AN EVALUATION OF A FIELD-BASED AQUATIC LIFE BENCHMARK FOR SPECIFIC CONDUCTANCE IN NORTHEAST MINNESOTA

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I. Introduction

A. Specific Conductance

Specific conductance is an accurate, low cost, easily completed measurement directly related to salinity, a difficult-to-measure combined effect of all ions in the water. Under most conditions, specific conductance is applicable to identify ionic changes in surface water that have been shown to affect aquatic life. Native ion concentration levels are necessary to aquatic life, but negative effects on aquatic life from anthropogenic cumulative ionic toxicity are related to higher specific conductance levels.

This evaluation answers two questions:

1. Are the methods used by U.S. Environmental Protection Agency (EPA) to develop a specific conductance aquatic life benchmark for Appalachian ecoregions applicable in developing specific conductance aquatic life protections for ecoregions in Minnesota? For purpose of this evaluation the primary reference is EPA's *A Field-Based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams* (EPA Conductivity Benchmark Study, 2011)[2].

2. Is the 300 micro Siemens per centimeter (μS/cm) guidance developed by EPA for the Appalachian ecoregions directly applicable as a maximum aquatic life benchmark for northeast Minnesota ecoregions 50n, the northern portion of 50p, and 50t (EPA, 2007)[3] or as a Minnesota NPDES permit condition when sufficient background data is available?

This evaluation for northeast Minnesota is not a comprehensive review of all data sources relating to chemistry and benthic invertebrates in the specified area. Its intent is to demonstrate that significant data exists, and that if other existing historical and current data is added, little new data would be needed to support Minnesota's adoption of a

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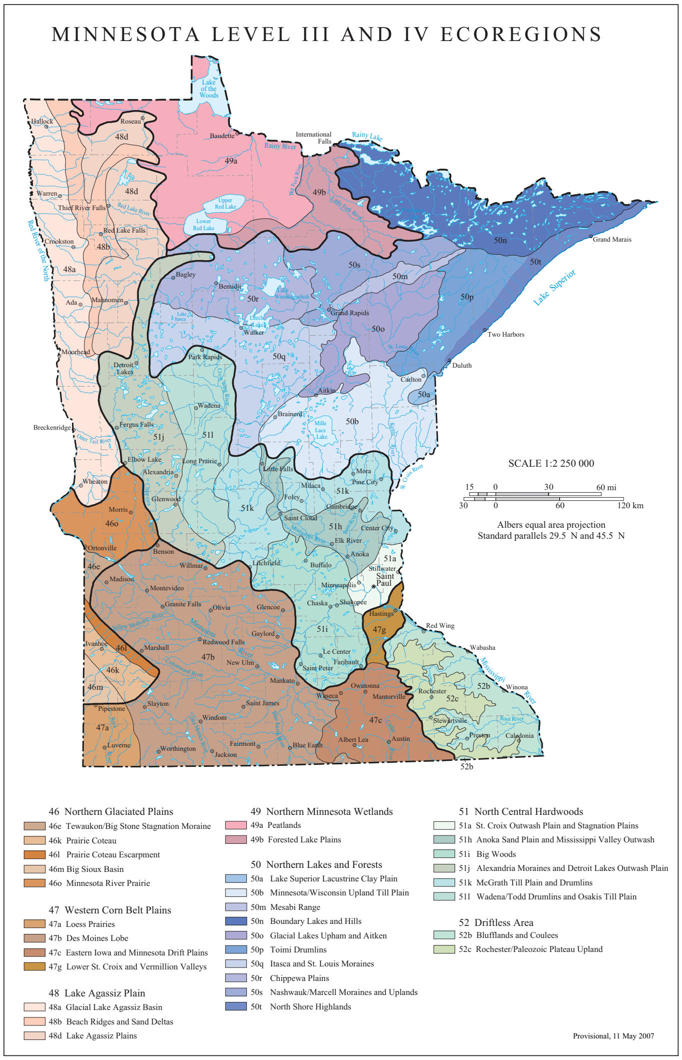
[2] U.S. Environmental Protection Agency, *A Field-Based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams,* Office of Research and Development, National Center for Environmental Assessment, Washington, DC., 2011 EPA/600/R-10/023F. (hereinafter "EPA Conductivity Benchmark Study")

[3] U.S. Environmental Protection Agency, *Minnesota Level III and IV Ecoregions*, 2007, www.epa.gov/wed/pages/ecoregions/mn_eco.htm.

numeric specific conductance benchmark or standard, at least as stringent as the Appalachian 300 µS/cm specific conductance benchmark, based on protection of aquatic life in Minnesota ecoregions 50n, the northern portion of 50p, and 50t.

Figure 1, Map of Minnesota Level III and IV Ecoregions, illustrates these northeast Minnesota ecoregions. Pending such adoption of a data-driven specific conductance rule, the data is sufficient to support permit conditions implementing this 300 µS/cm specific conductance benchmark in order to begin meeting Minnesota's existing narrative standards for aquatic life.

Figure 1. Map of Minnesota Level III and IV Ecoregions.



EPA defines "ecoregion" as an ecological region "identified through the analysis of the patterns and the composition of biotic and abiotic phenomena that affect or reflect differences in ecosystem quality and integrity. These phenomena include geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. The relative importance of each characteristic varies from one ecological region to another regardless of the hierarchical level." [4] (EPA, 2015). In general the Laurentian Divide delineates the southern boundary of the Ecoregion 50n and the coinciding northern boundary of 50p. At this interface, the area along the northern boundary of 50p is similar to 50n in climate, geology, topography, soils, hydrology, and vegetation. This inclusion is supported by the Minnesota Department of Natural Resources (MDNR) and U.S. Department of Agriculture Forest Service (USFS) Ecological Classification System, which differentiates between this 50p inclusion and the 50p region south of it (MDNR, USFS, et al. 1999).[5] Thus the review includes this area in evaluating a Specific Conductance benchmark for permit limits or standard development for the 50n, northern part of 50p, and 50t ecoregions in Minnesota.

This review evaluates some of the available data for establishment of a numeric benchmark or standard on which to base permit effluent limits to comply with existing narrative standards for aquatic life in Minnesota. It compares aquatic life genera (a biological classification of a group of species) and specific conductance levels of unimpacted and mining-impacted headwater streams in Minnesota as well as comparing water chemistry and biological data in unimpacted and impacted streams in the coal mining area in two Appalachian headwater ecoregions. These ecoregions were studied in the EPA Conductivity Benchmark Study. After internal, external and public review of the EPA Study, EPA's Science Advisory Board concluded, "the benchmark is applicable to the regions in which it was derived and the benchmark and the methodology may be applicable to other states and regions with appropriate validation." (EPA Conductivity Benchmark Study, 2011).[6]

In this evaluation of data, for each genus which both Minnesota and Appalachian ecoregions have in common, the EPA's specific conductance level at which 5 percent of the taxa have been lost as determined at the genus level (the XC95%) was recorded in column K of Table 1, Detailed Invertebrate Background, which is attached as Appendix A. As explained in the EPA Conductivity Benchmark Study, this evaluation criterion uses field data instead of lab data and is based on the EPA's "standard methodology for deriving water-quality criteria, in that it uses the 5th centile of a species sensitivity distribution (SSD) as the benchmark value. SSDs represent the response of aquatic life as a distribution with respect to exposure."[7] (EPA Conductivity Benchmark Study, 2011).

EPA's Conductivity Benchmark Study explains,

> The method used in this report is based on the standard methodology for deriving water-quality criteria, as explained in Stephan *et al*. (1985), in that it used the 5th centile of a species sensitivity distribution (SSD) as the benchmark value. SSDs represent the response of aquatic life as a distribution with respect to exposure.

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[4] U.S. Environmental Protection Agency, *Ecoregion Maps and GIS Resources*, updated March 30, 2015 and citations therein, including Wiken 1986; Omernik 1987; Omernik 1995. See http://archive.epa.gov/wed/ecoregions/web/html/ecoregions-2.html.

[5] Minnesota Department of Natural Resources, U.S. Department of Agriculture Forest Service, *et al*., *Ecological Classification System, and Subsections Map,* 1999. http://www.dnr.state.mn.us/ecs/index.html and http://files.dnr.state.mn.us/natural_resources/ecs/subsection.pdf

[6] *Ibid.,* 2, EPA Conductivity Benchmark Study, p. viii.

[7] *Id.,* 2, EPA Conductivity Benchmark Study, p. xiv.

> Data analysis followed the standard methodology in aggregating species to genera and using interpolation to estimate the centile. It differs primarily in that the points in the SSDs are extirpation concentrations (XCs) rather than median lethal concentrations (LC50s) or chronic values. The XC is the level of exposure above which a genus is effectively absent from water bodies in a region. For this benchmark value, the 95th centile of the distribution of the probability of occurrence of a genus with respect to conductivity was used as a 95th centile extirpation concentration. Hence, this aquatic life benchmark for conductivity is expected to avoid the local extirpation of 95% of native species (based on the 5thcentile of the SSD) due to neutral to alkaline effluents containing a mixture of dissolved ions dominated by salts of SO_4^{-2} and HCO_3^{-1}. Because it is not protective of all genera and protects against extirpation rather than reduction in abundance, this level is not fully protective of sensitive species or higher quality, exceptional waters designated by state and federal agencies.[8] (EPA Conductivity Benchmark Study, 2011).

EPA further notes, "an invertebrate genus may represent several species, and this approach identifies the pollutant level that extirpates all sampled species within that genus, that is, the level at which the least sensitive among them is rarely observed."[9] (EPA Conductivity Benchmark Study, 2011).

EPA provided Final Guidance in a memorandum to EPA Regional Administrators (EPA Final Guidance, 2011) on reviewing surface coal mining and applying the Conductivity Benchmark Study: "This final peer-reviewed study concludes that 5% of native macroinvertebrate genera are extirpated where the conductivity level reaches 300 µS/cm." EPA Final Guidance also stated that when 5% of the native macroinvertebrate genera are extirpated, that conductivity level is "associated with significant biological degradation from loss of stream life," and may prevent compliance with regulations for Clean Water Act Section 404 permits.[10] (EPA Final Guidance, 2011). In other words, "significant biological degradation" indicates unacceptable pollution.

Minnesota rules reflect a similar definition of toxicity for aquatic life, establishing that the absence of toxic effects means "the protection of no less than 95% of all the species in any aquatic community." (Minn. Rule 7050.0217, Subp. 2A).

It should be noted that this index of unacceptable pollution is not comparable to a watershed stressor evaluation using the Index of Biological Integrity (IBI)[11] (EPA, Index of Biological Integrity, 1998). IBI studies identify differences between unimpacted and impacted areas to determine the biological integrity (general health) of a component of a

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[8] *Id.*. 2, EPA Conductivity Benchmark Study, p. xiv. It should be noted that XC95% is equivalent to an EC5% standard.
[9] *Id., 2*, EPA Conductivity Benchmark Study, p. 26.
[10] U.S. EPA, *Improving EPA Review of Appalachian Surface Coal Mining Operations Under the Clean Water Act, National Environmental Policy Act, and the Environmental Justice Executive Order*, July 21, 2011, pp. 32-33. [Hereinafter "EPA Final Guidance"]. Guidance approved in *National Mining Association v. McCarthy*, 758 F.3d 243 (D.C. Cir. 2014). EPA reference to regulations at 40 C.F.R. 230.10 and to Clean Water Act Section 404(b).
[11] EPA Office of Water, Office of Wetlands and Watersheds, *Developing an Index of Biologic Integrity,* EPA843-F-98e, July 1998, http://water.epa.gov/type/wetlands/assessment/fact5.cfm

biological system such as taxa richness. But an IBI does not relate taxa to water chemistry parameters like specific conductance or numeric standards. The IBI score may ignore outliers caused by a stressor that could be damaging numerous genera but is not captured by the "general health."

B. Approach: Current Scientific Methods in Water Quality Protection

Due to the complexity and diversity of aquatic ecosystems, in practice no single or series of numeric standards or bioassays can be 100% protective of surface waters. There can be unidentified confounding factors such as unacceptable synergistic chemical (elemental and compound) impacts. Because of this, numerous methods have been developed to address impacts. The following is a brief discussion of some of the well-used methods:

> *Single chemical bioassays* use extensively studied aquatic organisms under laboratory conditions. From these tests, acute and chronic toxicity values are determined by using a single toxicant. The resultant standard is then developed for the most sensitive of the laboratory test species for the specific chemical tested. Bioassays are also used to determine the impacts from wastewater by testing known organisms with suspect wastewater over an arbitrary time limit.
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> *Synergistic impacts* (multiple chemical toxicity) often can be addressed by using whole effluent toxicity testing (WET) procedures (EPA-821-R-02-013) [12]. This method applies a series of standard bioassay organisms likely to be sensitive to the suspected contaminants. But, instead of single toxicant additions, it uses the field water in question to evaluate impact. The standard organisms may not be native to the field water.
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> *Narrative standards* may be used to address synergistic effects as well as the effects of single parameters. Examples of these standards in Minnesota are found in Minn. Rules 7050.0150, 7050.0170, 7050.0180, 7050.0185, 7050.0186, and 7052.0230.
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> *Numeric standards* can be based on uses such as irrigation of crops, as in Minn. Rule 7050.0224, Subp. 2. Numeric standards can also protect aquatic life and recreation, as in Minn. Rule 7050.0222, where Class 2 waters are protected for fishable and swimmable uses.
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> *Field based benchmark methods* are used to develop numeric standards. The field-based method has advantages over laboratory bioassays as follows:
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> 1. The species involved are indigenous to the water tested;
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> 2. The exposure time to the chemical is not arbitrarily limited;

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[12] EPA, *Short Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms.* October 2002. Available at http://water.epa.gov/scitech/methods/cwa/wet/disk3_index.cfm

3. The method assesses all life stages of the population and ecological interactions;

4. The method represents all exposure conditions for the parameter.

As stated previously, due to the complexity of aquatic life, all methods, among them water chemistry, bioassays, and species sensitivity distributions, must be used as applicable and appropriate to evaluate impacts. This field-based benchmark for specific conductance is the approach on which this paper is focused. Specific conductance is chosen because it is a synergistic measure of the effects of ionized substances in the water on aquatic life.[13]

C. Regulatory Provisions

Exceedances of individual numeric standards are accepted as indicative of polluted conditions (Minn. Rule 7050.0220, Subp. 1). Currently, Minnesota does not have a numeric specific conductance standard based on aquatic life criteria.

The existing Minnesota specific conductance standard of 1000 µS/cm is a numeric limit applied to class 4A waters used for irrigation statewide (Minn. Rule 7050.0224, Subp. 2). The standard has been in place since 1966 with no change, based on protection of waters for irrigation of crops or vegetation.

Since then, specific conductance has commonly been used to observe daily, seasonal, and significant changes in water quality. However, beyond application to irrigation, Minnesota's standard is antiquated and fails to adequately protect aquatic life. As in Appalachian regions of Kentucky and West Virginia, under Minnesota rules narrative standards also apply. If both numeric and narrative standards are in place, the more stringent standard applies (Minn. Rule 7050.0150, Subp. 2).

The narrative standard in Minn. Rule 7050.0150, Subp. 3 further requires that "lower aquatic biota" not be seriously impaired or altered materially. Minnesota toxic pollutant regulations are applicable to protect the aquatic community from toxic effects, defined to mean "the protection of no less than 95% of all the species in any aquatic community. Greater protection may be applied to a community if economically, recreationally, or ecologically important species are very sensitive." (Minn. Rule 7050.0217 Subp. 1, 2).

Minn. Rule 7050.0180 designates waters of the Boundary Waters Canoe Area Wilderness, Department of Natural Resources designated scientific and natural areas, Lake Superior, and other waters of the state that warrant stringent protection from pollution, as *Outstanding resource value waters*. Those listed waters, unlisted waters, and unlisted wetlands in the Lake Superior Basin that are not designated Outstanding resource value waters or Class 7 waters are designated as *Outstanding international resource waters* under Minn. Rule 7052.0300, Subp. 3. These designations provide specific protections.

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[13] American Public Health Association, *et al.*, *Standard Methods for the Examination of Water and Wastewater*, 12th Ed., 1965. p. 280.

Although specific conductance is not a listed toxic pollutant in Minnesota rules, "toxic pollutants" means pollutants, or combinations of pollutants, that will directly or indirectly cause "death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, including malfunctions in reproduction, or physical deformation." (Minn. Stat. §115.01, Subd. 20).

In summary, under Minnesota Rules, loss of 5% of the species in a community is considered polluted. The protection of 95% of all genera is the criterion EPA has determined to be protective for specific conductance in the Appalachians. EPA has also determined a loss of 5% of the genera within a community represents a significant degradation[14] (EPA Conductivity Benchmark Study, 2011) and unacceptable. Minnesota's rules are consistent with the EPA Appalachian specific conductance benchmark determination method, and an aquatic life benchmark for specific conductance could be implemented in Minnesota from a regulatory standpoint.

II. Methods

A. Applicability of Existing Specific Conductance Data

1. Existing Minnesota Data Sets

To obtain a relevant numeric specific conductance standard for Minnesota, existing water chemistry and biological data must be compared. As in the Appalachians, Minnesota has historical background data for the aforementioned Minnesota ecoregions. One source of such data is from the late 1970's, the State of Minnesota's Regional Copper-Nickel Study[15] (Copper-Nickel Study, 1980), a comprehensive examination of the potential cumulative impacts, including environmental impacts, of copper-nickel mineral development in northeast Minnesota. The Copper-Nickel Study includes an assemblage of numerous research reports authored by staff from Minnesota Environmental Quality Board, MDNR, Minnesota Pollution Control Agency (MPCA), and the former State Planning Agency, as well as University of Minnesota faculty and students, and consultants.

Objectives of the Copper-Nickel Study included:

1) to characterize the region in its pre-copper-nickel development state, and

2) to identify and assess the impacts of primary copper-nickel development and secondary regional growth.

The Copper-Nickel Study scientists collected sets of ecological data to assess the background of a 500-square mile area, mainly in ecoregion 50n, preparatory to potential mining. These included lake and stream surface water chemistry and invertebrate identifications. This Regional Study is a relevant background for evaluating current unimpacted and impacted chemistry and invertebrate populations. The Copper-Nickel

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[14] *Ibid.,* 2, EPA Conductivity Benchmark Study, p. 32.

[15] State of Minnesota, *Regional Copper-Nickel Study*, 1976-1980, a collection of research papers located at the Minnesota Legislative Reference Library, www.leg.state.mn.us/lrl/lrl.asp. Several specific research papers are referenced in this review. (hereinafter "Copper-Nickel Study").

Study data significantly reduces the need for additional data collection to apply the EPA protocol to these regions of Minnesota.

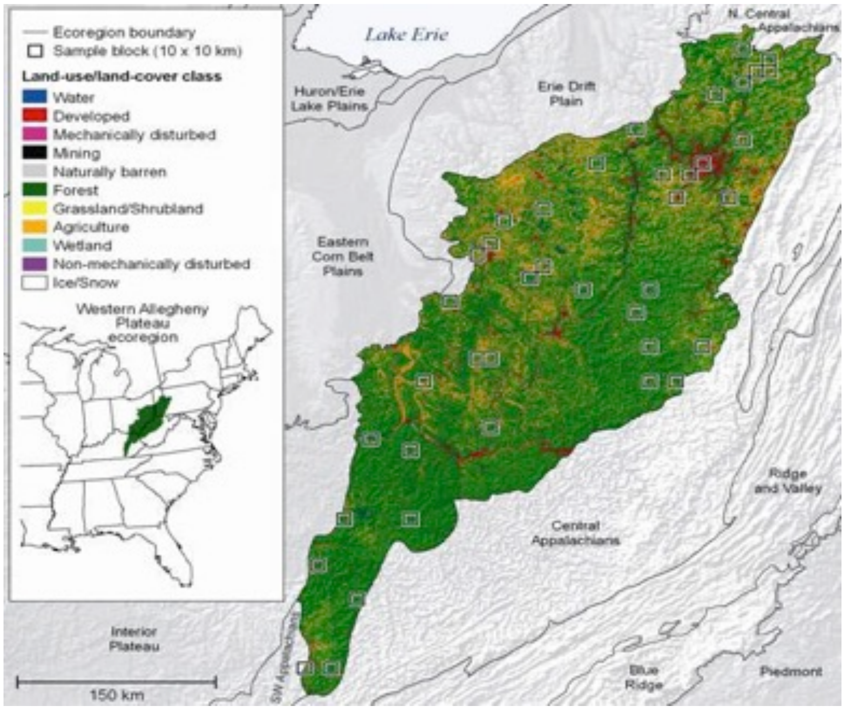
Additional more recent data was obtained by the authors from USFS Superior National Forest (SNF) and MPCA reports and National Permit Discharge Elimination System (NPDES) permit discharge monitoring reports (DMRs).

2 . Regional Similarities

Obviously climate differences exist between northeastern Minnesota and the West Virginia/Kentucky Appalachians. However the Appalachian Western Allegheny Plateau ecoregion can be compared to the northeast Minnesota ecoregions in terms of aquatic life. The Appalachian Ecoregions 68, 69, 70 and northeastern Minnesota Ecoregions 50n, the northern portion of 50p, 50t have the following similarities:

1. Both are defined by headwater streams (order 1 through 5);
2. Unimpacted streams all share low specific conductance, although Minnesota backgrounds are even lower;
3. Unimpacted ionic mixtures have similar important chemical constituents - low calcium (Ca), magnesium (Mg), sulfate ($S0_4$), and bicarbonate (HCO_3) at circumneutral to alkaline pH 6.0 to 10;
4. Unimpacted sites contain only trace amounts of heavy metals;
5. Both share benthic invertebrates with similar genera, however Minnesota has more genera than those in common.

Figure 2. Map of Appalachian Western Allegheny Plateau Ecoregion



3. Chemistry of Specific Conductance

Specific conductance is a measurement of the ability of water to conduct an electrical current. Salinity is the total concentration of all dissolved salts in water. Salinity can be calculated from specific conductance where complicating factors do not exist.

Specific conductance is a simple, fast, inexpensive test that can be performed in the field by persons with minimal training. The more cations and anions contained in water, the more electrical current it will conduct. Conductivity represents the sum of all cations and anions in water at 25 degrees Celsius (°C). The most common of these ions are calcium (Ca), magnesium (Mg), sodium (Na), bicarbonate (HCO_3), and sulfate (SO_4), but ions can also include one or more heavy metals including, but not limited to selenium (Se), copper (Cu), nickel (Ni), cobalt (Co), zinc (Zn), and cadmium (Cd).

Crushed and fractured rock from any mining increases the unweathered rock surface exposed to water dissolution and can drastically affect common cation and anion balances, with increases in both common and rare ions that are from within the rock structure. Minnesota has considerable specific conductance data from both unimpacted and impacted waters.

4. EPA Method for Specific Conductance Benchmark

The method EPA used to develop a specific conductance benchmark for West Virginia and Kentucky was based on a standard methodology[16] (EPA Conductivity Benchmark Study, 2011). The EPA method correlated water chemistries with observed changes in a community of benthic invertebrates to determine where there was impact or no impact. As stated previously, EPA applied the criterion that elimination of more than 5% of genera from a community caused by an increased specific conductance indicated an unacceptable level of impact or a polluted condition. This impact/no-impact determination is the same one that EPA uses to set other numeric standards using laboratory bioassays, for chemicals such as copper, nickel, selenium, etc.

In West Virginia and Kentucky ecoregions 69, 70, the threshold for unimpacted or low-impacted waters -- where 5% of the genera were eliminated, resulting in an unacceptable impact -- was determined to be a specific conductance level of 300 µS/cm or greater.[17] (EPA Conductivity Benchmark Study, 2011).

Many aquatic organisms are sensitive to imbalances in the ambient ion concentrations. The EPA has explained: "Exposure of aquatic organisms to salinity is direct. Fish, amphibians, mussels, and aquatic macroinvertebrates are especially exposed on their gills or other respiratory surfaces that are in direct contact with dissolved ions in water. All animals have specific structures to transport nutrient ions and control their ionic and osmotic balance (Bradley, 2009; Evans, 2008a, b, 2009; Wood and Shuttleworth, 2008;

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[16] *Ibid.,* 2, EPA Conductivity Benchmark Study, p. 1.

[17] *Id.*, EPA Conductivity Benchmark Study, pp. xiv- xv.

Thorp and Covich, 2001; Komnick, 1977; Smith, 2001; Sutcliff, 1962; Hille, 2001). However, these cell membrane and tissue structures function only within a range of salinities. For example, some aquatic insects such as most Ephemeroptera [mayflies] have evolved in a low-salt environment."[18] (EPA Conductivity Benchmark Study, 2011, p. 2).

Aquatic life is not dead during the winter. Although adaptations to lower temperatures occur, ion imbalances during the cold period can still cause stress or impact.

B. Application of the EPA Appalachian Method to Minnesota

All waters do not contain a similar diversity of organisms or similar concentrations of ions. In Minnesota, for example, conductivities (and compositional concentrations) in the Minneapolis/St. Paul area are naturally higher than in the northeastern part of the state. Thus, data on Minnesota's aquatic life and background ion levels in the specific region being evaluated are required to determine applicability of the benchmark found for the Appalachian ecoregions[19] (Thingvold, 1979).

Although EPA cautions that the numeric benchmarks themselves may not be directly applicable nationwide, EPA recommends the methods used for their determination. Generally, to duplicate the EPA's specific conductance evaluation for other ecoregions, the following basic methods and conditions would be required[20] (EPA Conductivity Benchmark Study, 2011):

1. Sampling of rivers with watershed areas under 155 km^2 (order 5 streams and lower) using sampling methods similar to EPA's Appalachian study, or other appropriate method; if streams are Order 5 or over, different sampling methods are required.
2. Sampling of surface waters with a natural background - unimpacted or near-unimpacted surface waters as well as impacted waters.
3. Presence of waters dominated by calcium, magnesium, sulfate, and bicarbonate at a circumneutral to alkaline, pH 6.0 to 10.
4. Invertebrate surveys, identified to at least genus level (species level when possible), once per year, in spring or summer, focusing on genera that are mostly sensitive to specific conductance, e.g. Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies).
5. Water chemistry analysis that includes analysis for confounding ions beyond the common ions as discussed in item 3 above.
6. Results are evaluated using a species sensitivity distribution with 95% confidence bounds.

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[18] *Id.,* EPA Conductivity Benchmark Study, p. 2.

[19] Thingvold, Daryl, Nancy Sather, Peter Ashbrook, *Water Quality Characterization of the Copper-Nickel Research Area,* December, 1979, pp. 7-19. Available at http://archive.leg.state.mn.us/docs/pre2003/other/CN153.pdf

[20] *Ibid.,* 2, EPA Conductivity Benchmark Study, pp. 4-22.

III. Results of Data Comparisons and Analysis

A. Minnesota Data to Support a Specific Conductance Benchmark

Minnesota's ecoregion 50n already has significant data that would support a specific conductance standard at least as stringent as the EPA's 300 µS/cm guideline for Appalachia. In this ecoregion of Minnesota, due to the naturally lower values of major cations and anions, coupled with the lack of confounding factors, the specific conductance standard that would protect 95% of lower aquatic biota may be even lower than 300 µS/cm. Other Minnesota ecoregions with geology and water chemistry similar to ecoregion 50n could be protected with the same specific conductance standard.

The above conclusion is based primarily on data produced in the late 1970's by the Copper-Nickel Study, a $4 million compilation of many research papers about potential environmental impact of copper-nickel mining on Minnesota's 500 square miles that could be affected. Water quality work was conducted to establish baseline conditions, mostly in ecoregion 50n. This water chemistry and biological data demonstrates significant similarities to the Appalachian study chemistry and biology.

Beyond the Copper-Nickel Study, important data sources demonstrating availability and quality to support Minnesota-specific benchmarks for conductivity include but are not limited to:

1. The United States Forest Service (USFS) has input additional stream water chemistry data to the EPA national water quality data base (STORET) from the lakes and streams in the Superior National Forest;

2. NPDES water chemistry data is available from the Minnesota Pollution Control Agency (MPCA) permit DMRs and in studies related to mine permitting;

3. MPCA also has an EQUIS database that contains water chemistry analyses of numerous streams in the area from their statewide water quality monitoring program.

4. MDNR Fisheries Division, Fond du Lac Resource Management, and 1854 Treaty Authority have compiled specific conductance data along with fish and macroinvertebrate surveys in the ecoregion.[21] (Lindgren *et al*., 2006).

5. U.S. Geological Survey (USGS) has been measuring flows and water parameters and conducting research accessible on its website.[22] (USGS, 2015)

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[21] Lindgren, John (Minnesota Department of Natural Resources), Nancy Schuldt (Fond du Lac Resource Management), Brian Borkholder (Fond du Lac Resource Management), Andrew Levar (DNR Grand Rapids), Caryle Olson (1854 Treaty Authority), Jeff Tillma (DNR Grand Rapids Area Fisheries), Darren Vogt (1854 Treaty Authority) *A Study of the St. Louis River*, 2006. [Hereinafter "MDNR/Tribal Agencies SLR Study"]. Available at http://files.dnr.state.mn.us/areas/fisheries/duluth/st_louis_river_study.pdf

[22] U. S. Geological Survey, www.USGS.gov/water, select surface water, water quality data.

The evaluation in this report includes some of the available water quality data, selected based on ease of access as well as professional judgment.

The unimpacted water chemistry concentrations in both the Appalachian study and the Minnesota ecoregions are similar in that they both have:

1. Similar headwater stream orders (1-5);
2. Low anion and cation concentrations and circumneutral pH;
3. Significant invertebrate data;
4. Impacts from mining waste rock drainage containing similar major ions and impacts to invertebrates;
5. Some of the same genera demonstrated to be sensitive to specific conductance.

Where Minnesota genera differed from those in EPA's Conductivity Benchmark Study, efforts have been made to match water chemistry data with genera data in this evaluation.

B. Chemical Data Comparisons

1. Minnesota Baseline Water Quality and Mining Impacts

Over 37 years of water chemistry data exists in the Minnesota ecoregions for both basic chemistry and other parameters, in reports or on the EPA national water quality database. Before entry into the EPA database, quality control/quality assurance has been checked for appropriate methods, precision and accuracy.

This evaluation uses multiple sources of water quality data, including the Copper-Nickel Study. This Copper-Nickel Study data was a major undertaking in the state of Minnesota designed to characterize the study area's baseline water quality with hundreds of sampling results over three years. It represents a solid baseline. The key parameters in the water chemistry in the Minnesota ecoregions and the Appalachian ecoregions are similar.

Table 2 below compares the Minnesota Copper-Nickel Study water chemistry data [23] (Thingvold, 1979) with the EPA Conductivity Benchmark Study water chemistry data for Appalachian streams. [24] (EPA Conductivity Benchmark Study, 2011).

Table 2- Water Chemistry Comparison - EPA Appalachia and Minnesota Copper Nickel Study

		EPA Appalachian streams					**Minnesota Cu-Ni Study streams**			
Parameter	**Units**	**Median**	**Min.**	**Max.**	**Number Samples**		**Median**	**Min.**	**Max.**	**Number Samples**
Conductivity	µS/cm	261	15.4	11,646	2,210		65	12	1198	463

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[23] *Ibid.,* 19, Thingvold, Copper-Nickel Study Water Quality Characterization.
[24] *Ibid.,* 2, EPA Conductivity Benchmark Study, Table 2, p. 10.

Hardness	mg/l	91.1	0.5	1,492	1,148		31	5.3	310	206
Alkalinity	mg/l	66.7	0.2	560	1425		23	1	190	457
Sulfate	mg/l	37	1	6000	1428		7.4	1	630	434
Chloride	mg/l	5.2	1	1153	1118		2	0.1	88	462
T. Calcium	mg/l	25.1	0.002	430	1154		7.4	1.8	80	333
T. Magnesium	mg/l	6.3	0.05	204	1150		3.8	1	40	333
TSS	mg/l	4	1	190	1442		nd	nd	nd	nd
T. Iron	mg/l	0.26	0.005	110	1433		0.61	0.099	5.5	457
NO_2-NO_3	mg/l	0.2	0.01	30	1178		0.1	0.01	13	260
T. Al	mg/l	0.11	0.01	12	1436		.090	0.0016	.760	270
Diss. Al	mg/l	0.05	0.01	0.93	1287		nd	nd	nd	0
Diss. Fe	mg/l	0.042	0.001	11.8	1259		nd	nd	nd	0
T. Mn	mg/l	0.004	0.003	7.25	1430		0.05	0.005	1.2	309
Diss. Mn	mg/l	0.07	0.01	1.06	20		nd	nd	nd	0
T. Phosphate	mg/l	0.02	0.01	2.36	1181		nd	nd	nd	260
Diss. Se	mg/l	0.001	0.001	1.26	313		nd	nd	nd	0
T. Se	mg/l	0.001	0.001	1.26	496		nd	nd	nd	0
Fecal Coliform	Counts/110ml	170	0	250,000	2035		nd	nd	nd	0
DO	mg/l	9.2	1.02	18.35	2182		nd	nd	nd	0
pH	std	7.62	6.02	10.48	2210		6.9	4.7	8.4	458
catchment area	km2	6.965	1.73	153.014	717		nd	nd	nd	0
temperature	C	18.4	-0.28	31.9	2210		nd	nd	nd	0
Potassium	mg/l	nd*	nd*	nd*	nd*		0.6	0.2	8.4	310
Sodium	mg/l	nd*	nd*	nd*	nd*		1.8	0.2	45	304
Bicarbonate	mg/l	nd*	nd*	nd*	nd*		25	6	151	257
T. Cu	mg/l	nd*	nd*	nd*	nd*		0.0015	0.0002	0.012	447
T. Ni	mg/l	nd*	nd*	nd*	nd*		0.0012	0.0002	0.21	447
T. Co	mg/l	nd*	nd*	nd*	nd*		0.0004	0.0001	0.011	410
T. Zn	mg/l	nd*	nd*	nd*	nd*		0.0022	0.0001	0.03	446

*nd= no data available

Median concentrations in Minnesota unimpacted waters for specific conductance , Ca (calcium), Mg (magnesium), SO_4 (sulfate), HCO_3 (bicarbonate), pH, and trace metals are comparable and, in some respects, are lower in Minnesota than in the unimpacted Appalachian streams. The one exception may be the Minnesota minimum pH of 4.7, the source of which was identified in the Copper-Nickel Study Water Quality Characterization report as a result of acid bog drainage in some headwater streams. This exception does not affect the median pH of 6.9 representing 459 samplings over three years. Background specific conductance and ionic levels compare favorably with the Appalachian data on unimpacted streams.

The Appalachian ecoregions studied are roughly four times larger in area than the northeastern Minnesota ecoregions. Although the number of samples of the Copper-Nickel Study is less than half of EPA Appalachian report, there is more concentrated data per unit area. Additionally, as stated previously, significant additional and confirmatory data exists from the USFS, MPCA and MDNR since the Copper-Nickel Study. The Copper-Nickel Study water quality reports also contain extensive data regarding heavy metals. This data demonstrates unimpacted waters in Minnesota have trace levels of heavy metals. Heavy metal protocols today use same analytical methods, with the exception of mercury. Thus the 1976 data are directly comparable from a methods standpoint.

Heavy metals values in unimpacted northeast Minnesota streams are near detection limits. Heavy metals would not add to benthic invertebrate toxicity in background streams. This is similar to the data EPA determined for background Appalachian streams.

In both locations, mining activities have increased the same major ions in the water and have increased specific conductivity. As in the Appalachians, the studied Minnesota ecoregions' major impacts are from mining. The difference is the type of ore mined: coal wastes (leachate from mountaintop removal and waste in valley fill) in Appalachia, and iron ore and taconite mining, some of which excavated sulfur-bearing rock (leachate from pits, waste rock, and tailings) in Minnesota. In both cases the major chemicals involved in mining that drive elevated specific conductance are Ca, Mg, SO_4, HCO_3 and pH. In Minnesota mining, sulfide minerals will increase heavy metals, as well as $S0_4$.[25] (MDNR, 2004). Further comparisons and impacts from these minerals will be discussed in the biology section.

Table 1, which is attached in Appendix A to this evaluation, identifies and provides detailed information on macroinvertebrate species. For genera common to Appalachia and the targeted Minnesota ecoregions, Table 1 provides specific conductance levels at which 95% of genera would survive, according to the EPA Conductivity Benchmark Study data. Table 1 also includes water chemistry information from the Minnesota Copper-Nickel Study on tolerances of various Minnesota genera to hardness, sulfate and pH. This table will be discussed in more detail later in terms of biological impacts of parameters on benthic invertebrates.

Dunka Mine.

Minnesota already has an example of consequences of sulfide mining waste rock, based on history with some of the waste rock at Dunka Mine, now owned and managed by Cliffs Erie corporate entities (Hereinafter "Cliffs"). At the Dunka Mine, Duluth Complex copper-nickel bearing waste rock was removed to mine the underlying taconite deposit. The Dunka site has over 37 years of data on waste rock seepages.

The chemistry and biology of the seepage is documented in the Copper-Nickel Study, in DMRs for NPDES permits, and in MDNR reports. When sampled, past and current Dunka Mine seepages routinely have specific conductance similar to 2011 data, which ranged from 350 to 2,761 μS/cm[26] (Cliffs, NPDES DMRs).

The seepages from the low sulfur Duluth Complex waste rock flow into recently reconstructed man-made wetland designed to treat some heavy metals. The wetland systems discharge into Unnamed Creek, a Class 2B water, which flows into Bob Bay of Birch

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[25] MDNR, *Drainage from Copper-Nickel Tailings: Summary of a Three Year Study*, Division of Lands and Minerals, July 2004, Table 3.

[26] Cliffs, NPDES Permit MN0042579, DMRs, 2011 -2014.

Lake. Birch Lake is a dammed portion of the Kawishiwi River, a Class 2Bd water which "shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats," and aquatic recreation of all kinds. (Minn. Rule 7050.0222, Subp. 3).

Since a 2010 Consent Decree as a result of Clean Water Act litigation, Cliffs modified its experimental passive wetland mitigation system with limestone to attempt to resolve the metals toxicity from Dunka Mine discharge. In 2011 the calculated acute toxicity and the chronic whole effluent toxicity bioassays on treated discharges did not violate chronic and acute toxicity limits, although SD009 approached the acute toxicity limit in January and February. However, several inconsistencies with Minnesota Rules contribute to the apparent compliance of the results:

1. Applying a variance to calculate toxicity differently from procedures in Minnesota Rules;

2. Using maximum hardness values of 400 mg/l in toxicity calculations rather than background hardness of unimpacted streams, consistent with Copper-Nickel Study data (see Table 2).

3. Allowing a mixing zone of almost a mile rather than sampling at the discharge. Since Unnamed Creek has a 7Q10 of zero, there is not enough water to dilute the seepages with a mixing zone conditionally allowed at Minn. Rule 7050.0210 Subp. 5.

The passive system at Dunka does not reduce specific conductance in the discharges even approaching background unimpacted levels. Even after dilution of Dunka discharge with clean water from approximately one mile of the unimpacted portions of the watershed, DMRs document that the specific conductance in Unnamed Creek, before it enters Bob Bay of Birch Lake, reaches between 800-900 µS/cm. In the winter, when wetland discharge flows are diminished, concentrations are substantially higher. Recently, from January through May 2014, Unnamed Creek data showed that even Minnesota's irrigation standard of 1,000 µS/cm is often exceeded downstream of Dunka, with sampling data respectively for each month of 1,225 µS/cm, 1,255 µS/cm, 1,111 µS/cm, 936 µS/cm, and 417 µS/cm. (Cliffs NPDES DMRs) The more concentrated creek water forms a measurable density current of higher specific conductance along the bottom of Bob Bay.[27]

Figure 3 shows the locations of Dunka Mine surface discharge sites (SD005 and SD007) and the downstream surface water sampling location (SW-001). Then, Table 3 compares the water chemistry of the Dunka waste rock-impacted Unnamed Creek with background levels from the Copper-Nickel Study Water Quality Characterization. The Copper-Nickel Study background represents the median average of three years of sampling of nine watersheds north of the Laurentian Divide and five watersheds south of the Divide in the 500 square mile Copper-Nickel Study region.

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[27] Johnson, Bruce, personal knowledge.

Figure 3. Map of Dunka Mine LTV Discharge Locations (Cliffs NPDES/SDS Permit)

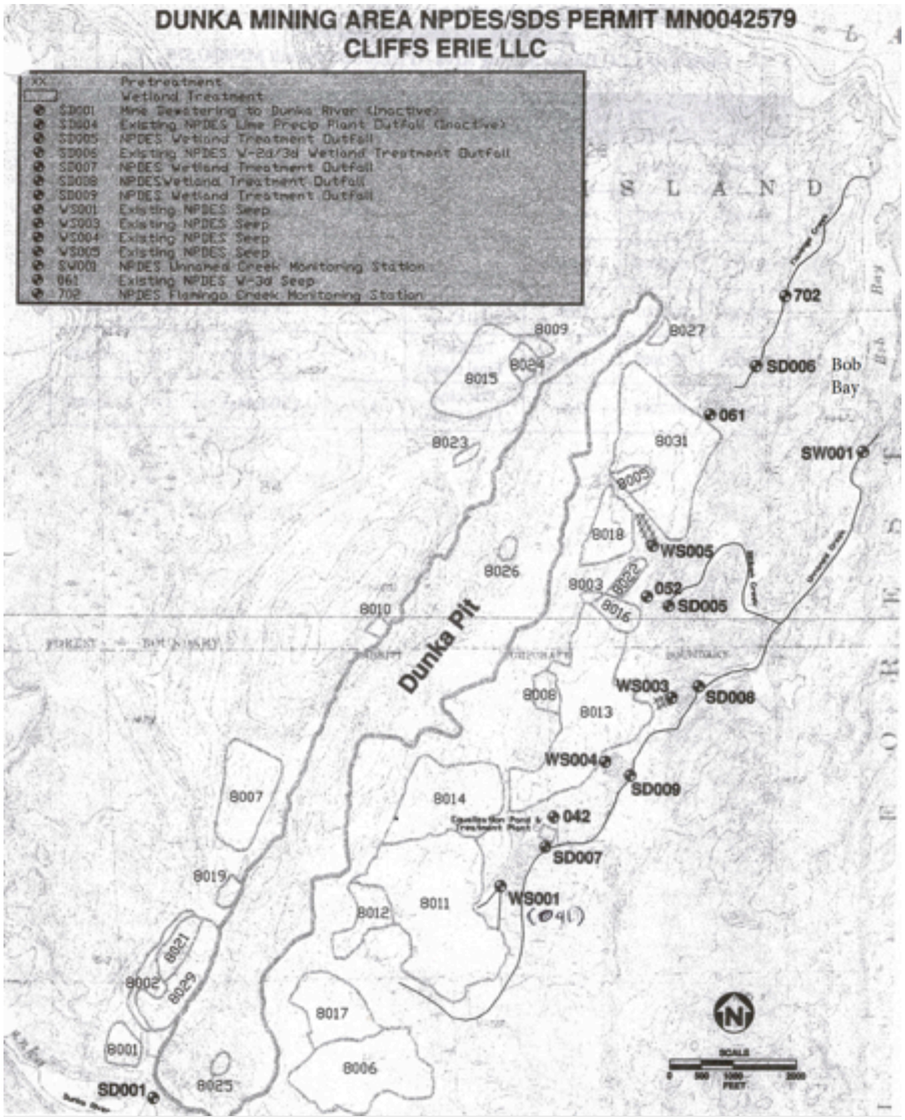

Table 3 shows specific conductance, calcium, magnesium, and sulfate from SD005 and SD007 discharges from Cliffs' wetland treatment outfalls into Unnamed Creek. Site SW001 on Unnamed Creek is downstream of the discharge sites near the Unnamed Creek confluence into Bob Bay of Birch Lake.

Table 3 – Water Chemistry Comparison of Copper-Nickel Study Background with Two Dunka Mine Discharges & Unnamed Creek

	Cu-Ni Study Median	Cliffs Impact 2011 Mean		
	Stream Background	SD005	SD007	SW001
Specific Conductance (μS/cm)	65	1,469	2,000	960
Calcium (mg/L)	7.4	131	269	84
Magnesium (mg/L)	3.8	133	153	70
Sulfate (mg/L)	7.4	1,181	1,166	445

Table 3 demonstrates that at the time of the NPDES permit study, all of the specific conductance-related parameters of concern (specific conductance, calcium, magnesium and sulfate) were highly elevated from the ecoregional background concentration. For example, the Dunka Mine NPDES discharge reports document specific conductance discharges between 1,469 and 2,000 µS/cm from the wetland treatment outfalls SD005 and SD007 into Unnamed Creek. These specific conductance values are between 22 times and 38 times the ecoregional background.

Site SW001, also a sampling location used by Cliffs and the Copper-Nickel Study for benthic invertebrates, is near where Unnamed Creek discharges into Bob Bay of Birch Lake. The specific conductance at this point remains at a mean of 960 µS/cm; this is 15 times the ecoregional background in Table 3. The slightly lower specific conductance values at SW001 are due to freshwater runoff dilution from unimpacted portions of the watershed. Dunka Mine discharges provide a perspective on specific conductance of leachate from sulfide-bearing rock. During 2011 wetland treatment at each of the seepages failed to reduce the source specific conductance below Minnesota's agricultural irrigation standard of 1,000 µS/cm.

Northshore Peter Mitchell Mine Pit

The Northshore Mining Company (Northshore) Peter Mitchell mine pit is one of the largest taconite mining discharge sources in the region. Mineralized rock from the mine is shipped by rail to the Northshore plant on the Lake Superior shore. Approximately eight miles in length, the pit straddles the Laurentian Divide and releases dewatering discharges to both the Dunka River in the Kawishiwi watershed of the Rainy River basin and to the Partridge River in the St. Louis River watershed of the Lake Superior basin. Specific conductance from Peter Mitchell pit dewatering discharged to the Dunka River ranges from 300 µS/cm to 900 µS/cm. This specific conductance is composed mainly of Ca, Mg, SO_4, and HC03 at elevated levels over background. [28] (Benzie, 1977)

Mesabi Nugget.

The Mesabi Nugget smelting facility (MN0067687) has a special process to remove slag from the taconite concentrate, leaving pig iron. It discharges into the former LTV Pit 1, an abandoned, inundated taconite mine pit, about 1.5 miles long and containing an estimated 13.7 billion gallons of water. During 2001, for example, specific conductance averaged 1,291 µS/cm at the surface. Although no point source discharges out of Pit 1 were reported at the time, Pit 1 demonstrates overflow of the hardrock rim to a shallow ground water flow in surficial soils to Second Creek[29] (Northeast Technical Services, 2002). In 2012, 2013 and 2014 DMRs, Second Creek stream sample site SW002 downstream of Pit 1 was reported to have specific conductance averaging 1076 µS/cm, 902 µS/cm, and 791 µS/cm

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[28] Benzie, Dan, *Water Quality of the Dunka River "the Characterization of a Watershed Affected by Mining"*, Plan B Thesis for Master of Science University of Minnesota, June 1977, p. 4. Minnesota Legislative Reference Library http://archive.leg.state.mn.us/docs/pre2003/other/CN023.pdf

[29] Northeast Technical Services, *Phase I – Environmental Assessment, Cliffs Erie Properties including: the Hoyt Lakes Facility, Dunka Property, Taconite Harbor, and Railroad Corridors*, September 2002, pp. 10, 13.

respectively. In addition, the DMRs reported elevated hardness (~500 to 750 mg/l) and bicarbonates (~300 mg/l, 4.91 meq/l) in both Pit 1 and Second Creek[30] (Mesabi Nugget , 2012-2014).

In October 2012, Mesabi Nugget obtained a variance to discharge hardness, bicarbonates, total dissolved salts (solids) and specific conductance pollutants above Minnesota effluent limits, exceeding even Minnesota's irrigation standard for specific conductance of 1,000 µS/cm. The effluent limits applied in this permit were 1,889 µS/cm monthly average and 1,965 µS/cm daily average[31] (Mesabi Nugget, 2012). Although the EPA overturned the variance that allowed this excursion from specific conductance standards in July 2014[32] (EPA, letter to MPCA, 2014), MPCA has to date taken no action to reopen or revise the Mesabi Nugget NPDES permit.

Abandoned mining pits.

Mined out iron ore and taconite mine pits are scattered over the eastern Mesabi (including the Embarrass Mountains) and Vermillion Iron Ranges. On maps they appear as lakes of various sizes and shapes, and some have lake names.

In addition to the chemistry of the economic minerals of interest, pit water chemistry is directly related to the chemical constituents of the host rock (the non-economic part of the rock, which is also known as waste rock and tailing). In taconite mining this can amount to approximately 60% of the total rock removed. The specific conductance in pit water will depend on the chemistry of the host rock. In an open pit mine, excess inflow into a pit discharges through or to one or all of the following: surface water, granular material on the edge of the pit to surface water and ground water [33] (Jones, 2002).

The MDNR has sampled water quality in 13 abandoned, inundated iron ore (not taconite) mine-pits in the Biwabik Iron Formation. These mines were small compared to today's taconite mines, ranging from 11 acres to 165 acres; in contrast, the Peter Mitchell pit is approximately 8 miles long.

Three of these abandoned iron mines are in the ecoregions covered by this report: St. James, closed in 1963; Embarrass, closed in 1977; and Miners Lake, an underground glory hole, closed in 1967.[34] (Pierce *et al.*, 1989). This MDNR study found there were differences in water quality and chemistry from pit to pit for these 13 mines, due to the host rock, including variability in NO_3 (nitrate), SO_4 (sulfate), dissolved solids, hardness, and phosphate.

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[30] Mesabi Nugget, *Permit MN0067687, DMRs*, 2012-2014.

[31] Mesabi Nugget, *NPDES/SDS Permit MN0067687*, approved October 23, 2012.

[32] U.S. EPA, letter, Dr. Susan Hedman, to MPCA Commissioner John Linc Stine, July 2, 2014.

[33] Jones, Perry M., *Characterization of Ground-Water Flow Between the Canisteo Mine Pit and Surrounding Aquifers, Mesabi Iron Range, Minnesota,* U.S. Geological Survey, Water-Resources Investigations Report 02-4198, 2002, available at http://pubs.usgs.gov/wri/wri024198/pdf/wri024198.pdf

[34] Pierce, Rodney B., Cynthia M. Tomcko, *Limnological Characterization of Mine Pit Lakes in Northeast Minnesota,* Minnesota Department of Natural Resources, Section of Fisheries, November 1989, #399, available at http://files.dnr.state.mn.us/publications/fisheries/investigational_reports/399.pdf

Miners Lake has a permanent chemocline at the 35 m (114 ft) depth, which has rotten egg odor, an indication of hydrogen sulfide (H_2S). Hydrogen sulfide is a toxic gas released during decomposition or degradation of sulfur compounds[35] (ATSDR, 2014). The three pits in this evaluation's ecoregions had specific conductance ranging from 289 to 1,380 μS/cm, SO_4 ranging from 13 to 300 mg/l, and hardness ranging from 194 to 353 mg/l. MDNR reported elevated specific conductance in all 13 pits tested [36] (Pierce *et al.*, 1989).

C. Biological Studies and Comparisons

1. Studies Reviewed

Substantial benthic invertebrate sampling data are reported for the Minnesota ecoregions evaluated in this paper. Studies used in this paper are as follows:

1. Minnesota's Regional Copper-Nickel Study surveyed benthic invertebrates on 55,516 km of streams in a 500-square mile study area using drift net and kick samplers[37] (Lager *et al.*, 1979). These are all headwater streams. The work surveyed populations to the lowest taxon possible, all to genus, many to species level. The streams were all Order 1 through 5 headwater streams, similar to the Appalachian Study.

2. A Copper-Nickel Study Tolerance Report assessed the environmental requirements and pollution tolerance of the area's Aquatic Insects[38] (Bartoo, 1978).

3. MDNR has performed a one-year study on the Pigeon River in far northeast Minnesota using drift nets, hand picking and kick net sampling; the study identified invertebrates to the genus level[39] (Montz, 1993);

4. MDNR, Fond du Lac Resource Management, and 1854 Treaty Authority sampled the lower, middle, and upper reaches of the St. Louis River for basic chemistry and invertebrates using kick nets, and identified taxa to the genus level[40] (Lindgren *et al.*, 2006);

5. As part of the Agency's statewide watershed base monitoring and assessment program, MPCA has identified a number of the St. Louis River headwater streams as impaired for benthic invertebrates in its draft St. Louis River Watershed Stressor Identification

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[35] Agency for Toxic Substances and Disease Registry, *DRAFT TOXICOLOGICAL PROFILE FOR HYDROGEN SULFIDE AND CARBONYL SULFIDE*, October 2014.

[36] *Ibid.,* 34, Pierce *et al*., Tables 4, 5, 6, and 9.

[37] Lager, Thomas, Steven Johnson, Jeffery McCulloch, Steven Williams, Mark Johnson, *Regional Copper-Nickel Study Stream Benthic Invertebrates*, Minnesota Environmental Quality Board, February, 1979, available at http://archive.leg.state.mn.us/docs/pre2003/other/CN088.pdf

[38] Bartoo, Paul, *The Environmental Requirements and Pollution Tolerance of Aquatic Insects of the Regional Copper-Nickel Study Area*, Minnesota Environmental Quality Board, Author: September 1978, available at http://archive.leg.state.mn.us/docs/pre2003/other/CN018.pdf

[39] Montz, Gary R., *Aquatic Macroinvertebrates of the Pigeon River, Minnesota*, Minnesota Department of Natural Resources, Ecological Services Section, November 1993, Conservation Biology Research Grants Program, Nongame Wildlife Program, Division of Ecological Services, Minnesota Department of Natural Resources

[40] *Ibid.,* 21, MDNR/Tribal Agencies SLR Study.

Report (MPCA, Draft SLR Stressor Report, 2013).[41]

6. The Regional Copper-Nickel Study performed a 3-year survey on invertebrates impacts at the Dunka Mine from low-level copper-nickel sulfide waste rock that was removed to mine the underlying taconite.[42] (Johnson *et al*., 1978). These leachates discharged into Unnamed Creek. Sampling methods used both Hester-Dendy artificial substrates and drift nets.

7. Unnamed Creek has received Dunka Mine sulfate waste rock leachate for over 37 years. Cliffs has sampled Unnamed Creek for the past ten years (after mine closure). They used Hester-Dendy artificial substrates.[43] (Hartman, 2011). These surveys identified Ephemeroptera, Plecoptera, and Trichoptera to the genus level. Other invertebrates were not all identified to the genus level, and are not cited in this report.

8. The USFS has sampled 16 streams in the Superior National Forest (SNF) - most of them for three years. This survey, summarized in Table 1, included all benthic invertebrates to the genus level and many to a species level. These samplings used kick nets and the MPCA benthic invertebrate protocols and QAQC.[44] (USFS SNF data, 2015). The USFS has also compiled significant water chemistry data on the SNF watersheds.

9. MDNR sampled iron ore mine pit lakes for chemistry, other parameters, and for benthic invertebrates.[45] (Pierce, *et al*., 1989).

Additional data may be available but are beyond the scope of this report.

2. Considerations for Evaluation of Biological Impacts

Any evaluation of water chemistry and biological impacts in aquatic ecosystems must be examined holistically. Such analysis must consider all life stages of each biological system (plant and/or animal). Both maximum and mean water chemistry concentrations must be used for data for all 12 months of the year.

In this case benthic invertebrates overwinter underwater and are alive, but undergo substantial changes in their metabolic activities. The winter is marginal for survival for most taxa; high single concentrations in water chemistry during this period can result in significant population impacts or mortality. Thus, environmental chemistry data cannot be limited solely to means during open water months.

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[41] MPCA, *St Louis River Watershed Identification Report,* Draft October 2013, electronic copy labeled as "12-31-13 (142 pages)," provided in Attachment B. (hereinafter "Draft SLR Stressor Report").

[42] Johnson, Mark, Steve Williams, *Regional Copper-Nickel Study Erie Mining Project Biological Sampling*, Minnesota Environmental Quality Board, October 1978, available at http://archive.leg.state.mn.us/docs/pre2003/other/CN083.pdf

[43] Hartman, Craig, *Memo from Cliffs Natural Resources to Richard Clark*, Minnesota Pollution Control Agency, December 9, 2011.

[44] Butcher, Jason, USDA Forest Service Superior National Forest, unpublished data, provided as a result of correspondence with Bruce Johnson. April, 2015. (hereinafter "USFS SNF data"). This data was used in the attached Table 1 to provide detailed invertebrate background in columns F through J.

[45] *Ibid.,* 33, Pierce *et al*., Limnological Characterization of Mine Pit Lakes.

In addition, over-emphasis on average water chemistry concentrations ignores impacts from periods of elevated chemical concentrations. For example, a single relatively short occurrence of a high concentration can heavily impact benthic invertebrates and other populations in any season.

Averaging of concentrations must also be scrutinized since it can demonstrate a continuous low-level stressor impact to populations. These stressors can reduce a population's ability to survive or reproduce, leaving the remaining individuals of a populations open to predation and subsequent extirpation.

In determining impacts of specific conductance on aquatic organisms, stream assemblages are far more reliable indicators than are conventional whole effluent toxicity (WET) tests.

> "Generally WET limits alone have not been shown to protect water quality from the effects of conductivity. Available scientific information, including the SAB [Scientific Advisory Board] review of EPA's conductivity benchmark report, has highlighted that the current WET testing organisms are not good surrogates for the native aquatic organisms with respect to the effects of conductivity. EPA believes this evidence makes clear that the macroinvertebrate assemblage in central Appalachian streams is more sensitive to the effects of elevated TDS [Total Dissolved Solids] or conductivity than the standard WET testing organisms."[46] (EPA Final Guidance, 2011)

For example, some commonly tested invertebrates are quite insensitive to specific conductance. Cliffs' Request for Variance for the Dunka Mining Area stated that Kennedy *et al.* (2005) produced data to show "significant adverse responses from Ceriodaphnia specifically due to specific conductance are not likely until specific conductance reaches approximately 4,000 to 8,000 μmhos/cm" (equal to 4,000 to 8,000 μS/cm)[47] (Cliffs, 2011, p. 24).

3. Pollution Tolerance of Minnesota Benthic Invertebrates

The Copper-Nickel Study Tolerance Report surveyed the pollution tolerance of benthic invertebrates in the Minnesota study area.[48] (Bartoo, 1979) for the orders Plecoptera (stoneflies), Ephemeroptera (mayflies), Trichoptera (caddisflies), Diptera (true flies), Coleoptera (beetles), and Odonata (dragonflies). This Tolerance Report identified the sensitivity of genera to pH, alkalinity, hardness, sulfate, temperature, and dissolved oxygen (Table 3). In general, the Copper-Nickel study data suggested Plecoptera were sensitive to most parameters other than high pH. Many Ephemeroptera taxa are known to be very sensitive to pollution. With few exceptions, Trichoptera can tolerate high pH and hardness. Diptera demonstrated tolerance to extremes in pH and other chemical stresses. In general, Coleoptera also had tolerance to extremes of pH and hardness, alkalinity and other water

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[46] *Ibid.*, 10, EPA Final Guidance, p. 19-20.

[47] Cliffs, *Request for Variance from Hardness and Specific Conductance Water Quality Standards at the Dunka Mining Area*, June 7, 2011, p. 24.

[48] *Ibid.,* 38, Bartoo, Copper-Nickel Study Tolerance Report, 1979.

chemistry parameters.

Overall, the Copper-Nickel Study Tolerance Report concluded that polluted conditions impacted resulted in fewer overall genera. Trichoptera numbers of genera remained the same; Ephemeroptera and Plecoptera numbers of genera decreased; and Odonata and Diptera increased.

4. Minnesota Benthic Invertebrate Data

Two other Copper-Nickel Study reports surveyed stream benthic invertebrates in both unimpacted waters and waters impacted by mining[49] (Thingvold, 1979; Lager *et al*., 1979) . The main objective of these reports was to identify general population dynamics. Although the reports were not designed to look at genera sensitivity to specific conductance, the data on genera identified is applicable here, since specific conductance is strongly related to hardness in Minnesota ecoregion waters and other confounding chemistry is documented to be minimal (see Table 2).

In the Appalachian ecoregions, the EPA identified genera and developed an extirpation concentration for each genus.[50] (EPA Conductivity Benchmark Study, 2011). EPA cited 40 C.F.R. § 230.10(c)(2) and (3) for the requirement to prevent "significantly adverse effects of the discharge of pollutants on life stages of aquatic life and other wildlife dependent on aquatic ecosystems" and "on aquatic ecosystem diversity, productivity, and stability." The EPA Benchmark Study, as well as other EPA bioassay studies, concluded that extirpation of 5% of sensitive native benthic invertebrate genera would demonstrate significant surface water degradation. In the Appalachians this value was determined to be a specific conductance greater than 300 µS/cm[51] (EPA Conductivity Benchmark Study, 2011). This benchmark is generally protective of significant impacts from pollutants to life stages of benthic invertebrates at the genera level, dependent on the aquatic ecosystems or ecosystem diversity.[52] (EPA Conductivity Benchmark Study, 2011).

Table 1 in Appendix A of this report demonstrates that, in unimpacted waters within the study ecoregion, Minnesota invertebrates are exposed to low ionic strength, low heavy metal water, with specific conductance at a median of 65 µS/cm. The median specific conductance in unimpacted Minnesota waters is below the Appalachian median of 261 µS/cm. This would suggest that sensitive genera in Minnesota may be unable to tolerate high levels of specific conductance from mining activities, particularly at the levels reflected by Minnesota's irrigation-based standard of 1,000 µS/cm. The invertebrate orders of Ephemeroptera, Trichoptera and Plecoptera are numerous in unimpacted Minnesota ecoregion study streams.[53] (Lager *et al*., 1979). Many of these genera are known to be sensitive to elevated specific conductance ion concentrations.

Table 1 in Appendix A compares some Minnesota streams, which have substantial benthic

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[49] *Ibid.,* 19, Thingvold *et al*., *Copper-Nickel Study Water Quality Characterization*, 1979; *Ibid.,* 37, Lager *et al*., *Copper-Nickel Study Invertebrates*, 1979.

[50] *Ibid.,* 2, EPA Conductivity Benchmark Study,, p. 13.

[51] *Ibid.,* 2, EPA Conductivity Benchmark Study,. p. 23.

[52] *Ibid.,* 2, EPA Conductivity Benchmark Study, p. xiv.

[53] *Ibid.,* 37, Lager *et al*., *Copper-Nickel Study Invertebrates*. 1979.

invertebrate data, with the Appalachian streams data. Table 1 Column D summarizes all the genera/species that were identified in the specific northeast Minnesota ecoregions by the Copper-Nickel Study. Column C identifies the Appalachian genera common to both areas. Columns D through J identify genera/species in Minnesota unimpacted headwater sites and the study/year(s) where and when each genus was found. Column K identifies the EPA XC95% specific conductance for each genus in common.[54] Columns L, M and N identify the Hardness (Ca and Mg), Sulfate and pH tolerances for benthic invertebrates derived from the Minnesota Copper-Nickel Study Tolerance Report. (Bartoo, 1978).

The complete Table 1 data demonstrate that Minnesota shares 92 genera or 28% of the total genera identified in Appalachian ecoregional streams. Among the common genera, Minnesota has 31 of the common genera demonstrated to be sensitive below 1,000 µS/cm, 21 sensitive below 600 µS/cm, and 12 that are sensitive below 350 µS/cm. For the remainder of the Minnesota invertebrate genera, there are no comparable EPA calculations of XC95% for specific conductance in the Appalachian Study.

Table 4 below summarizes data on identified benthic invertebrate genera from unimpacted waters of Minnesota and the Appalachians:

Table 4 – Common Benthic Invertebrates in Unimpacted Appalachian and Minnesota Streams

Order	**MN Genera**	**Genera in Common**
Ephemeroptera	45	18
Plecoptera	29	13
Trichoptera	56	14
Odonata	25	3
Coleoptera	12	4
Megaloptera	4	3
Hemiptera	16	1
Diptera	136	36
TOTAL:	***323***	***92***

For a point of reference to evaluate low and high specific conductance, Pond, *et al.,* divided coal mined waters with elevated specific conductance into "low" conductivity at < 500 µS/cm [n = 7], "medium" at 500-1,000 µS/cm [n = 8], and "high" at >1,000 µS/cm [n = 12]." (Pond *et al*., 2008).[55] These categories were used primarily for graphical interpretations and to interpret taxonomic composition along a categorical gradient.

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[54] The same genus in Minnesota is assumed to be sensitive to the specific conductance identified in the Appalachian study, above which 5% of the individual genus population was extirpated.

[55] Pond, Gregory J., Margaret E. Passmore, Frank A. Borsuk, Lou Reynolds, and Carole J. Rose, *Downstream effects of mountaintop coal mining: comparing biological conditions using family- and genus-level macroinvertebrate bioassessment tools,* Region 3, US Environmental Protection Agency; J. N. Am. Benthol. Soc., 27(3):717–737 (8 July 2008).

In addition to the data on sensitivity for genera in common with the EPA, Column L in Table 1 of Appendix A identifies Minnesota genera/species that the Copper-Nickel Tolerance Report identified as sensitive to hardness, sulfate, and pH. In many cases, these values identify genera/species that are sensitive to mining pollutants in addition to those found in the EPA's Appalachian XC95% Column K values.

IV. Discussion: Mining Impacts to Northeast Minnesota Waters

This Section of the evaluation will review impacted mining areas in Ecoregion 54n (see Figure 1 Minnesota Ecoregion Map) using some of the existing benthic invertebrate and water chemistry data. Open-pit taconite and copper-nickel mining and production facilities produce waste rock and tailing. As in mountain-top mining for coal, Minnesota's mining leachates contain elevated specific conductance, composed mainly of Ca, Mg, SO_4 and HCO_3, which are released into waters with natural low concentrations of these ions in circumneutral pH. Taconite mine dewatering has not been documented to release levels of heavy metals beyond chronic numeric stream water standards, with some exceptions for iron and mercury where the Duluth Complex or the Virginia Formation have been disrupted.

A. Kawishiwi River Subwatershed, Rainy River Basin

In addition to elevated specific conductance, Duluth Complex and Virginia Formation waste leachates have been demonstrated to contain levels of heavy metals above chronic surface water standards and to be acutely and chronically toxic. Heavy metal ions have been documented in the following Minnesota sites: Cliffs' Dunka taconite mine Duluth Complex waste rock, Minnamax Copper-Nickel test shaft (closed), and INCO's Copper-Nickel bulk sample site (closed) near Filson Creek, all north of the Laurentian Divide. The proposed NorthMet PolyMet would also produce heavy metals, but its primary drainage effects would occur in the St. Louis River subwatershed of the Lake Superior Basin.

1. Dunka Taconite Mine with Sulfide-Bearing Waste Rock

At the Dunka taconite mine (currently owned by Cliffs), the prior owner, LTV, encountered low-level sulfide-bearing waste rock, including both Duluth Complex and Virginia Hornfels overlying the Biwabik Iron Formation (taconite). Leachate seepages from 1970's stockpiles of Duluth Complex waste rock discharge to Unnamed Creek, classified as a water of the United States and of the State in the Rainy River watershed. MDNR reports and NPDES permit DMRs for over 37 years have documented significantly elevated specific conductance at this site.

For example, as illustrated in Table 5, derived from Cliffs NPDES permit MN00042579 DMRs, despite wetland treatment, Dunka discharge into Unnamed Creek and to Birch Lake from January through May 2014, contain elevated levels of specific conductance.[56] (Cliffs, Permit DMRs, 2014) as follows:

Table 5 - Dunka Discharge to Unnamed Creek (2014)
Specific Conductance Levels

Site	Mean (µS/cm)	High (µS/cm)	Low (µS/cm)	Number
SD007	2,133	2,512	2,133	9
SD009*	2,765	3,284	2,001	9
SW001 (Unnamed Creek)	579	1,225	203	10

* Cycled back to SD007 due to elevated levels.

The Copper-Nickel Study classified Unnamed Creek as an order 1-2 stream. Since mining has ceased, this Creek is likely an order 1 stream due to the cessation of pit dewatering. The Copper-Nickel Study biologically evaluated the Creek and compared it with six other streams in the study region. The Study's Biological Sampling established that benthic invertebrates in Unnamed Creek "should be similar in streams of nearly equal stream order although the species in each stream may be different." It concluded:

> "[A] number of major biological differences between Unnamed Creek and other streams in the region are evident. Most of these differences indicate that Unnamed Creek is stressed. Low invertebrate population size, diversity of drifting invertebrate population, and the number of invertebrate taxa all indicate stress conditions."[57] (Johnson *et al.,* 1978)

This Biological Sampling report noted that highly fluctuating mine dewatering and heavy metals might have adversely affected the benthic invertebrates in the Creek.[58] (Johnson *et al.*, 1978). Cliffs has contracted for benthic invertebrate studies starting in 2000.[59] (Doran, 2012). The sampling is not robust in that it is limited to results from Hester-Dendy multiple plate artificial substrate samplers. Cliffs' contracted research also has not performed detailed genus level identification of all taxa beyond Ephemeroptera, Plecoptera, and Trichoptera (hereinafter referred to as "EPT"). However, Hester-Dendy multiple plate samplers are documented to be more selective for EPT than other invertebrates, and studies have shown that average total abundance and species richness for EPT did not differ between Hester-Dendy and kick samples.[60] (Letovsky *et al.*, 2012). Thus, for EPT abundance and richness evaluations, the Hester-Dendy samplers should be adequate for EPT comparisons.

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[56] *Ibid.,* 26.

[57] *Ibid.,* 42, Johnson *et al.*, Copper-Nickel Study Erie Biological Sampling, p. 31.

[58] *Id.*, p. 31.

[59] Doran, Peter, Letter to Bruce Trebnick Northeast Technical Services copied to MPCA, September 17, 2012.

[60] Letovsky, Erin, Ian E. Myers, Alexandra Canepa, Declan McCabe, *Differences between kick sampling techniques and short-term Hester-Dendy sampling for Stream Macroinvertebrates*, 2012, Department of Biology, Saint Michael's College, Colchester Vermont 05439, p. 53, available at http://wolfweb.unr.edu/~cmmoore/Christopher_Moore/BIOL322_files/CritiquePaper_SamplingTechniques.pdf

The Cliffs analysis did not compare Unnamed Creek with other unimpacted similar streams in the area. On December 9, 2011 Cliffs reported the benthic invertebrate sampling results for 2011 to the MPCA with the following summary statements: "This total [invertebrates] compares favorably with the previous 12 years of sampling, and suggests no significant decline in overall insect diversity over the 12 year period of sampling." [61] (Hartman, 2011). Cliffs further stated: "this riffle is characterized by more of the fist-sized, cobble type rocks typically considered optimum habitat for benthic invertebrates in a stream system." The riffle habitat described by Cliffs is near MPCA NPDES site SW001 in Unnamed Creek, before the Creek discharges into Bob Bay of Birch Lake, shown on the Figure 3 Dunka Mine Map.

Almost 40 years ago, Copper-Nickel Study biological sampling suggested that mine dewatering causing varying flows and substrate disruption might have contributed to the negatively impacted Unnamed Creek invertebrate populations.[62] (Johnson, 1978). Since the LTV Dunka Mine closure, no pit dewatering discharges have entered the Creek. Cliffs has concluded that the substrate at the sampling location is suitable and the recent 12 years of invertebrate data has had no significant change.[63] (Cliffs, Request for Variance, 2011). With neither flow issues nor poor substrates as potential contributors to observed invertebrate impacts, *contaminant chemicals in the water are the most likely cause of continuing negative invertebrate impacts*. Recent invertebrate data underscore that passive wetland treatment and management changes since 2010 have not re-established the invertebrate populations.

Comparison of Cliffs' report of Unnamed Creek family and genera richness for Ephemeroptera, Plecoptera, Trichoptera with Table 1 Appendix A data from four unimpacted similar streams in the same ecosystem indicates there are far fewer families, fewer genera, and less total richness of EPT than background streams. This data is reflected in the following Table 6.[64] (Cliffs, 2011; Doran, 2014).

Table 6 - Benthic Invertebrate Richness Comparison
Dunka (Impacted) Unnamed Creek & Background Creeks (Cu-Ni Study)

	Unnamed (6 yrs)	Background Creek Mean	Unimpacted Streams (3 yrs)			
			Keeley	Filson	August	Nira
Ephemeroptera families	3	6.25	7	7	6	5
Plecoptera families	1	3.75	3	3	5	4
Trichoptera families	10	9	7	9	10	10
Ephemeroptera genera	4	11	12	12	9	11
Plecoptera genera	2	5	4	3	8	5
Trichoptera genera	13	15.8	17	17	18	21
Total EPT Genera Richness	19	33.3	29	32	35	37
Total EPT Family Richness	14	19.5	17	19	21	19

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[61] *Ibid.,* 43, Hartman, Cliffs Memo to MPCA.
[62] *Ibid.,* 42, Johnson *et al., Copper-Nickel Study Erie Biological Sampling*, p. 37.
[63] *Ibid.,* 47, Cliffs Variance Request, Part 1, p. 31.
[64] *Id.,* Appendix 2, Table 1; Doran, Peter D., 2014 *Summary Report of Aquatic Macroinvertebrate Sampling for Unnamed Creek, Dunka Mine Area*, Northeast Technical Services Inc., December 5, 2014.
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In Table 6, a summary of six years of family and genera EPT for Unnamed Creek is compared with a summary of three years of data from four unimpacted background streams in the same area. Background streams are close to Unnamed Creek and of similar stream order. This table suggests Unnamed Creek is substantially less rich in both Ephemeroptera and Plecoptera families and genera. In the underlying data, the unimpacted Keeley Creek has 29 EPT genera; Filson Creek has 32 EPT genera; August Creek has 35 EPT genera; and Nira Creek has 37 EPT genera. Unnamed Creek has only 19 EPT genera. The composition measure of EPT also decreases when compared with background streams.

In general as discussed previously, Trichoptera tend to be insensitive to pollutants, so the differences in Trichoptera are minor. Far more significant disparities in Ephemeroptera and Plecoptera families and genera are evident: there are more than twice as many Ephemeroptera families and more than three times as many Plecoptera families in unimpacted waters. There are also 275 percent more Ephemeroptera genera and 250 percent more Plecoptera genera in unimpacted waters than in the Unnamed Creek waters impacted by Dunka Mine discharge. These values are consistent with EPT richness losses reported by Pond[65] (Pond, 2008) in the mined areas of the Appalachians.

This disparity in taxa richness cannot be attributed to non-anthropogenic geology. Filson Creek is located on an exposed Duluth Complex rock similar to the location of Dunka Mine. Yet, as shown in Table 6, Filson Creek has demonstrated no invertebrate impairment. With Filson as a paired background creek, the exposed Duluth Complex at Dunka is unlikely to be a significant contributor to the invertebrate impairment.

Cliffs' report on Unnamed Creek used the Hilsenhoff Biotic Index (HBI) to estimate the overall health of the invertebrate population in Unnamed Creek. The HBI estimates the *general* overall tolerance of the community according to relative abundance of the family taxonomic groups in the Creek community that were given a numeric sensitivity value. In using the HBI, the Cliffs report missed some important aspects of data interpretation.

The HBI protocol counts all Ephemeroptera families as highly sensitive. In fact, for specific conductance, this is not the case. The EPA has determined that many Ephemeroptera genera common to Minnesota (Table 1, Column K, in Attachment A) are tolerant to high specific conductance. For example, Ephemeroptera Caenis sp. has a XC95% tolerance that exceeds >3,923 µS/cm, compared to Ephemeroptera Leptophlebia sp. with a tolerance of 251 µS/cm. Compared to the methods of the EPA Conductivity Benchmark Study, the HBI as used by Cliffs is a gross method of evaluation and lacks necessary sensitivity for this report, as follows:

1. The HBI was developed using invertebrate sensitivity to organic pollutants that deplete oxygen, such as nutrients.[66]

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[65] *Ibid.*, 55, Pond *et al.*, *Downstream effects of mountaintop coal mining*, 2008.

[66] *See e.g.*, University of Vermont, Manual for Calculation of Metrics, http://www.uvm.edu/~streams/PDFFiles/Manual_Calc_Of_Metrics.pdf

2. Cliffs used a family tolerance value to calculate the HBI, but often genera within a family are not uniformly tolerant.

3. Although Cliffs described the population in each genus within the Unnamed Creek community, its report failed to compare similar unimpacted communities.

To further establish the relationship between elevated specific conductivity in Unnamed Creek and the loss of EPT richness, Unnamed Creek EPT genera can be compared with the EPA XC95% specific conductivity values and the Copper-Nickel Study Tolerance Study values[67] (EPA Conductivity Benchmark Study, 2011; Bartoo, 1978). The mean specific conductance for Unnamed Creek at SW001 in 2014 was 579 µS/cm. However, as shown in Table 5 above, Unnamed Creek experienced specific conductance as high as 1,225 µS/cm.

As shown in Table 7 below, each genus identified by Cliffs in Unnamed Creek can be compared to data on sensitivity to contaminants. Two of the genera in Ephemeroptera - Baetis sp. and Caenis sp. - are very tolerant of elevated specific conductance, hardness, sulfate and pH. Two other genera - Leptophlebia and Paraleptophlebia - are more sensitive. Plecoptera has one genus that is very tolerant of specific conductance as high as >3,314 µS/cm, and the other genus is sensitive at 463 µS/cm. Among the 13 Trichoptera genera, two of the seven for which data is identified are sensitive to high specific conductance - Pycnopsyche sp. and Lepidostoma sp. The remaining six genera have no sensitivity levels documented or have inconclusive taxonomies.

Table 7 - EPT Taxa Identified by Cliffs in Unnamed Creek
Analysis for Sensitivity to Specific Conductance, other Pollutants

Cliffs (2005-2010) Unnamed Creek Genera	EPA Benchmark Study XC95% for SC	Copper-Nickel Study Tolerance Report		
		Hardness	Sulfate	pH
Ephemeroptera				
Baetis sp.	>1,395	16-1,000	<10-5,700	5.6-8.5
Caenis sp.	>3,923	6-705	<1-450	5.4-8.5
Leptophlebia sp.	251	nd*	nd*	nd*
Paraleptophlebia sp.	463	nd*	nd*	nd*
Plecoptera		nd*	nd*	nd*
Isoperla sp.	460	nd*	nd*	nd*
Perlesta sp.	3,314	nd*	nd*	nd*
Trichoptera		nd*	nd*	nd*
Hydropsyche sp.	>7,010	nd*	nd*	nd*
Cheumatopsyche sp.	>9,180	nd*	nd*	nd*
Chimarra sp.	>3,792	4-800	7.3-510	6.8-8.7
Pycnopsyche sp.	295	4-705	2.4-750	6-8.8

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[67] *Ibid.,* 2, EPA Conductivity Benchmark Study, 2011; *Ibid* 38, Bartoo, Copper-Nickel Study Tolerance Report, 1979. This data is reflected in Table 1, Appendix A.

Lepidostoma	~121	6-66	2.5-25	6.4-7.3
Polycentropus sp.	>4,713	nd*	nd*	nd*
Ptilostomis sp.	nd*	nd*	nd*	nd*
Anabolia sp.	nd*	nd*	nd*	nd*
Limnephilis sp.	nd*	nd*	nd*	nd*
Phryganea sp.	nd*	nd*	nd*	nd*
Ochrotrichia sp.	>2,971	nd*	nd*	nd*
Neureclipsis sp.	nd*	nd*	nd*	nd*
Ceraclea sp.	nd*	nd*	nd*	nd*
nd* = no data available				

At least five of the 13 genera for which specific conductance XC95% levels are known, or 38% of the identified EPT genera, are sensitive to specific conductance. Additional genera, such as Trichoptera Lepidostoma sp. and Chimarra sp. might also be sensitive to increased hardness or sulfate.

The Copper-Nickel Study Biological Sampling report from 1978 stated that the sampling areas immediately downstream of the Dunka Mine waste rock seepages had two to ten times fewer organisms than further downstream near Birch Lake.[68] (Johnson *et al.,* 1978). The Sampling report further stated the "Recolonization of impacted stream areas by aquatic insects is generally rapid after a stress is discontinued."[69] The Cliffs data near the SW001 Unnamed Creek site is similar to the Copper-Nickel Study data near the same location despite the passage of 37 years. Unnamed Creek continues to demonstrate significant EPT stress when compared with similar unimpacted streams in the area.

2. Northshore Peter Mitchell Pit

The Northshore Peter Mitchell taconite mine pit, as previously discussed, discharges its eastern dewatering to the Dunka River in the Rainy River watershed. Specific conductivity concentrations in this discharge range from 300 µS/cm to 900 µS/cm, and are high enough to have potential impacts on sensitive genera.

Research in Minnesota has concluded that Peter Mitchell Mine discharge is toxic to aquatic life: "Using toxicity data compiled by Clark (12), parameters in Reserve's [now Northshore] discharge with a mean concentration above the minimum known toxicity to fish or aquatic invertebrates include Na [sodium], Ca [calcium], NH_3 [ammonia], Mn [magnesium], and Fe [iron]."[70] (Benzie, 1977).

Peter Mitchell NPDES discharges SD001, SD002, SD003, SD004, and SD005 enter the Dunka River watershed and flow into Birch Lake, a reservoir in the Kawishiwi River.

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[68] *Ibid.,* 42, Johnson *et al*., Copper-Nickel Study Biological Sampling, 1978, p. 22.
[69] *Id.*, p . 9.
[70] *Ibid*., 28, Benzie, *Water Quality of the Dunka River*, p. 38.

Figure 4. Map of Northshore Peter Mitchell Mine Pit Discharge Sites

The NPDES DMRs document discharges at different times during the years from 2002 to 2015, including specific conductance mean and maximum levels at these discharge points that are high enough to have potential impacts on sensitive genera of invertebrates. These data are summarized in Table 8 below[71] (Northshore DMRs)

Table 8 - Northshore Peter Mitchell Specific Conductance Discharge to Dunka River (NPDES 0046981 DMRs 2002-2015)

Location	Mean Conductivity (µS/cm)	Maximum Conductivity (µS/cm)
SD001	374	667
SD002	494	711
SD003	305	527
SD004	667	833
SD005	605	918

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[71] Northshore Mining Company, NPDES Permit MN0046981 and DMRs, 2002-2015.

Considering EPA's benchmark and the data on invertebrates in Unnamed Creek, most if not all of these levels are high enough to have potential impacts on sensitive genera.

B. St. Louis River Watershed, Lake Superior Basin

1. Minnesota Pollution Control Agency Draft SLR Stressor Report

In a report prepared in 2013 but not released to the public, the MPCA determined that 32% of the St. Louis River tributary assessment units tested were impaired for fish and/or invertebrates. In the segment of the St. Louis River from mile 72 to mile 193.3 the following major tributaries were determined by the MPCA to be impaired: Embarrass River - fish; Spring Mine Creek - invertebrates, fish; Wyman Creek – fish[72] (MPCA, Draft SLR Stressor Report, 2013). The MPCA Draft St. Louis River Stressor Identification Report explicitly attributed impairments to discharge from mining facilities:

> "Fish results from the upper Embarrass River (the portion upstream of the town of Embarrass) show extremely low fish counts and limited taxa richness. . . Two of the impaired streams in this watershed zone, Spring Mine Creek and the Embarrass River, receive water originating from mine pits. Sampling results from these streams show elevated specific conductance and sulfate concentrations."[73] (MPCA, Draft SLR Stressor Report, 2013)

In explaining the impairment of Spring Mine Creek, MPCA's Draft SLR Stressor report acknowledged the difference in sensitivity of invertebrates and the potential for taxa imbalance as a result of mine discharge:

> "Spring Mine Creek is the only stream in this watershed zone that is listed as impaired for macroinvertebrate bioassessments. . . [A]ncillary information considered in the assessment process (elevated specific conductivity readings; invertebrate samples dominated by Gammarus and Corixidae) resulted in an impairment listing. Symptoms of impairment observed in Spring Mine Creek include a very low relative percentage of non-hydropsychid caddisfly taxa (1.6%) and imbalance in the distribution of taxa present. Over 76% of the individuals counted were from the five most abundant taxa in the sample. Bear Creek, the potential reference stream for this watershed zone, shows more balance among taxa present, supports more intolerant taxa, and better representation from the order trichoptera."[74] (MPCA, Draft SLR Stressor Report, 2013)

MPCA methods were different from and less sensitive than the methods in the EPA Conductivity Benchmark Study. MPCA used a single background reference stream, and MPCA's statements regarding the relationship between fish or aquatic invertebrate impairments and specific conductance were not definitive. Even with these limitations,

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[72] *Ibid.,* 41, MPCA, Draft SLR Stressor Report, 2013, pdf auto pp. 16, 25, 26, 97 Attachment B.

[73] *Id.*, pdf auto p. 16,

[74] *Id.*, pdf auto p. 109..

MPCA's analysis suggests that there are adverse impacts on fish and invertebrates in the St. Louis River watershed resulting from sulfate and conductivity originating from mine facilities.

In general, the MPCA Draft SLR Stressor Report noted, "With increases in ionic strength, macroinvertebrate taxa richness (particularly Ephemeroptera sp.) have been found to decrease (Piscart *et al*., 2005). Echols et. al (2009) observed a reduction in EPT abundance as conductivity values increased." MPCA found that sites with conductivities "higher than 1,000 μS/cm rarely meet the biological thresholds for general use streams."[75] (MPCA, Draft SLR Stressor Report, 2013)

2. Northshore, LTV & Mesabi Nugget Discharges to Yelp Creek and Partridge River

As shown in Figure 4, Map of Northshore Peter Mitchell Mine Pit Discharge Sites, several St. Louis River watershed tributaries receive direct mine drainage and/or flow through heavily mined areas, including Yelp Creek and the Partridge River.

Under Permit MN0046981 the Peter Mitchell Pit has eight permitted discharges south of the Laurentian Divide, all of which eventually reach the Partridge River: two discharge to Yelp Creek, then into the Partridge River and another six discharge to unnamed creeks or to wetlands of the Partridge River.

A winter survey of the Partridge River by the MDNR[76] (Kruse, 2011) documented that Partridge River flows from November 2008, December 2010, January 2011, February 2011, and March 2011 showed large volumes of discharge. The flows reported ranged from 0 to 41.9 cubic feet per second or cfs (219,912 gallons per minute or gpm). From November 24-26, 2008, the Partridge River had flows between .040 cfs and .063 cfs. Again on Jan. 25, 2011 flows ranged from .030 cfs to 0.41 cfs. This data demonstrates that the main Partridge River flows upstream of Colby Lake are significantly affected by Peter Mitchell discharges. NPDES DMR data reported discharges for the month of January 2010 from SD009 (Yelp Creek) of 5.5 cfs. During certain portions of the year, Partridge River discharge fluctuations mimic the reported fluctuations from the Peter Mitchell Pit to the Dunka River watershed as reported in the Copper-Nickel Study.[77] (Benzie, 1977). Northshore's NPDES permit requires water chemistry monitoring of the Partridge River at SW004 at the Highway 666 bridge east of Hoyt Lakes, just before Wyman Creek enters the Partridge River. The DMR reports from 2010 to 2014 demonstrate specific conductance in the range of 250 to 350 μS/cm level.[78] (Northshore DMRs).

The closed LTV taconite plant and tailing basin were constructed over the headwaters of

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[75] I*d*. pdf auto p. 38.

[76] Kruse, G., Minnesota Department of Natural Resources, *Partridge and Embarrass River Winter Base Flow Study*, 2011, 2008-2011 data.

[77] *Ibid*., 28, Benzie, *Water Quality of the Dunka River*, 1977, pp. 3-41.

[78] *Ibid.,* 71, Northshore NPDES permit DMRs.

three streams. (U.S.F.S., Superior National Forest maps 1938,[79] and 1977, revised 2011[80]). Figures 5a, 5b, and 5c below illustrate the progression of LTV tailings facility construction.

Figure 5a. Area of LTV facility portions of map, Superior National Forest, Minnesota, 1938.[81]

The above map from 1938 shows township, range and section notations along with creek names for Second Creek, Trimble Creek, Wyman Creek, Spring Mine Creek and Unnamed Creek. The LTV tailings basin will be located in the sections of Figure 5a identified as 3, 4, 5, 8, 9, and 10.

The origin of Second Creek lies under the LTV southern tailing basin, facility in the area identified as section 10 on Figure 5a and under mine waste rock piles in and near section 16 on Figure 5a. Second Creek flows south and southwest to the Partridge River. Trimble Creek runs beneath the tailings basin in section 3 of Figure 5a in the northeast quarter of the tailing basin and flows northwest toward the Embarrass River. An unnamed creek

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[79] U.S. Department of Agriculture Forest Service, *Superior National Forest, Minnesota*, 1938, map area of R14 T59N, T60N.

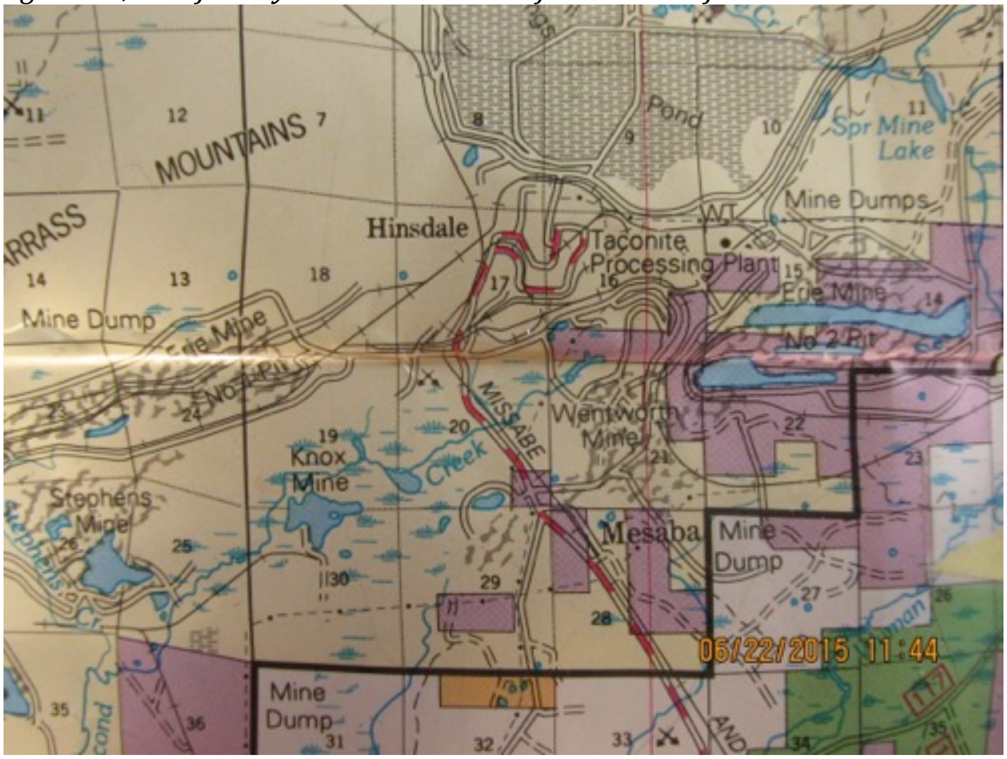
[80] U.S. Department of Agriculture Forest Service, *Superior National Forest, Minnesota*, map constructed in 1997, revised in 2011, map area of R14 T59N, T60N.

[81] *Ibid*., 78, U.S.F.S. Superior National Forest, map, 1938.

emerges from under the northwest corner of the tailing basin in approximately section 5 of Figure 5a and flows generally west to Embarrass River.

Over time, in addition to headwaters for Second Creek the LTV tailings basin will inundate Trimble Creek and Unnamed Creek. Figure 5b below features portions of the Superior National Forest reflecting 1997 conditions.[82] Figure 5b also shows the relationship of Second Creek to wetlands. As of 1997, the northeast quadrant of the LTV tailing basin, north of the Taconite Processing Plant still shows Trimble Creek headwaters that will later be inundated with tailings, as shown in Figure 5c.

Figure 5b, LTV facility and Second Creek features as of 1997.



Since the 1997 conditions shown in Figure 5b, Second Creek has received cumulative mining discharges impacting its water quality. Its headwaters are impacted by the plant site and seepage from the LTV tailings basin, monitored at SD026, shown in Figure 5c. This surface discharge location reported bicarbonates averaging 454 mg/l, hardness of 610 mg/l, and specific conductance of 1,115 µS/cm.[83] (Cliffs, 2012). Under a 2010 Consent Decree, surface water contaminated with seepage is collected and pumped back to the tailing basin. The pump-back does not capture all seepage and SD026 specific conductance remains high, likely due to continued seepage with underground flow through subsurface tills.

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[82] *Ibid*., 77, USFS, Superior National Forest, map, constructed 1997, updated 2011.

[83] Cliffs, NPDES/SDS Permit MN0042536, Variance Addendum Renewal Cliffs Erie Hoyt Lakes Mining Area Surface Discharge Stations SD026 and SD033, December 10, 2012. p. 2, Table 1,

Monitoring at SD026 in 2013, more than a decade after processing of tailings ceased and despite the implemented pump-back, indicates specific conductance ranging from 666.2 μS/cm to 980.9 μS/cm, with a mean of 842.5 μS/cm.[84] (Barr, 2014). These levels are high enough to have potential impacts on sensitive genera.

Figure 5c, Map of PolyMet Proposed Tailings & Mine Locations, with Sampling Sites

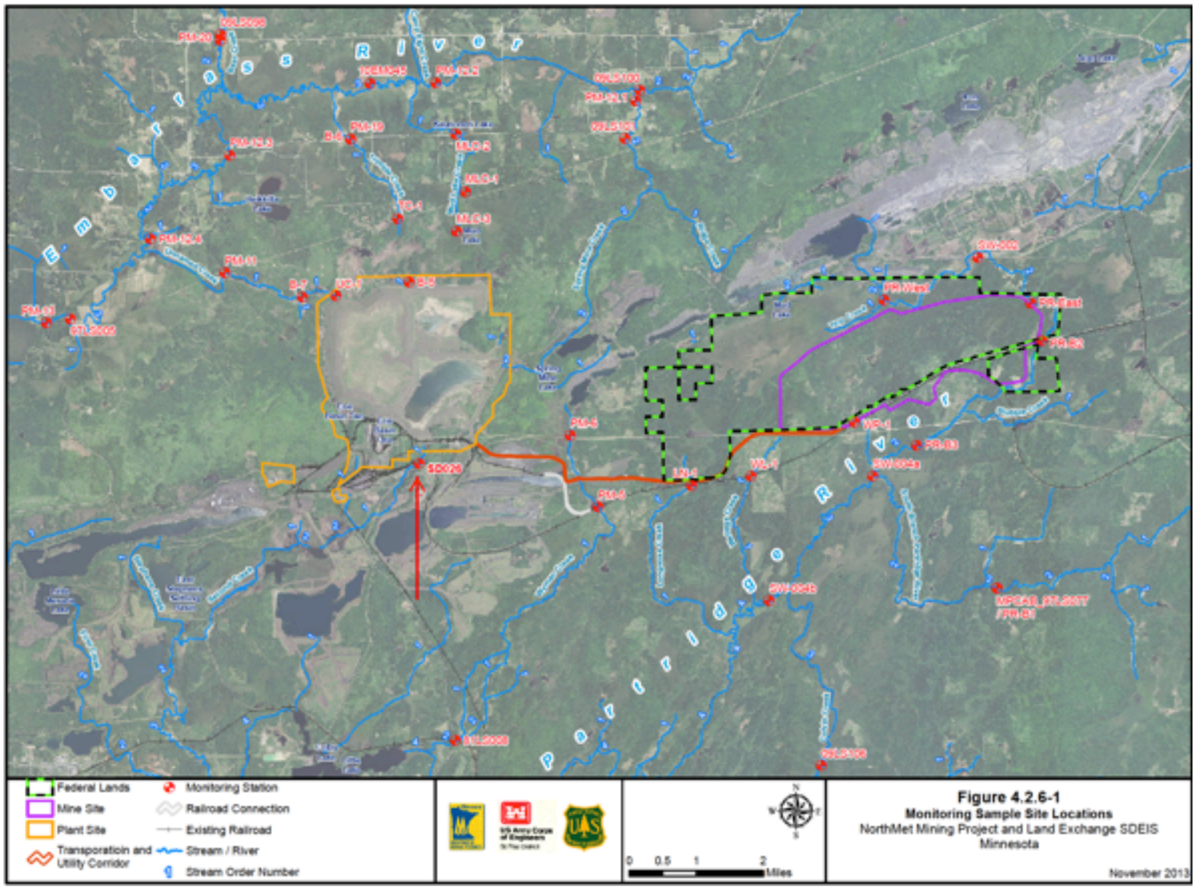

Figure 5c shows the former LTV tailing basin and facility in orange and the SD026 monitoring location on Second Creek with a red arrow. LTV Pit 1 extends to the west from the small orange portion of the facility.[85] (MDNR *et al.,* 2013).

Downstream from SD026, Second Creek may receive pit water from additional mine sources: from LTV Pit 2/2E water moving through groundwater to Pit 2W, which then flows to Second Creek.[86] (MDNR *et al.*, 2015); from flow from the Knox and Stephens mines through surface water or shallow groundwater (Figure 5b); and from Pit 9 ground water

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[84] Barr Engineering, Summary of 2013 NorthMet Groundwater and Surface Water Monitoring Data, , *Summary of 2013 NorthMet Groundwater and Surface Water Monitoring Data,* Technical Memorandum to MPCA, March 28, 2014, Table 1.

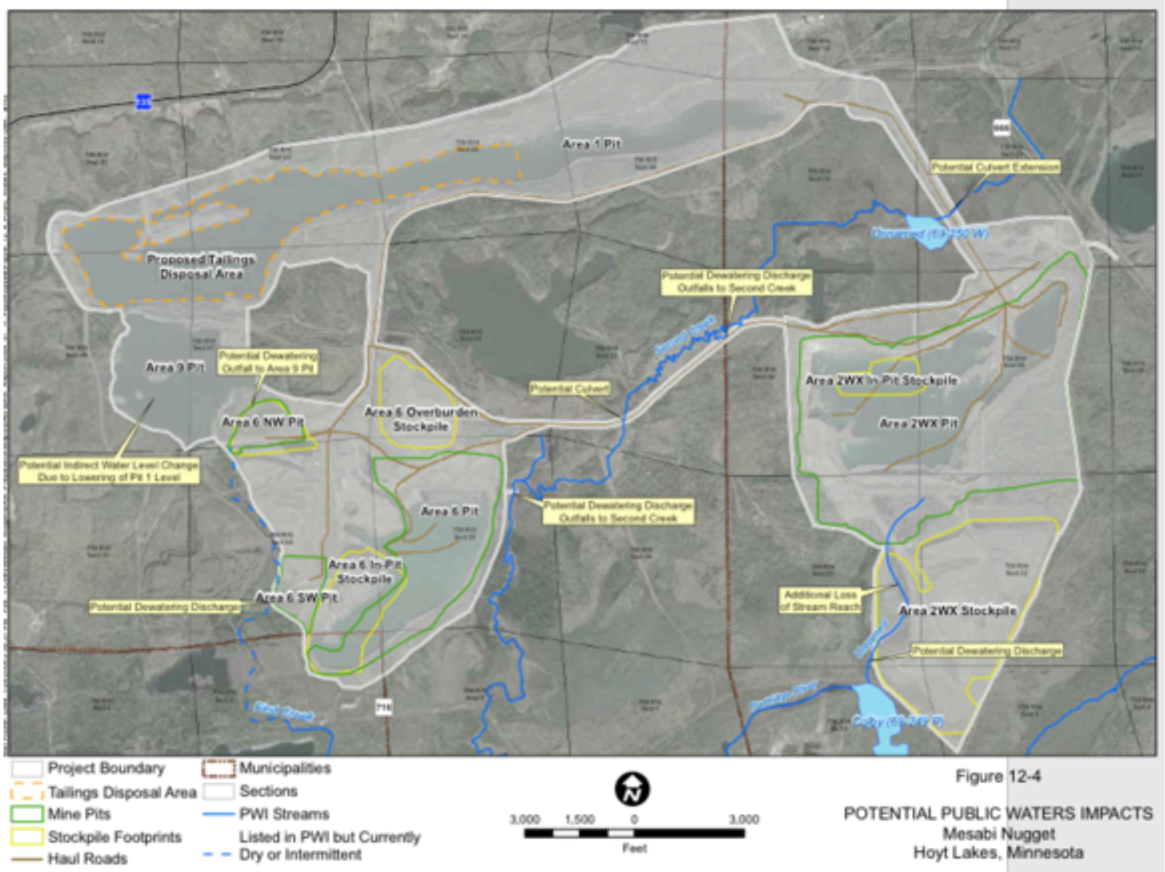
[85] MDNR, U.S. Army Corps of Engineers, and U.S. Department of Agriculture Forest Service, *PolyMet Supplemental Draft Environmental Impact Statement NorthMet Mining Project and Land Exchange*, November 2013 Figure 4.2.6-1.

[86] MDNR, U.S. Army Corps of Engineers, and U.S. Department of Agriculture Forest Service, *PolyMet NorthMet Preliminary Final Environmental Impact Statement*, June 2015, p. 6-13. (hereinafter "PolyMet PFEIS")

inflows to Pit 1. According to an EPA site visit report,[87] LTV mine pits also contain waste rock, increasing the potential release of contaminants from pit water.

Second Creek may also receive Pit 1 discharge from Mesabi Nugget in permit-approved months. Figure 6 illustrates potential locations where Mesabi Nugget could impact public waters during smelting operations.[88] (Barr, 2008).

Figure 6, Map of Mesabi Nugget Potential Public Waters Impacts



As a result of upstream discharges, specific conductance at Mesabi Nugget NPDES SW001, Second Creek just upstream of Pit 1 discharge location, in 2014 averaged 699 µS/cm. Bicarbonates were also elevated at 266 mg/L and hardness averaged 343 mg/L, with a sulfate mean concentration of 80.9 mg/L. When operating, Mesabi Nugget's smelter discharges into Pit 1, with discharge to WS003 of 75.9 mg/l bicarbonates; 1,224 mg/l hardness (Ca and Mg); 2,031 mg/l sulfate; and specific conductance of 3,873 µS/cm. (Mesabi Nugget DMRs, 2014). Pit 1 is estimated to contain 13.7 billion gallons of water.

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[87] U.S. EPA, Technical Resource Document Extraction and Beneficiation of Ores and Minerals, Volume 3*, Iron*, August 1994, EPA 530-R94-030, NITS PB94-195203, Mine Site Visit: LTV Steel Mining Company

[88] Barr Engineering, Mesabi Nugget EAW Report, July 28, 2008, Figure 12-4. The proposal for mining has recently been withdrawn.

Average specific conductance of Pit 1 water discharged at SD001 in 2013 (January –March, October -December) was 1,290 μS/cm. Discharge from Pit 1 at SD001 into Second Creek, for 2014 January through March, averaged 334 mg/l bicarbonates; 752 mg/l hardness (Ca and Mg); 480 mg/l sulfate; and 1,389 μS/cm in specific conductance. From 2013-2014, specific conductance in this discharge ranged from 974 μS/cm to 1434 μS/cm. [89] (Mesabi Nugget DMRs, 2013-2014).

PolyMet's environmental review documents provide little characterization of benthic invertebrate populations. The PolyMet PFEIS applies the Hilsenhoff Biotic Index (HBI) to two sampling sites downstream of Northshore Peter Mitchell Mine discharge (PR-West and PR-East), and characterizes these sites as having an HBI ranking of "fair." No other Partridge River sites are assessed for HBI ranking. No invertebrate data is provided downstream of the LTV discharge site SD026.[90] (MDNR *et al.*, 2015). Single sampling dates at the few locations sampled in either the Partridge River or Embarrass River watershed, and failure to identify specific invertebrate genera and species,[91] and the paucity of data does not permit an assessment of the relative richness of taxa related to various discharge sites. With so little and such poor quality data available regarding benthic invertebrates under current conditions, effective monitoring of potential impacts of the proposed PolyMet copper-nickel mine project on sensitive macroinvertebrate genera is unlikely.

In summary, specific conductance, hardness, sulfate, and bicarbonates concentrations are elevated in Second Creek as a result of mine and smelting drainage. These values are higher than levels in Unnamed Creek impacted by Dunka mine discharge that seem to demonstrate significant invertebrate impact. The scarce data available suggests that benthic invertebrates at the genera and species levels in Second Creek are likely to be significantly impacted by elevated specific conductance and other mining discharge. Background invertebrate data provided for PolyMet environmental review are inadequate either to characterize current conditions or evaluate potential future impacts.

It should be noted that, like other unlisted waters in the northeast Minnesota ecoregions in the Lake Superior basin, Second Creek is considered to be an Outstanding International Resource Value Water. Minn. Rule 7052.0010 Subp. 34.

3. LTV and Impaired Waters - Wyman Creek and Spring Mine Creek

Wyman Creek is a headwaters stream that flows southeast of the LTV tailing basin and then south to the Partridge River just above Colby Lake (See Figures 5a- 5c). Cliffs' abandoned

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[89] Mesabi Nugget NPDES Permit MN0067687, DMRs, 2013-2014.

[90] *Ibid. 85*, see PolyMet PFEIS, Table 4.2.6-6, p. 4-259 and sites in Figure 4.2.6-1. See also p, 4-252, "No aquatic biota studies have been conducted in Longnose Creek, Wetlegs Creek, or Second Creek, and no fish or macroinvertebrate community or habitat characteristics could be documented, although, like Yelp Creek, all are first-order streams within the vicinity of the NorthMet Project area."

[91] *Id*., see Table 4.2.6-14, p. 4-276 regarding macroinvertebrates in the Embarrass River watershed and sites in Figure 4.2.6-1.

Pit 3 discharges to Wyman Creek at 350 gpm (0.8 cfs). [92] (MDNR *et al*., 2015).

The LTV tailing basin has contaminated groundwater that emerges as seeps including one measured at SD012, the closest to Wyman Creek. In 2010, average specific conductance in SD012 tailings seepage was 1,097 µS/cm, and specific conductance at PM5 in Wyman Creek was 431 µS/cm.[93] (Barr, 2010). Other Cliffs mining facilities - Pit 5S and Pit 3 discharge to Wyman Creek and may also indirectly discharge to Wyman Creek via groundwater.[94] (MPCA, Cliffs Permit Approach, 2013).

The MPCA Draft St. Louis River Stressor Report noted that the headwaters of Wyman Creek are impacted by a series of mine pits and that historically Wyman Creek supported small populations of brook trout. In 2012, MPCA determined that Wyman Creek is impaired for fish communities. MPCA automatic sampling "SONDI" recorders reported a mean specific conductance of 360 µS/cm (range 350 to 364 µS/cm) in 196 samples taken in August 2012 and a mean specific conductance level of 366 µS/cm (range 350 to 374 µS/cm) in 583 samples taken in August and September of 2013. The MPCA's Draft SLR report did not complete the analysis of the potential anthropogenic stressors for Wyman Creek or other impaired waters.[95] (MPCA, Draft SLR Stressor Report, 2013).

Spring Mine Creek originates from a mine pit high on Giants Ridge. Spring Mine Creek headwaters in Section 2 (Figures 5a and 5b) are affected by mine pits and, possibly, by the LTV tailing basin. Buried stream beds continue to conduct water and act as underground conduits after burial. Some drainage from the tailing basin appears to follow a "former channel" into a pit named Spring Mine Lake.[96] (Barr, 2014). The pit/lake then discharges into Spring Mine Creek to the Embarrass River. Area mine pits and LTV tailing seepages contain elevated specific conductance, bicarbonates, hardness, and sulfates.

Table 9 below summarizes data on Spring Mine Creek specific conductance and sulfate from MPCA site S006-548, just upstream from the Creek's confluence with Embarrass River approximately 4.5 miles from the tailing basin. [97] (MPCA, 2015). During this period of sampling in 2011 and 2012, mean specific conductance was 819 µS/cm.

Although detailed benthic invertebrate sampling was provided in this report, MPCA has listed Spring Mine Creek as impaired for both fish and macroinvertebrates.[98] (MPCA, Draft SLR Stressor Report, 2013).

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[92] *Id*., PolyMet PFEIS, p. 6-13.

[93] Barr Engineering, *Short Term Mitigation Evaluation and Implementation Plan for the Tailing Basin NPDES/SDS Permit No. MN0054089*, June 2010, Table 2 Water Quality Summary SD002,

[94] MPCA, *Cliffs Erie Permitting Approach* Preliminary Draft, February 27, 2013.

[95] *Ibid.,* 41, MPCA, Draft SLR Stressor Report, 2013, pdf auto pp. 98, 109,

[96] *Ibid.*, 84, Barr, *Summary of 2013 NorthMet Groundwater and Surface Water Monitoring Data*, 2014, Figure 1

[97] MPCA, EQUIS database, on line, 2015.

[98] *Ibid.,* 41, MPCA, Draft SLR Stressor Report, pdf auto p. 109..

Table 9 - Spring Mine Creek Water Chemistry Specific Conductance and Sulfate

Date	Specific Conductance (µS/cm)	Sulfate (mg/l)
4/13/11	372	115
6/23/11	788	246
11/30/11	1,406	585
4/17/12	936	378
5/30/12	555	192
7/10/12	858	nd*
nd*= no data available	Mean 819	

6. Mining Impacts and St. Louis River

The MDNR, Fond du Lac Resource Management, and 1854 Treaty Authority produced a detailed St. Louis River Study in 2006.[99] (Lindgren, *et al.,*, 2006). This Study identified conditions such as flow and stream bed conditions, basic water chemistry, habitat, fisheries and benthic invertebrate populations at numerous sites along the St. Louis River. Although the Study was only one year in duration, it confirmed biosurveys conducted in prior decades and provided basic data suggesting that impacts related to elevated specific conductance are occurring in what the Study calls the upper and middle St Louis.

In the 2006 St. Louis River Study, benthic invertebrates are identified to the genus level at 22 sites along the St. Louis River and specific conductance and other chemicals are provided in 23 sites.[100] (Lindgren, *et al.,* 2006). From mile 139. 6 to the headwaters at 193.3, in the "upper" St. Louis, specific conductance has a mean of 59 µS/cm. At mile 129, the Report documents significant mining activity and the specific conductance increases to 258 µS/cm.[101] (Lindgren, *et al.*, 2006). From mile 129 to what was selected as the end of the "middle" St. Louis at Mile 72, specific conductance had a mean of 260 µS/cm.

This "middle" segment of the St. Louis River receives significant mining facility discharges, some of which have been described previously. Identified NPDES permitted discharge sources include Northshore's active Peter Mitchell Pit, the LTV inundated mine pits, the four-and-a-half square mile tailings facility left when LTV went bankrupt and transferred permits to Cliffs, and the Mesabi Nugget facility.

Table 10 summarizes specific conductance in the upper reaches and the mining-impacted middle segment of the St. Louis River.

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[99] *Ibid.,* 21, MDNR/Tribal Agencies SLR Study, 2006.

[100] *Id.*, Appendices 11 to 17.

[101] *Id.*, Appendix 6.

Table 10 - St. Louis River Specific Conductivity Upper Reaches and Mining-Impacted Middle Segment

	Specific Conductance (µS/cm)		
	Mean	Minimum	Maximum
Upper Reaches Mile 139.6 to 193.3	59	41.4	101
Mining-Impacted Segment Mile 72 to 129	260	160	386

Benthic richness in the two reaches of the St. Louis River studied by the MDNR and Tribal Agencies is summarized in Table 11 below. (Lindgren, *et al.,* 2006).[102]

Table 11- St. Louis River Benthic Invertebrates Richness in Upper Reaches and Mining-Impacted Middle Segment

Total Richness	**Mile 193.3 to 139.6** (59 µS /cm Mean Conductivity)	**Mile 129 to 72** (260 µS Mean Conductivity)
Family	45	44
Genera	88	72
EPT Richness		
Family	19	17
Genera	35	27

Although this is just one year of sampling, the St. Louis Report data shows a difference in the total richness and richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) at a genus level. In the mining impacted middle segment of the St. Louis River, from Mile 129 to Mile 72, specific conductance was elevated to 260 µS/cm - more than 400 percent of background levels in the upper St. Louis. The number of genera observed in this impacted segment was reduced by about 18% and the number of EPT genera observed was reduced by about 23% as compared to the unimpacted reaches further upstream in the St. Louis River.

EPA recommends three years of sampling to provide a more robust data set, but there appear to be some interesting and significant genera losses in the existing data. Comparing genera in the upper segment unimpacted by mining with data in the downstream middle segment impacted by mining activity, some invertebrate genera with populations of over 10 individuals identified in the upstream sampling have only 0 or 1 individuals present in the middle segment of the St. Louis River. Table 12 provides a more detailed analysis of

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[102] *Id*., Appendices 11 to 17.

these deficits. (Lindgren *et al.*, 2006)[103]

Table 12 - St. Louis River Presence of Specific Benthic Invertebrates in Upper Segment and Mining-Impacted Middle Segment*

Genus and Species	**Upper Segment** **Mile 193.3 TO 139.6** (**59 µS/cm** Mean Conductivity) Population Present	**Middle Segment** **Mile 129 to 72** **(260 µS/cm** Mean Conductivity) Population Present
Ephemeroptera		
Baetiscicae		
Baetisca sp.	129	0
Heptageniidae		
Stenacron		
Vicarium sp.	86	1
Leptophlebiidae		
Leptophlebia sp.	114	0
Hemiptera		
Corixidae		
Hesoerocorixa sp.	62	0
Plecoptera		
Perlidae		
Paragnetina sp.	10	0

There are other genera present in the unimpacted upper reaches of the St. Louis River that do not exist in the middle reaches impacted by mining. But, since this is only one year of data, genera with fewer than 10 individuals in the upper reaches were not included in this table.

Currently available data demonstrates that headwater streams in the mining impacted area of the St. Louis River watershed have specific conductance levels far above background levels and diminished invertebrate richness. Mine facility discharges, waste rock, seepages, a tailing basin, and inundated pits containing waste rock are sources of minerals and salts resulting in high levels of specific conductance. These high levels of specific conductance may persist many miles downstream in the St. Louis River.[104]

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[103] *Id.*, Appendices 11, 12, 16

[104] *Tribal Cooperating Agencies Cumulative Effects Asses*sment, NorthMet Mining Project and Land Exchange, September 2013, contained in Appendix C of the PolyMet NorthMet Supplemental Draft Environmental Impact Statement, November 2013, at pp. 16-18 suggests that specific conductivity persisted above 150 µS/cm as much as 200 kilometers downstream of elevated discharge from mining.

V. Conclusions: Recommendation for Development of Aquatic Life Benchmark for Specific Conductance in Northeast Minnesota

A. Findings

Based on the EPA Conductivity Benchmark Study research and the references discussed in this evaluation, this report makes the following findings:

1. The EPA protocols described are applicable to northeast Minnesota surface waters.
2. The median of all 463 Copper-Nickel Study samples (including impacted streams) is 68 µS/cm, so the background conductivity for unimpacted streams alone based on the Copper-Nickel Study would be less than 68 µS/cm.
3. Existing data from Minnesota ecoregions 50n, northern 50p, and 50t demonstrate impacts on invertebrate genera from elevated specific conductance in mining impacted waters.
4. In the Minnesota ecoregions discussed in this report, discharge of specific conductance above the level of 300 µS/cm, established as guidance for Appalachian streams is highly likely to result in extirpation of 5% or more of invertebrate genera. Such discharge should be prohibited under Minnesota narrative standards preventing degradation and toxic pollution.

B. Recommendations

The following recommendations would protect aquatic life and ensure the development of a protective Field-Based Benchmark for specific conductance in Northeast Minnesota:

1. Apply the aquatic life benchmark of 300 µS/cm as a chronic value for year-round application for organisms exposed throughout their life cycle in ecoregions 50n, the northern part of 50p, and 50t, pending further analysis to determine if a more stringent limit on specific conductance is needed to protect aquatic life in northeast Minnesota ecoregions, according to the XC 95% criterion.

2. Complete existing data gathering for ecoregion 50n and 50t, focusing on invertebrate genera and water chemistry parameters in mining impacted and unimpacted waters and complete the development of a specific conductance benchmark for the specified Minnesota ecoregions.

3. Facilitate and encourage sources with single year benthic invertebrate sampling to add two more years of data and focus on impacts to headwaters streams from mine dewatering, seepage and discharge.

4. Require a reasonable potential analysis for any NPDES-permitted mining facility and make determinations whether the facility discharge would have the potential to

result in degradation and/or toxic pollution under Minnesota narrative standards in addition to potential violation of numeric standards for irrigation.

5. Gather data for other nearby ecoregions in the Lake Superior and Rainy River Basins to determine whether a wider applicability of the 300 μS/cm specific conductance guideline should be generally applicable or whether a more stringent limit on specific conductance must be developed.

In mining impacted areas, large discharges into headwaters streams from pit dewatering, surface runoff and tailing basin seepages are likely to require regulatory controls without consideration of possible dilution. See Minn. Rules 7050.0210, Subp. 7; 7050.0222, Subp. 7(C). Minnesota's narrative standards that prevent toxic pollution (Minn. Rules 7050.0150 and 7050.0217, Subp. 1, 2) would seem to require that levels of specific conductance that would be chronically toxic to 5% or more of benthic invertebrates in low-volume headwaters streams should be prohibited for NPDES-permitted discharge.

EPA has suggested that "the salt mixture dominated by salts of SO_4^{2-} and HCO_3^{-1} is believed to be an insurmountable physiological challenge for some species."[105] (EPA Conductivity Benchmark Study, 2011). In Minnesota ecoregions discussed in this evaluation, special attention will need to be given to discharges with high sulfate and bicarbonates.

C. Qualifiers

To understand the limits of this review, note that EPA Conductivity Benchmark Study specifically states, "Because it is not protective of all genera and protects against extirpation rather than reduction in abundance, this level is not fully protective of sensitive species or higher quality, exceptional waters designated by state and federal agencies."[106] (EPA Conductivity Benchmark Study, 2011). Additional work will be needed to ensure adequate protection of Minnesota waters affected by mining and governed by NPDES permits, particularly given the lower background level of specific conductance in Minnesota waters and the potential prevalence of more intolerant genera as compared with Appalachia.

This qualification is important, since in Minnesota ecoregions 50n, 50p, and 50t BWCAW waters, scientific and natural areas, unlisted high value waters, and other listed waters are Outstanding Resource Value Waters (ORVW) with special protections for higher quality or exceptional waters. (Minn. Rule 7050.0180, Subp. 2). Subp. 3 of this Rule states, "No person may cause or allow a new or expanded discharge of any sewage, industrial waste, or other waste to waters within the Waters in the Boundary Waters Canoe Area Wilderness; portions of Lake Superior . . . or Department of Natural Resources designated scientific and natural areas." Subp. 9 of this Rule precludes deterioration in the quality of any downstream ORVW.

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[105] *Ibid.*, 2, EPA Conductivity Benchmark Study, 2011, p. xv.

[106] *Id.*, 2, p. xiv

Surface waters and wetlands of Minnesota in the Lake Superior Basin not specifically listed as Outstanding Resource Value Waters (ORVW) are "Outstanding International Resource Waters" or "OIRWs" subject to non-degradation standards. (Minn. Rule 7052.0300, Subp. 1(C)(2), Subp. 3). For OIRWs, "Existing water uses under part 7050.0185 and the level of water quality necessary to protect existing uses must be maintained and protected. Where designated uses of the waterbody are impaired, there must be no lowering of the water quality with respect to the GLI pollutants causing the impairment." (Minn. Rule 7052.0300, Subp. 2).

D. Permit Requirements

A lack of attention in northeast Minnesota to designing and enforcing mining permits has resulted in elevated specific conductance in headwaters and further downstream, including waters of the middle segment of the St. Louis River. Minnesota's narrative standards apply to mining discharges and should be enforced to prevent impairment or alteration of lower aquatic life. Under the Clean Water Act, EPA requires that a state permitting authority must examine whether elevated conductivity levels could create a reasonable potential for violation of the narrative standard.[107] (EPA Final Guidance, 2011).

Permit requirements concerning specific conductance should include but are not limited to:

1. Prior to approving new or expanding discharge of specific conductance, multi-year baseline sampling of benthic invertebrates to the genus level both upstream and downstream of the proposed discharge using MPCA methodology.
2. Pertinent sampling and water chemistry including specific conductance and major cations and anions related to specific conductance for the benthic invertebrate community in the area;
3. Sampling and flow measurements of the company discharge, receiving water and similar order streams;
4. Limits based on ORVW/OIRW status and cumulative effects on the receiving water;
5. Bioassays using at least three organisms (one of which should be an aquatic plant) known to be sensitive to low levels of chemicals and possible synergies contained in the tailing process such as flotation reagents and flocculants; and
6. Invertebrate sampling to the species level downstream close to the discharge, and in at least one background site, with permits to reopen if impacts are detected.

E. Requirements for new/expanded facilities

Technical and environmental review for any new or expanded facility must include these

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[107] *Ibid.,* 10, EPA Final Guidance, 2011, Appendix 6, p. xviii.

items that concern specific conductance:

1. Establishment of site specific background water chemistry and invertebrate community data to genus and species, using all available data with quality assurance, not only the monitoring of the proposing company, and requiring additional background data where quality and duration is insufficient.

2. Monitoring plans, sampling and analysis immediately upstream of a discharge, of the discharge, at a distance downstream of the discharge, and just after any permit-allowed mixing zone; detection monitoring; and monitoring of both public waters and waters used as treatment systems in time to prevent meromixis, or a lack of mixing between surface and deep water lake strata.

3. Estimates of contaminants, concentrations, and mass loadings of waste rock, tailing, waste and pit inflow and outflow water must be derived from data obtained that is representative of all possible chemicals in the host rock and of all chemicals used in beneficiation and processing.

4. Detailed modeling based on sufficient and quality assured data, rather than assumptions, of specific conductance and contaminants for any proposed new or expanded mining facility to predict whether facility discharges result in degradation or toxic pollution under both numeric and narrative Minnesota rules, including direct, indirect and cumulative impacts. Where facts are insufficient, additional data must be gathered prior to modeling and decision-making.

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