# *Technical Support Document for Numeric Site-Specific Criteria for Nutrients, Aluminum, and Specific Conductance within the Reservation of the Grand Portage Band of Lake Superior Chippewa*

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## Cover photo

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# EXECUTIVE SUMMARY

This technical support document describes the rationale and analyses used to develop quantitative aquatic life criteria for the Grand Portage Reservation for four ecological stressors: excess total phosphorus, total nitrogen, aluminum, and dissolved ions. The intent is to protect aquatic life, the ecosystems upon which they depend, and the ecological services that they provide. Analyses and assessments have shown that the levels of these four potential stressors are currently within background levels and that in some cases, relatively small changes could alter these ecosystems.

Grand Portage Reservation is located in the southern portion of North America's boreal forest. Within the Reservation there are abundant forests and wetlands that support diverse ecosystems that over millennia have deposited organic matter forming peat. When water percolates through the peat, organic compounds leach into groundwater that feeds wetlands, lakes, and streams. The dissolved organic material, tannins, stain the water a transparent brown like tea or root beer. Tannins support the microorganisms in these waters and reduce the amount of light for algal growth. At present and historically, the cooler temperatures of northeastern Minnesota modulate the length of time that is conducive for bloom development.

Ions are leached from slow-to-weather crystalline bedrock into the groundwater. Both precipitation and groundwater are often filtered by peat before entering surface water on the reservation. Therefore, the concentrations of dissolved ions in surface waters are among the lowest in the United States. The aquatic flora and fauna on the reservation thrive in these low salinity waters and do not do as well at higher dissolved ion levels. For example, with a small change in ion levels, the probability of observing brook trout decreases by half.

Because these waters are different from non-tannic systems, the nationally established thresholds based on natural condition observed in non-tannic systems may not be protective or may be overly protective. Therefore, Grand Portage has carefully evaluated the special conditions of its tannin-rich waters that are unique from clear surface waters to ensure that these exceptional ecosystems are well protected for generations to come.

Most of the Reservation is heavily forested and sparsely populated except near Lake Superior's shores. Therefore, the levels of phosphorus and nitrogen in lakes and streams on the Reservation occur at nearly natural background levels. A weight of evidence was used to assess whether observed nutrient levels in lakes and streams, which at times are higher than in some pristine clear water systems, were caused by human activity or sources. Independent types of evidence consistently indicated that observed nutrient levels are not caused by anthropogenic sources on the reservation. To be conservative, median values estimated from site specific nutrient levels were used to set criteria for total phosphorus and total nitrogen. Median values were also used to set site specific criteria for chlorophyll-a and all of the criteria are below the threshold for mild algal blooms (Chl-a >10 µg/L). Because of the high variability of DOC, the range of concentrations were used to set criteria. The calculated annual median concentrations of total nitrogen, total phosphorus, and chlorophyll-a shall not exceed criteria by more than twenty-five percent once every three years. Median annual concentrations of dissolved organic carbon shall be maintained within its natural range.

Aluminum criteria were developed using conventional laboratory-based toxicity test results adjusted for natural conditions in Grand Portage by using the water quality parameters that have the greatest impact on aluminum's bioavailability including locally low ion levels as measured by total hardness, high dissolved organic carbon levels, and circumneutral pH. Site specific chronic criteria for lakes and streams on the Reservation are provided. Aluminum chronic criteria are expressed as a four-day average concentration not to be exceeded more than once every three years.

Specific conductivity ("SC") criteria were developed using field observations of the ion levels that support many different aquatic benthic invertebrates and fish. Two assessment endpoints were included. Where brook trout are known to occur, the criteria is the SC levels associated with a 50 percent reduction in the probability of observing these fish. Many shallow lakes do not support brook trout and the criteria for these waters are set at the SC level associated with a loss of 5% of salt sensitive genera like mayflies from a model developed from waters across the country that also have naturally low background SC. SC chronic criteria are expressed as a four-day average concentration not to be exceeded more than once every three years.

Waters of the Reservation either flow into Lake Superior or the Pigeon River, which flows into Lake Superior. Grand Portage believes that maintaining the natural condition of inland waters will have a positive impact on the downstream waters of Lake Superior. These proposed numeric criteria are expected to 1) maintain and protect existing uses; 2) preserve good to excellent water quality and biological conditions that have been documented by the Grand Portage water monitoring program; and 3) ensure that water treatment costs for the community and nearby jurisdictions are reasonable.

# PURPOSE AND SCOPE

The purpose of this document is to expand on the US EPA-approved Water Quality Standards ("WQS") for the Grand Portage Reservation by adding site specific numeric criteria for nutrients, aluminum, and specific conductance based upon a risk assessment approach aimed at protecting sensitive aquatic life and recreation in and on the water. Grand Portage WQS include implementation procedures for Clean Water Act purposes such as 401 certifications for federal permits, antidegradation demonstrations, and 402 NPDES Water Quality Based Effluent Limitation (WQBEL) process to in wastewater permitting.

Review of Grand Portage WQS identified the need to add aluminum and specific conductance criteria to protect sensitive aquatic life uses. This document provides supporting information for the specific protocols chosen and their appropriateness for the development of site-specific aluminum and specific conductance criteria for waters of Grand Portage Reservation. The scope of this document also covers the body of research that documents the unique nutrient conditions of the Grand Portage Reservation, the numeric nutrient criteria approaches considered by the Tribe to date, and the methodology to develop appropriate numeric criteria to protect sensitive aquatic life and recreational uses to supplement the Tribe's narrative nutrient criteria for Clean Water Act purposes.

## Cultural Importance of Water

The Tribe's existence has been dependent on the ability of the land and waters to provide natural resources for consumption, subsistence, cultural preservation, religious practice, and sustainable economic development. Areas within the Reservation serve as a refuge for Tribal members to continue to practice a life that exemplifies sustainable economic development and that preserves the resources critical for cultural integrity and survival of the Tribe. Therefore, a priority of Grand Portage's current water quality standards framework is to ensure that high quality resources are adequately protected.

# INTRODUCTION

## Geography

The Grand Portage Reservation lies in the extreme northeastern tip of Minnesota, in the southern range of the Boreal Forest. The Reservation consists of 56,000 contiguous acres within the exterior boundaries. The Canadian province of Ontario marks the Reservation's northern boundary. The western boundary is state and federal forest lands. Lake Superior forms the rocky, wave-swept boundary on the south and east and includes islands in Lake Superior.

The Reservation contains some of the most rugged terrain in Minnesota. Glacial activity has scoured the landscape to produce long, steep ridges with vertical rock outcrops and wetland valleys. Twenty-four miles of irregular shoreline along Lake Superior provide several deep bays between the long, narrow projecting highlands. Elevations vary from 602 to 1,814 feet.

Approximately 42 miles of perennial and 55 miles of intermittent streams flow through the Reservation (Figure 1). These streams and tributaries drain into Lake Superior and generally flow along steeply graded channels incised in bedrock. The Pigeon and Reservation Rivers flow along the northern and western boundaries, respectively. The Pigeon River Basin has a total drainage area of about 600 square miles (more than half of this area is in Canada) and encompasses the northern one-third of the Reservation. There are seventeen inland boreal lakes in Grand Portage that collectively comprise approximately 816 acres and about 7,204 acres of wetlands within the Reservation boundaries.

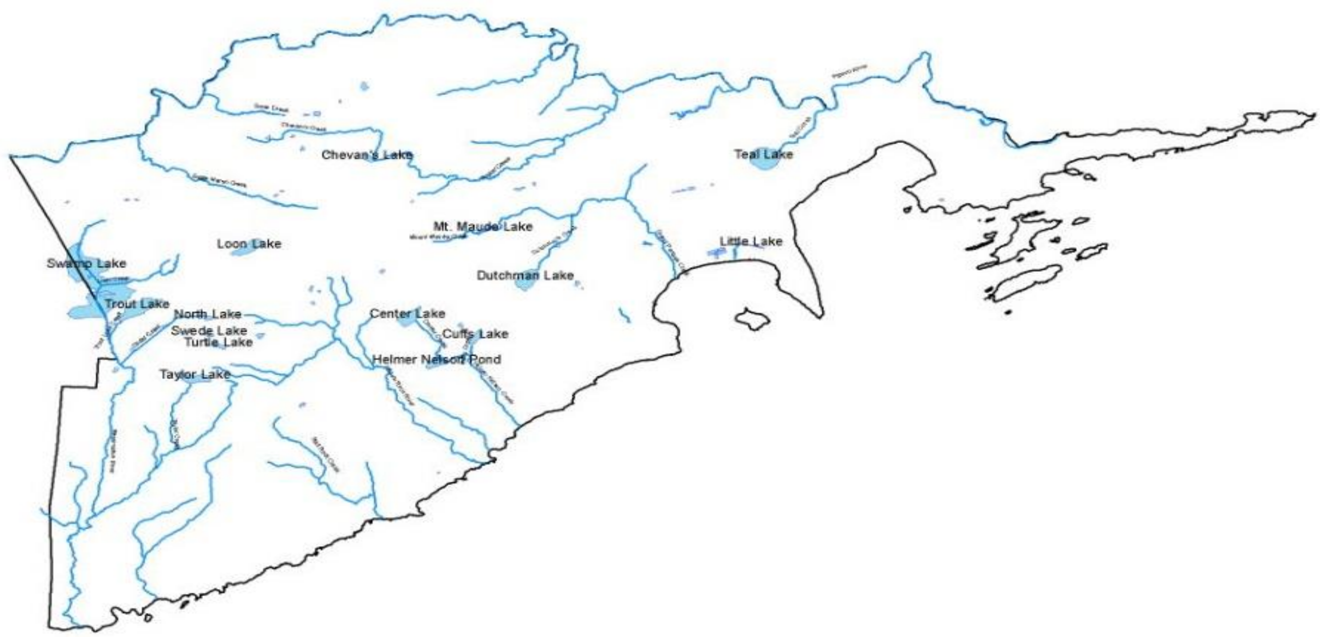



**Figure 1. Grand Portage Inland Lakes and Streams**

## Land Use

In keeping with the Tribe's core beliefs, extensive areas of the Reservation are designated for preservation, wildlife habitat, and forest management to enhance ecological services (Figure 2). 97% of the Reservation is forested with sparsely populated areas near Lake Superior's shores.

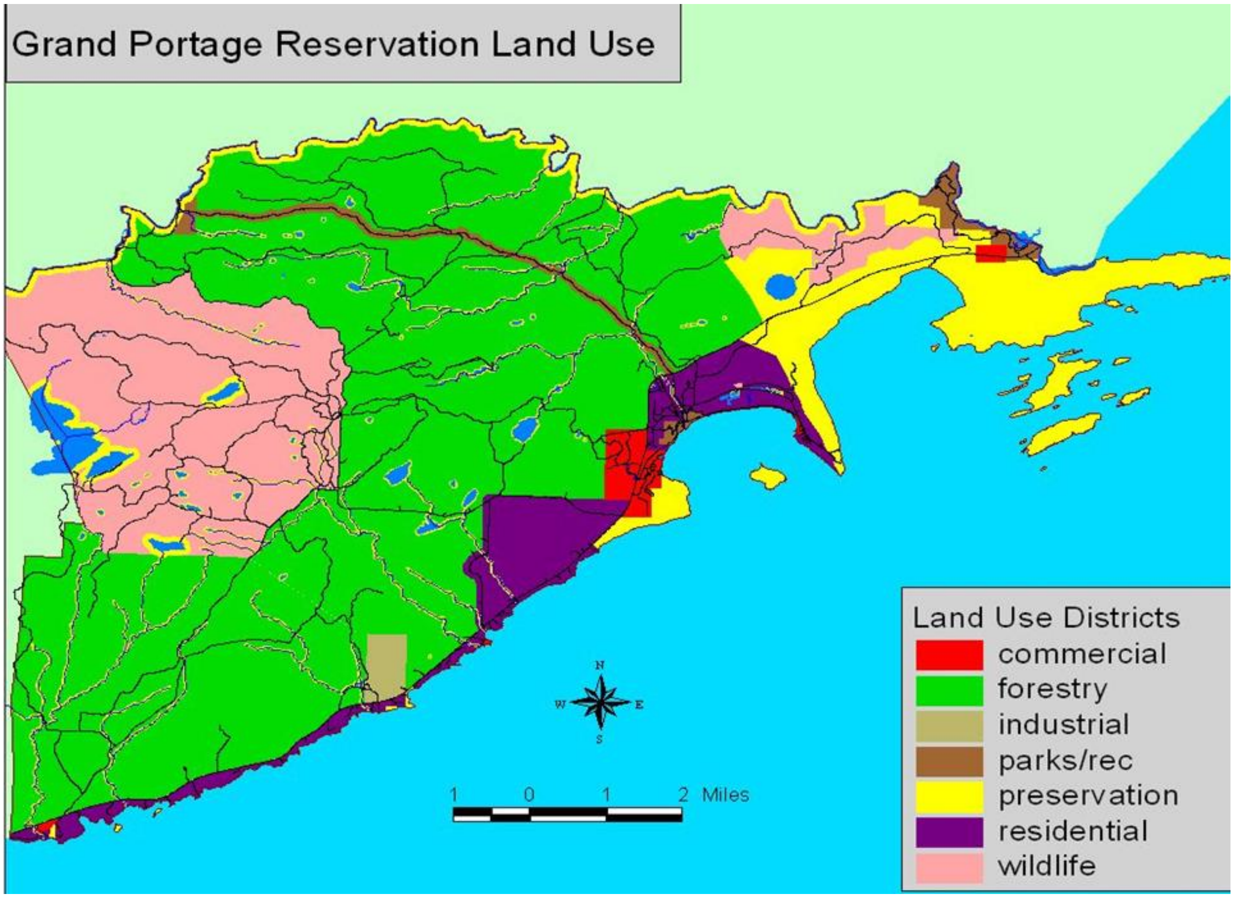



**Figure 2. Land use within the Grand Portage Reservation.**

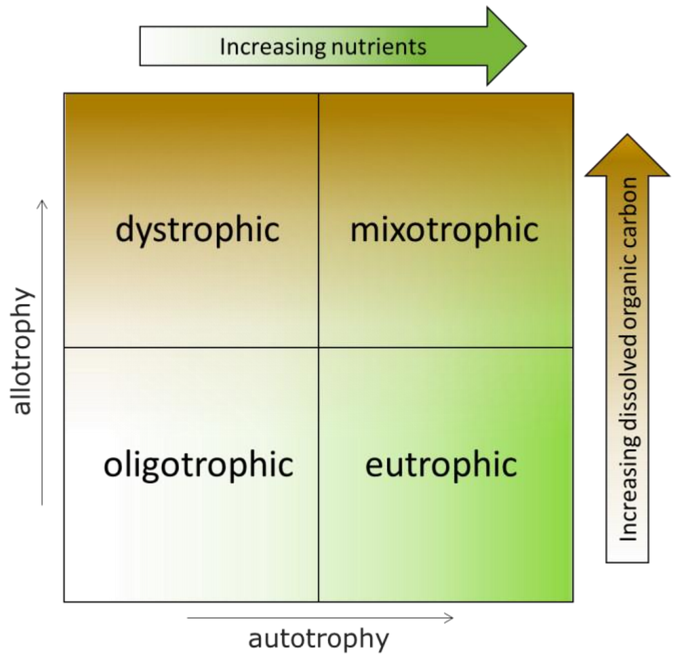
## Regulated Discharges

The Grand Portage community wastewater treatment system is the only point-source discharge regulated under the Clean Water Act. The facility is located in the center red portion of the map in Figure 2. Treated wastewater is discharged into Grand Portage Bay of Lake Superior. The facility operates under a NPDES permit and variance from mercury criteria issued by the US EPA. 401 certifications of the permit and variance are issued by Grand Portage. Grand Portage has issued conditional 401 certifications for US Army Corps Nationwide and Regional General permits and US EPA Stormwater Industrial, Construction, and Pesticide General permits.

## Waterbody Classification

The boreal lakes and streams within the reservation have naturally high dissolved organic carbon (DOC) and although the water is clear, it is stained by humic and tannic acids. The source of the DOC is from slowly decaying vegetation in the catchment and from peaty deposits leaching DOC into groundwater. These root beer- or tea-colored waters common to the region are referred to in the literature by a variety of names: blackwater, tannic, humic, stained, dystrophic, or mixotrophic.

Lakes can be classified along two axes: nutrients on one axis and dissolved organic carbon on the other (Thienemann 1925, Rodhe 1969, Williamson et al, 2020) (Figure 3). Autotrophy relates to the rates of primary production and allotrophy refers to the rate of allocthonous supply from the environment (Rodhe 1969). Williamson proposed corresponding measures for




the access using CDOC (0-50 α320/m) and total P (1-100 µg/l). Grand Portage lakes have mesotropic to eutrophic nutrient levels (> 10 µg/l TP) and high dissolved organic carbon > 25 CDOC α320/m) (Lafrançois et al. 2009) putting them in the mixotrophic quadrant.

**Figure 3. Waterbody classification system adapted from Rodhe 1969 and Williamson et al. 1999**

Many other forested boreal lakes around the world are also highly colored and are classified as either dystrophic or mixotrophic (Williamson et al. 2020, Saad et al 2016, Hagman 2020; Hansson et al. 2019). In the literature, mixotrophism is not commonly used to describe rivers except to discuss how organisms obtain energy by autotrophy or heterotrophy, i.e., by photosynthesizing or by assimilating organic carbon. However, we have applied the lake classification to Grand Portage streams because the characteristics of stream water are intimately tied to their source water and headwaters, i.e., boreal lakes, wetlands, and springs. Typically, but not exclusively, dystrophic and mixotrophic systems are characterized by clear (i.e., low turbidity) stained water color; water chemistry that includes high dissolved organic carbon (DOC), high tannins (i.e., humic and fulvic acids), slightly lower pH/acidic water, slightly lower dissolved oxygen, and low conductivity (Williamson et al., 1999; Hagman et al, 2020, Flotemersch 2023). These systems often have a low gradient, a soft mucky bottom, and unique biota.

On the reservation, nutrient and carbon sinks include forest, wetland, and aquatic plants that from organic rich soils and geologic deposits (Figure 4 and 5). In a study in Sweden, extensive phosphorus pools were associated with charophyte meadows (200-600 mg/m$^2$) with about 2/3 of P incorporated in alga tissue and 1/3 in carbonate crust (Sand-Jansen et al., 2021) that also becomes associated with sediment. Aquatic insects export nutrients back to land after emergence either directly or as feces from insectivores (e.g., birds, bats) and other predators (e.g., raptors) (Suter and Cormier, 2015).

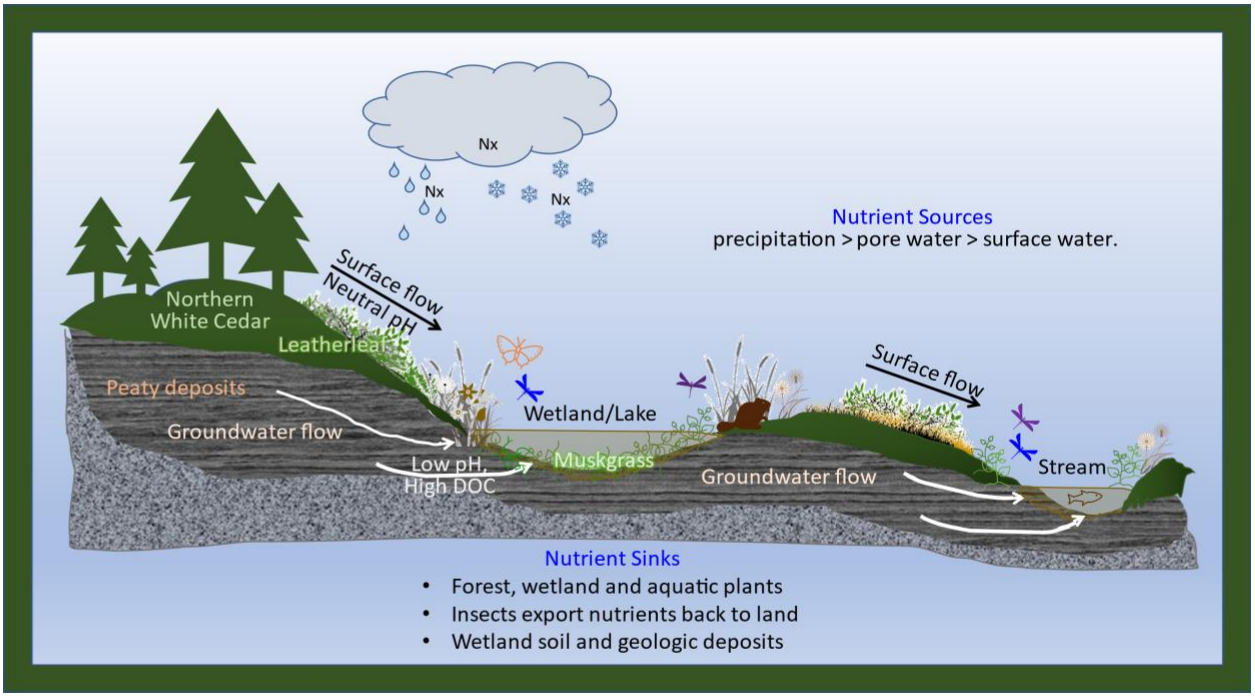



**Figure 4. Representation of dystrophic ecosystem.**

Although the groundwater which has low pH from tannic acid leached from peaty deposits, the lakes and streams in GP are circumneutral. Muskgrass (*Chara sp*.), a branching alga in wetland meadows and lake bottoms, forms external calcareous lime encrustation that accumulate in sediments that neutralize in-flowing lower pH groundwater (Barbosa et al., 2021, Sand-Jansen et al. 2019, Pelechaty et al., 2013).

Dystrophic and mixotrophic systems pose a challenge for developing aquatic life criteria because natural conditions may exceed established thresholds for non-dystrophic systems. Therefore, it is necessary to characterize natural background conditions and associated environmental parameters that may affect the exposure and potential adverse effects from nutrient enrichment, and aluminum and dissolved ion levels.

# NUTRIENT CRITERIA

## Current US EPA-Approved Narrative Nutrient Criteria

Grand Portage has US EPA approved narrative nutrient criteria. These water quality standards are intended to provide the basis for all water management decisions affecting water quality within the Reservation boundaries, including, but not limited to point-source permitting, non-point source controls and the physical alterations of water bodies including wetlands, water quality assessments, antidegradation demonstrations, and 401 certifications. This Technical Support Document (TSD) identifies the information and methods used to develop numeric nutrient criteria based upon the goals of the US EPA-approved narrative criteria and the existing natural conditions of the waters within the Reservation. The Grand Portage narrative criteria are as follows:

> "A. Policy and Scope.
>
> Nutrient monitoring data are used as an assessment tool for interpreting the narrative criterion for lakes, rivers, and wetlands within the exterior boundaries of the Reservation. The nutrient assessment tools are derived from data which reflects the natural condition of Reservation waters and represent a direct measure of the support for aquatic life use designations for Grand Portage lakes, rivers, and wetlands. The criterion will be used to assess attainment of designated uses, prioritize abatement projects, and inform 401 certifications.
>
> B. Narrative Criterion.
>
> Waters must be free from nutrients entering the waters as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae. Nutrient concentrations in surface waters must not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna, or impair the maintenance or attainment of designated uses."

## Addition of Numeric Nutrient Criteria

For ten years, Grand Portage has been working towards US EPA approvable numeric nutrient criteria for inland waters to supplement narrative nutrient criteria. Dr. Pat Saranno from Michigan State University, the National Park Service, USGS and Midwest Biodiversity Institute have worked with Grand Portage staff to develop several different approaches to create numeric nutrient criteria for the Reservation when needed for Clean Water Act implementation of the narrative criterion (Saranno 2011; Edland et al., 2007, 2009; MBI 2015). Each approach was designed to prevent degradation of current conditions thereby protecting water quality that supports tribal subsistence activities (e.g., fishing and wild rice harvest) and other existing aquatic life uses.

## Problem Formulation

### *Sources of Nutrients*

The State of Minnesota identifies its greatest threats to water quality as agricultural and urban changes. Lafrancois (2009), however, points to climate change and atmospheric deposition as the most likely stressors within the Grand Portage Reservation. Grand Portage enacted a Land Use Ordinance in 1996. The “Preservation Zone” in the Land Use Ordinance is adjacent to the “No Discharge Zone” mapped and described in Grand Portage Water Quality Standards. Grand Portage protects both its lands and waters for seven generations to come. However, the Band has little control over climate change and atmospheric deposition of pollutants into Grand Portage waters. Therefore, unlike the State of Minnesota, Grand Portage considers climate change to be the single greatest challenge to protecting water quality within the Reservation.

In our Climate Change Adaptation Plans, we anticipate atmospheric pollutants “washing” DOC out of the waters thereby increasing the risk of harmful algal blooms. Increased stormwater run-off from stronger more frequent storms, and less infiltration of rainwater to groundwater will likely increase concentrations of bacteria and nutrients to Lake Superior. Warming winter temperatures indicate warmer water temperatures that will reduce the concentrations of dissolved oxygen, and rising temperatures will create amenable habitat for aquatic invasive species and harmful agal blooms.

Even though there is substantive evidence that Grand Portage waters are in near-reference condition, and that using a percentile-of-reference approach to developing numeric nutrient criteria may be appropriate for some Reservations waters, Grand Portage is proposing using more protective median ambient concentrations as a basis for numeric nutrient criteria, given their closer correspondence to the national models.

Grand Portage lakes generally produce less chlorophyll-a per unit nutrient than NLA reference lakes compared with nutrient outputs from national models. This is likely due to an under-representation in the NLA of shallow lakes with naturally high concentrations of DOC.

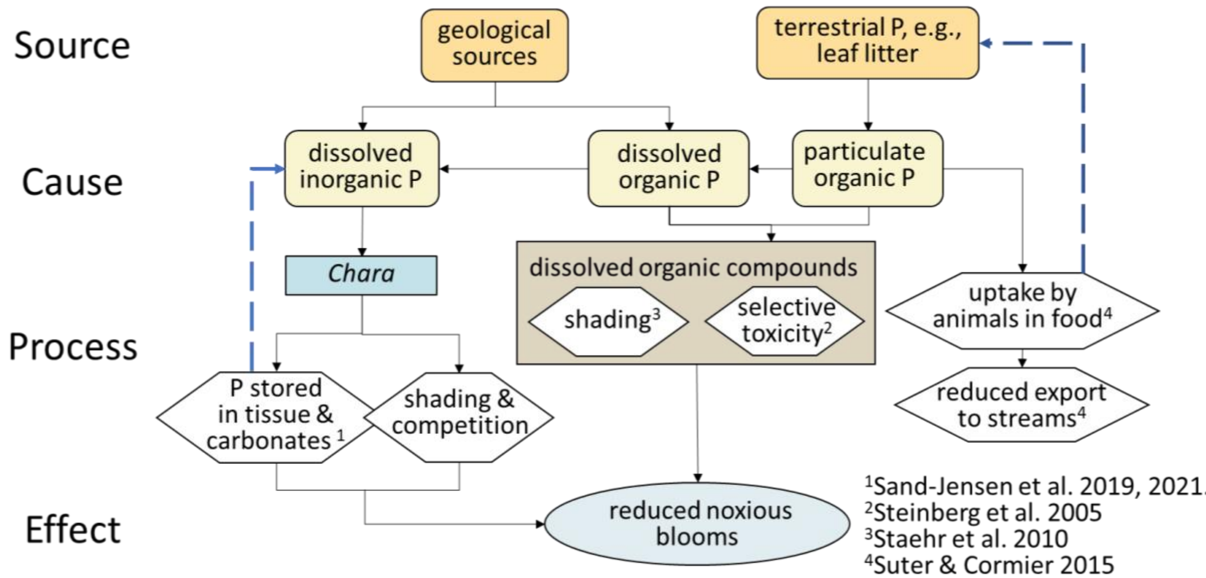



**Figure 5. Conceptual model of phosphorus cycling and processes in Grand Portage lakes affecting a criterion assessment endpoint, cyanobacterial blooms.**

## Importance of Dissolved Organic Carbon

As mentioned previously, US EPA's nutrient criteria recommendations for Ecoregion VIII (US EPA 2000b), where the Tribe is located, are often not appropriate. Based upon the classic trophic state indices, Grand Portage lakes would be considered mesotrophic to eutrophic. However, based on their naturally high dissolved organic carbon (DOC), Grand Portage waters are more accurately described as dystrophic/mixotrophic (Wetzel 2001) (Figure 3). The Grand Portage dystrophic/mixotrophic system classification is also supported by research on lakes in the nearby national parks of Isle Royale and Voyageurs National Park, where both parks exceeded ecoregional nutrient criteria and have little anthropogenic disturbance (Elias 2009). Grand Portage has historical data to establish background and enrichment trends within the Reservation. Criteria cannot be set below natural background conditions because this would alter the natural ecological balance.

US EPA recognizes that some parts of the country have naturally higher soil material, different precipitation regimes, geology, vegetation, and climate necessitating adjustment of the criteria development process (US EPA 2000, p.3) (Figure 6). Based upon Grand Portage research and analysis of US EPA nutrient criteria development efforts in Ecoregion VIII, sub-ecoregion 50, the Tribe determined that the site-specific approach is the most scientifically defensible way to proceed with criteria development for the Reservation waters.

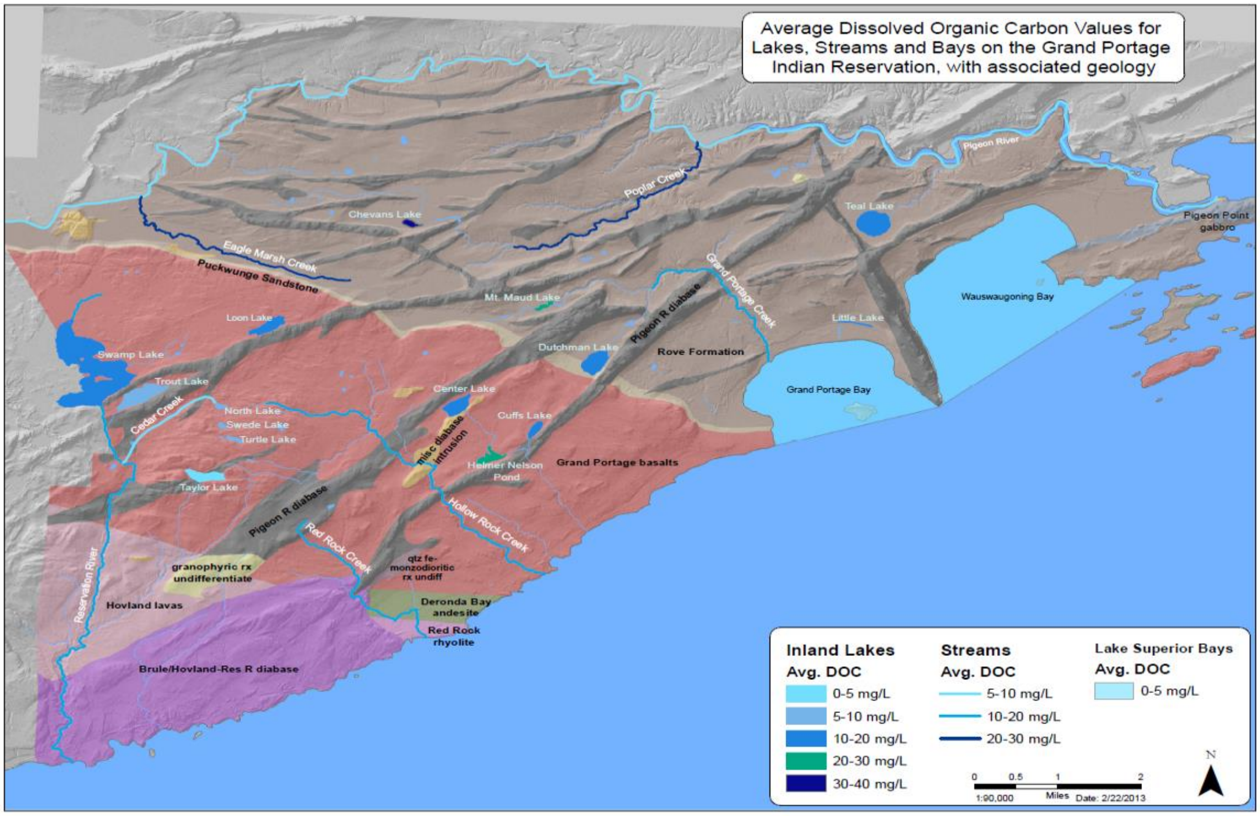



**Figure 3. Grand Portage Average DOC Values for Lakes, Streams and Bays (various shades of blue) with Associated Geology (shown as brown, ocher, gray, olive, mauve, violet polygons).**

## Grand Portage's Numeric Nutrient Criterion Approach

Grand Portage has been collecting macroinvertebrate and macrophyte community data from all inland waters in conjunction with water column data (nitrogen, phosphorus, chlorophyll-a, and dissolved organic carbon). These data have been the main source of information used to develop numeric nutrient criteria given the uniqueness of Reservation waterbodies.

Grand Portage waters are in near-reference condition generally producing less chlorophyll-a per unit nutrient than reference lakes in this ecoregion and the lakes used to build national models. Climate change is the single greatest challenge to protecting water quality within the Reservation. Therefore, Grand Portage is proposing a reference approach using median ambient concentrations as a basis for numeric nutrient criteria, and the natural range of DOC.

## Criteria Parameters

Grand Portage nutrient criteria parameters are: total phosphorus, total nitrogen, dissolved organic carbon, and chlorophyll-a. Shallow stained-water lakes (and streams whose headwaters are stained water lakes) tend to have higher levels of nitrogen, phosphorus, and dissolved organic carbon than clear water systems. Light availability and nutrient concentrations are important factors in determining the structure of the food web in the pelagic zones of lakes.

## Exposure measures

TN mg/L, TP mg/L, and DOC mg/L

### *Dissolved Organic Carbon (DOC)*

DOC strongly affects chemical, biological, and physical processes in boreal lakes. The increased color that results from DOC reduces light penetration, thereby impeding primary production and reducing harmful ultraviolet radiation (Morris et al., 1995, Steahr et al. 2010). DOC is a nutrient that is required for many aquatic biological processes, and some lakes with high DOC have higher primary production (Wetzel 2001). However, higher primary productivity is not occurring based on chlorophyll-a data collected from local waters. DOC affects thermal stratification (Snucins and Gunn, 2000, Heiskary et al. 2016), pH, and alkalinity (Oliver et al., 1983). DOC also mitigates the toxic effects of some pollutants including PAH's and heavy metals (Williamson, et. al. 1999).

Although high concentrations of DOC may correspond with lower concentrations of dissolved oxygen, DOC has a stronger influence on epilimnetic depths, and nocturnal mixing (related to the vertical partitioning from thermal changes) than wind-driven mixing (Read and Rose 2013). DOC can impede light penetration and reduce primary production thereby preventing harmful algal blooms (Staehr et al. 2010). With naturally high concentrations of nitrogen and phosphorus, this is particularly important. Algal blooms can block sunlight from reaching beneficial, sensitive, and rare aquatic plants that generate oxygen, control pH, and provide food and habitat for aquatic insects, fish, and amphibians, thereby negatively impacting the entire ecosystem (Figure 4). Therefore, the reduction or loss of DOC in boreal lakes can have catastrophic effects on sensitive and rare aquatic life and the ecological communities and processes that have evolved within these specific ecosystem types (Hudson et al., 2013; Schindler et al., 1997). Grand Portage maintains a database that has established the presence of many rare plants and aquatic insects, some of which have not been found anywhere else in Minnesota to date. Given the minimally disturbed condition of Grand Portage waters, maintaining the natural range of DOC will maintain ecosystem functions and further the protection of sensitive aquatic life (Figure 5).

### *Total Nitrogen and Total Phosphorus*

Nationally, agriculture is often the largest anthropogenic source of nitrogen and phosphorus. Nearly all of Grand Portage is forested. Community gardens and fruit trees are the extent of agriculture in Grand Portage and residential areas are generally along or near the shore of Lake Superior. In order of magnitude, the sources of nitrogen in Grand Portage are atmospheric deposition > groundwater > surface water. Phosphorus loadings are primarily from peat and decaying organic matter, and soil erosion.

Most of the inland lakes within the Reservation are relatively small and shallow surrounded by large natural catchments. Catchment:lake area ratios strongly affect nutrient concentrations. At catchment:lake area ratios of 10:1, precipitation supplies about half of the total nitrogen and phosphorus to lakes, and the catchment supplies the other half (Schindler et al., 1996). However, nutrient uptake via forest and wetland vegetation can decrease the catchment nutrient yields to the lake water column by roughly 90% (Schindler et al., 1996). Lake retention time is also shorter with larger catchment:volume ratios, creating a relatively quick response to chemical changes. The average catchment:lake ratio in Grand Portage is 36:1 (range 3.5:1-240:1). This means that on average 75 percent of the nutrients entering the water column are from the natural catchment surrounding the waterbody and that lake retention time in Grand Portage is relatively short.

## Effect endpoints

Two effect/management endpoints were assessed: Prevention of extirpation of sensitive aquatic species and prevention of unwanted algal blooms estimated as chlorophyll-a by maintaining natural background nutrient levels. Reference to "blooms" follows descriptions offered in Heiskary and Wilson (2008) whereby Chl-a > 10 µg/L "mild bloom," > 20 µg/L "nuisance bloom," and > 30 µg/L "severe nuisance blooms."

### *Chlorophyll-a*

Chlorophyll-a is used to measure the amount of phytoplankton growing in a waterbody. Algae form the base of the aquatic food web and are responsible for ninety percent of photosynthetic $CO_2$ fixation. Therefore, lakes and peatlands are carbon sinks. However, too much algae can reduce dissolved oxygen, create aesthetic problems, and some species of algae and cyanobacteria are harmful or toxic to humans and animals. Proposed chlorophyll-a criteria are below the threshold for mild algal blooms (Chl-a >10 µg/L).

## Criterion Characterization Method

The numeric criteria for total nitrogen, total phosphorus, and chlorophyll-a are estimated from the median concentrations of the lakes and streams with multiple years of measurements. DOC criteria are based on the natural range of concentrations measured from each location. Maintaining the natural "reference" condition of the waterbodies supports existing aquatic communities and designated uses.

Additionally, candidate criteria were compared to US EPA's national nutrient criteria recommendations and ecoregional statistics (US EPA 2010, MNPCA 2016; US EPA 2017). Background nutrient concentration was assessed by a causal weight of evidence (Herlihy and Sifneos, 2008, Cormier et al. 2010).

## Characterization of high quality 'reference' or minimally impacted condition

Two common ways for setting nutrient thresholds include 1) estimating undisturbed background nutrient levels (US EPA 2001, Herlihy and Sifneos, 2008) and 2) characterizing protective thresholds using models of relationships between nutrients and aquatic life (US EPA 2010). Grand Portage chose the first approach to identify nutrient criteria and the waterbody scale and the second to qualitatively confirm the protectiveness of the identified criteria using chlorophyll-a. Candidate criteria were also compared to US EPA's national nutrient criteria recommendations and ecoregional statistics. Options for selecting data set characteristics, geographic extent, and an appropriate statistic of undisturbed background conditions were considered while developing criterion values.

“Selection of appropriate reference conditions that represent a level of water quality at which there are no known impairments of a use due to nutrient over-enrichment” (US EPA, 2001) is one approach to develop nutrient criteria. Stoddard et al., (2006) defined reference conditions as “the condition of streams in the absence of significant human disturbance.” According to US EPA thresholds for predicting nonpoint source impacts, adverse impacts to water quality are likely to occur where impervious cover in a watershed exceeds 10% of the catchment (US EPA, 1997). Herlihy and Sifneos (2008) evaluated several options for estimating background and recommended scales finer than the level III ecoregion (i.e., US EPA Ecoregion 50, Northern Lakes and Forests) and evaluated several descriptive statistics to estimate background conditions as possible options for setting nutrient criteria and undisturbed samples. Among these options are using the $10^{th}$ or $25^{th}$ centile of found data, the $75^{th}$ centile of undisturbed sites, and models to predict background.

For the development of Grand Portage nutrient criteria, where data and conditions are undisturbed, criteria were identified at the water body scale. The smaller the geographic scale, the more relevant the estimate (Herlihy and Sifneos 2008). Land use, reconnaissance, and paleolimnological evidence was used to assess disturbance status. Based on the paleolimnological studies Grand Portage lakes are undisturbed reference sites (Edlund et al., 2007, 2009). Lafrancois (2009) also indicated that Grand Portage watersheds are relatively undisturbed and that setting nutrient criteria based on current conditions may be appropriate.

Grand Portage’s approach for establishing nutrient criteria is to maintain strong antidegradation protection for waters that meet the commonly accepted definition of “reference condition”. “[H]uman disturbance is very low at most places in the Grand Portage Reservation. Ninety-seven percent of the Reservation is forested and currently no lands within the Reservation are categorized as agricultural (Figure 2). At the Grand Portage sampling sites, catchment mean impervious surface is 1.94% (range: 0-7.8%) for lakes and 1.32% (range: 0-4.0%). When we look at developed land types and exclude the developed, open space” category where impervious surfaces account for less than 20 percent of total cover, the remaining developed land cover in catchments is very low: 0.10% (range: 0-1.27%) for lakes and 0.02% (range: 0-0.14%) for streams” (MBI, 2015). Based on percent impervious cover alone, Grand Portage inland waters meet the definition of “reference condition”. The Grand Portage Reservation sampling sites are clearly consistent with the definition of “minimally disturbed” reference category of Stoddard et al. (2006), i.e., “the condition of streams in the absence of significant human disturbance” (MBI 2015).

To validate that the inland waters represented reference conditions for nutrient criteria development, a paleolimnological study was initiated with the US Geological Survey, the Science Museum of Minnesota, and the St. Croix Water Research Station. Lake sediments integrate inputs from the water column, catchment, and airshed that can be temporally apportioned. Therefore, paleolimnological methods can be used to reconstruct historical water quality characteristics. To that end, lake sediment cores were collected at Trout and Swamp Lake to determine the historical nutrient productivity of the lakes by characterizing the fossil remains of diatoms and chrysophytes. Using the diatom and chrysophte analysis with lead-210 dating of sediment core sections historical total phosphorus concentrations were inferred.

Water-quality data including nutrients, DOC, major ions, collected between May and October from 2000-2008 were then compared to the inferred historical total phosphorus concentrations from 1781–2006 (Edlund et al., 2007, Edlund et al., 2009).

Many rare species and several unknown taxa of diatoms were found in the diverse diatom flora of Swamp and Trout lakes. Diatom-inferred total phosphorus concentrations ranged from 0.017 to 0.025 mg/L in Swamp Lake from sediment samples dated 1781–2005 and from 0.008 to 0.014 mg/L in the Trout Lake core based on sediments dated 1825–2006. Differences among the diatom-inferred total phosphorus concentrations and the median concentrations measured in the water column from 2000-2008 were not greater than the model error estimates. Therefore, we were able to reasonably conclude that no statistically significant changes in total phosphorus concentrations had occurred during the past 200 years in either Swamp Lake or Trout Lake (Edlund et al., 2007, 2009). Given the similar land use history, we can reasonably assume phosphorus concentrations measured in other Reservation waterbodies reflect natural conditions, too.

Most of the streams in Grand Portage originate from a lake or spring head within the Reservation. The only exception is the Pigeon River that originates many miles upstream of the Reservation in the Boundary Waters Canoe Area and Quetico Provincial Park, a vast wilderness area that forms the boundary between the US and Canada. Swamp Lake is the headwater of Reservation River. Chevans Lake is the headwater of Poplar Creek. North Lake is the headwater of Cedar Creek. Springs are the headwaters of Red Rock Creek, Hollow Rock Creek, and Eagle Marsh Creek. Mount Maude Lake, Dutchman Lake, and a spring, form the headwaters of Grand Portage Creek. Therefore, it is also reasonable to conclude that Grand Portage streams reflect mostly natural, undisturbed conditions.

In summary, the nutrient levels in streams and lakes at reference stations appear to be due to natural causes based on five characteristics associated with causal relationships (Cormier et al., 2010, Norton et al., 2014). On this basis, it can be concluded that nutrient concentrations at reference stations may be used to establish quantitative nutrient criteria for the Reservation.

The five causal characteristics are listed below and the evidence is summarized in Table 1.

(1) Time order—The cause precedes the effect.
(2) Antecedence—Each causal relationship is a result of a larger web of cause-and-effect relationships.
(3) Co-occurrence—The cause co-occurs with the unaffected entity in space and time.
(4) Sufficiency—The intensity, frequency, and duration of the cause are adequate to cause the effect and the entity is susceptible to produce the type and magnitude of the effect.
(5) Alteration—The entity is changed by the interaction with the cause.

**Table 1. Evidence that most observed nutrient levels are not due to anthropogenic inputs**

| Causal Characteristic | Evidence | Relevance |
|---|---|---|
| Time order | Comparison of lake sediment cores diatom-inferred total phosphorus (1781–2006) and recent water column samples (2000-2008) were not statistically different in two lakes (Edlund et al., 2007, 2009). | If present day nutrient levels are caused by anthropogenic inputs, nutrient levels should be lower in precolonial times. Nutrients levels did not increase since colonial times; therefore, anthropogenic inputs are minimal. *Supports natural background.* |
| Antecedence | Sources of nitrogen were greater from precipitation than from local ground water or surface water at reference stations. Sources are distant from areas used to assess background. 97% of reservation is in natural vegetation, primarily forest. Reconnaissance did not reveal nearby sources. | If observed nutrient levels have anthropogenic inputs, then sources should be apparent. Some inputs from atmospheric deposition may have increased background nutrient levels, but no local sources were identified. *Supports natural background.* |
| Cooccurrence | Observed concentrations on reservation and nearby pristine areas have similar nutrient ranges.<br>Comparison with other dystrophic systems suggests ranges are within those of other minimally affected systems. (Heiskary et al. 2016, Anderson et al. 2020, Flotemersch, et al., in review.) | If observed nutrient levels are due to anthropogenic inputs, then concentrations at least disturbed locations and at locations with known nutrient inputs should be similar, but that is not the case. Apparent background nutrient levels are similar to other dystrophic lakes and streams on the reservation and elsewhere.<br>The few anthropogenically altered stations have higher nutrient levels. *Supports natural background* |
| Sufficiency | Apparent background nutrient levels are not sufficient to cause biological impairments nor noxious algal bloom on the Reservation.<br>The threshold for mild algal blooms (Chl-a >10 µg/L) has been exceeded, but algal blooms have not been observed on the reservation.<br>In a non-dystropic lake, nutrients were sufficient to cause an algal bloom but not in a comparable dystrophic lake and was attributed to insufficient light (Staehr et al. 2010). | If observed nutrient levels are due to anthropogenic inputs then nutrients should be sufficient to cause noxious algal blooms on the reservation, but they did not.<br>If the nutrient levels are sufficient to cause cyanobacterial bloom in non-dystrophic lakes, then the same nutrient levels should cause blooms in dystrophic lakes, but they did not due to shading by DOC. *Supports natural background.* |

| Causal Characteristic | Evidence | Relevance |
|---|---|---|
| Alteration | Diatom community change is small since 1970's (Heiskary et al. 2016, Edlund et al. 2022). Rare plants occur in the waterbodies and are ecologically adapted to dystrophic systems observed on the Reservation.<br>BI scores (1.03 – 3.69) indicate excellent water quality. | Algal community change would be expected with an altered nutrient regime, but change has been small.<br>Endemic species adapted to the natural nutrient regime should occur in the area and they do. Suggesting that the nutrient and DOC regime is necessary for these dystrophic lakes and streams. *Supports natural background.* |

## Comparison to MN and US EPA Reference Approaches and US EPA Lake Models

***Comparison to State of MN Nutrient Criteria for Lakes***

Research shows that Grand Portage lakes and streams are "dilute, with intermediate nutrient levels, low transparency, and high dissolved organic carbon concentrations" (Lafrancois, et al.,2009). The lakes are smaller, shallower, more acidic, and more highly stained than the State of Minnesota's nutrient reference data set for the Northern Lakes and Forests (NLF) ecoregion. The water quality differs significantly in Grand Portage lakes compared to Minnesota's NLF ecoregional data (Lafrancois, et al., 2009).

***Naturally high nutrients, ecological uniqueness of waterbodies***

Grand Portage has carried out research projects, some with funding from US EPA, to show that the dystrophic system is unique and that US EPA's nutrient criterion recommendations for Ecoregion VIII (US EPA 2001) are often not appropriate, primarily due to US EPA's focus on non-dystrophic lakes and streams where the food resource is primarily algal rather than microbial communities using DOC as their energy source (Figure 5). Grand Portage reservation rivers and streams are naturally high in nutrients and would be considered mesotrophic to eutrophic according to common trophic classifications; whereas, they are more appropriately classified as dystrophic or mixotrophic (Williamson et al. 1999) (Figure 3). Furthermore, US EPA's national nutrient ecoregions are too coarse to account for natural variation in stream nutrient concentrations. Herlihy and Sifneos (2008) asserted that "setting appropriate nutrient criteria often requires finer-scale analysis and classification of sites that better controls for natural variation." Grand Portage, therefore, decided to pursue site-specific nutrient criteria based on ambient data collected from each of the reservation rivers and streams.

Previous US EPA nutrient criteria recommendations for rivers and streams (USEPA 2001; see Table 2 and 3) are predicated on the concept that criteria based on nutrient concentrations in undisturbed streams (i.e., the reference site approach) could be applied to other rivers and streams and would result in protection of the designated uses of those water bodies. Herlihy and Sifneos (2008) found that US EPA's suggestion for using the 25$^{th}$ percentile of all waterbodies (disturbed and undisturbed) to approximate the 75$^{th}$ percentile of reference sites is a flawed approach because the disturbed sites vary over time with changing human nutrient use and other environmental practices.

Ideally, observed nutrient concentrations in undisturbed systems would form the most appropriate nutrient criteria for rivers and streams (Herlihy and Sifneos 2008). Because reservation waters fit this model, the Tribe has decided to propose nutrient criteria for individual waterbodies based upon data for Grand Portage's undisturbed system.

In the ecoregion where the Grand Portage Reservation is located, the US EPA criteria recommendations include the following (tables 2 and 3).

**Table 2. Grand Portage Data Compared to US EPA Nutrient Criteria Recommendations for Rivers/Streams in Ecoregion VIII, Subecoregion #50 *Northern Lakes and Forests***

| | **US EPA[a]** | **Grand Portage data** | | | |
|---|---|---|---|---|---|
| **Parameter** | **25th centiles** | **25th centile** | **25th centile range** | **75th centile** | **75th centile range** |
| Total Nitrogen (calculated) (mg/L) | 0.36 | 0.5 | 0.4 – 0.86 | 0.96 | 0.71 -1.36 |
| Total Nitrogen (reported) µg /L | 0.44 | - | 0.55 | - | 0.8 |
| Total Phosphorus (µg/L) | 12 | 13 | 11 - 22 | 46 | 33 - 68 |
| Turbidity (NTU) | 0.63 | - | - | - | - |
| Chlorophyll a (µg/L) - F | 0.6 | 0.5 | 0.5 – 1.0 | 2.0 | 0.1 – 8.0 |

[a]based on all-season data

In these earlier recommendations, US EPA suggested that total nitrogen, total phosphorus, chlorophyll-a and a measure of turbidity were considered best suited for protecting designated uses (US EPA 2000, p.2). Nitrogen and phosphorus are causal parameters and turbidity and chlorophyll-a are response variables. For chlorophyll-a, Fluorometric (F) and Spectrophotometric (S) methods are preferred as are acid-corrected median values. US EPA considered these parameters essential to nutrient assessment as early indicators of system enrichment for surface waters. The reference conditions above for both US EPA and Grand Portage, represent the least anthropogenically impacted lakes at the present time, with the caveats discussed above for US EPA criteria which applied to the 25$^{th}$ percentile of broad survey results.

**Table 3. Grand Portage Data Compared to previous US EPA Nutrient Criteria Recommendations for Lakes (based on reference condition).**

| | **US EPA[a]** | | **Grand Portage** | | **MN state** |
|---|---|---|---|---|---|
| **Parameter** | **25th Percentiles** | **75th Percentile** | **25th Percentile** | **75th Percentile** | **Criteria** |
| Total Nitrogen (calculated) (mg/L) | 0.323 | | 0.60 | 1.10 | |
| Total Nitrogen (reported) (mg/L) | 0.4 | | 0.70 | 0.93 | N/A |

| | | | | | |
|---|---|---|---|---|---|
| Total Phosphorus (µg/L) | 9.69 | | 11 | 30 | 30 |
| Secchi (meters) | | 4.2 | 1.2 | 0.77 | 2.0 |
| Chlorophyll a (µg/L) – Fluorometric (F) | 1.38 | | 2.0 | 6.0 | 4.0 |

[a]based on all-season data

## US EPA's National Recommended Nutrient Criteria for Lakes and Reservoirs (2021)

US EPA published updated nutrient criteria recommendations using interactive models for lakes and reservoirs in 2021. The interactive models are intended to assist Tribes and States in the development of protective water quality criteria for aquatic life uses, drinking water sources, and recreational uses. Grand Portage has compared the Microcystin (MC), Hypoxia, and Zooplankton models to our existing water quality data to assess their merits and suitability in developing nutrient criteria for Grand Portage inland lakes.

Grand Portage lakes are generally shallow (all but three have maximum depths <3.4 m) and do not support cold-water fish species. Possibly because of limited light availability from stained waters and abundant macrophytes, Reservation waters have not experienced problematic cyanobacterial blooms. Therefore, the focus of Grand Portage's review of US EPA's 304(a) lake nutrient models has primarily been the zooplankton model.

In the national zooplankton model, using both a 'low' slope factor of 0.05 and a 'high' slope factor of 0.3, ambient median concentrations of chlorophyll-a in Grand Portage lakes are lower than the national model criteria for almost all lakes (Table 4.). None of the relevant lakes exceed the national model TN or TP criteria for the 0.05 slope. Three of five slightly exceed the national model TP criteria, and one of five exceeds national model TN criteria using a 0.3 slope (Table 5.).

When examining the national MC model using US EPA 8 µg/L MC recreational threshold (US EPA 2000) with a 0.01 exceedance probability and a certainty level of 90%, all median chlorophyll-a values from Grand Portage lakes are lower than the national model chlorophyll-a criteria output (US EPA 2021). However, six of fifteen lakes exceed the national TN criterion and five of fifteen lakes exceed the national TP criterion (Table 6.). This indicates that the designated use may be supported at nutrient levels greater than the US EPA regional estimate.

Comparing 90$^{th}$ percentiles of Grand Portage data to national model outputs resulted in substantially more exceedances (Tables 7 – 9).

**Table 4. Grand Portage Median Nutrient Concentrations Compared with the National**

| Lake Name | Max Depth | Grand Portage Median Values - Lakes | | | | National models - zooplankton low slope (0.05) | | |
|---|---|---|---|---|---|---|---|---|
| | **Meters** | **Chl-a** (µg/L) | **TN** (mg/L) | **TP** (mg/L) | **DOC** (mg/L) | **Chl-a** (µg/L) | **TN** (mg/L) | **TP** (mg/L) |
| Center Lake | 3.4 | 5.5 | 0.81 | 0.027 | 16.7 | 26 | 1.2 | 0.039 |
| Chevan's Lake | 0.91 | 2.0 | 1.10 | 0.017 | 30.1 | - | - | - |
| Cuffs Lake | 1.22 | 3.2 | 0.79 | 0.025 | 12.2 | - | - | - |
| Dutchman Lake | 3.35 | 6.5 | 0.90 | 0.026 | 17.0 | 26 | 1.2 | 0.039 |
| Helmer-Nelson Pond | 1.83 | 3.0 | 1.10 | 0.039 | 22.1 | - | - | - |
| Little Lake | 1.22 | 3.0 | 0.70 | 0.014 | 11.6 | - | - | - |
| Loon Lake | 1.52 | 5.0 | 0.83 | 0.023 | 10.0 | - | - | - |
| Mt Maud Lake | 1.83 | 5.0 | 0.90 | 0.032 | 18.8 | - | - | - |
| North Lake | 1.83 | 2.0 | 0.54 | 0.011 | 8.5 | - | - | - |
| Swamp Lake | 4.57 | 6.6 | 0.92 | 0.024 | 19.0 | 26 | 1.3 | 0.038 |
| Swede Lake | 1.53 | 4.0 | 0.70 | 0.015 | 7.2 | - | - | - |
| Taylor Lake | 7.01 | 2.8 | 0.46 | 0.011 | 4.5 | 26 | 0.53 | 0.036 |
| Teal Lake | 1.52 | 2.0 | 0.83 | 0.012 | 17.4 | - | - | - |
| Trout Lake | 5.49 | 3.0 | 0.60 | 0.010 | 6.8 | 26 | 0.65 | 0.037 |
| Turtle Lake | 2.44 | 1.0 | 0.52 | 0.020 | 6.4 | - | - | - |
| Median Ave. | 2.64 | 3.64 | 0.78 | 0.0204 | 13.9 | 26 | 0.96 | 0.0378 |

**Zooplankton Model Using a Low Slope Factor. On average, Grand Portage Chl-a and nutrient levels are less than the National model.**

**Table 5. Grand Portage Median Nutrient Concentrations Compared with the National Zooplankton Model Using a High Slope Factor. On average, Grand Portage Chl-a are less than and nutrient levels are similar to the National model.**

| Lake Name | Max Depth | Grand Portage Median Values - Lakes | | | | National models - zooplankton high slope (0.3 except for deeper lakes 0.1) | | |
|---|---|---|---|---|---|---|---|---|
| | Meters | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) | DOC (mg/L) | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) |
| Center Lake | 3.4 | 5.5 | 0.81 | 0.027 | 16.7 | 8 | 0.96 | 0.02 |
| Chevan's Lake | 0.91 | 2.0 | 1.10 | 0.017 | 30.1 | | | |
| Cuffs Lake | 1.22 | 3.2 | 0.79 | 0.025 | 12.2 | | | |
| Dutchman Lake | 3.35 | 6.5 | 0.90 | 0.026 | 17.0 | 8 | 0.97 | 0.02 |
| Helmer-Nelson Pond | 1.83 | 3.0 | 1.10 | 0.039 | 22.1 | | | |
| Little Lake | 1.22 | 3.0 | 0.70 | 0.014 | 11.6 | | | |
| Loon Lake | 1.52 | 5.0 | 0.83 | 0.023 | 10.0 | | | |
| Mt Maud Lake | 1.83 | 5.0 | 0.90 | 0.032 | 18.8 | | | |
| North Lake | 1.83 | 2.0 | 0.54 | 0.011 | 8.5 | | | |
| Swamp Lake | 4.57 | 6.6 | 0.92 | 0.024 | 19.0 | 8 | 1.1 | 0.019 |
| Swede Lake | 1.53 | 4.0 | 0.70 | 0.015 | 7.2 | | | |
| Taylor Lake | 7.01 | 2.8 | 0.46 | 0.011 | 4.5 | 8 | 0.33 | 0.018 |
| Teal Lake | 1.52 | 2.0 | 0.83 | 0.012 | 17.4 | | | |
| Trout Lake | 5.49 | 3.0 | 0.60 | 0.010 | 6.8 | 8 | 0.45 | 0.019 |
| Turtle Lake | 2.44 | 1.0 | 0.52 | 0.020 | 6.4 | | | |
| Median average | | 3.64 | 0.78 | 0.020 | 13.88 | 8 | 0.762 | 0.0192 |

**Table 6. Grand Portage Median Nutrient Concentrations Compared with the National Microcystin Model. On average, Grand Portage Chl-a are less than and nutrient levels are similar to the National model.**

| Lake Name | Max Depth | Median Values - Lakes | | | | National models - MC chl-a | | |
|---|---|---|---|---|---|---|---|---|
| | Meters | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) | DOC (mg/L) | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) |
| Center Lake | 3.4 | 5.5 | 0.81 | 0.027 | 16.7 | 8 | 0.96 | 0.02 |
| Chevans Lake | 0.91 | 2.0 | 1.10 | 0.017 | 30.1 | 8.9 | 1.1 | 0.028 |
| Cuffs Lake | 1.22 | 3.2 | 0.79 | 0.025 | 12.2 | 8 | 0.73 | 0.026 |
| Dutchman Lake | 3.35 | 6.5 | 0.90 | 0.026 | 17.0 | 8 | 0.97 | 0.02 |
| Helmer-Nelson Pond | 1.83 | 3.0 | 1.10 | 0.039 | 22.1 | 8.9 | 1.1 | 0.024 |
| Little Lake | 1.22 | 3.0 | 0.70 | 0.014 | 11.6 | 8.9 | 0.71 | 0.028 |
| Loon Lake | 1.52 | 5.0 | 0.83 | 0.023 | 10.0 | 8.9 | 0.62 | 0.028 |
| Mt Maud Lake | 1.83 | 5.0 | 0.90 | 0.032 | 18.8 | 8.9 | 1.1 | 0.024 |
| North Lake | 1.83 | 2.0 | 0.54 | 0.011 | 8.5 | 8.9 | 0.55 | 0.024 |
| Swamp Lake | 4.57 | 6.6 | 0.92 | 0.024 | 19.0 | 7.2 | 1.1 | 0.018 |
| Swede Lake | 1.53 | 4.0 | 0.70 | 0.015 | 7.2 | 8.9 | 0.48 | 0.028 |
| Taylor Lake | 7.01 | 2.8 | 0.46 | 0.011 | 4.5 | 7.2 | 0.44 | 0.017 |
| Teal Lake | 1.52 | 2.0 | 0.83 | 0.012 | 17.4 | 8.9 | 1 | 0.028 |
| Trout Lake | 5.49 | 3.0 | 0.60 | 0.010 | 6.8 | 7.2 | 0.44 | 0.017 |
| Turtle Lake | 2.44 | 1.0 | 0.52 | 0.020 | 6.4 | 8.9 | 0.44 | 0.024 |
| Median average | | 3.0 | 0.81 | 0.020 | 12.2 | 8.9 | 0.73 | 0.024 |

**Table 7. Grand Portage 90$^{th}$ Percentile Nutrient Concentrations Compared with the National Zooplankton Model Using a Low Slope Factor. On average the 90$^{th}$ Percentile Chl-a is lower, Total Phosphorus is the same, and Total Nitrogen is higher than the National Model.**

| Lake Name | Max Depth | 90th Percentiles - Lakes | | | | National models - zooplankton low slope (0.05) | | |
|---|---|---|---|---|---|---|---|---|
| | Meters | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) | DOC (mg/L) | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) |
| Center Lake | 3.4 | 25.4 | 1.373 | 0.0514 | 20.5 | 26 | 1.2 | 0.039 |
| Chevans Lake | 0.91 | | | | | | | |
| Cuffs Lake | 1.22 | | | | | | | |
| Dutchman Lake | 3.35 | 13.7 | 1.34 | 0.0388 | 20.3 | 26 | 1.2 | 0.039 |
| Helmer-Nelson Pond | 1.83 | | | | | | | |
| Little Lake | 1.22 | | | | | | | |
| Loon Lake | 1.52 | | | | | | | |
| Mt Maud Lake | 1.83 | | | | | | | |
| North Lake | 1.83 | | | | | | | |
| Swamp Lake | 4.57 | 11 | 1.6 | 0.038 | 21.94 | 26 | 1.3 | 0.038 |
| Swede Lake | 1.53 | | | | | | | |
| Taylor Lake | 7.01 | 6 | 1.1 | 0.0286 | 5.4 | 26 | 0.53 | 0.036 |
| Teal Lake | 1.52 | | | | | | | |
| Trout Lake | 5.49 | 5 | 1.3 | 0.0207 | 7.95 | 26 | 0.65 | 0.037 |
| Turtle Lake | 2.44 | | | | | | | |
| Median average | | 11 | 1.34 | 0.038 | 20.3 | 26 | 0.925 | 0.038 |

**Table 8. Grand Portage 90th Percentile Nutrient Concentrations Compared with the National Zooplankton Model Using a High Slope Factor. On average Chl-a, Total Nitrogen, and Total Phosphorus are higher than the National Model.**

| Lake Name | Max Depth | Grand Portage 90th Percentiles - Lakes | | | | National models - zooplankton high slope (0.3) | | |
|---|---|---|---|---|---|---|---|---|
| | Meters | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) | DOC (mg/L) | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) |
| Center Lake | 3.4 | 25.4 | 1.373 | 0.0514 | 20.5 | 8 | 0.96 | 0.02 |
| Chevan's Lake | 0.91 | | | | | | | |
| Cuffs Lake | 1.22 | | | | | | | |
| Dutchman Lake | 3.35 | 13.7 | 1.34 | 0.0388 | 20.3 | 8 | 0.97 | 0.02 |
| Helmer Nelson Pond | 1.83 | | | | | | | |
| Little Lake | 1.22 | | | | | | | |
| Loon Lake | 1.52 | | | | | | | |
| Mt Maud Lake | 1.83 | | | | | | | |
| North Lake | 1.83 | | | | | | | |
| Swamp Lake | 4.57 | 11 | 1.6 | 0.038 | 21.94 | 8 | 1.1 | 0.019 |
| Swede Lake | 1.53 | | | | | | | |
| Taylor Lake | 7.01 | 6 | 1.1 | 0.0286 | 5.4 | 8 | 0.33 | 0.018 |
| Teal Lake | 1.52 | | | | | | | |
| Trout Lake | 5.49 | 5 | 1.3 | 0.0207 | 7.95 | 8 | 0.45 | 0.019 |
| Turtle Lake | 2.44 | | | | | | | |
| Median average | | 11 | 1.34 | 0.038 | 20.3 | 8 | 0.96 | 0.019 |

**Table 9. Grand Portage 90th Percentile Nutrient Concentrations Compared with the National Microcystin Model. On average Chl-a is about the same as the same as the National Model, TN and TP are higher.**

| Lake Name | Max Depth | 90th Percentiles - Lakes | | | | National models - MC chl-a | | |
|---|---|---|---|---|---|---|---|---|
| | Meters | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) | DOC (mg/L) | Chl-a (µg/L) | TN (mg/L) | TP (mg/L) |
| Center Lake | 3.4 | 25.4 | 1.373 | 0.0514 | 20.5 | 8 | 0.96 | 0.02 |
| Chevans Lake | 0.91 | 13.6 | 1.638 | 0.0326 | 42.74 | 8.9 | 1.1 | 0.028 |
| Cuffs Lake | 1.22 | 8.27 | 1.294 | 0.0448 | 15.26 | 8 | 0.73 | 0.026 |
| Dutchman Lake | 3.35 | 13.7 | 1.34 | 0.0388 | 20.3 | 8 | 0.97 | 0.02 |
| Helmer-Nelson Pond | 1.83 | 29.4 | 1.7 | 0.0782 | 29.05 | 8.9 | 1.1 | 0.024 |
| Little Lake | 1.22 | 7.93 | 1.39 | 0.0254 | 13.84 | 8.9 | 0.71 | 0.028 |
| Loon Lake | 1.52 | 10.4 | 1.29 | 0.0319 | 12.64 | 8.9 | 0.62 | 0.028 |
| Mt Maud Lake | 1.83 | 23.1 | 2.005 | 0.0635 | 24.63 | 8.9 | 1.1 | 0.024 |
| North Lake | 1.83 | 4 | 1.178 | 0.0196 | 10.34 | 8.9 | 0.55 | 0.024 |
| Swamp Lake | 4.57 | 11 | 1.6 | 0.038 | 21.94 | 7.2 | 1.1 | 0.018 |
| Swede Lake | 1.53 | 7.9 | 1.33 | 0.03 | 10.78 | 8.9 | 0.48 | 0.028 |
| Taylor Lake | 7.01 | 6 | 1.1 | 0.0286 | 5.4 | 7.2 | 0.44 | 0.017 |
| Teal Lake | 1.52 | 8 | 1.318 | 0.0196 | 20.97 | 8.9 | 1 | 0.028 |
| Trout Lake | 5.49 | 5 | 1.3 | 0.0207 | 7.95 | 7.2 | 0.44 | 0.017 |
| Turtle Lake | 2.44 | 9 | 1.4 | 0.0612 | 10.7 | 8.9 | 0.44 | 0.024 |
| Median average | | 9 | 1.34 | 0.0326 | 15.26 | 8.9 | 0.73 | 0.024 |

## Grand Portage Lake and Stream Nutrient Criteria

Calculated annual median concentrations of total nitrogen, total phosphorus, and chlorophyll-a shall not exceed criteria by twenty-five percent more than once every three years. Median annual concentrations of dissolved organic carbon shall be maintained within the range shown in tables 10 and 11.

In Section VII, Implementation of Antidegradation Policy, Grand Portage Water Quality Standards require the protection of downstream waters.

“Protection of Designated and Existing Uses:

For all waters, the Reservation Water Resources Board will ensure that the level of water quality necessary to protect existing uses is maintained. In order to achieve this requirement, and consistent with 40 CFR 131.10, these water quality standards contain use designations which include all existing uses. Controls will be established as necessary for point and non-point sources of pollutants to ensure the water quality criteria applicable to the designated uses are achieved and that any designated use of downstream water is protected. Where water quality does not support the designated use of a water body or ambient pollutant concentrations exceed water quality criteria and values applicable to the water body, the Reservation Water Resources Board must not allow a lowering of water quality for the pollutant or pollutants preventing attainment of such uses."

**Table 10. Proposed Nutrient Criteria for Grand Portage Creeks and Rivers**

| **Median Values – Creeks and Rivers** | | | | **Range** |
|---|---|---|---|---|
| **Site** | **Chl-a (µg/L)** | **TN (mg/L)** | **TP (mg/L)** | **DOC (mg/L)** |
| Cedar Creek | 0.5 | 0.33 | 0.012 | 4.5 - 14.7 |
| Eagle Marsh | 2.9 | 1.00 | 0.035 | 13.6 - 30.5 |
| Grand Portage Creek | 0.5 | 0.60 | 0.025 | 7.9 - 30.1 |
| Hollow Rock Creek | 0.5 | 0.59 | 0.018 | 6.0 - 20.5 |
| Pigeon River | 1.0 | 0.50 | 0.026 | 4.3 - 17.5 |
| Poplar Creek | 2.0 | 0.80 | 0.052 | 13.2 - 31.6 |
| Red Rock Creek | 0.6 | 0.87 | 0.020 | 9.7 - 24.5 |
| Reservation River | 1.0 | 0.70 | 0.026 | 6.2 - 16.8 |

**Table 11. Proposed Nutrient Criteria for Grand Portage Inland Lakes**

| **Median Values - Lakes** | | | | **Range** |
|---|---|---|---|---|
| **Site** | **Chl-a** (µg/L) | **TN** (mg/L) | **TP** (mg/L) | **DOC** (mg/L) |
| Center Lake | 5.5 | 0.81 | 0.027 | 12.2 - 22.9 |
| Chevans Lake | 2.0 | 1.10 | 0.017 | 16.1 - 46.0 |
| Cuffs Lake | 3.2 | 0.79 | 0.025 | 8.3 - 17.6 |
| Dutchman Lake | 6.5 | 0.90 | 0.026 | 11.4 - 23.2 |
| Helmer-Nelson Pond | 3.0 | 1.10 | 0.039 | 13.4 - 37.5 |
| Little Lake | 3.0 | 0.70 | 0.014 | 7.4 - 22.8 |
| Loon Lake | 5.0 | 0.83 | 0.023 | 7.2 - 14.9 |
| Mt. Maud Lake | 5.0 | 0.90 | 0.032 | 10.7 - 31.5 |
| North Lake | 2.0 | 0.54 | 0.011 | 4.8 - 11.8 |
| Swamp Lake | 6.6 | 0.92 | 0.024 | 11.9 - 22.7 |
| Swede Lake | 4.0 | 0.70 | 0.015 | 2.6 - 17.1 |
| Taylor Lake | 2.8 | 0.46 | 0.011 | 2.9 - 9.4 |
| Teal Lake | 2.0 | 0.83 | 0.012 | 11.5 - 23.1 |
| Trout Lake | 3.0 | 0.60 | 0.010 | 4.8 - 12.5 |
| Turtle Lake | 1.0 | 0.52 | 0.020 | 2.2 - 17.3 |

## Downstream Impacts and Benefits

US EPA suggests that the final element of the criteria development process is the assessment of the likely downstream effects of the criterion (US EPA 2000, p. 2). All of the waters of the Reservation either flow into Lake Superior or the Pigeon River, which flows into Lake Superior. Grand Portage believes that maintaining the natural condition of inland waters will have a positive impact on the downstream waters of Lake Superior (Figure 7). The downstream benefits that we anticipate from developing numeric nutrient criteria based upon existing natural conditions include: 1) maintenance and protection of existing uses; 2) preservation of good to excellent water quality and biological conditions that have been documented by the Grand Portage water monitoring program; and 3) ensuring that water treatment costs for the community and nearby jurisdictions are as minimal as possible.


**Figure 4. Grand Portage Reservation Shoreline Waters**

# ALUMINUM CRITERIA

To maintain the exceptional quality of the reservation's water, Grand Portage chose to estimate waterbody specific criteria within its jurisdictional waters rather than a single value for the entire Reservation.

## Exposure measure

µg/L total aluminum

## Effect endpoints

Chronic toxicity endpoints. Protection of approximately 95 percent of a group of diverse taxa, with special consideration given to any commercially and recreationally important species (Stephan et al 1985).

## Criterion Characterization Method

Grand Portage criteria were developed using US EPA's Final Aquatic Life Ambient Water Quality Criteria for Aluminum, 2018, aluminum criteria calculator-v2.0[1] to calculate chronic criteria. Section 10. Methodology to develop or revise water quality criteria, pg. 30, Grand Portage WQS provides:

"For future numeric criteria development or modification, or where numeric criteria are needed to implement a narrative criterion, the Grand Portage Water Resources Board will use the methodologies required by 40 CFR 132.4(a)(2) through (5) which are hereby adopted and incorporated by reference into this chapter:

Appendix A to Part 132 – Great Lakes Water Quality Initiative Methodology for development of aquatic life criteria. However, *Chronic Criteria will be used in place of Acute Criteria and shall not be exceeded in waters of the Reservation*."

[1] https://www.epa.gov/wqc/aquatic-life-criteria-aluminum

**Table 12. Aluminum Criteria Data**

| Site | Number of samples | Years | Range of DOC | Range of Hardness | Range of pH |
|---|---|---|---|---|---|
| **Streams** | | | | | |
| Cedar Creek | 38 | 2005 - 2019 | 4.5 - 14.7 | 26.4 - 82.0 | 6.37 - 7.97 |
| Eagle Marsh Creek | 33 | 2006 - 2020 | 4.5 - 30.5 | 21.5 - 82.0 | 5.60 - 7.97 |
| Grand Portage Creek | 38 | 2005 - 2021 | 7.9 - 30.1 | 28.1 - 111.0 | 6.36 - 7.94 |
| Hollow Rock Creek | 35 | 2006 - 2020 | 6.0 - 20.5 | 21.9 - 80.0 | 6.02 - 8.71 |
| Pigeon River | 38 | 2005 - 2021 | 4.3 - 17.5 | 28.1 - 50.8 | 6.83 - 8.80 |
| Poplar Creek | 38 | 2005 - 2021 | 13.2 - 31.6 | 21.1 - 212.0 | 5.97 - 7.70 |
| Red Rock Creek | 29 | 2006 - 2018 | 9.7 - 24.5 | 25.4 – 140.0 | 5.09 - 7.62 |
| Reservation River | 34 | 2006 - 2020 | 6.2 - 16.8 | 26.4 - 106.0 | 6.29 - 8.59 |
| **Lakes** | | | | | |
| Center Lake | 35 | 2005 - 2019 | 12.2 - 22.9 | 13.6 - 30.0 | 5.00 - 7.77 |
| Chevans Lake | 36 | 2005 - 2019 | 16.1 - 46.0 | 12.0 - 55.9 | 5.68 - 7.01 |
| Cuffs Lake | 33 | 2006 - 2020 | 8.3 - 17.6 | 12.2 - 57.0 | 5.27 - 7.16 |
| Dutchman Lake | 35 | 2005 - 2019 | 11.4 - 23.2 | 13.2 - 26.6 | 5.55 - 7.42 |
| Helmer-Nelson Pond | 38 | 2005 - 2021 | 13.4 - 37.5 | 18.9 - 46.0 | 5.7 - 7.32 |
| Little Lake | 30 | 2006 - 2018 | 7.4 - 22.8 | 33.2 - 91.0 | 5.99 - 7.73 |
| Loon Lake | 33 | 2006 - 2020 | 7.2 - 14.9 | 8.4 - 12.5 | 5.89 - 7.32 |
| Mt Maud Lake | 41 | 2005 - 2021 | 10.7 - 31.5 | 18.9 - 41.0 | 5.60 - 7.39 |
| North Lake | 34 | 2006 - 2020 | 4.8 - 11.8 | 40.0 - 60.1 | 6.35 - 8.02 |
| Swamp Lake | 32 | 2006 - 2020 | 11.9 - 22.7 | 11.0 - 23.5 | 5.88 - 7.52 |
| Swede Lake | 34 | 2005 - 2019 | 2.6 - 17.1 | 54.2 - 84.4 | 6.56 - 8.46 |
| Taylor Lake | 36 | 2006 - 2020 | 2.9 - 9.4 | 20.5 - 42.5 | 5.81 - 7.37 |
| Teal Lake | 34 | 2006 - 2020 | 11.5 - 23.1 | 22.6 - 55.0 | 6.49 - 8.52 |
| Trout Lake | 35 | 2006 - 2020 | 4.8 - 12.5 | 16.2 - 24.4 | 5.80 - 7.54 |
| Turtle Lake | 40 | 2005 - 2021 | 2.2 - 17.3 | 17.9 - 39.0 | 5.98 - 10.00 |

The data requirements for the calculator are total hardness, dissolved organic carbon (DOC) and pH measured in the water column at the location where DOC and total hardness samples were collected. Data were obtained from Grand Portage's water quality database from 1997 to 2021 (Table 12). Only years 2005-2021 had data for all three input parameters. An estimate of the highest concentration in ambient water to which an aquatic community can be *exposed indefinitely* without resulting in an unacceptable adverse effect called the criteria continuous concentration ("CCC" ) or chronic criteria, were calculated for each sampling event at a site using EPA's calculator spreadsheet. The 10$^{th}$ percentile of CCCs was taken as the final site-specific criterion for a site, following "Method 2" from EPA's "Draft Technical Support

Document: Implementing the 2018 Recommended Aquatic Life Water Quality Criteria for Aluminum". Where there were multiple measures of the same input parameter for the same sampling event, the lowest value was used to represent conditions where aluminum would be more available and therefore provide a more stringent criterion. Site specific aluminum criteria are listed in Table 13.

**Table 13. Site Specific Aluminum Criteria**

| Site | Total Aluminum CCC (µg/L) |
|---|---|
| **Streams** | |
| Cedar Creek | 476 |
| Eagle Marsh Creek | 359 |
| Grand Portage Creek | 710 |
| Hollow Rock Creek | 625 |
| Pigeon River | 684 |
| Poplar Creek | 602 |
| Red Rock Creek | 643 |
| Reservation River | 804 |
| **Lakes** | |
| Center Lake | 86 |
| Chevans Lake | 126 |
| Cuffs Lake | 190 |
| Dutchman Lake | 325 |
| Helmer-Nelson Pond | 340 |
| Little Lake | 610 |
| Loon Lake | 160 |
| Mt Maud Lake | 318 |
| North Lake | 524 |
| Swamp Lake | 246 |
| Swede Lake | 594 |
| Taylor Lake | 270 |
| Teal Lake | 653 |
| Trout Lake | 295 |
| Turtle Lake | 350 |

Aluminum chronic criteria are expressed as a four-day average concentration not to be exceeded more than once every three years.

# SPECIFIC CONDUCTANCE CRITERIA

Dissolved ions naturally occur in freshwater systems; however, anthropogenic additions of ions have been shown to cause adverse effects to aquatic life (Cañedo-Argüelles et al., 2016, US EPA 2011). Grand Portage is updating their water quality standards to include limits for ionic mixtures measured as specific conductance (SC). This measure of ionic concentration is based on an electrical property of water and dissolved ions standardized to 25°C. As ionic concentration increases, SC increases. Grand Portage is proposing only chronic criteria because its water quality standards do not allow acute criteria as provided in Section 10, Methodology to develop or revise water quality criteria, pg. 30, Grand Portage Water Quality Standards:

> "For future numeric criteria development or modification, or where numeric criteria are needed to implement a narrative criterion, the Grand Portage Water Resources Board will use the methodologies required by 40 CFR 132.4(a)(9) through (11) which are hereby adopted and incorporated by reference into this chapter:
>
> 1. Appendix A to Part 132 – Great Lakes Water Quality Initiative Methodology for development of aquatic life criteria. However, *Chronic Criteria will be used in place of Acute Criteria and shall not be exceeded in waters of the Reservation*."

## Exposure Measure

SC was selected as the exposure metric because it is inexpensive to measure, accurate, and precise because it is less affected by non-ionic constituents. Using a conductivity meter, SC instantaneously measures all and only dissolved ions within a wide range, without sample filtration in the field or in the laboratory.

## Effect Endpoints

Conventionally, aquatic life water quality criteria are developed using laboratory toxicity tests; however, other data may be used.

> "IX. Other Data—Pertinent information that could not be used in earlier sections might be available concerning adverse effects on aquatic organisms….Especially important are data for species for which no other data are available. Data from behavioral, biochemical, physiological, microcosm, and field studies might also be available… Such data might affect a criterion if the data were obtained with an important species, the test concentrations were measured, and the endpoint was biologically important."(https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-132/appendix-Appendix%20A%20to%20Part%20132, also Stephan et al, 1985 p28.)

The conventional approach for deriving aquatic life criteria were not used because field and mesocosm data suggest that adverse effects occur at SC levels are less than criteria derived from conventional toxicity test references using either mixtures or individual ions. Furthermore, brook trout are a subsistence species that are also a commercially and recreationally important species that are known to be particularly sensitive to SC. Therefore, two entities and attributes were selected as effect endpoints, extirpation of aquatic benthic invertebrates and reduction in the probability of observing brook trout.

**Aquatic benthic invertebrates** were selected as an effect endpoint because they are accepted indicators of ecological integrity, and environmental monitoring and assessment. They provide food for fish, amphibians and wildlife. Aquatic insects are important processors of energy and nutrients including capturing nutrients and returning them to terrestrial ecosystems and purifying water. They are culturally important and an essential part of a resilient ecosystem. The attribute and threshold for the effect endpoint is the extirpation of 5% of genera.

**Brook Trout** were also selected as an effect endpoint because streams on the reservation are among the few places providing spawning and rearing habitat for juvenile Coaster Brook Trout (*Salvelinus fontinalis*). This species is an important source of food and cultural heritage for the Tribe. The attribute and threshold for the effect endpoint is 50% reduction in the probability of observing brook trout.

Some species of fish and macroinvertebrates, that are known to inhabit low SC environments, may only occur in a narrow range of SC (US EPA, 2011; Griffith et al., 2018). Of particular concern is the Coaster Brook Trout (*Salvelinus fontinalis*). Grand Portage is home to one of the few places along the north shore of Lake Superior where Coaster Brook Trout are naturally reproducing (Wilson et al., 2008). Coaster Brook Trout have been virtually extirpated from much of their former range and persist in a limited number of tributaries in the Great Lakes Region (Newman and DuBois 1997, Schreiner et al.,2008). Streams on the reservation are among the few places providing spawning and rearing habitat for juveniles and also allow access to Lake Superior where adults grow larger than brook trout in streams. These adfluvial Coaster Brook Trout are an ecotype (life history variant) of brook trout. According to a study by Scott et al.,2010, Coaster Brook Trout on nearby Isle Royale are genetically distinct from the other sites that they surveyed (Stott et al. 2010). Coaster Brook Trout and brook trout in general are among the most sensitive species to SC within reservation waters. The probability of observing brook trout decreases by 50% at 158 µS/cm SC in Minnesota and 130 µS/cm SC in Appalachia and may be due to altered food resources (Figure 8).

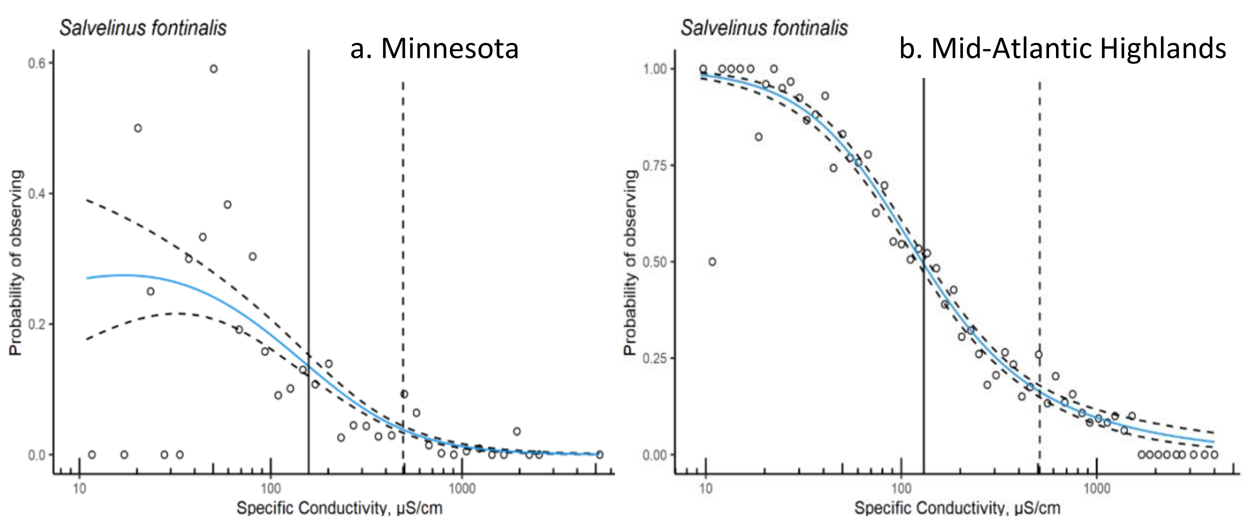



**Figure 8. Generalized additive models for brook trout(a) In Minnesota (MN), and (b) in Mid-Atlantic Highlands.**

**Figure 8. legend continued from page 34**. (a) In Minnesota (MN), and (b) in Mid-Atlantic Highlands. XC95 is 492 µS/cm for MN, Optimum is 17 µS/cm, < 50% probability of observing at ≥ 158 µS/cm. (b) For Mid-Atlantic Highlands, XC95 is 510 µS/cm for Mid-Atlantic Highlands, Optimum is 10 µS/cm; < 50% probability of observing > 130 µS/cm. Proportion of observances due to stocking are unknown in both data sets and may result in under-estimation of the adverse effect. (Data sources: MPCA 1996-2013 and Mid-Atlantic Highlands 1990-2014) (Source Cormier 2022).

## Criterion Characterization Method

Prior to developing water quality standards for SC for the reservation, Grand Portage considered water quality standards adopted by the Fond du Lac Band of Lake Superior Chippewa. Fond du Lac and Grand Portage Reservations are both located within the same ecoregion, Northern Lakes and Forests Ecoregion, MN50, although in different sub-ecoregions. The ionic composition in assayed lakes and rivers on both reservations is dominated by bicarbonate and sulfate anions and calcium and magnesium cations (*see appendix 4.*). While water quality is similar, there are some differences in geology and soils. The Fond du Lac Reservation is within the boundaries the Toimi Drumlins Level IV Ecoregion (50p) and Grand Portage Reservation is in North Shore Highlands Ecoregion (50t) bordered Lake Superior and the Boundary Lakes and Hills in the west (50n) (White 2020). Further, Fond du Lac has been affected by a greater scale of human development.

In 2016, the Fond du Lac adopted their 300 µS/cm criterion for SC based on an examination of ionic mixtures of mining effluents (Johnson and Johnson, 2015) and their impact on northeast Minnesota waters. The Fond du Lac standard of 300 µS/cm relied upon comparisons with an ecoregion that has low background SC. Johnson and Johnson (2015) inferred that organisms in waters of northeast Minnesota waters are likely to be affected at the same SC levels as other parts of the country given a similar mineral composition and background SC. They noted that in Appalachian streams where natural background is 146 µS/cm, benthic macroinvertebrates are extirpated by mineral additions where inputs increase SC to 300 µS/cm (US EPA, 2011). A mean stream SC of 68 µS/cm for Northern Lakes and Forests ecoregion MN50 was reported by Johnson and Johnson (2015), less that the 25th centile background in Appalachia streams reported by US EPA in 2011 (Cormier 2016). Therefore, the benchmark values for SC in northeastern Minnesota would be expected to be as low or lower than the benchmark value of 300 µS/cm in Ecoregions 69 and 70 in Central Appalachia.

In 2018, US EPA confirmed Johnson and Johnson's 2015 inference by estimating the SC levels associated with 5% extirpation in 24 ecoregions in the contiguous U.S that had different SC ranges. The threshold for a 5% loss of aquatic benthic invertebrate genera derived using the US EPA method (2011) increased as the 25th centile of SC increased in the ecoregional data set (Cormier et al., 2018). This established that losses of taxa are predictable based on stream-background SC and can be estimated with a log-log regression model, the background-to-criterion (B-C) model. Because SC niches are related to background SC in lotic systems, similar relationships of background to effects can be expected for lentic systems. Grand Portage estimated background for its streams and lakes and compared them to background estimates for states with similar background and benchmarks estimated for those areas, and they inferred that SC criteria could be estimated for the Grand Portage Reservation using the B-C model (Cormier et al., 2018).

To maintain the exceptional quality of the reservation's water, Grand Portage chose to estimate 5% extirpation of local extirpation thresholds by waterbody within its jurisdictional waters rather than a single value for the entire Reservation. Grand Portage measured mean SC concentrations in their lakes and streams (Table 14 and 15). Chronic Criterion thresholds were calculated using Reservation background SC estimates and the regression model of 25$^{th}$ centile SC and 5 percent extirpation estimates (B-C model) (Cormier et al., 2018). Local background median SC values were calculated based on data collected from Grand Portage waters from 1997 through 2021. Background SC values were input as the independent model to yield water body estimates likely to cause extirpation of 5% of aquatic species. Local background SC was verified by cross-checking and confirming that US EPA estimated background concentration of SC from local streams in our geographic area of Northern Lakes and Forests ecoregion MN50 closely matched the median SC values measured in the streams within Grand Portage Reservation reported by independent sources (Cormier et al., 2018b, Cormier et al., 2021). Based on these analyses, the following criteria have been developed.

SC chronic criteria are expressed as a four-day average concentration not to be exceeded more than once every three years.

**Table 14. Specific Conductance Criteria for Grand Portage Inland Lakes (known trout lakes in blue)**

| Location | Date | Specific Conductance | Benthic invertebrate B-C Model Criterion using median values |
|---|---|---|---|
| | | Median Value µS/cm | Criterion µS/cm |
| Center Lake | 1999-2021 | 45 | 144 |
| Chevans Lake | 1997-2021 | 50 | 154 |
| Cuffs Lake | 1997-2020 | 35 | 122 |
| Dutchman Lake | 1997-2021 | 37.8 | 129 |
| Helmer-Nelson Pond | 1997-2021 | 60.9 | 176 |
| Little Lake | 1997-2020 | 123 | 279 |
| Loon Lake | 1997-2020 | 20 | 85 |
| Mt Maud Lake | 1999-2021 | 57.3 | 169 |
| North Lake | 1997-2020 | 90.6 | 228 |
| Swamp Lake | 1997-2020 | 31.4 | 114 |
| Swede Lake | 2001-2021 | 127.7 | 286 |
| Taylor Lake | 1997-2020 | 45 | 144 |
| Teal Lake | 1997-2020 | 112.7 | 264 |
| Trout Lake | 1997-2020 | 41.4 | 136 |
| Turtle Lake | 1997-2021 | 42.4 | 139 |

**Table 15. Specific Conductance Criteria for Grand Portage Creeks and Rivers (gray) (known trout streams in blue)**

| Location | Date | Specific Conductance | Benthic invertebrate B-C Model Criterion using median values | Less than 50% probability of observing brook trout |
|---|---|---|---|---|
| | | Median µS/cm | Criterion µS/cm | Criterion µS/cm |
| Cedar Creek | 2000-2021 | 96.8 | 239 | 158 |
| Eagle Marsh Creek | 2000-2020 | 81 | 212 | |
| Grand Portage Creek | 1997-2021 | 96.5 | 238 | 158 |
| Hollow Rock Creek | 1997-2020 | 93.2 | 233 | 158 |
| Pigeon River | 1997-2021 | 66 | 185 | 158 |
| Poplar Creek | 1999-2021 | 123 | 279 | |
| Red Rock Creek | 1997-2020 | 99.05 | 242 | 158 |
| Reservation River | 1998-2020 | 74.2 | 200 | 158 |

## DATA SOURCES

Primary data were collected by the Grand Portage Reservation and are available as supplementary files upon reasonable request.

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# APPENDICES

## Appendix 1. Other Approaches Considered

***US EPA Regional Criteria*** – Adoption of US EPA EcoRegion VIII, Subecoregion 50 Reference Approach using 25th percentiles for all waterbodies or 75th percentiles for reference sites. Note: US EPA ecoregional criteria for nitrogen, phosphorus, and chlorophyll-a, are significantly lower than the concentrations found in half of our monitored streams and most of our inland lakes.

***Reservation-wide criteria*** – grouping water bodies, or following the US EPA approach for criteria based upon reference conditions (5th percentile and 95th percentile)

***Site Specific Alternative Nutrient Criteria*** – based on a tiered system of minimally disturbed conditions, and some human influence. Criteria are established to maintain and protect designated and existing uses. Criteria would include water quality parameters, macroinvertebrate, and vegetation surveys.

***Hybrid approach*** – grouping where it makes sense and reserving odd waterbodies for development of site-specific criteria (e.g., water bodies impacted by beavers, etc.).

## Appendix 2. Data Collection and Sampling Protocols

Methods for analysis are listed in Table A.2.1. All sample containers are provided by the laboratory performing the analysis. Unless the containers are pre-cleaned with a manufacturers certificate, the laboratory must verify the cleaning procedure by randomly selecting at least one of each type of container per month, filling it with deionized water and an appropriate preservative, waiting at least 24 hours, and analyzing the water for all analytes of interest. A record of these checks is to be maintained by the Laboratory Director.

Lake samples are collected with an integrated sampler that has been cleaned with a non-phosphate detergent, then thoroughly rinsed with tap water and distilled water. The sampler is lowered into the water and withdrawn. The water is then discarded back into the waterbody. The sampler is lowered into the water again and withdrawn. Water is poured into the appropriate bottles. The bottles are capped and gently shaken. Each container is labeled, indicating location, date, and time of collection.

Stream sample collection methods depend upon accessibility and depth of the water. Wherever the water is at least at least one meter deep, the Van Dorn sampler is used to collect samples. When it is not, samples may be collected by dipping sample containers directly into the water. All stream samples are collected as near as possible to the center of the flow. The bottles are capped and gently shaken. Each container is labeled, indicating location, date, and time of collection.

Samples collected for specific parameters are taken in specific containers with specific preservatives in order to yield valid test results. All samples are put on ice immediately after collection and are kept as close to 4°C as possible during storage and transport to the lab. In the lab, water samples are kept refrigerated while awaiting analysis. Lab analyses are completed within maximum allowable holding times to prevent degradation. We collect one duplicate for every sixteen samples collected.

**Table A.2.1. Analytical methods, detection limits and other factors relevant to analysis of nutrients, chlorophyll-a, and dissolved organic carbon.**

| Parameter | Analytical Method Reference | Reporting Limit (mg/L) | Holding Time (days) | Preservation Requirements | Sample Containers |
|---|---|---|---|---|---|
| Chlorophyll-a | SM10200 H | 1 | 7 | Cool to 4 °C | 2-liter amber plastic bottles |
| Total Nitrogen (calculation) | EPA 351.1 +353.2 | 0.1 | 28 | Cool to 4 °C + $H_2SO_4$ to pH < 2 | 250 or 500 ml wide-mouth plastic bottles |
| Total Phosphorus | EPA 365.3 | 0.002 | 28 | Cool to 4 °C + $H_2SO_4$ to pH < 2 | 250 or 500 ml wide-mouth plastic bottles |
| Dissolved Organic Carbon | SM5310C | 0.2 | 28 | Cool to 4 °C | 1-liter wide-mouth plastic bottles |

## Appendix 3. Rare and Sensitive Aquatic Plants and Insects to Support Ambient Nutrient Criteria

**Table A.3.1. Rare Aquatic Insects found in Grand Portage Waters**

| Location | Year | Order | Family | Genus | Species | Pollution Tolerance | Status |
|---|---|---|---|---|---|---|---|
| Grand Portage Creek | 2000 | *Trichoptera* | *Limnephilidae* | *Oncocosmoecus* | *unicolor* | 4 | New State Record |
| Dutchman Lake | 2003 | *Coleoptera* | *Gyrinidae* | *Dineutus* | *nigrior* | 4 | New State Record |
| Taylor Lake | 2004 | *Odonata* | *Gomphidae* | *Gomphus* | *borealis* (Needham) | 5 | New State Record |
| Grand Portage Creek | 2006 | *Diptera* | *Blephariceridae* | *Blephraricera* | *tenuipes* | 0 | Second record in MN, 86 specimens. 1st record 1968 in Cook County, MN, one male specimen. |
| Teal Lake | 2006 | *Coleoptera* | *Carabidae* | *Agonum* | *Nigriceps* (Le Conte) | | Second record in MN |
| Pigeon River @ Hwy 61 | 2007 | *Hemiptera* | *Corixidae* | *Sigara* | *compressoidea* (Hung.) | 3 | New State Record |
| Pigeon River @ Hwy 61 | 2007 | *Hemiptera* | *Corixidae* | *Sigara* | *defecta* (Hung) | 3 | New State Record |
| Poplar Creek | 2007 | *Hemiptera* | *Corixidae* | *Sigara* | *knighti* (Hung) | 3 | Rare in MN |
| Cedar Creek | 2007 | *Coleoptera* | *Gyrinidae* | *Gyrinus* | *latilimbus* (Fall) | 4 | New State Record |
| Pigeon River @ Eagle Marsh | 2007 | *Coleoptera* | *Gyrinidae* | *Gyrinus* | *pugionis* (Fall) | 4 | New State Record |
| Grand Portage Creek | 2007 | *Coleoptera* | *Elmidae* | *Dubiraphia* | *quadrinotata* (Say) | 6 | New State Record |
| Pigeon River @ Hwy 61 | 2007 | *Hemiptera* | *Corixidae* | *Sigara* | *signata* (Fieber) | 3 | New State Record |
| Pigeon River @ Polar Creek | 2007 | *Ephemeroptera* | *Heptageniidae* | *Epeorus* | *vitreus* (Walker) | 0 | Rare in Midwest |
| Red Rock Creek | 2008 | *Coleoptera* | *Curculionidae* | *Otiorhynchus* | *ovatus* (Linnaeus) | 5 | New State Record |
| Red Rock Creek | 2008 | *Coleoptera* | *Dytiscidae* | *Hygrotus* | *picatus* (Kirby) | 5 | New State Record |
| Red Rock Creek | 2008 | *Coleoptera* | *Dytiscidae* | *Agabus* | *anthracinus* (Mann) | 5 | New State Record |
| Red Rock Creek | 2008 | *Coleoptera* | *Dytiscidae* | *Rhantus* | *binotatus* (Harr.) | 5 | New State Record |
| Red Rock Creek | 2008 | *Hemiptera* | *Gerridae* | *Gerris* | *dissortis* (Drake & Harris) | 5 | New State Record |
| Teal Lake | 2008 | *Coleoptera* | *Haliplidae* | *Haliplus* | *leopardus* (Roberts) | 5 | New State Record |

| Location | Year | Order | Family | Genus | Species | Pollution Tolerance | Status |
|---|---|---|---|---|---|---|---|
| Grand Portage Creek | 2008 | *Trichoptera* | *Limnephilidae* | *Oncocosmoecus* | *unicolor* | 4 | Second record in MN (same location as first record) |
| Helmer-Nelson Pond | 2009 | *Odonata* | *Libellulidae* | *Somatochlora* | *albicincta* (Burmeister) | 2 | New State Record |
| Pigeon River @ Eagle Marsh | 2009 | *Coleoptera* | *Curculionidae* | *Listronotus* | *appendiculatus* (Boheman*)* | 5 | New State Record |
| Turtle Lake | 2009 | *Coleoptera* | *Curculionidae* | *Lixus* | *caudifer* (LeConte) | 5 | New State Record |
| Mt Maude Lake | 2009 | *Odonata* | *Gomphidae* | *Arigomphus* | *cornutus* (Tough) | 4 | New State Record |
| Mt Maude Lake | 2009 | *Odonata* | *Libellulidae* | *Sympetrum* | *costiferum (Hagen)* | 2 | New State Record |
| Pigeon River @ Eagle Marsh | 2009 | *Coleoptera* | *Dytiscidae* | *Agabus* | *erichsoni* (Gemminger & Harold) | 5 | New State Record |
| Turtle Lake | 2009 | *Coleoptera* | *Hydrophilidae* | *Helophorus* | *lineatus* (Say) | 5 | New State Record |
| Pigeon River @ Eagle Marsh | 2009 | *Hemiptera* | *Hydrometridae* | *Hydrometra* | *martini* | 5 | New State Record |
| Turtle Lake | 2009 | *Coleoptera* | *Dytiscidae* | *Hydroporus* | *notabilis* (LeConte) | 5 | New State Record |
| Mt Maude Lake | 2009 | *Odonata* | *Libellulidae* | *Sympetrum* | *obtrusum* (Hagen) | 2 | New State Record |
| Mt Maude Lake | 2009 | *Odonata* | *Lestidae* | *Lestes* | *unguiculatus* (Hagen) | 6 | New State Record |
| Turtle Lake | 2009 | *Hemiptera* | *Corixidae* | *Hesperocorixa* | *vulgaris* (Hungerford) | 5 | New County Record |
| Helmer-Nelson Pond | 2011 | *Coleoptera* | *Chrysomelidae* | *Phyllobratica* | *decorata* (Say) | | New State Record |
| Turtle Lake | 2011 | *Coleoptera* | *Curculionidae* | *Listronotus* | *echinodori* | 5 | New State Record |
| Turtle Lake | 2011 | *Coleoptera* | *Dytiscidae* | *Hygrotus* | *falli* | 5 | New State Record |
| Swede Lake | 2011 | *Coleoptera* | *Gyrinidae* | *Gyrinus* | *impressicollis* | 4 | New State Record |
| Dutchman Lake | 2011 | *Coleoptera* | *Gyrinidae* | *Gyrinus* | *minutus* | 4 | New State Record |
| Swede Lake | 2011 | *Odonata* | *Aeshnidae* | *Aeshna* | *sitchensis* | 3 | New State Record |
| Dutchman Lake | 2011 | *Trichoptera* | *Phryganeidae* | *Oligostomis* | *sp.* | 3 | New State Record |
| Swede Lake | 2011 | *Odonata* | *Libellulidae* | *Tetragoneuria* | *spinigera* | 2 | New State Record |
| Dutchman Lake | 2011 | *Odonata* | *Aeshnidae* | *Aeshna* | *subarctica* | 3 | Rare and New State Record |
| Turtle Lake | 2011 | *Coleoptera* | *Dytiscidae* | *Hygrotus* | *turbidus* | 5 | New State Record |

| Location | Year | Order | Family | Genus | Species | Pollution Tolerance | Status |
|---|---|---|---|---|---|---|---|
| Trout Lake | 2012 | *Ephemeroptera* | *Ephemerellidae* | *Eurylophella* | *temporalis* | 2 | New State Record |
| Loon Lake | 2012 | *Coleoptera* | *Curculionidae* | *Listronotus* | *echinoderi* | 5 | Second Record in MN |
| Teal Lake | 2012 | *Trichoptera* | *Phryganeidae* | *Fabria* | *inornata* | 4 | Not recorded for NE MN |
| Teal Lake | 2012 | *Heteroptera* | *Notonectidae* | *Buenoa* | *limnocastoris (Hungerford)* | 5 | New State Record |
| Trout Lake | 2012 | *Coleoptera* | *Curculionidae* | *Phyllobius* | *oblongus* | 5 | New State Record |
| Trout Lake | 2012 | *Odonata* | *Aeshnidae* | *Nasiaescha* | *pentacantha* | 3 | New State Record |
| Trout Lake | 2012 | *Coleoptera* | *Carabidae* | *Bembidium* | *rapidum* | | New State Record |
| Teal Lake | 2012 | *Odonata* | *Aeshnidae* | *Aeshna* | *sitchensis* | 3 | Second Record in MN |
| Taylor Lake | 2012 | *Ephemeroptera* | *Ephemerellidae* | *Eurlophella* | *temporalis* | 5 | New State Record |
| Trutle Lake | 2013 | *Coleoptera* | *Chrysomelidae* | *Galerucella* | *nymphaeae (L.)* | | New State Record |
| Poplar Creek | 2013 | *Ephemeroptera* | *Heptageniidae* | *Epeorus* | *vitreus (Walker)* | 0 | New State Record |

**Table A.3.2. Grand Portage macrophytes known to require high quality natural areas due to sensitivity to anthropogenic disturbance (Mean Coefficient-values of 9 or 10).**

| Location | Mean Coeffiecients | Plant_Latin |
|---|---|---|
| North, Teal, Cuffs Lakes | 10 | *Arethusa bulbosa* |
| Chevans, Poplar Creek, Teal Lakes | 10 | *Nymphaea tetragona* |
| Helmer-Nelson Pond, Dutchman, Swamp, Teal, Trout Lakes | 10 | *Lobelia dortmanna* |
| Cuffs, Loon, Taylor Lake | 10 | *Carex sterilis* |
| Center, Loon, North Lakes | 10 | *Trichophorum alpinum* |
| Chevans, Cuffs Lakes, Poplar Creek | 10 | *Utricularia cornuta* |
| Center, Chevans, Dutchman, Loon, North, Swamp, Swede, Teal Lakes | 9 | *Andromeda polifolia* |
| Chevans, Taylor Lakes | 9 | *Caltha natans* |
| Hollow Rock Creek, Reservation River, Taylor Lake | 9 | *Carex flava* |
| Center, Chevans, Dutchman, Eagle Marsh, Little, Loon, North, Swamp, Taylor Lakes | 9 | *Carex limosa* |
| Loon Lakes | 9 | *Carex pauciflora* |
| Cuffs, Dutchman, Loon, North, Swamp, Taylor, Teal, Trout, Turtle Lakes | 9 | *Eriocaulon aquaticum* |
| Center, Teal Lakes | 9 | *Eriophorum gracile* |
| Center, Eagle Marsh, Teal Lakes | 9 | *Eriophorum vaginatum* |
| Chevans, Eagle Marsh, Little, Mt Maud, Pigeon River, North, Swamp Lakes | 9 | *Hippuris vulgaris* |
| Loon, North, Swamp, Swede, Taylor, Trout, Turtle Lakes | 9 | *Isoetes sp.* |
| Center, Chevans, Cuffs, Dutchman, Loon, Pigeon River, North, Swamp, Swede, Teal Lakes | 9 | *Kalmia polifolia* |
| Center, Chevans, Cuffs, Dutchman, Eagle Marsh, Helmer-Nelson Pond, Hollow Rock Creek, Little, Loon, Mt Maud, North, Pigeon River, Swamp, Swede, Taylor, Teal, Trout Lakes | 9 | *Menyanthes trifoliate* |
| Center, Chevans Lake, Cuffs, Dutchman, Loon, North, Swamp, Teal Lakes | 9 | *Sarracenia purpurea* |
| Center, Chevans, Cuffs, North, Teal Lakes | 9 | *Scheuchzeria palustris* |
| Center, Chevans, Cuffs, Dutchman, Pigeon River, Trout Lakes | 9 | *Schoenoplectus subterminalis* |
| Cuffs, Helmer-Nelson Pond, Hollow Rock Creek, Little, Loon Lakes | 9 | *Sparganium natans* |
| Center, Chevans, Eagle Marsh, Helmer-Nelson Pond, Pigeon River, Teal Lakes | 9 | *Trichophorum cespitosum* |
| Center, Chevans, Loon, North, Pigeon River, Swamp, Teal, Trout, Turtle Lakes | 9 | *Vaccinium angustifolium* |