Nemadji River Watershed Monitoring and Assessment Report

Minnesota Pollution Control Agency

November 2014

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List of acronyms

AUID Assessment Unit Identification Determination

CCSI Channel Condition and Stability Index

CD County Ditch

CI Confidence Interval

CLMP Citizen Lake Monitoring Program

CR County Road

CSAH County State Aid Highway

CSMP Citizen Stream Monitoring Program

CWA Clean Water Act

CWLA Clean Water Legacy Act

DO Dissolved Oxygen

DOP Dissolved Orthophosphate

E Eutrophic

E. coli Escherichia coli

EQuIS Environmental Quality Information System

EMAP Environmental Monitoring and Assessment Program

EX Exceeds Criteria (Bacteria)

EXP Exceeds Criteria, Potential Impairment

EXS Exceeds Criteria, Potential Severe Impairment

FS Full Support

ETSC Endangered, threatened or special concern

FWMC Flow Weighted Mean Concentration

H Hypereutrophic

HUC Hydrologic Unit Code

IBI Index of Biotic Integrity

IF Insufficient Information

IWM Intensive Watershed Monitoring

K Potassium

LRVW Limited Resource Value Water

M Mesotrophic

MCES Metropolitan Council Environmental Services

MDA Minnesota Department of Agriculture

MDH Minnesota Department of Health

MDNR Minnesota Department of Natural Resources

MINLEAP Minnesota Lake Eutrophication Analysis Procedure

MLRA Major Land Resource Area

MPCA Minnesota Pollution Control Agency

MSHA Minnesota Stream Habitat Assessment

MTS Meets the Standard?

N Nitrogen

Nitrate-N Nitrate Plus Nitrite Nitrogen

NA Not Assessed

NHD National Hydrologic Dataset

NH3 Ammonia

NLF Northern Lakes and Forest

NRCS Natural Resources Conservation Service

NS Not Supporting

NT No Trend

OP Orthophosphate

P Phosphorous

PCB Poly Chlorinated Biphenyls

PFOS Perfluoroocatanesulfonic Acid or Perfluorooctane Sulfonate

PWI Protected Waters Inventory

RNR River Nutrient Region

SWAG Surface Water Assessment Grant

SWCD Soil and Water Conservation District

SWUD State Water Use Database

TALU Tiered Aquatic Life Uses

TKN Total Kjeldahl Nitrogen

TMDL Total Maximum Daily Load

TP Total Phosphorous

TSS Total Suspended Solids

TSVS Total Suspended Volatile Solids

USDA United State Department of Agriculture

EPA United State Environmental Protection Agency

USGS United States Geological Survey

VHS Viral Hemorrhagic Septicemia

WPLMN Water Pollutant Load Monitoring Network

WAT Watershed Assessment Team

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Executive summary

The Beartrap-Nemadji River Watershed (04010301) lies in northeastern Minnesota and northwestern Wisconsin. This watershed covers an estimated 1,928 mi^2 or 1,233,920 acres. Approximately 14% of the watershed lies within Minnesota and is addressed in this report. The Minnesota side of the Beartrap-Nemadji River Watershed is solely comprised of the Nemadji River drainage, which encompasses 35 lakes (>10 acres) and 258 stream segments (AUIDs). Both drinking water quality and the recreational value of lakes and streams are vital assets to the health and wealth of local economies throughout this watershed. These waterways not only provide habitat for aquatic life, but also offer riparian corridors for wildlife, and recreational opportunities such as fishing, swimming, and canoeing. Today, over 81% of this watershed consists of forest and wetlands and is utilized for timber production, hunting, fishing, hiking, and other recreational opportunities. Large tracts of public land exist within this watershed, including county land, state forests, wildlife management areas, and other public lands.

In 2011, the Minnesota Pollution Control Agency (MPCA) undertook an intensive watershed monitoring (IWM) effort of surface waters within the Nemadji River Watershed. Twenty stream stations were sampled for biology at the outlets of variable sized subwatersheds. These locations included the mouth of the Nemadji River and the South Fork Nemadji River, as well as the upstream outlets of major tributaries, and the headwater outlets of smaller streams. As part of this effort, MPCA staff joined with the Carlton County Soil and Water Conservation District (CSWCD) to conduct stream water chemistry sampling at the outlets of the Nemadji River and the South Fork Nemadji River. Eight of the watershed's larger and more notable lakes were monitored in 2011 and 2012 by MPCA staff, citizen volunteers, and surface water assessment grantees.

In 2013, a holistic approach was taken to assess all surface water bodies within the Nemadji River Watershed for support of aquatic life, recreation, and consumption (where sufficient data was available). Additional data from other agencies, groups, and/or individuals were used in the assessment of designated beneficial uses. Twenty-two stream segments and eight lakes were assessed in this effort.

Of the assessed streams, only 10 AUIDs fully-supported aquatic life while the other 12 did not. Two stream segments were assessed for aquatic recreation with none of them fully supporting their beneficial use. Specific impairments found throughout this watershed included: fish and macroinvertebrate index of biological integrity, turbidity, dissolved oxygen, and bacteria (*E. coli*). Fish collected from both the Nemadji River and Nemadji Creek in 2011 tested above the state standard for mercury in fish tissue, resulting in aquatic consumption impairments.

All but two of the assessed lakes met eutrophication standards for cool and warm water lakes in the Northern Lakes and Forest Ecoregion, and had good water quality that indicated mesotrophic conditions. Aquatic recreational impairments were found on both Lac La Belle and Net Lake.

Overall, the water quality in rivers, streams, and lakes in the Nemadji River Watershed is in fair to good condition. Problem areas do occur and persist but they are typically limited to the lower reaches where stressors from land use may accumulate. Impairments found within this watershed are likely a function of both natural and anthropogenic stressors. Residential development, vegetation alterations, draining of wetlands/lakes, undersized culverts, erosion, damming of streams, poor geomorphology, and other hydrological alterations all occur within the watershed and are all likely contributing to a reduction in the number of sensitive fish and macroinvertebrate species. However, a number of streams with exceptional biological, chemical, and physical parameters are worthy of additional protections in order to preserve these valuable aquatic resources.

Introduction

Water is one of Minnesota's most abundant and precious resources. The MPCA is charged under both federal and state law with the responsibility of protecting the water quality of Minnesota's water resources. The MPCA's water management efforts are tied to the 1972 Federal Clean Water Act (CWA) which requires states to adopt water quality standards to protect their water resources and the designated uses of those waters, such as for drinking water, recreation, fish consumption, and aquatic life. States are required to provide a summary of the status of their surface waters and develop a list of water bodies that do not meet established standards. Such waters are referred to as "impaired waters" and the state must make appropriate plans to restore these waters, including the development of Total Maximum Daily Loads (TMDLs). A TMDL is a comprehensive study determining the assimilative capacity of a water body, identifying all pollution sources causing or contributing to impairment, and an estimation of the reductions needed to restore a water body so that it can once again support its designated use.

The MPCA currently conducts a variety of surface water monitoring activities that support our overall mission of helping Minnesotans protect the environment. To successfully prevent and address problems, decision makers need good information regarding the status of the resources, potential and actual threats, options for addressing the threats, and data on the effectiveness of management actions. The MPCA's monitoring efforts are focused on providing that critical information. Overall, the MPCA is striving to provide information to assess, and ultimately, to restore or protect the integrity of Minnesota's waters.

The passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and the initial resources for state and local governments to accelerate efforts to monitor, assess, restore, and protect surface waters. This work is implemented on an on-going basis with funding from the Clean Water Fund created by the passage of the Clean Water Land and Legacy Amendment to the state constitution. To facilitate the best use of agency and local resources, the MPCA has developed a watershed monitoring strategy which uses an effective and efficient integration of agency and local water monitoring programs to assess the condition of Minnesota's surface waters, and to allow for coordinated development and implementation of water quality restoration and improvement projects.

The strategy behind the watershed monitoring approach is to intensively monitor streams and lakes within a major watershed to determine the overall health of water resources, identify impaired waters, and to identify waters in need of additional protection. The benefit of the approach is the opportunity to begin to address most, if not all, impairments through a coordinated TMDL process at the watershed scale, rather than the reach-by-reach and parameter-by-parameter approach often historically employed. The watershed approach will more effectively address multiple impairments resulting from the cumulative effects of point and non-point sources of pollution and further the CWA goal of protecting and restoring the quality of Minnesota's water resources.

This watershed-wide monitoring approach was implemented in the Nemadji River Watershed beginning in the summer of 2011. This report provides a summary of all water quality assessment results in the Nemadji River Watershed and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring, and monitoring conducted by local government units.

I. The watershed monitoring approach

The watershed approach is a 10-year rotation for monitoring and assessing waters of the state on the level of Minnesota's 81 major watersheds (Figure 1). The major benefit of this approach is the integration of monitoring resources to provide a more complete and systematic assessment of water quality at a geographic scale useful for the development and implementation of effective TMDLs, project planning, effectiveness monitoring, and protection strategies. The following paragraphs provide details on each of the four principal monitoring components of the watershed approach. For additional information see *Watershed Approach to Condition Monitoring and Assessment (MPCA 2008)* (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

Watershed Pollutant Load Monitoring Network

Funded with appropriations from Minnesota's Clean Water Legacy Fund, the Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term program designed to measure and compare regional differences and long-term trends in water quality among Minnesota's major rivers including the Red, Rainy, St. Croix, Mississippi, and Minnesota, and the outlets of the major tributaries (8 digit HUC scale) draining to these rivers. Since the program's inception in 2007, the WPLMN has adopted a multi-agency monitoring design that combines site specific stream flow data from United States Geological Survey (USGS) and Minnesota Department of Natural Resources (MDNR) flow gaging stations with water quality data collected by the Metropolitan Council Environmental Services (MCES), local monitoring organizations, and MPCA WPLMN staff to compute annual pollutant loads at 79 river monitoring sites across Minnesota. Data will also be used to assist with: TMDL studies and implementation plans; watershed modeling efforts; and watershed research projects.

Figure 1. Major watersheds within Minnesota (8-Digit HUC).

Intensive watershed monitoring

The IWM strategy utilizes a nested watershed design allowing the sampling of streams within watersheds from a coarse to a fine scale (Figure 2). Each watershed scale is defined by a hydrologic unit code (HUC). These HUCs define watershed boundaries for water bodies within a similar geographic and hydrologic extent. The foundation of this approach is the 81 major watersheds (8-HUC) within Minnesota. Using this approach many of the smaller headwaters and tributaries to the main stem river are sampled in a systematic way so that a more holistic assessment of the watershed can be conducted and problem areas identified without monitoring every stream reach. Each major watershed is the focus of attention for at least one year within the 10-year cycle.

River/stream stations are selected near the outlet of each of three watershed scales, 8-HUC, 10-HUC and 14-HUC (Figure 2). Within each scale, different water uses are assessed based on the opportunity for that use (i.e., fishing, swimming, supporting aquatic life such as fish and insects). The major river watershed is represented by the 8-HUC scale. The outlet of the major 8-HUC watershed (purple dot in Figure 3) is sampled for biology (fish and macroinvertebrates), water chemistry and fish contaminants to allow for the assessment of aquatic life, aquatic recreation and aquatic consumption use support. The 10-HUC is the next smaller watershed scale which generally consists of major tributary streams with drainage areas ranging from 75 to 150 mi^2. Each 10-HUC outlet (green dots in Figure 3) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use support.

Within each 10-HUC, smaller watersheds (14 HUCs, typically 10-20 mi^2), are sampled at each outlet that flows into the major 10-HUC tributaries. Each of these minor watershed outlets is sampled for biology to assess aquatic life use support (red dots in Figure 3).

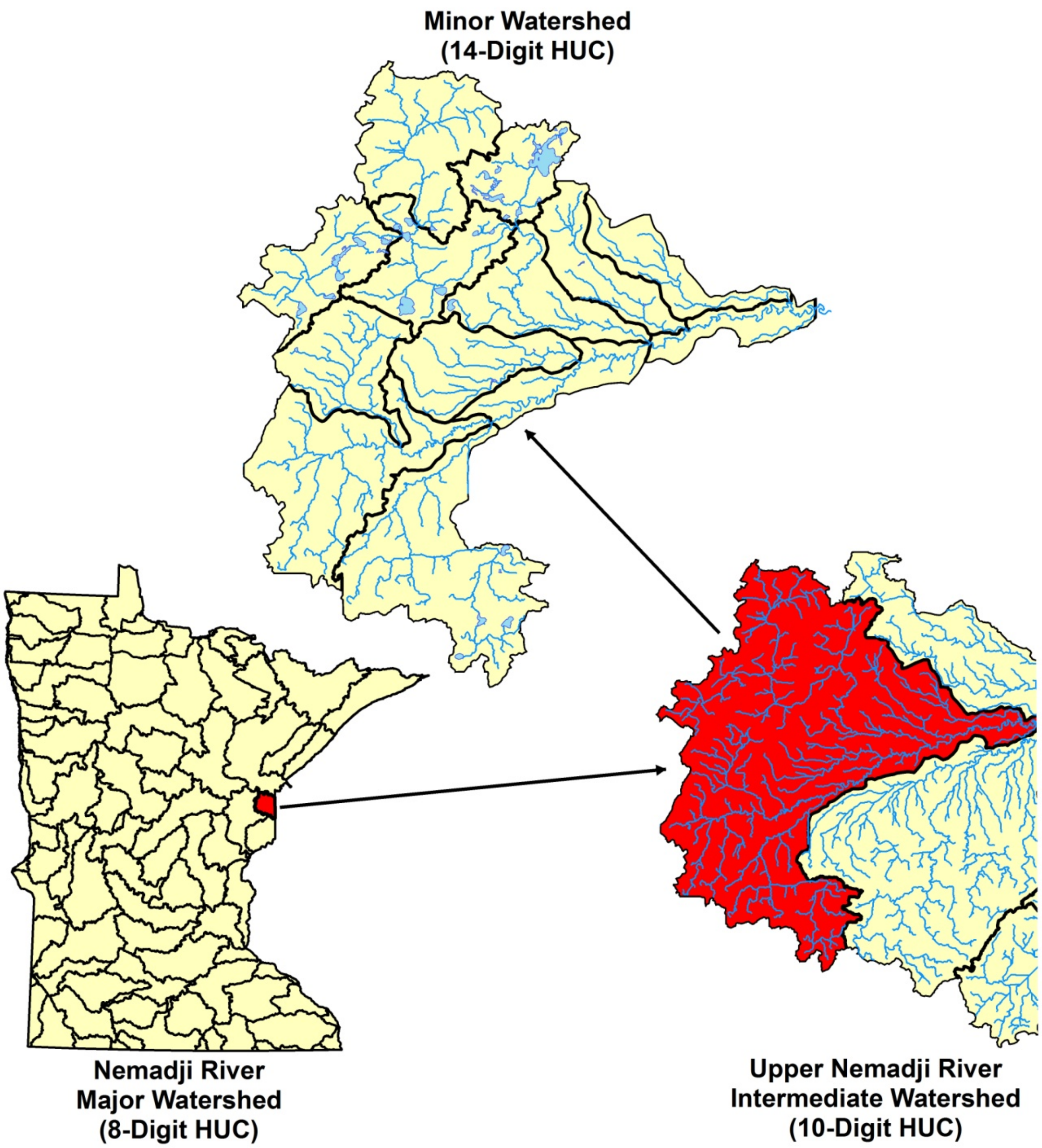

Figure 2. The IWM design

Within the IWM strategy, lakes are selected to represent the range of conditions and lake type (size and depth) found within the watershed. Lakes most heavily used for recreation (all those greater than 500 acres and at least 25% of lakes 100-499 acres) are monitored for water chemistry to determine if recreational uses, such as swimming and wading, are being supported. Lakes are sampled monthly from May-September for a two-year period. There is currently no tool that allows us to determine directly if lakes are supporting aquatic life; however, a method that includes monitoring fish and aquatic plant communities is in development.

Specific locations for stations sampled as part of the intensive monitoring effort in the Nemadji River Watershed are shown in Figure 3 and are listed in Appendix 2, Appendix 3, Appendix 4, Appendix 6, Appendix 7, and Appendix 9.

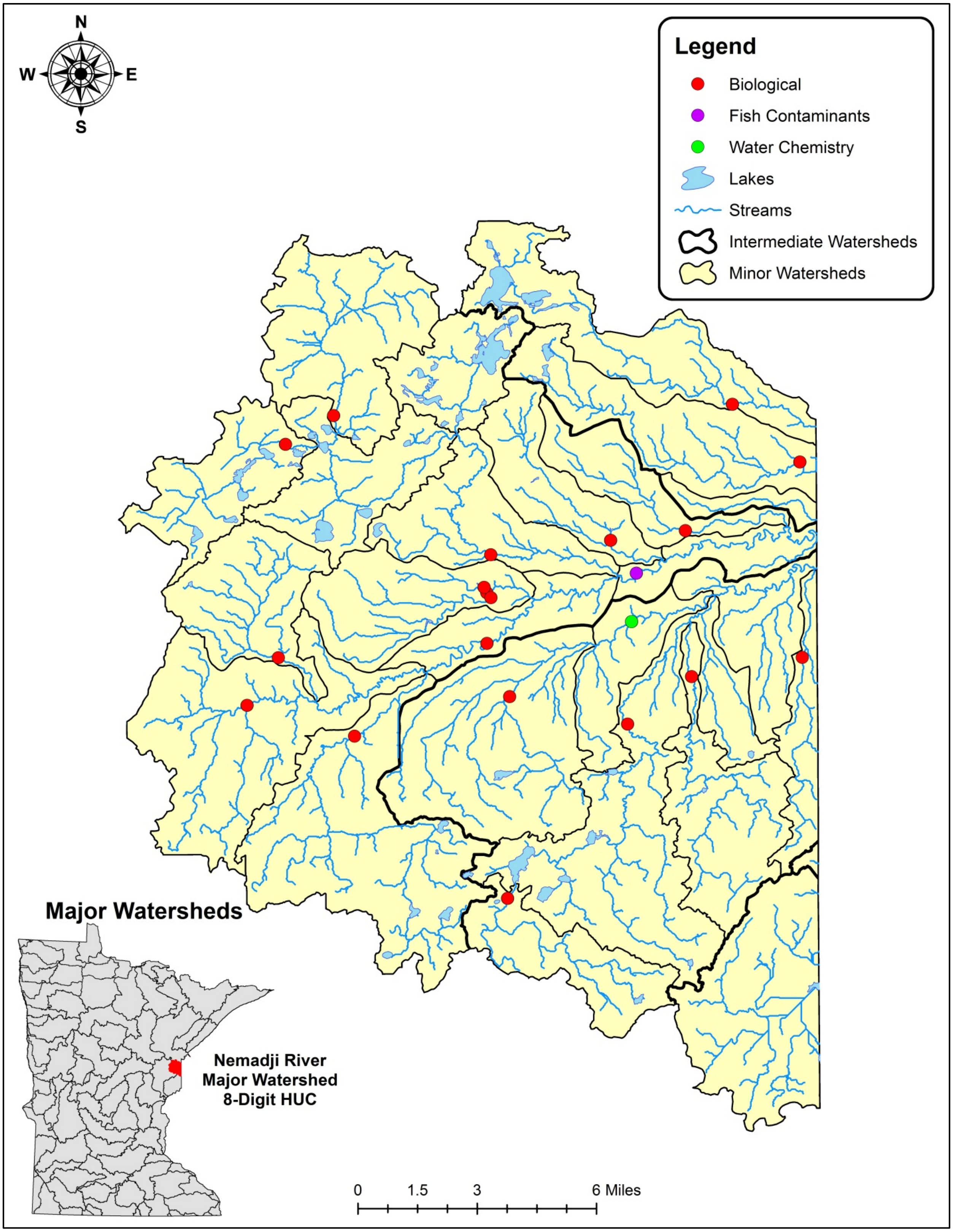

Figure 3. IWM stations for streams in the Nemadji River Watershed.

Citizen and local monitoring

Citizen and local monitoring is an important component of the watershed approach. The MPCA and its local partners jointly select the stream stations and lakes to be included in the IWM process. Funding passes from MPCA through Surface Water Assessment Grants (SWAGs) to local groups such as counties, soil and water conservation districts, watershed districts, nonprofits and educational institutions to support lake and stream water chemistry monitoring. Local partners use the same monitoring protocols as the MPCA, and all monitoring data from SWAG projects are combined with the MPCA's to assess the condition of Minnesota lakes and streams. Preplanning and coordination of sampling with local citizens and governments helps focus monitoring where it will be most effective for assessment and observing long-term trends. This allows citizens/governments the ability to see how their efforts are used to inform water quality decisions and track how management efforts affect change. Many SWAG grantees invite citizen participation in their monitoring projects and their combined participation greatly expand our overall capacity to conduct sampling. The CSWCD conducted stream water chemistry sampling at the outlets of the Nemadji River and the South Fork Nemadji River as a SWAG grantee.

The MPCA also coordinates two programs aimed at encouraging long term citizen surface water monitoring: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Like the permanent load monitoring network, having citizen volunteers monitor a given lake or stream station monthly and from year to year can provide the long-term picture needed to help evaluate current status and trends. Citizen monitoring is especially effective at helping to track water quality changes that occur in the years between intensive monitoring years. Figure 4 provides an illustration of the locations where citizen monitoring data were used for assessment in the Nemadji River Watershed.

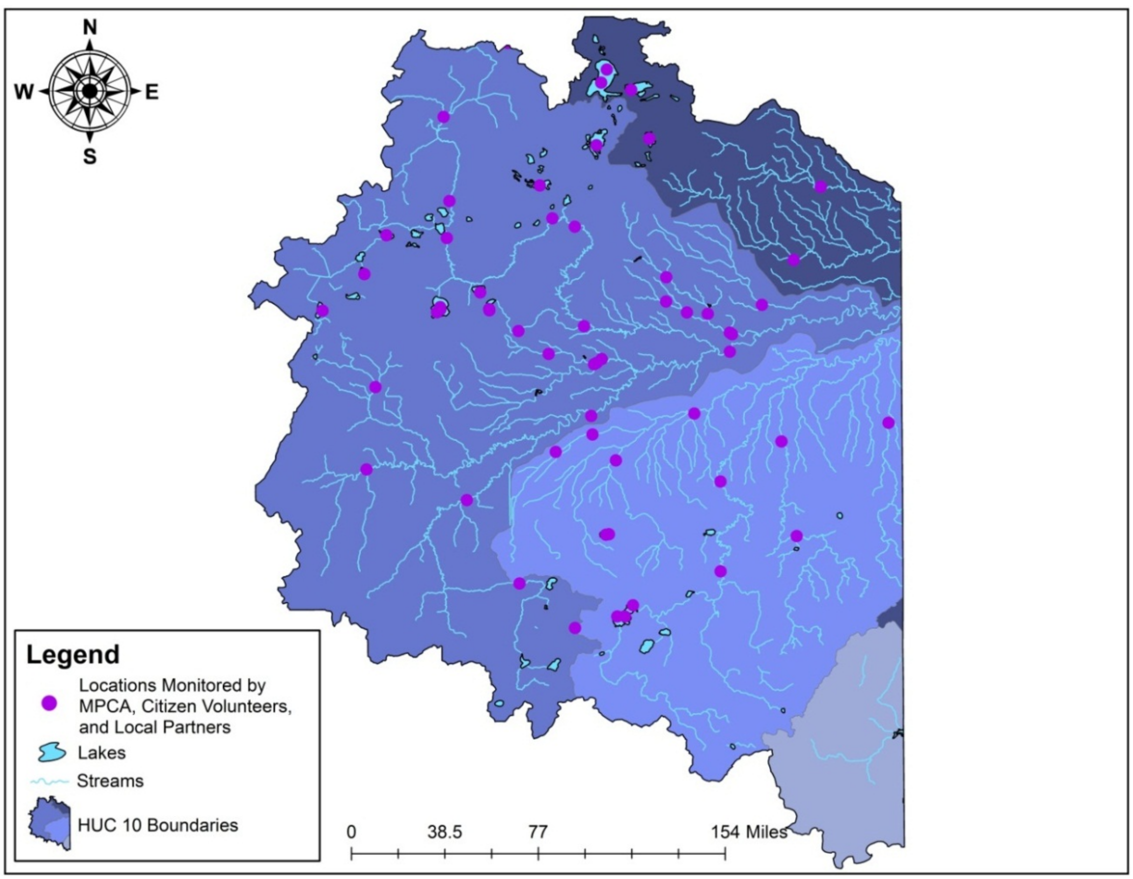

Figure 4. Monitoring locations of local groups, citizens and the MPCA lake monitoring staff in the Nemadji River Watershed.

II. Assessment methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters that are determined to be supporting or non-supporting of their designated uses as evaluated by the comparison of monitoring data to criteria specified by Minnesota Water Quality Standards (Minn. R. ch. 7050 2008; https://www.revisor.leg.state.mn.us/rules/?id=7050). The assessment and listing process involves dozens of MPCA staff, other state agencies, and local partners. The goal of this effort is to use the best data and best science available to assess the condition of Minnesota's water resources. For a thorough review of the assessment methodologies see *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA 2012).* http://www.pca.state.mn.us/index.php/view-document.html?gid=16988.

Water quality standards

Water quality standards are the fundamental benchmarks by which the quality of surface waters are measured and used to determine impairment. These standards can be numeric or narrative in nature and define the concentrations or conditions of surface waters that allow them to meet their designated beneficial uses, such as for fishing (aquatic life), swimming (aquatic recreation), or human consumption (aquatic consumption). All surface waters in Minnesota, including lakes, rivers, streams, and wetlands are protected for aquatic life and recreation where these uses are attainable. Numeric water quality standards represent concentrations of specific pollutants in water that protect a specific designated use. Narrative standards are statements of conditions in and on the water, such as biological condition, that protect their designated uses.

Protection of aquatic life means the maintenance of a healthy aquatic community, including fish, macroinvertebrates, and plants. The sampling of aquatic organisms for assessment is called biological monitoring. Biological monitoring is a direct means to assess aquatic life use support, as the aquatic community tends to integrate the effects of all pollutants and stressors over time. Interpretations of narrative criteria for aquatic life in streams are based on multi-metric biological indices including the Fish Index of Biological Integrity (F-IBI), which evaluates the health of the fish community, and the Macroinvertebrate Index of Biological Integrity (M-IBI), which evaluates the health of the aquatic macroinvertebrate community. Additionally, chemical parameters are measured and assessed against numeric standards developed to be protective of aquatic life, including pH, dissolved oxygen, un-ionized ammonia nitrogen, chloride and turbidity.

Protection of aquatic recreation means the maintenance of conditions safe and suitable for swimming and other forms of water recreation. In streams, aquatic recreation is assessed by measuring the concentration of E. coli bacteria in the water. To determine if a lake supports aquatic recreational activities, its trophic status is evaluated using total phosphorus (TP), secchi depth, and chlorophyll-a as indicators. Lakes that are enriched with nutrients and have abundant algal growth are eutrophic and do not support aquatic recreation.

Protection of consumption means protecting citizens who eat fish from Minnesota waters or receive their drinking water from water bodies protected for this beneficial use. The concentrations of mercury and polychlorinated biphenyls (PCBs) in fish tissue are used to evaluate whether or not fish are safe to eat in a lake or stream and to issue recommendations regarding the frequency that fish from a particular water body can be safely consumed. For lakes, rivers and streams that are protected as a source of drinking water the MPCA primarily measures the concentration of nitrate in the water column to assess this designated use.

A small percentage of stream miles in the state (~1% of 92,000 miles) have been individually evaluated and re-classified as a Class 7 Limited Resource Value Water (LRVW). These streams have previously demonstrated that the existing and potential aquatic community is severely limited and cannot achieve aquatic life standards either by: a) natural conditions as exhibited by poor water quality characteristics, lack of habitat or lack of water; b) the quality of the resource has been significantly altered by human activity and the effect is essentially irreversible; or c) there are limited recreational opportunities (such as fishing, swimming, wading or boating) in and on the water resource. While not being protective of aquatic life, LRVWs are still protected for industrial, agricultural, navigation and other uses. Class 7 waters are also protected for aesthetic qualities (e.g., odor), secondary body contact, and groundwater for use as a potable water supply. To protect these uses, Class 7 waters have standards for bacteria, pH, dissolved oxygen, and toxic pollutants.

Assessment units

Assessments of use support in Minnesota are made for individual water bodies. The water body unit used for river systems, lakes and wetlands is called the "assessment unit". A stream or river assessment unit usually extends from one significant tributary stream to another or from the headwaters to the first tributary. A stream "reach" may be further divided into two or more assessment reaches when there is a change in use classification (as defined in Minn. R. ch. 7050) or when there is a significant morphological feature, such as a dam or lake, within the reach. Therefore, a stream or river is often segmented into multiple assessment units that are variable in length. The MPCA is using the 1:24,000 scale high resolution National Hydrologic Dataset (NHD) to define and index stream, lake, and wetland assessment units. Each river or stream reach is identified by a unique water body identifier (known as its AUID), comprised of the USGS 8-HUC plus a three character code that is unique within each HUC. Lake and wetland identifiers are assigned by the MDNR. The Protected Waters Inventory (PWI) provides the identification numbers for lake, reservoirs and wetlands. These identification numbers serve as the AUID and are composed of an eight digit number indicating county, lake, and bay for each basin.

It is for these specific stream reaches or lakes that the data are evaluated for potential use impairment. Therefore, any assessment of use support would be limited to the individual assessment unit. The major exception to this is the listing of rivers for contaminants in fish tissue (aquatic consumption). Over the course of time it takes fish, particularly game fish, to grow to "catchable" size and accumulate unacceptable levels of pollutants, there is a good chance they have traveled a considerable distance. The impaired reach is defined by the location of significant barriers to fish movement such as dams upstream and downstream of the sampled reach and thus often includes several assessment units.

Determining use attainment

For beneficial uses related to human health, such as drinking water or aquatic recreation, the relationship is well understood and thus the assessment process is a relatively simple comparison of monitoring data to numeric standards. In contrast, assessing whether a water body supports a healthy aquatic community is not as straightforward and often requires multiple lines of evidence to make use attainment decisions with a high degree of certainty. Incorporating a multiple lines of evidence approach into MPCA's assessment process has been evolving over the past few years. The current process used to assess the aquatic life use of rivers and streams is outlined below and in Figure 5.

The first step in the aquatic life assessment process is a comparison of the monitoring data to water quality standards. This is largely an automated process performed by logic programmed into a database application and the results are referred to as 'Pre-assessments'. Pre-assessments are then reviewed by either a biologist or water quality professional, depending on whether the parameter is biological or chemical in nature. These reviews are conducted at the workstation of each reviewer (i.e., desktop) using computer applications to analyze the data for potential temporal or spatial trends as well as gain a better understanding of any attenuating circumstances that should be considered (e.g., flow, time/date of data collection, or habitat).

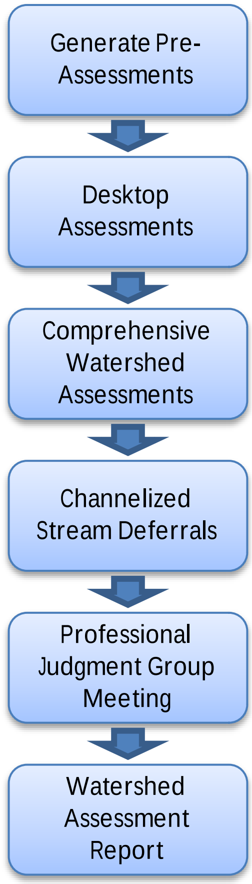

Figure 5. Flowchart of aquatic life use assessment process.

The next step in the process is a Comprehensive Watershed Assessment meeting where reviewers convene to discuss the results of their desktop assessments for each individual water body. Implementing a comprehensive approach to water quality assessment requires a means of organizing and evaluating information to formulate a conclusion utilizing multiple lines of evidence. Occasionally, the evidence stemming from individual parameters are not in agreement and would result in discrepant assessments if the parameters were evaluated independently. However, the overall assessment considers each piece of evidence to make a use attainment determination based on the preponderance of information available. See the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List* (MPCA 2012) http://www.pca.state.mn.us/index.php/view-document.html?gid=16988 for guidelines and factors considered when making such determinations.

Any new impairment (i.e., water body not attaining its beneficial use) is first reviewed using Geographic Information System (GIS) to determine if greater than 50% of the assessment unit is channelized. Currently, the MPCA is deferring any new impairments on channelized reaches until new aquatic life use standards have been developed as part of the Tiered Aquatic Life Use (TALU) framework. For additional information, see: http://www.pca.state.mn.us/index.php/water/water-permits-and-rules/water-rulemaking/tiered-aquatic-life-use-talu-framework.html. There are currently no channelized reaches within the Nemadji River Watershed with biological data, therefore all stream segments with sufficient data were assessed for aquatic life use support.

The last step in the assessment process is the Professional Judgment Group meeting. At this meeting, results are shared and discussed with entities outside of the MPCA that may have been involved in data collection or that might be responsible for local watershed reports and project planning. Information obtained during this meeting may be used to revise previous use attainment decisions (e.g., sampling events that may have been uncharacteristic due to annual climate or flow variation, local factors such as impoundments that do not represent the majority of conditions on the AUID). Water bodies that do not meet standards and therefore do not attain one or more of their designated uses are considered impaired waters and are placed on the draft 303(d) Impaired Waters List. Assessment results are also included in watershed monitoring and assessment reports.

Data management

It is MPCA policy to use all credible and relevant monitoring data to assess surface waters. The MPCA relies on data it collects along with data from other sources, such as sister agencies, local governments and volunteers. The data must meet rigorous quality assurance protocols before being used. All monitoring data required or paid for by MPCA are entered into EQuIS (Environmental Quality Information System), MPCA's data system and are also uploaded to the U.S. Environmental Protection Agency's (EPA) data warehouse. Data for monitoring projects with federal or state funding are required to be stored in EQuIS (e.g., Clean Water Partnership (CWP), CWLA Surface Water Assessment Grants and TMDL program). Many local projects not funded by MPCA also choose to submit their data to the MPCA in an EQuIS-ready format so that the monitoring data may be utilized in the assessment process. Prior to each assessment cycle, the MPCA sends out a request for monitoring data to local entities and partner organizations.

Period of record

The MPCA uses data collected over the most recent 10 year period for all water quality assessments. This time-frame provides a reasonable assurance that data will have been collected over a range of weather and flow conditions and that all seasons will be adequately represented; however, data for the entire period is not required to make an assessment. The goal is to use data that best represents current water quality conditions. Therefore, recent data for pollutant categories such as toxics, lake eutrophication, and fish contaminants may be given more weight during assessment.

III. Watershed overview

The Beartrap-Nemadji River Watershed (04010301) occupies a cumulative total of 1,928 mi^2 or 1,233,920 acres of land distributed between Minnesota and Wisconsin. The portion of the watershed that lies within Minnesota drains an estimated 276 mi^2 or 176,640 acres and is comprised solely of the Nemadji River drainage (473mi^2). The Nemadji River, also known as the “Left Hand” river by the Ojibwe, drains the former bed of glacial Lake Duluth (Farrand, 1969). The Nemadji River spans a total of 75 miles, with 52% of the stream length within Minnesota. The largest portion of this watershed is in Carlton County, with a smaller proportion in Pine County.

The Nemadji River begins near the town of Nickerson and flows an estimated 39 miles to the northeast, where it crosses the border into Wisconsin just southeast of Frogner, Minnesota. After crossing the border into Wisconsin, the Nemadji River continues to flow an additional 36 miles towards Lake Superior and eventually pours into Allouez Bay, which is a part of the Duluth-Superior Harbor in Superior, Wisconsin. The Nemadji River drainage has been grouped together with several other Lake Superior tributaries of the Beartrap-Nemadji River Watershed in USGS’s hydrologic unit classification system. Unless noted otherwise, statistics reported in the watershed overview section are from the entire watershed, including the portion of the watershed lying within Wisconsin.

The Nemadji River Watershed lies in the southeast portion of the Northern Lakes and Forest (NLF) Ecoregion (Figure 6). The NLF is dominated by relatively nutrient-poor glacial soils which support the growth of coniferous and northern hardwood forests (Omernik, 1988). This heavily forested ecoregion is made up of many steep, rolling hills that have pockets of wetlands, bogs, lakes, and ponds. It also contains undulating till plains, morainal hills, broad lacustrine basins, and extensive sandy outwash plains (Omernik, 1988). This ecoregion’s soils are generally thicker than those to the north and lack the arability of soils in the adjacent ecoregions to the south (Omernik, 1988). Lakes are numerous throughout the NLF ecoregion and are clearer and less productive than those that are located to the south (Omernik, 1988). Throughout the NLF, many Precambrian granitic bedrock outcropping exist between shallow-to-deep deposits of moraine, these moraine deposits left by the last glacier retreat date back to 12,000 years ago (Omernik, 1988).

The United States Department of Agriculture Major Land Resource Areas (MLRA) for the Nemadji River Watershed includes two classifications; the central and eastern half of the watershed is classified as Superior Lake Plain, while the other half in the far west, south, and north are classified as Wisconsin and Minnesota Thin Loess and Till, northern part (Figure 7). The topography within the Superior Lake Plain is generally sloping with some steep ravines. Soils within this MLRA consist of a clayey and loamy lakebed deposit with some organic material that tends to be well drained to somewhat poorly drained (NRCS 2007). The northern part of the Wisconsin and Minnesota Thin Loess and Till is best described as a loamy, sandy and organic soil on a level to moderately steep topography.

Given the geologic history of the valley, karst features, natural springs, and other “upwellings” can be found throughout this watershed. Many natural coldwater streams within the watershed support, or once supported brook, brown, and/or rainbow trout populations. Segments of the watershed still contain high quality trout fisheries and special regulations are currently in place to protect those populations. The MDNR continues to stock portions of this watershed with rainbow trout.

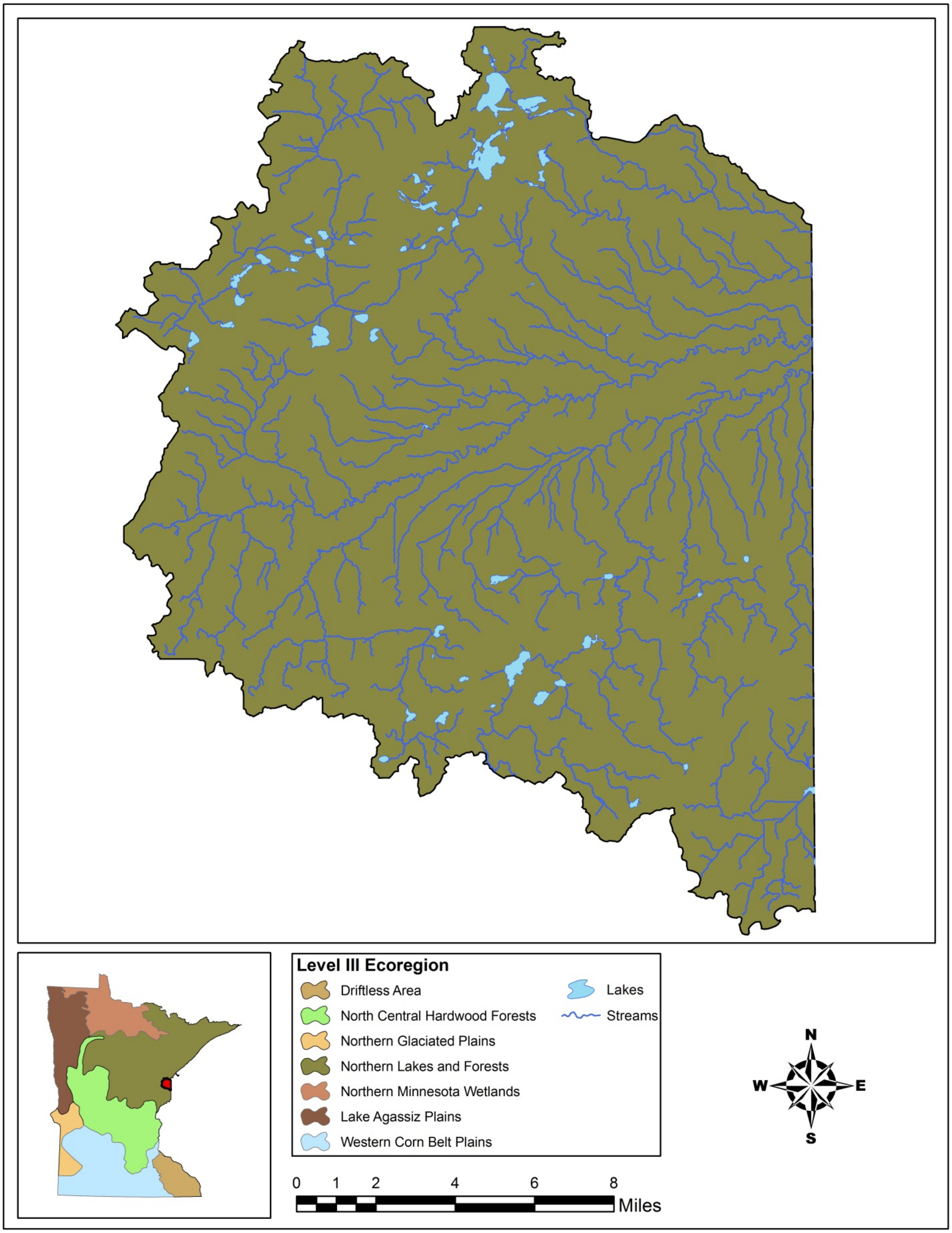

Figure 6. The Nemadji River Watershed within the Northern Lakes and Forest ecoregion of northeastern Minnesota.

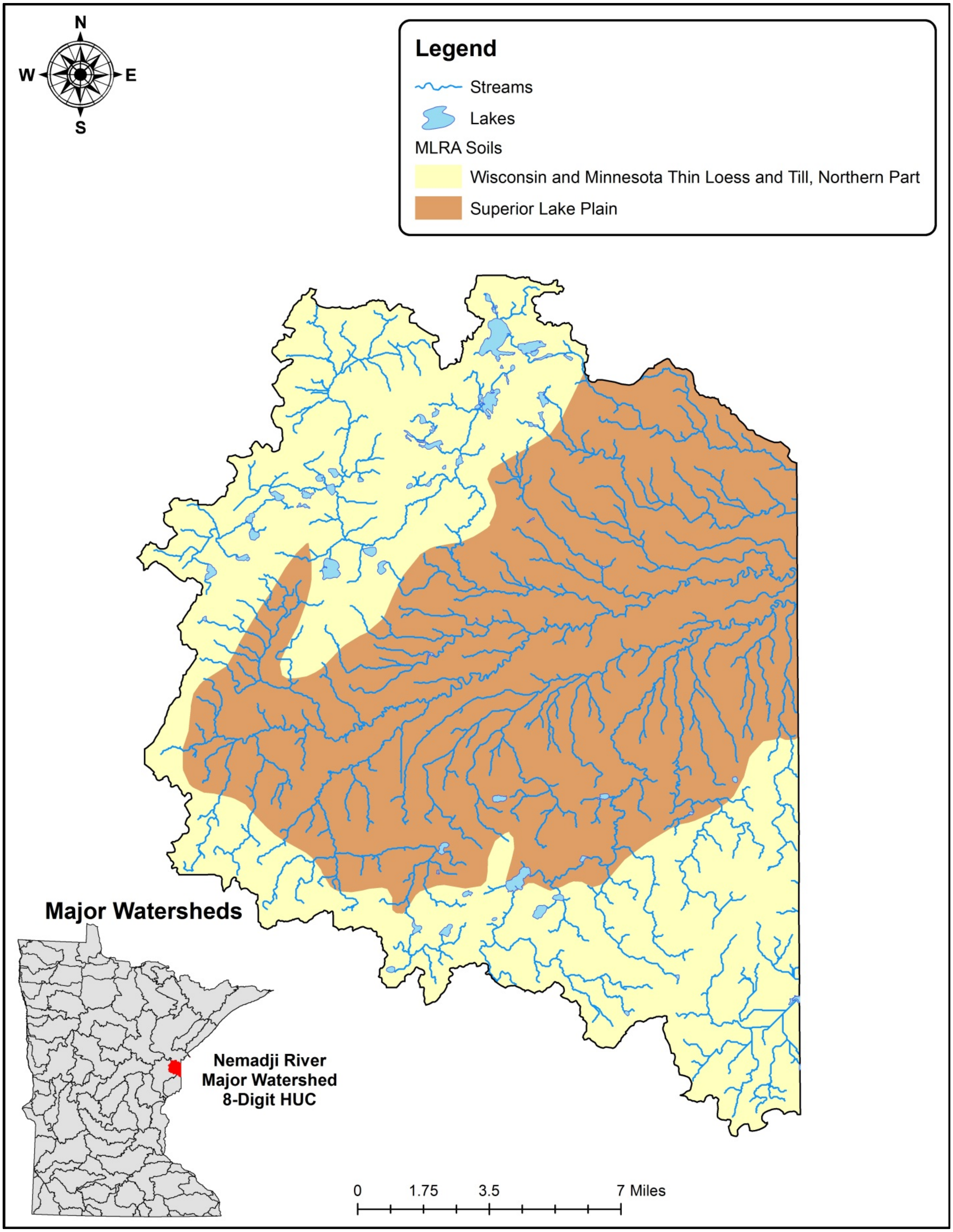

Figure 7. Major Land Resource Areas (MLRA) in the Nemadji River Watershed.

Land use summary

Historically, land cover in the Nemadji River Watershed was largely forest with a mixture of brushland, wetlands, and open water. Pre-settlement vegetation was dominated by old growth forest of white spruce, white pine, quaking aspen, and yellow birch (Waters, 1977). The forest was dependent on infrequent low lying fires to clear our thick brush and alders to regenerate saplings (Larson, 2007). Stream corridors were heavily forested and provided ample shade to tributary streams, while the floodplain of the Nemadji River was enclosed by steep, clay bluffs that provided a buffer between the river corridor and the upland forest. The majority of this corridor was forested, with small patches of thick alder, marsh, and sedge meadows in the river's meanders and abandoned oxbows.

Although a large portion of the current land use within the Nemadji River is still forest, settlement of western Lake Superior that began in the 1800s has changed the landscape in many ways. As settlers arrived in the new territory, logging quickly became the largest occupation throughout the region. At that time the Nemadji River was used to transport pine logs to saw mills as far away as Superior, Wisconsin. As the lumber industry continued to grow, two temporary railroads were created that crisscrossed between Nickerson and Holyoke, Minnesota and supplied a large sawmill on Delong Lake just southeast of Nickerson (Larson, 2007). With the increase of productivity from many logging camps, the forest began to be cleared at a high rate, which depleted many of the old growth pine that once existed (Larson, 2007). With this decrease in large pine stands, most logging camps switched to producing railroad ties, cedar shingles, barrel staves, pulpwood, and fuel wood (King, 2013). After much of the forest was depleted, large fires would frequently burn through cutover lands (Larson, 2007). The disturbance transformed the forest from a pine dominated system to a forest consisting mostly of quaking aspen, paper birch and other deciduous species (Waters, 1977). As time progressed, a few settlers began to move into the area to establish small cattle farms.

Currently, about 60% of the land within the watershed is owned by private landowners, with the second largest ownership being miscellaneous public land (25.1%) (NRCS, 2011). In the 1900s a portion of the forest switched hands to state management due to nonpayment of taxes. Forest is the most extensive land use, with numerous hay fields interlaced in the northwestern portion of the Nemadji River drainage. Today, land cover within the Minnesota portion of the Nemadji River Watershed is distributed as follows: 62.65% forest/shrub, 19.28% wetlands, 13.42% rangeland, 2.6% developed, 1.08% open water, and 0.97% cropland (Figure 8).

The Natural Resources Conservation Service (NRCS) estimates that there are 1,617 farms located in the Beartrap-Nemadji River Watershed, with approximately 60% of them operating on less than 180 acres, 37% on 180 to 1,000 acres, and the remaining farms are larger than 1,000 acres. A total of 1,533 operators run those farms and approximately 54% of them are full time and do not rely on off-farm income. There are only 559 permitted feedlots within the watershed, with 22% cattle (beef and dairy), 21% swine, 4% chickens, and 53% being other animals (NRCS, 2011). The main crop within the watershed is alfalfa and other grazing grasses, with a low percentage of row crops.

The population of this watershed is estimated at 49,264, equating to roughly about 26 people per square mile (NRCS 2011). A large proportion of the population in the Beartrap-Nemadji River Watershed lies within the boundaries of Wisconsin and may be increasing the overall density of individuals per square mile for the entire watershed, including Minnesota. The largest population center in the Beartrap-Nemadji River Watershed is Superior, Wisconsin which is not within the scope of this study. Some of the largest population centers on the Minnesota side of the watershed are located at the state Highway 23 corridors, including the small town of Nickerson and Pleasant Valley. There are many smaller towns found throughout the Nemadji River Watershed that once were or still are in existence including Blackhoof, Duesler, Frogner, Harlis, Holyoke, Nemadji, and Scotts Corner. Townships within this watershed include, Atkinson, Barnum East, Blackhoof, Clear Creek, Holyoke, Kerrick, Mahtowa, Moose Lake East, Nickerson East, Nickerson West, Silver Brook, Twin Lakes West, and Wrenshall.

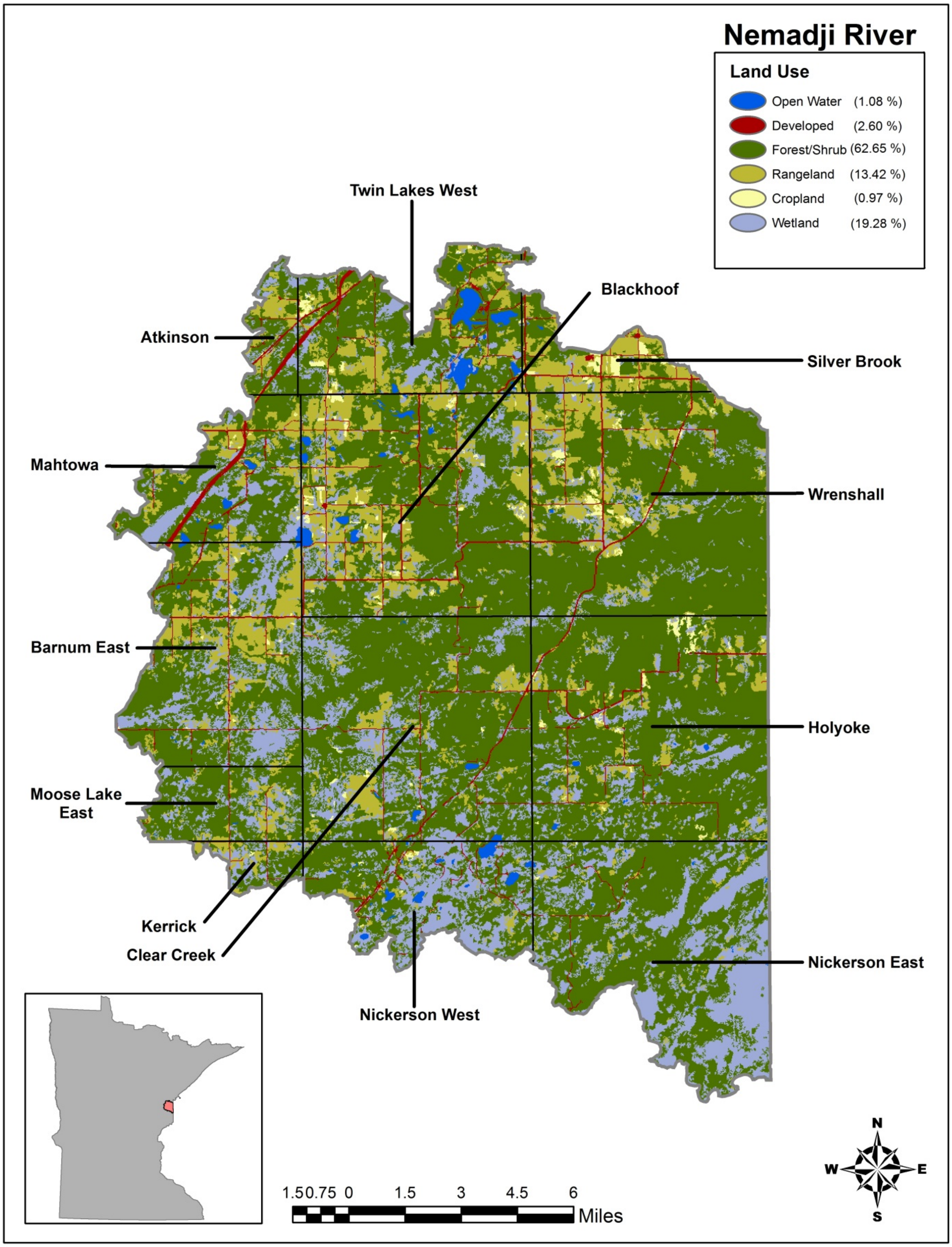

Figure 8. Land use in the Nemadji River Watershed by townships.

Surface water hydrology

The portion of the Nemadji River Watershed that lies within Minnesota contains four intermediate watersheds (10-digit HUC) and 25 minor watersheds (14-digit HUC), in which there are three primary perennial streams: the Nemadji, the South Fork Nemadji, and the Blackhoof Rivers. In addition, many smaller tributaries flow directly into the Nemadji River and into other major tributaries. Streams within this watershed tend to seep slowly through bogs and marshes at their headwaters and later begin their descent into steep river valleys and ravines (Waters, 1977). A large proportion of the streams are naturally meandering with little to no channelized sections. The Nemadji River proper begins near the town of Nickerson and flows an estimated 39 miles before crossing the border into Wisconsin just southeast of Frogner, Minnesota. The mainsteam of the Nemadji River drops an estimated 530 feet in elevation and has an average gradient of 7 feet per river mile.

The headwaters of the Nemadji River originate from Maheu Lake, which is a small and shallow lake located high on the moraine. As the river meanders to the north, it passes through a landscape dominated by wetland riparian. After reaching Soper Lake, it turns to the west and flows an additional 3.5 miles before abruptly switching direction towards the northeast. The river receives additional flow from Nemadji, Spring, Skunk, and many other unnamed creeks, before it reaches its confluence with the Blackhoof River. The lower reaches of the Nemadji River and its contributing waters are deeply incised into the red clay soils and often form a steep stream bank with exposed clay soils (Waters, 1977). This exposed clay soil is susceptible to slumping and accelerated erosion that contributes over 120,000 tons of sediment to Lake Superior annually (NRCS, 2011). Vegetation alterations throughout this watershed have likely transformed natural evapotranspiration rates to where runoff and stream flow has increased. This increase in runoff is likely contributing to aquatic life and recreation impairments. An increase in stream flow and runoff due to an altered evapotranspiration regime has likely resulted from forest cover change. This vegetation modification is likely contributing to the increase in bank failure and sedimentation of the Nemadji River proper and its tributaries (Reidel etal, 2005).

The Blackhoof River, a main tributary to the Nemadji River, flows a distance of 27.5 miles and drains an estimated 53 mi^2. The headwaters can be found in a large wetland complex that is located in the far northwest corner of the watershed. As the river continues to flow to the southwest, it eventually enters into an agricultural/rangeland area before connecting with Ellstrom Lake. From there it continues to the south through that same agricultural area and eventually turns to the east as it descends into a steep river valley. This valley is heavily forested and provides a substantial amount of shading to its contributing waters. This lower section of the Blackhoof River is known to hold various species of trout and provides suitable habitat for numerous coldwater obligate fish and macroinvertebrate species. The Blackhoof River drops an estimated 350 feet throughout its course to the Nemadji River and has an average gradient of 13 feet per river mile.

After receiving additional flow from the Blackhoof River, the Nemadji River continues downstream to the northeast while receiving contributing waters from Deer Creek, Rock Creek, and many other unnamed tributaries. Just 3 miles southeast of Frogner the river crosses the border into Wisconsin having flowed 39 river miles through Minnesota. Other tributary waters from Minnesota connect with the Nemadji River proper in Wisconsin and include the South Fork Nemadji River, Mud Creek, Clear Creek, Black River, and many other unnamed tributaries. Both Deer and Mud Creeks are known to have groundwater upwellings which contribute extensive amounts of sediment to their individual waterways and the Nemadji River (NRCS, 1996; Figure 16). These two known upwellings pick up fine lacustrine clays as they reach the surface and contribute large sediment loads to their associated waterways.

The South Fork Nemadji River, another major tributary to the Nemadji River, starts its journey at the confluence of Anderson Creek and Stony Brook. It continues eastward while receiving water from the Net and Little Net River, Section 36 Creek, and State Line Creek. After crossing the border into Wisconsin, the South Fork Nemadji River continues an additional 1.8 miles before connecting with the Nemadji River proper. The South Fork Nemadji River spans a course of 15 river miles, dropping 210 feet in elevation, and averages a gradient of about 14 feet per river mile. Some high quality trout streams are known to exist throughout this subwatershed.

Select drainages within this watershed provide excellent brook trout habitat near the middle and lower reaches but usually lack them near the headwaters where habitat is limiting (thermal, substrate, and gradient). Tributary streams to the Nemadji River are generally cooler, with trout (brook, brown, and rainbow) as the principal game fish. Two-hundred and fifty-eight stream assessment units (AUIDs), totaling 474.74 stream miles exist throughout this major watershed, of which 341 stream miles are designated as coldwater (2A) in 215 AUID's.

There are 21 dams located on various sized tributaries, including a tributary to the Net River, a tributary to Deer Creek, Skunk, and Elim Creeks (NRCS, 2007; CSWCD, 2014). Most of these dams were originally created to prevent erosion on their individual tributaries and other downstream resources. Most of these sediment dams are well beyond their life spans and are falling into disrepair. Together these dams pose a massive sediment load threat to the Nemadji River proper. A limited amount of stream channels have been altered, with many natural meandering streams present throughout this watershed. The majority of the streams within this watershed is colored to some degree and has a wide range of alkalinities. There is one long-term and continuous USGS stream flow monitoring station located in South Superior, Wisconsin near the mouth of the Nemadji River. A total of 35 lakes greater than 10 acres and 42,355 acres of wetlands exist with in this watershed. The majority of the lakes and wetlands are found in the headwaters and function as water storage for continued stream flow throughout the seasons.

Climate and precipitation

The ecoregion has a continental climate, marked by warm summers and cold winters. The mean annual temperature for Minnesota is 4.5˚C; the mean summer temperature for the Nemadji River watershed is 16.7˚C, and the mean winter temperature is -12.2˚ C (MSCO, 2003).

Figure 9 shows recent precipitation trends in Minnesota for calendar year 2011 and 2012. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the southeast portion of the state. To its right is a depiction of how that precipitation total deviated from normal. When observing the precipitation averages for these years, the Nemadji River Watershed was slightly drier than normal in 2011 and in 2012 received a single heavy summer storm event that caused the precipitation totals to appear heavier than normal.

According to this map, the Nemadji River Watershed received 24 to 32 inches of precipitation in 2011, which was approximately two inches higher to four inches lower than normal. In 2012, the watershed received 32 to 40 inches, which exceeded normal levels by up to six inches, as a result of the record heavy rain events in the early summer of 2012.

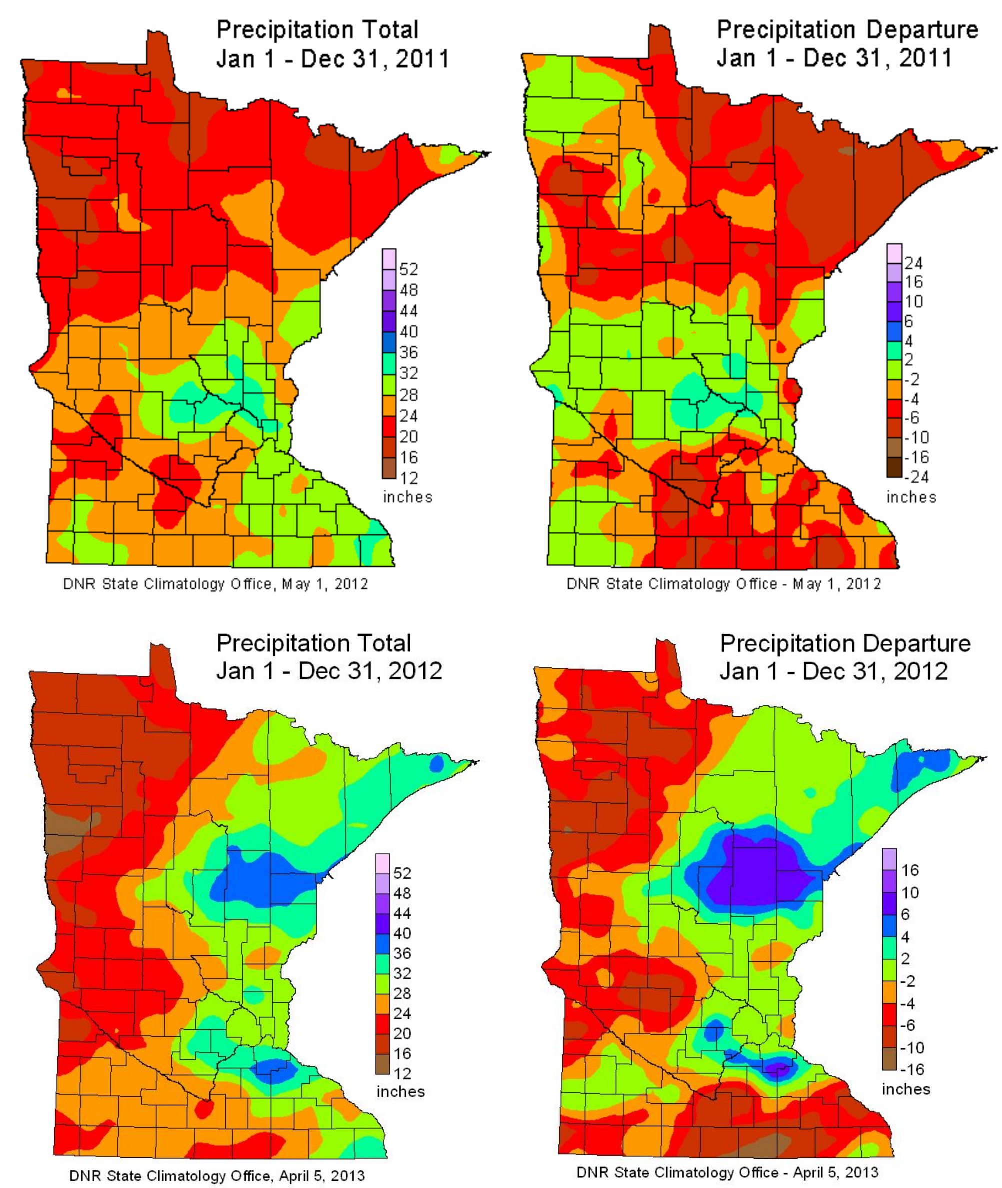

Figure 9. Statewide precipitation levels during the 2011 and 2012 water year.

Figure 10 and Figure 11 display the areal average representation of precipitation in East Central Minnesota. An areal average is a spatial average of all the precipitation data collected within a certain area presented as a single dataset. This data is taken from the Western Regional Climate Center, available as a link on the University of Minnesota Climate website: http://www.wrcc.dri.edu/spi/divplot1map.html.

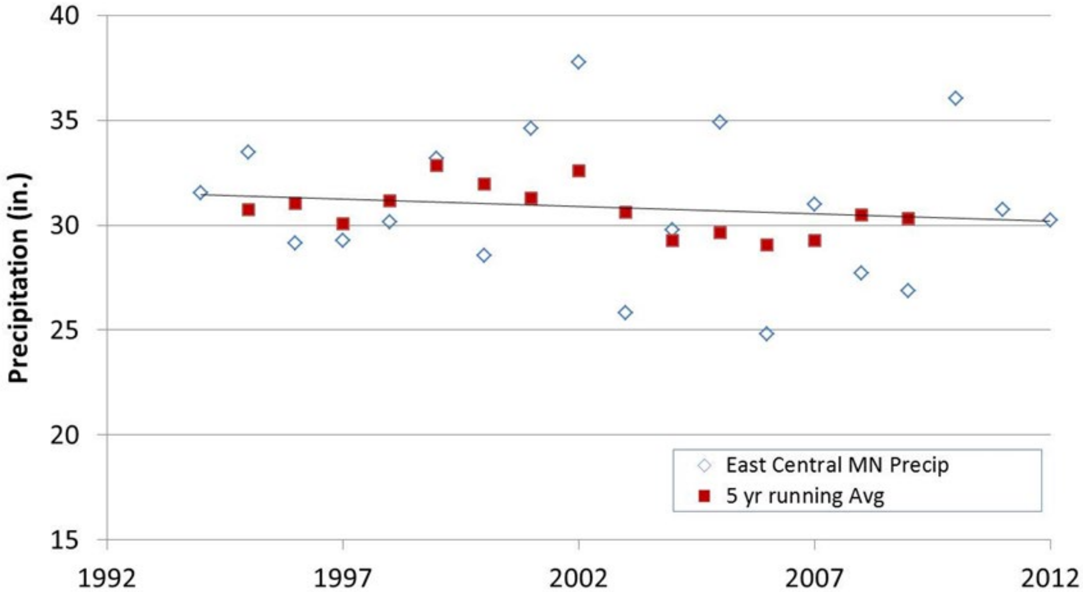

Figure 10. Precipitation trends in east central Minnesota (1992-2012) with five year running average (Red Squares).

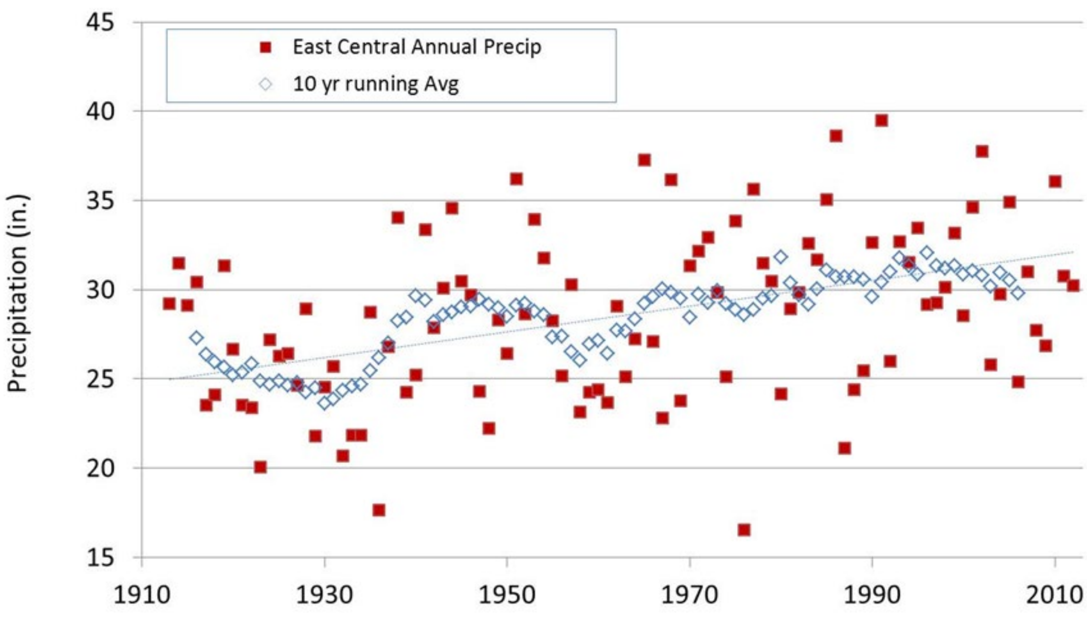

Figure 11. Precipitation trends in east central Minnesota (1912-2012) with 10 year running average (Blue Diamonds).

Though it can vary in intensity and time of year, it would appear that rainfall in the east central region experienced no significant trend over the last 20 years (Figure 10). However, over the 100-year period from 1912 to 2012 East Central Minnesota has experienced a statistically significant (p=0.001) increase in precipitation (Figure 11). This follows the statewide spatial average, which shows a statistically significant rising trend for the same time period. In addition, dry periods seem to be lengthening with total precipitation staying roughly the same, resulting in larger run-off events.

Hydrogeology and groundwater quality

The Nemadji River Watershed is a geographic area that was significantly impacted by glacial activity. Surficial geology near the north, west and southern perimeters of the watershed is composed of sandy beach deposits interspersed with areas of silt and clay; both are remnants of glacial Lake Superior when it extended far beyond its current shore (Hobbs, 2009). These deposits surround an area of finer glacial till through which the Nemadji River flows (Berg, 2011).

In these surficial sands, groundwater is typically shallow (0-10 feet). There are intermittent locations, though, where groundwater is estimated to be 50 feet or more from the ground surface. Surface water bodies likely receive groundwater in the Nemadji watershed, helping to maintain lake levels and stream flow. The direction of groundwater flow through these aquifers is generally inward from the perimeter of the watershed toward the Nemadji River (Berg, 2011).

Wetlands

Wetlands are common in the Nemadji River Watershed. National Wetlands Inventory data estimate 42,355 acres of wetlands, which is approximately 24% of the watershed area (Figure 12). This coverage is just above the statewide wetland coverage rate of 19% (Kloiber & Norris, 2013). The predominant wetland cover types in the Nemadji are Forested and Shrub-Scrub swamps (Figure 12).

The glacial landforms are varied in the watershed (MNGS, 1997) which leads to different wetland patterns. The heart of the watershed, where the stream courses begin to merge and form the north and south forks of the Nemadji River to the Wisconsin border, consists of parent materials that were deposited when Glacial Lake Duluth formed during the last glacial retreat. Coarser sands and gravels were deposited along the outer margin of the area, with silts and clays deposited in the interior. The terrain was generally flat initially. Over time the natural stream network developed, creating valley walls and thereby generally prohibiting wetlands in this part of the watershed. Some flat hydrogeomorphic (HGM) type wetlands occur where the flat terrain remains above the valleys, and soils are saturated (Smith et al. 1995). The outer margin of the watershed is a mix of moraine and glacial outwash landforms. Moraine landforms have rolling to hilly terrain with depressional (HGM) type wetlands tending to form where surface water concentrates into discrete basins (Smith et al. 1995). Depressional wetlands may be connected to the surface water network of the watershed or they may be isolated. Glacial outwash landforms have generally flat terrain and tend to support flat HGM type wetlands—some of which can be very extensive.

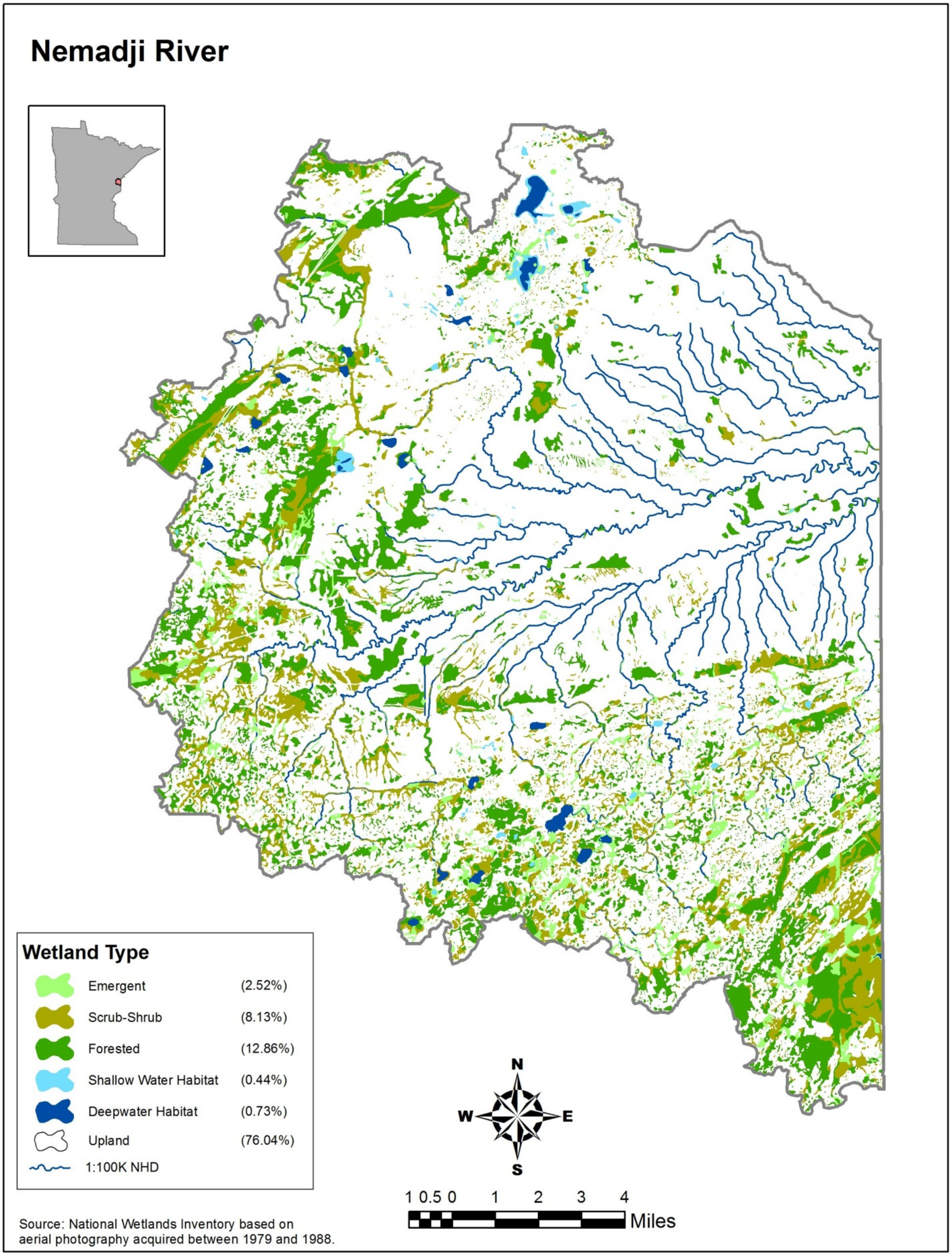

Figure 12. Wetland and surface water in the Nemadji River Watershed according to the National Wetland Inventory

IV. Watershed-wide data collection methodology

Watershed Pollutant Load Monitoring Network

Intensive water quality sampling occurs throughout the year at all WPLMN sites. Between 22 and 27 mid-stream grab samples were collected per year at the Nemadji River on County Road C near South Superior, Wisconsin focusing the sampling frequency greatest during periods of moderate to high flow (Figure 13). Because correlations between concentration and flow exist for many of the monitored analytes, and because these relationships can shift between storms or with season, computation of accurate load estimates requires frequent sampling of all major runoff events. Low flow periods are also sampled and are well represented, but sampling frequency tends to be less as concentrations are generally more stable when compared to periods of elevated flow. Despite discharge-related differences in sample collection frequency, this staggered approach to sampling generally results in samples being well distributed over the entire range of flows.

Annual water quality and daily average discharge data are coupled in the “Flux32,” pollutant load model, originally developed by Dr. Bill Walker and recently upgraded by the U.S. Army Corp of Engineers and the MPCA. Flux32 allows the user to create seasonal or discharge constrained concentration/flow regression equations to estimate pollutant concentrations and loads on days when samples were not collected. Primary outputs include annual and daily pollutant loads and flow weighted mean concentrations (pollutant load/total flow volume). Loads and flow weighted mean concentrations are calculated for total suspended solids (TSS), total phosphorus (TP), dissolved orthophosphate (DOP), and nitrate plus nitrite nitrogen (nitrate-N).

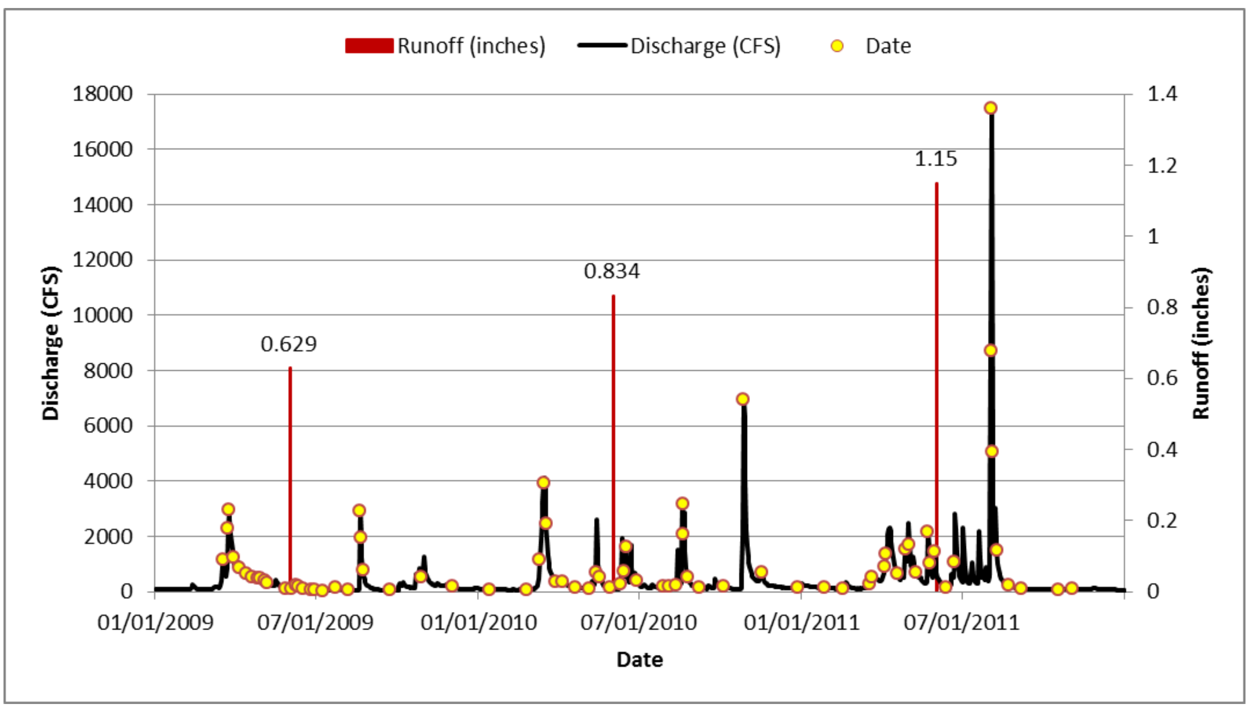

Figure 13. Hydrograph and annual runoff for the Nemadji River near South Superior, WI (2009-2011).

Stream water chemistry sampling

Two water chemistry stations were sampled from May through September in 2010, and again June through August of 2011, to provide sufficient water chemistry data to assess all components of the Aquatic Life and Recreation Use Standards. Following the IWM design, water chemistry stations were placed at the outlet of each HUC-10 subwatershed that was >40 square miles in area (purple circles and green circles/triangles in (Figure 3). A SWAG was awarded to the CSWCD to conduct the monitoring at the two outlet locations in the Nemadji River Watershed (see Appendix 2 for locations of stream water chemistry monitoring stations; see Appendix 1 for definitions of stream chemistry analytes monitored in this study). Chemistry data on several other smaller streams within this watershed were collected through the SWAG and were also reviewed as supporting information for assessment purposes. This data included some event based sampling in preparation for a TMDL starting in 2008, along with a CWP grant that was awarded to CSWCD in 2006 and 2007.

Stream biological sampling

The biological monitoring component of the IWM in the Nemadji River Watershed was completed during the summer of 2011. A total of 18 stations were newly established across the watershed and sampled. These stations were located near the outlets of most minor HUC-14 watersheds. In addition, two existing biological monitoring stations within the watershed were revisited in 2011. These monitoring stations were initially established as part of a project to support the development of biological criteria in 1997 or as part of a 1990 survey conducted by the MDNR. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2013 assessment was collected in 2011. A total of 20 AUIDs were sampled for biology in the Nemadji River Watershed. Water body assessments to determine aquatic life use support based on biological parameters were conducted for 19 AUIDs. Water body assessments were not conducted for one AUID due to the sampling station having predominantly wetland characteristics.

To measure the health of aquatic life at each biological monitoring station, indices of biological integrity (IBIs), specifically fish and macroinvertebrate IBIs, were calculated based on monitoring data collected for each of these communities. A fish and macroinvertebrate classification framework was developed to account for natural variation in community structure, which is attributed to geographic region, watershed drainage area, water temperature and stream gradient. As a result, Minnesota's streams and rivers were divided into seven distinct warm water classes and two cold water classes, with each class having its own unique F-IBI and M-IBI. Each IBI class uses a unique suite of metrics, scoring functions, impairment thresholds, and confidence intervals (CIs) (For IBI classes, thresholds and CIs, see Appendix 5). Index of Biotic Integrity scores higher than the impairment threshold and upper CI indicate that the stream reach supports aquatic life. Contrarily, scores below the impairment threshold and lower CI indicate that the stream reach does not support aquatic life. When an IBI score falls within the upper and lower confidence limits, additional information may be considered when making the impairment decision, such as the consideration of potential local and watershed stressors and additional monitoring information (e.g., water chemistry, physical habitat, observations of local land use activities). For IBI results for each individual biological monitoring station, see Appendix 6 and Appendix 7.

Fish contaminants

Mercury and PCBs were analyzed in fish tissue samples collected from the Nemadji River in 2011 by the MPCA biomonitoring staff. In addition, both Chub (09-0008-00) and Sand (09-0016-00) lakes were sampled for both Mercury and PCBs by the MDNR between 1982 and 2007.

Captured fish were wrapped in aluminum foil and frozen until they were thawed, scaled, filleted, and ground. The homogenized fillets were placed in 125 mL glass jars with Teflon™ lids and frozen until thawed for mercury or PCBs analyses. The Minnesota Department of Agriculture laboratory performed all mercury and PCBs analyses of fish tissue.

The Impaired Waters List is submitted every even year to the EPA for the agencies approval. The MPCA has included waters impaired for contaminants in fish on the Impaired Waters List since 1998. Impairment assessment for PCBs and Perfluoroctane Sulfonate (PFOS) in fish tissue is based on the fish consumption advisories prepared by the Minnesota Department of Health. If the consumption advice is to restrict consumption of a particular fish species to less than a meal per week because of PCBs or PFOS, the MPCA considers the lake or river impaired. The threshold concentration for impairment (consumption advice of one meal per month) is an average fillet concentration of 0.22 mg/kg for PCBs and 0.200 mg/kg (200 ppb) for PFOS.

Prior to 2006, mercury concentrations in fish tissue were assessed for water quality impairment based on the Minnesota Department of Health's fish consumption advisory. A water body with an advisory more restrictive than a meal per week was classified as impaired for mercury in fish tissue. Since 2006, a water body has been classified as impaired for mercury in fish tissue if 10% of the fish samples (measured as the 90^{th} percentile) exceed 0.2 mg/kg of mercury, which is one of Minnesota's water quality standards for mercury. At least five fish samples per species are required to make this assessment and only the last 10 years of data are used for statistical analysis. The MPCA's Impaired Waters List includes waterways that were assessed as impaired prior to 2006 as well as more recent impairments.

PCBs in fish have not been monitored as intensively as mercury in the last three decades due to monitoring completed in the 1970s and 1980s. These earlier studies identified that high concentrations of PCBs were only a concern downstream of large urban areas in large rivers, such as the Mississippi River and in Lake Superior. Therefore, continued widespread frequent monitoring of smaller river systems was not necessary. The current watershed monitoring approach includes screening for PCBs in representative predator and forage fish collected at the outlet stations in each major watershed.

Lake water sampling

The MPCA awarded a SWAG grant to the CSWCD to conduct lake monitoring on eight lakes within the watershed. This monitoring was done cooperatively with citizen volunteers. There are currently three volunteers enrolled in the MPCA's CLMP that are conducting lake monitoring within the watershed. Sampling methods are similar among monitoring groups and are described in the document entitled "MPCA Standard Operating Procedure for Lake Water Quality" found at http://www.pca.state.mn.us/publications/wq-s1-16.pdf. The lake water quality assessment standard requires eight observations/samples within a 10 year period for phosphorus, chlorophyll-a, and Secchi depth.

Groundwater quality

The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of chemicals including nutrients, metals, and volatile organic compounds. These ambient wells represent a mix of deeper domestic wells and shallow monitoring wells. The shallow wells interact with surface waters and exhibit impacts from human activities more rapidly. Available data from federal, state and local partners are used to supplement reviews of groundwater quality in the region.

Groundwater/surface water withdrawals

The MDNR requires a permit on all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons/day or one million gallons/year (See Figure 27 for locations of permitted groundwater and surface water withdrawals). Permit holders are required to track water use and report back to the MDNR yearly. Information on the program and the program database are found at: http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html.

The changes in withdrawal volume detailed in this report are a representation of water use and demand in the watershed and are taken into consideration when the MDNR issues permits for water withdrawals. Other factors not discussed in this report but considered when issuing permits include: interactions between individual withdrawal locations, cumulative effects of withdrawals from individual aquifers, and potential interactions between aquifers. This holistic approach to water allocations is necessary to ensure the sustainability of Minnesota's groundwater resources.

Monitoring wells from the MDNR Observation Well Network track the elevation of groundwater across the state. The elevation of groundwater is measured as depth to water in feet and reflects the fluctuation of the water table as it rises and falls with seasonal variations and anthropogenic influences. Data from these wells and others are available at: http://www.dnr.state.mn.us/waters/groundwater_section/obwell/waterleveldata.html.

Stream flow

The USGS maintains real-time stream flow gaging stations across the United States. Measurements can be viewed at http://waterdata.usgs.gov/nwis/rt.

Wetland monitoring

The MPCA is actively developing methods and building capacity to conduct wetland quality monitoring and assessment. Currently, the MPCA does not monitor wetlands systematically by watershed. Our primary approach is to track changes in biological communities using statewide and ecoregional random surveys—where results from a small sample can be extrapolated to a larger population. The MPCA has developed macroinvertebrate and vegetation IBIs for depressional wetlands that have emergent marsh vegetation and open water and have completed an initial baseline estimate of depressional wetland quality for Minnesota (MPCA 2012).

Unfortunately, the landforms present in the Nemadji River Watershed support few wetlands that meet our depressional definition so that our IBIs can be applied. No MPCA depressional wetland monitoring stations have been established in the watershed. The MPCA has conducted the field sampling and is in the process of compiling results for an expanded statewide random wetland quality survey that includes all wetland types. These results should be more applicable for documenting wetland condition in the Nemadji River Watershed when they become available. For more information please see the MPCA wetland monitoring and assessment webpage: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/wetlands/wetland-monitoring-and-assessment.html

V. Individual watershed results

HUC-10 watershed units

Assessment results for aquatic life and recreation use are presented for each HUC-10 subwatershed within the Nemadji River. The primary objective is to portray all the full support and impairment listings within a 10-HUC subwatershed resulting from the complex and multi-step assessment and listing process. A summary table of assessment results for the entire 8-HUC watershed including aquatic consumption, and drinking water assessments (where applicable) is included in Appendix 3. This scale provides a robust assessment of water quality condition at a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The graphics presented for each of the HUC-10 watershed units contain the assessment results from the 2013 assessment cycle, as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2011 IWM effort, but also considers available data from the last 10 years.

The proceeding pages provide an account of each HUC-10 watershed. Each account includes a brief description of the subwatershed, and summary tables of the results for each of the following: a) stream aquatic life and aquatic recreation assessments, b) biological condition of channelized streams and ditches, c) stream habitat quality d) channel stability, and where applicable e) water chemistry for the HUC-10 outlet, and f) lake aquatic recreation assessments. Following the tables is a narrative summary of the assessment results and pertinent water quality projects completed or planned for the subwatershed. A brief description of each of the summary tables is provided below.

Stream assessments

A table is provided in each section summarizing aquatic life and aquatic recreation assessments of all assessable stream reaches within the watershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2013 assessment process (2014 EPA reporting cycle); however, impairments from previous assessment cycles are also included and are distinguished from new impairments via cell shading (see footnote section of each table). These tables also denote the results of comparing each individual aquatic life and aquatic recreation indicator to their respective criteria (i.e., standards) - determinations made during the desktop phase of the assessment process (see Figure 5). Assessment of aquatic life is derived from the analysis of biological (F and M IBIs), dissolved oxygen, turbidity, chloride, pH and un-ionized ammonia (NH_3) data, while the assessment of aquatic recreation in streams is based solely on bacteria (Escherichia coli or fecal coliform) data. Included in each table is the specific aquatic life use classification for each stream reach: cold water community (2A); cool or warm water community (2B); or indigenous aquatic community (2C). Stream reaches that do not have sufficient information for either an aquatic life or aquatic recreation assessment (from current or previous assessment cycles) are not included in these tables. Where applicable and sufficient data exists, assessments of other designated uses (e.g., class 7, drinking water, aquatic consumption) are discussed in the summary section of each HUC-10 as well as in the Watershed-Wide Results and Discussion section.

Stream habitat results

Habitat information documented during each fish sampling visit is provided in each HUC-10 section. These tables convey the results of the Minnesota Stream Habitat Assessment (MSHA) survey, which evaluates the section of stream sampled for biology and can provide an indication of potential stressors (e.g., siltation, eutrophication) impacting fish and macroinvertebrate communities. The MSHA score is comprised of five scoring categories including adjacent land use, riparian zone, substrate, fish cover and channel morphology, which are summed for a total possible score of 100 points. Scores for each category, a summation of the total MSHA score, and a narrative habitat condition rating are provided in the tables for each biological monitoring station. Where multiple visits occur at the same station, the scores from each visit have been averaged. The final row in each table displays average MSHA scores and a rating for the HUC-10 watershed.

Stream stability results

Stream channel stability information evaluated during each invert sampling visit is provided in each HUC-10 section. These tables display the results of the Channel Condition and Stability Index (CCSI) which rates the geomorphic stability of the stream reach sampled for biology. The CCSI rates three regions of the stream channel (upper banks, lower banks, and bottom). The CCSI rating provides an indication of stream channel geomorphic changes and loss of habitat quality, which may be related to changes in watershed hydrology, stream gradient, sediment supply, or sediment transport capacity. The CCSI was recently implemented in 2008, and is collected once at each biological station. Consequently, the CCSI ratings are only available for biological visits sampled in 2010 or later. The final row in each table displays the average CCSI scores and a rating for the HUC-10 watershed.

Watershed outlet water chemistry results

These summary tables display the water chemistry results for the monitoring station representing the outlet of the HUC-10 watershed. This data along with other data collected within the 10 year assessment window can provide valuable insight on water quality characteristics and potential parameters of concern within the watershed. Parameters included in these tables are those most closely related to the standards or expectations used for assessing aquatic life and recreation. While not all of the water chemistry parameters of interest have established water quality standards, McCollor and Heiskary (1993) developed ecoregion expectations for a number of parameters that provide a basis for evaluating stream water quality data and estimating attainable conditions for an ecoregion. For comparative purposes, water chemistry results for the Nemadji River Watershed are compared to expectations developed by McCollor and Heiskary (1993) that were based on the 75th percentile of a long-term dataset of least impacted streams within each ecoregion.

Lake assessments

A summary of lake water quality is provided in the HUC-10 sections where available data exists. For lakes with sufficient data, basic modeling was completed. Assessment results for all lakes in the watershed are available in Appendix 4. Lake models and corresponding morphometric inputs can be found in Appendix 9.

South Fork Nemadji River Subwatershed HUC 0401030101

The South Fork Nemadji River Subwatershed drains 89.19 square miles or 57,081.6 acres between Minnesota (96.22%) and Wisconsin (3.78%). The portion of the watershed that lies within Minnesota consists of 85.82 square miles of Carlton and Pine Counties and is the second largest subwatershed. The headwaters of the South Fork Nemadji River begin at the confluence of Anderson Creek and Stony Brook. It continues eastward and receives additional flow from Clear Creek, Net River (including Little Net River), Section 36 Creek, State Line Creek, and many other unnamed tributaries. The river eventually crosses the Minnesota/Wisconsin border where it empties ultimately into the mainstem Nemadji River.

This subwatershed contains eight lakes larger than 10 acres, with majority of them located in the headwaters. Prominent lakes include Net, Pickerel, and Graham.

This subwatershed is dominated by forest (60.55%), wetland (31.80%), and rangeland (3.30%). Only 2.08% is developed land, 1.21% is open water, and 1.06% is row-crop agriculture. It is the least disturbed subwatershed within the Nemadji River Watershed, with the headwaters heavily forested.

The outlet of the watershed was monitored just 2 miles northwest of Holyoke, adjacent to Nemadji River Road (off Minnesota Truck Highway 23) on the South Fork Nemadji River. The outlet is represented by MPCA's STORET/EQuIS station S006-214 and biological station 11LS057.

Table 1. Aquatic life and recreation assessments on stream reaches: South Fork Nemadji River Subwatershed. Reaches are organized upstream to downstream in the table.

AUID *Reach Name*, *Reach Description*	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
04010301-516 **Anderson Creek** *T46 R17W S26, S Line to T46 R17W S14, N Line*	4.24	2A	11LS065	Upstream of CSAH 8, 3 mi. W of Holyoke	MTS	MTS	- -	IF	MTS	- -	- -	- -	- -	FS	NA
04010301-569 **Little Net River** *T46 R16W S34, S Line to Net R*	10.02	2A	11LS067	Upstream of CSAH 8, 1.5 mi. NE of Holyoke	MTS	MTS	- -	IF	MTS	- -	- -	- -	- -	FS	NA
04010301-760 **Net River** *T46 R16W S29, N Line of SE quarter to S Fk Nemadji R*	10.99	2A	11LS066	Upstream of CSAH 8, in Holyoke	MTS	MTS	MTS	IF	MTS	- -	- -	- -	- -	FS	NA
04010301-558 **Nemadji River, South Fork** *Stony Bk/Anderson Cr to Net R*	7.3	2A	11LS057	Adjacent to Nemadji River Rd, 2 mi. NW of Holyoke	MTS	MTS	MTS	EXS	MTS	MTS	MTS	- -	EX	NS	NS
04010301-564 **State Line Creek** *Headwaters to S Fk Nemadji R*	9.13	2A	11LS069	Upstream of CSAH 8, 3.5 mi. S of Frogner	MTS	MTS	- -	IF	MTS	MTS	- -	- -	- -	FS	NA

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use.

Table 2. Minnesota Stream Habitat Assessment (MSHA): South Fork Nemadji River Subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	11LS065	Anderson Creek	5	13	13.5	16	29	76.5	Good
1	11LS067	Little Net River	4	15	17.7	10	22	68.7	Good
1	11LS066	Net River	4.5	14.5	22.4	16	30	87.4	Good
1	11LS057	Nemadji River, South Fork	5	11	17.2	16	26	75.2	Good
1	11LS069	State Line Creek	5	13	16.75	13	32	79.75	Good
		Average Habitat Results: *South Fork Nemadji River Subwatershed*	**4.7**	**13.3**	**17.51**	**14.2**	**27.8**	**77.51**	**Good**

Qualitative habitat ratings

- = Good: MSHA score above the median of the least-disturbed stations (MSHA > 66)
- = Fair: MSHA score between the median of the least-disturbed stations and the median of the most-disturbed stations (45 < MSHA < 66)
- = Poor: MSHA score below the median of the most-disturbed stations (MSHA < 45)

Table 3. Channel Condition and Stability Assessment (CCSI): South Fork Nemadji River Subwatershed

# Visits	Biological Station ID	Stream Name	Stream Type	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11LS065	Anderson Creek	MHL	20	38	34	2	94	Severely Unstable
1	11LS067	Little Net River	HBC	14	11	4	4	33	Fairly Stable
1	11LS068	Net River	LGL	4	5	9	1	19	Stable
1	11LS066	Net River	MHL	11	20	11	2	44	Fairly Stable
1	11LS057	Nemadji River, South Fork	MHL	13	23	15	2	53	Moderately Unstable
1	11LS069	State Line Creek	MHL	28	31	18	2	79	Moderately Unstable
			Average Stream Stability Results: *South Fork Nemadji River Subwatershed*	**15**	**21.33**	**15.17**	**2.17**	**53.67**	**Moderately Unstable**

Qualitative channel stability ratings

= Stable: CCSI < 27 = Fairly stable: 27 < CCSI < 45 = Moderately unstable: 45 < CCSI < 80 = Severely unstable: 80 < CCSI < 115 = Extremely unstable: CCSI > 115

Stream Types

HBC = High Gradient Confined; **MHL** = Meandering, w/ High-Low Banks; **MW** = Meandering Wetland Channel; **TC** = Trapezoidal Channelized; **TCM** = Trapezoidal Channelized Meandering; **WC** = Wetland Channelized

Table 4. Outlet water chemistry results: South Fork Nemadji River Subwatershed.

Station location:	**Nemadji River, S. Fork**
STORET/EQuIS ID:	**S006-214**
Station #:	**0401030101**

Parameter	Units	# of Samples	Minimum	Maximum	Mean	WQ Standard[1]	NLF Ecoregion Expectation [2]	# of WQ Exceedances[1]
Ammonia-nitrogen	mg/L	9	<0.02	0.03	<0.02	0.016		0
Chloride	mg/L	10	2.1	5.3	4.2	230		0
Dissolved Oxygen (DO)	mg/L	16	8.29	12.7	9.9	7		0
pH		17	7.54	8.18	7.8	6.5 – 8.5	7.9	0
Secchi tube/Transparency Tube	100 cm					>20		
Transparency tube	60 cm	19	4	34	19.7			9
Turbidity	FNU	10	19	160	53	10	4	10
Escherichia coli (geometric mean)	MPN/100ml	15	63	283	185	126		2
Escherichia coli	MPN/100ml	15	40	610	173	1260		0
Chlorophyll-a, Corrected	ug/L	0						
Inorganic nitrogen (nitrate and nitrite)	mg/L	10	<0.05	<0.05	<0.05			
Kjeldahl nitrogen	mg/L	10	0.2	1.6	0.88		0.18 – 0.73	
Orthophosphate	ug/L	0						
Pheophytin-a	ug/L	0						
Phosphorus	ug/L	10	42	360	105		50	
Specific Conductance	uS/cm	19	88	192	138		270	
Temperature, water	deg °C	19	7.76	19.5	15.6			
Total suspended solids	mg/L	10	6	166	39.3		5.6	
Total volatile solids	mg/L	9	1	18	6.1			
Sulfate	mg/L	9	1.9	7.2	4.1			
Hardness	mg/L	10	60	118	87			

[1]Secchi Tube/Transparency tube standards are surrogate standards derived from the turbidity standard of 25.
[2]Based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW, EPA 822 B-01-015. 2001
Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the South Fork Nemadji River Subwatershed, a component of the IWM work conducted between May and September in 2011 and 2012. This specific data does not necessarily reflect all data that was used to assess the AUID.

Table 5. Lake water aquatic recreation assessments: South Fork Nemadji River Subwatershed.

Name	DOW#	Area (acres)	Trophic Status	% Littoral	Max. Depth (m)	Avg. Depth (m)	CLMP Trend	Mean TP (µg/L)	Mean Chl-a (µg/L)	Secchi Mean (m)	Support Status
Net	58-0038-00	142	E	100	3.6	1.6	D	40.27	8.5	0.79	NS

Abbreviations:
D -- Decreasing/Declining Trend
I -- Increasing/Improving Trends
NT – No Trend
H – Hypereutrophic
E – Eutrophic
M – Mesotrophic
O -- Oligotrophic
FS – Full Support
NS – Non-Support
IF – Insufficient Information
[1] – Depth Is Estimated

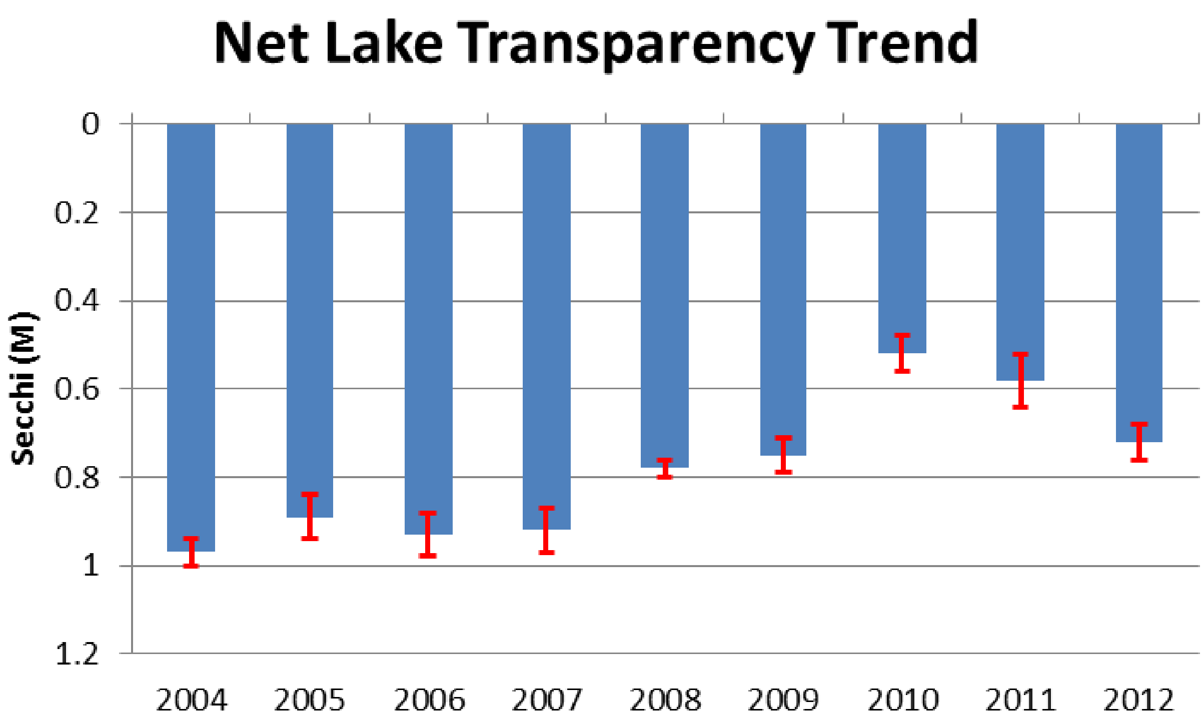

Figure 14. Net Lake transparency trend; standard errors noted by red lines.

Summary

The South Fork Nemadji River Subwatershed had five assessable stream segments containing five biological monitoring stations, and one lake assessed for aquatic recreation (Table 1 & Table 5). Nearly all streams met the applicable standards or criteria and fully supported aquatic life and aquatic recreation. Habitat throughout this entire subwatershed was in "good" condition, as demonstrated by MSHA scores (Table 2). In some cases high quality habitat may be mitigating any real change in F/M-IBI. The low amount of disturbance within the subwatershed almost assured excellent biological integrity. One stream in particular, State Line Creek (04010301-564), had the highest F-IBI score within the entire Nemadji River Watershed, with similar M-IBI scores. Streams that had exceptional performing biological, chemical, and physical parameters are worthy of additional protection in order to preserve their valuable aquatic resources.

The South Fork Nemadji River (04010301-558) was the only stream segment within this subwatershed that was impaired for aquatic life and recreation uses. Most conventional aquatic life parameters were meeting water quality standards with the exception of turbidity, which consistently exceeded the 10 Nephelometric Turbidity Unit (NTU) coldwater standard. There are systemic levels of high turbidity in much of the Nemadji River Watershed, which likely can be attributed to the watershed's geological setting and non-point pollution. Although habitat is in relatively good condition throughout the South Fork Nemadji River Subwatershed, CCSI rating varies widely (Table 3). This is likely attributed to soil types within the subwatershed that are contributing to stream instability and mass wasting. There is a considerable amount of geomorphic habitat variability amongst streams and stream reaches in this subwatershed. The lower reaches that tend to be in clay soils are considerable less stable than in the upper reaches where more stable hydrology exists. In most cases a limited amount of sediment is being deposited within the South Fork Nemadji River and tributaries due to the higher stream gradient that flushes sediment out of the drainage and into Lake Superior.

Nutrient concentrations were also relatively high in this subwatershed, with mean total phosphorus concentrations three times the NLF ecoregion expectation (Table 4). These nutrient concentrations were likely bounded to fine particulates and tended to be higher when elevated flows were present. Similar to nutrients, bacteria (E. coli) levels were also higher during elevated flows and resulted in an aquatic recreation impairment. It is likely that both bacteria and nutrients levels are linked to sediment input into the South Fork Nemadji River and could be mitigated by addressing this aquatic life impairment. Sources of the sediment and turbidity are numerous, and are a function of the watershed's geologic setting (Figure 25), the river's geomorphology and current/historical land use practices (Reidel et al, 2005). Restoration work within the watershed has been ongoing since the 1970s, with Carlton County compiling a summary of the watershed and restoration activities, which can be found at: http://carltonswcd.org/watersheds/nemadji-river.

The subwatershed has assessment-level data on one lake, Net Lake (58-0038-00), which is located in northern Pine County and southern Carlton County. This lake covers 142 acres and has a maximum depth of 12 feet. The lake is 100% littoral and drains a relatively large 10.4 square mile watershed of forests and wetlands; the Net River flows through the lake. Over half of the lakeshore is developed. The lake does not support aquatic recreational use. Total phosphorus concentrations averaged 40 µg/L (Table 5), chlorophyll-a concentrations were slightly below the standard at 8.5 µg/L, and Secchi transparency was also not meeting standards (1.6 meters or 5.2 feet). Transparency is likely naturally low due to bog staining from the surrounding wetlands. Net is one of the few lakes in the Nemadji River Watershed with sufficient Secchi transparency data to determine long-term trends. The lake has a declining trend in transparency since 2004, on the order of 0.3 meters (1 foot) over the last 8 years (Figure 14).

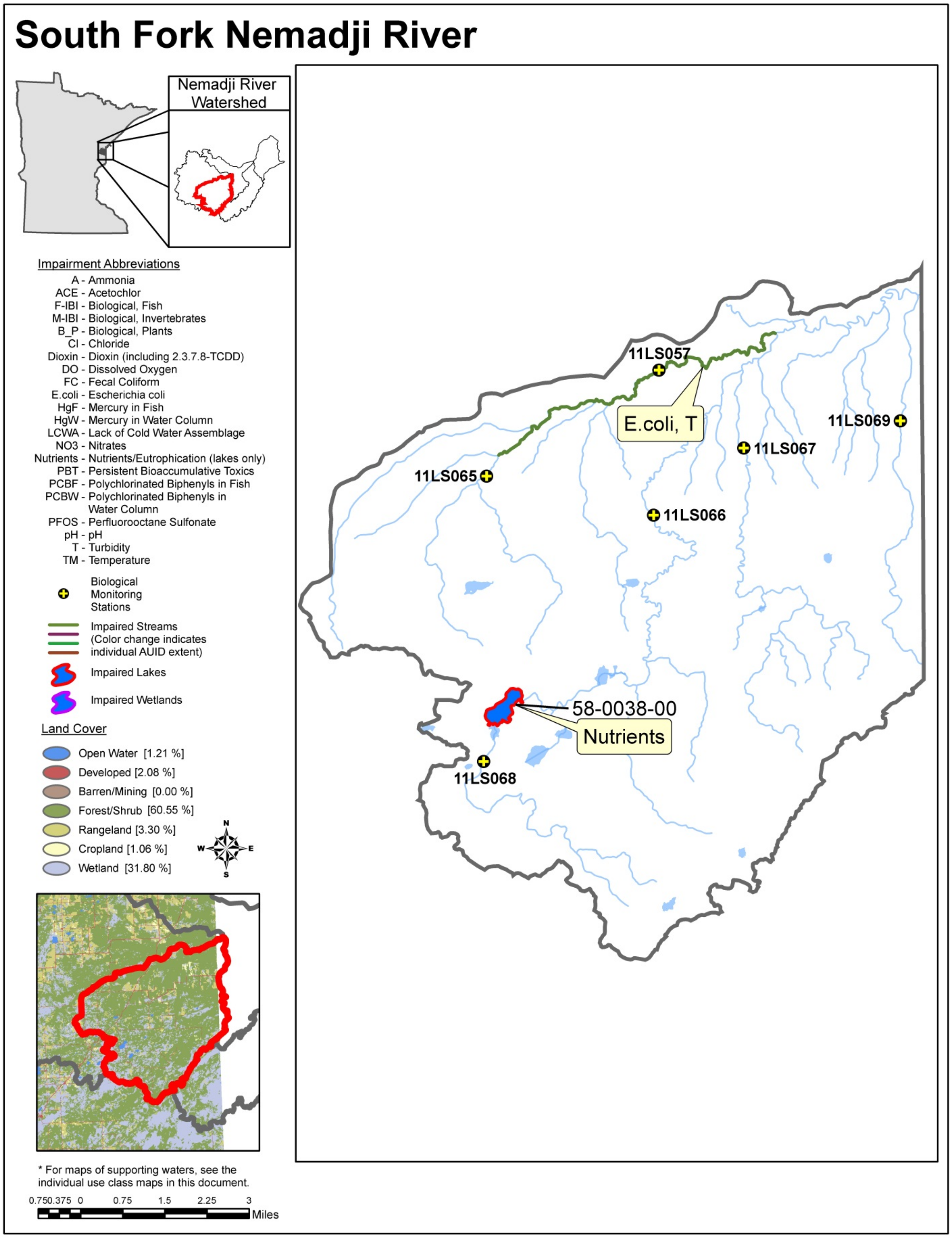

Figure 15. Currently listed impaired waters by parameter and land use characteristics in the South Fork Nemadji River Subwatershed.

Upper Nemadji River Subwatershed HUC 0401030102

The Upper Nemadji River Subwatershed drains 143.79 square miles, or 92,025.6 acres, between Minnesota (99.83%) and Wisconsin (0.17%). The portion that lies within Minnesota consists of 143.54 square miles of Carlton and Pine Counties and is the largest subwatershed. The mainstem Nemadji River starts near the town of Nickerson, Minnesota and flows to the northeast. It continues northeast while receiving additional flow from Nemadji Creek, Spring Creek, Skunk Creek, Blackhoof River, Deer Creek, and Rock Creek, before crossing the Minnesota/Wisconsin border and ultimately emptying into Lake Superior.

There are 19 lakes greater than 10 acres in this subwatershed, with the most prominent being Bear, Hay, Sand, and Spring.

This watershed is dominated by forest (48.03%), wetland (32.72%), and rangeland (13.26%). Only 3.44% is developed land, 1.63% is open water, and 0.92% is row-crop agriculture.

The outlet of the subwatershed was monitored 1 mile south of Pleasant Valley, off Minnesota Truck Highway 23 on the Nemadji River. The outlet is represented by MPCA's STORET/EQuIS station S000-110 and biological station 11LS055.

Table 6. Aquatic life and recreation assessments on stream reaches: Upper Nemadji River Subwatershed. Reaches are organized upstream to downstream in the table.

AUID *Reach Name*, *Reach Description*	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
04010301-534 **Hunters Creek** *Headwaters to Nemadji Cr*	5.37	2A	11LS070	Adjacent to Deer Park Rd, 1 mi. NE of Nemadji	MTS	MTS	- -	IF	MTS	- -	- -	- -	- -	FS	NA
04010301-545 **Nemadji Creek** *Headwaters to Nemadji R*	12.23	2A	11LS060	Downstream of CR 11, 0.5 mi. S of Nemadji	MTS	MTS	- -	IF	- -	- -	- -	- -	- -	FS	NA
04010301-757 **Nemadji River** *T46 R17W S33, South Line to Unnamed Cr*	18.27	2B†	11LS061 97LS087	Downstream of CSAH 8, 2 mi. SE of Nemadji Downstream of CR 103, 4 mi. NW of Holyoke	MTS	MTS	EXP	EXS	- -	MTS	- -	- -	- -	NS	NA
04010301-501 **Unnamed Creek (Elim Creek)** *Innamed Cr to Skunk Cr*	2.45	2A	11LS072	Upstream of CR 103, 1 mi. S of Blackhoof	EXS	MTS	- -	- -	- -	- -	- -	- -	- -	NS	NA
04010301-504 **Skunk Creek** *Headwaters to Unnamed Cr*	7.22	2A	11LS059	Upstream of CR 103, 1 mi. S of Blackhoof	MTS	MTS	- -	- -	- -	- -	- -	- -	- -	FS	NA

04010301-502 **Skunk Creek** *Unnamed Cr to Nemadji R*	1.72	2A	- -	- -	- -	- -	MTS	EXS	- -	MTS	- -	- -	- -	NS	NA
04010301-519 **Blackhoof River** *Unnamed Cr to Ellstrom Lk*	5	2B†	90LS031	Upstream of CR 4, 2 mi. SE of Atkinson	EXS	EXS	- -	- -	- -	- -	- -	- -	- -	NS	NA
04010301-756 **Unnamed Creek** *Unnamed Cr to Ellstrom Lk*	1.72	2B	11LS071	Downstream of CR 139, 2 mi. E of Mahtowa	MTS	- -	- -	- -	- -	- -	- -	- -	- -	FS	NA
04010301-762 **Blackhoof River** *Co Rd 105 to Spring Lk Outlet*	9.84	2A	- -	- -	- -	- -	MTS	MTS	- -	MTS	- -	- -	- -	FS	NA
04010301-510 **Blackhoof River** *Spring Lk Outlet to Unnamed Cr*	2.59	2A	11LS062	Downstream of CSAH 6, in Blackhoof	MTS	MTS	- -	- -	- -	- -	- -	- -	- -	FS	NA
04010301-758 **Nemadji River** *Unnamed Cr to MN/WI Border*	14.99	2A	11LS055	Downstream of Hwy 23, 1 mi. S of Pleasant Valley	MTS	MTS	MTS	EXS	MTS	MTS	MTS	- -	EX	NS	NS
04010301-532 **Unnamed Creek** *Headwaters to Deer Cr*	3.04	2A	- -	- -	- -	- -	MTS	EXS	- -	MTS	- -	- -	- -	NS	NA
04010301-531 **Deer Creek** *Headwaters to Nemadji R*	6.93	2A	11LS064	Downstream of CSAH 6, 1 mi. S of Pleasant Valley	EXS	MTS	MTS	EXS	MTS	MTS	MTS	- -	- -	NS	NA
04010301-573 **Rock Creek** *Headwaters to Unnamed Cr*	4.49	2A	- -	- -	- -	- -	IF	EXS	MTS	MTS	MTS	- -	- -	NS	NA
04010301-508 **Rock Creek** *Unnamed Cr to Nemadji R*	3.92	2A	11LS063	Upstream of Soo Line Trail, 2.5 mi. W of Frogner	EXP	EXP	- -	- -	- -	- -	- -	- -	- -	NS	NA

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support

Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use.

† Reach was assessed based on use class included in the above table and existing use class as defined in Minn. R. 7050 is different. The MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Table 7. Minnesota Stream Habitat Assessment (MSHA): Upper Nemadji River Subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	11LS070	Hunters Creek	2.5	14	14.7	16	32	79.2	Good
1	11LS060	Nemadji Creek	4	13	14.5	13	27	71.5	Good
1	11LS061	Nemadji River	5	15	17.75	6	30	73.75	Good
1	97LS087	Nemadji River	5	10.5	21	11	31	78.5	Good
1	11LS072	Unnamed Creek (Elim Creek)	5	13	19.7	5	20	62.7	Fair
1	11LS059	Skunk Creek	5	13	19.7	14	33	84.7	Good
1	90LS031	Blackhoof River	2.5	14	9	15	20	60.5	Fair
1	11LS071	Unnamed Creek	4	11	10	13	23	61	Fair
1	11LS062	Blackhoof River	5	13	16.25	17	30	81.25	Good
1	11LS064	Deer Creek	4.5	12	15.6	13	21	66.1	Good
1	11LS063	Rock Creek	4.5	11	16.4	13	23	67.9	Good
2	11LS055	Nemadji River	5	9.75	22.2	14.5	28.5	79.95	Good
Average Habitat Results: *Upper Nemadji River Subwatershed*			**4.33**	**12.44**	**16.4**	**12.54**	**26.54**	**72.25**	**Good**

Qualitative habitat ratings

- = Good: MSHA score above the median of the least-disturbed stations (MSHA > 66)
- = Fair: MSHA score between the median of the least-disturbed stations and the median of the most-disturbed stations (45 < MSHA < 66)
- = Poor: MSHA score below the median of the most-disturbed stations (MSHA < 45)

Table 8. Channel Condition and Stability Assessment (CCSI): Nemadji River Subwatershed.

# Visits	Biological Station ID	Stream Name	Stream Type	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11LS070	Hunters Creek	MHL	18	23	20	2	63	Moderately Unstable
1	11LS060	Nemadji Creek	MHL	24	30	22	2	78	Moderately Unstable
1	11LS061	Nemadji River	MHL	7	13	8	3	31	Fairly Stable
1	97LS087	Nemadji River	MHL	20	20	11	2	53	Moderately Unstable
1	11LS072	Unnamed Creek (Elim Creek)	HBC/MHL	19	30	20	2	71	Moderately Unstable
1	11LS059	Skunk Creek	HBC	11	21	16	2	50	Moderately Unstable
1	90LS031	Blackhoof River	LGL	9	21	22	4	56	Moderately Unstable
1	11LS071	Unnamed Creek	MHL	14	26	32	4	76	Moderately Unstable
1	11LS062	Blackhoof River	MHL	13	18	8	2	41	Fairly Stable
1	11LS064	Deer Creek	MHL	24	22	9	3	58	Moderately Unstable
1	11LS063	Rock Creek	MHL	22	28	16	3	69	Moderately Unstable
1	11LS055	Nemadji River	MHL	21	19	25	3	68	Moderately Unstable
Average Stream Stability Results: *Upper Nemadji River 10 HUC*				**16.83**	**22.58**	**17.42**	**2.67**	**59.5**	Moderately Unstable

Qualitative channel stability ratings
= Stable: CCSI < 27 = Fairly stable: 27 < CCSI < 45 = Moderately unstable: 45 < CCSI < 80 = Severely unstable: 80 < CCSI < 115 = Extremely unstable: CCSI > 115

Stream Types
HBC = High Gradient Confined; **MHL** = Meandering, w/ High-Low Banks; **MW** = Meandering Wetland Channel; **TC** = Trapezoidal Channelized; **TCM** = Trapezoidal Channelized Meandering; **WC** = Wetland Channelized

Table 9. Outlet water chemistry results: Upper Nemadji River Subwatershed.

Station location:	Nemadji River							
STORET/EQuIS ID:	S000-110							
Station #:	04010301-758							
Parameter	**Units**	**# of Samples**	**Minimum**	**Maximum**	**Mean**	**WQ Standard[1]**	**NLF Ecoregion Expectation [2]**	**# of WQ Exceedances[1]**
Ammonia-nitrogen	mg/L	9	<0.02	0.03	<0.02	0.016		0
Chloride	mg/L	10	2.1	6.2	5.4	230		0
Dissolved Oxygen (DO)	mg/L	11	8.2	11.4	9.8	7		0
pH		12	7.76	8.38	7.98	6.5 – 8.5	7.9	0
Secchi tube/Transparency Tube	100 cm	0				>20		
Transparency tube	60 cm	10	2	48	20.6	>20		5
Turbidity	FNU	10	13	340	76	10	4	10
Escherichia coli (geometric mean)	MPN/100ml	15	64	250	185	126		2
Escherichia coli	MPN/100ml	15	31	980	212	1260		0
Chlorophyll-a, Corrected	ug/L	0						
Inorganic nitrogen (nitrate and nitrite)	mg/L	10	<0.05	0.16	<0.05	0.1		
Kjeldahl nitrogen	mg/L	10	0.3	1.6	0.92		0.18 – 0.73	
Orthophosphate	ug/L	0						
Pheophytin-a	ug/L	0						
Phosphorus	ug/L	10	25	415	109		50	
Specific Conductance	uS/cm	14	112	232	165		270	
Temperature, water	deg °C	14	10.3	20.3	16.3			
Total suspended solids	mg/L	10	8	660	113		5.6	
Total volatile solids	mg/L	10	1	50	9			
Sulfate	mg/L	9	1.9	7.2	4.0			
Hardness	mg/L	10	60	118	87			

[1]Secchi Tube/Transparency tube standards are surrogate standards derived from the turbidity standard of 25.

[2]Based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCollor and Heiskary 1993). TKN range based on EPA Rivers and Streams in Nutrient Ecoregion VIII, NLF and NMW, EPA 822 B-01-015. 2001

Data found in the table above was compiled using the results from data collected at the outlet monitoring station in the Upper Nemadji River Subwatershed, a component of the IWM work conducted between May and September in 2011 and 2012. This specific data does not necessarily reflect all data that was used to assess the AUID.

Table 10. Lake water aquatic recreation assessments: Upper Nemadji River Subwatershed.

Name	DOW#	Area (acres)	Trophic Status	% Littoral	Max. Depth (m)	Avg. Depth (m)	CLMP Trend	Mean TP (µg/L)	Mean Chl-a (µg/L)	Secchi Mean (m)	Support Status
Bear	09-0005-00	32	M	63	8.5	3.0	NT	23	9.11	3.19	FS
Spring	09-0007-00	41	E	81	7.6	2.0	NT	24.5	5.5	3.19	FS
Hay	09-0010-00	103	E	95	4.2	1.2	NT	27.91	7.27	1.59	FS
Sand	09-0016-00	123	E	99	8.2	0.9	NT	29.38	6.55	1.27	FS

Abbreviations:
D -- Decreasing/Declining Trend
I -- Increasing/Improving Trends
NT – No Trend

H – Hypereutrophic
E – Eutrophic
M – Mesotrophic
O -- Oligotrophic

FS – Full Support
NS – Non-Support
IF – Insufficient Information
[1] – Depth Is Estimated

Figure 16. Top Left: Groundwater upwelling in Deer Creek, Top Right: Aerial view of Deer Creek's confluence with the Nemadji River, Bottom Left: Deer Creek's confluence with the Nemadji River (Photo Courtesy of Carlton SWCD), Bottom Right: Turbidity at Deer Creek biological monitoring station (11LS064).

Summary

There is considerable variation in the assessment results across the Upper Nemadji River Subwatershed. In some cases the differences between the assessment parameters appear to relate to landscape and land use patterns. Areas of more intense land use exist in the northwestern half of the subwatershed where rangeland and agriculture dominate the landscape. Soils also vary throughout the subwatershed, with highly erosive clay and clayey silt located near the Nemadji River corridor. This subwatershed contains 15 assessable stream AUIDs and 12 biological monitoring stations, in addition, four lakes were assessed for aquatic recreation (Table 6). Stream habitat conditions were "good" overall, with individual stations fluctuating between "good" and "fair" (Table 7). Two of the three stations (90LS031 & 11LS071) with "fair" habitat conditions were located in the headwaters where fine substrate composition and poor channel morphology may be naturally limiting the biota. The overall channel condition and stability rating for this subwatershed was "moderately stable" (Table 8). This is likely attributed to soil types within the subwatershed that are contributing to stream instability and mass wasting.

Select tributaries, and the Nemadji River proper, show significant signs of degradation that may be linked to both natural and anthropogenic stressors. Four stream segments within this subwatershed did not support aquatic life based on biological parameters including the Blackhoof River (F/M-IBI; 04010301-519), Deer Creek (F-IBI; 04010301-531), Elim Creek (F-IBI; 04010301-501), and Rock Creek (F/M-IBI; 04010301-508). Although stream gradient, size, and water temperature vary between stations, an overall lack of sensitive species, along with an increase in warmwater tolerant species were contributing factors to the aquatic life non-support. With generally "good" habitat found throughout this subwatershed, likely contributing factors to the loss of sensitive fish and/or macroinvertebrates are other aquatic life stressors driven by both natural processes and current land use.

The most prevalent aquatic life stressor within this subwatershed is turbidity, with six of the seven stations assessed not supporting aquatic life. Streams with the most predominant turbidity issues were located in the Superior Lake Plain MLRA. Soils within this MLRA are dominated by red clays, which can exceed over 60 meters in depth, and can contribute an extensive amount of sediment to the Nemadji River and ultimately Lake Superior. This transport and deposition of sediment are likely the result of natural erosion from active geologic uplifting and climate. This natural process is amplified by both historical and current land use patterns that have altered vegetation throughout the Nemadji River Watershed. In addition, two known groundwater upwellings exist within the Nemadji River Watershed; with one located on Deer Creek (04010301-532). These natural springs contribute an extensive amount of sediment not only to their contributing waters but also to the Nemadji River proper (Mossberger, 2010; Figure 16).

Other aquatic recreation and consumption indicators also appear to be responding to both historical and current land use changes within select drainages. Fish consumption impairments were identified on four stream segments (Nemadji River, 04010301-556, -757, & -758; Nemadji Creek, 04010301-545) and one lake (Sand Lake, 09-0016-00) (Table 18). In addition, bacteria (E. coli) levels were relatively high in the Nemadji River proper (04010301-758), with two of the three summer months (July and August) exceeding the 126 colonies/100 mL standard (Table 9). These aquatic recreation and consumption impairments are likely associated with overland runoff and could be mitigated by addressing other aquatic life impairments.

Stressors throughout individual catchments vary widely and are likely a function of both natural and anthropogenic factors. Point source pollution sources are limited throughout the Nemadji River Watershed. Non-point pollutants are likely the main contributing factor to current aquatic life, recreation, and consumption impairments. Stressors are numerous and include bank erosion, altered hydrology (dam and undersized culverts), vegetation modification, habitat fragmentation and destruction, thermal regime alteration, and turbidity. Hydrological alterations are numerous throughout this subwatershed and include dams and other fish barriers on Elim Creek, Skunk Creek, Tributary to Deer Creek and many other unnamed tributaries. Although Skunk Creek (04010301-504) is not impaired for aquatic life (F-IBI), a barrier located just upstream of its confluence with the Nemadji River prevents migration and survival of trout species in available habitat found within Elim and Skunk Creeks. Other barriers located on streams within this subwatershed alter both flow and thermal regimes to where aquatic life is impacted.

The subwatershed contains assessment level data on four lakes: Bear, Spring, Hay, and Sand. All lakes were sampled by the Carlton County Soil and Water Conservation District staff and citizen volunteers. Bear Lake covers 32 acres and is located 3 miles north of the community of Blackhoof. Bear is a seepage lake that outlets through a wetland complex and eventually to the Blackhoof River. The lake has a small watershed of 1.7 square miles, consisting primarily of forest and wetlands. The lakeshore is mostly undeveloped; the lake does not have public access. Data indicate mesotrophic conditions, with moderate levels of phosphorus and average values below the 30 µg/L standard. Chlorophyll-a concentrations were very near NLF standards (Table 10). Overall the lake was assessed as fully supporting of aquatic recreational use, however some samples did indicate occasional high levels of chlorophyll-a, at levels associated with mild to moderate algae blooms (greater than 10-15 µg/L). Transparency is quite high compared to other area lakes, averaging 3.2 meters (10.5 feet). There are insufficient Secchi transparency data to determine trends.

Spring Lake covers 41 acres and is located about 2 miles west of Blackhoof. The lake forms the headwaters of a Blackhoof River tributary and drains a very small wetland dominated watershed of 287 acres (0.45 square miles). The lake is about 80% littoral, with a max depth of 2 meters. The lakeshore is primarily undeveloped. Data indicate mesotrophic conditions. Phosphorus, chlorophyll-a, and Secchi transparency values are meeting standards, and the lake was assessed as fully supporting of aquatic life. There are insufficient Secchi transparency data to determine trends. In summary, water quality conditions in Spring Lake are at expected levels given the lake's environmental setting.

Hay Lake covers approximately 103 acres and is located 5 miles south of Carlton. Hay is a shallow lake (95% littoral) with a maximum depth of 14 feet (4.2 m). The lake is surrounded by a large wetland complex. The lake drains a 2,300 acre (3.6 square mile) watershed of forest and wetland; the lake's outlet is in the southwest corner and flows toward the Blackhoof River. Most of the lakeshore is undeveloped. Similar to other assessed lakes within the watershed, data indicate mesotrophic conditions, with moderate levels of phosphorus and chlorophyll-a. Secchi transparency averaged 1.6 m (5.2 feet) and was slightly below standards; and was likely naturally limited from bog staining.

Sand (Sandy) Lake covers 123 acres and is located 5 miles west of Blackhoof. The lake drains a small wetland dominated watershed, although there is a fair amount of pastureland in the vicinity. The lake is shallow (99% littoral) with a maximum depth of 27 feet (8.2 m). Sandy is a productive lake, with an average total phosphorus concentration of 29 µg/L, just below the NLF standard. Chlorophyll-a concentrations are at lower than expected levels given the relatively high TP concentrations in the lake. Like many lakes draining wetland dominated watersheds, transparency is limited by bog staining. Overall, the lake was assessed as fully supporting of aquatic recreation. There are insufficient Secchi transparency data to determine trends.

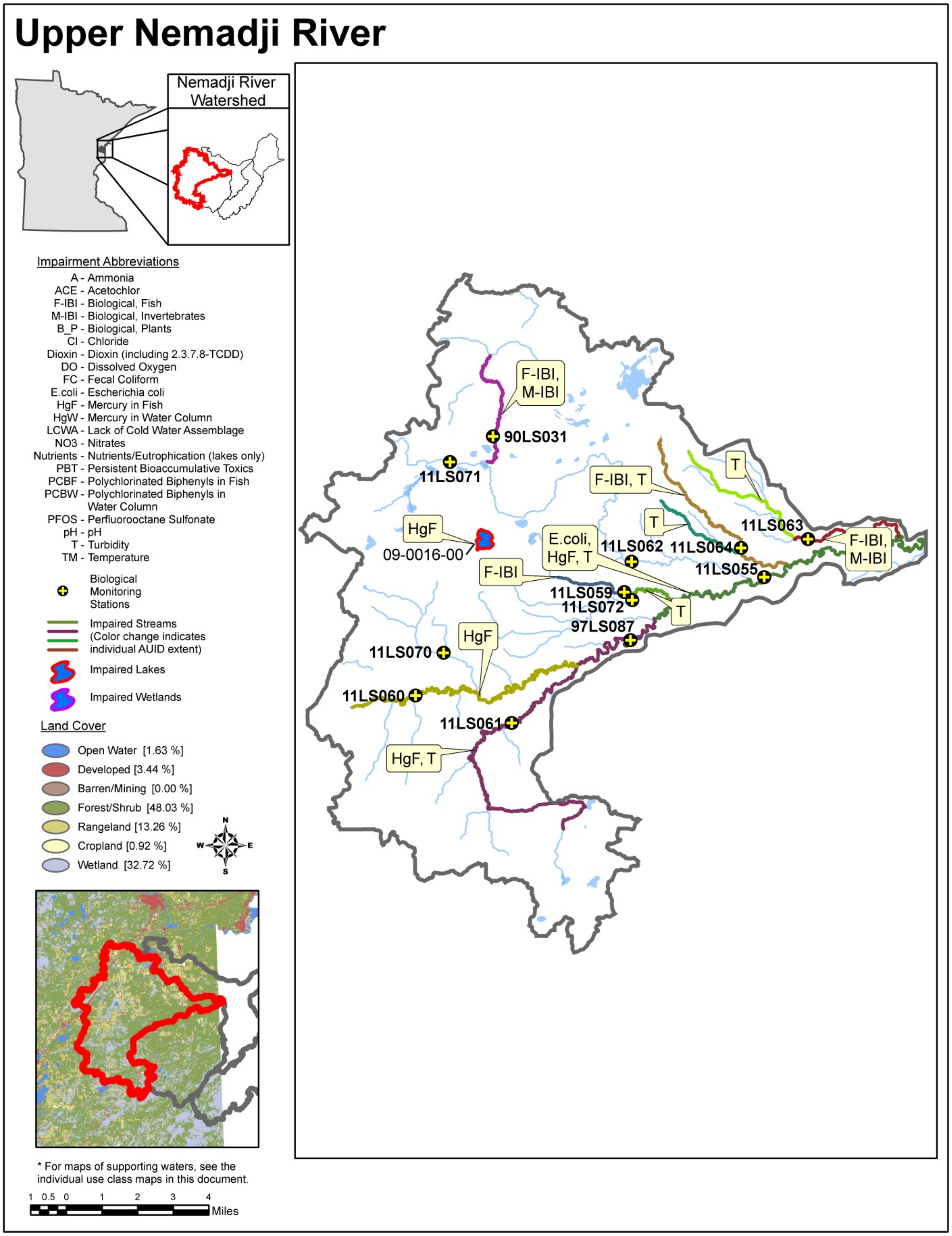

Figure 17. Currently listed impaired waters by parameter and land use characteristics in the Upper Nemadji River Subwatershed.

Black River Subwatershed HUC 0401030103

The Black River Subwatershed drains 92.78 square miles or 59,379.2 acres between Minnesota (17.89%) and Wisconsin (82.11%). The portion that lies within Minnesota consists of 16.6 square miles of Pine County and is the smallest subwatershed. The headwaters of the Black River starts just 2.5 miles north of Belden and flows to the east where it crosses the Minnesota/Wisconsin border, and ultimately into the mainstem Nemadji River.

There is only one lake greater than 10 acres. Due to the lack of public access and the overall remoteness of the lake, it was not sampled.

This subwatershed is dominated by forest (62.34%), wetland (30.58%), and rangeland (3.34%). Only 1.98% is developed land, 1.16% is open water, 0.59% is row-crop agriculture, and 0.01% is barren/mining. Portions of this watershed are within the Black Lake Bog Scientific and Natural Area.

Only a small portion of this subwatershed lies within Minnesota and consists of the headwaters of the Black River. There is little to no road access throughout the watershed. Due to the overall remoteness of this subwatershed, no biological or water chemistry stations were sampled.

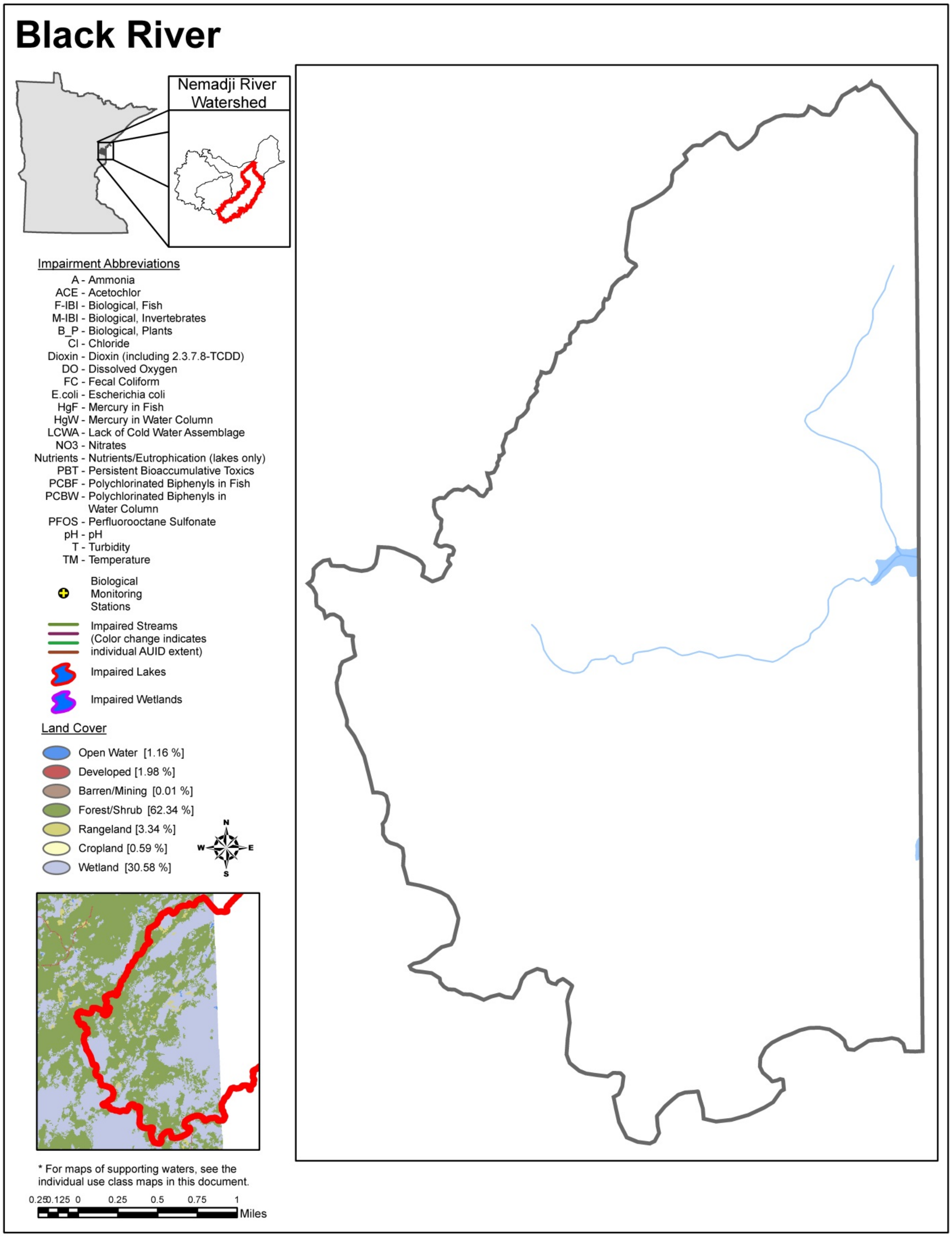

Figure 18. Currently listed impaired waters by parameter and land use characteristics in the Black River Subwatershed.

Middle Nemadji River Subwatershed HUC 0401030104

The Middle Nemadji River Subwatershed drains 75.13 square miles or 48,083.2 acres between Minnesota (39.84%) and Wisconsin (60.16%). The portion that lies within Minnesota consists of 29.93 square miles of Carlton County and is the third largest subwatershed. Only three minor watersheds are within Minnesota boundaries and all flow to the southeast, directly into the Nemadji River. The three minor watersheds (HUC-14) are Clear Creek, Mud Creek, and Unnamed Creek (Nemadji River Tributary). The headwaters of the three minors are near the town of Wrenshall and Scotts Corner.

This subwatershed contains a total of seven lakes greater than 10 acres, with the most prominent lakes being Chub, Venoah, and Lac La Belle.

This subwatershed is dominated by forest (66.23%), wetland (13.62%), and rangeland (13.26%). Only 3.80% is developed land, 2.02% is open water, and 1.07% is row-crop agriculture.

The portion of this subwatershed that lies within the Minnesota boundaries consists of only minor drainages and for that reason no outlet water chemistry monitoring was conducted.

Table 11. Aquatic life and recreation assessments on stream reaches: Middle Nemadji River Subwatershed. Reaches are organized upstream to downstream in the table.

AUID **Reach Name**, *Reach Description*	Reach Length (miles)	Use Class	Biological Station ID	Location of Biological Station	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Pesticides	Bacteria	Aquatic Life	Aquatic Rec.
04010301-537 **Mud Creek** *T47 R16W S6, West Line to MN/WI Border*	11.01	2A	11LS058	Upstream of Soo Line Trail, in Frogner	EXP	MTS	- -	EXS	MTS	- -	MTS	- -	- -	NS	NA
04010301-527 **Clear Creek** *T48 R16W S33, West Line to MN/WI Border*	7.93	2A	11LS056	Downstream of Hwy 23, 2 mi. SW of State Line	EXS	EXP	MTS	EXP	- -	- -	- -	- -	- -	NS	NA

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria).
Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, **FS** = Full Support
Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use.

Table 12. Minnesota Stream Habitat Assessment (MSHA): Middle Nemadji River Subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-15)	Substrate (0-27)	Fish Cover (0-17)	Channel Morph. (0-36)	MSHA Score (0-100)	MSHA Rating
1	11LS058	Mud Creek	4.5	10	17.3	12	28	71.8	Good
1	11LS056	Clear Creek	4.5	12	19	8	29	72.5	Good
Average Habitat Results: *Middle Nemadji River Subwatershed*			**4.5**	**11**	**18.15**	**10**	**28.5**	**72.15**	**Good**

Qualitative habitat ratings

- = Good: MSHA score above the median of the least-disturbed stations (MSHA > 66)
- = Fair: MSHA score between the median of the least-disturbed stations and the median of the most-disturbed stations (45 < MSHA < 66)
- = Poor: MSHA score below the median of the most-disturbed stations (MSHA < 45)

Table 13. Channel Condition and Stability Assessment (CCSI): Middle Nemadji River Subwatershed.

# Visits	Biological Station ID	Stream Name	Stream Type	Upper Banks (43-4)	Lower Banks (46-5)	Substrate (37-3)	Channel Evolution (11-1)	CCSI Score (137-13)	CCSI Rating
1	11LS058	Mud Creek	MHL	28	27	15	2	72	Moderately Unstable
1	11LS056	Clear Creek	MHL	24	36	22	7	89	Severely Unstable
Average Stream Stability Results: *Middle Nemadji River Subwatershed*				**26**	**31.5**	**18.5**	**4.5**	**80.5**	**Severely Unstable**

Qualitative channel stability ratings

= Stable: CCSI < 27 = Fairly stable: 27 < CCSI < 45 = Moderately unstable: 45 < CCSI < 80 = Severely unstable: 80 < CCSI < 115 = Extremely unstable: CCSI > 115

Stream Types

HBC = High Gradient Confined; **MHL** = Meandering, w/ High-Low Banks; **MW** = Meandering Wetland Channel; **TC** = Trapezoidal Channelized; **TCM** = Trapezoidal Channelized Meandering; **WC** = Wetland Channelized

Table 14. Lake water aquatic recreation assessments: Middle Nemadji River Subwatershed.

	DOW#	Area (acres)	Trophic Status	% Littoral	Max. Depth (m)	Avg. Depth (m)	CLMP Trend	Mean TP (µg/L)	Mean Chl-a (µg/L)	Secchi Mean (m) Name	Support Status
Chub	09-0008-00	274	M	54	8.5	4.1	I	22	11.3	3.9	FS
Venoah	09-0009-00	82	M	90	5.4	1.0	NT	15	2.8	3.4	FS
Lac La Belle	09-0011-00	36	E	- -	- -	1.0	NT	61	43.4	1.6	NS

Abbreviations:
D -- Decreasing/Declining Trend
I -- Increasing/Improving Trends
NT – No Trend
H – Hypereutrophic
E – Eutrophic
M – Mesotrophic
O -- Oligotrophic
FS – Full Support
NS – Non-Support
IF – Insufficient Information
[1] – Depth Is Estimated

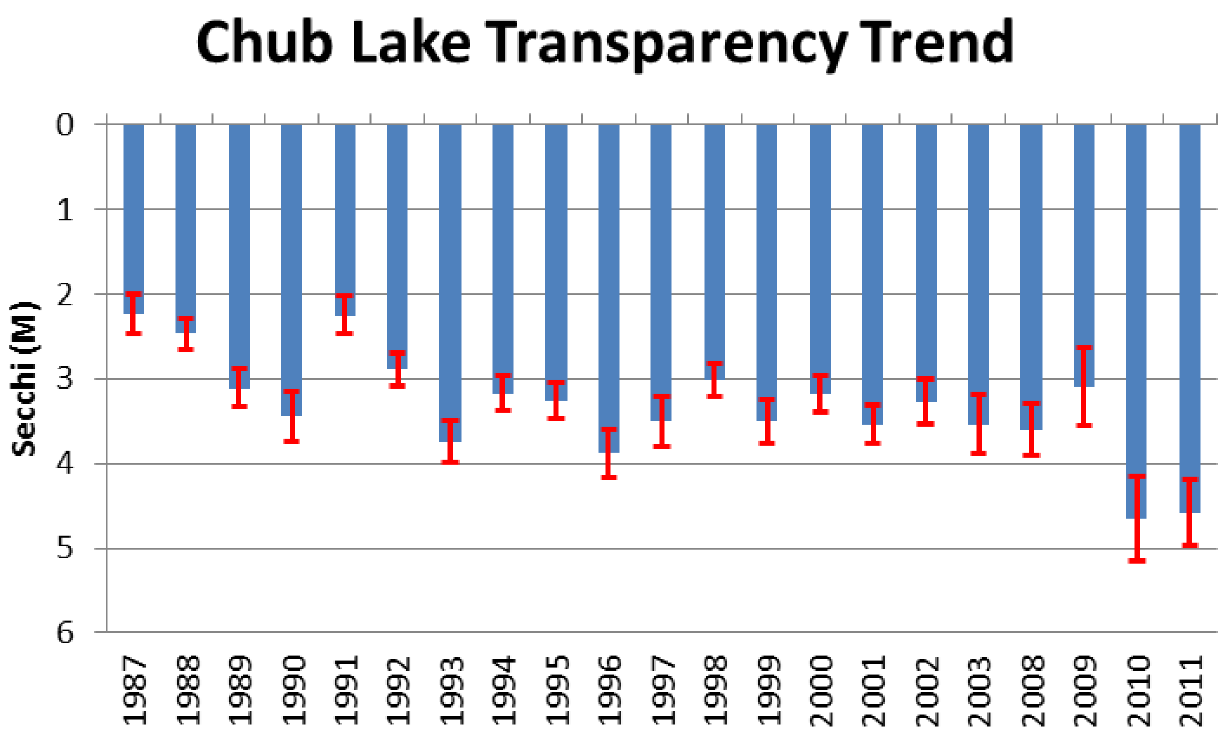

Figure 19. Chub Lake transparency trend.

Summary

The Middle Nemadji River Subwatershed had two assessable AUIDs on two coldwater designated streams and three lakes assessed for aquatic recreation (Table 11 & Table 14). Relatively poor water quality can be found throughout this subwatershed; all assessable stream segments do not support aquatic life based on biological (F/M-IBI) and chemical (turbidity) parameters. Although stream habitat appears to be in "good" condition (Table 12), CCSI ratings indicate a "moderately unstable" to "severely unstable" channel (Table 13). The contradictory results between the high quality of stream habitat and poor channel stability can occur when there is sufficient flow to suspend fine grained, erodible bank material through higher gradient portions of the stream system. This condition exists throughout the Nemadji River Watershed where, in spite of high levels of bank erosion, the relatively high stream gradient results in flow rates with enough energy to carry the erodible clay soils through riffle habitats. Thus, in the Nemadji coarse substrate is often present on the stream bottom, particularly in riffle habitats, and the stream morphology is better than one would expect given the lack of stream stability. Natural channel evolution driven by geologic uplifting, climate, current/historical land use changes, and other natural processes all may be contributing to the poor channel stability.

Systemic levels of high turbidity can be found in both Clear (04010301-527) and Mud Creeks (04010301-537). Similar to other tributaries impaired by turbidity in the Nemadji River Watershed, both streams are located in the Superior Lake Plain MLRA where soils are dominated by red clays. These red clays are highly erodible and contribute extensive amounts of sediment to the Nemadji River, and ultimately Lake Superior. The transport and deposition of sediment are likely the result of natural erosion from active geologic uplifting and climate that are amplified by both historical and current land use patterns that have altered vegetation throughout the watershed. In addition, this subwatershed also contains a groundwater upwelling on Mud Creek (04010301-537), which contributes an extensive amount of sediment not only to its own contributing waters but also to the Nemadji River proper (Mossberger, 2010). A current TMDL study is underway within the Nemadji River Watershed to address turbidity and other existing impairments.

Just one biological monitoring station (11LS056) was located on Clear Creek. Both F-IBI and M-IBI indicate poor water quality. This station featured a fish community dominated by pioneer species (76%) that are typically the first to recolonize after a disturbance. Ambient water temperatures throughout the summer months (June-September) of 2003-2005 were well within the range of brook trout growth, with only 3% thermal stress. Although suitable habitat and temperatures were present for coldwater obligate species, the fish community was dominated by tolerant warmwater species that are often found at the most disturbed stations. The macroinvertebrate community was also comprised of many tolerant species, with low species richness, and a lack of both stoneflies and dragonflies. Considering this information, along with the high levels of Nitrite-Nitrate (NO_2/NO_3), it is possible that poor land use (~41% disturbed) practices are likely contributing to the poor biological condition found within this drainage. Potential barriers also exist within this drainage and are located at the Soo Line Trail in Wisconsin and upstream of Minnesota Highway 23 (MPCA, 2014).

The only other biological monitoring station within this subwatershed was located on Mud Creek (04010301-537). Similar to Clear Creek, the fish community was dominated by both pioneer (60%) and tolerant (53%) species. Although ambient water temperature was slightly warmer than Clear Creek, the thermal regime was still adequate for the growth of brook trout, with only 17% stressful conditions recorded during the summer months of 2004-2006. The M-IBI score was below the threshold but within the confidence interval, with several sensitive species present. Likely contributing factors to the lower M-IBI score are the absence of dragonflies, other predacious species, and very few intolerant individuals.

Considering this information, likely contributing factors to aquatic life impairment based on fish include: a potential barrier to fish migration at Soo Line Trail, stream instability driven by soil types, current land use, and sediment contributed by groundwater upwelling.

Chub Lake is a popular recreational lake within Carlton County and is located at the northwest corner of the subwatershed, south of Carlton. The lake covers 274 acres, and has a maximum and mean depth of 8.5 and 4.1 meters, respectively. Chub Lake is deeper than most lakes in the subwatershed. The lake is highly developed and designated as an infested water due to the presence of Eurasian water milfoil. Chub is a mesotrophic lake; phosphorus concentrations averaged 22 µg/L. Average chlorophyll-a concentrations (11.2 µg/L) were higher than expected given the lake's phosphorus concentration, and influenced by a few samples taken in the late summer during mild bloom conditions. There is a long-term Secchi dataset, with annual CLMP data collected since 1987 (Figure 19). The data indicate an increasing trend in transparency and clearer water than most lakes within the subwatershed; higher Secchi readings were observed in recent years. Overall, the lake fully supported aquatic recreation.

Venoah Lake covers 82 acres and is located 1 mile east of Chub Lake. The lake drains a 2,815 acre (4.4 square mile) watershed of forests and wetlands. The lakeshore is in a natural state; there is just one developed property in the vicinity. The lake does not have a public access. Water quality in Venoah Lake is excellent and fully supported aquatic recreation. The lake had the lowest average phosphorus and chlorophyll-a concentrations of any monitored lake in the entire Nemadji Watershed (see Appendix 9).

Lac La Belle covers 36 acres and is located 2 miles west of Wrenshall. The lake does not have a public access, bathymetric map or MDNR fisheries assessment. The lake is likely very shallow. The lakeshore is moderately developed, and most of it has occurred in the last 5 years. Lac La Belle is very productive and has poor water quality. It had the highest phosphorus and chlorophyll-a concentrations of all monitored lakes in the Nemadji watershed. Chlorophyll concentrations averaged 43 µg/L, more than four times the NLF standard. Individual samples in mid-summer periodically exceeded 50-100 µg/L, indicative of very severe algal blooms. Secchi transparency averaged 1.6 meters (5.2 feet), and was likely affected by bog stain water from the surrounding wetlands. Lac La Belle does not support aquatic recreation.

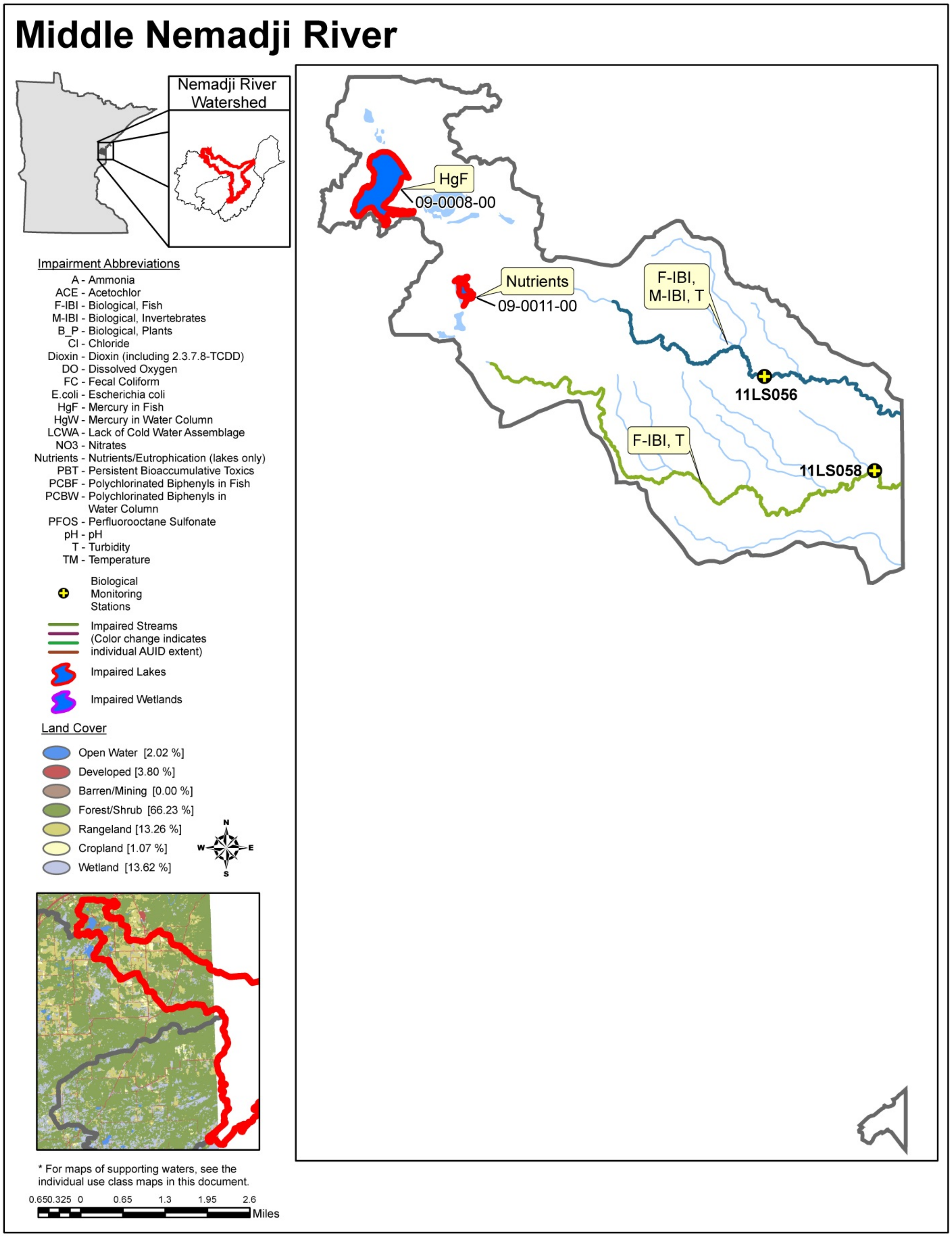

Figure 20. Currently listed impaired waters by parameter and land use characteristics in the Middle Nemadji River Subwatershed.

VI. Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed of the Nemadji River, grouped by sample type. Summaries are provided for load monitoring data results near the mouth of the river, aquatic life and recreation uses in streams and lakes throughout the watershed, and for aquatic consumption results at select river and lake locations within the watershed. Additionally, groundwater monitoring results and long-term monitoring trends are included where applicable.

Following the results are a series of graphics that provide an overall summary of assessment results by designated use, impaired waters, and fully supporting waters within the entire Nemadji River Watershed.

Watershed Pollutant Load Monitoring Network

The Nemadji River is monitored at Country Road C near South Superior, Wisconsin before flowing into Lake Superior. Many years of water quality data from throughout Minnesota combined with the previous analysis of Minnesota's ecoregion patterns, resulted in the development of three "River Nutrient Regions" (RNR), each with unique nutrient standards (MPCA, 2008). Of the state's three RNRs (North, Central, South), the Nemadji River's monitoring station is located within the North RNR.

Annual flow weighed mean concentrations (FWMCs) were calculated and compared for years 2009-2011 (Figure 21, Figure 22, Figure 23, and Figure 24) and compared to the RNR standards (only TP and TSS draft standards are available for the North RNR). It should be noted that while a FWMC exceeding a given water quality standard is generally a good indicator that the water body is out of compliance with the RNR standard, the rule does not always hold true. Waters of the state are listed as impaired based on the percentage of individual samples exceeding the numeric standard, generally 10% and greater, over the most recent 10 year period and not based on comparisons with FWMCs (MPCA, 2012). A river with a FWMC above a water quality standard, for example, would not be listed as impaired if less than 10% of the individual samples collected over the assessment period were above the standard.

Pollutant sources affecting rivers are often diverse and can be quite variable from one watershed to the next depending on land use, climate, soils, slopes, and other watershed factors. However, as a general rule, elevated levels of TSS and nitrate plus nitrate-N are generally regarded as "non-point" source derived pollutants originating from many small diffuse sources such as urban or agricultural runoff. Excess TP and DOP can be attributed to both "non-point" as well as "point", or end of pipe, sources such as industrial or waste water treatment plants. Major "non-point" sources of phosphorus include dissolved phosphorus from fertilizers and phosphorus adsorbed to and transported with sediment during runoff.

Within a given watershed, pollutant sources and source contributions can also be quite variable from one runoff event to the next depending on factors such as: canopy development, soil saturation level, and precipitation type and intensity. Surface erosion and in-stream sediment concentrations, for example, will typically be much higher following high intensity rain events prior to canopy development rather than after low intensity post-canopy events where less surface runoff and more infiltration occur. Precipitation type and intensity influence the major course of storm runoff, routing water through several potential pathways including overland, shallow and deep groundwater, and/or tile flow. Runoff pathways along with other factors determine the type and levels of pollutants transported in runoff to receiving waters and help explain between-storm and temporal differences in FWMCs and loads, barring differences in total runoff volume. During years when high intensity rain events provide the greatest proportion of total annual runoff, concentrations of TSS and TP tend to be higher and DOP and nitrate-N concentrations tend to be lower. In contrast, during years with high snow melt runoff and less intense rainfall events, TSS levels tend to be lower while TP, DOP, and nitrate-N levels tend to be elevated (Table 15).

Table 15. Annual pollutant loads by parameter calculated for the Nemadji River.

	2009	2010	2011
Parameter	**Mass (kg)**	**Mass (kg)**	**Mass (kg)**
Total Suspended Solids	20,703,349	50,137,402	120,131,100
Total Phosphorus	27,574	63,687	114,585
Ortho Phosphorus	9,467	60,603	106,874
Nitrate + Nitrite Nitrogen	19,037	26,949	24,179

Total suspended solids

Water clarity refers to the transparency of water. Turbidity is a measure of the lack of transparency or "cloudiness" of water due to the presence of suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter, and plankton or other microscopic organisms. By definition, turbidity is caused primarily by suspension of particles that are smaller than one micron in diameter in the water column.

Analysis has shown a strong correlation to exist between the measures of TSS and turbidity. The greater the level of TSS, the murkier the water appears and the higher the measured turbidity. High turbidity results in reduced light penetration that harms beneficial aquatic species and favors undesirable algae species (MPCA and MSUM 2009). An overabundance of algae can lead to increases in turbidity, further compounding the problem. Periods of high turbidity often occur when heavy rains fall on unprotected soils. Upon impact, raindrops dislodge soil particles and overland flow transports fine particles of silt and clay into rivers and streams (MPCA and MSUM 2009).

At the time of the writing of this report, the state of Minnesota's TSS standards were moving from development to approval, and must be considered to be draft standards until complete approval. Within the North RNR, the TSS draft standard is 15 mg/L (MPCA 2010c), when greater than 10% of the individual samples exceed the draft standard, the river is out of compliance. Calculations from 2009 through 2011 show 68, 74, and 81% of the individual TSS samples exceeded the 15 mg/L draft standard, respectively. In addition, for the computed FWMCs for the three sampling years, all three years exceeded the 15 mg/L draft standard as shown in Figure 21. In 2011, the sample with the highest measured TSS concentrations (1200mg/L) was collected on the rising limb of a high intensity rainfall event in early May and again in early August. One possible explanation for the increase in annual TSS load for the 3 years is that most of the runoff occurred in the early summer and early fall during high intensity rain events, and each year the intensity and frequency of these events increased.

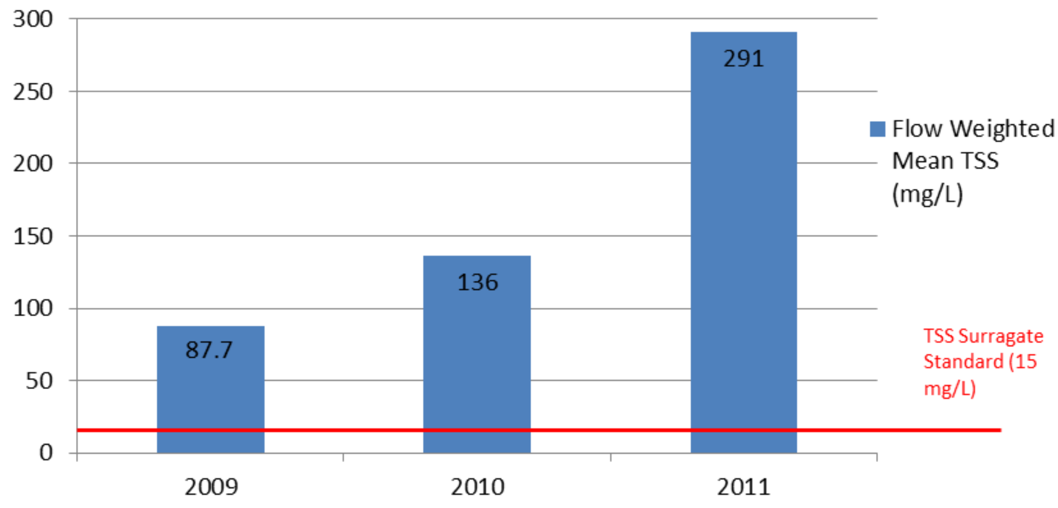

Figure 21. Total suspended solids (TSS) flow weighted mean concentrations in the Nemadji River Watershed.

Total phosphorus

Nitrogen (N), phosphorus (P), and potassium (K) are essential macronutrients and are required for growth by all animals and plants. Lack of sufficient nutrient levels in surface water often restricts the growth of aquatic plant species (University of Missouri Extension 1999). In freshwaters such as lakes and streams, phosphorus is typically the nutrient limiting growth; increasing the amount of phosphorus entering a stream or lake will increase the growth of aquatic plants and other organisms. Although phosphorus is a necessary nutrient, excessive levels overstimulate aquatic growth in lakes and streams resulting in reduced water quality. The progressive deterioration of water quality from overstimulation of nutrients is called eutrophication where, as nutrient concentrations increase, the surface water quality is degraded (University of Missouri Extension 1999). Elevated levels of phosphorus in rivers and streams can result in: increased algae growth, reduced water clarity, reduced oxygen in the water, fish kills, altered fisheries, and toxins from cyanobacteria (blue green algae) which can affect human and animal health (University of Missouri Extension 1999). In "non-point" source dominated watersheds, TP concentrations are strongly correlated with stream flow. During years of above average precipitation, TP loads are generally highest.

Total phosphorus standards for Minnesota's rivers are also in the final approval phase and must be considered draft standards until approved. Within the North RNR, the TP draft standard is 50 ug/L as a summer average (Figure 22). Summer average violations of one or more "response" variables (pH, biological oxygen demand (BOD), dissolved oxygen flux, chlorophyll-a) must also occur along with the numeric TP violation for the water to be listed. Concentrations from 2009, 2010 and 2011 show that 68, 70, and 77% of the individual TP samples exceeded the 50 ug/L draft standard, respectively. In 2011, the sample with the highest measured TP concentrations (1.12 mg/L) was collected on the rising limb of a high intensity rainfall event in August. One possible explanation for the increase in annual TP load for the 3 years is that most of the runoff occurred in the late summer/early fall during high intensity rain events, and each year the intensity and frequency of these events increased.

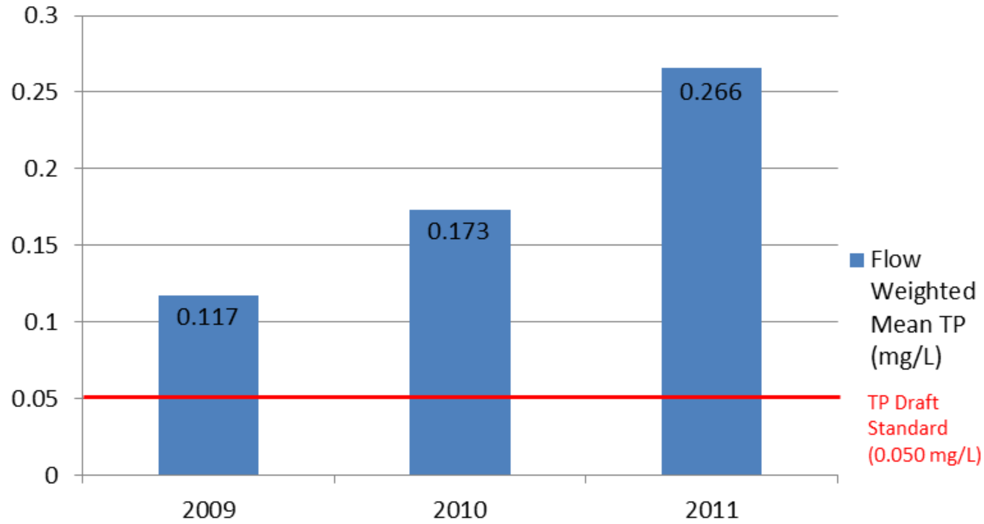

Figure 22. Total phosphorus (TP) flow weighted mean concentrations for the Nemadji River.

Dissolved orthophosphate

Dissolved orthophosphate is a water soluble form of phosphorus that is readily available to algae (bioavailable) (MPCA and MSUM 2009). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from wastewater treatment plants, noncompliant septic systems, and fertilizers in urban and agricultural runoff. The 2009 through 2011 FWMC ratio of DOP to TP shows that 34 to 95% of TP is in the orthophosphate form (Figure 23).

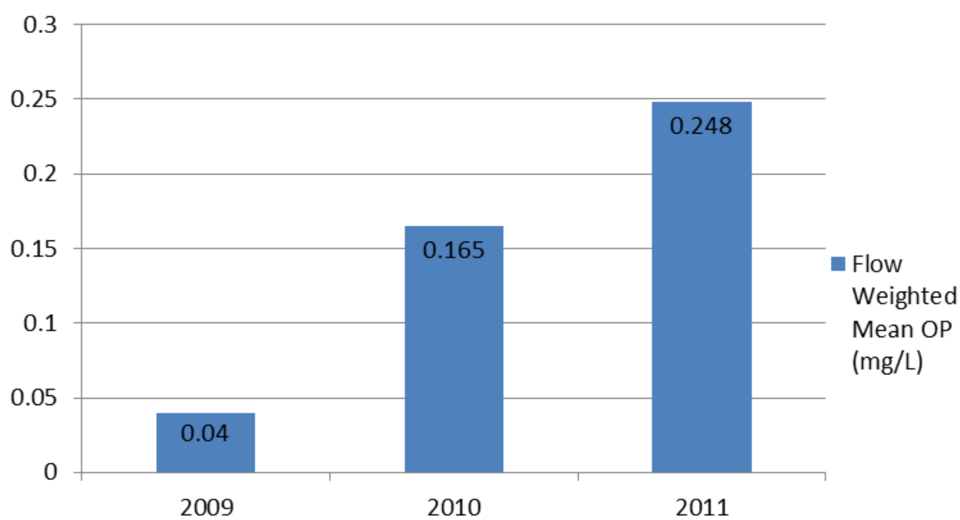

Figure 23. Dissolved orthophosphate (DOP) flow weighted mean concentrations for the Nemadji River.

Nitrate plus nitrite - nitrogen

Nitrate and nitrite-nitrogen are inorganic forms of nitrogen present within the environment that are formed through the oxidation of ammonia-nitrogen by nitrifying bacteria (nitrification). Ammonia-nitrogen is found in fertilizers, septic systems, and animal waste. Once converted from ammonia-nitrogen to nitrate and nitrite-nitrogen, they too, like phosphorus, can stimulate excessive levels of some algae species in streams (MPCA, 2008). Because nitrate and nitrite-nitrogen are water soluble, transport to surface waters is enhanced through agricultural drainage. The ability of nitrite-N to be readily converted to nitrate-nitrogen is the basis for the combined laboratory analysis of nitrate plus nitrite-nitrogen, with nitrite-nitrogen typically making up a small proportion of the combined total concentration. These and other forms of nitrogen exist naturally in aquatic environments; however concentrations can vary drastically depending on season, biological activity, and anthropogenic inputs. Environmentally, studies have shown that the elevated nitrate-nitrogen levels in the Minnesota River basin contribute to hypoxia (low levels of dissolved oxygen) in the Gulf of Mexico. This occurs by nitrate-nitrogen stimulating the growth of algae which, through death and biological decomposition, consume large amounts of dissolved oxygen and thereby threaten aquatic life (MPCA and MSUM, 2009).

Nitrate-N can also be a common toxicant to aquatic organisms in Minnesota's surface waters with invertebrates appearing to be the most sensitive to nitrate toxicity. Draft nitrate-N standards have been proposed for the protection of aquatic life in lakes and streams. The draft acute value (maximum standard) for all Class 2 surface waters is 41 mg/L nitrate-N for a 1-day duration, and the draft chronic value for Class 2B (warm water) surface waters is 4.9 mg/L nitrate-N for a 4-day duration. In addition, a draft chronic value of 3.1 mg/L nitrate- N (4-day duration) was determined for protection of Class 2A (cold water) surface waters (MPCA, 2010).

Nitrate-N FWMCs from 2009 through 2011 for the Nemadji Watershed were 0.08, 0.073, and 0.056 mg/L, respectively (Figure 24). There were no exceedences of the draft chronic standard. Figure 13 shows the nitrate-N FWMCs over the three-year period for the Nemadji River monitoring station. The FWMC for all three years were below the draft acute and chronic nitrate-N standards.

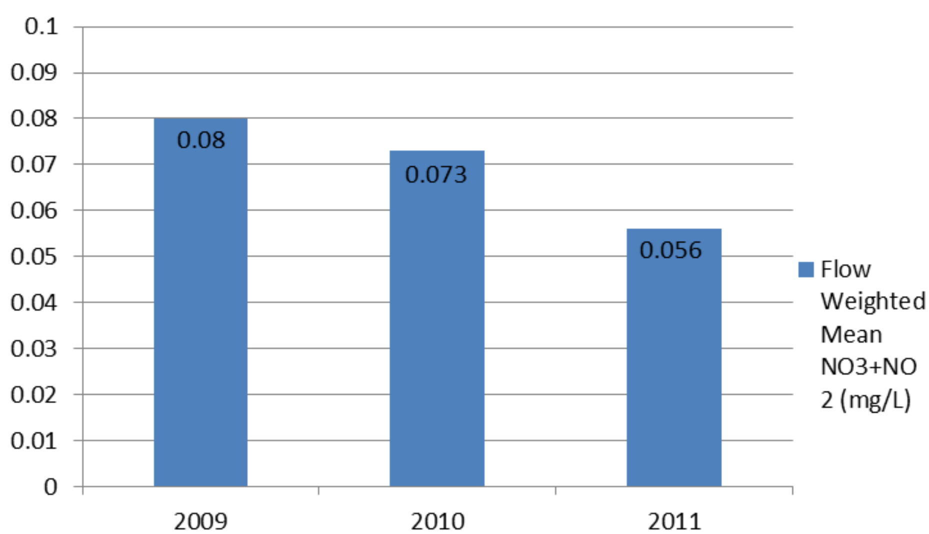

Figure 24. Nitrate + nitrite nitrogen (Nitrate-N) flow weighted mean concentrations for the Nemadji River.

Stream water quality

Twenty-two of the 258 stream segments within this watershed were assessed for the support of aquatic life, recreation, and/or consumption (Table 16). Of the assessed streams, only 10 streams fully supported aquatic life and none fully supported aquatic recreation. Throughout the watershed, 12 stream segments did not support aquatic life and/or recreation. Of those stream segments, 12 did not support aquatic life and two did not support aquatic recreation. Both the Nemadji River (04010301-556, -757, & -758) and Nemadji Creek (04010301-545) were assessed for fish consumption. They did not meet the standard and were listed as impaired for aquatic consumption due to elevated levels of mercury in fish tissue.

Overall, water quality conditions are fair, and reflect the forests and wetlands that dominate land cover within the Nemadji River Watershed. Problem areas do occur and persist throughout this watershed but are typically limited to the lower reaches of tributaries and major waterways where a combination of current landuse and soil erodibility are likely limiting the biological community. TSS and turbidity are the most prevalent water quality stressors within the watershed. Sources of the sediment and turbidity are numerous, and are a function of the watershed's geological setting (Figure 25), the river's geomorphology and current/historical land use practices (Reidel etal, 2005). Bio-accumulation of mercury in fish tissue was present throughout the watershed and is likely associated with overland runoff. Dissolved oxygen throughout the Nemadji River Watershed was good and can most likely be attributed to the cool water temperatures and high gradient nature of some waterways found within the watershed. Chloride and pH were within normal ranges reflecting the forested/wetland dominated watershed. Bacteria levels were elevated in all stream segments that were assessed for E. coli and are likely attributed to over land runoff and sediment input driven by soil erodibility and current land use practices. Many coldwater streams are present throughout the Nemadji River Watershed with exceptional water quality, and additional protections should be considered for streams that display outstanding biological, chemical, and physical parameters.

Table 16. Assessment summary for stream water quality in the Nemadji River Watershed.

				Supporting		Non-supporting			
Watershed	**Area (acres)**	**# Total AUIDs**	**# Assessed AUIDs**	**# Aquatic Life**	**# Aquatic Recreation**	**# Aquatic Life**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
Nemadji River (MN) HUC 8	**176,570**	**258**	**22**	**10**	**0**	**12**	**2**	**3**	**0**
South Fork Nemadji River	54,925	93	5	4	0	1	1	2	0
Upper Nemadji River	91,866	127	15	6	0	9	1	1	0
Black River	10,624	1	0	0	0	0	0	0	0
Middle Nemadji River	19,155	37	2	0	0	2	0	0	0

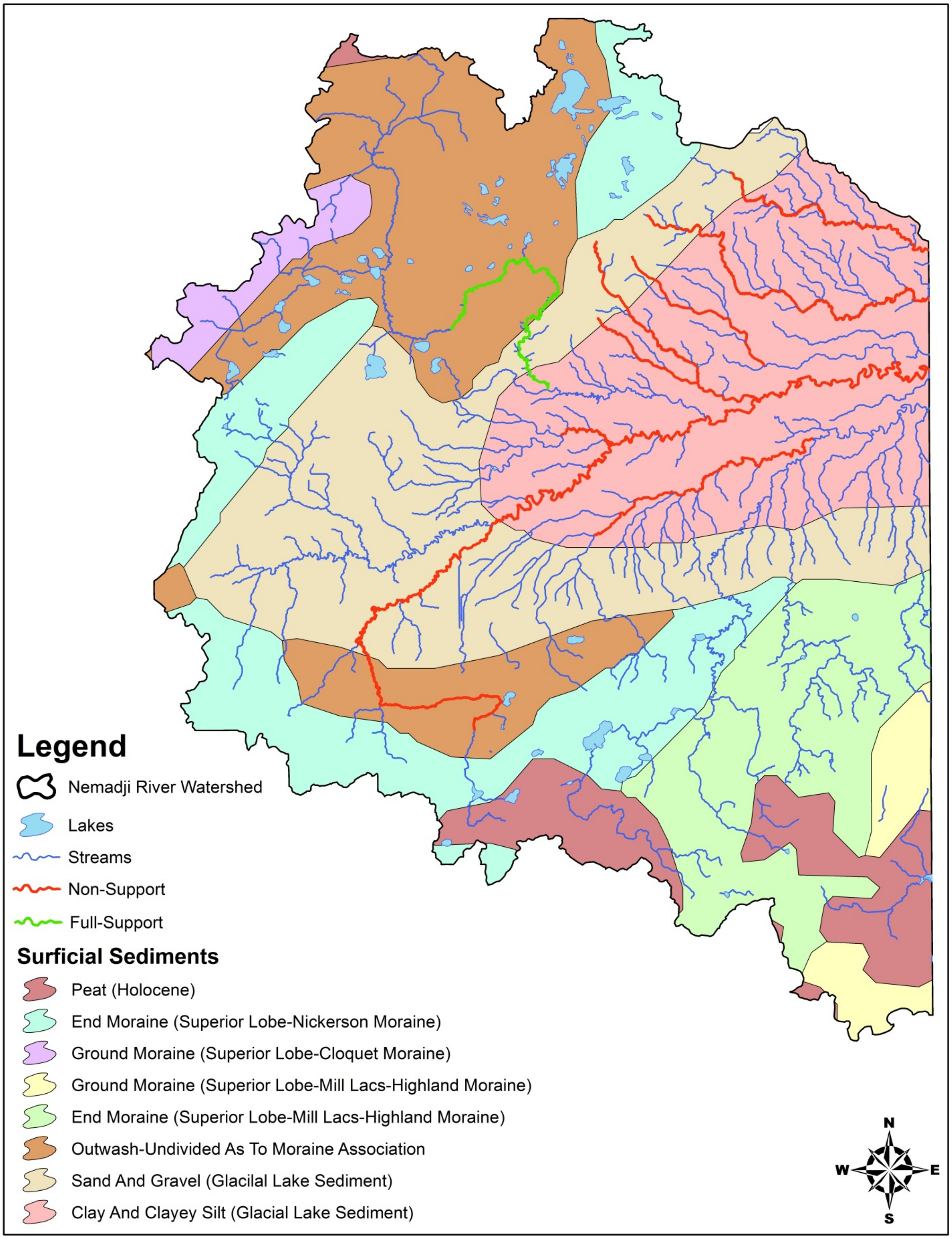

Figure 25. Turbidity full-support/non-support of aquatic life use as it relates to Major Land Resource Areas (MLRA)

Lake water quality

The Nemadji River Watershed contains 35 lakes greater than 10 acres in size (Table 17). Eight of the watershed's large and notable lakes were monitored in 2011 and 2012 by a mix of citizen volunteers and Carlton County Soil and Water Conservation District staff. These lakes included Bear, Chub, Hay, Lac La Belle, Net, Sand, Spring, and Venoah. Most of the lakes met eutrophication standards for cool and warm water lakes in the Northern Lakes and Forest ecoregion, and had phosphorus and chlorophyll-a concentrations at expected levels given the area's land use. Two lakes, Net and Lac La Belle, did not meet eutrophication standards and were listed as impaired for aquatic recreation. These lakes often had chlorophyll-a levels >10 ug/L, which indicate mild to moderate algae blooms and eutrophic conditions overall. Lakes listed as impaired prompt an investigative study termed a Total Maximum Daily Load (TMDL) to determine the sources and magnitude of the pollution problem and to set pollutant reduction goals needed to restore the waters.

Table 17. Assessment summary for lake water chemistry in the Nemadji River Watershed.

			Supporting	Non-Supporting		
Watershed	**Area (Acres)**	**Lake >10 Acres**	**# Aquatic Recreation**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
Nemadji River (MN) HUC 8	**176,570**	**35**	**6**	**2**	**27**	**0**
South Fork Nemadji River	54,925	8	0	1	7	0
Upper Nemadji River	91,866	19	4	0	15	0
Black River	10,624	1	0	0	1	0
Middle Nemadji River	19,155	7	2	1	4	0

Biological monitoring

Fish

The Lake Superior Basin spans a total of 49,300 square miles, encompassing three states (Michigan, Minnesota, and Wisconsin) and one Province (Ontario). Eighty-eight different species of fish can be found within this basin (including Lake Superior). Although the Minnesota portion of the Nemadji River Watershed encompasses only a small percentage (~0.5%) of the entire basin, 40 fish species were encountered during this survey (Appendix 10). Historically, fisheries management in streams of this region has focused on the stocking of various trout species. This stocking began as early as 1895 and still continues to this date to supplement recreational fishing within the watershed. As a result, various stream trout occur throughout the watershed, including this watershed's only native stream trout, the brook trout (*Salvelinus fontinalis*).

The Nemadji River Watershed does not have any endangered species under federal law but has a total of six species listed by the state of Minnesota as being of concern (Appendix 12). In addition, many introduced and invasive species are known to exist within the watershed, including zebra mussels (*Dreissena polymorpha*), quagga mussels (*Dreissena rostriformis bugensis*), spiny water flea (*Bythotrephes longimanus*), and numerous fish species (Appendix 12). Many of the fish species were either introduced during historical stocking efforts or likely through the exchange of ballast water from oceangoing vessels. This makes streams near the Duluth/Superior Harbor the most vulnerable to aquatic invasive species. In 2010, viral hemorrhagic septicemia (VHS), a microscopic fish disease, was discovered in Lake Superior. This fish disease possesses a relatively high risk to fish health within the entire Lake Superior Basin. Only three introduced species were encountered during sampling for this report, including *Petromyzon marinus* (sea lamprey), *Salmo trutta* (brown trout) and *Oncorhynchus mykiss* (Rainbow Trout).

The most frequently captured species was the *Etheostoma nigrum* (johnny darter), which occurred at 17 of the 20 stations (Appendix 10). Although the johnny darter was the most frequently captured, it was not the most abundant fish species within the Nemadji River Watershed. While only encountered at 16 stations throughout the watershed, the *Semotilus atromaculatus* (creek chub) was the most abundant fish species with 918 individuals collected. Numerous other species of fish were encountered at a majority of the station including *Cottus bairdii* (mottled sculpin), *Rhinichthys atratulus* (blacknose dace), *Catostomus commersonii* (white sucker), *Umbra limi* (central mudminnow), *Rhinichthys cataractae* (longnose dace), and *Luxilus cornutus* (common shiner). Fish that were encountered during sampling consisted of both warmwater riverine and coldwater obligate species. This is likely due to the diversity of water temperatures, habitat, and overall channel morphology found throughout the Nemadji River Watershed.

Certain attributes of the fish community, such as pollution tolerance, trophic (feeding) habits, reproductive traits, habitat preferences, species richness, and life history strategies can provide insight into the quality of the streams in which they inhabit. These attributes can not only be beneficial in identifying a streams status but also in identifying environmental stressors that may be contributing to aquatic life impairments. Fish species that are known to be intolerant or sensitive of disturbances are almost always a good indication of quality stream habitat, water chemistry, and connectivity. On the contrary, a fish assemblage that is dominated by tolerant species is likely an indication of poor water quality, habitat, or other natural or anthropogenic factors. Though there were many tolerant fish species captured throughout the watershed, select tributaries still held healthy populations of sensitive fish species. These sensitive species were generally found in coldwater tributaries where sufficient habitat and water chemistry were present to support these assemblages. The most frequently captured sensitive species was the mottled sculpin, which was found at 16 of the 20 stations. Although found at majority of the biological stations, its relative abundance was low. Many pioneering and tolerant species were found throughout this watershed. Tributaries that had relatively high turbidity were usually limited in the number of sensitive species and the total number of fish collected. This was not always true for larger systems where turbidity levels were often quite high but stream habitat was generally in good condition.

Macroinvertebrates

A total of 122 unique genera, representing 31 families and 49 species of macroinvertebrates were collected throughout the Nemadji River Watershed between 2010 and 2011. The most frequently captured macroinvertebrate taxa was *Simulium* (blackfly larvae), which occurred at 19 of the 21 stations (Appendix 11). Blackfly larvae were also the most abundant macroinvertebrate species within the Nemadji River Watershed. Other abundant species encountered at a majority of stations include caddisflies from the genera *Ceratopsyche* and *Cheumatopsyche*, midges from the genera *Polypedilum*, *Rheotanytarsus* and *Tvetenia*, riffle bettles from the genus *Optioservus*, and mayflies from the genera *Baetis flavistriga* and *Maccaffertium*. No Minnesota endangered, threatened or of special concern (ETSC) were encountered during the survey. Some notable species collected during the watershed survey include a stonefly species *Attaneuria ruralis*, caddisfly species *Micrasema gelidum*, *Neophylax aniqua* and *N. mitchelli*, mayfly species *Cercobrachys Etowah* and a dragonfly species *Cordulegaster maculata*. Many of these notable species were collected from Stateline Creek (11LS069), which had one of the highest F/M-IBI scores within the watershed.

Watershed-wide

Fish and macroinvertebrate communities throughout the Nemadji River Watershed are in generally fair to good condition, with most F-IBI and M-IBI scores meeting impairment thresholds. Habitat, water chemistry, and flow may all play a role in the diversity of the species and the relative abundance of sensitive aquatic life. Problem areas do occur and persist throughout the watershed and are likely a function of both natural and anthropogenic stressors. Current and historical land use practices have likely contributed to of the poor condition of some streams within this watershed. Bank erosion is severe in many streams of the watershed resulting in high levels of turbidity. Tributaries with high turbidity tended to have a low number of sensitive species and a limited amount of individuals. The high rate of stream bank erosion results in transportation and deposition of bank material that can impact stream habitat and aquatic assemblages; although to some extent the impacts may be lessened somewhat in the Nemadji because coarse substrates remain relatively free of embedded material in some higher gradient streams. Still, areas of exceptional water quality do exist and are typically limited to tributaries with minimal disturbance. Streams with exceptional biological, chemical, and physical parameters are worthy of additional protections in order to preserve their valuable aquatic resources. One of the most noteworthy streams based on biological parameters was State Line Creek (04010301-564), where both F-IBI and M-IBI were well above the threshold of impairment.

Fish contaminant results

Thirteen fish species from the Nemadji River, Chub Lake (Lake ID 09-0008-00), and Sand Lake (Lake ID 09-0016-00) were tested for mercury and/or PCBs. A total of 170 fish were tested between 1982 and 2011.

Table 18 is a summary of contaminant concentrations by waterway, fish species, and year. The table shows which contaminants, species, and years were sampled. “No. Fish” indicates the total number of fish analyzed and “N” indicates the number of samples. The number of fish exceeds the number of samples when fish are combined into a composite sample. This was typically done for panfish, such as bluegill sunfish and yellow perch. Since 1989, most of the samples have been skin-on fillets (FILSK) or for fish without scales (catfish and bullheads), skin-off fillets (FILET).

Five fish species were collected from the Nemadji River in 2011 and tested for mercury. All seven walleye had mercury concentrations above the state water quality standard for mercury in fish tissue (0.2 mg/kg); consequently, the river was recommended for the 2014 Draft Impaired Waters List. The two tested rock bass and three of the five tested white suckers also exceeded the mercury standard. The three muskies were small and had mercury levels below the mercury standard.

The two largest shorthead redhorse and walleye from the Nemadji River were also tested for PCBs. Concentrations of PCBs were all below the reporting limit of 0.025 mg/kg. PCBs concentrations were below the reporting limits for most of the fish tested in Chub and Sand lakes. The only significant PCBs concentration was in a bigmouth buffalo collected from Sand Lake in 1982; the PCBs concentration was 0.1 mg/kg. When averaged with the other bigmouth buffalo collected that same year, which had a PCBs concentration below the reporting limit (0.05 mg/kg), the average concentration is reported as 0.075 mg/kg.

Mercury concentrations in largemouth bass collected from Chub Lake in 2007 were high enough to trigger an impairment (the calculated 90th percentile mercury concentration exceeded 0.2 mg/kg) designation. Sand Lake has been on the Impaired Waters List since 1998. Many fish from Sand Lake have been tested for mercury, but the data are relatively old, with 1993 as the most recent year of collection.

The highest mercury concentration from all tested fish was 1.3 mg/kg in a northern pike collected from Sand Lake in 1988. The most recent results for Sand Lake’s northern pike, collected in 1993, show continued high mercury concentrations.

Overall, the fish contaminant results shows PCBs are not a concern in the Nemadji River, Chub Lake or Sand Lake. Mercury concentrations in fish tissue are sufficiently high for classification as impaired in the Nemadji River, as well as in the lakes. Sand Lake should be retested for mercury in fish because the last collection was in 1993.

Table 18. Summary statistics of mercury and PCBs, by waterway-species-year.

Waterway	AUID	Location	Species	Year	Anatomy[1]	No. fish	Length (in)			Mercury (mg/kg)				PCBs (mg/kg)	
							Mean	Min	Max	N	Mean	Min	Max	N	Mean
Nemadji River**	04010301 -545, -758 -757, -556	Downstream of HWY 23	Muskellunge	2011	FILSK	3	16.8	14.1	18.3	3	0.177	0.166	0.195		
			Rock Bass	2011	FILSK	2	7.4	7.2	7.5	2	0.231	0.228	0.233		
			Shorthead Redhorse	2011	FILSK	4	14.6	12.8	16	4	0.173	0.129	0.231	2	< 0.025
			Walleye	2011	FILSK	7	14.7	12.6	16.7	7	0.287	0.237	0.421	2	< 0.025
			White Sucker	2011	FILSK	5	14.6	14.2	15.5	5	0.233	0.184	0.303		
Chub*	09-0008-00		Black Crappie	2007	FILSK	7	7.1	7.1	7.1	1	0.045				
			Largemouth Bass	2007	FILSK	8	13.1	10.3	15.1	8	0.207	0.118	0.272		
			Northern Pike	1987	FILSK	5	23.3	23.3	23.3	1	0.180			1	0.018
			Walleye	1987	FILSK	5	16.5	16.5	16.5	1	0.230			1	< 0.01
Sand*	09-0016-00		Bigmouth Buffalo	1982	FILSK	5	20.4	16.3	24.5	2	0.045	0.020	0.070	2	0.075
			Bluegill Sunfish	1988	FILSK	15	6.7	6.7	6.7	1	0.100			1	< 0.01
				1993	FILSK	10	6.6	6.6	6.6	1	0.087				
			Black Bullhead	1982	FILET	9	10.4	10.4	10.4	1	0.050			1	< 0.05
			Black Crappie	1982	WHORG	5	8.4	8.4	8.4						
				1985	FILSK	5	6.7	6.7	6.7	1	0.080				
					WHORG	5	6.7	6.7	6.7						
			Common Carp	1982	FILSK	4	20.2	20.2	20.2	1	0.030			1	< 0.05
			Freshwater Drum	1982	FILSK	5	10.8	10.8	10.8	1	0.030			1	< 0.05
			Northern Pike	1982	FILSK	5	19.1	19.1	19.1	1	0.370				
					WHORG	5	19.1	19.1	19.1						
				1985	FILSK	10	22.4	18.6	28	3	0.447	0.360	0.580		
					WHORG	4	20.5	20.5	20.5						
				1988	FILSK	10	25.5	19.7	32.2	5	0.740	0.440	1.300	5	< 0.01
				1993	FILSK	16	23.8	18.9	28.3	4	0.408	0.220	0.580	1	< 0.01
			White Sucker	1982	FILSK	5	14.2	14.2	14.2	1	0.060			1	< 0.05
				1993	FILSK	6	19.4	19.4	19.4	1	0.160			1	0.013

[1] – *Anatomy Codes: FILSK – Edible Fillet, WHORG – Whole Fish*

* **Impaired for Mercury in Fish Tissue as of 2012 Draft Impaired Waters List; categorized as EPA Class 4a for waters covered by the Statewide Mercury TMDL.**

**** Impaired for mercury in water column as of 1998 and categorized as EPA Class 5; recommended for 2014 Draft Impaired Waters List for Mercury in Fish Tissue.**

Groundwater monitoring

In 1999, the MPCA published a study of baseline water quality in northeast Minnesota. This report found that for this region "concentrations of major cations and anions were lower in surficial and buried drift aquifers compared to similar aquifers statewide, while concentrations of trace metals were higher. There appears to be interaction between surficial drift, buried unconfined aquifers, and underlying bedrock. Processes occurring in the unsaturated zone appear to have less impact on water quality of these aquifers than in the remainder of the state. Water quality in Precambrian aquifers varies widely, probably due to wide variability in residence times. As residence time increases, concentrations of trace elements increase. Concentrations of most chemicals were well below drinking water criteria, but there were occasional exceedances of drinking criteria by metals such as beryllium, boron, and manganese." The MPCA's Ambient Groundwater Monitoring program has sampled just one station within the Nemadji River Watershed, and several in similar settings near the watershed (Figure 26). Results from these wells did not indicate a significant change from the baseline study findings.

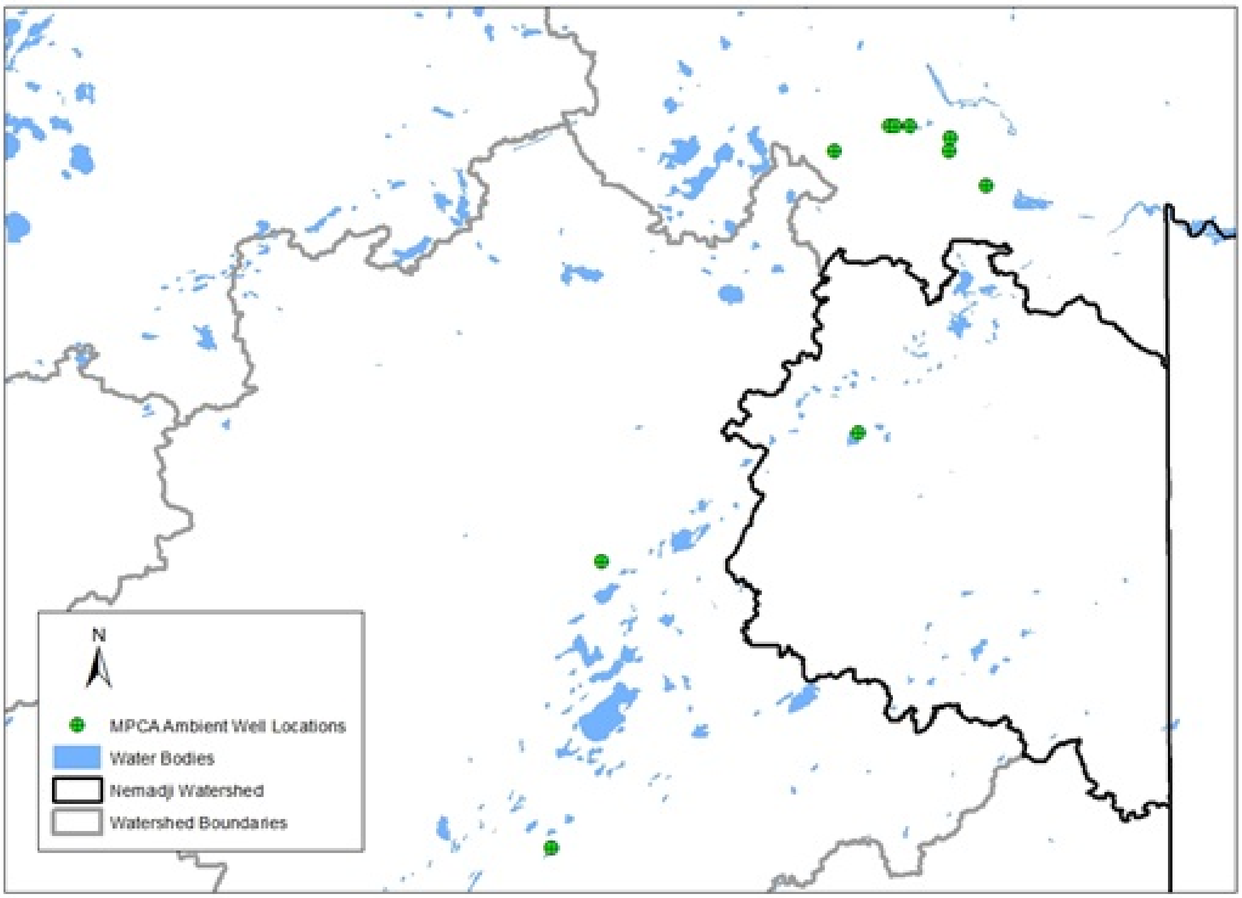

Figure 26. MPCA ambient groundwater monitoring well locations in and around the Nemadji River Watershed.

Displayed in Figure 27 are the locations of permitted high-capacity groundwater and surface water withdrawals in and near the Nemadji River Watershed. Blue symbols are groundwater withdrawals and red are surface water, taken from lake, stream or other surface water feature. The three largest permitted consumers of water in the state (in order) are municipalities, industry and irrigation. The withdrawals within the Nemadji River Watershed are mostly non-crop irrigation.

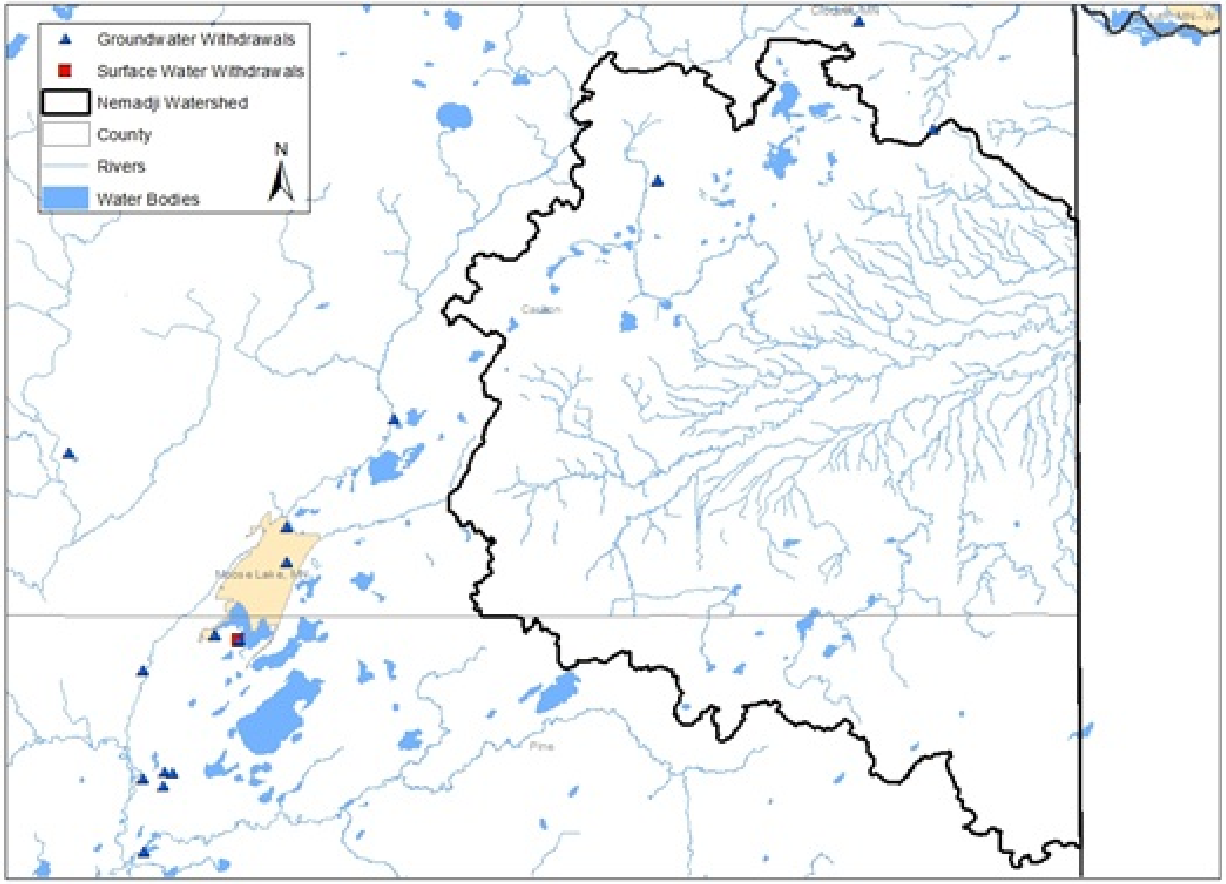

Figure 27. Locations of permitted high-capacity withdrawals in the Nemadji River Watershed.

Figure 28 displays total groundwater withdrawals from the watershed from 1991-2011. During this time period within the Nemadji River Watershed, groundwater withdrawals exhibit a statistically significant rising trend (p=0.001) with a dramatic increase in withdrawals in 2004.

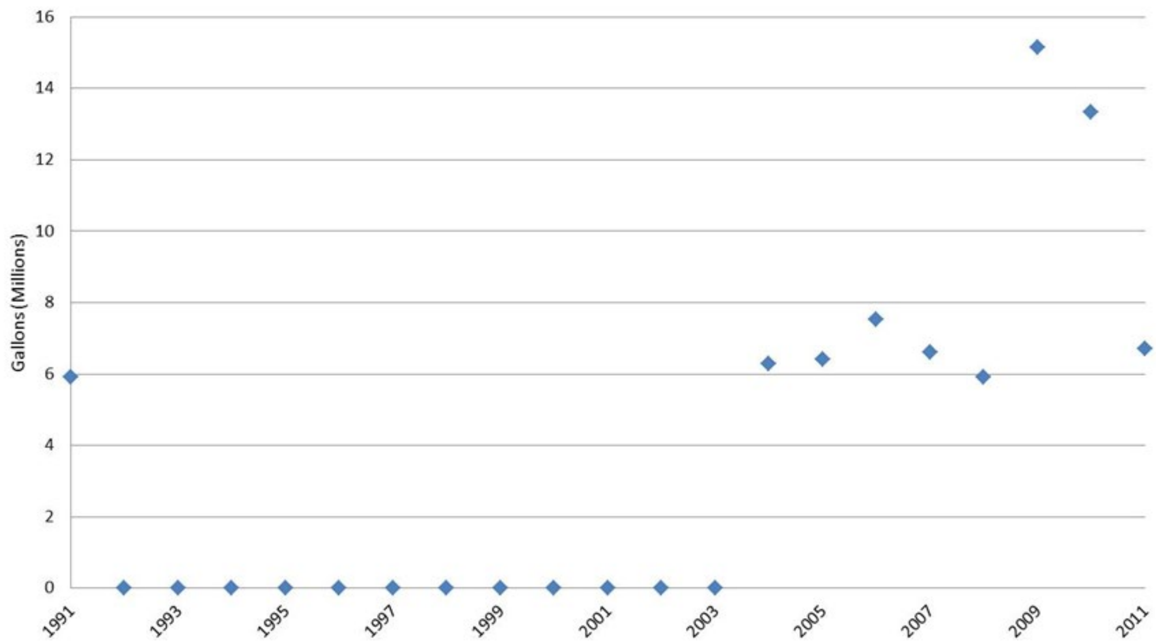

Figure 28. Total annual permitted groundwater and surface water withdrawals within the Nemadji River Watershed (1991-2011).

One observation well (09030) within the Nemadji River Watershed was chosen based on data availability and geologic location (Figure 29). This observation well exhibits a statistically significant declining trend in groundwater elevation change over the last 20 years (p=0.001).

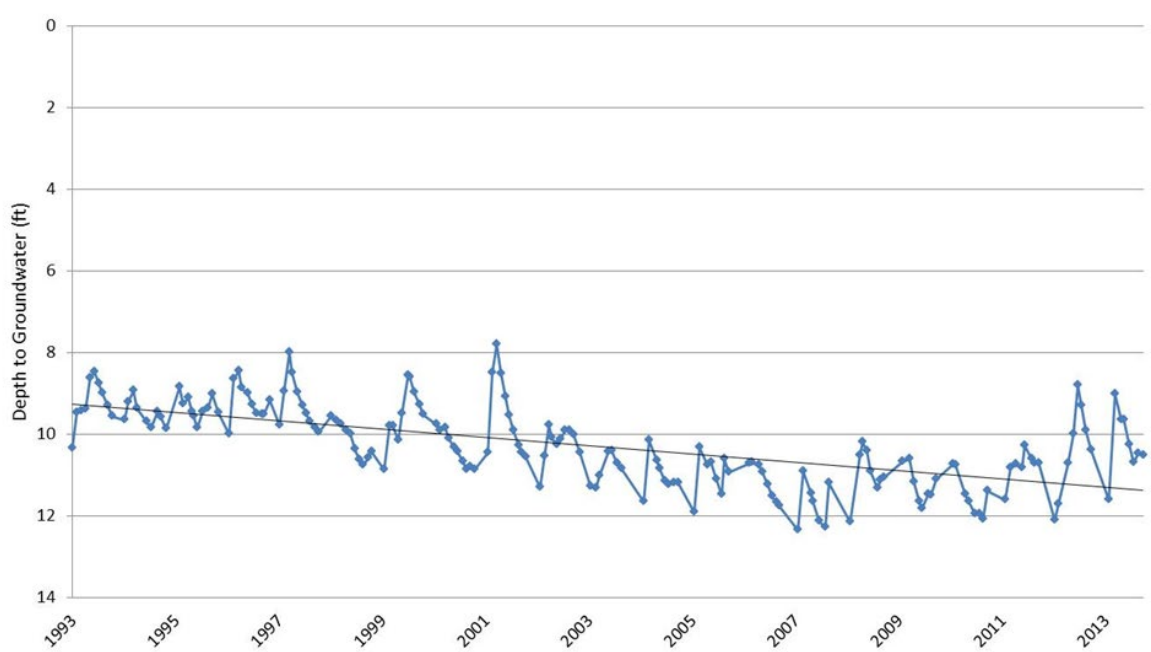

Figure 29. Observation Well 09030, located in the northern area of Nemadji River Watershed near Atkinson, MN in Carlton County (1993-2013).

Stream flow

Figure 30 is a display of the annual mean discharge for the Nemadji River near South Superior, Wisconsin from 1992 to 2012. The data shows that there is a decrease in stream flow over time, but not at a level of statistical significance. Figure 31 displays July and August mean flows for the last 20 years for the same water body. Although July months appear to display a decreasing flow trend and August months appear to be increasing, neither month exhibits a statistically significant trend. By way of comparison, summer month flows have declined at a statistically significant rate at the majority of streams selected randomly for a study of statewide trends.

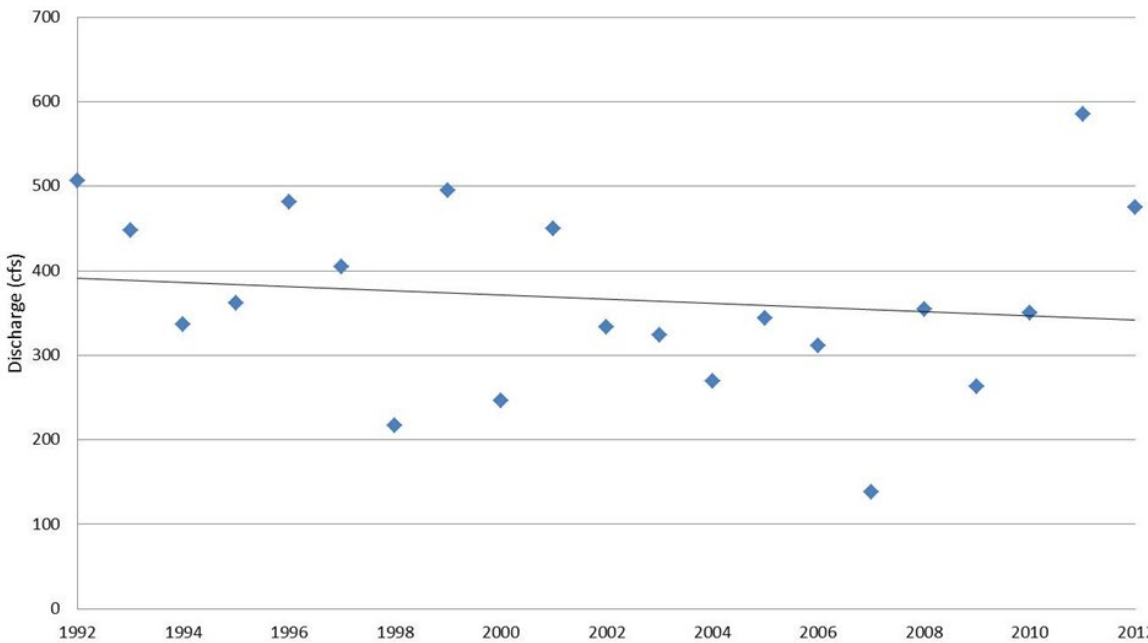

Figure 30. Annual mean discharge for Nemadji River near South Superior, WI (1992-2012).

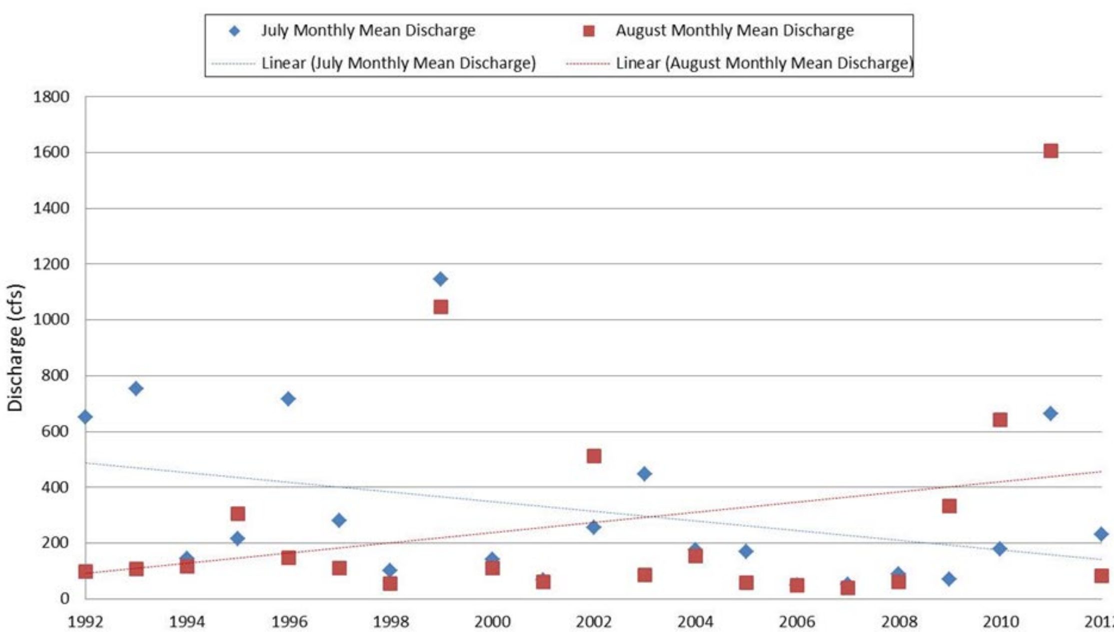

Figure 31. Mean monthly discharge measurements for July and August flows for Nemadji River near South Superior, WI (1992-2012).

Pollutant trends for the Nemadji River

Unfortunately, no long term pollutant stations exist on the Minnesota side of the Nemadji River Watershed and therefore there are no data to display.

Water clarity trends at citizen monitoring stations

Citizen volunteer stream monitoring did not occur within the Nemadji River Watershed within the 10 year assessment cycle. Twenty-eight historical stream monitoring stations are present within this watershed and show no statistically significant trend in water clarity. A total of three lakes were monitored with a mixture of results. Water clarity in Chub Lake in the Middle Nemadji River Subwatershed increased (Figure 19), while water clarity in Net Lake in the South Fork Nemadji River Subwatershed decreased (Figure 14). One other lake was monitored by citizen volunteers but that data set was incomplete and did not show a statistically significant trend. Overall, the water clarity results throughout the Nemadji River Watershed are mixed. Locations of citizen volunteer stations are displayed in Figure 4, with all historical and recent stations identified.

Table 19. Water clarity trends at citizen stream monitoring stations.

Nemadji River HUC 04010301	Citizen Stream Monitoring Program	Citizen Lake Monitoring Program
number of stations w/ increasing trend	0	1
number of stations w/ decreasing trend	0	1
number of stations w/ no trend	0 (28 Historical stations)	1

Biological impairments and stressor identification

Six stream reaches in the Nemadji River Major Watershed are impaired for fish and/or macroinvertebrates (Table 20). All impaired reaches are currently classified as aquatic life use class 2A (coldwater fisheries). However, MPCA staff recommended the Blackhoof River (04010301-519) be reclassified as aquatic life use class 2B (warmwater fisheries) and was assessed against this recommended use class for this investigation.

Table 20. Biological impairments in the Nemadji River Watershed, assessment year 2013.

Stream Reach Name	Stream Segment (AUID)	Affected Use	Impairment
Elim Creek	04010301-501	Aquatic Life	Fish
Rock Creek	04010301-508	Aquatic Life	Fish & Invert IBI
Blackhoof River	04010301-519	Aquatic Life	Fish & Invert IBI
Clear Creek	04010301-527	Aquatic Life	Fish & Invert IBI
Deer Creek	04010301-531	Aquatic Life	Fish IBI
Mud Creek	04010301-537	Aquatic Life	Fish IBI

Candidate stressors

Eighteen candidate causes were initially evaluated as potential drivers of biological impairments in the Nemadji River watershed. These 18 candidates were chosen to represent the broadest range of causes in the watershed. A list of corresponding supporting data was developed for each candidate stressor to evaluate the potential impact of the stressors to the biological impairments. In addition, data gaps were identified and a monitoring plan was developed to collect missing data during the summer of 2013.

A wide range of desktop data was collected and summarized prior to field data collection, including climate, land cover, hydrology, groundwater, historical photography, and sediment load data. Additional targeted data collected during the summer season of 2013 included stream surveys identifying channel sediment contributions, geomorphology, groundwater and stream flow inputs, continuous temperature and stage measurements, synoptic survey sampling and a beaver study to investigate the stressors associated with beaver impoundments and activity in the Nemadji River watershed.

A paired watershed approach was used to compare stream conditions in impaired and reference (background condition) sites. Two sites from streams fully supporting of aquatic life within the Nemadji watershed were selected as reference reaches to help isolate stressors in the biologically impaired reaches. All supporting desktop and targeted investigation data were reviewed and used to determine whether or not there was supporting evidence for each candidate cause in the six biologically impaired stream reaches. An initial list of candidate stressors was presented and reviewed by the technical advisory team.

Based on the consensus from the technical review meeting of February 17, 2014, the initial list of 18 candidate causes was narrowed down to eight primary candidate causes (Table 21). In order to keep the causal analysis process more succinct and avoid repetition, all eight candidate causes were evaluated across the entire watershed, even though several of them are likely to be operative only on a sub-watershed scale or within specific streams. Each stream has its own unique subset of primary stressors from these eight candidate causes. In the full stressor ID report, a more detailed summary is provided for each candidate cause with supporting or strong supporting evidence driving the individual stream biological impairments.

Table 21. List of candidate stressors.

Candidate Stressors	Blackhoof	Clear	Deer	Elim	Mud	Rock
Low Do	0	-	-	-	-	0
Hydrologic Regime Alteration	++	0	++	++	0	+
Bed Sediment Load Changes - Including Siltation	+	0	++	0	+	+
Suspended Solids and/or Turbidity	-	+	++	+	++	++
Water Temperature Regime Alteration	+	-	0	-	++	++
Habitat Destruction	+	0	++	+	+	+
Habitat Fragmentation	++	0	+	++	+	+
Heavy Metals (Aluminum Toxicity)	-	0	0	0	0	0

++ = Strong Supporting Evidence
+ = Supporting Evidence
0 = Potential, Some Supporting Evidence
- = Evidence Does Not Support
NE = No Evidence/Data Available

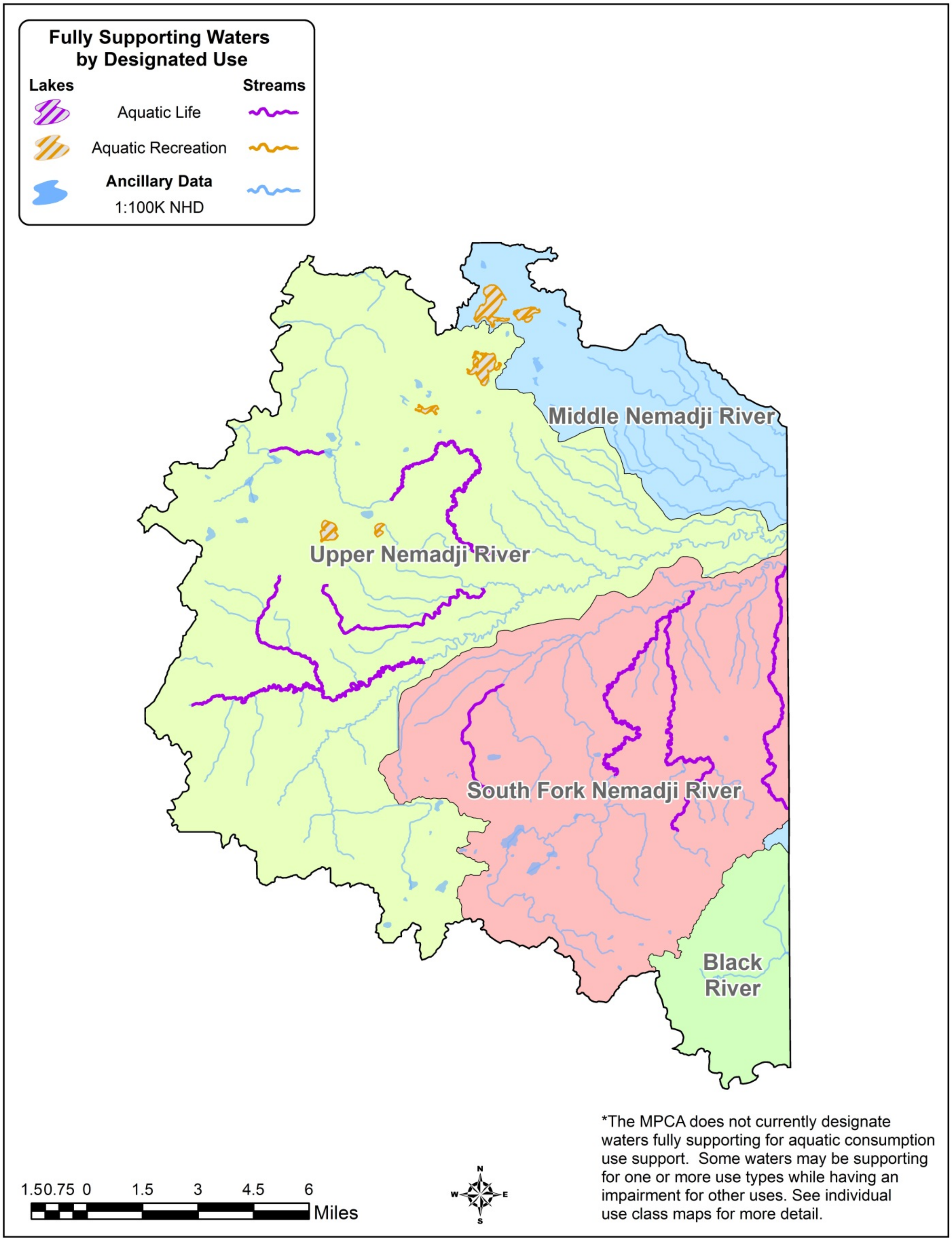

Figure 32. Fully supporting waters by designated use in the Nemadji River Watershed.

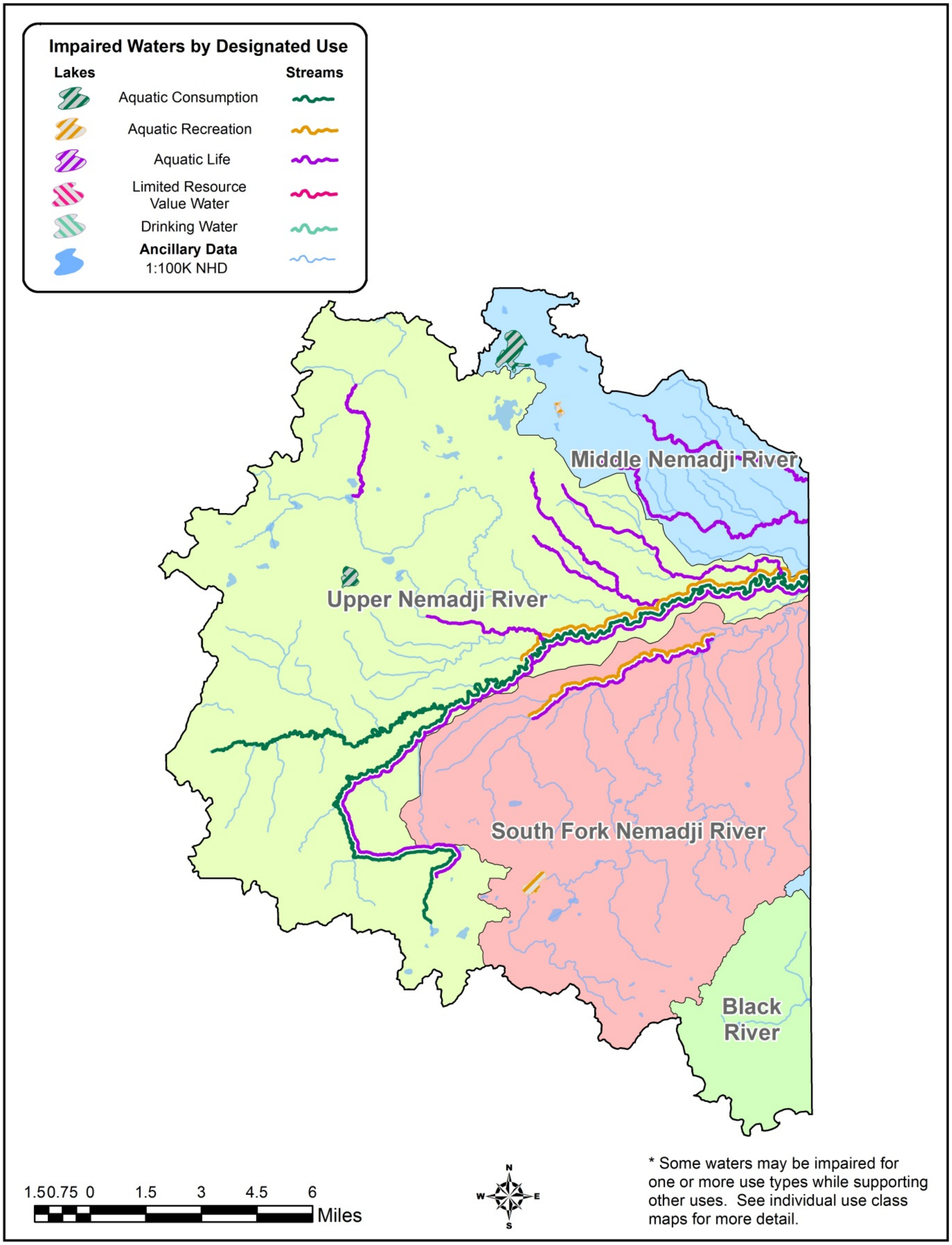

Figure 33. Impaired waters by designated use in the Nemadji River.

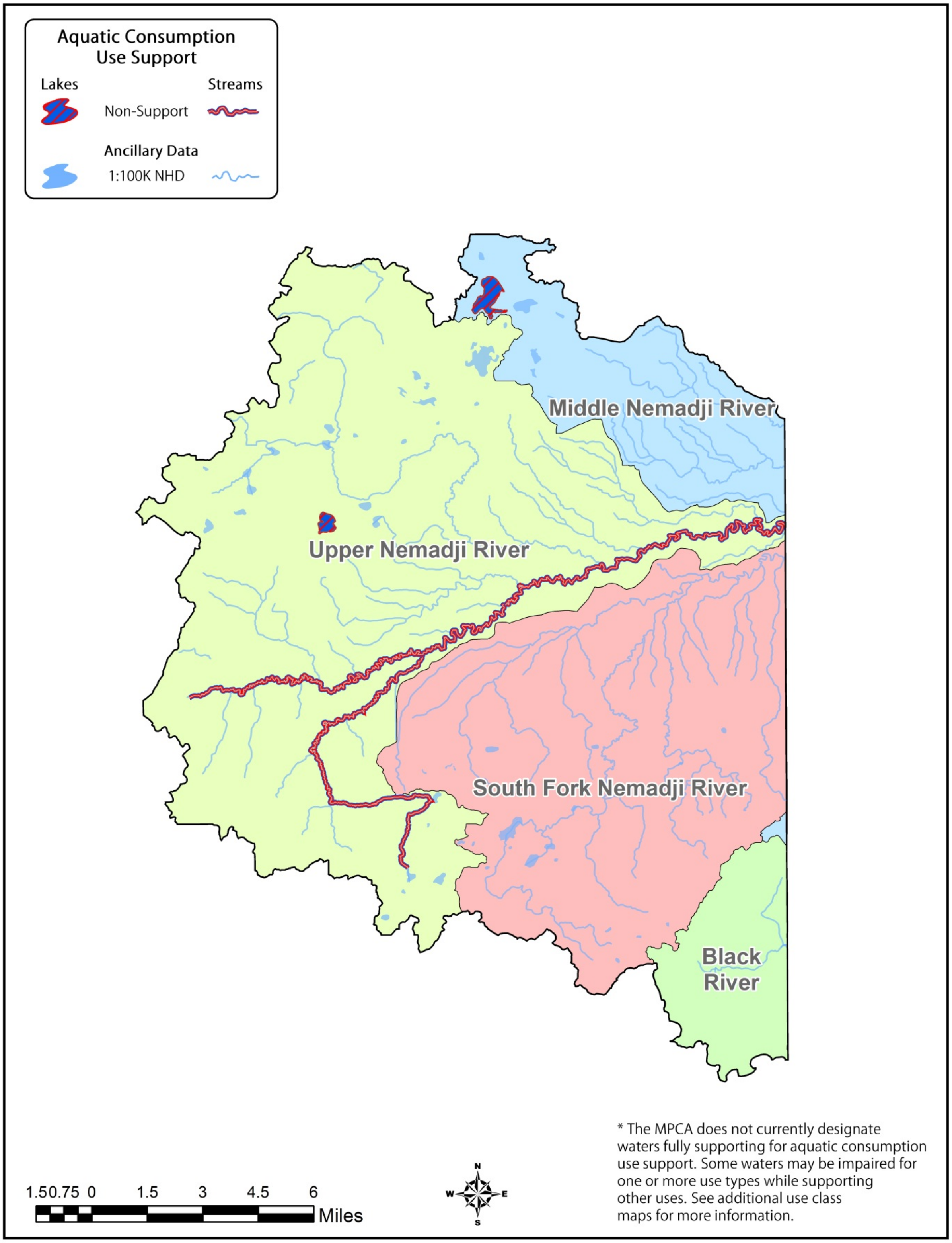

Figure 34. Aquatic consumption use support in the Nemadji River Watershed.

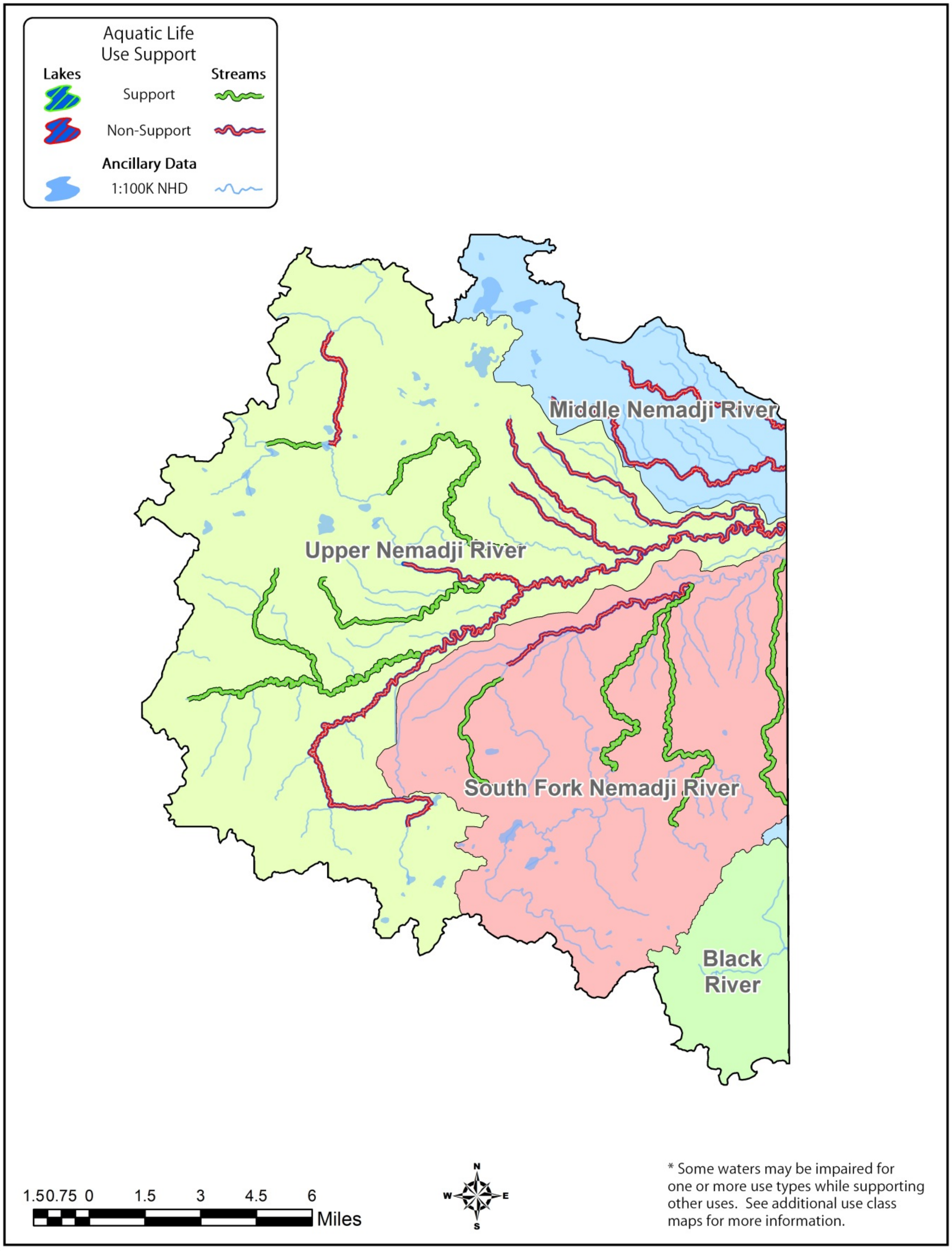

Figure 35. Aquatic life use support in the Nemadji River Watershed.

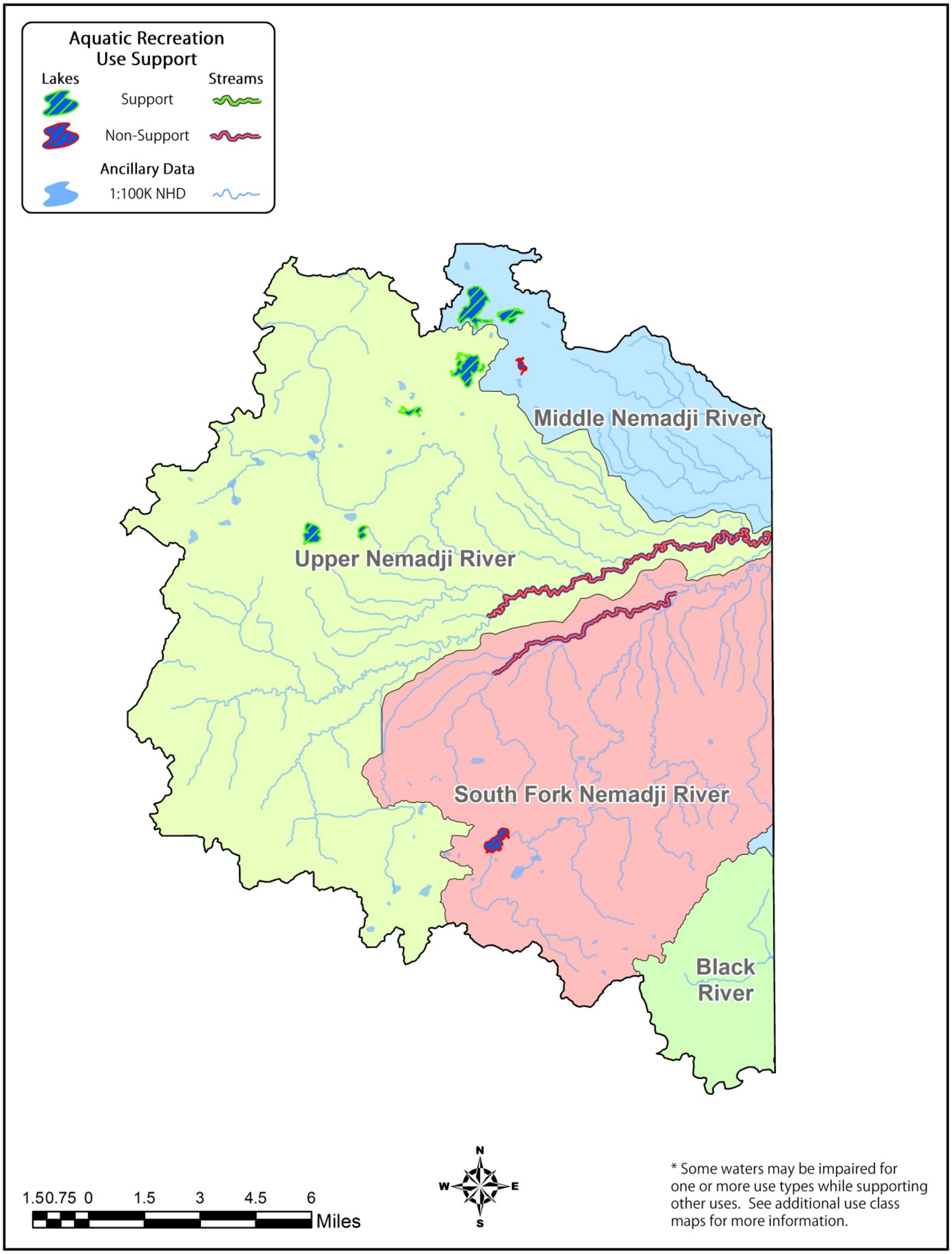

Figure 36. Aquatic recreation use support in the Nemadji River Watershed.

VII. Summary and recommendations

The Nemadji River Watershed is known for its red clay soils that contribute over 120,000 tons of sediment to Lake Superior annually (NRCS, 1998). Portions of this watershed have been listed on the Clean Water Act (CWA), Section 303(d) impaired waters list since 2004, with the most prevelant aquatic life stressor being turbidity. Although much of the watershed consists of forest and wetlands (81.93%), localized areas of more intensive land use related to agriculture and rural development occur throughout the watershed and may be contributing to aquatic life, recreation, and consumption impairments. In addition, many natural aquatic life, recreation, and consumption stressors are present within this watershed, including natural erosion driven by geological uplift and climate, and groundwater upwellings.

The biological surveys identified a mixture of both tolerant and intolerant fish and macroinvertebrate species throughout the Nemadji River Watershed. The majority of the stream segments that were assessable (66%) met biological criteria for both fish and macroinvertebrates, and were at times significantly above the biological impairment thresholds. A limited number of stations did not meet biological standards and were considered impaired for aquatic life. These aquatic life impairments were typically limited to the lower reaches of tributaries and major waterways where a combination of current landuse and soil erodibility are likely limiting the biological community. In addition, potential barriers (perched culverts, dams) exist on select tributaries to the Nemadji River and are likely having an effect on both stream flow and connectivity. These alterations are potentially impacting fish migration, along with destorying fish habitat. Although many of the reaches were found to be in fair condition biologically, some chemical aquatic life indicators, particularly turbidity, exceeded state standards. While the turbidity levels often corresponded to poor biological health, deposition of sediments in this watershed are somewhat mitigated by the high stream gradient and fine clays surrounding the streams in this watershed that allow the sediments to flush out of the system into Lake Superior. Consequently, habitat, as indicated by MSHA scores, ranged from fair to good, with a relatively high amount of quality habitat accessible for biological communities. In some cases high quality in-stream habitat may be mitigating any real change in biological composition from point and non-point pollutants.

Lake water quality was generally good with six of the eight lakes that were sampled meeting eutrophication standards. In most lakes, concentrations of phosphorus and chlorophyll-a, and Secchi transparencies, were at expected levels given the area’s dominant forest and wetland land use, and limited amounts of lakeshore development. A limited number of lakes had naturally low transparency due to “bog staining” from the surrounding wetlands. Lac La Belle had a chlorophyll-a concentration that averaged more than four times the NLF standard, while Net lake was just slightly below the standard at 8.5 µg/L. Total phosphorus concentrations in Net Lake were higher than expected levels, with an average of 40 µg/L.

Streams reaches located in the Lake Superior Plain MLRA, where red clay sediments dominate the landscape, tended to have higher turbidity. Nine of the 10 stream segments that were assessed did not meet the turbidity standard and did not support aquatic life. Much of the sediment load in the Nemadji River is likely attributed to natural erosion in response to active geologic uplifting and climate (Reidel etal, 2005). These conditions, while natural, can result in stressful conditions for biological communities and may be amplified by poor land use practices. It is likely that current and historical land use has increased sediment transport and deposition within the Nemadji River. Changes in forest cover within the watershed from one type of vegetation to another or from forested to non-forested can alter not only the hydrologic regime but evapotranspiration rates (Reidel etal, 2005). Changes in flow combined with disturbances within the riparian corridors likely contribute to the extensive mass wasting of stream banks and bluffs. Aquatic consumption impairments, caused primarily by atmospheric deposition of mercury from the global burning of fossil fuels, were wide spread and included many lakes and rivers. Overland runoff and poor land use may also be contributing to these aquatic consumption impairments.

Dissolved oxygen throughout the Nemadji River Watershed was in good standings and is attributed to the cool water temperatures and high gradient nature of most waterways found in this watershed. One dissolved oxygen impairment occurred on the Nemadji River (04010301-757) near its headwaters. This impairment is likely associated with both low flows during summer drought periods and the wetland dominated riparian zone in the upstream watershed. All other aquatic life indicators were meeting standards and indicated fair to good water quality. Bacteria levels (E. coli.) were often elevated with aquatic recreation impairments found on both the Nemadji River (04010301-758) and the South Fork Nemadji River (04010301-558). Increased level of E. coli. are likely linked to sediment input and overland runoff and could be mitigated by addressing other aquatic life impairments.

In general, groundwater quality within this watershed is in good condition. Ground water chemistry is largely influenced by residence time in bedrock material. Longer residence time will allow for increased concentrations of naturally-occurring elements. The direct correlation of increasing groundwater withdrawals and decreasing surficial water quantity has been documented in other areas of Minnesota such as Little Rock Creek and White Bear Lake. To this date a detailed cause and effect relationship has not been determined between groundwater withdrawals and surface water quantity in the Nemadji River Watershed and is beyond the scope of this report. The relatively small reliance on groundwater for high-capacity use in this watershed does not make it a priority for review of groundwater/surface water interactions. However, shallow groundwater, unique geology and a decrease in water level in observation wells is cause for continued study of those interactions.

Biologically, lakes and streams within the Nemadji River Watershed are in fair to good condition. One of the more pristine streams in the watershed is State Line Creek, where both F-IBI and M-IBI were well above impairment thresholds. A continued vigilance is needed as anthropogenic stressors within the drainage continue to threaten water quality. The top two highest quality stream resources within this watershed as indicated by biological (F-IBI & M-IBI) and physical (MSHA) parameters are displayed in Table 22. Those streams that have exceptional biological, chemical, and physical parameters are worthy of additional protections in order to preserve their valuable aquatic resources.

Areas of concern occur throughout the Nemadji system but particularly in the Lake Superior Plain MLRA region of the watershed where severe stream bank instability remains a significant problem. A tremendous amount of sediment is transported and lost through the system, largely the result of stream bank erosion. Although habitat is in relatively good condition throughout the Nemadji River Watershed, CCSI rating tended to vary widely. Stream instability and mass wasting is likely the result of soil types found within the Nemadji River corridor where glacial Lake Duluth deposited clay and clayey silts. In most cases a limited amount of this sediment is being deposited within the Nemadji River and its tributaries due to the higher stream gradient that flushes sediment out of the drainage and into Lake Superior. Sources of the sediment and turbidity are numerous, and are a function of the watershed's geological setting (Figure 25), the river's geomorphology and current/historical land use practices (Reidel etal, 2005). Water quality is impacted by the high sediment load in the form of excessive turbidity and ultimately deposition of sediments into the slower, low gradient portions of streams in the Nemadji River Watershed and Lake Superior. A continued vigilance is necessary to monitor areas where developmental pressures are or will be expected to occur. Non-point pollutants should be considered one of the likely contributors to current aquatic life, recreation, and consumption impairments within this watershed and will be addressed in future TMDLs. A combination of stressors, including residential development, vegetation alterations, draining of wetlands/lakes, undersized culverts, erosion, damming of streams, unstable geomorphology, and other hydrological alterations are all likely contributing to the reduction of sensitive species throughout the watershed. An emphasis should be given to maintaining natural vegetative buffer areas along shore lines to prevent overland runoff and reduce erosion potential, and should be considered a key protection strategy to obtain high quality lakes and streams in this watershed.

Table 22. Top two stream resources in the Nemadji River Watershed as indicated by biological (F-IBI & M-IBI) and physical (MSHA) parameters.

Rank	Stream Name	Biological Station ID	Location of Biological Station
1	State Line Creek	11LS069	Upstream of CSAH 8, 3 mi. W of Holyoke
2	Net River	11LS066	Upstream of CSAH 8, 3.5 mi. S of Frogner

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Appendix 1 – Water chemistry definitions

Dissolved oxygen (DO) - Oxygen dissolved in water required by aquatic life for metabolism. Dissolved oxygen enters into water from the atmosphere by diffusion and from algae and aquatic plants when they photosynthesize. Dissolved oxygen is removed from the water when organisms metabolize or breathe. Low DO often occurs when organic matter or nutrient inputs are high, and light inputs are low.

Escherichia coli (E. coli) - A type of fecal coliform bacteria that comes from human and animal waste. E. coli levels aid in the determination of whether or not fresh water is safe for recreation. Disease-causing bacteria, viruses and protozoans may be present in water that has elevated levels of E. coli.

Nitrate plus Nitrite – Nitrogen - Nitrate and nitrite-nitrogen are inorganic forms of nitrogen present within the environment that are formed through the oxidation of ammonia-nitrogen by nitrifying bacteria (nitrification). Ammonia-nitrogen is found in fertilizers, septic systems and animal waste. Once converted from ammonia-nitrogen to nitrate and nitrite-nitrogen, these species can stimulate excessive levels of algae in streams. Because nitrate and nitrite-nitrogen are water soluble, transport to surface waters is enhanced through agricultural drainage. The ability of nitrite-nitrogen to be readily converted to nitrate-nitrogen is the basis for the combined laboratory analysis of nitrate plus nitrite-nitrogen (nitrate-N), with nitrite-nitrogen typically making up a small proportion of the combined total concentration. These and other forms of nitrogen exist naturally in aquatic environments; however concentrations can vary drastically depending on season, biological activity, and anthropogenic inputs.

Orthophosphate - Orthophosphate (OP) is a water soluble form of phosphorus that is readily available to algae (bioavailable). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from waste water treatment plants, noncompliant septic systems and fertilizers in urban and agricultural runoff.

pH - A measure of the level of acidity in water. Rainfall is naturally acidic, but fossil fuel combustion has made rain more acid. The acidity of rainfall is often reduced by other elements in the soil. As such, water running into streams is often neutralized to a level acceptable for most aquatic life. Only when neutralizing elements in soils are depleted, or if rain enters streams directly, does stream acidity increase.

Specific Conductance - The amount of ionic material dissolved in water. Specific conductance is influenced by the conductivity of rainwater, evaporation and by road salt and fertilizer application.

Temperature - Water temperature in streams varies over the course of the day similar to diurnal air temperature variation. Daily maximum temperature is typically several hours after noon, and the minimum is near sunrise. Water temperature also varies by season as doe's air temperature.

Total Kjehldahl nitrogen (TKN) - The combination of organically bound nitrogen and ammonia in wastewater. TKN is usually much higher in untreated waste samples then in effluent samples.

Total Phosphorus (TP) - Nitrogen (N), phosphorus (P) and potassium (K) are essential macronutrients and are required for growth by all animals and plants. Increasing the amount of phosphorus entering the system therefore increases the growth of aquatic plants and other organisms. Excessive levels of Phosphorous over stimulate aquatic growth and resulting in the progressive deterioration of water quality from overstimulation of nutrients, called eutrophication. Elevated levels of phosphorus can result in: increased algae growth, reduced water clarity, reduced oxygen in the water, fish kills, altered fisheries and toxins from cyanobacteria (blue green algae) which can affect human and animal health.

Total Suspended Solids (TSS) – TSS and turbidity are highly correlated. Turbidity is a measure of the lack of transparency or "cloudiness" of water due to the presence of suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter and plankton or other microscopic organisms. The greater the level of TSS, the murkier the water appears and the higher the measured turbidity.

Higher turbidity results in less light penetration which may harm beneficial aquatic species and may favor undesirable algae species. An overabundance of algae can lead to increases in turbidity, further compounding the problem.

Total Suspended Volatile Solids (TSVS) - Volatile solids are solids lost during ignition (heating to 500 degrees C.) They provide an approximation of the amount of organic matter that was present in the water sample. ''Fixed solids'' is the term applied to the residue of total, suspended, or dissolved solids after heating to dryness for a specified time at a specified temperature. The weight loss on ignition is called ''volatile solids.''

Unnionized Ammonia (NH3) - Ammonia is present in aquatic systems mainly as the dissociated ion $NH4^+$, which is rapidly taken up by phytoplankton and other aquatic plants for growth. Ammonia is an excretory product of aquatic animals. As it comes in contact with water, ammonia dissociates into $NH4^+$ ions and ^-OH ions (ammonium hydroxide). If pH levels increase, the ammonium hydroxide becomes toxic to both plants and animals.

Appendix 2 – Intensive watershed monitoring water chemistry stations in the Nemadji River Watershed

Biological Station ID	STORET/EQuIS ID	Water body Name	Location	10-digit HUC
11LS057	S006-214	Nemadji River, South Fork	Downstream of Hwy 23, 2 mi. Northwest of Holyoke	0401030101
11LS055	S000-110	Nemadji River	Downstream of Hwy 23, 1 mi. South of Pleasant Valley	0401030102

Appendix 3 – AUID table of stream assessment results (by parameter and beneficial use)

AUID DESCRIPTIONS					USES					BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS					
Assessment Unit ID (AUID)	Stream Segment Name	Reach Description	Reach Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Aquatic Consumption	Drinking Water	303d List Impairments 2012	Fish	Macroinvertebrates	Dissolved Oxygen	Turbidity	Chloride	pH	NH_3	Bacteria (Aquatic Recreation)
	HUC 10: 0401030101 (South Fork Nemadji River)																
04010301-512	Net River	Headwaters to T46 R17W S36, S Line	8.48	2B	IF	NA	- -	- -	- -	IF	IF	- -	- -	- -	- -	- -	- -
04010301-516	Anderson Creek	T46 R17W S26 S Line to T46 R17W S14, N Line	4.24	2A	FS	NA	- -	IF	- -	MTS	MTS	- -	IF	MTS	- -	- -	- -
04010301-526	Clear Creek	Headwaters to S Fk Nemadji R	6.43	2A	IF	NA	- -	IF	- -	- -	- -	- -	IF	- -	- -	- -	- -
04010301-558	Nemadji River, South Fork	Stony Bk/Anderson Cr to Net R	7.3	2A	NS	NS	- -	IF	- -	MTS	MTS	MTS	EXS	MTS	MTS	MTS	EX
04010301-564	State Line Creek	Headwaters to S Fk Nemadji R	9.13	2A	FS	NA	- -	IF	- -	MTS	MTS	- -	IF	MTS	MTS	- -	- -
04010301-569	Little Net River	T46 R16W S34 S Line to Net R	10.02	2A	FS	NA	- -	IF	- -	MTS	MTS	- -	IF	MTS	- -	- -	- -
04010301-759	Net River	Mud Lk to T46N R 16W S29, N Line of SE quarter	3.12	2B	IF	NA	- -	NA	- -	- -	- -	- -	IF	- -	- -	- -	- -
04010301-760	Net River	T46 R16W S29, N Line of SE quarter to S Fk Nemadji R	10.99	2A	FS	NA	- -	IF	- -	MTS	MTS	MTS	IF	MTS	- -	- -	- -

	HUC 10: 0401030102 (Upper Nemadji River)																
04010301-501	Unnamed Creek (Elim Creek)	Unnamed Cr to Skunk Cr	2.45	2A	NS	NA	- -	- -	- -	EXS	MTS	- -	- -	- -	- -	- -	- -
04010301-502	Skunk Creek	Unnamed Cr to Nemadji R	1.72	2A	NS	NA	- -	IF	- -	- -	- -	MTS	EXS	- -	MTS	- -	- -
04010301-504	Skunk Creek	Headwaters to Unnamed Cr	7.22	2A	FS	NA	- -	- -	- -	MTS	MTS	- -	- -	- -	- -	- -	- -
04010301-508	Rock Creek	Unnamed Cr to Nemadji R	3.92	2A	NS	NA	- -	- -	- -	EXP	EXP	- -	- -	- -	- -	- -	- -
04010301-510	Blackhoof River	Spring Lk Outlet to Unnamed Cr	2.59	2A	FS	NA	- -	- -	- -	MTS	MTS	- -	- -	- -	- -	- -	- -
04010301-519	Blackhoof River	Unnamed Cr to Ellstrom Lk	5.0	2B†	NS	NA	- -	- -	- -	EXS	EXS	- -	- -	- -	- -	- -	- -
04010301-523	Unnamed Creek (Blackhoof Trib)	Spring Lk to T47 R17W S28, N Line	2.28	2A	IF	NA	- -	IF	- -	- -	- -	- -	MTS	MTS	- -	- -	- -
04010301-531	Deer Creek	Headwaters to Nemadji R	6.93	2A	NS	NA	- -	IF	T	EXS	MTS	MTS	EXS	MTS	MTS	MTS	- -
04010301-532	Unnamed Creek	Headwaters to Deer Cr	3.04	2A	NS	NA	- -	- -	- -	- -	- -	MTS	EXS	- -	MTS	- -	- -
04010301-534	Hunters Creek	Headwaters to Nemadji Cr	5.37	2A	FS	NA	- -	IF	- -	MTS	MTS	- -	IF	MTS	- -	- -	- -
04010301-545	Nemadji Creek	Headwaters to Nemadji R	12.23	2A	FS	NA	NS	- -	- -	MTS	MTS	- -	IF	- -	- -	- -	- -
04010301-573	Rock Creek	Headwaters to Unnamed Cr	4.5	2A	NS	NA	- -	IF	T	- -	- -	IF	EXS	MTS	MTS	MTS	- -
04010301-756	Unnamed Creek (Blackhoof Trib.)	Unnamed Cr to Ellstrom Lk	1.72	2B	FS	NA	- -	- -	- -	MTS	- -	- -	- -	- -	- -	- -	- -
04010301-757	Nemadji River	T46 R17W S33, S Line to Unnamed Cr	18.27	2B†	NS	NA	NS	NA	- -	MTS	MTS	EXP	EXS	- -	MTS	- -	- -
04010301-758	Nemadji River	Unnamed Cr to MN/WI Border	15.0	2A	NS	NS	NS	IF	- -	MTS	MTS	MTS	EXS	MTS	MTS	MTS	EX
04010301-762	Blackhoof River	Co Rd 105 to Spring Lk Outlet	9.84	2A	FS	NA	- -	IF	- -	- -	- -	MTS	MTS	- -	MTS	- -	- -
	HUC 10: 0401030103 (Black River)																
	HUC 10: 0401030104 (Middle Nemadji River)																
04010301-527	Clear Creek	T48 R16W S 33, W Line to MN/WI Border	7.93	2A	NS	NA	- -	IF	- -	EXP	EXP	- -	EXP	- -	- -	- -	- -
04010301-537	Mud Creek	T47 R16W S6, W Line to MN/WI Border	11.01	2A	NS	NA	- -	IF	- -	EXP	MTS	- -	EXP	MTS	- -	MTS	- -

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets standards or ecoregion expectations (MT/MTS), Potential Exceedence (EXP), Exceeds standards or ecoregion expectations (EX/EXS).
Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use.
*Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50%) channelized or having biological data limited to a station occurring on a channelized portion of the stream.
† Reach was assessed based on use class included in the above table and existing use class as defined in Minn. R. 7050 is different. The MPCA is currently in the process of changing the existing use class for this AUID in rule based on an analysis of the biological community and temperature data.

Appendix 4 – Assessment results for lakes in the Nemadji River Watershed

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral	Mean depth (m)	Support Status
58-0038-00	Net	Pine	0401030101	NLF	142	3.6	6513	100	1.6	NS
09-0005-00	Bear	Carlton	0401030102	NLF	32	8.5	1094	63	3.0	FS
09-0007-00	Spring	Carlton	0401030102	NLF	41	7.6	246	81.2	2.0	FS
09-0008-00	Chub	Carlton	0401030104	NLF	274	8.5	2074	54.3	4.1	FS
09-0009-00	Venoah	Carlton	0401030104	NLF	82	5.4	2746	90	1.0	FS
09-0010-00	Hay	Carlton	0401030102	NLF	103	4.2	2207	95	1.2	FS
09-0011-00	Lac La Belle	Carlton	0401030104	NLF	36	- -	463	- -	1.0	NS
09-0016-00	Sand	Carlton	0401030102	NLF	123	8.2	344	99	0.9	FS

Abbreviations: **FS** – Full Support **N/A** – Not Assessed
NS – Non-Support
IF – Insufficient Information

Key for Cell Shading: = existing impairment, listed prior to 2012 reporting cycle; = new impairment; = full support of designated use.
*These depths were estimated by MPCA Staff.
** Excludes the area of the lake

Appendix 5 – Minnesota statewide IBI thresholds and confidence limits

Class #	Class Name	Use Class	Threshold	Confidence Limit	Upper	Lower
Fish						
1	Southern Rivers	2B, 2C	39	±11	50	28
2	Southern Streams	2B, 2C	45	±9	54	36
3	Southern Headwaters	2B, 2C	51	±7	58	44
10	Southern Coldwater	2A	45	±9	58	32
4	Northern Rivers	2B, 2C	35	±9	44	26
5	Northern Streams	2B, 2C	50	±9	59	41
6	Northern Headwaters	2B, 2C	40	±16	56	24
7	Low Gradient	2B, 2C	40	±10	50	30
11	Northern Coldwater	2A	37	±10	47	27
Macroinvertebrates						
1	Northern Forest Rivers	2B, 2C	51.3	±10.8	62.1	40.5
2	Prairie Forest Rivers	2B, 2C	30.7	±10.8	41.5	19.9
3	Northern Forest Streams RR	2B, 2C	50.3	±12.6	62.9	37.7
4	Northern Forest Streams GP	2B, 2C	52.4	±13.6	66	38.8
5	Southern Streams RR	2B, 2C	35.9	±12.6	48.5	23.3
6	Southern Forest Streams GP	2B, 2C	46.8	±13.6	60.4	33.2
7	Prairie Streams GP	2B, 2C	38.3	±13.6	51.9	24.7
8	Northern Coldwater	2A	26	±12.4	38.4	13.6
9	Southern Coldwater	2A	46.1	±13.8	59.9	32.3

Appendix 6 – Biological monitoring results – fish IBI (assessable reaches)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Threshold	FIBI	Visit Date
HUC 10: 0401030101 (South Fork Nemadji River)							
04010301-516	11LS065	Anderson Creek	8.06	11	37	54	6/20/2011
04010301-558	11LS057	Nemadji River, South Fork	25.17	11	37	37	8/29/2011
04010301-564	11LS069	State Line Creek	5.30	11	37	74	6/21/2011
04010301-569	11LS067	Little Net River	11.33	11	37	44	6/14/2011
04010301-760	11LS066	Net River	26.99	11	37	43	6/13/2011
HUC 10: 0401030102 (Upper Nemadji River)							
04010301-501	11LS072	Unnamed Creek (Elim Creek)	1.79	11	37	20	9/15/2011
04010301-504	11LS059	Skunk Creek	7.23	11	37	49	8/1/2011
04010301-508	11LS063	Rock Creek	5.77	11	37	37	9/15/2011
04010301-510	11LS062	Blackhoof River	49.05	11	37	54	6/15/2011
04010301-519	90LS031	Blackhoof River	13.34	7	40	45	6/14/2011
04010301-531	11LS064	Deer Creek	5.22	11	37	19	6/16/2011
04010301-534	11LS070	Hunters Creek	8.21	11	37	49	6/20/2011
04010301-545	11LS060	Nemadji Creek	14.19	11	37	31	6/14/2011
04010301-756	11LS071	Unnamed Creek (Blackhoof Trib.)	9.09	7	40	47	6/15/2011
04010301-757	11LS061	Nemadji River	21.39	6	40	69	9/14/2011
04010301-757	97LS087	Nemadji River	56.63	5	50	67	9/20/2011
04010301-758	11LS055	Nemadji River	124.58	11	37	53	9/20/2011
04010301-758	11LS055	Nemadji River	124.58	11	37	54	6/16/2011
HUC 10: 0401030103 (Black River)							
NONE							
HUC 10: 0401030104 (Middle Nemadji River)							
04010301-527	11LS056	Clear Creek	12.20	11	37	26	9/15/2011
04010301-537	11LS058	Mud Creek	12.40	11	37	29	9/15/2011

Appendix 7 – Biological monitoring results – macroinvertebrate IBI (assessable reaches)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Threshold	MIBI	Visit Date
HUC 10: 0401030101 (South Fork Nemadji River)							
04010301-516	11LS065	Anderson Creek	8.06	8	26	48	8/25/2011
04010301-558	11LS057	Nemadji River, South Fork	25.17	8	26	29	8/23/2011
04010301-564	11LS069	State Line Creek	5.30	8	26	64.3	8/1/2011
04010301-569	11LS067	Little Net River	11.33	8	26	31.7	8/24/2011
04010301-760	11LS066	Net River	26.99	8	26	44.5	8/25/2011
HUC 10: 0401030102 (Upper Nemadji River)							
04010301-501	11LS072	Unnamed Creek (Elim Creek)	1.79	8	26	32.9	8/24/2011
04010301-504	11LS059	Skunk Creek	7.23	8	26	26.7	8/24/2011
04010301-508	11LS063	Rock Creek	5.77	8	26	16.1	8/24/2011
04010301-510	11LS062	Blackhoof River	49.05	8	26	32.7	8/24/2011
04010301-519	90LS031	Blackhoof River	13.34	4	52.4	36.2	9/19/2011
04010301-531	11LS064	Deer Creek	5.22	8	26	44.4	8/1/2011
04010301-534	11LS070	Hunters Creek	8.21	8	26	28.7	8/24/2011
04010301-545	11LS060	Nemadji Creek	14.19	8	26	35.6	8/24/2011
04010301-756	11LS071	Unnamed Creek (Blackhoof Trib.)	9.09	4	52.4	20.7	9/19/2011
04010301-757	11LS061	Nemadji River	21.39	3	50.3	61.5	8/23/2011
04010301-757	97LS087	Nemadji River	56.63	3	50.3	70.9	8/24/2011
04010301-758	10EM004	Nemadji River	68.94	8	26	40.5	8/17/2011
04010301-758	11LS055	Nemadji River	124.58	8	26	26.5	8/1/2011
HUC 10: 0401030103 (Black River)							
NONE							
HUC 10: 0401030104 (Middle Nemadji River)							
04010301-527	11LS056	Clear Creek	12.20	8	26	16.2	8/24/2011
04010301-537	11LS058	Mud Creek	12.40	8	26	25.3	8/23/2011

Appendix 8 – Minnesota's ecoregion-based lake eutrophication standards

Ecoregion	TP µg/L	Chl-a µg/L	Secchi meters
NLF – Lake Trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
NCHF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2B) Shallow lakes	< 60	< 20	> 1.0
WCBP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCBP & NGP – Aquatic Rec. Use(Class 2B) Shallow lakes	< 90	< 30	> 0.7

Appendix 9 – MINLEAP model estimates of phosphorus loads for lakes in the Nemadji Watershed

Lake ID	Lake Name	Obs TP (µg/L)	MINLEAP TP (µg/L)	Obs Chl-a (µg/L)	MINLEAP Chl-a (µg/L)	Obs Secchi (m)	MINLEAP Secchi (m)	Avg. TP Inflow (µg/L)	TP Load (kg/yr)	Background TP (µg/L)	%P Retention	Outflow (hm3/yr)	Residence Time (yrs)	Areal Load (m/yr)	Trophic Status
58-0038-00	Net	40	39	8.5	14	0.8	1.6	53	324	27	26	6.14	0.1	10.6	E
09-0005-00	Bear	23	33	9.1	11	3.2	1.9	53	55	22	37	1.04	0.4	7.9	M
09-0007-00	Spring	24	26	5.5	8.0	3.2	2.3	57	14	25	55	0.25	1.3	1.5	M
09-0008-00	Chub	22	22	11.2	6	4.0	2.7	56	117	20	61	2.0	2.2	1.8	M
09-0009-00	Venoah	15	40	2.8	14	3.4	1.6	53	138	31	25	2.6	0.1	7.8	M
09-0010-00	Hay	27	37	7.2	13	1.6	1.7	54	113	30	32	2.1	0.2	5.0	M/E
09-0011-00	Lac La Belle	61	35	43.4	12	1.6	1.8	55	25	31	35	0.45	0.3	3.1	E
09-0016-00	Sand	29	29	6.5	9	1.3	2.1	63	24	33	54	0.4	1.2	0.7	M/E

Abbreviations: **H** – Hypereutrophic, **E** – Eutrophic, **M** – Mesotrophic, **O** – Oligotrophic, --- No data

Appendix 10 – Fish species encountered during biological monitoring surveys

Taxonomic Name	Common Name	Number of Stations Where Present	Quantity of Individuals Collected
Cypriniformes			
Catostomus catostomus	Longnose Sucker	1	1
Catostomus commersoni	White Sucker	13	250
Hybognathus hankinsoni	Brassy Minnow	3	12
Luxilus (Notropis) cornutus	Common Shiner	10	360
Margariscus (Semotilis) margarita	Pearl Dace	5	52
Moxostoma anisurum	Silver Redhorse	1	7
Moxostoma macrolepidotum	Shorthead Redhorse	2	32
Nocomis biguttatus	Hornyhead Chub	6	135
Notemigonis crysoleucas	Golden Shiner	1	1
Notropis (stramineus) ludibundus	Sand Shiner	1	2
Phoxinus eos	Northern Redbelly Dace	8	32
Pimpephales promelas	Fathead Minnow	6	17
Rhinichthys atratulus	Blacknose Dace	15	227
Rhinichthys cataractae	Longnose Dace	11	280
Semotilis atromaculatus	Creek Chub	16	918
Esociformes			
Esox lucius	Northern Pike	1	4
Esox masquinongy	Muskellunge	1	4
Umbra limi	Central Mudminnow	11	330
Gadiformes			
Lota lota	Burbot/Eelpout	1	1
Gasterosteiformes			
Culaea inconstans	Brook Stickleback	6	13
Hyperoartia			
	Lamprey Ammocoete	1	9
Petromyzon marinus	Sea Lamprey	2	2

Taxonomic Name	Common Name	Number of Stations Where Present	Quantity of Individuals Collected
Perciformes			
Ambloplites rupestris	Rockbass	2	11
Etheostoma exile	Iowa Darter	1	2
Etheostoma nigrum	Johnny Darter	17	367
Lepomis cyanellus	Green Sunfish	1	1
Lepomis gibbosus	Pumpkinseed	1	3
Lepomis macrochirus	Bluegill	3	10
Micropterus salmoides	Largemouth Bass	4	8
Perca flavescens	Yellow Perch	2	2
Percina caprodes	Logperch	3	59
Pomoxis nigromaculatus	Black Crappie	1	2
Sander (Stizostedion) vitreus	Walleye	1	14
Percopsiformes			
Percopsis omiscomaycus	Trout Perch	8	333
Salmoniformes			
Oncorhynchus mykiss (Salmo gairdneri)	Rainbow Trout	1	4
Salmo trutta	Brown Trout	3	32
Salvelinus fontinalis	Brook Trout	3	13
Scorpaeniformes			
Cottus bairdi	Mottled Sculpin	16	269
Siluriformes			
Noturus flavus	Stonecat	2	4
Noturus gyrinus	Tadpole Madtom	1	1

Appendix 11 – Macroinvertebrate species encountered during biological monitoring surveys

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Acari		
Acari	16	42
Amphipoda		
Amphipoda	1	1
Gammarus	1	23
Hyalella	6	51
Coleoptera		
Dubiraphia	9	22
Dytiscidae	1	5
Elmidae	4	14
Gyrinus	1	1
Haliplus	3	4
Helichus	3	4
Hydrophilidae	1	1
Liodessus	1	3
Macronychus glabratus	2	3
Optioservus	18	322
Stenelmis	7	42
Decapoda		
Orconectes	6	6
Diptera		
Ablabesmyia	3	3
Acricotopus	2	2
Antocha	7	20
Atherix	12	110
Bittacomorpha	1	1
Brillia	9	12
Chironomini	2	2
Chironomus	3	557
Cladotanytarsus	2	2
Conchapelopia	1	1
Corynoneura	3	4
Cricotopus	11	31
Cryptochironomus	1	1

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Culex	1	1
Culicidae	1	1
Dasyhelea	2	53
Diamesa	1	1
Dicranota	5	7
Dicrotendipes	1	1
Diplocladius cultriger	1	1
Dixella	2	4
Empididae	4	6
Ephydridae	3	12
Eukiefferiella	12	45
Forcipomyia	1	1
Guttipelopia	1	11
Helius	1	1
Hemerodromia	3	3
Heterotrissocladius	2	2
Hexatoma	2	2
Labrundinia	1	7
Limnophyes	3	3
Mallochohelea	2	5
Meropelopia/Thienemannimyia	1	3
Micropsectra	15	84
Microtendipes	2	5
Nanocladius	4	5
Natarsia	1	1
Neoplasta	1	5
Nilotanypus	1	1
Nyctiophylax (Paranyctiophylax)	1	1
Orthocladiinae	3	3
Orthocladius	13	33
Orthocladius (Symposiocladius)	3	18
Parakiefferiella	3	5
Paramerina	2	4
Parametriocnemus	15	84
Paratanytarsus	10	36
Paratendipes	1	1
Pentaneura	1	6

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Pericoma	1	1
Polypedilum	19	367
Potthastia	1	1
Procladius	3	17
Psectrocladius	1	1
Psychodidae	1	1
Rheocricotopus	11	42
Rheosmittia	1	1
Rheotanytarsus	18	246
Roederiodes	2	3
Saetheria	2	2
Serromyia	2	5
Simulium	19	1035
Stempellinella	2	2
Stenochironomus	3	6
Sublettea coffmani	1	1
Tanypodinae	3	5
Tanytarsini	4	5
Tanytarsus	13	103
Thienemanniella	6	11
Thienemannimyia	12	37
Tipula	8	21
Tipulidae	2	2
Tribelos	1	1
Tvetenia	15	192
Xylotopus par	1	4
Zavrelimyia	2	4
Ephemeroptera		
Acentrella	3	3
Acentrella parvula	1	4
Acentrella turbida	5	68
Acerpenna	2	11
Baetidae	5	67
Baetis	5	14
Baetis brunneicolor	9	74
Baetis flavistriga	12	164
Baetis intercalaris	3	9

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Baetis tricaudatus	8	270
Caenis	6	38
Caenis youngi	2	6
Cercobrachys etowah	1	1
Ephemera	1	3
Ephemerella excrucians	6	27
Eurylophella	1	1
Fallceon quilleri	1	2
Heptageniidae	5	28
Hexagenia	1	1
Isonychia	9	33
Isonychia bicolor	1	1
Labiobaetis	2	52
Labiobaetis propinquus	2	22
Leptophlebiidae	8	136
Maccaffertium	12	113
Maccaffertium luteum	4	5
Paraleptophlebia	2	2
Procloeon	1	4
Pseudocloeon	1	50
Tricorythodes	4	9
Gastropoda		
Ferrissia	5	26
Gyraulus	2	3
Helisoma anceps	3	4
Physa	6	24
Hemiptera		
Belostoma flumineum	3	2
Corixidae	1	1
Notonecta	1	1
Ranatra	1	1
Rhagovelia	1	1
Sigara	1	1
Hirudinea		
Hirudinea	3	4
Lepidoptera		
Crambidae	1	1

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Megalotptera		
Corydalidae	1	1
Sialis	3	4
Mollusca		
Pisidiidae	7	22
Nematoda		
Nematoda	4	7
Odonata		
Aeshnidae	1	5
Bezzia/Palpomyia	4	13
Boyeria	1	1
Boyeria vinosa	9	17
Calopterygidae	4	13
Calopteryx	1	4
Calopteryx aequabilis	2	7
Calopteryx maculata	1	1
Ceratopogonidae	1	1
Ceratopogoninae	4	11
Coenagrionidae	2	3
Cordulegaster maculata	2	3
Corduliidae	1	2
Enallagma	3	6
Gomphidae	4	11
Hetaerina	1	2
Ophiogomphus	2	2
Ophiogomphus carolus	1	1
Somatochlora minor	2	2
Oligochaeta		
Oligochaeta	19	102
Plecoptera		
Acroneuria	1	2
Acroneuria lycorias	5	18
Amphinemura linda	2	10
Attaneuria ruralis	1	1
Capniidae	4	7
Isoperla	4	18
Leucrocuta	6	31

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Neoplea striola	1	2
Paragnetina media	10	20
Perlesta	1	1
Perlidae	3	10
Pteronarcys	3	4
Taeniopteryx	1	1
Trichoptera		
Brachycentrus americanus	2	32
Brachycentrus occidentalis	2	44
Ceraclea	8	11
Ceratopsyche	12	375
Ceratopsyche alhedra	5	82
Ceratopsyche bronta	4	14
Ceratopsyche morosa	4	11
Ceratopsyche slossonae	9	97
Ceratopsyche sparna	1	38
Cheumatopsyche	11	180
Glossosoma	6	15
Glossosoma intermedium	4	34
Glossosomatidae	5	16
Goera	1	1
Helicopsyche borealis	3	14
Hydatophylax argus	1	1
Hydropsyche	2	13
Hydropsyche betteni	7	43
Hydropsyche dicantha	1	12
Hydropsychidae	14	226
Hydroptila	4	12
Hydroptilidae	2	3
Lepidostoma	8	31
Limnephilidae	7	19
Lype diversa	3	8
Micrasema gelidum	1	2
Nemotaulius hostilis	3	4
Neophylax aniqua	1	2
Neophylax mitchelli	1	1
Neotrichia	1	2

Taxonomic Name	Number of Stations Where Present	Quantity of Individuals Collected
Oecetis avara	2	7
Oecetis persimilis	1	1
Oxyethira	1	3
Phryganeidae	1	3
Phylocentropus	1	1
Polycentropodidae	1	3
Protoptila	3	13
Psychomyia flavida	5	33
Psychomyiidae	1	1
Ptilostomis	1	1
Pycnopsyche	2	3
Triaenodes	2	3
Uenoidae	1	1

Appendix 12 – Lake Superior Basin fish species: endangered, special concern, threatened, and introduced

Taxonomic Name	Common Name
Minnesota Species Of Special Concern	
Acipenseriformes	
Acipenser fulvescens	Lake Sturgeon
Cypriniformes	
Notropis anogenus	Pugnose Shiner
Perciformes	
Etheostoma microperca	Least Darter
Petromyzoniformes	
Ichthyomyzon fossor	Northern Brook Lamprey
Salmoniformes	
Coregonus kiyi	Kiyi
Coregonus zenithicus	Shortjaw Cisco
Species Introduced	
Atheriniformes	
Labidesthes sicculus	Brook Silverside
Clupeiformes	
Alosa pseudoharengus	Alewife
Cypriniformes	
Cyprinus carpio	Common Carp
Gasterosteiformes	
Apeltes quadracus	Fourspine Stickleback
Gasterosteus aculeatus	Threespine Stickleback
Osmeriformes	
Osmerus mordax	Rainbow Smelt
Perciformes	
Morone americana	White Perch
Neogobius melanostomus	Round Goby
Proterorhinus marmoratus	Tubenose Goby
Petromyzoniformes	
Petromyzon marinus	Sea Lamprey
Salmoniformes	
Oncorhynchus gorbuscha	Pink Salmon
Oncorhynchus kisutch	Coho Salmon
Oncorhynchus mykiss	Rainbow Trout
Oncorhynchus tshawytscha	Chinook Salmon
Salmo salar	Atlantic Salmon
Salmo trutta	Brown Trout