Upper Big Sioux River Watershed Biotic Stressor Identification Report

Minnesota Pollution Control Agency

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Executive summary

This report summarizes the stressor identification (SID) work done in the Upper Big Sioux River Watershed.

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 factors causing harm to aquatic organisms such as fish and macroinvertebrates. Stressor identification is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water, Land, and Legacy Amendment.

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 assess the composition of fish and macroinvertebrate populations, as well as evaluate the related habitat conditions. These assessments take place at monitoring sites throughout Minnesota's major watersheds. The resulting information is used to produce an Index of Biological Integrity (IBI). IBI scores can then be compared to regional standards, and segments of streams and rivers with low IBI scores are deemed "impaired."

The purpose of stressor identification is to interpret the data collected during the biological monitoring and assessment process. This analysis provides insight as to why one stream has a low IBI score, while another has a high score. It considers causal factors – negative ones harming fish and insects, and positive ones leading to healthy biology. Stressors may be physical, chemical, or biological.

The Upper Big Sioux River Watershed encompasses 154,921 acres in southwest Minnesota while the remaining 1,197,507 acres are in South Dakota. This watershed includes several small streams that flow into Medary Creek, a tributary to the Big Sioux River which eventually joins the Missouri River.

Medary Creek was determined to be impaired for aquatic life due to its macroinvertebrate assemblage.

After examining the many candidate causes for this biological impairment, the following stressors were identified for Medary Creek:

- Low Dissolved Oxygen
- High Phosphorus levels
- High Nitrate levels
- Altered Hydrology
- High Total Suspended Solids
- Lack of Habitat

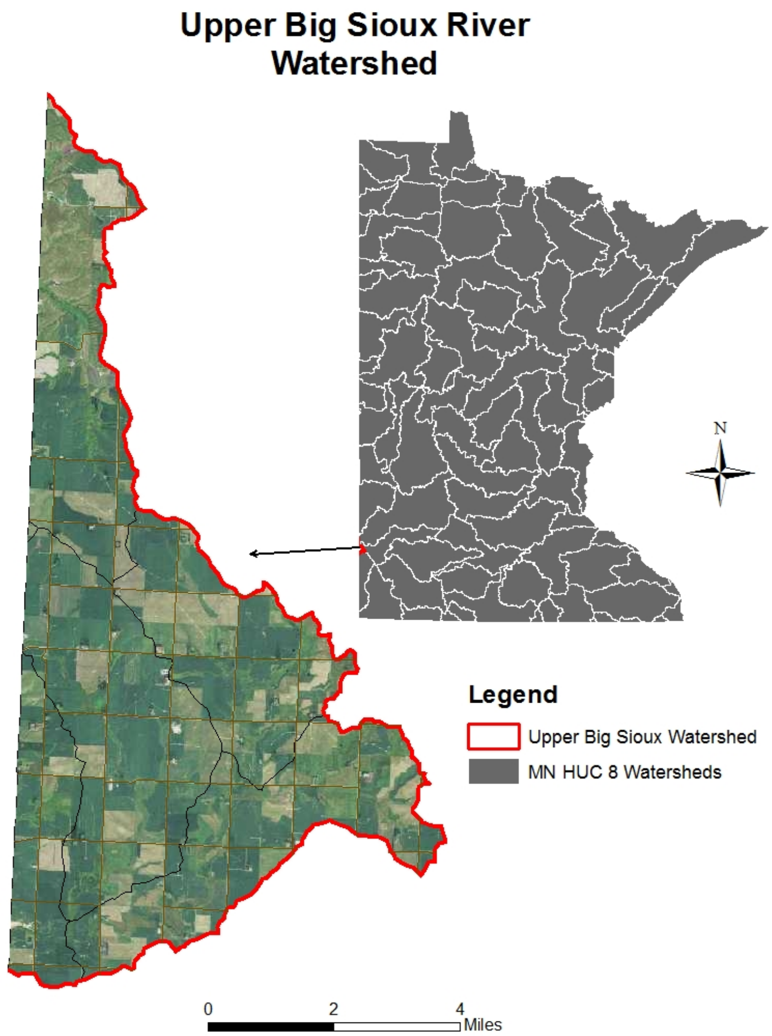

Figure 1: Location of Upper Big Sioux Watershed in Minnesota

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 1.1).

Once a biological impairment is discovered, the next step is to identify the source(s) of stress on the biological community. A 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) study. The product of the SID process is the identification of the stressor(s) for which the TMDL may be developed.

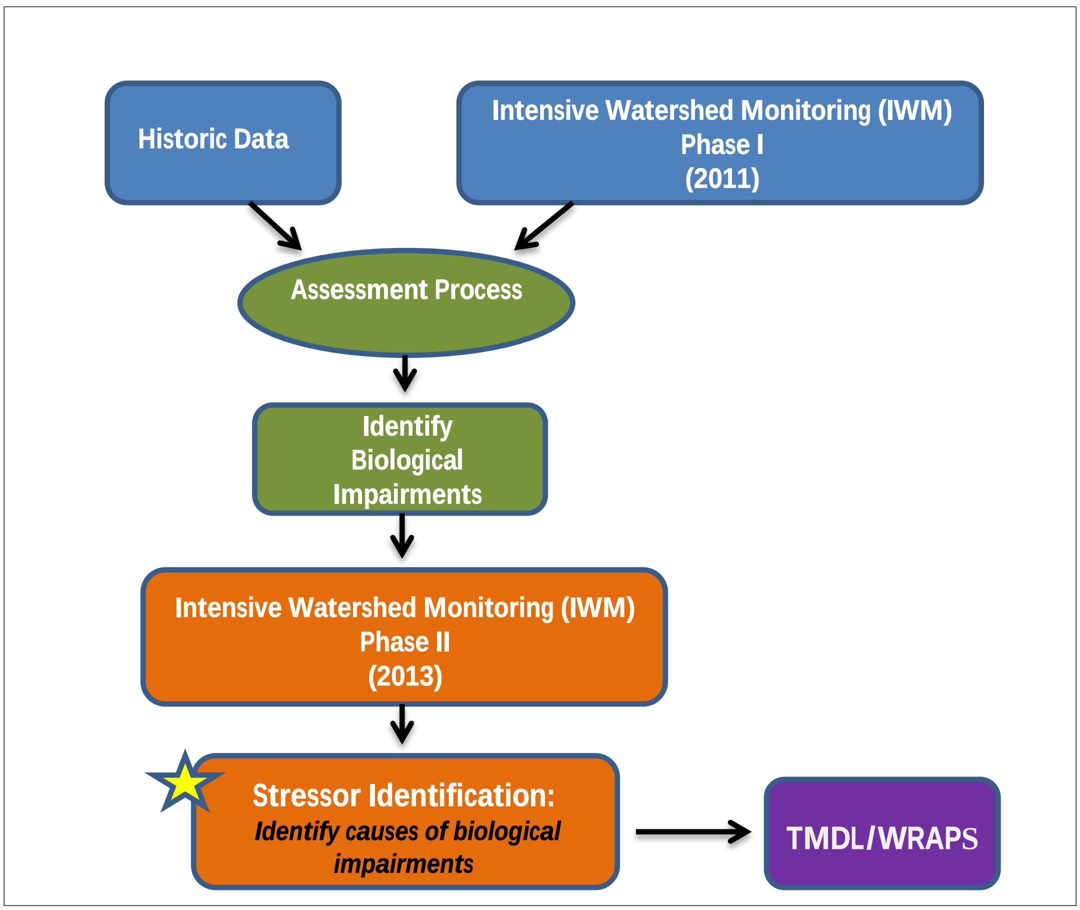

Figure 1.1: Process map of IWM, Assessment, Stressor Identification, and TMDL processes

Organizational framework of stressor identification

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 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).

SID 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.

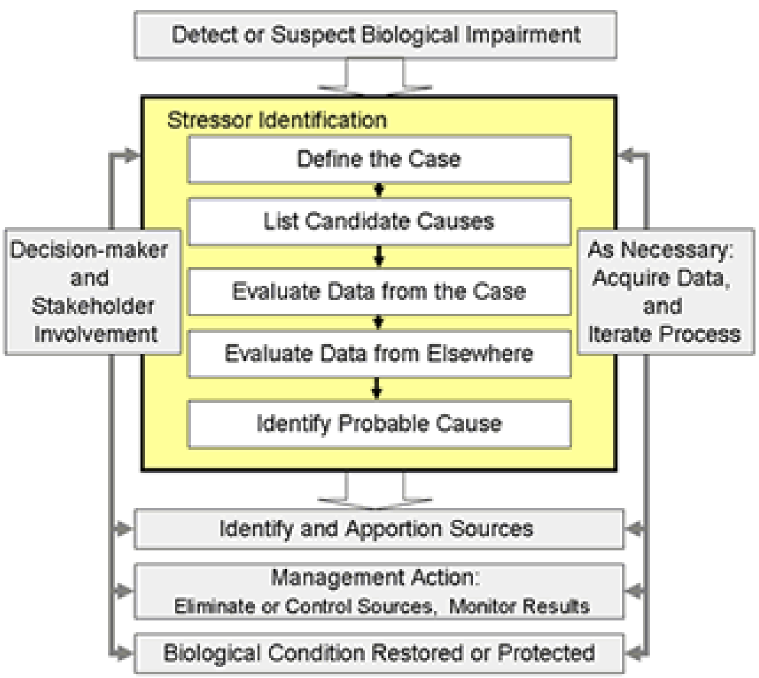

Figure 2: Conceptual model of stressor identification (SID) process

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 water body. Table 1 lists the common stream stressors to biology relative to each of the major stream health categories.

Table 1: 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

Following an introduction to the biologically impaired reach, Medary Creek (10170202-501), this SID report follows a format to first describe candidate causes of stress to the biological communities at the 8-digit HUC scale. Information is presented on water quality standards and general effects on biology. The candidate causes effect on the biology in Medary Creek (10170202-501), are analyzed and discussed in these sections.

Upper Big Sioux River Watershed

Report overview

The Upper Big Sioux River Watershed consists of two 12-digit Hydrologic Unit Code (HUC) sub-watersheds. One Assessment Unit Identification (AUID) (10170202-501) located in this watershed is listed as impaired for macroinvertebrates (Figure3). This report describes the step-by-step analytical approach, based on the U.S. Environmental Protection Agency's (EPA) SID process for identifying the probable cause(s) of impairment(s) in a particular system.

The MPCA uses an integrated monitoring approach. Biological, physical, and chemical data along with the relationships between these data are used to assess the quality of a water body. This report utilizes the integrated approach in an attempt to describe the connection between the biological community and the stressors that are impacting this community.

This report includes a discussion of the data collected to support the determination of candidate stressors at the stream AUID level. A comprehensive review of biological, chemical, and physical data was performed to select probable causes for the impairments. The initial list of candidate causes was reduced after additional data analysis, leaving six candidate causes for final analysis in this report. The candidate causes for the biologically impaired Medary Creek (10170202-501) in the Upper Big Sioux River Watershed are listed below:

- Low Dissolved Oxygen
- High Phosphorus
- High Nitrates
- Altered Hydrology
- High Total Suspended Solids
- Lack of Habitat

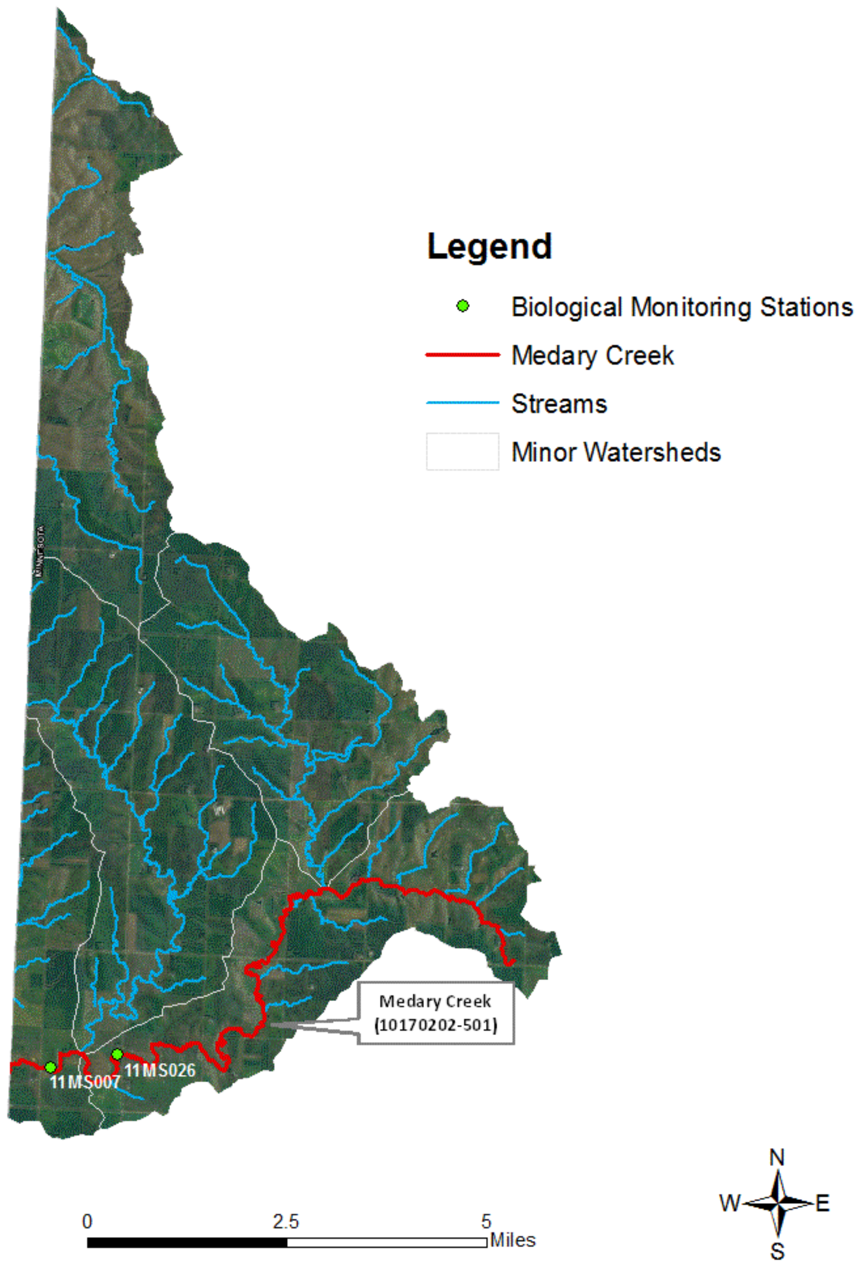

Figure 3: Location of impaired reach and sampling sites in the Upper Big Sioux

Hydrological Simulation Program – FORTRAN (HSPF) 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 and Non-Point Source 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 the Upper Big Sioux Watershed to help simulate outputs used for analysis. In this report, the minor watersheds with biological impairments used the model results to supplement information that was not collected.

Impaired reach: Medary Creek (10170202-501)

Medary Creek (AUID: 10170202-501) was assessed in 2013 and was determined to be impaired for aquatic macroinvertebrates. The impaired reach extends from the headwaters just northwest of the intersection of U.S 14 and 170th Avenue in Lake Benton to the Minnesota/South Dakota border just north of County Road 10 in Elkton. See Figure 4 for a detailed map of Medary Creek.

Through utilization of the National Land Cover Database (NLCD) (Figure 5), it was determined that the Upper Big Sioux River Watershed has a land use dominated by cultivated crops (60.15%) followed by rangeland (34.19%), and developed land (4.59%). Additionally, there are 26 feedlots in the watershed holding a total of approximately 19,350 animals (~15,300 pigs, ~3,500 cattle, ~550 sheep). The prevalence of cropland and feedlot operations makes Medary Creek susceptible to large amounts of nutrient and sediment runoff. This can be especially damaging to the river system in the sensitive headwaters contained within this watershed.

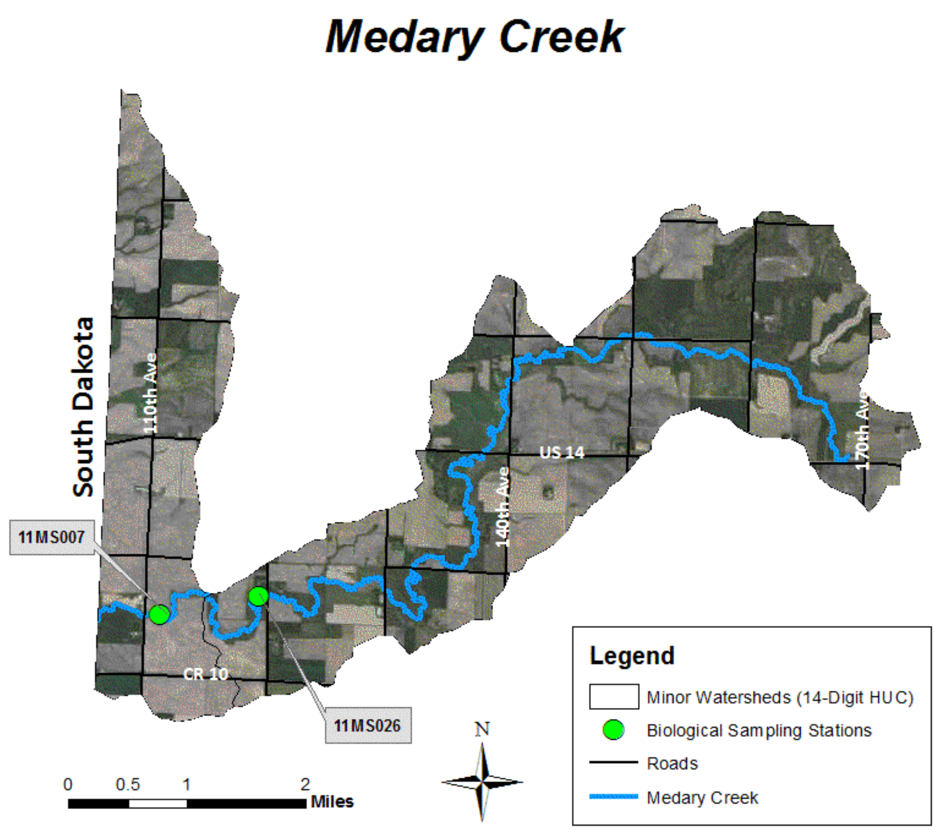

Figure 4: Medary Creek Minor Watersheds showing biological monitoring stations and nearby roads

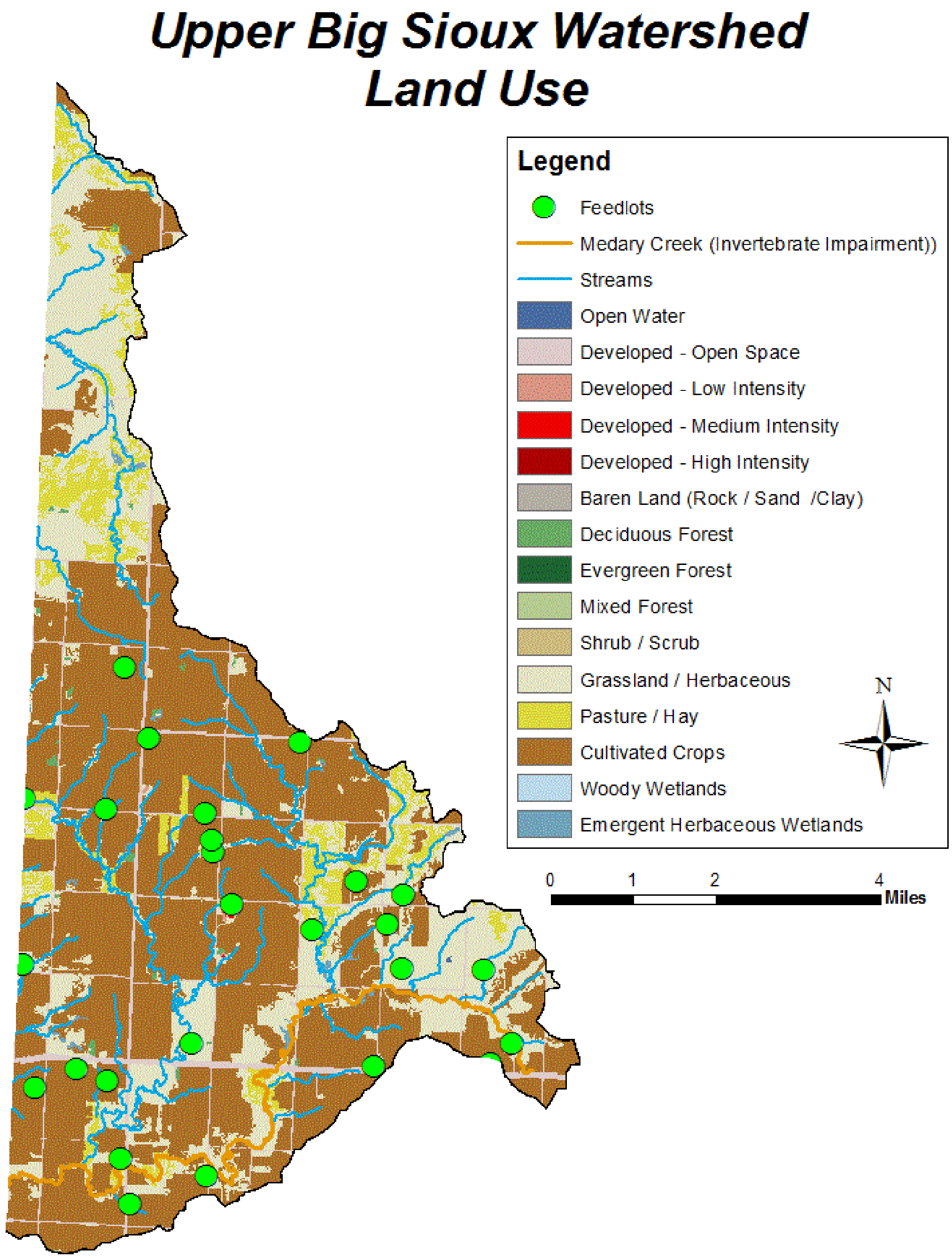

Figure 5: Land use in the Upper Big Sioux River Watershed using the National Land Cover Database

Biology in Medary Creek

Overview

The Upper Big Sioux River Watershed (8-Digit HUC: 10170202) was sampled in 2011-2012. The fish and macroinvertebrate communities within each AUID were compared to a regionally developed threshold and confidence interval utilizing a weight of evidence approach. The assessment process determined that one stream reach was impaired for the macroinvertebrate community (Medary Creek, 10170202-501.

Biological monitoring is used in addition to chemical monitoring because stream biota is a better indicator of stream health than chemical parameters alone. There are a multitude of potential stream contaminants and testing for each one chemically would be an inefficient use of time and money. Biological communities within a stream are sensitive to the cumulative effects of these contaminants as well as physical alterations (e.g., channelization, riparian zone variation, sedimentation); therefore assessing the integrity of the biological community is an excellent indicator of overall stream health.

Procedure

The following procedure description focuses on macroinvertebrate sampling techniques as Medary Creek was determined to be impaired for macroinvertebrates and not fish. However, some fish metrics will be used in forthcoming analyses, and fish sampling procedures can be found at the MPCA website.

The first step in the process of assessing the integrity of the biological community is data collection. The macroinvertebrate sampling done in Medary Creek was conducted in accordance with MPCA standard operating procedures (SOP). SOP dictates that a multi-habitat sampling approach is to be used with the goal of collecting a representative sample of the macroinvertebrate community at a particular site. This entails a MPCA biologist determining which of the five possible general habitats are present in the stream (riffle\cobble\boulder, emergent\submerged vegetation, undercut banks\overhanging vegetation, woody debris\root wads, and leaf packs). After this determination is made, 20 samples are spread out over the dominant habitats based on their prevalence. For example, if it was determined that riffles and overhanging vegetation were the dominant habitats and equally present, 10 samples from each of these habitat types would be collected along the reach. The habitats sampled at 11MS007 were emergent\submerged vegetation (7 samples), riffle\cobble\boulder (7 samples), and overhanging vegetation (6 samples). At 11MS026 emergent\submerged vegetation and riffle\cobble\boulder habitats were sampled with 10 samples at each.

To interpret the data, MPCA has developed regional IBI thresholds and confidence intervals. The IBI score is a sum of a group of metrics that were determined to be effective at identifying community health. These metrics evaluate community attributes such as species richness, pollution tolerance, composition, and trophic structure (feeding habits). Once determined, the IBI score is compared with the established threshold for that particular stream class based on stream size, stream morphology, and ecoregion. Medary Creek was determined to be a class 5 stream (Southern Stream with Riffle/Run habitat), with surrounding land representative of the Northern Glaciated Plains ecoregion. For more detailed information on how biological communities are assessed see the Biological Monitoring page on MPCA's website.

Table 2 shows the fish and macroinvertebrate IBI scores for the sites studied further in this report. For more detailed information on the fish and macroinvertebrate classification criteria, see Appendix 1.1-2.

Table 2: Macroinvertebrate thresholds and confidence limits by class

Class	Class Name	Thresholds	Upper CL	Lower CL
		Macroinvertebrate IBI		
5	Southern Streams RR	35.9	48.5	23.3
		Fish IBI		
3	Southern Headwaters	51	58	44

The impaired AUIDs are color coded by their relationship to the IBI threshold and confidence intervals in Table 3. See Table 4 for the color descriptions of the IBI scores.

Table 3: Fish and macroinvertebrate IBI scores by biological station within AUID with descriptive color
*** Multiple scores are a result of multiple sampling visits.**

AUID & Reach	Station	Year	Fish IBI Score	Fish Class	Macroinvertebrate IBI Score	Macroinvertebrate Class
10170202-501 (Medary Creek)	11MS007	2010	**61**	3	**33.4**	5
10170202-501 (Medary Creek)	11MS026	2010	**55**	3	**21.3**	5

Table 4: IBI color descriptions

At or Below Lower Confidence Limit	**At or Below Threshold, Above Lower Confidence Limit**	**At or Above Threshold, Below Upper Confidence Limit**	**At or Above Upper Confidence Limit**

This AUID was sampled at two stations, 11MS007 and 11MS026. 11MS007 is located upstream of 11th Street, about 4 miles west of Ellsworth. 11MS026 is located downstream of CR 1, about 7 miles west of Lake Benton. 11MS007 scored below the IBI threshold for a macroinvertebrate class 5 stream, but was within the lower confidence limit. 11MS026 had an IBI score below the threshold and the lower confidence limit (Table 3). The metric scores can be seen below in figures 8 and 9. After these sites were determined to be impaired, additional physical and chemical monitoring took place in 2012/2013 by MPCA as well as the Nobles County Soil and Water Conservation District.

Results

In order to meet the Macroinvertebrate Index of Biological Integrity (M-IBI) threshold for a macroinvertebrate class 5 stream, each metric would need to average 3.59 points. The majority of metrics scored below this average (Figure 6). A general description of metrics for class 5 streams in Minnesota can be seen in Table 5.

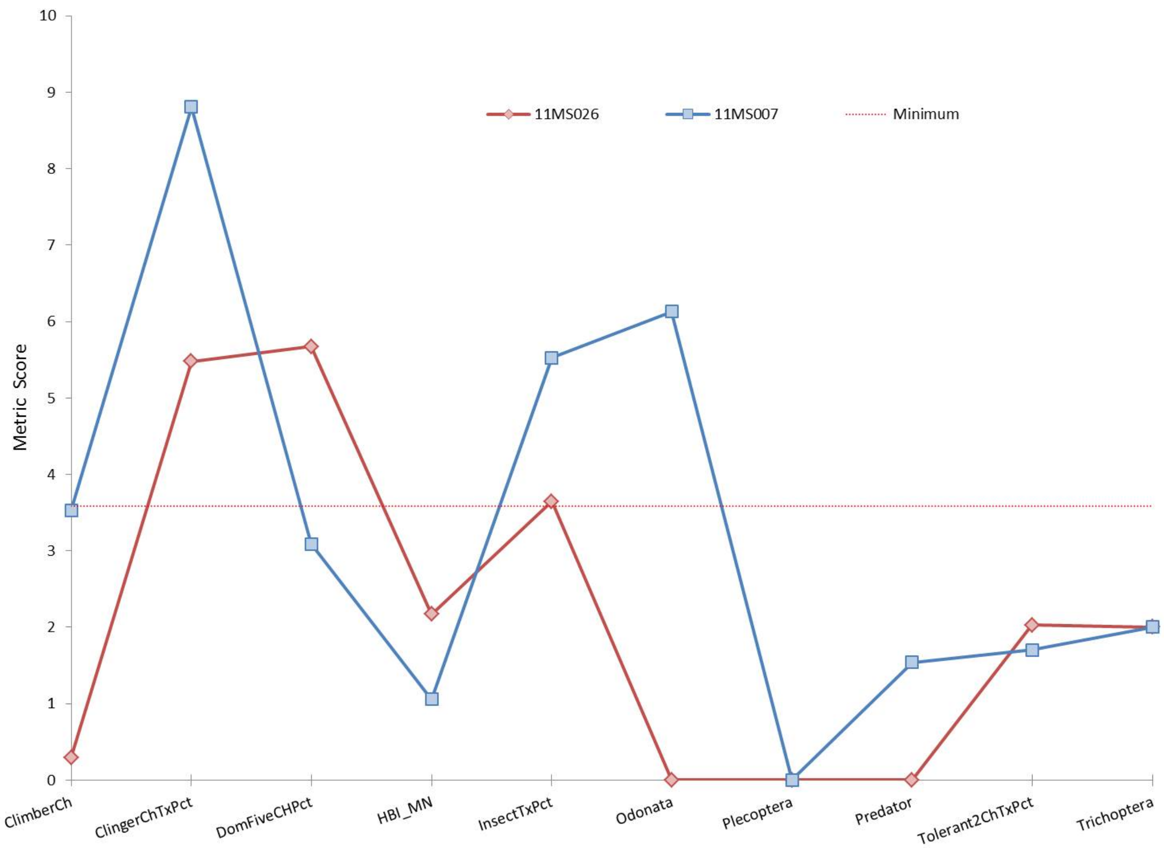

Figure 6: Individual macroinvertebrate IBI metric scores at 11MS026 at Medary Creek

Table 5: General description of metrics for Class 5 streams in Minnesota and their response to increased stress

Metric Name	Category	Response	Metric Description
ClimberCh	Habitat	Decrease	Taxa richness of climbers
ClingerChTxPct	Habitat	Decrease	Relative percentage of taxa adapted to cling to substrate in swift flowing water
DomFiveChPct	Composition	Increase	Relative abundance (%) of dominant five taxa in subsample (chironomid genera treated individually)
HBI_MN	Tolerance	Increase	A measure of pollution based on tolerance values assigned to each individual taxon, developed by Chirhart
InsectTxPct	Composition	Decrease	Relative percentage of insect taxa
Odonata	Richness	Decrease	Taxa richness of Odonata
Plecopotera	Richness	Decrease	Taxa richness of Plecoptera
PredatorCh	Trophic	Decrease	Taxa richness of predators
Tolerant2ChTxPct	Tolerance	Increase	Relative percentage of taxa with tolerance values equal to or greater than 6, using MN TVs
Trichoptera	Richness	Decrease	Taxa richness of Trichoptera

Some of the metrics to take note of are Plecoptera, HBI_MN, Trichoptera, Tolerant2ChTxPct and Predator as they scored poorly at both sites.

Plecoptera, commonly known as stoneflies, were absent at both sites. This order is considered to be among the most sensitive to pollution. Plecoptera require high dissolved oxygen (DO) concentrations in order to respirate. Generally, they also require quality substrate (boulder/cobble/gravel) so channel modification or high sedimentation rates can negatively impact these organisms (Harper, 1979).

Trichoptera, commonly known as caddisflies, had lower than average populations at both sites. In general, many families of Trichoptera are sensitive to excess nutrients (mainly nitrates) and excess sedimentation.

The HBI_MN and Tolerant2ChTxPct metrics both involve community responses to increasing pollution. It was determined that the macroinvertebrates grouped into these metrics are more abundant in poor quality class 5 streams. A low score at both sites for each of these metrics indicates excess amounts of organic material, which is a common waste product of domestic sewage and agriculture. These organic compounds are decomposed in the stream by aeorbic microorganisms that use up DO faster than it can be replenished, decreasing oxygen availability for macroinvertebrates and fish. Organic pollution also increases the amount of total suspended solids (TSS) in the water column, causing increased sediment deposition to the stream bed, in turn reducing suitable habitat for sensitive macroinvertebrates and fish.

The data collected on the macroinvertebrate community structure provides a good indication of whether or not stressors are affecting a water body, however this alone is not enough to form solid conclusions on what these stressors are. Throughout the remainder of this report additional fish and macroinvertebrate metrics will be used as evidence in conjunction with water quality monitoring data.

Candidate cause: Low Dissolved Oxygen

Overview

Dissolved oxygen (DO) refers to the concentration of oxygen molecules dissolved in the water. In lotic environments, these oxygen molecules naturally diffuse from the air into the water since concentrations in the air are much higher than in the water. Oxygen is also released into the water as a by-product of photosynthesis from aquatic plants. DO is important to aquatic organisms such as fish and macroinvertebrates because this is the oxygen that they use for respiration.

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, and point-source discharges are just some of the anthropogenic factors that can cause unnaturally high, low, or volatile DO concentrations.

DO concentrations also depend heavily on temperature, hydrology (e.g., flow), and biochemical oxygen demand (BOD). In response to cooling water temperatures, water molecules become more densely packed together; in turn trapping DO molecules that are more easily lost in warmer water. Flow patterns can also affect DO levels; turbulent flow increases the surface area available for diffusion of oxygen from the air to the water. BOD is the amount of oxygen required by aerobic microbes in the water to metabolize organic compounds for energy; therefore a high BOD would decrease the amount of DO in the water column. A landscape dominated by agriculture often increases the BOD of a system by increasing inputs of organic matter. Low DO concentrations are typical in late summer when water temperatures are high and baseflow conditions are present or when there is a high amount of organic material input to the stream (high BOD). Daily fluctuations in DO are normal and the lowest concentrations can be expected overnight when plants are not photosynthesizing. However, if DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995). See Figure 7 below for a conceptual model of DO.

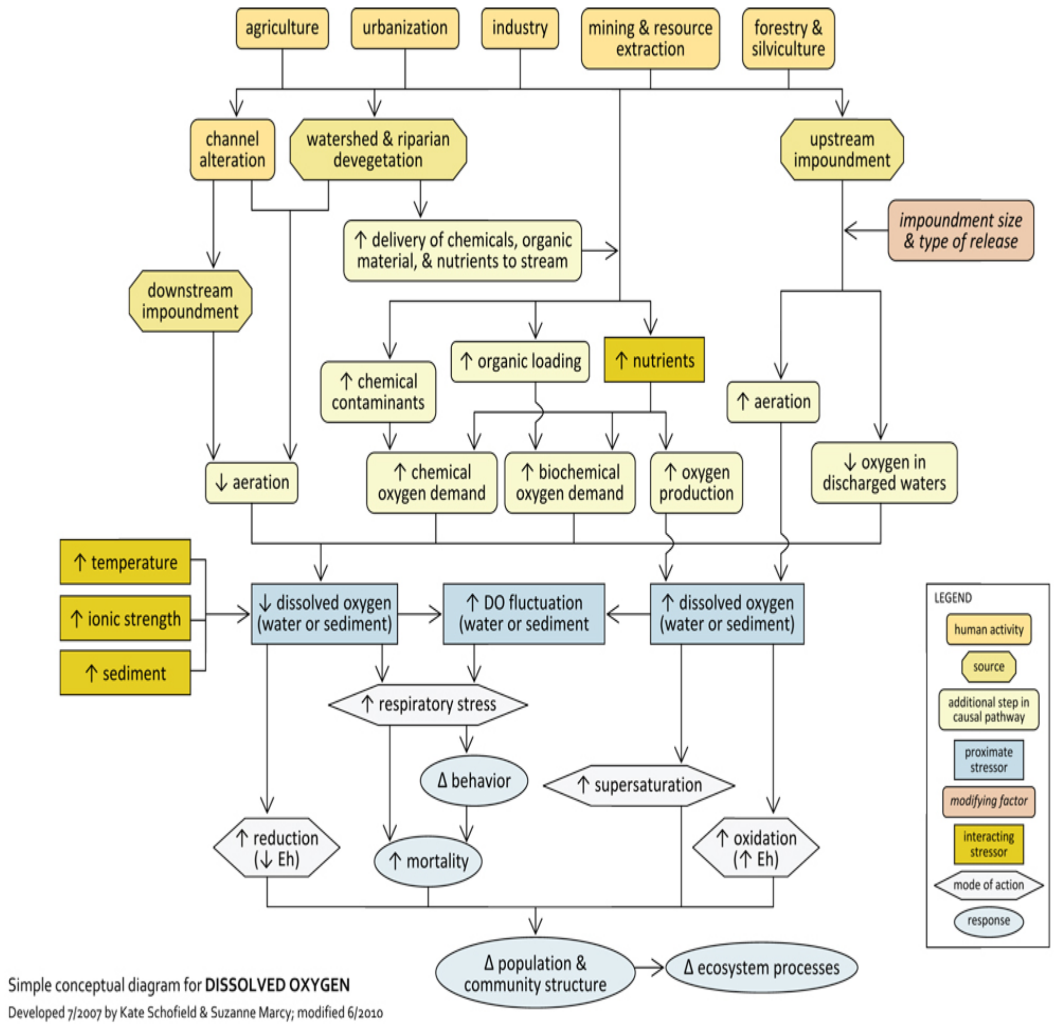

Figure 7: Dissolved oxygen conceptual model

Water quality standards

In class 2B streams, the Minnesota standard for DO is 5.0 mg/L as a daily minimum. Additional criteria 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.*

Dissolved oxygen in Medary Creek

Instantaneous DO data are the only data available for Medary Creek. These measurements were taken using a YSI Sonde and represent a discrete point sample. Because DO concentrations can vary depending on flow conditions and sampling time, these measurements need to be used carefully.

A total of 31 instantaneous DO measurements were taken from 2011-2012 (Table 6). Five of these measurements were taken before 9 AM and one of these five (20%) was below the standard of 5 mg/L. Out of all the measurements, three were below the standard (9.7%) (Figure 8)

Table 6: Summary of all DO observations for Medary Creek

Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Number of Observations
15.00	3.31	7.86	31

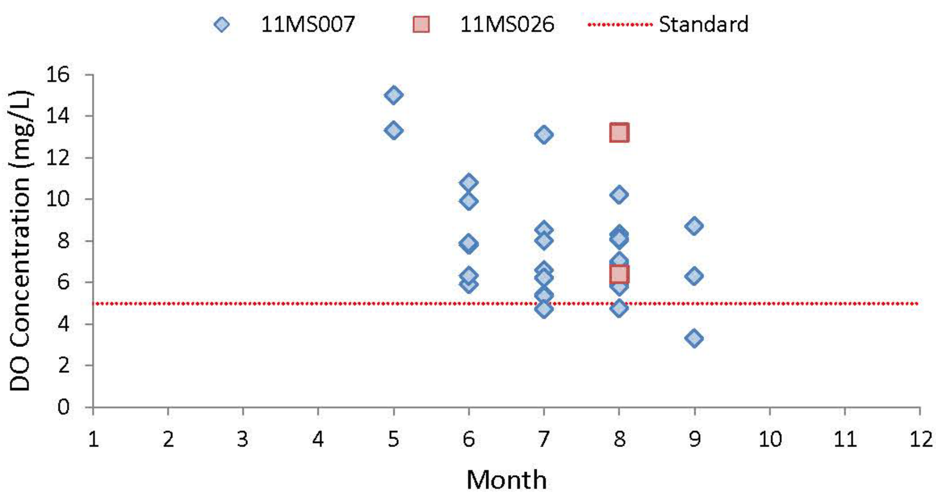

Figure 8: Graphical DO results by month

The HSPF model predicted hourly DO conditions from 1996-2009. These values ranged from 2.79-14.04 mg/L with an average value of 10.56 mg/L. Only 0.1% of these samples fell below 5 mg/L.

Biological connections

There are many fish and macroinvertebrate metrics that can indicate if a stream has healthy DO concentrations or not. A handful will be examined in this section. Headwater streams are generally groundwater fed, therefore experiencing colder water temperatures and higher DO when compared to larger streams. The HdwTxPct or "Headwater Taxa Percent" metric accounts for fish species adapted to living in these conditions. It indicates the percent of total fish taxa in the sample that are headwater dwelling species. Since the Upper Big Sioux River Watershed is home to the headwaters of Medary Creek, this is an extremely useful metric. Sites 11MS007 and 11MS026 along Medary Creek had much fewer headwater taxa (6.67%) when compared to other Fish Index of Biological Integrity (F-IBI) class 3 (*i.e.,* southern headwaters) sites around Minnesota. This is highly indicative of stressful conditions due to altered DO concentrations. Additionally, these sites along Medary Creek had high amounts of serial spawning (37.39%) and tolerant taxa (60.43%), while also having few species categorized as darters/sculpins/round-bodied suckers (7.68%). These results often characterize a stream affected by low DO conditions (Table 7). The fish communities at sites 11MS007 and 11MS026 did have above average tolerance indicator value (TIV) scores when compared to all other Minnesota streams. Streams with low DO TIV scores often have low or wide ranging DO values.

From the macroinvertebrate samples, the EPTPct metric is of particular importance while assessing in-stream DO conditions. This metric indicates the percent of individuals from orders Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) that were present in the sample. Generally, species within these three orders are sensitive to poor DO conditions. Medary Creek had a macroinvertebrate assemblage consisting of 30.1% EPT individuals, which is below average when compared to other macroinvertebrate class 5 streams throughout Minnesota (Table 7).

Additionally, the macroinvertebrate community along Medary Creek had a lower amount of overall taxa (21.5 species), which is also indicative of a system negatively affected by the DO conditions. Sites 11MS007 and 11MS026 did have an average of five DO intolerant taxa, while also having a small amount of DO tolerant individuals (7.61%) when compared to all other Minnesota streams.

Table 7: Fish and macroinvertebrate metrics generally associated with DO. Included are scores from each assessment site, their class respective statewide average IBI scores, and predicted responses to pollution. Red indicates lower than average, green indicates above average.

Metric	Statewide Class Average	11MS007	11MS026	Expected Response
Fish	Class 3			
HdwTxPct	21.41	13.04	6.67	Decrease
MA>3TxPct	10.98	13.04	13.33	Decrease
SensitiveTxPct	7.35	13.04	6.67	Decrease
Macroinvertebrates	Class 5			
EPTChTxPct	26.13	22.86	23.68	Decrease
EPTPct	38.92	30.12	32.92	Decrease
TrichopteraChTxPct	11.71	11.43	10.53	Decrease
TrichopteraPct	17.92	15.53	14.11	Decrease
EphemeropteraChTxPct	13.53	11.43	13.16	Decrease
EphemeropteraPct	20.70	14.60	18.81	Decrease

Measured levels of DO along this AUID did occasionally dip below the 5 mg/L standard, however, the HSPF model predicted very few exceedances, and the related biological metrics were fairly mixed. It is likely that other stressors are impacting the impaired macroinvertebrate assemblage in Medary Creek, and therefore, low DO is not a stressor at this time.

Candidate cause: High Phosphorus

Overview

Phosphorus is essential to life as it is a component of DNA, RNA, ATP (cellular energy) and the phospholipids that make up cell membranes (Conley et al., 2009). In a water body that is not heavily influenced by human activity, phosphorus is generally the limiting growth factor of aquatic organisms. On the other hand, in areas where urban/agricultural runoff is excessive, elevated phosphorus concentrations can be a problem. Dissolved oxygen, pH, water clarity, changes in food resources and changes in habitat are all potential stressors as a result of excess phosphorus.

Excess phosphorus is largely a product of agriculture, wastewater, and urban runoff. Phosphorus is a common additive to animal feed on feedlots in order to promote animal growth (INPI, 1999) and it accumulates in animal manure. This manure is often spread on fields as fertilizer, along with other phosphorus fertilizers, providing a pathway for phosphorus to enter nearby water bodies. Wastewater effluent that is not treated properly can be high in phosphorus content and urban stormwater runoff laden with grass clippings, leaves, lawn fertilizers, and pet waste is a source of phosphorus as well.

When an abundance of phosphorus is available in a fresh water ecosystem, it promotes rapid and widespread macrophyte growth such as algal blooms (Figure 9). When these algae die, they are decomposed by microorganisms in the water that use DO in the process. This can cause hypoxic (i.e., low oxygen) conditions which places stress on other aquatic organisms such as fish and macroinvertebrates. This process is called eutrophication and also leads to decreased recreational value of the water body due to poor water clarity, repulsive smells, and in some cases toxic algae. See Figure 12 for a conceptual model of phosphorus pathways.

Figure 9: Excessive macrophyte growth due to phosphorus concentrations in Medary Creek at site 11MS007

Water quality standards

There is currently no standard for total phosphorus in Minnesota; however there is a draft standard of 0.15 mg/L. According to EPA's Ambient Water Quality Criteria Recommendations, the reference condition phosphorus concentration for the Northern Glaciated Plains ecoregion is 0.102 mg/L. This number was determined by averaging the median total phosphorus concentration for all seasons in streams of the ecoregion and finding the 25th percentile concentration from the resulting distribution of the data. The 25th percentile concentration is meant to reflect stream conditions that are minimally impacted for the ecoregion.

Phosphorus in Medary Creek

Phosphorus was identified as a candidate cause for biological impairment in Medary Creek due to the presence of excessive macrophyte growth and because the surrounding land use is largely agriculture. There were a total of 22 discrete point observations made on Medary Creek in 2011-2012 (Table 8).

These samples were analyzed at a Minnesota Department of Health certified laboratory. The range of phosphorus values was 0.024 mg/L to 0.202 mg/L. Six of these samples were above the MPCA proposed draft standard of 0.15 mg/L and 10 were above the EPA's reference condition for the ecoregion (Figure 10).

Table 8: Summary of all phosphorus observations for Medary Creek

Figure 10: Graphical phosphorus results by month.

The HSPF model predicted daily phosphorus values along Medary Creek from 1996-2009. These values ranged from 0.04-0.62 mg/L with an average of 0.13 mg/L. Of these calculations, 25.1% were at or above the 0.15 mg/L proposed draft standard for phosphorus.

Biological connections

As with DO, there are many metrics that are indicative of healthy phosphorus levels in a stream. A group of metrics to consider while assessing phosphorus levels are metrics that indicate sensitive and tolerant species presence and/or absence. These metrics (*e.g.,* IntolerantTxPct, SensitiveTxPct, TolerantChTxPct, TolerantPct, IntolerantPct, etc.) measure the percentage of individuals or taxa within a sample that are considered to be sensitive or tolerant to pollution. For fish metrics of this nature, the data were mixed between sites. Site 11MS026 exhibited below average populations of intolerant and sensitive taxa, while site 11MS007 revealed the opposite (Table 9). The macroinvertebrate metrics exhibited more concrete evidence of stress, as 74.22 percent of individuals at 11MS007 and 71.16% at site 11MS026 were tolerant of pollution (TolerantPct metric, Table 9). This is much higher than the average of 55.36% in all class 5 streams. Congruently, a much lower composition of intolerant individuals were found at both sites; 1.24% at site 11MS007 and 0.63% at site 11MS026, while the average for class 5 streams is 7.62%.

Increased nutrient levels in streams can change water chemistry through eutrophication and acidification, while toxicity can increase directly as an effect of nitrogen/phosphorus levels as well as indirectly through algal decomposition processes. Studies (Alonso & Camargo, 2006 & Ashton et al., 2013) show that there is a negative correlation between certain macroinvertebrate families' (e.g. Ephemeroptera, Plecoptera, Trichoptera) species composition and increasing nutrient levels. Thus, the EPTPct metric is important again, and as discussed earlier streams of M-IBI class 5 in Minnesota had an EPTPct score 38.9 on average, while Medary Creek scored as low as 30.1 (Table 9).

Table 9: Fish and macroinvertebrate metrics generally associated with nutrient pollution. Included are scores from each assessment site, their class respective statewide average IBI scores, and predicted responses to pollution. Red indicates lower than average, green indicates above average.

Metric	Statewide Class Average	11MS007	11MS026	Expected Response
Fish	Class 3			
IntolerantTxPct	1.71	4.35	0.00	Decrease
SensitiveTxPct	7.35	13.04	6.67	Decrease
Macroinvertebrates	Class 5			
TolerantChTxPct	59.18	62.86	63.16	Increase
TolerantPct	55.36	74.22	71.16	Increase
EPTChTxPct	26.13	22.86	23.68	Decrease
EPTPct	38.92	30.12	32.92	Decrease
TaxaCount	24.20	23.00	20.00	Decrease
TanytarsiniChTxPct	6.89	8.57	5.26	Decrease
TanytarsiniPct	24.54	20.13	30.56	Decrease
IntolerantChTxPct	9.30	2.86	2.63	Decrease
IntolerantPct	7.63	1.24	0.63	Decrease
CrustMollPct	12.01	8.39	4.08	Increase
TrichopteraChTxPct	11.71	11.43	10.53	Decrease
TrichopteraPct	17.92	15.53	14.11	Decrease

Abnormally low abundances of sensitive taxa and individuals as well as abnormally high abundances of tolerant taxa and individuals indicate stress. Due to chemistry data showing that 45% of the phosphorus measurements were above the EPA's Ambient Water Quality Criteria Recommendations, therefore, excess phosphorus is a stressor to the biological communities in Medary Creek.

Candidate cause: High Nitrates

Overview

As with phosphorus, nitrogen is essential to life and it can be found in several forms in the environment. For the purposes of this report only the most mobile forms (dissolved inorganic nitrogen as nitrate and nitrite) are considered (Figure 11).

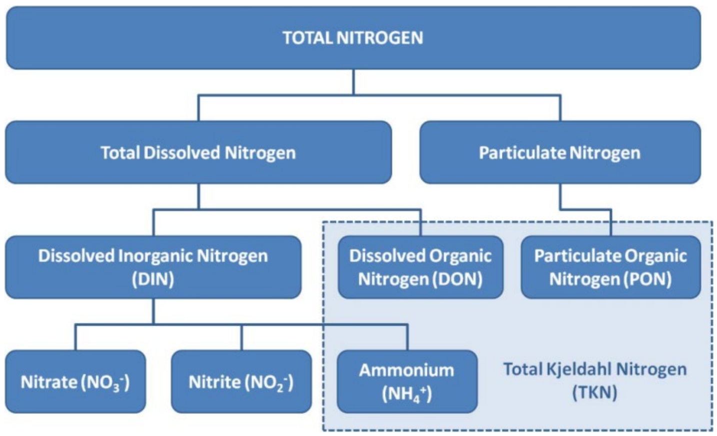

Figure 11: Forms of nitrogen found in the environment

The most common pathway for nitrogen to enter a water body in rural areas such as Medary Creek is agriculture. When nitrogen fertilizer is applied in an agricultural setting, it is typically in the form of nitrate or ammonium. The nitrification process will naturally oxidize ammonium into nitrate through several steps, ultimately leading to high nitrate levels in agricultural areas. According to the USDA, 87% of Minnesota's corn received nitrogen fertilizer in 2010. Due to the negative charge and dissolvability of nitrate, it is highly mobile in the soil. When fertilizer is applied to a field and not assimilated by the crops, it is susceptible to transport through the soil with precipitation and irrigation. Tile drainage quickly moves water out of soil, and when these systems are present nitrate loss from fields is more prevalent. The problems associated with nitrogen runoff are not limited to Minnesota, as this runoff contributes to the hypoxic zone in the Gulf of Mexico through transport in the Mississippi River. For more information on nitrogen in Minnesota reference the Nitrogen in Minnesota Surface Waters report. For a conceptual diagram on nitrogen and phosphorus sources and pathways see Figure 12.

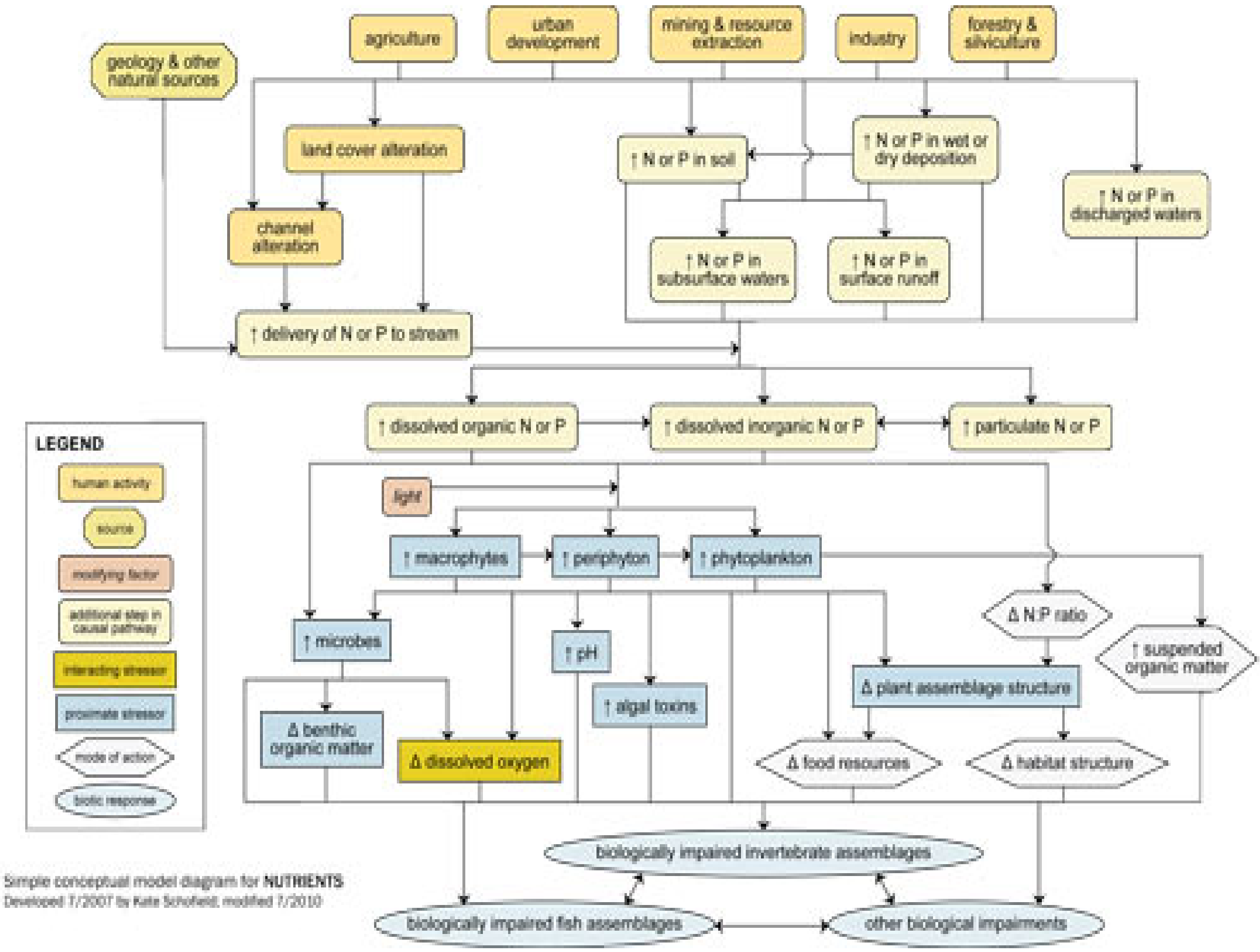

Figure 12: Nitrogen and phosphorus conceptual model

Water quality standards

There is currently no standard for nitrate-nitrite concentrations in Minnesota class 2 streams; however there is a class 1 stream standard of 10 mg/L. This standard is meant to protect water for human consumption and does not necessarily reflect the needs of aquatic organisms. According to EPA's Ambient Water Quality Criteria Recommendations, the reference condition nitrate-nitrite concentration for the Northern Glaciated Plains ecoregion is 0.074 mg/L. This number was determined by averaging the median nitrate-nitrite concentration for all seasons in streams of the ecoregion and finding the 25th percentile concentration from the resulting distribution of the data. The 25th percentile concentration is meant to reflect stream conditions that are minimally impacted for the ecoregion.

Nitrates in Medary Creek

Nitrogen was identified as a candidate cause for biological impairment in Medary Creek due to its known negative effects on aquatic biology and the high frequency of agriculture and tile drainage in the Upper Big Sioux River Watershed. From 2011-2012 a total of 22 nitrate samples were taken from Medary Creek. These samples were analyzed in a Minnesota Department of Health certified lab. Values from the samples ranged from 2.46-7.39 mg/L (Table 10 and Figure 13). All of these values were above the 25th percentile concentration for the ecoregion which indicates that nitrogen is adding stress to the system.

Table 10: Summary of all nitrogen observations for Medary Creek

Maximum Concentration (mg/L)	Minimum Concentration (mg/L)	Average Concentration (mg/L)	Number of Observations
7.39	2.46	4.27	22

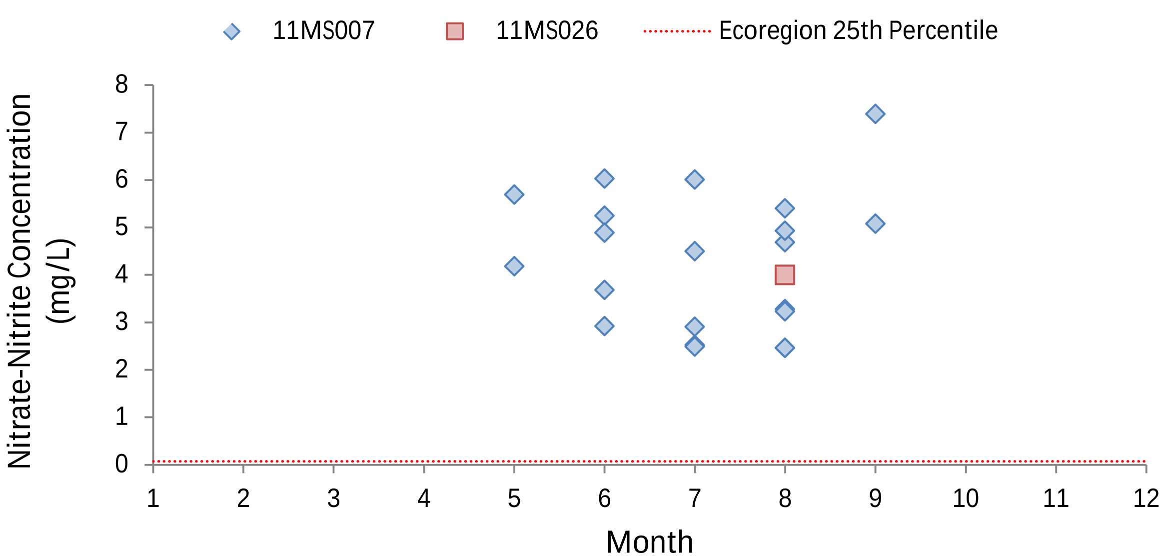

Figure 13: Graphical nitrogen results by month

It is generally accepted that total nitrogen concentrations below 10 mg/L do not create a human health concern, but sensitive aquatic organisms can begin to exhibit negative effects at concentrations as low as 1.0 mg/L (Alonso & Camargo, 2006). Nitrate in an aquatic ecosystem can lead to a decrease in pH as nitric acid disassociates to hydrogen and nitrate. Additionally, nitrate can cause oxygen carrying pigments (*e.g.*, hemoglobin) of organisms to convert to non-oxygen carrying pigments (e.g., methemoglobin), essentially choking the organism.

The HSPF model calculated daily nitrate values from 1996-2009 along this reach of Medary Creek. These values ranged from 1.51-19.1 mg/L with an average value of 4.2 mg/L.

Biological connections

A group of metrics to consider while assessing nitrate levels are metrics that indicate sensitive, nitrate tolerant, and intolerant species as well as Trichoptera taxa presence and/or absence. For fish metrics of this nature, the data were mixed between sites. Site 11MS026 exhibited below average populations of intolerant and sensitive taxa, while with site 11MS007, the opposite was true (Table 11).

The macroinvertebrate metrics exhibited more concrete evidence of stress, as 74.22% of individuals at site 11MS007 and 71.16% at 11MS026 were tolerant of pollution (TolerantPct metric, Table 11). This is much higher than the average of 55.39% in class 5 streams. Congruently, a much lower composition of intolerant individuals were found at both sites; 1.24% at site 11MS007 and 0.63% at site 11MS026, while the average for class 5 streams is 7.62%. Trichoptera individuals were also slightly below average, as they composed 14.11% of individuals within the sample compared with the average of 17.92% (Table 11).

Table 11: Fish and macroinvertebrate metrics generally associated with nitrate pollution. Included are scores from each assessment site, their class respective statewide average IBI scores, and predicted responses to pollution. Red indicates lower than average, green indicates above average.

Metric	Statewide Class Average	11MS007	11MS026	Expected Response
Fish	Class 3			
IntolerantTxPct	1.71	4.35	0.00	Decrease
SensitiveTxPct	7.35	13.04	6.67	Decrease
Macroinvertebrates	Class 5			
TaxaCount	24.20	23.00	20.00	Decrease
IntolerantChTxPct	9.30	2.86	2.63	Decrease
IntolerantPct	7.63	1.24	0.63	Decrease
TrichopteraChTxPct	11.71	11.43	10.53	Decrease
TrichopteraPct	17.92	15.53	14.11	Decrease

These metrics combined with water chemistry monitoring data indicate that high nitrate levels are stressing aquatic life in Medary Creek. Abnormally low abundances of sensitive taxa and individuals as well as abnormally high abundances of tolerant taxa and individuals indicate stress. Due to chemistry data showing that 45% of the phosphorus measurements were above the EPA's Ambient Water Quality Criteria Recommendations and all of the nitrate measurements being above these recommendations, nutrient pollution is a likely cause of this stress.

Candidate cause: Altered Hydrology

Overview

Stream hydrology is altered in several ways, most commonly through modifying stream channels and through changing land use. Stream courses are often channelized (e.g., widened, straightened, narrowed, lined) in agricultural settings to control the path of the water so that the surrounding land is efficiently drained. This eliminates the natural ability of the stream to control flow. A natural, meandering stream regulates flow by decreasing water velocity at bends, and over time the alternating structure of a stream between slow moving pools and fast moving runs is tailored specifically to normal water levels experienced by the system. When this is altered through channelization, faster stream flows are experienced. If the surrounding land use has been modified from deep rooted trees or prairie grasses to shallow rooted row crops, the banks become unstable and highly susceptible to increased erosion as a result of the faster flow combined with the weak bank structure.

Increased erosion brings an excess of suspended solids into the stream, negatively affecting sensitive organisms such as Plecoptera (i.e., Stoneflies). In general, stoneflies require coarse bottom substrates. Too much sedimentation will lead to high embeddedness of bottom substrate, reducing available suitable habitat for many species of Plecoptera and other macroinvertebrate species within orders such as Trichoptera and Ephemeroptera.

Altered hydrology in Medary Creek

Altered hydrology is being considered due to the low M-IBI scores for the Plecoptera and Trichoptera metrics as well as the prevalence of channelization and agriculture surrounding Medary Creek (Figure14). Roughly 35% of Medary Creek has been channelized; however these sections of the stream are upstream of the biological sampling sites. From the current available information it does not seem likely that altered hydrology due to channelization is a major stressor on the system since a limited number of small tributaries and stream sections of Medary Creek have been altered. Conversely, it is likely that altered hydrology due to land use is causing stress on the system as was evident in the nitrogen section of this report (tile drainage increases nitrogen inputs to nearby water bodies). The agriculture dominated land use surrounding Medary Creek can contribute excess sedimentation and habitat loss that will be investigated later in this report.

The Minnesota Department of Natural Resources 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.

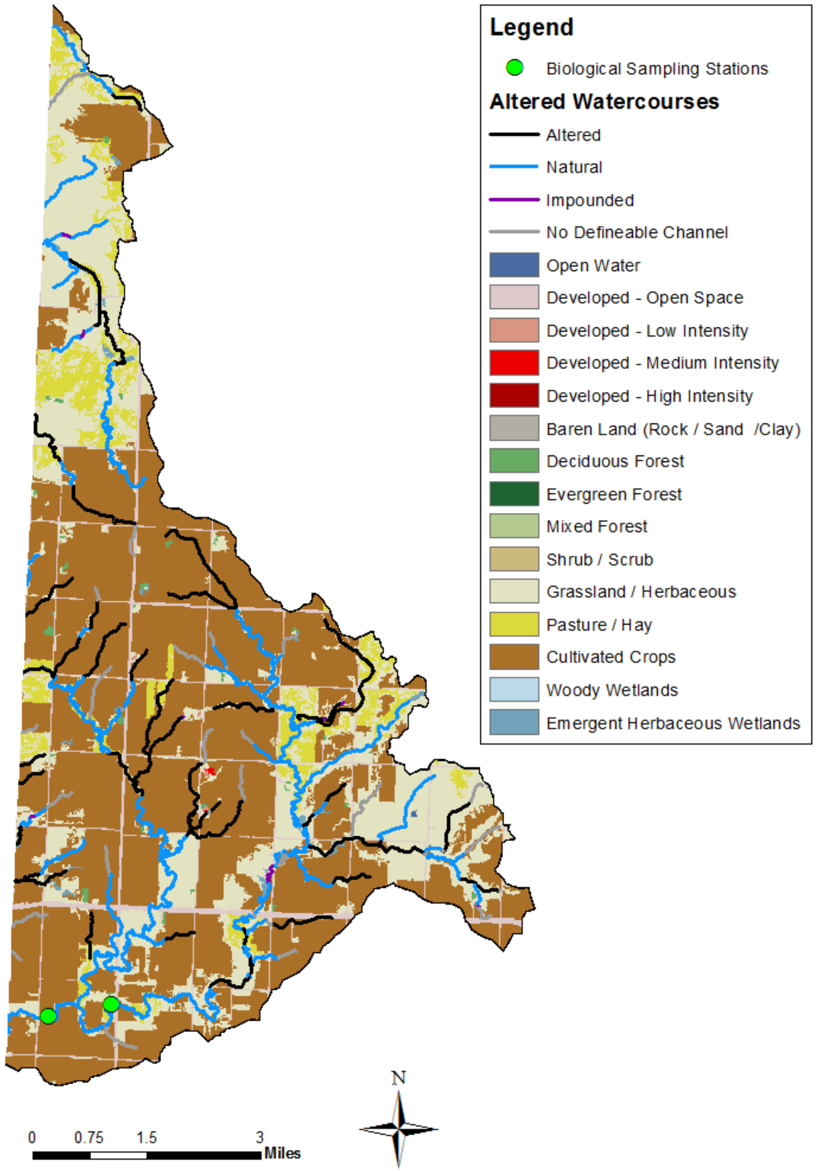

Figure 14: Surrounding land use and stream channel type in the Upper Big Sioux Watershed

Candidate cause: High Total Suspended Solids

Overview

An increase in suspended sediment within aquatic systems is now considered one of the greatest causes of water quality and biological impairment in the United States (EPA, 2003). Suspended sediment clouds the water column, preventing the penetration of light. This reduces primary production of submerged plants (a vital food source for many aquatic organisms) by preventing photosynthesis. Clouded water also decreases visibility which can alter the behavior of macroinvertebrates. When suspended sediments are in excess and settle out of the water column, they fill the spaces between coarser bottom substrates, increasing embeddedness of the substrate. This reduces essential habitat for many macroinvertebrates as these interstitial spaces are where they feed and oviposit. For a conceptual diagram illustrating how sediments enter a stream system, see Figure 15.

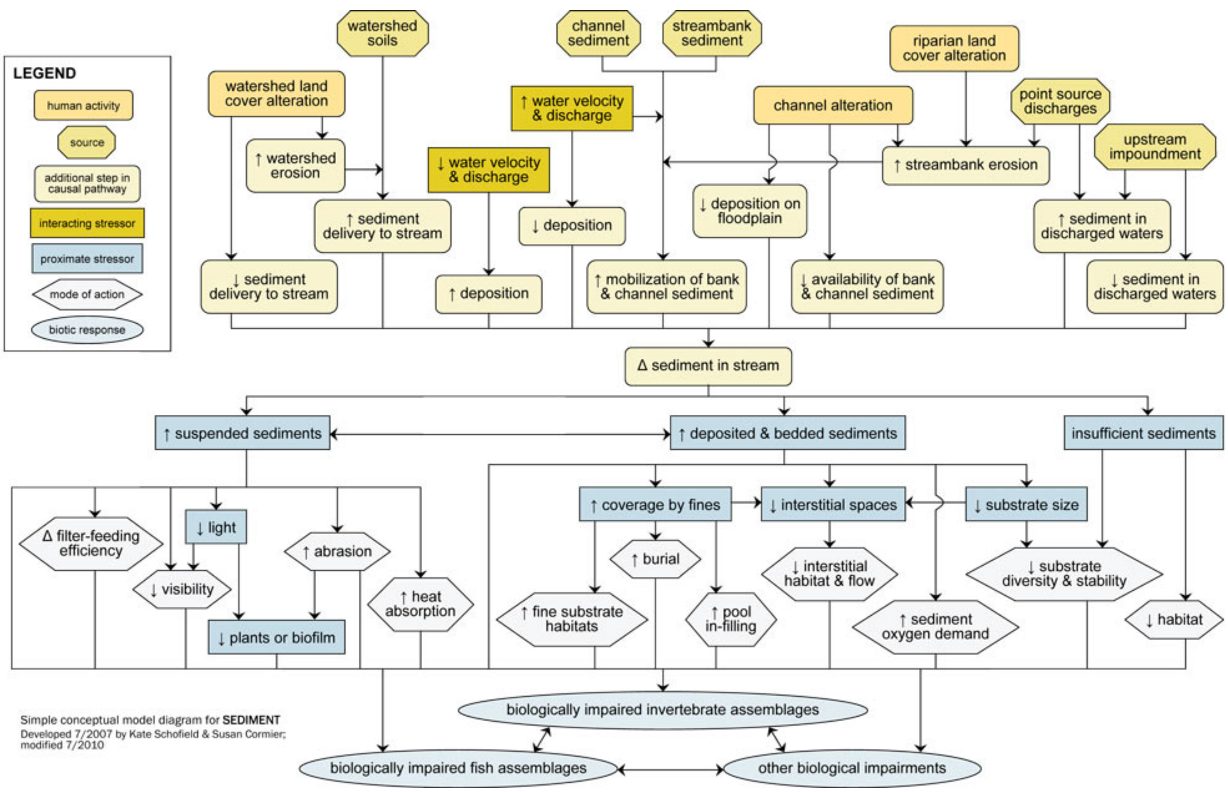

Figure 15: Conceptual diagram illustrating sediment pathways to stream systems

Water quality standards

The state of Minnesota currently sets the TSS concentration standard at 65 mg/L for Southern Streams. This is based upon a large collection of bio-monitoring data and statistical analysis. The EPA's Ambient Water Quality Criteria Recommendations set the standard at 60 mg/L for the Northern Glaciated Plains ecoregion. The EPA used similar methods but within a larger range than just southern Minnesota, hence a slightly different threshold.

Total suspended solids in Medary Creek

There were a total of nine TSS measurements taken along Medary Creek from 2011-2013, none of which were above either standard (Figure 16).

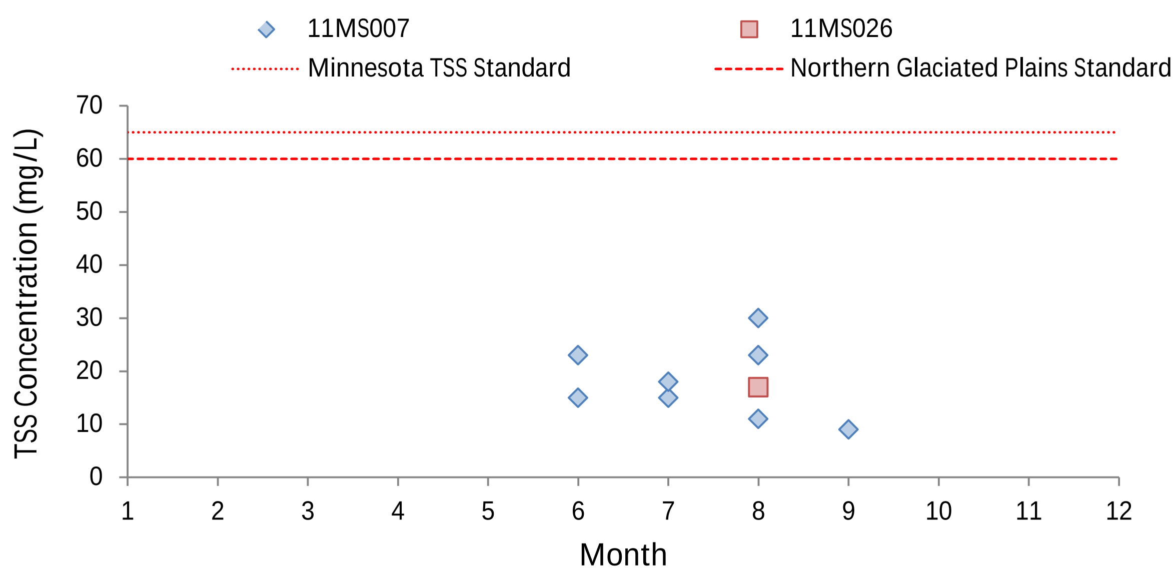

Figure 16: Graphical TSS results by month.

The HSPF model calculated daily TSS values along Medary Creek from 1996-2009. These values ranged from 0.014-3590.9 mg/L with an average value of 21.83 mg/L. The proposed TSS standard of 65 mg/L was only exceeded 3.37% of the time.

Biological connections

Several fish and macroinvertebrate metrics were looked at in connection with TSS. These metrics are used with the knowledge that certain groups of organisms are sensitive to TSS while others can survive in high TSS conditions, effectively taking over the vacant community space left by those organisms that have been displaced.

One F-IBI metric that scored above the class respective statewide average was BenInsectTxPct, which decrease with an increase in TSS (Table 12). This metric reports the percent of the sample that was composed of benthic insectivorous taxa. These taxa feed primarily on benthic insects and therefore require suitable bottom substrate (*e.g.,* cobble or gravel with low embeddedness). Interestingly, the SLithopTxPct which indicates the percent of the sample that was composed of simple lithophilic spawning species (*i.e.,* require gravel/cobble substrate for spawning) scored lower than average, which contradicts the results of the BenInsectTxPct metric. Additionally, sites along this AUID had an above average TSS TIV score when compared to all other Minnesota streams.

Macroinvertebrate results are also slightly contradictory. For example, the ClingerPct metric which indicates what percent of individuals in the sample that are considered "clingers", scored above average. Clingers have behavioral and morphological adaptions for attachment to surfaces in stream riffles; therefore in an area with high embeddedness the presence of clingers would not be expected. In Medary Creek, the ClingerPct metric scored significantly higher when compared to similar Minnesotan streams which is indicative of suitable bottom substrate (Table 12). The ChironomidaeChPct metric measures the percentage of individuals in the sample that are classified in the family Chironomidae. These non-biting midges are typically tolerant of pollution in their aquatic immature life stages. They seem to thrive in environments that most other insects cannot (e.g., low DO, high TSS, wide temperature ranges). The Chironomidae composition in Medary Creek was substantially higher than other M-IBI class 5 streams around the state. This is a red flag indicating that these tolerant species are taking over vacant space in the macroinvertebrate community as less tolerant species disappear. Furthermore, sites 11MS007 and 11MS026 had a high amount of TSS tolerant macroinvertebrates individuals (49.03%) when compared to all other Minnesota streams.

Coupling the TSS measurements and modeled data with the biological monitoring data, it seems that TSS concentrations are likely not a major stressor on the biota of Medary Creek. The fact that clingers, benthic insectivorous fish, and riffle dwelling fish were present near or above average numbers combined with TSS concentrations below EPA and MPCA water quality standards support this claim. Although some tolerant species such as those within the Chironomidae family are abundant, this could be a product of other stressors.

Table 12: Fish and macroinvertebrate metrics generally associated with TSS. Included are scores from each assessment site, their class respective statewide average IBI scores, and predicted responses to pollution. Red indicates lower than average, green indicates above average.

Metric	Statewide Class Average	11MS007	11MS026	Expected Response
Fish	Class 3			
BenInsectTxPct	15.85	17.39	26.67	Decrease
DarterSculpSucTxPct	10.59	8.70	6.67	Decrease
GeneralTxPct	52.07	47.83	53.33	Increase
RiffleTxPct	15.58	13.04	20.00	Decrease
SLithopTxPct	22.97	13.04	20.00	Decrease
SSpnTxPct	25.71	34.78	40.00	Increase
Macroinvertebrates	Class 5			
ClingerChTxPct	34.57	42.86	34.21	Decrease
ClingerPct	43.10	50.00	55.49	Decrease
Collector-filtererChTxPct	15.48	17.14	13.16	Decrease
Collector-filtererPct	25.09	17.08	29.78	Decrease
ChironomidaeChTxPct	33.26	37.14	47.37	Increase
ChironomidaeChPct	29.21	47.83	56.43	Increase

Candidate cause: Lack of Habitat

Overview

Habitat is simply the area in which organisms depend on for their livelihood. It encompasses physical attributes (e.g., substrate, riparian vegetation, in-stream vegetation), chemical parameters (e.g., pH, DO, temperature), and biological features (e.g., food availability, predation). For the purposes of this section, physical habitat characteristics are the focal point of discussion.

To assess the quality of habitat in Medary Creek, the MPCA Stream Habitat Assessment (MSHA) score was determined. This is done by judging the following 4 categories of habitat: 1) surrounding land use, 2) riparian zone, 3) instream zone, and 4) channel morphology. Surrounding land use accounts for 5% of the maximum MSHA score and takes into account the predominant land use outside of the riparian zone. The highest score is given to a landscape consisting mainly of forest, wetland, shrub land, or prairie. The riparian zone score can account for up to 15% of the total MSHA score. This score takes into account the width of the riparian buffer zone, the prevalence of bank erosion, and the amount of canopy shade experienced by the stream. The instream zone section composes 44% of the total MSHA score and takes into account substrate, embeddedness, and cover amount/type (vegetative and non-vegetative). Finally, channel morphology composes the last 36% of the total MSHA score and points are assigned based on observed depth variability, channel stability, stream velocity, sinuosity, and channel development.

Habitat in Medary Creek

The MSHA scores for Medary Creek were 63.3 and 60.4 out of 100 at sites 11MS007 and 11MS026, respectively. These scores classify Medary Creek as having fair habitat for aquatic organisms. The land surrounding Medary Creek is predominately agriculture (Figure 17) and this is reflected in the land use and riparian MSHA scores (Figure 20). The instream zone MSHA scores indicate that there is satisfactory instream cover for habitat but the substrate is highly embedded and of low quality (e.g., clay/silt). This would explain the lack of organisms that depend on coarse substrates. From the available evidence, lack of habitat is likely a stressor on the macroinvertebrates of Medary Creek. The lack of habitat in this case seems to be a result of poor surrounding land use that leads to higher erosion potential, therefore increasing the TSS concentration in the water column and increasing embeddedness of streambed substrate.

Figure 17: Photograph of surrounding land use at site 11MS007 on Medary Creek

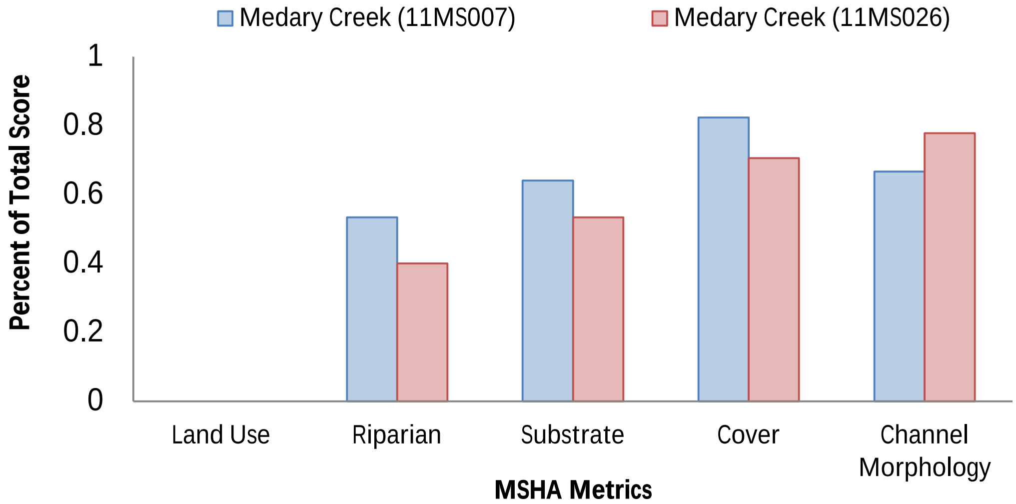

Figure 18: Proportion of possible MSHA subcategory scores at Medary Creek biological sampling stations

Biological connections

In order to form a more robust conclusion regarding the impact of habitat loss in Medary Creek, biological indicators are used. The metrics in Table 13 highlight groups of organisms that are known to respond either positively or negatively to a change in habitat.

Looking at the fish metrics, one group of organisms was present in higher than average numbers for similar streams around Minnesota; taxa that are benthic insectivores (BenInsectTxPct). Conversely, five metrics scored below the statewide average at least at one site. The headwater taxa metric (HdwTxPct) includes taxa that are typically found in headwater streams such as Medary Creek. At both monitoring sites Medary Creek showed significantly lower numbers of headwater taxa compared to similar headwater streams throughout Minnesota. Headwater streams typically have lush riparian vegetation zones that contribute significant allochthonous material (e.g., twigs, leaves, cones, bark) and provide shade. Suitable riparian habitat is not found on Medary Creek, and this could explain why headwater taxa are stressed. Additionally, simple lithophilic spawning taxa (SLithopTxPct) have comparatively low abundance. These species typically require gravel/cobble stream substrate for spawning. Medary Creek suffers from excess sedimentation, which causes the gravel/cobble substrate to become embedded with finer sediment. Excess sediment enters Medary Creek through bank erosion (a result of changing hydrology and pasture access) and agricultural runoff.

During the macroinvertebrate sampling event, equal parts of riffle/run/rock, overhanging vegetation, and aquatic macrophytes habitat types were sampled. The amount of Clinger individuals (ClingerPct) showed above average numbers at both sites. Most of these groups of organisms (Clingers, Scrapers, Collector-filterers) need clean rocky substrates to hang on to, and the embeddedness of Medary Creek may be enough of a stressor to extirpate them. The moderate amount of embeddedness of the course substrates is likely attributing to the high numbers of the genus polypedilum and physa. These types of macroinvertebrates are classified as climbers and are very tolerant to degraded habitat conditions.

Based on the MSHA scores, fish and macroinvertebrate biology, and physical observations, lack of habitat is a stressor to the impaired macroinvertebrate assemblage in Medary Creek. As stated earlier, other factors play into this stressor such as surrounding land use and altered landscape hydrology.

Table 13: Fish and macroinvertebrate metrics generally associated with habitat. Included are scores from each assessment site, their class respective statewide average IBI scores, and predicted responses to pollution. Red indicates lower than average, green indicates above average.

Metric	Statewide Class Average (%)	11MS007	11MS026	Response
Fish	Class 3			
BenInsectTxPct	15.85	17.39	26.67	Decrease
DarterSculpSucTxPct	10.59	8.70	6.67	Decrease
GeneralTxPct	52.07	47.83	53.33	Increase
HdwTxPct	21.41	13.04	6.67	Decrease
MA>3TxPct	10.98	13.04	13.33	Decrease
RiffleTxPct	15.58	13.04	20.00	Decrease
SLithopTxPct	22.97	13.04	20.00	Decrease
Macroinvertebrates	Class 5			
ClingerChTxPct	34.57	42.86	34.21	Decrease
ClingerPct	43.10	50.00	55.49	Decrease
DomTwoCHPct	37.66	42.24	36.68	Increase
ScraperChTxPct	12.75	14.29	10.53	Decrease
ScraperPct	14.29	16.46	8.78	Decrease
Collector-filtererChTxPct	15.48	17.14	13.16	Decrease
Collector-filtererPct	25.09	17.08	29.78	Decrease
ClimbersPct	18.98	40.68	25.71	Increase

Strength of evidence

For each likely stressor, the quantity and quality of each type of evidence is evaluated. The consistency and credibility of the evidence is also evaluated. Each step for Medary Creek was scored and summarized in Table 14. For further information on scoring please see Appendix 1.3 and 1.4.

Table 14: Weight of evidence scoring at Medary Creek (10170202-502).

Medary Creek (10170202-501)			
	Scores of Candidate Causes		
Types of Evidence	High Phosphorus	High Nitrates	Lack of Habitat
Spatial/temporal co-occurrence	+	+	+
Temporal sequence	+	+	0
Field evidence of stressor-response	+ +	+	+
Causal pathway	+	+	+
Evidence of exposure, biological mechanism	NE	NE	NE
Field experiments /manipulation of exposure	NE	NE	NE
Laboratory analysis of site media	NE	NE	NE
Verified or tested predictions	+	+	+
Symptoms	+	+	+
	Evidence using data from other systems		
Mechanistically plausible cause	+	+	NE
Stressor-response in other lab studies	NE	NE	NE
Stressor-response in other field studies	+	+	+
Stressor-response in ecological models	NE	NE	NE
Manipulation experiments at other sites	NE	NE	NE
Analogous stressors	NE	NE	NE
	Multiple lines of evidence		
Consistency of evidence	+ + +	+ + +	+
Explanatory power of evidence	+ +	+ +	+ +

Conclusions and recommendations

In the Minnesota portion of the Upper Big Sioux River Watershed, Medary Creek (10170202-501) is impaired for aquatic life due to its macroinvertebrate assemblage. This impaired reach has a multitude of stressors (Table 15) that need to be addressed to help improve the aquatic life in this system.

The phosphorus conditions in the Upper Big Sioux River Watershed as well as the Missouri River basin are causing significant problems to water quality in this region. Medary Creek had a high percentage of its phosphorus samples above the proposed draft standard. A likely source for these high values is the intensive grazing and agriculture commonly found throughout the watershed. Medary Creek has a very limited riparian buffer that easily allows phosphorus to enter the waterways. A watershed wide phosphorus reduction plan that focuses on improving the timing and rate of fertilizer application, as well as increasing riparian buffers and minimalizing cattle access to streams is recommended. These actions will help reduce the excessive algal and macrophyte growth, but also aid in balancing out the DO conditions within Medary Creek.

Similar to phosphorus, the nitrate conditions in the Upper Big Sioux River Watershed and the Missouri River basin are at levels that negatively impact the biological conditions. While nitrate levels are currently not at the same degree of severity as phosphorus, nitrate conditions still need to be addressed to help prevent future stress to the fish and macroinvertebrate assemblages in this watershed. A watershed-wide nitrate reduction plan is recommended to limit the amounts of nitrates entering the stream systems. Often, nitrate levels spiked during times of fertilizer applications. Fine-tuning the application time and rate and reducing pathways for nitrates to reach 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).

The habitat conditions in the Upper Big Sioux River Watershed were found to be limiting the success of the impaired macroinvertebrate assemblage and could potentially be negatively impacting the fish community as well. A primary reason for the lack of habitat found in Medary Creek can be attributed to the high intensity grazing practiced throughout the watershed. Cattle with easy access to the stream and immediate corridor lead to unstable banks and erosion. This results in sedimentation that covers the course substrates that many desirable fish species need to complete their respective life cycles. Sites 11MS007 and 11MS026 along Medary Creek are beginning to show signs of gravel and cobble substrates being covered by finer sand and silt particles. Limiting cattle access to the streams, practicing rotational or flash grazing, having a larger riparian buffer, and planting deep-rooted vegetation will aid in stabilizing the banks, which will result in more desirable habitat conditions for both the fish and macroinvertebrate assemblages within Medary Creek and the rest of the Upper Big Sioux River Watershed. Until some of these changes are made, expect the habitat and corresponding fish and macroinvertebrate communities to slowly degrade.

Overall, significant problems and stressors to the biological assemblages exist in the Upper 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. Without long term changes and improvements to this watershed, Medary Creek will more than likely remain impaired for aquatic life.

Table 15: Stressor to the impaired macroinvertebrate assemblage in Medary Creek (10170202-501)

		Stressors				
Stream Name	**AUID #**	**Low Dissolved Oxygen**	**High Phosphorus**	**High Nitrates**	**High Turbidity/TSS**	**Lack of Habitat**
Upper Big Sioux River Watershed						
Medary Creek	10170202-501	-	•	•	-	•

Appendix 1.1 - MPCA Fish IBI class criteria for Upper Big Sioux River Watershed streams

Fish IBI Class	Class Name	Drainage Area	Gradient
3	Southern Headwaters	< 30 mi^2	> 0.50 m/km

Appendix 1.2- MPCA Macroinvertebrate IBI class criteria for Upper Big Sioux River Watershed streams

M-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.

Appendix 1.3- Values used to score evidence in the stressor identification process developed by EPA

Rank	Meaning	Caveat
+++	*Convincingly supports*	*but other possible factors*
++	*Strongly supports*	*but potential confounding factors*
+	*Some support*	*but association is not necessarily causal*
0	*Neither supports nor weakens*	*(ambiguous evidence)*
-	*Somewhat weakens support*	*but association does not necessarily reject as a cause*
--	*Strongly weakens*	*but exposure or mechanism possible missed*
---	*Convincingly weakens*	*but other possible factors*
R	*Refutes*	*findings refute the case unequivocally*
NE	*No evidence available*	
NA	*Evidence not applicable*	
D	*Evidence is diagnostic of cause*	

Appendix 1.4- Strength of evidence scores for various types of evidence used in stressor identification analysis

Types of Evidence	Possible values, high to low
Evidence using data from case	
Spatial / temporal co-occurrence	+, 0, ---, R
Evidence of exposure, biological mechanism	++, +, 0, --, R
Causal pathway	++, +, 0, -, ---
Field evidence of stressor-response	++, +, 0, -, --
Field experiments / manipulation of exposure	+++, 0, ---, R
Laboratory analysis of site media	++, +, 0, -
Temporal sequence	+, 0, ---, R
Verified or tested predictions	+++, +, 0, -, ---, R
Symptoms	D, +, 0, ---, R
Evidence using data from other systems	
Mechanistically plausible cause	+, 0, --
Stressor-response relationships in other field studies	++, +, 0, -, --
Stressor-response relationships in other lab studies	++, +, 0, -, --
Stressor-response relationships in ecological models	+, 0, -
Manipulation of exposure experiments at other sites	+++, +, 0, --
Analogous stressors	++, +, -, --
Multiple lines of evidence	
Consistency of evidence	+++, +, 0, -, --
Explanatory power of evidence	++, 0, -

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