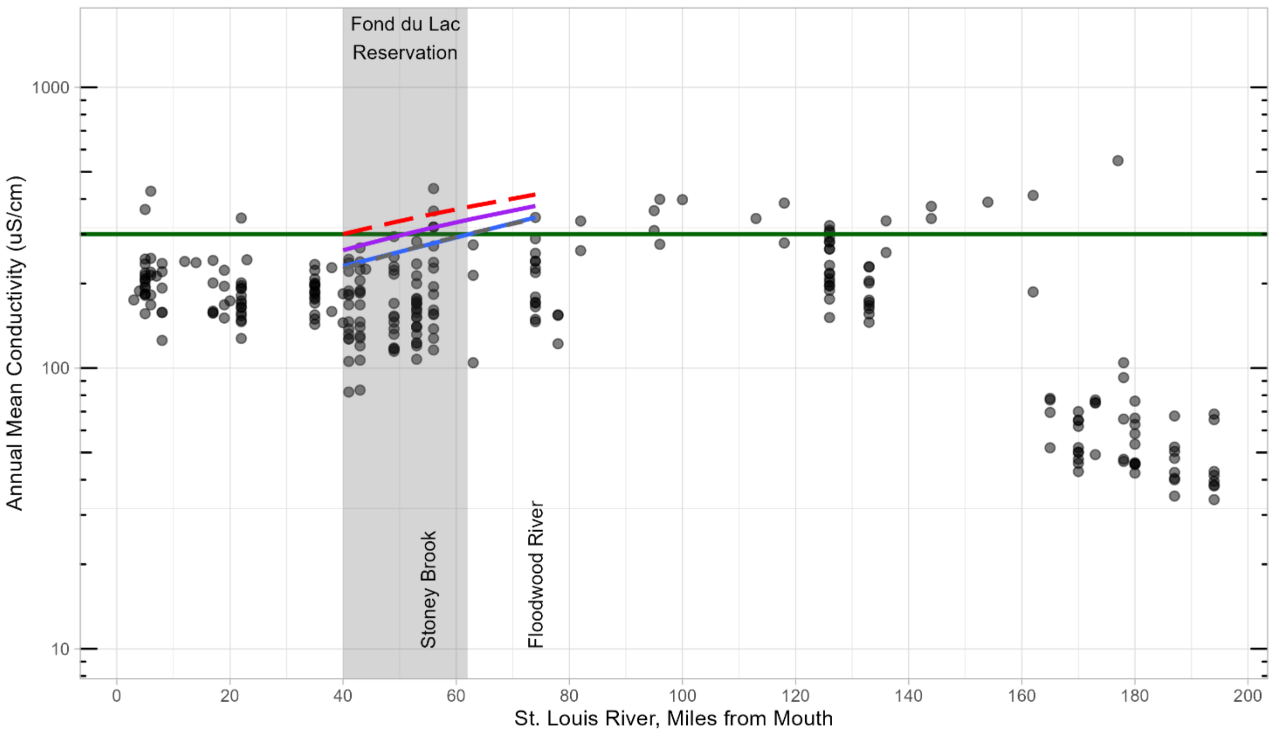

Figure 7. Scatterplot of annual average SC observed in St. Louis River between 1997 and 2021. River flows from right to left. The St. Louis River > 300 µS/cm at the confluence of the Partridge River (near river mile (RM) 160) southward and marginally meets the 300 µS/cm criterion (horizontal green line) in the Fond du Lac jurisdiction (vertical gray area). The solid blue line (overlapped by gray dashed line) is a 90th quantile regression from the confluence with the Floodwood River (RM 74) to the downstream border of the Fond du Lac Reservation (RM 40). Three scenarios are shown where the quantile regression intercepts 300 µS/cm at the upper boundary (RM 62) (red dashed), lower boundary (RM 40) (gray dash overlaps blue line), and mid-point (RM 51) (solid violet) of reservation. (*Data Source: WQP (1996-2021)).*

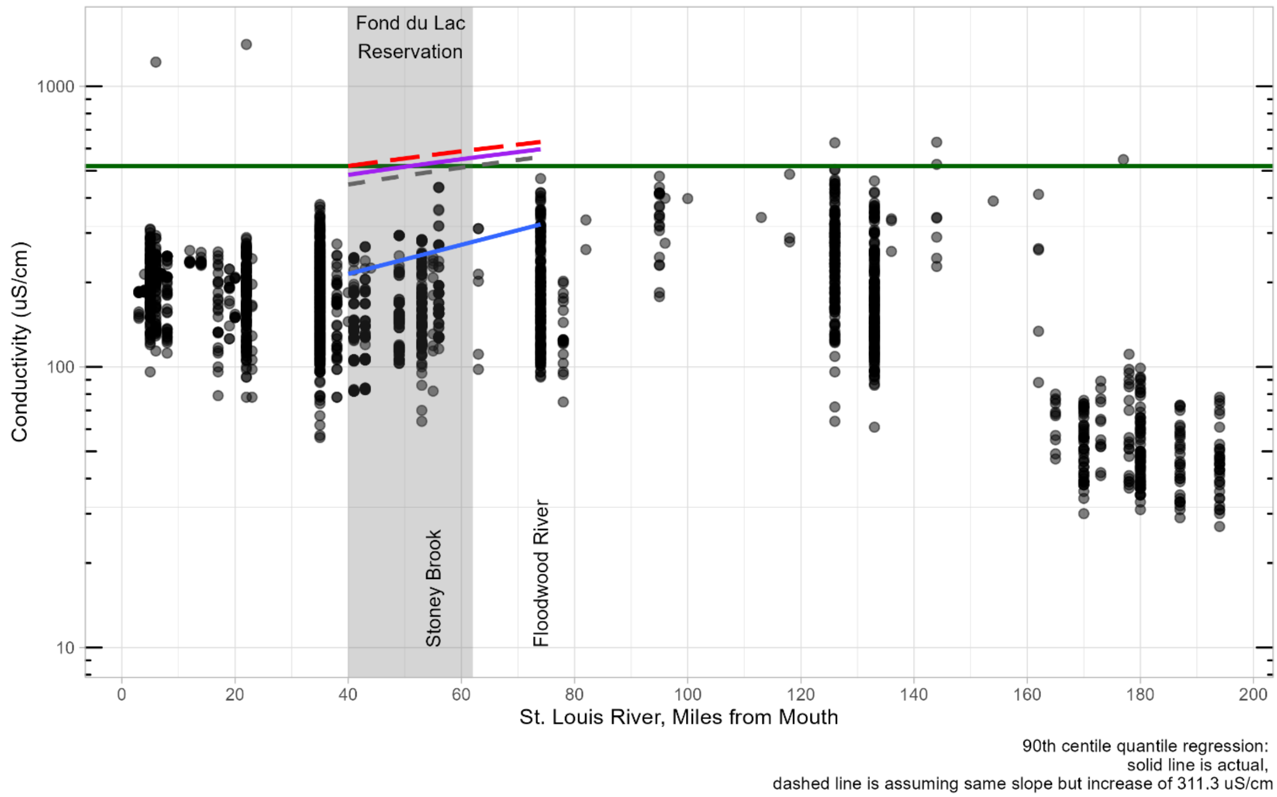

Figure 8. Scatterplot of SC observed in St. Louis River between 1997 and 2021, not averaged. River flows from right to left. The reservation is shown as a vertical gray area and an example CMEC of 520 µS/cm is depicted as a horizontal green line. The solid blue line is a 90th quantile regression of all observations at a station from the confluence with the Floodwood River (RM 74) to the downstream border of the Fond du Lac Reservation (RM 40). Three scenarios are shown where a shift in the quantile regression intercepts 520 µS/cm at the upper boundary (RM 62) (red dashed), lower boundary (RM 40) (gray dashed), and mid-point (RM 51) (solid violet) (*Data Source: WQP (1996-2021)).*

5.2.7. Summary: Background SC

Based on the independently measured and the empirically modeled data sets, the median least disturbed SC for the St. Louis watershed is 76 µS/cm, with an interquartile range of 56 to 102 µS/cm. (Table 3). The SC measurements of all WQP stations on the St. Louis River mainstem above the confluence with the Partridge River have a median of 49.5 µS/cm (*N* samples = 234, *N* stations = 18) with an interquartile range of 40.25 to 64 µS/cm, which is similar to reference locations with a median of 55 µS/cm reported by Thingvold et al., (1979). Currently and 40 years ago, background SC in the vicinity of the proposed mine is very low, serving as a refugium for mineral-intolerant species and helping to maintain better water quality downstream (Table 3 and **Error! Reference source not found.**).

Due to numerous mineral inputs along the length of the river, the observed SC level is elevated above natural background for a large portion of the St. Louis River mainstem. Therefore, SC background estimated from observed data are likely to be greater than background without anthropogenic inputs (Table 3).

The quantile regression analysis shows that small increases in the SC levels of the St. Louis River associated with normal operations or from a spill at the confluence of the Partridge River (near RM 160) southward is likely to result in a violation of the marginally met the 300 µS/cm criterion (horizontal green line) in the jurisdiction of the Fond du Lac Reservation (Figures 7 and 8).

5.3. Biological Effects

5.3.1. Selection of Assessment Endpoints

5.3.1.1. *Benthic Invertebrates*

Aquatic and semi-aquatic benthic invertebrates are food for fish, amphibians, and wildlife that people value. They contribute to ecosystem functions, and they provide direct benefits to people. They are important contributors to energy and nutrient processing, including capturing and returning nutrients to terrestrial ecosystems, and purifying water (Baxter et al., 2005, Jacobus et al., 2019). The functional services of insects depend on diverse assemblages. When benthic invertebrate species are lost, there is little redundancy for critical functions (Carlisle and Clements, 2005). Diversity is important to anglers, to the fish, and to piscivorous wildlife (Suter and Cormier, 2014, Jacobus et al., 2019). Emergence of adult stream insects can constitute 25–100% of the energy or carbon to birds, bats, lizards, and spiders. Emergence typically peaks in June in the temperate zone with lower amounts in late summer to spring (Baxter et al., 2005). The MPCA and the Band use benthic invertebrates to assess water quality (MPCA, 2014, USEPA, 2020).

The Band adopted water quality standards to protect aquatic life that includes a SC criterion of 300 µS/cm annual average (USEPA, 2020). This criterion is based on the USEPA field-based method applied to benthic invertebrate assemblages (USEPA, 2011) and analyses performed using data from Ecoregion 50 in Minnesota (Johnson and Johnson, 2015, Cormier, 2016).

5.3.1.2. *Fish*

Fish are important food and recreational resources. We considered two species of native fish, brook trout (*Salvelinus fontinalis*) and lake sturgeon, *Acipenser fulvescens*. Brook trout were assessed because they are ubiquitous in streams in Minnesota. Lake sturgeon were assessed because the Band has been active in restoring sturgeon to the St. Louis River watershed.

The lake sturgeon is a Minnesota species of special concern (MDNR, 2013) because it was nearly extirpated from the St. Louis River freshwater estuary. The lake sturgeon is a migratory species that is present in limited numbers in the St. Louis River watershed and some lakes in the

Boundary Waters Canoe Area (MDNR, 2021a). The Minnesota DNR (MDNR) stocked 16 lake sturgeon year-classes in the St. Louis River estuary between 1983 and 2000 (MDNR, 2021b). In 2003, the Great Lakes Fishery Commission completed a lake sturgeon rehabilitation plan for Lake Superior including the St. Louis River (Auer, 2003). In the spring of 2007, MDNR reported mature sturgeon returning to historical spawning grounds from Lake Superior. In 2009, a cooperative project among The Nature Conservancy, the Environmental Protection Agency, the U.S. Fish and Wildlife Service and the MDNR restored roughly 245 m (800 ft.) of suitable spawning habitat below the Fond du Lac Dam, located at RM 21.3 (Figure 9). Young sturgeon have been observed below the Fond du Lac Dam, but we did not find any reports of observations of adult females. The Band reported lake sturgeon throughout the watershed including the mainstem and tributaries (Dupuis, 2021).

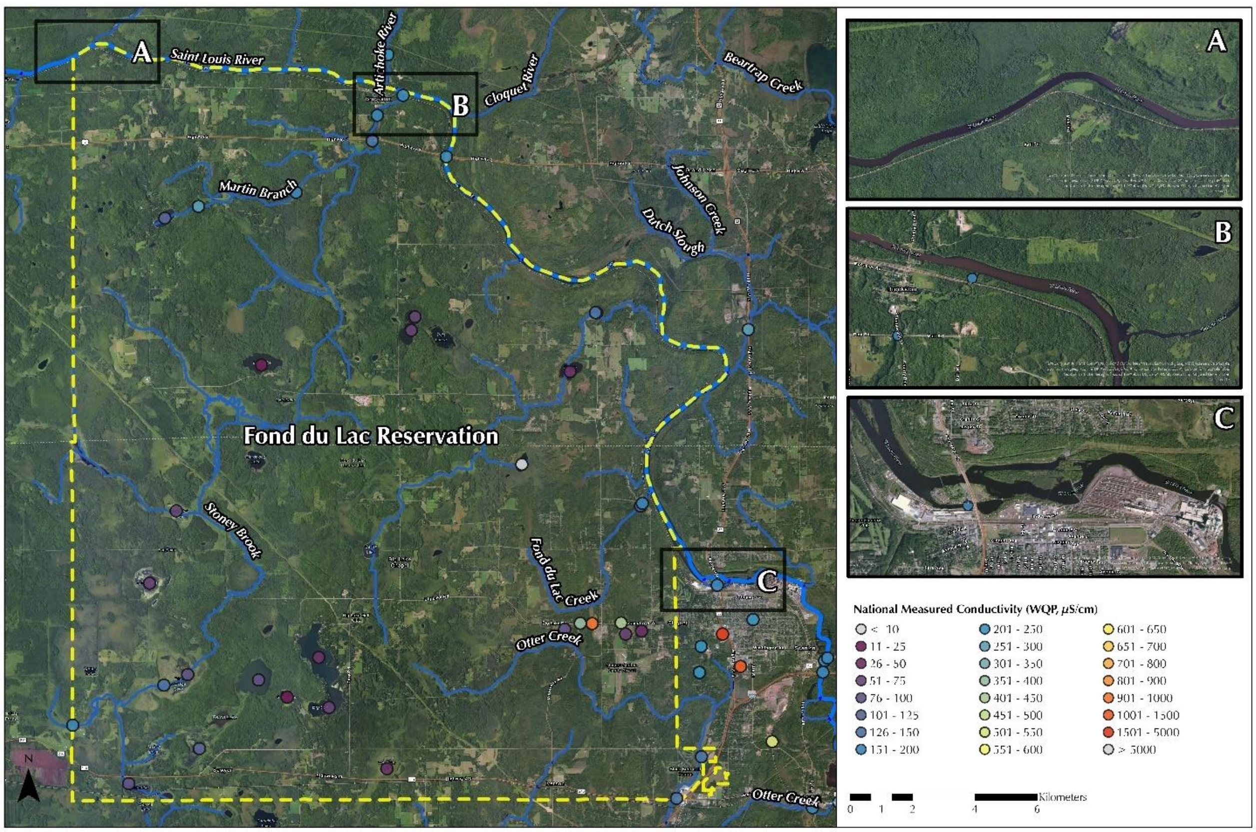

Figure 9. Satellite imagery of area near Fond du Lac Reservation. Stream segments (blue lines). Inserts A and B are within the watershed. Insert C shows the area near the Fond du Lac Dam. Selection of an Effect Statistics.

5.3.1.3. *Extirpation*

Extirpation is the effective loss of a taxon from a portion of its normal habitat, such as a portion of a stream or geographic area. For this assessment, we define the level of SC resulting in extirpation of a species (fish) as the SC level above which less than 5% of observations of the species occurred in an area (i.e., the state of Minnesota and the Mid-Atlantic Highlands). It is expressed as the extirpation concentration (XC_{95}) (USEPA, 2011). For benthic invertebrates, extirpation of 5% of the benthic invertebrate community is estimated from a distribution of benthic invertebrate genera XC95 values at the 5th centile (XCD05) (USEPA, 2011, Cormier et al., 2018a, b).

5.3.1.4. *Optima and 50% decline in occurrence*

The probability of observing a taxon in a sample lessens as it become rarer. The probability of observing a taxon at a particular SC can be characterized with a scatter plot of occurrences weighted by the number of stations within discrete SC bin ranges (USEPA, 2011). The SC with the greatest probability of observing a taxon (optimum) and the SC associated with a 50% reduction in observing a taxon can be calculated from a generalized additive model (GAM) fitted to the occurrences weighted by each bin (Hastie and Tibshirani, 1986; USEPA, 2011). We estimated the SC optimum for brook trout at the maximum occurrence from scatter plots fit with a GAM. We estimated the adverse effect of a 50% reduction of the probability of observing brook trout from the GAM at one-half the maximum probability of observing brook trout (USEPA, 2011).

5.3.2. Results

5.3.2.1. *5% extirpation of benthic macroinvertebrate community*

The water quality criterion adopted by the Band is based on the best available science vetted by many independent studies using different data sets and approaches (Table 5) (Cormier et al., 2020). For Minnesota Ecoregion 50, calculated from data from MPCA, the XCD05 is 320 µS/cm (Cormier et al., 2018b). The MPCA independently estimated the XCD05 at 329 µS/cm (MPCA, 2020). Both MPCA data sets (Cormier et al., 2018b, MPCA, 2020) have no samples collected in the first half of the year prior to ephemeropteran (mayfly) emergence and thus have fewer salt-intolerant taxa. Therefore, these XCD05 values based on MPCA data sampling protocols underestimate SC values resulting in extirpation.

Outside of Minnesota, in areas where least disturbed background SC is low, various effect levels for benthic invertebrate genera ranged from 124 µS/cm to 413 µS/cm, with a median of 284 µS/cm (Table 5). When other stressors were controlled in artificial stream studies in Colorado (Kotalik and Clements, 2016), adverse effects occurred near 300 µS/cm. In a field observational study of headwaters with and without salts from valley fill mine sites in Virginia, taxa known to be salt-intolerant were absent from streams with SC greater than 300 µS/cm (Timpano et al., 2018). Salt intolerant genera were less likely to be observed in Appalachia when only conductivity was high and other measured stressors were low or absent (USEPA, 2011). Therefore, it is reasonable to estimate that in the absence of other stressors, SC > 300 µS/cm will lead to the extirpation of species.

However, in some areas with background SC less than 100 µS/cm, as occurs in the St. Louis River watershed, a lower level of SC would be needed to protect aquatic life, as has been found in the low SC areas of North Carolina (Cormier et al., 2018a, b). Because the sample size is limited, one approach is to estimate an effect level from background SC using a least-squares regression model (Cormier et al., 2018a). The background-to-criterion (B-C) model was developed from estimated background of 24 data sets and XCD05 derived from paired benthic aquatic macroinvertebrate occurrences and SC measurements. As an example, an XCD05 effect level was calculated from the B-C model using the observed background of 55 µS/cm for the Upper St. Louis River watershed as the independent variable (Eq. 1). The mean XCD05 is 165 µS/cm, quite a bit less than the Ecoregion 50 benchmark of 300 µS/cm.

$$0.658\ X_{\log 10} + 1.071 = Y_{\log 10} \qquad \text{Eq. 1.}$$
$$0.658 * \log_{10} \text{ of } 55\ \mu S/cm + 1.071 = Y_{\log 10}$$
$$0.658 * 1.7404\ \mu S/cm + 1.071 = 2.2161832_{\ \log 10}$$
$$10^{2.2161832}\ \mu S/cm = 164.5\ \mu S/cm$$

In summary, because background environmental conditions in a watershed vary, adverse effects are expected to occur at different thresholds. So, although the criterion for SC (300 µS/cm) set by the Band is reasonable for the St. Louis River mainstem near the reservation, in the upper St. Louis River watershed where background SC is lower, a lower protective SC value is needed.

Table 5. For areas with naturally low mineral content as occurs in the St. Louis River watershed, estimates of SC effect levels are quantitatively consistent in different studies with differing methods and/or different sampling intensities applied to benthic invertebrate assemblages. Table from Cormier et al., 2020 with added citations.

Citation	Benchmark (µS/cm)	Context
Pond et al., 2008	< 500	The number and percentage of mayflies declined at < 500 µS/cm. The only mayflies observed frequently at (500–1000 µS/cm), were *Baetis* and *Plauditus*, 2 relatively facultative genera.
Gerritsen et al., 2010	300	Using a large data set in West Virginia, USA, conditional probability and change point analysis identified a median threshold where more than half of sites > 300 µS/cm were expected to have a family-level multi-metric index (WVSCI) score of < 71.
Pond, 2010	124–336	An analysis of spring data indicated that the percentage of *Ephemeroptera* in mining-salinized streams was less than in unsalinized least disturbed streams, with a changepoint in the range of 124–336 µS/cm
Merriam et al., 2011	168	Sampling in spring, ephemeropteran richness and percentage of *Ephemeroptera*-less-*Baetidae* were less than least disturbed stream levels at SC ≥ 168 µS/cm
Bernhardt et al., 2012	308	In southern West Virginia, impairment occurred, based on the WVSCI and a genus level multimetric index (GLIMPSS) and the TITAN method, when specific conductivity (SC) was > 308 µS/cm.
	178–289	Analysis of 50 taxa that declined in abundance with increasing salinity, 17 of which were *Ephemeroptera*, showed that the greatest cumulative decline in community diversity occurred from 178 to 289 µS/cm.
Pond and North, 2013	200–300	In a predictive model of taxonomic completeness, the probability of capture (O/E0.5, SD = 0.159) decreased with increasing SC with declines apparent at about 200–300 µS/cm.
Vander Laan et al., 2013	300	A random forest model of field data from streams in Nevada, USA, indicated effects when SC increased 100 µS/cm above background. Levels were associated with a 5% reduction in taxa collected in standard samples, and taxa richness decreased 20% in streams with SC > 300 µS/cm above background levels.
Timpano et al., 2015	560 and 903	Benchmarks estimated from a Virginia, USA family-level index (VASCI) were 560 and 903 µS/cm for fall and spring. The authors acknowledged that their values were much higher than others, which they attributed to their family level index, their statistical method, and potentially other factors.
Cook et al., 2015	326	In a field study in southwestern streams in Virginia, changepoint analysis showed community effects at 326 µS/cm.
Clements and Kotalik, 2016	221–382	Ephemeropteran drift, abundance, and community metabolism were affected at SC near or lower than 300 µS/cm in mesocosm experiments with mining-induced salinity.
	153–271	Ephemeropteran drift occurred at 153–271 µS/cm in $NaHCO_3$ and 135–172 µS/cm in MgSO4, with drift rate increasing strongly as SC increased.
Timpano, 2017	200	Non-Baetid-*Ephemeroptera* were most sensitive to salinity, with richness and abundance lower than reference at SC > 200 µS/cm in spring based on single sample SC. Equivalent effects were predicted by mean monthly SC of 250–300 µS/cm from the prior autumn.
Olson and Hawkins, 2017	Increase of 100 from background	Field experiments indicated that small to modest changes in total dissolved solids (TDS) (~100 µS/cm in low SC streams) could put some stream invertebrate taxa at risk of local extirpation and SC optima estimated from field data were < 100 µS/cm.
Timpano et al., 2018	–	Critical SC value = SC at intersection of 10th centile of metric from a fitted general additive mixed model. Spring critical SC value followed by 95% confidence limits in parentheses
	294 (184–413)	Spring critical SC value for Percentage *Ephemeroptera*
	236 (163–291)	Spring critical SC value for Percentage *Ephemeroptera*-less-*Baetidae*
	284 (217–341)	Spring critical SC value for *Ephemeroptera* richness

	276 (136–394)	Spring critical SC value for Total Taxa
	214 (159–259)	Spring critical SC value for *Ephemeroptera*-less-*Baetidae*
Cormier et al., 2018b	320	The XCD05 for Ecoregion 50 using base flow data from MPCA.
	261 (217-313)	Ecoregion 50 XCD05 estimated from an ecoregional background of 111 µS/cm and an empirical regression model, followed by 50 % prediction limits in parentheses.
Govenor et al., 2019	366	Community sensitivity threshold for SC was estimated at 366 µS/cm for the combined Mountain and Piedmont ecoregions in Virginia, USA.
Cormier et al., 2020	304, 338	Permutation analyses show that the data sets can reliably estimate the extirpation of 5% of genera in Ecoregion 69 and 70, respectively, which have low SC background similar to Ecoregion 50.
MPCA, 2020	329	SC estimated to extirpate 5 % of benthic invertebrates in Ecoregion 50 using base flow data primarily collected July through August.

5.3.2.2. *Lake Sturgeon*

There were only 20 stations where the lake sturgeon, *Acipenser fulvescens,* occurred in the MPCA data set, so an XC95 was not calculated. The maximum SC where lake sturgeon were observed was 310 µS/cm in the 20 station MPCA data set. In a metadata analysis of 19 peer reviewed publications and one personal communication regarding 32 reported occurrences within lake and river systems covering most of the distribution of the species in the U. S. and Canada, the maximum reported SC was 365 µS/cm (Fortin et al., 1996). The maximum SC where lake sturgeon were observed in 2008 in St. Mary's River, MI was 107.2, but areas of higher conductivity may not have been sampled (Gerig et al., 2011).

Anecdotal evidence from a Canadian report noted that juveniles were reared in 12 and 18 ppt salt water (Dick et al., 2006). Assuming the authors meant parts per thousand, the SC would be in the brackish range; however, the parental stock of the juveniles was not reported. Dick et al. (2006) also noted occasional observations of lake sturgeon in the estuaries of Hudson Bay. However, based on genetic studies of variation at nuclear microsatellite loci, the Hudson Bay sturgeon are distinct from those in Minnesota (Dick et al., 2006). In addition to potential genetic differences or physiological adaptation, the discrepancy between tolerance of juveniles in a laboratory setting in Canada and Minnesota field observations may be related to reduced benthic invertebrate prey with increased SC rather than physiological stress (Olson and Hawkins, 2017, Hutton et al., 2021).

Because there are areas of the St. Louis River that are greater than the maximum SC at which lake sturgeon have been observed in Minnesota, those areas may exceed a limit of tolerance or at least preference of SC level. This suggests that the reestablishment of lake sturgeon could be adversely affected in the St. Louis River watershed by increased SC levels. Additional monitoring of SC and lake sturgeon cooccurrence, especially developing fry and juveniles, is needed to estimate XC95 values and other tolerance metrics to enable a better assessment of potential impacts to self-sustaining populations. A study of feeding preference and gut-content of newly hatched and young of year sturgeon would be helpful for assessing the potential reliance of sturgeon on salt-sensitive mayflies.

5.3.2.3. *Brook Trout*

Brook trout were observed state-wide at 226 out of 3,694 Minnesota stations in the MPCA data set. No brook trout were observed in stations with SC < 10 µS/cm. The XC95 for brook trout was estimated at 492 µS/cm in Minnesota (Figure a). To characterize the decreasing trend with increasing SC, stations < 10 µS/cm were removed prior to fitting a GAM. The SC with the greatest probability of observing brook trout is 17 µS/cm, its optimum. The probability of observing brook trout was less than 50% at stations with SC greater than 158 µS/cm. These values are comparable to SC estimates for brook trout in the Mid-Atlantic Highlands. The XC95 for Mid-Atlantic Highlands brook trout was 510 µS/cm, optimum was 10 µS/cm, and the probability of observing brook trout was less than 50% at SC greater than 130 µS/cm (Figure b).

Stocking of brook trout occurs in both Minnesota and the Mid-Atlantic Highlands and may result in overestimation of the effect thresholds. The introductions of brown and rainbow trout are likely confounders of brook trout occurrence in the St. Louis River watershed due to competition and predation (MDNR, 2021). However, it is clear that brook trout would be affected by any increases in SC in the St. Louis River and watershed.

Research suggests that SC-associated effects of juvenile fish may be due to reduced food resources rather than physiological stress. Dependence on ephemeroptera, among the most salt-intolerant aquatic insects, can be substantial representing > 50% of gut content (Grant, 2001). Trout and salamanders have been shown to change foraging behavior and for fish and salamanders to rely on terrestrial insects when aquatic insects are affected by mine discharges (Baxter et al., 2005, Kraus et al., 2016, Hutton et al., 2021). Hutton (2021) showed that as SC increases, occupancy and abundance decline consistently among all species and life stages of salamanders in Kentucky. Their results provide additional evidence that SC indirectly affects aquatic and semiaquatic populations of vertebrates by changing the composition of diet and that food availability is a proximate mechanism that leads to reduced population occupancy, abundance, and persistence in streams with elevated SC.

The SC effect levels reported by Hutton et al. (2021) are similar to the SC associated with a 50% reduced probability of observing brook trout (158 µS/cm). Larval salamanders experienced a 12–fold decline in the ratio of aquatic to terrestrial prey at 153 µS/cm, a 4.2–fold decline in total prey volume at 100 µS/cm, a 2.2-fold decline in aquatic prey importance at 135 µS/cm, and a rapid decline in body condition as SC increased. Adult salamanders experienced a 3-fold decline in ratio of aquatic to terrestrial prey at 382 µS/cm, no change in prey volumes, a 2-fold decline in aquatic prey importance at 163 µS/cm, and a decline in body condition as SC increased.

5.3.2.4. ***Summary of fish results***

As noted in the USEPA (1985, 2017), water quality guidelines allow for site specific criteria for locally important species and species of concern because they might be stressed by diseases, parasites, predators, other pollutants, contaminated or insufficient food, and fluctuating and extreme conditions of flow, water quality, and temperature, or species interactions. These studies indicate that a criterion lower than 300 µS/cm may be required to maintain populations of brook trout and lake sturgeon.

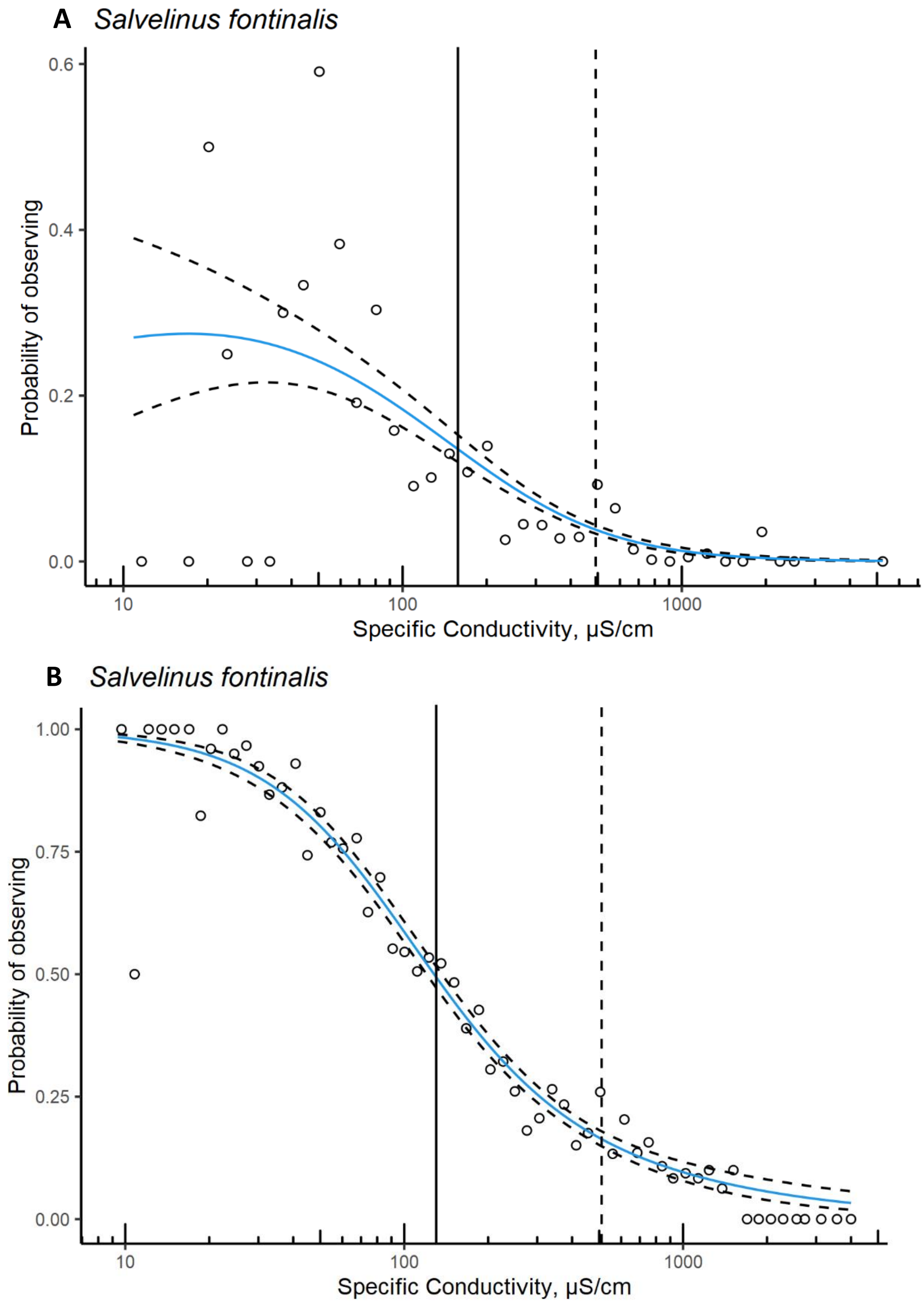

Figure 10. Generalized additive models for brook trout (a) in Minnesota (MN), and (b) in Mid-Atlantic Highlands. (a) XC95 is 492 µS/cm for MN, Optimum is 17 µS/cm, < 50% probability of observing at ≥ 158 µS/cm. (b) For Mid-Atlantic Highlands, XC95 is 510 µS/cm for Mid-Atlantic Highlands, Optimum is 10 µS/cm; < 50% probability of observing ≥ 130 µS/cm. Proportion of observances due to stocking are unknown and may result in under-estimation of the adverse effect. *(Source: MPCA 1996-2013 and Mid-Atlantic Highlands 1990-2014).*

6. CONCLUSION AND RECOMENDATIONS

6.1. POTENTIAL TO VIOLATE THE BAND'S WATER QUALITY CRITERIA

Our review confirmed that very low background SC levels measured between 1975-1977 still occur in the area studied by the MEQB (MEQB, 1979). The median SC was 55 µS/cm from Class C (reference) stations, which included the Partridge and Embarrass Rivers (Thingvold et al., 1979). In our analysis of more recent data, the median SC is estimated at 49.5 µS/cm for 18 stations from the MPCA data set in the St. Louis River mainstem above the confluence with the Partridge River. For the St. Louis River watershed in Minnesota, the median least disturbed background SC is 76 µS/cm with an interquartile range of 46–102 µS/cm. SC levels in the upper reaches are lower than in downstream areas, providing refugia for mineral-intolerant species and dilution of tributaries draining the mining regions

In comparison, SC is often greater streams associated with mining in the Mesabi Range. For example, in catchments of the Embarrass River, White Two River, and East Swan River, SC levels often exceed 500 µS/cm. Downstream from mining areas, SC increases in the St. Louis River watershed (Figure 1, 5, 6). Other sources that increase SC may include waste-water treatment, agricultural run-off, unpaved roads, waste sites, and road salt application especially near highways and urban areas.

The middle St. Louis River receives ongoing high ionic loadings from an inactive open pit mine/tailings and processing plant (old plant site) located at the proposed plant site between the Embarrass and Partridge Rivers and from other mining operations that are on tributaries to the Partridge River, Embarrass River, and others in the headwaters and downstream to the border of the reservation at RM 62. The very low SC water in the Upper St. Louis watershed, along with dilution from the Whiteface and Floodwood Rivers among others, are essential for maintaining lower SC water quality conditions from RM 99 through the reservation and to the outskirts of Duluth, MN.

Forested and wetland areas in the St. Louis River Watershed maintain the low SC waters that dilute dissolved mineral loadings from developed and mining areas. For example, the Partridge River watershed, which includes the proposed mine site, currently has low background SC levels due to undisturbed vegetation and soils. Whereas several small tributaries receive high SC discharges from the old plant site through First Creek, the low SC water in the Partridge River draining from the currently undisturbed area of the proposed mine site dilutes the discharge from First Creek but not back to natural background levels. After its confluence with First Creek, the Partridge River SC levels are sufficiently increased such that after draining into the St. Louis River, the St. Louis River exceeds 300 µS/cm. SC in the St. Louis River remains above 300 µS/cm until it receives low SC dilution further downstream from the Water Hen and Mud Hen Rivers. SC then increases again with inputs from the Mesabi Range watersheds, with some annual averages > 300 µS/cm from RM 120 to about RM 80 until diluted by tributaries entering nearer to the reservation.

Inputs to the St. Louis River from tributaries with mining influence and mining permits have increased SC in the St. Louis River and have exceeded MPCA benchmark of 329 µS/cm (MPCA, 2020). Some tributaries are reported with SCs at more than 20-times background, e.g., tributaries to Partridge River (MPCA, 2020). The cumulative inputs of dissolved ions to the watershed have raised the St. Louis River SC background and contributed to SC values greater than the Band's SC criterion of 300 µS/cm (annual average) as the St. Louis River enters the reservation in some years (

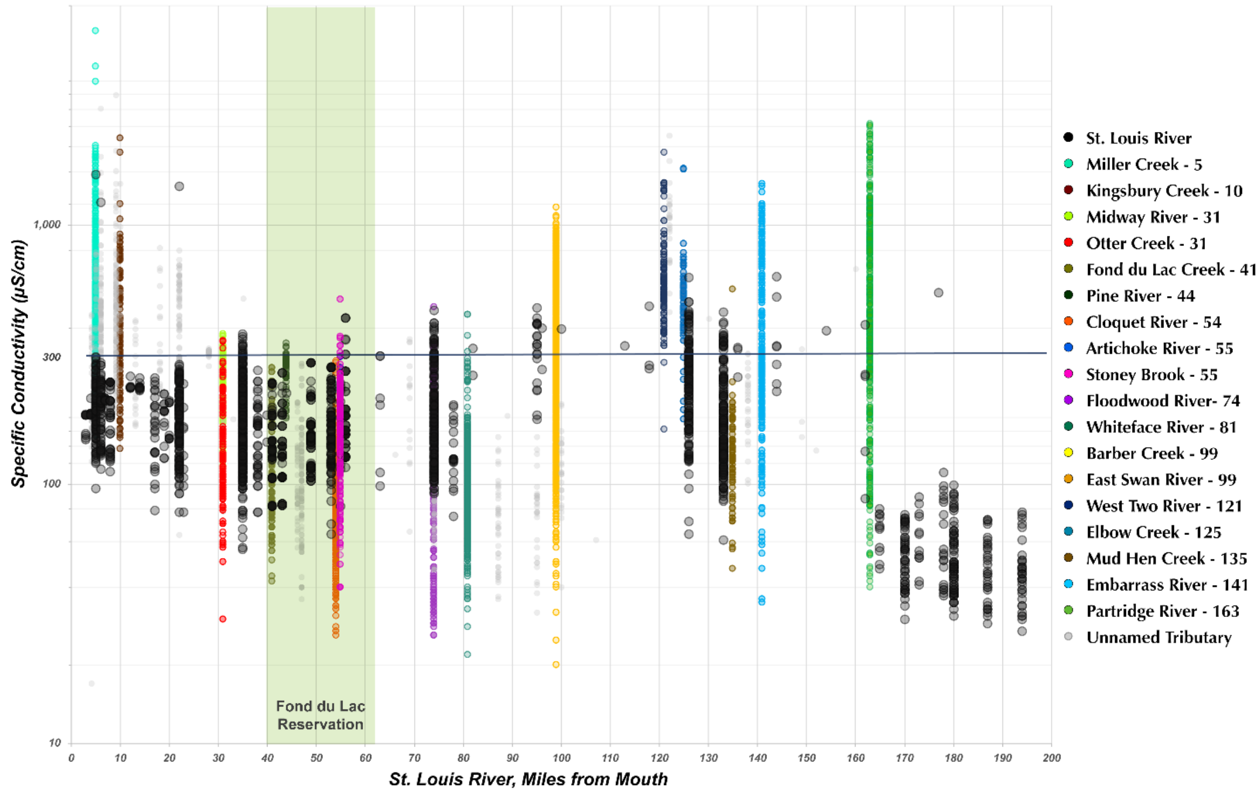

Figure and 7). In some years, the annual average exceeded 300 µS/cm within the reservation west of Stoney Brook (Figure 5). Adding more upstream ionic inputs and reducing the area of unimpacted watershed contributing low SC dilution water is expected to raise the St. Louis River's SC and increase the frequency of SC > 300 µS/cm on the Fond du Lac Reservation.

Changes in SC levels that are expected for the St. Louis River during mine operations are ambiguous (MPCA 2015). At the plant site and at the proposed mine site, the plan is to capture and treat the high SC discharges. At the proposed mine site, treated water may be maintained at MPCA recommended limits (329 µS/cm; MDNR et al., 2020); however, this SC level is about 260 µS/cm greater than least disturbed background SC (< 59 µS/cm) for First Creek, Partridge River, and Embarrass Rivers. Therefore, this will increase the SC levels of receiving waters in the headwaters and downstream. Furthermore, it is unclear what the limits will be and the mine-operator's expectations for a SC limit may be much greater. The EIS (2015) lists limits of 500 and 700 mg/L total dissolved solids (TDS). Depending on the ionic mixture, these TDS limits are approximately 800 µS/cm and 1200 µS/cm, much greater than the newer MPCA recommended benchmarks of 329 µS/cm.

Mitigation at the proposed plant site could reduce effluent SC near the plant site, but it could also raise SC depending on the permit limits. To maintain the status quo, reductions in loadings from the plant site would need to compensate for the increases from the transportation corridors and from the proposed mine site.

For this report we have assumed that all current sources that contribute dissolved mineral loading that are not within the proposed mine complex would continue to adversely raise SC loadings. For example, high SC discharges from Stephens Creek (to First Creek) do not appear to be included in mitigation associated with mine development (Figure 6). It also assumes that ionic loadings will increase from dust, roadways, and the proposed mine site.

Consequently, the available information indicates that net loadings are likely to increase overall loadings to the St. Louis River if the mining operation is permitted and activated. With increased dissolved ionic loadings and less dilution or from the upper St. Louis River Watershed, the elevated SC loads from the Mesabi Range watersheds will have a greater influence and will further raise the SC of the St. Louis River below its confluence with the Partridge River. SC has already exceeded 300 µS/cm at RM 74 in the St. Louis River, 12 miles from the Reservation boundary at RM 63, and SC has exceeded the annual average within the Reservation boundary in in several years (Figures 5 and 7).

An annual increase of 3.4 µS/cm in the background SC of the St. Louis River is projected to result in violation of the criterion at the Reservation boundary. With an increase of the St. Louis River annual average SC levels by 37.9 µS/cm or 71.2 µS/cm upstream from the reservation is estimated that 50% or 100%, respectively, of the St. Louis River within the reservation's jurisdiction would exceed the SC criterion. With a one-day exposure at RM 74 of 560 µS/cm, 101 µS/cm greater than the recorded maxima, the SC would likely be greater than the 300 µS/cm as an annual average with concomitant impacts to aquatic life. However, even with implementation of proposed BMPs described in the NPDES permit, the disturbance of vegetation and increased exposure of soil and unweathered waste rock due to the activities authorized by the 404 permit to construct the mine will also raise the ionic concentration (Clark et al., 2018, MPCA, 2015). Consequently, the potential for violations of the Band's water quality criteria will be increased.

In sum, even if the proposed controls required by the CWA 402 permit perform exactly as expected, the dissolved ions added to the St. Louis River are likely to cause the St. Louis River to exceed the water quality criterion of 300 µS/cm at the Fond du Lac Reservation because the proposed mining and associated land alterations will increase ionic inputs and reduce the dilution potential of the Partridge River. Therefore, the Band's assertion that the mine will cause violations of their SC water quality criterion is a reasonable concern.

6.2. AQUATIC LIFE

6.2.1. Brook Trout and Lake Sturgeon

In addition to affecting ambient water quality, increased SC can affect source water for drinking, agricultural, and industrial purposes, and can affect aquatic life. Both lake sturgeon and brook trout require low conductivity water for naturally sustained populations as well as the benthic invertebrates upon which they feed. Among the most adverse effects is extirpation, the loss of a taxon. In this memo, extirpation is operationally defined as the point above which only 5% of the observations of a genus or species occurs; this definition is consistent with the MPCA, Band, and EPA's prior work (e.g., USEPA 2011).

Analysis of MPCA data from Minnesota indicates that brook trout are extirpated at SCs of 492 µS/cm and higher; however, those data also indicate population reductions occur at SCs well below those associated with extirpation (Figure 10). Based on MPCA data in Minnesota, the probability of observing brook trout decreases to 50% at 158 µS/cm SC. These findings are comparable to effects on brook trout characterized from an independent dataset from Appalachia (Griffith et al., 2018). The addition of more dissolved minerals will affect brook trout exposed to increased SC levels.

Among the 20 locations where lake sturgeon are reported in the MPCA (1996-2013) data set, the maximum SC observed was 310 µS/cm. In a metadata analysis of 20 sources, Fortin et al. (1996) reported that the maximum reported SC was 365 µS/cm based on 32 occurrences of lake sturgeon in lake and river systems encompassing most of the species' distribution in the U.S. and Canada. Based on the available information, lake sturgeon in the St. Louis River segment within the reservation and in the spawning area below the Fond du Lac Dam may be at the SC limit for sustainable populations.

6.2.2. Benthic Invertebrates

The Band adopted water quality standards to protect aquatic life that include a criterion of 300 µS/cm not to be exceeded as an annual average. (USEPA, 2020). This criterion is based on the USEPA field-based method (USEPA, 2011) and analyses performed using data from Ecoregion 50 in Minnesota (Johnson and Johnson, 2015, Cormier, 2016). The benchmark SC value is the 5^{th} centile of the distribution of values at which invertebrate taxa are extirpated, i.e., an extirpation concentration distribution at the 5^{th} centile (XCD05). The estimated XCD05 for Ecoregion 50 using base flow data from MPCA is 320 µS/cm (Cormier et al., 2018b). With a more recent data set also using base flow data in the 2020-2021 Triennial Standards Review, the MPCA (2020) recommended a SC benchmark of 329 µS/cm for Ecoregion 50. However, these estimates may be upwardly biased because of the timing of sampling used to create the estimates. Samples in Minnesota are primarily obtained during mid-July through November with most samples collected during August and September when salt-intolerant ephemeroptera (mayflies) are less likely to be captured due to the predominance of univoltine hatches of mayflies in June and early July in Minnesota. Also, SC is at its maximum during the sampling period and so the base flow estimates may represent the annual maximum rather than an annual average that results in extirpation. Until such studies are completed, it would be more prudent to consider the 329 µS/cm the maximum rather than an annual average.

The water quality criterion adopted for the protection of aquatic life by the Band is consistent with findings by many independent studies including some from other areas of the country (Table 5) and if maintained is expected to protect 95% of aquatic species from extirpation. Although total invertebrate abundance may not be affected (Drover et al., 2019), declines in abundance for some macroinvertebrate taxa critical as food for fish will occur at SC levels lower than 300 µS/cm (USEPA, 2011, Hitt et al., 2016). The Band's concern that increases in SC may affect aquatic life is reasonable.

6.3. RECOMMENDATIONS

6.3.1. Potential NorthMet project to cause increased SC at the Reservation

In order to more precisely assess cumulative impacts locally and at the Reservation, a quantitative watershed source/loading characterization and assessment of loadings levels that would be likely to cause adverse SC levels is needed for the various stages of mine development and operation. Without a quantitative assessment of existing and projected total maximum daily loads of dissolved ions, the projected change in SC levels for the St. Louis River cannot be more precisely defined. A total maximum daily load for the upper St. Louis Watershed should include consideration of existing and future run-off that will affect loadings of mineral and metal ions, not only for the proposed mine and plant site, but also relative to ongoing and abandoned mining and other activities in the watershed. If the proposed mine becomes operational, sources of total dissolved ion loadings would include but are not limited to (1) the plant site, (2) the proposed mine site, (3) transportation routes, and (4) sources not within the proposed mine-complex. Furthermore, high-SC surficial groundwater plumes are expected to emerge from both the mine and the plant, but the potential for such groundwater's interaction with surface waters including wetlands has not been well characterized. Fugitive mineral dust from mining, processing operations, and rail transport is likely to deposit outside of the project boundaries, but its potential to generate total dissolved solids has not been well characterized or studied. Both wet and dry deposition of ions needs to be characterized.

For the direct impacts of the proposed mine site changes to the SC levels, more precise estimates of loadings and dilution capacity might be possible with a more complete source allocation of current ionic loadings in the Embarrass and Partridge River watershed. This should include total inputs from the proposed project and other sources that contribute to loadings but are not a part of the project. Some factors include but are not limited to: areal extent of unpaved roads and barren land, volume and expected ionic composition and concentration of discharge water, characterization of tailings and settling ponds, peat dewatering loadings, effect of drought on dilution capacity, etc. Groundwater flow patterns should be mapped to characterize potential contamination and lags between loading and contamination of water resources especially at the new mine site. The assessment should demonstrate that the net loading from the mining-impacted area (mitigation of the old plant site and increased loadings at the proposed mine site) will be less than current conditions. Strong evidence or pilot demonstrations should characterize the proposed mitigation of legacy discharges and new discharges from the proposed plant and proposed mine sites and show that the technology is effective and scalable. Disposal of waste from RO should be clearly stated. A subwatershed total maximum daily load assessment may suggest engineering controls to balance changes in loadings due to the development of the proposed mine. However, as currently described, SC is likely to increase in the St. Louis River with mining operations and land use change (e.g., Clark et al., 2018, Cormier et al., 2013, Merriam et al., 2013, Kaushall et al., 2017, 2021).

In addition to a quantitative assessment of SC, a much more detailed analysis of the specific major ions likely to increase with mining is also warranted because there is significant variation in the toxicity of these compounds (Mount et al., 2016, Erickson et al., 2017).

6.3.2. Need for specific criteria for species of concern

USEPA water quality guidelines allow for site specific criteria for locally important species that are indirectly affected by a contaminant causing insufficient food or species interactions (USEPA (1985, 2017). Additional monitoring and study are needed to determine the requirements to sustain reproducing populations of brook trout and lake sturgeon, and possibly other wildlife. Dissolved ion concentrations that are elevated above background levels have been shown to cause freshwater animals to experience osmoregulatory difficulties and, hence, physiological stress (e.g., Griffith, 2017). Research also suggests the possibility that SC-associated effects on fish may be due to reduced food resources, with effect thresholds as low as 100 µS/cm (Griffith et al., 2018, Hitt et al., 2016, Hutton et al., 2021). These studies indicate that a criterion less than 300 µS/cm may be required to maintain acceptable abundance levels and naturally reproducing populations of brook trout and lake sturgeon in the St Louis River.

Although not included in this review, additional assessment of wild rice is needed. The MPCA has estimated the extirpation of wild rice at 398 μS/cm in the mixed wood plains ecoregion (MPCA 2020). Reduced abundance, production, and occurrence are likely to occur at much lower levels and if the data used to assess extirpation are available, those estimates might be calculated using the same method employed to estimate optimum and 50% probability of occurrence for brook trout.

6.4. SUMMARY STATEMENT

Current ion concentrations in the St. Louis River entering the Fond du Lac Reservation are close to criterion exceedance levels for total ions measured as specific conductivity (SC). The Band has established a water quality criterion of 300 µS/cm annual average. Based on available data, this criterion has been exceeded within the Fond du Lac Reservation and 12 RMs upstream from the border. Consequently, additional inputs may increase the frequency of exceedances. If the background for SC in the St. Louis River upstream of the reservation were to increase by 71.2 µS/cm on average, the SC of the St. Louis River within the reservation jurisdiction would be expected to > 300 µS/cm (annual average) for its entire length. With a SC increase of 33.9 µS/cm, half of the St. Louis River within the reservation boundary would be expected to violate the Fond Du Lac water quality criterion. Qualitatively, the evidence suggests that additional mineral loadings and removal of dilution are likely if the mine is established and would result in increased risk of WQ criterion violations on the Fond du Lac Reservation for total ions measured as specific conductivity (SC). We recommend that potential effects by the proposed PolyMet mine on water quality and aquatic life in the St. Louis River within the Fond du Lac Reservation be thoroughly evaluated as a component of the Clean Water Act 404 regulatory process.

7. ACKNOWLEDGEMENTS

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8.1. DATA AVAILABILITY

Data sets will be made available from the Environmental Data Gateway. The Central Appalachian brook trout data are available at: https://doi.org/10.23719/1376690.

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8.3. APPENDICES

Figure A-1. Proposed mine site is contained with the Partridge River watershed. The proposed plant site is situated within the partridge and Embarrass River watersheds.

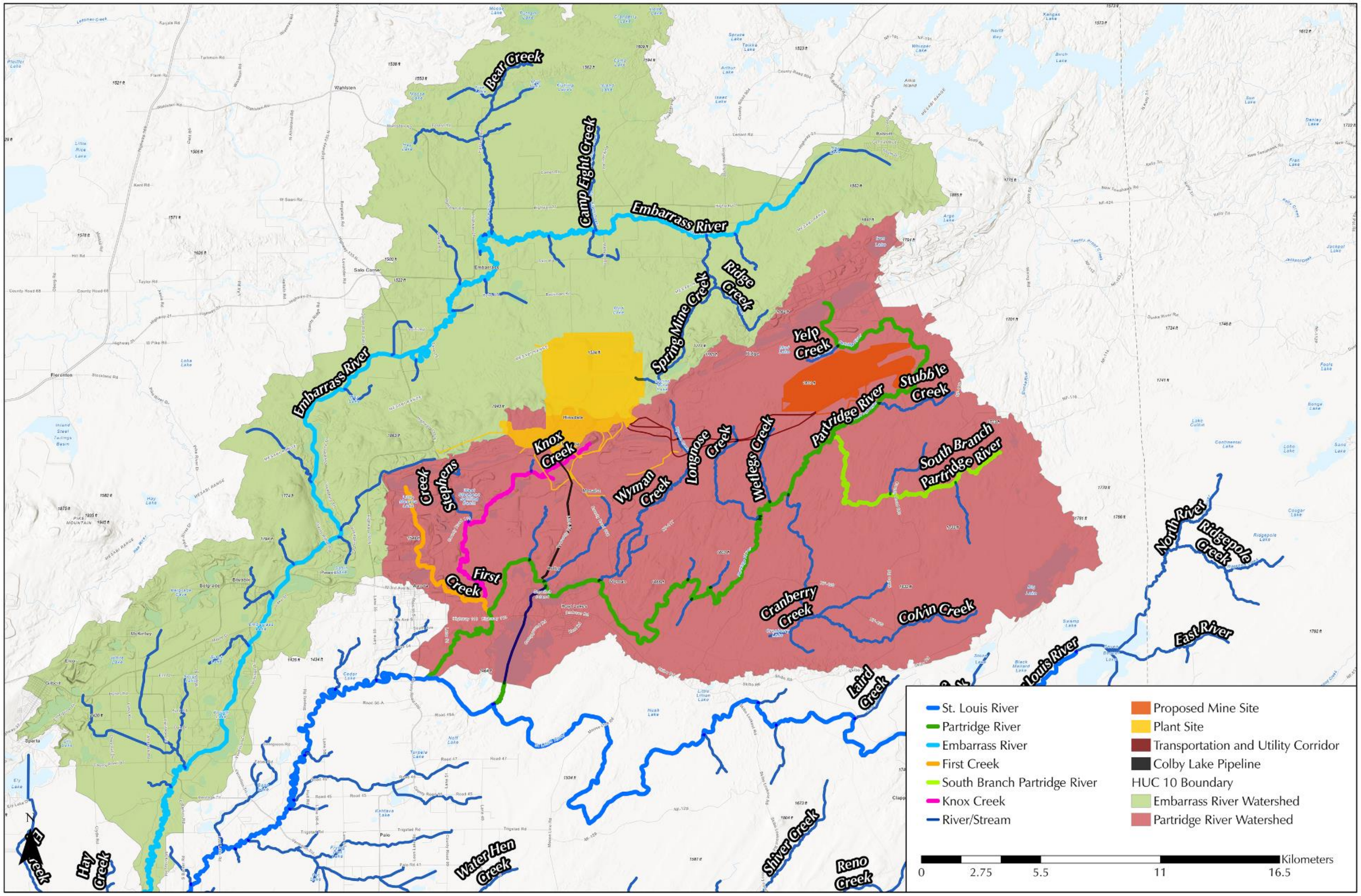

Table A-1. Summary of stations in Ecoregion 50 in Minnesota used to estimate least disturbed background SC (µS/cm). (*Source: WQP least disturbed (1996- 2013)*

Location Identifier	Stream Name	Road Density km/km^2	Percent Natural Land Cover	Percent Impervious Surface	Canal Density km/km^2	Minimum SC	Maximum SC	Mean SC	Median SC	*N*
USGS-04013300	Manitou River	0.2139	99	0	0	100	100	100	100	1
USGS-04015430	Saint Louis River	0.2633	95	0	0	26	74	44	44	26
USGS-04015441	Saint Louis River	0.3317	97	0	0	37	111	63	54	20
USGS-04015443	Saint Louis River	0.2091	95	0	0	41	89	61	55	11
USGS-04015444	Saint Louis River	0.4746	97	0	0	36	74	53	51	25
USGS-04015445	Saint Louis River	0.0125	100	0	0	47	80	65	68	11
USGS-04015455	South Branch Partridge River	0.2721	99	0	0	40	113	76	68	15
USGS-04015461	Colvin Creek	0.4872	98	0	0	43	113	81	82	17
USGS-05124985	Filson Creek Trib.	0.4091	99	0	0	26	51	35	37	13
USGS-05124988	Filson Creek Trib.	0.4091	99	0	0	24	50	34	36	17
USGS-05125450	Greenwood River	0.4374	98	0	0	30	46	36	35	6
USGS-05128100	Loon River	0	99	0	0	27	28	28	28	2
USGS-05128340	Pike River	0.2689	98	0	0	56	244	128	100	5
USGS-05199935	Not Named	0	96	0	0	235	238	237	237	2
USGS-460746093110200	Chelsey Brook	0.4712	99	0	0	119	163	145	154	3
USGS-470410092540601	Joula Creek	0.2609	97	0	0	26	100	39	35	19
USGS-470535092570801	Not Named	0.1362	98	0	0	28	86	45	39	20
USGS-475422089463801	Red Rock Creek	0.1836	99	0	0	51	83	67	66	4
USGS-475456089462801	Red Rock Creek	0.1836	99	0	0	83	126	105	105	4
USGS-482239092491101	Ash River	0	98	0	0	207	211	209	209	2
USGS-482513092400501	Not Named	0	99	0	0	39	57	48	48	2
GLIFWC-MN-01	Saint Louis River	0.4746	97	0	0	34	76	56	58	18
GLIFWC-MN-04	Saint Louis River	0.2633	95	0	0	27	78	49	45	15
MNPCA-S000-196	Scott Bevier Creek	0.2228	97	0	0	82	82	82	82	1
MNPCA-S000-200	Not Named	0	99	0	0	29	29	29	29	1
MNPCA-S000-204	Not Named	0.0438	100	0	0	43	43	43	43	1

Location Identifier	Stream Name	Road Density km/km^2	Percent Natural Land Cover	Percent Impervious Surface	Canal Density km/km^2	Minimum SC	Maximum SC	Mean SC	Median SC	*N*
MNPCA-S000-209	Not Named	0	100	0	0	56	56	56	56	1
MNPCA-S000-211	Not Named	0	100	0	0	53	53	53	53	1
MNPCA-S000-259	Manitou River	0.2139	99	0	0	34	97	67	63	31
MNPCA-S002-279	Castle Creek	0.2497	99	0	0	232	424	274	257	12
MNPCA-S002-593	Colvin Creek	0.4872	98	0	0	80	152	121	120	10
MNPCA-S002-597	Saint Louis River	0.2633	95	0	0	48	95	63	56	8
MNPCA-S002-807	Greenwood River	0.4374	98	0	0	54	70	61	60	4
MNPCA-S002-842	Rat Root River	0.3805	99	0	0	170	250	219	232	6
MNPCA-S004-104	Lower Tamarack River	0.2751	98	0	0	30	69	50	43	5
MNPCA-S005-766	Bug Creek	0.2394	99	0	0	45	184	118	126	26
MNPCA-S005-767	South Branch Partridge River	0.2721	99	0	0	45	129	84	87	20
MNPCA-S006-267	McCarthy Creek	0.0137	100	0	0	50	165	119	127	14
MNPCA-S007-248	Not Named	0.4019	97	0	0	103	103	103	103	1
MNPCA-S007-249	Not Named	0.4019	97	0	0	106	106	106	106	1
MNPCA-S007-262	Vaara Creek	0.1260	99	0	0	102	102	102	102	2
MNPCA-S007-361	East Branch Beaver River	0.3269	99	0	0	53	93	66	59	4
MNPCA-S007-603	East Branch Beaver River	0.2387	99	0	0	38	100	60	50	4
MNPCA-S007-674	Snake Creek	0.0624	99	0	0	48	296	179	167	8
MNPCA-S007-767	South Greenwood Creek	0.4099	98	0	0	27	73	41	37	33
MNPCA-S007-825	French River	0	100	0	0	136	142	139	139	2
MNPCA-S007-831	Not Named	0.4228	98	0	0	36	148	100	108	4
MNPCA-S007-902	Ash River	0.4470	98	0	0	29	304	220	228	48
MNPCA-S007-903	Little Indian Sioux River	0.3124	96	0	0	12	25	21	22	22
MNPCA-S008-001	Captain Jacobson Creek	0.4077	98	0	0	107	186	141	128	7
MNPCA-S008-002	Brophy Creek	0	100	0	0	157	195	180	185	6
MNPCA-S008-032	Cabin Creek	0.4478	98	0	0	51	104	71	60	7
MNPCA-S008-297	Saint Louis River	0.4746	97	0	0	30	56	46	50	5
MNPCA-S008-433	Elbow River	0.1559	99	0	0	25	87	38	30	16
MNPCA-S008-594	Bug Creek	0.4638	98	0	0	64	164	97	79	4
MNPCA-S008-605	Hog Creek	0.3033	98	0	0	30	55	41	39	4

Location Identifier	Stream Name	Road Density km/km^2	Percent Natural Land Cover	Percent Impervious Surface	Canal Density km/km^2	Minimum SC	Maximum SC	Mean SC	Median SC	*N*
MNPCA-S008-608	Larch Creek	0.0247	99	0	0	44	316	138	97	4
MNPCA-S008-620	Ninemile Creek	0.2301	98	0	0	101	348	173	154	26
MNPCA-S008-817	Redhorse Creek	0.2582	99	0	0	52	186	128	130	17
MNPCA-S008-905	Kit Creek	0.3443	100	0	0	140	140	140	140	1
MNPCA-S009-129	Fawn Creek	0.0754	97	0	0	161	275	202	199	19
MNPCA-S014-216	Ash River	0	98	0	0	165	273	239	256	6
MNPCA-S014-218	Little Net River	0.2091	99	0	0	24	24	24	24	1
MNPCA-S014-219	Little Net River	0.2091	99	0	0	23	84	64	75	4
MNPCA-S014-233	Fawn Creek	0.0754	97	0	0	276	386	333	331	14
MNPCA-S014-428	East Branch Rat Root River	0.2517	99	0	0	288	288	288	288	1
MNPCA-S015-069	Rat Root River	0.4160	98	0	0	172	286	245	277	3
MNPCA-S015-180	Rat Root River	0.2236	98	0	0	137	224	186	191	4
MNPCA-S015-204	Not Named	0.2238	97	0	0	67	67	67	67	1
MNPCA-S015-205	Not Named	0.2238	97	0	0	75	75	75	75	1
MNPCA_BIO-S002-842	Rat Root River	0.3805	99	0	0	225	266	246	246	2
MNPCA_BIO-S007-903	Little Indian Sioux River	0.3124	96	0	0	21	22	22	22	2
MNPCA_BIO-S009-581	McCackron Brook	0.4882	98	0	0	60	130	93	89	5
MNPCA_BIO-S010-205	Not Named	0.0131	100	0	0	42	42	42	42	1
MNPCA_BIO-S010-216	Clear Creek	0.4706	99	0	0	38	48	43	43	2
MNPCA_BIO-S010-228	Not Named	0.4256	98	0	0	23	23	23	23	1
MNPCA_BIO-S010-229	Hog Creek	0.3033	98	0	0	52	52	52	52	1
MNPCA_BIO-S010-251	Moose Brook	0.2456	98	0	0	291	291	291	291	1
MNPCA_BIO-S010-329	Chelsey Brook	0.0463	96	0	0	100	201	151	151	2
MNPCA_BIO-S010-341	East Fork Crooked Creek	0.4195	97	0	0	202	202	202	202	1
MNPCA_BIO-S010-346	McDermott Creek	0.0322	100	0	0	34	46	40	40	2
MNPCA_BIO-S010-349	Not Named	0.2335	100	0	0	145	145	145	145	1
MNPCA_BIO-S010-356	Lower Tamarack River	0.3752	99	0	0	84	84	84	84	1
MNPCA_BIO-S010-370	Not Named	0.1425	97	0	0	183	183	183	183	1
MNPCA_BIO-S010-843	Not Named	0.4891	98	0	0	108	108	108	108	1
MNPCA_BIO-S010-845	Not Named	0.4351	97	0	0	117	159	140	143	3
MNPCA_BIO-S011-029	Bug Creek	0.2394	99	0	0	124	124	124	124	1
MNPCA_BIO-S011-060	Colvin Creek	0.4872	98	0	0	86	86	86	86	1
MNPCA_BIO-S011-063	Joula Creek	0.2609	97	0	0	116	116	116	116	1

Location Identifier	Stream Name	Road Density km/km^2	Percent Natural Land Cover	Percent Impervious Surface	Canal Density km/km^2	Minimum SC	Maximum SC	Mean SC	Median SC	*N*
MNPCA_BIO-S011-315	Skunk Creek	0.4562	100	0	0	93	262	194	228	3
MNPCA_BIO-S011-328	Saint Louis River	0.4746	97	0	0	56	62	59	59	2
MNPCA_BIO-S011-335	Not Named	0	99	0	0	56	56	56	56	1
MNPCA_BIO-S011-338	Portage River	0.0084	100	0	0	23	23	23	23	1
MNPCA_BIO-S011-366	Brophy Creek	0	100	0	0	152	165	159	159	2
MNPCA_BIO-S011-386	Two Island River	0.2471	99	0	0	52	52	52	52	1
MNPCA_BIO-S011-615	Wagner Creek	0.4723	97	0	0	302	302	302	302	1
MNPCA_BIO-S011-831	Knife River	0.0980	97	0	0	157	166	162	162	2
MNPCA_BIO-S011-835	Captain Jacobson Creek	0.4077	98	0	0	112	180	146	146	2
MNPCA_BIO-S011-846	Not Named	0.2472	100	0	0	160	174	167	167	2
MNPCA_BIO-S011-848	Skunk Creek	0	100	0	0	194	194	194	194	1
MNPCA_BIO-S012-319	Caribou River	0.2215	100	0	0	58	110	90	95	6
MNPCA_BIO-S012-582	Castle Creek	0.2497	99	0	0	215	215	215	215	1
MNPCA_BIO-S012-689	East Branch Beaver River	0.2387	99	0	0	52	52	52	52	1
MNPCA_BIO-S012-905	Ash River	0.4470	98	0	0	244	244	244	244	1
MNPCA_BIO-S012-906	Horse River	0	100	0	0	24	24	24	24	1
MNPCA_BIO-S012-917	Moose River	0.1156	99	0	0	23	23	23	23	1
MNPCA_BIO-S012-918	Bezhik Creek	0.0604	98	0	0	24	35	30	30	2
MNPCA_BIO-S012-919	Stuart River	0	100	0	0	27	27	27	27	1
MNPCA_BIO-S012-920	Nina Moose River	0	100	0	0	42	42	42	42	2
MNPCA_BIO-S012-921	Portage River	0.0084	100	0	0	25	25	25	25	1
MNPCA_BIO-S012-923	Duck Creek	0.1644	100	0	0	23	23	23	23	1
MNPCA_BIO-S012-925	Crab Creek	0	100	0	0	20	20	20	20	1
MNPCA_BIO-S012-941	Greenwood River	0.4374	98	0	0	36	38	37	37	2
MNPCA_BIO-S012-953	Kawishiwi River	0	100	0	0	26	26	26	26	1
MNPCA_BIO-S012-954	Phoebe River	0	98	0	0	21	21	21	21	1
MNPCA_BIO-S012-955	Larch Creek	0.0247	99	0	0	75	118	95	91	3
MNPCA_BIO-S012-957	Hog Creek	0.3033	98	0	0	29	54	42	42	8
MNPCA_BIO-S013-018	Royal River	0	100	0	0	42	42	42	42	1
MNPCA_BIO-S013-029	Caribou River	0.4270	99	0	0	62	71	67	67	2
MNPCA_BIO-S013-049	Stewart River	0.0101	100	0	0	82	272	177	177	2
MNPCA_BIO-S013-124	Stump River	0.4357	98	1	0	28	42	35	35	2
MNPCA_BIO-S013-130	Knife River	0.0980	97	0	0	107	194	151	151	2
MNPCA_BIO-S013-259	Elbow River	0.1559	99	0	0	28	28	28	28	2
MNPCA_BIO-S013-268	Bug Creek	0.4638	98	0	0	60	86	73	73	2

Location Identifier	Stream Name	Road Density km/km^2	Percent Natural Land Cover	Percent Impervious Surface	Canal Density km/km^2	Minimum SC	Maximum SC	Mean SC	Median SC	*N*
MNPCA_BIO-S013-282	Longstorff Creek	0.4397	100	0	0	63	82	73	73	2
MNPCA_BIO-S013-305	Not Named	0.4368	98	0	0	39	39	39	39	1
MNPCA_BIO-S013-306	Michaud Brook	0.3986	98	0	0	39	149	79	64	4
MNPCA_BIO-S013-309	North Fork Willow River	0.3958	98	0	0	232	232	232	232	1
MNPCA_BIO-S013-331	East River	0.0013	100	0	0	113	177	145	145	2
MNPCA_BIO-S013-339	Sand Creek	0.3131	96	0	0	99	99	99	99	1
MNPCA_BIO-S013-351	Not Named	0	100	0	0	130	247	189	189	2
MNPCA_BIO-S013-356	Sand Creek	0.3131	96	0	0	191	191	191	191	1
MNPCA_BIO-S013-402	Bremen Creek	0.2502	98	0	0	61	64	63	63	2
MNPCA_BIO-S013-453	McDermott Creek	0.4992	99	0	0	41	48	45	45	2
MNPCA_BIO-S013-460	Redhorse Creek	0.2582	99	0	0	129	158	144	144	2
MNPCA_BIO-S013-462	Lower Tamarack River	0.3752	99	0	0	63	71	67	67	2
MNPCA_BIO-S013-584	Plouff Creek	0.3476	98	0	0	57	57	57	57	1
MNPCA_BIO-S013-586	Cabin Creek	0.4478	98	0	0	37	58	52	54	6
MNPCA_BIO-S013-587	Manitou River	0.4196	95	0	0	102	108	105	105	2
MNPCA_BIO-S013-634	Sixmile Creek	0.3563	99	0	0	44	78	61	61	2
MNPCA_BIO-S013-639	East Branch Beaver River	0.3269	99	0	0	163	175	169	169	2
MNPCA_BIO-S013-737	Cascade River	0.2745	100	0	0	73	74	74	74	2
MNPCA_BIO-S013-738	Cascade River	0.4301	98	0	0	45	71	58	58	2
MNPCA_BIO-S013-778	McDermott Creek	0.0004	100	0	0	66	66	66	66	1
MNPCA_BIO-S013-807	Redhorse Creek	0.2582	99	0	0	206	206	206	206	1
MNPCA_BIO-S013-814	East Fork Crooked Creek	0.4195	97	0	0	126	126	126	126	1
MNPCA_BIO-S013-817	Lower Tamarack River	0.3752	99	0	0	74	74	74	74	1
MNPCA_BIO-S013-842	Saint Louis River	0.2091	95	0	0	75	75	75	75	1
MNPCA_BIO-S013-849	Bug Creek	0.0393	100	0	0	78	78	78	78	1
MNPCA_BIO-S013-861	Not Named	0.4105	99	0	0	64	64	64	64	1
MNPCA_BIO-S013-872	Schoolhouse Creek	0.2322	99	0	0	76	76	76	76	1
MNPCA_BIO-S013-874	East Branch Beaver River	0.3269	99	0	0	55	55	55	55	1
MNPCA_BIO-S013-876	Cascade River	0.3917	98	0	0	38	62	50	50	2
MNPCA_BIO-S013-879	Not Named	0.3404	100	0	0	36	36	36	36	1
MNPCA_BIO-S013-883	Reservation River	0.4628	99	0	0	153	153	153	153	1

Location Identifier	Stream Name	Road Density km/km^2	Percent Natural Land Cover	Percent Impervious Surface	Canal Density km/km^2	Minimum SC	Maximum SC	Mean SC	Median SC	*N*
MNPCA_BIO-S013-884	Stump River	0.4357	98	1	0	31	49	38	37	4
MNPCA_BIO-S013-890	South Branch Partridge River	0.2721	99	0	0	93	93	93	93	1
MNPCA_BIO-S013-959	Plouff Creek	0.3476	98	0	0	52	97	66	58	5
MNPCA_BIO-S013-984	Hornby Creek	0	100	0	0	56	56	56	56	1
MNPCA_BIO-S013-991	Rice River	0.0681	100	0	0	73	90	80	78	3
MNPCA_BIO-S013-992	Stumble Creek	0.3479	100	0	0	70	70	70	70	1
MNPCA_BIO-S014-050	Bug Creek	0.0393	100	0	0	90	90	90	90	1
MNPCA_BIO-S014-054	Lower Tamarack River	0.3752	99	0	0	66	66	66	66	1
MNPCA_BIO-S014-123	Not Named	0.2759	99	0	0	78	83	81	81	2
MNPCA_BIO-S014-132	Not Named	0	98	0	0	35	35	35	35	1
MNPCA_BIO-S014-133	Not Named	0	95	0	0	262	262	262	262	1
MNPCA_BIO-S014-238	Toimi Creek	0.3119	99	0	0	135	139	137	137	2
MNPCA_BIO-S014-426	Rat Root River	0.0438	99	0	0	194	206	200	200	2
MNPCA_BIO-S014-428	East Branch Rat Root River	0.2517	99	0	0	243	278	261	261	2