Lower Big Sioux River Watershed Biotic Stressor Identification Report

Minnesota Pollution Control Agency

December 2014

Authors

Michael Koschak

Contributors/acknowledgements

Kim Laing
Chandra Carter
Chuck Regan
Mark Hanson
Katherine Pekarek-Scott
Colton Cummings
Paul Marston
Tim Larson
Chessa Frahm
Brooke Hacker

Editing and graphic design

PIO staff
Graphic design staff
Administrative staff
Cover photo: Clockwise from Top Left: Flandreau Creek at site 11MS005; Eroded bank at site 11MS012; Cattle in Flandreau Creek at site 11MS005

Project dollars provided by the Clean Water Fund
(From the Clean Water, Land and Legacy Amendment)

Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 | www.pca.state.mn.us | 651-296-6300
Toll free 800-657-3864 | TTY 651-282-5332

This report is available in alternative formats upon request, and online at www.pca.state.mn.us

Document number: wq-ws5-10170203a

Contents

Executive summary

The purpose of stressor identification is to explain the results of the biological monitoring and assessment process. The information obtained answers the questions of why one stream has a low index of biological integrity (IBI) score, while another has a high score. It looks at causal factors – negative ones harming fish and insects, and positive ones leading to healthy biology. Stressors may be physical, chemical, or biological.

Stressor identification is a formal and rigorous process that identifies stressors causing biological impairment of aquatic ecosystems, and provides a structure for organizing the scientific evidence supporting the conclusions (EPA, 2000). In simpler terms, it is the process of identifying the major factors causing harm to fish and other river and stream life. Stressor identification is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act.

This report summarizes stressor identification work in the Lower Big Sioux River watershed. Located in southwest Minnesota, the Lower Big Sioux River watershed encompasses approximately 326,556 acres within the state of Minnesota. This watershed includes many large and small tributaries to the Big Sioux River.

Over the past few years, the Minnesota Pollution Control Agency (MPCA) has substantially increased the use of biological monitoring and assessment as a means to determine and report the condition of rivers and streams. The basic approach is to look at fish and aquatic macroinvertebrates (mostly insects), and related habitat conditions, at sites throughout a major watershed. The resulting information is used to produce an IBI. Index of biological integrity scores can then be compared to a range of regionally developed thresholds. The regional thresholds were developed to maintain a healthy community of aquatic life and meet water quality standards. Stream and river reaches are assigned an Assessment Unit Identification (AUID) number and will be referred to as the AUID in this report. AUIDs with low IBI scores are determined to have a biological impairment.

This report analyzed the biological impairments in six subwatersheds within the Lower Big Sioux River watershed. The subwatersheds having a biological impairment were: Beaver Creek, Blood Run, Flandreau Creek, Pipestone Creek, Split Rock Creek, and Spring Creek. After examining many candidate causes for the biological impairments, the following stressors were identified in their respective subwatershed (Table 1).

Table 1: Stressors to the biologically impaired reaches within the Lower Big Sioux River watershed
(• = stressor, - = not a stressor, and blank = inconclusive/not enough evidence)

		Stressors				
Stream Name	**AUID #**	**Low Dissolved Oxygen**	**High Phosphorus**	**High Nitrates**	**High Turbidity/TSS**	**Lack of Habitat**
Beaver Creek watershed						
Lower Beaver Creek	10170203-522	-	•	•	•	•
Upper Beaver Creek	10170203-521	•	•	•	-	•
Blood Run watershed						
Blood Run	10170203-555	-	•	•	-	-
Flandreau Creek watershed						
Flandreau Creek	10170203-502	•	•			•
Flandreau Creek	10170203-517		•		•	•
Willow Creek	10170203-515	•	•		•	•
Unnamed Creek	10170203-531	•	•	-	•	•
Pipestone Creek watershed						
Pipestone Creek	10170203-501	•	•	•	•	•
Pipestone Creek	10170203-505	-	•	•	•	•
Pipestone Creek	10170203-506		•	•	•	•
North Branch Pipestone Creek	10170203-514	•	•	•	•	-
Unnamed Creek	10170203-549	•	•	-	•	•
Split Rock Creek watershed						
Split Rock Creek	10170203-512	•	•	-	•	•
Split Rock Creek	10170203-507	-	•	-		-
Split Rock Creek	10170203-509	•	•		•	•
Unnamed Creek	10170203-538		•	-	-	•
Unnamed Creek	10170203-553	•	•		-	-
Upper Spring Creek watershed						
Spring Creek	10170203-518		•		-	

Introduction

Monitoring and assessment

As part of the MPCA's intensive watershed monitoring (IWM) approach, monitoring activities increased in rigor and intensity during the years of 2011-2012, and focused more on biological monitoring (fish and macroinvertebrates) as a means of assessing stream health. The data collected during this period, as well as historic data dated back until 2001, were used to identify stream reaches that were not supporting healthy fish and macroinvertebrate assemblages (Figure 1).

Once a biological impairment is discovered, the next step is to identify the source(s) of stress on the biological community. A Stressor Identification (SID) analysis is a step-by-step approach for identifying probable causes of impairment in a particular system. Completion of the SID process does not result in a finished Total Maximum Daily Load (TMDL). The product of the SID process is the identification of the stressor(s) for which the TMDL may be developed. In other words, the SID process may help investigators nail down excess fine sediment as the cause of biological impairment, but a separate effort is then required to determine the TMDL and implementation goals needed to restore the impaired condition.

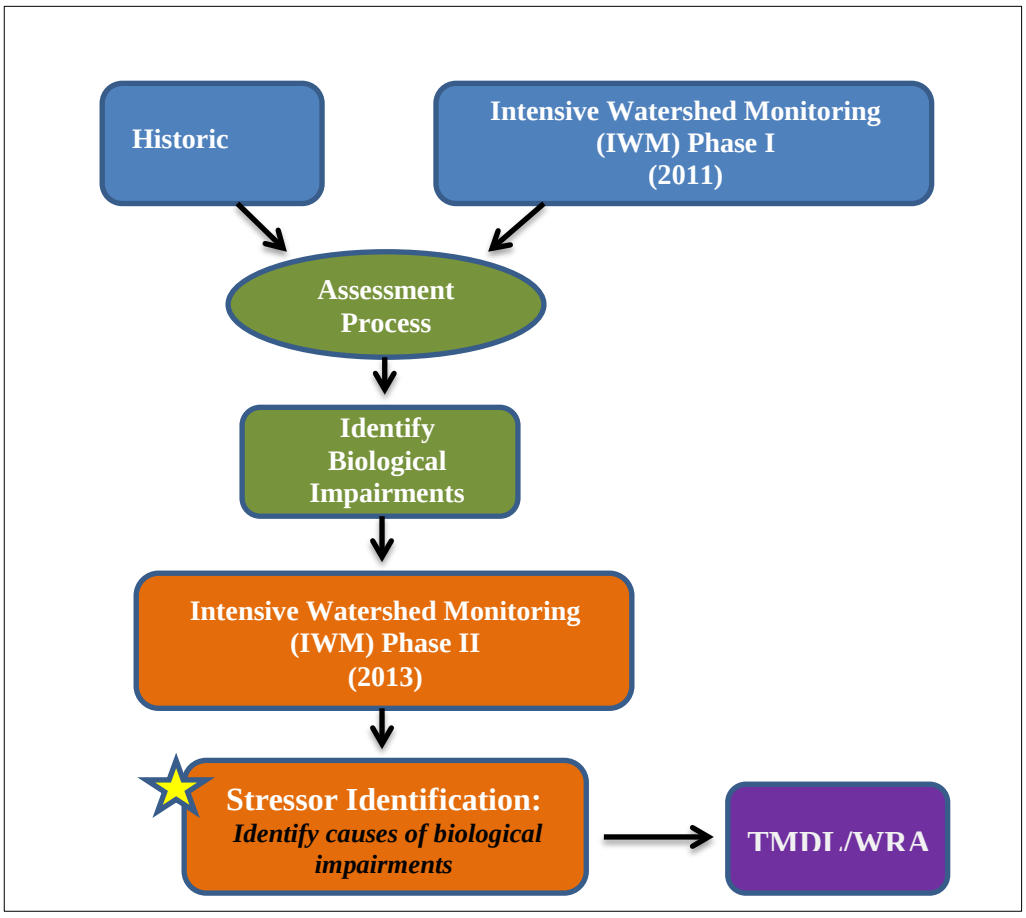

Figure 1: Process map of IWM, assessment, SID, and TMDL processes

Stressor identification process

The SID process is used in this report to weigh evidence for or against various candidate causes of biological impairment (see Cormier et al., 2000). The SID process is prompted by biological assessment data indicating that a biological impairment has occurred. Through a review of available data, stressor scenarios are developed that may accurately characterize the impairment, the cause, and the sources/pathways of the various stressors (Figure 2). Confidence in the results often depends on the quality of data available to the SID process. In some cases, additional data collection may be necessary to accurately identify the stressor(s).

Stressor identification draws upon a broad variety of disciplines, such as aquatic ecology, geology, geomorphology, chemistry, land-use analysis, and toxicology. Strength of evidence (SOE) analysis is used to develop cases in support of, or against various candidate causes. Typically, the majority of the information used in the SOE analysis is from the study watershed, although evidence from other case studies or scientific literature can also be drawn upon in the SID process.

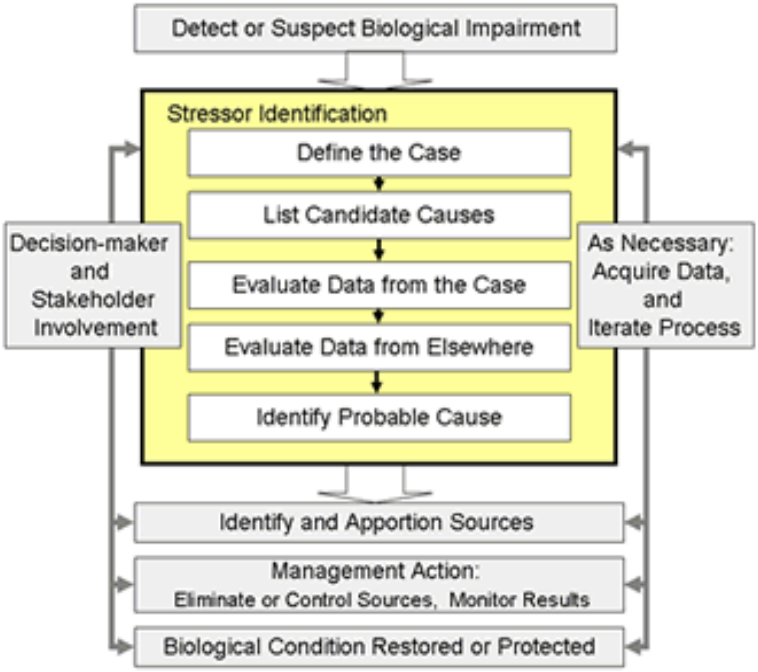

Figure 2: Conceptual model of stressor identification (SID) process

Completion of the SID process does not result in completed TMDL allocations. The product of the SID process is the identification the stressor(s) for which the TMDL load allocation will be developed. For example, the SID process may help investigators identify excess fine sediment as the cause of biological impairment, but a separate effort is then required to determine the TMDL and implementation goals needed to address and correct the impaired condition.

Common stream stressors

The five major elements of a healthy stream system are stream connections, hydrology, stream channel assessment, water chemistry, and stream biology. If one or more of the components are unbalanced, the stream ecosystem may fail to function properly and is listed as an impaired waterbody. Table 2 lists the common stream stressors to biology relative to each of the major stream health categories.

Table 2: Common streams stressors to biology (i.e., fish and macroinvertebrates)

Stream Health	Stressor(s)	Link to Biology
Stream Connections	**Loss of Connectivity** · Dams and culverts · Lack of Wooded riparian cover · Lack of naturally connected habitats/ causing fragmented habitats	Fish and macroinvertebrates cannot freely move throughout system. Stream temperatures also become elevated due to lack of shade.
Hydrology	**Altered Hydrology** **Loss of habitat due to channelization** **Elevated Levels of TSS** · Channelization · Peak discharge (flashy) · Transport of chemicals	Unstable flow regime within the stream can cause a lack of habitat, unstable stream banks, filling of pools and riffle habitat, and affect the fate and transport of chemicals.
Stream Channel Assessment	**Loss of Habitat due to excess sediment** **Elevated levels of TSS** · Loss of dimension/pattern/profile · Bank erosion from instability · Loss of riffles due to accumulation of fine sediment · Increased turbidity and or TSS	Habitat is degraded due to excess sediment moving through system. There is a loss of clean rock substrate from embeddedness of fine material and a loss of intolerant species.
Water Chemistry	**Low Dissolved Oxygen Concentrations** **Elevated levels of Nutrients** · Increased nutrients from human influence · Widely variable DO levels during the daily cycle · Increased algal and or periphyton growth in stream · Increased nonpoint pollution from urban and agricultural practices · Increased point source pollution from urban treatment facilities	There is a loss of intolerant species and a loss of diversity of species, which tends to favor species that can breathe air or survive under low DO conditions. Biology tends to be dominated by a few tolerant species.
Stream Biology	Fish and macroinvertebrate communities are affected by all of the above listed stressors	If one or more of the above stressors are affecting the fish and macroinvertebrate community, the IBI scores will not meet expectations and the stream will be listed as impaired.

Report format

This report follows a format to first summarize candidate causes of stress to the biological communities at the 8-digit HUC scale. Within the summary, there is information about how the stressor relates broadly to the Lower Big Sioux River watershed, water quality standards and general effects on biology. After that section, the report is organized into six different subwatersheds. Each biological impairment within the subwatersheds is evaluated and discussed in further detail.

Overview of Lower Big Sioux River watershed

Background

The Lower Big Sioux River watershed consists of twenty-two 12-digit Hydrologic Unit Code (HUC) subwatersheds (Figure 3). The Lower Big Sioux River watershed encompasses approximately 326,556 acres within the state of Minnesota. This area includes the cities or villages of Jasper, Pipestone, Verdi, Holland, among others. Land use in the watershed consists mainly of cropland (77.37%), followed by rangeland (15.28%), and developed land (5.85%).

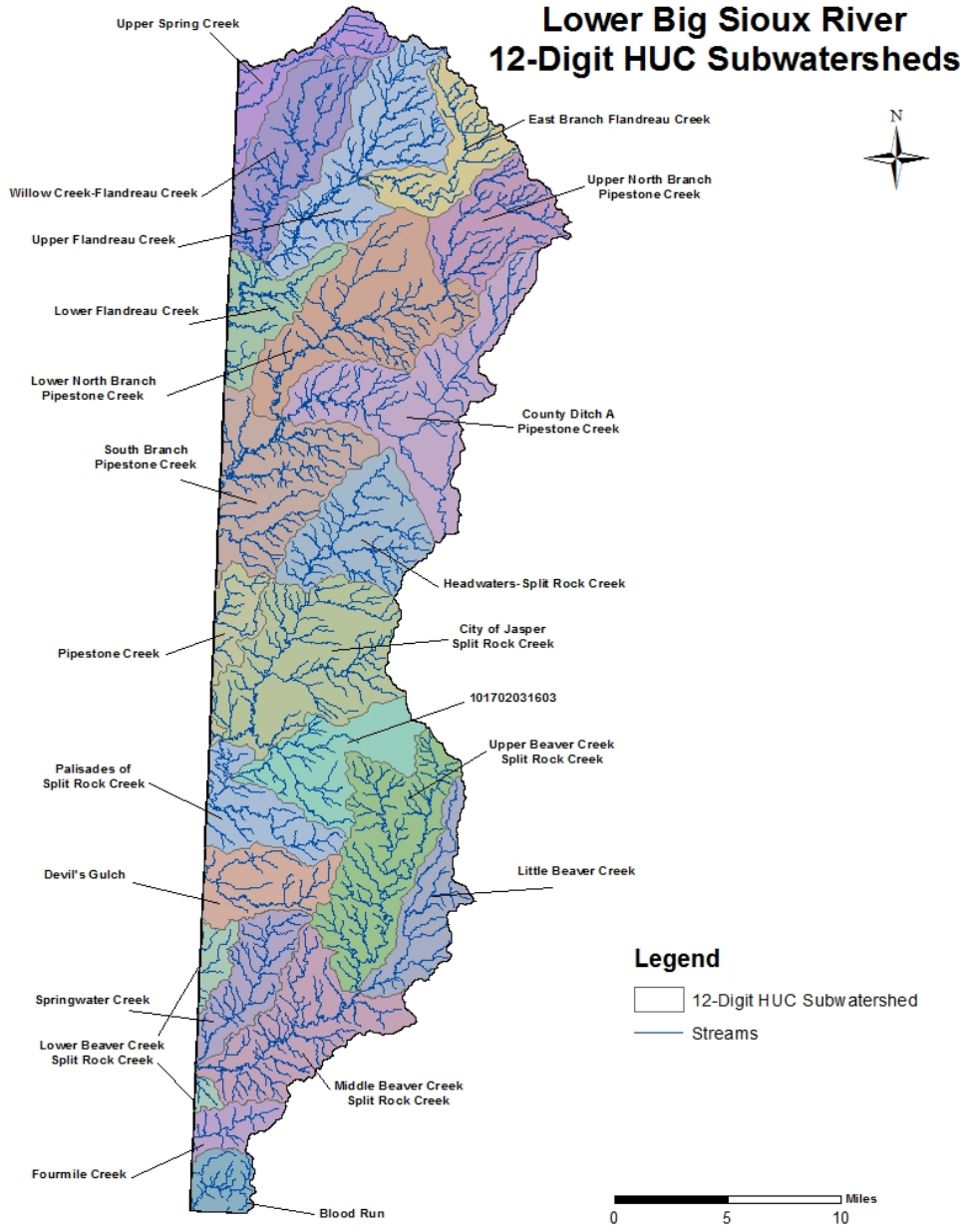

Figure 3: The 12-HUC subwatersheds in the Lower Big Sioux River watershed

Monitoring overview

In 2011-2012, IWM was performed in the Lower Big Sioux River watershed. This sampling effort included 31 biological monitoring sites. Additionally, another 18 biological monitoring stations exist in the watershed and were sampled in previous years and also used for assessment purposes. Biological monitoring and water chemistry data from these sites as well as data from other water monitoring stations taken within ten years of the biological monitoring were used to assess the conditions of the Lower Big Sioux River watershed. The watershed assessment for this area occurred in 2013. Figure 4 displays all of the biological monitoring stations and the biological impairments that exist in the watershed.

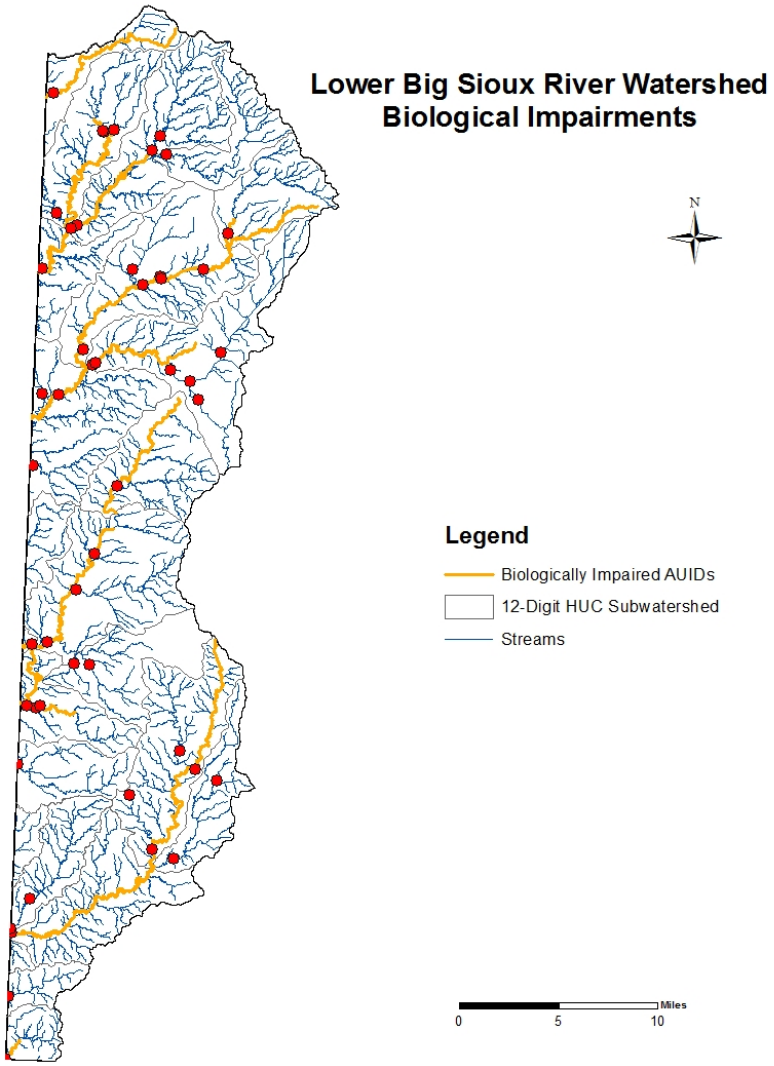

Figure 4: Biological monitoring stations and biological impairments in the Lower Big Sioux River watershed

Summary of biological impairments

The approach used to identify biological impairments includes monitoring of fish and aquatic macroinvertebrates communities and related habitat conditions at sites throughout a watershed. The resulting information is used to develop an IBI. The IBI scores can then be compared to a range of regionally developed thresholds. For further descriptions of the fish and macroinvertebrate IBI class criteria, please see Appendices 1.1-2.

The fish and macroinvertebrates within each AUID were compared to a regionally developed threshold and confidence interval and utilized a weight of evidence approach. The water quality standards call for the maintenance of a healthy community of aquatic life. Intensive watershed monitoring scores provide a measurement tool to assess the health of the aquatic communities. Intensive watershed monitoring scores higher than the impairment threshold indicate that the stream reach supports aquatic life. Conversely, scores below the impairment threshold indicate that the stream reach does not support aquatic life. Confidence limits around the impairment threshold help to ascertain where additional information may be considered to help inform the impairment decision. When IBI scores fall within the confidence interval, interpretation and assessment of the waterbody condition involves consideration of potential stressors, and draws upon additional information regarding water chemistry, physical habitat, and land use, etc.

In the Lower Big Sioux River watershed, 18 AUIDs are currently impaired for a lack of biological assemblage (Table 3).

Table 3: Biologically impaired AUIDs in the Lower Big Sioux River watershed

				Impairments	
Stream Name	**AUID #**	**HUC-12**	**Reach Description**	**Biological**	**Water Quality**
Pipestone Creek	10170203-501	101702031304	N Br Pipestone Cr to MN/SD border	Macroinvertebrate IBI, Fish IBI	Turbidity
Flandreau Creek	10170203-502	101702030304	Willow Cr to MN/SD border	Fish IBI	
Pipestone Creek	10170203-505	101702031305	MN/SD border to Split Rock Cr (Rock County)	Macroinvertebrate IBI, Fish IBI	
Pipestone Creek	10170203-506	101702031301	Headwaters to N Br Pipestone Cr	Macroinvertebrate IBI, Fish IBI	
Split Rock Creek	10170203-507	101702031602	Split Rock Lk to Pipestone Cr	Macroinvertebrate IBI, Fish IBI	
Split Rock Creek	10170203-509	101702031601	Headwaters to Split Rock Lk	Macroinvertebrate IBI, Fish IBI	
Split Rock Creek	10170203-512	101702031605	Pipestone Cr to MN/SD border	Fish IBI	Turbidity
Pipestone Creek, N Branch	10170203-514	101702031303	Headwaters to Pipestone Cr	Macroinvertebrate IBI, Fish IBI	Turbidity
Willow Creek	10170203-515	101702030303	Headwaters to Flandreau Cr	Macroinvertebrate IBI, Fish IBI	
Flandreau Creek	10170203-517	101702030302	T108 R46W S14, north line to Willow Cr	Macroinvertebrate IBI, Fish IBI	
Spring Creek	10170203-518	101702030101	Headwaters to MN/SD border	Macroinvertebrate IBI	
Beaver Creek	10170203-521	101702031501	Headwaters to Little Beaver Cr	Macroinvertebrate IBI	
Beaver Creek	10170203-522	101702031503	Little Beaver Cr to MN/SD border	Macroinvertebrate IBI, Fish IBI	Turbidity
Unnamed Creek	10170203-531	101702030303	Unnamed cr to Willow Cr	Macroinvertebrate IBI	
Unnamed Creek	10170203-538	101702031605	Unnamed cr to Unnamed cr	Macroinvertebrate IBI	
Unnamed Creek	10170203-549	101702031302	Unnamed cr to N Br Pipestone Cr	Macroinvertebrate IBI, Fish IBI	
Blood Run	10170203-555	101702031702	Unnamed cr to MN/SD border	Macroinvertebrate IBI	
Unnamed Creek	10170203-553	101702031603	Unnamed cr to Unnamed cr	Macroinvertebrate IBI, Fish IBI	

For further information regarding the fish and macroinvertebrate classes, their respective thresholds, and the IBI scores of all sites within the Lower Big Sioux River watershed, please see the Missouri River Basin Monitoring and Assessment Report.

Hydrological Simulation Program - FORTRAN Model

The Hydrological Simulation Program - FORTRAN (HSPF) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates watershed-scale Agricultural Runoff Model (ARM) and Non-Point Source (NPS) models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at the outlet of any subwatershed. HSPF simulates three sediment types (sand, silt, and clay) in addition to a single organic chemical and transformation products of that chemical.

The HSPF watershed model contains components to address runoff and constituent loading from pervious land surfaces (PERLNDs), runoff and constituent loading from impervious land surfaces (IMPLNDs), and flow of water and transport/transformation of chemical constituents in stream reaches (RCHRESs). Primary external forcing is provided by the specification of meteorological time series. The model operates on a lumped basis within subwatersheds. Upland responses within a subwatershed are simulated on a per-acre basis and converted to net loads on linkage to stream reaches. Within each subwatershed, the upland areas are separated into multiple land use categories.

The HSPF watershed model was run for Lower Big Sioux River watershed to help simulate outputs used for analysis. In this report, AUIDs with biological impairments used the model results to supplement information that was not collected to further confirm or refute a stressor.

Candidate cause: low dissolved oxygen

Dissolved oxygen (DO) refers to the concentration of oxygen gas within the water column. Low or highly fluctuating concentrations of DO can have detrimental effects on many fish and macroinvertebrate species (Davis, 1975; Nebeker et al., 1991). Dissolved oxygen concentrations change seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995). Some macroinvertebrates that are intolerant to low levels of DO include mayflies, stoneflies and caddisflies (Marcy, 2007). Many species of fish avoid areas where DO concentrations are below 5 mg/L (Raleigh et al., 1986). Additionally, fish growth rates can be significantly affected by low DO levels (Doudoroff and Warren, 1965).

In most streams and rivers, the critical conditions for stream DO usually occur during the late summer season when water temperatures are high and stream flows are reduced to baseflow. As temperatures increase, the saturation levels of DO decrease. Increased water temperature also raises the DO needs for many species of fish (Raleigh et al., 1986). Low DO can be an issue in streams with slow currents, excessive temperatures, high biological oxygen demand, and/or high groundwater seepage (Hansen, 1975).

Water quality standards

In class 2B streams, the Minnesota standard for DO is 5.0 mg/L as a daily minimum. Additional stipulations have been recently added to this standard. The following is from the Guidance Manual for Assessing the Quality of Minnesota Surface Waters (MPCA, 2009):

Under revised assessment criteria beginning with the 2010 assessment cycle, the DO standard must be met at least 90 percent of the time during both the 5-month period of May through September and the 7-month period of October through April. Accordingly, no more than 10 percent of DO measurements can violate the standard in either of the two periods.

Further, measurements taken after 9:00 in the morning during the 5-month period of May through September are no longer considered to represent daily minimums, and thus measurements of > 5 DO later in the day are no longer considered to be indications that a stream is meeting the standard.

A stream is considered impaired if 1) more than 10 percent of the "suitable" (taken before 9:00) May through September measurements, or 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 2) there are at least three total violations.

Types of dissolved oxygen data

Point measurements

Instantaneous DO data is available throughout the watershed and can be used as an initial screening for low DO. These measurements represent discrete point samples, usually conducted in conjunction with surface water sample collection utilizing a YSI sonde. Because DO concentrations can vary significantly as a result of changing flow conditions and time of sampling, instantaneous measurements need to be used with caution and are not completely representative of the DO regime at a given site.

Diurnal (continuous)

YSI sondes were deployed for 14 day intervals at two locations in the Lower Big Sioux River watershed in late summer to capture diurnal fluctuations over the course of a number of diurnal patterns. This information was then used to look at the diurnal flux of DO along with the patterns of DO fluctuation. Hieskary et al. (2010) observed several strong negative relationships between fish and macroinvertebrate metrics and DO flux. Their study found that a diurnal (24 hour) DO flux over 4.5 mg/L reduced macroinvertebrate taxa richness and the relative abundance of sensitive fish species in a population.

Overview of dissolved oxygen in the Lower Big Sioux River watershed

Dissolved oxygen was measured throughout the watershed. Continuous DO monitoring was performed along Flandreau Creek as well as Split Rock Creek. Both of these stream reaches had a daily flux greater than 4.5 mg/L. Sites along both of these reaches had reduced macroinvertebrate taxa richness and few sensitive fish species.

Unfortunately, due to vast number of biological impairments in this watershed and in the entire Missouri basin, continuous DO monitoring could not feasibly be done at all impaired reaches. Frequent DO monitoring was performed along these reaches instead. This data, along with the modeling data and biological responses will be used to determine the degree of stress DO is having on the impaired reach.

Sources and causal pathways for low dissolved oxygen

Dissolved oxygen concentrations in lotic environments are often driven by a combination of natural and anthropogenic factors. Natural background characteristics of a watershed, such as topography, hydrology, climate, and biological productivity can influence the DO regime of a waterbody. Agricultural and urban land-uses, impoundments (dams), and point-source discharges are just some of the anthropogenic factors that can cause unnaturally high, low, or volatile DO concentrations. The conceptual model for low DO as a candidate stressor in the Lower Big Sioux River watershed is modeled at EPA's CADDIS Dissolved Oxygen webpage. (MPCA 2012, PdT)

Candidate cause: high phosphorus

Phosphorus is an essential nutrient for all aquatic life, but elevated phosphorus concentrations can result in an imbalance which can impact stream organisms. Excess phosphorus does not result in direct harm to fish and macroinvertebrates. Rather, its detrimental effect occurs as it alters other factors in the water environment. Dissolved oxygen, pH, water clarity, and changes in food resources and habitat are all stressors that can result when there is excess phosphorus.

Water quality standards

There is no current water quality standard for total phosphorus; however there is a draft nutrient standard for rivers of Minnesota as well as ecoregion data to show if the data is within the expected norms. The current draft standard is a maximum concentration of 0.15 mg/l. For more information, please reference the Missouri River Basin Monitoring and Assessment Report.

Total phosphorus concentrations in the Lower Big Sioux River watershed

From 2001-2014, there has been 763 phosphorus samples collected in streams in the Lower Big Sioux River watershed. Of those samples, 324 (42.46%) were at or above the 0.15 mg/L proposed draft standard for phosphorus. The high rate and degree of exceedance of the standard shows that phosphorus is a watershed-wide issue and will need to be addressed.

Sources and causal pathways for high phosphorus

Phosphorus is delivered to streams by wastewater treatment facilities, urban stormwater, agriculture, and direct discharges of sewage. The causes and potential sources for excess phosphorus in the Lower Big Sioux River watershed are modeled at U. S. Environmental Protection Agency (EPA's) Nutrient CADDIS webpage.

Candidate cause: high nitrate - nitrite

Exposure to elevated nitrite or nitrate concentrations can lead to the development of methemoglobinemia. The iron site of the hemoglobin molecule in red blood cells preferentially bonds with nitrite molecules over oxygen molecules. Methemoglobinemia ultimately limits the amount of oxygen which can be absorbed by fish and macroinvertebrates (Grabda et al., 1974). Certain species of caddisflies, amphipods, and salmonid fishes seem to be the most sensitive to nitrate toxicity according to Camargo and Alonso (2006).

Water quality standards

Streams classified as class 1 waters of the state, designated for domestic consumption, in Minnesota have a nitrate-N (nitrate plus nitrite) water quality standard of 10 mg/L. At this time, none of the AUIDs in the Lower Big Sioux River watershed that are impaired for biota are classified as class 1 streams. Minnesota currently does not have a nitrate standard for other waters of the state besides for class 1.

Ecoregion data

McCollor & Heiskary (1993) developed a guidance of stream parameters by ecoregion for Minnesota streams. The Lower Big Sioux River watershed encompasses portions of two ecoregions: the majority being Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) which is located in the northern one third of the watershed. The annual 75th percentile nitrate-N values were used for comparison (Table 4).

Table 4: Ecoregions in the Lower Big Sioux River watershed with the associated annual 75 percentile nitrate-nitrite level

Ecoregion	75 Percentile value (mg/L)
Northern Glaciated Plains (NGP)	0.52
Western Corn Belt Plains (WCBP)	6.9

Collection methods for nitrate and nitrite

Water samples analyzed for nitrate-N were collected throughout the watershed for purposes of assessment and stressor identification. Nitrate-N is comprised of both nitrate (NO3-) and nitrite (NO2-). Typically water samples contain a small proportion of nitrite relative to nitrate due to the instability of nitrite, which quickly oxidizing to nitrate. The water samples collected were analyzed for nitrate-N at a Minnesota Department of Health certified lab.

Nitrate and nitrite in the Lower Big Sioux River watershed

From 2001-2014, there were 755 nitrate samples collected throughout the Lower Big Sioux River watershed. Values ranged from less than 0.05 mg/l up to 37 mg/l. In general, the months with the highest nitrate values were March through June. There are many high values throughout the watershed and a nitrate reduction plan is needed to control and reduce the impact it is having on water quality.

Sources and causal pathways for nitrate and nitrite

The elevated nitrate levels during the spring months coincide with fertilizer applications and periods of snowmelt/runoff. The abundance of row crop agriculture and intensive grazing in the watershed makes this a large scale issue. For a complete model of causes and potential causes of nitrates in the Lower Big Sioux River watershed, please see the EPA's CADDIS Nitrogen webpage.

Candidate cause: altered hydrology/connectivity/geomorphology

Increased flows may directly impair the biological community or may contribute to additional stressors. Increased channel shear stresses, associated with increased flows, often causes increased scouring and bank destabilization. With these stresses added to the stream, the fish and macroinvertebrate community may be influenced by the negative changes in habitat and sediment.

High flows can also cause the displacement of fish and macroinvertebrates downstream if they cannot move into tributaries or refuges along the margins of the river; or if refuges are not available. Such aspects as high velocities, the mobilization of sediment, woody debris and plant material can also be detrimental especially to the fish and macroinvertebrates which can cause significant dislodgement. When high flows become more frequent, species that do not manage well under those conditions will be reduced, leading to altered population. Macroinvertebrates may shift from those of long life cycles to short life cycles needing to complete their life history within the bounds of the recurrence interval of flow conditions (CADDIS, 2011).

Across the conterminous United States, Carlisle et al. found that there is a strong correlation between diminished streamflow and impaired biological communities (2010). Habitat availability can be scarce when flows are interrupted, low for a prolonged duration, or extremely low, leading to a decreased wetted width, cross sectional area, and water volume. Aquatic organisms require adequate living space and when flows are reduced beyond normal baseflow, competition for resources increases. Pollutant concentrations often increase when flows are lower than normal, making it more difficult for populations to maintain a healthy diversity. Often tolerant individuals that can outcompete in limiting situations will thrive. Low flows of prolonged duration tend to lead to macroinvertebrate and fish communities that have preference for standing water or are comprised of generalist species (CADDIS, 2011).

Altered hydrology/connectivity/geomorphology in the Lower Big Sioux River watershed

The Minnesota Department of Natural Resources (MDNR) has done a comprehensive study on altered hydrology, connectivity, and geomorphology in the entire Missouri River basin. This study, "Missouri River watershed Hydrology, Connectivity, and Geomorphology Assessment Report" analyzes historical gage data along the Rock River, stream crossing data, and applied fluvial geomorphology assessment to find relationships that would help understand water quality and biological impairments throughout the watershed.

Candidate cause: high turbidity/total suspended solids

Increases in suspended sediment and turbidity within aquatic systems are now considered one of the greatest causes of water quality and biological impairment in the United States (U.S. EPA, 2003). Although sediment delivery and transport are important natural processes for all stream systems, sediment imbalance (either excess sediment or lack of sediment) can result in the loss of habitat in addition to the direct harm to aquatic organisms. As described in a review by Waters (1995), excess suspended sediments cause harm to aquatic life through two major pathways: (1) direct, physical effects on biota (i.e. abrasion of gills, suppression of photosynthesis, avoidance behaviors); and (2) indirect effects (i.e. loss of visibility, increase in sediment oxygen demand). Elevated turbidity levels and total suspended solids (TSS) concentrations can reduce the penetration of sunlight and thus impede photosynthetic activity and limit primary production (Munawar et al., 1991; Murphy et al., 1981).

Elevated volatile suspended solids (VSS) concentrations can impact aquatic life in a similar manner as TSS – with the suspended particles reducing water clarity – but unusually high concentrations of VSS can also be indicative of nutrient imbalance and an unstable DO regime.

Water quality standards

The water quality standard for turbidity is 25 Nephelometric Turbidity Units (NTUs) for class 2b waters. Total suspended solids and transparency tube measurements can be used as surrogate standards.

Turbidity is a measure of reduced transparency that can increase due to suspended particles such as sediment, algae and organic matter.

A strong correlation exists between the measurements of TSS concentration and turbidity. In 2010, MPCA released draft TSS standards for public comment (Markus). The new TSS criteria are stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The draft TSS standard for the Lower Big Sioux River watershed has been set at 65 mg/L. For assessment, this concentration is not to be exceeded in more than 10% of samples within a 10-year data window.

As well as TSS, sestonic algae can lead to increases in turbidity and can be evaluated by tests which measure the percentage of the solids from a sample that are burned off (volatile suspended solids – VSS) and by total phosphorus (TP). There are no current standards for either.

For the purposes of stressor identification, transparency tube measurements, TSS, VSS, and HSPF modeling results will be relied upon to quantify the suspended material present from which inferences can be made regarding the effects of suspended solids on fish and macroinvertebrate populations.

Turbidity in the Lower Big Sioux River watershed

The most recent assessments for the Lower Big Sioux River watershed determined there were five turbidity impairments. These impairments are located on Beaver Creek (AUID: 10170203-522), Pipestone Creek (AUID: 10170203-501), North Branch Pipestone Creek (AUID: 10170203-514), Split Rock Creek (AUID: 10170203-512), and Main Ditch (10170203-527).

For a spatial reference of turbidity issues in the Lower Big Sioux River watershed, see Figure 5.

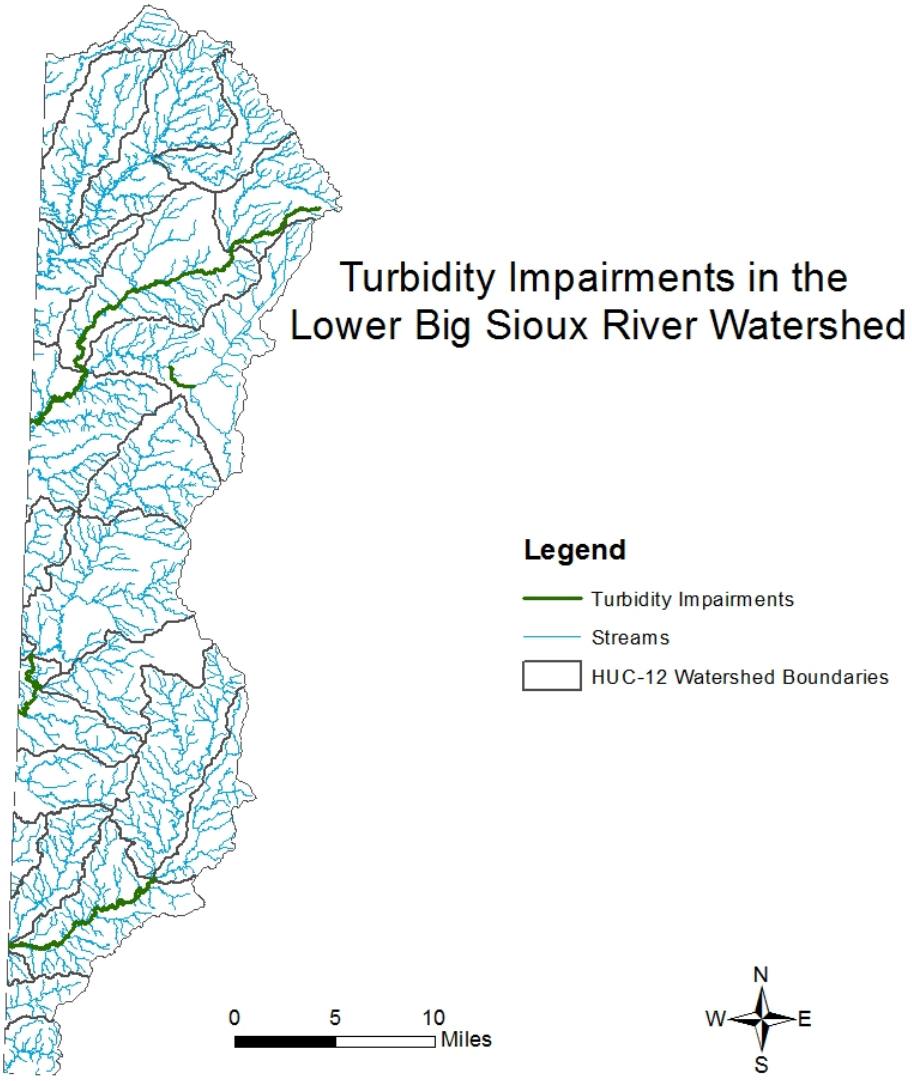

Figure 5: Turbidity impairments in the Lower Big Sioux River watershed

Sources and causal pathways for turbidity

The causes and potential sources for increases in turbidity in the Lower Big Sioux River watershed are modeled at EPA's CADDIS Sediments webpage. High turbidity occurs when heavy rains fall on unprotected soils, dislodging the soil particles which are transported by surface runoff into the rivers and streams (MPCA and MSUM, 2009). The soil may be unprotected for a variety of reasons, such as construction, mining, agriculture, or insufficiently vegetated pastures. Decreases in bank stability may also lead to sediment loss from the stream banks, often caused by perturbations in the landscape such as channelization of waterways, riparian land cover alteration, and increases in impervious surfaces.

Candidate cause: lack of habitat

Habitat is a broad term encompassing all aspects of the physical, chemical, and biological conditions needed to support a biological community. This section will focus on the physical habitat structure including geomorphic characteristics and vegetative features (Griffith et al., 2010). Physical habitat is often interrelated to other stressors (e.g., sediment, flow, DO) and will be addressed separately. Fish passage will also be addressed in a separate section.

Physical habitat diversity enables fish and macroinvertebrate habitat specialists to prosper, allowing them to complete their life cycles. Some examples of the requirements needed by habitat specialists are: sufficient pool depth, cover or refuge from predators, and riffles that have clean gravel or cobble which is and are unimpeded by fine sediment (Griffith et al., 2010).

Specific habitats that are required by a healthy biotic community can be minimized or altered by practices on our landscape by way of resource extraction, agriculture, forestry, silviculture, urbanization, and industry. These landscape alterations can lead to reduced habitat availability, such as decreased riffle habitat; or reduced habitat quality, such as embedded gravel substrates. Biotic population changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (Griffith et al., 2010).

Water quality standards

At this time there are no applicable standards for lack of habitat for biotic communities.

Habitat characteristics in the Lower Big Sioux River watershed

Habitat quality differs throughout the Lower Big Sioux River watershed and is an essential tool when understanding and describing the biological communities. Habitat was measured using the Minnesota Stream Habitat Assessment (MSHA) during the fish sampling event. The MSHA is useful in describing the aspects of habitat needed to obtain an optimal biological community. It includes five subcategories: land use, riparian zone, substrate, cover, and channel morphology.

In the Lower Big Sioux River watershed, habitat scores were predominantly fair or poor throughout (See Figure 6). Many of these areas are farmed intensively or have been channelized in some cases.

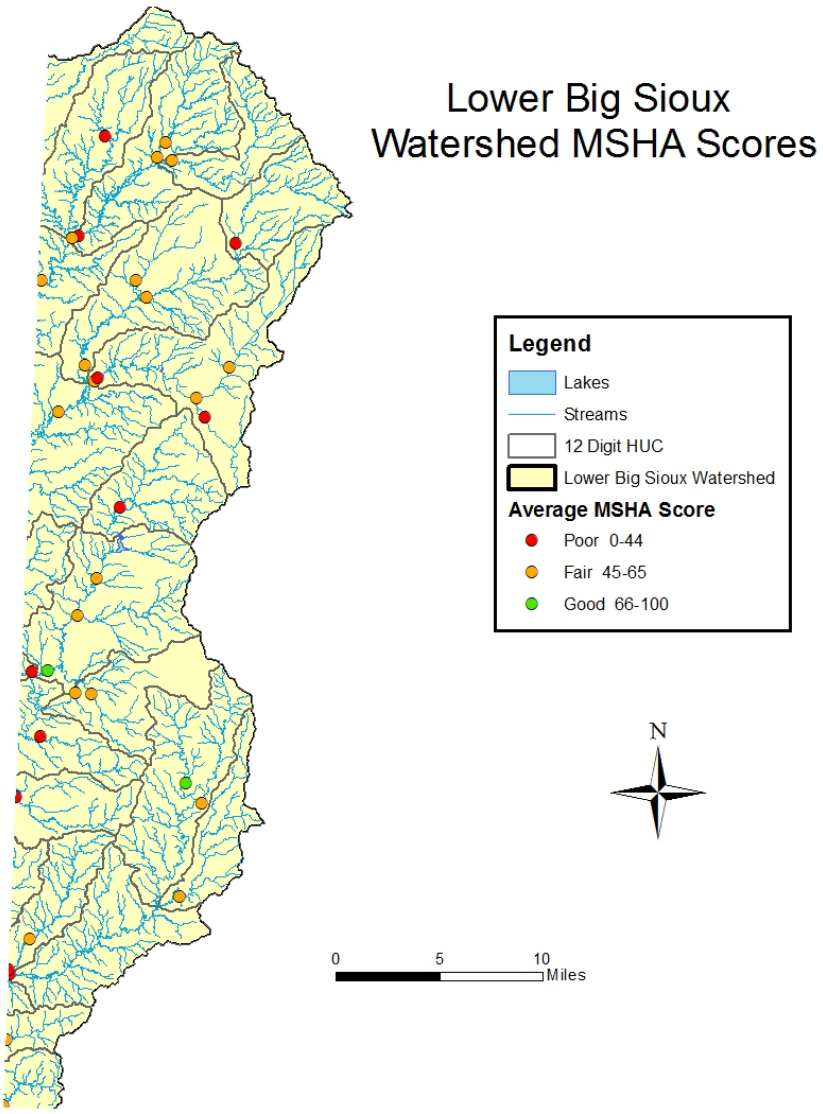

Figure 6: Average MSHA scores at biological sampling stations in the Lower Big Sioux River watershed

Sources and causal pathways model for habitat

The causes and potential sources for lack of habitat in the Lower Big Sioux River watershed are modeled at EPA's CADDIS Physical Habitat webpage. Many riparian areas in this watershed are dominated by row crops and intensive grazing, which decreases the riparian and bank vegetation which leads to unstable and erodible banks.

Subwatersheds with biological impairments

Beaver Creek watershed

Beaver Creek is located in the southern portion of the Lower Big Sioux River watershed. Beaver Creek has two biologically impaired AUIDs (10170203-521 and 10170203-522) across two 12-digit HUC subwatersheds (Figure 7). The land use in the watershed mainly consists of 80.91% cropland, 11.61% rangeland, and 6.1% developed.

Lower Beaver Creek (10170203-522) is a 17.68 mile reach extending from the confluence of Little Beaver Creek to the Minnesota/South Dakota border. This stream reach was sampled for fish and macroinvertebrates at its one biological monitoring station, 11MS012, in 2011 and 2012. The AUID was determined to be impaired for aquatic life due to its fish and macroinvertebrate assemblages as well as turbidity.

Upper Beaver Creek (10170203-521) is a 20.81 mile AUID that extends from the headwaters of this watershed down to the confluence with Little Beaver Creek. This reach was sampled for fish at its two biological stations, 11MS043 and 11MS040 in various years from 2011-2013 and was sampled for macroinvertebrates at these sites in 2011. This AUID was determined to be impaired for aquatic life due to its macroinvertebrate assemblage.

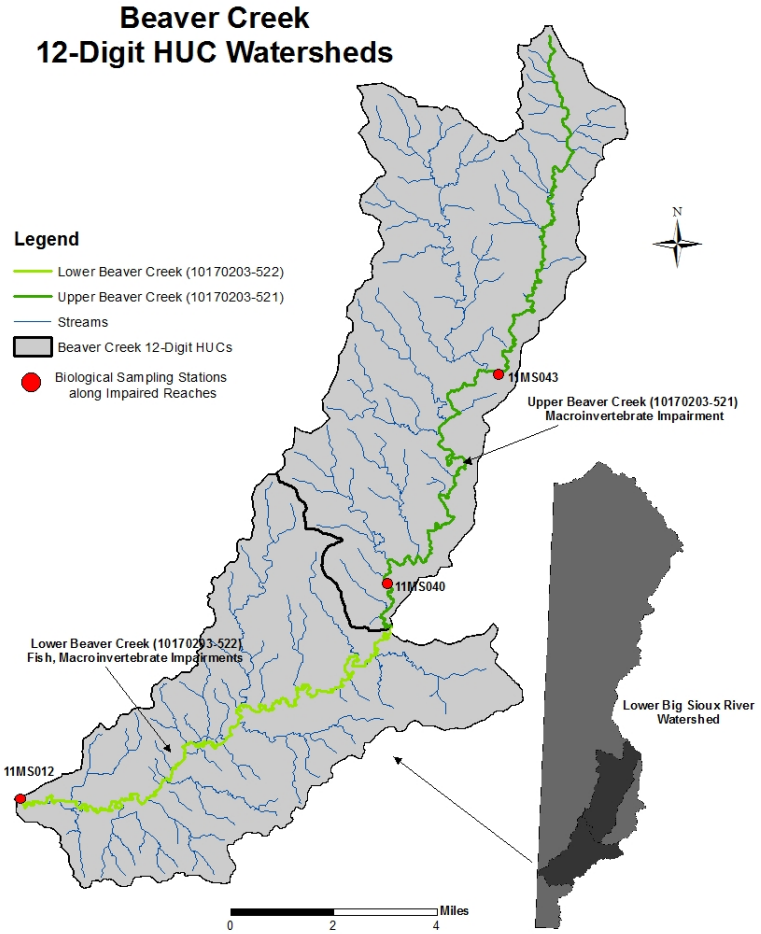

Figure 7: Beaver Creek watershed with biologically impaired reaches highlighted

Biology in Beaver Creek

Fish

Lower Beaver Creek (10170203-522) has one biological monitoring station located on it. This site, 11MS012, is located upstream of 10th Ave, 1 mile north of Manley and was sampled for fish on June 13th, 2012. Moving upstream, Upper Beaver Creek (10170203-521) has two biological monitoring stations. Site 11MS040 is located downstream of 100th Ave, 4 miles west of Luverne and was sampled on June 11th, 2012 and July 9th, 2013. Further in the headwaters lies site 11MS043, which is located downstream of CR 11, 7 miles northwest of Luverne and it was sampled on August 10th, 2011.

Site 11MS012 along Lower Beaver Creek (10170203-522) has a fish class 2 (Southern Streams) designation (Figure 8). The IBI threshold for this class is 45 and to reach this level, each metric would need an average value score of 5.625. This site had fish IBI score of 25 and only reached the average metric score needed to reach the threshold in one metric (SLvd). This metric scored well because of the few short-lived species found at this site. Short-lived fish species tend to be very tolerant as they can quickly adapt to most conditions and carry out their respective life cycles.

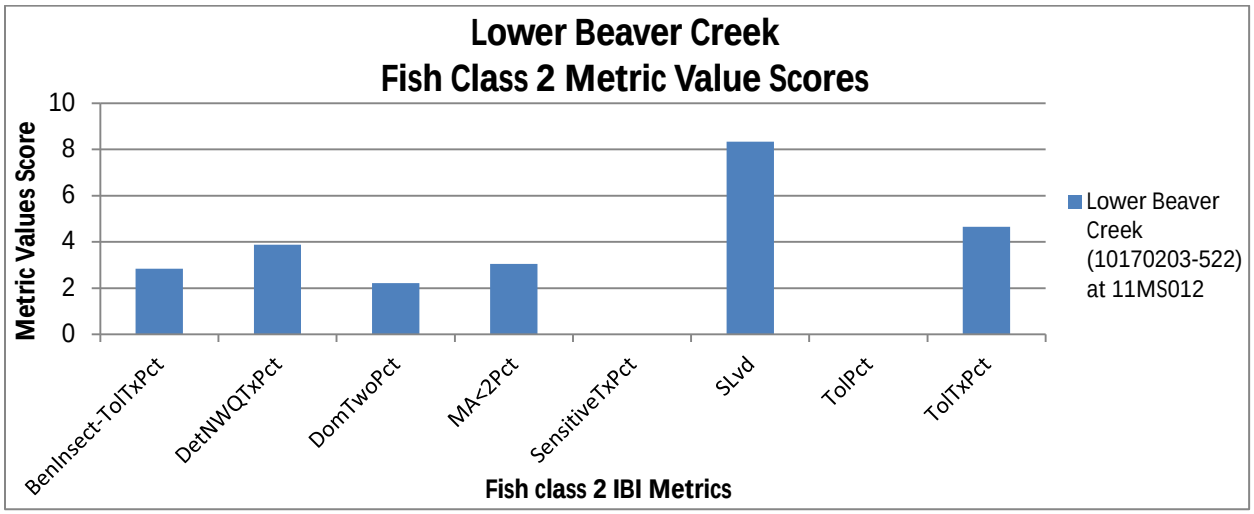

Figure 8: Fish class 2 IBI metric value scores along Lower Beaver Creek at site 11MS012

The fish assemblage in Upper Beaver Creek (10170203-521) was determined to be in full support of aquatic life and is not impaired at this time.

Macroinvertebrates

Site 11MS012 along Lower Beaver Creek (10170203-522) was sampled for macroinvertebrates on August 9th, 2011, while sites 11MS040 and 11MS043 along Upper Beaver Creek (10170203-521) were both sampled on August 10th, 2011.

To reach the MPCA's macroinvertebrate IBI (MIBI) threshold of 35.9 for a class 5 (Southern Streams RR) stream, each metric would need an average score of 3.59. Both sites, 11MS040 and 11MS043, along Upper Beaver Creek (10170203-521) have this classification and their macroinvertebrate MIBI scores were 16.1 and 32.2 respectively. Site 11MS040 only scored well in two of the metrics by having high amounts of clinger taxa (ClingerChTxPct) and Insect taxa (InsectTxPct) (Figure 9). Site 11MS043 scored well in half of the metrics, but was brought down by having a high measure of pollution based on tolerance values (HBI_MN). The community also had few Plecoptera, predator, and Trichoptera taxa, while also having a high percentage of taxa with tolerance values equal to or greater than 6, which drove down the metric value score.

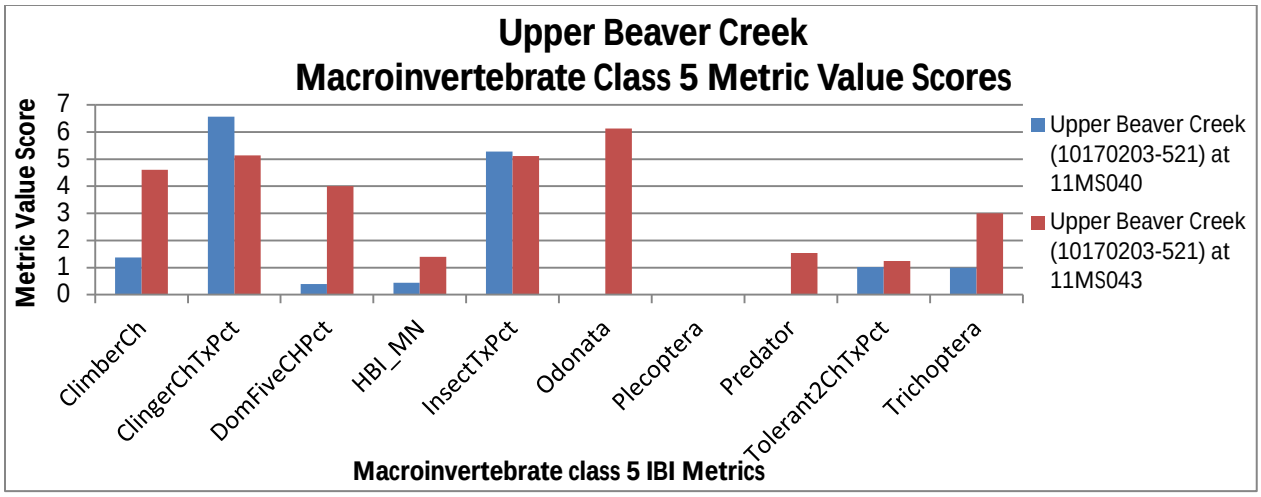

Figure 9: Macroinvertebrate class 5 metric value scores at the two sites in Upper Beaver Creek (10170203-521)

Site 11MS012 along Lower Beaver Creek (10170203-522) has a macroinvertebrate class 7 (Prairie Streams GP) designation (Figure 10). This class has an IBI threshold of 38.83, so each metric would need an average score of 3.83 to achieve this level. Site 11MS012 had a macroinvertebrate IBI score of 32.8. This site had high combined numbers of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET) taxa, predator taxa (PedatorCh), Trichoptera taxa (TrichopteraChTxPct) and non-hydropsychid Trichoptera taxa (TrichwoHydroPct).

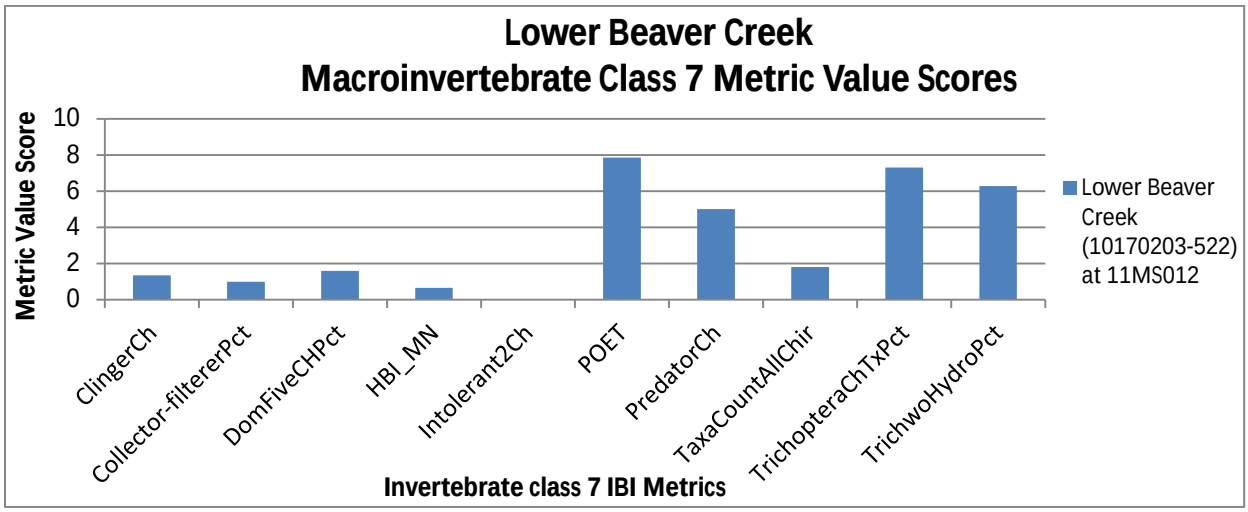

Figure 10: Macroinvertebrate class 7 IBI metric value scores along Lower Beaver Creek (10170203-521) at site 11MS012

Candidate cause: low dissolved oxygen

The daily minimum standard for DO in Minnesota class 2B streams is 5 mg/L. All streams in the Beaver Creek watershed have this 2B classification. No streams in this grouping are currently listed as impaired for DO.

Lower Beaver Creek (10170203-522):

From 2008-2013, 91 DO measurements were taken from Lower Beaver Creek. These values ranged from 7.03-13.12 mg/L. Ten of these samples were taken before 9:00 a.m. when daily minimum values are expected.

The HSPF model calculated hourly DO measurements along this reach from 1996-2009. During this time frame, only 10 (.008%) values were below the 5 mg/L daily minimum standard.

Figure 11: An example of the mayfly, Trichorythodes

Biologically, the macroinvertebrate community in Lower Beaver Creek had a lower amount of overall taxa (21) and also had a high amount of tolerant species (52%). This site did have a very high amount of EPT macroinvertebrates (85.09%). However, these numbers may be misleading as the macroinvertebrate sample was dominated by the mayfly, Trichorythodes (Figure 11), which comprised 41.9% of the individuals sampled. These mayflies are commonly present in large quantities in degraded conditions.

The fish assemblage in this stream lacked sensitive fish taxa and had high amounts of both tolerant (63.64%) and serial spawning (27.27%) species. This reach did have a high amount of late maturing fish taxa (36.36%). These types of fish are less abundant in streams stressed by DO conditions.

Considering the numerous DO raw data with no values below 5 mg/L, the extremely low standard exceedances calculated by the HSPF model, and the mixed biological results, it has been determined that low DO is not stressing the impaired biological communities in Lower Beaver Creek at this time. The tolerant and sensitive metrics likely scored poorly due to other stressors.

Upper Beaver Creek (10170203-521):

From 2011-2013, 12 DO measurements were taken from Upper Beaver Creek. These values ranged from 5.66-17.18 mg/L. This wide range of values suggests a possible issue with the daily flux of DO in this stream.

The HSPF model predicted few instances in which the DO levels were below 5 mg/L in the lower portion of this reach from 1996-2009. However, the far headwaters predicted over 2.05% of the values to be below the daily minimum standard, with wide ranges of values predicted (0-14.57 mg/L) during this time frame.

Biologically, the macroinvertebrate community in Upper Beaver Creek had a high percentage (45.7%) of EPT individuals and an above average tolerance indicator value (TIV) score when compared to all other macroinvertebrate communities sampled across the state. Sites 11MS040 and 11MS043 also averaged a very low amount of DO tolerant individuals (4.01%), which suggests that the majority of the macroinvertebrate community is comprised of species that cannot survive in poor DO conditions. The higher amounts of tolerant species (59.94%) and a low overall taxa count (18) are likely caused by other stressors. The fish population along this AUID had a high number of serial spawning taxa (38.79%) and tolerant species (61.04%), while also having few sensitive fish taxa (12.43%) and a below average amount of late maturing fish species (20.41%). However, the fish community in Upper Beaver Creek did have an above average TIV score when compared to all other sites sampled throughout Minnesota.

Based on the sampled and modeled data with very few exceedances of the DO standard, both the fish and macroinvertebrate TIV scores conclude that DO does not appear to be stressing the impaired biological communities at this time. Continuous DO monitoring is recommended to further assess the impact that this parameter may be having.

Candidate cause: high phosphorus

The proposed draft standard for phosphorus for streams in the Missouri River Basin is currently 0.15 mg/L. Although phosphorus is an essential nutrient for all aquatic life, elevated levels can lead to an imbalance which impacts stream ecology. In the Beaver Creek watershed phosphorus levels have exceeded this proposed standard multiple times.

Lower Beaver Creek (10170203-522):

There were a total of 90 phosphorus samples taken from Lower Beaver Creek from 2008-2012 (Figure 12). Phosphorus values ranged from 0.055-1.63 mg/L with 49 (54.44%) at or above the proposed draft standard of 0.15 mg/L.

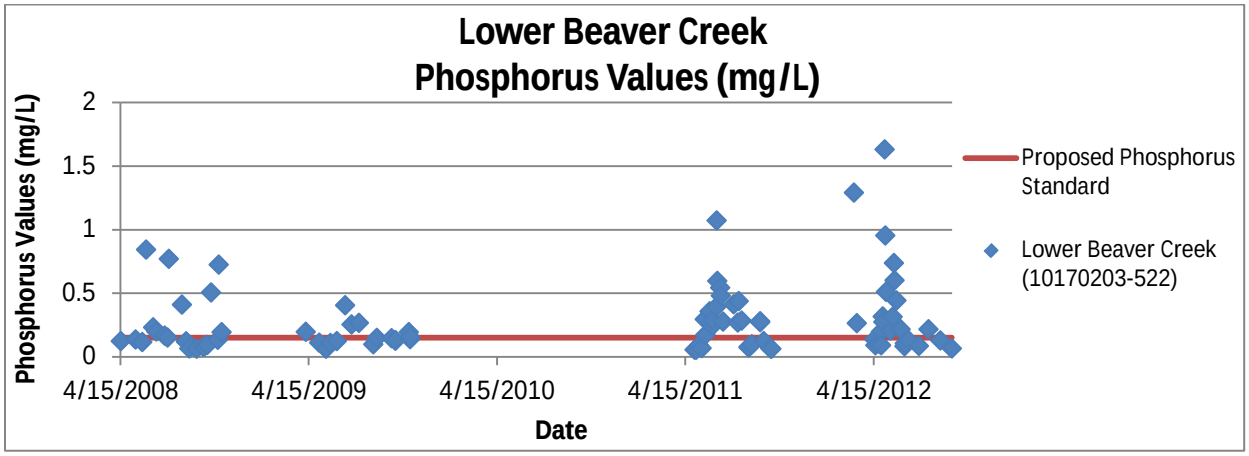

Figure 12: Phosphorus sample values from 2008-2012 along Lower Beaver Creek (10170203-522)

Biologically, the macroinvertebrate assemblage in Lower Beaver Creek had a good amount of EPT taxa (40%) and intolerant taxa (16%) while also having low numbers of both scraper (4%) and crustacean/Mollusca species (8%). These results are common in streams unaffected by elevated phosphorus levels. The stream did also have a high number of tolerant taxa (52%) and few Tanytarsini taxa. The fish community in this reach was very tolerant (63.64% taxa), completely lacked any sensitive fish species, while also having zero darter species and few simple lithophilic spawning individuals (16.54%). These results are commonly found in streams with high amounts of phosphorus.

Based on the extremely high number of exceedances of the proposed phosphorus standard, and the majority of the biological metrics, especially the fish community; high phosphorus levels are stressing the impaired biological communities in Lower Beaver Creek.

Upper Beaver Creek (10170203-521):

There were a total of 10 phosphorus samples taken from the upper portion of Beaver Creek from 2011-2013 (Table 5). Phosphorus values ranged from 0.022-0.248 mg/L with only one sample above the proposed draft standard of 0.15 mg/L.

Table 5: Phosphorus sample values along Upper Beaver Creek (10170203-521) from 2011-2013

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS043	8/10/2011	0.1	0.15
11MS040	6/11/2012	0.026	0.15
11MS040	5/6/2013	0.022	0.15
11MS040	6/10/2013	0.248	0.15
11MS040	7/1/2013	0.06	0.15
11MS043	7/8/2013	0.027	0.15
11MS040	7/9/2013	0.043	0.15
11MS040	7/15/2013	0.051	0.15
11MS040	9/10/2013	0.127	0.15
11MS040	9/30/2013	0.06	0.15

The HSPF model calculated daily phosphorus concentrations along Upper Beaver Creek from 1996-2009. Of these calculations, 35.3% were above the 0.15 mg/L proposed draft standard.

The macroinvertebrate population in Upper Beaver Creek had a high number of EPT taxa (33.33%), while also having low numbers of both scraper (8.25%) and crustacea/Mollusca (4.88%) taxa. Scraper and crustacean/Mollusca taxa tend to be much more abundant in streams affected by an excess of phosphorus. This community also had few Tanytarsini (6.4%) and intolerant (6.4%) species. These taxa are typically more abundant in streams unaffected by phosphorus levels. The fish assemblage in this stream had few sensitive fish species (12.43%) and many tolerant taxa (61.04%), while also having very few numbers of darter individuals (2.98%) at site 11MS040 in the lower portion of this AUID.

Figure 13: Excessive algae growth at site 11MS043 along Upper Beaver Creek (10170203-521)

The collected phosphorus data does not seem to capture the severity of the problem that excess phosphorus is having on the stream. The photographic evidence (Figure 13), the likely presence of DO flux, the HSPF predicted data, and the majority of the phosphorus related biological data all indicate that excess phosphorus is indeed stressing the impaired macroinvertebrate community in Upper Beaver Creek at this time.

Candidate cause: high nitrates

Currently, the state of Minnesota does not have a nitrate standard in place for streams not used as a drinking water source. However, the overabundance of nitrates can stress a biological community. Nitrates in the Beaver Creek watershed did at times reach levels that could potentially be stressing the biological assemblages.

Lower Beaver Creek (10170203-522):

From 2008-2012 a total of 89 nitrate samples were taken from Lower Beaver Creek. These samples ranged from 0.81-15.4 mg/L (Figure 14) with an average value of 6.15 mg/L.

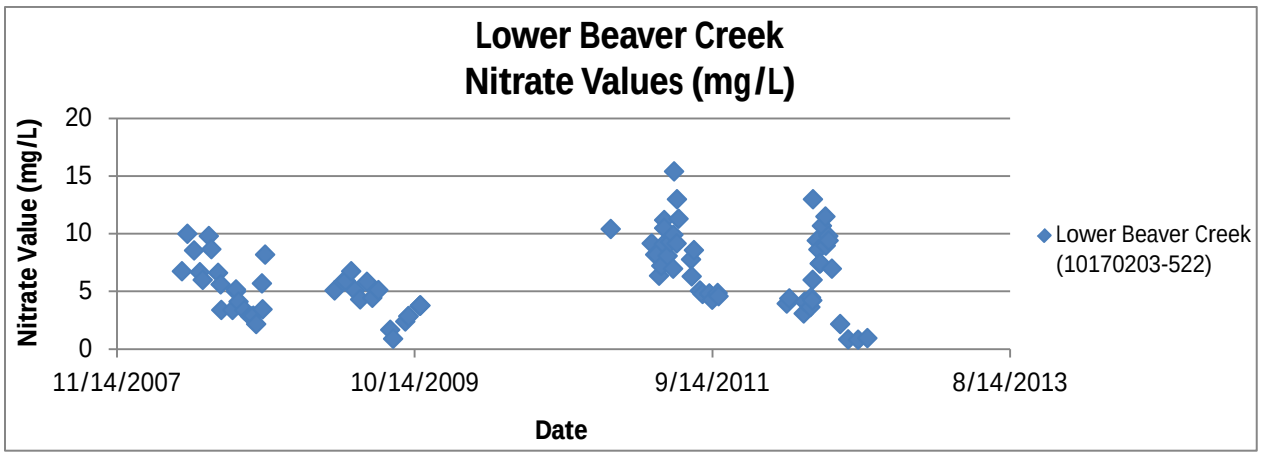

Figure 14: Lower Beaver Creek (10170203-522) nitrate values from 2008-2012

Biologically, the macroinvertebrate community in Lower Beaver Creek had a slightly above average amount of Trichoptera taxa (12%), while having a lower amount of overall taxa (21). A regression comparing nitrate tolerant individuals with the MIBI score showed that sites with over 87.71% of nitrate

tolerant individuals have a 90% chance of being impaired in a class 2 site like 11MS012. Site 11MS012 in this reach had a population consisting of 92.83% of nitrate tolerant individuals. The fish assemblage in this AUID had an average number of overall taxa (11), while also completely lacking any sensitive fish species.

Nitrate values in Lower Beaver Creek can reach fairly high levels. This along with the majority of biological data available makes the excess of nitrate a stressor to the impaired biological communities in Lower Beaver Creek.

Upper Beaver Creek (10170203-521):

From 2011-2013 a total of 10 nitrate samples were taken from Upper Beaver Creek (Table 6). These values ranged from 0.31-22 mg/L.

Table 6: Upper Beaver Creek (10170203-521) nitrate sample values from 2011-2013

Sample Location	Sample Date	Result (mg/l)	Nitrate Standard (mg/l)
11MS043	8/10/2011	4.5	n/a
11MS040	6/11/2012	12	n/a
11MS040	5/6/2013	5.2	n/a
11MS040	6/10/2013	22	n/a
11MS040	7/1/2013	22	n/a
11MS043	7/8/2013	9.7	n/a
11MS040	7/9/2013	10	n/a
11MS040	7/15/2013	4.2	n/a
11MS040	9/10/2013	0.31	n/a
11MS040	9/30/2013	0.38	n/a

The macroinvertebrate assemblage in Upper Beaver Creek had a slightly above average amount of Trichoptera taxa (13.13%) as compared to all other Minnesota streams, but this reach did have a lower than normal overall taxa count (18). Based on a regression analysis, a macroinvertebrate class 5 sites like 11MS040 and 11MS043, would have a 90% chance of being deemed impaired due to the high amount of nitrate tolerant individuals (86.07%). The fish assemblage in Beaver Creek had a good number of overall taxa (16), but was represented with few sensitive fish species (12.43%).

Based on the majority of the biological data along with some very high nitrate measurements, nitrate is a stressor to the impaired macroinvertebrate community in Upper Beaver Creek.

Candidate cause: high turbidity/TSS

The water quality standard for turbidity is 25 NTU, 65 mg/L for TSS, and 20 cm for transparency tube for these class 2B warmwater streams in the Beaver Creek watershed. Excess sediment is a commonly recognized stressor in many biologically impaired streams because it can reduce habitat, cause direct physical harm, as well as reduce visibility and increase oxygen demand. Lower Beaver Creek (10170203-521) is currently impaired for aquatic life due to turbidity in addition to their biological assemblages.

Lower Beaver Creek (10170203-522):

From 2008-2012, 89 TSS samples were taken from this lower section of Beaver Creek. TSS values ranged from 5-2040 mg/L and 51 (57.3%) values were at or greater than the proposed TSS standard of 65 mg/L. (Figure 15).

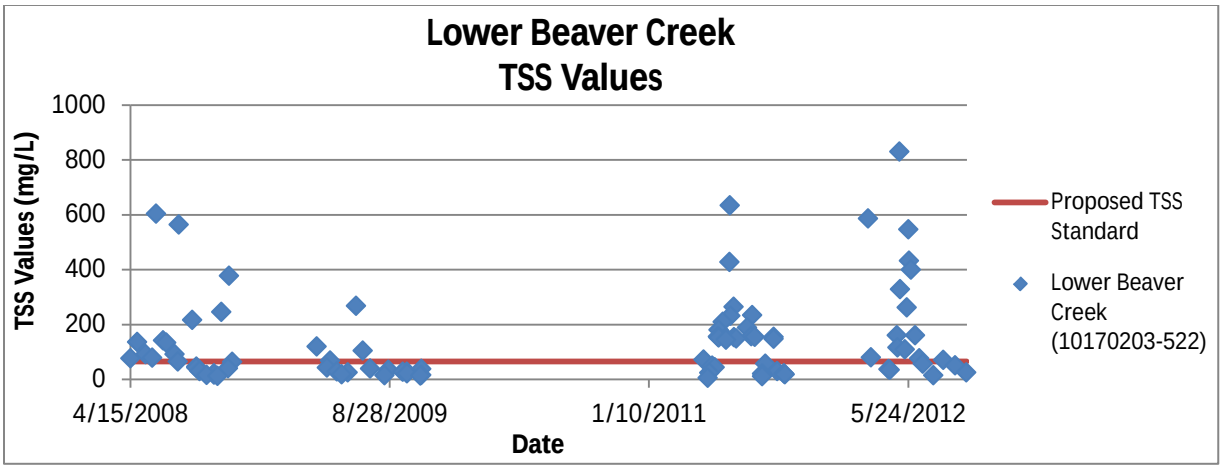

Figure 15: TSS values from 2008-2012 along Lower Beaver Creek (10170203-522)
***Upper limit of TSS samples, 2040 mg/L sampled on 5/6/2012 is not graphed.**

Biologically, the macroinvertebrate community in this stream had a good number of Ephemeroptera taxa (28%) while also having few chironomids (16%). Chironomids tend to increase with TSS while Ephemeroptera decrease with higher TSS levels. Lower Beaver Creek had few overall taxa (21), a lower amount of collector-filterer species (12%), few scraper taxa (4%), while having a high presence of tolerant taxa (52%). The fish assemblage completely lacked any herbivorous fish taxa, while also having a very tolerant community (63.64%), and few intolerant individuals (0.1%).

The current turbidity impairment designation is backed up by the majority of the turbidity/TSS related biological metrics. As a result, turbidity/TSS is a stressor to the impaired fish and macroinvertebrate communities in this reach.

Upper Beaver Creek (10170203-521):

From 2011-2013 a total of eight TSS samples were taken from Upper Beaver Creek (Table 7). These samples ranged from 8.4-89 mg/L with only one value exceeding the proposed TSS standard of 65 mg/L. Additionally, eight transparency/Secchi tube measurements were taken with values ranging from 8-76 cm. Only one of these values was under the 20 cm daily minimum standard for transparency.

Table 7: Upper Beaver Creek (10170203-521) TSS and Secchi tube values from 2011-2013
***Average of two measurements**

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS040	8/10/2011	n/a	65	76	20
11MS043	8/10/2011	8.8	65	38.25*	20
11MS040	6/11/2012	17	65	45	20
11MS040	5/6/2013	8.4	65	71	20
11MS040	6/10/2013	89	65	8	20
11MS040	7/1/2013	20	65	35	20
11MS040	7/15/2013	10	65	37	20
11MS040	9/10/2013	12	65	52	20
11MS040	9/30/2013	9.2	65	n/a	20

When averaging the upper and lower sections of this reach, the HSPF model predicted that from 1996-2009 that the TSS standard of 65 mg/L was exceeded only 3.47% of the time.

Biologically, the macroinvertebrate community in this stream reach had a good presence of Ephemeroptera taxa (20.2%), Trichoptera taxa (13.13%), and collector-filterer (16.16%) taxa. However, this stream did also have many tolerant taxa (59.94%), few scraper species (8.25%) and a low overall taxa count (18). There was also a large presence of Chironomids (36.7%). These types of macroinvertebrates tend to be less abundant in streams not affected by turbidity/TSS. The fish assemblage in this AUID had many tolerant taxa (60.27%) and a slightly above average amount of herbivorous species (6.7%) when compared to other streams in Minnesota.

Having few TSS and transparency measurements exceeding their respective standard, the relatively few model predicted values above 65 mg/L, along with the mixed biological results concludes that excess TSS/Turbidity is not a stressor to the impaired macroinvertebrate community at this time.

Candidate cause: lack of habitat

Habitat quality in Upper and Lower Beaver Creek varied from poor to fair in the biologically impaired reaches. The MSHA was the main tool used for evaluating this potential stressor and the results of these habitat scores can be seen in Figure 16.

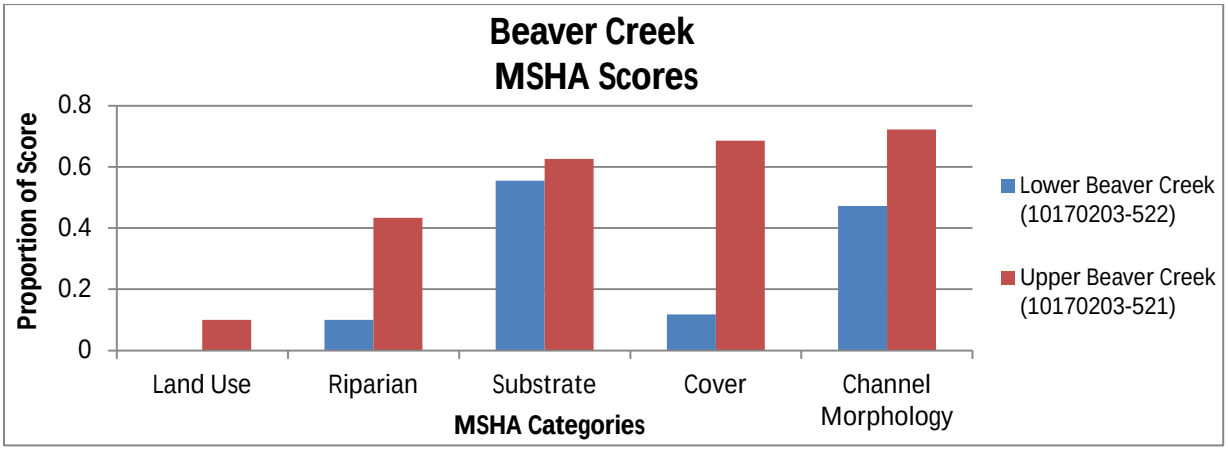

Figure 16: Proportion of scores of the MSHA categories along Upper and Lower Beaver Creek

Lower Beaver Creek (10170203-522):

Site 11MS012 on Lower Beaver Creek had a qualitative habitat assessment performed during its fish sampling visit in 2012. The MSHA score for this site was 35.5 which is considered to be poor. Factors lowering the MSHA score were the poor surrounding land use, the narrow riparian area, severe bank erosion (Figure 17), no stream shading, a sand dominated substrate, nearly absent fish cover, fair channel development, and low channel stability.

Figure 17: Severely eroded bank at site 11MS012 along Lower Beaver Creek (10170203-522)

Furthermore, the MDNR estimated 2.81 feet per year of erosion in a pool cross section along this section of Beaver Creek (MDNR 2014). This leads to a significant amount of sediment entering the stream system that not only increases TSS levels, but also covers vital habitat needed by the biological communities to survive and reproduce.

The macroinvertebrate assemblage in Lower Beaver Creek had a high presence of tolerant taxa (52%), while also having few clinger species (16%). These results are common in streams affected by a lack of habitat. The fish community in this reach had higher than normal levels of riffle dwelling (18.18%) and simple lithophilic spawning (27.27%) taxa, but also had lower amounts of benthic insectivore taxa (18.18%), few darter/sculpin/round-bodied sucker species (9.09%) and a high presence of tolerant taxa (63.64%) when compared to all other streams in Minnesota.

The majority of habitat related metrics reflect the poor MSHA score for this reach. As a result, the lack of habitat is a stressor to the impaired fish and macroinvertebrate communities in Lower Beaver Creek.

Upper Beaver Creek (10170203-521):

Qualitative habitat assessments were performed at each of the biological monitoring sites along Upper Beaver Creek. Site 11MS040 had one performed during its fish visit in 2013. This visit had an MSHA score of 63.9 which is considered to be fair. Site 11MS043 on Upper Beaver Creek had an MSHA score of 59.7 and 61.1 during visits in 2011 and 2013 respectively. These scores are also considered to be fair. Limiting the MSHA scores at these sites was the poor surrounding land use, the narrow riparian buffer, a presence of silty substrates, fair sinuosity, and bank erosion (Figure 18).

Figure 18: Eroded bank at 11MS040 along Upper Beaver Creek (10170203-521)

At the biological monitoring stations in Upper Beaver Creek, macroinvertebrate samples were taken mostly from overhanging vegetation and riffle habitats. The macroinvertebrate community had quite a few tolerant species (59.94%), but also had good numbers of clinger taxa (35.19%), which are more prevalent in streams with good habitat conditions. The macroinvertebrate samples at both 11MS040 and 11MS043 had very high numbers of Polypedilum. These types of climbers are often found in degraded habitat conditions. The fish assemblage in this reach had higher numbers of riffle dwelling taxa (23.22%) and benthic insectivore species (27.84%), but also had a higher amount of tolerant taxa (60.27%), and lower numbers of simple lithophilic spawning species (19.65%) and darter/sculpin/round-bodied sucker taxa (12.95%).

With the fair MSHA scores and many poorly scoring habitat related biological metrics, the lack of habitat is a stressor to the impaired macroinvertebrate community in Upper Beaver Creek.

Weight of evidence

Weight of evidence tables for the biologically impaired streams in the Beaver Creek watershed, as well as all of the biologically impaired AUIDs are available upon request.

Conclusion

The two biologically impaired reaches in the Beaver Creek watershed are being stressed by multiple candidate causes (Table 8).

Phosphorus levels were very high throughout the Beaver Creek watershed. In Lower Beaver Creek, levels even reached 10 times the proposed draft standard. These extremely high levels have led to excessive algae growth and stream productivity. The high phosphorus levels appear to have also affected the DO conditions. The high range of daily flux in the headwaters is likely due to the increase in excess phosphorus entering the system. The excess phosphorus is a likely result from the highly pastured riparian areas where concentrations of phosphorus tend to be highest. Runoff following rain events is a likely pathway for these phosphorus contributions.

The nitrate levels in the Beaver Creek watershed were also found to be stressing the impaired biological communities in both Lower and Upper Beaver Creek. These elevated levels do not appear to be just seasonal, as high levels were both observed and calculated from January through August. High percentages of nitrate tolerant individual macroinvertebrates were present, which often signals impairment. The high levels of nitrates are likely a result from fertilizer applications and have entered the stream as runoff.

The turbidity/TSS values in Lower Beaver Creek (10170203-521) have been elevated for a long period of time. These conditions resulted in this stream's current impairment for turbidity. This lower portion of Beaver Creek is missing many of the fish and macroinvertebrate species that are sensitive to increased levels of sediment. These species are critical to the overall health of a properly functioning aquatic ecosystem. Again, the highly pastured land use with little to no buffer area has led to unstable and erosive banks. Fortunately, the conditions in Upper Beaver Creek are not yet to the point where turbidity/TSS is stressing the impaired macroinvertebrate assemblage, however, this will likely change if conditions do not improve.

Habitat conditions along Beaver Creek ranged from poor to fair according to the MSHA. The high presence of tolerant taxa, with lower numbers of darter/sculpin/round-bodied sucker species and simple lithophilic spawning species all signaled that the lack of habitat was indeed stressing the biological communities, especially in Lower Beaver Creek. These conditions are a result of the poor surrounding land use, narrow riparian buffers, sand/silt substrates, high bank erosion and low channel stability. Fish cover and spawning areas were very limited in Beaver Creek.

Overall, the biological conditions in Beaver Creek will remain limited with the numerous stressors impacting the fish and macroinvertebrate assemblages. Until significant changes are made to the land use and agricultural practices prevalent in this watershed, expect to see unhealthy biological communities in both Upper and Lower Beaver Creek.

Table 8: Biologically impaired reaches in the Beaver Creek watershed and their stressors
(• = stressor, - = not a stressor, and blank = inconclusive/not enough evidence)

		Stressors				
Stream Name	**AUID #**	**Low Dissolved Oxygen**	**High Phosphorus**	**High Nitrates**	**High Turbidity/TSS**	**Lack of Habitat**
Beaver Creek Watershed						
Lower Beaver Creek	10170203-522	-	•	•	•	•
Upper Beaver Creek	10170203-521	-	•	•	-	•

Blood Run watershed

Blood Run is located in the southern end of the Lower Big Sioux River watershed. The AUID, 10170203-555, is 1.86 miles long and extends from the confluence of Unnamed Creek to the Minnesota/South Dakota border (Figure 19). This reach was sampled for fish and macroinvertebrates in 2011 and found to be impaired for macroinvertebrates during the watershed assessment in 2013. Land use in the Blood Run 12-digit HUC watershed is dominated by cropland (82.13%). Rangeland (11.99%) and developed land (4.9%) make up the majority of the land not being farmed.

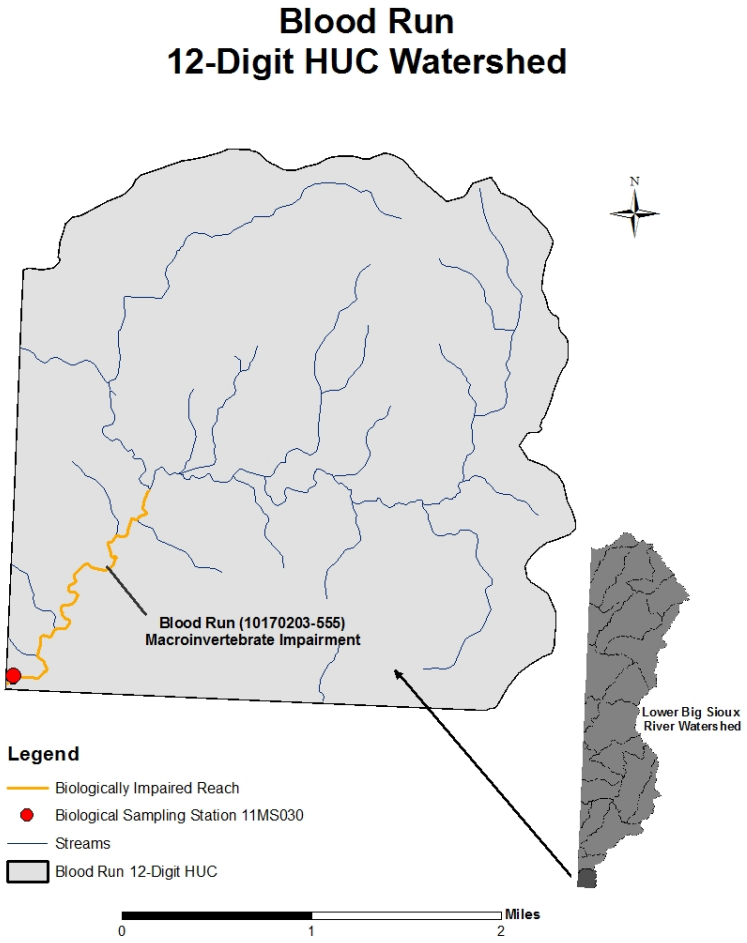

Figure 19: Blood Run watershed with biologically impaired reach highlighted

Biology in Blood Run

There was one biological sampling station, 11MS030, located along Blood Run. This site is located upstream of 448th Ave (10th Ave), 5 mi SW of Hills. This site was sampled for fish on August 9th, 2011, and for macroinvertebrates on August 3rd, 2011.

To reach the MPCA's MIBI threshold for a class 5 (Southern Streams RR) stream, each metric would need an average score of 3.59. Site 11MS030 along Blood Run had an IBI score of 19.9. Figure 20 shows that only two metrics scored well (Odonata, DomFiveChPct). This site on Blood Run was especially limited by the lack of Plecoptera presence. Other factors for the low scoring metrics were the low taxa richness of Predator species and low levels of Trichoptera taxa. Blood Run also had elevated HBI_MN scores and a high percentage of taxa with tolerance values equal to or greater than 6 (Tolerant2ChTxPct). These two metrics are negative metrics and result in a lower score with a higher presence.

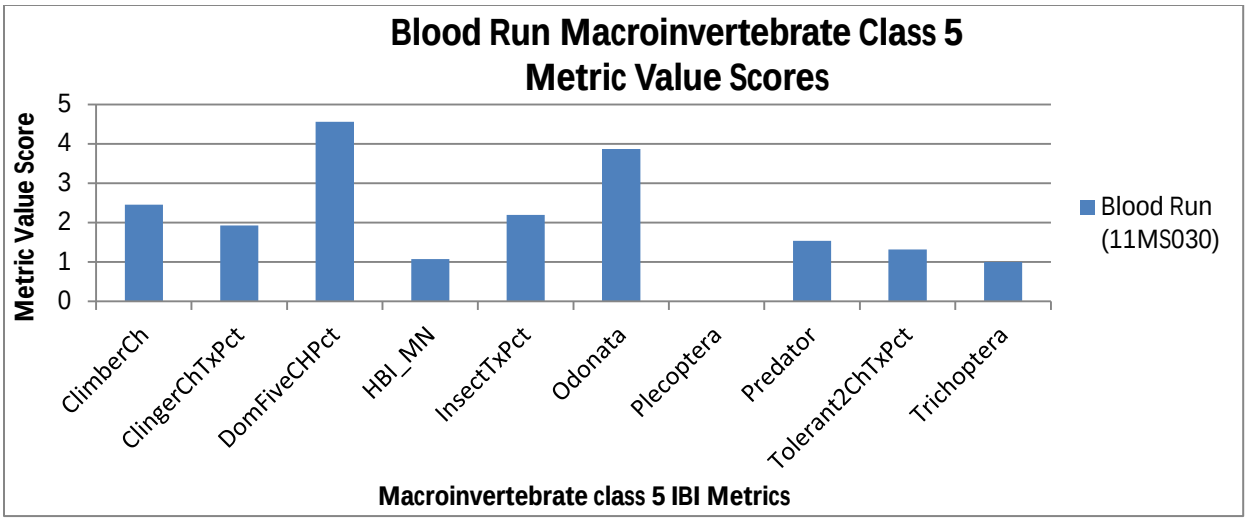

Figure 20: Macroinvertebrate IBI metric values scores at site 11MS030 along Blood Run

Candidate cause: low dissolved oxygen

The daily minimum standard for DO in Minnesota class 2B streams is 5 mg/L. All streams in the Blood Run watershed have this 2B classification. No streams in this grouping are currently listed as impaired for DO.

There were a total of seven DO readings taken at Blood Run from 2011-2013 (Table 9). Two of these were taken during the biological sampling events in 2011, while the remaining five were taken during the spring and summer months in 2013. All of the sampled values were above the daily minimum standard of 5 mg/L. The high value of 17.32 mg/L could potentially indicate a problem with daily flux and make Blood Run a prime candidate for continuous DO monitoring with a sonde. However, low flow conditions were present throughout the summer and prevented sonde placement.

Table 9: DO monitoring along Blood Run (10170203-555) at site 11MS030 from 2011-2013

Sample Location	Sample Date and Time	Result (mg/l)	Daily Minimum Standard (mg/l)
11MS030	8/3/2011 10:39 AM	8.55	5
11MS030	8/9/2011 8:05 AM	8.91	5
11MS030	5/6/2013 11:40 AM	17.32	5
11MS030	6/10/2013 10:10 AM	8.01	5
11MS030	7/1/2013 2:30 PM	8.09	5
11MS030	7/15/2013 10:45 AM	8.72	5
11MS030	8/14/2013 7:10 AM	7.7	5

The HSPF model made hourly DO predictions from 1996-2009. Of these calculations, only 0.0073% was below the 5 mg/L daily minimum standard.

Biologically, Blood Run had a statewide above average amount of macroinvertebrate taxa (21) and EPT taxa (25%) which tend to decrease if the stream is stressed by low DO levels. This stream had above average amounts of tolerant macroinvertebrate (65.63%) and fish taxa (55.56%), as well as serial spawning fish species (33.33%) when compared to all other Minnesota streams. These species are more prevalent in streams with low DO conditions. However, Blood Run also had a good presence of late maturing fish taxa (22.22%). These types of fish are not typically found in streams with low DO levels.

The HSPF model predictions, the mixed biological results along with the measured values suggest that DO is not a primary stressor to the impaired macroinvertebrate community in Blood Run. Continuous DO monitoring is recommended during base flow conditions to better understand the DO levels in this stream and what impact, if any, it might be having on the biological communities.

Candidate cause: high phosphorus

The proposed draft standard for phosphorus for streams in the Missouri River Basin is currently 0.15 mg/L. Although phosphorus is an essential nutrient for all aquatic life, elevated levels can lead to an imbalance which impacts stream ecology. In the Blood Run watershed phosphorus levels have exceeded this proposed standard multiple times.

From 2011-2013 there were six phosphorus samples taken from Blood Run (Table 10). Of these samples, four were above the proposed draft standard of 0.15 mg/L.

Table 10: Phosphorus sample results from 2011-2013 at site 11MS030 along Blood Run (10170203-555)
*** Average value of two samples**

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS030	8/9/2011	0.186	0.15
11MS030	5/6/2013	0.058	0.15
11MS030	6/10/2013	0.354*	0.15
11MS030	7/1/2013	0.120	0.15
11MS030	7/15/2013	0.213	0.15
11MS030	8/14/2013	0.207	0.15

From 1996-2009, daily phosphorus concentrations were calculated for Blood Run by the HSPF model. These results predict that during this time frame the proposed phosphorus standard was exceeded 49.34% of the time.

Biologically, Blood Run had an above average amount of EPT taxa (25%) when compared to other Minnesota streams. EPT taxa are more common in streams with low phosphorus. This stream also had above average amounts of scraper species (12.5%), mollusca/crustacea taxa (12.5%), and tolerant taxa (65.63%). These results are common in streams with high levels of phosphorus.

Blood Run also had zero sensitive fish species, an above average amount of tolerant fish taxa (55.65%), and fewer simple lithophilic spawning individuals (19.86%) when compared to all other Minnesota streams. These results are expected in streams with high phosphorus values.

With the high occurrence of samples violating the proposed standard, the HSPF model results, and the majority of biological results, phosphorus is a stressor to the impaired macroinvertebrate assemblage in Blood Run.

Candidate cause: high nitrates

Currently, the state of Minnesota does not have a nitrate standard in place for streams not used as a drinking water source. However, the overabundance of nitrates can stress a biological community. Nitrates in the Blood Run watershed did at times reach levels that could potentially be stressing the biological assemblages.

From 2011-2013 there were 6 nitrate samples taken from Blood Run (Table 11). These values ranged from 6.4-24 mg/L.

Table 11: Nitrate sampling results from 2011-2013 at site 11MS030 along Blood Run (10170203-555)

*** Average value of two samples**

Sample Location	Sample Date	Result (mg/l)	Nitrate Standard (mg/l)
11MS030	8/9/2011	14	n/a
11MS030	5/6/2013	7.2	n/a
11MS030	6/10/2013	23*	n/a
11MS030	7/1/2013	24	n/a
11MS030	7/15/2013	10	n/a
11MS030	8/14/2013	6.4	n/a

Biologically, Blood Run had a below average amount of overall macroinvertebrate species (21) when compared to other streams statewide. Nitrogen sensitive Trichoptera taxa were present in average amounts (9.38% taxa). Additionally, Blood Run had a macroinvertebrate community consisting of 88.78% of nitrate tolerant individuals. Quantile regression analysis for a class 5 macroinvertebrate stream showed that communities consisting of more than 83.78% of nitrate tolerant individuals have a greater than 90% chance of being impaired. The fish assemblage in Blood Run also had few overall taxa (9) and zero sensitive fish species. Sensitive fish species are more prevalent in streams with low nitrate values.

The multiple nitrate samples with extremely high values, poor scoring biological metrics, and the quantile regression analyses all suggest that excess nitrate levels in Blood Run are indeed a stressor to the impaired macroinvertebrate community.

Candidate cause: high turbidity/TSS

The water quality standard for turbidity is 25 NTU, 65 mg/L for TSS, and 20 cm for transparency tube for these class 2B warmwater streams in the Blood Run watershed. Excess sediment is a commonly recognized stressor in many biologically impaired streams because it can reduce habitat, cause direct physical harm, as well as reduce visibility and increase oxygen demand. Currently, there are no reaches in this watershed impaired for turbidity.

From 2011-2013 there were six TSS samples taken from Blood Run. Of these samples, one was above the TSS daily maximum standard of 65 mg/L for Blood Run (Table 12).

Table 12: TSS and Secchi tube sample values along Blood Run (10170203-555) from 2011-2013 at site 11MS030
*** Average value of two samples**

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS030	8/3/2011	n/a	65	8	20
11MS030	8/9/2011	77	65	16	20
11MS030	5/6/2013	2.8	65	> 100	20
11MS030	6/10/2013	44.5*	65	18*	20
11MS030	7/1/2013	40	65	25	20
11MS030	7/15/2013	25	65	18	20
11MS030	8/14/2013	18	65	25.5	20

The HSPF model made daily TSS calculations for Blood Run from 1996-2009. Of the numerous predicted values, only 3.32% were above the 65 mg/L maximum standard for TSS.

Biologically, there was an above average amount of Ephemeroptera taxa (15.63%) and scraper macroinvertebrate species (12.5%). These types of macroinvertebrates are typically found in more abundance in clear/transparent streams. Blood Run also had a below average amount of macroinvertebrate species (21) and a higher than average amount of tolerant taxa (65.63%) when compared to other streams across the state. The fish assemblage in Blood Run had a high presence of herbivorous fish taxa (22.22%). Herbivorous fish tend to prefer clear, transparent water and struggle in streams with high TSS values. However, tolerant fish species (55.55%) were present in higher than average numbers.

The majority of the field measurements, the HSPF modeling information, and many of the related biological metrics signal that TSS/turbidity is not a stressor to the impaired macroinvertebrate assemblage in Blood Run at this time.

Candidate cause: lack of habitat

A qualitative habitat assessment was performed on Blood Run during the fish sampling event. The MSHA score for this site was 58, which is considered to be a fair score. Habitat conditions were mainly limited by the surrounding land use (Figure 21), the narrow riparian buffer, lack of shade, and just a moderately stable channel. Figure 22 displays the MSHA categories and the proportion of score that site 11MS030 along Blood Run achieved.

Figure 21: Surrounding land use at 11MS030 along Blood Run (10170203-555)

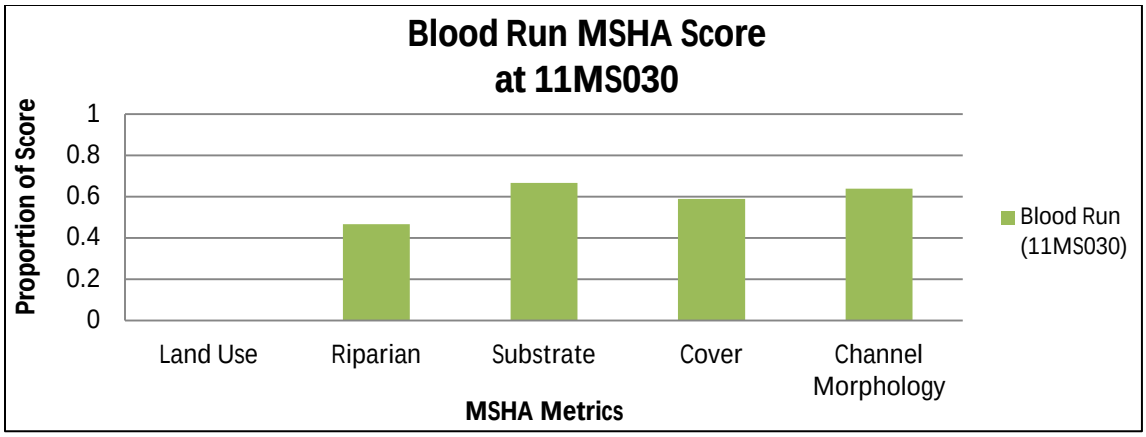

Figure 22: MSHA metric scores at site 11MS030 along Blood Run (10170203-555)

The macroinvertebrate sample was taken from equal parts of riffles and overhanging vegetation. Site 11MS030 had many Cheumatopsyche and Heptagenia macroinvertebrates. These types of macroinvertebrates are classified as clingers. Clingers have a tendency to be less abundant in streams with degraded habitat conditions. This AUID also had a lower amount of burrower individuals (4.17%). These types of macroinvertebrates are more prevalent in streams with high amounts of sediment on top of the course substrates.

Fish populations had high amounts of tolerant species (55.56%) which is common in streams with degraded habitat. There were also above average amounts of simple lithophilic spawner taxa (44.44%), benthic insectivore taxa (33.33%), riffle dwelling fish (33.33%), and darters/sculpin/round-bodied sucker species (22.22%).

While the habitat conditions along Blood Run could certainly be improved, the data provided shows that the habitat conditions should not be considered a major stressor to the impaired macroinvertebrate community at this time.

Conclusion

Blood Run (10170203-555) is a system that is affected by the abundant nutrients that are entering the stream (Table 13). In the limited phosphorus sampling that took place along Blood Run, phosphorus levels exceeded the proposed draft standard 66.67% of the time, with one reading well over double the proposed draft standard. The HSPF model predicted similar results to the collected phosphorus samples. While excess phosphorus itself does not directly result in harm to biological communities; it does however cause imbalances in the stream system affecting other factors that do. The intensively grazed and row cropped surrounding land use with minimal riparian buffers provide the necessary pathway for phosphorus to enter the system.

Nitrate levels in the Blood Run watershed were also found to be stressing the impaired macroinvertebrate community. Extremely high nitrate samples were collected throughout the summer months in this reach. These high conditions led to a macroinvertebrate assemblage dominated by nitrate tolerant taxa, while also lowering overall diversity for both the macroinvertebrate and fish communities. A likely source for these excess levels of nitrates is fertilizer application in the nearby farm fields adjacent to the stream. Land use without an ample riparian buffer easily allows runoff containing nitrates to enter the stream system.

The Blood Run watershed does show some potential for biological improvement. An increase in riparian buffers will help stabilize the banks and reduce the amount of runoff coming from farm fields. This, in addition to a nutrient management plan should help minimize the impacts that phosphorus and nitrates are having on the impaired macroinvertebrate community. These measures should also improve habitat conditions so both the fish and macroinvertebrate assemblages can thrive.

		Stressors				
Stream Name	**AUID #**	**Low Dissolved Oxygen**	**High Phosphorus**	**High Nitrates**	**High Turbidity/TSS**	**Lack of Habitat**
Blood Run Watershed						
Blood Run	10170203-555	-	•	•	-	-

Flandreau Creek watershed

Overview

The Flandreau Creek watershed is located in the northern part of the Little Big Sioux River watershed between Spring Creek and Pipestone Creek. This area consists of four impaired AUIDS (Figure 23). These include: Flandreau Creek (10170203-502), Flandreau Creek (10170203-517), Willow Creek (10170203-515) and Unnamed Creek (10170203-531). The land use in this watershed consists of mainly cropland (63.36%), followed by rangeland (29.93%), and developed land (4.42%).

Flandreau Creek (10170203-502) is a 7.69 mile reach that runs from the confluence of Willow Creek to the Minnesota/South Dakota border. This AUID is impaired for aquatic life due to the fish assemblage at its biological monitoring station, 11MS005.

Flandreau Creek (10170203-517) is a 12.34 mile reach that extends from T108 R46W S14, north line to Willow Cr. This AUID is impaired for aquatic life due to its fish and macroinvertebrate assemblages at its biological monitoring station, 11MS034.

Willow Creek (10170203-515) is a 15.33 mile reach that extends from the far headwaters of Willow Creek down to the confluence with Flandreau Creek. This AUID is impaired for aquatic life due to both its fish and macroinvertebrate assemblages at its two biological monitoring stations, 11MS033 and 11MS035.

Unnamed Creek (10170203-531) is a 1.73 mile tributary to Willow Creek. This AUID extends from a confluence of an unnamed creek to Willow Creek. This AUID is impaired for aquatic life due to its macroinvertebrate assemblage at its one biological monitoring station, 11MS032.

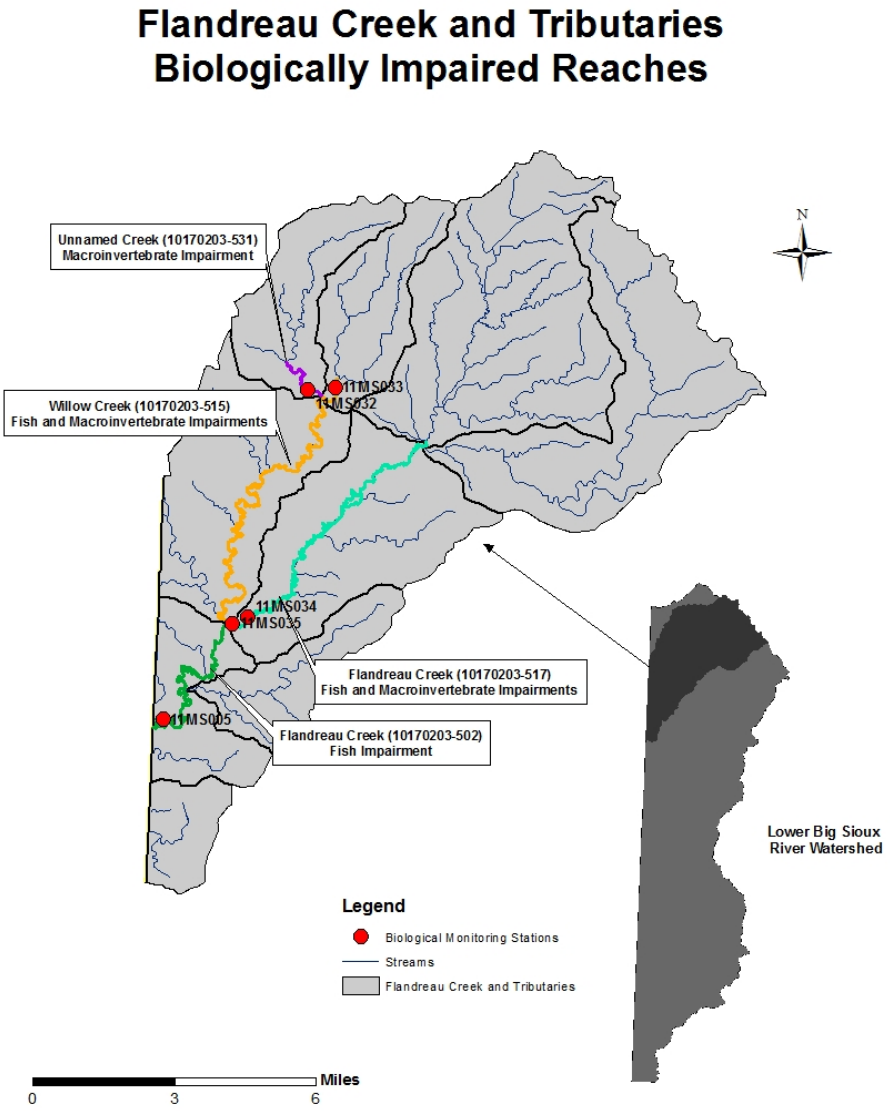

Figure 23: Flandreau Creek watershed with biologically impaired reaches highlighted

Biology in Flandreau Creek

Fish

The four biologically impaired reaches in the Flandreau Creek watershed had a total of four biological monitoring stations sampled for fish community. On the most downstream section, Flandreau Creek (10170203-502) has a biological monitoring station, 11MS005, that is located downstream of 10th Ave, 4 miles west of Cazenovi. This site was sampled on August 30th, 2011, and again on July 9th, 2013. Moving upstream is Flandreau Creek (10170203-517). This AUID's biological monitoring site is 11MS034, which is upstream of CR 8, 11 miles northwest of Pipestone and it was sampled for fish on August 9th, 2011. Willow Creek (10170203-515) had one biological monitoring site, 11MS035, which was sampled for fish on September 7th, 2011. This site is located downstream of CR 8, 8 miles southwest of Verdi. Finally, Unnamed Creek (10170203-531) had a lone biological site (11MS032) that is located downstream of CR 75, 2.5 miles southwest of Verdi and was sampled for fish on August 18th, 2011.

Two biological monitoring sites on the impaired reaches within this watershed are classified as fish class 2 (Southern Streams). To reach the fish class 2 IBI threshold, a site would need an IBI score of 45 and each metric would need an average metric value score of 5.625. Site 11MS005 on Flandreau Creek (10170203-502) had fish IBI scores of 37 and 39 between two visits. This site showed good numbers of benthic insectivore taxa that excluded tolerant taxa (BenInsect-TolTxPct), was not dominated by two species (DomTwoPct), and had a lower percentage of detritivorous taxa (DetNWQTxPct) resulting in a higher metric score (Figure 24). Further upstream, Flandreau Creek (10170203-517) also scored well in the DetNWQTxPct and DomTwoPct metrics at site 11MS034. However, these are the only metrics that scored well resulting in an IBI score of 31.

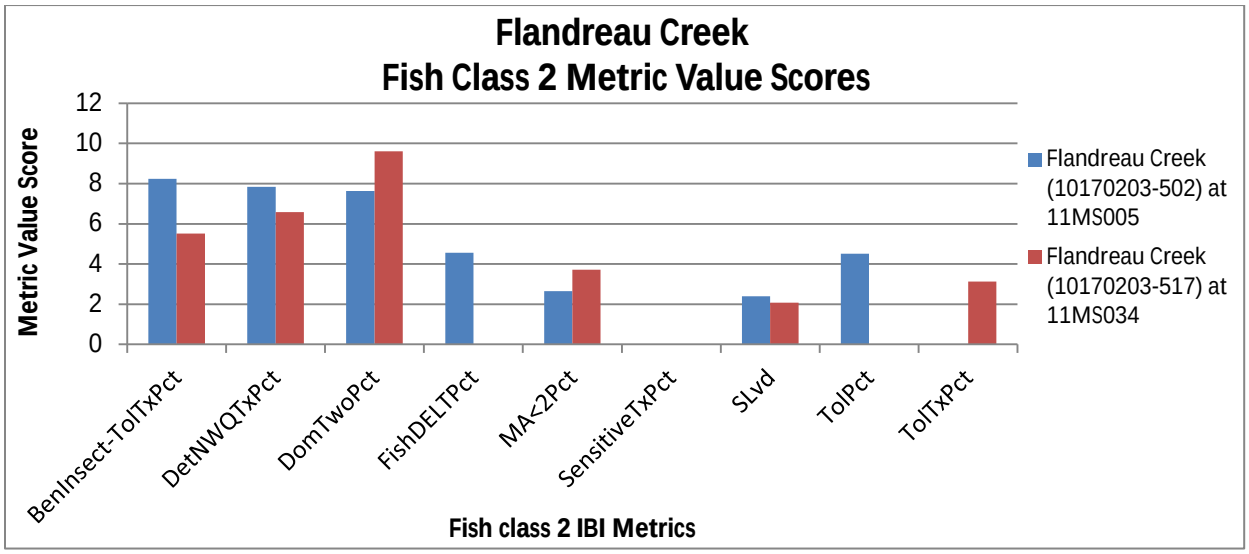

Figure 24: Fish class 2 IBI metric value scores in the Flandreau Creek watershed

Two biological monitoring sites (11MS035 and 11MS032) had a fish class 3 (Southern Headwaters) designation in this subwatershed. To reach the IBI threshold of 51, each metric would need a metric value score of 8.5. Site 11MS035 on Willow Creek (10170203-515) had an IBI score of 42 andreached this mark on just two of the six IBI metrics (Figure 25). This site had few short lived (SLvdPct) and serial spawning (SSpnPct) individuals resulting in a higher metric value score. Site 11MS032 on Unnamed Creek (10170203-531) had an IBI score of 67 and scored well on the majority of the metrics. This AUID is not impaired for its fish community at this time.

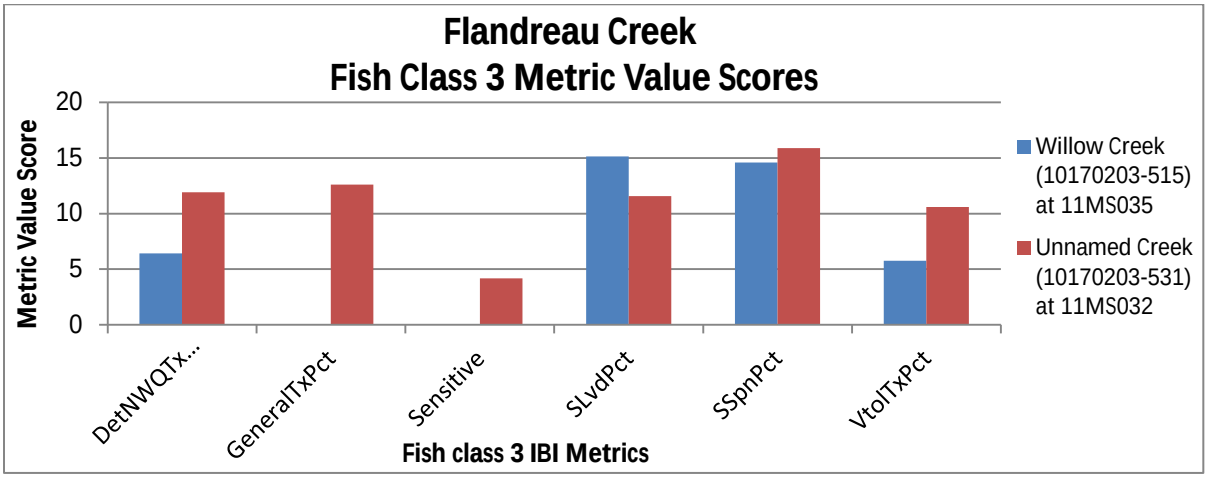

Figure 25: Fish class 3 IBI metric value scores in the Flandreau Creek watershed

Macroinvertebrates

Flandreau Creek (10170203-502) had one macroinvertebrate sample taken on August 4th, 2011, at its biological monitoring site 11MS005. Site 11MS034 on Flandreau Creek (10170203-517) had a macroinvertebrate sample taken on August 4th, 2011. Willow Creek (10170203-515) had two biological sites located along it. Site 11MS035 was sampled on August 4th, 2011. Site 11MS033 was not sampled for fish due to low flow conditions, located upstream of CR 75, 1.75 miles southeast of Verdi and had multiple samples taken on August 9th, 2011. Unnamed Creek (10170203-531) had a macroinvertebrate sample taken on August 9th, 2011, at its lone biological site 11MS032.

All four of the impaired biological reaches in the Flandreau Creek watershed had sites designated as macroinvertebrate class 7 (Prairie Streams GP). The IBI threshold for this class is 38.3 meaning each metric would need an average metric value score of 3.83 to achieve this level. Site 11MS005 on Flandreau Creek (10170203-502) had a MIBI score of 39. This reach is currently not impaired for its macroinvertebrate assemblage. Site 11MS034 on Flandreau Creek (10170203-517) had a MIBI score of 30.1 and scored well on four of the ten metrics (Figure 26). This site was fairly diverse and not overly dominated by five species (DomFiveCHPct), had good numbers of combined Plecoptera,Oodonata, Ephemeroptera, and Trichoptera taxa (POET), had high numbers of predator species (PredatorCh), and had good overall taxa richness (TaxaCountAllChir). Willow Creek had an average IBI score of 27.04 when accounting for multiple visits at 11MS033 and site 11MS035. This site also was not dominated by five species and had an acceptable amount of taxa richness. Unnamed Creek (10170203-531) at site 11MS032 had an IBI score of 24.9 and scored well in the same metrics as Willow Creek, while scoring poorly in the rest.

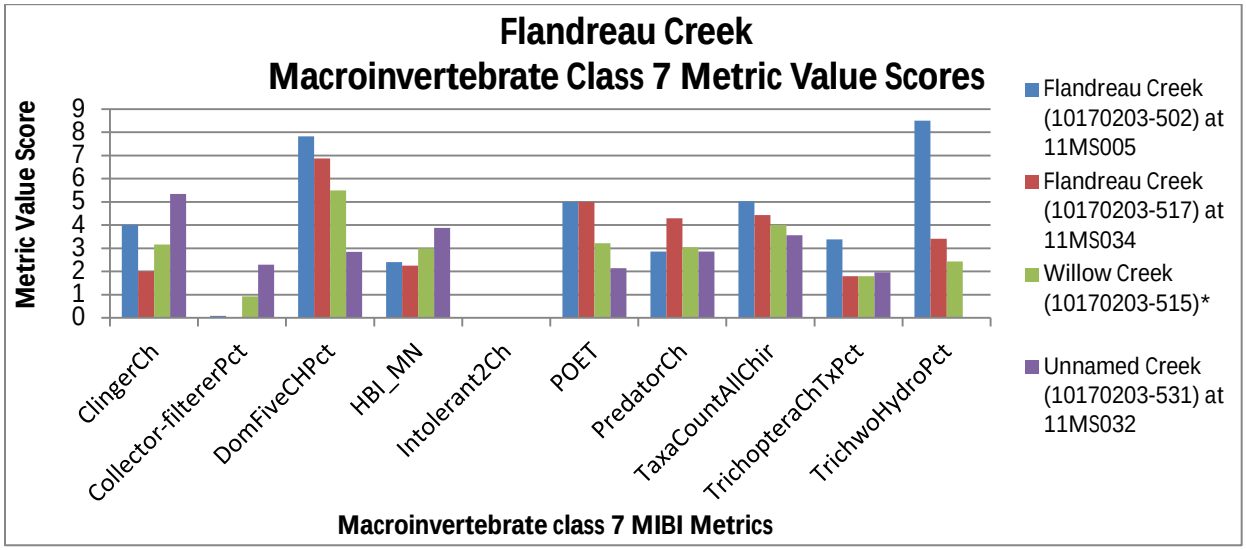

Figure 26: MacroInvertebrate class 7 MIBI metric value scores in the Flandreau Creek watershed
*** Average of two sites along Willow Creek (11MS033 and 11MS035)**

Candidate cause: low dissolved oxygen

The daily minimum standard for DO in Minnesota class 2B streams is 5 mg/L. All streams in the Flandreau Creek watershed have this 2B classification. No streams in this grouping are currently listed as impaired for DO.

Flandreau Creek (10170203-502):

From 2011-2013 a total of 31 DO readings were taken from this most downstream portion of Flandreau Creek in Minnesota. These measurements ranged from 5.77-13.44 mg/L. Additionally, a sonde was placed along this reach in August of 2013 for continuous DO monitoring (Figure 27). This monitoring showed that the 5 mg/L daily minimum and the 4.5 mg/L daily flux standards were exceeded frequently.

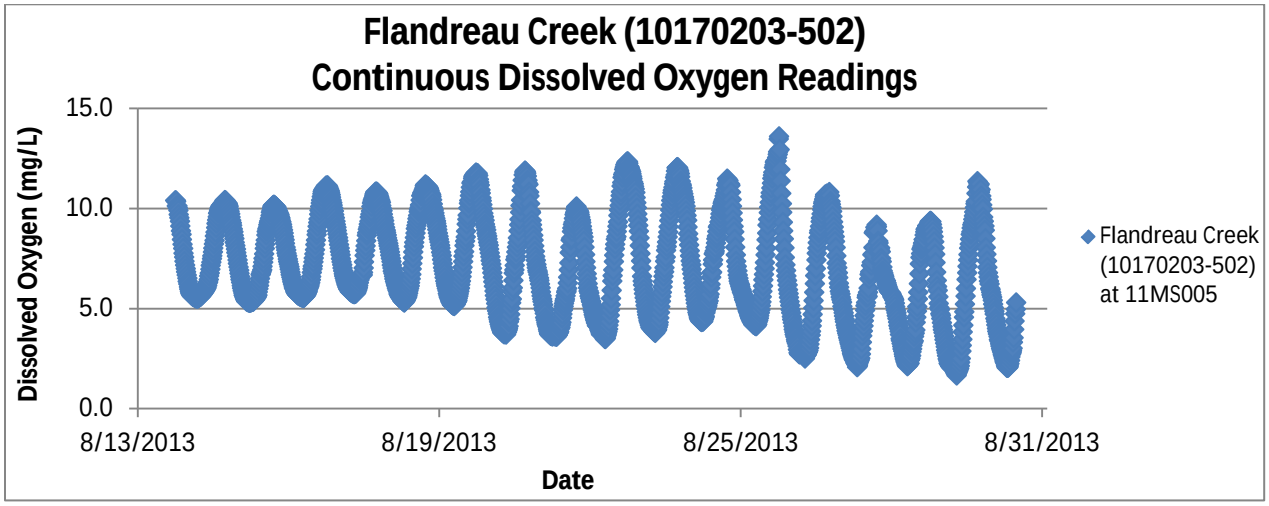

Figure 27: Continuous DO monitoring results from Flandreau Creek (10170203-502) at site 11MS005

Biologically, the macroinvertebrate community in this portion of Flandreau Creek had a high percentage of EPT taxa (33.33%) and individuals (53.57%). This stream also had a high amount of tolerant taxa (63.89%) and an average amount of overall macroinvertebrate taxa (24). The fish assemblage in this reach was comprised of mostly tolerant taxa (64.32%), while having high amounts of serial spawning species (42.96%), and low levels of sensitive species (9.55%) and late maturing taxa (14.32%). Late maturing fish species (female fish mature after 3 years) are much less tolerant and are much more abundant in streams unaffected by DO conditions.

The continuous DO data along with the biological information show that low values and high fluctuations of DO values are stressing the impaired fish community in this stream.

Flandreau Creek (10170203-517):

From 2011-2013, 11 DO readings were taken from this AUID of Flandreau Creek. These values ranged from 4.59-10.48 mg/L, with one value falling below the 5 mg/L daily minimum standard (Table 14).

Table 14: Flandreau Creek (10170203-517) DO values from 2011-2013

Sample Location	Sample Date and Time	Result (mg/l)	Daily Minimum Standard (mg/l)
11MS034	8/4/2011 8:35 AM	7.06	5
11MS034	8/9/2011 8:30 AM	7.79	5
11MS034	5/7/2013 8:10 AM	10.48	5
11MS034	6/12/2013 9:50 AM	7.06	5
11MS034	6/26/2013 12:20 PM	6.46	5
11MS034	7/2/2013 9:32 AM	7.27	5
11MS034	7/11/2013 11:45 AM	7.71	5

Sample Location	Sample Date and Time	Result (mg/l)	Daily Minimum Standard (mg/l)
11MS034	7/17/2013 9:00 AM	6.67	5
11MS034	7/31/2013 8:10 AM	7.37	5
11MS034	8/8/2013 11:45 AM	6.8	5
11MS034	8/21/2013 12:30 PM	4.59	5

The HSPF model calculated hourly DO values for this reach of Flandreau Creek from 1996-2009. These values ranged from 6.2-14.32 mg/L with no values below the daily minimum standard for DO.

Similarly to Flandreau Creek (10170204-502), this portion of the stream had a higher amount of EPT taxa (23.53%), but also had many tolerant species (70.59%). The fish community in this reach was completely absent of sensitive fish taxa, while also having few late maturing species (11.76%). This stream did also have many DO tolerant serial spawning species (29.41%) and tolerant taxa (70.59%). The fish assemblage did have a DO TIV score that was above average when compared to all other Minnesota streams.

The monitoring and biological results are conflicting. More rigorous DO sampling including continuous monitoring with a sonde is needed to determine the actual effect that DO is having on the impaired biological assemblages in this reach before it is declared a stressor.

Willow Creek (10170203-515):

From 2011-2013 a total of 12 DO measurements were taken from Willow Creek. These values ranged from 2.02-10.24 mg/L, with three readings below the 5 mg/L daily minimum standard. Five other values were in the 5-6 mg/L range.

The HSPF model predicted that from 1996-2009, this reach along Willow Creek would have 680 hourly measurements under the 5 mg/L standard, with twelve of these readings below 1 mg/L. Conditions this low could be extremely detrimental to the biological communities in this stream.

Biologically, the macroinvertebrate community in Willow Creek had a lower amount of EPT taxa (18.02%), while also having a very tolerant population (76.51% taxa). The fish assemblage in this stream had few late maturing species (7.69%) and sensitive taxa (0%). This site also had many tolerant taxa (76.92%) and serial spawning species (30.77%). The results from both of these indicators are typically found in streams experiencing problems with DO levels.

The low measured DO values, the many low calculated measurements, along with the majority of the biological metrics indicate that the low DO conditions present in Willow Creek is indeed stressing the biological assemblages.

Unnamed Creek (10170203-531):

Unnamed Creek had 12 DO readings taken from 2011-2013. These measurements ranged from 4.53-10.07 mg/L with one value falling below the 5 mg/L daily minimum standard.

The HSPF model calculated that the DO level in Unnamed Creek fell below the 5 mg/L standard 0.78% of the time from 1996-2009.

The macroinvertebrate assemblage in Unnamed Creek had very few EPT taxa (9.68%), while also having a very high amount of tolerant taxa (87.1%). The fish community consisted of few sensitive (7.14%) and late maturing (7.14%) taxa, while also having a high amount of tolerant species (64.29%). Unlike the other biologically impaired reaches in the Flandreau Creek watershed, this AUID had a lower amount of serial spawning taxa (14.29%).

Based on the DO related biological metrics, many modeling calculations below 5 mg/L, an observed value below the daily minimum standard, plus the presence of elevated phosphorus levels makes low DO a stressor to the impaired macroinvertebrate community in Unnamed Creek. Further continuous DO monitoring with a sonde is recommended to determine the extent of the stress inhibiting this assemblage.

Candidate cause: high phosphorus

The proposed draft standard for phosphorus for streams in the Missouri River basin is currently 0.15 mg/L. Although phosphorus is an essential nutrient for all aquatic life, elevated levels can lead to an imbalance which impacts stream ecology. In the Flandreau Creek watershed, phosphorus levels have exceeded this proposed standard multiple times.

Flandreau Creek (10170203-502):

From 2011-2013, 13 phosphorus samples were taken from this portion of Flandreau Creek. Sample values ranged from 0.027-0.414 mg/L with eight of these samples having values above the 0.15 mg/L proposed standard for phosphorus.

Biologically, the macroinvertebrate community at 11MS005 of Flandreau Creek had lower levels of both Tanytarsini (2.78%) and intolerant (8.33%) taxa, while also having higher amounts of crustacea/mollusca (16.67%), scraper (19.44%), and tolerant taxa (63.89%). These metric scores are common in streams affected by high levels of phosphorus. The fish assemblage was comprised of mostly tolerant taxa (63.64%) and had few sensitive species (9.55%).

With the high percentage of phosphorus values above the proposed draft standard, the poor scoring biological metrics, along with DO issues this reach is experiencing; phosphorus is a stressor to the biological assemblages in Flandreau Creek.

Flandreau Creek (10170203-517):

Flandreau Creek had a total of ten phosphorus samples taken from 2011-2013. The sample values ranged from 0.054-0.334 mg/L. Four of the samples had a phosphorus value above the proposed draft standard of 0.15 mg/L. Figure 28 shows the values from the 9 phosphorus samples taken in 2013.

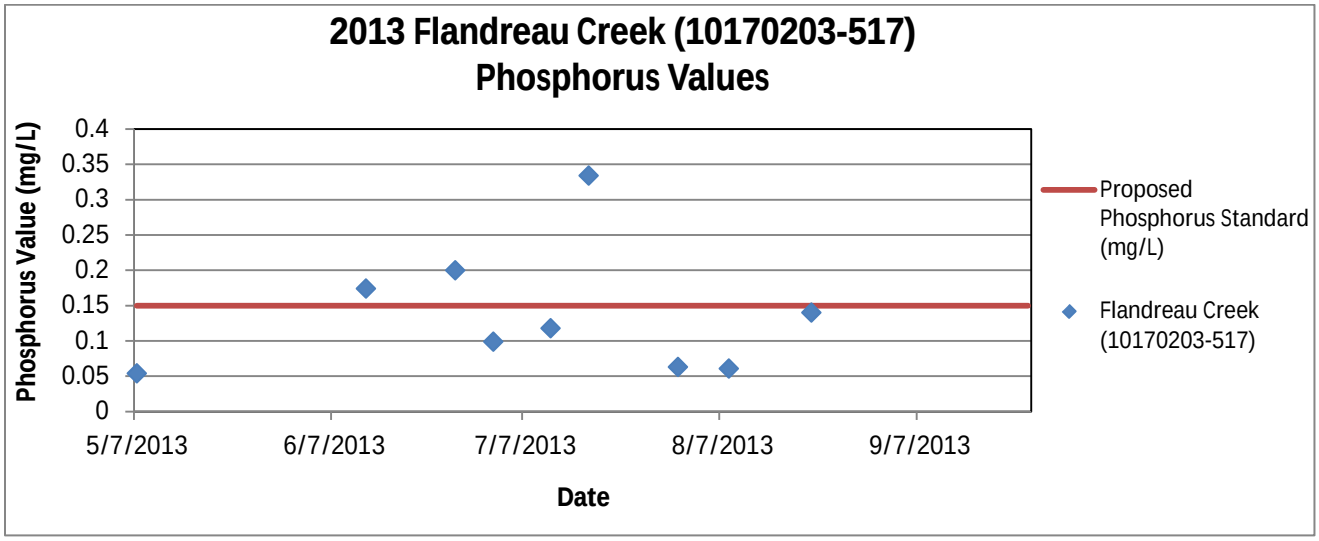

Figure 28: 2013 phosphorus values along Flandreau Creek (10170203-517)

The HSPF model calculated that daily from 1996-2009, the proposed phosphorus standard was exceeded 20.83% of the time along Flandreau Creek (10170203-517).

The macroinvertebrate community in this section of Flandreau Creek had lower levels of Tanytarsini taxa (5.88%), intolerant species (2.94%) in addition to higher numbers of crustacean/Mollusca (14.71%) and tolerant (70.59%) taxa. The fish assemblage of this reach had many tolerant species (70.59%) and lacked any sensitive taxa.

The high number of observed and predicted exceedances agrees with the biological metrics that excess phosphorus is stressing the impaired biological assemblages in this reach along Flandreau Creek.

Willow Creek (10170203-515):

Willow Creek had a total of 11 phosphorus samples taken from 2011-2013. The sample values ranged from 0.026-0.342 mg/L. Ten of the samples had values above the proposed draft standard of 0.15 mg/L. Figure 29 shows the values from the 10 phosphorus samples taken in 2013.

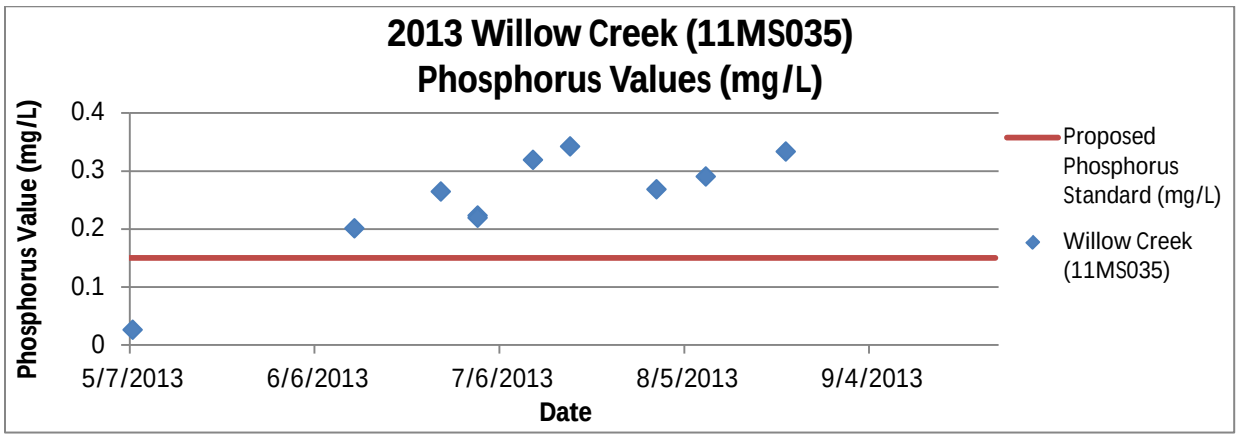

Figure 29: 2013 phosphorus values along Willow Creek (10170203-515) at site 11MS035

Biologically, the macroinvertebrate population in Willow Creek had a higher amount of Tanytarsini (10.07%) which normally corresponds to streams with lower levels of phosphorus. However, this reach did have a lower number of EPT taxa (18.02%), intolerant species (2.17%), while also having a higher amount of crustacean/mollusca (16.65%) and tolerant (76.51%) taxa. These results are more commonly found in streams with elevated phosphorus levels like Willow Creek. The fish assemblage was also very tolerant (76.92% taxa), while completely lacking sensitive species.

The majority of the biological information corresponds to the high levels of phosphorus sampled in 2013. These high levels may also be contributing to the lower levels and high fluctuations of daily DO. Therefore, phosphorus is a stressor to the impaired biological communities in Willow Creek.

Unnamed Creek (10170203-531):

Unnamed Creek had a total of 11 phosphorus samples taken from 2011-2013. The sample values ranged from 0.021-0.202 mg/L. Five of the samples had values above the proposed draft standard of 0.15 mg/L. Figure 30 shows the values from the 10 phosphorus samples taken in 2013.

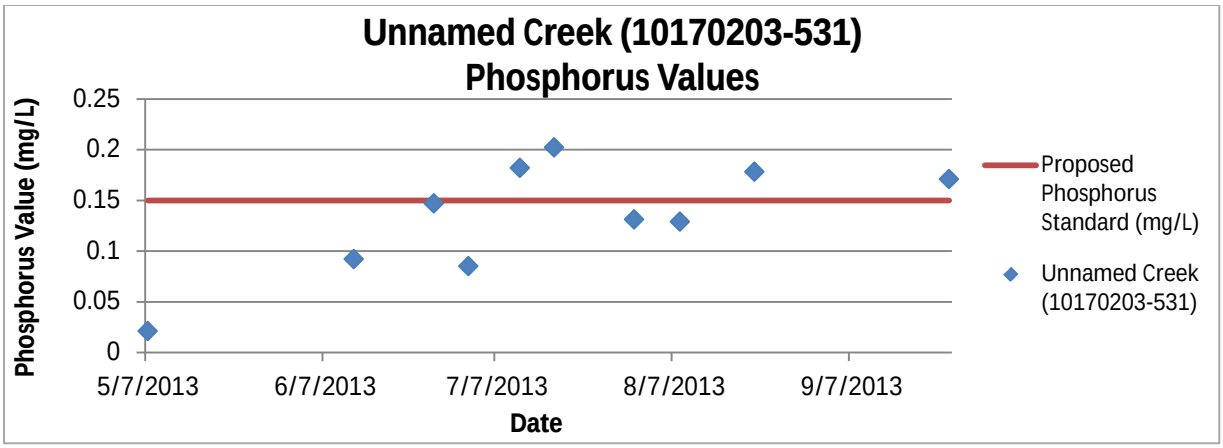

Figure 30: 2013 phosphorus values along Unnamed Creek (10170203-531)

From 1996-2009, the HSPF model calculated daily phosphorus values for Unnamed Creek. Of these values, 26.34% were above the proposed draft standard for phosphorus.

Biologically, the macroinvertebrate assemblage in Unnamed Creek had low levels of EPT taxa (9.68%) and intolerant species (0%), while also a greater amount of tolerant (87.1%) and crustacea/mollusca (16.13%) species which are common results for streams affected by excess phosphorus. This community did have a lower amount of scraper taxa (3.23%). The fish population in Unnamed Creek had many tolerant taxa (64.29%) and a well below average amount of sensitive species (7.14%) and simple lithophilic spawning individuals (11.43%) when compared to other Minnesota streams. These results often suggest problems caused by high phosphorus levels.

The numerous measured and calculated exceedances of the proposed phosphorus standard along with the agreement by the majority of the phosphorus related biological metrics signal that excess phosphorus is stressing the impaired macroinvertebrate community in Unnamed Creek at this time.

Candidate cause: high nitrates

Currently, the State of Minnesota does not have a nitrate standard in place for streams not used as a drinking water source. However, the overabundance of nitrates can stress a biological community. Nitrates in the Flandreau Creek watershed did at times reach levels that could potentially be stressing the biological assemblages.

Flandreau Creek (10170203-502):

From 2011-2013, 12 nitrate samples were taken from this section of Flandreau Creek. These values ranged from 1.2-3.62 mg/L. These sample values are fairly low when compared to other streams throughout the Lower Big Sioux watershed.

The HSPF model calculated daily nitrate values for this section of Flandreau Creek from 1996-2009. These values ranged from 1.38-18.77 mg/L. The high nitrate values correspond to high flow events that the model calculated, which may not reflect the normal base flow conditions in Flandreau Creek.

The macroinvertebrate assemblage in this portion of Flandreau Creek did have a lower than expected amount of Trichoptera taxa (5.56%), but had a fairly diverse community (24 taxa). Additionally, class 7 macroinvertebrate streams with greater than 79.53% of their population to be consisting of nitrate tolerant individuals have a greater than 75% chance of being impaired. Site 11MS005 along this reach had 82.89% of its population consisting of these types of macroinvertebrates. The fish population was also fairly diverse (21 taxa), but it did have few sensitive species (9.55%).

While many of the related biological metrics suggest that this parameter may be stressor, many of the observed values and baseflow calculated nitrate values were relatively low. More rigorous nitrate sampling is recommended before excess nitrates are considered a stressor to the biological communities in this reach of Flandreau Creek.

Flandreau Creek (10170203-517):

Flandreau Creek had a total of ten nitrate samples taken from 2011-2013. The sample values ranged from 0.085-3.9 mg/L. Figure 31 shows the values from the 9 nitrate samples taken in 2013.

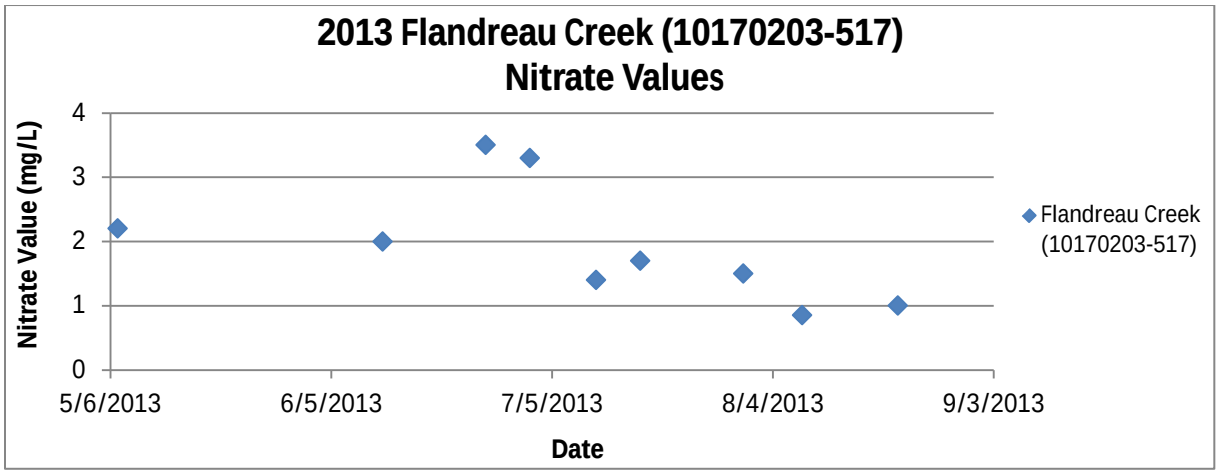

Figure 31: 2013 nitrate sample values along Flandreau Creek (10170203-517)

The HSPF model calculated daily nitrate values for Flandreau Creek (10170203-517) from 1996-2009. These values ranged from 1.42-18.8 mg/L with an average calculation of 4.09 mg/L. The high nitrate values correspond to high flow events that the model calculated, which may not reflect the normal base flow conditions in Flandreau Creek.

Biologically, this section of Flandreau Creek had very few Trichoptera taxa (2.94%). Trichoptera species decrease in streams with elevated nitrate levels. There was an average amount of macroinvertebrate diversity (23 species) while having an above average amount of fish species (17) when compared to all other Minnesota streams. A quantile regression study showed that a class 7 macroinvertebrate site would have a greater than 75% probability of being impaired if the population consisted of 79.53% of nitrate tolerant individuals. Site 11MS034 had 78.07% of nitrate tolerant individuals. No sensitive fish taxa were sampled in this section of Flandreau Creek.

While many of the related biological metrics suggest that this parameter is a stressor, many of the observed values and baseflow calculated nitrate values were relatively low. More rigorous nitrate sampling is recommended before excess nitrates are considered a stressor to the biological communities in this reach of Flandreau Creek.

Willow Creek (10170203-515):

Willow Creek had 11 nitrate samples taken from 2011-2013. These nitrate values ranged from 0.34-3.5 mg/L. Figure 32 shows the values of the 10 samples taken in 2013.

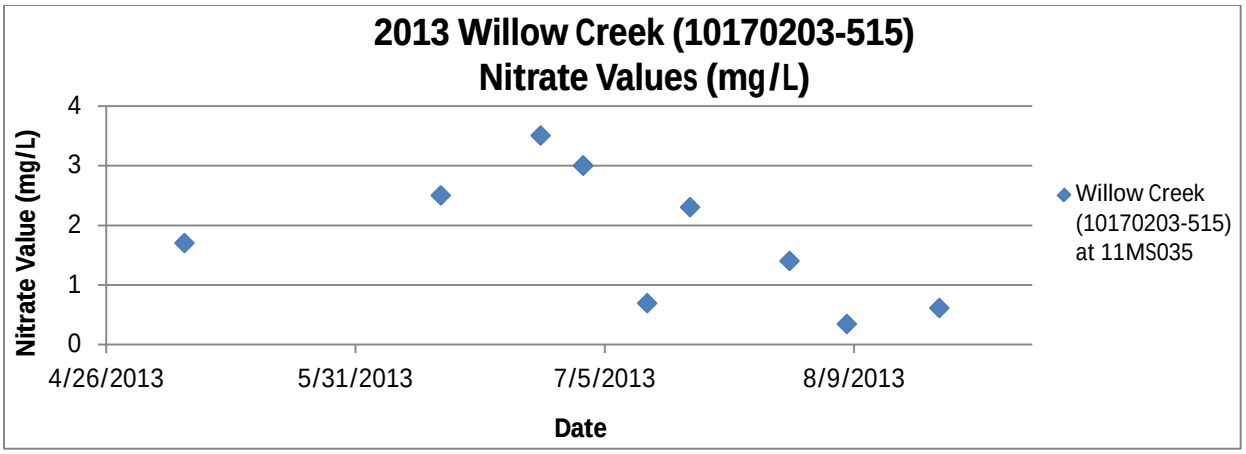

Figure 32: 2013 nitrate sample values along Willow Creek (10170203-515) at site 11MS035

The HSPF model predicted that daily nitrate values for Willow Creek ranged between 1.45-19.93 mg/L from 1996-2009. The high nitrate values correspond to high flow events that the model calculated, which may not reflect the normal base flow conditions in Flandreau Creek.

Biologically, the macroinvertebrate community in Willow Creek had an average amount of taxa (24) when compared to other streams statewide, while also having few nitrate sensitive Trichoptera species (5.88%). Site 11MS035 had a lower amount of nitrate tolerant individuals (67.15%). This total shows that this reach has a less than 50% chance of being impaired according to a quantile regression study. Fish diversity in this AUID was slightly above average (13 species) when compared to all Minnesota streams and no sensitive fish species were present.

While many of the related biological metrics suggest that this parameter is a stressor, many of the observed values and baseflow calculated nitrate values were relatively low. More rigorous nitrate sampling is recommended before excess nitrates are considered a stressor to the biological communities in Willow Creek.

Unnamed Creek (10170203-531):

From 2011-2013, Unnamed Creek had 11 nitrates samples taken at biological monitoring station 11MS032. One sample was taken during the fish sampling event in 2011, while the remaining ten were taken in 2013 (Figure 33). Nitrate values ranged from 1.7-6.5 mg/L.

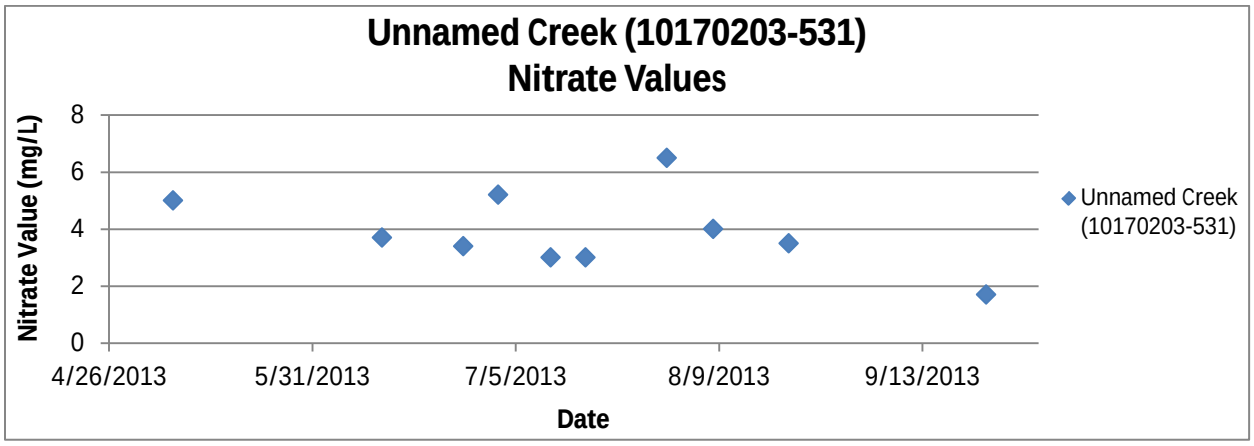

Figure 33: Unnamed Creek (10170203-531) nitrate sample values at site 11MS032 in 2013

The HSPF model calculated daily nitrate values along Unnamed Creek from 1996-2009. These values ranged from 1.7-20.85 mg/L with an average value of 4.68 mg/L. The elevated nitrate values again correlated with high flow events.

Biologically, the macroinvertebrate assemblage in Unnamed Creek had a lower count of taxa (19) present while also having very few nitrate sensitive Trichoptera species (3.23%). Site 11MS032 did have a lower amount of nitrate tolerant individuals (29.87%). The fish community in Unnamed Creek had a lower amount of sensitive fish taxa (7.14%), but did have an above average amount of fish diversity (14 species).

The low presence of nitrate tolerant individual taxa along with many lower observed nitrate values concludes that excess nitrates are not a stressor to the impaired macroinvertebrate community at this time.

Candidate cause: high turbidity/TSS

The water quality standard for Turbidity is 25 NTU, 65 mg/L for TSS, and 20 cm for transparency tube for these class 2B warmwater streams in the Flandreau Creek watershed. Excess sediment is a commonly recognized stressor in many biologically impaired streams because it can reduce habitat, cause direct physical harm, as well as reduce visibility and increase oxygen demand. Currently, none of the biologically impaired reaches in this watershed are also impaired for turbidity.

Flandreau Creek (10170203-502):

From 2011-2013, twelve TSS samples were taken from Flandreau Creek (10170203-502). These values ranged from 7-96.5 mg/L with one sample over the 65 mg/L proposed standard. Additionally, 31 transparency/Secchi tube readings were taken during this time period. Of these measurements, 19 fell below the 20 cm minimum standard for transparency.

The HSPF model calculated daily TSS values from 1996-2009. These values exceeded the proposed TSS standard 4.65% of the time.

Biologically, the macroinvertebrate community in Flandreau Creek had good numbers of Ephemeroptera taxa (27.78%) and scraper taxa (19.44%). However, this reach also had few collector-filterer taxa (5.56%) and Trichoptera species (5.56%), while having a high amount of tolerant taxa (63.89%). The fish assemblage in this stream had an above average amount of herbivorous taxa (9.55%), but also did have a high amount of tolerant species (64.32%).

The TSS and transparency/Secchi tube results show mixed results as does the turbidity/TSS related biological metrics. Additional biological and chemistry sampling is recommended before this parameter is considered a clear stressor to the impaired biological communities in Flandreau Creek.

Flandreau Creek (10170203-517):

From 2011-2013, 10 TSS samples were taken from this portion of Flandreau Creek. These values ranged from 17-140 mg/L with four samples registering above the proposed TSS standard of 65 mg/L (Table 15). Furthermore, 11 transparency/Secchi tube measurements were taken during this time period. Eight of these values fell below the 20 cm minimum standard for transparency.

Table 15: TSS and Secchi tube sample results along Flandreau Creek (10170203-517) at site 11MS034 from 2011-2013

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS034	8/4/2011	n/a	65	8	20
11MS034	8/9/2011	67	65	9	20
11MS034	5/7/2013	26	65	28	20
11MS034	6/12/2013	86	65	12	20
11MS034	6/26/2013	100	65	11	20
11MS034	7/2/2013	44	65	16	20
11MS034	7/11/2013	38	65	17	20
11MS034	7/17/2013	140	65	11.5	20
11MS034	7/31/2013	23	65	26.5	20
11MS034	8/8/2013	17	65	44	20
11MS034	8/21/2013	41	65	15	20

The HSPF model predicted daily suspended solid values from 1996-2009. These values ranged from 0.03-3343.6 mg/L with 207 (4.05%) values above the proposed TSS standards.

Biologically, the macroinvertebrate assemblage in this reach had low numbers of Trichoptera taxa (2.94%), scraper species (11.76%), and collector filterer taxa (0%) while also having many tolerant species (70.59%). The fish population had an above average amount of herbivore taxa (11.76%), but had an elevated amount of tolerant fish species (70.59%) when compared to all other Minnesota streams.

The frequent collected and predicted measurements violating their respective standards is backed up by the majority of the related biological metrics as well as the observed run and pool sedimentation noted during a habitat assessment. The amount of sediment in this stream is stressing the impaired biological communities in Flandreau Creek (10170203-517).

Willow Creek (10170203-515):

From 2011-2013, Willow Creek had 11 TSS samples taken. These values ranged from 6-93 mg/L with three samples above the 65 mg/L proposed standard for TSS (Table 16). Additionally, 12 transparency/Secchi tube measurements were taken during this time frame. These readings contained 10 values that were below the 20 cm minimum standard set forth for transparency.

Table 16: TSS and Secchi tube measurements along Willow Creek (10170203-515)

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS035	8/4/2011	n/a	65	6	20
11MS035	9/7/2011	46	65	13.5	20
11MS035	5/7/2013	6	65	62	20
11MS035	6/12/2013	45	65	22	20
11MS035	6/26/2013	86	65	10	20
11MS035	7/2/2013	56	65	11	20
11MS035	7/2/2013	61	65	11	20
11MS035	7/11/2013	62	65	11	20
11MS035	7/17/2013	90	65	11	20
11MS035	7/31/2013	64	65	9.5	20
11MS035	8/8/2013	93	65	11	20
11MS035	8/21/2013	51	65	12	20

The macroinvertebrate community in Willow Creek had lower numbers of Trichoptera taxa (2.94%), collector-filterer species (8.42%) and scraper taxa (11.87%), while also having many tolerant taxa (76.51%). These results are common in streams affected by an excess amount of turibidity/TSS. This stream did have a good amount of Ephemeroptera taxa (15.08%), which tend to be less abundant in turbid streams. The fish assemblage in this reach had a slightly above average amount of herbivorous species (7.69%), but did have a high amount of tolerant taxa (76.92%). The fish assemblage did have a TSS TIV score that was slightly above average when compared to all other streams in Minnesota.

The high degree of exceedances with the Secchi tube as well as the majority of the TSS/turbidity related biological metrics signal that excess TSS/turbidity is a stressor to the impaired biological assemblages in Willow Creek.

Unnamed Creek (10170203-531):

From 2011-2013, Unnamed Creek had 11 TSS samples taken. These values ranged from 2.4-120 mg/L with four samples above the 65 mg/L proposed standard for TSS (Table 17). Additionally, 12 transparency/Secchi tube measurements were taken during this time frame. These readings contained six values that were below the 20 cm minimum standard set forth for transparency.

Table 17: Unnamed Creek (10170203-531) TSS and Secchi tube sample results at site 11MS032 from 2011-2013

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS032	8/9/2011	n/a	65	13	20
11MS032	8/18/2011	17	65	39.5	20
11MS032	5/7/2013	2.4	65	>100	20
11MS032	6/12/2013	6.8	65	81	20
11MS032	6/26/2013	9.2	65	64	20
11MS032	7/2/2013	36	65	21.5	20
11MS032	7/11/2013	100	65	14	20
11MS032	7/17/2013	14	65	49	20
11MS032	7/31/2013	70	65	12.5	20
11MS032	8/8/2013	90	65	12	20
11MS032	8/21/2013	120	65	11	20
11MS032	9/24/2013	31	65	17	20

Biologically, the macroinvertebrate population in Unnamed Creek consisted of few Trichoptera species (3.23%), Ephemeroptera species (6.45%), scraper taxa (3.23%), while having a low overall taxa count (19) and high numbers of chironomids (41.94%) and tolerant taxa (87.1%). All of these metrics reflect a stream that is affected by high levels of turbidity/TSS. The fish community in this reach, like the other reaches in this watershed, had an above average amount of herbivore species (14.29%), while also containing many tolerant taxa (64.29%).

The overwhelming biological and chemical data are reasons that turbidity/TSS is a stressor to the impaired macroinvertebrate community in Unnamed Creek.

Candidate cause: lack of habitat

Habitat quality in Flandreau Creek and its Tributaries varies from poor to fair in the biologically impaired reaches. The MSHA was the main tool used for evaluating this potential stressor and the results of these habitat scores can be seen in Figure 34.

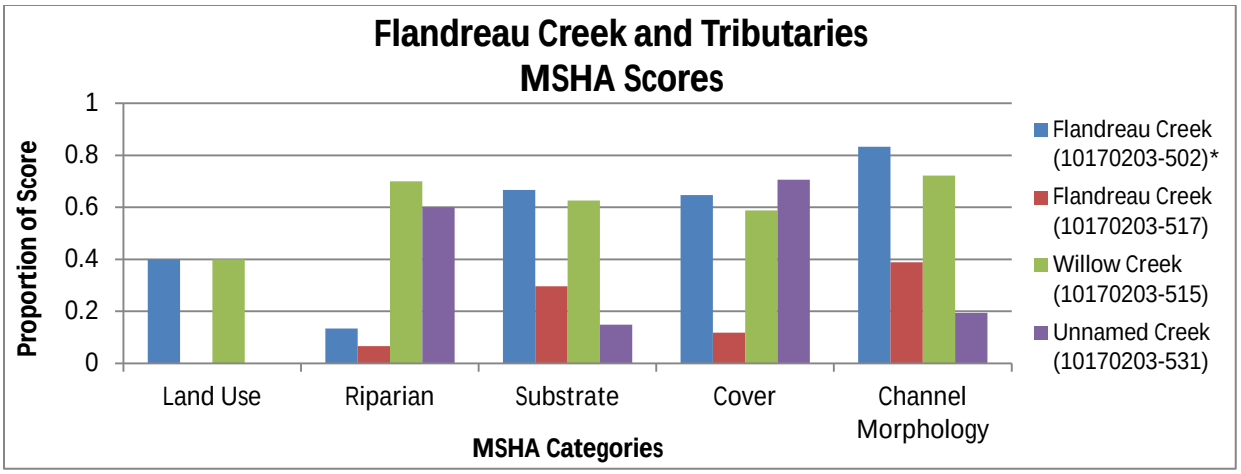

Figure 34: MSHA results from the biologically impaired reaches in the Flandreau Creek watershed
***Average of two visits at 11MS005.**

Flandreau Creek (10170203-502):

The most downstream section of Flandreau Creek had an average MSHA score of 55.4 after two visits at 11MS005. This score is considered to be fair. Factors lowering this score include surrounding land use, the lack of riparian buffer, heavily eroded banks (Figure X), and lack of shade. Filamentous algae, animal access to stream and trampling (Figure 35), as well as excess sedimentation in runs and pools were also observed at this site.

Additionally, the MDNR estimated that along a 1056 foot stream reach in this AUID would deliver 47.41 tons of sediment to Flandreau Creek (MDNR 2014). This high amount of sediment not only leads to problems with TSS, but it also covers vital habitats needed for the biological communities in Flandreau Creek.

Figure 35: Animal access to stream and severe bank erosion at 11MS005 along Unnamed Creek (10170203-502)

Biologically, the macroinvertebrate community in this portion of Flandreau Creek had a high amount of tolerant taxa (63.89%) and a low amount of clinger species (22.22%). These results are common in streams with degraded habitat conditions. The fish assemblage had good numbers of riffle dwelling (21.59%), benthic insectivore (31.14%), and darter/sculpin/round-bodied sucker (14.32%) species. However, this stream also had a high amount of tolerant taxa (64.32%) and a lower amount of simple lithophilic spawning taxa (21.59%).

With the fair MSHA score, obvious signs of degraded conditions, and the agreement of many habitat related biological metrics all lead to the lack of habitat being listed as a stressor to the impaired fish assemblage in Flandreau Creek.

Flandreau Creek (10170203-517):

Further upstream on Flandreau Creek, site 11MS034 had a MSHA score of 25 which was taken during the fish sampling event on August 9th, 2011. This score is considered to be poor. Factors lowering the MSHA score include: poor surrounding land use (Figure 36), no riparian buffer, heavy bank erosion, no shade, lack of course substrates, severe embeddedness, moderate channel stability, and fair channel development. The site was a heavily grazed pasture with animal access to the stream causing bank erosion.

Figure 36: Left: Heavily pastured land use on downstream side of road at 11MS034 along Flandreau Creek (10170203-517). Right: Eroded bank due to heavy grazing

Biologically, the macroinvertebrate community in this portion of Flandreau Creek had low amounts of habitat sensitive clinger taxa (14.71%), while also having a high amount of tolerant taxa (70.59%). The fish assemblage in this reach had lower amounts of simple lithophilic spawning species (23.53%) and dater/sculpin/round-bodied sucker species (14.32%), while also having a high amount of tolerant taxa (70.59%). This reach did have an above average amount of riffle dwelling species (17.65%) and benthic insectivore taxa (23.53%).

Based on the poor MSHA score and the majority of the biological metrics, the lack of habitat in this AUID of Flandreau Creek is stressing the macroinvertebrate community.

Willow Creek (10170203-515):

The main tributary to Flandreau Creek, Willow Creek, had a MSHA score of 65.4 at its biological sampling station 11MS035. This score is considered to be fair. Factors lowering the MSHA score are the fenced pasture in the surrounding land use (Figure 37), the lack of shade, and the fair channel development. Excess sedimentation in the pools is also a problem at this site.

Figure 37: Left: Downstream side of road land use at 11MS035. Right: Cattle access to stream at 11MS035

Biologically, the macroinvertebrate community in Willow Creek had a low amount of clinger taxa (20.74%) and high amounts of tolerant taxa (76.51%). The fish assemblage had low amounts of riffle dwelling species (15.38%), benthic insectivore taxa (7.69%), simple lithophilic spawning species (23.08%), and darter/sculpin/round-bodied sucker taxa (7.69%) while also have a high amount of tolerant species (76.92%).

The fair MSHA score along with the photos of degraded conditions and poor scores of habitat related biological metrics makes the lack of habitat a stressor to the impaired biological communities in Willow Creek.

Unnamed Creek (10170203-531):

Unnamed Creek had a MSHA score of 32 at its biological sampling station 11MS032. This score is considered to be poor. Factors lowering the MSHA score include: poor surrounding land use (Figure 38), no riparian buffer, no course substrates, low channel stability, limited depth variability, and few types of fish cover.

Figure 38: Surrounding land use at 11MS032 along Unnamed Creek (10170203-531)

The macroinvertebrate community in Unnamed Creek had a higher amount of clinger taxa (32.26%) and individuals (12.31%), but also had a very high amount of tolerant macroinvertebrates (87.1%). The fish population in this reach has a lower amount of riffle dwelling taxa (14.29%) and simple lithophilic spawning species (21.43%), while also having many tolerant species (64.29%). This stream did have above average amounts of darters/sculpin/round-bodied sucker taxa (21.43%) and benthic insectivore species (21.43%) when compared to all other Minnesota streams.

Based on the poor MSHA score and the majority of biological metrics suggest that the lack of habitat is indeed stressing the macroinvertebrate assemblage in Unnamed Creek.

Conclusion

The fish and macroinvertebrate assemblages in the Flandreau Creek watershed are being negatively impacted by numerous stressors throughout the watershed (Table 18).

Low dissolved conditions in the watershed that are impacting the biology are located along Flandreau Creek (10170203-502), Willow Creek (10170203-515), and Unnamed Creek (10170203-531). This is backed up by numerous DO measurements, continuous monitoring with a sonde, and the high presence of serial spawning fish taxa, while also having few late maturing fish species. The high presence of phosphorus in the watershed is likely also impacting the DO conditions in these impaired reaches.

The phosphorus concentrations are elevated throughout the Flandreau Creek watershed. These high levels are experienced at all of the biologically impaired reaches. At times, phosphorus concentrations have reached to levels twice that of the proposed draft standard. High presences of tolerant fish and macroinvertebrate taxa along with many crustacea/mollusca species also can signal a stream affected by

the elevated levels. The phosphorus conditions in the watershed are likely negatively impacting the DO levels. The intensively grazed and row cropped surrounding land use with minimal riparian buffers provide the necessary pathway for phosphorus to enter the system.

The biological communities in the Flandreau Creek watershed are also being stressed by the high presence of turbidity and TSS within the stream reaches. The most downstream reach, Flandreau Creek (10170203-502), is the only reach not currently stressed by these conditions. TSS and transparency standards were exceeded frequently in the remaining reaches. This can likely be attributed to the frequent cattle access to the stream which can lead to unstable and erodible banks resulting in excess sediment being distributed throughout the stream channel and water column. The lack of riparian buffers also allows runoff to easily enter the stream system.

In-stream habitat was also lacking at all of the biologically impaired reaches within this watershed. MSHA scores ranged from poor to fair with some especially low scores along Flandreau Creek (10170203-517) and Willow Creek (10170203-515). The habitat scores throughout the watershed were mainly limited by poor surrounding land use, lack of a riparian buffer, few course substrates, low channel stability, and a lack of stream shading. Properly fencing off cattle in the intensively grazed lands surrounding these streams would go a long way to stabilize the stream banks and help return the stream to a condition where habitat is not a stressor. Further habitat improvement projects would also help alleviate the stress causing the biological communities in this watershed.

The Flandreau Creek watershed has many stressors to the impaired fish and macroinvertebrate assemblages. Wide-spread changes in land use in the immediate riparian areas adjacent to streams are needed to help provide some bank stabilization and further limit the sediment and nutrients that easily enter the streams in these vulnerable areas. Nutrient management plans and other targeted BMPs are recommended to help alleviate the negative impacts of these watershed wide stressors.

Table 38: Biologically impaired reaches in the Flandreau Creek watershed and their stressors

(• = stressor, - = not a stressor, and blank = inconclusive/not enough evidence)

		Stressors				
Stream Name	**AUID #**	**Low Dissolved Oxygen**	**High Phosphorus**	**High Nitrates**	**High Turbidity/TSS**	**Lack of Habitat**
Flandreau Creek Watershed						
Flandreau Creek	10170203-502	•	•			•
Flandreau Creek	10170203-517		•		•	•
Willow Creek	10170203-515	•	•		•	•
Unnamed Creek	10170203-531	•	•	-	•	•

Pipestone Creek watershed

Overview

The Pipestone Creek watershed consists of six biologically impaired AUIDS (Figure 39). These include Pipestone Creek (10170203-501), Pipestone Creek (10170203-505), Pipestone Creek (10170203-506), North Branch Pipestone Creek (10170203-514), and Unnamed Creek (10170203-549). The land use in this watershed consists of mainly cropland (81.16%), rangeland (11.12%), and developed land (6.59%).

Pipestone Creek (10170203-501) is a 9.33 mile reach that extends from the confluence with the North Branch Pipestone Creek to the Minnesota/South Dakota border in Pipestone County. This AUID was determined to be impaired for aquatic life due to turbidity during an earlier assessment. During the 2013 assessments, the turbidity impairment was affirmed, and both fish and macroinvertebrate impairments were added following the biological monitoring at station 11MS019.

Pipestone Creek (10170203-505) is a 1.09 mile reach that extends from the Minnesota/South Dakota border to the confluence with Split Rock Creek. This AUID is impaired for aquatic life due to its fish and macroinvertebrate assemblages at its biological monitoring station 11MS015.

Pipestone Creek (10170203-506) is an 11.19 mile reach that extends from the Pipestone Creek headwaters to the confluence with North Branch Pipestone Creek. This AUID is impaired for aquatic life due to its fish and macroinvertebrate assemblages at its biological monitoring stations 04MS021 and 11MS038. Site 11MS038 is located on a channelized section of this stream reach.

North Branch Pipestone Creek (10170203-514) is a 28.34 mile reach extending from the headwaters of North Branch Pipestone Creek down to the confluence with Pipestone Creek. This AUID is impaired for aquatic life due to turbidity, fish, and macroinvertebrate assemblages at its four biological monitoring stations: 11MS056, 11MS050, 06MS001, and 06MS002.

Unnamed Creek (10170203-549) is a 2.27 mile stream reach that runs from Unnamed Creek to the confluence with North Branch Pipestone Creek. This AUID is impaired for aquatic life due to its fish and macroinvertebrate assemblages at its biological monitoring station 11MS049.

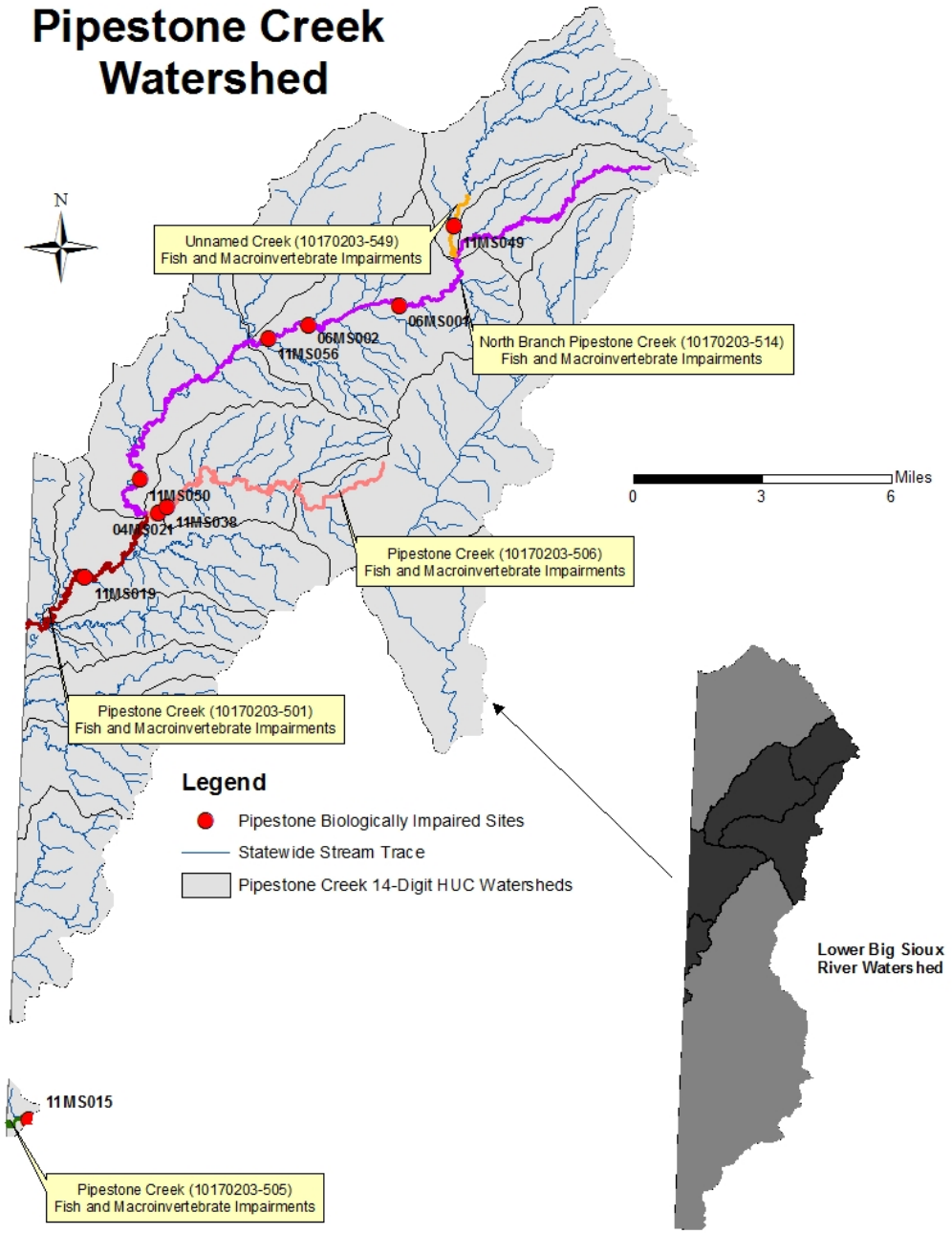

Figure 39: Pipestone Creek watershed with biologically impaired reaches highlighted

Biology in the Pipestone Creek watershed

Fish

The Pipestone Creek watershed contains five biologically impaired AUIDS. The most downstream AUID, Pipestone Creek (10170203-501) has one biological monitoring station (11MS019) that is located upstream of CR 13, 6 miles west of Pipestone. This site was sampled for fish on June 12th, 2012. Moving upstream is Pipestone Creek (10170203-505). This AUID has one biological site (11MS015) that is located south of Township Rd 21, 3 miles southwest of Jasper and was sampled on June 19th, 2012. Next is Pipestone Creek (10170203-506) which has two biological monitoring stations. Station 04MS021 is located upstream of State Route 30, 3 miles west of Pipestone and was sampled for fish on August 3rd,

2004. Site 11MS038 is downstream of 40th Ave, 4.5 miles northwest of Pipestone and was sampled for fish on August 9th, 2011. North Branch Pipestone Creek (10170203-514) contains two biological monitoring sites that were sampled for fish. Site 11MS050 is located downstream of CR 71, 5 miles northwest of Pipestone and had a fish sampling event occur on August 9th, 2011. Site 11MS056 (upstream of CR 76, 4.5 miles north of Pipestone) was sampled for fish on September 7th, 2011. Finally, Unnamed Creek is located upstream of 181st St, 9 miles southwest of Ruthton and was sampled for fish on August 17th, 2011.

Six biological monitoring sites distributed amongst four impaired AUIDs were designated as fish class 2 (Southern Streams) reaches (Figure 40). The IBI threshold for this classification is 45 and an average metric score of 5.625 is needed to reach the threshold. Site 11MS019 along Pipestone Creek (10170203-501) had a fish IBI score of 19. This site had a lower amount of detritivorous taxa resulting in the higher metric score (DetNWQTxPct). All other metrics scored poorly at this site. Pipestone Creek (10170203-505) had a fish IBI score of 17 at its biological monitoring station 11MS015. This site had few numbers of fish classified as short lived species (SLvd) resulting in a higher metric score. All other metric scores were lower than the needed average score. Pipestone Creek (10170203-506) had an average fish IBI score of 34.5 at its two sites, 04MS021 and 11MS038. This reach had few late maturing fish species (MA<2Pct), and sensitive fish taxa (SensitiveTxPct), while also having high numbers of individual short lived species (SLvd) tolerant individual fish (TolPct) and tolerant taxa (TolTxPct) resulting in lower metric scores. North Branch Pipestone Creek (10170203-514) had an average fish IBI score of 40 at its two sites, 11MS050 and 11MS056. This reach scored well in half of the IBI metrics, but scored poorly in the sensitive fish taxa (SensitiveTxPct), short lived species (SLvd), tolerant individual fish (TolPct), and tolerant taxa (TolTxPct) metrics.

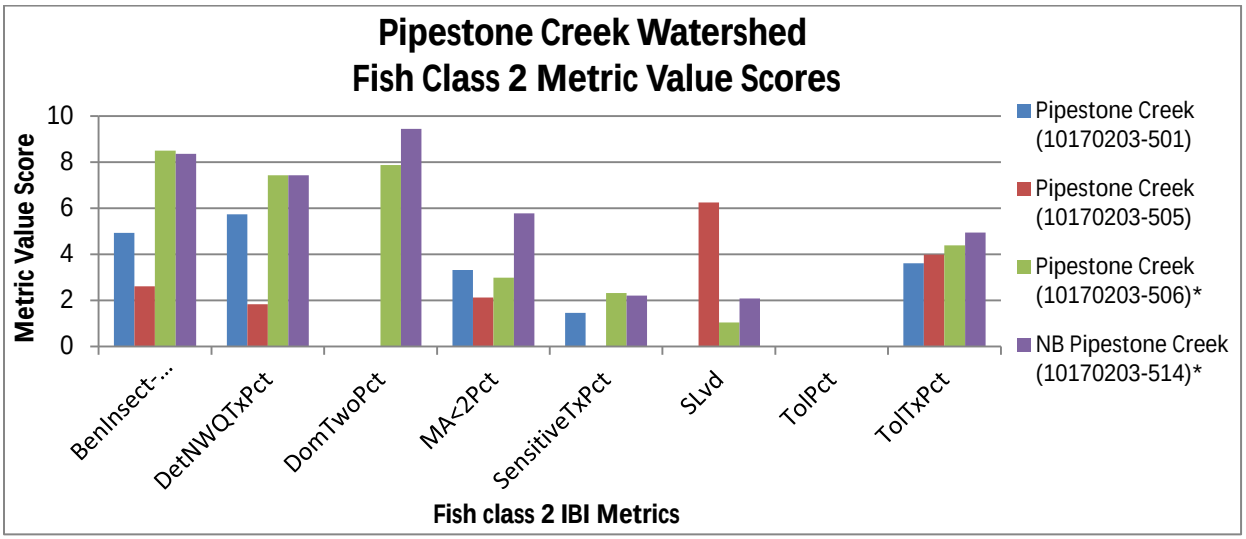

Figure 40: Fish class 2 IBI metric value scores in the Pipestone Creek watershed
***Average score of multiple sites**

Only one of the impaired AUIDs, Unnamed Creek (10170203-549) had a site with a fish class 3 (Southern Headwaters) designation (Figure 41). This classification has an IBI threshold of 51 and each metric would need an average score of 8.5 to reach this level. Site 11MS049 along Unnamed Creek had a fish IBI score of 44. This site had lower numbers of short lived individual species (SLvdPct) and serial spawning individuals (SSpnPct) resulting in a higher metric score. The remaining metrics scored poorly.

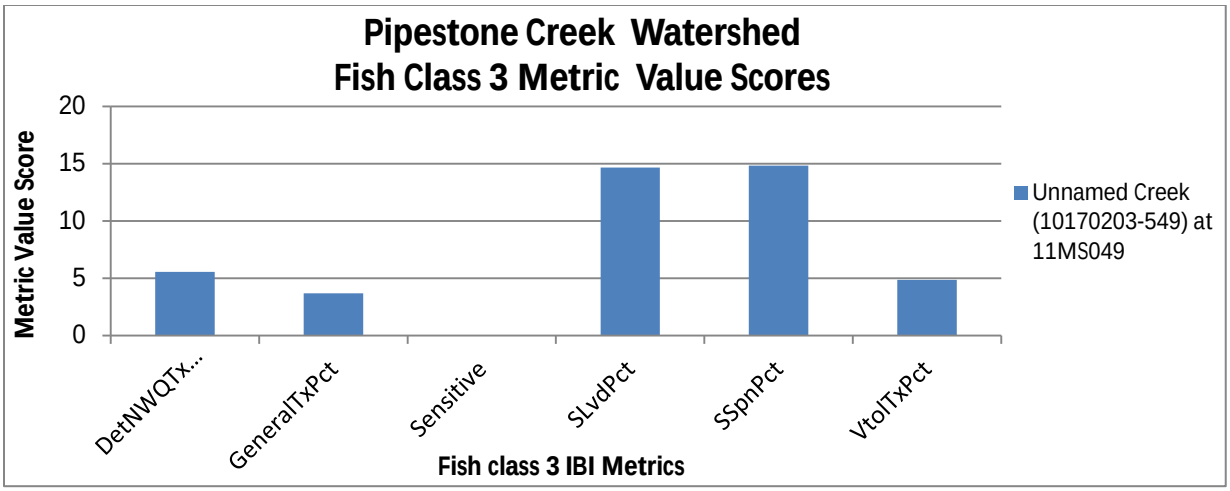

Figure 41: Fish class 3 IBI metric value scores in the Pipestone Creek watershed

Macroinvertebrates

Pipestone Creek (10170203-501) had one macroinvertebrate sample taken on August 3rd, 2011, at its biological monitoring site 11MS019. Site 11MS015 on Pipestone Creek (10170203-505) had macroinvertebrate sample taken on August 5th, 2011. Pipestone Creek (10170203-506) had samples taken on September 1st, 2004, and on August 3rd, 2011, at its respective biological monitoring sites 04MS021 and 11MS038. North Branch Pipestone Creek was sampled for macroinvertebrates at sites 11MS050 and 11MS056 on August 3rd and August 16th in 2011. This reach had two additional sites that were only sampled for macroinvertebrates. Site 06MS001 and 06MS002 were sampled on October 2nd, 2006. Unnamed Creek (10170203-549) had macroinvertebrate sample taken at its biological site, 11MS049, on August 4th, 2011.

Two biologically impaired stream reaches in this watershed had sites designated as macroinvertebrate class 5 (Southern Streams RR) sites (Figure 42). The IBI threshold for this classification is 35.9 meaning each metric would need an average value score of 3.59 to reach the threshold. Site 04MS021 on Pipestone Creek (10170203-506) had a macroinvertebrate IBI score of 29.3 and was not overly dominated by the five most abundant species (DomFiveCHPct), while also having good numbers of insectivore (InsectTxPct) and Odonata taxa. Site 11MS056 along North Branch Pipestone Creek (10170203-514) had an IBI score of 34.8. This site scored above the average needed in four of the metrics by having good numbers of climber species (ClimberCH), clinger taxa (ClingerChTxPct), and odonata species, while also not being dominated by the five most abundant species.

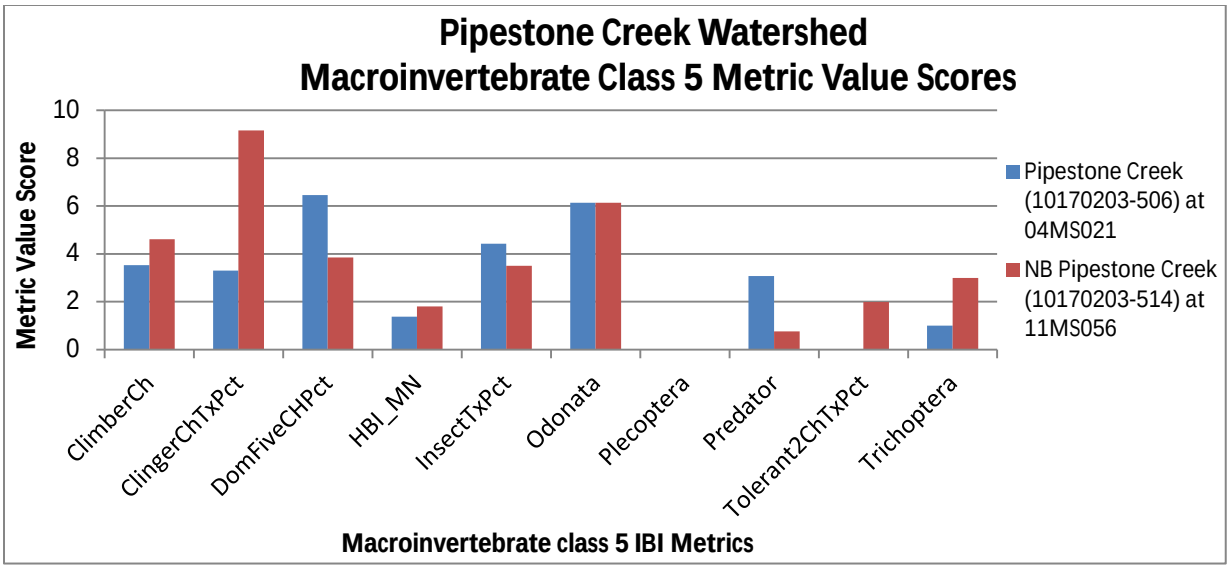

Figure 42: Macroinvertebrate class 5 IBI metric value scores in the Pipestone Creek watershed

Five of the biologically impaired reaches in the Pipestone Creek watershed had sites designated as class 7 (Prairie Streams GP) (Figure 43). The MIBI threshold for this class is 38.3 meaning each metric would need an average metric value score of 3.83 to achieve this level. Pipestone Creek (10170203-501) had a macroinvertebrate IBI score of 27.5 at site 11MS019. This site scored well in three of the metrics by having high numbers of combined Plecoptera, Odonata, Ephemeroptera, and Trichoptera species (POET), and high numbers of both Trichoptera taxa (TrichopteraChTxPct) and non-hydropsychid Trichoptera taxa (TrichowoHydroPct). Pipestone Creek (10170203-505) had an IBI score of 28.9 at site 11MS015. This site scored very similarly to 11MS019 except for having a higher amount of predator species (PredatorCh). Pipestone Creek (10170203-506) had an average IBI score of 33.35 at sites 04MS021 and 11MS038. This stream reach had few collector-filterer species and Trichoptera taxa. This reach also had a low HBI_MN score, which is a measure of pollution based on tolerance values assigned to each individual taxon, and low taxa richness of macroinvertebrates with tolerance values less than or equal to 2, using MN tolerance values. North Branch Pipestone Creek (10170203-514) had an average IBI score of 34.33 at sites 11MS050, 11MS056, 06MS001, and 06MS002. This reach had low numbers of collector-filterer taxa and predator taxa while also scoring low in the HBI_MN and Intolerant2Ch metrics. Lastly, Unnamed Creek (10170203-549) had an IBI score of 11.9 at site 11MS049. This reach had good overall taxa richness and was not dominated by the five most abundant species. However, this site scored poorly in all of the other metrics.

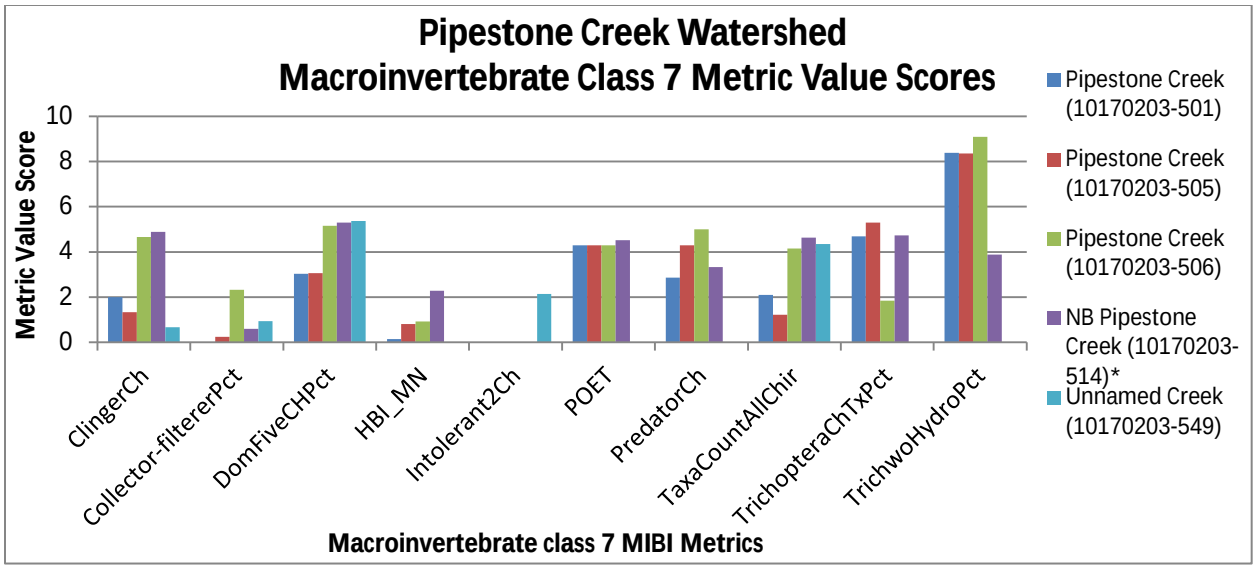

Figure 43: Macroinvertebrate class 7 IBI metric value scores in the Pipestone Creek watershed
***Average score of multiple sites**

Candidate cause: low dissolved oxygen

The daily minimum standard for DO in Minnesota class 2B streams is 5 mg/L. All streams in the Pipestone Creek watershed have this 2B classification. No reaches in this watershed are currently listed as impaired for DO.

Pipestone Creek (10170203-501):

From 2001-2013 a total of 84 DO measurements were taken from this section of Pipestone Creek. These values ranged from 3-16.4 mg/L with five readings falling below the 5 mg/L daily minimum standard. The wide range of values may indicate issues with daily flux.

The HSPF calculated hourly DO levels from 1996-2009 along this AUID of Pipestone Creek. These values ranged from 1.64-14.68 mg/L. There were very few instances of values being below 5 mg/L.

Biologically, the macroinvertebrate community in this AUID of Pipestone Creek had a significant population of Trichorythodes (36.9% of sample) which are a type of mayfly (Ephemeroptera) that can signify degraded conditions when present in very high numbers. The large numbers of Trichorythodes (Figure 44) resulted in a high presence of EPT taxa (30.77%) which are normally sensitive to wide ranges of DO values. This community also had many tolerant taxa (69.23%) and fewer overall species (18) than expected from a larger stream like Pipestone Creek. The fish assemblage in this stream had few sensitive species (5.26%) and late maturing fish taxa (15.79%), while also having many tolerant (68.42%) and serial spawning (36.84%) taxa. All of these results indicate biological communities affected by the current DO conditions in this stream.

Figure 44: Trichorythodes photo courtesy of (www.insectsofiowa.com)

The wide ranging measured and predicted values along with the many poor scoring biological metrics and high phosphorus values indicates that this portion of Pipestone Creek is being stressed by the high daily flux of DO. Continuous DO monitoring is recommended to further evaluate this condition.

Pipestone Creek (10170203-505):

From 2011-2012 a total of 22 DO measurements were taken on this portion of Pipestone Creek. These DO values ranged from 6.69-11.09 mg/L with no readings below the minimum standard. There were no readings taken before 9AM, when DO levels tend to be the lowest.

The HSPF model calculated hourly DO values for this reach from 1996-2009. These values ranged from 4.2-14.53 mg/L with an average value of 10.63 mg/L. The number of calculated values below the standard was very minimal (0.095%).

Biologically, the macroinvertebrate community had a lower overall taxa count (20), but did have a higher amount of EPT taxa (26.09%). Many tolerant taxa (69.23%) were also present. The fish assemblage lacked any sensitive taxa and had many tolerant taxa (66.67%) and serial spawning species (33.33%). The site, 11MS015, did have a higher amount of late maturing taxa (33.33%), which may indicate that conditions are suitable enough for older fish to survive.

Based on the measured and calculated DO values and many of the related biological metrics, the lack of DO is not a stressor to the impaired biological assemblages at this time.

Pipestone Creek (10170203-506):

Fourteen DO measurements were taken from this AUID from 2004-2013. The DO values ranged from 6.25-12.55 mg/L with no readings below the daily minimum standard for DO. No readings were taken before 9 AM.

The HSPF model calculated hourly DO values for this reach from 1996-2009. The range of DO levels was from 4.65-14.8 mg/L with only two values falling below the minimum standard.

Biologically, the macroinvertebrate assemblage in this section of Pipestone Creek had a higher amount of EPT taxa (27.27%) and a fair amount of overall taxa (25). This reach also had many tolerant taxa (67.64%). The fish assemblage had a very high percentage of serial spawning taxa (42.53%), while also having many tolerant fish taxa (64.86%), and few sensitive (8.38%) and late maturing (13.83%) species. These results are typical in streams affected by poor DO conditions. The fish communities at 04MS021 and 11MS038 both had above average DO TIV scores when compared statewide.

The measured and predicted DO levels do not indicate a stressor. The biological metric results are fairly mixed which can be attributed to other stressors. The lack of DO is not a conclusive stressor to the impaired fish and macroinvertebrate communities in this portion of Pipestone Creek at this time. Continuous DO monitoring is recommended to better understand the DO conditions in this portion of Pipestone Creek.

North Branch Pipestone Creek (10170203-514):

From 2003-2013, 61 DO readings were taken from North Branch Pipestone Creek. These values ranged from 3.82-13.83 mg/L with six values falling below the 5 mg/L daily minimum standard. The wide range in values may indicate problems with daily flux.

The macroinvertebrate population in North Branch Pipestone Creek had a higher amount of EPT taxa (24.63%), but also had a lower overall taxa count (22.5 average) and many tolerant taxa (68.3%). The fish community in this reach had few sensitive (7.94%) and late maturing fish (13.83%), while also having many serial spawning (32.21%) and tolerant species (62.36%). These results are common in streams with low DO conditions.

The frequent violations of the daily minimum standard, the wide range of DO values, and the agreement with many of the DO related biological metrics makes this parameter a stressor the impaired fish and macroinvertebrate assemblages in North Branch Pipestone Creek.

Unnamed Creek (10170203-549):

From 2011-2013 a total of 10 DO measurements were taken from Unnamed Creek. These readings ranged from 5.89-11.34 mg/L with no values falling below the 5 mg/L minimum standard for DO (Table 18).

Table 18: Unnamed Creek (10170203-549) DO values from 2011-2013 at site 11MS049

Sample Location	Sample Date and Time	Result (mg/l)	Daily Minimum Standard (mg/l)
11MS049	8/4/2011 9:58 AM	5.89	5
11MS049	8/17/2011 8:49 AM	6.9	5
11MS049	5/7/2013 8:30 AM	11.03	5
11MS049	6/12/2013 10:15 AM	8.22	5
11MS049	6/26/2013 11:45 AM	6.15	5
11MS049	7/2/2013 8:00 AM	7.3	5
11MS049	7/11/2013 11:30 AM	7.60	5
11MS049	7/17/2013 8:40 AM	6.14	5
11MS049	8/8/2013 12:10 PM	11.34	5
11MS049	8/21/2013 1:00 PM	8.14	5

The HSPF model calculated hourly DO values for this reach from 1996-2009. Of these values, 10.69% were below the daily minimum standard for DO.

Biologically, the macroinvertebrate community in Unnamed Creek at site 11MS049 had a higher amount of EPT taxa (25%), but only averaged 10.5 taxa during the two sampling visits inflating the EPT taxa percentage. The EPT individual percentage (11.04) was well below the statewide average. Many tolerant taxa (78.57%) were sampled as well. The fish assemblage had zero sensitive species and few late maturing taxa (8.33%). The site also had many serial spawning (25%) and tolerant (75%) taxa as well as a slightly above average DO TIV score when compared to all other Minnesota streams.

More rigorous DO sampling would likely conclude that values often fall below the daily minimum standard. The many predicted values below 5 mg/L, the majority of the biological metrics, and the high presence of phosphorus in this stream reach all signal that low DO levels are indeed stressing the impaired biological assemblages in Unnamed Creek.

Candidate cause: high phosphorus

The proposed draft standard for phosphorus for streams in the Missouri River basin is currently 0.15 mg/L. Although phosphorus is an essential nutrient for all aquatic life, elevated levels can lead to an imbalance which impacts stream ecology. In the Pipestone Creek watershed phosphorus levels have exceeded this proposed standard multiple times.

Pipestone Creek (10170203-501):

From 2001-2013 a total of 71 phosphorus samples were taken from this AUID of Pipestone Creek. These values ranged from 0.002-1.39 mg/L with 35 of the samples above the 0.15 mg/L proposed draft standard for phosphorus (Figure 45).

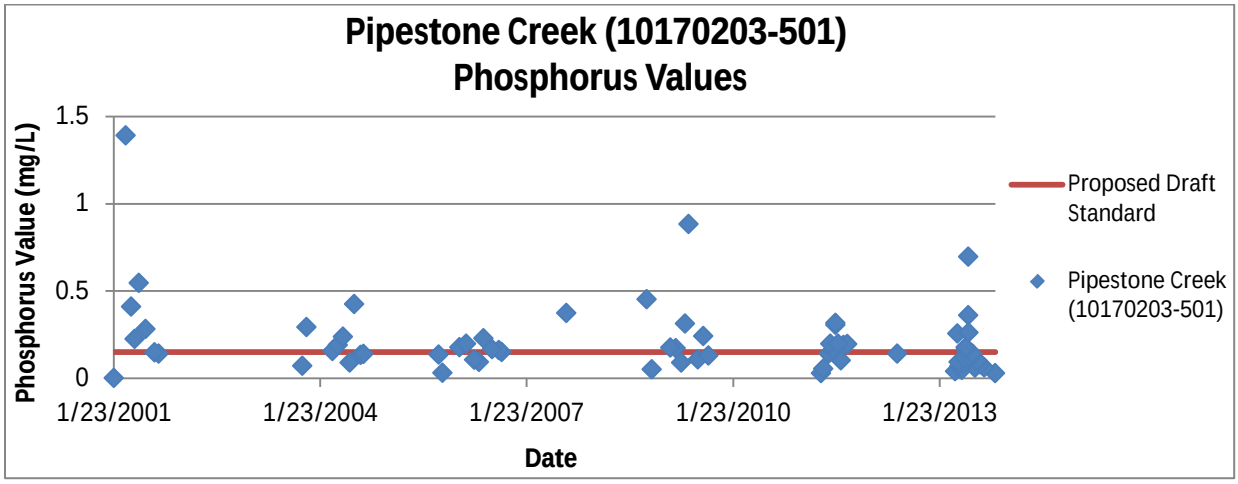

Figure 45: Pipestone Creek (10170203-501) phosphorus values from 2001-2013

Biologically, the macroinvertebrate community at site 11MS019 completely lacked any Tanytarsini taxa, which is typical of streams with elevated phosphorus levels. This site also had few intolerant taxa (3.85%), while having high levels of tolerant taxa (69.23%) and crustacean/Mollusca taxa (15.38%). Three individuals belonging to the genus *Physa* (snails) were found. These types of mollusks can often signal nutrient issues. Furthermore, the sample included 14 Hyalella individuals. These crustaceans can often signal impairment as they feed on organic material and detritus, so higher numbers can be a sign of eutrophication. The fish community in this stream was also very tolerant (68.42%) and had few sensitive species (5.26%). These numbers are normal in streams with excess phosphorus levels.

The numerous chemical samples above the draft standard along with the majority of the biological metrics related to phosphorus signal an issue. In addition, the wide range of DO values may be due to the excess phosphorus this stream reach experiences. For these reasons, phosphorus is a stressor to the impaired fish and macroinvertebrate communities in Pipestone Creek (10170203-501).

Pipestone Creek (10170203-505):

From 2011-2012, 11 phosphorus samples were taken along this portion of Pipestone Creek. These values ranged from 0.038-0.579 mg/L with six of the measurements above the 0.15 mg/L proposed draft standard for phosphorus (Table 19).

Table 19: Pipestone Creek (10170203-505) phosphorus values from 2011-2012
***Average of two values**

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
S006-580	5/4/2011	0.038	0.15
S006-580	5/16/2011	0.056	0.15
S006-580	6/15/2011	0.579	0.15
S006-580	6/23/2011	0.278	0.15
S006-580	7/7/2011	0.331	0.15
S006-580	7/20/2011	0.2845*	0.15
S006-580	8/3/2011	0.338	0.15
S006-580	8/17/2011	0.202	0.15
S006-580	9/1/2011	0.12	0.15
S006-580	9/20/2011	0.113	0.15
11MS015	6/19/2012	0.087	0.15

Biologically, the macroinvertebrate community at site 11MS015 along this portion of Pipestone Creek had zero Tanytarsini and intolerant taxa, while also having a high amount of tolerant (65.22%), scraper (17.39%) and crustacean/mollusca (21.74%) species. These results can be indicative of a stream with elevated phosphorus levels. This stream did have a high number of EPT taxa (26.09%), but much of these can be attributed to the high presence of Trichorythodes. This genus of mayfly is often present in large amounts in degraded conditions. The fish assemblage in this stream reach consisted of many tolerant taxa (66.67%) and no sensitive fish species.

The high rate of exceedance of the proposed phosphorus standard along with the strong agreement from the fish and macroinvertebrate communities makes phosphorus a stressor to the biological assemblages in this portion of Pipestone Creek.

Pipestone Creek (10170203-506):

From 2004-2013, thirteen samples were taken from this portion of Pipestone Creek. Eleven of these samples were taken in 2013. The range of values of all the samples was from 0.016-0.213 mg/L with two of the values above the 0.15 mg/L proposed draft standard for phosphorus.

The macroinvertebrate assemblage in Pipestone Creek (10170203-506) at sites 04MS021 and 11MS038 had higher numbers of Tanytarsini taxa (9.31%) than the previous two downstream reaches of Pipestone Creek. This reach also had an elevated number of Trichorythodes (66) at 04MS021. This AUID also had high presence of Polypedilum (109 individuals) at 11MS038, which is a genus of the non-biting midge family of chironomidae. These types of macroinvertebrates tend to be very abundant in eutrophic conditions. A high presence of tolerant individuals (67.64%) was also present in this stream reach. The fish community in this reach had many tolerant taxa (64.86%), while having few sensitive species (8.38%).

The phosphorus and related biological data have been fairly consistent throughout Pipestone Creek. The impaired fish and macroinvertebrate communities in this section of Pipestone Creek are also being stressed by the elevated levels of phosphorus.

North Branch Pipestone Creek (10170203-514):

From 2003-2011, 45 phosphorus samples were taken from North Branch Pipestone Creek. These values ranged from 0.036-0.422 mg/L with 19 (42.2%) samples above the proposed draft standard for phosphorus.

Figure 46: Algae at 11MS056

The macroinvertebrate population in this reach had few Tanytarsini taxa (3.06%), intolerant species (6.62%), while also having high amounts of tolerant taxa (68.3%), scraper species (16.18%), and crustacea/mollusca taxa (14.58%). These results are typical of streams experiencing periods of high phosphorus levels and eutrophication (Figure 46). High numbers of Hyalella and Trychorythodes are found at various sites along this AUID. The fish assemblage in this reach had a high amount of tolerant fish taxa (62.36%) and few sensitive fish species (7.94%).

The high exceedance rate of the proposed standard along with the agreement of the related biological metrics makes phosphorus a stressor to the impaired fish and macroinvertebrate assemblages in this reach.

Unnamed Creek (10170203-549):

From 2011-2013 a total of nine phosphorus samples were taken from Unnamed Creek. These values ranged from 0.03-0.394 mg/L with three of the samples above the proposed draft standard of 0.15 mg/L (Table 20).

Table 20: Unnamed Creek (10170203-549) phosphorus values from 2011-2013 at site 11MS049

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS049	8/17/2011	0.129	0.15
11MS049	5/7/2013	0.032	0.15
11MS049	6/12/2013	0.09	0.15
11MS049	6/26/2013	0.143	0.15
11MS049	7/2/2013	0.048	0.15
11MS049	7/11/2013	0.394	0.15
11MS049	7/17/2013	0.236	0.15
11MS049	8/8/2013	0.065	0.15
11MS049	8/21/2013	0.162	0.15

Biologically, the macroinvertebrate community in Unnamed Creek completely lacked any intolerant taxa, while having a high number of crustacean/Mollusca population (17.86% taxa). A total of 248 Hyalella (Figure 47) individuals (80.5%) were sampled. These crustaceans can often signal impairment as they feed on organic material and detritus, so higher numbers can be a sign of eutrophication. Few tolerant species (78.57%) existed in Unnamed Creek as well.

Figure 47: Hyalella

The fish assemblage in Unnamed Creek had many tolerant taxa (75%), while have no sensitive species and very few darter individuals (1.15%). These results are common in streams negatively impacted by excess phosphorus levels.

The number and degree of exceedances of the proposed phosphorus standard along and the agreement of the related biological metrics makes phosphorus a stressor to the impaired fish and macroinvertebrate communities in Unnamed Creek.

Candidate cause: high nitrates

Currently, the State of Minnesota does not have a nitrate standard in place for streams not used as a drinking water source. However, an overabundance of nitrates can stress a biological community. Nitrates in the Pipestone Creek watershed did, at times, reach levels that could potentially be stressing the biological assemblages.

Pipestone Creek (10170203-501):

Pipestone Creek had 76 nitrate samples taken from 2001-2013. These sample values ranged from 0.05-14 mg/L (Figure 48).

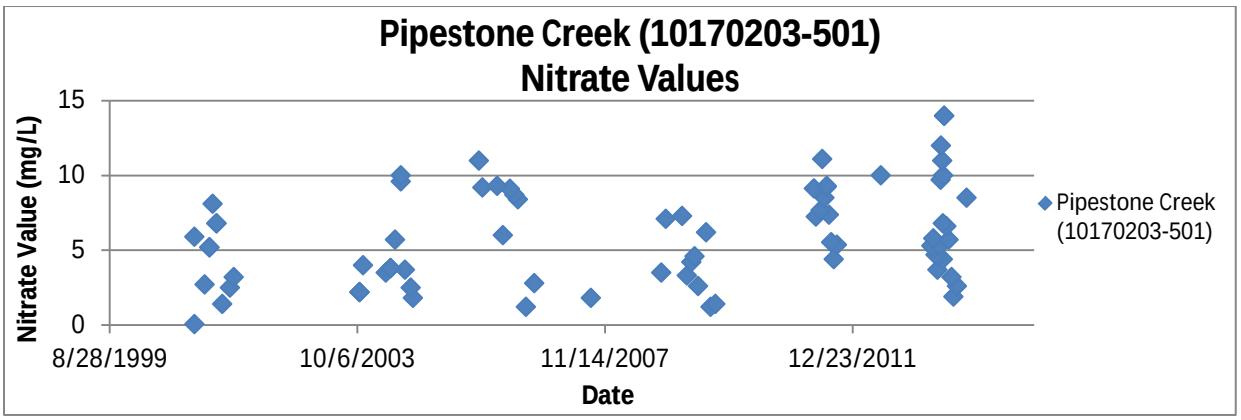

Figure 48: Pipestone Creek (10170203-501) nitrate values from 2001-2013

Biologically, the macroinvertebrate community in this most downstream portion of Pipestone Creek had a lower overall taxa count (18), while also having few Trichoptera taxa (7.69%). Furthermore, a quantile regression analysis showed that when macroinvertebrate class 7 sites like 11MS019 experienced nitrate levels above 11.5 mg/L, there is a 90% chance that the stream will be impaired for macroinvertebrates. This level was exceeded three different times from 2001-2013. The fish community had good overall taxa count (19), but had very few sensitive fish taxa (5.26%).

The elevated nitrate levels experienced in Pipestone Creek (10170203-501) along with the nitrate-related biological metrics in conjunction with the quantile regression analysis all signal that the impaired biological assemblages in this AUID are being stressed by excess levels of nitrate.

Pipestone Creek (10170203-505):

This AUID of Pipestone Creek had 11 nitrate samples taken from 2011-2012 with sample values ranging from 3.4-8.06 mg/L (Table 21).

Table 21: Pipestone Creek (10170203-505) nitrate values from 2011-2012

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
S006-580	5/4/2011	7.68	n/a
S006-580	5/16/2011	5.98	n/a
S006-580	6/15/2011	8.06	n/a
S006-580	6/23/2011	7.27	n/a
S006-580	7/7/2011	7.14	n/a
S006-580	7/20/2011	4.66	n/a
S006-580	8/3/2011	6.89	n/a
S006-580	8/17/2011	5.21	n/a
S006-580	9/1/2011	3.4	n/a
S006-580	9/20/2011	3.49	n/a
11MS015	6/19/2012	8.6	n/a

The HSPF model calculated daily nitrate values from Pipestone Creek from 1996-2009. These values ranged from 1.62-18.48 mg/L with an average value of 5.27 mg/L.

Biologically, the macroinvertebrate assemblage at 11MS015 along Pipestone Creek had few nitrate sensitive Trichoptera taxa (8.71%), while also having a lower overall taxa count (20). Quantile regression analysis comparing MIBI scores and nitrate tolerant taxa showed that class 7 sites with more than 87.71% nitrate tolerant taxa have a 90% chance of being impaired. Site 11MS015 exceeded this value by having a population of 89.03% nitrate tolerant taxa. The fish community in this reach had a relatively average overall taxa count (12), but was completely devoid of any sensitive species.

The observed nitrate levels show signs of reaching levels that may be stressing the biological assemblages. The model also predicted high levels of nitrates within this reach. The biological data available strongly suggests that elevated nitrates are negatively impacting the biological assemblages. Therefore, excess nitrates are a stressor to the biology in Pipestone Creek.

Pipestone Creek (10170203-506):

From 2004-2013, thirteen nitrate samples were taken along this reach of Pipestone Creek. These nitrate values ranged from 2-24 mg/L. A quantile regression analysis comparing nitrate values and macroinvertebrate IBIs showed that with 90% probability that a class 7 site like 11MS038 would be below the IBI threshold with nitrate values above 11.5 mg/L. This site had three values over 20 mg/L.

Biologically, the macroinvertebrate community at sites 04MS021 and 11MS038 had a higher overall taxa count (25) than the two downstream sections of Pipestone Creek, but did have fewer nitrate sensitive Trichoptera taxa (5.09%). These sites did have a good overall fish taxa count (18), but did have few sensitive taxa (8.38%).

The high recorded nitrate values, quantile regression analysis and the nitrate related biological metrics all indicate that excessive nitrates are indeed causing stress to the impaired fish and macroinvertebrate communities in this section of Pipestone Creek.

North Branch Pipestone Creek (10170203-514):

From 2002-2011 a total of 47 nitrate samples were taken along this AUID. These nitrate values ranged from 0.73-13 mg/L. The average nitrate value was 4.58 mg/L.

The HSPF model calculated daily nitrate levels from 1996-2009 along North Branch Pipestone Creek. These levels ranged from 1.07-20.4 mg/L with an average value of 4.63 mg/L. These results are similar to the observed results.

Biologically, the macroinvertebrate community at sites (11MS050, 11MS056, 06MS001, 06MS002) along this AUID averaged 22.5 taxa, which is low when compared to all other Minnesota streams. This reach did have the highest amount of nitrate sensitive Trichoptera taxa (9.74%) along Pipestone Creek, but this total is still considered low. Quantile regression analysis showed that class 7 macroinvertebrate sites with 87.71% nitrate tolerant taxa have a 90% probability of being impaired. Site 11MS050 is a class 7 macroinvertebrate site that had 87.25% nitrate tolerant taxa. The fish assemblage at these sites had a high overall taxa count (18.5), but had few sensitive fish taxa (7.94%).

Based on the observed, calculated, and the majority of the biological analysis, nitrate levels do become elevated enough in North Branch Pipestone Creek to stress the impaired fish and macroinvertebrate communities.

Unnamed Creek (10170203-549):

From 2011-2013 nine nitrate samples were taken from Unnamed Creek. These values ranged from 1-4.1 mg/L (Table 22).

Table 22: Unnamed Creek (10170203-549) nitrate sample values from 2011-2013 at site 11MS049

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS049	8/17/2011	3.6	n/a
11MS049	5/7/2013	4.1	n/a
11MS049	6/12/2013	1.5	n/a
11MS049	6/26/2013	3.2	n/a
11MS049	7/2/2013	2.9	n/a
11MS049	7/11/2013	1.7	n/a
11MS049	7/17/2013	2.1	n/a
11MS049	8/8/2013	1.3	n/a
11MS049	8/21/2013	1	n/a

Biologically, the macroinvertebrate community in Unnamed Creek at site 11MS049 had a low overall taxa count (10.5) and few Trichoptera taxa (7.14%). Site 11MS049 had a low amount of nitrate tolerant taxa (17.36%). The fish community had an ample overall taxa count (12), but lacked any sensitive fish taxa.

The low scores of some of the nitrate related biological metrics are likely due to other stressors. The low measured values and the low amount of nitrate tolerant taxa indicate that nitrate is not a stressor to the impaired fish and macroinvertebrate communities at this time.

Candidate cause: high turbidity/TSS

The water quality standard for turbidity is 25 NTU, 65 mg/L for TSS, and 20 cm for transparency tube for these class 2B warmwater streams in the Pipestone Creek watershed. Excess sediment is a commonly recognized stressor in many biologically impaired streams because it can reduce habitat, cause direct physical harm, as well as reduce visibility and increase oxygen demand.

Two reaches, Pipestone Creek (10170203-501) and North Branch Pipestone Creek (10170203-514) are currently impaired for aquatic life due to turbidity in addition to their biological assemblages. The other biologically impaired reaches in this watershed currently do not have enough data for a turbidity impairment designation, but these streams all have exceedances of the TSS and/or the transparency standards.

Pipestone Creek (10170203-501):

In this section of Pipestone Creek a total of 72 TSS samples were taken from 2001-2013 with values ranging from 6-220 mg/L. Twenty-one of these samples were at or above the 65 mg/L TSS standard (Figure 49). Additionally, the transparency data available for this AUID has a 47% exceedance rate of the 20 cm standard. This reach is currently listed as impaired for turbidity.

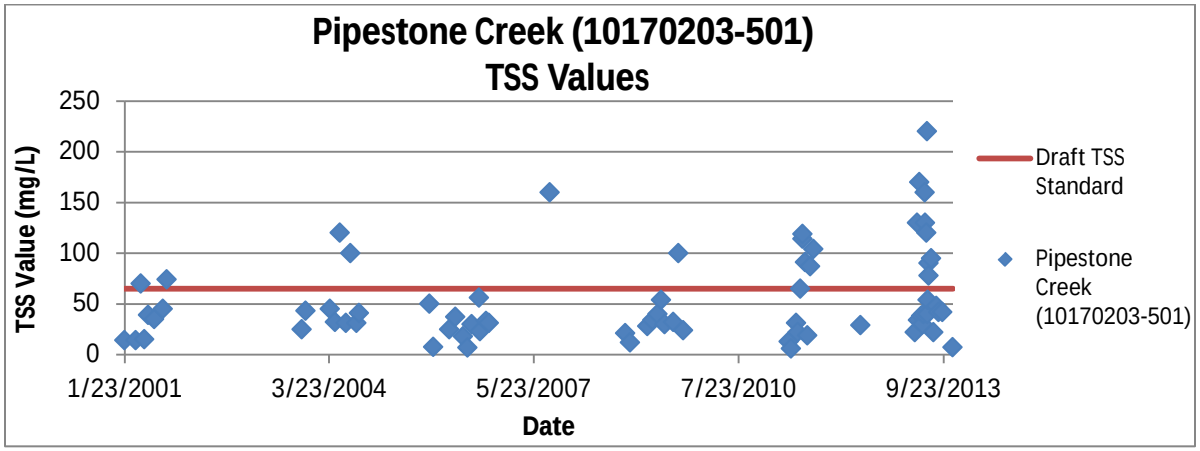

Figure 49: TSS values at Pipestone Creek (10170203-501) from 2001-2013

Biologically, the macroinvertebrate community at 11MS019 along this Pipestone Creek AUID had few Trichoptera (7.69%) and collector-filterer (3.85%) species, while having few overall taxa (18). This stream did have a higher amount of scraper species (19.23%) and Ephemeroptera taxa (23.08%), which was likely due to the overwhelming presence of Trichorythodes. The macroinvertebrate community also had a very high amount of TSS tolerant individuals (84.49%). The fish assemblage in this reach had few herbivorous fish species (5.26%) and many tolerant taxa (68.42%).

Pipestone Creek (10170203-501) is currently listed as impaired for turbidity. The recent chemical and biological data also confirm this impairment and that this parameter is indeed stressing the fish and macroinvertebrate communities in this reach.

Pipestone Creek (10170203-505):

From 2011-2012 a total of 12 TSS samples were taken from Pipestone Creek (10170203-505) with sample values ranging from 18-185 mg/L with four samples at levels above the 65 mg/L TSS standard. Additionally, there were 21 transparency/Secchi tube readings taken from this reach. These measurements ranged from 4.75-51 cm with 15 of the values below the 20 cm transparency standard (Figure 50).

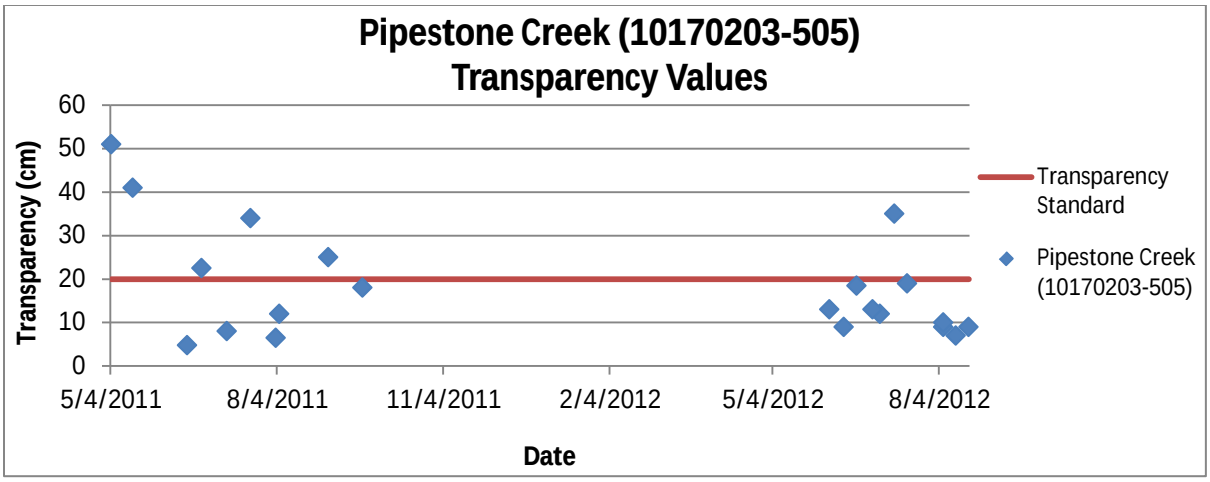

Figure 50: Pipestone Creek (10170203-505) transparency tube values from 2011-2012

Biologically, the macroinvertebrate community in this portion of Pipestone Creek had few Trichoptera taxa (8.7%), overall taxa (20), and collector-filterer species (4.35%), while also having a low amount of chironomid species (13.04%) and many tolerant taxa (65.22%). Additionally, this AUID did have a higher amount of scraper species (17.39%), TSS tolerant individuals (85.89%) and Ephemeroptera taxa (17.39%), which have a negative relationship with an increase in TSS. The fish assemblage along this reach had many tolerant taxa (66.67%) and zero herbivorous species. These results indicate potential stress.

The frequent exceedances of the TSS and transparency standards along with the agreement of the majority of the biological metrics makes TSS/turbidity a stressor to the impaired fish and macroinvertebrate communities in this portion of Pipestone Creek.

Pipestone Creek (10170203-506):

From 2004-2013 a total of 13 TSS samples were taken from this reach of Pipestone Creek with values ranging from 7.6-240 mg/L. Four of these samples were above the 65 mg/L TSS proposed draft standard. Additionally, 14 transparency/Secchi tube readings were taken during this time frame. These measurements ranged from 6-65 cm with five measurements falling below the 20 cm minimum standard for transparency.

Biologically, the macroinvertebrate assemblage in this portion of Pipestone Creek had small numbers of Trichoptera (5.09%) and collector-filterer (8.98%) taxa, while also having many tolerant species (67.64%). This reach also had a higher overall taxa count (25) and above average amounts of scraper (13.53%) and Ephemeroptera (22.19%) taxa when compared to all other Minnesota streams. The amount of TSS tolerant individuals (51.3%) was also higher than the statewide average. The fish community had few herbivorous taxa (5.44%) and also had many tolerant taxa (64.86%).

The frequent exceedances of the TSS and transparency standards are backed up by the majority of the TSS/turbidity related biological metrics, therefore making TSS/turbidity a stressor to the impaired fish and macroinvertebrate communities in this section of Pipestone Creek.

North Branch Pipestone Creek (10170203-514):

North Branch Pipestone Creek (10170203-514) is listed as impaired for turbidity. This reach had 49 TSS samples taken from 2002-2011 with values ranging from 5.2-96 mg/L. Five of the samples were above the 65 mg/L proposed standard for TSS. An extensive transparency data set exists for this reach. From 2002-2013, 268 measurements were taken with 147 of these readings falling below the 20 cm transparency standard.

Biologically, the macroinvertebrate community in North Branch Pipestone Creek had an average amount of chironomid species (33.1%) when compared to all other Minnesota streams. These species tend to be present in high amounts in streams with elevated TSS/turbidity levels. This stream also had a low overall taxa count (22.5), few Trichoptera (9.74%) and collector-filterer (9.19%) species, while also having many tolerant taxa (68.3%). The fish community had few herbivorous taxa (5.44%) and many tolerant species (62.36%).

This reach of North Branch Pipestone Creek is currently impaired for turbidity. The majority of the TSS/turbidity related biological metrics along with the chemical date indicate that TSS/turbidity is indeed stressing the impaired fish and macroinvertebrate communities in this stream.

Unnamed Creek (10170203-549):

Unnamed Creek had nine TSS samples taken from 2011-2013. These values ranged from 2.8-500 mg/L with two of the samples above the 65 mg/L TSS standard. Additionally, ten transparency/Secchi tube readings were taken from this reach during this time period. These values ranged from 6 to greater than 100 cm. Four of these measurements were below the 20 cm minimum standard for transparency (Table 23).

Table 23: TSS and Secchi tube values from 2011-2013 at site 11MS049 along Unnamed Creek (10170203-549)

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS049	8/4/2011	n/a	65	9	20
11MS049	8/17/2011	39	65	17	20
11MS049	5/7/2013	2.8	65	>100	20
11MS049	6/12/2013	3.6	65	66	20
11MS049	6/26/2013	7.2	65	70	20
11MS049	7/2/2013	4.8	65	>100	20
11MS049	7/11/2013	500	65	6	20
11MS049	7/17/2013	9.2	65	79.5	20
11MS049	8/8/2013	24	65	32	20
11MS049	8/21/2013	99	65	16	20

Biologically, the macroinvertebrate assemblage in Unnamed Creek at biological station 11MS049 had few Trichoptera species (7.14%), a low overall taxa count (10.5), and few scraper species (7.14%), while also having many tolerant taxa (78.57%). This site did show better numbers of collector-filterer taxa (21.43%) than the other biologically impaired reaches in this watershed. The fish community in this reach showed higher numbers of herbivorous taxa (8.33%), but also had a high amount of tolerant species (75%) and had a below average TSS TIV score when compared to all other Minnesota streams.

Similarly to the other biologically impaired reaches in this watershed, the high number of transparency exceedances, the very high degree of exceedance in the TSS measurements, and the agreement with many of the biological metrics in this stream alludes to TSS/turbidity being a stressor to the impaired fish and macroinvertebrate communities in Unnamed Creek.

Candidate cause: lack of habitat

Habitat quality in Pipestone Creek watershed varied from poor to fair in the biologically impaired reaches. The MSHA was the main tool used for evaluating this potential stressor and the results of these habitat scores can be seen in Figure 51.

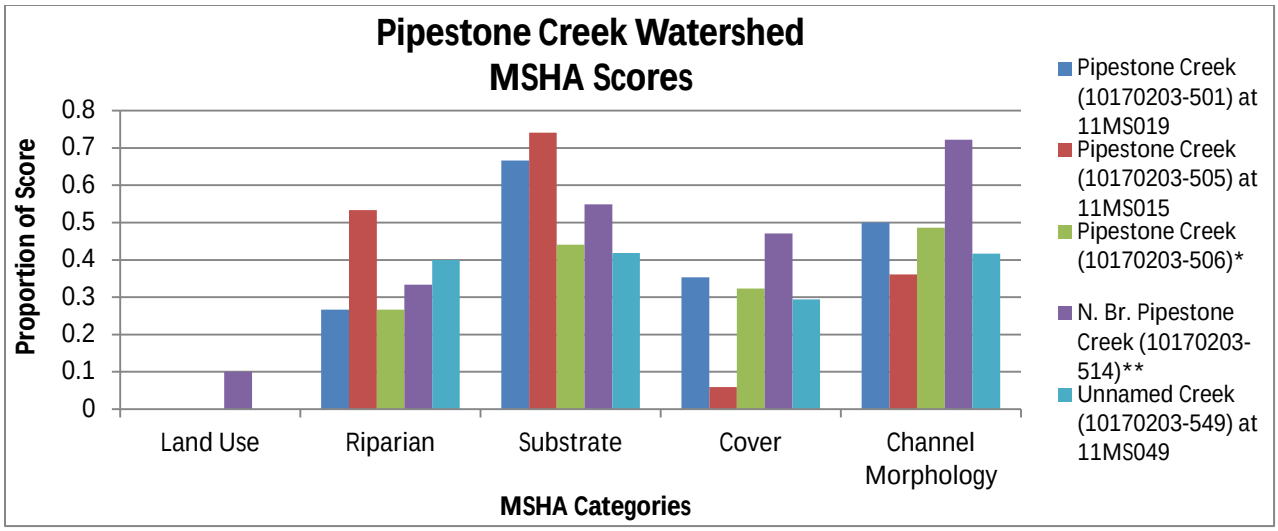

Figure 51: Pipestone Creek watershed MSHA scores
***Average MSHA scores from 04MS021 and 11MS038**
****Average MSHA scores from 11MS050 and 11MS056**

Pipestone Creek (10170203-501):

During the fish sampling event at site 11MS019, a qualitative habitat assessment was performed. The site had an MSHA score of 46, which is considered to be fair. Limiting the MSHA score at this site was the poor surrounding land use, the complete lack of a riparian buffer, very limited stream shading, sparse fish cover, low channel stability, and fair channel development.

The macroinvertebrate sample at 11MS019 was taken only from overhanging vegetation because suitable riffles and woody debris were unavailable. The macroinvertebrate community had lower amounts of clinger species, while also having many tolerant taxa (69.23%). The fish assemblage in this reach had low numbers of riffle dwelling (15.79%), simple lithophilic spawning (15.79%) and darter/sculpin/round-bodied sucker (10.53%) species. The low channel stability, embedded course substrates, and presence of sand is likely preventing more diverse fish and macroinvertebrate assemblages.

The relatively low MSHA score along with the majority of poorly scoring habitat related biological metrics makes the lack of habitat a stressor to the impaired fish and macroinvertebrate communities in Pipestone Creek (10170203-501).

Pipestone Creek (10170203-505):

Site 11MS015 along this AUID of Pipestone Creek had a qualitative habitat assessment performed during the fish sampling visit in 2012. The MSHA score of this site was 42, which is considered to be poor. The MSHA score was mainly limited by the poor surrounding land use, no stream shading, nearly absent fish cover, fair channel development, moderate channel stability and very little depth variability.

Biologically, the macroinvertebrate assemblage in this AUID had a low amount of clinger taxa (17.31%), while also having many tolerant taxa (65.22%). The fish community at site 11MS015 was very tolerant (66.67% taxa), while also having few benthic insectivores (16.67%), simple lithophilic spawning (16.67%), and darter/sculpin/round-bodied sucker species (8.33%).

The fair MSHA score along with the majority of habitat related biological metrics makes the lack of habitat a stressor to the impaired fish and macroinvertebrate communities in this section of Pipestone Creek.

Pipestone Creek (10170203-506):

This portion of Pipestone Creek had two qualitative habitat assessments taken at its biological stations 04MS021 and 11MS038 (Figure 52). The average score for these sites was 38.9, which is considered to be poor. Limiting the MSHA scores along this AUID was the poor land use (Figure 3X), non-existent riparian buffer, moderate bank erosion, light stream shading, a sand/silt dominant substrate, nearly absent fish cover, moderate channel stability, fair channel development, fair sinuosity, and limited depth variability.

Figure 52: Heavily pastured riparian land use at 11MS038

The macroinvertebrate sample came from all overhanging vegetation at site 11MS038 and equal parts overhanging vegetation and riffle habitats at site 04MS021. The macroinvertebrate community in this reach contained many tolerant taxa (67.64%), while also having a slightly below average amount of clinger taxa (27.92%) when compared to other streams throughout Minnesota. The fish assemblage in this reach did show good numbers of riffle-dwelling species (19.27%) despite very little riffle habitat available. This reach also had higher numbers of benthic insectivore (32.65%) and darter/sculpin/round-bodied sucker (18.83%) species. However, this reach had many tolerant taxa (64.86%) and had a lower number of simple lithophilic spawning species (21.33%), which may have been limited by the presence of sand/silt subtrates, and moderately embedded gravel substrates.

While the habitat related biological metric results were a bit mixed, the poor MSHA scores along with the photographic evidence overwhelmingly indicates that the fine sediment substrates and overall lack of habitat is indeed a stressor to the impaired fish and macroinvertebrate communities of this section of Pipestone Creek.

North Branch Pipestone Creek (10170203-514):

North Branch Pipestone Creek had qualitative habitat assessments taken at two of its biological monitoring stations, 11MS050 and 11MS056. The average MSHA score of these sites was 54.33, which is considered to be fair. Bringing down the MSHA scores along this stream reach was the poor land use, a very narrow riparian area, the presence of silt/sand substrates, moderate channel erosion, light stream shading, and low to moderate channel stability.

The macroinvertebrate assemblage in this reach showed a good number of clinger taxa (31.04%), but also had many tolerant species (68.3%). The fish community in this reach showed good numbers of riffle dwelling (19.27%), benthic insectivore (29.27%), simple lithophilic spawning (27.21%), and darter/sculpin/round-bodied sucker (18.83%) species. A high presence of tolerant taxa (62.36%) was also present in this reach.

The habitat conditions in North Branch Pipestone Creek were much better than the biologically impaired reaches further downstream. The lack of habitat is not a stressor to the impaired fish and macroinvertebrate assemblages in North Branch Pipestone Creek at this time.

Unnamed Creek (10170203-549):

Unnamed Creek had a qualitative habitat assessment performed during its fish sampling visit at its biological station 11MS049. The MSHA score for this site was 37.3 (poor). Limiting the habitat in this reach was the poor surrounding land use, the complete lack of riparian buffer, minimal stream shading, silty substrates, sparse fish cover and cover types, poor channel development, moderate channel stability, and fair channel sinuosity.

Biologically, the macroinvertebrate community had lower numbers of clinger taxa (21.43%) and a high presence of tolerant taxa (78.57%). The fish assemblage had fewer benthic insectivore (16.67%) and darter/sculpin/round-bodied sucker (8.33%) taxa, while also having a high amount of tolerant fish taxa (75%). Average numbers of simple lithophilic spawning taxa (25%) and riffle dwelling species (16.67%) were present.

The poor MSHA score which correlates with many of the poor scoring habitat related biological metrics makes the lack of habitat a stressor to the impaired fish and macroinvertebrate communities in Unnamed Creek.

Conclusion

Many stressors to the biological communities exist within the Pipestone Creek watershed as all of the candidate causes examined is present at the majority of the AUIDs studied (Table 24).

The lack of DO was determined to be a stressor at three of the five biologically impaired reaches within this watershed: Pipestone Creek (10170203-501), North Branch Pipestone Creek (10170203-514) and Unnamed Creek (10170203-549). These reaches had both observed and model predicted DO level well below the daily minimum standard. These values were also wide ranging which may indicate significant influence from the elevated phosphorus concentrations these reaches are also experiencing. These reaches lacked many sensitive and late maturing fish species, while having many tolerant and serial spawning fish taxa. The macroinvertebrate assemblages in these reaches lacked species richness and was dominated by tolerant species. Low DO in Pipestone Creek is likely due to the excess amounts of phosphorus and nutrient concentrations. These nutrients contribute to algae growth and as the algae die and decompose, the process consumes DO.

Phosphorus concentrations in the Pipestone Creek watershed exceeded the proposed draft standard frequently with one observed value reaching a concentration greater than nine times the draft standard. These high concentrations have led to excessive algae growth that can negatively impact the DO conditions as well as the habitat. The high levels of phosphorus are likely due to the easy access of fertilizers from the poor surrounding land use and limited riparian buffer along these impaired streams. Wide spread change is needed throughout this watershed to help mitigate the phosphorus problem.

High nitrates were also found to be stressing the biological communities at each of the impaired reaches within this watershed except for Unnamed Creek (10170203-549). Nitrate concentrations were found to be as high as 24 mg/L along these AUIDs. These conditions created macroinvertebrate communities with few Trichoptera taxa with many nitrate tolerant individuals. Excess nitrates may have also contributed to the excess algae growth observed in the watershed. Fertilizer runoff from fields adjacent to these streams is a likely source of these high nitrate concentrations. Installing a proper riparian buffer along with a nutrient management plan would help limit the abundance of nitrates entering the stream system.

Excess turbidity and TSS is a widespread problem within the Pipestone Creek watershed. Currently, two reaches are currently impaired for aquatic life due to turbidity. This study shows that all of the biologically impaired reaches are being negatively impacted by high levels of turbidity and TSS. These conditions are a likely result from the intensive grazing this watershed experiences. This practice leads to unstable and erodible bank resulting in excess sediment being distributed throughout the stream channel and water column.

In-stream habitat was also determined to be a stressor at all of the biologically impaired AUIDs within this watershed except North Branch Pipestone Creek. MSHA scores ranged from poor to fair with the lowest scores coming from the headwaters area in the watershed. The habitat was mainly limited by the poor surrounding land use, sparse fish cover, limited stream shading, a lack of riparian buffer, poor

channel development, low channel stability and many silty/sandy substrates. Properly fencing off cattle in the intensively grazed lands surrounding these streams would go a long way to stabilize the stream banks and help return the stream to a condition where habitat is not limiting. Further habitat improvement projects would also help alleviate the stress causing the biological communities in this watershed.

Stressors to the biological communities are wide-spread in the Pipestone Creek watershed. Significant improvements must be made to nutrient and sediment reduction, habitat, and surrounding land use. Biological conditions in this watershed will likely remain the same or worsen if advances in conservation are not made.

Table 24: Biologically impaired reaches in the Pipestone Creek watershed and their stressors

(• = stressor, - = not a stressor, and blank = inconclusive/not enough evidence)

		Stressors				
Stream Name	**AUID #**	**Low Dissolved Oxygen**	**High Phosphorus**	**High Nitrates**	**High Turbidity/TSS**	**Lack of Habitat**
Pipestone Creek Watershed						
Pipestone Creek	10170203-501	•	•	•	•	•
Pipestone Creek	10170203-505		•	•	•	•
Pipestone Creek	10170203-506		•	•	•	•
North Branch Pipestone Creek	10170203-514	•	•	•	•	
Unnamed Creek	10170203-549	•	•		•	•

Split Rock Creek watershed

Overview

The Split Rock Creek watershed consists of five impaired AUIDS. These include: Split Rock Creek (10170203-512), Unnamed Creek (10170203-553), Unnamed Creek (10170203-538), Split Rock Creek (10170203-507), and Split Rock Creek (10170203-509). See Figure 53 for a spatial view of the impaired reaches within the watershed. Land use in the Split Rock Creek watershed consists of mostly cropland (77.25%), followed by rangeland (14.79%) and developed (6.19%).

Split Rock Creek (10170203-512) is a 6.81 mile stream reach that runs from Pipestone Creek to the Minnesota/South Dakota border. This AUID is impaired for aquatic life due to turbidity and its fish assemblage at the biological monitoring station 11MS013. This section will focus on the fish community impairment.

Split Rock Creek (10170203-507) is a 13.64 mile reach that extends from Split Rock Lake to the confluence with Pipestone Creek. This AUID is impaired for aquatic life due to DO as well as the fish and macroinvertebrate assemblages at the two biological monitoring stations, 04MS005 and 11MS052. This section of the report will focus on the fish and macroinvertebrate impairments.

Split Rock Creek (10170203-509) is an 11.91 mile stream reach that extends from the headwaters to Split Rock Lake. This AUID is impaired for aquatic life due to its fish and macroinvertebrate assemblages at the biological monitoring station 04MS031.

Unnamed Creek (10170203-538) is a 4.03 mile stream reach that extends from a confluence with an unnamed creek (approximately 0.2 miles west of 40th Ave) to another confluence with an unnamed creek (approximately 0.25 miles west of 20th Ave). This AUID is impaired for aquatic life due to its macroinvertebrate assemblage at its biological monitoring station, 11MS045. This site was not assessed for its fish community as the sampling visit was deemed non-reportable due to the high flow conditions.

Unnamed Creek (10170203-553) is a 1.74 mile stream reach that extends from an unnamed creek (just north of 201st St) to a confluence with another unnamed creek (approximately 0.84 miles north of 211th St). This AUID is impaired for aquatic life due to both its fish and macroinvertebrate assemblages at its biological monitoring station, 11MS058.

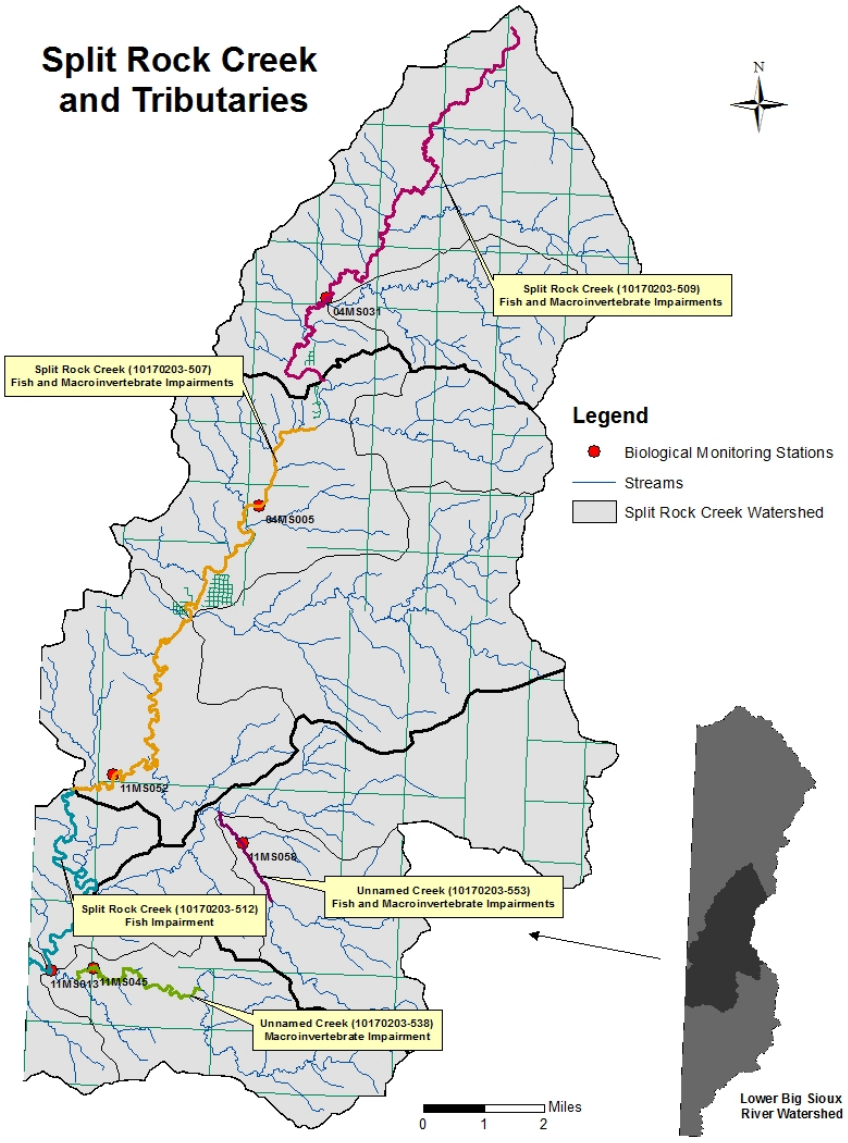

Figure 53: Split Rock Creek watershed with biologically impaired reaches highlighted

Biology in the Split Rock Creek watershed

Fish

The Split Rock Creek watershed contains five biologically impaired AUIDs. The most downstream AUID, Split Rock Creek (10170203-512), has a biological monitoring station (11MS013) that is located downstream of CR 7, eight miles south of Jasper. This site was sampled for fish on June 19th, 2012. Moving upstream is Split Rock Creek (10170203-507) and its two biological monitoring sites. Site 04MS005 is upstream of CR 53, 1.4 miles northeast of Jasper and was sampled for fish on August 11th, 2004 while site 11MS052 is located upstream of Township Rd 21, 3.75 miles southwest of Jasper and was sampled on June 20th, 2012. In the headwaters, Split Rock Creek (10170203-509) contained one biological monitoring site (04MS031) that is located downstream of Hwy 23, 0.75 miles north of Ihlen and was sampled on August 11th, 2004 and again on August 3rd, 2011. Lastly there is Unnamed Creek (10170203-553) and its biological site, 11MS058, located downstream of Township Rd 73, four miles south of Jasper. This site was sampled on August 2nd, 2011.

Split Rock Creek (101702033-512) is classified as a fish class 1 (Southern Rivers) stream (Figure 54). The fish sampling visit at biological monitoring station 11MS013 had an IBI score of 10.0. The IBI impairment threshold for this fish classification is 46. To reach the threshold, each fish metric would need a value score of 4.18. At this site, the only metric to reach this level was DomTwoPct, which means this site was not dominated by two taxa. This site scored slightly below average in the DetNWQTxPct metric, which shows a slightly higher amount of detritivorous fish taxa. All other metrics scored poorly.

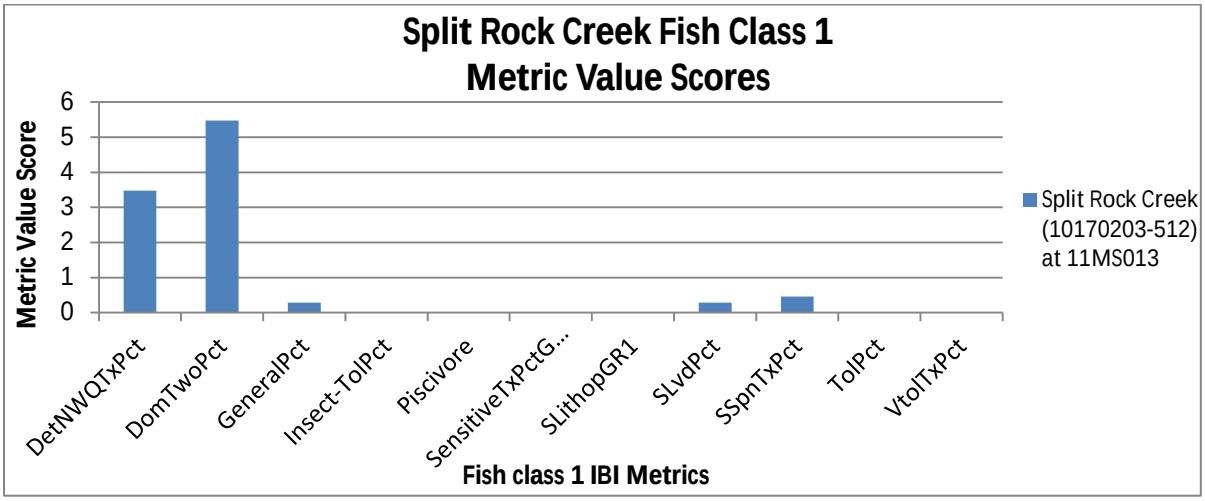

Figure 54: Fish class 1 metric value scores at site 11MS013 along Split Rock Creek (10170203-512)

The impaired stream reach, 10170203-507, located on Split Rock Creek is classified as a fish class 2 (Southern Streams) site (Figure 55). Fish IBI scores along this AUID were 26 at 04MS005 (the most upstream site) and 39 at 11MS052 (the most downstream site). The fish IBI threshold for a class 2 stream is 45 and each metric would need to have an average score of 5.625 to reach this level. Site 04MS005 only reached this level in the short lived taxa percentage metric (SLvd), meaning this site had lower amounts of short lived species which raised the fish IBI. All other metrics at this site scored below the average needed to reach the threshold. Site 11MS052 had metric value scores above the average needed to reach the threshold for half of the metrics. Metrics scoring poorly were the presence of early maturing individuals (MA<2Pct), low numbers of sensitive species (SensitiveTxPct), high presence of short lived taxa (SLvd) and high numbers of tolerant species (TolPct).

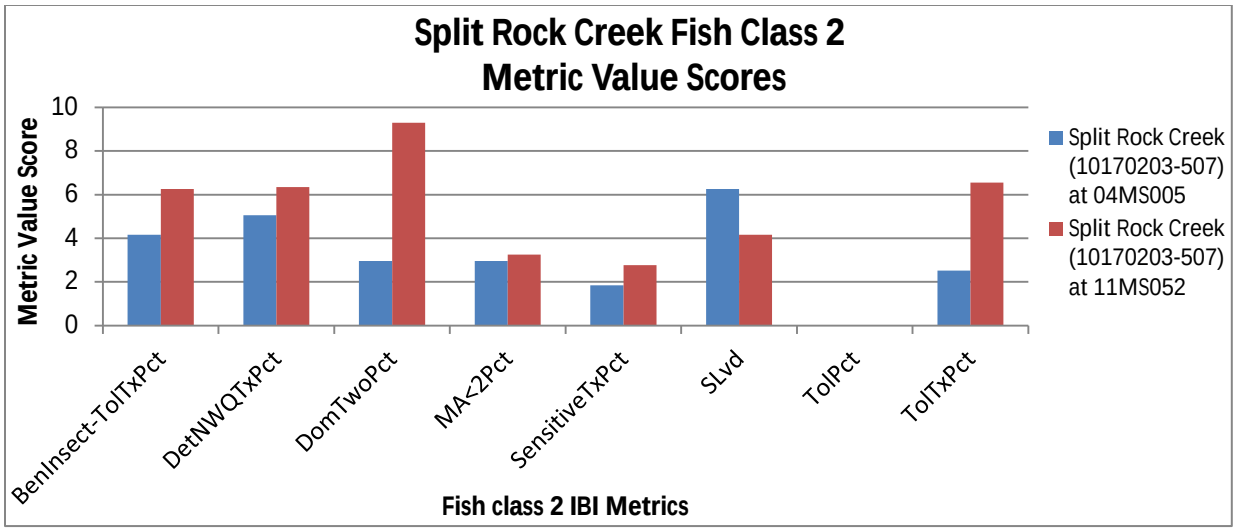

Figure 55: Fish class 2 metric value scores at sites along Split Rock Creek (10170203-507)

Two of the impaired AUIDS in the Split Rock Creek area are classified as class 3 Southern Headwaters streams (Figure 56). The threshold score for this stream classification is 51 and each metric would need an average score of 8.5 to reach this level. Split Rock Creek (10170203-509) had an average fish IBI score of 44.5 at site 04MS031 after visits in 2004 and 2011. Metrics meeting the average score needed were the percentage of short lived species (SLvdPct) and percentage serial spawner taxa (SSpnPct). Unnamed Creek (10170203-553) had a fish IBI score of 34 at its biological site 11MS058. This site had a lower amount of detritivorous taxa, which resulted in a high metric value score. The remaining metrics scored poorly.

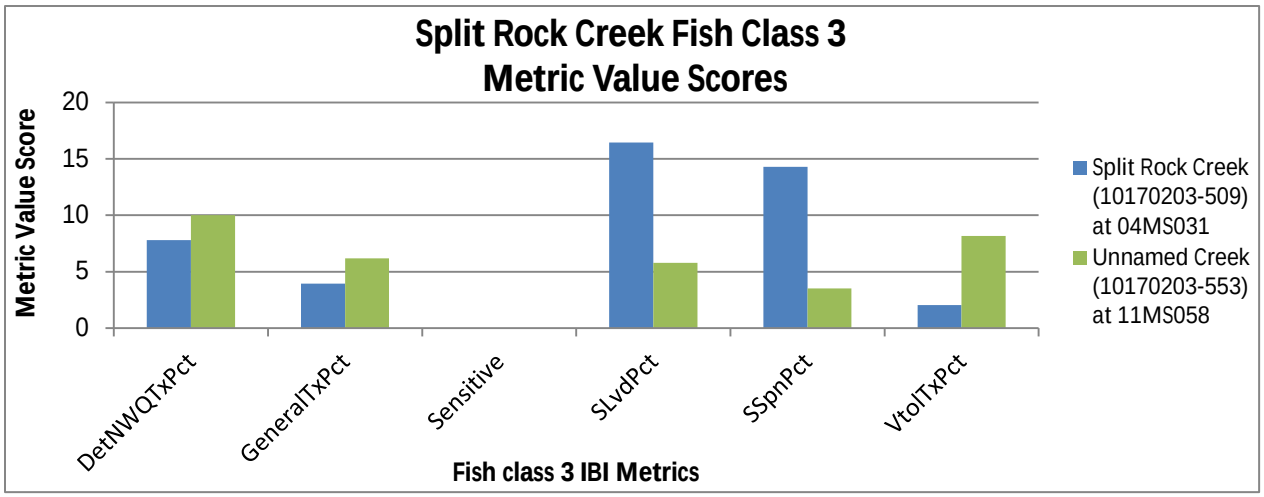

Figure 56: Fish class 3 metric value scores along two AUIDs in the Split Rock Creek watershed

Macroinvertebrates

Split Rock Creek (10170203-512) had one macroinvertebrate sample taken on August 10th, 2011 at its biological monitoring site 11MS013. Sites 04MS005 and 11MS052 on Split Rock Creek (10770203-507) were sampled on August 31st 2004 and on August 5th, 2011. The site located in the headwaters, 04MS031, along Split Rock Creek (10170203-509) had a macroinvertebrate sample taken on August 31st, 2004 and again on August 9th, 2011. Unnamed Creek (10170203-538) was sampled for macroinvertebrates on August 10th, 2011 at its site 11MS045 which is located upstream of CR 51, 7.5 miles south of Japser. Lastly, Unnamed Creek (10170203-553) had a macroinvertebrate sample collected on August 10th, 2011 as well at site 11MS058.

Three sites along two AUIDs had biological sites with a class 5 (Southern Streams RR) designation (Figure 57). The IBI threshold for this macroinvertebrate class is 35.9 and each metric comprising the IBI would need a metric value score average of 3.59 to reach this mark. Site 04MS005 had an IBI score of 30.8. This site lacked Climber taxa (ClimberCh), insect taxa (InsectTxPct), Plecoptera taxa (Plecoptera), had a high percentage of taxa with tolerance values equal to or greater than 6 (Tolerant2ChTxpCT), and was dominated by the five most abundant taxa (DomFiveCHPct). Also along this reach was site 11MS052, which had an IBI score of 21.1. This site had a high amount of Clinger taxa (ClingerChTxPct), insect taxa, and Odonata taxa (Odonata). Lastly, site 11MS058 along Unnamed Creek (10170203-553) had a MIBI score of 9.2. This site had a high presence of Clinger taxa, but scored poorly in every other MIBI metric.

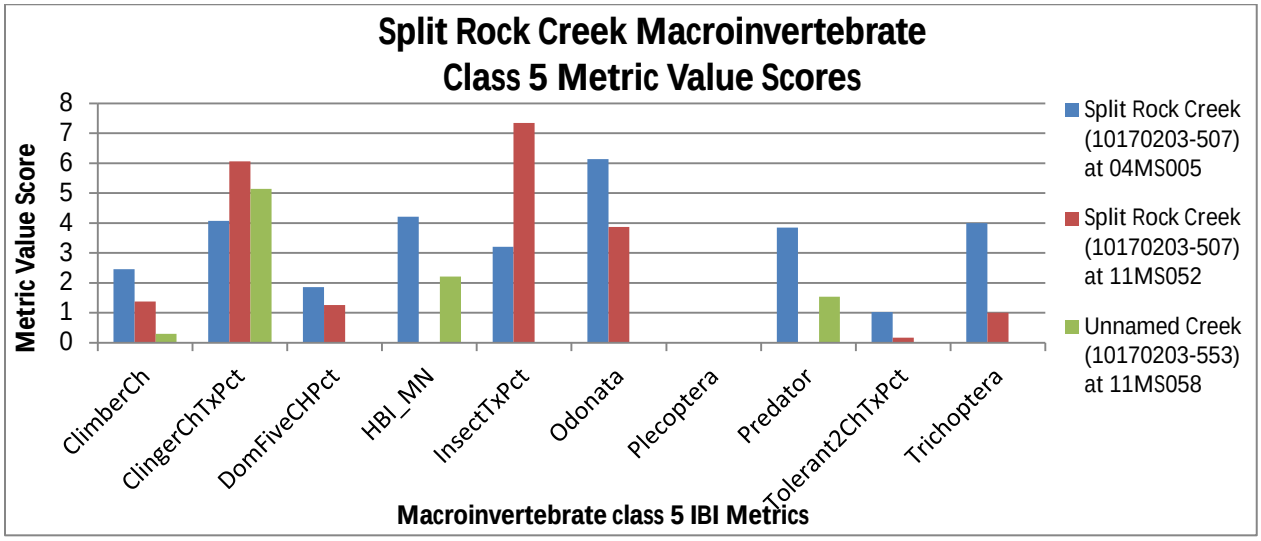

Figure 57: Macroinvertebrate class 5 metric value scores at three sites in the Split Rock Creek watershed

Three of the impaired biological reaches in the Split Rock Creek watershed had sites designated as macroinvertebrate class 7 (Prairie Streams GP) sites (Figure 58). The MIBI threshold for this class is 38.3 meaning each metric would need an average metric value score of 3.83 to achieve this level (Figure X). Site 04MS005 along Split Rock Creek (10170203-509) had an IBI score of 30.8. Limiting the IBI was the limited taxa richness of clinger taxa (ClingerCh), the low taxa richness of macroinvertebrates with tolerance values less than or equal to 2 (Intolerant2Ch), low amounts of combined Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET) taxa, a low total taxa richness (TaxaCountAllChir), and few non-hydropsychid Trichoptera individuals (TrichowoHydroPct). Site 11MS013 on Split Rock Creek (10170203-512) had a MIBI score of 41.5. This reach is not impaired for macroinvertebrates at this time.

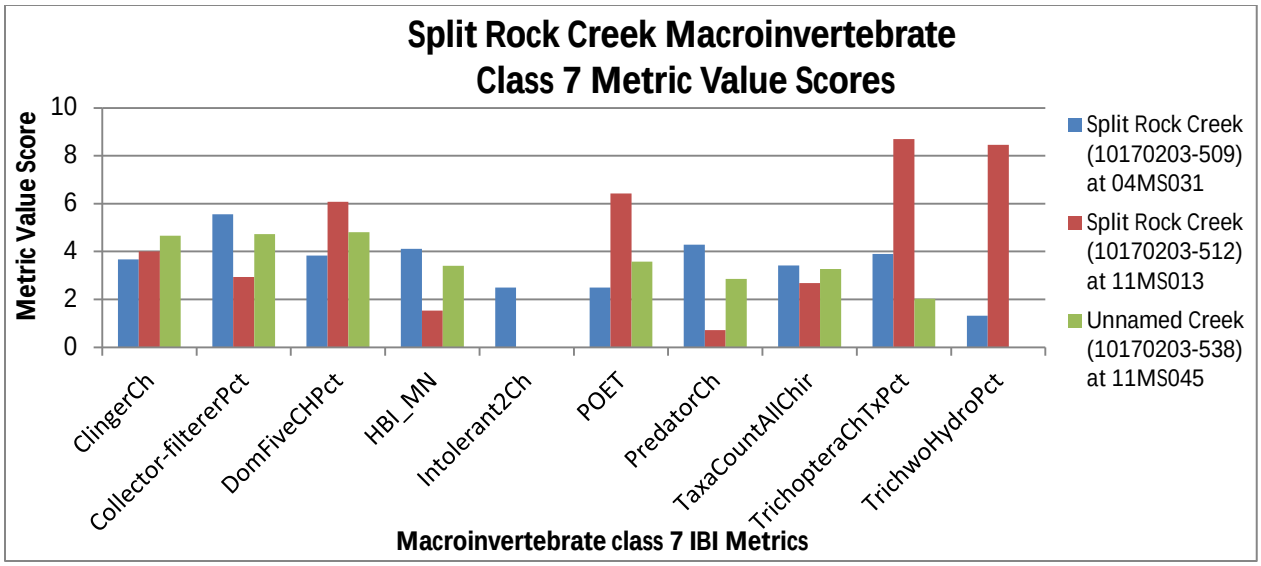

Figure 58: Macroinvertebrate class 7 metric value scores along three AUIDs in the Split Rock Creek watershed

Candidate cause: low dissolved oxygen

The daily minimum standard for DO in Minnesota class 2B streams is 5 mg/L. All streams in the Split Rock Creek watershed have this 2B classification. One reach, Split Rock Creek (10170203-507) is currently listed as impaired for DO.

Split Rock Creek (10170203-512):

From 2007-2012, a total of 145 DO measurements were taken along this portion of Split Rock Creek. Values during this time frame ranged from 3.88-16.66 mg/L with 3 measurements below the 5 mg/L daily minimum standard. This wide range of values may be an indication of problems related to daily flux.

Biologically, the macroinvertebrate community in Split Rock Creek (10170203-512) had a high percentage of EPT taxa (50%), while having a much lower amount of tolerant species (39.29%) and overall taxa count (20). The fish assemblage in this stream had a few sensitive species (5.26%) and also had a high amount of serial spawning (36.84%) and tolerant (68.42%) taxa.

Split Rock Creek had a wide range of DO values which possibly indicates problems with DO flux. The fish community for the most parts reflects a stream having DO issues. The lack of DO and high fluctuations in daily values makes this parameter a stressor to the impaired fish community in Split Rock Creek.

Split Rock Creek (10170203-507):

From 2003-2013 a total of 106 DO readings were taken from this section of Split Rock Creek. These values ranged from3.14-12.86 mg/L with 40 readings below the 5 mg/L daily minimum standard. This section of Split Rock Creek was deemed impaired due to DO during an assessment in 1994 and confirmed again during the most recent watershed assessment in 2013. It was found that most of the DO violations occur in the town of Jasper or downstream of Jasper.

Biologically, this section of Split Rock Creek had average amounts of tolerant macroinvertebrate taxa, higher amounts of EPT taxa (33.93%), and had an average of 22.5 species at the two sites. Furthermore, site 04MS005 had two DO intolerant taxa, while site 11MS052 had seven. Fish species had lower levels of sensitive taxa (8.33%), higher amounts of serial spawning fish species (37.5%), and large numbers of tolerant species (64.17%). These fish metric scores are typical of streams with low DO values. Split Rock Creek did also have below average amounts of late maturing fish (16.67%). Lower amounts of late maturing fish are common in streams experiencing low DO levels.

Upstream and downstream of Jasper showed fairly similar fish and macroinvertebrate assemblages. The most upstream site, 04MS005, did have five more fish and macroinvertebrate species than the site downstream of Jasper, 11MS052.

This reach along Split Rock Creek is currently impaired for DO however; it does not appear to be a stressor to the biological communities at this time based off of many of the DO related biological metrics.

Split Rock Creek (10170203-509):

A sonde was placed in Split Rock Creek (10170203-509) at monitoring station S000-652 during the summer of 2013 (Figure 59). The results from this monitoring show that the daily minimum did drop below 5 mg/L minimum standard and that the daily flux exceeds the 4.5 mg/L standard.

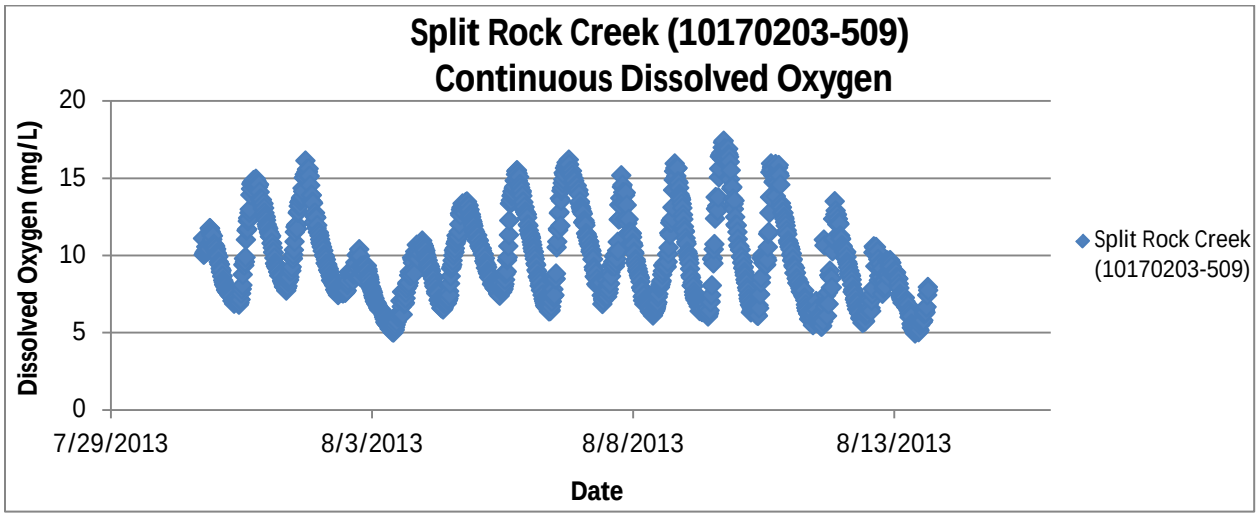

Figure 59: Continuous DO monitoring results at Split Rock Creek (10170203-509) in 2013

The macroinvertebrate community at nearby biological site 04MS031 had a low amount of EPT taxa (11.27%), few overall taxa (16.5), while having an assemblage consisting of many tolerant species (71.99%) and DO tolerant individuals (39.72%). The fish population consisted of zero sensitive taxa, few late maturing species (5.56%), and many tolerant taxa (78.89%).

The continuous DO data clearly shows that there are issues with the daily flux of DO and that conditions dipped below standard levels. The biological metrics in this stream reflect these conditions as well with decreased taxa count and EPT. For these reasons, DO is a stressor to the impaired fish and macroinvertebrate communities in Split Rock Creek.

Unnamed Creek (10170203-538):

From 2011-2013, Unnamed Creek (10170203-538) had eight DO readings taken from sampling site 11MS045 (Table 25). These measurements ranged from 3.5-16.33 mg/L, with two values falling below the 5 mg/L daily minimum standard. This site also had a wide range of values suggesting possible issues correlated to DO flux.

Table 25: Unnamed Creek DO measurements from 2011-2013 at site 11MS045

Sample Location	Sample Date and Time	Result (mg/l)	Daily Minimum Standard (mg/l)
11MS045	6/14/2011 9:45 AM	7.29	5
11MS045	8/10/2011 8:05 AM	7.99	5
11MS045	5/6/2013 1:15 PM	16.33	5
11MS045	6/11/2013 8:15 AM	4.38	5
11MS045	7/1/2013 3:50 PM	8.85	5
11MS045	7/16/2013 10:45 AM	7.11	5
11MS045	8/20/2013 8:30 AM	3.5	5
11MS045	9/30/2013 1:30 PM	7.37	5

The HSPF model calculated hourly DO values for Unnamed Creek from 1996-2009. These measurements ranged from 3.26-14.43 mg/L with an average value of 10.9 mg/L.

Biologically, the macroinvertebrate community in Unnamed Creek had a lower amount of EPT taxa (20%), while also having high numbers of tolerant taxa (80%). This site did have an average number of overall taxa (24). Only four taxa were considered tolerant to low DO, comprising of 7.3% of the sample. There was one low DO intolerant taxa present. The macroinvertebrate community is neither tolerant nor intolerant of low DO conditions but rather in the middle. The fish sampling event was not reportable due to the sample likely affected by the high flow conditions present during the time of sample.

Unnamed Creek had two values under the minimum standard in just eight samples. However, many of the DO related biological metrics do not appear to be stressed by the DO conditions at this time. Further monitoring is recommended to better determine the impact DO is having, if any, on the biological assemblages in Unnamed Creek.

Unnamed Creek (10170203-553):

Unnamed Creek had 5 DO readings taken from it from 2011-2013. These measurements ranged from 4.51-9.48 mg/L with one of the readings falling below the 5 mg/L daily minimum standard for DO (Table 26).

Table 26: Unnamed Creek DO measurements from 2011-2013 at site 11MS058

Sample Location	Sample Date and Time	Result (mg/l)	Daily Minimum Standard (mg/l)
11MS058	8/2/2011 12:00 PM	9.48	5
11MS058	8/10/2011 7:32 AM	5.76	5
11MS058	6/11/2013 5:40 PM	5.95	5
11MS058	7/1/2013 3:45 PM	9.35	5
11MS058	7/16/2013 9:30 AM	4.51	5

The HSPF model calculated hourly DO values for Unnamed Creek from 1996-2009. These values ranged from 2.21-14.19 mg/L with an average reading of 10.86 mg/L. There were very few exceedances of the 5 mg/L standard.

Biologically, the macroinvertebrate community in Unnamed Creek (10170203-553) at site 11MS058 had a low numbers of EPT taxa (9.52%), few overall taxa (12) and a high amount of tolerant taxa (85.71%). These results are common of streams affected by low DO conditions. Additionally there were no low DO intolerant macroinvertebrate taxa present, but only 3.2% individuals that were tolerant to low DO. The fish assemblage in this stream also had many tolerant taxa (80%), while completely lacking any sensitive species and having a lower amount of late maturing taxa (20%). This site did have few serial spawning fish species (10%).

Unnamed Creek had one measured DO reading below the daily minimum standard while other readings came close as well. The biological information available strongly signals that DO is impacting the fish and macroinvertebrate assemblages. Also, Unnamed Creek has a significant amount of algae growth which is likely caused by the high phosphorus levels, which ultimately affects the amount of DO available. Based on this evidence, low DO is a stressor to the impaired biological communities. Additional information about the DO regime should be collected, including diurnal measurements.

Candidate cause: high phosphorus

The proposed draft standard for phosphorus for streams in the Missouri River basin is currently 0.15 mg/L. Although phosphorus is an essential nutrient for all aquatic life, elevated levels can lead to an imbalance which impacts stream ecology. In the Split Rock Creek watershed phosphorus levels have exceeded this proposed standard multiple times.

Split Rock Creek (10170203-512)

From 2008-2012 there were a total of 148 phosphorus samples taken along this stretch of Split Rock Creek and ranged from 0.02 – 0.765 mg/L. Of these samples, 93 (62.84%) were above the proposed draft standard of 0.15 mg/L (Figure 60).

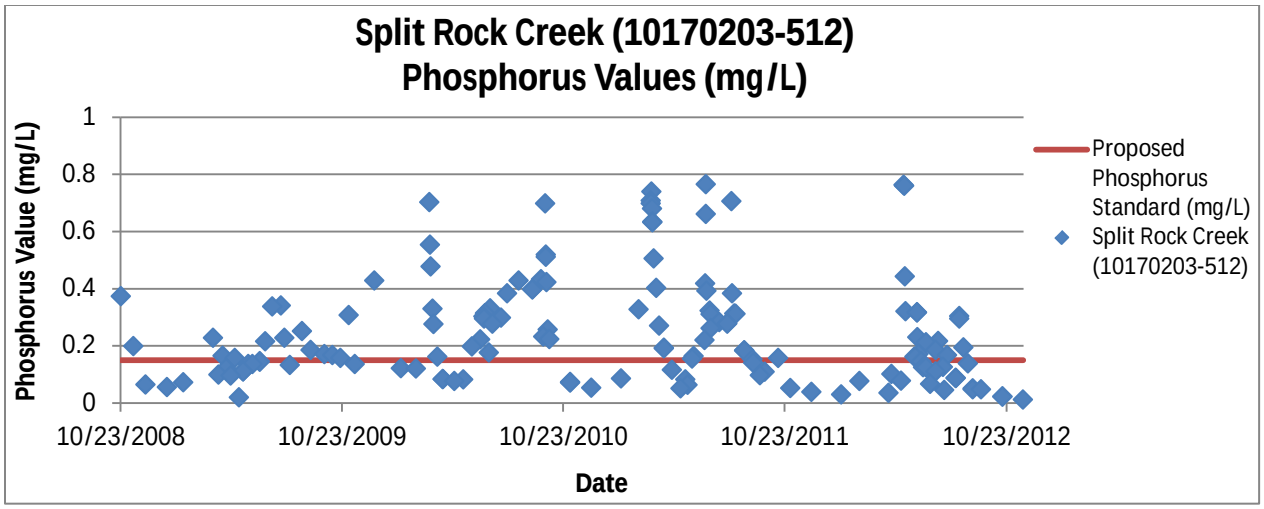

Figure 60: Phosphorus monitoring results from 2008-2012 along Split Rock Creek (10170203-512)

Biologically, the macroinvertebrate community in this stream reach had a high amount of EPT taxa (50%) and intolerant species (17.86%), while also having a lower amount of crustacean/mollusca taxa (10.71%). However, this site did have few Tanytarsini taxa (3.57%), and many scraper species (21.43%). These results are typical of a community with elevated phosphorus levels. The fish assemblage had many tolerant species (68.42%), while having few sensitive taxa (5.26%) and few darter individuals (3.73%).

With a very high exceedance rate, the agreement by many of the biological metrics, along with the poor DO conditions that are already present in this stream, it is likely that phosphorus is affecting these conditions. Therefore, phosphorus is a stressor to the impaired fish community in Split Rock Creek.

Split Rock Creek (10170203-507):

From 2003-2013, twelve phosphorus samples were taken from this portion of Split Rock Creek. These sample values ranged from 0.061-0.345 mg/L, with half of the samples above the proposed draft standard of 0.15 mg/L for phosphorus (Table 27).

Table 27: Phosphorus monitoring results along Split Rock Creek (10170203-507) from 2003-2013

***Represents the average of multiple samples.**

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
S001-142	8/27/2003	0.282	0.15
S001-139	8/28/2003	0.315	0.15
S001-144	8/28/2003	0.292	0.15
S001-141	8/28/2003	0.232	0.15
S002-358	8/28/2003	0.345	0.15
04MS005	8/11/2004	0.205	0.15
11MS052	6/20/2012	0.12	0.15
S001-139	5/6/2013	0.061	0.15
S001-139	6/11/2013	0.111	0.15
S001-139	7/1/2013	0.098	0.15
S001-139	8/20/2013	0.08	0.15
S001-139	9/12/2013	0.085*	0.15

Biologically, the macroinvertebrate community in Split Rock Creek showed a higher amount of EPT taxa (33.93%) and lower levels of scraper (9.93%) and crustacea/mollusca (10.91%). These results are typical in streams with lower phosphorus levels. However, this stream also had few Tanytarsini (6.35%) and intolerant (8.54%) taxa, while also having a high presence of tolerant taxa (61.11%). The fish population in this reach also had many tolerant taxa (64.77%) and few sensitive species (8.33%).

The high rate of exceedance and agreement with the majority of phosphorus related biological metrics all point to excess phosphorus as a stressor to the biological communities in this reach. These high levels may also be contributing to the DO problems also present in this stream reach.

Split Rock Creek (10170203-509):

Split Rock Creek had a total of 13 phosphorus samples taken from its biological station 04MS031 and monitoring station S000-652 from 2004-2013 (Table 28). These samples ranged from 0.067-0.518 mg/L and 10 of the 13 samples were above the proposed draft standard of 0.15 mg/L.

Table 28: Phosphorus sample values from 2004-2013 along Split Rock Creek (10170203-509)

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
04MS031	8/11/2004	0.429	0.15
S000-652	5/31/2005	0.238	0.15
S000-652	6/6/2005	0.307	0.15
S000-652	6/21/2005	0.518	0.15
S000-652	7/5/2005	0.206	0.15
04MS031	8/3/2011	0.237	0.15
S000-652	5/6/2013	0.103	0.15
S000-652	6/11/2013	0.309	0.15
S000-652	7/1/2013	0.125	0.15
S000-652	7/16/2013	0.067	0.15
S000-652	8/13/2013	0.163	0.15
S000-652	8/20/2013	0.324	0.15
S000-652	9/12/2013	0.169	0.15

Biologically, the macroinvertebrate community had few EPT taxa (11.27%), intolerant species (1.73%), and a high amount of tolerant taxa (71.99%). This AUID did have a lower amount of crustacean/mollusca (9.86%) and scraper (3.29%) taxa. These two types of macroinvertebrates tend to increase in streams with elevated phosphorus conditions. The fish assemblage completely lacked any sensitive and darter species, while having many tolerant taxa (78.89%).

Split Rock Creek is also experiencing DO issues, which may be partly contributed to the high phosphorus values that were present in this AUID. The macroinvertebrate and fish metrics both suggest potential stress due to high phosphorus levels. Based on all of the information available, elevated phosphorus conditions are stressing the impaired fish and macroinvertebrate communities in this reach.

Unnamed Creek (01070203-538):

Unnamed Creek had seven phosphorus samples taken from 2011-2013 (Table 29). Sample values ranged from 0.02-4.26 mg/L. Four (57.14%) of the samples were above the proposed draft standard of 0.15 mg/L.

Table 29: Phosphorus sample values from 2011-2013 at site 11MS045 along Unnamed Creek (10170203-538)

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS045	6/14/2011	0.129	0.15
11MS045	5/6/2013	0.02	0.15
11MS045	6/11/2013	0.165	0.15
11MS045	7/1/2013	0.13	0.15
11MS045	7/16/2013	0.301	0.15
11MS045	8/20/2013	0.741	0.15
11MS045	9/30/2013	4.26	0.15

Biologically, the macroinvertebrate assemblage in Unnamed Creek had a lower amount of EPT taxa (20%), few intolerant species (3.33%), while also having high numbers of crustacean/mollusca taxa (23.33%), scraper species (20%), and tolerant taxa (80%). The results of all of these metrics are indicative of elevated phosphorus conditions.

The numerous exceedances of the proposed standard, excessive algal growth (Figure 61), DO issues, and the biological metrics all signal that phosphorus is indeed stressing the impaired macroinvertebrate community in Unnamed Creek.

Figure 61: Excessive algae and weed growth at 11MS045 in Unnamed Creek (10170203-538)

Unnamed Creek (10170203-553):

There were a total of 4 phosphorus samples taken from Unnamed Creek from 2011-2013 (Table 30). Three (75%) were above the proposed draft standard of 0.15 mg/L. Two of the samples (6/11/2013, 7/16/2013) were at levels more than 7 times the standard.

Table 30: Phosphorus values from 2011-2013 at site 11MS058 along Unnamed Creek (10170203-553)

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS058	8/2/2011	0.293	0.15
11MS058	6/11/2013	1.13	0.15
11MS058	7/1/2013	0.01	0.15
11MS058	7/16/2013	1.33	0.15

Biologically, the macroinvertebrate community at 11MS058 had a low percentage of EPT taxa (9.52), zero intolerant species, and a high amount of tolerant taxa (85.71%). This site did have lower amounts of scraper (4.76%) and crustacean/mollusca (9.52%) species. The fish assemblage in this stream was mostly tolerant taxa (80%) with zero sensitive fish species present.

The photographic evidence (Figure 62), the extremely high phosphorus values, along with the agreement of the majority of phosphorus related biological metrics makes excess phosphorus a stressor to the impaired fish and macroinvertebrate communities in Unnamed Creek. These high levels may also be impacting the low DO conditions that this stream experiences.

Figure 62: Excess algae at 11MS058 on Unnamed Creek (10170203-553)

Candidate cause: high nitrates

Currently, the State of Minnesota does not have a nitrate standard in place for streams not used as a drinking water source. However, the overabundance of nitrates can stress a biological community. Nitrates in the Split Rock Creek watershed did at times reach levels that could potentially be stressing the biological assemblages.

Split Rock Creek (10170203-512):

From 2008-2012 a total of 147 nitrate samples were taken from this AUID along Split Rock Creek. These values ranged from 0.2-13 mg/L (Figure 63) with an average reading of 4.33 mg/L.

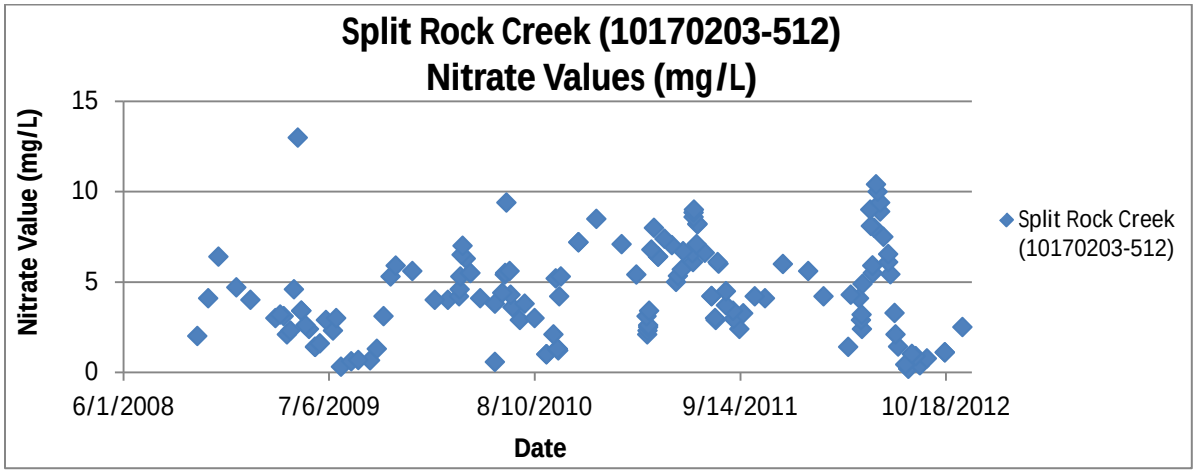

Figure 63: Split Rock Creek (10170203-512) nitrate values from 2008-2012

The HSPF model calculated daily nitrate values for Split Rock Creek (1017023-512) from 1996-2009. These values ranged from 1.65-17.7 mg/L with an average value of 5.15 mg/L.

Biologically, the macroinvertebrate community in Split Rock Creek had a lower overall taxa count (20), but did have a higher amount of Trichoptera taxa (14.29%). The fish assemblage had a relatively high number of fish species sampled (19), but very few sensitive fish taxa (5.26%) which can be a signal for potential nitrate issues.

Nitrate values were relatively low in both the observed and predicted data sets but do seem to be elevated during high flow events. The biological results are fairly mixed for this reach and are likely due to other stressors affecting the biological communities much greater than nitrates. Therefore, nitrates are not considered to be a stressor to the impaired fish assemblage in Split Rock Creek.

Split Rock Creek (10170203-507):

This reach of Split Rock Creek had eight nitrate samples taken from sites 04MS005 and 11MS052 from 2004-2013. Nitrate values ranged from 0.6-6.2 mg/L (Table 31).

Table 31: Nitrate sample values from 2004-2013 along Split Rock Creek (10170203-507)

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
04MS005	8/11/2004	0.6	n/a
11MS052	6/20/2012	2.6	n/a
11MS052	5/6/2013	1.4	n/a
11MS052	6/11/2013	1.6	n/a
11MS052	7/1/2013	6.2	n/a
11MS052	8/20/2013	0.78	n/a
11MS052	9/12/2013	0.86	n/a
11MS052	9/12/2013	0.84	n/a

Biologically, the macroinvertebrate assemblage in this portion of Split Rock at sites 04MS005 and 11MS052 had a lower overall taxa count (21.5), but did have an above average amount of Trichoptera taxa (13.69%) when compared to other streams throughout Minnesota. The two sites, 04MS005 and 11MS052, averaged 59.54% nitrate tolerant individuals. A quantile regression analysis predicts these class 5 sites would have between a 25-50% chance of being impaired due to its nitrate levels. The fish community was fairly diverse (17.5 species), but few sensitive taxa were present (8.33%).

The relatively low nitrate sample values along with many of the biological metrics conclude that excess nitrate is not a stressor to the impaired macroinvertebrate community in Split Rock Creek (1017203-507) at this time.

Split Rock Creek (10170203-509):

This section of Split Rock Creek had 11 nitrate samples taken at its monitoring station S000-652 from 2005-2013. Nitrate values ranged from 0.05-23 mg/L (Table 32).

Table 32: Nitrate sampled values from 2005-2013 at station S000-652 along Split Rock Creek (10170203-509)

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
S000-652	5/31/2005	1.02	n/a
S000-652	6/6/2005	2.46	n/a
S000-652	6/21/2005	3.72	n/a
S000-652	7/5/2005	2.4	n/a
S000-652	5/6/2013	1.3	n/a
S000-652	6/11/2013	8.3	n/a
S000-652	7/1/2013	23	n/a
S000-652	7/16/2013	4.3	n/a
S000-652	8/13/2013	0.4	n/a
S000-652	8/20/2013	0.05	n/a
S000-652	9/12/2013	0.05	n/a

The HSPF model calculated daily nitrate values for Split Rock Creek (10170203-509) from 1996-2009. These values ranged from 1.45-20.97 mg/L with an average value of 4.92 mg/L.

The biological monitoring station, 04MS031, showed a lower than normal amount of macroinvertebrate richness with only an average of 16.5 taxa sampled. This site had a below average amount of Trichoptera species present averaging only 6.45% during the two macroinvertebrate sampling visits. These taxa are typically more sensitive to elevated nitrate conditions. Also, the site had a macroinvertebrate community consisting of 69.62% of nitrate tolerant individuals. A quantile regression analysis of class 7 sites like 04MS031 showed that sites with more than 69.05% of nitrate tolerant taxa have a greater than 50% probability of being impaired.

Fish diversity at 04MS031 was very low with only an average of 7 species sampled during the two fish sampling visits. This site also lacked any sensitive fish species during both visits.

The biological information tends to show communities that are affected by high levels of nitrates. However, only one of the nitrate values is excessive. Further nitrate monitoring is needed to better understand the stress, if any, that high levels of nitrates are having on the impaired biological communities in Split Rock Creek.

Unnamed Creek (10170203-538):

Unnamed Creek had a total of seven nitrate samples taken from 2011-2013 at its biological monitoring station 11MS045 (Table 33). Nitrate values ranged from 0.24-6 mg/L.

Table 33: Nitrate sample values from 2011-2013 at site 11MS045 along Unnamed Creek (10170203-538)

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS045	6/14/2011	5.2	n/a
11MS045	5/6/2013	2.5	n/a
11MS045	6/11/2013	6	n/a
11MS045	7/1/2013	3.7	n/a
11MS045	7/16/2013	1.3	n/a
11MS045	8/20/2013	0.26	n/a
11MS045	9/30/2013	0.24	n/a

The HSPF model calculated daily nitrate values from 1996-2009 along Unnamed Creek. These values ranged from 1.59-19.78 mg/L with an average value of 4.93 mg/L.

Biologically, the impaired macroinvertebrate community had an average amount of taxa (24), but only 3.33% of those species were Trichoptera taxa. Additionally, site 11MS045 had a macroinvertebrate community consisting of 63% nitrate tolerant individuals. A quantile regression analysis showed this site to have between 25-50% probability of being impaired due to its nitrate levels.

The relatively low nitrate sample values along with many of the biological metrics conclude that excess nitrate is not a stressor to the impaired macroinvertebrate community in Unnamed Creek at this time.

Unnamed Creek (10170203-553):

Four nitrate samples were taken from Unnamed Creek at sampling site 11MS058 from 2011-2013. These values ranged from 0.52-9.4 mg/L (Table 34).

Table 34: Nitrate sample values from Unnamed Creek (10170203-553) from 2011-2013

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS058	8/2/2011	5.4	n/a
11MS058	6/11/2013	9.4	n/a
11MS058	7/1/2013	5.1	n/a
11MS058	7/16/2013	0.52	n/a

The HSPF model calculated daily nitrate values for Unnamed Creek (10170203-553) from 1996-2009. These calculations ranged from 1.74-20.08 mg/L with an average value of 4.78 mg/L.

Biologically, the macroinvertebrate population in Unnamed Creek had a lower amount of Trichoptera taxa (9.52%) and had very few overall taxa (12), while also having an above average amount of nitrate tolerant individuals (61.89%) when compared to all other Minnesota streams. The fish assemblage also had a lower taxa count (10) and had no sensitive fish species.

While the biological metrics signal potential stress from elevated nitrate levels, there currently is not enough chemical information to determine if high nitrate values are indeed stressing the biological community at this time. Further nitrate sampling is recommended to better understand the impacts, if any, this parameter is having on the biological assemblages in Unnamed Creek.

Candidate cause: high turbidity/TSS

The water quality standard for turbidity is 25 NTU, 65 mg/L for TSS, and 20 cm for transparency tube for these class 2B warmwater streams in the Split Rock Creek watershed. Excess sediment is a commonly recognized stressor in many biologically impaired streams because it can reduce habitat, cause direct physical harm, as well as reduce visibility and increase oxygen demand.

One reach, Split Rock Creek (10170203-512), was determined to be impaired for aquatic life due to turbidity in addition to their biological assemblages.

Split Rock Creek (10170203-512):

Split Rock Creek was listed as impaired for turbidity for the 2010 reporting cycle. This designation was affirmed during the 2013 assessments. During these assessments turbidity was found to be exceeding the chronic standard of 25 Nephelometric Turbidity Units (NTU) over 81% of the time. TSS values were found to be exceeding the 65 mg/L standard 41% of the time and Secchi/transparency tube data showed an exceedance rate of 65.9% (Figure 64).

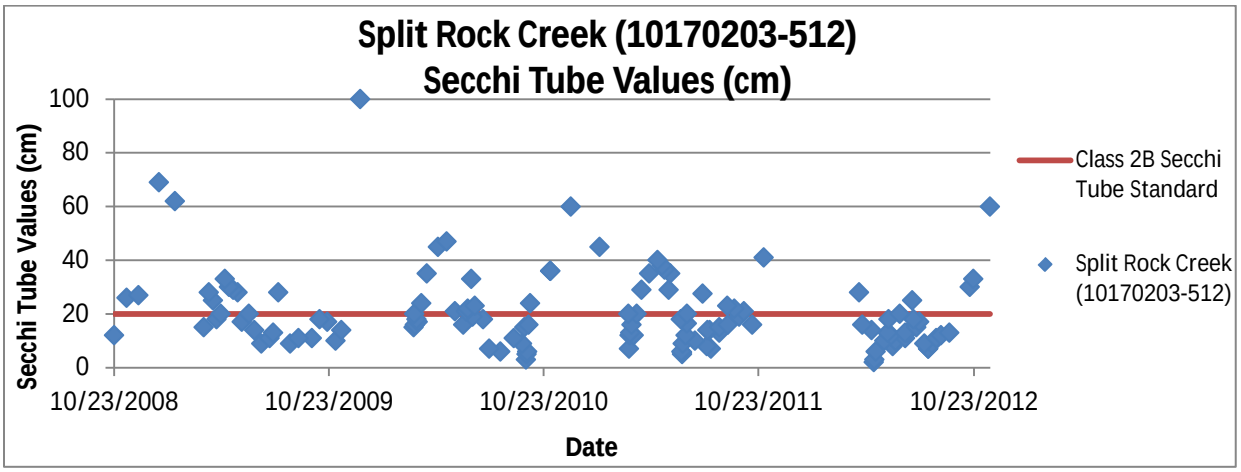

Figure 64: Secchi tube values on Split Rock Creek (10170203-512) from 2008-2012

The macroinvertebrate assemblage in this portion of Split Rock Creek scored fairly well in turbidity/TSS related biological metrics. This reach had a lower amount of chironomids (17.86%), while also having higher amounts of Trichoptera (14.29%), collector-filterer (14.29%), scraper (21.43%), and Ephemeroptera (35.71%) taxa. The amount of tolerant taxa was also low (39.29%). The fish community in this reach had few herbivore taxa (5.26%) and many tolerant species (68.42%).

The high presence of suspended solids and a lack of transparency led to this reach being designated as impaired for turbidity. The conditions in this stream do not seem to be stressing the macroinvertebrate assemblage, but are negatively affecting the fish community; therefore, turbidity/TSS is a stressor to this assemblage in this reach.

Split Rock Creek (10170203-507):

From 2004-2013, a total of seven TSS samples were taken from this reach of Split Rock Creek. These samples ranged from 17-89 mg/L with one value over the 65 mg/L standard. Additionally, eight transparency/Secchi tube measurements were taken along this AUID. These values ranged from 5-84 cm with three measurements falling below the transparency standard of 20 cm (Table 35).

Table 35: TSS and Secchi tube values from 2004-2013 along Split Rock Creek (10170203-507)
*** Average of two values**

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
04MS005	8/11/2004	32	65	43	20
11MS052	8/5/2011	n/a	65	15	20
11MS052	6/20/2012	17	65	52	20
S001-139	5/6/2013	34	65	80	20
S001-139	6/11/2013	89	65	5	20
S001-139	7/1/2013	44	65	14	20
S001-139	8/20/2013	39	65	37	20
S001-139	9/12/2013	46.5*	65	84	20

The HSPF model calculated daily TSS values from 1996-2009 along Split Rock Creek (10170203-507). These values ranged from 0.012-3515.1 mg/L with an average exceedance rate of 30.68% of the proposed standard.

Biologically, the macroinvertebrate community along this section of Split Rock Creek had a lower overall average taxa count (21.5), had few scraper species (9.93%) and had a fairly tolerant population (61.11% taxa). This stream did show higher levels of Trichoptera (13.69%), collector-filterer (17.66%), and Ephemeroptera (20.24%) taxa. The fish assemblage had few herbivorous taxa (5.84%) and many tolerant species (64.17%), but did have an above average TSS TIV score when compared to all other sites with a fish class 2 designation.

The observed results did show some exceedances of the TSS and transparency/Secchi tube standards. The HSPF model also predicted a high percentage of samples above the 65 mg/L proposed TSS standard, however, many of the biological metrics used do not suggest TSS as a stressor. More TSS monitoring is needed to better determine the impact, if any, that high levels of TSS/turbidity is having on the impaired biological assemblages in Split Rock Creek.

Split Rock Creek (10170203-509):

From 2011-2013, four TSS samples were taken from this reach of Split Rock Creek. These values ranged from 2-47 mg/L with no readings above the 65 mg/L standard for TSS. Additionally, five transparency/Secchi tube measurements were taken during this time period. None of these measurements fell below the 20 cm minimum standard (Table 36).

Table 36: TSS and Secchi tube values from 2011-2013 along Split Rock Creek (10170203-509) at site 11MS058

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS058	8/2/2011	11	65	80	20
11MS058	8/10/2011	n/a	65	89	20
11MS058	6/11/2013	6	65	71	20
11MS058	7/1/2013	47	65	42	20
11MS058	7/16/2013	2	65	>100	20

The HSPF model calculated daily TSS values from 1996-2009 along Split Rock Creek (10170203-509). These values ranged from 0.014-1455.7 mg/L with an average exceedance rate of 34.59% of the proposed standard.

Biologically, the macroinvertebrate community in this reach had a high percentage of chironomids (47.62) and tolerant taxa (85.71). These values tend to be higher in streams affected by turbidity and TSS. This stream also had few scraper taxa (4.76%), zero Ephemeroptera species, a low amount of Trichoptera taxa (9.52%) and few overall species (12). The fish assemblage in this reach had many tolerant taxa (80%) and 10% of the species were herbivorous, but did have an above average TSS TIV score when compared to all other Minnesota streams.

The few TSS and transparency/Secchi tube measurements taken along this reach did not show any violations of the standard. However, the high exceedance rate according to the model, the agreement of the majority of biological metrics , and the fact that the AUID downstream of this one is also affected negatively by the high presence of suspended sediment all indicate that excess turbidity/TSS is a stressor to the impaired biological communities in this section of Split Rock Creek. Additional data should be collected to verify elevated TSS as predicted by the model.

Unnamed Creek (10170203-538):

Unnamed Creek had seven TSS samples taken from 2011-2013 from site 11MS045. These values ranged from 2.4-2800 mg/L with one sample above the 65 mg/L proposed standard for TSS. Additionally, this site had seven transparency/Secchi tube measurements taken during this same time period. These values ranged from 13cm to greater than 100 cm with one sample falling below the 20 cm standard (Table 37).

Table 37: TSS and Secchi tube value from 2011-2013 along Unnamed Creek (10170203-539) at site 11MS045

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS045	6/14/2011	29	65	32	20
11MS045	8/10/2011	n/a	65	13	20
11MS045	5/6/2013	2.4	65	>100	20
11MS045	6/11/2013	14	65	55	20
11MS045	7/1/2013	14	65	36	20
11MS045	7/16/2013	18	65	35	20
11MS045	8/20/2013	27	65	26	20
11MS045	9/30/2013	2800	65	n/a	20

The HSPF model predicted daily TSS values from 1996-2009 along Unnamed Creek (10170203-538). These values ranged from .004-4021.4 mg/L with an average value of 36.45 mg/L. Only 5.53% of the values were above the 65 mg/L proposed TSS standard.

Biologically, the macroinvertebrate assemblage in Unnamed Creek showed low numbers of scraper (4.76%), Trichoptera (3.33%), and collector-filterer (10%) species. This site also had many tolerant taxa (80%). The stream did have a low number of chironomids (20%) and an above average amount of Ephemeroptera species (16.67%) when compared to all other streams in Minnesota. There were no reportable fish visits on this AUID.

With the mixed macroinvertebrate metric results along with the relatively low number of observed and predicted TSS and transparency standards, excess TSS and turbidity is not a stressor to the impaired macroinvertebrate community.

Unnamed Creek (10170203-553):

Unnamed Creek had four TSS samples and five Secchi tube readings taken from 2011-2013 (Table 38) at biological station 11MS058. All TSS values were below the TSS proposed standard of 65 mg/L, while all Secchi tube readings were above the Secchi tube standard of 20 cm.

Table 38: TSS and Secchi tube values from 2011-2013 along Unnamed Creek (10170203-553) at site 11MS058

Sample Location	Sample Date	TSS Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS058	8/2/2011	11	65	80	20
11MS058	8/10/2011	n/a	65	89	20
11MS058	6/11/2013	6	65	71	20
11MS058	7/1/2013	47	65	42	20
11MS058	7/16/2013	2	65	>100	20

The HSPF model predicted daily TSS values from 1996-2009 along Unnamed Creek (10170203-553). These values ranged from 0.0031-3335.4 mg/L with an average value of 21.26 mg/L. Of these calculations, only 2.54% were above the proposed TSS standard.

Biologically, macroinvertebrate populations contained zero Ephemeroptera taxa, a low species count (12), very low amounts of scraper taxa (4.76%) and individuals (0.34%), high amounts of tolerant taxa (85.71%) and tolerant individuals (96.31%), and also high amounts of chironomidae taxa (47.62%) and individuals (78.19%). All of these results are expected in streams with elevated turbidity/TSS levels. Unnamed Creek did also have an average amount of Trichoptera taxa (9.52%) present and an above average amount of collector-filterer taxa (14.29%). These metrics are normally much lower in streams with high turbidity/TSS levels. Fish populations in Unnamed Creek had a high amount of tolerant species (80%), but they also had an above average amount of herbivore taxa (10%).

Unnamed Creek had no observed TSS or transparency/Secchi tube proposed standard exceedances. The exceedance rate was also very low according to the HSPF model predictions. The biological metrics showed a mixed signal and are likely being affected by other stressors. Elevated turbidity/TSS is not a stressor to the impaired biological communities in Unnamed Creek at this time.

Candidate cause: lack of habitat

Qualitative habitat assessments using the MSHA were conducted in the five impaired reaches in the Split Rock Creek study area. MSHA scores ranged from poor to good. The MSHA was the main tool used for evaluating this potential stressor and the results of these habitat scores can be seen in Figure 65.

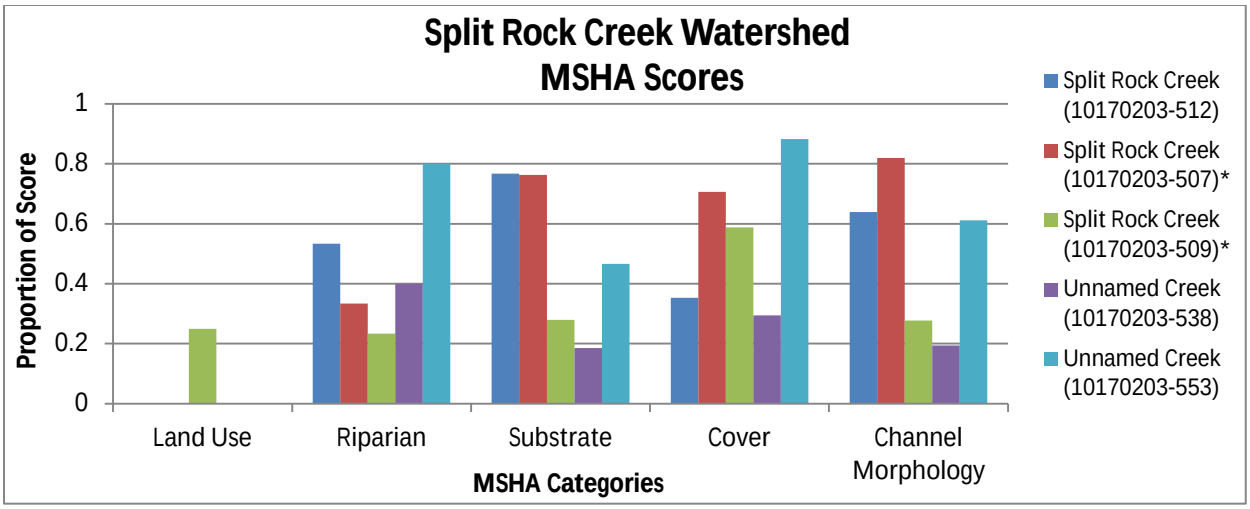

Figure 65: MSHA metric scores from the five biologically impaired reaches in the Split Rock Creek watershed
*** Average of multiple visits/sites along AUID.**

Split Rock Creek (10170203-512):

The most downstream section of Split Rock Creek had an MSHA score of 57.7 at biological monitoring station 11MS013. This score is considered to be fair. Factors lowering this score include the poor surrounding land use, the moderate bank erosion, the lack of stream shade, the sparse amount of fish cover, as well as the moderate channel stability. Excess sedimentation was also found in the runs and pools at this site.

The macroinvertebrate sample along this reach was taken from equal parts of overhanging vegetation and riffle habitats. The macroinvertebrate community had an average amount of clinger species (28.57%) when compared to other streams in the state, while also having relatively few amounts of tolerant taxa (39.29%) and burrower individuals (0.92%). These results are expected from a stream that has fair/good habitat conditions.

The fish populations in this section of Split Rock Creek contained a high amount of riffle dwelling species (21.05%) and benthic insectivore taxa (21.05%). These species are more commonly found in streams with good habitat conditions. Simple lithophilic spawning species of fish (15.79%) and darters/sculpins/round bodied suckers (10.53%) were both found in below average amounts. These species are also more common in streams with good habitat. Many tolerant fish species (68.42%) were also present. Tolerant fish species can easily adapt to any habitat condition.

The mixed biological results along with the fair MSHA score concludes that habitat, while not a primary stressor, is indeed having an effect on the impaired fish community. Improvements to the habitat conditions are needed to no longer consider habitat a stressor to Split Rock Creek.

Split Rock Creek (10170203-507):

The middle section of Split Rock Creek had an average MSHA score of 67.1 after visits to the biological monitoring stations 11MS052 and 04M005. This score is considered to be good. There were no major differences in the habitat available at each site. Factors lowering the MSHA at these sites were the surrounding land use, the lack of a riparian buffer, and some embeddedness of the course substrates.

Biologically, populations of clinger macroinvertebrates were above average (33.14%), while there was an average amount of tolerant macroinvertebrate taxa (72.22%) when compared to all other Minnesota streams. These sites also had a lower amount of burrower individuals (4.69%), which is normal for a stream with abundant course substrates. The fish assemblage had an above average amount of riffle dwelling fish species (20%) and had below average amounts of simple lithophilic spawners (16.67%),

benthic insectivores (16.67%), and darter/sculpin/round bodied suckers (10.84%). Those species tend to be present in higher numbers in streams with good habitat conditions. Tolerant fish species were also more abundant (64.2%) than an average Minnesota stream.

The mixed biological results and the MSHA score reflect a stream that has fair/good habitat. Habitat should not be considered a major stressor to the impaired fish and macroinvertebrate communities at this time, however improved habitat conditions will be vital to the overall health of the biological communities in this section of Split Rock Creek.

Split Rock Creek (10170203-509):

The most upstream section of Split Rock Creek had an average MSHA score of 32.3 at its biological monitoring station 04MS031 after two visits. This score is considered to be poor. Reasons for the poor habitat score are the row crop land use, the minimal riparian buffer, heavy bank erosion, no stream shading, severe embeddedness, low channel stability, and poor channel development.

Biologically, the macroinvertebrate community at site 04MS031 had low levels of clinger taxa (24.25%) and many tolerant species (71.99%), while also having a high amount of burrower individuals (31.33%). The fish assemblage had few species of riffle dwelling (5.56%), benthic insectivore (5.56%), darters/sculpin/round-bodied sucker (0%), and simple lithophilic spawning (5.56%) taxa while also having a high amount of tolerant fish species (78.89%). All of these results reflect a stream affected by the poor habitat conditions.

The poor MSHA scores at both visits along with the low scoring habitat related biological metrics makes the lack of habitat a stressor to the impaired fish and macroinvertebrate communities along this section of Split Rock Creek.

Unnamed Creek (10170203-538):

Unnamed Creek had an MSHA score of 23 at its biological monitoring station 11MS045. This score is considered to be poor. Factors limiting the habitat score are the surrounding row crop land use, the lack of a riparian buffer, minimal stream shading, the predominantly silt substrate, the sparse amount of fish cover, poor channel development, low channel stability, and little depth variability. This stream also had excess sedimentation throughout, as well as animal access to the stream.

Macroinvertebrate populations in Unnamed Creek consisted of many tolerant taxa (80%) that can tolerate poor habitat conditions. An average amount of clinger species (30%) were also present, while fewer burrower individuals (3.49%) were present. Clingers tend to be more abundant in streams with good habitat conditions. The fish sample at 11MS045 was deemed non-reportable, due to high flows. The fish assemblage sampled 10 different species, but only 21 total individuals. This number is very low and would likely be much higher during base flow conditions.

The MSHA at 11MS045 had a very poor score, but the macroinvertebrate community did not signal stress in many of its related biological metrics. The fish sample was non-reportable and may not accurately reflect the habitat conditions present. Further monitoring during base flow conditions is needed before the lack of habitat is considered a stressor in this stream reach.

Unnamed Creek (10170203-553):

Unnamed Creek had an MSHA score of 61.6 at its biological monitoring station 11MS058. This score is considered to be fair. Factors limiting the MSHA score in Unnamed Creek were the surrounding row crop land use, moderate embeddedness of course substrates, moderate channel stability and a fair stream sinuosity. The runs and pools in Unnamed Creek also had excess sedimentation.

Macroinvertebrate populations did have high amounts of tolerant taxa (85.71%), but Unnamed Creek did support an above average amount of clinger taxa (taxa). Clingers are typically found in less abundance in streams limited by habitat conditions.

The fish assemblage of Unnamed Creek did have a higher amount of riffle dwelling fish individuals (28.2%) when compared to all other Minnesota streams. Riffle dwelling species tend to be more prevalent in streams with good habitat conditions. However, Unnamed Creek did have a high amount of tolerant fish taxa (80%), lower numbers of benthic insectivore species (10%), simple lithophilic spawning species (20%), and fish taxa classified as darter/sculpin/round bodied suckers (10%).

With the fair habitat scores and the mix of good and poorly scoring biological indicators, habitat conditions in Unnamed Creek should be considered a secondary stressor to the impaired fish and macroinvertebrate communities at this time. Habitat improvement should be considered to eliminate this candidate cause as a stressor in the future.

Conclusion

The Split Rock Creek watershed has many stressors contributing to the five biologically impaired reaches within the watershed. These stressors include lack of DO, excess phosphorus, high turbidity/TSS and a lack of habitat (Table 39).

Low DO was found to be a stressor at all of the biologically impaired reaches except at Split Rock Creek (10170203-507) and Unnamed Creek (10170203-538). The reaches in this watershed had values falling below the daily minimum standard as well as experienced a wide range of values. An example of this is from the continuous DO monitoring at Split Rock Creek (10170203-509), which had a daily flux of DO well above 4.5 mg/L. These reaches also have an excess of phosphorus, which often creates algae blooms. These algae blooms tend to deplete oxygen conditions.

Excess phosphorus was determined to be a stressor at all five of the biologically impaired reaches. Phosphorus levels in these AUIDs was regularly over the 0.15 mg/L proposed draft standard and also had one value along Unnamed Creek (10170203-538) that was 28 times the proposed standard. These excessive levels have led to significant algae blooms that have negative impacts to the habitat and DO conditions within the stream reaches. Excess phosphorus in this watershed can likely be attributed to the intensive grazing and agricultural activities prevalent in the watershed. A limited or often times absent riparian buffer allows fertilizer runoff to easily access these streams. A significant change in phosphorus conditions in this watershed is needed regarding this stressor.

High turbidity/TSS was found to be a stressor in three of the biologically impaired reaches within this watershed. Split Rock Creek (10170203-512) was determined to be impaired for aquatic life due to its high turbidity/TSS values, while the biological communities in Split Rock Creek (10170203-507) and Split Rock Creek (10170203-509) were also being stressed by the elevated amounts of TSS present. Violations of both the TSS and Secchi tube standards were present and strongly backed by the modeling and biological information. These conditions are a likely result from the intensive grazing this watershed experiences. This practice leads to unstable and erodible banks resulting in excess sediment being distributed throughout the stream channel and water column.

The lack of habitat was determined to be a stressor at all of the biologically impaired AUIDs in this watershed except for Split Rock Creek (10170203-507). MSHA scores ranged from poor to good with the habitat within the watershed mainly limited by the poor surrounding land use, minimal stream riparian buffers, sparse fish cover, limited stream shading, poor channel development, low channel stability and the high presence of silty/sandy substrates. Properly fencing off cattle and restricting their access to the stream would help stabilize the banks and improve habitat conditions. Further habitat improvement projects would also help alleviate the stress causing the biological communities in this watershed.

Table 39: Biologically impaired reaches in the Split Rock Creek watershed and their stressors
(• = stressor, - = not a stressor, and blank = inconclusive/not enough evidence)

		Stressors				
Stream Name	**AUID #**	**Low Dissolved Oxygen**	**High Phosphorus**	**High Nitrates**	**High Turbidity/TSS**	**Lack of Habitat**
Split Rock Creek Watershed						
Split Rock Creek	10170203-512	•	•	-	•	•
Split Rock Creek	10170203-507	-	•	-		-
Split Rock Creek	10170203-509	•	•		•	•
Unnamed Creek	10170203-538		•	-	-	•
Unnamed Creek	10170203-553	•	•		-	-

Upper Spring Creek watershed

Overview

Spring Creek is located in the far northern part of the Lower Big Sioux River watershed. The AUID, 10170203-518, is 12.65 miles long extending from the headwaters of the Spring Creek watershed to the Minnesota/South Dakota border (Figure 66). This reach was sampled for macroinvertebrates in 2011 and was found to be impaired during the watershed assessment in 2013. Land use in this watershed is dominated by cropland (82.13%), followed by rangeland (11.99%), and developed land (4.9%).

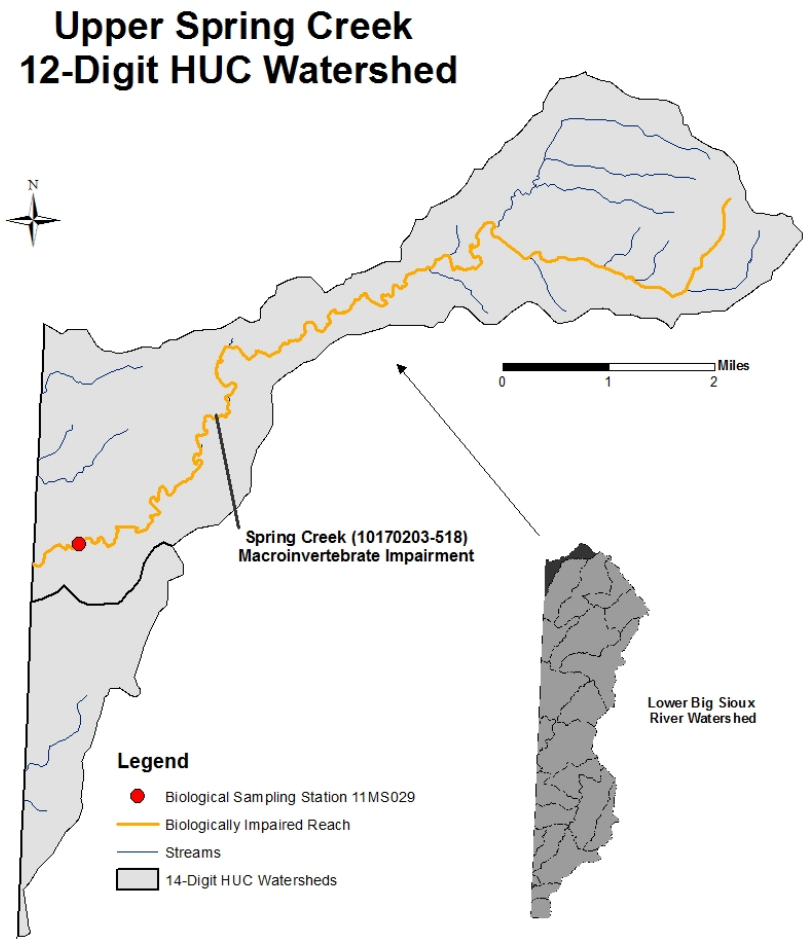

Figure 66: Upper Spring Creek watershed with biologically impaired reach highlighted

Biology in Spring Creek

There was one biological sampling station, 11MS029, located along Spring Creek. This site is located upstream of 110th Ave, 4.5 miles west of Verdi and was sampled for macroinvertebrates on August 8th, 2011.

To reach the MPCA's macroinvertebrate IBI threshold of 38.3 for a class 7 stream each metric would need an average score of 3.83. As shown in Figure 67, Spring Creek at biological station 11MS029 only reached this level at the predator species metric (PredatorCH). This site was especially limited by the lack of collector-filterer individuals (Collector-filterer Pct), the taxa richness of macroinvertebrates with tolerance values less than or equal to 2, using MN TVs (Intolerant2CH), lack of Trichoptera taxa (TrichopteraCHTxPct), and lack of non-hydropsychid Trichoptera (TrichwodHydroPct).

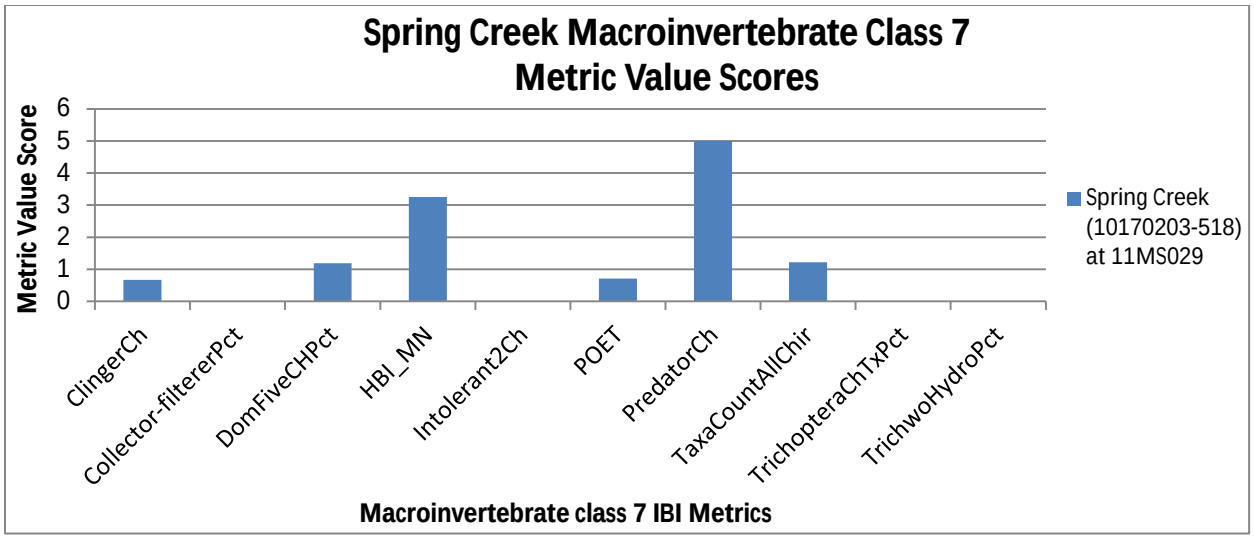

Figure 67: Macroinvertebrate class 7 IBI metric value scores at site 11MS029 along Spring Creek (10170203-518)

Candidate cause: low dissolved oxygen

The daily minimum standard for DO in Minnesota class 2B streams is 5 mg/L. All streams in the Upper Spring Creek watershed have this 2B classification. No streams in this grouping are currently listed as impaired for DO.

There were 5 DO readings taken at Spring Creek from 2011-2013 (see Table 39). The very high values and values close to the daily minimum standard of 5 mg/L made Spring Creek a good candidate for continuous DO monitoring. Unfortunately, Spring Creek became intermittent and dried up altogether before a sonde could be placed.

Table 39: DO measurements at site 11MS029 along Spring Creek (10170203-518) from 2011-2013

Sample Location	Sample Date and Time	Result (mg/l)	Daily Minimum Standard (mg/l)
11MS029	8/8/2011 5:39 PM	16.16	5
11MS029	6/12/2013 9:00 AM	6.72	5
11MS029	6/26/2013 10:45 AM	6.79	5
11MS029	7/2/2013 8:30 AM	12.12	5
11MS029	7/17/2013 8:00 AM	5.43	5

The HSPF model calculated hourly DO values for Spring Creek from 1996-2009. These values ranged from 1.29-14.42 mg/L with an average value of 10.85 mg/L. Of the calculations, only 0.21% were below the 5 mg/L daily minimum standard for DO.

The macroinvertebrate populations in Spring Creek lacked EPT taxa. Only 0.91% of individuals caught were of this group which is well below the state average. Macroinvertebrate species richness (21) was also slightly lower than expected for a stream in Minnesota.

The collected and model data do not indicate a DO stressor to the impaired macroinvertebrate community in Spring Creek, while the limited biological data does suggest potential problems. More DO monitoring, and biological sampling is needed to fully understand the conditions of this parameter in Spring Creek.

Candidate cause: high phosphorus

The proposed draft standard for phosphorus for streams in the Missouri River basin is currently 0.15 mg/L. Although phosphorus is an essential nutrient for all aquatic life, elevated levels can lead to an imbalance which impacts stream ecology.

There were a total of 4 phosphorus samples taken from Spring Creek in 2013 (Table X). None of these samples were above the proposed draft standard of 0.15 mg/L (Table 40).

Table 40: Phosphorus sample values from 2013 along Spring Creek (10170203-518) at site 11MS029
***An average of two samples collected**

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS029	6/12/2013	0.0275*	0.15
11MS029	6/26/2013	0.123	0.15
11MS029	7/2/2013	0.025	0.15
11MS029	7/17/2013	0.01	0.15

The HSPF model made daily phosphorus calculations for Spring Creek from 1996-2009. These values ranged from 0.047-0.705 mg/L with an average value of 0.133 mg/L. Of these values, 26.1% were above the 0.15 mg/L proposed standard for phosphorus.

Biologically, the macroinvertebrate populations in Spring Creek had very low levels of EPT taxa (0.91%) and intolerant species (4.35%), while completely lacking any Tanytarsini species. Tanytarsini taxa tend to be more abundant in streams not affected by phosphorus. Spring Creek also possessed high amounts of scraper species (17.39%), crustacean/mollusca taxa (17.39%) and number of tolerant species (82.61%). All of these results are typical of a stream affected by elevated phosphorus levels.

The biological and modeling information both strongly suggest that phosphorus is negatively impacting the macroinvertebrate community in Spring Creek. When ample flow exists in Spring Creek, observed data will likely show the same result. Given the evidence provided, phosphorus is a stressor to the impaired macroinvertebrate community in Spring Creek.

Candidate cause: high nitrates

Currently, the State of Minnesota does not have a nitrate standard in place for streams not used as a drinking water source. However, the overabundance of nitrates can stress a biological community. Nitrates in the Upper Spring Creek watershed did at times reach levels that could potentially be stressing the biological assemblages.

In 2013, Spring Creek had four nitrate samples taken at its biological monitoring site, 11MS029. These values ranged from 0.05-7.7 mg/L (Table 41).

Table 41: Spring Creek (10170203-518) nitrate values from 2013 at site 11MS029

Sample Location	Sample Date	Result (mg/l)	Proposed Draft Standard (mg/l)
11MS029	6/12/2013	4.15*	n/a
11MS029	6/26/2013	7.7	n/a
11MS029	7/2/2013	2.9	n/a
11MS029	7/17/2013	0.05	n/a

The HSPF model calculated daily nitrate values for Spring Creek from 1996-2009. These values ranged from 1.75 -20.189 mg/L with an average value of 4.67 mg/L.

Biologically, macroinvertebrate populations had a slightly below average amount of species richness (21) while containing zero Trichoptera taxa. These results are expected in streams with high nitrate values.

Given the limited nitrate related macroinvertebrate data, chemical, and modeling information, more information is needed to better understand the nitrate conditions in Spring Creek and how they may be affecting the biological communities. More sampling is needed during base flow conditions before determining if nitrates are indeed a stressor to the biological assemblages.

Candidate cause: high turbidity/TSS

In 2013, there were five TSS measurements taken from Spring Creek (Table 42). All TSS values were well below the TSS standard of 65 mg/L. There were also five Secchi/transparency tube measurements taken from Spring Creek. All of these values were very high.

Table 42: TSS and Secchi tube sampling results from 2011-2013 along Spring Creek (10170203-518) at site 11MS029 *Average of multiple samples

Sample Location	Sample Date	Result (mg/l)	TSS Standard (mg/l)	Secchi Tube Value (cm)	Secchi Tube Standard (cm)
11MS029	8/8/2011	n/a	65	>100	20
11MS029	6/12/2013	2.0*	65	>100	20
11MS029	6/26/2013	< 1.0	65	>100	20
11MS029	7/2/2013	5.2	65	86	20
11MS029	7/17/2013	3.6	65	>100	20

The HSPF model calculated daily TSS values along Spring Creek from 1996-2009. The TSS calculations ranged from 0.024-2990.1 mg/L with an average value of 30.86 mg/L. Of these values, 7.8% were above the proposed TSS standard of 65 mg/L.

Biologically, Spring Creek had macroinvertebrate populations that were high in the number of scraper species (17.39%), while having a lower amount of chironomidae (13.04%) species, which is expected in streams not affected by elevated turbidity/TSS levels. There was also an absence of turbidity/TSS sensitive Trichoptera and collector-filterer species. Macroinvertebrate richness was low (21 species) as was Ephemeroptera taxa (4.5%).

Given the lower amount of HSPF predicted violations of the proposed standard, low observed TSS values, and mixed biological information. High turbidity/TSS does not appear to be a stressor to the impaired macroinvertebrate community at this time.

Candidate cause: lack of habitat

No MSHA or habitat measurements were taken at this site on Spring Creek due to the insufficient water flow during the fish sampling visit. Macroinvertebrates in Spring Creek had high amounts of tolerant taxa (82.61%) which are common in streams with degraded habitat conditions. Also, this site had a below state average amount of clinger taxa (13.04%). Clingers tend to decrease in streams lacking abundant habitat. The macroinvertebrate community also had few burrower individuals (1.52%). These organisms are typically more abundant in streams with high amounts of fine sediment that tends to be present in streams with degraded habitat conditions.

With the limited habitat information for Spring Creek, it is too early to tell if this potential stressor is directly harming the impaired macroinvertebrate community. A habitat assessment along with a fish collection will help determine the impact habitat is having on the biological assemblages in Spring Creek.

Conclusion

This study showed that currently there is one stressor (high phosphorus) to the impaired macroinvertebrate community in the Spring Creek watershed (Table 43). Overall, this watershed lacked many chemical and biological measurements due to the flow conditions present.

In the case of phosphorus, the macroinvertebrate community as well as the HSPF model provided significant evidence that the assemblage was being stressed due to high phosphorus conditions. Elevated phosphorus conditions were consistent throughout the entire Lower Big Sioux River watershed. As previously mentioned, a large scale phosphorus plan is needed to help reduce these levels. Actions such as limiting the amounts of phosphorus fertilizer applications and increasing riparian buffers will aid in phosphorus reductions in not only the Spring Creek subwatershed, but also the entire Missouri River basin.

Figure 68: Various water level conditions at site 11MS029 along Spring Creek during the summer of 2013

Overall, the water levels in the Spring Creek watershed tend to fluctuate greatly (Figure 68), which can greatly impact the concentrations of nutrients, as well as the DO and habitat conditions. An increase in monitoring during base flow conditions would help better understand other potential stressors this watershed likely has.

Table 43: Biologically impaired reach in the Spring Creek watershed and its stressor
(• = stressor, - = not a stressor, and blank = inconclusive/not enough evidence)

		Stressors				
Stream Name	**AUID #**	**Low Dissolved Oxygen**	**High Phosphorus**	**High Nitrates**	**High Turbidity/TSS**	**Lack of Habitat**
Upper Spring Creek Watershed						
Spring Creek	10170203-518		•		-	

Summary and recommendations

The Lower Big Sioux River watershed is impaired for aquatic life due to its biology assemblages at 18 different AUIDs across six subwatersheds.

Dissolved oxygen was determined to be a stressor in nine of the AUIDS. Many sites lacked pre 9:00 AM dissolved oxygen data sets that can often provide more insight of the dissolved oxygen conditions during these times. Continuous dissolved oxygen monitoring with a sonde is also recommended in the sites with relatively few data points, as this method of data collection will provided a clear understanding of the dissolved oxygen conditions that the stream experiences.

High fluxes in dissolved oxygen can often be correlated with the high phosphorus levels that are present in much of the watershed. Phosphorus was found to be a stressor in all 18 AUIDs. In the Lower Big Sioux River watershed, a large scale plan to reduce phosphorus levels is greatly needed. This plan should include efforts to improve the timing and rate of fertilizer application, as well as increasing riparian buffers and minimalizing cattle access to streams. Without some of these changes, phosphorus will continue to easily runoff into the stream system and negatively impact the biological assemblages within this watershed, but also the Missouri River basin.

Elevated nitrate values are also of concern in the Lower Big Sioux River watershed. This study found that seven AUIDs were having there impaired biological assemblage stressed by high nitrate levels. This was frequently evidenced by high numbers of nitrate tolerant macroinvertebrate individuals, low numbers of Trichoptera taxa, as well as many tolerant fish and macroinvertebrate taxa among other nitrate related biological metrics. Similar to phosphorus, a large scale plan to reduce nitrate levels is needed in this watershed. Often times nitrate levels spiked during times of fertilizer applications. Reducing the application time and rate, and improving the pathways nitrates have to the surface water will greatly improve the nitrate conditions in this watershed. Until improvements are made, expect the biological conditions to degrade.

To read more about nitrate conditions, trends, sources, and ways to reduce nitrates throughout Minnesota, please refer to *Nitrogen in Minnesota Surface Waters* (MPCA 2013).

Excess amounts of turbidity and TSS are issues that will also need to be addressed in the Lower Big Sioux River watershed. This study found that 11 biologically impaired reaches are being stressed due to high turbidity and TSS levels. Effects from this parameter were especially profound in the Flandreau, Pipestone, and Split Rock Creek watersheds where the majority of impaired reaches were also stressed by high turbidity/TSS levels. Currently, five reaches in this watershed are impaired for aquatic life due to the turbidity conditions present, so this problem has existed for an extended period of time. Ways to reduce this watershed wide issue would be to limit cattle access to streams, practicing rotational and flash grazing, maintaining an ample riparian corridor, and to install deep rooted vegetation along the stream banks. These improvements would help stabilize the stream channel and banks, which often lead to eroded banks and the release of sediment throughout the water column. These upgrades would also help lessen the impact on stream banks during high flow events.

The habitat conditions in the Lower Big Sioux River watershed often limited the success and health of the biological assemblages. This study identified 13 stream reaches that were found to be stressed due to their lack of suitable habitat conditions. Habitat conditions in the watershed were mostly fair to poor. Commonly found problems were the poor surrounding land use, lack of ample riparian buffer, minimal stream shading, eroding banks, low channel stability, the high presence of silt or sand substrates, and sparse fish cover. Like the other stressors found, habitat conditions will improve by increasing the immediate riparian area, limiting cattle access to the stream, and incorporating other best management

practices. Stabilizing the stream banks will also help limit the amount of sediment entering the stream covering the course substrates that are preferred by many types of sensitive types of fish species. This may be achieved by incorporating natural channel design practices to restore stream channels by moving them to their stable form. Other habitat improvement projects that provide more cover for fish are greatly needed in this watershed.

Overall, significant problems and stressors to the biological communities exist in the Lower Big Sioux River watershed. Substantial changes are needed watershed wide to help mitigate the damages caused by the prolonged poor land use and lack of riparian buffer. Until these improvements and long term changes are made, expect the fish and macroinvertebrate assemblages in the Lower Big Sioux River watershed to remain stressed and impaired.

Appendix 1.1 - MPCA fish IBI class criteria for Lower Big Sioux River watershed streams

Fish IBI Class	Class Name	Drainage Area	Gradient
1	Southern Rivers	> 300 mi^2	not specified
2	Southern Streams	> 30 mi^2, < 300 mi^2	not specified
3	Southern Headwaters	< 30 mi^2	> 0.50 m/km

Appendix 1.2- MPCA macroinvertebrate IBI class criteria for Lower Big Sioux River watershed streams

M-IBI IBI Class	Class Name	Drainage Area	Description
5	Southern Streams (Riffle/Run Habitats)	<500 mi^2	Sites within this class are representative of the Eastern Broadleaf forest, Prairie Parklands, and Tall Aspen Parklands ecological provinces, as well as streams in HUC 07030005.
7	Prairie Streams (Glide/Pool Habitats)	<500 mi^2	Sites in Minnesota that are representative of the Prairie Parklands and Tall Aspen Parklands ecological provinces

Works cited

Allan, J. D. 1995. Stream Ecology - Structure and function of running waters. Chapman and Hall, U.K.

Belden, J., and M.J. Lydy. "Impact of atrazine on organophosphate insecticide toxicity." Environmental Toxicology and Chemistry, 2000: 19:2266-2274.

Camargo J. and A. Alonso. 2006. Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment. Environment International 32:831-849.

Carlisle D.M., Wolock D.M. and M.R. Meador. 2010. Alteration of streamflow magnitudes and potential ecological consequences: a multiregional assessment. Front Ecol Environ 2010; doi:10.1890/100053

Davis, J. 1975. Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: A Review. Journal of the Fisheries Research Board of Canada, p 2295-2331.

Doudoroff, P. and C. E. Warren. 1965. Dissolved oxygen requirements of fishes. Biological Problems in Water Pollution: Transactions of the 1962 seminar. Cincinatti, Ohio. Robert A. Taft Sanitary Engineering Center, U.S. Public Health Service, Health Service Publication, 999-WP-25

Grabda, E., Einszporn-Orecka, T., Felinska, C. and R. Zbanysek. 1974. Experimental methemoglobinemia in trout. Acta Ichthyol. Piscat., 4, 43.

Griffith, M.B., B. Rashleigh, and K. Schofield. 2010. Physical Habitat. In USEPA, Causal Analysis/Diagnosis Decision Information System (CADDIS). http://www.epa.gov/caddis/ssr_phab_int.html

Hansen, E. A. 1975. Some effects of groundwater on brook trout redds. Trans. Am. Fish. Soc. 104(1):100-110.

Heiskary, S., R.W. Bouchard Jr., and H. Markus. 2010. Water Quality Standards Guidance and References to Support Development of Statewide Water Quality Standards, Draft. Minnesota Pollution Control Agency, St. Paul, Minnesota. 126 p.
http://www.pca.state.mn.us/index.php/view-document.html?gid=14947

"Hyalella". Photo. http://www.shl.uiowa.edu/env/limnology/macroinvertebrates/OtherTaxa/scuds-Amphipoda/Gammarus%20psuedolimnaeus16x12.jpg

Marcy, SM. 2007. Dissolved Oxygen: Detailed Conceptual Model Narrative. In USEPA, Causal Analysis/Diagnosis Decision Information System (CADDIS).
http://www.epa.gov/caddis/pdf/conceptual_model/Dissolved_oxygen_detailed_narrative_pdf

Markus, H.D. 2010. Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity). MPCA.
http://www.pca.state.mn.us/index.php/view-document.html?gid=14922

McCollor, S. and Heiskary, S. (1993). Selected Water Quality Characteristics of Minimally Impacted Streams From Minnesota's Seven Ecoregions. Minnesota Pollution Control Agency.

MDNR. 2014. Missouri River Watershed Hydrology, Connectivity, and Geomorphology Assessment Report. Minnesota Department of Natural Resources, Mankato, MN.

MPCA. 2009. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. Minnesota Pollution Control Agency, St. Paul, MN.

MPCA. 2012. Pomme de Terre Watershed Biotic Stressor Identification.
http://www.pca.state.mn.us/index.php/view-document.html?gid=18229

MPCA Stream Habitat Assessment (MSHA) Protocol for Stream Monitoring Sites. Available at: http://www.pca.state.mn.us/index.php/view-document.html?gid=6088

MPCA and MSUM. 2009. State of the Minnesota River, Summary of Surface Water Quality Monitoring 2000-2008. http://mrbdc.wrc.mnsu.edu/reports/basin/state_08/2008_fullreport1109.pdf

MPCA. (2013). Nitrogen in Minnesota Surface Waters: conditions, trends, sources, and reductions. Chapter D1 prepared in collaboration with the University of Minnesota. Minnesota Pollution Control Agency, St. Paul, Minnesota. http://www.pca.state.mn.us/index.php/view-document.html?gid=19846

Munawar, M., W. P. Norwood, and L. H. McCarthy. 1991. A method for evaluating the impacts of navigationally induced suspended sediments from the Upper Great Lakes connecting channels on the primary productivity. Hydrobiologia, 219: 325-332.

Murphy, M. L., C. P. Hawkins, and N. H. Anderson. 1981. Effects of canopy modification and accumulated sediment on stream communities. Trans. Am. Fish. Soc 110:469–478.

Nebeker, A., Domingue.z, S., Chapman, G., Onjukka, S., & Stevens, D. (1991). Effects of low dissolved oxygen on survival, growth and reproduction of Daphnia, Hyalella and Gammarus. Environmental Toxicology and Chemistry , Pages 373 - 379.

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: brown trout. Biological Report 82 (10.124). U.S. Fish and Wildlife Service. 65 pp.

“Trichorythodes”. Photo. (www.insectsofiowa.com).

U. S. EPA. 2003. National Water Quality Report to Congress (305(b) report). http://www.epa.gov/OWOW/305b/

Waters, T. 1995. Sediment in Streams: Sources, Biological Effects, and Control. Bethesda, Maryland: American Fisheries Society.