Deer Creek/Nemadji River Turbidity TMDL Monitoring Plan 2008-2011 (2010 Update)

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N. Fork Nemadji River, April 2008

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Note to readers:

This document was first released in February 2009. Subsequent versions were released in June 2009 and now October 2010, due to changes and finalizations of monitoring plans. This document reflects those changes. The section titles denote a * where the 2010 changes or additions were made to the plan.

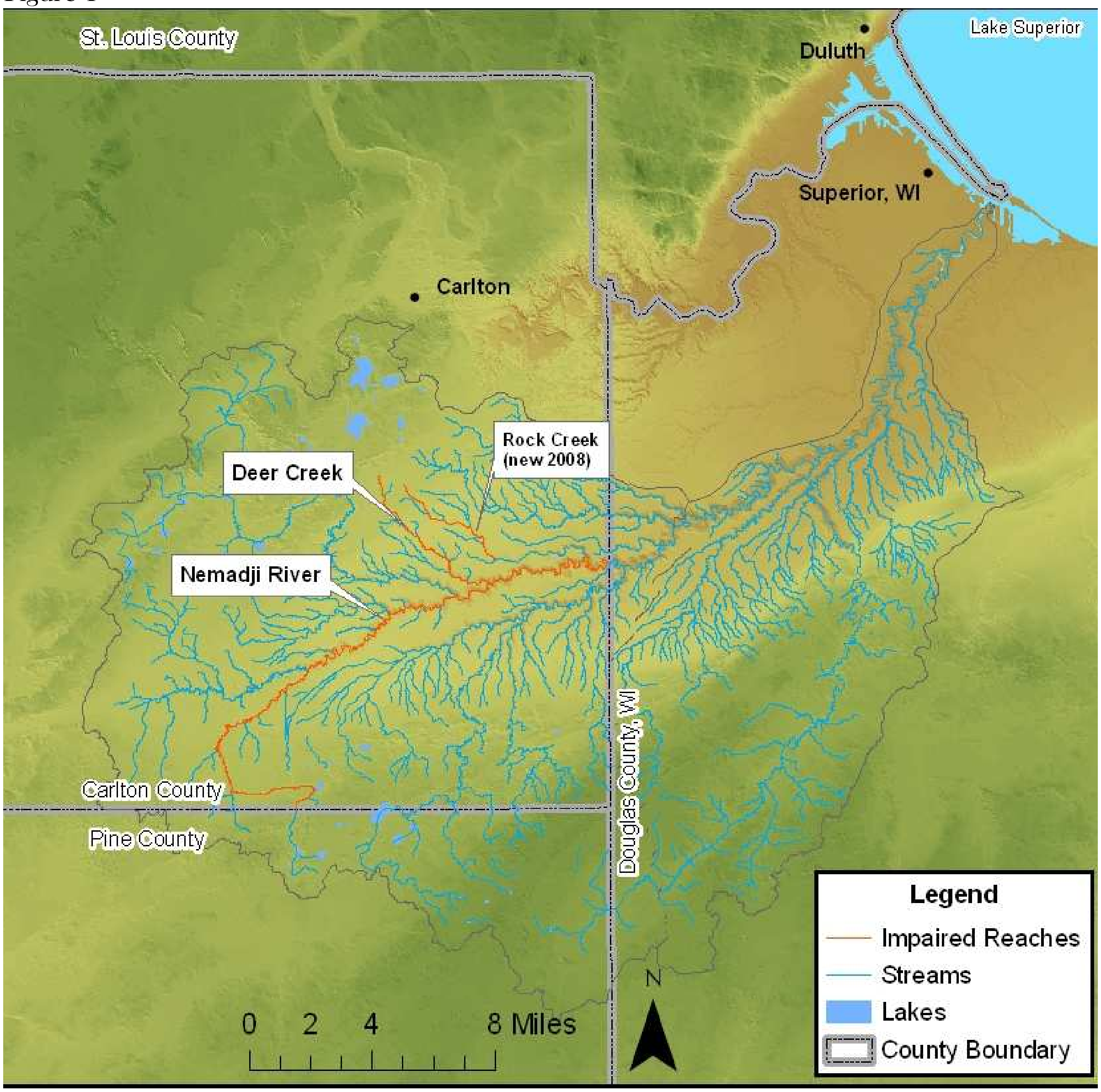
The purpose of this document is to serve as a general guidance plan for the monitoring efforts to be carried out during the Deer Creek/Nemadji River Turbidity Total Maximum Daily Load (TMDL) Project. For details of monitoring methods, please refer to the "Deer Creek/Nemadji River Turbidity TMDL Quality Assurance Project Plan" (Fischer, 2009) and other documents referred to within this plan.

1.0 Background and Introduction

1.1 Location

The Nemadji River Basin is located south of Duluth, Minnesota, draining approximately 277,400 acres (433 square miles) of land in Carlton and Pine Counties, Minnesota and Douglas County, Wisconsin (Figure 1). The Nemadji River begins in southern Carlton County and ends in Superior, Wisconsin at Superior Bay on the western end of Lake Superior. Deer Creek lies entirely in Carlton County and is a tributary to the Nemadji River. It drains approximately 5,118 acres (8 square miles).

Figure 1



1.2 Geology

Roughly one third of the Nemadji River Basin is comprised of glacial till and glacial lake-laid clay soils that are highly prone to erosion and mass wasting. Huge valley walls and steep slumping banks are characteristic of the Nemadji River in the clay portion of the watershed. High sediment load in the Nemadji River is primarily caused by channel incision and mass wasting due geologically recent glacial rebound. Previous watershed studies have identified stream bank erosion and mass wasting (together referred to as "bluff erosion") as the predominate contributor of sediment to the Nemadji River (NRCS, USFS, 1998). The upland portion of the river basin is mainly composed of sandy and loamy tills and glacial outwash that are less susceptible to eroding.

Slightly over one half of Deer Creek subwatershed lies within the clay soil region. In addition to clay banks prone to erosion and mass wasting, groundwater seepage has been identified as a major contributor to the sediment load in Deer Creek. Water carrying sediment travels up through faults in the clay, discharging at points on the surface known as "sand volcanoes" (Mooers and Wattrus 2005). Sediment contribution via groundwater has been identified in Deer Creek and Mud Creek, both tributaries to the Nemadji River. Studies are currently underway assessing the extent of the groundwater sediment contribution.

1.3 Land Cover

Vegetation of the Nemadji River Basin has been dramatically altered from its natural state due to a history of logging, fires, and a conversion to agriculture. The loss of native coniferous species, predominantly white pine, took place during the logging era of the late 1800s. Subsequent fires in 1894 and 1918 were followed by conversion of land use to agriculture in the early 1900s. Today the watershed is composed of a mix of land use, with a small percentage of coniferous forest remaining. A 1998 report indicated that Nemadji River Basin land cover is 69 percent forest, 18 percent cropland and pasture, 11 percent wetlands and lakes, and two percent other categories. Of the 69 percent forest cover, approximately 30 percent of it remains coniferous (NRCS and USFS, 1998).

Although the high sediment load in the Nemadji River is due to channel incision and mass wasting due to geologically recent glacial rebound, these processes have been accelerated in the last 150 years due to the alteration of vegetation. The loss of water storage and moderation once provided by the large coniferous population has resulted in higher water yields which have increased rates of downcutting and incision producing more sediment loading to the system (Riedel, Verry and Brooks, 2002).

In recognition of the land use impacts on the system's hydrology, reforestation efforts were a major focus of the most recent comprehensive project in the watershed known as the Nemadji River Basin Project. In 1978 the St. Louis River system, including the Nemadji River, was designated an Area of Concern (AOC) by the Great Lake Water Quality Agreement between the United States and Canada. The Nemadji River was identified as a high contributor of sediment to the Superior Bay. As a result of the designation, Remedial Action Plans (RAP) were developed for the area and in 1993, the Citizen's Advisory

Committee of the RAP requested the Natural Resource Conservation Service (NRCS) to identify methods for reducing sedimentation in the Nemadji River system. The following year, the Nemadji River Basin Project began and continued through 2007 with efforts on sediment reduction. The goal of the final phase of the project, Phase II, was to "positively affect the hydrology of the system." Best Management Practices (BMPs) were completed in this phase with the recognition that reforestation is the primary means of affecting the hydrology of the system.

1.4 TMDL Listing Background

Minnesota Rules, Chapter 7050.0470, identify classifications for waters in major surface water drainage basin, including those applicable in the Nemadji River. Per Chapter 7050.0470, classifications applicable to both the N. Fork Nemadji River and Deer Creek include Classes 1B, 2A, 3B. The following provides a description of each of these classifications.

Class 1B waters. The quality of Class 1B waters of the state shall be such that with approved disinfection, such as simple chlorination or its equivalent, the treated water will meet both the primary (maximum contaminant levels) and secondary drinking water standards issued by the United States Environmental Protection Agency as contained in Code of Federal Regulations, title 40, part 141, subparts B and G, and part 143, (1992); and sections 141.61 and 141.62, as amended through July 17, 1992; except that the bacteriological standards shall not apply.

Class 2A waters. The quality of Class 2A surface waters shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water.

Class 3B waters. The quality of Class 3B waters of the state shall be such as to permit their use for general industrial purposes, except for food processing, with only a moderate degree of treatment. The quality shall be generally comparable to Class 1D waters of the state used for domestic consumption, except chlorides (Cl) (100 milligrams per liter), Hardness, Ca + Mg as $CaCO_3$ (250 milligrams per liter), pH value (6.0 - 9.0).

A turbidity standard is associated with each of these classes. Of the three listed classes, Class 2A has the most restrictive turbidity standard, which is 10NTU. Documentation of the system's sedimentation and turbidity issues during the Nemadji River Basin Project lead to the current impaired waters listings in the watershed. In December of 2003, Deer Creek (headwaters to Nemadji River) and the Nemadji River from the Minnesota – Wisconsin border upstream in Minnesota to the headwaters were listed on the Federal Clean Water Act's 303 (d) list of impaired waters for turbidity for exceeding the state standard of 10NTU for class 2A waters.

In response to the listing, the state is required to conduct a Total Maximum Load Study (TMDL) study in order to define the load of sediment the water body can deliver while still meeting state standards. The study will identify sediment sources, quantify sediment load amounts from each potential source, and determine potential ways to reduce the sediment loads to meet the state standard of 10NTU. In 2008 a contract was drawn between the Minnesota Pollution Control Agency (MPCA) and the Carlton County Soil and Water Conservation District (SWCD) to carry out the Deer Creek/Nemadji River TMDL study. In the spring of 2008 the work began on the Deer Creek portion of the study. In 2009 monitoring will begin on the greater Nemadji River system. This document will serve as a guide to the monitoring efforts planned for the Deer Creek/Nemadji River Turbidity TMDL Study.

*1.5 Nemadji River Watershed Assessment 2010-2011

The Minnesota Pollution Control Agency recently began a Watershed Assessment Program where all major watersheds with 8-digit HUCs in Minnesota were placed on 10-year cycle for scheduled assessment. The Nemadji River Watershed appeared on the assessment cycle for 2011. The MPCA gives out Surface Water Assessment Grants (SWAG) to local units of government, watersheds groups, and other organizations to aid the MPCA in their assessment efforts. The Carlton County SWCD received SWAG funds for 2010-12 to do additional water quality monitoring in the watershed outside of the TMDL studied areas. Beginning in 2010, the SWCD led a team of volunteers to complete a water quality assessment on 8 new stream sites in the Nemadji River watershed as well as 2 additional MPCA targeted river sites. Monitoring efforts for this project are summarized in section 6.0.

2.0 Past Data Collection

Data collection on the Nemadji River Basin began as early as 1925 according to found records. Early stream reports consisted of fish surveys and documentation of water conditions. Much of the early sediment data was produced from a project called the Red Clay Project, which began in 1972. The project produced data on erosion sources, turbidity, sediment discharge, hydrology, vegetative cover, stream biota and other information relating to sediment in the river. The program included an extensive sediment treatment program where several structures were placed in the Skunk Creek and Deer Creek watersheds to control the sediment.

In the early 1990s, intensive data collection began on geomorphologic and hydrologic conditions of the Nemadji River systems. Several reports were produced providing information on relationships between slumping and watershed characteristics, land use impacts on sedimentation, and in depth geotechnical information on the watershed. Related reports have recently been produced regarding groundwater contributions to sediment in the streams.

As mentioned previously, the Nemadji River Basin project was the last comprehensive project done on the Nemadji River until the recent TMDL study. In the early stages of the project, a sediment budget was produced, allocating source and deposition locations in the Nemadji River system. Chemistry, hydrological, biological, and land use data was collected throughout the project which began in 1994 and ended in 2007.

Preliminary work for this TMDL study called for compilation of existing data for the Nemadji River Basin. A report was produced titled, "Deer Creek/Nemadji River Total Maximum Daily Load Summary of Existing Data." The document outlines all accessible data and details the usefulness of the information. The data summary report supports this monitoring document and will aid in determining possible existing sediment loading data for final TMDL calculations. Further detail of the above mentioned data can be found in the document.

*3.0 Monitoring

The following section describes each monitoring parameter that will be part of the data collection efforts for the Deer Creek/Nemadji River Turbidity TMDL. An introduction to each parameter provides rationale for data collection and background of data collection. The sub-sections also contain site selection rationale and general methods of data collection. All flow, chemistry and transparency tube monitoring will be done according to the Deer Creek/Nemadji River Turbidity TMDL Project Quality Assurance Project Plan (QAPP), which supports this document. Procedures for other monitoring parameters not included in the TMDL QAPP have separate SOPs or guidance manuals that are referred to in this plan. * Note that any QA/QC concerns or changes in the monitoring plan will be notated in Appendix A: Supplementary notes.

3.1 Flow

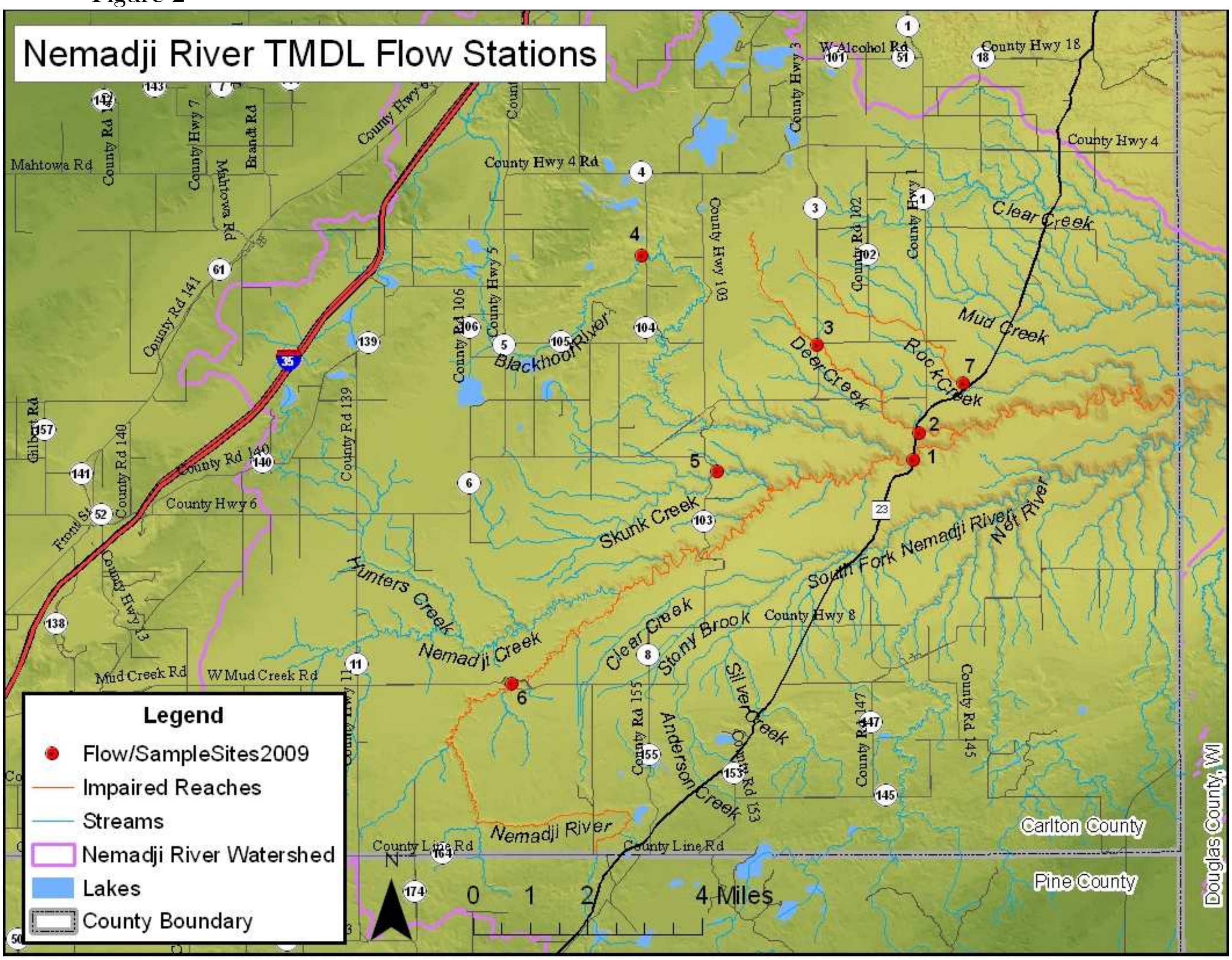
Flow data is essential information to characterize a stream. Baseflow and stream responses to rain events are a product of the watershed topography, geology, land use, soil types, and weather patterns. Measurements of the stream at all conditions combined with knowledge of the surrounding land aids in the understanding a stream's behavior. Additionally, flow data provides critical information for sediment loading calculations. In this case, sediment loading will be measured by collecting suspended sediment samples for lab analysis and pairing the information with stream flow data. The suspended sediment samples will be taken across a wide range on stream conditions. The corresponding flows (cfs) and sediment samples (mg/l) will be calculated in order to obtain a "load" which will be expressed in units such as tons/day.

3.1.1 Site Selection

Three automated stage-recording stations have been previously established in the Nemadji River system. The existing stations will remain active during the Deer Creek/Nemadji River TMDL study. Four new automated stage-recording stations were subsequently established in the Nemadji River system for data collection beginning in 2009. All seven stations will aid in loading calculations (Figure 2). Sites were selected based on representation as a type of subwatershed and access to monitoring sites. Site selections attempt to address variations such as clay influenced and the non-clay influenced portions of the watershed. Variations in land cover are also represented in site selection as areas with forest cover, agriculture areas, and wetlands influenced headwaters of the main stem. Significant tributaries are also considered and sites chosen according to their unique features. Subwatershed descriptions were determined from previous watershed studies. The following provides a brief description of each site and site selection rationale. Sites are listed beginning with existing stations and ending with new stations.

Sites without STORET identification numbers were established in the STORET system and all data will be submitted according to STORET timelines.

Figure 2



Site 1: N. Fork Nemadji River at State Highway 23 (STORET S000-110)
Since 2003, an ultrasonic sensor collecting continuous stage data has been in place on the bridge crossing the N. Fork Nemadji River at State Highway 23. The site is representative of the main stem of the N. Fork Nemadji River, upstream of the Deer Creek confluence. This site lies within the area of the watershed characterized by huge bluffs and lacustrine clay soils.

Site 2: Deer Creek at State Highway 23 (STORET S003-250)
Since 2005, a hydraulic pressure transducer collecting continuous stream stage data has been in place downstream of the culvert crossing Deer Creek at State Highway 23. This reach of the stream has a history of data collection that began in 1967. At that time, a stage data collection station was in place approximately 179 feet west of the Highway 23 bridge overpass. USGS records indicated that site was active until September 2001. No records are found from the period 2002-2004. The MPCA has maintained the site since 2005 in cooperation with the MnDNR. The MnDNR and MPCA are working together to develop a stage-discharge relationship with data taken from flow measurements made 2005-2008. The site is approximately 1 mile upstream from the confluence with the Nemadji River and is the last accessible entry point to the stream before its mouth. This site is downstream of the "sand volcano" area that has been determined to be a significant source of sediment to Deer Creek. The site serves a part of the groundwater investigation to aid in the determination of the groundwater contribution of sediment to Deer Creek and ultimately the N. Fork Nemadji River. Land cover is approximately 60% forestland and 40% open land. The lower 50% of the watershed lies within the lacustrine clay soil region. This monitoring site lies within the lacustrine clay influenced region of the watershed.

Site 3: Deer Creek at CSAH 3 (STORET S004-929)
In the spring of 2008, a hydraulic pressure transducer collecting continuous stream stage data was installed downstream of the culvert crossing County State Aid Highway 3 at Deer Creek. The site will remain active and represents Deer Creek, upstream of the "sand volcano" area. A majority of the open land existing in Deer Creek subwatershed is upstream of this monitoring site. This site lies within the lucustrine clay influenced region of the watershed.

Site 4: Blackhoof River at County Road 104 (STORET S005-620)
An ultrasonic sensor collecting continuous stage data will be installed at the upstream end of the culvert crossing County Road 104 at the Blackhoof River. The section of the Blackhoof River upstream of the site lies entirely in the upland portion of the watershed. The Blackhoof River is a large tributary to the Nemadji River system and the subwatershed represents roughly 28,000 acres of the 277,000 acres of the Minnesota portion of the Nemadji River Watershed. Approximately 1% of the Blackhoof River subwatershed lays in the lacustrine clay influenced portion of the Nemadji River Watershed. The clay portion of the Blackhoof River subwatershed is downstream of the data collection site.

Site 5: Skunk Creek at County Road 103 (S005-617)
A hydraulic pressure transducer collecting continuous stream stage data will be installed approximately 1,150 feet downstream of the bridge crossing County Road 103 of Skunk Creek. Skunk Creek subwatershed represents approximately 6,600 acres of drainage area

of the Minnesota portion of the Nemadji River Watershed. Approximately 43% of the Skunk Creek subwatershed lays in the lacustrine clay influenced portion of the Nemadji River Watershed. The site location is less than two miles upstream of the confluence with the Nemadji River and within the clay influenced portion of the subwatershed. The site serves as the last accessible entry to the river before entering the Nemadji River. The monitoring site is downstream of several dam structures and other types of sediment control treatments that were installed in the 1970s. Study of treatments implemented on Skunk Creek in the 1970s may also lead to further understanding of the effectiveness of these methods and can aid in decisions on Best Management Practices during the implementation phase of the study.

Site 6: Upper N. Fork Nemadji River at CSAH 8 (S005-619)

A hydraulic pressure transducer collecting continuous stream stage data was installed in downstream of the culverts crossing County State Aid Highway 8 of the N. Fork Nemadji River. The site will be representative of the upland portion of the Nemadji River watershed and includes the wetland area headwaters of the Nemadji River. Data collected at this site can aid in the determination of continued impaired water listing of the reach of the N. Fork Nemadji River predominately outside of the clay influenced area of the watershed.

Site 7: Rock Creek at Highway 23 (STORET S003-251)

A hydraulic pressure transducer collecting continuous stream stage data will be installed in the pool downstream of the culvert crossing State Highway 23 at Rock Creek. Rock Creek subwatershed represents approximately 4,500 acres of the Minnesota portion of the Nemadji River watershed. A majority of Rock Creek subwatershed is 50-60% open land with no wetland. Roughly 74% of the subwatershed lies in the lacustrine clay influenced portion of the Nemadji River watershed. Past studies have indicated that Rock Creek is a significant contributor of sediment to the Nemadji River, falling slightly less in comparison to Deer Creek. Rock Creek was recently listed for turbidity on the 2008 Federal Clean Water 303d list of impaired waters. Data collection at this site will provide representation of tributary lying predominately in the clay soils and will jump start data collection for the Rock Creek turbidity TMDL study.

3.1.2 Methods

Station maintenance and data downloads will be completed by MPCA staff with the assistance of the Carlton County SWCD staff when deemed appropriate. MPCA staff will perform flow measurements at all new stations in order to establish a stage-discharge relationship. MnDNR will complete the flow measurements at the *Deer Creek at State Highway 23* station; and will work cooperatively with the MPCA to complete flow measurements at the *N. Fork Nemadji River at State Highway 23* station. Flow measurements will be done at least one time per month at varying stream conditions with a SonTek Flowtracker Handheld Acoustic Doppler Velocimeter, a Price type AA current meter, or a Price pygmy current meter. When flows are too high to wade, a High Flow Acoustic Doppler Velocimeter will be used. A minimum of 3 years of flow measurements will be taken in order to establish a stage-discharge relationship. Three years of data will presumably take into account the range of seasonal variations that can change from year to year, eliminating the chances of data being based on an "abnormal" year. Once the stage-discharge relationship is established, flow measurements will be taken periodically to ensure the accuracy of the established stage-discharge relationship.

*3.2 Chemistry

Turbidity and total suspended solids (TSS) data will be the primary chemical data used in the study. Turbidity is caused by the presence of suspended solids that scatter light in the water column. Units of measurement for turbidity are Nephelometric Turbidity Units (NTU). The state standard of 10NTU was exceeded for Deer Creek and the Nemadji River, which led to the impaired water listing. TSS is the measurement of suspended solids per unit volume of water. TSS is a quantitative measurement while turbidity is a qualitative measurement of the scattering of light particles. In order to complete sediment loading calculations, a quantifiable number needs to be used. A relationship between turbidity and TSS will be established through the pairing of the data order to define a correlation between the exceedance of the 10NTU standard and a load number.

*Total Suspended Volatile Solids (TSVS) is the measurement of the organic content of Total Suspended Solids. In 2010 this monitoring parameter was added in order to characterize the relative amount of organic content of the TSS concentration. Due to the highly forested nature of the watershed, TSVS data on organic content of the suspended load may be valuable information regarding the natural load of the system. TSVS data will be collected for a limited number of flow conditions during the months of July through September, when stream productivity is highest.

Additional chemistry information will be collected at the time as turbidity and TSS data in order to understand the relative stream health. A YSI brand multiparameter sonde will be used to collect additional chemistry data in the field. The following gives a brief description of the additional chemistry parameters.

Hydrogen ion concentration (pH) will be measured, as it is an indicator of the solubility and biological availability of chemical nutrients and heavy metals. pH can determine how much and what form of phosphorus is most abundant in what and whether aquatic life can use it. Additionally, metals tend to be more toxic at low pH values because they are more soluble. Diurnal and seasonal changes in pH can also indicate use and production of carbon dioxide for photosynthesis and respiration. As carbon dioxide is removed for photosynthesis, the acidity of water is reduced and pH increases. During respiration, carbon dioxide is produced which dissolved in water as carbonic acid, which lowers the pH. The pH of most natural waters is generally between 6.5 and 8.5.

Measurement of dissolved oxygen (DO) will be taken to determine the amount of oxygen available for stream biota. When DO concentrations become low, they can cross a crucial threshold that can negatively affect aquatic life. DO is also related to water temperature. As water temperature rises, its ability to hold DO decreases. Seasonal changes in DO can be affected by seasonal water temperature changes. As water warms in the summer, the DO decreases. A healthy stream generally has a DO saturation above 90 percent.

Temperature measurement will also be taken with the sonde. Similar to oxygen concentration, certain biota have temperature thresholds that can be lethal if crossed. The Minnesota DNR Fisheries Division will be monitoring temperature at several sites in the watershed. See Fisheries Monitoring section for more information.

Specific conductivity will also be measured with the above parameters. This measurement of the waters ability to carry an electrical current can indicate the presence of inorganic dissolved solids. Conductivity is controlled predominately by the geology of the area. High clay content soils such as those of the Nemadji River Basin tend to have a higher specific conductivity because of the presence of materials that ionize which wash into the water. The case is similar for areas with groundwater influence. See Section 3.4 for more information on the groundwater study and ion monitoring parameters.

3.2.1 Site Selection

Chemistry data will be collected at all flow stations listed in the previous section and four additional sites where flow data is not being collected, totaling eleven sites in all (Figure 3). Descriptions of the four additional chemistry sites are given below.

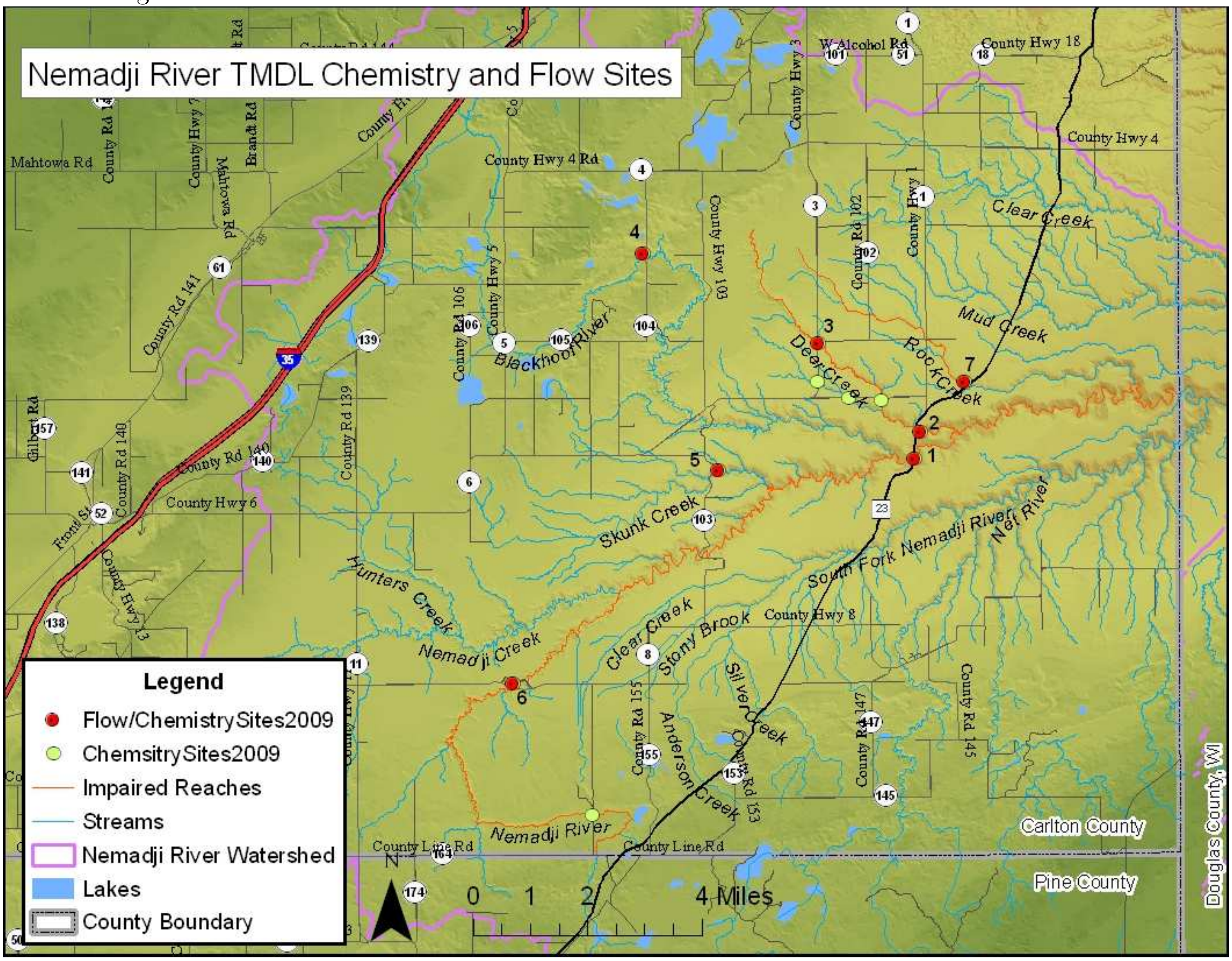
Tributary to Deer Creek at CSAH 3 (S004-930)
Deer Creek has one main tributary that is unnamed. Data will be collected at two different points on this tributary in order to have comparative data for the sites located on the main steam of Deer Creek. The first road access to the upper portion of the tributary is located on CSAH 3. Readings are taken upstream of the culvert. This site lies in the lacustrine clay influenced portion of the tributary and is representative to the upper portion of the tributary, paralleling the Deer Creek CSAH 3 monitoring site.

Tributary to Deer Creek at CSAH 6 (S004-931)
The last road access to the tributary of Deer Creek is located at CSAH 6. This site lies in the lacustrine clay influenced portion of the watershed and less than ½ mile from the confluence with the main stem of Deer Creek. Readings are taken downstream of the culvert.

Deer Creek at CSAH 6 (S004-932)
This site lies midway between the upper Deer Creek site on CSAH 3 and the lower Deer Creek site on State Hwy 23. Readings are taken downstream of the double culverts just before the first bend. This site is downstream of the "sand volcanoes" and lies within the lacustrine clay influenced portion of the watershed.

Nemadji River at Jean Duluth Road (S005-618)
This site was selected in order to obtain data on the portion of the Nemadji River that lies entirely outside of the influences of the lacustrine clay deposits. The portion of the watershed upstream of this site is predominately wetland and the water is characterized by deep tannin stained color. Although the monitoring site lies in a marsh, a clearly defined channel is visible and flow appears to be sustained throughout the monitoring season. Readings are taken off of the downstream end of the culvert.

Figure 3



3.2.2 Collection Methods

Chemistry data will be collected by Carlton County SWCD staff through the use of a YSI brand handheld sonde multiparameter probe at all eleven sites. Discrete field readings will be taken for turbidity, pH, dissolved oxygen, temperature, and conductivity.

Carlton SWCD personnel will collect grab samples for TSS and turbidity at the time of the sonde field readings only at the stations where continuous stage recorders exist. Samples will be taken with the appropriate bottle supplied by the lab, Era Laboratories, Duluth, MN. Each bottle will be labeled with the corresponding site name and time that the sample is drawn. The same information will be recorded in a field book. Water will be collected from the thalweg or mid depth of the stream in order to ensure a well mixed sample. When the stream is too high to wade, a reach pole will be used from the stream bank or a bucket will be lowered from a bridge. Carlton SWCD personnel will transport the field samples to the lab with regard to holding times. Samples will be stored in a cooler on ice at 4C.

A TSS/turbidity relationship will be established for each individual site after approximately three years of reliable data is established. Once the TSS/turbidity relationship is established, TSS can serve as a surrogate for calculations in order to have a quantifiable number for loading. Some TSS and turbidity data exists on various stations and will be considered when developing the TSS/turbidity relationship.

3.3 Physical Channel Assessment and Geomorphology Investigation

While this turbidity TMDL ultimately seeks a number based on sediment and flow, the broader system functioning of the stream and watershed must be considered to complete a full study. Channel assessment and geomorphology investigation will provide valuable information on sediment sources.

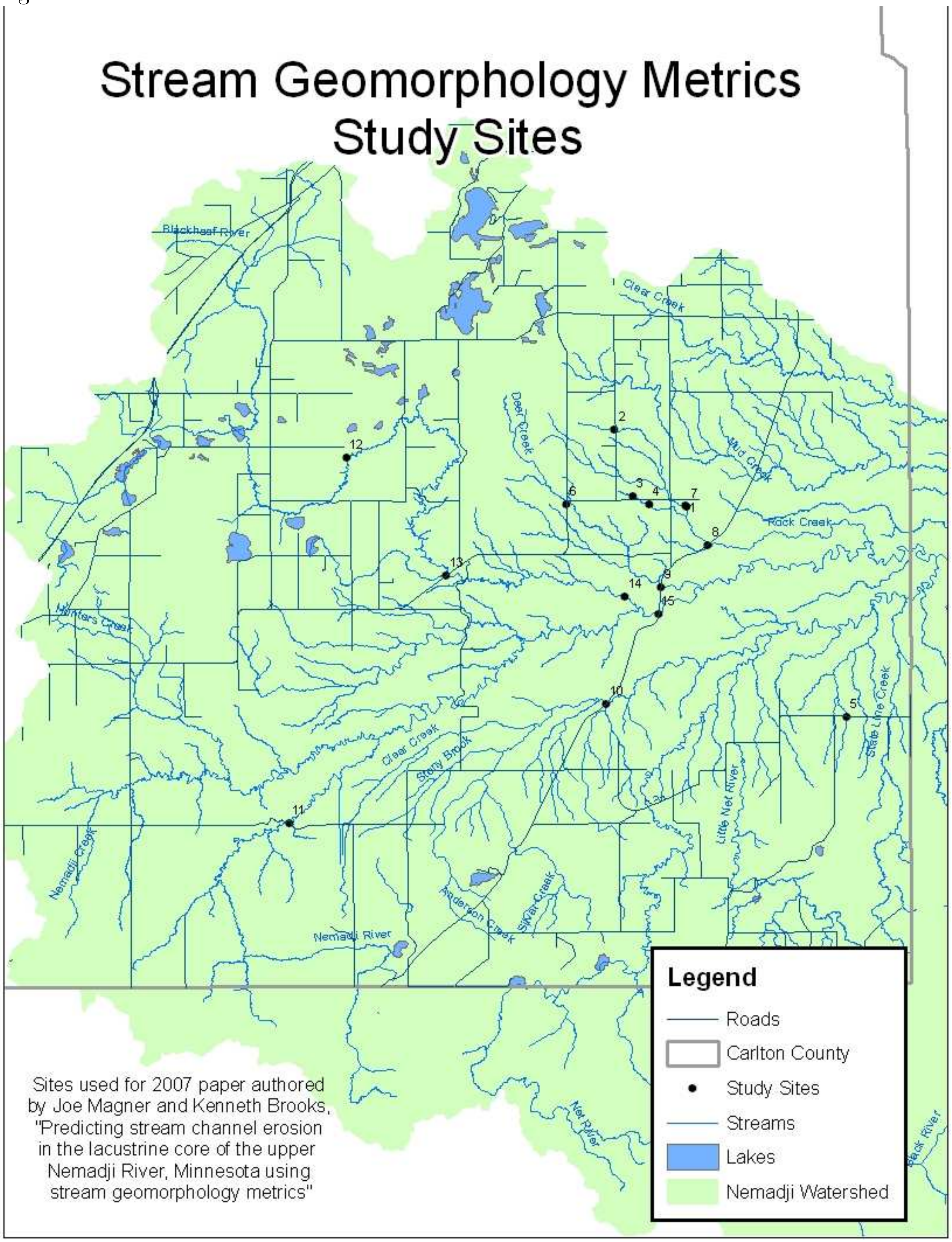
Physical channel assessment work in the Nemadji River basin began in the mid 1990's with studies done by Reidel(1998) measuring stream metrics at 8 sites and using Rosgen classification. The study identified relationships between stream hydraulics and mass wasting, stream type and mass wasting, and land use and stream type. Dendrochronology was used in a later study focusing on the impacts of land use on fluvial processes (Riedel, Verry, Brooks, 2002). Magner and Brooks (2004) then expanded the established sites and examined scale differences within the watershed and the relative channel stability associated with the stage of channel evolution. Schumm's channel evolution model (CEM) was used to estimate the direction of channel adjustment.

3.3.1 Site Selection

Previously established sites will be visited throughout the TMDL study. Site selection for those sites were explained in the associated papers Reidel, (1998), Magner and Brooks (2004), and Magner and Brooks (2007). Reidel (1998) selected sites on the N. Fork Nemadji River and four tributaries for a study using the Rosgen classification system. Deer Creek, Blackhoof River and Skunk Creek were the selected tributaries due to their flow through the slump prone red clay areas characteristic of the Nemadji River. These three tributaries in addition to the Nemadji River, begin in glacially deposited sands and gravel and eventually flow into clay soils. Two of the four tributaries, Deer Creek and Skunk Creek, lay predominately within the clay soil region. Blackhoof River lies between these two creeks yet is primarily outside of the clay soil region. Little Net Creek is the fourth tributary selected for this study and lies almost entirely outside of the clay soil region. Its headwaters drains out-wash sands, gravel, and cobbles, flowing into a bedrock fault system and eventually converging with the Net River. Little Net River was chosen to provide regionally representative data outside of the influences of the lacustrine clay deposits. It is noted that this type of stream is representative of the streams on which most hydrologic and geomorphic investigations have been applied. Additionally, the tributaries were considered for the study due to their varying degrees of land use.

The study reach of the Nemadji River begins upstream of its confluence with Skunk Creek and ends downstream of the confluence with Deer Creek. The upstream portion is outside of the clay soil area and the mid and downstream portion of the reach cut through the clay soils. The upstream portion is predominately wetland and forest. The mid section and lower section are located in lucustrine clay soils. Land use practices have been subject to timber harvesting and agriculture. The lower section has very steep valley walls and a deeply incised channel. See Figure 4 for map of sites.

Figure 4



3.3.2 Methods

In-stream sources will be investigated by evaluating the condition of stream banks in the study regions. Out-of-channel sediment sources will be investigated through field measurements and direct observation. Out-of-channel sources may include but are not limited to mass slumping, gully erosion, trail erosion, roadside erosion, ditch erosion and gully valley incision. Further detail on geomorphologic investigation methods are detailed in the DNR Stream Survey Manual Stream Survey Methods (DNR, 2007). The section of the manual describing a "full survey" details geomorphologic and channel cross section data collection methods among the many other types of data collection used in this type of survey.

The Nemadji River system will be monitored by the MPCA as part of a broader assessment of North Shore streams. Initial work plans are currently being created for a program to undertake a new approach in addressing sediment-related impacts on streams in the Minnesota portion of the Lake Superior watershed by defining an area-specific understanding of water quality. The new approach will use tools such as the WARSSS (Watershed Assessment of River Stability and Sediment Supply) which uses a broad framework for looking at watershed-hillslope-channel linkages. Bank-Stability and Toe Erosion Model (BESTEM) is a method that will address cohesive channel stability, building upon WARSSS method. TISWA (Tailored Integrated Stream Watershed Assessment) is a ranking scheme that will be used to prioritize erosion potential by watershed and for sites within a watershed. As the work plan for this broad scale plan develops, more detail will be incorporated into this monitoring plan.

In spring 2008, high-resolution aerial photography was taken of Deer Creek and the Nemadji River for reconnaissance level work to begin. The same year, ground level photos and waypoint of slumping banks, tributary entrances, and other significant points (such as beaver dams) were taken of Deer Creek and the Nemadji River. These photos have been hot-linked to waypoints, and when added to GIS overlay of aerial photos will aid in initial reconnaissance level assessments. Field reconnaissance visits will be conducted to verify aerial photo/GIS results. Data gaps will be identified during initial GIS and field evaluation. Hydrologic pathways and processes will be assed during the MPCA study. This work has begun with initial data collection for stable isotopes of the ground water investigation in Deer Creek and the Nemadji River.

3.4 Groundwater Investigation

Sediment contribution via groundwater flow can be responsible for high sediment even under baseflow conditions, which is rather unique for a turbidity related impairment. Past studies have analyzed such occurrences in the Nemadji River Watershed.

A groundwater seepage investigation was conducted along a reach of Deer Creek in 2005. The study concluded that groundwater from sand confined aquifers moves through fault scarps in lacustrine clays and clay till sediments bringing sand to the surface. These discharge points, called "sand volcanoes" or "sediment volcanoes," were found to be significant contributors of sediment in Deer Creek. The study suggested that the shear strength of the clay and the driving shear stress are very close to one another, leading to rotational failure when the shear strength is reduced, possibly due to increase in pore pressure. When the faults begin to form due to rotational failure, dewatering occurs, carrying along aquifer materials. The study indicated that the phenomenon is widespread throughout the region (Mooers and Wattrus, 2005).

A UM-Duluth Geology graduate student is currently conducting a follow up study to the 2005 groundwater seepage investigation on a broader scale in the Minnesota portion of the Nemadji River Watershed. Initial results have indicated that sheer strength is high in areas of low slope and sheer strength is low in areas of high slope. Slope failure was generally found to be susceptible in river valleys. Of 41 suspected slump areas, 21 slump areas have been verified. The final results of the study will be available in early 2009.

The MPCA recently completed a groundwater model for a portion of Deer Creek watershed that includes the sand volcano area. Results of the model have indicated a connection between the thinning of the clay layer and likeliness for surficial groundwater discharge. Further modeling will investigate the reduction of groundwater seepage through the establishment of new vegetation. The model will explore the idea of tree root interception of water discharge to streams through data collected on transpiration.

3.4.1 Stable Isotope Study

Groundwater contribution to the sediment load in Deer Creek and ultimately N. Fork Nemadji River will be explored during this TMDL project. The volume, frequency and pathways of the groundwater seepage need to be further investigated in order to quantify all sediment sources.

The use of stable isotope analysis of ^{18}O and Deuterium will assist in delineating hydrologic pathways of the sediment sources. Groundwater has a uniquely different isotopic composition than water from stream channels and precipitation. Samples will be taken from each of these hydrologic sources and analyzed for their isotopic composition. Once these different compositions are determined, the source and quantity of water can be allocated within the stream channel.

3.4.2 Site Selection

Site 1: N. Fork Nemadji River at State Highway 23 (STORET S000-110)
This site is located upstream of the Deer Creek confluence, addressing the isotopic makeup of channel water before it mixes with Deer Creek and other possible groundwater sediment contributors such as Rock Creek and Mud Creek.

Site 2: Deer Creek at State Highway 23 (STORET S003-250)
This site coincides with the flow and chemistry data collection site. The site is downstream of the identified sediment contributing "sand volcanoes" at Deer Creek. Data collected at this site will aid in separating the sediment allocation between groundwater and surface water.

Site 3: Rock Creek at State Highway 23 (STORET 003-251)
This site coincides with the flow and chemistry data collection site. Although sediment contributing "sand volcanoes" have not been identified along this stream, the creek has been recognized as a potential area for these conditions.

Site 4: Mud Creek at State Highway 23
This site is downstream of "sediment volcanoes" located near Mud Creek. As resources allow, flow data will be collected at the site as well.

Groundwater samples will also be taken during the course of the study. Possible sites include the sediment volcanoes located on Mud Creek and Deer Creek, and established wells in each of the identified watersheds.

3.4.3 Methods

Precipitation, groundwater, and stream samples will be taken over the course of 12-18 months in order to compare seasonal variation in isotopic content. Samples will be taken during spring snow melt, spring rainfall, summer rainfall, fall rainfall, fall snow melt and winter snow pack. Samples will also be taken at base flow conditions both during evapotranspiration (ET) and post ET. Samples will be shipped to a certified lab for analysis. In addition to ^{18}O and Deuterium, the following will be analyzed: Anions by IC; Alkalinity, Total; Sulfate by IC; Strontium HL, Tot, H20; Calcium, HL, Tot, H20; Magnesium, HL, Tot, H20; Sodium, HL, Tot, H20; Potassium; Iron; Manganese; Total Phosphorous; Orthophosphate, Total; Ammonia Nitrogen, Total; Nitrate + Nitrite Nitrogen. See "Workplan for the Application of Stable Isotopes ^{18}O and Deuteruim to Delineate Hydrologic Pathways of Flow into Deer Creek" for full explanation of monitoring methods.

3.5 Macroinvertebrate

Biological sampling can give an indication of direct effects of pollution on stream biota. Stream chemistry readings produce important information about the living conditions for biota, yet examination of the biota itself takes into account all possible types of impairments on living conditions.

In the case of the Nemadji River system, exceedance of the turbidity standard due to high sediment yields has been identified as a living condition that can cause impairment on biota. High sediment yields can cause adverse effects on aquatic biota in streams when fine sediments settle into small open spaces in the bed of the stream that serve as refuge for invertebrates and young fish. These small spaces are also used as spawning beds for adult fish and the loss of these spaces can ultimately reduce the fish fecundity. Algae and other primary food resources can also be buried by the fine sediment, disrupting the food web.

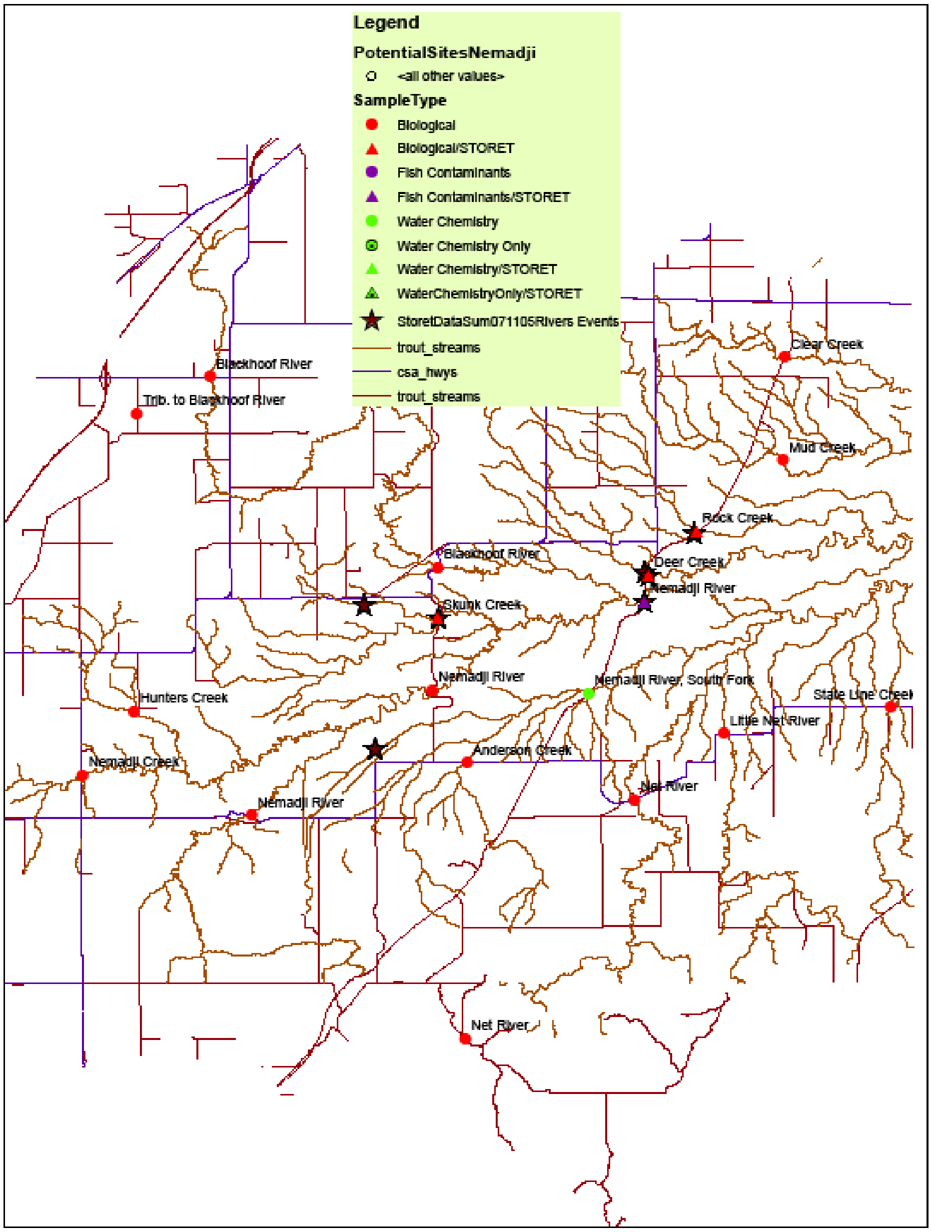
Biological sampling has been done in the past on the Nemadji River system. In 1997 and 1998 the Minnesota Pollution Control Agency gathered biological data in six locations in the Nemadji Watershed. The study was done in effort to develop baseline indices of biological integrity. The Index of Biological Integrity (IBI) is a multimetric approach using macroinvertebrates as indicators of pollution. Macroinvertebrates display a large range of living requirements, making them excellent indicators of water quality. The IBI is a scientifically validated tool typically using 8-12 attributes (metrics) of biological assemblage related to taxa richness, community composition, trophic structure, reproductive function, tolerance to human disturbance, abundance, and condition. Each metric is assigned a rating. The ratings are summed together and index score is given, representing the biological integrity of the site. (http://www.pca.state.mn.us/water/biomonitoring/bio-about.html)

The MPCA will continue monitoring for biological health through a recently developed watershed approach. This approach entails placing Minnesota's 81 major watersheds on a 10-year cycle of condition monitoring. Permanent flow and chemistry stations are set up at the outlets or "pour point" of each watershed. In this case, the Nemadji River Watershed has a "pour point" station at the mouth of the river in Superior, Wisconsin. Intensive monitoring is then done on a 10-year cycle. (http://www.pca.state.mn.us/water/cleanwatercouncil/resolution-080808.pdf) The timeline for the sampling Nemadji River system will be determined at a later date.

3.5.1 Site Selection

There are currently 13 proposed biological sampling sites that the MPCA will potentially visit during intensive monitoring through the pour point program. See Figure 5 for map of proposed sites.

Figure 5 Macroinvertebrate/Biological Monitoring Sites



3.5.2 Methods

The MPCA will carry out macroinvertebrate biological sampling according to the multihabitat method. This method begins with an initial walk of the stream in order to determine the habitats that dominate in each stream reach. Composite samples are taken from up to five different habitat types in a downstream to upstream method. The habitat types are defined as: hard bottom (riffle/cobble/boulder), aquatic macrophytes, undercut banks, snags, and leaf packs. 20 sampling efforts are made in each reach. Sampling is done by making a single dip or sweep using a D-net with 50-micron mesh. A sweep is made by disturbing the substrate in front of the net opening and making several sweeps over the area to make sure the sample is sufficient. Sampling material is put into a sieve bucket and transferred to properly labeled sample bottles with alcohol as quickly as possible in order to preserve the sample.

Please refer to Standard Operating Procedures (SOP) for full details on sampling methods and QA/QC (http://www.pca.state.mn.us/water/biomonitoring/biomonitoring-invertebratesampling.pdf)

3.6 Fisheries Monitoring

The Minnesota portion of the Nemadji River and most of its tributaries are designated trout streams. A warm-water fishery is located in the lower portion of the Nemadji River in Wisconsin. Both Wisconsin and Minnesota DNR agencies monitor the Nemadji River and it's tributaries in order to track the health of the fish populations.

The Minnesota DNR has two existing Index Stations in the Nemadji River watershed where annual population assessments are completed. These Index Stations are located on Net River and Blackhoof River. In 2009, population assessments will be conducted in additional locations. Population assessments give a general understanding of the abundance of game fish through data collection during fish counts.

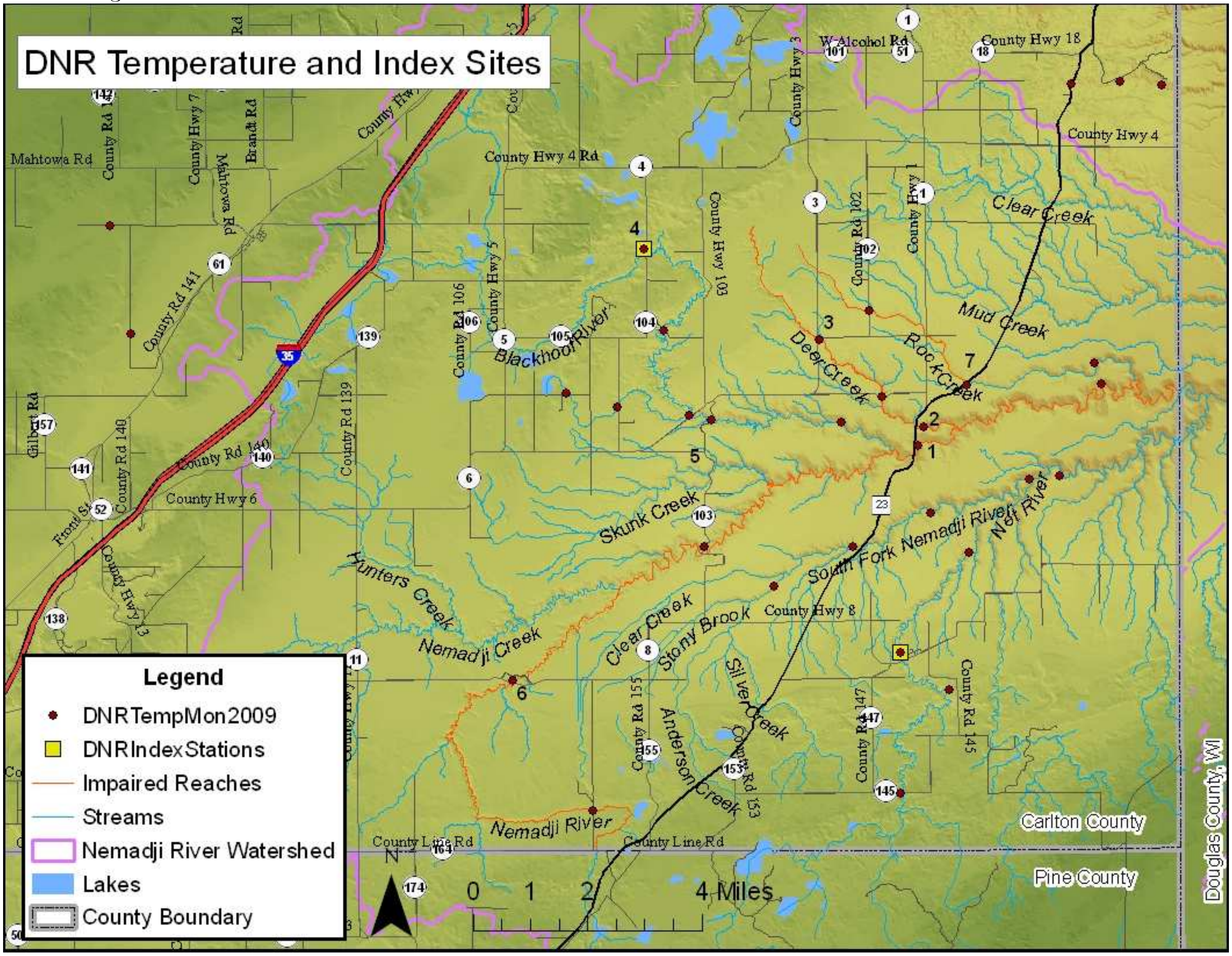
Additionally, the DNR has been monitoring temperature in several tributaries to the Nemadji River. Water temperature is an indicator of fish habitat suitability. Many species of fish have tolerance limit to certain water temperatures. High temperatures sustained over a certain period of time can be lethal to some fish. Data loggers collecting continuous stream temperature data have been placed in several streams to assess stream temperatures over a three-year period in order to monitor the water temperature range of conditions. Data loggers will be placed in four additional streams beginning in 2009.

A full population survey is the most intensive data collection method used for fisheries monitoring. Full surveys include a detailed account of all aspects of the stream habitat and includes data collection on hydrology, geomorphology, water quality, biology, and connectivity. In 2009 a full survey will be conducted on Spring Creek, which is a tributary to the Blackhoof River.

3.6.1 Site Selection

Each site was selected based on need for updated data and relevance to current watershed issues.

Figure 6



Blackhoof River at County Road 104 Crossing
This site is an Index Station where annual population assessments are completed. The Blackhoof River is one of the few rivers in the Nemadji River watershed that has continually sustained a healthy trout population. The site location coincides with the chemistry and flow station that will be newly established in 2009. Temperature monitoring will be conducted downstream of the Index Station.

Net River at County CSAH 8 Crossing
This location is also an Index Station where annual population assessments are completed. The Net River is a tributary to the South Fork Nemadji River. Trout populations have also been found to thrive in this stream. A culvert replacement was recently made on this stream in order to restore the connectivity of the river. Monitoring at this site may lead to further understanding of the success of the restoration project. Temperature monitoring will be completed on Net River also.

South Fork Nemadji River
Temperature data has been collected on a continual basis over the past two years. The 2009 monitoring season will be the final year of temperature data collection on the South Fork Nemadji River.

Deer Creek
A population assessment will be conducted on the stream in conjunction with temperature monitoring. Temperature probes collecting continuous data will be placed in the stream in order to monitor the temperature fluctuations for a three-year period. Deer Creek will be monitored in response to the impaired water listing and lack of recent data.

N. Fork Nemadji River
A population assessment will be conducted on the river in conjunction with temperature monitoring. Temperature probes collecting continuous data will be placed in the stream in order to monitor the temperature fluctuations for a three-year period. North Fork Nemadji River will be monitored in response to the impaired water listing and lack of recent data.

Rock Creek-
A population assessment will be conducted on the river in conjunction with temperature monitoring. Temperature probes collecting continuous data will be placed in the stream in order to monitor the temperature fluctuations for a three-year period. Rock Creek will be monitored in response to the impaired water listing and lack of recent data.

Spring Creek
A full population survey will be completed on Spring Creek in the summer of 2009. Spring Creek is a tributary to the Blackhoof River. Lack of recent data and the creek's role as a tributary to a significant trout stream have deemed the need for intensive data collection. Temperature monitoring will also take place on Spring Creek.

3.6.2 Methods

Population assessments are typically completed through the electrofishing method, which is done at one station per river mile. Continuous temperature probes will be monitored and information downloaded when deemed necessary by DNR staff. The population survey will be conducted according to methods described in the "DNR Fisheries Stream Survey Manual." The manual also specifies electrofishing methods used for the population assessments.

3.7 Water Clarity/Transparency Tube and Citizen Monitoring

Transparency tube readings are a visual measurement of water clarity, providing a broad characterization of the water transparency of a stream reach. A relationship between transparency tube readings and turbidity readings is being developed by the MPCA in order to identify a water clarity reading that represents the 10NTU standard of cold-water streams. SWCD staff and citizen volunteers will collect transparency tube readings to aid in the development of the turbidity/transparency tube relationship.

The simplicity and economic feasibility of transparency tube method makes it possible to involve citizen volunteers and organizations, providing more abundant data than would be otherwise obtained. This additional data will help characterize streams or reaches that are not currently monitored by the participating agencies, aiding in the understanding the entire system.

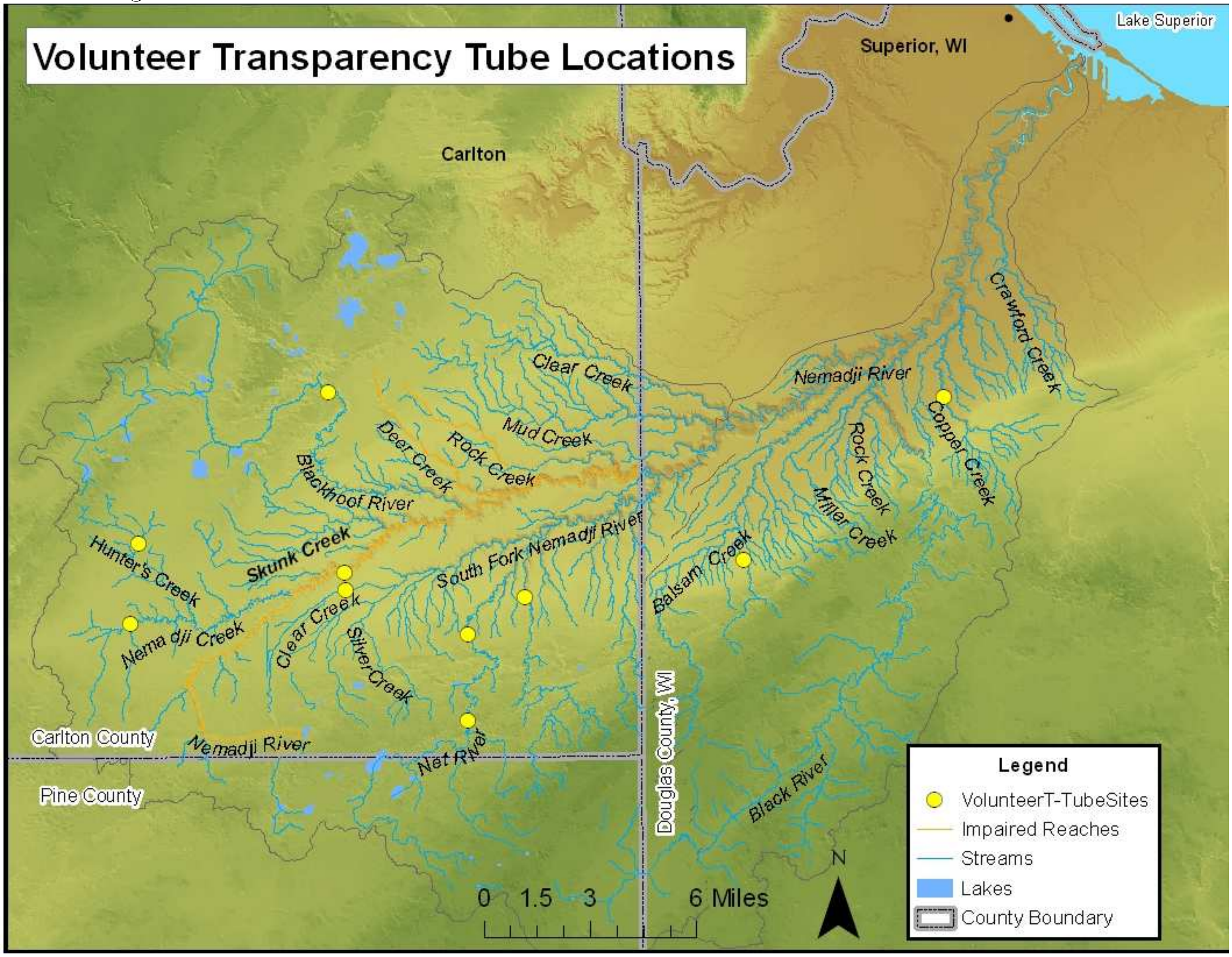
Involvement of volunteers also encourages interest in the health of water resources and public education. Promotion for volunteer recruitment began in August 2008 with the distribution of the TMDL project newsletter. The project was introduced along with information about transparency tube data collection. Volunteer forms were provided with the newsletters and on the Carlton County SWCD website. Public meetings were held in September 2008 where citizens were introduced to the project and volunteer options were discussed. Press releases were published indicating the opportunity to volunteer. A training was held in March where Minnesota Waters led a hands on training to take transparency tube readings and read rain gauges. At the beginning of the 2009-monitoring season, 12 volunteers from Carlton and Pine Counties Minnesota and Douglas County Wisconsin were enrolled in the program.

3.7.1 T-Tube Site Selection

Transparency tube readings will be obtained by Carlton County SWCD at each of the seven flow and chemistry sites in order to contribute data to the transparency tube/turbidity relationship. See Section 3.1 Flow and Section 3.2 Chemistry for rationale on site selections and descriptions.

Volunteers will monitor an additional ten sites in the Nemadji River watershed spanning Carlton and Pine Counties, Minnesota, and Douglas County, Wisconsin. Sites were chosen based on lack of monitoring data, accessibility, and availability of volunteers. See Figure 7 for monitoring site locations.

Figure 7



Volunteer Site 1: Blackhoof River at bridge crossing at private residence off Valley View Road (T47N, R17W, Sec10)

This site is located at a private residence just downstream of the TMDL monitoring station on County Road 104. This site is representative of the upland portion of the watershed, which is dominated by wetland and upland forest. Data collected at this site can be supportive of the data being collected just upstream of the site.

Volunteer Site 2: N. Fork Nemadji River at County Road 103

This site is located at the bridge crossing the N. Fork Nemadji River at County Road 103. The monitoring site lies within the lucustrine clay soils of the watershed. The location is upstream of the confluence with Skunk Creek and downstream of the confluence with Hunter's Creek and Nemadji Creek.

Volunteer Site 3: Clear Creek at County Road 103

Relatively little data has been collected on Clear Creek in the past. Clear Creek is the second named Clear Creek in the watershed but is distinguished as the tributary to the

South Fork Nemadji River as opposed the Clear Creek in the northern part of the watershed that is a tributary to the N. Fork Nemadji River after crossing the state line into Wisconsin. Clear Creek is about 5 miles in length. It flows through sandy and gravel soils in a northerly direction and turns eastward where it flows through luscustrine clay soils until it reaches the S. Fork River. Land use is predominately forest cover with some pasture and sparse wetlands.

Volunteer Site 4: Hunter's Creek at CSAH 8
Hunter's Creek is also an understudied creek and serves as one the first tributaries to the N. Fork Nemadji River. It lies almost entirely outside of the lucustrine clay soils. Land use is a mix of wetland, pasture, and forest cover.

Volunteer Site 5: Nemadji Creek at CSAH 11
Nemadji Creek is also one of the first tributaries to the N. Fork Nemadji River. Little data has been collected on the stream in the past. The creek flows out of wetlands and winds to the north through mixed forest until it joins Hunter's Creek and the N. Fork Nemadji River. Nemadji Creek is predominately outside of the lucustrine clay soils.

Volunteer Site 6: Net River at CSAH 8 Holyoke Park access
Net River is approximately 13.5 miles long and is a relatively significant sized tributary to the S. Fork Nemadji River. The stream lies predominately outside of the lucustrine clay soils and much of the land cover is state-owned forest. Wetlands dominate the upper reaches of the stream. The stream also serves as a feeder and outlet for Net Lake. Net River serves as important trout habitat and fish populations are monitored on a yearly basis by the Minnesota DNR at this location.

Volunteer Site 7: Little Net River at CSAH 8
Little Net River is approximately 9.5 miles long and runs parallel to the east of the Net River. The stream also lies predominately outside of the lucustrine clay soils and much of the land cover is state-owned forest. Wetlands influence the upper portion of the stream.

Volunteer Site 8: Net River at County Road 145
This monitoring site is located upstream of the CSAH site. This site is the first accessible entry point of the river after it flows out of Net Lake. Upstream of this site is heavily influenced by beaver activity.

Volunteer Site 9: Little Balsam River at private residence culvert at end of Severson Road
This monitoring site lies just inside the lucustrine clay soils of the Nemadji River Basin in Douglas County, WI. Little Balsam is a tributary the Balsam River which a significant tributary to the main stem of the Nemadji River after the north and south forks of the river converge. Upstream of the monitoring site, land use is predominately mixed forest cover.

Volunteer Site 10: Copper Creek (location to be determined)
Copper Creek lies predominantly within the lucustrine clay soils of the watershed and land use is a mix of hay/pasture land and coniferous forest. The stream has a high gradient and is flashy.

3.7.2 Methods

Citizen volunteers will collect transparency tube readings one time per week at the designated locations. Additional readings will be taken following storm events. Water will be collected from midstream where water movement is apparent. When feasible, the transparency tube will be submerged directly in the stream, facing upstream of the current. When the water is too deep or fast moving to wade for sample collection, the bucket method will be used. A clean bucket will be lowered over a bridge or culvert or thrown in the stream from a safe distance at the bank. The bucket will be triple rinsed with stream water prior to drawing the sample. Once the transparency tube is filled with stream water, the sample collector will stand with their back to the sun and look directly down into the top end of the tube. Water will be released slowly. When the black and white figure at the bottom of the tube is first visible, the water release will be stopped. A reading will be recorded on a field sheet. A second reading will be taken when the figure is clearly visible. An average of the two readings will be recorded as the final transparency tube measurement.

Transparency tubes, field sheets, and instruction will be provided to volunteers at a workshop held by Minnesota Waters prior to the field season.

3.8 Precipitation/Rain Gauge and Citizen Volunteers

Climactic conditions are critical information for characterizing a watershed. The relatively large size of the watershed makes it vulnerable to varied weather conditions in different areas at one given time. An abundant distribution of precipitation data collection sites will be necessary to accurately characterize the entire watershed. Existing and newly collected precipitation data will be used in modeling and important for runoff and flow calculations.

Existing precipitation data for the Nemadji River watershed and surrounding area is found in several locations. The State Climatology Office-DNR Waters reports monthly rainfall totals for six locations in Carlton County, five locations in Pine County. The Western Lake Superior Sanitary District collects real-time rainfall amounts for Wrenshall, MN, which is located just north of the Nemadji River watershed. Real-time precipitation data is also collected at the Cloquet Forestry Center, north of the Nemadji River watershed and reported in 1 hour, 3 hour, and 6 hour current rainfall totals and monthly totals. The United States Geological Service (USGS) has reported daily precipitation totals for Nemadji River in South Superior (USGS station 04024430) from 1997 to the present.

Citizens throughout the watershed will collect rainfall amounts in order to obtain a good representation of the entire watershed where continuous data collection is not possible.

Additional volunteers not enrolled in the t-tube volunteer program will also collect rainfall data.

3.8.1 Continuous Rain Gauge Data Site Selection

The MCPA will have two additional continuous rainfall data collection station to supplement to the existing two stations. Continuous rainfall data will be collected at the locations described below. See Figure 8 for Site locations.

Site 1: N. Fork Nemadji River at State Hwy 23
Since 2003, the MPCA has been collecting continuous rainfall data at this continuous flow station. Rainfall data will continue to be collected at this location throughout the study.

Site 3: Deer Creek at County Road 3
Since spring of 2008, the MPCA has also been collecting continuous rainfall data at this flow station. Rainfall data will continue to be collected at this location throughout the study.

Site 4: Blackhoof River at County Road 104
This location will produce precipitation data representative of the Blackhoof River, which is the largest tributary to the N. Fork Nemadji River in Minnesota portion of the watershed.

Site 6: Upper North Fork Nemadji River at County Road 8
Data will be collected at this site in order to have data representative of the upper portion of the N. Fork Nemadji River.

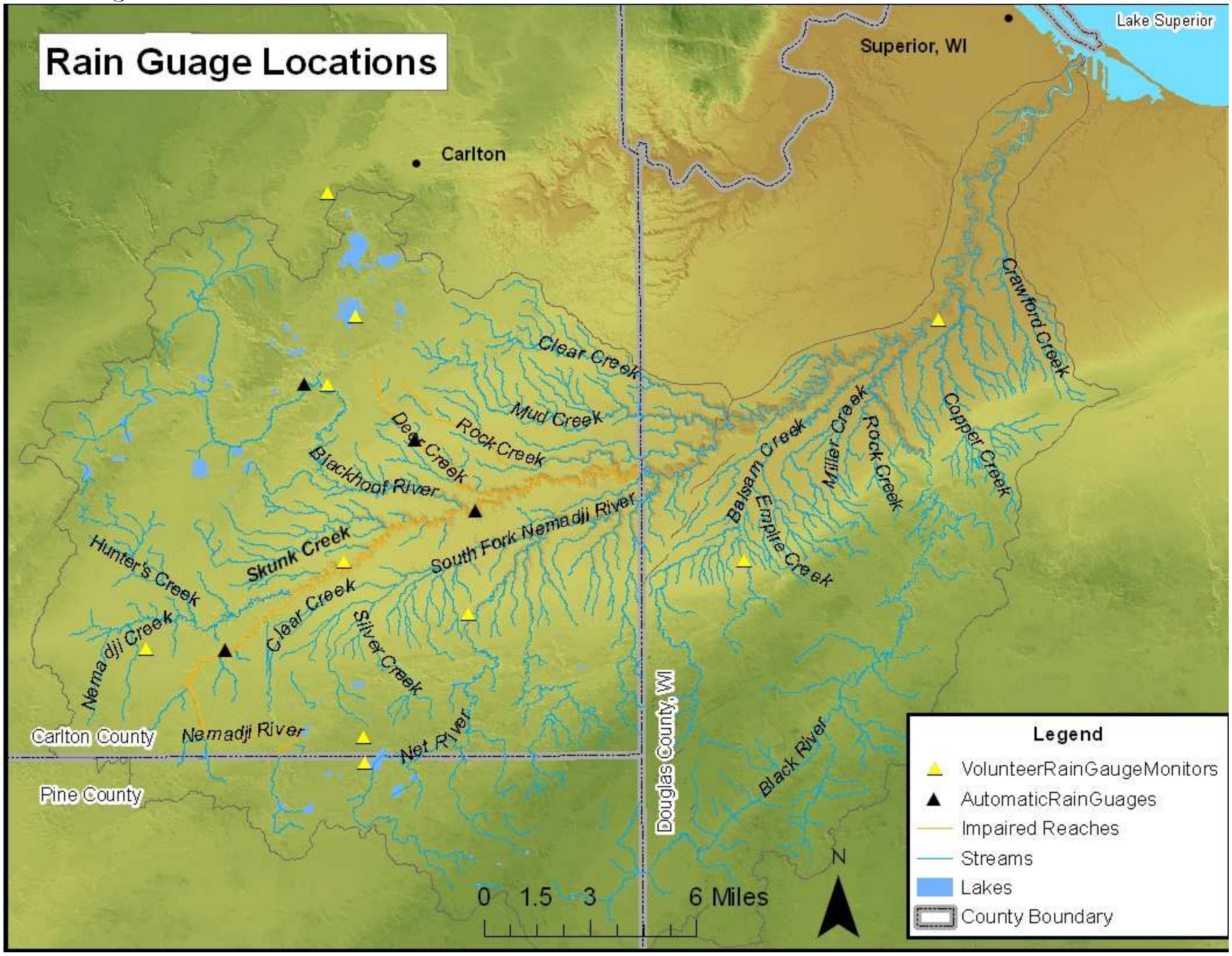
3.8.2 Continuous Rain Gage Data Collection Methods

Continuous rainfall data will be collected via a tipping bucket fixed to the top of a pole above the data collection box. The rainfall amounts will be electronically stored by a data logger in the data collection box. MPCA staff will download precipitation data along with stream stage data when deemed appropriate. MPCA staff will be responsible for storing data and entering it into the Hydstra data management system.

3.8.3 Citizen Volunteer Rain Gauge Site Selection

All volunteers collecting t-tube information will monitor rain amounts. See Section 3.6, Citizen Volunteer T-Tube Site Selection, for details on site selection at t-tube locations. Additional rain gage data will be collected volunteers not participating in the t-tube data collection. See Figure 8 for all rain gauge locations.

Figure 8



3.8.4 Citizen Volunteer Rain Gauge Data Collection Methods

Volunteers will record daily rainfall amounts on a datasheet. If no rainfall occurs, a “0” will be recorded for the day. If less than .01” occurs, a “T” will be recorded for trace. If rainfall accumulates for more than one day, the amount and date will be recorded followed by an “R” to indicate that the rainfall is more than a 24-hour accumulation. After a rainfall reading is made, the rain gauge will be emptied. Instruction on precipitation data collection will be provided at the Citizen Monitoring Workshop held by Minnesota Waters prior to the field season.

4.0 Monitoring Schedules

The following tables outline the sampling parameters, instruments, personnel, monitoring periods, frequency, and lab methods and timelines for monitoring tasks described in the previous section.

*Table 1 Monitoring Parameters and Responsibilities

Parameter	Responsible Agency	Lab Method	Instrument	Frequ.	Monitoring Period
Flow	MPCA	N/A	Handheld Flow Acoustic Doppler Velocimeter/ High Flow Acoustic Doppler Velocimeter	Monthly	April-October
Field Chemistry	Carlton SWCD	N/A	Handheld Multiparameter Sondes	Weekly	April-October
Grab Samples:					
Turbidity	Carlton SWCD	EPA 180.1	1 Liter Bottle	Weekly	April-October
TSS	Carlton SWCD	USGS I-3765-85	1 Liter Bottle	Weekly	April-October
*TSVS	Carlton SWCD	EPA 160.4	1 Liter Bottle	1 low flow 3 high flows	July-Sept
Physical Channel Assessment	MPCA/ Carlton SWCD	N/A	To be determined	To be determined	April-October
Isotope	MPCA	To be det.	To be determined	To be determined	January-December
Macroinvertebrate	MPCA	N/A	D-Net and sample Bottle	To be determined	Late Summer/ Early Fall
Fisheries:					
Fish Survey	MnDNR	N/A	Electroshocking	One Time	June-August
Full Survey	Mn DNR	N/A	See Manual	One Time	June-August
Temperature	MnDNR	N/A	Continuous Temperature Probes	Continuous	May-September
Water Clarity	SWCD/ Citizen Monitors	N/A	60cm and 100cm tubes	Weekly	April-October
Precipitation:					
Continuous	MPCA	N/A	Tipping bucket and data logger	Continuous	April-October
Daily	Citizen Monitors	N/A	Rain Gauge	Daily	April-October

Table 2 Monitoring Task Timelines 2009-2011

Task	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
CSMP Training			■									
STORET Station Establishment			■	■								
Continuous Temperature					■	■	■	■	■	■		
Flow				■	■	■	■	■	■	■		
Chemistry				■	■	■	■	■	■	■		
Physical Channel Assessment				■	■	■	■	■	■	■		
Isotope	■	■	■	■	■	■	■	■	■	■	■	■
Macroinvertebrate									■			
Fisheries Assess. and Survey						■	■	■				
Fisheries Temperature					■	■	■	■	■			
Water Clarity				■	■	■	■	■	■	■		
Precipitation				■	■	■	■	■	■	■		
STORET Submittal											■	
CSMP Data Submittal										■		
Hydstra Data Submittal											■	■

5.0 Data Management

5.1 Data Collected by Continuous Monitoring Equipment

Stream stage and precipitation data collected by continuous monitoring equipment will be entered into the Hydstra data management system by MPCA staff. Calculations for stream flow will be done when sufficient flow data is collected in the field and a rating curve is developed. A minimum of three years of data will be needed in order to produce a rating curve.

5.2 Water Chemistry data

Chemistry data collected in the field by SWCD staff will be recorded in a field book. Recordings of the site visit time, date, location, stream conditions, and general weather observations will be noted in the field book during each field visit. Grab sample times will also be recorded at the time of sampling. All TSS and turbidity data analyzed by the lab will be obtained by the SWCD staff for final data submittal.

Field and lab data will be entered on an excel spreadsheet and will be reviewed by Carlton SWCD staff for accuracy. SWCD staff will submit all field and lab data to STORET according to STORET timelines.

5.3 Physical Channel Assessment and Geomorphology Investigation

Data will be recorded in field books and when appropriate, data sheets will be completed according to the assessment method being used. Methods used will be addressed on a case-by-case approach according to decisions made by the monitoring team.

5.4 Stable Isotope Study

Field data including site location, grab sample times, and sonde data will be recorded in a field book by MPCA staff. Lab analysis data will be obtained by MPCA staff. All data will be entered on an Excel spreadsheet.

5.5 Macroinvertebrate Data

Macroinvertebrate data will be collected on proper field sheets and stored in the biological database by MPCA staff or an agency designated by MPCA.

5.6 Fisheries Data

Fish assessment and survey data will be recorded on designated field sheets by Minnesota DNR. Reports will be completed according to the DNR Fisheries Stream Survey Manual.

5.7 Transparency Tube and Rain Gauge Data

Transparency tube data collected by SWCD staff will be recorded in a field book and entered into the Excel spreadsheet for STORET submittal along with the chemistry information.

T-tube and rain gauge information collected by volunteers will be recorded on the proper field sheets and submitted to SWCD staff on a monthly basis. At the end of the field season, the SWCD staff will submit t-tube and rain gauge data sheets completed by volunteers to the MPCA Citizen Stream Monitoring Program staff. A map of sites along with ground truth readings will be sent with the data. Information will be submitted to the

MPCA in October in order for CSMP staff to make timely STORET submissions of CSMP data.

6.0 *Nemadji River Watershed Stream Assessment Project

This project focuses on collecting a broad set of water qualtiy data in Nemadji River Watershed streams that are lacking existing data and have not been assessed by the MPCA. Once the water quality condition monitoring data is collected, it will be assessed along with biological data collected by the MPCA. Data will be reviewed for 303(d) listing determination. Citizen volunteers and SWCD staff will complete water quality monitoring on two targeted river sites in the watershed and eight additional stream sites including prospective MPCA biological assessment sites. Data will be collected according to MPCA guidelines which appear in the 2009 document *Guidance Manual for Assessing the Water Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List.*

Note that this project is listed under a separate MPCA project number for contracting purposes. See emails dated 8/9/10 in Appendix A-Additional Notes for project number and rationale.

6.1 Site Selection

Sites were selected based on lack of existing water chemistry data, proximity to MPCA prospective biological monitoring locations, fishery priority streams, and site access. The new sites are outside of the 2009-11 TMDL study locations, with the exception of the Nemadji River-North Fork-Hwy 23 site, which was selected by the MPCA as one of two targeted stream sites for the assessment. Careful consideration was made not to duplicate sampling parameters at this location.

Below is a list of the selected sites and a brief description. See figure 9 for site locations.

Site 1: Clear Creek at MN-23 (STORET S006-213)
This site is located at State Highway 23 crossing Clear Creek in eastern Carlton County. Clear Creek is also referred to as Clear Creek 1 as there is another Clear Creek (2) located in the Nemadji watershed that is a tributary to the South Fork Nemadji River. Clear Creek 1 is the northernmost subwatershed in the Carlton County portion of the Nemadji River watershed. Clear Creek originates near Venoah Lake and flows southeast until it reaches the main stem of the Nemadji River in Douglas County, Wisconsin. Soils in the lower half of the watershed are predominately clay. The lower portion of the watershed is mainly forested while the upper two thirds of the watershed is comprised of over 40% open lands. Clear Creek has no past water chemistry records. A fish population assessment conducted by the Minnesota DNR in 2008 found trout to be present in the creek.

Site 2: Mud Creek at MN-23 (STORET S005-771)
This site is located at State Highway 23 crossing Mud Creek adjacent to Clear Creek. Mud Creek originates near Lac Labelle and flows southeast to join the North Fork Nemadji River in Douglas County, Wisconsin. Approximately two thirds of the watershed lie in the

clay soil region. The upper one third of the watershed is comprised of over 40% open land while the lower portion is mostly forested. Mud Creek was assessed for fish population in 2006 by the DNR and no trout were found to be present. The stream is being considered for reintroduction of trout. Mud Creek is part of the current isotope analysis study yet there are no records for water quality assessment for nutrients, turbidity and chloride.

Site 3: Spring Creek at Pioneer Road (STORET S006-218)
This site is located at Pioneer Road crossing Spring Creek just north of CSAH 6. Spring Creek originates near Spring Lake and travels southeast to join the Blackhoof River. Spring Creek watershed is comprised of approximately 40% open land and the upper three fourths of the watershed lie outside of the clay soil region. A full fish and habitat survey was conducted on Spring Creek by the DNR in 2009. Trout were found to be present and stream temperatures were found to be ideal for trout. The upper portion of the watershed has many groundwater seeps providing the stream with a cool, clear, perennial flow. Spring Creek has no past water chemistry records.

Site 4: Hunter's Creek at CSAH-6 (STORET S006-094)
This site is located at CSAH-6 crossing Hunter's Creek on the eastern edge of the Nemadji River watershed. This site was first established in 2009 as part of the volunteer transparency tube program through the Deer Creek/Nemadji River Turbidity TMDL Project. Transparency tube data collection continues along with the new assessment program data collection. The stream lies predominately outside of the clay soils and much of the watershed is comprised of open land percentages over 40%. No trout were found to be present in Hunter's Creek during a survey conducted by the DNR in 2005. Hunter's Creek has no past water chemistry records.

Site 5: Silver Creek at CSAH-8 (STORET S006-215)
This site is located at CSAH-8 crossing Silver Creek just east of County Road 103. Silver Creek flows north to join South Fork Nemadji River. The lower one eighth of the watershed lies within the clay soil region. Silver Creek watershed is mostly forested with very little open land. Silver Creek has no past water chemistry records. Trout were found to be present in the stream during a survey conducted by the DNR in 2007.

Site 6: Net River at CSAH-8 (STORET S006-078)
This site is located at CSAH-8 crossing Net River at Holyoke Park in the southern portion of the Nemadji River watershed. This site was first established in 2009 as part of the volunteer transparency tube program through the Deer Creek/Nemadji River Turbidity TMDL Project. Transparency tube data collection continues along with the new assessment program data collection. The stream lies predominately outside of the lucustrine clay soils and much of the land cover is state-owned forest. Wetlands dominate the upper reaches of the stream. The stream also serves as a feeder and outlet for Net Lake. Net River provides important trout habitat and fish populations are monitored on a yearly basis by the Minnesota DNR at this location.

Site 7: Little Net River at CSAH-8 (STORET S006-079)
This site is located at CSAH-8 road crossing the Little Net River, adjacent to the Net River. This site was first established in 2009 as part of the volunteer transparency tube program

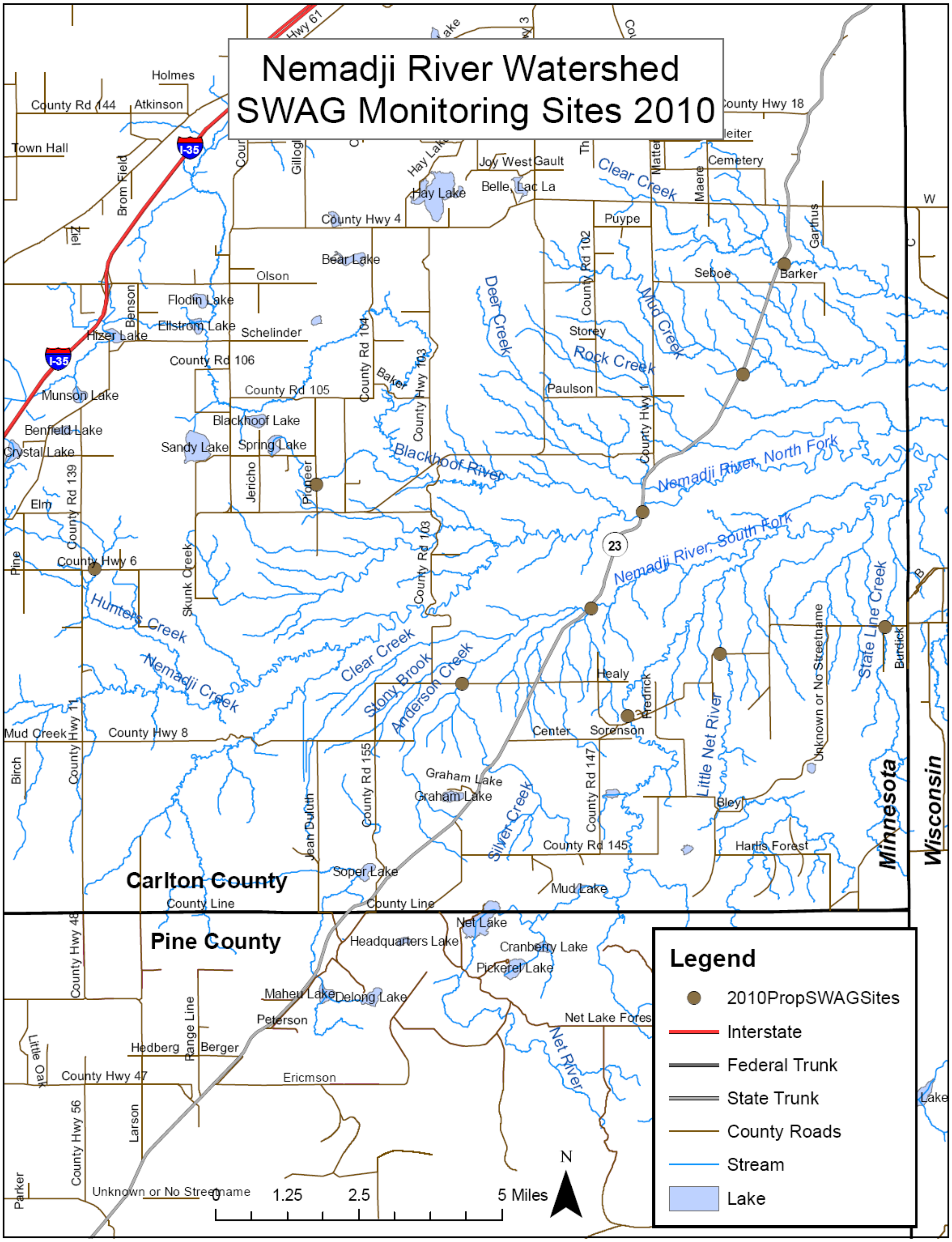
through the Deer Creek/Nemadji River Turbidity TMDL Project. Transparency tube data collection continues along with the new assessment program data collection. The stream also lies predominately outside of the lacustrine clay soils and much of the land cover is state-owned forest. Wetlands influence the upper portion of the stream.

Site 8: Stateline Creek at CSAH-8 (STORET S006-216)
This site is located at CSAH-8 crossing Stateline Creek in the southeastern portion of Carlton County, near the Wisconsin border. Stateline Creek runs north to join the South Fork Nemadji River. The northern one third of the watershed lies within the clay region of the Nemadji River watershed. The same region is comprised of approximately 40% open lands. The upper two thirds of the watershed is mostly forested and part of the Nemadji State Forest. A fish assessment conducted by the DNR in 2010 revealed the presence of a trout population.

Site 9: Nemadji River-North Fork (STORET S000-110)
This site is located at State Highway 23 crossing the North Fork Nemadji River. This site has been established prior to the assessment project and is also being monitored through the Deer Creek/Nemadji River Turbidity TMDL project. The MPCA selected this site as a targeted monitoring site for the assessment cycle, where a required set of parameters will be monitored.

Site 10: Nemadji River-South Fork (STORET S006-214)
This site is located at State Highway 23 crossing the South Fork Nemadji River, adjacent to the North Fork Nemadji River. This site lies within the area of the watershed characterized by high bluffs and lacustrine clay soils. Trout were found to be present in an assessment conducted by the DNR in 2007. There are no past records for water quality assessment in the last 10 years. The MPCA selected this site as a targeted monitoring site for the assessment cycle, where a required set of parameters will be monitored. A flow monitoring station will be installed at the site beginning in 2011.

Figure 9


Nemadji River Watershed
SWAG Monitoring Sites 2010
Legend
2010PropSWAGSites
Interstate
Federal Trunk
State Trunk
County Roads
Stream
Lake
Carlton County
Pine County
Minnesota
Wisconsin
Nemadji River, North Fork
Nemadji River, South Fork
Blackhoof River
Clear Creek
Deer Creek
Rock Creek
Mud Creek
Hunters Creek
Nemadji Creek
Stony Brook
Anderson Creek
Silver Creek
Little Net River
State Line Creek
Net River
0 1.25 2.5 5 Miles
N

6.2 Monitoring Parameters, Methods, and Schedule

Data collection at the 8 stream sites will include collection of grab samples for Turbidity, Total Suspended Solids, Chloride, Total Phosphorous, Total Kjeldahl Nitrogen and Nitrate-Nitrite Nitrogen. Transparency tube data and field notes such as stream stage, stream appearance, and stream suitability will also be collected at each site. All field work, including water sample collection and delivery within the required time to the certified lab, will be completed by Carlton SWCD staff and trained citizen volunteers.

Water samples will be collected using clean polyethylen bottles provided by the certified laboratory. Samples will be filled to the proper amount to perform the analyses, labeled, and placed in a cooler on ice. Samples will be collected at the thalweg to provide a well mixed sample. If the stream is safe to wade, the sampler will collect the sample by facing upstream, inverting the bottle below the surface, then turned upright to collect the sample. If the stream is not safe to wade, reach pole or bucket method may be used. When the bucket method is used, the bucket will be tripple rinsed with site water prior to taking the sample.

Data collected at the North Fork Nemadji River and South Fork Nemadji River will include required targeted site parameters as follows: Field measurements: Dissolved oxygen, pH, Transperency with tube, Specific Conductance, Turbidity, Temperature; Grab sample for lab analysis: Total Suspended Solids, Total Suspended Volitile Solids, Turbidity, Total Phosphorous, Total Kjeldahl Nitrogen, Nitrate and Nitrite, Ammonia Nitrogen, Sulfate, Chloride, Harndess, and E.coli. See Table 3 and Table 4 for 2010 and 2011 monitoring schedules.

*Table 3: 2010 Nemadji River Watershed Stream Assessment Monitoring Schedule

Waterbody	Site Location	No. of Samples	Parameters	Monitoring Date Range
*Nemadji River (S000-110)	Hwy 23, 0.5 miles south of Pleasant Valley	10 (9 + 1 duplicate)	**Set D:**E. coli,**Set A:** Dissolved Oxygen, pH, Transparency Tube, Specific Conductance, Temp, Rec. Suit, appearance, stage,water level measurement	**June-August**
*Nemadji River, South Fork (no site ID)	Hwy 23, 2 miles northwest of Holyoke	10 (9 + 1 duplicate)	**Set D:**E. coli,**Set A:** Dissolved Oxygen, pH, Transparency Tube, Specific Conductance, Temp, Rec. Suit, appearance, stage,water level measurement	**June-August**
Stateline Creek	CSAH 8, 4.5 miles east of Holyoke	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turbidity, TSS, Chloride **May-September** All other parameters
Hunter's Creek	CSAH 6, 4 miles east of Barnum	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turbidity, TSS, Chloride **May-September** All other parameters
Spring Creek	Pioneer Rd, 10 miles east of Barnum, north of CSAH 6	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turbidity, TSS, Chloride **May-September** All other parameters
Clear Creek	Hwy 23, 4 miles southeast of Wrenshall	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turbidity, TSS, Chloride **May-September** All other parameters
Mud Creek (S005-771)	Hwy 23, 4.5 miles southeast of Wrenshall	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turbidity, TSS, Chloride **May-September** All other parameters
Silver Creek	CSAH 8, 4 miles northwest of Holyoke	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turbidity, TSS, Chloride **May-September** All other parameters
Net River	75 ft D/S CSAH8, Holyoke Park	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turbidity, TSS, Chloride **May-September** All other parameters
Little Net River	CSAH 8, 1.5 miles east of Holyoke	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turbidity, TSS, Chloride **May-September** All other parameters

*Table 4: 2011 Nemadji River Watershed Stream Assessment Monitoring Schedule

Waterbody	Site Location	No. of Samples	Parameters	Monitoring Date Range
Nemadji River (S000-110)	Hwy 23, 0.5 miles south of Pleasant Valley	**Set A, B and C:** 11 (10 + 1 duplicate) **Set D:** 7 (6 + 1 duplicate)	**Set A:** Dissolved Oxygen, pH, Transp. Tube, Specific Conductance, Temp, Rec. Suit, Appearance, Stage, Water Level **Set B:** Total Suspended Solids, Total Suspended Volatile Solids, Total Phosphorous, Total Kjeldahl Nitrogen, Nitrate and Nitrite, Ammonia Nitrogen **Set C:** Sulfate, Chloride, Hardness **Set D:** E. coli	**April-October:** Turb, TSS, Chloride **June-August:** E. Coli **May-September** All other parameters
Nemadji River, South Fork (no site ID)	Hwy 23, 2 miles northwest of Holyoke	**Set A, B and C:** 11 (10 + 1 duplicate) **Set D:** 7 (6 + 1 duplicate)	**Set A:** Dissolved Oxygen, pH, Transp. Tube, Specific Conductance, Temp, Rec. Suit, Appearance, Stage, Water Level **Set B:** Total Suspended Solids, Total Suspended Volatile Solids, Total Phosphorous, Total Kjeldahl Nitrogen, Nitrate and Nitrite, Ammonia Nitrogen **Set C:** Sulfate, Chloride, Hardness **Set D:** E. coli	**April-October:** Turb., TSS, Chloride **June-August:** E. Coli **May-September** All other parameters
Stateline Creek	CSAH 8, 4.5 miles east of Holyoke	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turb., TSS, Chloride **May-September** All other parameters
Hunter's Creek	CSAH 6, 4 miles east of Barnum	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turb., TSS, Chloride **May-September** All other parameters
Spring Creek	Pioneer Rd, 10 miles east of Barnum, N of CSAH 6	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turb., TSS, Chloride **May-September** All other parameters
Clear Creek	Hwy 23, 4 miles southeast of Wrenshall	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turb., TSS, Chloride **May-September** All other parameters
Mud Creek (S005-771)	Hwy 23, 4.5 miles southeast of Wrenshall	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turb., TSS, Chloride **May-September** All other parameters
Silver Creek	CSAH 8, 4 miles northwest of Holyoke	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turb., TSS, Chloride **May-September** All other parameters
Net River	75 ft D/S CSAH8, Holyoke Park	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turb., TSS, Chloride **May-September** All other parameters
Little Net River	CSAH 8, 1.5 miles east of Holyoke	11 (10 + 1 duplicate)	Total Phosphorous, Total Kjeldahl Nitrogen, Total Suspended Solids, Turbidity, Nitrate-Nitrite Nitrogen, Chloride, Transparency Tube	**April-October:** Turb., TSS, Chloride **May-September** All other parameters

6.3 Data Management

Carlton SWCD staff will submit proper forms to STORET regarding new project, new sites, and lab establishment. All field and lab data will be entered on an excel spreadsheet and will be reviewed by Carlton SWCD staff for accuracy. SWCD staff will submit all field and lab data to STORET according to STORET timelines.

7.0 References

Department of Natural Resources (DNR), Division of Fish and Wildlife, Section of Fisheries. *Fisheries Stream Survey Manual Stream Survey Methods*. Special Publication No. 165, Version 2.1, May 1, 2007. Website visited Dec. 2008. <http://files.dnr.state.mn.us/publications/fisheries/special_reports/165.pdf>

Magner, J.A. and K.N. Brooks. 2004. *Channel stability across scale in the Nemadji River Basin.*

Magner, J.A. and K.N. Brooks. 2007. *Predicting stream channel erosion in the lacustrine core of the upper Nemadji River, Minnesota (USA) using stream geomorphology metrics.* Environmental Geology, May 2007.

Minnesota Pollution Control Agency, Division of Water Quality, *Invertebrate Sampling Procedures*. Website visited Dec. 2008. <http://www.pca.state.mn.us/water/biomonitoring/biomonitoring-invertebratesampling.pdf>

Minnesota Pollution Control Agency. 2009. *Deer Creek – Nemadji River Turbidity TMDL Stable Isotope Geochemistry Work Plan.*

*Minnesota Pollution Control Agency. 2009. *Guidance Manual for Assessing the Water Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List.* http://www.pca.state.mn.us/index.php/view-document.html?gid=8601

Natural Resources Conservation Service (NRCS) and U.S. Forest Service (USFS). 1998 *Erosion and Sedimentation in the Nemadji River Basin: Nemadji River Basin Project Final Report* .

Reidel, M.S. 1998. *Land use impacts on stream channel processes in the Nemadji watershed.* A report to the North Central Forest Experiment Station. USDA Forest Service.

Riedel, M.S., E.S. Verry and K.N. Brooks. 2002. *Land use impacts on fluvial processes in the Nemadji River watershed.* Hydrological Science and Technology, 18(1-4):197-205.