Grand Marais Creek Watershed (HUC 09020306)

Watershed Conditions Report - Addendum

May 22, 2014

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1 PROJECT OVERVIEW

1.1 Purpose

This document serves as a supplement to the Grand Marais Creek Watershed Conditions Report prepared by Emmons & Olivier Resources, Inc. for the Red Lake Watershed District dated 08/01/2013. The purpose of this report is to summarize stream water quality data; to identify and describe known impairments and the water quality standards that are relevant to the upcoming Total Maximum Daily Load study for the watershed; and to outline additional analyses that will be completed as part of the upcoming TMDL study. This document is organized by the Minnesota Pollution Control Agency template for Total Maximum Daily Load (TMDL) studies; however, it is not intended to serve as a TMDL document.

1.2 Identification of Waterbodies

The waters addressed in this report are listed in Table 1 and shown in Figure 1. Two of the streams listed in Table 1 are currently included on the draft 2014 USEPA 303(d) list of impaired waters. These listing are both for aquatic life use due to turbidity and/or dissolved oxygen, or pH (Table 2). Impairments within the watershed that are not addressed in this study include several impairments for aquatic consumption due to mercury in fish tissue or mercury in the water column that were addressed in the Minnesota State-Wide Mercury TMDL (2008), and for aquatic consumption due to polychlorinated biphenyls (PCBs) and for aquatic life use due to Chlorpyrifos (Table 3).

For the sake of providing information on current water quality concerns within the watershed, two additional analyses were completed as part of this report. *E.coli* data were evaluated for Grand Marais Creek, headwaters to CD2 (AUID 09020306-507) and turbidity data were evaluated for County Ditch 2 (AUID 09020306-515). No TMDLs will be undertaken water quality problems that are not officially listed as impairments in the most recent 303(d) List of Impaired Waters. However, the information provided may be incorporated into the Grand Marais Creek Watershed WRAPS report, which is also planned for completion in 2016.

The Grand Marais Creek Watershed HUC8 boundary includes geographic areas that drain directly to Grand Marais Creek and areas that do not. The HUC8 and WRAPS project boundary includes areas in the Red Lake Watershed District and Middle-Snake-Tamarac Rivers Watershed District (MSTRWD). Drainage systems in the MSTRWD that do not drain to Grand Marais Creek rather directly to the Red River of the North include JD9, CD7 and CD12 near Stephen, Minnesota and JD1 and JD75 in the extreme southern portion of MSTRWD. The ditch systems near Stephen are being included in the Snake River WRAPS. The two ditch systems including JD1 and JD75 are included in the Grand Marais Creek WRAPS.

Table 1. Grand Marais Creek Watershed streams and water quality parameters addressed in this report.

AUID	Reach Name	Location/Reach Description	Designated Use Class	Affected Use	Water Quality Parameters Addressed
09020306-507	Grand Marais Creek	Headwaters to CD2	2B, 3C	Aquatic Life	DO
					Turbidity
					pH
				Aquatic Recreation	E.Coli
09020306-512	Grand Marais Creek	CD2 to Red River	2B, 3C	Aquatic Life	Turbidity
09020306-515	County Ditch 2	CD66 to Grand Marais Creek	2B, 3C	Aquatic Life	Turbidity

Table 2. Grand Marais Creek Watershed stream impairments to be addressed in the Grand Marais Creek Watershed TMDL.

AUID	Reach Name	Location/Reach Description	Designated Use Class	Listing Year	Target Start/ Completion	Affected Use	Pollutant/ Stressor
09020306-507	Grand Marais Creek	Headwaters to CD2	2B, 3C	2006	2014/ 2018	Aquatic Life	DO
				2006			Turbidity
				2008			pH
09020306-512*	Grand Marais Creek	CD2 to Red River	2B, 3C	2006	2014/ 2018	Aquatic Life	Turbidity

*This stream reach is a cut-off channel for which current conditions are subject to change based on water quality project underway in the watershed (see 3.4.5.1)

Table 3. Other stream impairments in the Grand Marais Creek WRAPS Project Area

AUID/ Lake ID	Name	Location/Reach Description	Designated Use Class	Listing Year	Target Start/ Completion	Affected Use	Pollutant/ Stressor
09020306-501	Red River	Grand Marais Creek to North Marais River (ND)	1C, 2Bd, 3C	2008		Aquatic Consumption	Arsenic
				1998	1998/2025		Mercury in fish tissue
				2008	2008/2022		Mercury in water column
				2002	2002/2016		PCB in fish tissue
09020306-502	Red River	English Coulee (ND) to Grand Marais Creek	1C, 2Bd, 3C	1998	1998/2025	Aquatic Consumption	Mercury in water column
				2002	2002/2016		PCB in fish tissue
09020306-503	Red River	North Marais R (ND) to Forest (ND)	1C, 2Bd, 3C	1998	1998/2025	Aquatic Consumption	Mercury in water column
				2002	2002/2016		PCB in fish tissue
09020306-504	Red River	Forest River (ND) to Snake River	1C, 2Bd, 3C	1998	1998/2025	Aquatic Consumption	Mercury in water column
				2002	2002/2016		PCB in fish tissue
09020306-505	Red River	Snake River to Park River (ND)	1C, 2Bd, 3C	1998	1998/2025	Aquatic Consumption	Mercury in water column
				2002	2002/2016		PCB in fish tissue
09020306-507	Grand Marais Creek	Headwaters to CD2	2B, 3C	2014	2014/2018	Aquatic Life	Chlorpyrifos

1.3 Description of Impairments

1.3.1 Stream Dissolved Oxygen

Grand Marais Creek (headwaters to CD2, 09020306-507) is impaired for aquatic life use due to low dissolved oxygen (DO) levels. Dissolved oxygen is required for essentially all aquatic organisms to live. When dissolved oxygen drops below acceptable levels, desirable aquatic organisms, such as fish, can be killed or harmed. A stream is considered impaired if more than 10 percent of the "suitable" (taken before 9:00 am) May through September measurements, more than 10 percent of the total May through September measurements, or more than 10 percent of the October through April measurements violate the standard, and there are at least three total violations. A total of 20 independent observations are required for a DO assessment.

An investigation will be conducted as part of the Grand Marais Creek Watershed TMDL study to determine the cause of low dissolved oxygen levels in the impaired reach. Potential causes of low dissolved oxygen that will be assessed include excess nutrients (eutrophication), low stream flows, and high stream temperatures (Table 4).

Table 4. Potential causes of low dissolved oxygen

Cause	Description
Nutrients/Eutrophication	Excessive aquatic plant growth and subsequent decay or organic matter depletes dissolved oxygen.
Stream Flow	Reductions in flow can result in stagnant pools (reduced mixing) and/or increased temperatures (decreased oxygen solubility).
Temperature	The solubility of oxygen (and other gases) in water decreases as water temperature increases.

1.3.2 Stream pH

Grand Marais Creek (headwaters to CD2, 09020306-507) is impaired for aquatic life use due to high pH, which is the measure of the acidity or alkalinity of surface water. All living organisms have a limited pH tolerance. For most freshwater aquatic organisms, pH tolerance falls within the range of 6.0-9.0. For Class 2B waters, the applicable standard for pH is between 6.5 and 9.0. Any measurements outside of this range are considered to violate the water quality standard, except those due to natural causes.

Because the pH of natural water is a determined by many sources of acid species, an investigation will be conducted to identify the cause of high pH in the impaired reach. Potential causes of high pH that will be assessed include eutrophication, alkaline geology and soils, and discharge of ammonia producing waste (Table 5).

Table 5. Potential causes of high pH

Cause	Description
Eutrophication	Decomposition of excessive algal or plant production can result in very high levels of carbon dioxide in the water.
Alkaline geology and soils	Alkaline species as sodium carbonate or sodium bicarbonate may be leached into streams from runoff and seepage.
Discharge of ammonia producing waste.	Examples of wastes with high potential for conversion of nitrogenous compounds to ammonia include industrial sources such as paper mills, but also municipal (sewage) and agricultural (manure) sources.

1.3.3 Stream Turbidity

Grand Marais Creek (headwaters to CD2, 09020306-507) and Grand Marais Creek (CD2 to Red River, 09020306-512) are impaired for aquatic life use due to high turbidity. Turbidity is a physical characteristic of water that describes the degree to which light is scattered and absorbed in the water column (therefore reducing water clarity). Turbidity is caused by suspended matter or impurities, such as clay, silt, fine organic matter, algae, and other organic and inorganic sources. Turbidity caused by excessive algal growth can result in low DO levels, increased pH, or even fish kills. Turbidity caused by absorbance of light by excess suspended sediment can also limit algal growth and impact aquatic organisms. Other potential negative impacts on aquatic life due to excess turbidity include siltation of spawning beds or burial of fish eggs due to excess suspended solids; increased stream temperature due to increase absorbance of light by suspended matter; and direct health impacts on fish such as gill abrasion or clogging (Markus, 2011).

Preliminary analysis indicates that there is a positive relationship between turbidity and TSS for the impaired streams (see Section 3.4.3), suggesting that the pollutant TSS may be a cause of high turbidity in these streams. Grand Marais Creek (headwaters to CD2, 09020306-507) is also impaired for low DO and high pH, suggesting that stream eutrophication may also be a possible cause of high turbidity in this reach.

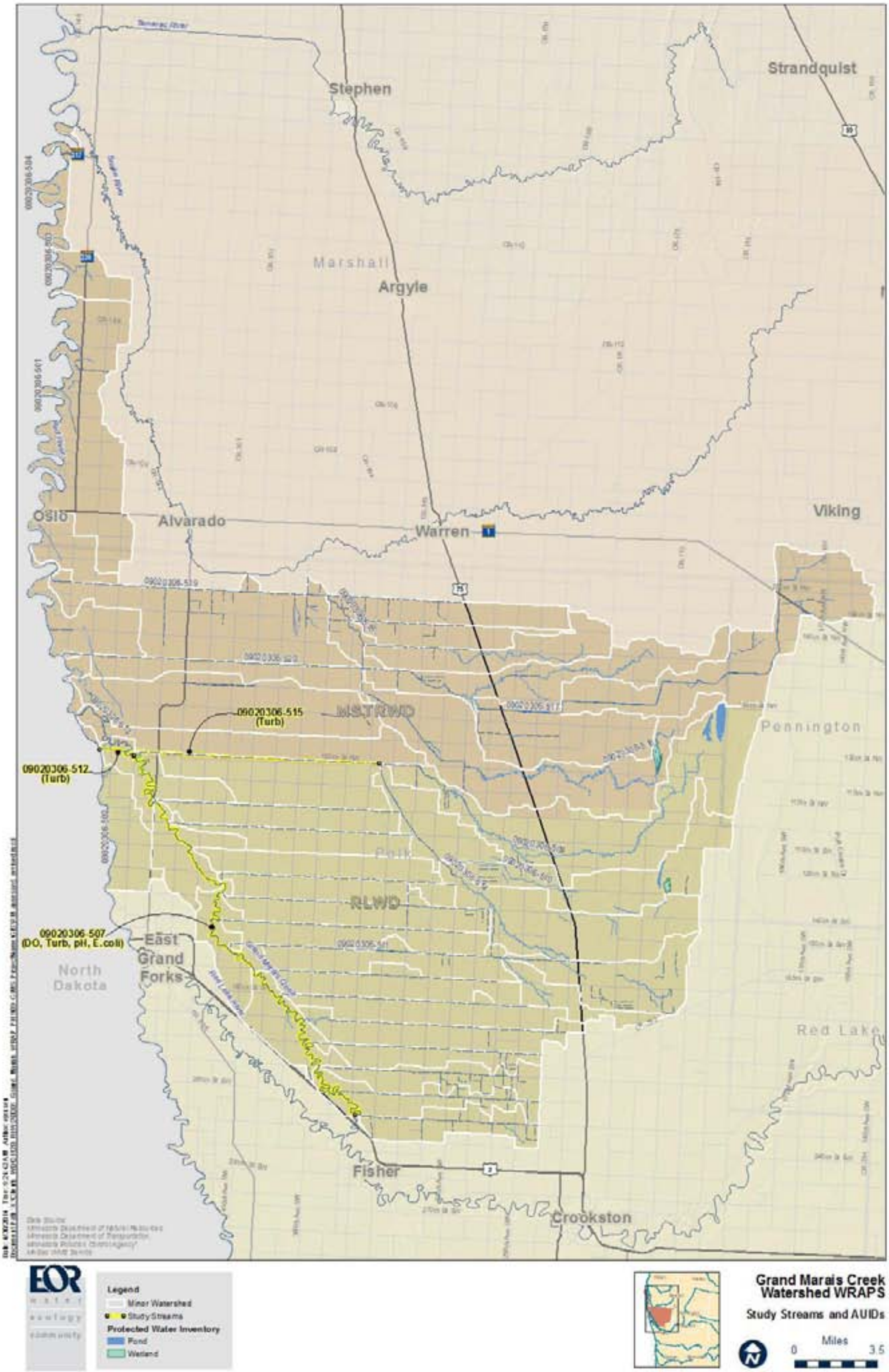


Figure 1. Grand Marais Creek Watershed study streams

2 APPLICABLE WATER QUALITY STANDARDS

2.1 Designated Use

Each stream reach has a Designated Use Classification defined by the MPCA which describes the optimal purpose for that waterbody (Table 1). The streams are all designated as class 2B, 3C - a healthy warm water aquatic community; industrial cooling and materials transport without a high level of treatment. Class 2 waters are protected for aquatic life and aquatic recreation, and Class 3 waters are protected for industrial consumption as defined by Minnesota Rules Chapter 7050.0140. The most protective of these classes is 2, for which water quality standards are provided below.

The Minnesota narrative water quality standard for all Class 2 waters (Rule 7050.0150 subp. 3) states that "the aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments, and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters".

2.1.1 Numeric Standards

2.1.1.1 Bacteria

No streams have been assessed by MPCA for aquatic recreation use impairments due to E. coli, and therefore will not be included in the upcoming TMDL project. However, bacteria is a pollutant of concern for the Red Lake Watershed District in the Grand Marais Creek Watershed and is addressed in this Watershed Conditions Report, and will also be included in the upcoming Watershed Restoration and Protection Strategy report for the Grand Marais Creek Watershed.

Numeric water quality standards have been developed for bacteria (Minnesota Rule 7050.0222), in this case *Escherichia coli* (*E. coli*), which are protective concentrations for short- and long-term exposure to pathogens in water. The past fecal coliform and current *E. coli* numeric water quality standards for Class 2 waters are shown in Table 6. *E. coli* and fecal coliform are fecal bacteria used as indicators for waterborne pathogens that have the potential to cause human illness. Although most are harmless themselves, fecal indicator bacteria are used as an easy-to-measure surrogate to evaluate the suitability of recreational and drinking waters, specifically, the presence of pathogens and probability of illness. Pathogenic bacteria, viruses, and protozoa pose a health risk to humans, potentially causing illnesses with gastrointestinal symptoms (nausea, vomiting, fever, headache, and diarrhea), skin irritations, or other symptoms. Pathogen types and quantities vary among fecal sources; therefore, human health risk varies based on the source of fecal contamination.

The *E. coli* assessment completed for this study used the standard for *E. coli*. The change in the water quality standard from fecal coliform to *E. coli* is supported by an EPA guidance document on bacteriological criteria (USEPA 1986). As of March 17, 2008, Minnesota Rules Chapter 7050 water quality standards for *E. coli* are:

> *Escherichia (E.) coli - Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.*

Although surface water quality standards are now based on *E. coli*, wastewater treatment facilities are permitted based on fecal coliform (not *E. coli*) concentrations.

Geometric mean is used in place of arithmetic mean in order to measure the central tendency of the data, dampening the effect that very high or very low values have on arithmetic means. The MPCA's *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List* provides details regarding how waters are assessed for conformance to the *E. coli* standard (MPCA 2012a).

Table 6. Past and current numeric water quality standards of bacteria (fecal coliform and *E. coli*) for the beneficial use of aquatic recreation (primary and secondary body contact).

Past Standard	Units	Current Standard	Units	Notes
Fecal coliform	200 orgs per 100 ml	*E. coli*	126 orgs per 100 ml	Geometric mean of ≥5 samples per month (April - October)
Fecal coliform	2,000 orgs per 100 ml	*E. coli*	1,260 orgs per 100 ml	<10% of all samples per month (April - October) that individually exceed

2.1.1.2 Dissolved Oxygen

Numeric standards for dissolved oxygen in class 2A and 2B waters are listed in Table 7. Dissolved oxygen standards are expressed as daily minimum concentrations.

Table 7. Stream dissolved oxygen standards (Minnesota Rule 7050.0220)

Stream Class	Daily Minimum Dissolved Oxygen (mg/L)
2A – Coldwater	7
2B – Coolwater or warmwater	5

2.1.1.3 Stream Eutrophication

Stream eutrophication standards are under development based on several studies and data collection efforts that have demonstrated significant and predictable relationships among summer nutrients, sestonic chlorophyll-a, and biochemical oxygen demand in several medium to large Minnesota rivers (Heiskary & Markus 2001, Heiskary & Markus 2003). Consistent with EPA guidance, criteria are being developed for three "River Nutrient Regions (RNR)". The draft eutrophication standards for South Region are listed in table Table 8. Because stream eutrophication is a candidate cause for low DO and high pH in Grand Marais Creek (headwater to CD2, AUID 09020306-507), these proposed standards are noted for reference. In the event that stream eutrophication is identified as a cause of any of the impairments listed in Table 1, the proposed standard may serve as a guideline for the development of numeric criteria used in the TMDL.

Table 8. Proposed river eutrophication criteria for streams in the South River Nutrient Region.

Nutrient	Stressor		
TP (µg/L)	Chl-a (µg/L)	DO flux (mg/L)	BOD_5 (mg/L)
≤150	≤35	≤4.5	≤3.0

For more information, refer to the draft Minnesota Nutrient Criteria Development for Rivers report, available online: http://www.pca.state.mn.us/index.php/view-document.html?gid=14947.

2.1.1.4 pH

The numeric standard for stream pH for class 2B waters is listed in Table 9. According to the MPCA Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment (2014), all pH observations outside of the minimum-maximum range under the water quality standard are considered water quality violations unless such extremes are due to natural causes. Although pH is not a pollutant in and of itself, pH outside the normal range is an indication of an imbalance in the normal chemical or biochemical cycles of a natural water. As such pH is an indicator, rather than a cause, of pollution.

Table 9. Stream pH standards (Minnesota Rule 7050.0220)

Stream Class	Minimum pH (su)	Maximum pH (su)
2B – Coolwater or warmwater	6.5	9.0

2.1.1.5 Turbidity

The State of Minnesota is in the process of amending the state water quality standards for turbidity. The proposed amendments include replacing stream water quality standards for turbidity with standards for TSS and Eutrophication. One component of the rationale for these changes is that the turbidity unit (NTUs) is not concentration-based and therefore not well-suited to load-based studies (Markus, 2011). More thorough discussion may be found in Markus, 2011: http://www.pca.state.mn.us/index.php/view-document.html?gid=14922

The current standard for turbidity is listed in Table 10. Under the current guidelines, a minimum of 20 independent observations are required for a turbidity assessment. A water body is listed as impaired for turbidity if 10 percent or more and at least three observations are in violation of the turbidity standard. Independent observations of water transparency or total suspended solids (TSS) can be used as surrogates for turbidity if the quantity of turbidity data is insufficient to complete the assessment. For more details on acceptable use of these surrogates in the

determination of turbidity impairment see the MPCA Guidance Manual for Assessing the Quality of Minnesota Surface Waters:
http://www.pca.state.mn.us/index.php/view-document.html?gid=16988

Table 10. Stream turbidity standards (Minnesota Rule 7050.0220)

Stream Class	Turbidity (NTUs)
2B – Coolwater or warmwater	25

2.1.1.6 Total Suspended Solids (TSS)

Current proposed amendments to MN Rule 7050.0220 include the addition of standards for total suspended solids (TSS). Proposed standards and listing criteria are discussed in detail in Marcus, 2011 (http://www.pca.state.mn.us/index.php/view-document.html?gid=14922). Proposed TSS standards for streams in the Southern River Nutrient Region are shown in Table 11. Under the proposed amendment, a stream is considered impaired for TSS if the TSS is greater than the specified standard more than 10% of the time over a multiyear data window.

Table 11. Proposed stream turbidity standards for the South River Nutrient Region

Designated Use Classification	TSS (mg/L)
Class 2A	10
Class 2Bd	65
Class 2B	**65**

3 WATERSHED DESCRIPTION

The impaired streams included in this study are located within the Grand Marais Creek Watershed (HUC 09020306), a tributary to the Red River in Minnesota (Figure 1). The Grand Marais Creek Watershed drains approximately 592 square miles (378,880 acres) in Polk, Marshall, and Pennington Counties with a majority of the watershed located in Polk County. Grand Marais Creek begins in agricultural land near Fisher, MN and flows North and West to the Red River. The predominant land use in the watershed is cropland (91.6%) and networks of drainage ditches are a prominent feature of the landscape.

3.1 Impaired Streams

The direct drainage areas of the impaired stream reaches are listed in Table 12. Direct drainage areas were delineated from USGS StreamStats (http://water.usgs.gov/osw/streamstats/). The direct drainage areas include only the area downstream of any monitored upstream lake or stream. Grand Marais Creek from CD2 to the Red River (AUID 09020306-512) is a cutoff channel that was installed in the early 1990s for flood reduction in the lower reach of Grand Marais Creek (AUID 09020306-513). The total drainage area for the cutoff channel includes the drainage areas of Grand Marais Creek upstream of the cutoff (AUID 09020306-512) and of County Ditch 2 (AUID 09020306-515); however, it does not carry the full flow volume of these upstream areas under all flow conditions. Furthermore, a restoration is currently underway to divert flow from the cut-off channel back to the original channel (Grand Marais Creek, diversion ditch to Red River, AUID 09020306-513). Implementation of the restoration will alter existing flow regimes in both the cut-off channel and the, natural creek bed (restored channel). For the TMDL study, existing and proposed flow regimes will be evaluated along with expected changes in pollutant loading due to altered flow regimes. Load reductions associated with reduced flows in the cut-off channel may be sufficient to meet TMDL goals for this reach.

Data has been collected in Judicial Ditch 1 and Judicial Ditch 75, but official assessments for ditches have been deferred for a number of years in anticipation of the approval of new Tiered Aquatic Life Use (TALU) Standards. Under the TALU standards a ditch will not be required to meet all of the same water quality and biological standards that are required of natural waterways.

Table 12. Study streams direct drainage and total watershed areas

AUID 09020306-XXX	Name	Direct Drainage Area (ac)	Total Drainage Area (ac)
-507	Grand Marais Creek, Headwaters to CD2	118,838	n/a
-512	Grand Marais Creek, CD2 to the Red River	646	186,084*
-515	County Ditch 2, CD66 to Grand Marais Creek	66,600	n/a

*Total drainage area includes the areas of both subwatershed 09020306-507 and 09020306-512, however, only a portion of the flow from these areas is diverted to the cut-off channel. The remainder is routed to stream reach Grand Marais Creek, diversion ditch to Red River (AUID 09020306-513).

3.2 Subwatersheds

The individual impaired stream subwatersheds are illustrated in Figure 2 below.

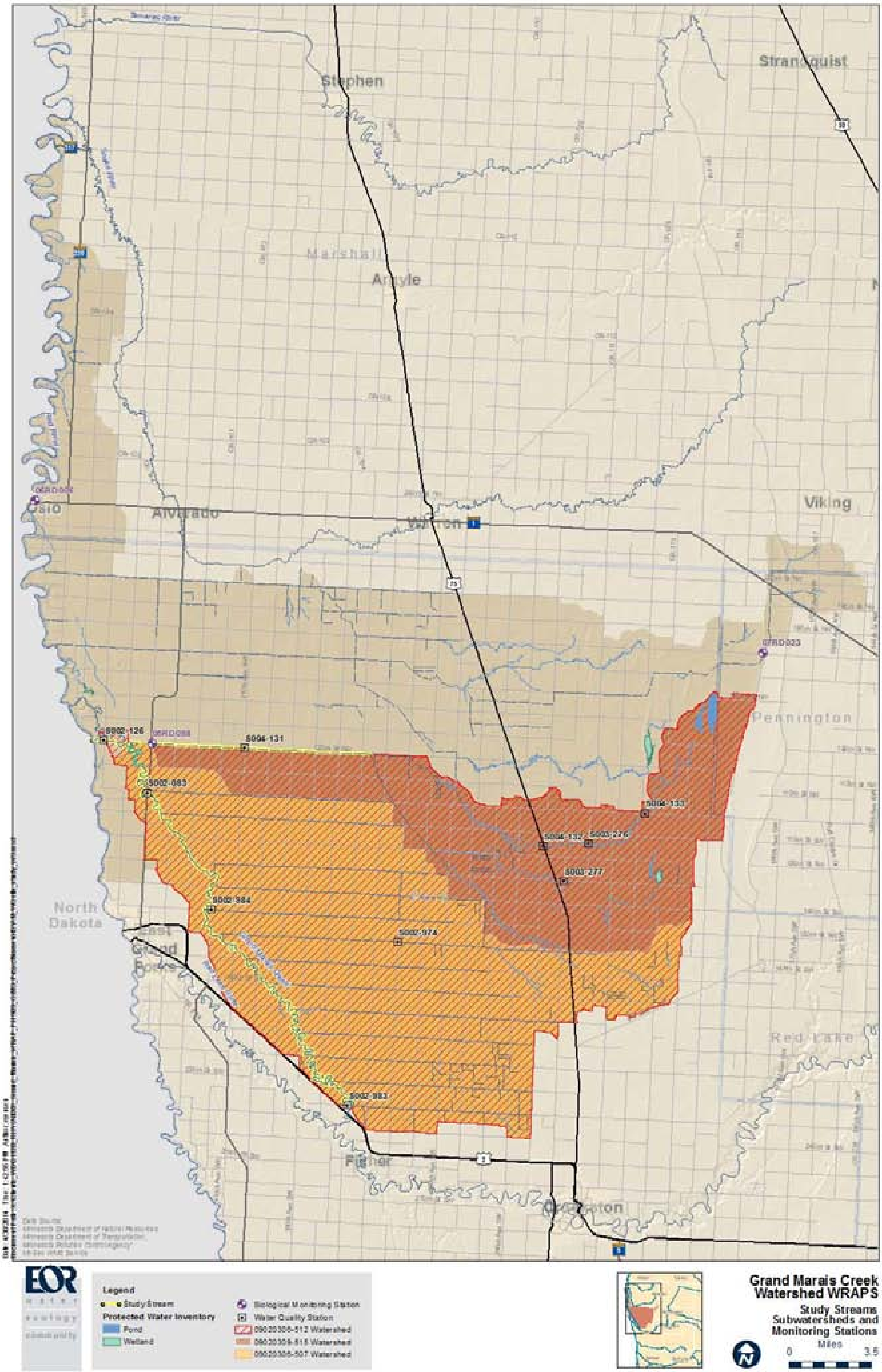


Figure 2. Grand Marais Creek Watershed study streams subwatershed areas.

3.3 Land Cover

Land cover in the Grand Marais Creek Watershed was assessed using the Multi-Resolution Land Characteristics Consortium 2006 National Land Cover Dataset (http://www.mrlc.gov/nlcd2006.php). This information is necessary to draw conclusions about pollutant sources and best management practices that may be applicable within each subwatershed. The land cover distribution within each impaired stream watershed is summarized in Table 13. This data was simplified to reduce the overall number of categories. Developed includes: developed open space, and low, medium and high density developed areas. Undeveloped includes: evergreen forests, deciduous forests, mixed forests, and shrub/scrub. Cropland includes: all annually planted row crops (corn, soybeans, wheat, oats, barley, etc.), and fallow crop fields. Grassland includes: native grass stands, alfalfa, clover, long term hay, and pasture. Open Water/Wetland includes: wetlands and marshes as well as water all lakes and rivers. The primary land cover within the Grand Marais Creek watershed is cropland (91.6%). The impaired stream subwatersheds have land cover distributions very similar to the Grand Marais Creek watershed as a whole. The dominant crop types are spring wheat and soybean which make up 28% and 21% respectively of the total land cover in the Grand Marais Creek watershed (Table 14).

Table 13. Land cover in Grand Marais Creek Watershed and subwatersheds of streams assessed in this report (NLCD 2006).

Waterbody Name	Developed	Undeveloped	Cropland	Grassland/ Pasture	Open Water/ Wetlands
Grand Marais Creek, Headwaters to CD2 09020306-507	4.8%	0.4%	93.2%	0.0%	1.6%
Grand Marais Creek, CD2 to Red River 09020306-512*	4.6%	0.4%	93.6%	0.0%	1.4%
County Ditch 2, CD66 to Grand Marais Creek 09020306-515	4.6%	0.9%	92.0%	0.5%	1.9%
Grand Marais Creek Watershed	**4.8%**	**1.0%**	**91.6%**	**0.3%**	**2.3%**

* Includes subwatersheds for 09020306-507 and 09020306-515.

Table 14. Breakdown of Cropland land use in the Grand Marais Creek Watershed type by annual crop type.

Crop	% Land Cover
Spring Wheat	28.0%
Soybeans	21.0%
Surgarbeets	13.0%
Dry Beans	7.4%
Corn	6.2%
Fallow/Other	16.0%
(Total Cropland)	91.6%

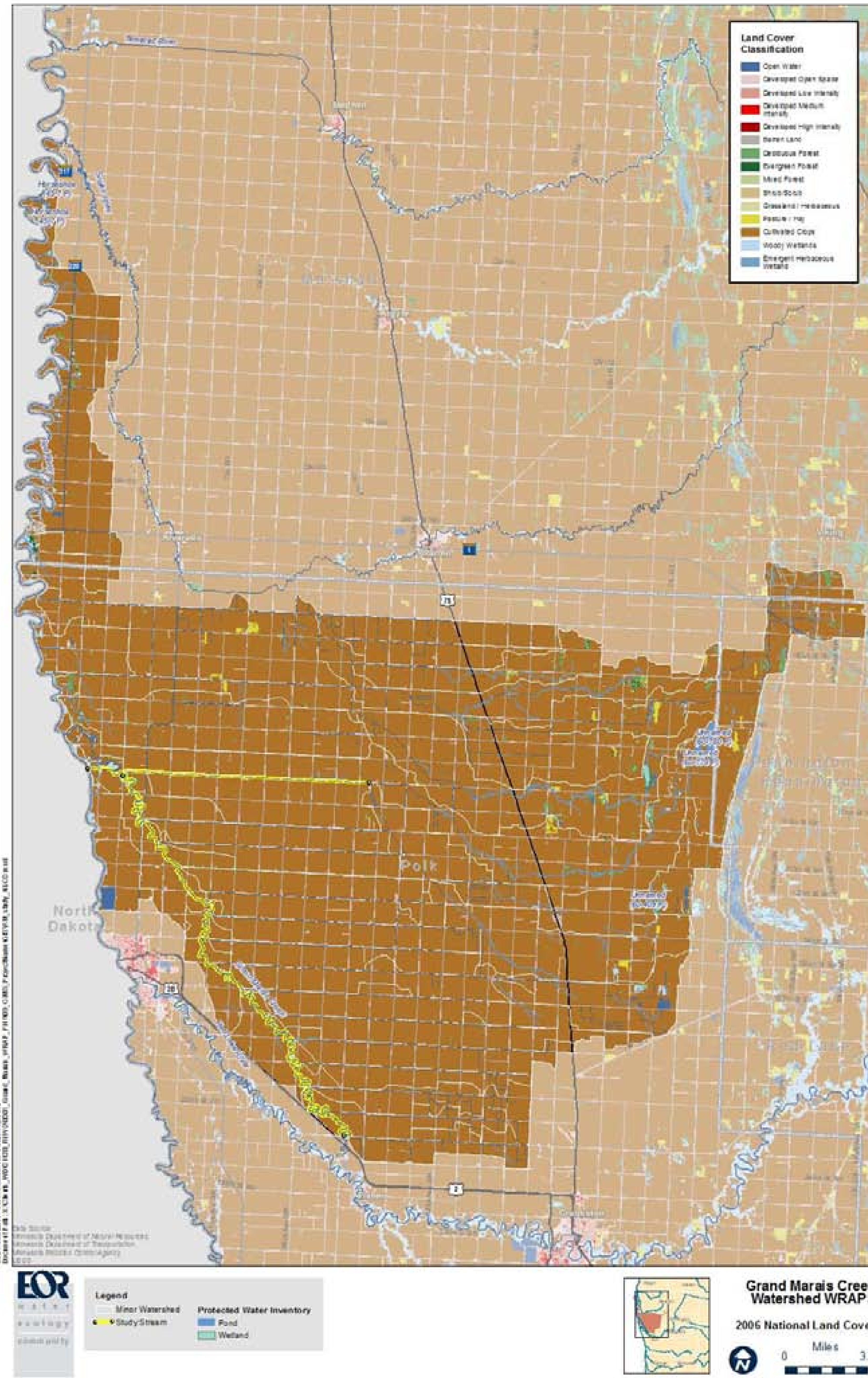


Figure 3. Land cover in the Grand Marais Creek Watershed (NLCD 2006)

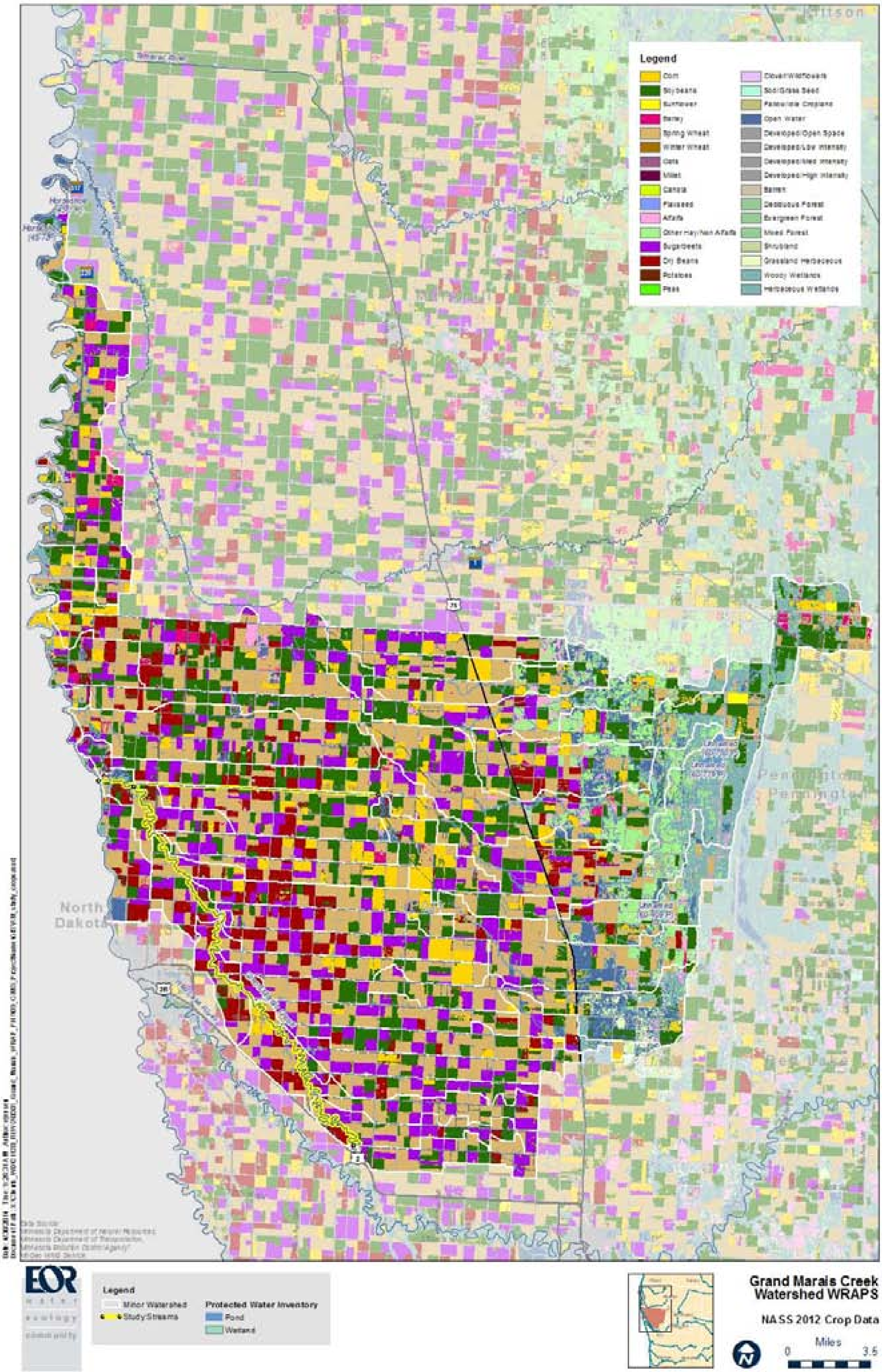


Figure 4. Crop cover in the Grand Marais Creek Watershed (NLCD 2006)

3.4 Historic Water Quality Conditions

The existing in-stream water quality conditions were quantified using data downloaded from the MPCA EQuIS database for the most recent ten year time period (2004-2013). This time period overlaps with the intensive watershed monitoring conducted in 2012-2013 as part of the MPCA's 10-year watershed assessment cycle.

3.4.1 Dissolved Oxygen

Ten-year (2004-2013) monthly mean and minimum dissolved oxygen concentrations were calculated by station for the impaired reach, Grand Marais Creek, headwaters to CD2 (Table 15). For each station, dissolved oxygen values generally decrease following spring, reach annual lows and sometimes drop below the water quality standard during the summer months, and then increase again in the fall.

Table 15. Dissolved oxygen (mg/L) by month, 2004-2013.
Bold red font highlights samples below the water quality standard for 2B waters (5 mg/L).

Waterbody	Monitoring Station	Month	No. of Samples	Minimum DO (mg/L)	No. of Samples < 5 mg/L
Grand Marais Creek, headwaters to CD2 (AUID 09020306-507)	S002-083	April	6	8.2	0
		May	5	6.8	0
		June	4	**4.1**	1
		July	3	**2.7**	2
		August	6	**1.0**	4
		September	4	**0.6**	1
		October	6	**2.3**	5
		November	3	5.2	0
	S002-983	May	2	**4.3**	1
		June	3	8.3	0
		July	1	**1.1**	1
		August	1	9.2	0
		September	1	10.4	0
		October	2	13.8	0
	S002-984	April	11	9.5	0
		May	7	6.1	0
		June	4	5.5	0
		July	4	**1.4**	3
		August	5	**<0.1**	4
		September	3	**3.0**	1
		October	4	**2.1**	2
		November	1	15.5	0

Dissolved oxygen data were also summarized under the criteria used to determine a DO impairment (1.3.1) for each water quality station in the impaired reach (Table 16). There are sufficient water quality data to list Grand Marais Creek (AUID 09020306-507) as impaired under any of the criteria used in assessing DO impairment. Thirty-four percent of the measurements taken during May-September, 21% of the measurements taken during October – April, and 100% of the 'suitable' samples violated the water quality standard. At least three violations were noted in each of these categories.

Table 16. Dissolved oxygen (mg/L) summarized by impairment assessment criteria, 2004-2013. Bold red font highlights assessments for which there are at least 3 samples and 10% or more violate the DO standard.

Monitoring Station	Suitable* May-September		Total May-September		Total October - April	
	Number of Samples	% violation	Number of Samples	% violation	Number of Samples	% violation
S002-083	1	100%	22	**36%**	15	**33%**
S002-983	0	n/a	8	**25%**	2	0%
S002-984	2	100%	23	**35%**	16	**13%**
All Stations	3	**100%**	53	**34%**	33	**21%**

*Samples taken before 9:00am. A designation of 'full support' requires least 20 'suitable' samples within a 2 year monitoring window.

Figure 5. Dissolved oxygen (mg/L) by month in Grand Marais Creek (S002-083), 2004-2013. Dashed red line shows the water quality standard for 2B waters (5 mg/L).

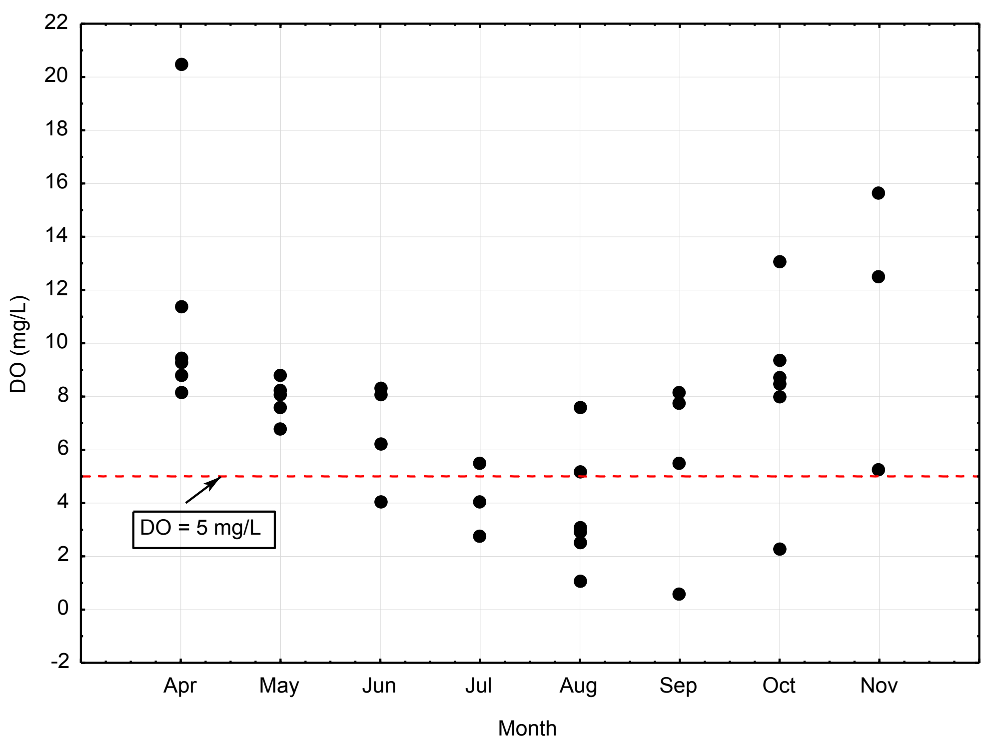


Figure 6. Dissolved oxygen (mg/L) by month in Grand Marais Creek (S002-983), 2004-2013. Dashed red line shows the water quality standard for 2B waters (5 mg/L).

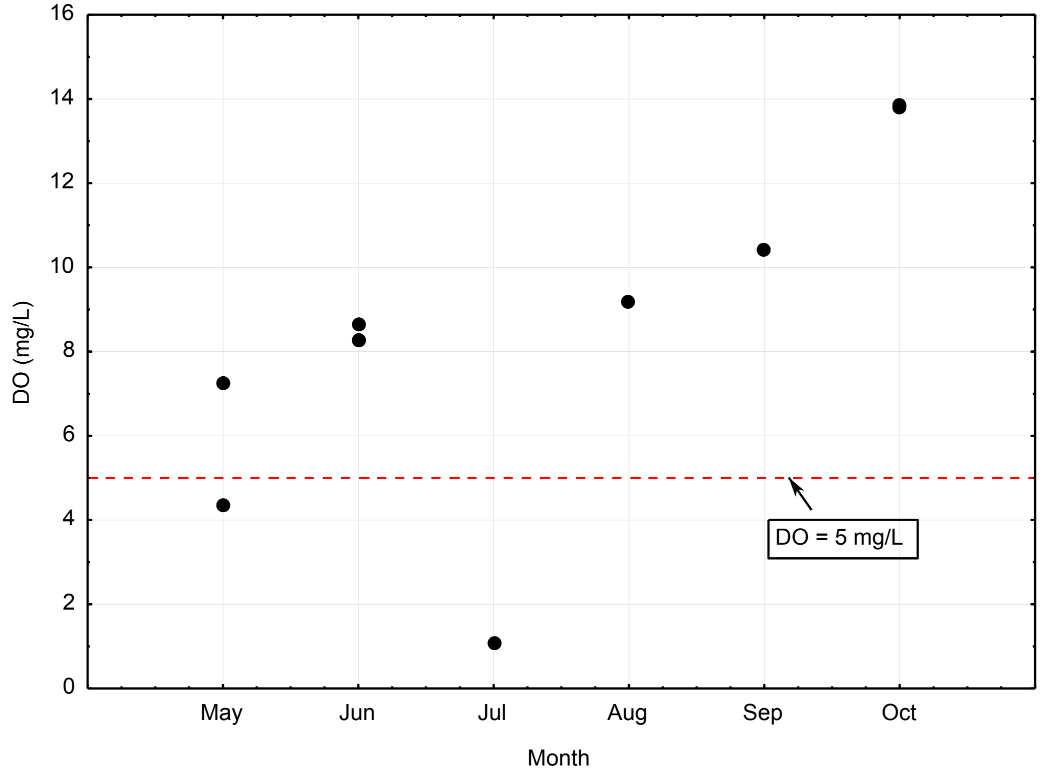
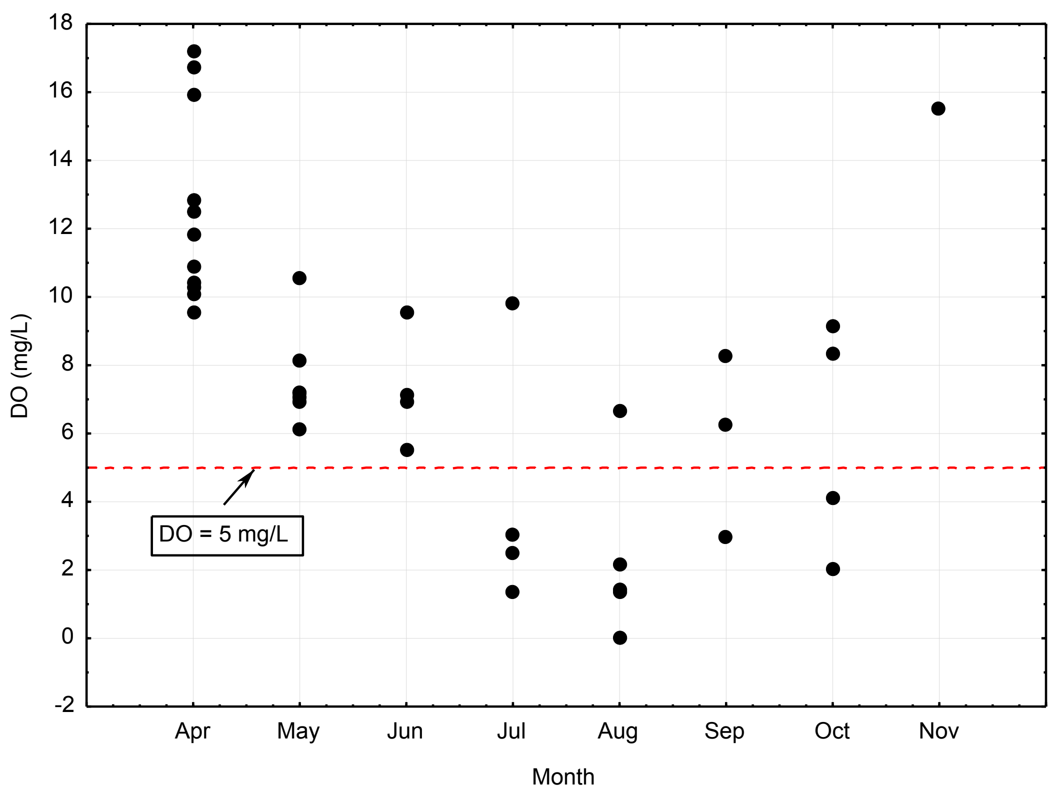


Figure 7. Dissolved oxygen (mg/L) by month in Grand Marais Creek (S002-984), 2004-2013. Dashed red line shows the water quality standard for 2B waters (5 mg/L).



3.4.2 *Escherichia coli*

Using data from the most recent ten year period (2004-2013), geometric mean *E. coli* concentrations were calculated by month for Grand Marais Creek, headwaters to CD2 (Table 17). There was only one month in which the geometric mean E. coli concentration was greater than the specified water quality standard of 126 org/100 mL (July, S002-984), however, in this case there was an insufficient number of samples (5 required) to meet the criteria for an impairment listing. Based on the criteria given in Table 6, the data do not meet the criteria for an *E. coli* impairment listing. Although this assessment indicates that an impairment listing is unlikely given current data and information, *E. coli* remains a general concern for water quality in the watershed. A bacterial source assessment will be included in the Grand Marais Creek WRAPS report.

Table 17. 10-year geometric mean *E. coli* (org/100mL) concentrations by month, 2004-2013.

Waterbody	Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
Grand Marais Creek, headwaters to CD2 (AUID 09020306-507)	S002-083	May	3	9.5	1.0 - 32.4
		June	2	88.9	24.3 - 325.5
		July	3	21.7	3.0 - 167.4
		August*	3	73.0	7.4 - 1413.6
		September	2	10.8	8.7 - 13.5
		Total	13	Total Samples >1,260 org/100 mL	1
	S002-983	May	1	58.3	n/a
		June	3	80.9	49.6 – 190.4
		July	n/a	n/a	n/a
		August	n/a	n/a	n/a
		September	n/a	n/a	n/a
		Total	4	Total Samples >1,260 org/100 mL	0
	S002-984	May	5	42.9	7.4 – 224.7
		June	4	29.6	3.1 – 119.8
		July	**3**	243.1	101.4 – 435.0
		August	4	98.2	23.0 – 1203.3
		September	1	54.8	n/a
		Total	17	Total Samples >1,260 org/100 mL	0
	All	May	9	26.9	1.0 - 224.7
		June	9	52.8	3.1 – 325.5
		July	6	72.6	3.0 – 435.2
		August	7	86.5	7.4 – 1413.6
		September	3	18.6	8.7 – 54.8
		Total	34	Total Samples >1,260 org/100 mL	1

3.4.3 pH

All available pH data from the most recent ten year period (2004-2013) was summarized by month for each water quality station located in Grand Marais Creek, headwaters to CD2, AUID 09020306-507 (Table 18).

Table 18. Data summary, pH sampling by month, Grand Marais Creek, headwaters to CD2, 2004-2013. Months in a violation of the pH standard for class 2B waters occurred are shown in **bold red font.**

Waterbody	Monitoring Station	Month	Number of Samples	Min-Max pH	No. Samples pH>9.0
Grand Marais Creek, headwaters to CD2 (AUID 09020306-507)	S002-083	**April**	**6**	**7.7 – 9.27**	**1**
		May	5	7.17 – 8.23	0
		June	4	7.50 – 8.31	0
		July	3	7.20 – 7.52	0
		August	**6**	**7.57 – 9.07**	**1**
		September	4	7.21 – 8.84	0
		October	6	7.49 – 8.76	0
		November	3	7.78 – 8.71	0
	S002-983	May	2	7.41 - 8.02	0
		June	2	7.76 – 7.77	0
		July	1	7.51	0
		August	1	7.60	0
		September	1	7.88	0
		October	2	7.57 – 7.76	0
	S002-984	April	11	7.30 – 8.90	0
		May	7	7.52 – 8.50	0
		June	4	7.57 – 8.49	0
		July	**4**	**7.32 – 9.19**	**1**
		August	5	7.50 – 8.33	0
		September	3	7.47 – 8.51	0
		October	4	7.04 – 8.60	0
		November	1	8.09	0

Figure 8. pH by month and year in Grand Marais Creek (S002-083), 2004-2013. Dashed red lines show the water quality standard for 2B waters (6.5 ≤ pH ≥ 9.0).

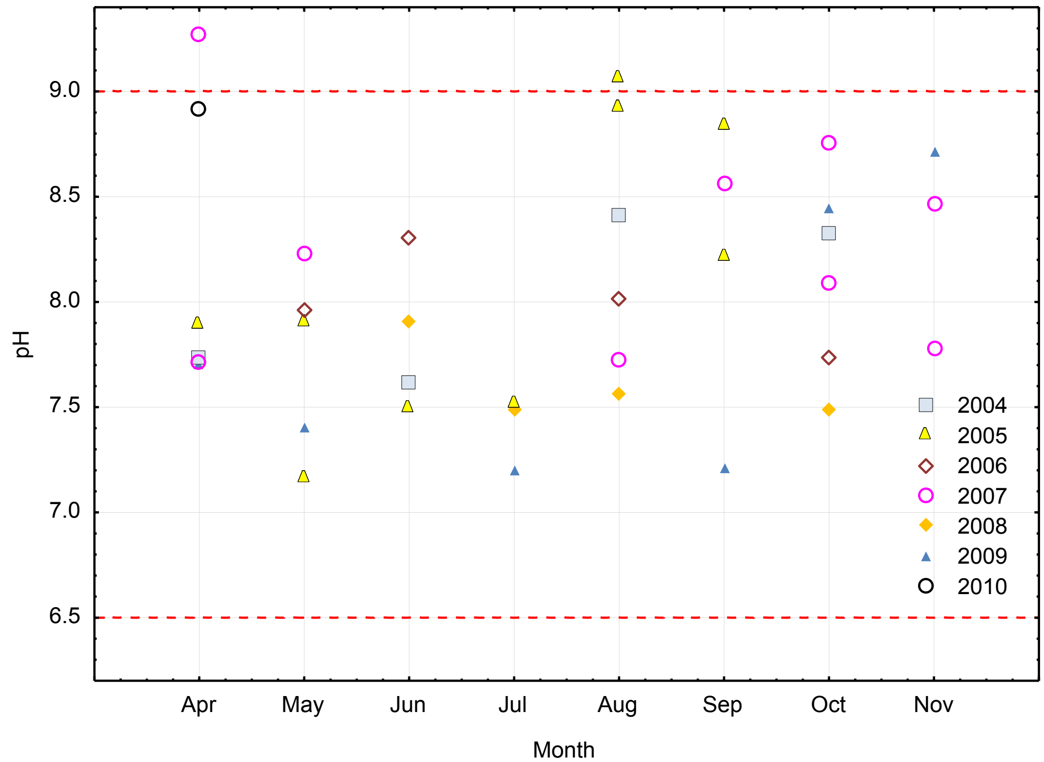
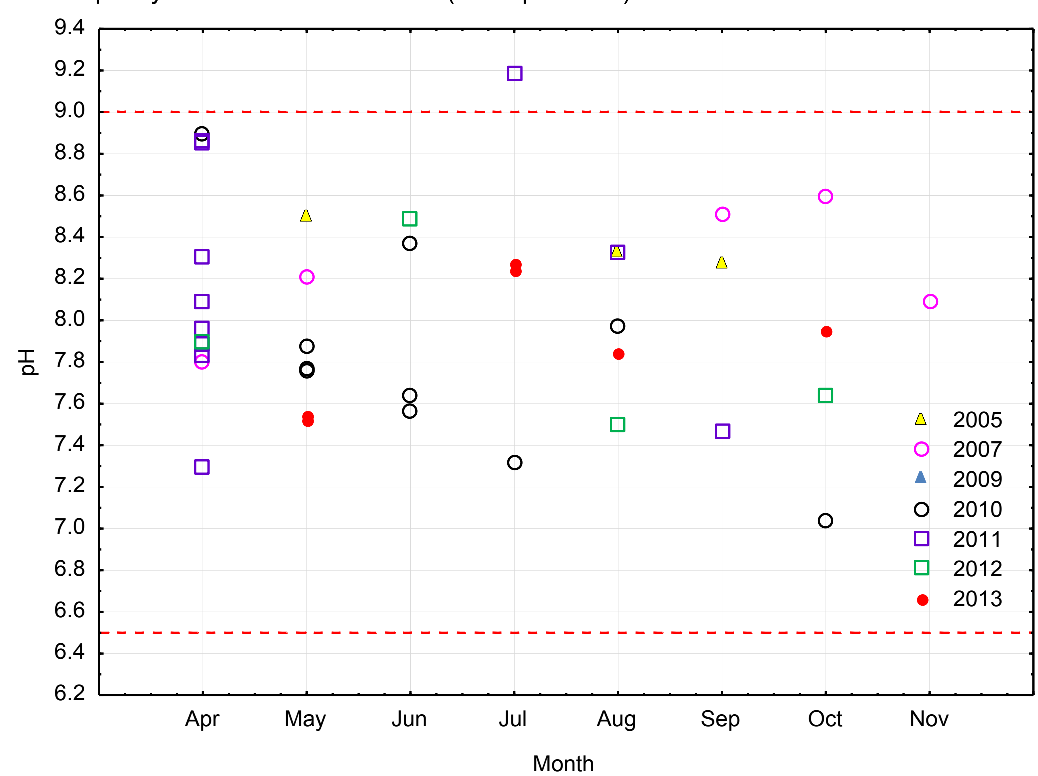


Figure 9. pH by month and year in Grand Marais Creek, (S002-984), 2004-2013. Dashed red lines show the water quality standard for 2B waters (6.5 ≤ pH ≥ 9.0).



3.4.4 Total Phosphorus

Total phosphorus will be summarized for each impaired stream as part of the turbidity and DO candidate cause assessment in the upcoming TMDL study.

3.4.5 Turbidity

Turbidity data from the most recent ten year period (2004-2013) was summarized by month for each impaired stream listed in Table 1 (Table 19, Table 20). Turbidity violations were most common in the cut-off channel of Grand Marais Creek (Grand Marais Creek, CD2 to Red River AUID 09020306-512) where 58% of the samples taken had measured turbidity greater than the water quality standard of 25 NTU. Improvements in in-stream turbidity are expected in response to the channel restoration that is underway in Grand Marais Creek, diversion ditch to Red River (AUID 09020306-513) which will divert a majority of flows from the cut-off to the historic channel (see section 3.4.5.1 below).

For each water quality station with sufficient data to support a turbidity impairment (all but S002-983), turbidity data were plotted by month and against overlapping TSS and TP data. In general, there appeared to be a strong relationship between turbidity and TSS and little or no relationship between turbidity and TP or turbidity and season (Figure 1 - Figure 21). The analysis provides evidence that turbidity impairments in the Grand Marais Creek watershed should addressed through TMDLs for TSS.

3.4.5.1 Grand Marais Creek Outlet Restoration

Red Lake Watershed District Grand Marais Creek Outlet Restoration Project (60F) will significantly alter flow regimes in both the existing cut-off channel (AUID 09020306-512) and in the historic channel (AUID 09020306-513) of Grand Marais Creek. A diversion structure is proposed to divert flows for up to a 2-year event from the existing cut-off channel to the original Grand Marais Creek channel. Project outcomes include the following objectives (Houston Engineering, 2012):

1. Reconstruct six miles of natural streambed.
2. Restore and sustain aquatic habitat conditions in the channel and up to 400 acres of riparian corridor habitat.
3. Divert flows from the existing outlet channel or Cutoff Ditch, and restore the hydrology to the original Grand Marais Creek channel.
4. Maintain or slightly reduce existing flood stages immediately upstream of the project limits by increasing conveyance abilities during flood events in the Grand Marais Creek.
5. Minimize/contain flood impacts throughout channel restoration segment through establishment of flowage easements and isolated setback levees.

When the flow diversion has been completed, flow in the existing cut-off channel will become intermittent and the cut-off may no longer be assessed. The cut-off channel will still deliver flow to the Red River under high flow conditions, but a second project (60FF) addressing channel stability is also expected to decrease sediment delivery from the ditch to the Red River. The

Grand Marais Creek Cut-Channel was completed in December, 2012 to improve channel stability and decrease sediment loading from the cut-off channel to the Red River (RLWD, 2012). The anticipated water quality and ecological benefits of these efforts are discussed in greater detail in the engineer's report and in the RLWD 2012 annual report: http://www.redlakewatershed.org/Annual%20Reports/2012%20Annual%20Report.pdf.

Given recent and anticipated changes to flow in the cut-off channel, the use designation and water quality expectations of that reach will also be changing.

Table 19. Data summary, turbidity sampling by month, Grand Marais Creek, headwaters to CD2, 2004-2013. Months in which >10% of samples violated the turbidity standard and at least three samples violated the standard are shown in **bold red font.**

Waterbody	Monitoring Station	Month	Number of Samples	Min-Max NTU	No. Samples >25 NTU
Grand Marais Creek, headwaters to CD2 (AUID 09020306-507)	S002-083	**April**	**8**	**5.9 – 183**	**5**
		May	**7**	**3.25 – 59.6**	**4**
		June	6	1.0 – 38.1	2
		July	5	0.7 – 3.3	0
		August	8	1.2 – 196.5	2
		September	5	1.4 – 24.0	0
		October	10	4.3 – 165.6	2
		November	3	16.3 -16.8	0
	S002-983	May	2	7.2 – 221.0	1
		June	5	4.8 – 9.8	0
		July	1	5.5	0
		August	1	30.4	1
		September	1	6.0	0
		October	3	11.7 – 16.9	0
	S002-984	**April**	**21**	**1.5 – 42.7**	**4**
		May	7	2.9 – 182.7	1
		June	5	0.7 – 13.5	0
		July	7	3.0 – 20.7	0
		August	7	1.3 – 58.0	2
		September	4	10.7 – 64.2	2
		October	**6**	**7.9 – 133.6**	**4**
		November	1	36.3	1

Table 20. Data summary, turbidity sampling by month, AUID 09020306-512 and AUID 09020306-515, 2004-2013. Months in which >10% of samples violated the turbidity standard and at least three samples violated the standard are shown in **bold red font.**

Waterbody	Monitoring Station	Month	Number of Samples	Min-Max NTU	No. Samples >25 NTU
Grand Marais Creek, CD2 to Red River (AUID 09020306-512)	S002-126	**January**	**4**	**36.1 – 38.0**	**4**
		February	6	6.3 – 32.2	2
		March	**26**	**19.4 – 280.0**	**22**
		April	**87**	**5.0 – 908.0**	**63**
		May	**99**	**0.7 – 1103.0**	**67**
		June	**98**	**1.8 – 1630.0**	**63**
		July	**65**	**0.8 – 125.0**	**35**
		August	27	1.1 – 105.0	3
		September	**36**	**2.65 – 63.1**	**16**
		October	**16**	**10.8 – 37.4**	**8**
		November	22	4.3 – 285.0	2
		December	4	15.8 – 17.7	0
County Ditch 2, CD66 to Grand Marais Creek (AUID 09020306-515)	S004-131	**March**	**6**	**71.0 – 255.5**	**6**
		April	**30**	**6.1 – 62.4**	**6**
		May	31	1.5 – 715.0	2
		June	**48**	**2.0 – 111.3**	**12**
		July	**32**	**1.9 – 37.9**	**4**
		August	**23**	**0.3 – 124.0**	**8**
		September	**20**	**1.2 – 80.2**	**6**
		October	**11**	**5.8 – 68.7**	**5**
		November	8	2.5 – 34.7	2

Figure 10. Turbidity (NTU) by month and year in Grand Marais Creek headwaters to CD2 (S002-083) 2004-2013. Dashed red line shows the water quality standard for 2B waters (25 NTU).

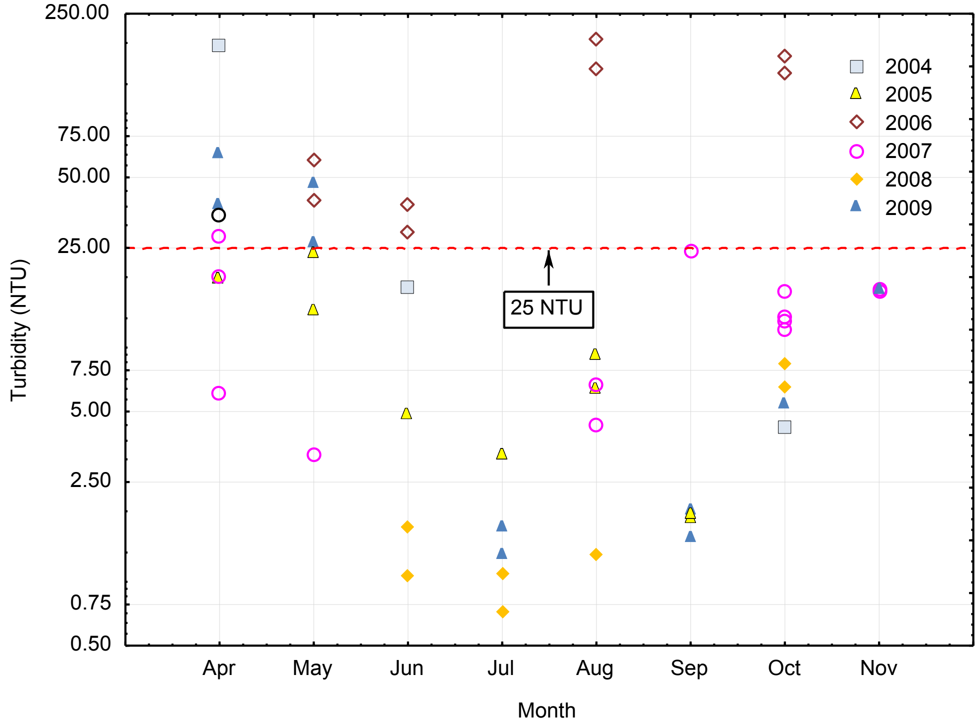


Figure 11. Turbidity vs. TSS in Grand Marais Creek, headwaters to CD2 (S002-083) 2004-2013.

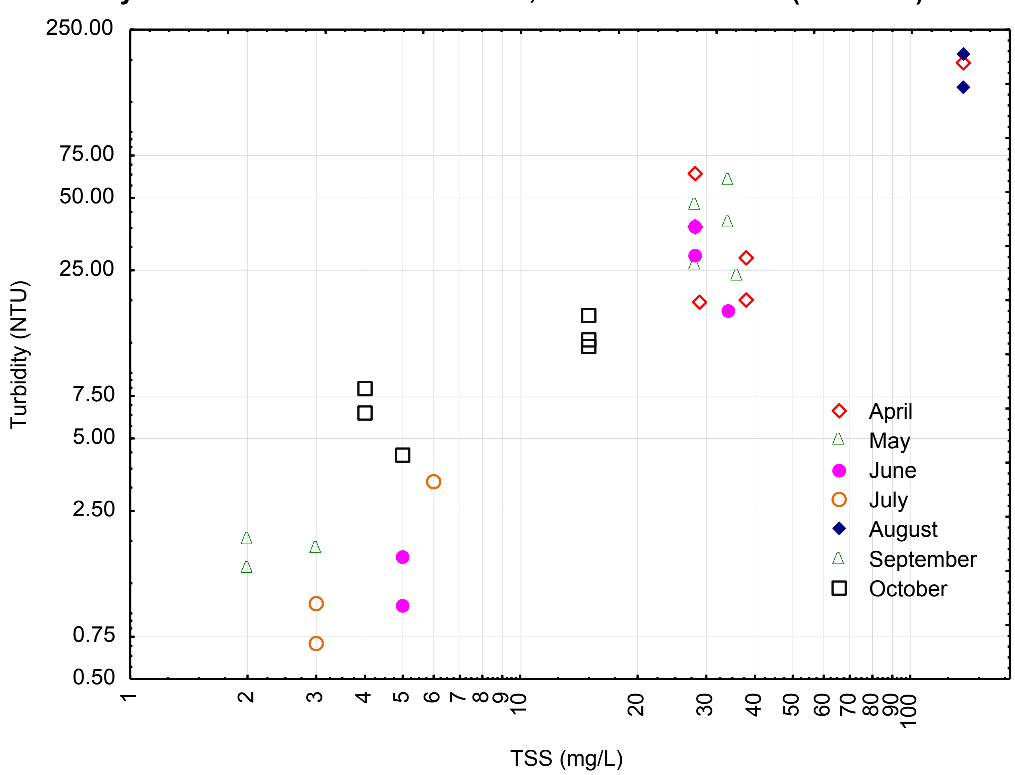


Figure 12. Turbidity vs. TP in Grand Marais Creek, headwaters to CD2 (S002-083) 2004-2013.

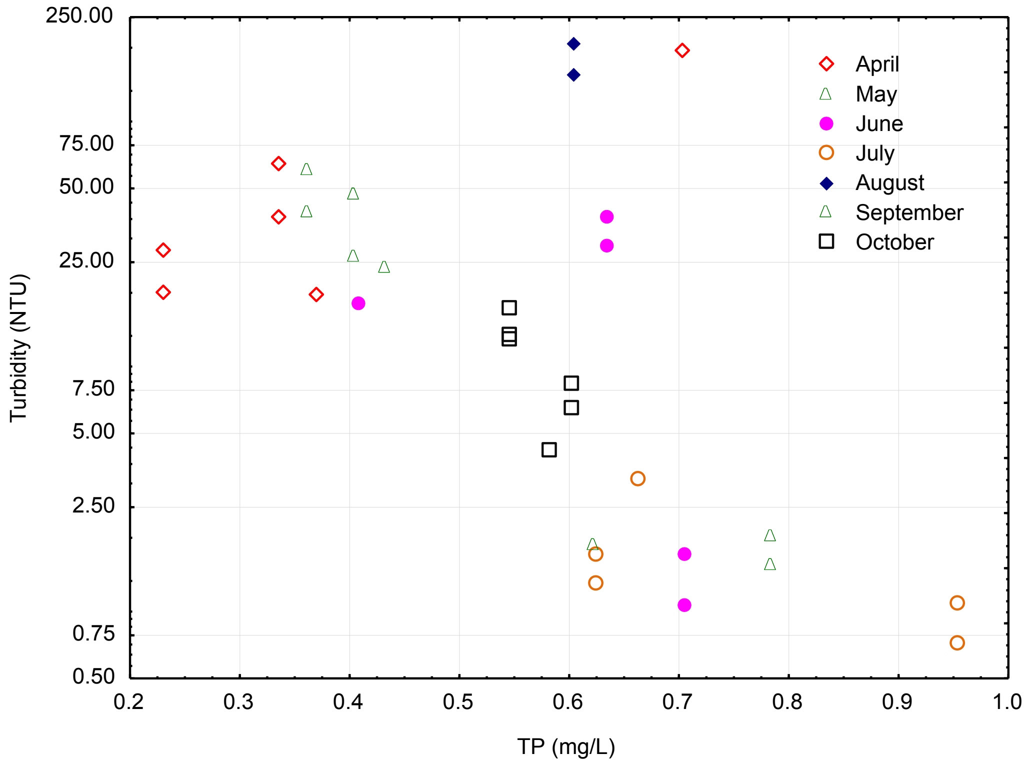


Figure 13. Turbidity (NTU) by month and year in Grand Marais Creek, headwaters to CD2 (S002-984) 2004-2013. Dashed red line shows the water quality standard for 2B waters (25 NTU).

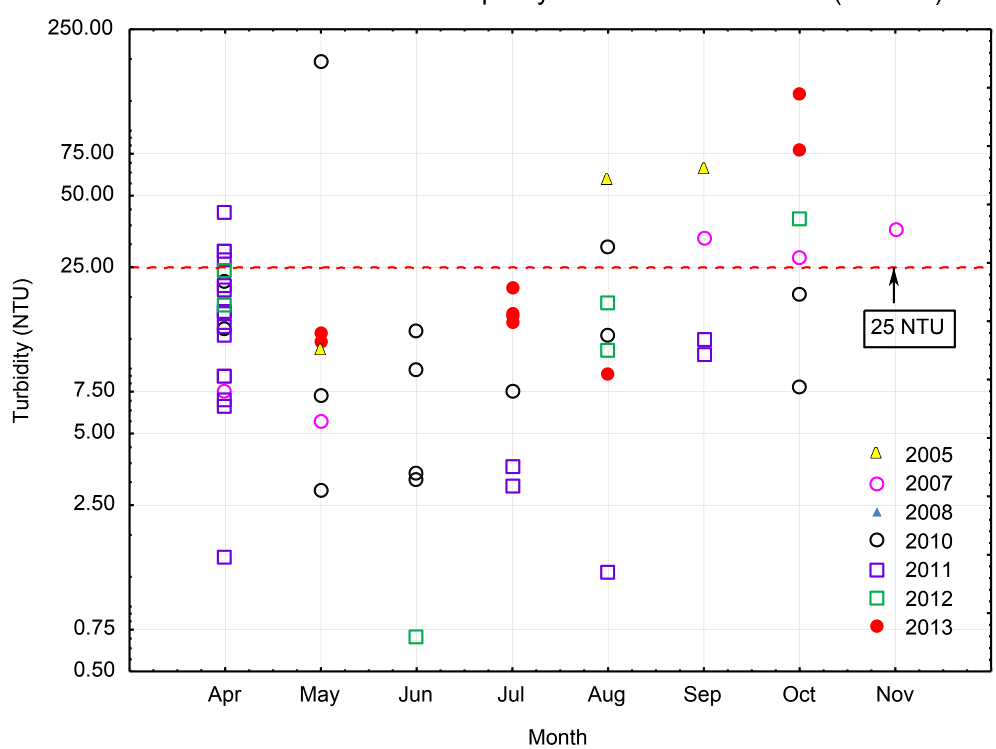


Figure 14. Turbidity vs. TSS in Grand Marais Creek, headwaters to CD2 (S002-984), 2004-2013.

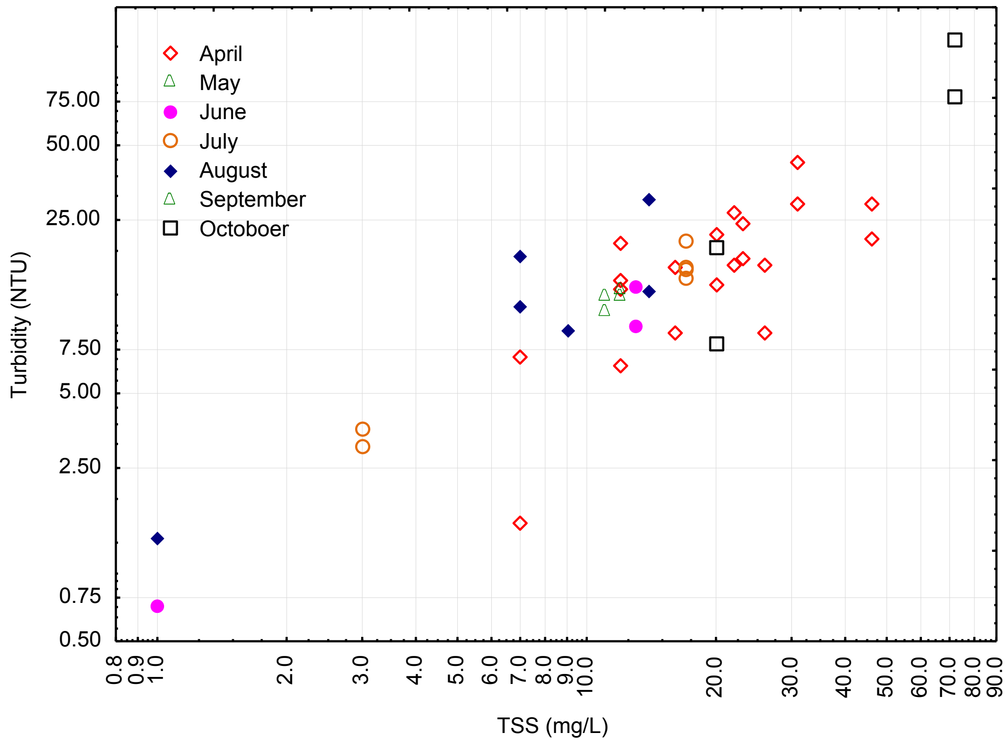


Figure 15. Turbidity vs. TP in Grand Marais Creek, headwaters to CD2 (S002-984), 2004-2013.

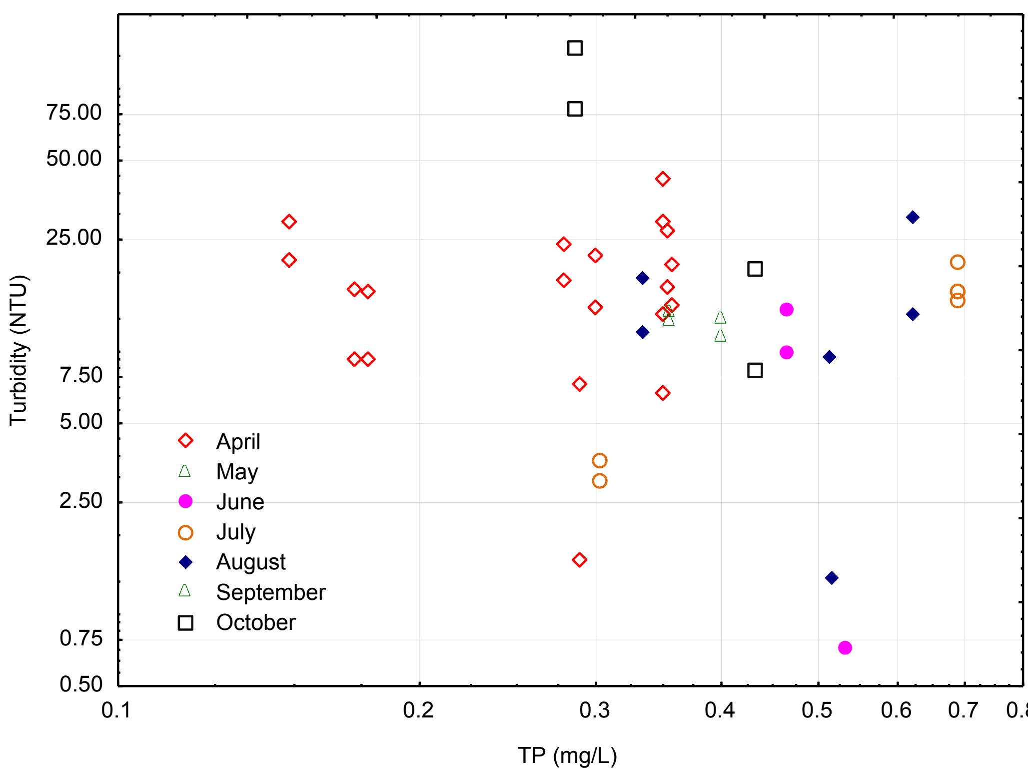


Figure 16. Turbidity (NTU) by month and year in Grand Marais Creek, County Ditch 2 to Red River (S002-126), 2004-2013. Dashed red line shows the water quality standard for 2B waters (25 NTU).

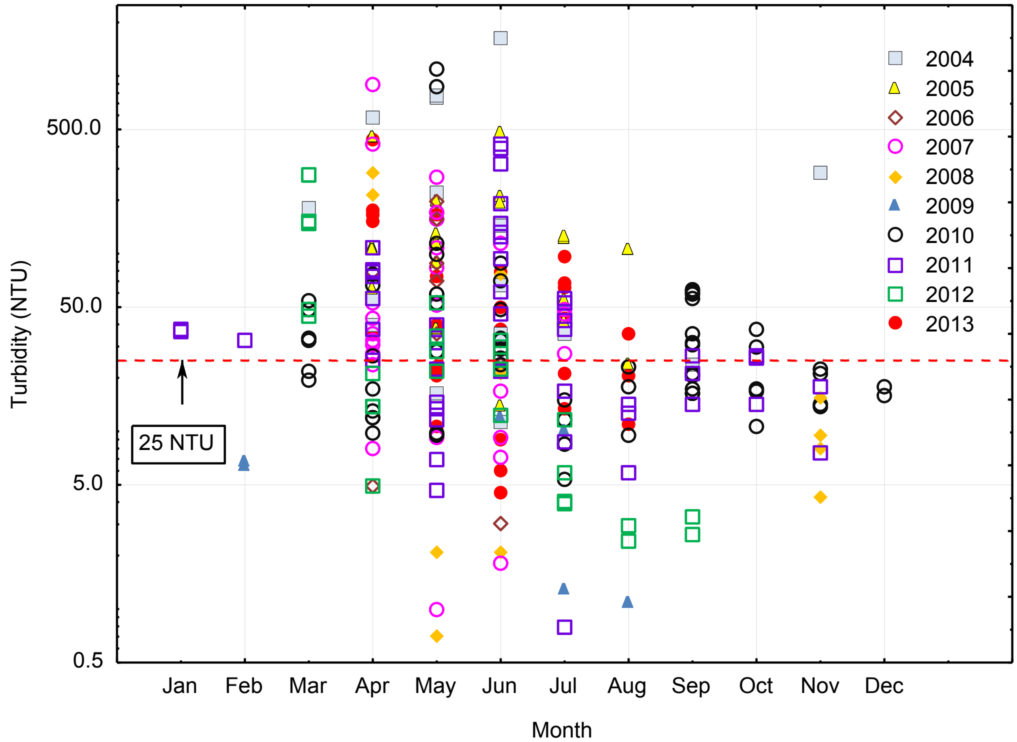


Figure 17. Turbidity vs. TSS in Grand Marais Creek, County Ditch 2 to Red River (S002-126), 2004-2013.

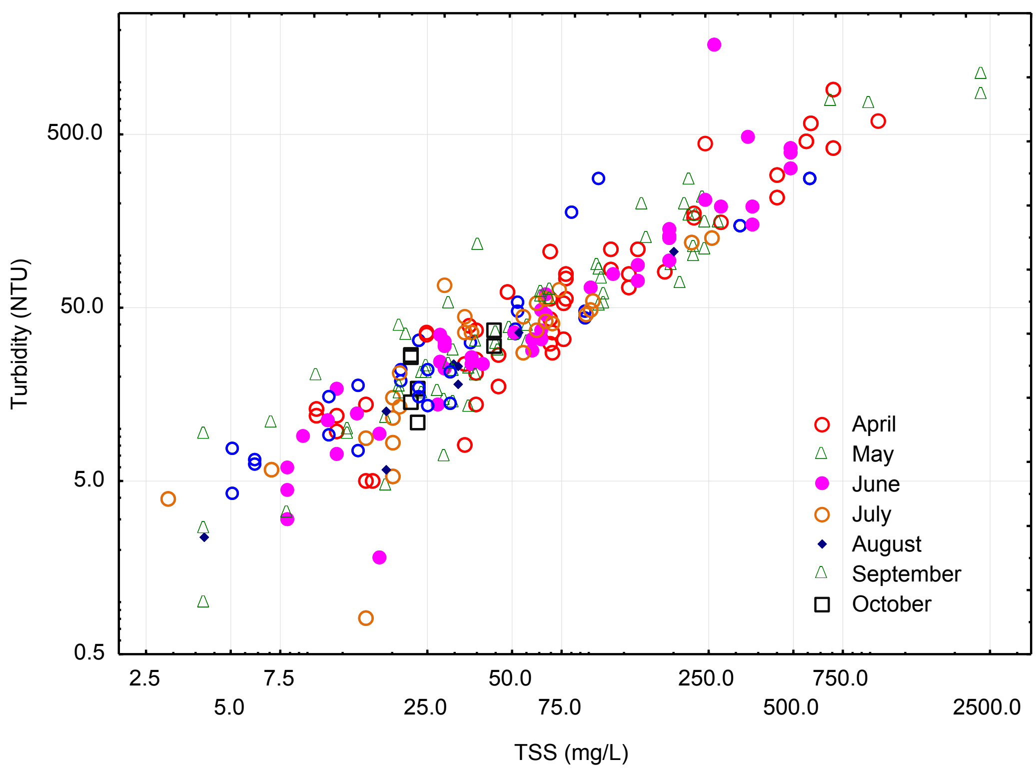


Figure 18. Turbidity vs. TP in Grand Marais Creek, County Ditch 2 to Red River (S002-126), 2004-2013.

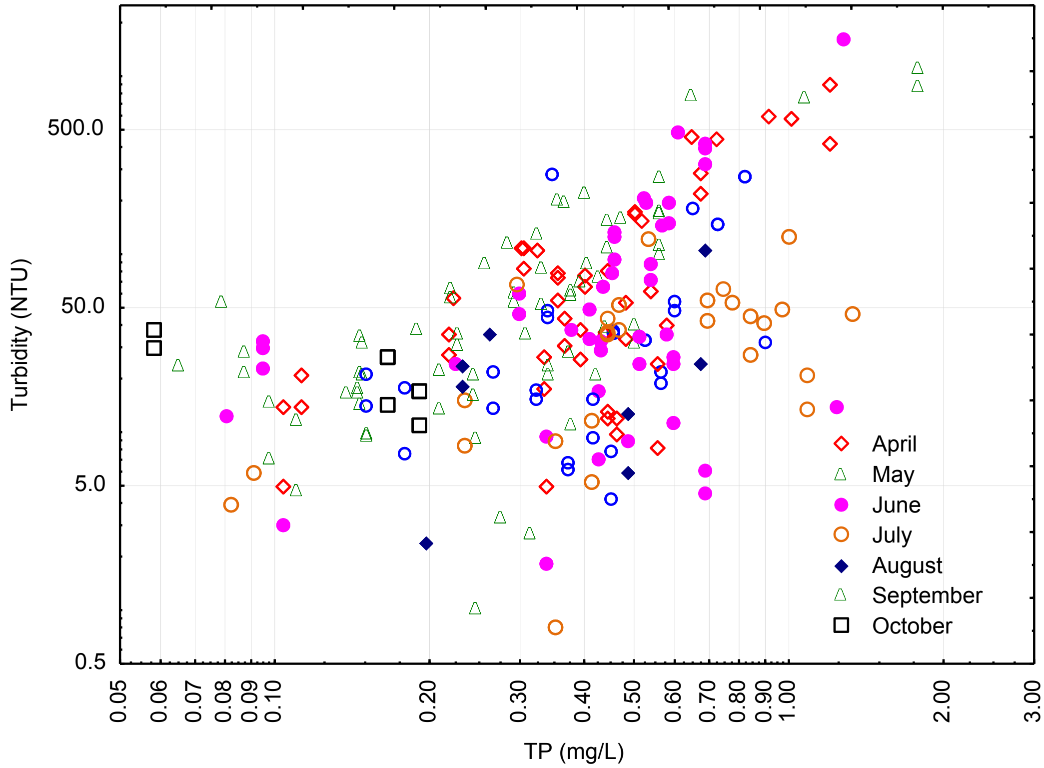


Figure 19. Turbidity (NTU) by month and year in County Ditch 2 (S004-131), 2004-2013. Dashed red line shows the water quality standard for 2B waters (25 NTU).

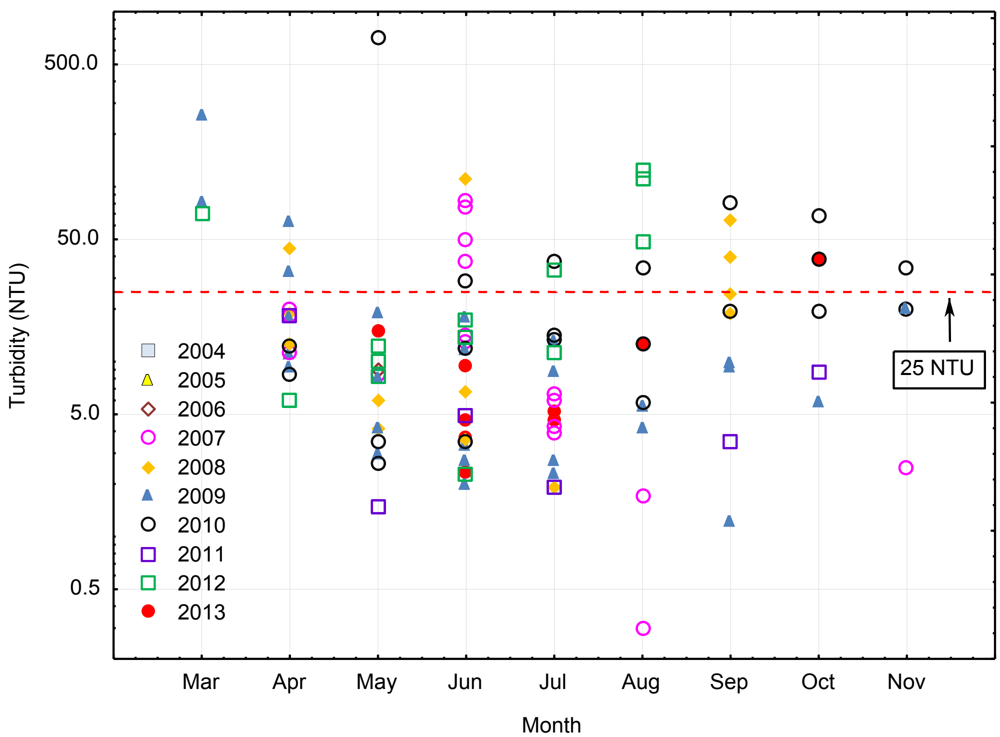


Figure 20. Turbidity vs.TSS in County Ditch 2, (S004-131), 2004-2013.

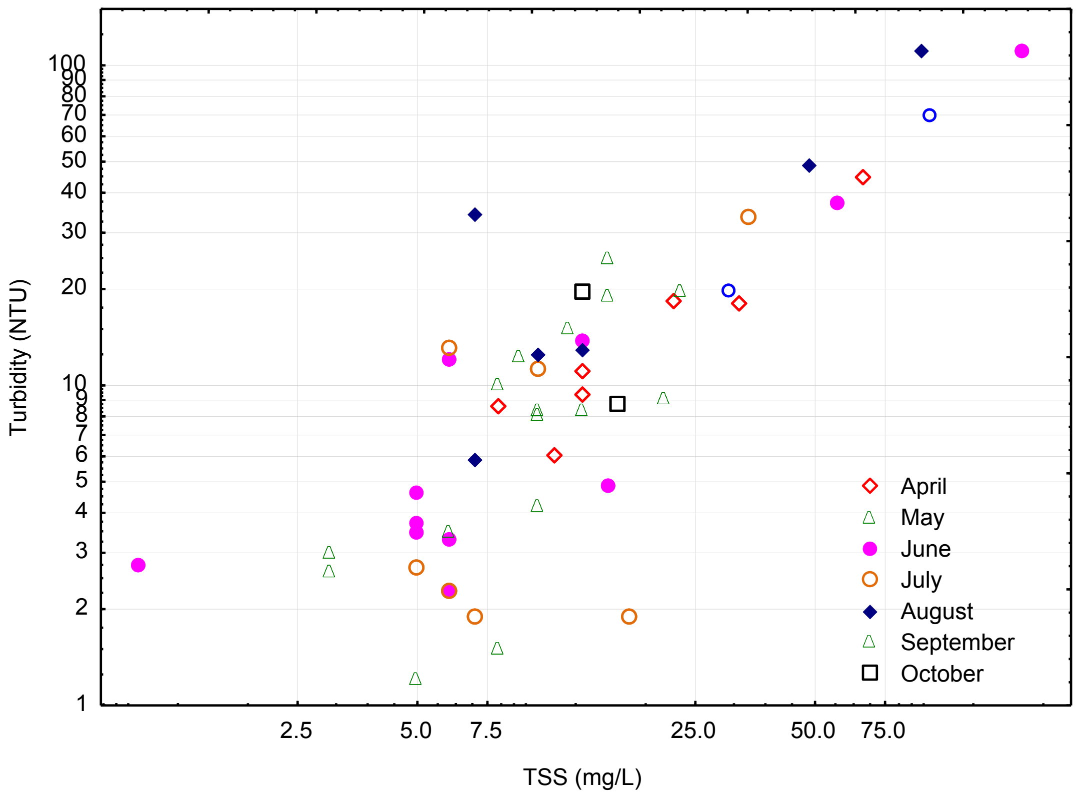
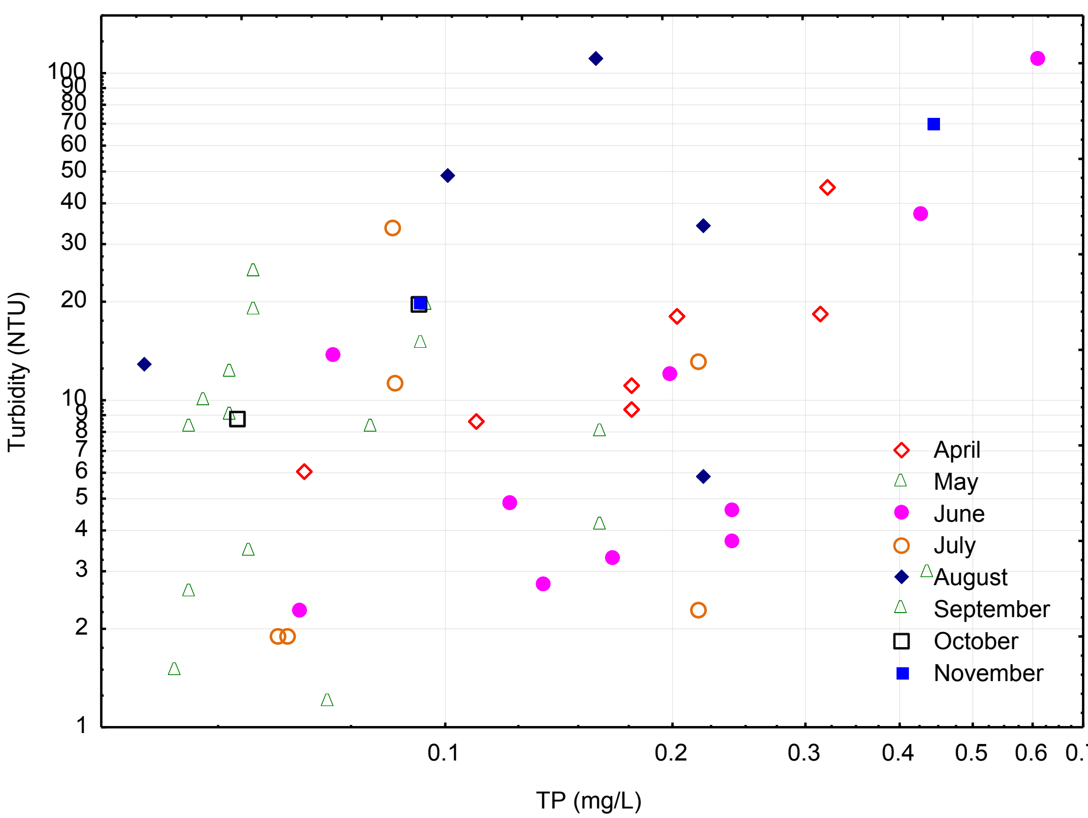


Figure 21. Turbidity vs.TP in County Ditch 2 (S004-131) 2004-2013.



3.4.6 Total Suspended Solids (TSS)

Total suspended solid (TSS) data were summarized by year at each water quality station for each stream listed in Table 1. Because minimum sampling requirements for determination of a TSS impairment are not listed in the draft documentation for proposed TSS standards (Markus, 2011), the sampling requirement for turbidity impairment have been assumed (at least independent 20 observations required) in this analysis. Using the minimum sampling requirements for assessment of turbidity and the proposed stream TSS standard for the South River Nutrient Region, only the cut-off channel (AUID 09020306-512) would meet the criteria for a TSS listing (Table 21, Table 22).

Table 21. Data summary, TSS sampling by year, Grand Marais Creek, headwaters to CD2, 2004-2013. Totals have been highlighted in **bold red font** for water quality stations where >10% of samples violated the proposed TSS standard, violations occurred in more than one year, and there are at least 20 observations.

Waterbody	Monitoring Station	Year	Number of Samples	Min-Max TSS	No. Samples >65 NTU
Grand Marais Creek, headwaters to CD2 (AUID 09020306-507)	S002-083	2004	4	5 – 136	1
		2005	4	3 - 36	0
		2007	2	15 - 38	0
		2009	3	2 - 28	0
		2006	3	28 - 136	2
		2008	3	3 - 5	0
		All	19	2 - 136	2
	S002-983	2012	1	8	0
		2013	4	6 - 263	2
		All	5	6 - 263	2
	S002-984	2010	4	13 – 20	0
		2011	11	1 – 46	0
		2012	3	1 – 23	0
		2013	6	9 - 72	1
		All	24	1 - 72	1
Grand Marais Creek, CD2 to Red River (AUID 09020306-512)	S002-126	2004	40	11 - 1100	28
		2005	38	27 - 555	28
		2006	18	8 - 270	10
		2007	32	4 - 700	18
		2008	6	5 - 436	2
		2009	2	6	0
		2010	62	10 - 2320	12
		2011	48	14 - 494	20
		2012	30	3 – 570	6
		2013	26	7 – 1000	10
		All	**302**	**3 - 2320**	**134**

Table 22. Data summary, TSS sampling by year, County Ditch 2, CD66 to Grand Marais Creek, 2004-2013.

Waterbody	Monitoring Station	Year	Number of Samples	Min-Max TSS	No. Samples >65 NTU
County Ditch 2, CD66 to Grand Marais Creek (AUID 09020306-515)	S004-131	2006	2	21	0
		2007	6	13 – 57	0
		2008	10	6 – 165	4
		2009	20	1 – 13	0
		2010	24	2 – 30	0
		2011	14	2 – 32	0
		2012	26	6 – 96	4
		2013	6	3 – 23	0
		All	108	1 - 165	8

3.5 Pollutant Source Summary

Pollutant source summaries will be included in the TMDL study. Likely pollutants to be included are sediment and phosphorus. Other pollutant may be addressed contingent on the findings of the causes of low DO, high pH, and high turbidity.

3.6 Geomorphology Assessment

The Grand Marais Creek Watershed contains mostly channelized streams or created ditches that are poor environments for aquatic life, though they tend to be fairly stable geomorphically. Hydrologically, increased flow from land-cover change and increased tile drainage has contributed to greater turbidity. On the other hand, intermittent flow which is typical of this region causes stress on aquatic life by driving them to migrate into deeper water s and/or river reaches with higher dissolved oxygen and lower temperatures. Lack of connectivity (both laterally with the floodplain and longitudinally within the river) particularly in the headwater reaches at low flow may greatly reduce usage of those river reaches by aquatic life.

In terms of specific metrics, the Minnesota Stream Health Assessment (MSHA) showed very poor aquatic habitat with a mean score of 27 / 100 based on surveys at 21 sites. The Minnesota Agricultural Ditch Reach Assessment for Stability (MADRAS) ditch geomorphology tool showed fairly stable channel conditions with a mean score of 14/60, (low scores show more stable conditions). Rosgen channel assessment shows that many of the ditches are highly entrenched, with low sinuosity and silt-clay stream beds. Many of the ditches had small Type E channels developing within the bottom of the larger ditch trapezoids that would provide better conditions for aquatic life. Alternative ditch management and design practices could be useful in improving IBI scores in channelized ditch networks by improving depth variety and reducing both turbidity and embeddedness.

4 LITERATURE CITED

Heiskary, S. and Markus, H. 2001. Establishing Relationships Among Nutrient Concentrations, Phytoplankton Abundance, and Biochemical Oxygen Demand in Minnesota, USA, Rivers. Journal of Lake and Reservoir Management 17(4): 251-262.

Houston Engineering Inc. 2012.RLWE Project 60F, Grand Marais Creek Outlet Restoration, Final Engineer's Plan Report to the Board of Managers of the Red Lake Watershed District and the Joint Powers Board, July 20, 2012.

Markus, Howard D. May 2011. Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity), Minnesota Pollution Control Agency.

Markus, Howard D. 2011. Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity), Triennial Water Quality Standard Amendments to Minn R. chs. 7050 and 7052., Minnesota Pollution Control Agency (MPCA).

Minnesota Pollution Control Agency (MPCA). 2014. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b), Report and 303(d) List.

Red Lake Watershed District (RLWD). 2012 Annual Report, http://www.redlakewatershed.org/Annual%20Reports/2012%20Annual%20Report.pdf