Zumbro River Watershed Stressor Identification Report

A study of stressors limiting the biotic communities in the Zumbro River Watershed

Minnesota Pollution Control Agency

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Key terms and abbreviations

ARM	Agricultural Runoff Model
AUID	Assessment Unit Identification
BOD	Biological Oxygen Demand
CADDIS	Causal Analysis/Diagnosis Decision Information System
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency of the United States
FIBI	Fish Index of Biotic Integrity
HSPF	Hydrological Simulation Program – FORTRAN
IBI	Index of Biotic Integrity
IWM	Intensive Watershed Monitoring
LMB	Lower Mississippi River Basin
MIBI	Macroinvertebrate Index of Biotic Integrity
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MRL	Method Reporting Limit
NPS	Non-Point Source
SID	Stressor Identification
SOE	Strength of Evidence
TIVS	Tolerance Indicator Values
TMDL	Total Maximum Daily Load
TSVS	Total Suspended Volatile Solids
TP	Total Phosphorus
TSS	Total Suspended Solids
WRAPS	Watershed Restoration and Protection Strategy

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Executive summary

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 the state's rivers and streams. This basic approach is to examine fish and aquatic macroinvertebrate communities and related habitat conditions at multiple sites throughout a major watershed. From these data, an Index of Biological Integrity (IBI) score can be developed, which provides a measure of overall community health. If biological impairments are found, stressors to the aquatic community must be identified.

Stressor identification (SID) 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 (Cormier et al. 2000). In simpler terms, it is the process of identifying the major factors causing harm to aquatic 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 Zumbro River Watershed. There were 28 stream reaches identified with biological impairment in the Zumbro Watershed. Each stream reach (Assessment Unit Identification (AUID) is described further in Section 4.

After examining many candidate causes for the biological impairments, the following stressors were identified as probable causes of stress to aquatic life:

- Temperature
- Dissolved Oxygen (DO) and Eutrophication
- Nitrate
- Total Suspended Solids (TSS)
- Habitat
- Flow Alteration and Connectivity

In the Zumbro Watershed, there were 3 streams with fish and macroinvertebrate impairments, 4 with fish only, and the remaining 21 with macroinvertebrate impairment only. A summary of the stressors identified in each stream reach is found at the end of this document, in Table 73.

1. Introduction

1.1 Monitoring and assessment

Water quality and biological monitoring in the Zumbro have been ongoing since 2004. As part of the MPCA's Intensive Watershed Monitoring (IWM) approach, monitoring activities increased in rigor and intensity in 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 within a 10-year window obtained prior to 2012, 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. 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. 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. Some stressors require TMDLs to be completed, while others do not.

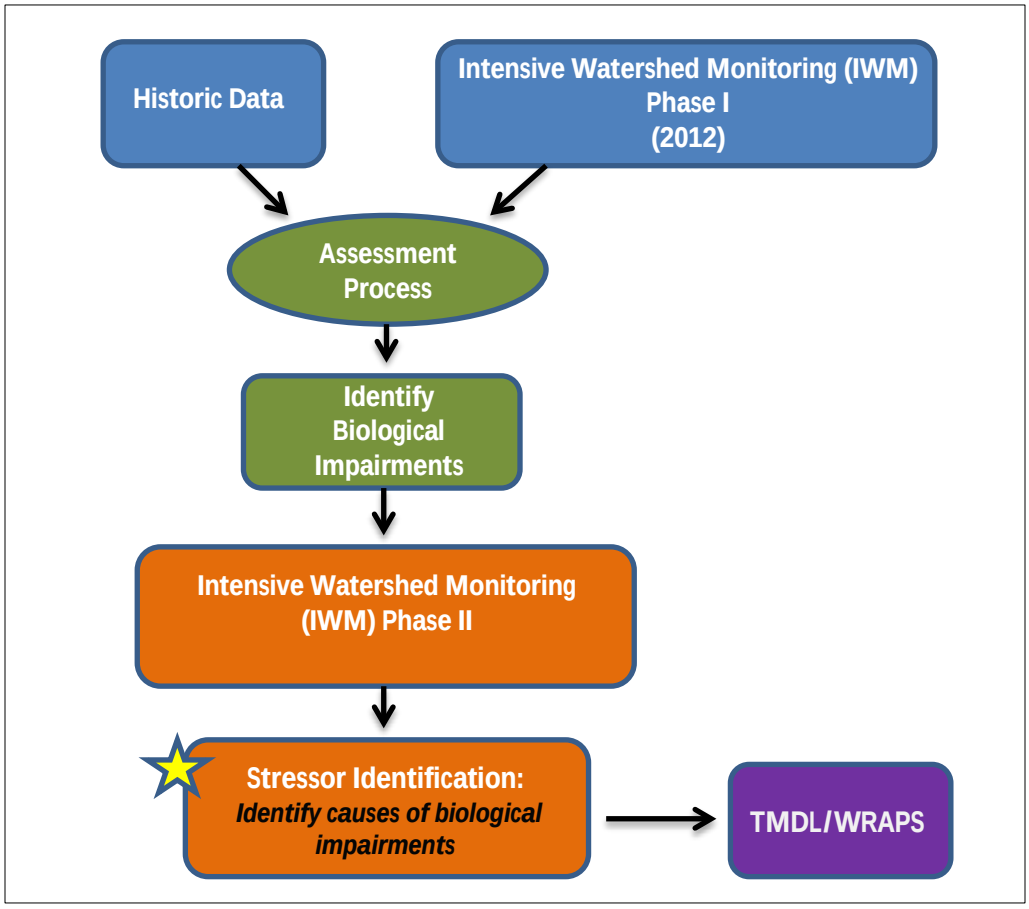

Figure 1. Process map of Intensive Watershed Monitoring, Assessment, Stressor Identification and TMDL processes.

1.2 Stressor Identification Process

The MPCA follows the U. S. Environmental Protection Agency's (EPA) process of identifying stressors that cause biological impairment, which has been used to develop the MPCA's guidance to stressor identification (Cormier et al. 2000; MPCA 2008). The EPA has also developed an updated, interactive web-based tool, the Causal Analysis/Diagnosis Decision Information System (CADDIS) (EPA 2010). This system provides an enormous amount of information designed to guide and assist investigators through the process of SID. Additional information on the SID process using CADDIS can be found here: http://www.epa.gov/caddis/.

SID is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act. SID draws upon a broad variety of disciplines and applications, such as aquatic ecology, geology, geomorphology, chemistry, land-use analysis, and toxicology. A conceptual model showing the steps in the SID process is shown in Figure 2. Through a review of available data, stressor scenarios are developed that aim to characterize the biological impairment, the cause, and the sources/pathways of the various stressors.

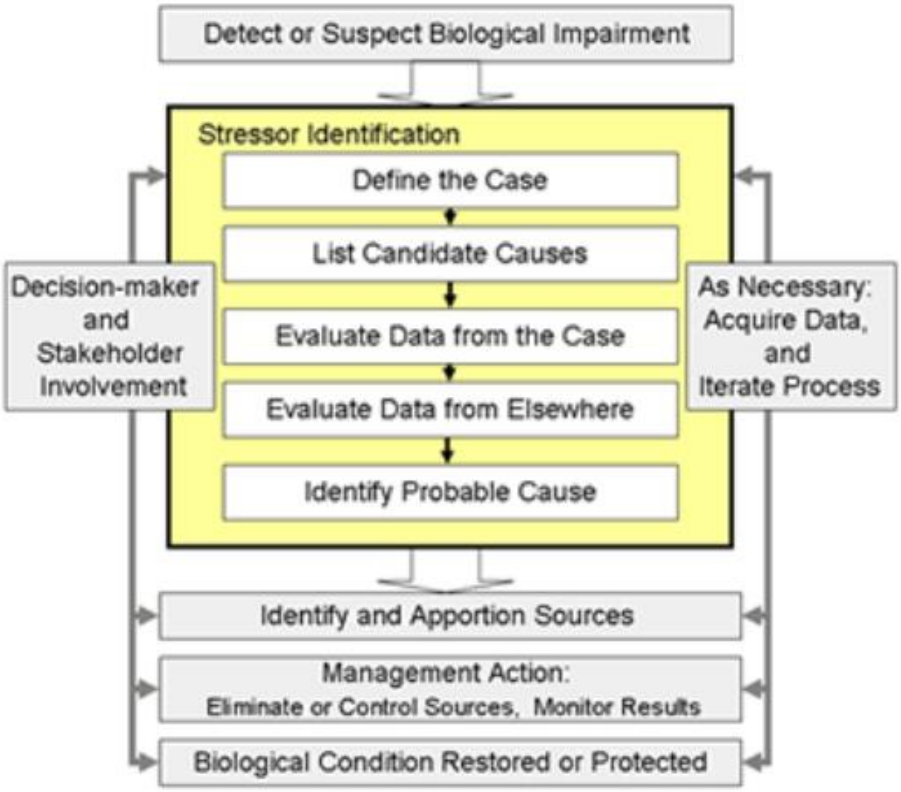

Figure 2. Conceptual model of SID process (Cormier et al. 2000).

Strength of evidence (SOE) analysis is used to evaluate the data for candidate causes of stress to biological communities. The relationship between stressor and biological response are evaluated by considering the degree to which the available evidence supports or weakens the case for a candidate cause. Typically, much of the information used in the SOE analysis is from the study watershed (i.e., data from the case). However, evidence from other case studies and the scientific literature is also used in the SID process (i.e., data from elsewhere).

Developed by the EPA, a standard scoring system is used to tabulate the results of the SOE analysis for the available evidence (Table A1, Appendix 7.1). A narrative description of how the scores were obtained from the evidence should be discussed as well. The SOE table allows for organization of all of the evidence, provides a checklist to ensure each type has been carefully evaluated and offers transparency to the determination process.

The existence of multiple lines of evidence that support or weaken the case for a candidate cause generally increases confidence in the decision for a candidate cause. The scoring scale for evaluating each type of evidence in support of or against a stressor is shown in Table A2 in Appendix 7.1. Additionally, confidence in the results depends on the quantity and quality of data available to the SID process. In some cases, additional data collection may be necessary to accurately identify the stressor(s) causing impairment. Additional detail on the various types of evidence and interpretation of findings can be found here: http://www.epa.gov/caddis/si_step_scores.html.

1.3 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.

Stream Health	Stressor(s)	Link to Biology
Water Chemistry	Low DO 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.

2. Overview of Zumbro Watershed

2.1 Background

The Zumbro River Watershed is located in Southeastern Minnesota, nestled between the Cannon River Watershed to the north and west and the Mississippi River Winona (Whitewater River) Watershed to the south and north. The watershed spans 1,422 square miles, stretching from the far eastern boundaries of Rice and Steele counties, moving east encompassing the southern third of Goodhue County and a majority of Dodge, Olmsted and Wabasha counties and mere three acres of Mower County. The drainage flows in a north easterly direction joining the Mississippi River near Kellogg.

The Zumbro River is comprised of three major branches bearing their watershed's name sake, distinguished by their geographic location within the watershed: South Branch Zumbro River, Middle Fork Zumbro River and North Branch Zumbro River.

The Zumbro River Watershed's streams are primarily classified as warmwater. Gently rolling plains in the western and central regions of the watershed transition into rolling hills and dramatic blufflands characteristic of Southeastern Minnesota; this topographical shift, in addition to underlying geology, gives rise to an abundance springs, supplying precious cold water to the watershed's eastern coldwater tributaries including: Mazeppa Creek, Cold Creek, Spring Creek, West Indian Creek, Trout Brook, Long Creek and Middle Creek. Significant portions of these streams are classified as wild or semi-wild trout waters making the region popular among anglers.

2.2 Monitoring overview

Eighty-two of the 474 stream AUIDs were assessed for aquatic life use, aquatic recreational use or both. Of the assessed streams, only 34 streams were considered to be fully supporting of aquatic life and no streams were fully supporting of aquatic recreation. Two AUIDs were not assessed due to their classification as limited resource waters.

Throughout the watersheds, 54 AUIDs are non-supporting for aquatic life and/or recreation. Of those AUIDs, 37 are non-supporting for aquatic life and 17 are non-supporting for aquatic recreation. Thirteen AUIDs had insufficient information to assess for aquatic life and/or recreational uses.

Seven AUIDs previously listed as impaired for aquatic life use due to excessive turbidity were found to now be meeting standards for TSS or Secchi tube and will be removed from the 303(d) Impaired Waters List in 2016.

The biological monitoring stations that led to aquatic life listing and are included in this report are mapped in Figure 3.

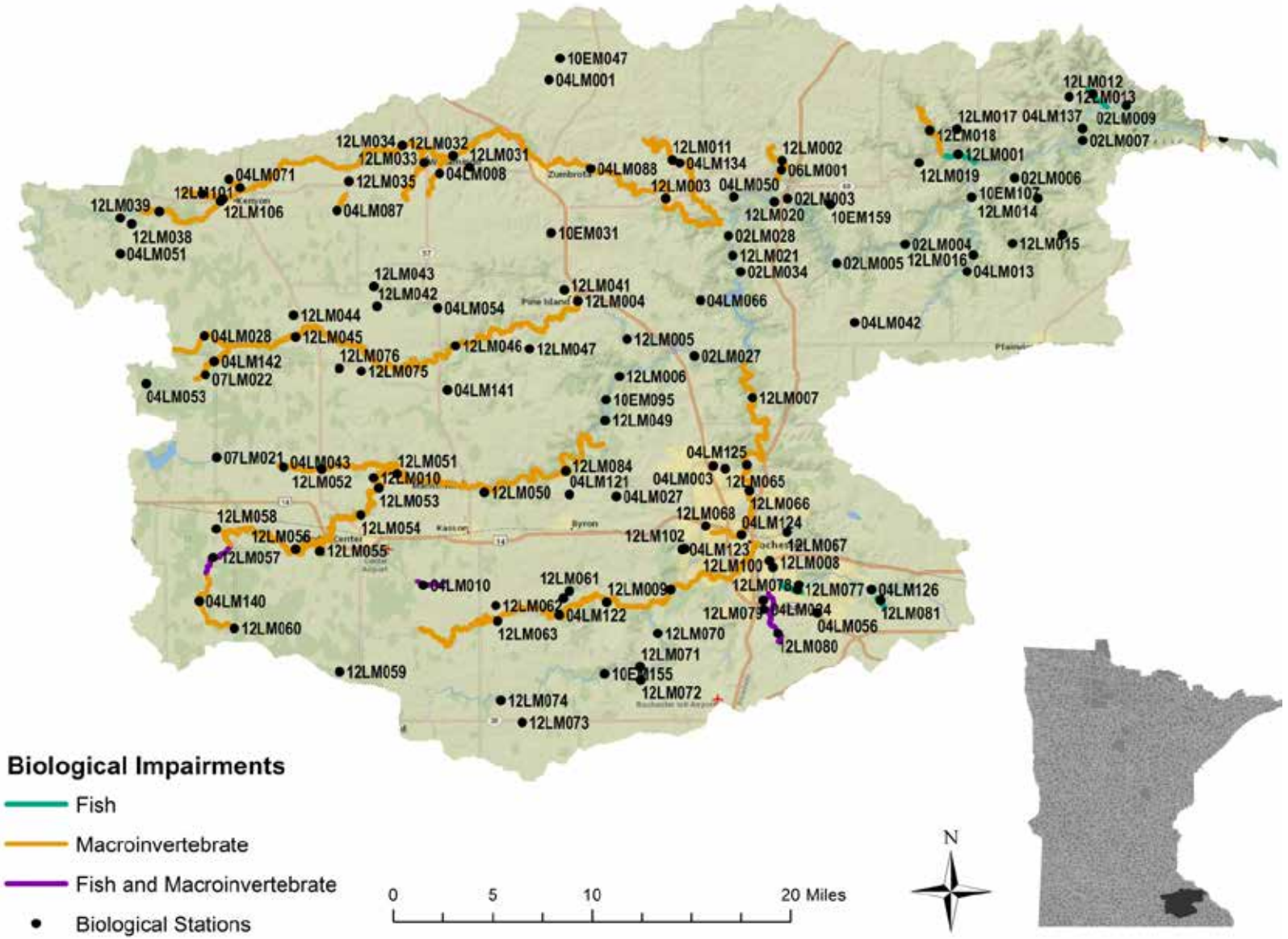

Figure 3. Map of monitoring stations in the Zumbro Watershed.

2.3 Summary of biological impairments

The approach used to identify biological impairments includes assessment of fish and aquatic macroinvertebrates communities and related habitat conditions at sites throughout a watershed. The resulting information is used to develop an index of IBI. The IBI scores can then be compared to range of thresholds.

The fish and macroinvertebrates within each Assessment Unit Identification (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. IBI scores provide a measurement tool to assess the health of the aquatic communities. IBI 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 Zumbro Watershed, 28 AUIDs are currently impaired for poor biological assemblage (Table 2).

Table 2. Biologically impaired AUIDs in the Zumbro Watershed and corresponding water quality impairments.

		Impairments	
Stream Name	**AUID #**	**Biological**	**Water Quality**
Spring Creek	07040004-568	Macroinvertebrates	---
Spring Creek	07040004-570	Fish	*E. coli*
Cold Creek (Cold Spring Brook)	07040004-510	Macroinvertebrates	---
Trout Brook (Mazeppa Creek)	07040004-515	Macroinvertebrates	*E. coli*
Trout Brook	07040004-585	Fish	---
Unnamed creek	07040004-964	Macroinvertebrates	---
Unnamed creek (Spring Creek Tributary)	07040004-605	Macroinvertebrates	---
Silver Creek/Spring Creek	07040004-606	Macroinvertebrates	---
Shingle Creek	07040004-562	Macroinvertebrates	---
Unnamed Creek	07040004-579	Macroinvertebrates	---
North Fork Zumbro	07040004-971	Macroinvertebrates	Turbidity, *E. coli*
Unnamed Creek	07040004-578	Macroinvertebrates	---
Middle Fork Zumbro	07040004-973	Macroinvertebrates	Turbidity, *E. coli*
Dodge Center Creek	07040004-989	Macroinvertebrates	Turbidity, *E. coli*

		Impairments	
Stream Name	**AUID #**	**Biological**	**Water Quality**
Henslin Creek	07040004-618	Macroinvertebrates	---
Judicial Ditch 1	07040004-987	Macroinvertebrates	---
Judicial Ditch 1	07040004-988	Fish and Macroinvertebrates	---
South Branch Middle Fork	07040004-980	Macroinvertebrates	Turbidity
South Branch Middle Fork	07040004-976	Macroinvertebrates	Turbidity
Salem Creek	07040004-503	Macroinvertebrates	Fecal Coliform
Salem Creek Trib	07040004-597	Fish and Macroinvertebrates	---
Unnamed Creek (Trib to Willow)	07040004-800	Fish and Macroinvertebrates	---
Badger Run	07040004-620	Fish	---
Unnamed Creek	07040004-621	Fish	---
South Fork Zumbro	07040004-507	Macroinvertebrates	Turbidity, Fecal Coliform
South Fork Zumbro	07040004-536	Macroinvertebrates	Turbidity, Fecal Coliform
Cascade Creek	07040004-581	Macroinvertebrates	Turbidity
Cascade Creek	07040004-991	Fish	---

The purpose of stressor identification is to interpret the data collected during the biological monitoring and assessment process. Trends in the IBI scores can help to identify causal factors for biological impairments.

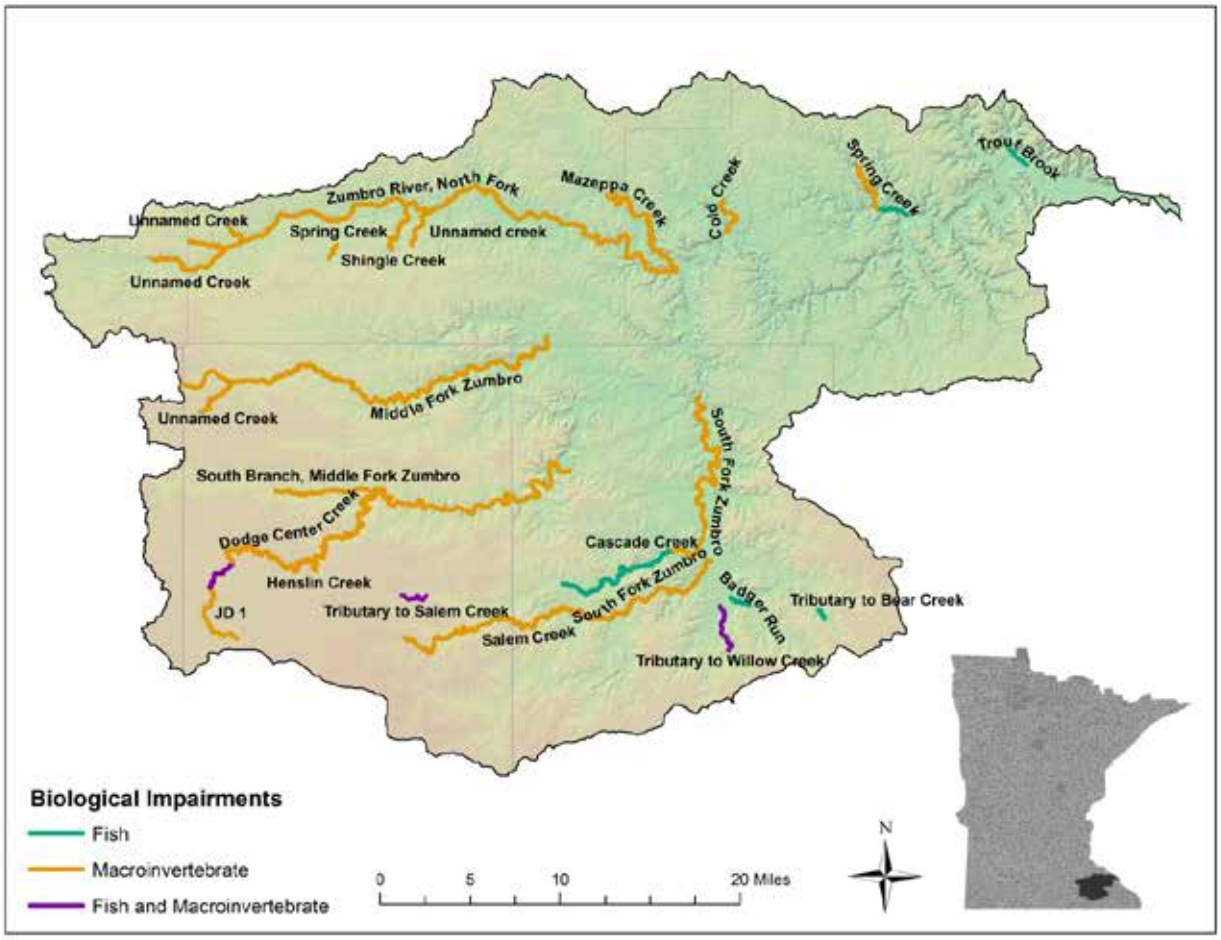

Figure 4. Biological impairment map of the Zumbro Watershed with colors to reflect the type of impairment (fish, macroinvertebrates, or both).

2.4 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 was developed from the watershed-scale Agricultural Runoff Management (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 product of that chemical.

The HSPF watershed model contains components to address runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/transformation of chemical constituents in stream reaches. 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 and the upland areas are separated into multiple land use categories.

An HSPF watershed model was run for the Zumbro Watershed to predict water quality condition throughout the watershed on an hourly basis from 1995-2009. Data from 1995, exclusively may not always be valid however, as the model may take up to one simulated year for parameters to reach calibration targets. Streams with biological impairments used the model output to supplement water quality analyses. The delineated subwatersheds and reaches are shown in Figure 5.

Simulated nitrate data was not used for coldwater streams due to HSPF's inability to adequately model subsurface flow which is applicable to nitrate pollutant transport. Simulations in coldwater systems, like West Indian Creek, compared to robust water quality datasets demonstrate the models inaccuracy in these coldwater streams. However, simulated nitrate data was summarized for the warmwater streams in the Zumbro and used for comparison to grab sample values. Additionally, simulated data TSS, DO and flow were also used for informational purposes.

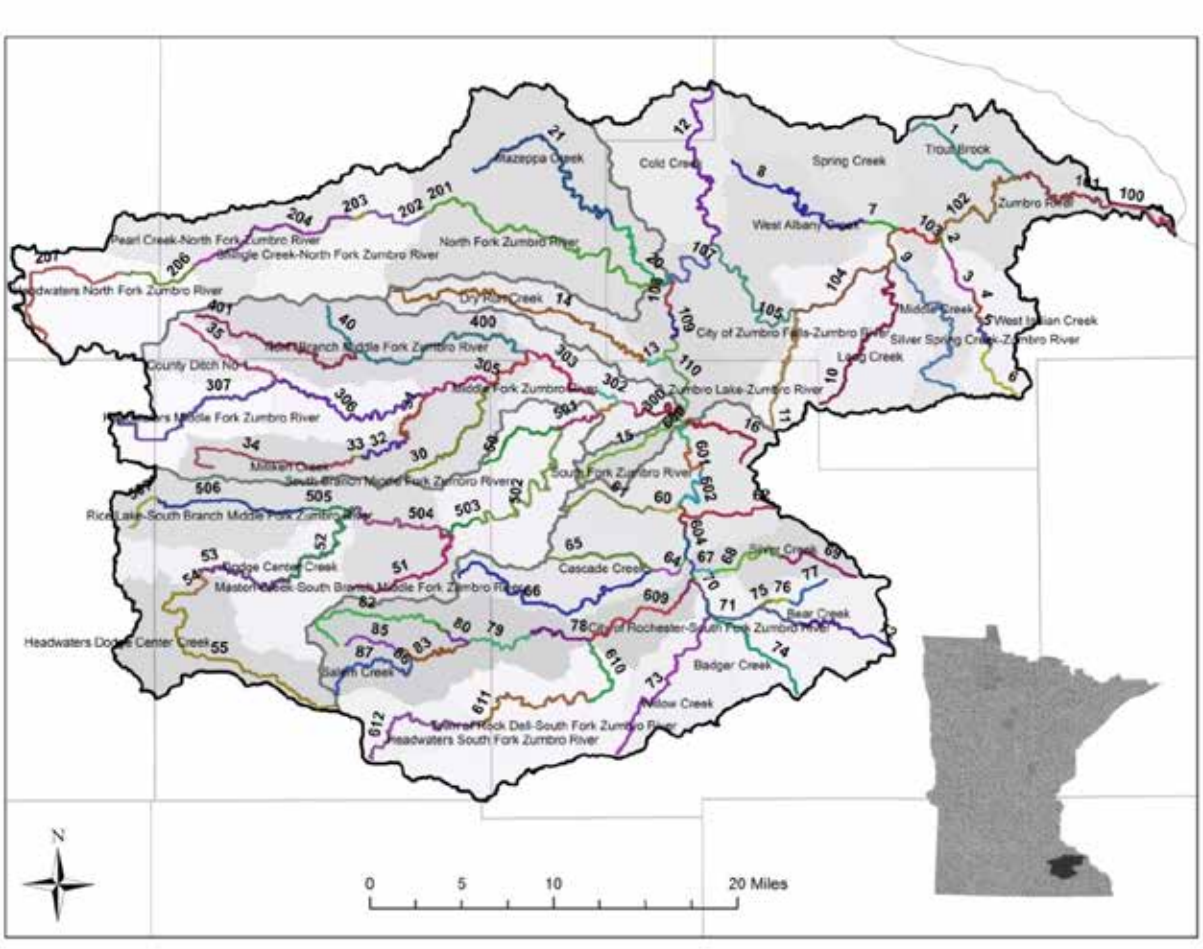

Figure 5. HSPF modeled subwatersheds in the Zumbro River Watershed

3. Possible stressors to biological communities

A comprehensive list of potential stressors to aquatic biological communities compiled by the EPA can be found here (http://www.epa.gov/caddis/si_step2_stressorlist_popup.html). This comprehensive list serves two purposes. First, it can serve as a checklist for investigators to consider all possible options for impairment in the watershed of interest. Second, it can be used to identify potential stressors that can be eliminated from further evaluation. In some cases, the data may be inconclusive and limit the ability to confidently determine if a stressor is causing impairment to aquatic life. It is imperative to document if a candidate cause was suspected, but there was not enough information to make a scientific determination of whether or not it is causing harm to aquatic life. In this case, management decisions can include modification of sampling plans and future evaluation of the inconclusive case. Alternatively, there may be enough information to conclude that a candidate cause is not causing biological impairment and therefore can be eliminated. The inconclusive or eliminated causes will be discussed in more detail in the following section.

3.1 Inconclusive causes (insufficient information)

Some candidate causes were not considered further due to the lack of understanding of the linkage between the potential stressor and the biological community; and/or there was not enough data available. The two candidate causes that were inconclusive were ammonia and pesticides. While there is a good record of pesticide data in the Zumbro Watershed, there is an overall lack of biological response information specific to pesticides for stressor analysis. Additional information regarding aquatic toxicity, duration, and responses to pesticide exposure is needed before stressor determination can be made.

Ammonia

Unionized ammonia values were evaluated throughout the Zumbro Watershed. The highest value sampled was < 0.01 mg/L, with the majority of values at 0. However, there wasn't a large dataset available for analysis. Given the lack of information available, ammonia is inconclusive as a stressor at this time.

Pesticides

A pesticide is defined by the EPA as "any substance intended for preventing, destroying, repelling or mitigating any pest." For the purpose of this document, pesticides refer to fungicides, insecticides, and herbicides used to control various pests.

Herbicides are chemicals used to manipulate or control undesirable vegetation. The most frequent application of herbicides occurs in row-crop farming, where they are applied before or during planting to maximize crop productivity by minimizing other vegetation. They also may be applied to crops in the fall to improve harvesting. In suburban and urban areas, herbicides are applied to lawns, parks, golf courses, and other areas. Herbicides are also applied to water bodies to control aquatic weeds that impede irrigation withdrawals or interfere with recreational and industrial uses of water (Folmar et al., 1979).

Insecticides are chemicals used to control insects by killing them or preventing them from engaging in behaviors deemed undesirable or destructive. Many insecticides act upon the nervous system of the insect, such as Cholinesterase inhibition, while others act as growth regulators. Insecticides are commonly used in agricultural, public health, and industrial applications, as well as household and commercial uses (control of roaches and termites). The U.S. Department of Agriculture (2001) reported

that insecticides accounted for 12% of total pesticides applied to the surveyed crops. Corn and cotton account for the largest shares of insecticide use in the United States. To learn about insecticides and their applications, along with associated biological problems, refer to the EPA website on insecticides and causal analysis on the EPA website (www.epa.gov/caddis/ssr_ins_int.html).

The Minnesota Department of Agriculture (MDA) annually collects samples from various surface water bodies throughout the state and analyzes those samples for the presence of pesticides and degradates. The MDA attempts to capture the influence of different land uses on surface water resources. Out of the 100-plus pesticides this program analyzed, three have been named a "surface water pesticide of concern" - acetochlor, atrazine, and chlorpyrifos. Detection frequency and detection maximums can vary among years for individual pesticides. When detection maximums reach certain thresholds, the MDA may focus monitoring and response efforts in the location of the detection. Since 1985, MDA and Minnesota Department of Health (MDH) have been monitoring the concentrations of common pesticides in groundwater near areas of intensive agricultural land-use. In 1991, these monitoring efforts were expanded to include surface water monitoring sites on select lakes and streams. To understand more about the MDA surface water monitoring program, visit the MDA website: (www.mda.state.mn.us/monitoring).

The Minnesota Department of Agriculture (MDA) has been monitoring for pesticides in surface waters since 1991. Annually, the MDA collects approximately 1,000 samples from rivers, streams, and lakes across the state. In general, MDA looks for pesticides that are widely used and/or pose the greatest risk to water resources. The purpose of MDA's pesticide monitoring program is to determine the presence and concentration of pesticides in Minnesota waters. Samples are collected statewide during the late spring and throughout the summer when the potential for pesticide movement is the greatest.

Pesticides in the Zumbro Watershed

The MDA has conducted a large amount of pesticide monitoring in the Zumbro River Watershed. Since 1991, the MDA has collected and analyzed 154 pesticide samples from 11 different river and stream locations. Most of the river and stream samples were collected from three locations: Cascade Creek in Rochester (S005-361), the North Fork of the Zumbro River near Wanamingo (S004-383), and the Zumbro River in Zumbro Falls (S001-729). Monitoring at the North Fork of the Zumbro near Wanamingo began in 2010, and will continue for several additional years. In addition to these locations, eight additional rivers/streams were sampled over several years as part of MDA's tiered network or as part of a MPCA randomized survey (EMAP) in 2010. Most samples were collected as grab samples. Pesticide monitoring locations in the Zumbro River Watershed are presented in Figure 6. For more information about MDA's monitoring, please refer to: http://www.mda.state.mn.us/chemicals/pesticides/maace.aspx.

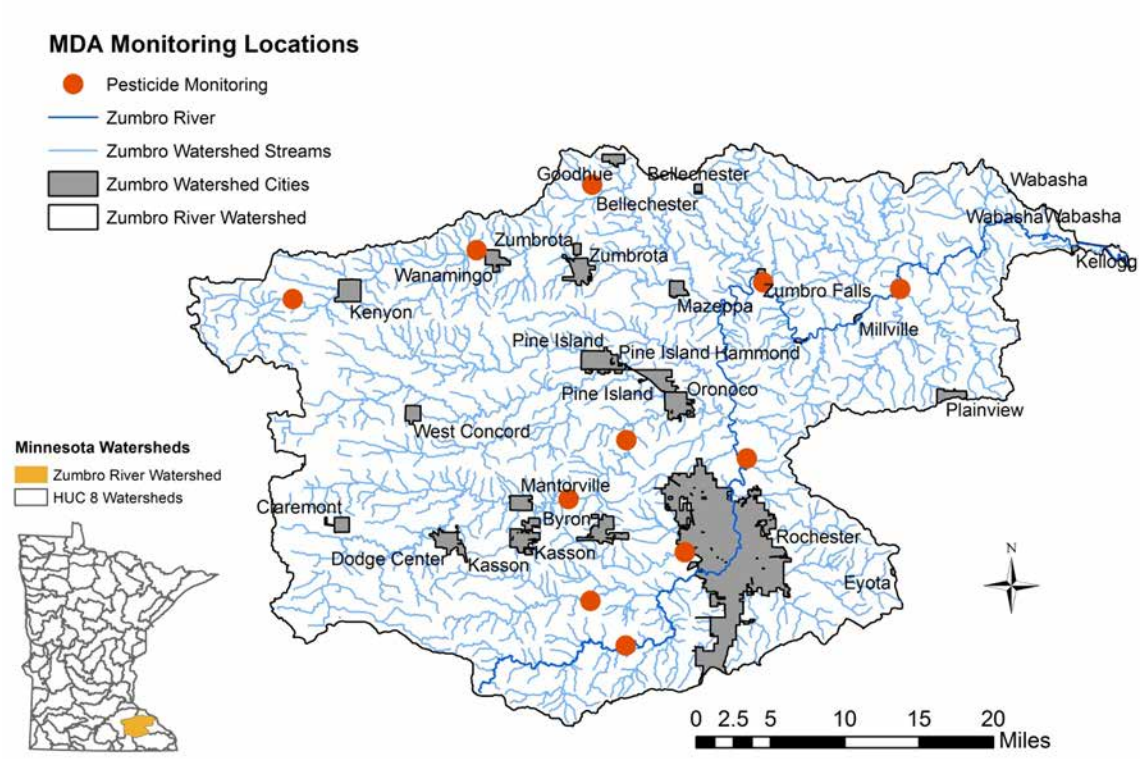

Figure 6. Map showing river and stream locations where pesticide data has been collected in the Zumbro River Watershed.

Pesticides (including herbicides, fungicides, and insecticides) are considered potential stressors in the Zumbro River Watershed due to the surrounding land use. River/stream pesticide results are presented in Appendix 7.2. Since 1991, a total of 41 different pesticides (29) or pesticide degradates (12) have been detected in rivers or streams. When comparing water quality pesticide results to standards and reference values, duration of pesticide occurrence in a water body must be assessed in conjunction with the numeric result. For example, MPCA Class 2Bd Chronic Standards are developed with a duration exposure of 4 days. Therefore, concentration data cannot solely be used for assessment. All of the data collected by MDA is reviewed annually by MPCA for the assessment of water quality standards. As of 2015, there are no water quality impairments related to pesticides in the Zumbro River Watershed.

Of the 41 different pesticide compounds detected in 154 samples, acetochlor was the only compound that was detected above the applicable numeric reference value (twice in 1999). Also, terbufos was detected at "Present but below the laboratory method reporting limit (MRL)" (<180 ng/L) from the North Fork of the Zumbro River near Wanamingo (S004-383) in 2012. None of these samples resulted in a water quality exceedance after assessment. Many pesticides have low detection frequencies, and many detections occur near the laboratory MRL and are extremely low when compared to applicable water quality reference values and standards (Appendix 7.2).

MDA will continue to conduct statewide pesticide monitoring in the future and will provide additional information related to the occurrence of pesticides in Minnesota surface waters. Please see the Appendix 7.2 for more detail on concentrations and detections of pesticides in the Zumbro River.

3.2 Summary of candidate causes in the Zumbro Watershed

Seven candidate causes were selected as possible drivers of biological impairments in the Zumbro watershed. The list of candidate causes was then narrowed down after initial data evaluation resulting in seven candidate causes for final analysis in this report. The seven remaining candidate causes are:

- Temperature
- Dissolved oxygen (DO) and Eutrophication
- Nitrate
- Total suspended solids (TSS)
- Habitat
- Flow Alteration and Connectivity
- Chloride/Conductivity

3.2.1 Candidate cause: Temperature

Temperature can be a major factor in determining macroinvertebrate and fish species composition in coldwater streams. Increases in temperature due to altered watersheds can lead directly to extirpation of coldwater assemblages. Warmer water impacts organisms indirectly due to the relationship with lower DO and directly through changes in growth and reproduction, egg mortality, disease rates, and direct mortality. Macroinvertebrate species have well-known tolerances to thermal changes, and community composition of macroinvertebrates is useful in tracking the effects of increasing temperature. Fish assemblages, likewise, change with temperature, and coldwater-adapted species either leave, are unable to reproduce, or die in warmer regimes. The temperature at which fish continue to feed and gain weight is called their functional feeding temperatures. The limits for brown trout growth are 4 – 19.5°C (Elliot and Elliot, 1995); however, for egg development, brown trout need temperatures between 0 and 15°C (Elliot, 1981). According to Bell (2006), brown trout may be physiologically stressed in the temperature range of 19-22°C. These temperatures are near the upper metabolic limit for trout and may affect the ability to maintain normal physical function and gain weight. When temperatures rise to near 21°C, other fish can have a competitive advantage over trout for the food supply (Behnke, 1992).

Brook trout functional feeding temperatures are between 12.7°C and 18.3° (Raleigh, 1982). They can briefly tolerate temperatures near 22.2°C, but temperatures of 23.8°C for a few hours are generally lethal (Flick, 1991). Juvenile brook trout density is negatively correlated with July mean water temperatures (Hinz and Wiley, 1997). Growth and distribution of juvenile brook trout is highly dependent on temperature (McCormick et al., 1972).

Stream temperature naturally varies due to air temperature, geology, shading, and the inputs from tributaries and springs. Different organisms are adapted to and prefer different temperature regimes. Water temperature regulates the ability of organisms to survive and reproduce (EPA, 1986). Thermal pollution can increase stream temperatures through loss of riparian shading, urban and agricultural runoff, and direct discharges to the stream. Warmer water holds less DO, and higher water temperatures also affects the toxicity of numerous chemicals in the aquatic environment. Algal blooms often occur with temperature increases (EPA, 1986).

Water quality standards

The standard for Class 2B (warmwater) waters of the state is not to exceed 5° Fahrenheit (°F) above natural (Minn. Stat. 7050.0222 subp. 4), based on a monthly average of maximum daily temperature. In no case shall it exceed a daily average temperature of 86° F (30° C).

The state standard for temperature in Class 2A streams is “no material increase” (7050.0222 subp.2).

Temperature in the Zumbro

Temperature stress in the Zumbro was found on one coldwater stream, Spring Creek. In coldwater streams, presence of warmwater species or lack of coldwater species can indicate temperature is a stressor, but it can also be in response to other stressors. In addition to community composition, in-field temperature measurements are used to understand thermal regime and dynamics when determining temperature stress. Additional evaluation of temperature as a stressor is detailed further in this report for all of the coldwater biologically impaired streams in the Zumbro (Spring Creek, Cold Creek, Mazeppa Creek, and Trout Brook). Only one of those reaches was also an identified temperature stressor (Figure 7).

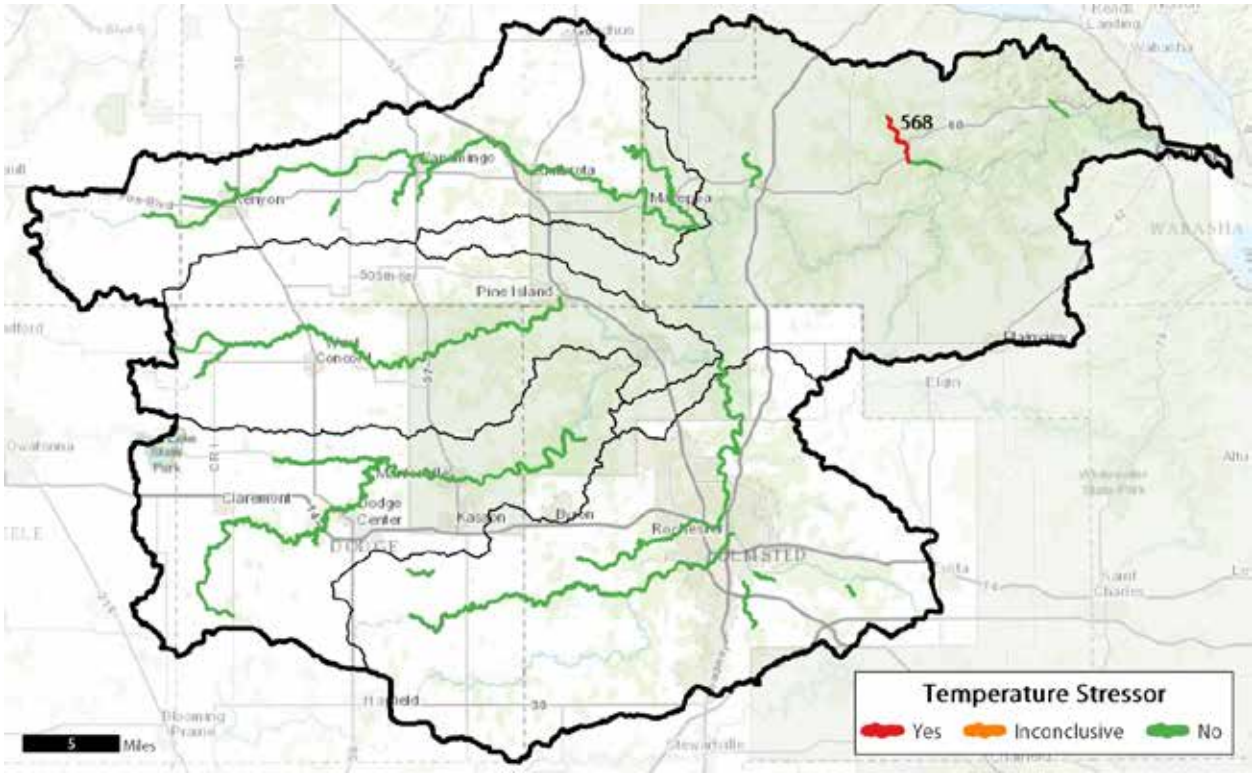

Figure 7. Temperature stress identified in the Zumbro River based on biologically impaired reaches

Many of the warmwater stations had continuous temperature data collected from YSI sondes, or HOBO temperature loggers. The information in Table 3 summarizes the high resolution temperature information available for warmwater reaches in the Zumbro Watershed. None of the data suggest a daily average that exceeds 30 degrees C, which is the current temperature standard. Some sites had short durations where the temperature was above 30 degrees C. Temperature should continue to be monitored in these areas, because temperature can influence other parameters and cause stress indirectly. The current information doesn’t link temperature as a direct stressor in any warmwater stream in the Zumbro. Daily averages at station 12LM060 were around 24-27 degrees C. Due to the information summarized in this table, and discrete temperature measurements taken throughout the watershed, it can be concluded that temperature is not a likely stressor to the warmwater systems of the Zumbro River and therefore each warmwater stream reach did not go through additional temperature related stressor analysis.

Table 3. Summary of available high resolution temperature data for warmwater streams in the Zumbro Watershed

Site	AUID/Stream	Year Collected	Data Type	Dates	Maximum Temperature Recorded °C	Max Time >30° C	July Average Temperature	August Average Temperature
12LM003	971-North Fork Zumbro	2012	YSI Sonde	7/3-7/20	28.05	NA	NA	NA
04LM087	606-Spring Creek	2014	YSI Sonde	7/15-7/29	27.96	NA	NA	NA
12LM004	793-Middle Fork Zumbro	2012	YSI Sonde	8/8-8/21	21.93	NA	NA	NA
12LM004	793-Middle Fork Zumbro	2012	HOBO	5/16-9/4	28.34	NA	23.6	20.2
12LM010	989-Dodge Center Creek	2012	HOBO	7/3-9/9	29.96	NA	24.3	20.3
12LM054	989-Dodge Center Creek	2014	YSI Sonde	7/15-7/29	26.73	NA	NA	NA
12LM060	987-Judicial Ditch 1	2014	YSI Sonde	7/15-7/29	**32.64**	3.5 hr	NA	NA
12LM077	620-Badger Run	2014	YSI Sonde	8/12-8/25	25.51	NA	NA	NA
04LM124	581-Cascade Creek	2014	YSI Sonde	8/12-8/25	27.39	NA	NA	NA
12LM102	991-Cascade Creek	2014	YSI Sonde	8/12-8/19	25.93	NA	NA	NA
12LM007	507-South Fork Zumbro	2012	HOBO	5/16-9/4	**30.14**	1.75 hr	23.8	20.5
12LM007	507-South Fork Zumbro	2007-2014	DTS12 Sonde	2007-2014	**29.85**	NA	NA	NA
12LM007	507-South Fork Zumbro	2012	YSI Sonde	6/20-7/2	27.59	NA	NA	NA
12LM066	507-South Fork Zumbro	2014	YSI Sonde	7/29-8/9	24.96	NA	NA	NA
12LM069	536-South Fork Zumbro	2014	YSI Sonde	7/29-8/12	22.71	NA	NA	NA
12LM009	503-Salem Creek	2012	YSI Sonde	6/20-7/3	27-34	NA	NA	NA

Sources and causal pathways

The causes and potential sources for elevated temperature are modeled at EPA's CADDIS Temperature webpage.

3.3.2 Candidate cause: DO

Low DO

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). DO concentrations and fluctuations are affected by shifts in ambient air and water temperature, precipitation, stream flow, atmospheric pressure, plant/algal growth and decomposition, salinity, and ammonia or nutrient concentrations. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan, 1995).

Fish require oxygen for respiration. Some macroinvertebrates that are intolerant to low levels of DO include mayflies, stoneflies and caddisflies (Marcy, 2011). Many species of fish avoid areas where DO concentrations are below 5 mg/L (Raleigh, 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 (BOD), and/or high groundwater seepage (Hansen, 1975). Heiskary et al. (2013) observed several strong negative relationships between fish and macroinvertebrate metrics and daily DO flux. Phosphorus is just one of multiple factors that may impact low DO and DO dynamics in streams and needs to be analyzed further before a TMDL is completed.

DO flux and eutrophication

Increased phosphorus levels can lead to increased algal and macrophyte growth which in turn leads to increased decomposition and respiration rates. Increased plant and algal growth causes increased oxygen production through photosynthesis during the day. The excess plant material eventually dies, and bacterial activity during decomposition strips oxygen from the water. This leads to low early morning DO readings in streams, and high readings in the afternoon. Streams dominated with submerged macrophytes experience the largest swings in DO and pH (Wilcox and Nagels 2001).

Water quality standards

Low DO standard

The Class 2B (warmwater) water quality standard for DO in Minnesota is 5 mg/L as a daily minimum. The Class 2A (coldwater) water quality standard for DO in Minnesota is 7 mg/L as a daily minimum.

DO flux and eutrophication standard

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 results in indirect impacts to fish and macroinvertebrates, and direct impacts to aquatic communities from response variables such as DO flux, chlorophyll-*a*, and BOD (Heiskary et al., 2013). Elevated phosphorus levels increase algae and

aquatic plant growth and decomposition, resulting in changes in DO and pH concentrations, water clarity, and available food resources and habitat.

The current TP (total phosphorus) standard for the central region of the state is a maximum concentration of 0.10 mg/L with at least one response variable out of desired range (BOD, DO flux, chlorophyll-*a*, and/or pH). The draft standard for DO flux is 3.5 mg/L, chlorophyll-*a* is 18 µg/L, and BOD is 2 mg/L. Portions of the Zumbro are also in the Southern region, with a maximum phosphorus concentration of 0.150 mg/L, flux of 4.5 mg/L, chlorophyll-*a* is 35 µg/L, and BOD 3 mg/L (Table below)

Table 4. River eutrophication regions and standards in Minnesota.

Region	TP µg/L	Related Stressor		
		Chl-a µg/L	DO flux mg/L	BOD_5 mg/L
North	≤ 50	≤ 7	≤ 3.0	≤ 1.5
Central	≤ 100	≤ 18	≤ 3.5	≤ 2.0
South	≤ 150	≤ 35	≤ 4.5	≤ 3.0

Dissolved oxygen and eutrophication in the Zumbro

DO was measured at multiple locations in the Zumbro River watershed. All biological monitoring stations had at least one DO measurement during the biological sampling visits, and others had continuous DO measurements collected with a sonde during the stressor identification process. Biological community composition can be important to look at when analyzing DO patterns, in addition to water chemistry information. One tool used is "Fish Tolerance Indicator Values" (TIVs). The common fish species in the Zumbro River Watershed were grouped into categories (quartiles) based on their tolerance to low DO levels (Table 5). Community composition at each site can then be evaluated by the relative abundance of fish from each quartile.

Table 5. Fish species in the Zumbro River Watershed separated by tolerance values (Sandberg, 2013). Species found in the 1st quartile are the most tolerant to low DO, while species in quartile 4 are the most intolerant to low DO

.1st Quartile		2nd Quartile		3rd Quartile		4th Quartile	
Common Name	*DO TIV*	*Common Name*	*DO TIV*	*Common Name*	*DO TIV*	*Common Name*	*DO TIV*
Brook Stickleback	0.091	Bluntnose Minnow	0.418	Silver Redhorse	0.612	Largescale Stoneroller	0.785
Green Sunfish	0.122	Freshwater Drum	0.428	Sand Shiner	0.632	Longnose Dace	0.795
Largemouth Bass	0.163	Creek Chub	0.448	Shorthead Redhorse	0.653	Southern Redbelly Dace	0.806
Fathead Minnow	0.173	Channel Catfish	0.459	Stonecat	0.663	Northern Hogsucker	0.816
Common Carp	0.193	Hornyhead Chub	0.469	Emerald Shiner	0.673	Fantail Darter	0.836
Bluegill	0.275	Slenderhead Darter	0.51	Mimic Shiner	0.693	Black Redhorse	0.846
White Bass	0.285	White Sucker	0.52	Blacknose Dace	0.704	Rainbow Darter	0.857
Brassy Minnow	0.295	Bigmouth Shiner	0.53	Banded Darter	0.714	Brook Trout	0.877
Rock Bass	0.326	Central Stoneroller	0.54	Redside Dace	0.724	Sauger	0.887
Common Shiner	0.346	Carmine Shiner	0.561	Ozark Minnow	0.734	Gizzard Shad	0.897
Johnny Darter	0.367	Logperch	0.581	Smallmouth Bass	0.744	American Brook Lamprey	0.969
Blackside Darter	0.387	Golden Redhorse	0.602	Quillback	0.775	Brown Trout	0.989
Spotfin Shiner	0.408					Slimy Sculpin	1

Tolerant to Low Dissolved Oxygen

Intolerant to Low Dissolved Oxygen

Currently, there are not any reaches in the Zumbro River Watershed that are designated impaired for aquatic life due to their DO. However, low DO conditions do exist in the watershed and are having negative impacts on the fish and macroinvertebrate communities. Those streams with identified DO stressors in the Zumbro Watershed are shown in the figure below.

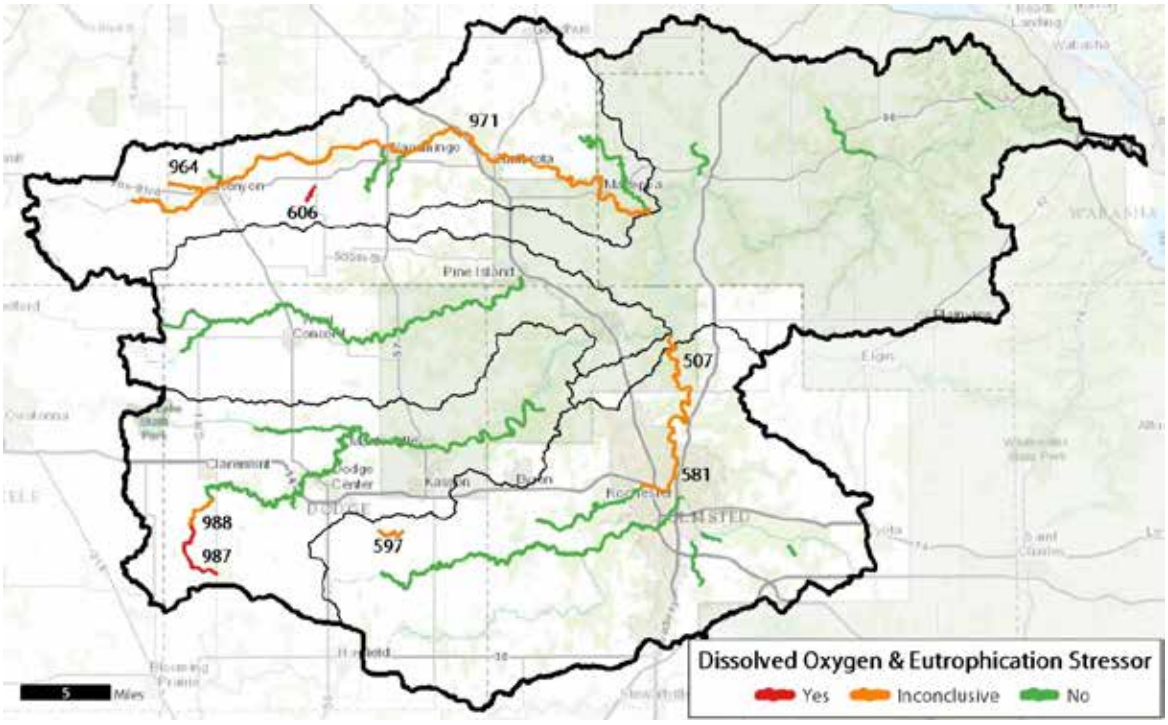

Figure 8. DO and eutrophication stress identified in the Zumbro based on biological impairments

Continuous DO monitoring was collected at 31 different locations from 2012-2015. Additionally, two sites had continuous DO monitoring collected in multiple years. This data showed for the most part that low DO conditions, along with high daily DO conditions were more often present in areas dominated by agriculture. High levels of phosphorus were frequently found in these reaches leading to increased productivity and eutrophication.

Eutrophication can lead to large DO swings and subsequent problems with low DO. However, that is not always the case. High levels of phosphorus can cause algae to grow faster than the stream environment is able to handle. These increases of algae harm water quality, food resources and habitat structure. The food web can be altered, and is reflected in the fish and macroinvertebrate community composition leading to species that can tolerate these conditions.

Sources and causal pathways

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

Excess phosphorus can drive increased plant and algal growth, which causes increased oxygen production through photosynthesis during the day. The excess plant material eventually dies, and bacterial activity during decomposition strips oxygen from the water. This leads to low early morning DO readings in streams, and high readings in the afternoon. Streams dominated with submerged macrophytes experience the largest swings in DO and pH (Wilcox and Nagels 2001). Additionally, increasing primary production due to high nutrients can change plant species composition and cause proximate impacts to stream biology by altering food resources, altering habitat structure, or by algal toxins. Phosphorus is delivered to streams by wastewater treatment facilities, urban stormwater,

agricultural runoff, and direct discharges of sewage. The causes and potential sources for excess phosphorus are modeled at EPA's CADDIS Phosphorus webpage.

3.3.3 Candidate cause: Nitrate

Nitrate toxicity to freshwater aquatic life is dependent on concentration and exposure time, as well as the particular sensitivity of the organism(s) in question. Certain species of caddisflies, amphipods, and salmonid fishes seem to be the most sensitive to nitrate toxicity according to Camargo and Alonso (2005). Camargo et al (2005) cited a maximum level of 2 mg/L nitrate-N as appropriate for protecting the most sensitive freshwater species and that nitrate concentrations under 10 mg/L, are protective of several sensitive fish and aquatic macroinvertebrate taxa. The intake of nitrite and nitrate by aquatic organisms converts oxygen-carrying pigments into forms that are unable to carry oxygen, thus inducing a toxic effect on fish and macroinvertebrates (Grabda et al., 1974; Kroupova et al., 2005).

Water quality standards

Minnesota's Class 1 waters, designated for domestic consumption, have a nitrate water quality standard of 10 mg/L (Minn. Stat. 7050.0222 subp. 3). Minnesota currently does not have a nitrate standard for other use classes though an aquatic life nitrate standard is being drafted. Many factors can contribute to a biological response to nitrate including, but not limited to timing, duration, and flux of concentrations.

Nitrate in the Zumbro

Nitrate data were collected at each biological station on the same date as fish sampling. Additional chemical data assisted in understanding the magnitude and duration of nitrate concentrations under various conditions and are summarized in this report for each AUID. Biological stress due to nitrate has been identified in multiple reaches in this watershed (Figure 9).

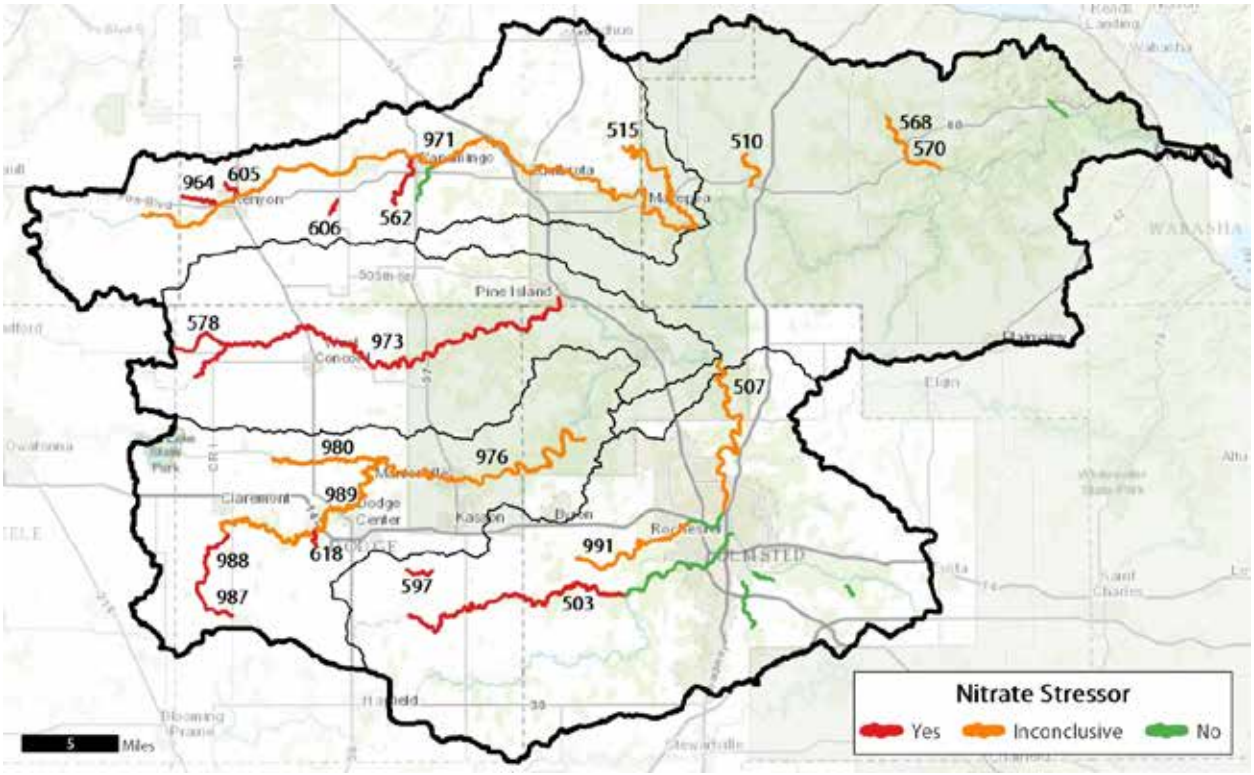

Figure 9. Nitrate stressors identified in the Zumbro based on biological impairment.

The variability and concentrations of nitrate in the Zumbro River Watershed vary depending on location, land use, and underlying geology. Additional work has been completed to document nitrate variability in the eastern part of the watershed. According to Runkel et al (2013), the most important factor identified that impacts both the magnitude and variability of nitrate concentration in spring water and stream baseflow is the proportion of regionally sourced, nitrate-poor water contributed from deep aquifers relative to more locally sourced, nitrate-enriched water from shallower aquifers. In addition, nitrate-nitrogen concentrations in southeast Minnesota's trout streams show a strong linear relationship to row crop land use. A linear regression showed a slope of 0.16, suggesting that the average baseflow nitrate concentration in the trout stream watersheds of southeast Minnesota can be approximated by multiplying a watershed's row crop percentage by 0.16 (Watkins, et al., 2011). The strong correlation between nitrate-nitrogen concentrations in streams and watershed row crop percentage suggests that, in general, nitrogen application over a span of decades has impacted the condition of the underlying aquifers that are the source of these streams' baseflow (Watkins, et al, 2011). Runkel describes much of Bluffland (eastern part) of the Zumbro River Watershed as characterized by deeply incised valleys in the Prairie du Chien Plateau, each have stream water sampling sites that are dominated by low nitrate concentrations relative to row crop production, compared against the correlation for all watersheds combined. Shallow groundwater in the Prairie du Chien at higher elevations in these areas is known to be nitrate enriched. Runkel did not study the areas in the far western part of the watershed, but focused on the coldwater eastern section of the watershed for this analysis.

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be nitrate enriched. Runkel did not study the areas in the far western part of the watershed, but focused on the coldwater eastern section of the watershed for this analysis.

Additional HSPF information models nitrate concentrations throughout the watershed. The highest total nitrogen load in the watershed comes from the western areas. The transport of nitrate to streams in these areas is largely sourced from agricultural lands which are tile drained. The statewide nitrogen study (MPCA 2013) describes tile drainage as the largest pathway for nitrates to reach surface waters. This is further evidenced by the nitrate concentrations analyzed in the western part of the watershed which show high concentrations in the spring months (May and June) when flows are higher and tiles are contributing more water and nitrate to the system. When flow is reduced in late summer, concentrations drop significantly. In contrast, the eastern watersheds see little to no fluctuation in nitrate concentrations and are typically very constant throughout the year. In many other areas of the Zumbro and LMB, agriculture groundwater is the greatest source of delivery of nitrate to streams (MPCA 2013).

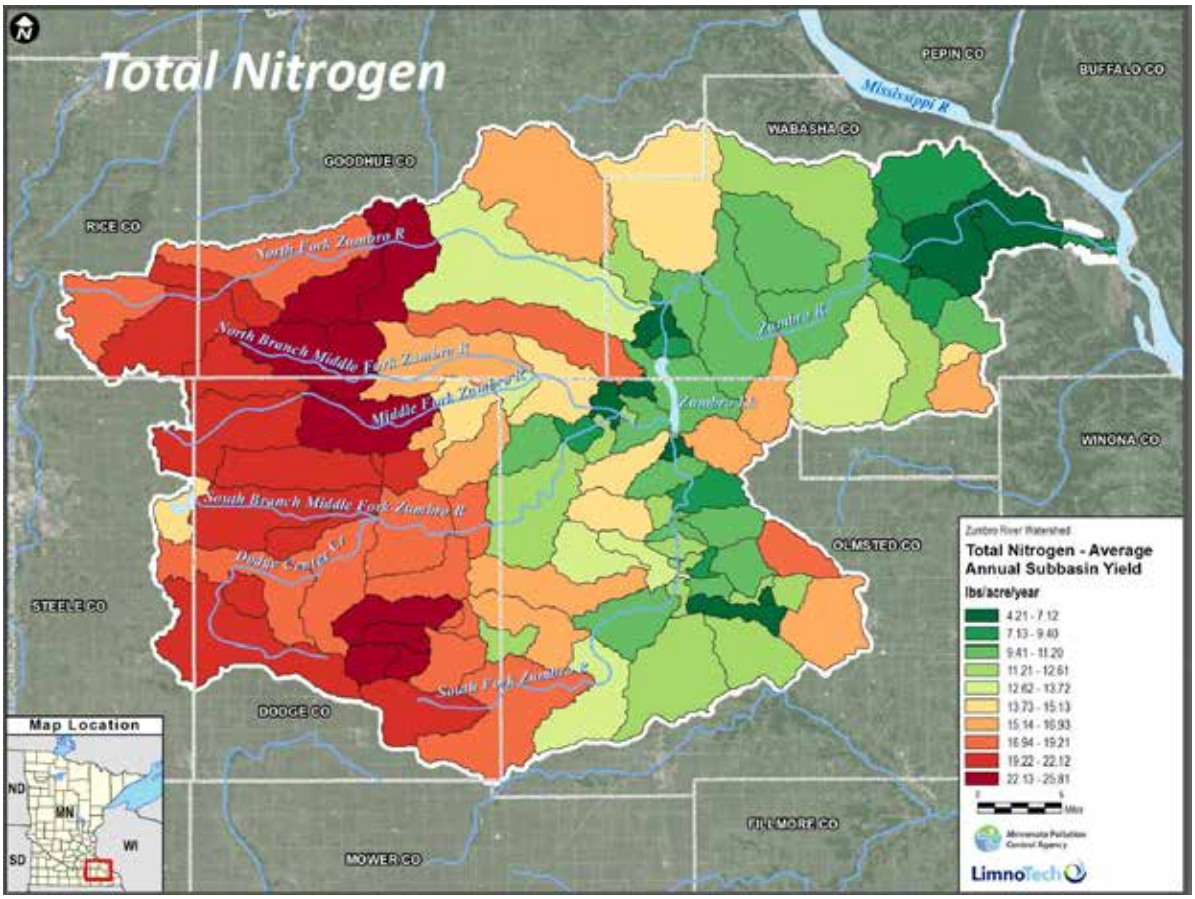

Figure 10. HSPF modeled Total Nitrogen Annual Yield for the Zumbro Watershed subwatersheds.

Biological response to nitrate varies and is different for warmwater streams compared to coldwater streams. Overall, fish lack strong biological response evidence in relation to elevated nitrate in coldwater streams. Better metric relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater macroinvertebrate stations in Minnesota show a 75% confidence that if a stream has a nitrate reading of 12 mg/L or higher, the macroinvertebrate index of biotic integrity (MIBI) score will be below the threshold (46. 1). Similarly, the HBI_MN metric value and consequent metric score have a significant relationship with nitrate concentration at the time of fish sampling. The HBI_MN value increases with increased nitrate. Utilizing quantile regression

analysis for stations in the Southern Coldwater class, there is a significant change point at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN value will be less than 6.57. The macroinvertebrate IBI metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN metric score decreases with increased nitrate. All of these metric tools can give us an idea of the potential for biological response to nitrate, in connection with the concentrations in coldwater streams.

In warmwater streams, fish also lack strong biological response, but can show some response with the percentage of sensitive fish species compared to tolerant fish species. Macroinvertebrate metrics that often respond to elevated nitrate include, taxa count, the presence of sensitive Trichoptera (including non-hydropsychids), and intolerant taxa and individuals. In addition, there are tolerance values and metrics specific to nitrate that can be analyzed given the macroinvertebrate community composition. The percentage of nitrate tolerant individuals can indicate higher nitrate concentrations may exist. For example, at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the Class 6 MIBI. The average percentage of nitrate tolerant individuals for the impaired Zumbro stations is around 70%, with many sites nearing 80%-90%. Compare that with the overall statewide average, which is 53%; highlighting the elevated nitrate concentrations seen not only in the Zumbro Watershed, but the entire Lower Minnesota River Basin (LMB).

Sources and causal pathways model for nitrate and nitrite

The conceptual model for nitrate as a candidate stressor is modeled at EPA's CADDIS Nitrogen webpage. Lefebvre et al. (2007) determined that fertilizer application and land-cover were the two major determinants of nitrate signatures observed in surface water and that nitrate signatures in surface waters increased with fertilization intensity. Nitrogen is commonly applied as a crop fertilizer, predominantly for corn. A statewide nitrogen study found that cropland commercial fertilizers make up 47% of nitrogen added to the landscape, while 21% occurs through cropland legume fixation, 16% from manure application, and 15% from atmospheric deposition (MPCA, 2013). These land applications can reach waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013). Large wastewater treatment facilities in a watershed can also be a contributing source of nitrate, but often do not make up a large portion of the total nitrogen load.

3.3.4 Candidate cause: Total suspended solids

Increases in suspended sediment and turbidity within aquatic systems are considered one of the greatest causes of water quality and biological impairment in the United States (EPA, 2003). Although sediment delivery and transport are an important natural process for all stream systems, sediment imbalance (either excess sediment or lack of sediment) can result in the loss of habitat and/or 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 TSS concentrations can reduce the penetration of sunlight and can thwart photosynthetic activity and limit primary production (Munawar et al., 1991; Murphy et al., 1981). Sediment can also cause increases in water temperature through particles trapping heat.

TSS and bedded sediment are related through several common watershed sources and processes, but each can affect aquatic biota in different ways. Due to the inter-related nature of these parameters, they are grouped together in this report for causal analysis purposes, but ultimately each of these candidate causes will be evaluated independently in terms of impact on fish and macroinvertebrate

Total suspended volatile solids

The presence of algae and other volatile solids, such as detritus in the water column can contribute to elevated TSS concentrations and high turbidity. Total suspended volatile solids (TSVS) can provide a rough estimation of the amount of organic matter present in suspension in the water column. Elevated TSVS concentrations can impact aquatic life in a similar manner as suspended sediment-with the suspended particles reducing water clarity, but unusually high concentrations of TSVS can also be indicative of nutrient imbalance and an unstable DO regime.

Water quality standards

Total suspended solids and transparency tube/Secchi tube measurements can both be used to understand suspended solids since a strong correlation exists between the measurements of TSS concentration and turbidity. The new TSS standard 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. For the central region the TSS standard has been set at 65 mg/L for warmwater streams and 10 mg/L for coldwater streams. For assessment, this concentration is not to be exceeded in more than 10% of samples within a 10-year data window. There is no current standard for bedded sediment in Minnesota. There is currently no standard for TSVS.

Total suspended solids in the Zumbro

The top two priorities/issues in the Zumbro River Watershed (ZWP), according to the ZWP Watershed management plan are 1) Excessive sediment and surface water runoff due to changes in land use and 2) Loss and degradation of aquatic and terrestrial habitats; both which are interrelating factors with elevated TSS. In 2006, 13 new reaches were listed as impaired for turbidity, some of which are described in this report. The TMDLs for those reaches were completed in 2012 for a total 17 turbidity listings in the watershed. This work preceded the fish and macroinvertebrate sampling and subsequent stressor analysis described in this report.

The macroinvertebrate and fish communities were analyzed and a TIV score was created for each site. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community. Fish and macroinvertebrates that are tolerant to TSS can also be tolerant of many other stressors, which is why multiple lines of evidence are used to support determination of stressors. Multiple biological metrics were analyzed for fish and macroinvertebrates to help determine if TSS may be impacting the communities. Overall, 8 reaches in the Zumbro were identified as being stressed by TSS (Figure 11), and 11 reaches were inconclusive in terms of TSS stress.

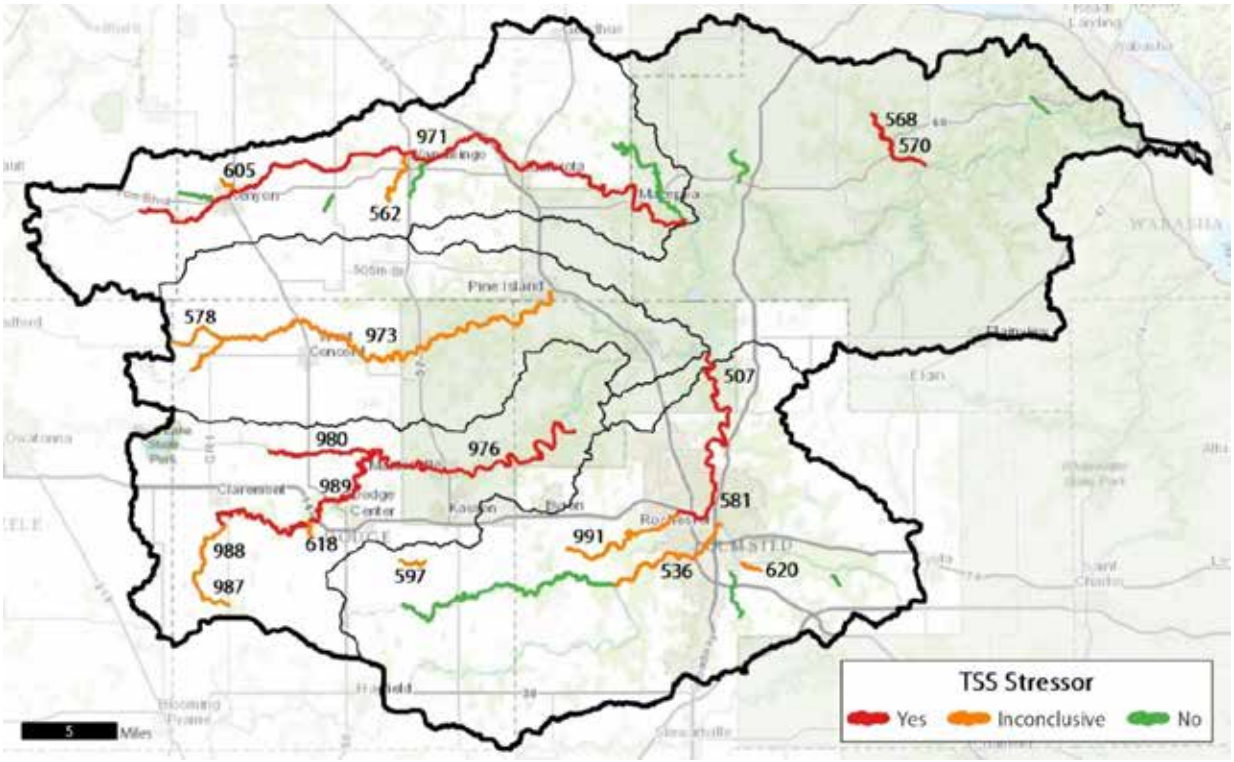

Figure 11. TSS stressors identified in the Zumbro Watershed based on biologically impaired reaches

Sources and causal pathways for total suspended solids

High TSS 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 land. 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.

Rangeland and pasture are also common landscape features in Minnesota. Cattle pasture within the riparian corridor of rivers and streams has been shown to increase streambank erosion and reduce substrate quality (Kauffman, 1984). In some areas, the riparian corridor has been cleared for pasture and is heavily grazed, resulting in a riparian zone that lacks deep-rooted vegetation necessary to protect streambanks and provide shading. Exposures of these areas to weathering, trampling, and shear stress (water friction) from high flow events are increasing the quantity and severity of bank erosion. The causes and potential sources for increases in sediment are modeled at EPA's CADDIS Sediments webpage.

3.3.5 Candidate cause: 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, Rashleigh, & Schofield, 2010). Physical habitat is often interrelated to other stressors (e.g., sediment, flow, DO) but will be addressed separately here.

Excess fine sediment deposition on benthic habitat has been proven to adversely impact fish and macroinvertebrate species that depend on clean, coarse stream substrates for feeding, refuge, and/or reproduction (Newcombe et al., 1991). Aquatic macroinvertebrates are generally affected in several

ways: (1) loss of certain taxa due to changes in substrate composition (Erman and Ligon, 1988); (2) increase in drift (avoidance) due to sediment deposition or substrate instability (Rosenberg and Wiens, 1978); and (3) changes in the quality and abundance of food sources such as periphyton and other prey items (Pekarsky, 1984). Fish communities are typically influenced through: (1) a reduction in spawning habitat or egg survival (Chapman, 1988); and (2) a reduction in prey items as a result of decreases in primary production and benthic productivity (Bruton, 1985; Gray and Ward, 1982).

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 increase the amount of sediment inputs to streams, and 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, Rashleigh, & Schofield, 2010).

According to the U.S Environmental Protection Agency (EPA) CADDIS website, there are six attributes of physical habitat structure provided by a stream: *stream size and channel dimensions, channel gradient, channel substrate size and type, habitat complexity and cover, vegetation cover and structure in the riparian zone, and channel-riparian interactions.* To learn more about physical habitat go to the EPA CADDIS webpage here.

Water quality

There currently is no applicable standard for degraded habitat due to deposited sediment for biotic communities.

Habitat in the Zumbro

Habitat quality differs throughout the Zumbro River Watershed and is an essential tool when understanding and describing the biological communities and their conditions. 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 Zumbro River Watershed habitat conditions were often lowest in areas dominated by agriculture. This includes many areas in the western portion of the watershed (Figure 12). This is often correlated with the land use in this region. The increased amounts of drain tile, animal pasturing, and lack of riparian buffer are frequent causes of the poor habitat conditions. Some small tributaries near the lower end of the Zumbro River in the northeast section of the watershed also scored poorly. Additionally, sites in and around the city of Rochester often had low MSHA scores. Streams with identified habitat stressors are found in Figure 11.

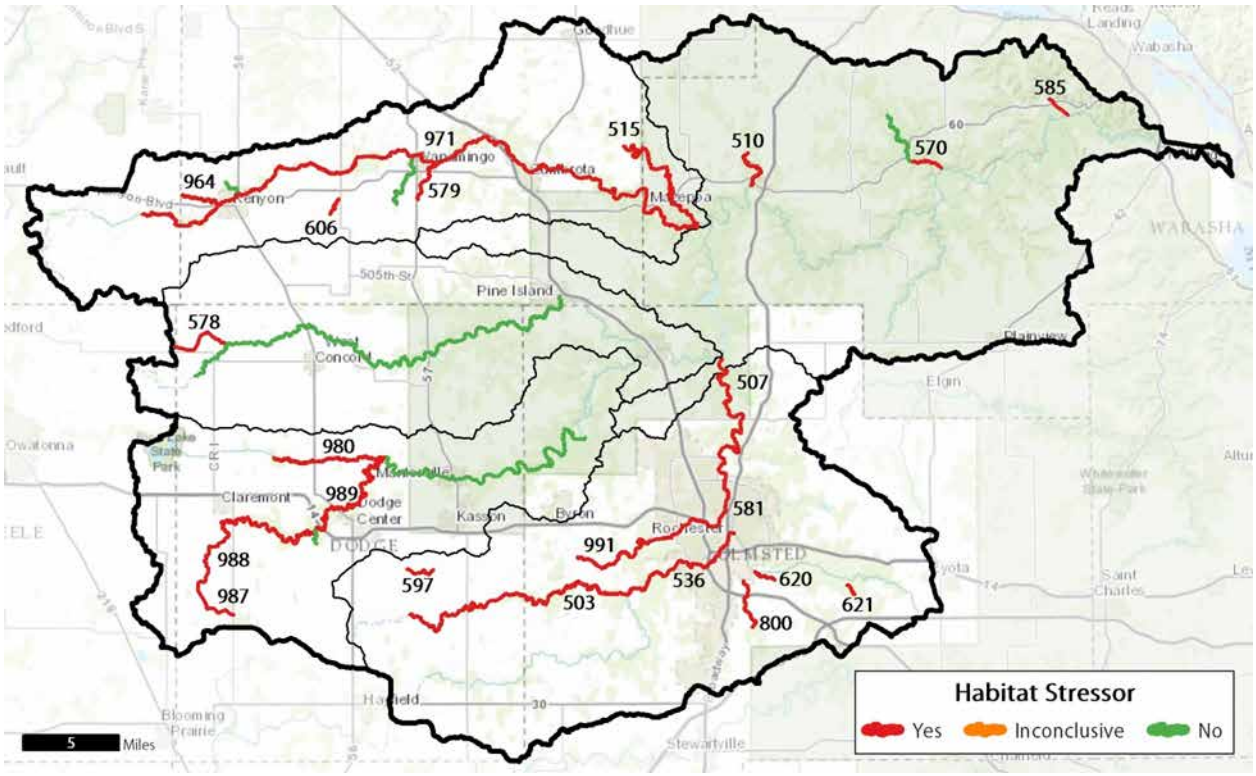

Figure 12. Habitat stress identified in the Zumbro River based on biologically impaired reaches

Sources and causal pathways

Alterations of physical habitat, defined here as changes in the structural geomorphic or vegetative features of stream channels, can adversely affect aquatic organisms. Many human activities and land uses can lead to myriad changes in in-stream physical habitat. Mining, agriculture, forestry and silviculture, urbanization, and industry can contribute to increased sedimentation (e.g., via increased erosion) and changes in discharge patterns (e.g., via increased stormwater runoff and point effluent discharges), as well as lead to decreases in streambank habitat and instream cover, including large woody debris.

Direct alteration of streams channels also can influence physical habitat, by changing discharge patterns, changing hydraulic conditions (water velocities, channel widening, decreased depths), creating barriers to movement, and decreasing riparian habitat. These changes can alter the structure of stream geomorphological units (e.g., by increasing the prevalence of run habitats, decreasing riffle habitats, and increasing or decreasing pool habitats).

Typically, physical habitat degradation results from reduced habitat availability (e.g., decreased snag habitat, decreased riffle habitat) or reduced habitat quality (e.g., increased fine sediment cover). Decreases in habitat availability or habitat quality may contribute to decreased condition, altered behavior, increased mortality, or decreased reproductive success of aquatic organisms; ultimately, these

effects may result in changes in population and community structure and ecosystem function. Narrative and conceptual model can be found on the U.S. EPA CADDIS web page here.

3.3.8 Candidate cause: Flow alteration and connectivity

Flow alteration is the change of a stream's flow volume and/or flow pattern caused by anthropogenic activities, which include channel alteration, water withdrawals, land cover alteration, wetland drainage, agricultural tile drainage, and impoundment. Changes in landscape vegetation, pavement, and drainage can increase how fast rainfall runoff reaches stream channels. This creates a stronger pulse of flow, followed later by decreased baseflow levels. According to the authors of a review on flow effects (Poff, 1997), "Streamflow quantity and timing are critical components of water supply, water quality, and the ecological integrity of river systems. Indeed, streamflow, which is strongly correlated with many critical physicochemical characteristics of rivers, such as water temperature, channel geomorphology, and habitat diversity, can be considered a 'master variable'.

Reduced flow or baseflow reduction

Fish and macroinvertebrate species have many habits and traits that can either be helpful or detrimental in different flow conditions and will either respond positively or negatively with reduced flow. Across the conterminous U.S., Carlisle et al. (2011) found that there is a strong correlation between diminished streamflow and impaired biological communities. Habitat availability can be scarce when flows are interrupted, low for a prolonged duration, or extremely low, leading to decreased wetted width, cross sectional area, and water depth. Flows that are reduced beyond normal baseflow decrease living space for aquatic organisms and competition for resources increases. Pollutant concentrations can increase when flows are lower than normal, increasing the exposure dosage to organisms. Tolerant organisms can out-compete others in such limiting situations and will thrive. Low flows of prolonged duration lead to macroinvertebrate and fish communities comprised of generalist species or that have preference for standing water (U.S.EPA, 2012a). Changes in fish community can occur related to factors such as species' differences in spawning behavior (Becker, 1983), flow velocity preference (Carlisle et al., (2011)), and body shape (Blake, 1983). When baseflows are reduced, nest-guarding fish species increase and simple nesters, which leave eggs unattended, are reduced (Carlisle et al., (2011)). Nest-guarding increases reproductive success by protecting eggs from predators and providing "continuous movement of water over the eggs, and to keep the nest free from sediment" (Becker, 1983). Active swimmers, such as the green sunfish, contend better under low velocity conditions (Carlisle et al., (2011)). In their review paper on low-flow effects on macroinvertebrates, Dewson et al. (2007) found that responses were complex, and not easy to generalize. Some cited studies showed increased density, and others decreased. More often, the behavior called drift (using the current to be transported to a new location) increased. Many studies reported that species composition changed, and taxonomic richness generally decreased in streams experiencing prolonged low flows. Those invertebrates that filter food particles from the water column have shown negative responses to low flows. EPA's CADDIS website (U.S.EPA, 2012a) lists the responses of reduced flow as lower total stream productivity, elimination of large fish, changes in taxonomic composition of fish communities, fewer migratory species, fewer fish per unit area, and more-concentrated aquatic organisms, potentially benefiting predators.

Increased flow or channelization

Increasing surface water runoff and seasonal variability in stream flow have the potential for both indirect and direct effects on fish populations (Schlosser, 1990). Indirect effects include alteration in habitat suitability, nutrient cycling, production processes, and food availability. Direct effects include decreased survival of early life stages and potentially lethal temperature and oxygen stress on adult fish (Bell, 2006). Increased flow volume increases channel shear stress, which results in increased scouring

and bank destabilization. This subsequently has a negative impact on the fish and macroinvertebrate communities via loss of habitat, including habitat smothering by excess sediment. High flows and the associated increased flow velocities can cause displacement of fish and macroinvertebrates downstream, and mobilization and possible removal to the floodplain of habitat features such as woody debris, which are important as flow refugia for fish and living surfaces for clinging invertebrates. Macroinvertebrate types may shift from those species having long life cycles to shorter ones; species that can complete their life history within the bounds of the recurrence interval of the elevated flow conditions (U.S.EPA, 2012a). Fish species that have streamlined body forms experience less drag under high velocities and will have advantage over non-streamlined fish species (Blake, 1983).

Increased flows may directly impair the biological community or may contribute to additional stressors. Increased channel shear stresses, associated with increased flows, often cause 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. To learn more about flow alteration as a stressor go to the EPA CADDIS webpage here.

Connectivity in river ecosystems refers to how waterbodies and waterways are linked to each other on the landscape and how matter, energy, and organisms move throughout the system (Pringle, 2003). Impoundment structures (dams) on river systems alter steamflow, water temperature regime, and sediment transport processes – each of which can cause changes in fish and macroinvertebrate assemblages (Cummins, 1979; Waters, 1995). Dams also have a history of blocking fish migrations and can greatly reduce or even extirpate local populations (Brooker, 1981; Tiemann et al., 2004). In Minnesota, there are more than 800 dams on streams and rivers for a variety of purposes, including flood control, wildlife habitat, and hydroelectric power generation.

Dams, both human-made and natural, can cause changes in flow, sediment, habitat and chemical characteristics of a waterbody. They can alter the hydrologic (longitudinal) connectivity, which may obstruct the movement of migratory fish causing a change in the population and community structure. The stream environment is also altered by a dam to a predominately lentic surrounding (Mitchell and Cunjak, 2007). Longitudinal connectivity of flowing surface waters is of the utmost importance to fish species. Many fish species' life histories employ seasonal migrations for reproduction or overwintering. Physical barriers such as dams, waterfalls, perched culverts and other instream structures disrupt longitudinal connectivity and often impede seasonal fish migrations. Disrupted migration not only holds the capacity to alter reproduction of fish, it also impacts mussel species that utilize fish movement to disperse their offspring. Structures, such as dams, have been shown to reduce species richness of systems, while also increasing abundance of tolerant or undesirable species (Winston et al. 1991, Santucci et al. 2005, Slawski et al. 2008, Lore 2011).

Lateral and longitudinal connectivity of a system's immediate riparian corridor is an integral component within a healthy watershed. Continuous corridors of high quality riparian vegetation work to sustain stream stability and play an important role in energy input and light penetration to surface waters. Improperly sized bridges and culverts hinder the role of riparian connectivity as they reduce localized floodplain access, disrupt streambank vegetation, and bottle neck flows that can scour downstream banks and vegetation and result in perched culverts.

Water quality standards

There currently is no applicable standard flow alteration or connectivity.

Flow alteration and connectivity in the Zumbro

Flow alteration and channelization in the Zumbro River Watershed are mostly found in the western and northern portions of the watershed, however channelized sections are also present throughout in the southern and eastern sections as well. Flow alteration refers to any activity that alters the discharge patterns of a stream and local flow characteristics associated with structural habitat changes. In the Zumbro, flow alteration encompasses multiple aspects including factors such as stream channelization, tile drainage, urbanization, impoundments and perched culverts. These varying factors can have varying impacts to the biological community, and are explained further in each stream section. Connectivity refers to the physical connections in a stream that have been disrupted. For the purposes of this report, connectivity refers to the longitudinal connections, like dams or perched culverts, which can also affect the flow regime. The locations of Flow Alteration and Connectivity stress are mapped in Figure 13.

Adding to the issue of altering flow by channelizing streams is the high degree of drain tile use in the western portion of the watershed. This area is the headwaters for many of the main rivers and streams within the watershed.

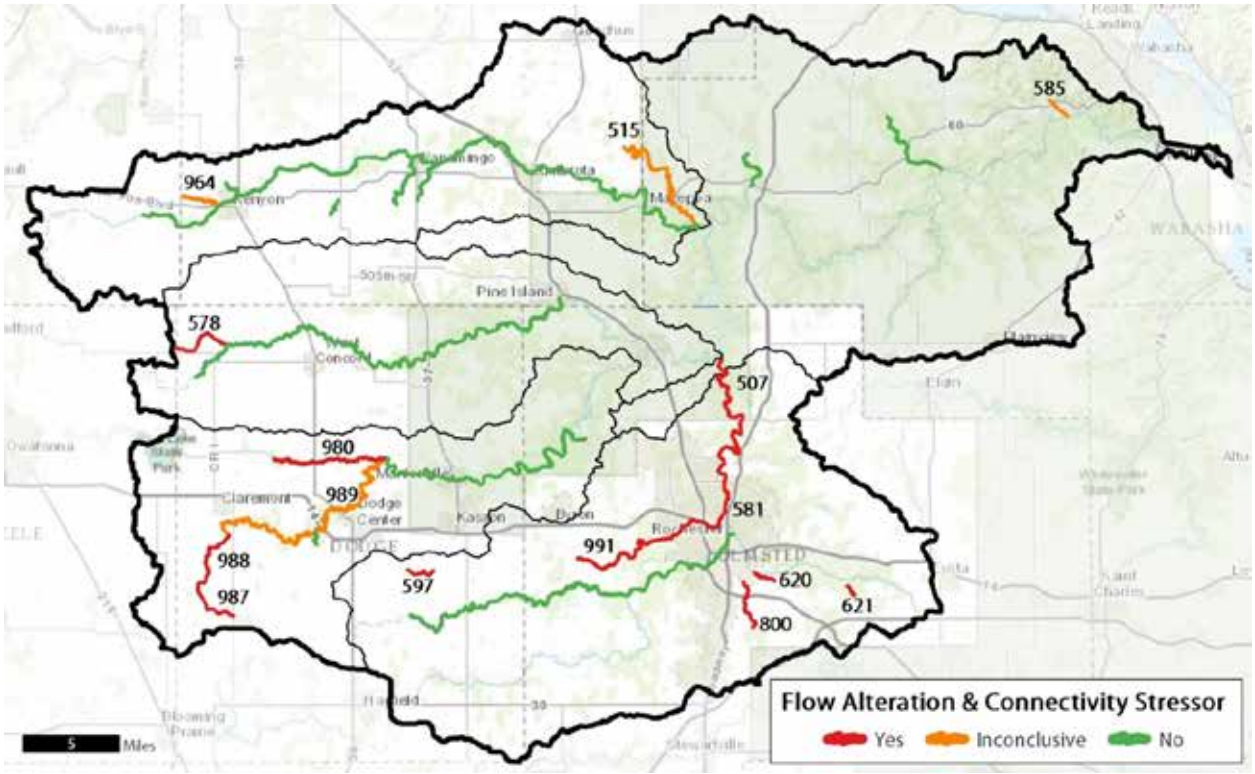

Figure 13. Flow Alteration and Connectivity stress in the Zumbro Watershed by biologically impaired reach.

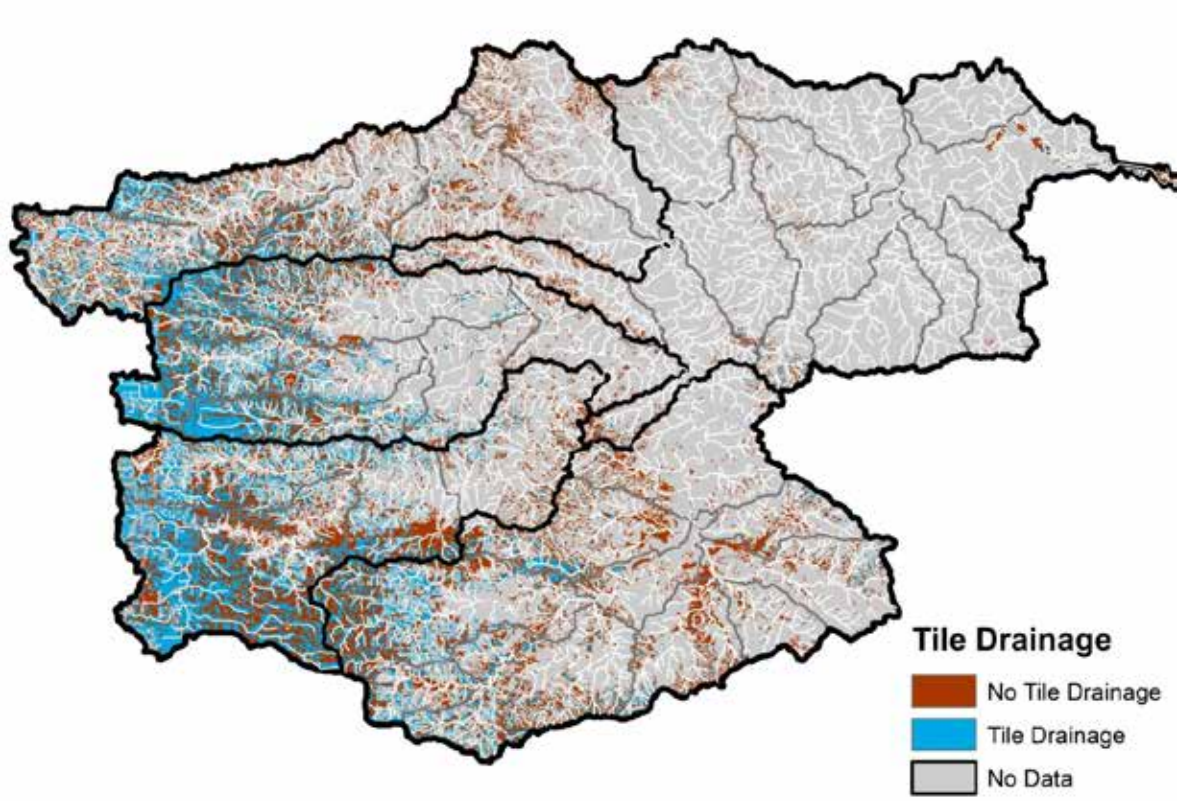

Figure 14. Estimated tile drainage in the Zumbro River Watershed

Flow alteration and connectivity issues in the Zumbro River Watershed were noted in the turbidity TMDL report (2012):

"Although each fork of river has not gone through significant channelization, other alterations to the waterbody have occurred in the form of dams, which are located at several locations along several river segments. These include a large main stem dam at Lake Zumbro and another significant dam structure at Lake Shady upstream of where the Middle Fork of the Zumbro River enters Lake Zumbro. There is a dam on the South Branch Middle Fork of the Zumbro River at Mantorville. Smaller dams and large regional flood control basins exist upstream of the City of Rochester in the South Fork Zumbro Watershed. Significant dam structures also exist at Mazeppa and Zumbro Falls."

Additionally, the Zumbro Watershed Partnership (ZWP) has a watershed management plan mentioning the impacts of flow alteration and connectivity:

"Increased development and increased impervious surfaces throughout the watershed have resulted in larger stormwater runoff rates and volumes. Studies have consistently shown that during storm events, pollutant loads are directly related to watershed imperviousness. Also, the reduction in water storage capacity in the Zumbro region has led to increased stormwater rates. Wetlands in the region have been reduced to less than 50% of their original numbers. Wetlands act as a sponge for surface runoff pollutants. In addition, wetlands are very important to help regulate water infiltration for groundwater recharge. With the reduction in these filter areas; only limited amounts of water have a chance to infiltrate, resulting in water flowing over the land surface carrying sediment and pollutants."

Increasing precipitation and climate change may also be a factor contributing to flow alteration issues. MNDNR completed some precipitation analysis in 2015 for the Zumbro Watershed. Overall, watershed wide precipitation trends show a relatively dry period from 1907-1693 where the seven year moving average remained at or below the long term average (Figure 15). After 1963, the average precipitation showed an increasing trend in the seven year moving average. Additional analysis showing the South

Fork at Rochester monitoring station demonstrations that both precipitation and average discharge show an increasing trend over the 60-year period (Figure 15). Additionally, both data sets appear to track with each other signifying consistency in the precipitation and the discharge relationship over time at this site.

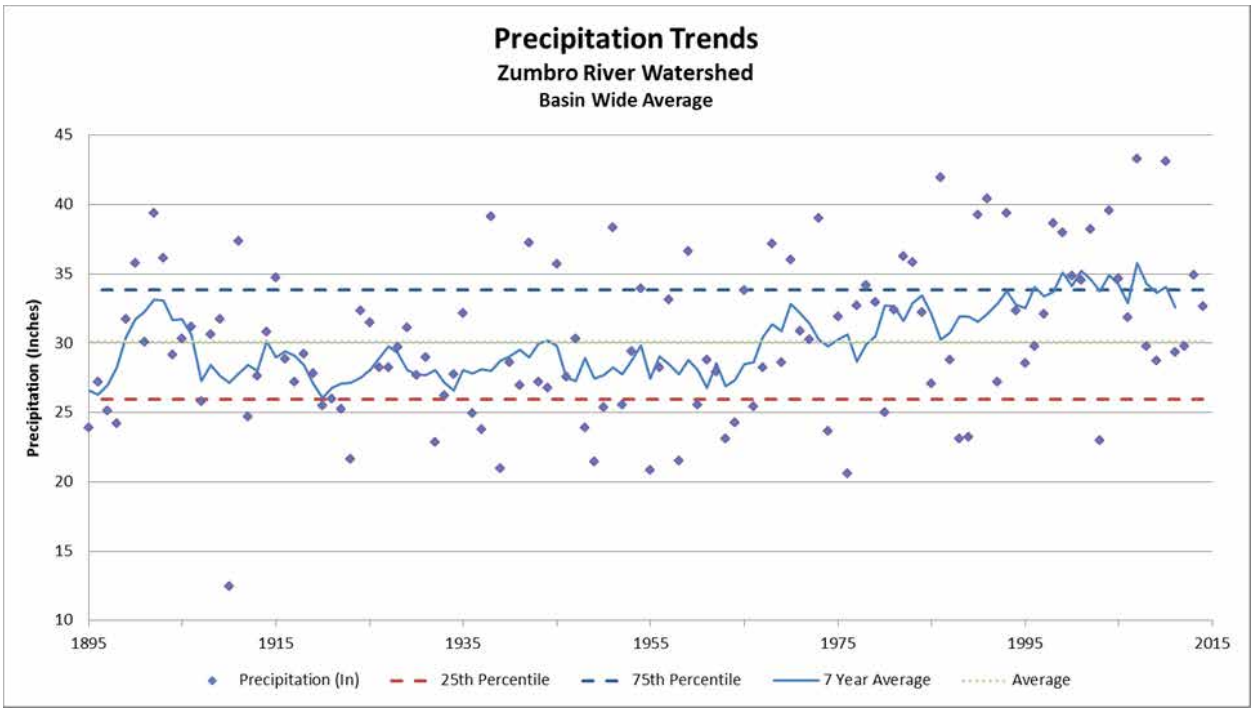

Figure 15. Precipitation trends for the Zumbro River Watershed based off of averages from cities within and near the watershed. Averaged data was taken from Rochester, Kenyon, and Zumbro Falls Gauging Locations utilizing the Minnesota Climatology Working Group's High Spatial Density Precipitation Network (HIDEN).

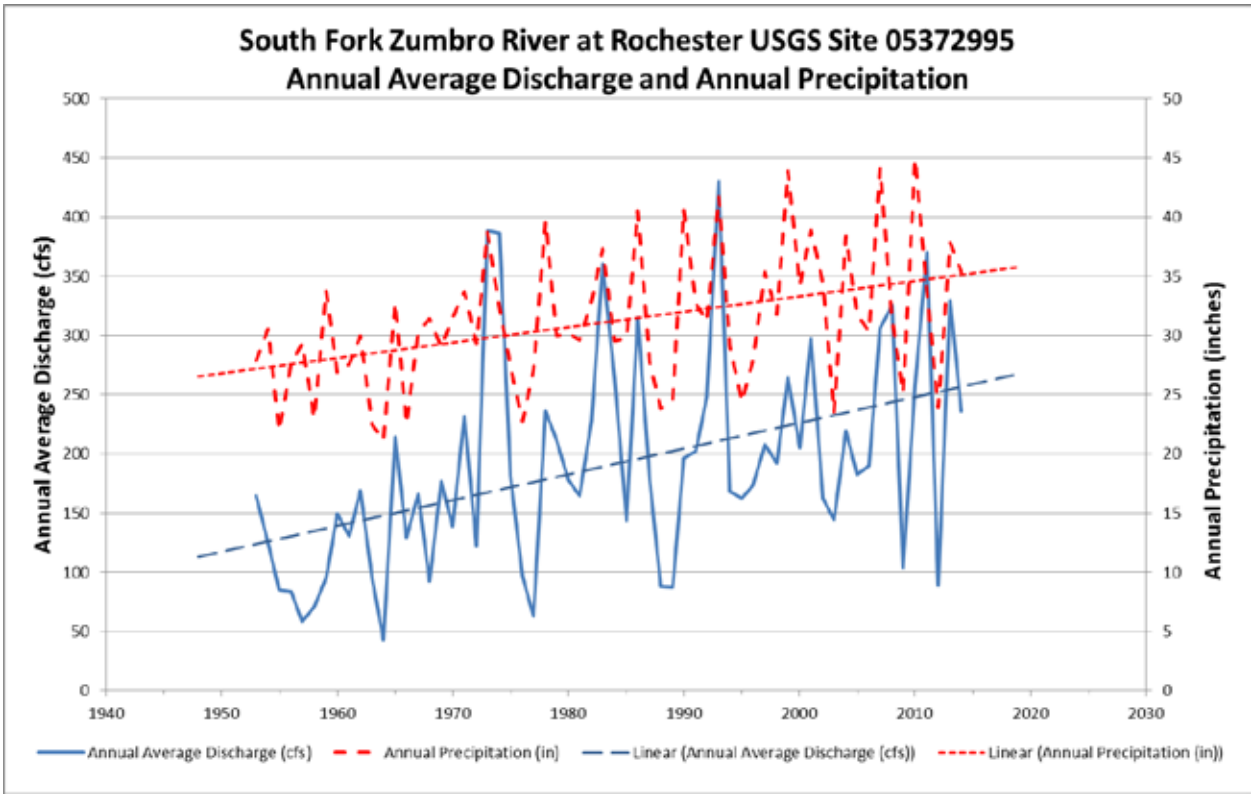

Figure 16. Average annual discharge plotted against annual precipitation for the South Fork Zumbro River gage in Rochester, Minnesota.

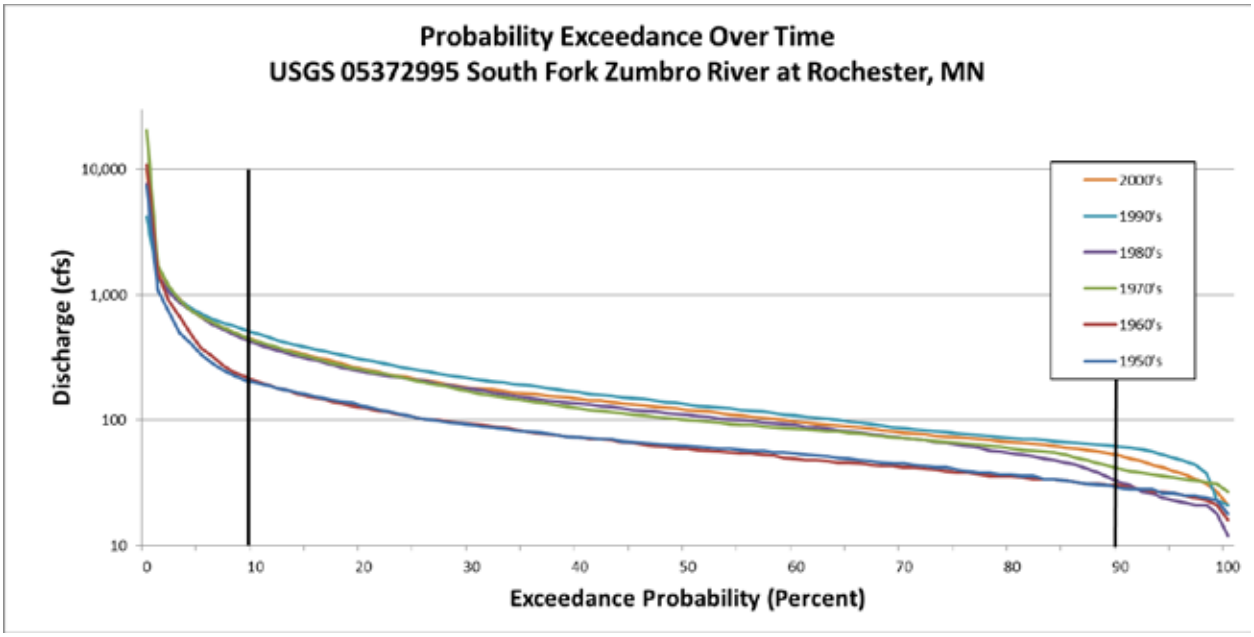

Figure 17. Flow Duration curve developed from data on the South Fork Zumbro River at Rochester, Minnesota for the period of record. Duration curves were computed for each decade on record to show the changes over time over the entire range of flows for the site.

A distinct change occurred in high flows (less than 10% probability) from the 1960's to the 1970's where an increase of 108% occurred. Low flows have fluctuated during the period of record (above 90% probability) and are most recently around 80% higher than at the beginning of data collection The

1990's saw the highest flows on record which have been observed in other watersheds in the region as well.

Sources and causal pathways

Many anthropogenic changes can alter stream channels and flow regime, while dams create impoundments, all of which can lead to a change in the habitat structure and connectivity of a stream system. Increasing discharge in a watershed and changes in discharge regulation can also have biological impacts. This all can affect plant, fish, and macroinvertebrate diversity and richness. The conceptual model for physical connectivity including flow alteration as a candidate stressor can be found on the U.S. EPA CADDIS webpage here.

3.3.9 Chloride/conductivity (Ionic strength)

Specific conductance refers to the collective amount of ions in the water. In general, the higher the level of dissolved minerals in a volume of water, the more electrical current (or conductance) can be transmitted through that water. Aquatic organisms maintain a careful water and ion balance, and can become stressed by an increase in ion concentrations (SETAC, 2004). Calcium, sodium, and magnesium are all necessary for aquatic health, and occur naturally, but imbalances can be toxic (SETAC, 2004).

Elevated conductivity may be caused by multiple ions, including elevated chloride. Therefore, it can serve as a surrogate or indicator for issues such as chloride. The negative effects of elevated chloride concentrations on aquatic life have been well documented. The use of road salt and de-icing products has increased considerably in the United States since 1950, putting more urban streams at risk for this stressor (Kostick, 1993).

Water quality standards

Minnesota has set a chronic water quality standard of 230 mg/L and an acute water-quality standard of 860 mg/L for chloride.

A standard of 1,000 µmhos/cm at 25 °C exists for Class 4 waters of the state (Minn. Stat. 7050.0224 subp. 2) that is protective of agricultural and irrigation uses, but is not an aquatic life standard.

Chloride/conductivity in the Zumbro

Chloride toxicity/conductivity was considered a candidate cause for impairment due to the expanding urban, commercial, and residential development in the watershed. There was one reach (South Fork, 507) which had sufficient datasets to be analyzed more extensively for chloride and conductivity. The remaining reaches were not analyzed for chloride/conductivity because values were within suitable range, and the overall probability of these issues was less compared to the South Fork Watershed, which drains the city of Rochester and includes a major wastewater treatment facility; both of which are likely sources of chloride to the South Fork.

Specific conductivity in the watershed was reviewed as high chloride concentrations would result in elevated specific conductivity measurements. The specific conductivity data ranged from 7.41 – 1312 µS/cm. There were a total of 1,176 field conductivity measurements in the watershed, with most below 900 µS/cm. A few were above 900 µS/cm and a handful above 1000 µS/cm. These measurements occurred on the South Fork, 507 stream reach. Data from the Shingle Creek Chloride TMDL indicated that specific conductivity readings above 1000 µS/cm indicated that chloride levels were high enough to cause toxicity problems for aquatic organisms.

Chloride has been collected on 40 different stream reaches in the Zumbro Watershed, with a total of 1,164 chloride samples taken from 1999-2014. This extensive dataset did not show any exceedances of

the chloride standard (230 mg/L). The average chloride concentration of all the data in the watershed was 26 mg/L. The highest measurements were taken on the South Fork of the Zumbro (507), downstream of the City of Rochester and the WWTP. Higher values were recorded either in mid-summer or during the winter months. Overall, this reach had an average chloride concentration of 45 mg/L, with some measurements taken above the WWTP, and some below. Further analysis of this reach is described later in this report.

According to the MPCA milestone monitoring, data collected at the Zumbro River South Fork (CSAH-14, 3 miles north of Rochester; period of record 1973-2008) showed an increasing trend in chloride concentrations overall. The average annual change was a yearly increase of 3%, while the total change was 186%. The median concentrations in the most recent 10 years of data was 54 mg/L while the first 10 years of data was 36 mg/L.

Some chloride and conductivity information exists in the winter months. Additional data should be collected in urbanized areas, specifically Rochester during the winter months to better characterize the concentrations. More data during the low baseflow period may also be helpful. Those are the two time periods when it appears that conductivity/chloride concentrations appear to be the highest and biology most susceptible. Therefore, chloride was inconclusive as a stressor until further information is collected (Figure 18).

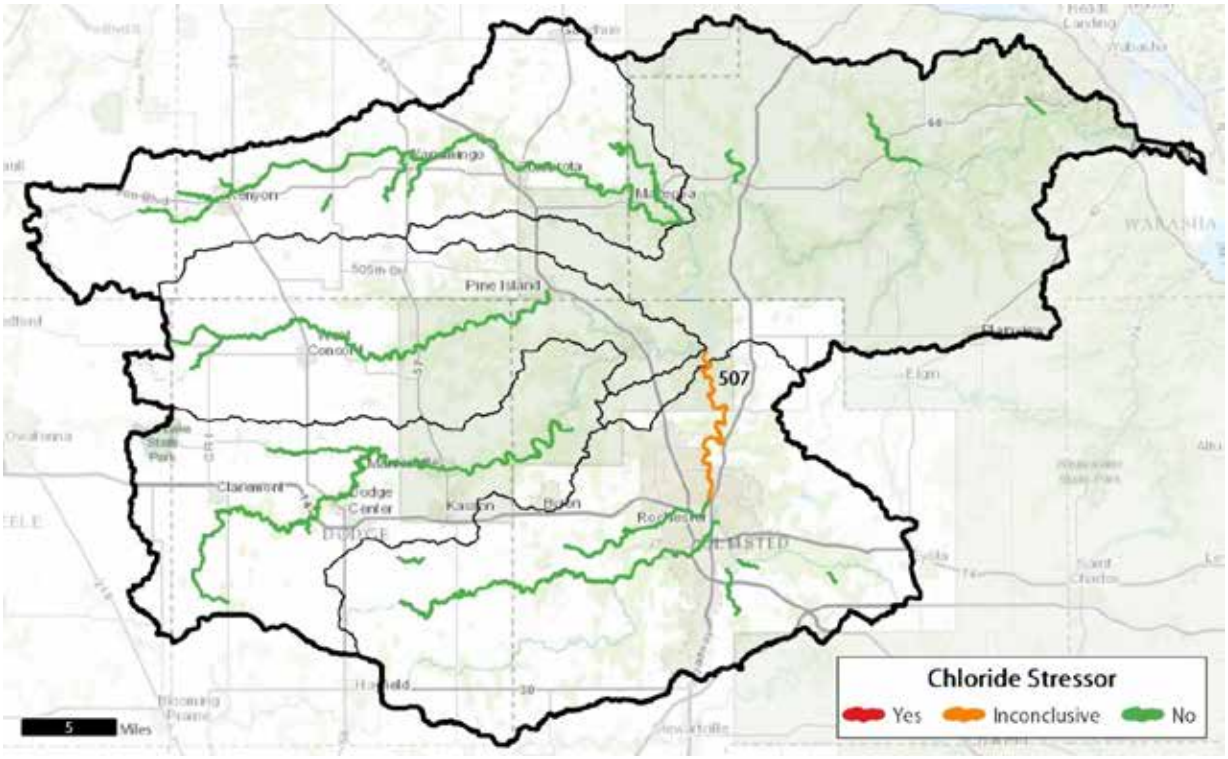

Figure 18. Chloride stressors identified in the Zumbro based on biological impairments.

Sources and causal pathways

The presence of dissolved salts and minerals in surface waters does occur naturally, and biota are adapted to a natural range of ionic strengths. However, industry runoff and discharges, road salt, urban stormwater drainage, agricultural drainage, WWTP effluent, and other point sources can increase ions in downstream waters. The causes and potential sources for ionic strength are modeled at EPA's CADDIS Ionic strength webpage.

4. Evaluation of candidate causes by watershed area

Candidate causes were evaluated in the Zumbro Watershed by each major branch (North, Middle, South, etc.), and also addressed in each tributary with biological impairment.

4.1 Spring Creek Watershed

Spring Creek is a coldwater stream that originates in Wabasha County. The watershed drains 39,904 acres, 64% of which is in agricultural use. Section 4.1 includes two biologically impaired stream reaches adjacent to one another. The upstream reach of Spring Creek is listed as impaired for macroinvertebrates and downstream reach for fish (Figure 19).

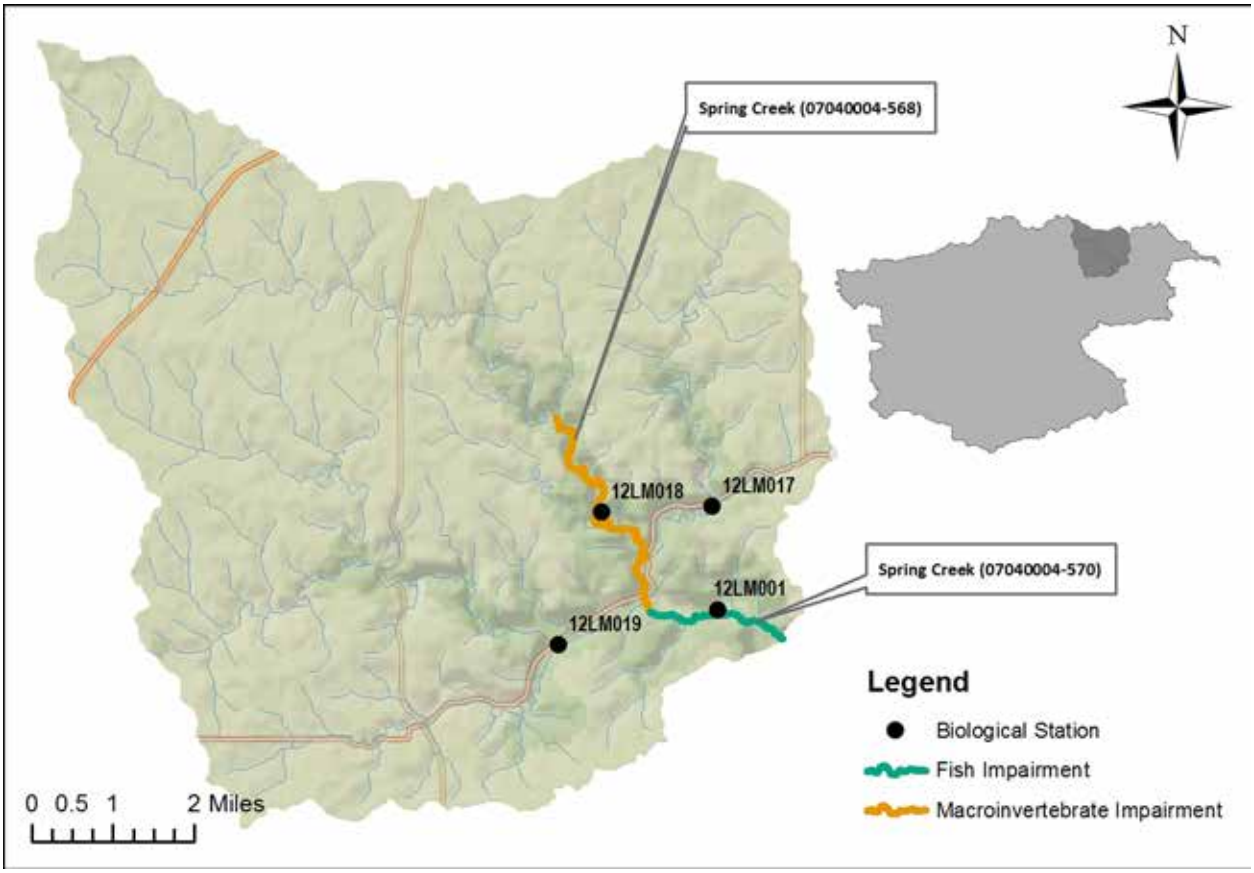

Figure 19. Map of the Spring Creek Watershed, biological stations, and impaired AUIDs.

4.1.1 Spring Creek (568)

Biological and background information

Spring Creek is split into two AUIDs. On the upstream AUID (07040004-568) there is one biological sample collected at station 12LM018 on August 1, 2012, which resulted in a macroinvertebrate impairment. The stream is designated macroinvertebrate Class 9 (Southern Coldwater). The MIBI impairment threshold for this class is 43, with an average score per metric of 6.14 needed to achieve that threshold. Station 12LM018 has an MIBI score of 27.97 and all but one (VeryTolerant2Pct) of the metric scores fall below the average metric score needed. This led to the macroinvertebrate impairment on this reach. However, on the downstream reach (570; 12LM001) the MIBI score was higher, at 51.21. Both sites are displayed in Figure 19, for comparison.

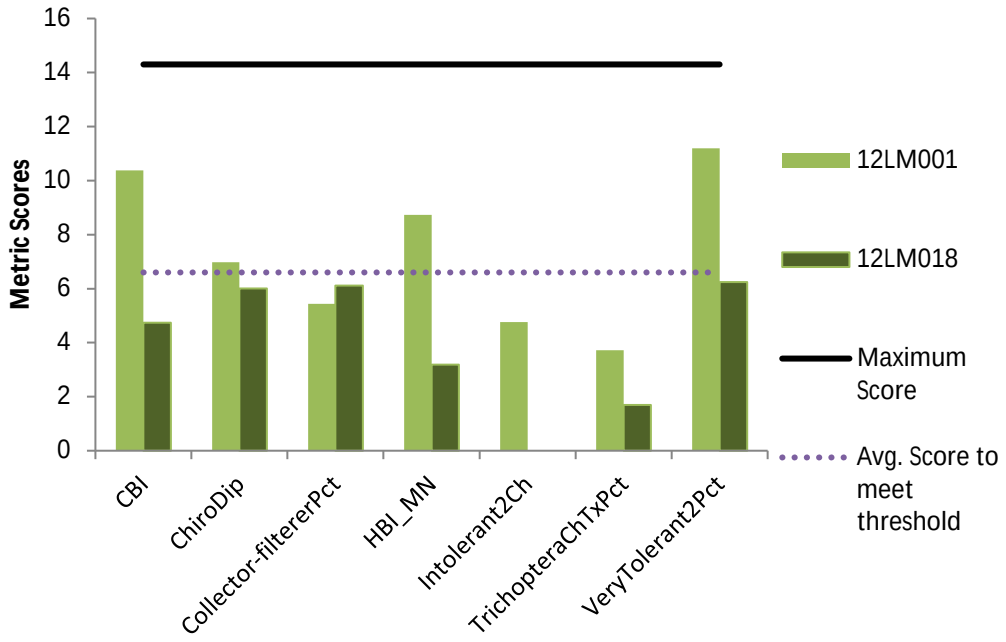

Figure 20. Macroinvertebrate IBI metrics in Spring Creek (Southern coldwater)

Temperature

In the summer of 2014, from May to October, temperature loggers were placed at biological station 12LM018. A fairly high maximum temperature (25.01 °C) was collected on July 22, 2014. The July and August averages were 17.5 and 17.38 °C respectively. While this station is upstream in the watershed, it reveals a warmer thermal regime overall compared to the station farther downstream (Figure 27). The stream spends a fair amount of time in the threat temperature for brown trout and also exceeds the critical temperature threshold for brown trout (Figure 21).

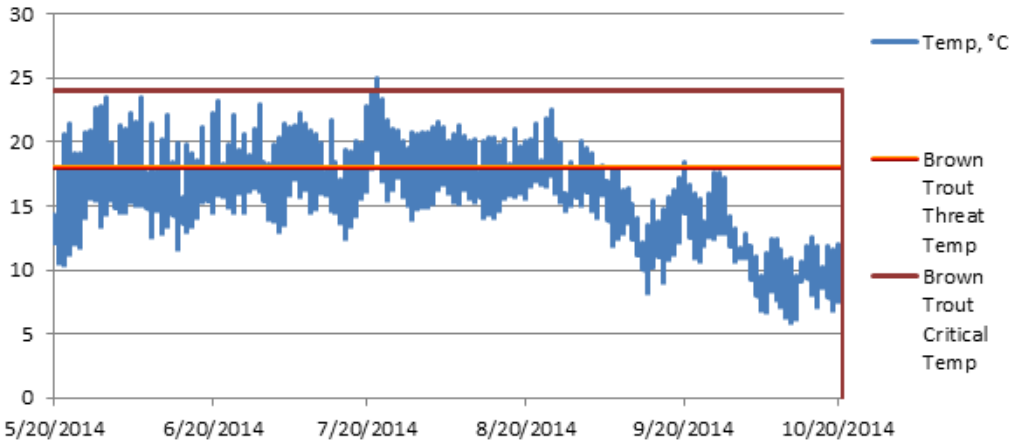

Figure 21. Stream water temperature (Site 12LM018) May - October 2014, with respect to the Brown Trout Critical and Threat temperatures.

From a biological standpoint, the fish communities in Spring Creek show a general lack of coldwater fish species, which can indicate thermal degradation along with other stressors. The percentage of coldwater fish species at 12LM018 was 10.85% (ColdPct). Most coldwater streams in the area have a minimum of 50% coldwater fish species present, with many nearing 100%. Similarly, coldwater sensitive fish species (CWSensitivePct), and native coldwater species (NativeColdPct) were low or absent resulting in low IBI metric scores (Figure 20). Coldwater macroinvertebrate taxa were more limited at station 12LM018 compared to station downstream, 12LM001. This is evidenced by a low CBI (coldwater biotic index) metric score at 12LM018 (Figure 20).

The temperature and biological evidence confirms that temperature is a stressor to this upper reaches of Spring Creek. Even though fish are not impaired in these upper reaches, the community is degraded and the FIBI is only slightly above impairment threshold. The thermal regime, which shows temperatures reaching brown trout threat temperature nearly every day, is likely limiting the fish community from thriving and is considered a stressor, even though temperature may not be driving the macroinvertebrate impairment. It's likely that thermal regime, in conjunction with other stressors are limiting the biological communities in this reach.

Dissolved oxygen and eutrophication

Continuous DO monitoring in Spring Creek took place at biological monitoring site 12LM018 in 2014 (Figure 22). This monitoring effort showed that the DO levels stayed above the 7 mg/L daily minimum standard for a Class 2A stream, however, the daily flux frequently exceeded the 3.5 mg/L standard.

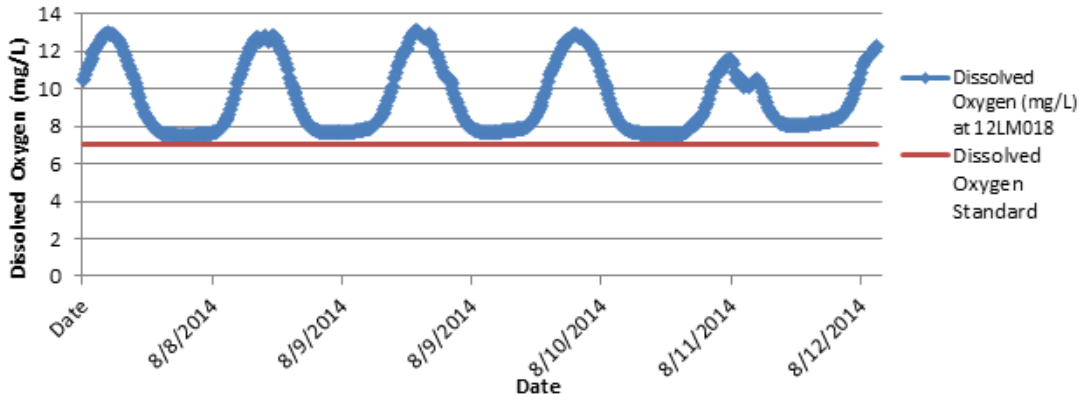

Figure 22: Continuous DO monitoring in 2014, along Spring Creek (07040004-568) at 12LM018.

Additionally, three phosphorus samples were taken along this reach of Spring Creek. These values ranged from 0.03-0.056 mg/L, with no values exceeding the phosphorus standard. Figure 24 shows the build-up of algae observed near the biological station. Excessive amounts of attached and suspended algae can lead to eutrophication and result in high amounts of DO flux, which can negatively impact the biological communities in multiple ways, including an increased potential for low DO. Metrics for addressing DO flux in coldwater streams are not yet available and therefore difficult to analyze from a biological standpoint. As a result, metrics for low DO response are used here.

Figure 23. Algae located on rocks at site 12LM018.

The macroinvertebrate assemblage at site 12LM018 had a decreased amount of low DO tolerant individuals (5.14%), while also having an increased amount of EPT individuals (40.13%). These results signal an assemblage not being negatively impacted by the low DO conditions. The DO TIV score for the macroinvertebrate community was slightly below the coldwater average.

The fish community along Spring Creek had an increased amount of late-maturing (47.29%), and sensitive (28.68%) individuals, while also having zero serial spawning species. The DO TIV score for the fish community was below average for a Class 10 (Coldwater) site. These results indicate the fish community is not being impacted by low DO.

The below average TIV scores for both the fish and macroinvertebrate communities as well as the DO flux exceeding 3.5 mg/L signals some potential DO related stress. However, the majority of DO related biological metrics score very well and little or no biological response is observed at this time. Therefore, low DO and eutrophication is not a stressor to this section of Spring Creek at this time. The presence of algae and high DO flux is a cause for concern and further monitoring is recommended to ensure DO levels remain adequate. Additional information on phosphorus, chlorophyll-*a*, and periphyton may also be needed to understand the sources and responses.

Nitrate

During fish sample, the nitrate concentration measured at 12LM018 was 2.3 mg/L. There were two additional samples on this reach, both taken in August of 2014, (2.1 and 2.0 mg/L). On the downstream reach of Spring Creek, documented nitrate concentrations are very similar.

The macroinvertebrate survey at station 12LM018 had 36 taxa, (TaxaCountAllChir). This is above the average taxa count for the coldwater macroinvertebrate class for the LMB (30.01). There were two generally intolerant taxa present and 3 Trichoptera taxa, comprising of 8.33% of the total taxa (TrichopteraChTxPct). This results in a very low metric score; less than the average metric score needed to be at the Southern Coldwater MIBI threshold (Figure 20).

Station 12LM018 had 22 nitrate tolerant taxa (66% individuals). At 20.18 nitrate tolerant taxa there is only a 25% probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in the macroinvertebrate survey at 12LM018.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. In Spring Creek, the metric score at 12LM018 was 3.1 (out of 14.3), well below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). This is also shown in the HBI_MN value, which increases with increased nitrate. At stations 12LM018 the HBI_MN value was 7.21, greater than the average HBI_MN value for stations meeting the MIBI (6.27).

The nitrate concentrations in Spring Creek are relatively low, and the biological response seems to be mixed between the two stations on Spring Creek. It's more likely that some other stressor is causing a varied response between the two stations given the lack of consistency and almost the same nitrate concentration. However, it's difficult to completely rule it out as a stressor given some of the response present (high HBI_MN, and high nitrate tolerant taxa and %), therefore nitrate is inconclusive as a stressor to this reach of Spring Creek (568).

Suspended sediment

At the time of biological monitoring a one-time chemistry sample was collected at 12LM018 and the TSS value recorded was 16 mg/L. Four additional TSS and transparency values were recorded on August 6, 2012 and August 12, 2014. On August 6 the TSS was 5.6 mg/L and transparency, measured with a secchi tube, was 100 cm. On August 12 TSS was 3.2 mg/L, and the secchi transparency was also 100 cm.

The fish community composition varies between the two stations on Spring Creek. Station 12LM018 is showing more sensitivity with 37% of the community considered most sensitive to high TSS (blacknose dace and longnose dace). The remaining individuals in the fish community at 12LM018 are in the second most sensitive group (brown trout, white sucker). The percentage of carnivores can also respond to increases in TSS at coldwater stations. Overall, the percentage of carnivores at 12LM018 was only 20%. This is lower than most coldwater stations in the LMB, which typically have at least 50% carnivores. Additionally, station 12LM018 had a high percentage of fish that are considered generally tolerant (66%) which can indicate issues with TSS, among other stressors.

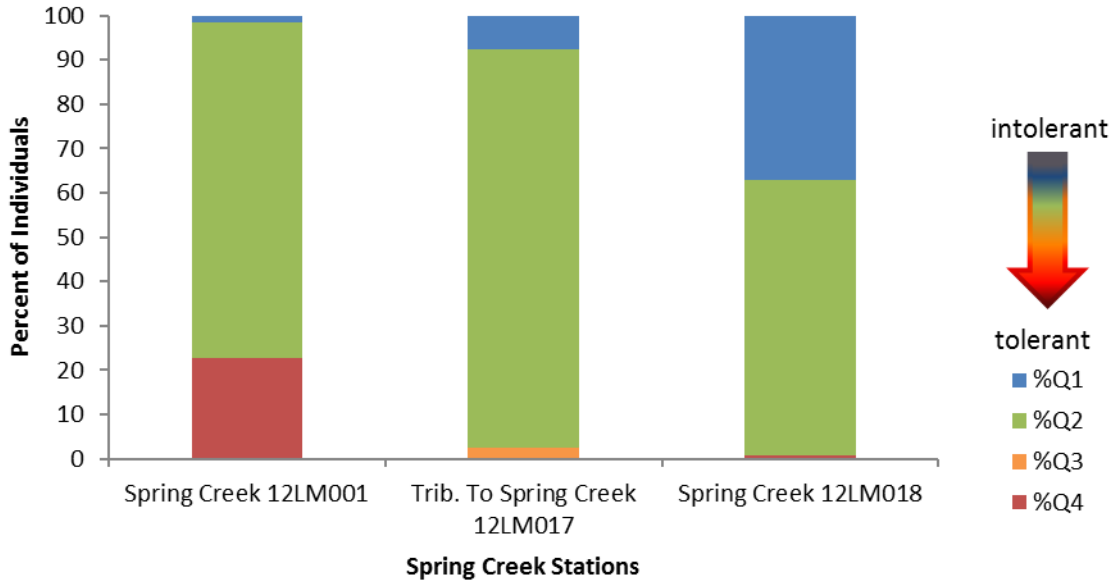

Figure 24. TSS tolerance values for fish community at three stations in Spring Creek (Sandberg, MPCA)

All of the macroinvertebrate metrics show response to elevated TSS; and more so than the other coldwater reaches in the area comparatively (Table 6). The small chemical dataset suggests issues with TSS in addition to the consistent fish and macroinvertebrate response. Additional monitoring information would help understand the magnitude and duration of TSS concentrations throughout this stream. At this time, the chemical, biological and site observation information point to TSS as a stressor to the fish and macroinvertebrate communities of Spring Creek.

Figure 25. Left: Rip-Rap near biological station 12LM018. Right: Raw bank downstream of 12LM018, both photos demonstrating instability and erosion within the upstream area.

Table 6. Macroinvertebrate metrics relevant to TSS for stations in Spring Creek compared to statewide averages for southern coldwater stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	LongLivedPct	Intolerant2Pct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
12LM018	**0**	**0**	**15.82**	**0**	**10**	**14.65**
12LM001	**0.31**	**0.32**	**15.45**	**1**	**8**	**11.67**
Statewide average for Southern Coldwater stations that are meeting the MIBI Threshold (46.1)	*2.8*	*2.5*	*14.7*	*1.7*	*3.75*	*7.35*
Expected response to stress	↓	↓	↑	↓	↑	↑

Habitat

Spring Creek (07040004-568) had a qualitative habitat assessment at its biological monitoring site, 12LM018, during the fish sampling event in 2012. The MSHA score for this site was 58.2, which is considered to be fair. Limiting the MSHA was the surrounding land use, moderate riparian buffer, presence of bank erosion, limited stream shading, sandy substrates, light embeddedness, sparse fish cover, and low channel stability.

The macroinvertebrate sample at station 12LM018 was taken from equal parts of the riffle and overhanging vegetation habitat types. This sample showed that the macroinvertebrate community had a decreased amount of burrower (2.23%) individuals, while also having increased amounts of both climber (22.93%) and clinger (53.18%) individuals when compared statewide. Clinger species are typically found in streams with ample amounts of woody debris and course substrates. Site 12LM018 did have a macroinvertebrate community consisting of 45% legless individuals. Legless species typically contain many midges and snails that are generally tolerant.

The fish assemblage along this reach had increased amounts of benthic insectivore (22.48%), riffle dwelling (55.81%), and simple lithophilic spawning (72.87%) individuals, while also having a decreased amount of pioneering species individuals (13.95%) when compared to all other fish Class 10 (Southern Coldwater) sites. These results all indicate that the habitat conditions are not stressing the fish community.

The habitat conditions could be improved, evidenced by the fair MSHA score and a number of limiting factors to the MSHA. The biological metrics for both the fish and macroinvertebrate communities, both generally indicate that the lack of habitat is not a stressor at this time.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 4.19-mile-long reach of Spring Creek (07040004-568) is 100% natural. The only designated modified sections are in the far reaching headwaters of the watershed. These sections likely have very minimal impact on the impaired sections of Spring Creek. Given the consistent baseflow of Spring Creek from the springs located in the headwaters of the reach, the minimal stream channelization, and the lack of dams or perched culverts along the reach; flow alteration and connectivity is not a stressor at this time.

Conclusions and recommendations

See conclusions section for 570, which incorporates 568 as Spring Creek, is a fairly small watershed as a whole.

4.1.2 Spring Creek (570)

Biological and background information

On the downstream AUID of Spring Creek (07040004-570) there was also one biological sample collected at site 12LM001 on July 18, 2012, which resulted in a fish impairment. Both sites in the Spring Creek Watershed are designated fish Class 10 (southern coldwater; Figure 26). The FIBI threshold for this class is 45, with an average score per metric of 6.42 needed to meet the impairment threshold. Site 12LM018 had an FIBI score of 49, and site 12LM001 had an FIBI score of 48. 12LM018 and 12LM001 both scored below average on 3 out of 7 metrics, and had a score of zero for the measure of relative abundance of taxa that are native coldwater species (NativeColdPct). However, they both reached the maximum score of 14.3 for the relative abundance of individuals that are herbivore species (HerbvPct). Overall the FIBI values and metric scores for both sites are fairly similar, but only one AUID (570; 12LM001) resulted in a fish impairment.

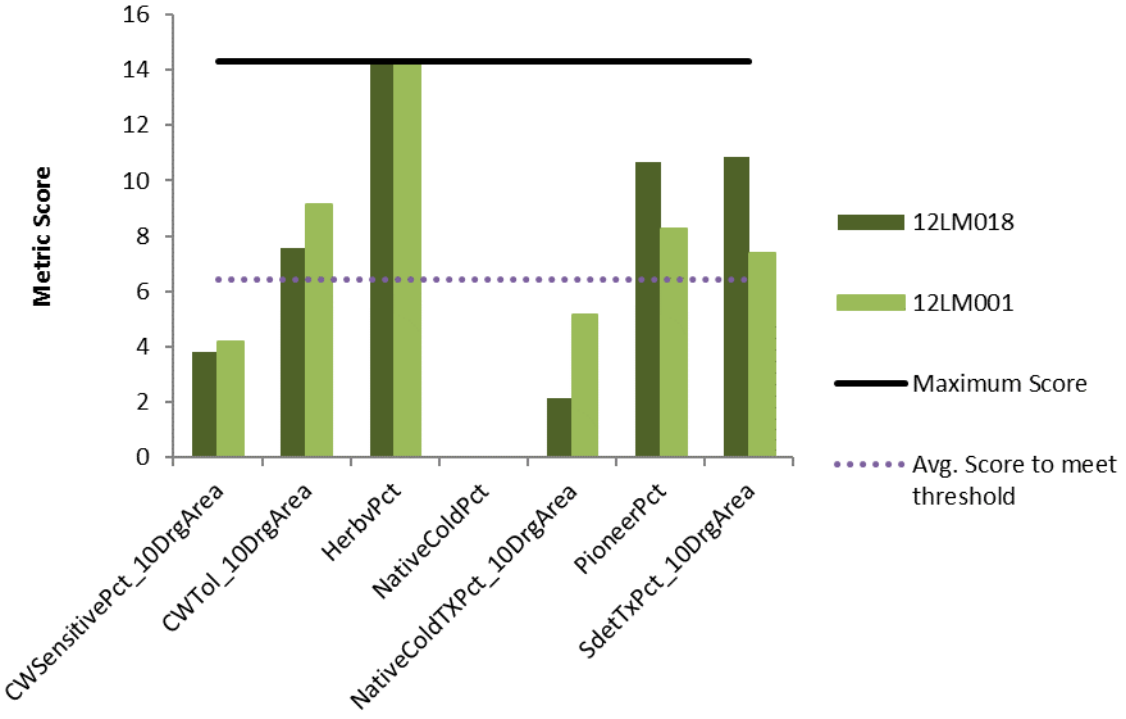

Figure 26. Fish IBI metrics for Spring Creek (Southern Coldwater)

Temperature

From July 30, 2012-August 3, 2012, a YSI sonde was deployed at station 12LM001. The sonde recorded temperature for 15 minute intervals. The results were a maximum temperature of 22.74 °C, and an average temperature of 17.11 °C. Air temperatures were above normal, and precipitation was below normal during this time period, but stream water temperatures appear reasonable.

In the summer of 2014 from May to October, temperature loggers were placed at biological station 12LM001. The maximum temperature recorded in 2014, was 22.01°C on July 22. The July average was 15.57°C, while the August average was 15.52 °C (Figure 27). Even though there may be room for improvement, this thermal regime seems fairly normal for a coldwater stream of this size.

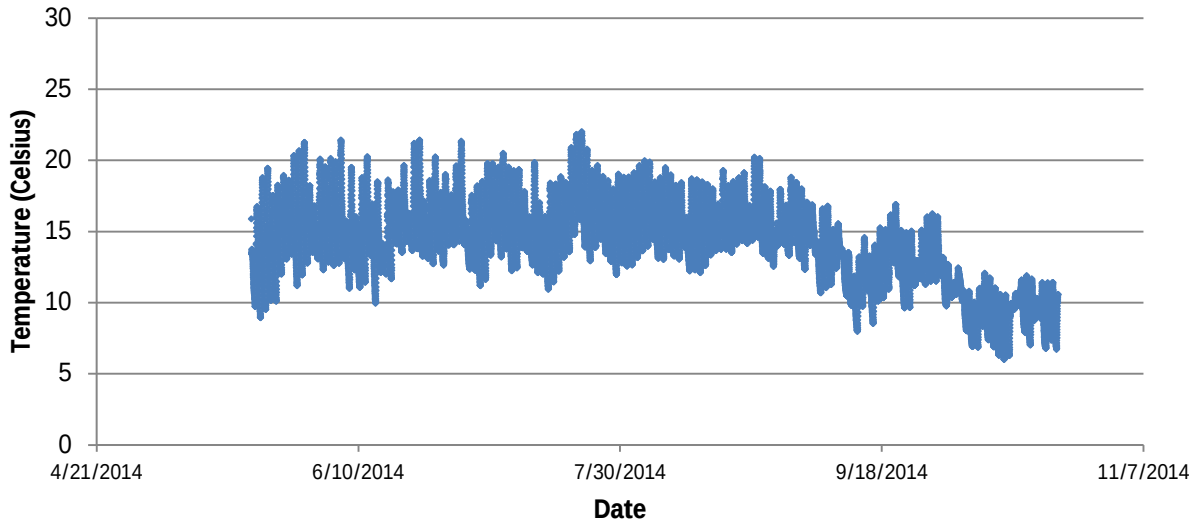

Figure 27. Stream Water Temperature (Site 12LM001) May - October 2014.

The better CBI score for station 12LM001 corroborates the fact that the thermal regime is slightly more suitable (cooler) in this area downstream. This seems reasonable given the potential influence of West Albany Creek, a large coldwater tributary which likely provides some thermal buffering, in addition to a few other small coldwater tributaries.

The temperature data and macroinvertebrate community showed good percentages of coldwater macroinvertebrates and suitable temperature data suggest that temperature is not likely driving stress at station 12LM001. The fish response seen there is more likely a result of other stressors and not a result of thermal regime, therefore temperature is not a stressor to Spring Creek (570).

Dissolved oxygen and eutrophication

Continuous DO monitoring also took place at station 12LM001 along Spring Creek (07040004-570) in 2012 and again in 2014. This monitoring showed that the DO levels stayed above the 7 mg/L daily minimum standard for a Class 2A stream, while also not exceeding the 3.5 mg/L daily flux standard.

A total of 14 phosphorus samples were also taken along this reach from 2012-2014. These values ranged from 0.037-0.390 mg/L with two values exceeding the 0.10 mg/L phosphorus standard. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

The macroinvertebrate community at station 12LM001 had very few low DO tolerant individuals (1%), while also having an increased amount of EPT individuals (35.92%). Ten DO intolerant taxa were also sampled, which is above average when compared to all sites statewide. The DO TIV score for this site was slightly above the Class 9 average.

The impaired fish assemblage had an increased amount of late maturing (74.16%) individuals. The presence of late maturing fish species can indicate that the DO conditions are stable over time and likely don't fall below stressful levels allowing older fish species to survive. There was also a below average amount of sensitive individuals (16.39%), and an increased amount of serial spawning individuals (22.97%) when compared to all other sites in Minnesota. The DO TIV score was also below average when compared to all other Class 10 sites.

Despite the low scoring DO related fish metrics, the DO levels never fell below the daily minimum standard when continuously monitored and the macroinvertebrate metrics showed no signs of stress from the DO conditions. It is likely that the fish community is being stressed by other parameters and low DO and eutrophication should not be considered a stressor at this time.

Nitrate

During fish sample, the nitrate concentration measured at station 12LM001 was 2.2 mg/L. In August 2014, there were two samples on 570, with very similar concentrations (2.3 mg/L for both). There were a total of 13 additional nitrate samples taken in 2012, with an average concentration of 2.43 mg/L. The maximum concentration was 4.34 mg/L measured in July of 2012. The rest of the samples ranged from 2 mg/L-2.4 mg/L.

The macroinvertebrate survey at station 12LM001 had 37 taxa. (TaxaCountAllChir). This is above the average taxa count for the coldwater macroinvertebrate class for the LMB (30.01). There were two generally intolerant taxa present and 4 Trichoptera taxa, comprising 10.81% of the total taxa (TrichopteraChTxPct). This results in a very low metric score; less than the average metric score needed to be at the Southern Coldwater MIBI threshold (Figure 20).

Station 12LM001 had 21 nitrate tolerant taxa (71% individuals). At 20.18 nitrate tolerant taxa there is only a 25% probability of meeting the Southern Coldwater MIBI. However, there were two nitrate intolerant taxa present at 12LM001. This shows a mixed result in terms of nitrate related stress.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. Station 12LM001 had a metric score of 8.73, which is above the average metric score needed to meet impairment threshold. The HBI_MN value increases with increased nitrate. At station 12LM001 the HBI_MN value was 6.77, greater than the average HBI_ MNvalue for stations meeting the MIBI (6.27).

The nitrate concentrations in Spring Creek are relatively low throughout, and the biological response seems to be mixed. It's more likely that some other stressor is causing a varied response between the two biological stations of Spring Creek given the lack of consistency and almost the same nitrate concentration. However, it's difficult to completely rule it out as a stressor given some of the response present (high HBI_MN, and high nitrate tolerant taxa and %). Nitrate is inconclusive as a stressor to Spring Creek (570).

Suspended sediment

At the time of biological monitoring one sample was collected at 12LM001 with a TSS value of 8.4 mg/L. Fourteen additional TSS values from 2012 and 2014 range from 3 mg/L-102 mg/L with an average of 19 mg/L. Of the 13 values, 5 exceed the TSS standard of 10 mg/L for designated coldwater streams.

Daily TSS values were calculated for Spring Creek (AUID 07040004-570) subshed 7 by the HSPF model from 1995-2009. These values ranged from 1.40-1036.92 mg/L with an average value of 12.29 mg/L. Additionally, a little over 10% of the values were above 10 mg/L, which is the TSS impairment threshold for designated coldwater streams.

Over 20% of the fish community is tolerant to high TSS (fathead minnows) at station 12LM001. The remaining fish (mainly brown trout and white sucker) display a slight sensitivity, but are not considered the most sensitive of coldwater species (Figure 24). This is further demonstrated in the TSS fish community index score (16.68) which is much higher than the average for southern coldwater stations (12.45) which confirms the community is dominated by fish tolerant to high TSS. The percentage of carnivores can also decrease along with increases in TSS at coldwater stations. Overall, the percentage of carnivores at 12LM001 was 15%; lower than most coldwater stations in the LMB, which typically have at least 50% carnivores. Additionally, there was a high percentage of fish that are considered generally tolerant (82%) which can be related to increases in TSS, among other stressors.

All of the macroinvertebrate metrics show response to elevated TSS; and more so than the other coldwater streams in the area comparatively (Table 7). The small chemical dataset suggests issues with TSS in addition to the consistent fish and macroinvertebrate response. The fish show more tolerance at the downstream station 12LM001, but may also have more sources (tributaries, streambanks, etc.) of suspended sediment. There is also more coarse sand in the lower reaches, which can cause additional stress due to bedload effects.

Table 7. Macroinvertebrate metrics relevant to TSS for stations in Spring Creek compared to statewide averages for southern coldwater stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	LongLivedPct	Intolerant2Pct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
12LM018	**0**	**0**	**15.82**	**0**	**10**	**14.65**
12LM001	**0.31**	**0.32**	**15.45**	**1**	**8**	**11.67**
Statewide average for Southern Coldwater stations that are meeting the MIBI Threshold (46.1)	*2.8*	*2.5*	*14.7*	*1.7*	*3.75*	*7.35*
Expected response to TSS stress	↓	↓	↑	↓	↑	↑

This area also includes the tributary in Figure 28, which goes through the Spring Creek MX Park, and may be a sediment source to Spring Creek. This small stream runs through a large area of bare ground before entering Spring Creek just upstream of 12LM001. There is a recently proposed turbidity impairment listing on this small tributary (green dot is the sampling site on the tributary). Other tributaries upstream of this point may also be impacting sediment transport. Stream geomorphology information (detailed in next section on habitat) demonstrates that this stream has an excess sediment supply and is trying to reach stability. The chemical, biological, and site observation information confirm TSS is a stressor to the fish and macroinvertebrate communities of Spring Creek (570).

Figure 28. Tributary to Spring Creek which drains through Spring Creek MX Park.

Habitat

Spring Creek (07040004-570) had a qualitative habitat assessment at station 12LM001, during the fish sampling event in 2012. The MSHA score for this site was 39.4, which is considered to be poor. Limiting the MSHA was the surrounding land use, severe bank erosion, light stream shading, dominant sandy substrates, severe embeddedness, sparse fish cover, no riffles, poor channel development and low channel stability.

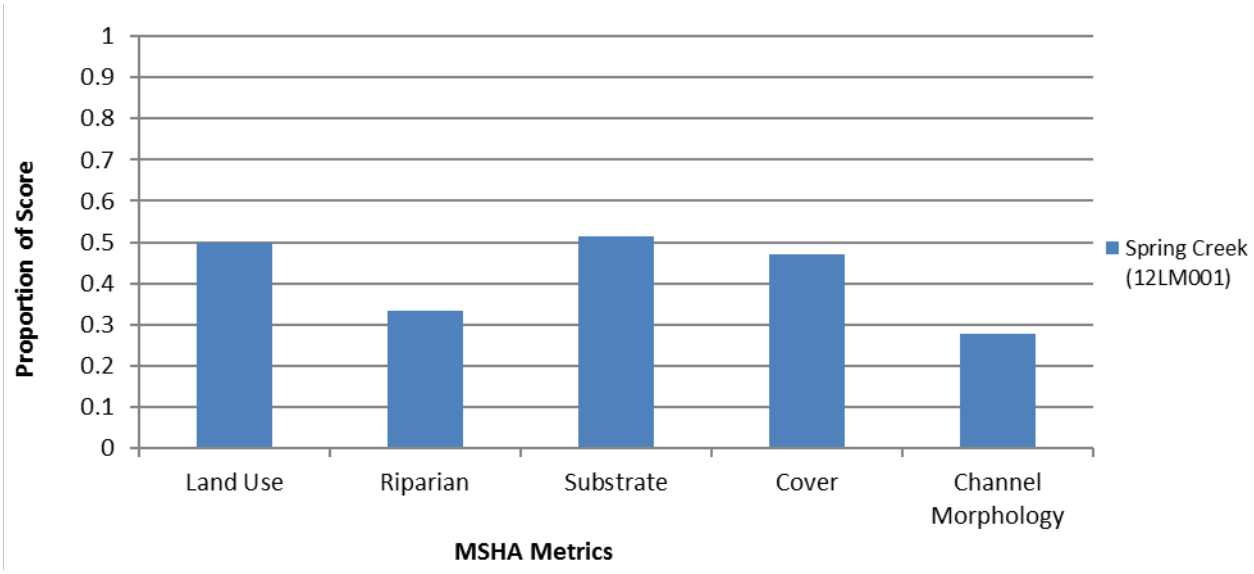

Figure 29. MSHA metric value scores for site 12LM001 along Spring Creek

Figure 30. Sand substrate at site 12LM001.

The macroinvertebrate sample at site 12LM001 was taken from equal parts of overhanging vegetation and riffle habitat. This assemblage had decreased numbers of burrower (3.88%) and legless (34.95%)

individuals, while also having average amounts of both sprawler (23.3%) and clinger (51.46%) individuals. These results do not signal an assemblage being strongly impacted by the habitat conditions.

The fish community in this portion of Spring Creek did have increased numbers of riffle dwelling (60.14%) and simple lithophilic spawning (61.15%) individuals. However, this reach also had decreased amounts of benthic insectivore (1.86%), darter/sculpin/round-bodied sucker (0.84%), while also having increased numbers of both pioneering species (23.31%) and tolerant (82.94%) individuals. These results often reflect a stream being negatively impacted by the habitat conditions. Benthic insectivores and darters/sculpin require good stable substrates, and pioneers/tolerant species will thrive in unstable areas, similar to these.

The MNDNR did an extensive geomorphic evaluation just upstream of sampling station 12LM001. This work determined that this stream is classified as a C5 stream type with a sand bed. The water surface slope is 0.00173, with a width to depth ratio of 17.7, and entrenchment ratio of 2.22. A low entrenchment ratio shows slight incision and suggests a recent succession from an F stream type to a C. This succession scenario is supported by the sediment competence models predicting stability. A Pfankuch stability rating of poor was observed for this reach when compared to a potential C stream type.

Figure 31. Stream Bank (160 ft) with extreme BEHI and moderate NBS.

A total of 10 banks were observed in this 1,100 ft. survey. An average of 0.25 tons/yr/ft, equivalent to 277.92 tons or 27 dump trucks, is predicted to be eroding from the banks. The worst bank is estimated to be contributing 0.77 tons/yr/ft. (Figure 31). Tall banks with little vegetative bank cover and primarily composed of sandy material contributed to the predicted erosion rates. As a general rule of thumb, one needs to address and pay attention to erosion rates above 0.20 tons/yr/ft.

The current C stream type is possibly the end point in the stream succession. This is evidenced by numerous point bars and side bars. The sediment competence also predicts the stream is able to move the largest particle made available. Utilizing LiDAR, the stream appears to have very little floodplain, which leads to lateral containment being an issue. Spring Creek has a Meander Width Ratio (MWR) of 3.9, the range for a C stream type is 4 to 20, indicating lateral confinement. Streams that are confined are often associated with high bank erosion rates and sediment transport problems. Further investigation revealed large meander migrations (Figure 32). The two largest migrations within this reach are hitting banks of farm land with very little vegetation protection.

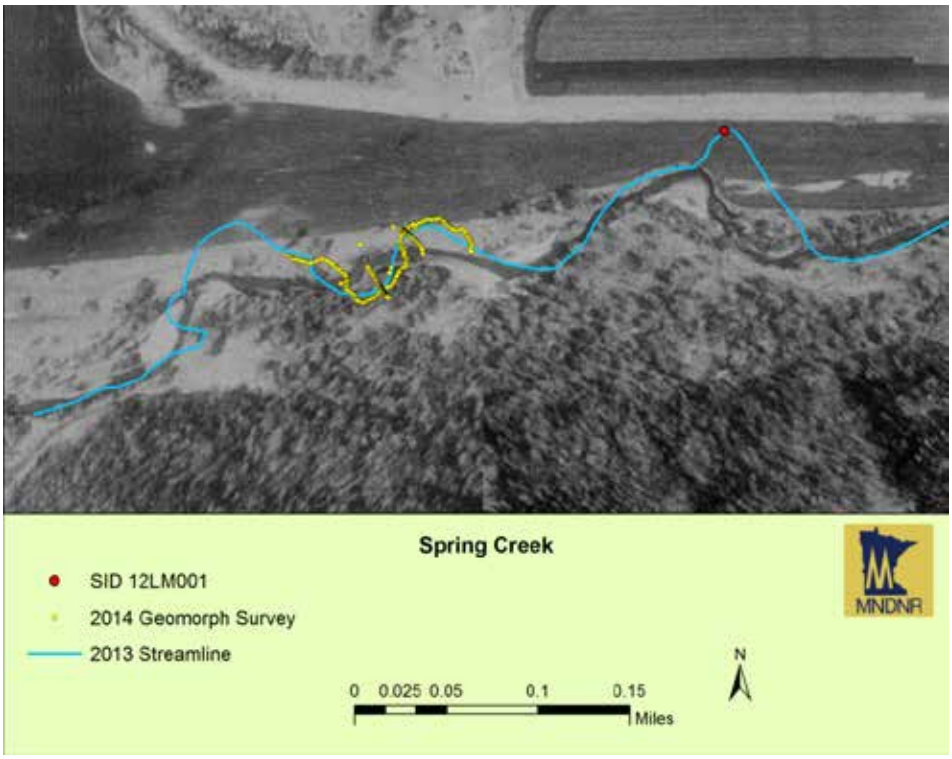

Figure 32. 2013 streamline and 2014 survey overlaying 1991 aerial photo.

Spring Creek (07040004-570) is impaired for aquatic life due to its poor fish community. The habitat related biological metrics of this assemblage reflect those being impacted by poor habitat conditions. The qualitative habitat score for this reach was poor and the extensive geomorphic study done by the MNDNR showed a high amount of sediment and bedload within the reach that covers much of the needed habitat. Therefore, the lack of habitat is a stressor to the fish assemblage at this time.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 1.96-mile-long reach of Spring Creek (07040004-570) is 100% natural. The only designated modified sections are in the far reaching headwaters of the watershed. These sections likely have very minimal impact on the impaired sections of Spring Creek. Given the consistent baseflow of Spring Creek from the springs located in the headwaters of the reach, the minimal stream channelization, and the lack of dams or perched culverts along the reach; flow alteration and connectivity is not a stressor.

Conclusions and recommendations

The upstream AUID of Spring Creek (07040004-568) is impaired for macroinvertebrates, and the biology is being stressed by elevated temperatures and TSS. Even though the fish community is not impaired in this AUID, the FIBI score is only one point higher than the downstream (impaired) reach, and is at risk of impairment. The downstream AUID of Spring Creek (570) is impaired for fish and is stressed by TSS and lack of habitat. See Table 8.

In the upstream AUID, temperatures are nearing 24 degrees regularly at station 12LM018 (data from 2014) with a maximum temperature recorded of 25.01 degrees. Biologically, both fish and macroinvertebrates are lacking characteristic coldwater species which could be explained by the increased temperature. Farther downstream, near 12LM001, temperatures are more suitable. This may be due to more coldwater inputs, like West Albany Creek. Continuous temperature monitoring at both

locations demonstrates a much cooler thermal regime in the downstream location compared to the upstream location.

DO is not considered a stressor to either AUID on Spring Creek. The upstream AUID did show some high DO flux, which may be due to larger amounts of periphyton observed in the stream channel. Both sections had continuous DO data collected in 2014, which did not fall below the DO standard. The biological response in both reaches did not suggest that DO was a likely stressor at this time, as there was a fair amount of low DO intolerant species present as well.

Nitrate is inconclusive for both AUID's of Spring Creek. While the concentrations were generally low for both reaches, there was a mixed biological response and lack of consistency comparatively to make a sound decision on nitrate as a potential stressor. At this point, it doesn't seem likely, but cannot be ruled out.

Habitat is a stressor to the fish community at the downstream reach at station 12LM001. Severe bank erosion and the sand dominated channel substrate limit the fish habitat. MNDNR geomorphology information shows the stream had an excess sediment supply, as evidenced by many photos of eroding banks and a widening stream channel (Figure 33).

Figure 33. Meander migration over an approximate four-year time period in Spring Creek (Imagery 2011 compared to 2015) showing excessive bank erosion in areas with little vegetative protection.

Both stream reaches show consistent response with elevated TSS as well, suggesting a systematic issue. The sources of TSS are most likely from stream bank erosion and land use activities near the stream are also tied to the documented habitat stress. The stream has demonstrated areas of significant erosion problems. Vegetated buffers surrounding the stream would help reduce erosion and help reduce the current sediment supply which causes this massive instability and subsequent habitat degradation.

Table 8. Summary of stressor determinations for Spring Creek (568 and 570)

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Spring Creek (Upstream)	07040004-568	●	---	o	●	---	---
Spring Creek (Downstream)	07040004-570	---	---	o	●	●	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.2 Cold Creek Watershed (Cold Spring Brook)

Cold Creek (often refered to as Cold Spring Brook) is a coldwater stream which has drainage that originates in Goodhue County, but the perennial stream system is contained in Wabasha County. The watershed drains a total of 28,396 acres, 72% of which is in agricultural use. Section 4.2.1 describes the macroinvertebrate impairment on AUID 07040004-510 (Figure 34).

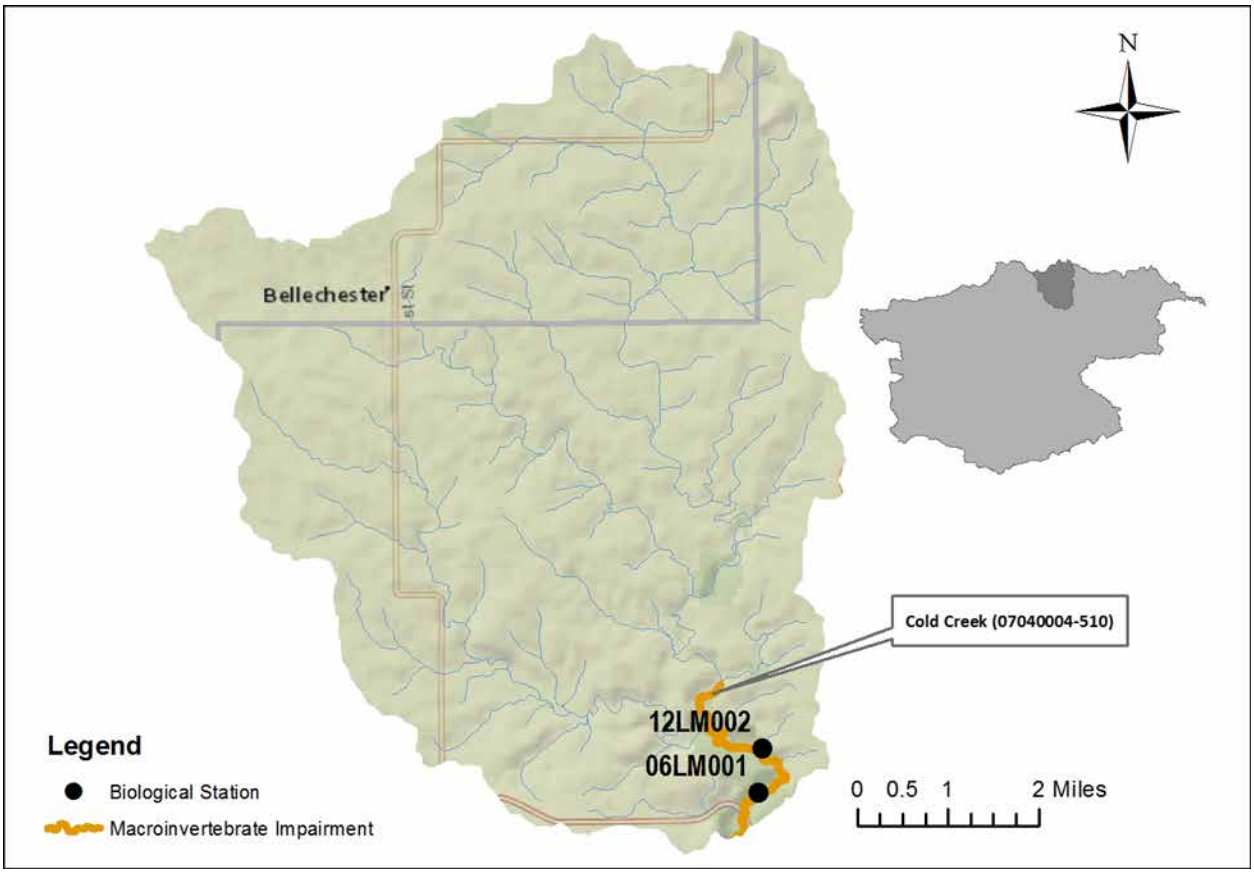

Figure 34. Map of the Cold Creek Watershed, biological stations, and impaired AUIDs.

4.2.1 Cold Creek (510)

Biological and background information

Cold Creek (07040004-510) has one biological station, 12LM002, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 9 (Southern Coldwater). The MIBI threshold for this class is 43, with an average score per metric of 6.14 needed to achieve that threshold. The MIBI score at 12LM002 is 18.68. The metric scores are below the average metric score needed (6.14) to meet the threshold for every macroinvertebrate Class 9 metric (Figure 35). The highest scoring metric was VeryTolerant2Pct with a score of 5.31, while Intolerant2CH was the lowest scoring metric with a score of zero. The fish community scored very well at this station, with an IBI of 92.

Biological station 06LM001 was sampled for fish, and dominated by trout and sculpin. Macroinvertebrates were not sampled at 06LM001.

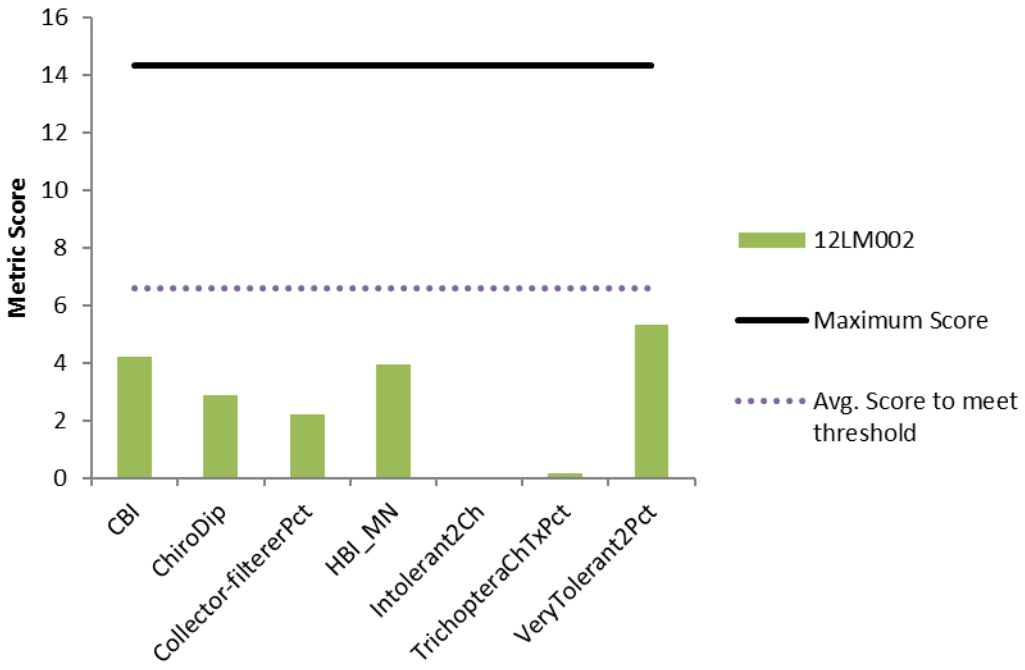

Figure 35. Macroinvertebrate IBI metrics for Cold Creek (Southern Coldwater)

Temperature

A temperature logger was placed at station 12LM002 in 2012, and showed very cold and stable temperatures for most of the year. The maximum temperature recorded at the site was 20.94 degrees C on June 20. In that area on the 15th of June, 2012, there were 2.63 inches of rain recorded, and on June 21, 2.76 inches. The July average temperature was 12.6 degrees C and August average was 12.13 degrees C. On most days, the daily maximum temperature was around 16 degrees C. The data shows some of the coldest temperatures when compared among multiple trout streams in southeast Minnesota and reflects a good thermal regime. According to MNDNR, Cold Creek is sourced by two large springs, which are very important to the coldwater fishery this stream maintains.

Station 12LM002 had 97.17% coldwater fish species (ColdPct) and 84.38% fish species that are coldwater sensitive (CWSensitivePct Metric) which is expected given the cold temperatures measured. However, the macroinvertebrates had a low CBI (coldwater biotic index) metric score. The disparity between the fish and macroinvertebrates is likely due to another stressor which is reducing the number of coldwater macroinvertebrates, not unsuitable temperature. There is very strong evidence supporting cold water temperatures and healthy populations of coldwater fish and coldwater sensitive fish species are present; therefore, temperature is not a stressor to the macroinvertebrate community of Cold Creek.

Dissolved oxygen and eutrophication

Cold Creek had continuous DO monitoring taken in 2012 () and 2014 at site 12LM002. This monitoring showed that the daily flux of DO frequently exceeds the 3.5 mg/L standard. Monitoring from 2014, also showed DO levels fall just below the 7 mg/L daily minimum standard for coldwater streams, but not for extended durations.

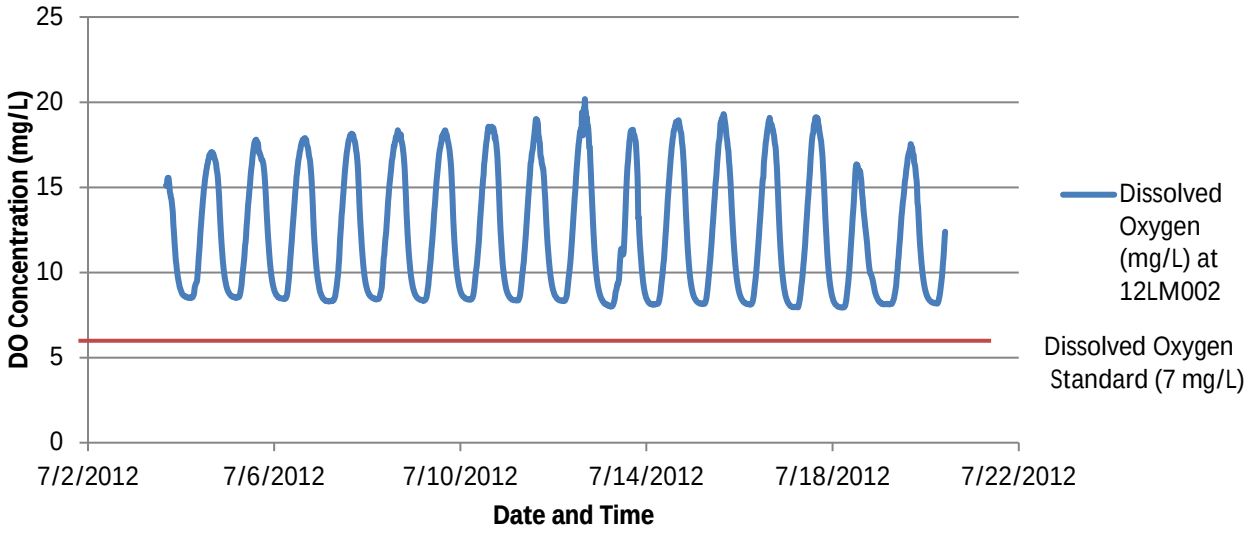

Figure 36. Continuous DO monitoring data from Cold Creek (07040004-510) in 2012.

Additionally, from 2012-2014, 16 phosphorus samples were taken along this reach. These samples ranged from 0.041-0.48 mg/L with two samples above the 0.10 mg/L phosphorus standard. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

Biologically, the macroinvertebrate community in Cold Creek had an increased amount of low DO tolerant individuals (41.84%), with a DO TIV score that was well below the Class 9 average. Site 12LM002 also had a decreased amount of EPT individuals (4.32%), which can indicate stress from the DO, or can be the result of other stressors. Metrics for addressing DO flux in coldwater streams are not yet available.

The fish assemblage in Cold Creek had many late maturing (97.19%) and sensitive (97.1%) individuals, while also having few serial spawning individuals (1.25%). The DO TIV score for this reach was very high, indicating a fish community not being negatively impacted by the DO conditions.

Despite the high DO flux and poor scoring macroinvertebrate community, the fish assemblage shows no indication of low DO stress. Additionally, the phosphorus values in Cold Creek were very low. High levels of phosphorus can often lead to high DO flux as a result of the increase in primary production (algae, periphyton, aquatic macrophyte growth, etc.). While the current flux conditions cannot be explained without further monitoring, it is likely that the macroinvertebrate community is being stressed by other factors, therefore, low DO and eutrophication is not a stressor at this time. Continued monitoring to ensure oxygen levels remain adequate may be warranted. Additional information on phosphorus, chlorophyll-*a*, and periphyton may also be needed to understand the potential sources and responses.

Nitrate

During fish sampling, the nitrate concentration was measured at 5.2 mg/L (June 2012). There were 30 additional nitrate samples taken on this reach from 2009-2014. The concentrations ranged from 4.49 mg/L to 6.31 mg/L, with an average of 5.4 mg/L. The slightly higher concentrations seemed to correspond to the monitoring site farther downstream (S005-362), where there is more flow and input from springs carrying nitrate rich water.

The macroinvertebrate survey in station 12LM002 had 31 taxa (TaxaCountAllChir), just above the average taxa count for the coldwater macroinvertebrate class for the LMB (30.01). There were no generally intolerant taxa present and two Trichoptera taxa, comprising 6.45% of the total taxa

(TrichopteraChTxPct). This results in a very low metric score; less than the average metric score needed to be at the Southern Coldwater MIBI impairment threshold.

Station 12LM002 had 21 nitrate tolerant taxa (59% individuals). At 20.18 nitrate tolerant taxa there is only a 25% probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in the macroinvertebrate survey. The macroinvertebrate community nitrogen index score was 2.9, while the average for southern coldwater stations meeting impairment threshold is 3.2. This suggests that overall the community is not overly tolerant to nitrate concentrations.

The HBI_MN metric (measure of pollution based tolerance) score decreases with increased nitrate. In Cold Spring, the metric score was 3.83 (out of 14.3), well below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). This is also reflected in a HBI_MN value of 7.26, which is higher than average for stations meeting the MIBI (6.27). This value increases with an increase in nitrate.

It's not clear if the macroinvertebrates are responding to nitrate or another stressor in this reach. The chemical dataset does suggest some moderate nitrate concentrations, but the biological response data does clearly support nitrate related stress. It is important to mitigate sources of nitrate in the watershed with the susceptibility of nitrate contamination given the karst hydrology. At this time there is not enough information to definitively conclude nitrate is causing stress to the macroinvertebrates and is inconclusive as a stressor in Cold Creek.

Suspended sediment

At the time of biological monitoring a one-time chemistry sample was collected at station 12LM002 and the TSS value recorded was 2 mg/L. From the months of May to October during 2012 and 2014, 14 additional TSS values were collected ranging from 1 mg/L-100 mg/L with an average of 14.7 mg/L. Only two values of 56 and 100 mg/L exceed the TSS standard of 10 mg/L for designated coldwater streams. Additionally, 28 Transparency values using a 100 cm transparency tube were collected between 2009 and 2010. The values ranged from 34 cm to >100 cm. Of the 28 values, 22 of them were recorded to be >100 cm. Transparency measurements were also calculated from 2012-2014 using a secchi tube, and the 31 values ranged from 12 cm to > 100 cm. Of the 31 secchi measurements made, 29 values were 100 cm or greater. The other two values were 12 cm and 65 cm, on July 22, 2014 and August 6, 2014, respectively.

Daily TSS values were calculated for Cold Creek (AUID 07040004-510) subshed 12 by the HSPF model from 1995-2009. These values ranged from 1 mg/L -1474 mg/L with an average value of 15 mg/L. Additionally, 9% of the values were above 10 mg/L, which is the TSS impairment threshold for designated coldwater streams.

Table 9. Macroinvertebrate metrics relevant to TSS for stations in Cold Creek compared to statewide averages for southern coldwater stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	LongLivedPct	Intolerant2Pct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
12LM002	**0**	**0**	13.89	**1**	**5**	5.63
Statewide average for Southern Coldwater that are meeting the MIBI Threshold (46.1)	*2.8*	*2.5*	*14.7*	*1.7*	*3.75*	*7.35*
Expected response to TSS stress	↓	↓	↑	↓	↑	↑

The fish community is made up of mostly brook trout and slimy sculpin, both of which are very sensitive to high TSS. In fact, 98% of the fish community is made up of fish in either the first or second quartile of TSS sensitivity. The fish community also has a good percentage of carnivores and sensitive species, which also can respond negatively to high TSS. The macroinvertebrate community shows some slight indications of responding to TSS stress, but is more likely responding to another stressor. The metrics presented in the table do not show strong indication of TSS stress, with a good TSS index score, which demonstrates overall a community that isn't dominated by TSS tolerant taxa and fewer than average percentage of TSS tolerant macroinvertebrates. The lack of intolerant and long lived macroinvertebrates could easily be due to other types of stressors. It's more probable that the evidence of channel instability and in stream sedimentation are more likely driving macroinvertebrate issues and metrics response seen, instead of suspended sediment. The fish community is very intolerant to elevated TSS, and fish metrics are all above average and not suggestive of TSS stress. The chemical data also does not support a TSS stressor, but the dataset is limited. Visual observations also show this stream is clear often. Given the chemical, biological, and physical information, TSS is not a stressor to Cold Creek at this time.

Habitat

Cold Creek had a qualitative habitat assessment take place at site 12LM002 during the fish sampling event in 2012. The MSHA score for this site was 66.9, which is considered to be good (Figure 37). Limiting the habitat at this site was row crops in the surrounding land use, light stream shading, light embeddedness, and moderate channel stability.

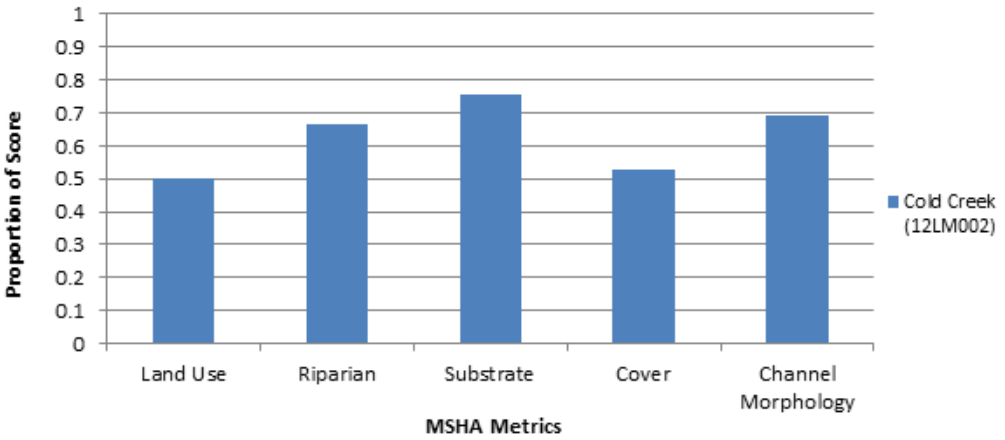

Figure 37. MSHA metric value scores for site 12LM002 along Cold Creek (07040004-510).

The macroinvertebrate sample at site 12LM002 was collected from equal parts riffle, overhanging vegetation, and woody debris. This sample contained an increased amount of burrower (29.85%) and legless (68.31%) individuals. These types of macroinvertebrates typically prefer fine substrates for habitat. This site also had decreased numbers of climber (6.46%), clinger (27.69%), and EPT (4.31%) individuals when compared with all other sites in Minnesota. These macroinvertebrates can be negatively impacted by poor habitat conditions, like unstable substrate and lack of riffle habitat.

The fish assemblage along Cold Creek had increased amounts of benthic insectivore (42.19%), darter/sculpin/round-bodied sucker (42.19%), and riffle dwelling (42.19%) individuals. This site also had just 2.81% of its population consisting of tolerant fish. The MNDNR fisheries management plan for Cold Creek (2001) states this stream has had numerous habitat improvement projects over the years. A shifting sand bottom has been noted for many years, first evidenced by Surber in 1924 and still observed today. Flooding is also a contributing factor to the erosion and bedload found in this stream.

The MNDNR performed an extensive geomorphological assessment in the Cold Creek Watershed. These results confirmed areas, specifically upstream of biological site 12LM002, that have an unstable stream bed. These areas are predicted to aggrade with sediment.

The macroinvertebrate assemblage along Cold Creek strongly signals that it is being negatively impacted by the high amounts of fine sediment and bedload. This information is validated by the MNDNR. Therefore, the lack of habitat is a stressor to the macroinvertebrate community along Cold Creek at this time.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 3.26-mile-long reach of Cold Creek (07040004-510) is 100% natural. The only designated modified sections are in the far reaching headwaters of the watershed. These sections likely have very minimal impact on the impaired sections of Cold Creek.

Possibly contributing to the impairment along Cold Creek is a beaver dam located roughly 1,000 feet below the biological sampling site, 12LM002. The beaver dam reduces flow and deepens the stream by causing water to back up to the site, inhibiting the transport of sediment. At the time of visit, the beaver dam had a hydraulic head of roughly 3 feet. Sediment fills in pools and riffles, decreasing habitat quality for fish and invertebrates. In addition, deeper and wider stream with slow flowing water causes

increased water temperature which also reduces habitat for cold water fish and invertebrate species (MNDNR).

Removing the beaver dam along Cold Creek is recommended to improve sediment transport and fish migration, as well as habitat conditions along the stream reach. Given the consistent baseflow of Cold Creek from the springs located along Cold Creek and throughout its watershed, the minimal stream channelization, and the lack of perched culverts along the reach; flow alteration and connectivity are not considered a stressor at this time.

Conclusions and recommendations

The macroinvertebrate community in Cold Creek (510) is being stressed by poor habitat (Table 10). The observed shifting sand bottom was first by Surber in 1924. Flooding is also a contributing factor to the erosion and bedload found in this stream. A MNDNR geomorphological assessment of the area near station 12LM002 revealed an unstable stream bed and incised channel predicted to aggrade with sediment and areas of high bedload. These physical habitat issues are clearly demonstrated with the macroinvertebrate community, with an abundance of burrowing and legless macroinvertebrates (which can thrive in these poor substrate conditions) and a lack of clinger and EPT taxa which require stable, course, and clean substrates. A beaver dam was also identified just downstream of station 12LM002, which potentially reduces flow and deepens the stream by causing water to back up, inhibiting the transport of sediment. While this may be contributing to the amount of fine sediment and deposition observed at station 12LM002, it doesn't appear to be causing connectivity issues for fish, given the populations found upstream and downstream of the dam. This dam will require further evaluation if stream restoration in this area is pursued.

With adequate coldwater stream temperatures, and mainly clear water, temperature and TSS were ruled out as potential stressors. DO flux in Cold Creek is rather high; showing daily values that exceed 3.5 mg/L which is concerning. This is likely the result of excessive periphyton and algae growth near the biological station. However, it's more likely that the macroinvertebrates are responding to other stress given the fish assemblage scored exceptionally well and is dominated by species that are intolerant to a poor DO regime. Additional information on the DO may be warranted to better understand DO dynamics in this stream and its effects on biology. In terms of nitrate, the concentrations are moderate, but the biological response data does not clearly support nitrate related stress, and therefore is inconclusive as stressor. However, it is important to mitigate sources of nitrate in the watershed with the susceptibility of nitrate contamination given the karst hydrology to prevent concentrations from increasing further. A long term monitoring station on a large spring show very little change in concentrations in the past 10 years, but the slope of the line appears slightly positive (Runkel et al, 2014).

Table 10. Summary of Stressor determinations for Cold Creek.

Stream Name	AUID	Stressors: Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Cold Spring/Cold Creek	07040004-510	---	---	o	---	●	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.3 Trout Brook Watershed (Mazeppa Creek)

Trout Brook (also known as Mazeppa Creek) is a coldwater stream which has drainage that originates in Goodhue County, but the majority of the perennial stream system is contained in Wabasha County. The watershed drains a total of 31,443 acres, 59.77% of which is in cropland, while 32.23% is rangeland, 4.57% is developed and 3.34% is forested. Section 4.3.1 describes the macroinvertebrate impairment on AUID 07040004-515 (Figure 38).

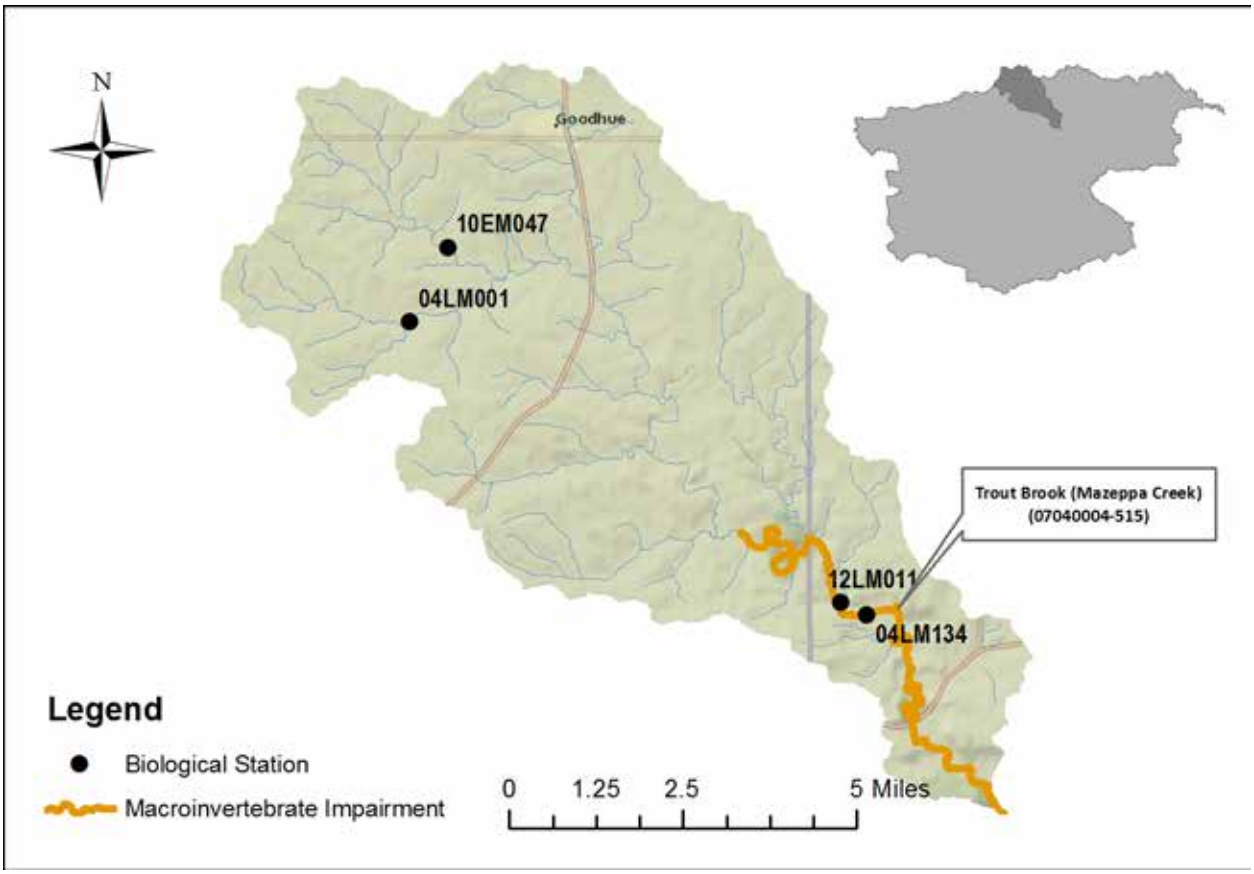

Figure 38. Map of the Mazeppa Creek Watershed, biological stations, and impaired AUIDs.

4.3.1 Trout Brook (Mazeppa Creek, 515)

Biological and background information

Trout Brook (07040004-515) has one site that is assessable for macroinvertebrates which resulted in a macroinvertebrate impairment. Site 12LM011 was sampled on August 9, 2012. Station 04LM134 was only sampled for fish, not macroinvertebrates. Station 12LM011 is designated macroinvertebrate Class 9 (Southern Coldwater). The MIBI impairment threshold for this class is 43, with an average score per metric of 6.14 needed to achieve that threshold. Station 12LM011 has an MIBI of 33.06, with 4 out of 7 metrics below the average score needed to meet the threshold (Table 39). The metrics that scored moderately well were CBI, HBI_MN, and Very Tolerant2Pct.

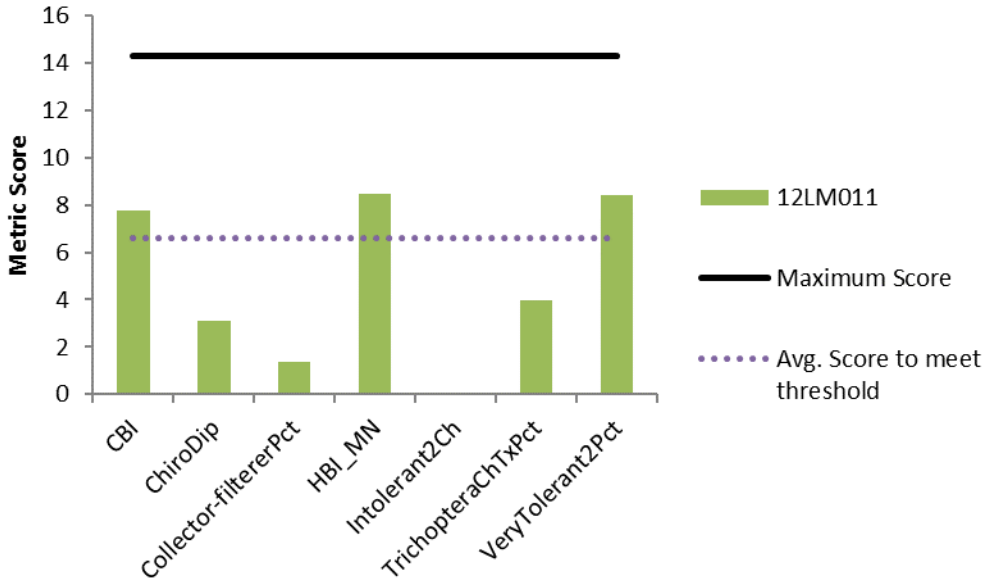

Figure 39. Macroinvertebrate IBI metrics for Trout Brook (Southern Coldwater)

Temperature

A temperature logger was placed at station 12LM011 in 2012 and showed normal temperatures compared to other coldwater streams in the area. The maximum temperature recorded at the site was 22.08 degrees C on June 19. In that area on the 15th of June, 2012, there were 2.63 inches of rain recorded, and on June 21, 2.76 inches, which were likely a result of runoff increasing stream temperatures. The July average temperature was 14.136 degrees C and August average was 12.85 degrees C, both showing temperatures appear suitable.

Biological evidence also supports a good thermal regime is present at station12LM011. The CBI (coldwater biotic index) score was just above average, indicating a decent population of coldwater macroinvertebrates exists at this location (Figure 39). In addition, the percentage of coldwater fish species at station 12LM011 was well above average, at 75%. The percentage of coldwater sensitive fish species was also high (76%), demonstrating that sensitive coldwater fish are present in good numbers as well. Given the high resolution temperature data, and good percentages of coldwater sensitive fish and macroinvertebrates, temperature is not considered a stressor or contributing to the macroinvertebrate impairment in Mazeppa Creek.

Dissolved oxygen and eutrophication

Continuous DO monitoring took place at two locations along Mazeppa Creek. At water chemistry station S005-739, which is located along Highway 60 just east of Mazeppa, continuous DO monitoring took place in 2014. This sonde deployment showed that the dissolved oxygen values ranged from 8.6-11.5 mg/L. The daily flux of DO had never exceeded the standard of 3.5 mg/L and never fell below 7 mg/L. Additionally, the two phosphorus samples taken from this location had values of 0.028 mg/L and 0.04 mg/L, which are both well below the 0.10 mg/L standard for phosphorus.

Further upstream of this location, is the biological monitoring site 12LM011, which had a sonde deployed for continuous DO monitoring in 2012. This data shows that the DO levels do not fall below the 7 mg/L daily minimum standard, however the daily flux reached as high as 12.18 mg/L and stayed above the 3.5 mg/L standard for daily flux.

Additionally, 46 phosphorus samples were taken from this portion of the reach. These values ranged from 0.014-1.76 mg/L with only one value above the 0.15 mg/L phosphorus standard. This value, 1.76 mg/L, can be attributed to the nearly 9 inch rainfall that took place in this area over a two day span (9/22/2010-9/23/2010). Chlorophyll-*a* data taken from this reach was generally low; with 29 samples taken from 2009-2010 at S005-551. The average chlorophyll-*a* concentration during this time period was 2.86 mg/L, with a range from 1 to 21 mg/L. All but one sample was below 5 mg/L. The 21 mg/L sample, which is above the standard (18 mg/L) was taken on September 23, 2010 (large rain event). It's possible the sample is picking up periphyton that was scoured away after that event. There was no BOD data available to further assess eutrophication impacts.

There was only one macroinvertebrate sample taken along this reach. This sample took place at site 12LM011. This site contained many low DO intolerant taxa (8), while having a very low amount of Do tolerant individuals (1%). As expected, the DO TIV score for the macroinvertebrate community was above average when compared statewide. Site 12LM011 also had a lower HBI_MN score. The HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon within Minnesota. A higher HBI_MN score often correlates to streams negatively impacted by low DO conditions.

The fish assemblage along this reach was comprised of a very high amount of late maturing individuals (96.18%) as well as many sensitive individuals (54.15%). This reach also had very few serial spawning species (0.32%). The DO TIV score for the fish community was also very high when compared to all other Class 10 fish sites.

Based on the very low phosphorus values, the continuous DO monitoring along Highway 60, as well as all of the evaluated DO related biological metrics, low DO and eutrophication is not a stressor to Mazeppa Creek.

Nitrate

During biological sampling, the nitrate concentration on this reach was 7 mg/L in 2012 and 5.3 in 2004. From 2009-2014, there were 59 additional samples taken, with an average concentration of 4.9 mg/L. The maximum concentration was 8.36 mg/L, taken in June of 2012. Overall, the concentration of the samples varied little; around 5 mg/L for most samples and some lower concentrations that correspond to storm event flow. The maximum concentration in June of 2012, was collected the week after a fairly large storm event, when nitrate was probably still actively moving through the watershed system. This further highlights the dynamic nature of the hydrology in this area.

The macroinvertebrate survey in station 12LM011 had 27 taxa (TaxaCountAllChir), below the average taxa count for the coldwater macroinvertebrate class for the LMB (30.01). There were one generally intolerant taxa present and three Trichoptera taxa, comprising 11.1% of the total taxa

(TrichopteraChTxPct). This results in a very low metric score; less than the average metric score needed to be at the Southern Coldwater MIBI impairment threshold (Figure 39). Trichoptera taxa have been found to be generally sensitive of increasing nitrate concentrations.

Station 12LM011 had 19 nitrate tolerant taxa (78% tolerant individuals). At 20.18 nitrate tolerant taxa there is only a 25%t probability of meeting the Southern Coldwater MIBI. There were no nitrate intolerant taxa present in the macroinvertebrate survey. The macroinvertebrate community nitrogen index score was 3.5, while the average for southern coldwater stations meeting impairment threshold is 3.2. This suggests that overall the community is fairly tolerant to higher nitrate concentrations.

The macroinvertebrate metric HBI_MN is a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart. The HBI_MN metric score decreases with increased nitrate. In Mazeppa Creek, the metric score was 8.49 (out of 14.3), above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6). This is also displayed in Figure 39.

It's not clear if the macroinvertebrates are responding to nitrate or another stressor in this reach. The chemical dataset does suggest some moderately high nitrate concentrations, but the biological response data does not strongly support nitrate related stress compared to other coldwater stations in the region. It is important to mitigate sources of nitrate in the watershed with the susceptibility of nitrate contamination given the karst hydrology. Additional monitoring could prove to be useful in understanding the full range and variability of nitrate concentrations in this stream. At this time there is not enough information to definitively conclude nitrate is causing stress to the macroinvertebrates, and is inconclusive as stressor to Mazeppa Creek.

Suspended sediment

At the time of biological monitoring in 2004 a one-time chemistry sample was collected at 04LM134 and the TSS value recorded was 26 mg/L. During biological monitoring in 2012, at 12LM011 the recorded TSS value was 49 mg/L. There were also 40 TSS samples collected from 2009-2014, with values ranging from 1 mg/L to 808 mg/L. Of the 40 TSS values recorded, only three of them exceeded the 10 mg/L standard for designated coldwater streams with values of 12, 32, and 808 mg/L. The TSS value of 808 mg/L was from September 23, 2010, and was a result of high precipitation in the region. The State Climatology Office recorded a total rainfall of 6.37 inches on that day in the Zumbrota-Mazeppa area.

Daily TSS values were calculated for Trout Brook (Mazeppa Creek) (AUID 07040004-515) subshed 20 by the HSPF model from 1995-2009. These values ranged from 1.23-1794.9 mg/L with an average value of 17.5 mg/L. Additionally, a little over 14% of the values were above 10 mg/L, which is the TSS threshold for designated coldwater streams.

Table 11. Macroinvertebrate metrics relevant to TSS for stations in Trout Brook compared to statewide averages for southern coldwater stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	LongLivedPct	Intolerant2Pct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
12LM011	**0**	**0**	14.48	**0**	2	2.5
Statewide average for Southern Coldwater that are meeting the MIBI Threshold (46.1)	*2.8*	*2.5*	*14.7*	*1.7*	*3.75*	*7.35*
Expected response to TSS stress	↓	↓	↑	↓	↑	↑

The fish community shows sensitivity to TSS, with brown trout dominating the fish community. Brown trout are not considered the most sensitive to elevated TSS, but also not the most tolerant to elevated TSS. Close to 95% of the fish community fell into TSS quartile 2, demonstrating overall, a fish community with some sensitivity to high TSS concentrations.

The macroinvertebrate community may be responding to TSS, but is more likely responding to another stressor. The TSS index score, and TSS tolerant taxa and percentage do not show strong indications that TSS is impacting the community. The lack of long lived and intolerant taxa is not strong evidence supporting TSS stress to the macroinvertebrate community, because those metrics often also respond to other stressors and are less specific to TSS. Channel instability and in stream sedimentation seem more probable in driving the macroinvertebrate issues and metric response, instead of suspended sediment. The fish community metrics are above average and not suggestive of TSS stress and the chemical data also does not support a TSS stressor. Visual observations also show this stream is clear often. Given the chemical, biological, and physical information, TSS is not a stressor to Trout Brook at this time.

Habitat

Trout Brook had qualitative habitat assessments performed at sites 04LM134 and 12LM011 during the fish sampling events in 2004 and 2011 (Figure 40). Site 04LM134 had a MSHA score of 55.4 (Fair) while site 12LM011 scored 75.5 (Good). Limiting the habitat conditions at these sites was the presence of row crop agriculture as a nearby land use, some bank erosion (Figure 40), the presence of silt and sand substrates, light to moderate embeddedness, limited sinuosity, moderate channel stability, and the presence of steep or non-cohesive soils.

The macroinvertebrate sample at 12LM011 was taken from equal parts of riffle, overhanging vegetation, aquatic macrophytes, and woody debris habitat. This site had increased numbers of burrower (36.19%) and legless (77.4%) individuals, while also having decreased number of climber (5.4%), sprawler (14.29%), and EPT (14.6%) individuals. These results signal a community being impacted by the lack of instream habitat conditions.

The fish assemblage along Trout Brook (07040004-515) had increased numbers of riffle dwelling (68.1%) and simple lithophilic spawning individuals (68.1%) at site 04LM134. These results tend to indicate good habitat conditions. Site 12LM011 had decreased amounts of riffle dwelling (21%) and simple lithophilic

spawning individuals (18.83%). Inversely, site 04LM134 had many more tolerant individuals (68.25%) than site 12LM011 (22.08%).

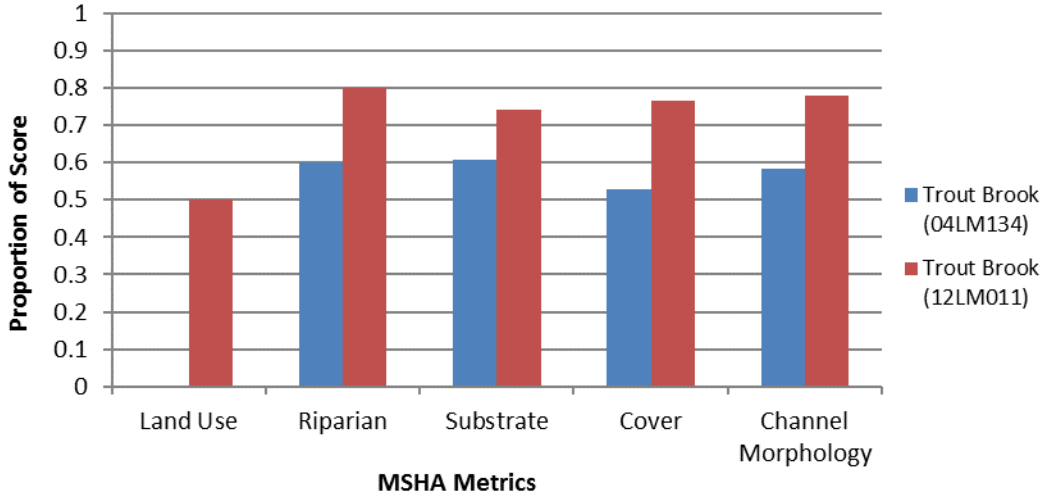

Figure 40. MSHA metric value scores for sites along Trout Brook (07040004-515).

According to the MNDNR fisheries management plan of 2014, extensive row crop agriculture throughout the watershed and grazing in the stream corridor has degraded physical habitat. Bank erosion is severe and sedimentation is problematic throughout the stream. Trout spawning substrates are very limited by the high amount of fines and unstable stream bed. The stream is wide and shallow in many areas, especially where heavy grazing occurs. Instream habitat is generally poor and unstable."

There is a significant shift in gradient from site 12LM011 to site 04LM134, which is located approximately 0.5 miles downstream of 12LM011. The MSHA scores from these sites goes from good (12LM011) to fair (04LM134), with a noticeable decrease in channel stability and increase in fine sediments. These fine sediments coming from eroding banks throughout the reach limit the habitat available for spawning trout.

The habitat related fish metrics are rather mixed; however, the macroinvertebrate assemblage signals that habitat is a likely stressor along this reach. The fair MSHA score at site 04LM134 also signals that the habitat conditions could be improved, in addition to historical MNDNR information. Therefore, lack of habitat is a stressor along Mazeppa Creek at this time.

Flow alteration and connectivity

The headwaters in the Trout Brook (Mazeppa Creek) Watershed have been altered or modified in many instances according to the Altered Watercourses GIS layer for Minnesota streams. This layer also indicated that the majority of the sampling site, 12LM011, has been altered. The MNDNR noted the severe bank erosion and sediment problems throughout the reach. According to CADDIS, bank erosion and instability, and undercut banks are site evidence that flow alteration is a potential stressor.

Portions of Mazeppa Creek flow underground making it difficult to analyze the flow regime and impacts of flow alteration occurring in the headwaters of the watershed. Flow alteration and connectivity is inconclusive as a stressor at this time. More work studying the impacts of the karst hydrology on the flow conditions is needed to better determine if the biological communities are being negatively affected.

Conclusions and recommendations

The macroinvertebrate community in Trout Brook (Mazeppa Creek; 515) is being stressed by poor habitat. The MNDNR has documented habitat stress in this reach as well. They note extensive row crop agriculture in the watershed, and grazing in the stream corridor which has degraded physical habitat. The stream is wide and shallow with some areas of severe bank erosion and instability. Biologically the macroinvertebrates are responding to these physical habitat issues with more burrowing taxa (often found in embedded riffles), legless macroinvertebrates-which tolerate these poor habitat conditions, and there is a lack sensitive EPT taxa, which require good habitat conditions.

Temperature, DO, and TSS were ruled out as potential stressors. Nitrate in this watershed is elevated, but the biological response information does not clearly link nitrate as a stressor, and is considered inconclusive at this time. It is important to mitigate sources of nitrate in the watershed with the susceptibility of nitrate contamination given the karst hydrology. Restricting cattle access to the stream, with improvement in riparian buffer areas, would also help the instability and sedimentation issues seen in this watershed.

Connectivity and flow alteration are also inconclusive as stressors in Mazeppa Creek. Much of the biological station 12LM011 has been altered and there is also some channelization occurring in the headwater areas that may be contributing to habitat degradation seen further downstream. However, it's not clear if this is contributing to the habitat stress observed or if the natural karst hydrology is impacting flow conditions and subsequent habitat issues. More work understanding these issues is needed to fully confirm or rule out this stressor.

Table 12. Summary of stressor determinations for Mazeppa Creek

Stream Name	AUID	Stressors: Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Trout Brook (Mazeppa Creek)	07040004-515	---	---	o	---	●	o

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.4 Trout Brook Watershed (Dumfries)

Trout Brook is a small coldwater/warmwater stream which originates in Wabasha County. The watershed drains a total of 13,760 acres, 67% of which is in agricultural use. Section 4.4.1 describes the fish impairment on AUID 07040004-585 (Figure 41).

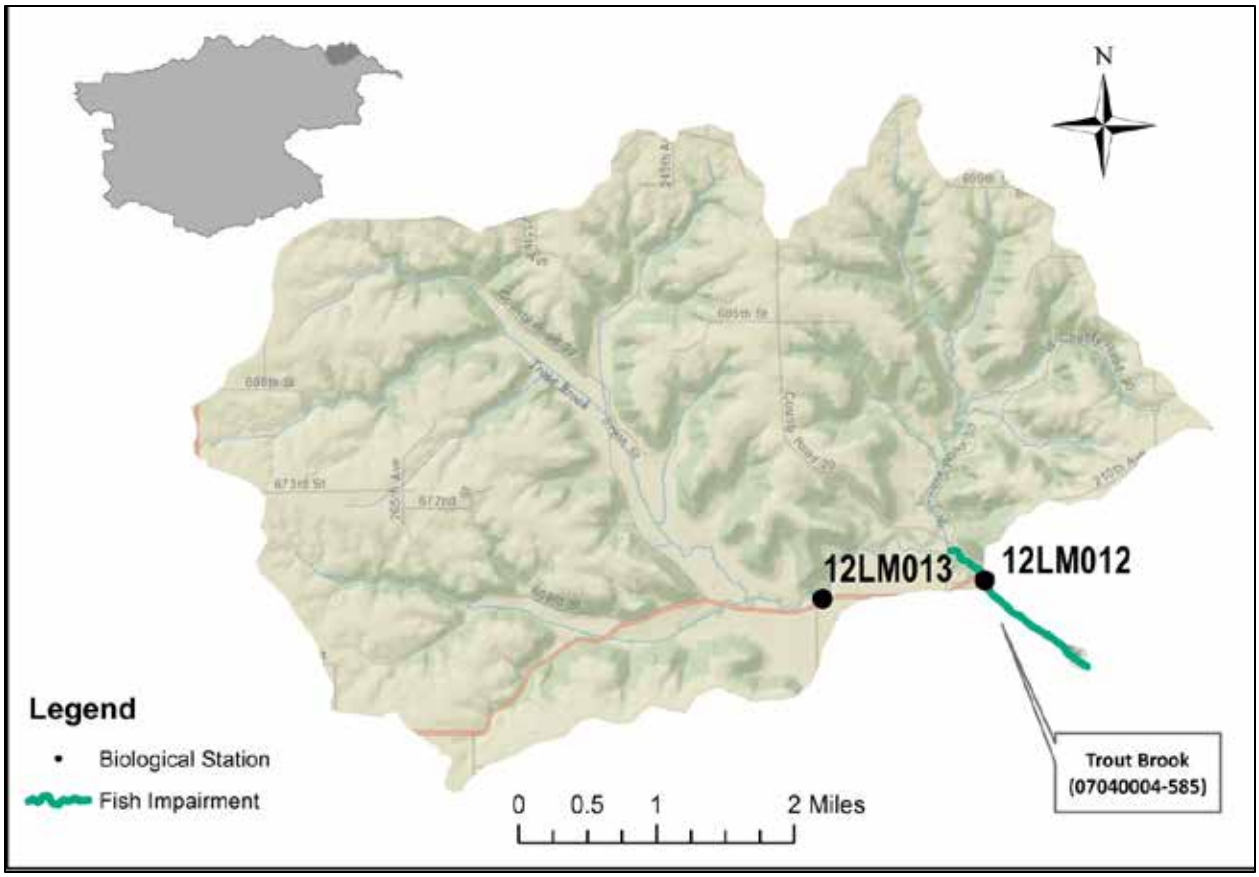

Figure 41. Map of the Trout Brook Watershed, biological stations, and impaired AUIDs.

4.4.1 Trout Brook (585)

Biological and background information

Trout Brook (07040004-585) has one biological station (12LM012) which was sampled on July 9, 2012; and had an FIBI score of 23, and resulted in a fish impairment. The site is designated fish Class 3 (Southern Headwaters) and was also given a modified use threshold due to the channelization on this reach and limited habitat characteristics. The modified FIBI threshold is 33 with an average score per metric of 5.3 needed to meet that threshold. All of the metrics scored below the average metric needed to meet the threshold, except the percentage of short lived species (SLvdPct). An increase in short lived species decreases the metric score. The sensitive metric scored zero, indicating a complete absence of sensitive fish. Overall, the metrics show uniform degradation among the fish community (Figure 42).

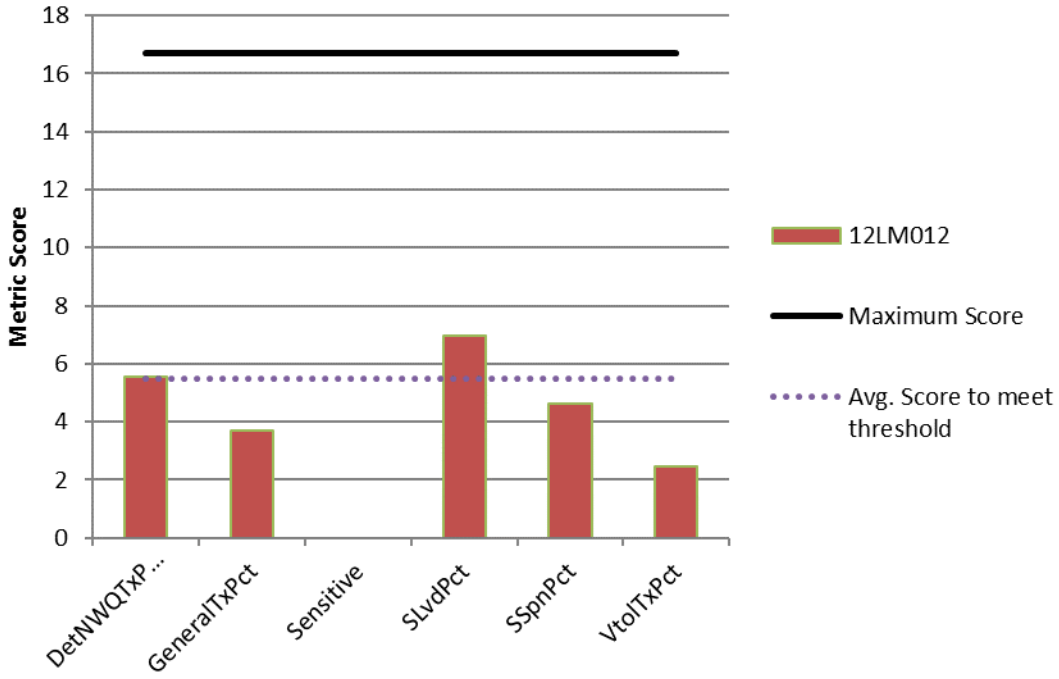

Figure 42. Fish IBI metrics for Trout Brook (Modified Southern Headwater).

Temperature

There are some indications based on MNDNR reports and information that show this area of the stream is influenced by the karst hydrology (part of the stream disappears underground, but exact location can vary depending on flow conditions). A spring tributary between the two biological stations may contribute colder water to the system. During biological sampling, the temperature was 22.8 °C on July 9, 2012 but further monitoring of temperature is needed to help understand the potential for this stream to be considered coldwater. The designated coldwater reach of this stream is upstream of both biological stations, and was not sampled by MPCA. The MNDNR confirms a brook trout population in the upstream reach, but only on a short stream length. It would be advantageous to not only sample the coldwater reach of this stream but to also gather high resolution temperature information farther downstream to understand the true thermal dynamics throughout. Temperature is not considered a stressor to the biological community at 12LM012, since the area assessed is currently considered warmwater. If monitoring reveals the stream has coldwater potential farther downstream of this location, temperature as a stressor will need to be reevaluated.

Dissolved oxygen and eutrophication

Trout Brook had two DO readings take place in 2012, during the fish and macroinvertebrate sampling events. These measurements were 8.3 and 9.86 mg/L, with one of the samples taken before 9:00 AM.

The macroinvertebrate assemblage in Trout Brook at site 12LM012 showed a decreased amount of DO tolerant individuals (7.12%), while also having 5 taxa that are considered very intolerant of low DO conditions. The DO TIV score for this Class 6 site was also above average. All of the evidence indicates that low DO is not causing stress to the macroinvertebrate community.

The fish community in Trout Brook had an increased amount of late maturing (93.07%) and sensitive (76.84%) individuals, while also having a decreased amount of serial spawning fish (0.65%). These results

all reflect a stream not being affected by poor DO levels. Additionally, the DO TIV score for the fish community was also above average when compared to other Fish Class 3 sites across the state.

Additional monitoring for DO in Trout Brook is recommended. However, despite the limited measured data set, the DO related biological metrics for both assemblages strongly suggest that low DO is not a stressor to the fish and macroinvertebrate communities in Trout Brook.

Nitrate

During fish sample, the nitrate concentration at 12LM012 was 1.5 mg/L (July 9, 2012). There are no other nitrate data available on this stream reach. The only other nitrate data available in this watershed is from the headwater area where nitrate concentrations were generally quite low, ranging from 1.09-2.98 (17 samples from 2009 and 2010). Given the heavy influence of karst and geology in this area, HSPF model simulated values for nitrate were not considered for further analysis, but it is likely that nitrate concentrations don't vary much when moving downstream.

Station 12LM012 had an above average taxa count (TaxaCountAllChir; 38). The average taxa count for this macroinvertebrate Class 6, (Southern Forest Streams GP) is 33. Trichoptera are found to be generally sensitive to elevated nitrate concentrations. There were only 2 Trichoptera taxa, which is below the average for the Southern Forest Streams GP stations of the LMB (2.2). Additionally, the percentage of Trichoptera individuals was at the average, at 5.2% (Average is 5.3%). The station did have only 66% nitrate tolerant individuals. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (Class 6) MIBI. There was one nitrate intolerant taxon found. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. Non-hydropsychid trichoptera are all caddisflies that do not spin nets. Station 12LM012 had only 0.64% non-hydropsychid trichoptera. This is below average compared to all biological sites in the LMB (3.39%) and for this stream class (2.21%). The macroinvertebrate community nitrogen index score was 2.9, while the average for southern coldwater stations meeting impairment threshold is 3.2. This suggests that overall the community is not overly tolerant to nitrate concentrations.

While metrics signal potential for nitrate stress in this reach, it's more likely the response seen is attributed to other stressors since the nitrate concentration is quite low. Data is limited in this reach, but given geology of the area, nitrate concentrations are likely lower compared to other areas of the Zumbro Watershed. Runkel et al studied nitrate concentrations related to bedrock geology in southeast Minnesota, and characterized most coldwater reaches in the Zumbro Watershed and towards the Mississippi River as being lower in the stratigraphic section and thus lower in nitrate concentrations (less nitrate-rich water contributing to in-stream concentrations).

Despite signals from the macroinvertebrate community, nitrate concentrations were found to be low in Trout Brook and within the watershed. It is likely that another stressor is impacting the impaired fish community, especially because macroinvertebrates who are more sensitive to elevated nitrate are not impaired. Therefore, nitrate is not considered a stressor to Trout Brook.

Suspended sediment

At the time of biological monitoring on July 9, 2012, a one-time chemistry sample was collected at 12LM012 and the TSS value recorded was 20 mg/L. This is the only TSS sample information available on this reach.

Daily TSS values were calculated for Trout Brook (AUID 07040004-584) subshed 1 by the HSPF model from 1995-2009. These values ranged from 1.04-899.9 mg/L with an average value of 12.25 mg/L. In

addition, about 3% of the values were above 65 mg/L, which is the TSS threshold for designated warmwater streams.

The fish community at this site was dominated by two species: bigmouth shiners and white suckers, both of which are somewhat tolerant to elevated TSS, among other stressors. While the site is lacking herbivores, sensitive fish, intolerant and long lived fish, it shows above average percentages of benthic feeders, riffle species, and simple lithophilic spawners. The mixed response, and domination of the community by two species makes the percentages seem skewed. The macroinvertebrate community, which is not impaired, does not signal TSS issues, given the little response observed (Table 13). It is more likely the fish community is responding to other stress, but not from suspended sediment. Certainly sediment reductions in this watershed are necessary, and erosion is prevalent, but there is not strong indication that the sediment is staying suspended; it is more likely causing poor substrate and habitat conditions, as evidenced by site visits and photos. TSS is not considered a stressor to Trout Brook at this time.

Table 13. Macroinvertebrate metrics relevant to TSS for stations in Trout Brook compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
12LM012	14.62	2.00	5.00	7.40	25.64	**0.00**
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to TSS stress	↑	↓	↑	↑	↓	↓

Habitat

Trout Brook (07040004-585) had a qualitative habitat assessment at site 12LM012 during the fish sampling event in 2012. The resulting MSHA score for this site was 28.5, which is considered to be poor. This MSHA score was the second lowest recorded in the Zumbro River Watershed. Limiting the MSHA in Trout Brook was the row crop in the nearby land use, the lack of shade, the high presence of sand, limited fish cover types and overall cover, moderate embeddedness, low channel stability, no depth variability, no riffles, poor channel development, and poor sinuosity.

Channelizing or modifying stream reaches often severely limit the amount of habitat available. This portion of Trout Brook has been modified and as a result, the channel morphology is very limited decreasing the MSHA and overall available habitat.

The macroinvertebrate sample at site 12LM012 along Trout Brook was taken completely from the overhanging vegetation present. This sample contained decreased amounts of burrower (7.69%) and climber (6.73%) individuals. Climber species prefer overhanging vegetation and woody debris habitat types. This site also had increased numbers of legless individuals (62.18%). Legless species are tolerant species like midges and snails and tolerant of poor habitat. This reach did have an increased amount of

clinger (43.91%) which can signal a community not affected by poor habitat conditions. However, the increase in sprawlers (25.64%) may signal the presence of fine sediments.

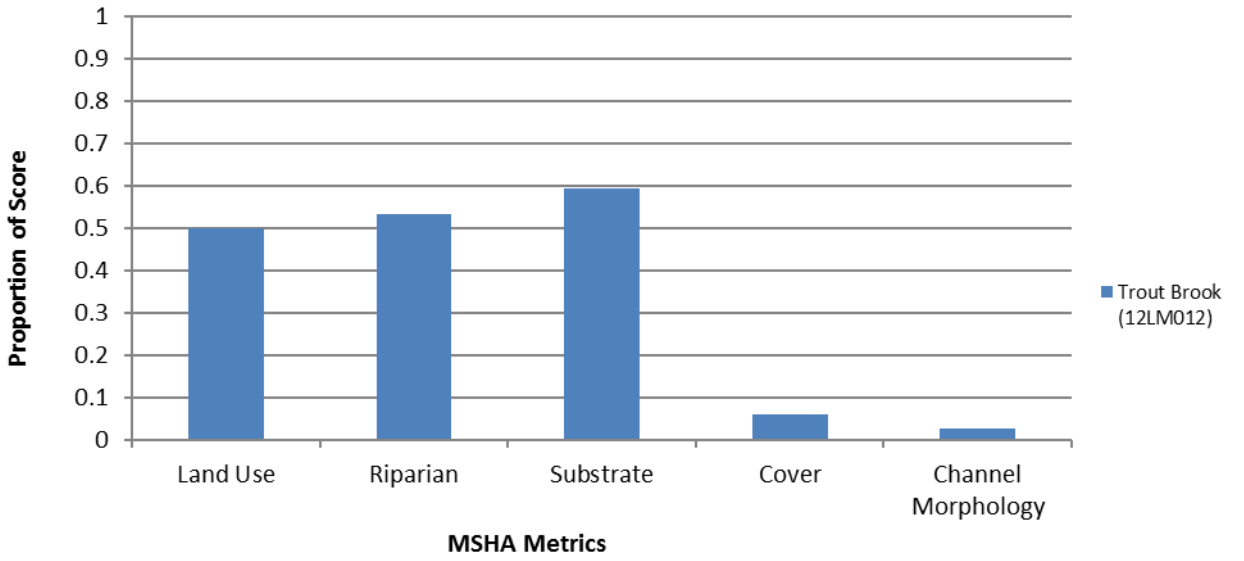

Figure 43. MSHA metric value scores at site 12LM012 along Trout Brook (07040004-585).

The fish assemblage in this reach was comprised primarily of bigmouth shiners (54.55%) and white suckers (41.75%). These two tolerant species overwhelmed the fish community in this reach, which is not normal. This lack of diversity is often a sign of poor habitat conditions. The rest of the sampled fish were also tolerant species.

Based on the poor MSHA score, the poorly scoring habitat related macroinvertebrate metrics, in addition to the very tolerant and poorly diversified fish community and stream channelization, lack of habitat is a stressor to the biotic communities in Trout Brook.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 1.35-mile-long reach of Trout Brook (07040004-585) was 100% modified. Modified channels typically lead to reduced habitat conditions, eroded banks, and an overall reduction in diversity. Other modified sections in the 12-digit HUC Watershed include portions of the far headwaters of Trout Brook and a section of a small unnamed tributary to Trout Brook. The largest tributary to Trout Brook, Hope Coulee is completely natural.

According to a MNDNR report from 1998, “The flow from Trout Brook disappears in the sand bottom stream bed in Section 9. Thorn, 1977 described the point where the stream disappeared as the Section 9-10 line.” The current MNDNR management plan (2012) also indicated the stream had gone underground due to dry weather. This location is in-between biological stations 12LM013 and 12LM012. A spring in Section 8 is also impounded. The impact of this on temperature and connectivity is unknown, but should be explored further.

In the case of Trout Brook, the fact that the stream has been documented as disappearing or flowing underground will have an impact on connectivity and fish migration. The frequency and duration of this will need to be studied further. While the stream section is considered modified, there are few eroding banks present that may indicate high fluctuations in stream flow due to the channelized section. Some of the modified channel may be indirectly impacting the poor habitat conditions present at site 12LM012. More work is needed to determine if flow alteration and connectivity is a stressor at this time and therefore, it should be considered inconclusive.

Conclusions and recommendations

The fish community in Trout Brook (585) is being stressed by poor habitat conditions (Table 14). This stream reach is considered "modified" (channelized) with a poor MSHA score and demonstrates poor habitat conditions with the presence of primarily sand substrates, limited fish cover/depth, and substrate embeddedness (Figure 44).

There are some large areas of bank erosion and instability just upstream of this reach which likely contributes to the habitat and sedimentation issues seen. The fish assemblage in this reach was made up of bigmouth shiners and white suckers, two species who are considered very tolerant and can survive in poor habitats. The macroinvertebrate community, which was not impaired, is also showing signs of habitat related stress. Additional biological monitoring in future years may be useful in understanding how habitat conditions have changed in this channelized reach.

Figure 44. Photo taken just upstream of 12LM012 demonstrating poor habitat conditions; lack of depth, instability, widening, and sand deposition.

Flow alteration and Connectivity are inconclusive as stressors at this time. The fact that the stream has been documented as disappearing or flowing underground will have an impact on connectivity and fish migration. The frequency and duration of this will need to be studied further in addition to the channel modifications and how together they all play a potential role in the stress observed.

Temperature, DO, TSS and nitrate were all ruled out as potential stressors. Given the relative health of the macroinvertebrates, chemical parameters are less probable as stressors because typically the macroinvertebrates will be first to show signs of stress related to chemistry. There was also very little indication (chemical or biological) that any of these parameters were likely causes of impairment. While temperature was ruled out as a stressor because this reach is considered warmwater, the designated coldwater reach of this stream is upstream of the biological stations, and was not sampled by MPCA. MNDNR confirms brook trout in the upstream coldwater reach, but only on a short stream length. It would be advantageous to not only sample biology in the true coldwater reach of this stream, but to gather high resolution temperature information farther downstream to understand the true thermal dynamics throughout this entire stream. If monitoring reveals the stream has coldwater potential (in the downstream reaches) temperature as a stressor would need to be reevaluated. Current MNDNR reports suggest this reach is not suitable coldwater and the current sampling area often lacks flow during low baseflow years.

Table 14. Summary of stressor determinations for Trout Brook

Stream Name	AUID	Stressors					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Trout Brook (Dumfries)	07040004-585	---	---	---	---	●	o

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.5 North Fork Zumbro Watershed

The North Fork Zumbro Watershed is a warmwater stream that originates in Rice County and ends in Wabasha County, with the majority of the drainage and stream system contained in Goodhue County. This large subwatershed drains a total of 111,360 acres, 75% of which is in agricultural use. Section 4.5 will discuss one single macroinvertebrate impairment on AUID 07040004-971 (Figure 46). The subsequent section (4.6) will discuss the impaired tributary streams to the North Fork Watershed.

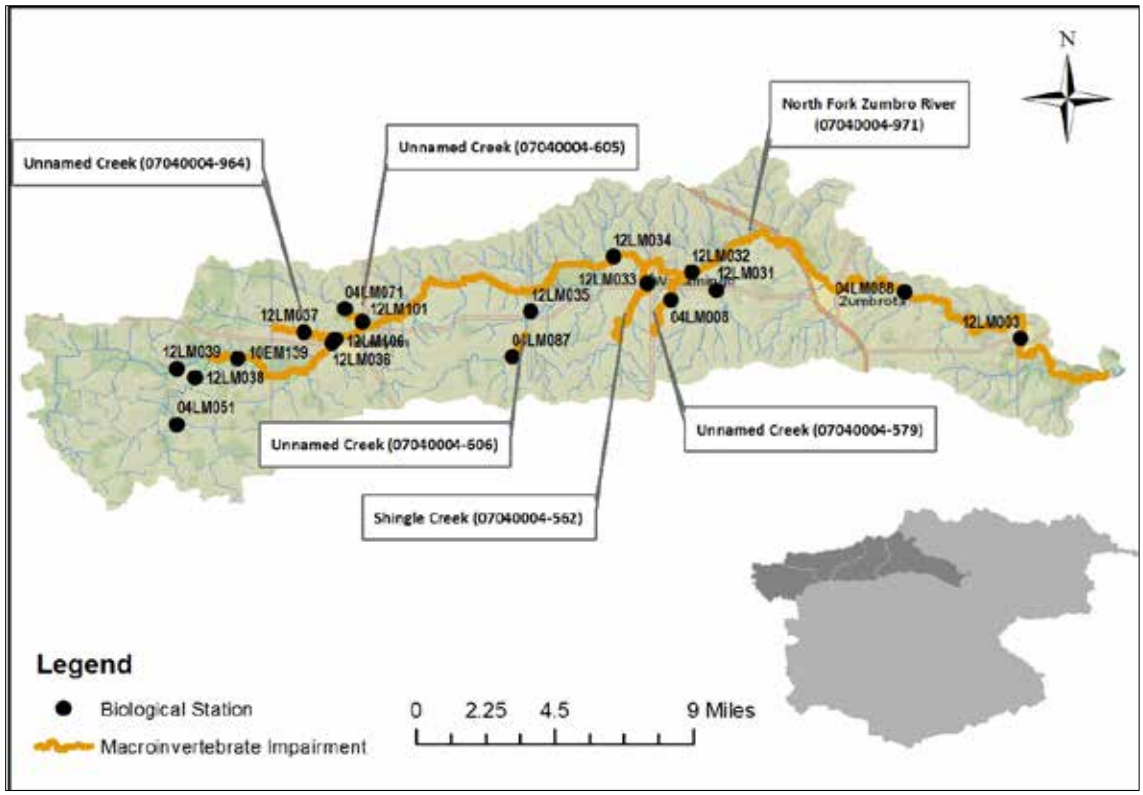

Figure 45. Map of the North Fork Watershed, biological stations, and impaired AUIDs.

4.4.2 North Fork Zumbro (971)

Biological and background information

The North Fork Zumbro River (07040004-971) has three biological samples collected in 2012 on the designated Class 5 (Southern Streams RR) reach, and three biological samples collected from 2004, 2010, and 2012 on the designated macroinvertebrate Class 6 (Southern Forest Streams GP) stations (Figure 46 and Figure 47). The data resulted in a macroinvertebrate impairment on this reach.

The MIBI impairment threshold for Class 5 streams is 37, with an average score per metric of 3.7 needed to achieve that threshold. This includes sites 12LM034, 12LM003, and 12LM106 with MIBI scores of 27.18, 42.03, and 31.39, respectively (threshold= 37). Overall there is a trend towards greater taxa richness of clingers and Odonata, fewer climbers, fewer predators, and fewer Trichoptera taxa. Site 12LM034 is the only site that frequently exceeds the average metric score needed on 6 out of 10 metrics, while the other two sites are most often below the average metric score needed.

For Class 6 streams the MIBI impairment threshold is 43, with an average score per metric of 4.3 needed to achieve that threshold. This includes sites 04LM088, 10EM139, and 12LM032 with MIBI scores are 58.85, 34.78, and 42.77, respectively (threshold=43). Site 04LM088 was sampled on August 30, 2004, and has the highest MIBI, with the average metric score only below average with Intolerat2Ch and TrichwoHydroPct metrics. The community at this site in 2004, is generally diverse, and abundant in clinger and collector-filterer taxa. All sites have a metric score of zero for the Intolerant2Ch metric, and all sites trend towards low metric scores in predator taxa richness (PredatorCh) and non-hydropsychid Trichoptera (TrichwoHydroPct) taxa. Additionally, sites 10EM139 and 12LM032 have some of their lower below average metric scores in the taxa richness of Plecoptera, Odonata, Trichoptera, and Ephemeroptera (POET).

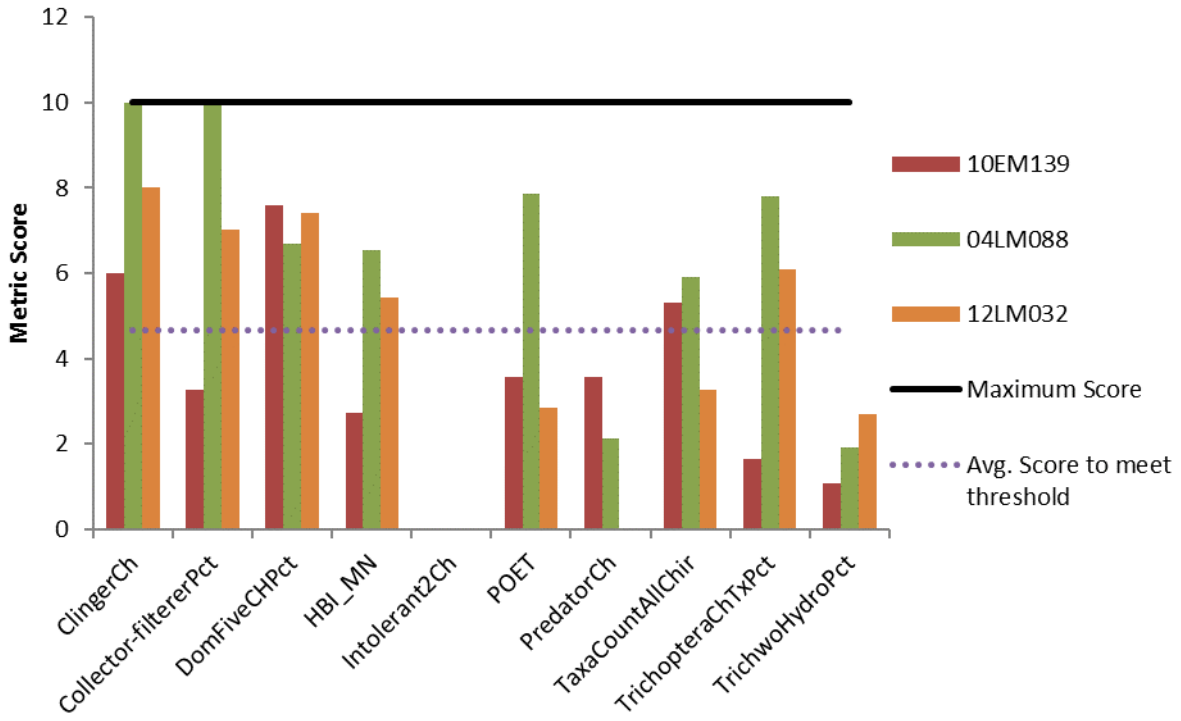

Figure 46. Macroinvertebrate IBI metrics for the North Fork (Class 6; Southern Streams Glide/Pool)

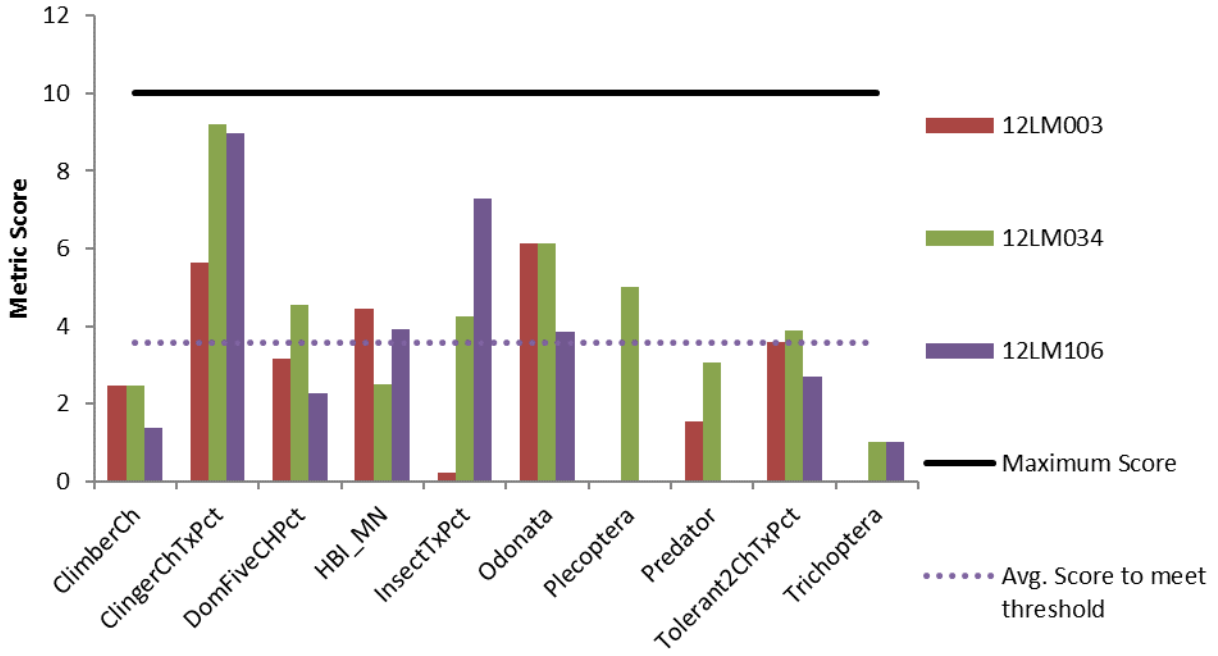

Figure 47. Macroinvertebrate IBI metrics for the North Fork (Class 5; Southern Streams Riffle/Run)

Dissolved oxygen and eutrophication

North Fork Zumbro River (07040004-971) had 70 DO measurements taken from 2009-2013. These values ranged from 6.33-16.44 mg/L. Continuous DO monitoring also took place at site 12LM003 in 2012, (Figure 48). During this monitoring, the daily flux of the DO conditions frequently exceeded 3.5 mg/L.

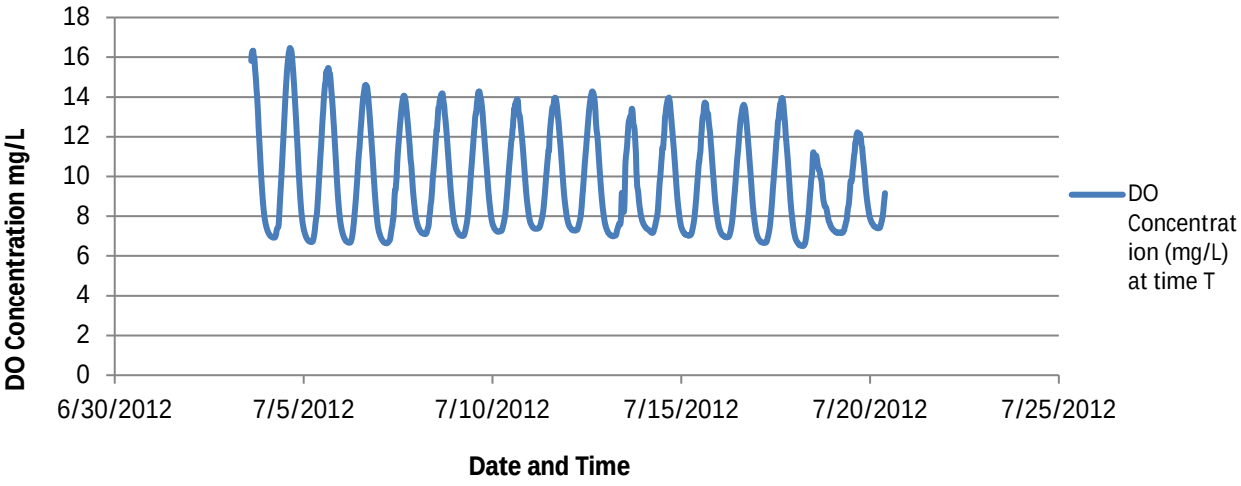

Figure 48. Continuous DO data at site 12LM003 along North Fork Zumbro River (07040004-971) from 2012.

Additionally, 73 phosphorus samples were taken from 2004-2013 along this portion of the North Fork Zumbro River. These values ranged from 0.023-1.33 mg/L with 47 values being above the 0.10 mg/L phosphorus standard. The relationship of TSS to TP is shown in Figure 49. The data shows some instances where the TP is elevated with TSS (assumed events) and without events (assumed baseflow conditions).

When TP is elevated during all flow conditions, there is a potential for issues related to river eutrophication and additional variables are needed to determine if the elevated phosphorus conditions are leading to eutrophication issues. As stated already, the DO flux that was measured in 2012 did show exceedances of the recommended daily flux. Chlorophyll a data was available (32 samples from 2009-2012). Only one of those samples (20 µg/L) was greater than the chlorophyll a standard for the central region (18 µg/L). BOD data was not available on this reach.

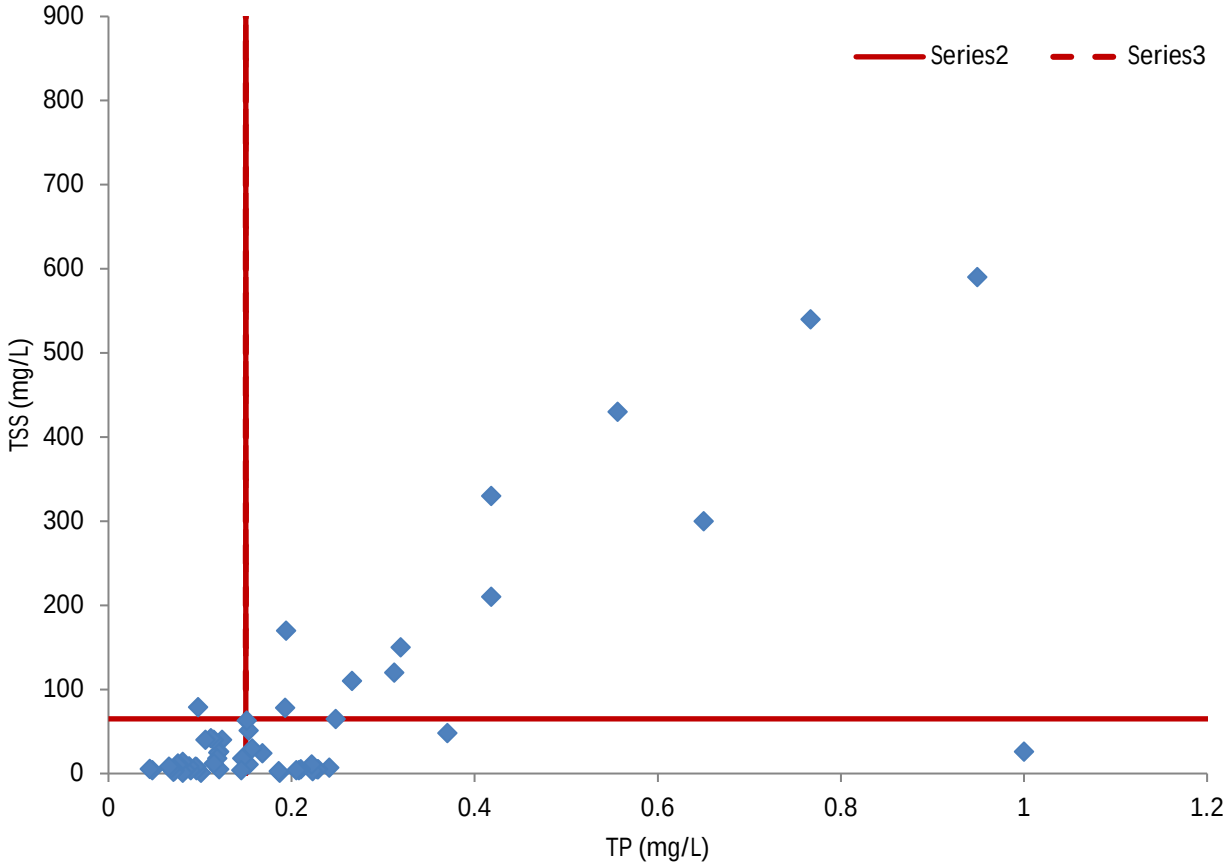

Figure 49. TSS and TP relationship in the North Fork Zumbro (2007-2012; multiple monitoring locations). The points that exceed both the TSS and TP standards (red lines) are showing samples with phosphorus likely tied to sediment. Those that are below the TSS standard, but greater than the TP standard are more likely not tied to sediment.

The macroinvertebrate community in North Fork Zumbro River averaged 36.53% EPT individuals at its five biological sites, with site 12LM003 having a very high amount (70.32%) and 04LM088 having very few EPT individuals (5.83%). These sites averaged seven DO intolerant taxa per site and also had a below average amount of DO tolerant taxa (8.08%). The average DO TIV scores were also above average for all sites when compared to all other sites within the Zumbro River Watershed.

The fish assemblage along this reach had a high amount of late maturing individuals (30.55%). The two downstream sites, 04LM088 and 12LM003 had decreased amounts of serial spawning (9.54%)

individuals. Low levels of these species typically signal that the fish community is not being negatively impacted by the DO conditions. The sites located further upstream did show an increase in numbers of serial spawning individuals (24.97%). The DO TIV scores for the biological stations along this reach were above average when compared to all other sites within the Zumbro River Watershed.

Despite the high daily flux of DO, the DO levels did not fall below 5 mg/L. While there were many exceedances of the phosphorus standard; the majority of the DO related biological metrics including the TIV scores do not show significant signs of DO stress. High DO flux in the reach is also concerning, but a lack of connecting biological response and large AUID many potential differences throughout. Continued high levels of phosphorus may eventually lead to DO and eutrophication issues in the reach, so at this time DO is inconclusive in the North Fork Zumbro River. Additional information collected throughout this reach may also help tease out causes and effects of phosphorus and DO.

Nitrate

During biological sampling, the nitrate concentration ranged from 1.2-9.7 mg/L (Table 15). There were 97 additional nitrate samples taken from multiple stations on this reach, from 2007-2013. The average concentration of those samples was 5.5 mg/L with a maximum concentration measured at 19.6 mg/L in June of 2009 (S000-033). There were 12 total samples collected that were above 10 mg/L; these were also taken at multiple different locations on the reach, over the course of many different years, most of them in the month of June.

Daily nitrate values were calculated for the North Fork River (AUID 07040004-971) subsheds 201-206 by the HSPF model from 1995-2009. These values ranged from 1.09-26.15 mg/L with an average value of 4.82 mg/L. In addition, for the entire 07040004-971 reach, 3.7% of the values are above 10 mg/L and less than 1% are above 20 mg/L.

The macroinvertebrate communities in the North Fork show a mixed response to elevated nitrate. Taxa Count or species richness are below class averages for two of the six stations (Table 15). The number of Trichoptera taxa are less than average at most stations. The majority of stations are lacking intolerant macroinvertebrate taxa (non-hydropsychid Trichoptera and nitrate intolerant taxa). All of the sites had some nitrate tolerant individuals present, but they were only above average at two of the six stations. The data do not strongly link nitrate as a cause for macroinvertebrate impairment in this reach. Concentrations are elevated at times, but usually fairly low for most of the year. While the biology may show some response to nitrate, it's not clear if the response is due to other types of stress. Nitrate should be reduced in this reach if possible. At this time there is not enough to conclude nitrate is a stressor, since there is a mixed response, and therefore it is considered inconclusive.

Table 15. Nitrate relevant metrics for the North Fork Zumbro

Station (Stream Class)	Taxa Count (TaxaCountAllChir)	Trichoptera Taxa	% Non-hydropsychid tricoptera	Nitrate Intolerant Taxa	% Nitrate Tolerant Individuals	Nitrate concentration at time of fish sample (mg/L)
12LM003 (Class 5)	**26**	**2**	**0.96**	NA	NA	3.3
12LM034 (Class 5)	41	**3**	4.06	**1**	**82.95**	8.1
12LM106 (Class 5)	37	**3**	3.75	**0**	**74.07**	1.2
10EM139 (Class 6)	37	**1**	**0.30**	**1**	63.78	7.8
04LM088 (Class 6)	39	5	**0.61**	**1**	39.13	9.7
12LM032 (Class 6)	**30**	**3**	**0.95**	**0**	68.31	5.1
Expected response with increased Nitrate stress	↓	↓	↓	↓	↑	
Class 5 Averages	***37.76***	***4.3***	***3.39***	***1.49***	***69.8***	
Class 6 Averages	***33***	***2.2***	***2.21***	***1.49***	***69.8***	

Suspended sediment

All of the chemistry samples taken during biological sampling were collected between the months of June through September, and 50 mg/L or lower with an average concentration of 18 mg/L. Between 2007 and 2013, a total of 60 TSS values were recorded on this reach. The values range from <1 mg/L to 960 mg/L with an average value of 60 mg/L. Of the 60 TSS values, 15 (25%) were greater than 65 mg/L, which is the TSS standard for designated warm water streams. However, it is important to note that this information was collected as the result of TMDL load monitoring and is biased towards event based sampling, when concentrations are typically the highest.

Further evidence to support this is from the HSPF dataset, which looks at all the simulated data and is not biased towards events. Daily TSS values were calculated for the North Fork Zumbro River (AUID 07040004-971) subsheds 201, 202, 203, 204, 205, and 206 by the HSPF model from 1995-2009. These values ranged from 0.96-1621.1 mg/L with an average value of 14.0 mg/L. In addition, 3.8% of the values from the North Fork Zumbro River were above 65 mg/L.

At the North Fork Mazeppa load monitoring station (2013-2014), any flows above ~300 cfs were almost always greater than 65 mg/L (N=25). For approximately the entire month of April (2013), flows were >300 cfs, (four samples taken during this time period all of which were above 65 mg/L, with average concentration of 177 mg/L) representing an extended time period where TSS concentrations were sustained above the standard. Normal events during the summer often produce flows >300 cfs as well, but for a shorter duration; anywhere from 1 to 11 days depending on the event and conditions. For example, a June event in 2014 had sustained flows above 300 cfs for 11 continuous days, and had an average concentration of 260 mg/L from five samples; all of them above the TSS standard. While the TSS benchmark used here is 65 mg/L (current WQ standard), stress to biology is believed to occur before this concentration is reached, and especially at longer durations of elevated TSS.

Overall, the macroinvertebrate metrics signal TSS stress (Table 16). The biological stress appears to increase when moving downstream. There is consistent response across most sites with the high TSS index score, the lack of TSS intolerant taxa, and higher than average percentage of TSS tolerant taxa. The fish community, while not impaired, doesn't show much signal towards TSS stress. Only a few of the fish metrics show a TSS related response at the downstream stations where TSS is thought to be the highest. The TSS index score for fish is below average for all stations in the North Fork, which demonstrate the fish community isn't dominated by TSS tolerant fish.

There is a large chemical dataset, and consistent macroinvertebrate response, indicating TSS is a stressor to macroinvertebrate community of the North Fork Zumbro especially in the lower reaches (12LM003). Just upstream of this station there is a large bank and old dam site which could be causing additional sediment to enter the system and cause more localized stress near 12LM003 ().

Figure 50. Excessive bank erosion upstream of 12LM003, Google Earth 2011.

Table 16. Macroinvertebrate metrics relevant to TSS for stations in the North Fork Zumbro compared to statewide averages for southern streams GP and southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Stations, from upstream to downstream (Class)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
10EM139 (GP)	**16.66**	**0.00**	**11.00**	22.26	**12.58**	**0.00**
12LM106 (RR)	16.65	**0.00**	11.00	**35.93**	**18.13**	**0.00**
12LM034 (RR)	**17.40**	**1.00**	10.00	30.82	**16.88**	**0.31**
12LM032 (GP)	**17.30**	**0.00**	10.00	**42.90**	26.67	**0.00**
04LM088 (GP)	**18.36**	**2.00**	**12.00**	**38.80**	37.92	**0.00**
12LM003 (RR)	**19.24**	**1.00**	7.00	**75.24**	53.67	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Seven sites along North Fork Zumbro River (07040004-971) had qualitative habitat assessments performed during their fish sampling events in 2012. The MSHA scores along this reach ranged from poor (37) – 73.5 (Good). Limiting the MSHA scores along this reach was poor surrounding land uses, limited riparian buffers, bank erosion, embeddedness, sparse fish cover, the presence of sand and silt substrates, and moderate channel stability.

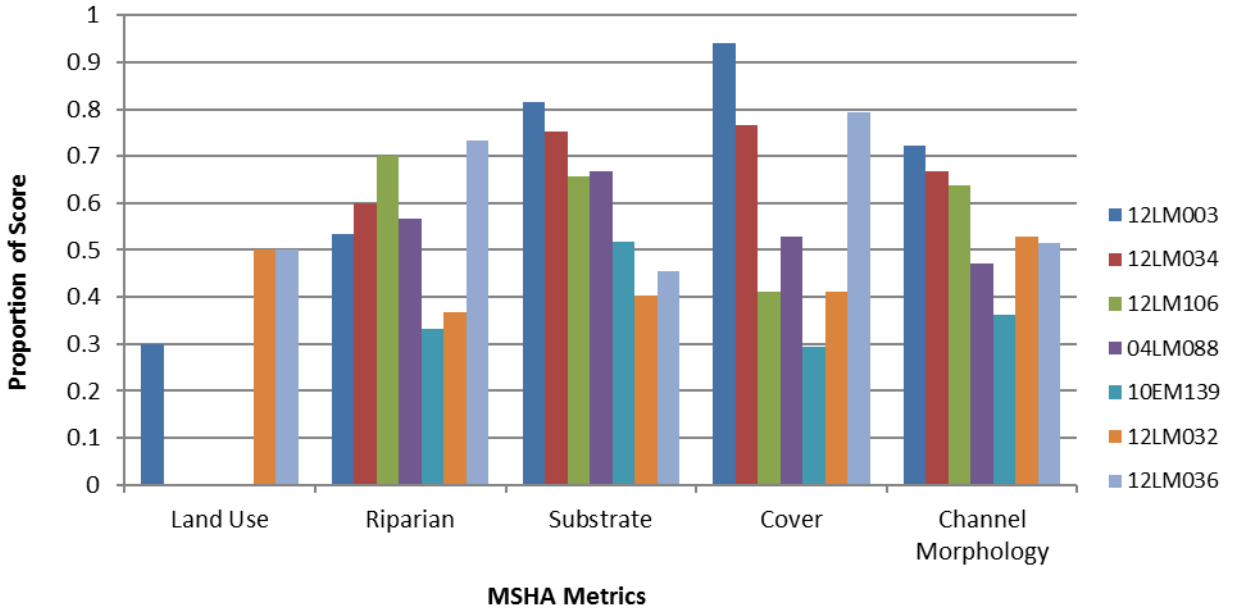

Figure 51. MSHA metric value scores at various sites along North Fork Zumbro River (07040004-971).

The macroinvertebrate samples were taken from a variety of riffle, overhanging vegetation, and woody debris at the six biological monitoring stations sampled for macroinvertebrates along the North Fork Zumbro River. The macroinvertebrate community had an average of 9.45% burrower individuals. This result is an average amount of burrowers at Class 5 sites (12LM003, 12LM034, and 12LM106), and above average for Class 6 sites (04LM088, 10EM139, 12LM039, 12LM032). The highest levels of burrower individuals were found at site 04LM088, located on the lower or downstream portion of the reach, and 12LM106, which is located on mid to upper portion of the reach. Burrower species tend to be more abundant in streams that contain many fine substrates. This stream reach also contained a high average of legless individuals (60.47%). Legless species are typically tolerant and found in higher numbers at sites with degraded habitat conditions. Site 12LM003, the most downstream site along this reach, had the highest MSHA score and the fewest amount of legless individuals (22.9%). The remaining sites all had high amounts of legless individuals. This reach did also have increased numbers of climber (24.47% average) and clinger (52.42% average). The most downstream site 04LM088 and 12LM003 had the most clingers as these numbers tended to decrease travelling upstream. Clingers are more prevalent in streams with course substrates and woody debris.

The fish assemblage along this reach had increased numbers of benthic insectivore (20.86%), darters/sculpin/round-bodied sucker (16.8%), simple lithophilic spawning (58.02%), and riffle dwelling (40.83%) individuals, while also having a below average amount of tolerant individuals (45.43%) when compared to all other Minnesota streams. These metric scores all indicate a fish community not negatively impacted by the habitat conditions.

Habitat conditions in the North Fork Zumbro River ranged from poor to good. The fish community along this reach is not impaired and the habitat related metrics score well throughout. The macroinvertebrate community in the lower section of this reach had habitat metrics score quite well, which corresponded with the high MSHA scores. Moving upstream, the conditions and habitat metric scores worsen. The increase in fine sediments and overall lack of habitat is negatively impacting the macroinvertebrate assemblage. However, on the downstream end of the AUID (12LM003) there is a large eroding bank and old dam site which is causing excess sediment to enter the system. This dam does not appear to be impacting habitat in this area due to higher gradient, but rather TSS instead (see TSS section for more

detail). Therefore, the lack of habitat, particularly in the mid to upstream sections of North Fork Zumbro River is a stressor to the impaired macroinvertebrate community.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 45.22-mile-long reach of North Fork Zumbro River (07040004-971) was 13.51% modified. Along this portion of the North Fork Zumbro River, only smaller sections were modified. For the most part, many of the tributaries feeding this stream are considered natural with the far reaching headwaters in the western portion of the watershed being the exception as it contains many small channelized streams.

Dams are located along the North Fork Zumbro River in Wanamingo and Mazeppa. Dams can often limit fish and mussel diversity by limiting their migration and ability to travel upstream. MNDNR Mussel surveys were conducted upstream of these dams and living mussels were sampled.

Given the large size of this AUID and the relatively low percentage of modified sections as well as the presence of living mussels upstream of the dams and migratory fish species; flow alteration and connectivity are not stressors to the impaired biological communities at this time.

Conclusions and recommendations

The macroinvertebrate community in the North Fork Zumbro is being stressed by lack of habitat and elevated TSS (Table 17). This AUID is rather long and not homogenous throughout (extending from just east of Kenyon all the way to Mazeppa). TSS stress does show some consistent signal throughout the reach, but stress does appear to increase towards the mouth of the watershed (12LM003), where there is also a strong chemical dataset to support the elevated concentrations. The elevated TSS is then also connected to poor habitat conditions. Moving upstream on this reach, the conditions and habitat metric scores worsen as the stream gradient decreases. The increase in fine bedded sediments and overall lack of habitat is negatively impacting the macroinvertebrate assemblage, particularly in the mid to upstream sections of North Fork (near more channelization). Habitat stress is not as apparent in the downstream station (12LM003), most likely due to higher gradient and the streams ability to continue to move sediment before it accumulates on the streambed. This is further demonstrated in the eroded banks in that reach.

While the nitrate concentrations on this reach are moderately elevated, nitrate is considered inconclusive as a stressor. The data do not strongly link nitrate as a cause for macroinvertebrate impairment in this reach. Concentrations are elevated at times, but usually fairly low for most of the year. The highest concentrations are observed in late spring then tail off by mid-summer when flows drop. This is typical of many streams that have a fair amount of tile drainage or shallow groundwater flow. While the biology may show some slight response to nitrate stress, it's not clear if the response is due to other types of stress identified (i.e., habitat and TSS) that may mimic nitrate response. Regardless, nitrate should be reduced in this reach to prevent the macroinvertebrate community from further degrading.

Minimum DO levels are sufficient in this reach, but DO and eutrophication was inconclusive as a potential stressor. There was some high daily flux observed, and some high phosphorus, but DO levels never fell below 5 mg/L given a fairly decent chemical dataset. The majority of the biological response metrics also did not point to DO related stress and did not provide much indication suggesting DO was a likely stressor at this time. Overall the information was very mixed, and difficult to discern given the large stream reach. Additional information is needed to understand the differences throughout the North Fork.

Flow Alteration and Connectivity were ruled out as stressors given the low percentage of modified streams and adequate migratory fish species/mussels found throughout the AUID.

Table 17. Summary of stressor determinations for the North Fork Zumbro

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen and Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
North Fork Zumbro	07040004-971	---	o	o	●	●	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.6 Tributaries to the North Fork Zumbro

The impaired tributary streams in the North Fork Watershed are all contained within Goodhue County. This section will discuss five different macroinvertebrate impairements in this watershed (Figure 52).

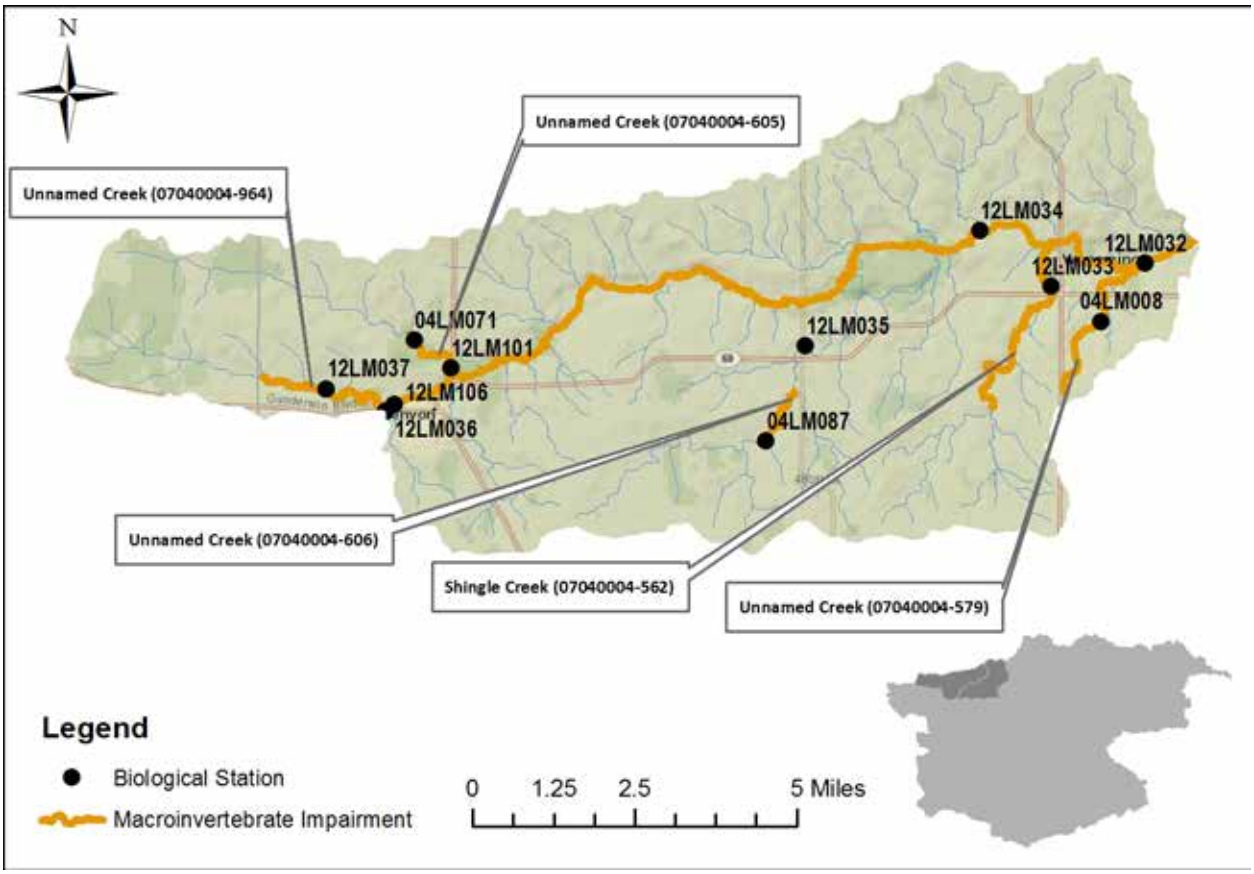

Figure 52. Map of the North Fork Watershed tributary streams, biological stations, and impaired AUIDs.

4.6.1 Unnamed Creek (964)

Biological and background information

Unnamed Creek (07040004-964) has one biological station, 12LM037, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 5 (Southern Streams RR). The MIBI impairment threshold for this class is 37, with an average score per metric of 3.7 needed to meet that threshold. 12LM037 has a low MIBI score of 26.51, and scored above the average metric in 4 out of 10 categories, and scored a zero on 3 metrics. An overall trend with all of the Class 5 North Fork Zumbro Tributaries is to have higher metric scores in the ClingerChTxPct, InsectTxPct metrics, and metric score of zero for Plecoptera. Site 12LM037 follows that trend.

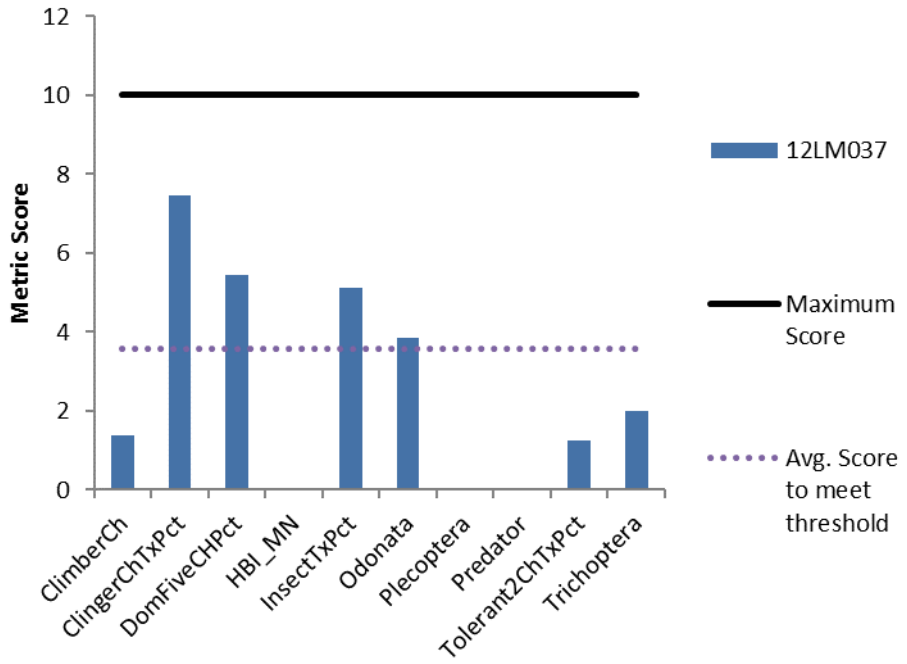

Figure 53. Macroinvertebrate IBI metrics for Unnamed Creek (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

Unnamed Creek had a total of 10 DO readings taken from 2012-2014. These values ranged from 8.26-13.25 mg/L. Additionally, 11 phosphorus samples were taken from this reach. These values ranged from 0.015-0.395 mg/L with only one value exceeding the 0.15 mg/L Phosphorus standard in the South nutrient region. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

Biologically, the macroinvertebrate assemblage in Unnamed Creek had few EPT individuals (15.32%) and overall taxa (15) when compared to all other Minnesota streams. Site 12LM037 also had a higher amount of DO tolerant individuals (12.46%) and a below average DO TIV score when compared to all other sites in the Zumbro River Watershed as well as a below average amount of DO intolerant species (5) when compared to all other Class 5 sites.

The fish community in this reach had a high amount of serial spawning (30.33%) and few late maturing (8.22%) individuals. These results are characteristic of a fish community negatively impacted by DO conditions. This reach did however, have a higher amount of sensitive individuals (19.37%) when compared statewide and also an average DO TIV score when compared to all other biological sites in the Zumbro River Watershed.

While many biological metrics indicate potential stress due to the DO conditions, the observed DO and Phosphorus values rarely exceeded their respective standard. The elevated phosphorus value could potentially indicate problems with eutrophication and DO flux, but additional data are needed to understand this dynamic. The presence of many sensitive fish individuals and average fish DO TIV score show inconsistent biological response; therefore, low DO and eutrophication is inconclusive as a stressor at this time. Continuous DO monitoring is recommended to better understand impacts low DO levels are having on the fish and macroinvertebrate communities.

Nitrate

During the fish sample, the nitrate concentration at 12LM037 was 9.5 mg/L (July 10, 2012). There were nine additional samples taken on this reach in 2014, from April through September. The nitrate concentration ranged from 7.6 mg/L in September, up to 25 mg/L in June. The average concentration was 18.1 mg/L. Five of the nine samples were above 20 mg/L, all taken in May and June.

Station 12LM037 had an average taxa count (TaxaCountAllChir; 33). The average taxa count for this macroinvertebrate Class 6; (Southern Forest Streams GP) is 33. Trichoptera are found to be generally sensitive to elevated nitrate concentrations. There were 4 Trichoptera taxa, which is above the average for the Southern Forest Streams GP stations of the LMB (2.2). Additionally, the percentage of Trichoptera individuals was above the average, at 12.1% (average is 5.3%). However, this site had 86% nitrate tolerant individuals. At 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the Class 6 MIBI. Nitrate intolerant taxa were not found. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. Non-hydropsychid trichoptera are all caddisflies that do not spin nets. Station 12LM037 had only 2.70% non-hydropsychid trichoptera. This is below average compared to all biological sites in the LMB (3.39%) but just above the average for this stream class (2.21%).

This site is dominated by *Physa* (snails) and *Chironomidae* (midges) which suggest degraded conditions. This site had a very high percentage of nitrate tolerant individuals, and few sensitive individuals present overall. There were four Trichoptera taxa, which is above average, but many of them are rather tolerant (Hydropsychidae). Nitrate concentrations in this reach are elevated, and should be reduced if possible. Nitrate is a stressor to Unnamed Creek.

Suspended sediment

At the time of biological monitoring in 2012, as part of a one-time chemistry sample, the TSS value recorded at site 12LM037 was 11 mg/L. Additionally; TSS and transparency samples were collected between April and September of 2014. There were nine total TSS values that ranged from 1.6 mg/L to 280 mg/L, with an average value of 37.2 mg/L. The only value to exceed the 65 mg/L TSS standard was the 280 mg/L value from a June 18th rain event. There were seven total secchi tube transparency values recorded that range from 3 cm to 100 cm, with an average value on 75.8 cm.

The macroinvertebrate metrics do not show a consistent response to TSS. The index score, tolerant taxa and percentage are all less than average, and do not signal stress (Table 18). However, there were zero intolerant and plecoptera taxa, a low percentage of collector filterers, all of which can decrease with increases in TSS stress. These metrics can also reflect a response from another stressor. TSS doesn't appear to be a likely stressor at this time given the weak macroinvertebrate response, and lack of strong chemical information to support. Fish metrics that often respond to TSS also do not show a response. TSS is not a stressor to the macroinvertebrate community of Unnamed Creek at this time.

Table 18. Macroinvertebrate metrics relevant to TSS for stations in Unnamed Creek compared to statewide averages for southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM037	16.42	**0.00**	5.00	16.19	**12.61**	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to TSS stress	↑	↓	↑	↑	↓	↓

Habitat

Unnamed Creek (07040004-964) had a qualitative habitat assessment at site 12LM037 during the fish sampling event in 2012. The resulting MSHA score for this site was 64.1, which is considered to be fair (Figure 54). Limiting the MSHA at this site was row crop agriculture in the surrounding land use, light stream shading the dominance of sand and silt substrates, moderate embeddedness, and limited depth variability.

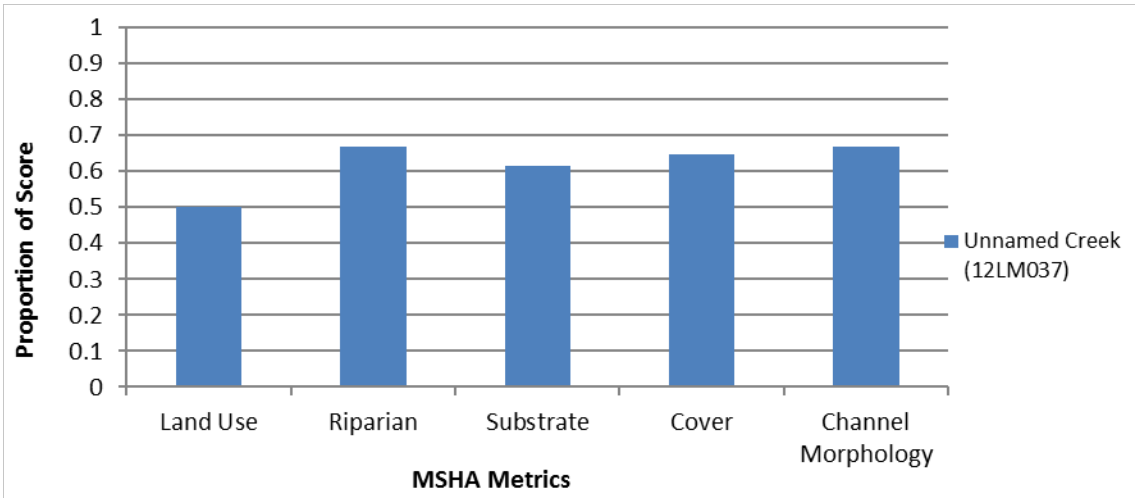

Figure 54: MSHA metric value scores at site 12LM037 along Unnamed Creek (07040004-964).

Site 12LM037 had its macroinvertebrate sample taken from equal parts of the woody debris, overhanging vegetation, and riffle habitat available. This sample showed that this stream has an above average amount of burrower (11.41%) individuals when compared to all other Class 5 streams. Burrower species prefer habitats consisting of fine sediments, and clingers require course substrates or woody debris. This site also had a lower amount of EPT (15.32%), clinger (32%) and sprawler (15.32%) individuals, while also having an above average amount of legless individuals (74.47%) when compared to all other Minnesota streams. Legless macroinvertebrates tend to be very tolerant of degraded habitat. These results are common in streams with poor habitat conditions.

The fish assemblage along Unnamed Creek had increased numbers of benthic insectivore (26.42%), simple lithophilic spawning (51.27%), riffle dwelling (30.92%), and darter/sculpin/round-bodied sucker (26.03%) individuals when compared to all other Minnesota streams. These results indicate the fish community is not affected by poor habitat conditions.

The sand and silt substrates present has led to an increase in the numbers of burrower individuals and few sprawler/clinger species along this reach. The remaining habitat related macroinvertebrate metrics scored poorly as well. The fish IBI metrics related to habitat scored very well, but fish are much more mobile than macroinvertebrates. The lack of habitat in Unnamed Creek is stressing the macroinvertebrate assemblage at this time.

Flow alteration and connectivity

Unnamed Creek (07040004-964) is completely a natural channel according to the Altered Watercourses GIS layer of Minnesota. Upstream of the impaired reach, many miles of altered water systems exist. Currently, the effects of channelization do not appear to be negatively impacting the biotic conditions in Unnamed Creek.

Conclusions and recommendations

The macroinvertebrate community in Unnamed Creek is being stressed by elevated nitrate and poor habitat conditions (Table 19). A lack of suitable habitat for macroinvertebrates is due to the dominance of sand and silt substrates which show a disproportionately higher number of burrowing and legless macroinvertebrates (that can tolerant embeddedness and poor habitat) and few clingers, which require course substrates or woody debris. The beaver dam, on this reach may also be impacting habitat conditions and availability. The elevated nitrate concentrations (max of 25 mg/L) are also stressing the macroinvertebrates as evidenced by high percentages of nitrate tolerant macroinvertebrates and a complete lack of intolerant taxa. Overall, macroinvertebrates are generally more sensitive of elevated nitrate, and have different habitat requirements than fish, which is why fish do not appear to be showing the same stress. All of the nitrate sources are not completely understood, but the highest concentrations are in May and June, when the highest proportion of stream water comes from tile drainage. As noted in the statewide nitrogen study, nitrate reaches waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013).

DO was inconclusive as a stressor. While many biological metrics indicate potential stress due to the DO conditions, the observed DO values did not exceed the respective standard. One Phosphorus sample did exceed the 0.15 mg/L standard, while the other samples were well below this level. Further monitoring is needed to determine if DO conditions are negatively impacting the biological conditions.

TSS was ruled out as a potential stressor to this reach. There was very little evidence (chemical or biological) that supported TSS as a stressor.

Table 19. Summary of stressor determinations for Unnamed Creek

Stream Name	AUID	Stressors: Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Unnamed Creek	07040004-964	---	o	●	---	●	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.6.2 Spring Creek Tributary

Biological and background information

Spring Creek Tributary (07040004-605) has one biological station, 12LM101, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 5 (Southern Streams RR). The MIBI impairment threshold for this class is 37, with an average score per metric of 3.7 needed to achieve that threshold. 12LM101 has an MIBI score of 23.62, the lowest of all the North Fork Zumbro tributaries with biological samples collected. The three metric scores that are above the average score of 3.7 are ClingerChTxPct, InsectTxPct, and Tolerant2ChTxPct. The only metric score that was below the average and not zero was the HBI_MN metric score of 1.84. This community is not diverse, and is much degraded. 12LM101 does follow the same trend among other Class 5 North Fork Zumbro tributary streams of the highest metric scores in the ClingerChTxPct, and InsectTxPct metrics, and a zero metric score for Plecoptera.

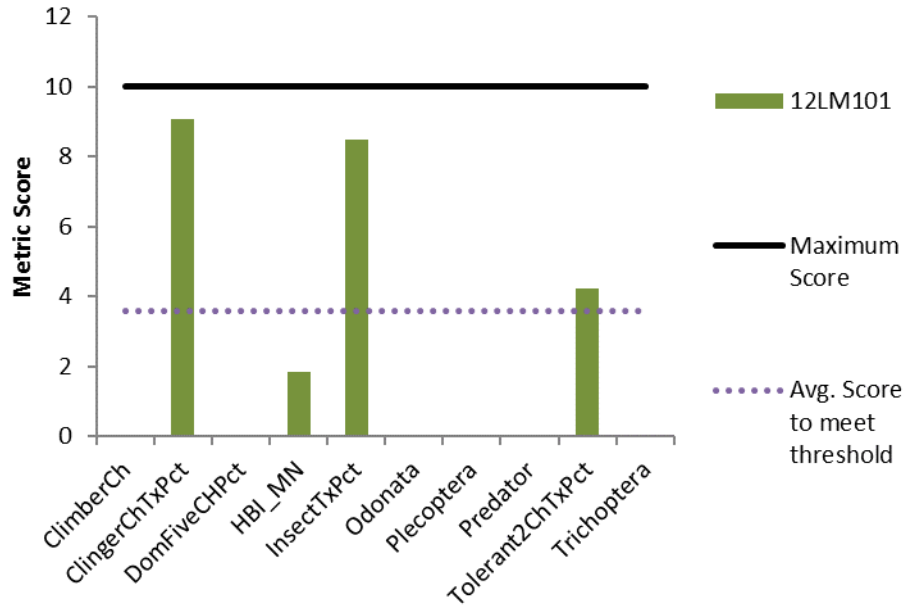

Figure 55. Macroinvertebrate IBI metrics for Spring Creek (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

From 2012-2014, a total of 13 DO measurements were taken from Spring Creek Tributary (07040004-605). These values ranged from 8.71-12.41 mg/L. None of these measurements were taken before 9 AM. Additionally, 11 phosphorus samples were taken from this stream reach from 2012-2014. These values ranged from 0.018-0.258 mg/L with only one value above the 0.15 mg/L standard for phosphorus in the South nutrient region. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

Biologically, the macroinvertebrate community at site 12LM101 had a high amount of EPT (42.01%) individuals. This stream reach also had very few overall taxa (10). Site 12LM101 had a very high amount of DO intolerant taxa (8), while not having any taxa that are tolerant of DO. The DO TIV score was above average when compared to all other Class 5 streams.

The fish assemblage in this reach had very few late maturing (1.9%) as well as a very high amount of serial spawning (59.49%) individuals. However, this stream also had many sensitive individuals (58.86%), and an above average DO TIV score when compared to all other streams statewide.

Based on the observed DO data, the low phosphorus values, as well as the majority of the biological metrics, low DO and eutrophication are not stressors to the impaired macroinvertebrate community.

Nitrate

During fish sample, the nitrate concentrations at 12LM101 was 19 mg/L. There were 10 additional samples taken on this reach in 2014, from April through October. The nitrate concentration ranged from 1.3 mg/L in October, up to 22 mg/L in June. The average concentration was 13.9 mg/L. Three of the ten samples were above 20 mg/L; taken in May and June. The lower concentrations were seen later in the year during baseflow conditions (July-October).

The one macroinvertebrate sample taken at station 12LM101 had 88.36% nitrate tolerant species collected. At 83.78%, there is only a 10% probability of meeting the MIBI. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At this station, taxa richness was below average,

at only 23. Similarly, there were few Trichoptera taxa overall (2), and only one generally intolerant taxon. There were no nitrate intolerant taxa at station 12LM101. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These trichoptera include all caddisflies that do not spin nets. The percentage at this station was 0%, while the average for sites in the LMB is 3.39%.

All macroinvertebrate metrics show response consistent with nitrate degradation. Interestingly, there was a higher percentage of sensitive fish species (58%) and not that many tolerant fish species (26%). The sensitive species found at this station were fantail darter, longnose dace, reside dace, and hornyhead chub. However, the dominant sensitive species found (fantail darter; 76 individuals) is not particularly sensitive to high nitrate, since its weighted mean value for nitrate sensitivity is in the upper portion of Minnesota's taxa. Given all the information, nitrate is considered a stressor in this reach, and concentrations should be reduced to prevent further degradation of the biological community.

Table 20. Macroinvertebrate metrics relevant to TSS for stations in Trout Brook compared to statewide averages for southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (sampling year)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM101 (2012)	**18.87**	**0.00**	4.00	**67.61**	42.01	**0.00**
04LM071 (2004)	14.25	**1.00**	4.00	4.03	**20.07**	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Spring Creek Tributary (07040004-605) had a qualitative habitat assessment take place at its biological site, 12LM101, during its fish sampling event in 2012. The resulting MSHA score for this site was 80.65 (Good), which is one of the highest scores within the Zumbro River Watershed. Limiting the MSHA at this site was the presence of sand located in the pools within the reach, light embeddedness and moderate/high channel stability.

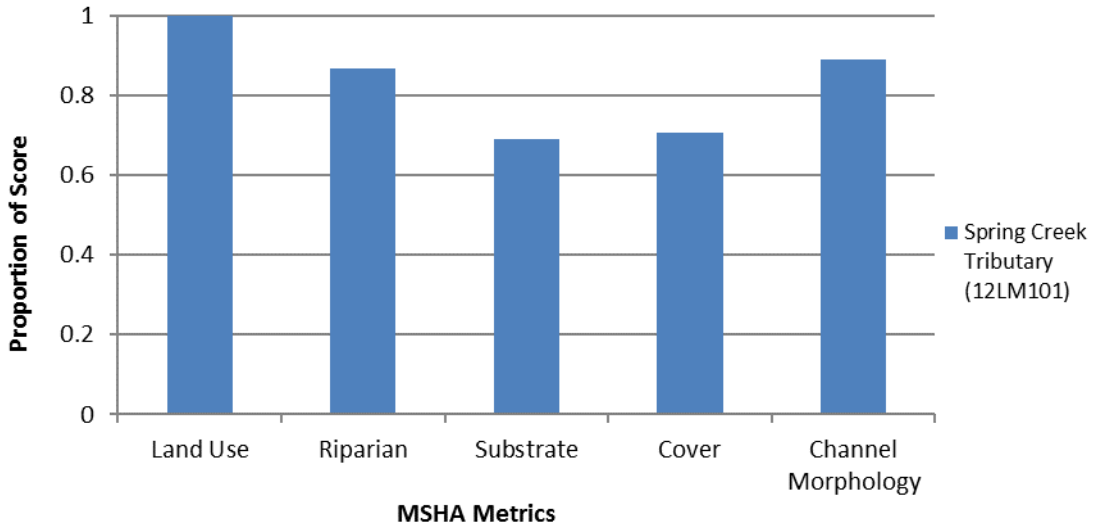

Figure 56. MSHA metric value scores at site 12LM101 along Spring Creek Tributary (07040004-605).

The macroinvertebrate sample at 12LM101 was taken from the riffle/rock habitat available. The community contained few burrower (1.88%) individuals. Burrower species prefer habitat consisting of many fine substrates. This reach also had an increased amount of climber (36.36%), clinger (52.66%) and EPT (42.01%) individuals. These results reflect a macroinvertebrate community not affected by poor habitat conditions.

The fish assemblage at 12LM101 had an increased amount of benthic insectivore (66.46%), darters/sculpin/round-bodied sucker (55.06%), riffle dwelling (66.46%) individuals, while also having very few tolerant individuals (26.58%). These results signal a fish community not limited by the present habitat conditions.

Based on the good MSHA score, as well as the high scoring habitat related biological metrics, the lack of habitat is not a stressor to the impaired biological communities in Spring Creek Tributary (07040004-961) at this time.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that Spring Creek Tributary (07040004-961) is completely natural. Smaller sections in the headwaters of this stream have been altered. Modified or altered sections have the potential to reduce habitat conditions in streams. However, that is not the case in this stream reach as site 12LM101 had one of the highest MSHA scores in the Zumbro River Watershed.

Water levels in Spring Creek Tributary can get low in the fall (Figure 57). These levels may limit fish passage at times. Further monitoring of the flow conditions at this location may be needed to ensure low flow does not create fish passage issues and lead to a fish impairment. However, flow alteration and connectivity is not a stressor to the impaired macroinvertebrate community in this reach at this time.

Figure 57. Low stream flow at site 12LM101 during the fall of 2014.

Conclusions and recommendations

The macroinvertebrate community in Spring Creek is being stressed by elevated nitrate (Table 21). All the macroinvertebrate metrics show a consistent response with nitrate degradation. The maximum concentration collected on this reach was 22 mg/L, with all the samples taken in May and June of 2014, above 20 mg/L. Nitrate needs to be reduced in this watershed and is likely a result of land applications of nutrients and also tile drainage, which is common in this watershed. Seeps have also been noted in the reach, so there may be a groundwater component to the elevated nitrate as well. The proportion of these sources is not completely understood, but the highest concentrations are in May and June, when the highest proportion of stream water comes from tile drainage. As noted in the statewide nitrogen study, nitrate reaches waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013).

Habitat and DO were ruled out as potential stressors in this reach. There is sufficient habitat available, which includes rock substrate, good riparian area, and diverse habitat types. Station 12LM101 also has one of the highest MSHA scores of the entire Zumbro Watershed. DO levels also are suitable with no sign of biological stress. TSS is considered inconclusive due to a mixed biological response and limited

chemical data to adequately understand concentrations. Additional information regarding the duration of TSS after storm events would help understand if TSS is impacting the biology.

Table 21. Summary of stressor determinations for Spring Creek Tributary

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Spring Creek Tributary	07040004-605	---	---	●	o	---	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.6.3 Spring Creek (606)

Biological and background information

Spring Creek (07040004-606) has one biological station, 04LM087, sampled in 2004, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 6 (Southern Forest Streams GP). The MIBI impairment threshold for this class is 43, with an average score per metric of 4.3 needed to achieve that threshold. 04LM087 has an MIBI score of 34.83. There are scores for every metric except for Intolerant2Ch, and two metrics exceed the average score needed to meet the threshold; DomFiveCHPct and TaxaCountAllChir.

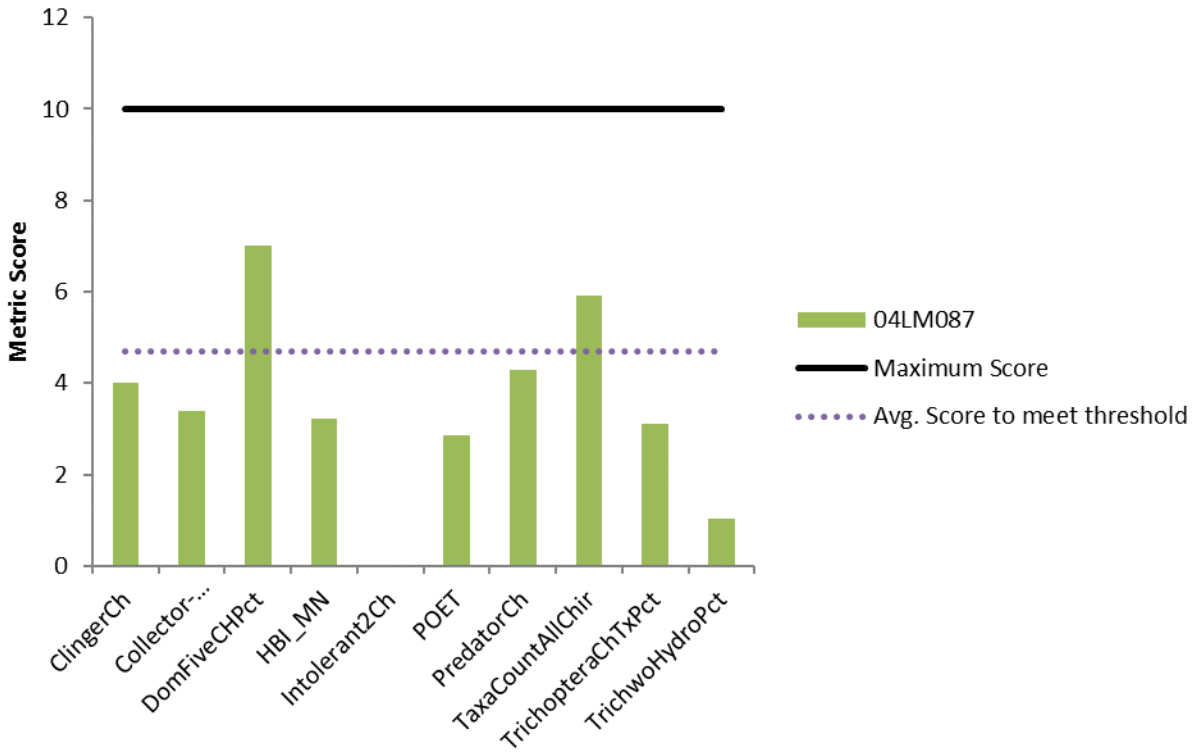

Figure 58. Macroinvertebrate IBI metrics for Spring Creek (Class 6; Southern Streams Glide/Pool).

Dissolved oxygen and eutrophication

Spring Creek had a total of 10 DO readings taken from 2012-2014. These readings ranged from 5.68-17.04 mg/L. Continuous DO monitoring was collected along Spring Creek at site 04LM087 (S007-920) during July 2014 (Figure 58). Daily DO values frequently fell below the 5 mg/L daily minimum standard. The daily flux often exceeded 7 mg/L. Flux in excess of 3.5 mg/L can often signal stress due to the DO conditions.

Additionally, 11 phosphorus samples were taken along Spring Creek from 2004-2014. These values ranged from 0.013-0.244 mg/L with one sample above the 0.10 mg/L phosphorus standard. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

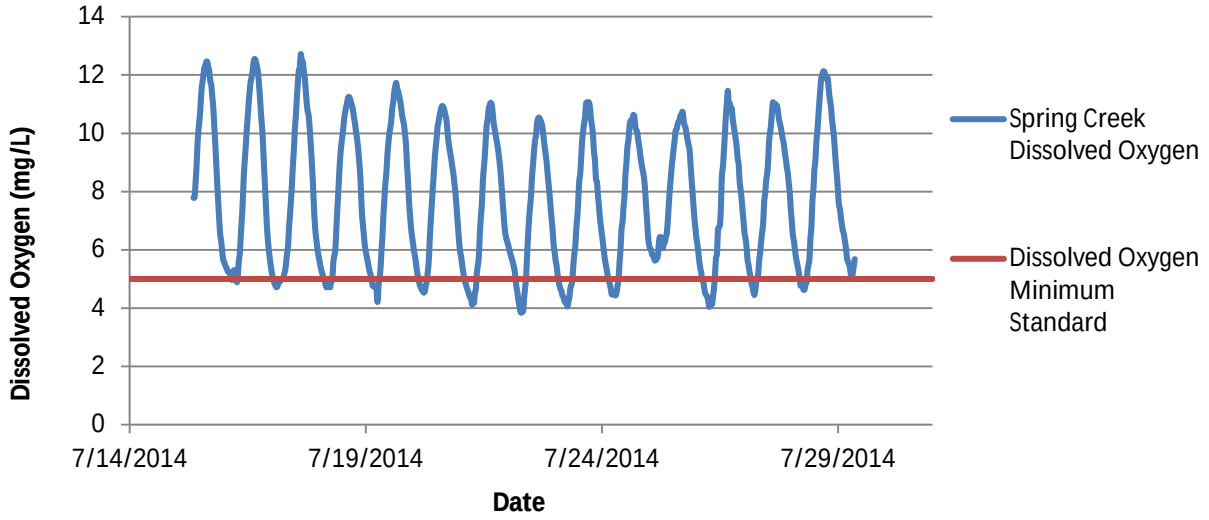

Figure 59. Continuous DO data along Spring Creek (07040004-606) in 2014.

The macroinvertebrate community in Spring Creek had very few EPT (1.46%) individuals, while also having a high amount of low DO tolerant individuals (48.56%) and tolerant species (7). The DO TIV score for the macroinvertebrate assemblage was below average when compared to all other Class 6 sites.

The fish assemblage in this reach had a below average amount of serial spawning individuals (16.79%) when compared statewide, but this reach had few sensitive individuals (4.82%), while also having a below average amount of late maturing fish individuals (16.96%) and a lower DO TIV score when compared to all other reaches within the Zumbro River Watershed.

The phosphorus levels in Spring Creek stay relatively low for the most part, but based on the continuous DO data, the values consistently fall below the 5 mg/L minimum standard, while also having a daily flux greater than 3.5 mg/L. The water velocity was noted as slow for most of the year, with no riffles, which may be contributing to the poor oxygen conditions. At this time, it is not clear if eutrophication is contributing to the low DO, due to lack of connecting information. Further monitoring, to include additional phosphorus, chlorophyll-*a*, and BOD data would be helpful. The majority of the DO related biological metrics are in agreement that low DO conditions are stressing the impaired macroinvertebrate community in Spring Creek.

Nitrate

During fish sample, the nitrate concentration at 04LM087 was 5.7 mg/L in August of 2004 and 23 mg/L in June of 2004. There were nine additional samples taken on this reach, from April through September of 2014. The nitrate concentration ranged from 1.6 mg/L in July, up to 22 mg/L in June. The average concentration was 12.6 mg/L. Two of the nine samples were above 20 mg/L; both collected in June. All four samples in June scored 15 mg/L and above.

Station 04LM087 had a better than average taxa count (TaxaCountAllChir; 39). The average taxa count for this macroinvertebrate Class 6; (Southern Forest Streams GP) is 33. Trichoptera are found to be generally sensitive to elevated nitrate concentrations. There were only 2 Trichoptera taxa, which is just below the average for the Southern Forest Streams GP stations of the LMB (2.2). Similarly, the percentage of Trichoptera individuals was right at the average; at 5.12% (Average is 5.3%). This site had 89% nitrate tolerant individuals, which is high. At 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. There weren't any nitrate intolerant taxa found. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly)

individual percentages in warmwater streams. Non-hydropsychid trichoptera are all caddisflies that do not spin nets. Station 04LM087 had only 0.29% non-hydropsychid trichoptera. This is below average compared to all biological sites in the LMB (3.39%) and of this stream class (2.21%).

Overall, the macroinvertebrate metric response and nitrate concentrations demonstrate nitrate is a stressor to Spring Creek.

Suspended sediment

At the time of biological monitoring in 2004, as part of a one-time chemistry sample at site 04LM087 two TSS values were recorded. On June 24, 2014, TSS was 2.8 mg/L, and on August 23, 2014, TSS was 3.6 mg/L. Additionally, nine TSS values were recorded during the months April through September in 2014. These values ranged from <1-100 mg/L with an average value of 18.45 mg/L, and only one exceeded the 65 mg/L TSS standard. This sample was taken during a storm event in June.

The macroinvertebrate metrics do not show a consistent response to elevated TSS. The index score, tolerant taxa and percentage are all less than average, and do not signal stress (Table 22). However, there were zero intolerant and plecoptera taxa, a low percentage of collector filterers, all of which can decrease with increases in TSS stress. However, these metrics can also reflect a response from another stressor. TSS doesn't appear to be a likely stressor at this time given the weak macroinvertebrate response and lack of strong chemical information. Fish metrics that often respond to TSS also do not show a consistent response. TSS is not a stressor to the macroinvertebrate community of Spring Creek.

Table 22. Macroinvertebrate metrics relevant to TSS for stations in Spring Creek compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
04LM087 (2004)	14.30	**0.00**	9.00	8.78	**13.12**	**0.00**
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Spring Creek (07040004-606) had qualitative habitat assessments take place at its biological station, 04LM087, during the fish sampling events in 2004 and 2012. The average MSHA score for this site was 67.15, which is considered to be good. Limiting the MSHA at this site was the surrounding land use, a narrow riparian buffer, light stream shading, moderate embeddedness, poor sinuosity, a lack of riffles, and limited depth variability.

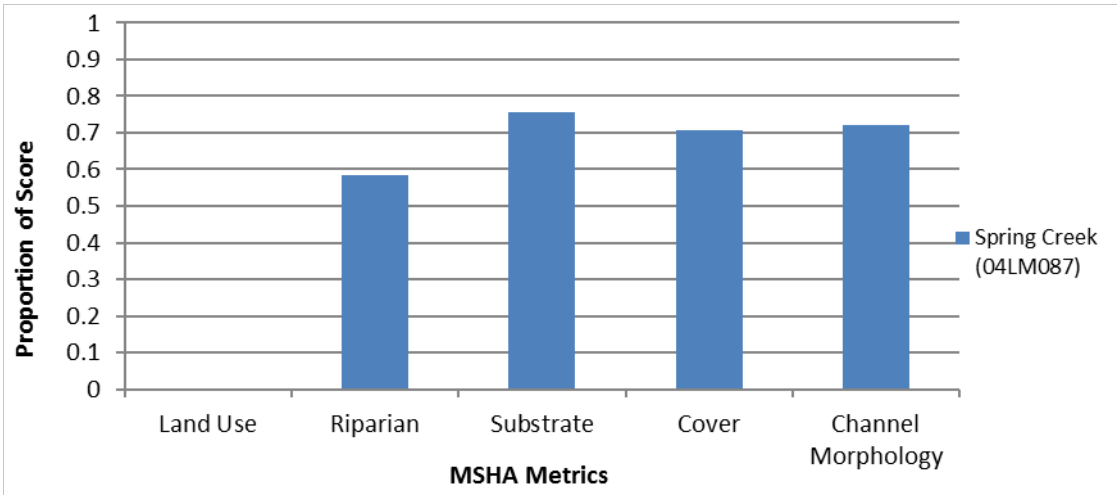

Figure 60. MSHA metric value scores at site 04LM087 along Spring Creek (07040004-606).

The macroinvertebrate sample at site 04LM087 was taken from equal parts riffle and overhanging vegetation. This sample contained extremely high numbers of burrower individuals (44.89%). Burrower species prefer fine substrate habitats. This reach also had an increased number of legless individuals (96.79%). Legless species are typically very tolerant and include species like midges and snails. Additionally, Spring Creek had below average numbers of climber (18.66%), clinger (19.24%) and EPT (1.46%) individuals when compared statewide. These metrics typically score low in streams with poor habitat conditions.

The fish community along this reach had above average numbers of benthic insectivore (31.65%), darter/sculpin/round-bodied sucker (31.47%), riffle dwelling (29.99%), and simple lithophilic spawning (33.72%) individuals. These results signal that the fish community is not affected by poor habitat conditions.

While the MSHA and habitat related fish metrics score well along Spring Creek (07040004-606), the macroinvertebrate community is showing signs of stress. Therefore, the lack of habitat is a stressor to the impaired macroinvertebrate community in this reach.

Flow alteration and connectivity

Spring Creek (07040004-606) was determined to be a 100% natural stream section according to the Altered Watercourses GIS layer for Minnesota streams. Immediately upstream of this AUID, there is a significant amount of channelized stream sections. These channelized sections could eventually lead to degraded habitat conditions, eroded banks, etc.

Currently, this portion of Spring Creek is completely natural and seems to be void of many poor scoring habitat metrics often related to flow alteration. At this time, flow alteration and connectivity is not a stressor to the biological communities of Spring Creek, however, it will be important to further monitor the effects of the upstream channelization moving forward.

Conclusions and recommendations

The macroinvertebrate community in Spring Creek is being stressed by DO, nitrate, and habitat (Table 23). DO concentrations fell consistently below the 5 mg/L standard (during a two-week deployment in 2014). The biological community reflects these conditions; with a high percentage of low DO tolerant fish and macroinvertebrates. Nitrate levels are also elevated with concentrations in June exceeding 20 mg/L. All four samples taken in June exceeded 15 mg/L, demonstrating some duration of high nitrate concentrations. The highest nitrate concentrations are in May and June, when the highest

proportion of stream water comes from tile drainage. As noted in the statewide nitrogen study, nitrate reaches waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013). The physical habitat issues are clearly demonstrated with the macroinvertebrate community composition given the abundance of burrowing and legless macroinvertebrates (which can thrive in poor substrate conditions) and a lack of clinger and EPT taxa which require stable clean substrates.

The macroinvertebrate metrics do not show response consistent with elevated TSS, nor do the chemical samples provide enough information to suggest TSS stress. Similarly, Flow Alteration and Connectivity were ruled out as potential stressors, due to little biological indication, despite a fair amount of channelization in the AUID immediately upstream. This channelized section may lead to degraded habitat conditions on this natural AUID and should be monitored over time.

This biological station should be re-sampled because the data used for assessment is dated (from 2004). It would be beneficial to verify the current condition of this stream and verify the conditions haven't changed.

Table 23. Summary of stressor determinations for Spring Creek.

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Spring Creek	07040004-606	---	●	●	---	●	---

4.6.4 Shingle Creek (562)

Shingle Creek (07040004-562) has one biological station, 12LM033, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 5 (Southern Streams RR). The MIBI impairment threshold for this class is 37, with an average score per metric of 3.7 needed to achieve that threshold. 12LM033 has an MIBI score of 27.44. Seven out of 10 metric scores are poor, or below the average score needed. However, the ClingerChTxPct metric score was the maximum of 10, and the second highest metric score was 4.89 (InsectTxPct). 12LM033 does follow the same trend among other Class 5 North Fork Zumbro tributary streams of the highest metric scores in the ClingerChTxPct, and InsectTxPct metrics.

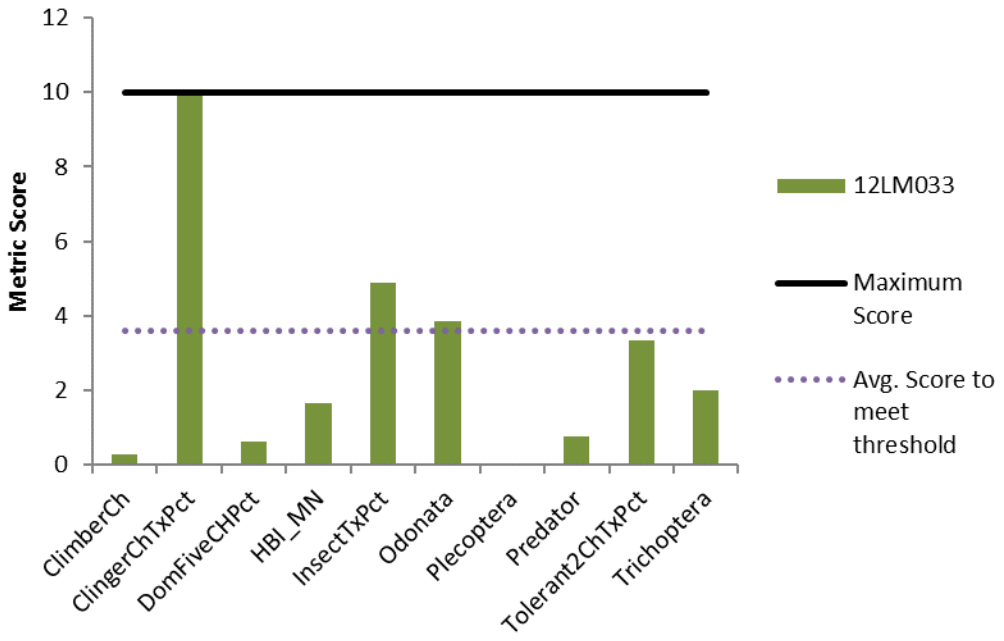

Figure 61. Macroinvertebrate IBI metrics for Shingle Creek (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

Shingle Creek had a total of nine DO measurements taken from site 12LM033 (S007-921) from 2012-2014. These values ranged from 8.95-14.86 mg/L. None of these measurements were taken before 9 AM. Additionally, nine phosphorus samples were taken along Shingle Creek from 2012-2014. These values ranged from 0.028-0.224 mg/L with two measurements above the 0.10 mg/L phosphorus standard. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

The macroinvertebrate assemblage in Shingle Creek had a high amount of EPT individuals (55.59%), a low amount of DO tolerant individuals (3.93%), and a high DO TIV score. This indicates that the community isn't dominated by individuals that are commonly found in low DO waters.

The fish community in Shingle Creek had few late maturing individuals (9.27%) and a high amount of serial spawning (29.12%) individuals. Site 12LM033 also had a high amount of sensitive (23.78%) individuals. The DO TIV score for fish at this site was below average when compared to all other sites within the Zumbro River Watershed, which indicates the fish community is somewhat tolerant of low DO but could be responding to other types of stress.

Shingle Creek is impaired for aquatic life due to its macroinvertebrate assemblage. The observed DO levels, as well as the high scoring biological metrics and TIV score for the macroinvertebrate community, all signal that this community is not being stressed by low DO levels, and DO and eutrophication are not stressors at this time.

Nitrate

During fish sample, the nitrate concentration at 12LM033 was 0.82 mg/L (June 13, 2012). There were eight additional samples taken on this reach in 2014, from April through September. The nitrate concentration ranged from 3.3 mg/L in September, up to 14 mg/L in June. The average concentration was 9.5 mg/L. The four highest samples were from June alone, all 9 mg/L and above.

The one macroinvertebrate sample taken at station 12LM033 had 88.27% nitrate tolerant species collected. At 83.78%, there is only a 10% probability of meeting the MIBI threshold. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At this station, taxa richness was below average, at only 32. Also, there were an average number Trichoptera taxa overall (4), and two generally intolerant taxa. There were no nitrate intolerant taxa at station 12LM033. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These trichoptera include all caddisflies that do not spin nets. The percentage at this station was 0.39%, while the average for sites in the LMB is 3.39%.

The macroinvertebrate response, especially the percentage of nitrate tolerant species, and complete lack of nitrate intolerant and non-hydropsychid Trichoptera suggest nitrate is an issue in Shingle Creek. There were two generally intolerant taxa but they were not abundant (made up less than 1% of the community). Also, even though there were 50% Trichoptera, the dominant species was a very tolerant caddisfly (*Cheumatopsyche*). Overall the macroinvertebrate community metrics and stream concentrations suggest nitrate is a stressor in this reach and concentrations should be reduced.

Suspended sediment

At the time of biological monitoring in 2012, site 12LM033 had a TSS concentration 6.8 mg/L. In addition, there were eight TSS values and six secchi transparency values recorded from April through September 2012. The TSS values range from 2.8-170 mg/L with an average of 30.75 mg/L. Only one value exceeded the TSS standard of 60 mg/L. The transparency values range from 9-100 cm with an average value of 66 cm.

The macroinvertebrate metrics do show some consistent response to elevated TSS. The index score, intolerant taxa and tolerant taxa percentage, and plecoptera percent are all signaling stress (Table 23). However, there were only seven tolerant taxa, a good percentage of collector filterers, all of which can decrease with increases in TSS stress. Fish metrics that often respond to TSS also do not show a consistent response (only 2 of 10 respond). Additional chemical information on this reach would be helpful. The macroinvertebrate community does show some indication of potential TSS issues, but the response may be due to another stressor. With the lack of a strong chemical dataset, and mixed response between the fish and macroinvertebrate communities, it's difficult to conclude that TSS is a stressor at this time. TSS is inconclusive as a stressor to the macroinvertebrate community of Shingle Creek.

Table 24. Macroinvertebrate metrics relevant to TSS for stations in Shingle Creek compared to statewide averages for southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM033	**19.24**	**1.00**	7.00	**75.24**	53.67	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to TSS stress	↑	↓	↑	↑	↓	↓

Habitat

Shingle Creek (07040004-562) had a qualitative habitat assessment take place at its biological monitoring station, 12LM033, during the fish sampling event in 2012. The MSHA score for this site was 44.8, which is considered to be fair. Limiting the MSHA (Figure 63) at this site was the row crops in the surrounding land use, a limited riparian buffer, the presence of some severe bank erosion (Figure 62), moderate stream shading, sand and silt substrates, moderate embeddedness, excess sedimentation in the runs and pools, sparse fish cover, and low channel stability.

Figure 62. Eroding bank at site 12LM033.

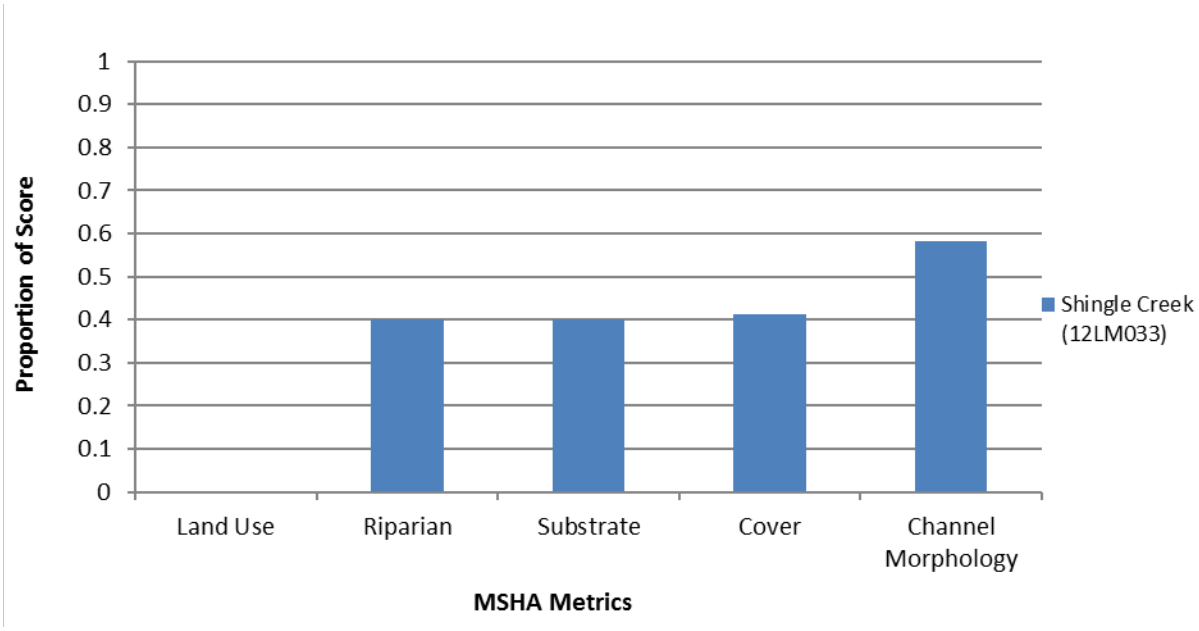

Figure 63. MSHA metric value scores at site 12LM033 along Shingle Creek (07040004-562).

The macroinvertebrate sample at site 12LM033 was collected from equal parts riffle and overhanging vegetation habitat. This sample contained a decreased amount of burrower (2.56%) and legless (37.38%) individuals. These types of macroinvertebrates are typically much more abundant in degraded habitat conditions. This reach also had above average amounts of climber (21.73%), clinger (70.29%), and EPT (55.59%) individuals. These results are common in streams with good habitat conditions.

The fish assemblage along this reach had elevated numbers of benthic insectivore (24.34%), darter/sculpin/round-bodied sucker (23.22%), riffle dwelling (40.45%), and simple lithophilic spawning (42.7%) individuals. These results all reflect a fish community that is not negatively impacted by the habitat conditions. Furthermore, this stream reach also had a below average amount of tolerant individuals (43.82%) when compared statewide.

While the habitat conditions can certainly be improved in Shingle Creek, the habitat related biological metrics scored well for both assemblages and do not provide strong evidence that lack of habitat is driving stress in this reach; therefore, lack of habitat is not considered a stressor at this time.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 4.53-mile-long reach of Shingle Creek (07040004-562) is 100% natural. The only designated modified sections are in the far reaching headwaters of watershed and short sections of small tributaries. These sections likely have very minimal impact on the Shingle Creek biological impairment and are not a stressor at this time. There also are no known connectivity issues that would be contributing to the macroinvertebrate impairment on this reach.

Conclusions and recommendations

The macroinvertebrate community in Shingle Creek is being stressed by elevated nitrate (Table 25). The macroinvertebrate community is dominated by species tolerant to high nitrate, while containing few intolerant or sensitive species. There wasn't a large chemical dataset, but enough to show that the concentrations are moderately elevated, and do persist for a period of time (4 samples above 9 mg/L in June of 2014). Land use and tile drainage are likely contributors to the high nitrates observed.

TSS is inconclusive as a stressor and could use additional chemical information to understand the variation of concentrations in this reach. The macroinvertebrate community does show some indication of potential TSS issues, but the response may be due to another stressor identified (nitrate). With the lack of a strong chemical dataset, and mixed response between the fish and macroinvertebrate communities, it's difficult to make the stressor connection to TSS.

DO/Eutrophication and habitat were ruled out as stressors. While the habitat conditions could use improvement, the communities themselves do not appear to show habitat related stress with an abundance of fish and macroinvertebrate individuals that are typically found in good habitat conditions. There was also no indication that the DO regime was inadequate or that the biology suggested DO was a stressor at this time.

Table 25. Summary of stressor determinations for Shingle Creek.

Stream Name	AUID	Stressors					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Shingle Creek	07040004-562	---	---	●	o	---	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.6.5 Unnamed Creek (579)

Biological and background information

Unnamed Creek (07040004-579) has one biological station, 04LM008, sampled in 2004, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 5 (Southern Streams RR). The MIBI impairment threshold for this class is 37, with an average score per metric of 3.7 needed to achieve that threshold. 04LM008 has an MIBI score of 25.99, the second lowest MIBI score of the North Fork Zumbro Tributaries that were assessed for macroinvertebrates. None of the metric scores stood out as dominant compared to one another. Six of the 10 metrics were below or at the average metric score needed, and the Plecoptera metric scored zero. The consistently poor scoring metrics show a degraded community.

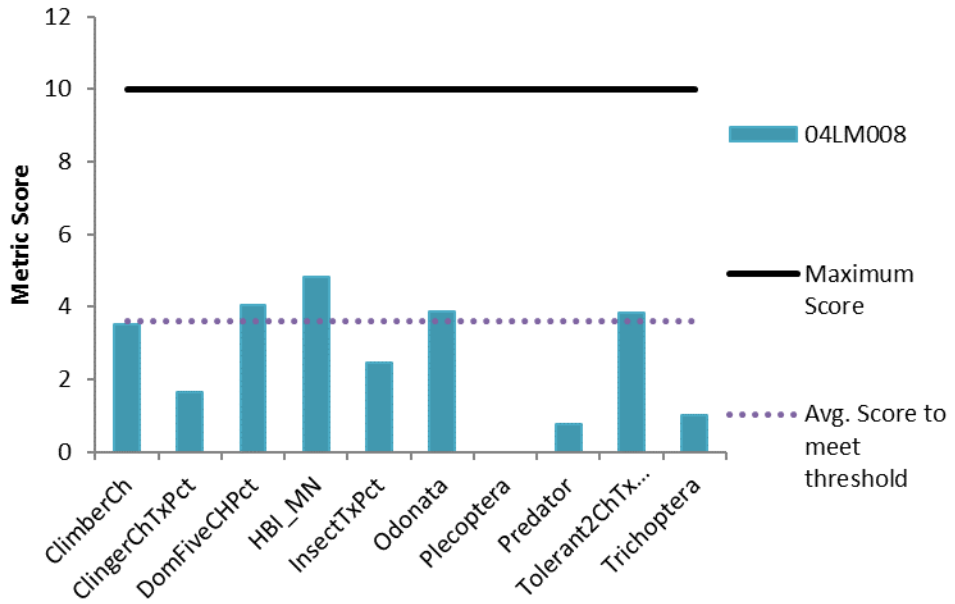

Figure 64. Macroinvertebrate IBI metrics for Unnamed Creek (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

From 2004-2014, Unnamed Creek had a total of seven DO measurements taken. These values ranged from 8.3-12.54 mg/L with none of these measurements taking place prior to 9 AM.

Additionally, eight phosphorus samples were collected from Unnamed Creek in 2014. These values ranged from 0.029-0.172 mg/L with two samples above the 0.10 mg/L phosphorus standard. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

Biologically, the macroinvertebrate assemblage along Unnamed Creek had a low percentage of DO tolerant individuals (4.33), while also containing six species that are very intolerant of low DO conditions. The DO TIV score for the macroinvertebrate community was well above average when compared statewide. This data indicates that the DO conditions do not appear to be negatively impacting this assemblage.

The fish assemblage in Unnamed Creek had very few late maturing (0.25%) and sensitive individuals (1.01%). This site did have a lower amount of serial spawning individuals (12.12%), which is common in streams not being affected by the DO condition. Site 04LM008 did have an above average scoring DO fish TIV score when compared to all other sites in Minnesota, which also indicates that the fish community isn't dominated by fish found in low DO conditions.

Based on the observed values, the TIV scores for both assemblages, as well as the high presence of species very intolerant to low dissolved conditions and low phosphorus values; low DO and eutrophication are not a stressor to the impaired macroinvertebrate community in Unnamed Creek.

Nitrate

During fish sample, the nitrate concentration at 04LM008 was 5.1 mg/L (June 2004). There were seven additional samples taken on this reach in 2014, from April through September. The nitrate concentration ranged from 3.7 mg/L in September, up to 5.2 mg/L in June. The average concentration was 4.3 mg/L. The highest samples were from June (similar to the other North Fork tributaries) but the concentrations were not as dramatically high as the other areas of the North Fork Watershed.

The one macroinvertebrate sample taken at station 04LM008 had 39.13% nitrate tolerant species collected, which is also much lower than the other impaired tributaries to the North Fork. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At this station, taxa richness was below average, at only 33. Also, there were a below average number Trichoptera taxa overall (3), but still two generally intolerant taxa. There was one nitrate intolerant taxon at station 04LM008. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These trichoptera include all caddisflies that do not spin nets. The percentage at this station was 0%, while the average for sites in the LMB is 3.39%. There is a lack of sensitive fish species (1%) and higher percentage of tolerant fish species (72%) which also can be consistent with nitrate stress, among other stressors. The macroinvertebrate community nitrogen index score was 2.7, while the average for warmwater stations meeting impairment threshold is 2.9. This suggests that overall the community is not overly tolerant to high nitrate concentrations.

Given the lower nitrate concentrations comparatively, low percentage of nitrate tolerant individuals and intolerant taxa present, nitrate doesn't seem to be driving the stress in this reach. It's more likely that other stressors are playing a larger role explaining the slight response observed (i.e., richness, Trichoptera), and the response seen in the fish community, which isn't currently impaired. Nitrate is not considered a stressor to Unnamed Creek at this time.

Suspended sediment

At the time of biological monitoring in 2004 site 04LM008 had a TSS value of 42 mg/L. Photos taken during biological sampling suggest this was right after a storm event. Additionally, seven values were recorded for TSS, and five values were recorded for secchi transparency April through July of 2014. The TSS values range from 1.6-62 mg/L with an average value 19.9 mg/L. None of the values have exceeded the 65 mg/L TSS standard for warm water streams, even though at least one sample was taken during stormflow conditions.

The macroinvertebrate metrics do not show a consistent response to elevated TSS. The index score, tolerant taxa and percentage are all less than average, which is expected in streams with suitable TSS concentrations (Table 26). However, there were zero intolerant and plecoptera taxa, a low percentage of collector filterers, all of which can decrease with increases in TSS stress. However, these metrics can also reflect a response from another stressor. Given the mixed macroinvertebrate response, in addition to the lack of strong supporting chemical data, TSS is not a stressor to the macroinvertebrate community of Unnamed Creek.

Table 26. Macroinvertebrate metrics relevant to TSS for stations in Unnamed Creek compared to statewide averages for southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
04LM008 (2004)	15.13	**0.00**	7.00	9.72	**15.89**	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Unnamed Creek (07040004-579) had a qualitative habitat assessment take place at its biological monitoring station, 04LM008, during the fish sampling event in 2004. The MSHA score for this site was 65.1, which is considered to be fair. Limiting the MSHA (Figure 65) at this site was the pasture in the surrounding land use, the narrow riparian buffer, sand and silt substrates, light embeddedness, and fair channel development. This reach also had eroded banks (Figure 66) located downstream of the sampled site.

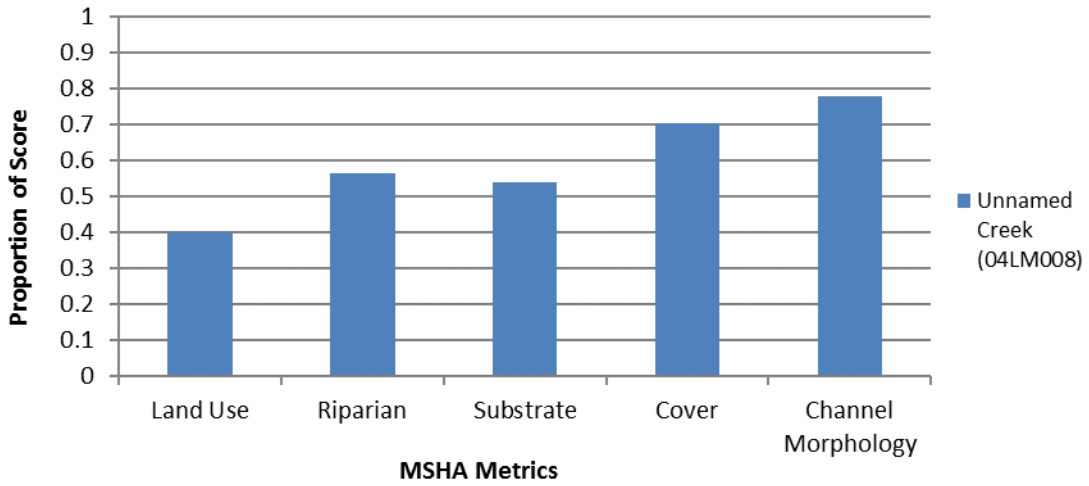

Figure 65. MSHA metric value scores at site 04LM008 along Unnamed Creek (07040004-579).

Figure 66. Eroded bank along Unnamed Creek (07040004-579).

The macroinvertebrate sample at 04LM008 was collected from equal parts of riffle and overhanging vegetation habitat. The macroinvertebrate community along this reach had a decreased amount of burrower individuals (6.23%). These species are often found in abundance in streams dominated by sand and silt substrates. This reach did have a below average amount of legless (44.86%) individuals, but had an increased amount of sprawler (43.3%) individuals when compared statewide. Sprawlers are macroinvertebrates which sprawl on top of fine sediments and correlate to poor substrate conditions in streams. In addition, site 04LM008 did also have decreased amounts of climber (20.56%), clinger (18.38%), and EPT (20.87%) individuals when compared to all other Minnesota streams. These results can characterize a macroinvertebrate community being negatively impacted by the habitat conditions present.

The fish assemblage at 04LM008 had above average numbers of benthic insectivore (15.66%), darter/sculpin/round-bodied sucker (15.15%), and simple lithophilic spawning (39.39%) individuals. These results reflect a stream unaffected by a lack of fish habitat. Conversely, this site did have a decreased amount of riffle dwelling individuals (9.85%) and a higher amount of tolerant individuals (72.47%), which can potentially indicate habitat issues.

The fair MSHA score as well as the mixed fish and macroinvertebrate habitat related metrics signal that there are habitat related issues in Unnamed Creek. Photographic evidence of eroded banks and fines show that habitat conditions are less than ideal and need to improve. Therefore, the lack of habitat is a stressor to the impaired biological communities in Unnamed Creek at this time.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 2.81-mile-long reach of Unnamed Creek (07040004-579) is 100% natural. There were no modified sections in the headwaters or tributaries to this stream. There also are no known connectivity issues. As a result, flow alteration and connectivity are not stressors to the impaired macroinvertebrate community in Unnamed Creek.

Conclusions and recommendations

The macroinvertebrate community in Unnamed Creek is being stressed by poor habitat conditions (Table 27).

A lack of stable habitat for macroinvertebrates is due to instability and poor substrate. At this station there was a disproportionate percentage of macroinvertebrates that are considered sprawlers; macroinvertebrates that sprawl on top of aquatic vegetation or fine sediment. There were also few clingers (which require course substrates or woody debris) and EPT taxa (sensitive to habitat degradation).

DO, Nitrate, TSS, and Flow Alteration/Connectivity were ruled out as potential stressors to this reach. There was also very little evidence (chemical or biological) that supported these stressors. Interestingly, this tributary had a lower nitrate concentration in comparison to other North Fork tributaries, for reasons unknown. Resampling this reach would be helpful in further understanding the current state of the biological community, considering 2004 was the only biological sample available. In addition, temperature monitoring of this reach may be useful to determine thermal regime given the site has many coldwater indicator macroinvertebrate taxa.

Table 27. Summary of stressor determinations for Unnamed Creek, 07040004-579.

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Unnamed Creek (579)	07040004-579	---	---	---	---	●	---

4.7 Middle Fork Zumbro Watershed

The Middle Fork Zumbro River is a warmwater stream that originates in western Dodge County. The river is 43.5 miles-long and joins with the South Fork Zumbro River at Lake Zumbro, an impoundment on the Zumbro River northeast of Rochester, Minnesota. The watershed drains 102,189 acres, 73% of which is in agricultural use. Section 4.7 includes two stream reaches, one which is the Middle Fork Zumbro, the other which is a tributary ditch in the headwaters, Unnamed Creek (Figure 67).

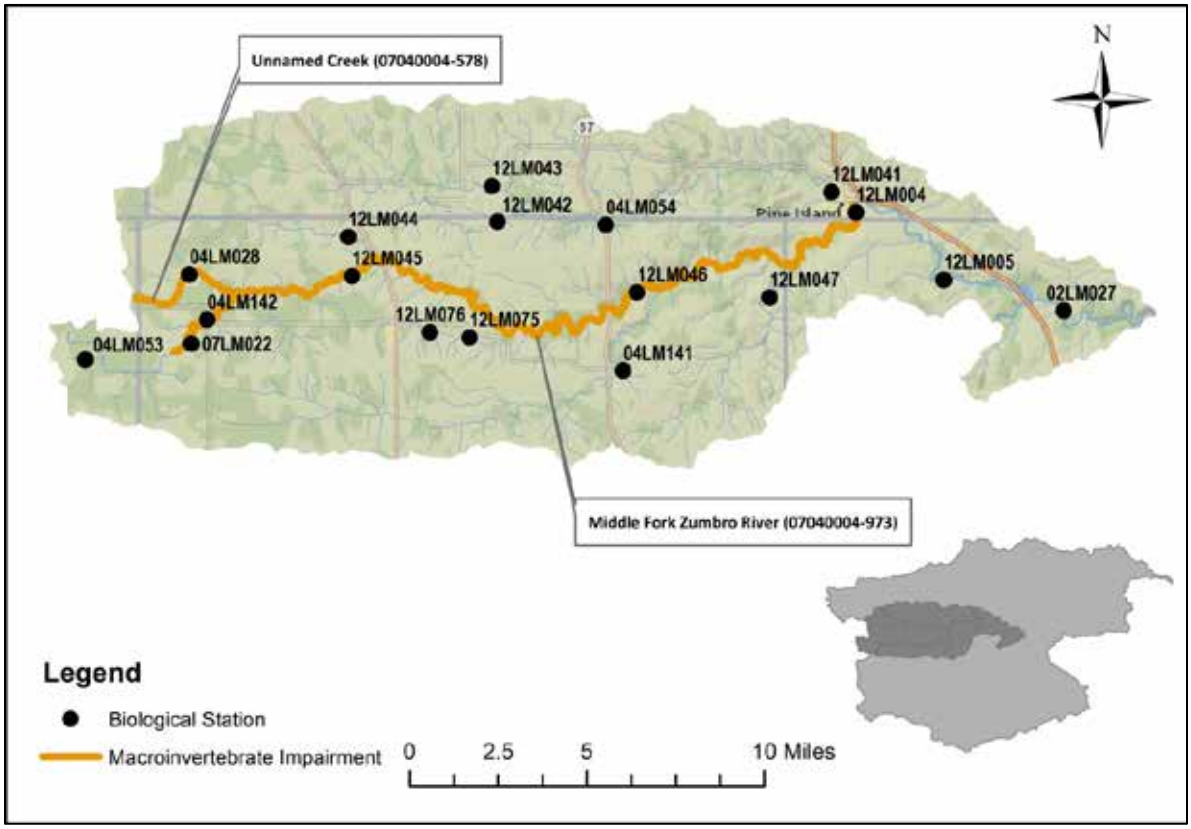

Figure 67. Map of the Middle Fork Zumbro Watershed, biological stations, and impaired AUIDs.

4.7.1 Middle Fork Zumbro (973)

Biological and background information

The Middle Fork Zumbro River (07040005-973) has four biological stations with visits in 2004 and 2012. These sites all fit in the macroinvertebrate MIBI Class 5 (Southern Streams RR). The MIBI threshold for this Class is 37, with an average score per metric of 3.7 needed to achieve that threshold (Figure 68). The data resulted in a macroinvertebrate impairment on this reach.

The station farthest upstream, 04LM142 had the lowest MIBI of 28.97 (2004). It scored above the average on 4 out of 10 metrics, yet scored zero on 3 out of 10 metrics. In 2012, at sites 12LM004, 12LM045, and 12LM046, the MIBI scores were 48.76, 41.79, and 33.71, respectively. An overall trend is observed at all four sites; that being the highest scoring metrics were ClingerChTxPct, InsectTxPct, DomFiveCHPct, and Odonata. Additionally, the metric scores for those categories were much higher than the average score needed to meet the threshold. There also seems to be an overall trend of lack of Predator taxa. One stark difference is at site 12LM004. Plecoptera were collected in the sample, and they scored very well as opposed to all other sites with zero Plecoptera scores.

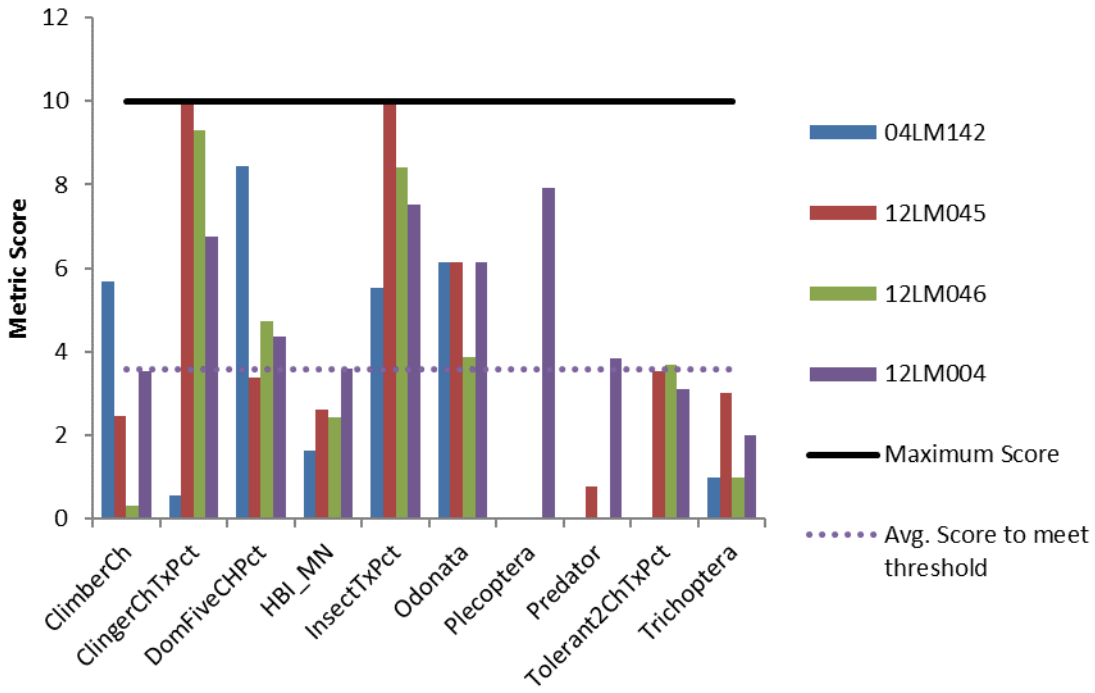

Figure 68. Macroinvertebrate IBI metrics for the Middle Fork Zumbro (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

The Middle Fork Zumbro River had a total of 29 DO readings taken from 2004-2014. These values ranged from 6.57-11.17 mg/L. Of these measurements, only one was before 9 AM.

Additionally, 49 phosphorus samples were taken along this reach from 2004-2014. These results ranged from 0.01-1.13 mg/L with 14 values above the 0.15 mg/L standard for Phosphorus in the South nutrient region. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

The macroinvertebrate community in the Middle Fork Zumbro River had a very low amount of DO tolerant individuals (4.08%), while averaging nearly 10 DO intolerant species per site. The DO TIV scores for this reach were also above average when compared to all other Minnesota streams, indicating the community is not dominated by low DO tolerant macroinvertebrate species.

The fish community in the Middle Fork Zumbro River had many late maturing individuals (22.8%), however, site 04LM142-in the headwaters, had none. There was also a large difference in the number of serial spawning individuals throughout the reach as site 04LM142 had a fish community consisting of 50.84% individuals, while the remaining sites averaged 12.63%. A high presence of serial spawning species can often signal stress to the fish assemblage. The DO TIV score for the fish assemblage was above average when compared statewide. The lowest TIV score was at 12LM045, which is still above average for Class 3 sites.

Based on the measured data, as well as the high scoring TIVs, and DO related biological metrics for both the fish and macroinvertebrate communities, low DO and eutrophication are not stressors to the impaired macroinvertebrate community at this time. High levels of phosphorus observed in this stream could eventually lead to DO issues and will need to be addressed. Additional DO monitoring at site 04LM142 is recommended, and reductions in phosphorus would be helpful.

Nitrate

During fish sample, the nitrate concentrations measured on this reach ranged from 2.4 to 23 mg/L (June 2004 and July 2012). The highest value, 23 mg/L, was measured at the site farthest upstream (04LM142). There were 42 nitrate values taken on this reach, from multiple locations from 2007 through 2014. The average nitrate concentration collected from these samples was 7.9 mg/L, which the maximum concentration in June of 2014, at 20 mg/L. Sixteen percent of the samples collected were above 15 mg/L, all of which were collected in either May or June.

Daily nitrate values were calculated for the Middle Fork River (AUID 07040004-973) for subsheds 304, 305, and 306 by the HSPF model from 1995-2009. These values ranged from 1.53-22.8 mg/L with an average value of 5.29 mg/L. In addition, for the entire 07040004-973 reach, 5.1% of the values are above 10 mg/L and less than 1% are above 20 mg/L.

The four macroinvertebrate samples taken on this reach had between 49% and 90% nitrate tolerant species collected. At 83.78%, there is only a 10% probability of meeting the MIBI. The site with the highest percentage of nitrate tolerant species was 04LM142, which is also where the highest nitrate concentration was measured on this reach. The site farthest downstream (12LM004) had the lowest percentage of nitrate tolerant species present, at 49%. The other two stations both had 75% nitrate tolerant individuals. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At these stations, taxa richness was mixed; below average at two stations and above average at two stations (12LM004 and 04LM142). There were a decent number of Trichoptera taxa among the sites (between 3 and 5; average is 4.3 for this stream class). There were no nitrate intolerant taxa at any of the sites, but between 2 and 7 generally intolerant taxa. Station 12LM004 had 7 intolerant taxa. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These trichoptera include all caddisflies that do not spin nets. The average for sites in the LMB is 3.39%, and the percentage on this reach ranged from 0.93% to 5.89%. Interestingly, the highest percentage is found upstream and lower percentages downstream; opposite of what was expected, based on the previous longitudinal trends.

Since most of the metrics are showing response in the upper reach, and high concentrations have been documented, it's likely that nitrate is stressing this reach. The stress is much more apparent and consistent farthest upstream (04LM142), then seems to diminish some when moving downstream. The HSPF map, also shows decreasing concentrations of nitrate when moving towards the mouth of the Middle Fork Zumbro River Watershed. Elevated nitrate is a stressor to the Middle Fork Zumbro River.

Suspended sediment

At the time of biological monitoring in 2004 as part of a one-time chemistry sampling, the TSS value recorded at site 04LM142 was 14 mg/L. During one-time chemistry sampling again in 2007 at site 07LM022 TSS was 8 mg/L. Finally, in 2012 during biological monitoring, the one-time chemistry TSS values at sites 12LM004, 12LM045, 12LM046 were 5.6 mg/L, 7.2 mg/L, and 2.8 mg/L, respectively. All of the one-time chemistry samples were collected between the months of June through August, and were below the 65 mg/L TSS standard for warmwater streams in this area.

Between 2007 and 2014 43 TSS values were recorded. These values ranged from 1.6-800 mg/L with an average value of 89.5 mg/L. Of the 43 values, 12 were above the 65 mg/L TSS standard. This reach has an existing turbidity listing. Due to this, it is also important to note that most of this information was collected as the result of TMDL monitoring and is biased towards event based sampling.

Daily TSS values were calculated for the Middle Fork Zumbro River (AUID 07040004-973) subsheds 304, 305, and 306 by the HSPF model from 1995-2009. These values ranged from 1.83-1989.9 mg/L with an average value of 20.9 mg/L. In addition, 5.7% of the values from the Middle Fork Zumbro River were above 65 mg/L.

The fish do not signal a strong response with only a few metrics below average. Overall the fish community TSS index scores show a community that isn't overly tolerant to high TSS with most scores well below the average. If the fish community was being impacted by high TSS, an increase in the TSS index scores would be expected. The macroinvertebrate communities seem to show a mixed response to elevated TSS. More response is demonstrated with the two stations in the middle of the watershed, with higher TSS index scores and percentage of TSS tolerant macroinvertebrates. The mix of response on this long AUID makes it difficult to conclude TSS is a stressor (Table 28). Most of the stress is seen in the middle of the reaches, while most of the data has been collected towards the mouth. TSS cannot be ruled out as a stressor, but remains inconclusive until further data collection and better characterization of the TSS concentrations throughout the reach can be determined.

Table 28. Macroinvertebrate metrics relevant to TSS for stations in the Middle Fork Zumbro compared to statewide averages for southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
04LM142 (2004)	16.29	**0.00**	**15.00**	25.42	**17.13**	**0.00**
12LM045 (2012)	**17.80**	**2.00**	10.00	**59.38**	38.65	**0.00**
12LM046 (2012)	**18.51**	**0.00**	10.00	**60.91**	26.09	**0.00**
12LM004 (2012)	16.51	**1.00**	**14.00**	31.09	46.73	0.62
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

The four biological monitoring stations along Middle Fork Zumbro River (07040004-973) had qualitative habitat assessments performed during the fish sampling events in 2004 and 2012 (Figure 69). The MSHA scores at these stations ranged from 63.15 (Fair) to 76.2 (Good). Limiting the MSHA at these sites was row crops land use along some sites, moderate bank erosion, sparse fish cover, light embeddedness, and moderate channel stability.

The macroinvertebrate samples from the sites along the Middle Fork Zumbro River were taken from mostly riffle and woody debris habitat, and where present, samples were collected from overhanging vegetation. The macroinvertebrate community in this reach had a decreased average amount of burrower (9.44%) and sprawler individuals (6.33%) while also having increased average numbers of clinger (47.87%) and climber (30.07%) individuals. These metric scores often signal a stream not being

impacted by the habitat conditions. However, this reach did have an increased amount of legless individuals (65.23%), which can be common in streams having poor habitat.

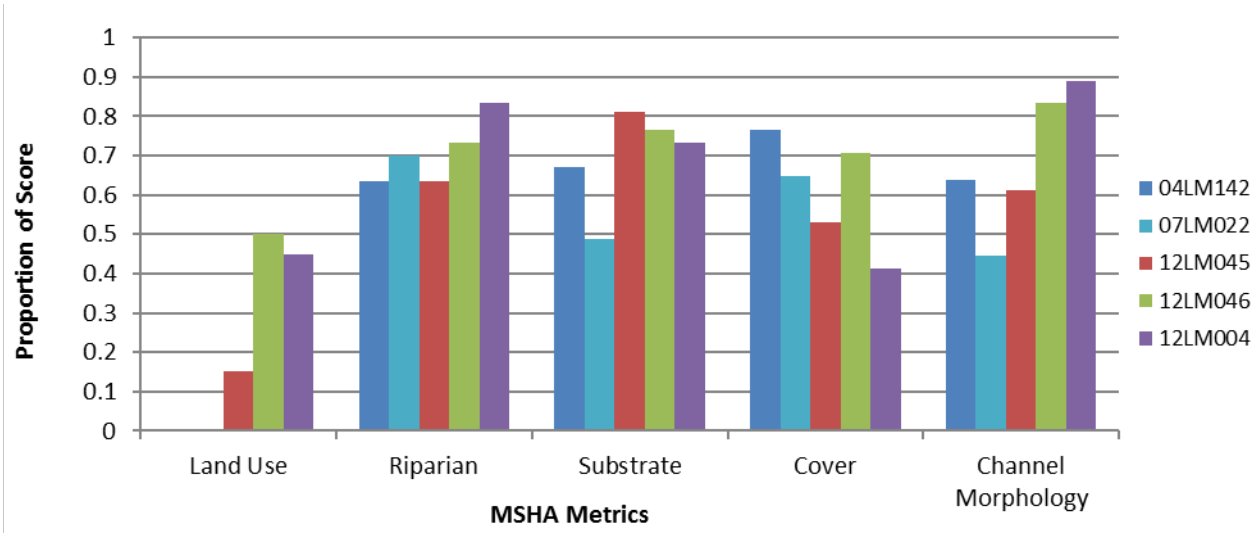

Figure 69. MSHA metric value scores at sites along the Middle Fork Zumbro River (07040004-973).

The fish community in the Middle Fork Zumbro River had decreased amounts of both benthic insectivore (12.51%) and darter/sculpin/round-bodied sucker (7.25%) individuals. These sites did have an increased amount of riffle dwelling (40.92%) and simple lithophilic spawning (50.58%) individuals, while also having a decreased amount of pioneer species individuals (21.21%). These results can reflect a stream not being negatively impacted by the habitat conditions.

The MSHA scores along the Middle Fork Zumbro River scored fairly well, while the habitat related biological metrics had fairly mixed results. It is likely that the fish and macroinvertebrate communities are being stressed by other sources and lack of habitat should not be considered a stressor at this time.

Flow alteration and connectivity

According to the Altered Watercourses GIS layer of Minnesota, the 34.25-mile-long stretch of the Middle Fork Zumbro River (07040004-973) is only 4.56% altered or channelized. Channelization also leads to the reduction of habitat by limiting a streams ability to push fine sediment through a system, which can cover the coarse substrates. Some of the many tributaries to this AUID were completely modified. However, these small channelized tributaries do not appear to be having many negative impacts to the Middle Fork Zumbro River.

A dam once existed along the Middle Fork Zumbro River in Oronoco that impounded the river to form Lake Shady. The dam was damaged as a result of September 2010 flood events and the Olmsted County board voted to remove the dam and eliminate Lake Shady. Both Middle Fork and South Branch Middle Fork channels have been reconstructed in the former lakebed of Lake Shady. (MNDNR)

The removal of a potential barrier to fish migration eliminated a potential source of stress for connectivity. Additionally, the relatively low amount of channel alteration occurring on the Middle Fork Zumbro River reduces flow alteration concerns as well. There is a fair amount of tile drainage in the upper half of the watershed, but a lack of information demonstrating changes in flow regime overall. Therefore, flow alteration and connectivity are not considered stressors to the impaired macroinvertebrate community at this time.

Conclusions and recommendations

The macroinvertebrate community of the Middle Fork Zumbro (973) is being stressed by elevated nitrate (Table 29). The stress related to nitrate is much more apparent and consistent farthest upstream, then seems to diminish some when moving downstream. HSPF data and chemical data indicate concentrations are likely highest on the upstream portion of this reach. The proportion of nitrate sources is not completely understood, but the highest concentrations are in May and June, when the highest proportion of stream water comes from tile drainage. As noted in the statewide nitrogen study, nitrate reaches waterways through surface runoff, tile drainage, and leaching to groundwater, with tile drainage being the largest pathway (MPCA, 2013).

TSS as a stressor is considered inconclusive due to the mixed biological response along this long reach. The majority of indication of stress is seen on the middle parts of the reach, while the majority of chemical data is towards the mouth. Further data collection and better characterization of the TSS concentrations throughout the reach would be helpful.

There was little indication that DO and habitat are stressing the macroinvertebrates, which were ruled out as stressors at this time. Some high phosphorus was noted, but little biological response throughout the AUID to confirm a stressor. For both parameters, the location that shows some stress from DO and habitat are in the upper reaches, near 04LM142.

Table 29. Summary of stressor determinations for the Middle Fork Zumbro

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Middle Fork Zumbro	07040004-973	---	---	●	o	---	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.7.2 Unnamed Creek (578-Modified)

Biological and background information

Unnamed Creek (07040004-578) has one biological station, 04LM028 with a sample in August 2004, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 6 (Southern Forest Streams GP). This site is in the modified use class and has a MIBI impairment threshold of 30, with an average score per metric of 3.0 needed to achieve that threshold. 04LM028 has an MIBI score of 23.03, and scored below the average metric on all but one metric; DomFiveCHPct, which is a measure of the relative abundance of dominant five taxa in a subsample. Overall, the macroinvertebrate metrics signal a degraded community.

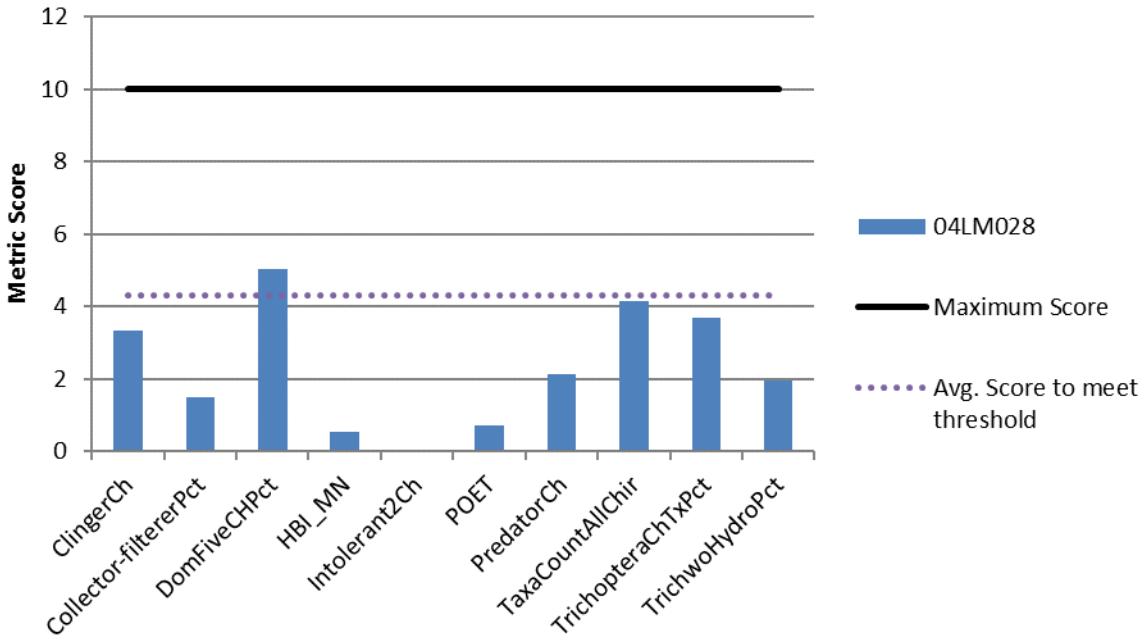

Figure 70. Macroinvertebrate IBI metrics for Unnamed Creek (Class 6; Southern Streams Glide/Pool).

Dissolved oxygen and eutrophication

From 2004-2014, Unnamed Creek had eight DO readings taken from sites 04LM028 and S007-917. These values ranged from 7.36-15.2 mg/L. Of these samples, two were taken before 9 AM; none below the standard of 5 mg/L. Additionally, eight phosphorus samples were taken from this site. One sample was taken during the fish sampling event in 2004 and had a value of 0.04 mg/L, which is below the 0.10 mg/L phosphorus standard. Additional phosphorus samples (7) were collected in 2014 and had an average of 0.09 mg/L. Only one of those samples was above the 0.15 mg/L standard in the South nutrient region. This sample was taken in June during a storm event. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

The HSPF model calculated DO values containing Unnamed Creek (07040004-578) from 1995-2009. These values ranged from 4.38-14.05 mg/L with an average value of 9.72 mg/L. Of these calculations only 16 values fell below the 5 mg/L daily minimum standard.

The macroinvertebrate assemblage in Unnamed Creek at site 04LM028 had few EPT (9.69%) individuals, a high amount of DO tolerant species (6) and individuals (15.96%), and a lower DO TIV score when compared to all other sites within the Zumbro River Watershed.

The fish community had many serial spawning individuals (27.36%), which is common is streams potentially impacted by low DO conditions. This stream reach also had few late maturing (0.17%), and sensitive (0.17%) individuals. The DO TIV score for 04LM028 was also low when compared to all other sites within the watershed.

While the biological metrics for both the fish and macroinvertebrates suggest potential stress from low DO conditions, no field observations and very few (0.29%) HSPF calculated measurements were below 5 mg/L. Continuous DO monitoring with a sonde is recommended to better understand the impact, if any that DO is having on these assemblages. DO and eutrophication are inconclusive as a stressor to Unnamed Creek, until further information is collected.

Nitrate

During two fish sample visits in 2004 (June and July), nitrate concentration was measured at 25 mg/L and 24 mg/L. There were seven additional nitrate samples taken in 2014. The nitrate concentration ranged from 9.3 mg/L in September to 23 mg/L in June. The average concentration for samples collected in 2014 was 15.4 mg/L.

Station 04LM028 had an average taxa count (TaxaCountAllChir; 33) which is on par with the average taxa count for this macroinvertebrate class (Class 6; Southern Forest Streams GP average of 33). Trichoptera are found to be generally sensitive to elevated nitrate concentrations. There were 2 Trichoptera taxa collected, which is below the average for the Southern Forest Streams GP stations of the LMB (2.2). However, even with the 2 taxa, the percentage of Trichoptera individuals was still very low at only 0.6%. The visit also had 88.3% nitrate tolerant individuals, which is higher than most sites in the watershed. At 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. There were no nitrate intolerant taxa found during the visit. Additionally, increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These comprise all caddisflies that do not spin nets. Station 04LM053 had only 0.6% non-hydropsychid Trichoptera. This is below average compared to all biological sites in the LMB (3.39%) and of this stream class (2.21%).

The elevated chemical concentration and consistent biological response evidence confirms elevated nitrate is degrading the macroinvertebrate community. Nitrate is a stressor to Unnamed Creek.

Suspended sediment

At the time of biological monitoring in 2004, as part of a one-time chemistry sample at site 04LM008 the TSS value recorded was 42 mg/L. Additionally, 7 values were recorded for TSS, and 5 values were recorded for secchi transparency April through September of 2014. The TSS values range from 1.6-130 mg/L with an average value 24.1 mg/L. The only value to exceed the 65 mg/L TSS standard for warm water streams was the TSS of 130 mg/L from June 18, 2014. The transparency values range from 6-100 cm with an average transparency of 79.2 cm.

The macroinvertebrate metrics do not show a consistent response to elevated TSS. The index score, intolerant taxa and collector-filterer percent are all worse than average, and signal stress (Table 30). However, there were few tolerant taxa which can increase with increases in TSS stress. It's not clear if the metric response is due to TSS or if they reflect a response from another stressor. There is a lack of strong chemical information to confirm that TSS is a problem at 04LM088, and fish show some response, but are not impaired. TSS is inconclusive as a stressor to the macroinvertebrate community of Unnamed Creek.

Table 30. Macroinvertebrate metrics relevant to TSS for stations in Unnamed Creek compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
04LM028 (2004)	**16.54**	**0.00**	6.00	8.83	**5.94**	**0.00**
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Unnamed Creek (07040004-578) had a qualitative habitat assessment take place at its biological site, 04LM028, during its fish sampling in 2004. The resulting MSHA score for this site was 44.8, which is considered to be fair (Figure 71). The MSHA at this site was limited by the poor surrounding land use the narrow riparian area, moderate stream shading, moderate embeddedness, the presence of silt and detritus substrates, as well as poor sinuosity and fair channel development. The stream channel along this reach has been modified, which can greatly reduce the amount of habitat available.

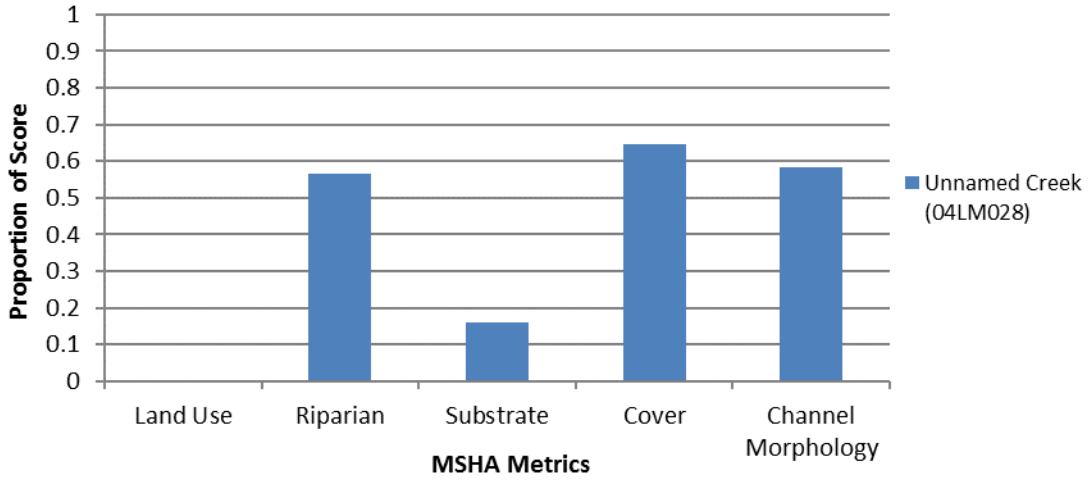

Figure 71. MSHA metric value scores at site 04LM028 along Unnamed Creek (07040004-578).

Figure 72. Surrounding land use at site 04LM028 along Unnamed Creek (07040004-578).

The macroinvertebrate sample at site 04LM028 was taken from equal parts aquatic macrophytes and overhanging vegetation. This site had a high amount of climber species (59.06%), which is expected with the high amount of overhanging vegetation present. Few clinger (8.75%) and sprawler (9.06%) individuals were sampled at site 04LM028 which corresponds to the lack of rocks and woody debris that these species prefer. Furthermore, few EPT individuals (9.69%) and a high amount of legless (85.31%) individuals were sampled. These results both reflect streams being stressed by poor habitat conditions.

The fish assemblage in Unnamed Creek had a higher amount of benthic insectivore 21.15%), simple lithophilic spawning (35.32%), and darters/sculpin/round-bodied suckers (20.98%) individuals. These results generally reflect streams unaffected by poor habitat conditions. However, this reach did have few riffle dwelling individuals (2.17%), while also having a high amount of tolerant (52.34%) and pioneer (45.7%) individuals. These results are common in streams with poor habitat conditions.

Based on the fair MSHA score, the high amount of fine sediments, poor land use conditions, modified stream use, and the agreement with the majority of the fish and macroinvertebrate habitat related biological metrics; the lack of habitat in Unnamed Creek is a stressor to the impaired macroinvertebrate community at this time.

Flow alteration and connectivity

According to the Altered Watercourses GIS layer of Minnesota, Unnamed Creek (07040004-578) is completely altered and unnatural. Modified channels often lead to bank erosion and instability. Flow alteration also leads to the reduction of habitat by limiting a streams ability to push fine sediment through a system, which can cover the coarse substrates. Site 04LM028 had a stream bed filled with silt, sand, and detritus. Additionally, channelizing a stream changes stream depth variability, which reduces the numbers of riffles and pools present, which are vital for some fish and macroinvertebrate species to survive.

Unnamed Creek was also observed having low flow. These conditions can encourage excessive plant growth. These conditions can limit habitat conditions and negatively impact the DO conditions as well. Flow alteration is a stressor to the biological communities in Unnamed Creek at this time.

Conclusions and recommendations

The macroinvertebrate community in Unnamed Creek is being stressed by lack of habitat, elevated nitrate and flow alteration (Table 31). Nitrate was measured multiple times in 2014 and found consistently high levels (maximum of 25 mg/L). Similar to other sites in the area, the maximum concentration of nitrate is in June and likely a result of increased tile flow. The macroinvertebrate community is dominated by nitrate tolerant species, and completely lacks any nitrate intolerant species, further validating the issue. Additionally, this modified (channelized) stream reach has many aspects of habitat that are stressing the macroinvertebrate community. The adjacent land use and poor substrate, with a lack of any rock or woody debris, favor a degraded macroinvertebrate community. This reach is completely altered and unnatural which leads to reduced habitat diversity and complexity. Additionally, very low flow was documented in this reach, with excessive macrophyte growth which can lead to habitat and DO issues.

Both DO and TSS are inconclusive as stressors in this reach. There are some indications that DO could be an issue but no field observations were available to better understand the DO regime. Macrophytes were found to be choking the stream channel in 2015. Similarly, a complete lack of TSS information and a weak biological response make it difficult to confirm TSS stress. Both of these parameters could be probable stressors, but need additional information collected to determine stressor status.

Overall, the biological stress seen in this reach can be tied back to the main stressor; flow alteration. The stream is designed to move water off the land quickly, which results in high seasonal nitrate concentration and low flow later in the year. The surrounding land use and channelization do not favor a stream with natural habitat and support the poor habitat conditions observed. It would take multiple large scale changes in this watershed and stream channel in order to improve the biological community here.

Table 31. Summary of stressor determinations for Unnamed Creek

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Unnamed Creek	07040004-578	---	o	●	o	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.8 South Branch Middle Fork Watershed

The South Branch Middle Fork Zumbro River is a warm/coolwater stream that originates at Rice Lake in Dodge County and flows 46.0 miles entering the Middle Fork Zumbro River upstream of Lake Shady in Oronoco. Rice Lake is a shallow, marshy lake ideal for waterfowl and migrating birds which is also sourdounded by a state park. Recent lake management efforts have improved water quality. The

watershed drains 135,680 acres, 71% of which is in agricultural use. The river drops 358 feet in elevation from headwaters to the mouth. Section 4.8 includes two stream reaches adjacent to one another, both on the South Branch, Middle Fork (Figure 73).

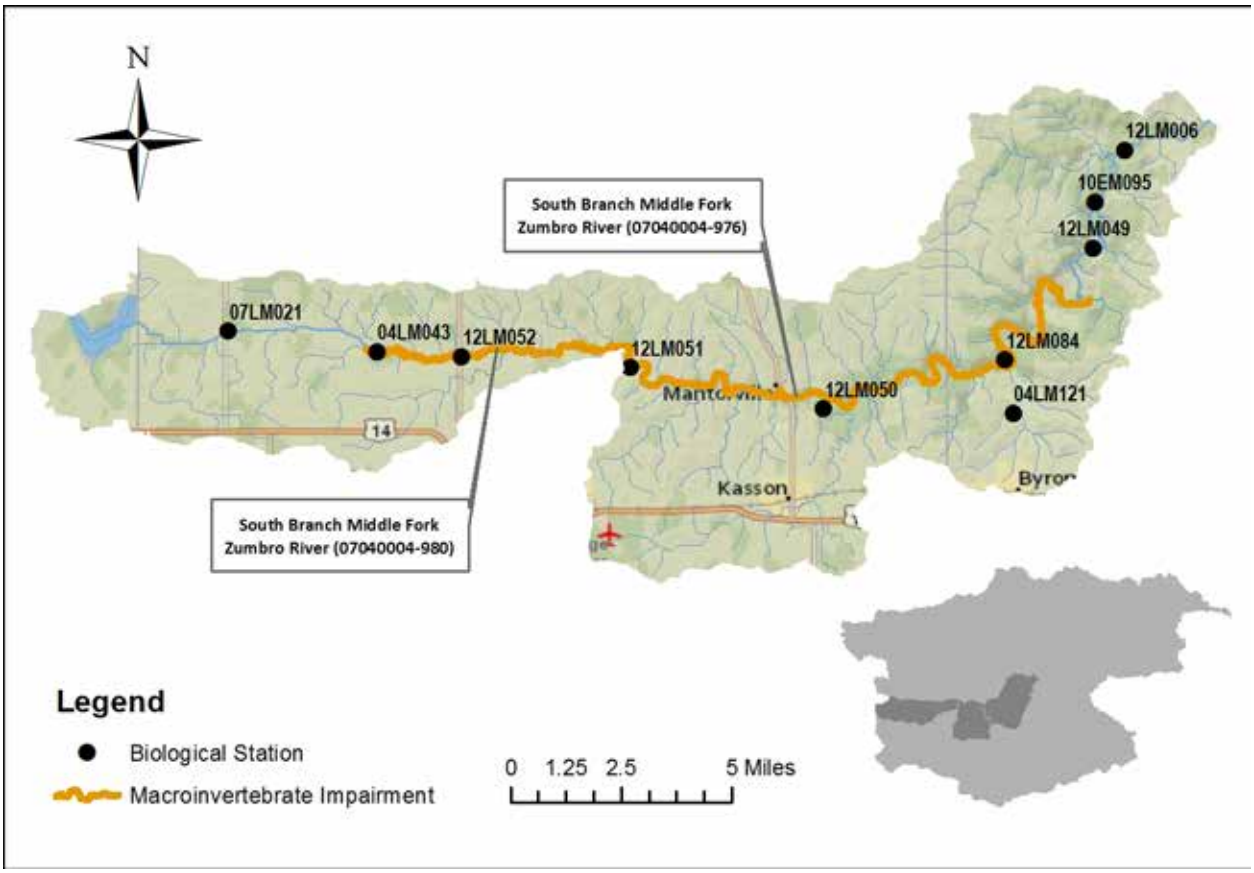

Figure 73. Map of the South Branch Middle Fork Watershed, biological stations, and impaired AUIDs.

4.8.1 South Branch Middle Fork Zumbro (980)

Biological and background information

The South Branch Middle Fork Zumbro (07040004-980) has two biological stations: 04LM043 and 12LM052, which resulted in a macroinvertebrate impairment. Site 04LM043 is on a reach designated macroinvertebrate Class 6 (Southern Forest Streams GP), and site 12LM052 is on a reach designated macroinvertebrate Class 5 (Southern Streams RR). The MIBI threshold for Class 6 streams is 43, and Class 5 is 37. Average scores per metric needed to meet the threshold are 4.3 and 3.7, respectively.

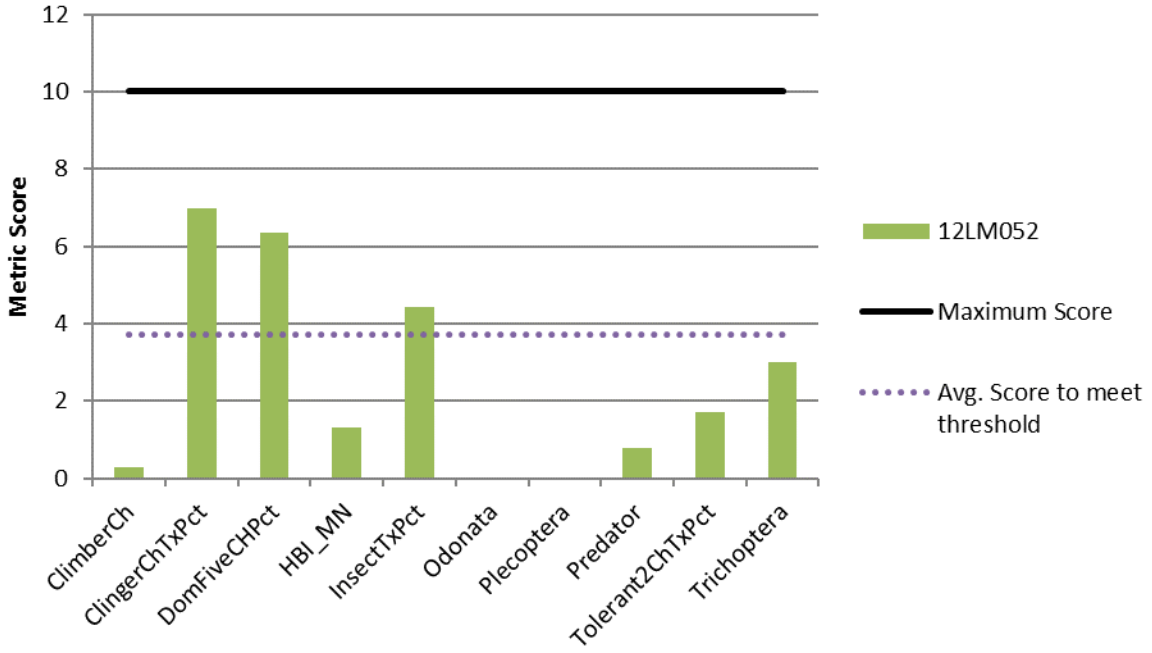

Figure 74. Macroinvertebrate IBI metrics for the South Branch Middle Fork (Class 5; Southern Streams Riffle/Run).

Station 12LM052 has an MIBI of 24.83, the lowest score for Class 5 streams in the South Branch Middle Fork Zumbro Watershed. The individual metric scores are below the average needed for 7 out of 10 metrics, and two of those (Odonata, Plecoptera) scoring at zero. Overall the macroinvertebrate community at this site is showing degradation.

Station 04LM043 has an MIBI of 48.19, which is above impairment threshold (43). Although the relative abundance of collector-filterer (Collector-filtererPct) individuals scores low, and the taxa richness of intolerant individuals (Intolerant2Ch) scores a zero, the overall health of the macroinvertebrate community appears fair. The relative abundance of dominant five taxa (DomFiveCHPct) scored very well with a maximum score of 10, meaning that the macroinvertebrate community is not dominated by any particular taxa. This is also supported by a good metric score for TaxaCountAllChir, the metric used to describe species richness.

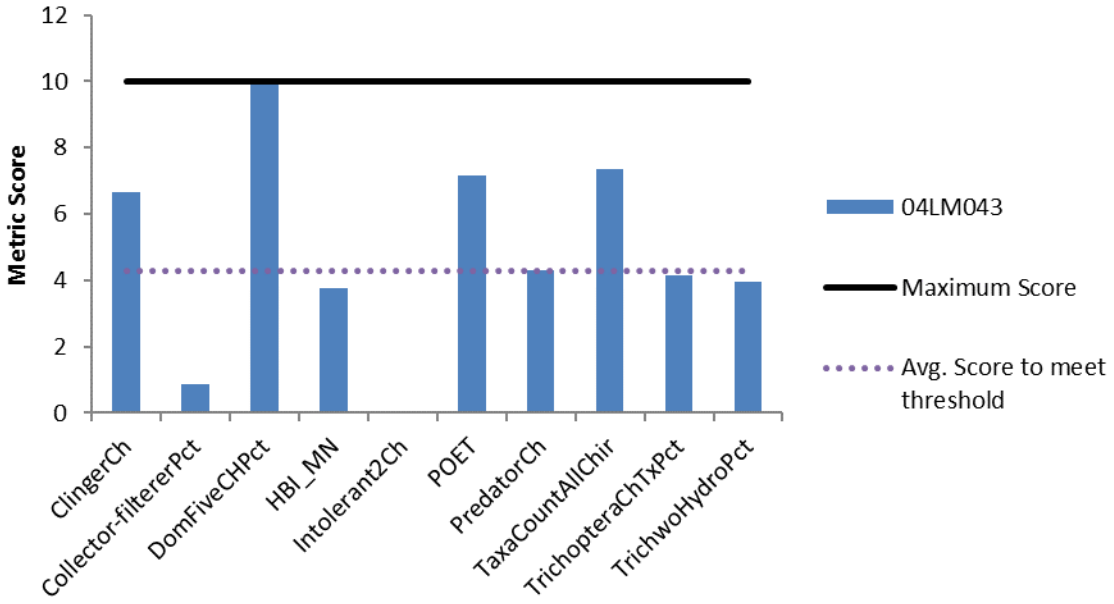

Figure 75. Macroinvertebrate IBI metrics for the South Branch Middle Fork (Class 6; Southern Streams Glide/Pool).

Dissolved oxygen and eutrophication

Continuous DO monitoring along this portion of the South Branch Middle Fork Zumbro River took place in August of 2015, at monitoring station 12LM052. This monitoring showed that no DO levels fell below the 5 mg/L standard although the daily flux exceeded the 4.5 mg/L standard for the South nutrient region.

Additionally, two phosphorus samples were taken from this site. One sample was taken during the fish sampling event in 2012, and had a value of 0.105 mg/L, which is below the 0.15 mg/L phosphorus standard for the South nutrient region. An additional phosphorus sample was collected in August of 2015, and had a value of 0.04 mg/L. During the fish sampling event in 2012, it was noted that the stream was likely green due to an algae bloom in Rice Lake, which is located upstream of 12LM052. Excessive algae blooms can often cause problems associated with DO flux. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts to this reach.

The macroinvertebrate community at sites 12LM052 and 04LM043 contained a lower amount of low DO tolerant individuals (8.11% average). Site 12LM052 also had seven DO intolerant species present, which signals that the DO levels present likely are not stressing the macroinvertebrate community. The DO TIV scores for the macroinvertebrate community were also above average for their respective classes.

The fish assemblage at 12LM052 had below average amounts of late maturing (11.86%) individuals, while also having an above average amount of serial spawning (37.29%) individuals. The DO TIV for the fish community was above average when compared to all other Class 3 sites.

Based on the continuous DO monitoring, the low amounts of DO tolerant individuals, as well as the above average TIV scores for both the fish and macroinvertebrate assemblages; low DO and eutrophication are not stressors to the impaired macroinvertebrate community in this portion of the South Branch Middle Fork Zumbro River at this time. Addressing potential eutrophication problems in Rice Lake is needed to prevent possible DO related issues in this stream section and farther downstream.

Nitrate

The nitrate concentration at 12LM052 during biological sampling was 2.4 mg/L. There wasn't a sample result for 04LM043. There were additional nitrate data collected in 2015 at 12LM052. On 4/29/15, the nitrate concentration was 9.4 mg/L, followed by an increase in concentration on 6/8/15 (22.6 mg/L), and then a drop in concentration by 8/11/15 (2.5 mg/L). This is consistent with observations taken in nearby watersheds, where the highest concentrations occur in the May-June timeframe.

Daily nitrate values were calculated for the South Branch Middle Fork Zumbro River (AUID 07040004-980) subsheds 54 and 55 by the HSPF model from 1995-2009. These values ranged from 1.37-22.9 mg/L with an average value of 5.1 mg/L. In addition, for the entire 07040004-980 reach, 3.3% of the values are above 10 mg/L and less than 1% were above 20 mg/L.

The macroinvertebrate communities in this reach show a mixed response to elevated nitrate. Taxa Count or species richness are well above class averages for both stations (44 and 42). Trichoptera taxa are also above class averages for both sites. Station 12LM052 had 5 intolerant taxa present, while 04LM043 had 2. Similarly, station 12LM052 had 6.1% non-hydropsychid Trichoptera which is well above average percentage expected for this stream class. Increasing nitrate concentrations correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. However, 04LM043 was below average for percentage of non-hydropsychid Trichoptera (1.6%). There were 80.9% nitrate tolerant individuals at 12LM052 (no info for 04LM043).

There is quite a bit of nitrate sensitivity shown at 12LM052, which had the lower IBI score between the two stations. It's possible that the macroinvertebrate response is due to other stressors. It's also possible that in 2012 when this reach was sampled, nitrate concentrations were lower in the spring due to the dry year, and intolerant taxa were able to survive when they otherwise would be subjected to higher nitrate concentrations in the spring. Additional chemical information would be helpful in understanding the potential concentrations in this reach including the duration of elevated nitrate concentrations and temporal variability. There is a lack of connecting chemical data, and a mix of biological response which makes nitrate as a stressor inconclusive at this time.

Suspended sediment

At the time of biological monitoring a one-time chemistry sample was collected at 12LM052 and the TSS value recorded was 89 mg/L. This particular sample was taken in July during an algal bloom from Rice Lake. The water was noted as looking like "pea soup" and the higher TSS was likely a result of higher amounts of organic matter. A TSS grab sample value was not available at 04LM043.

There is extensive transparency information available on this stream reach, which do show that this stream does have durations of fairly turbid water. One station, S001-639, has comparison information available (http://cf.pca.state.mn.us/water/cmp/resultDetail.cfm?siteid=S001-639). The transparency trends at this site compared to the rest of the sites in the watershed, show that in 2013, there were 57% of the total values below 20 cm transparency (Figure 76) This is significantly higher than the watershed average of 18%.

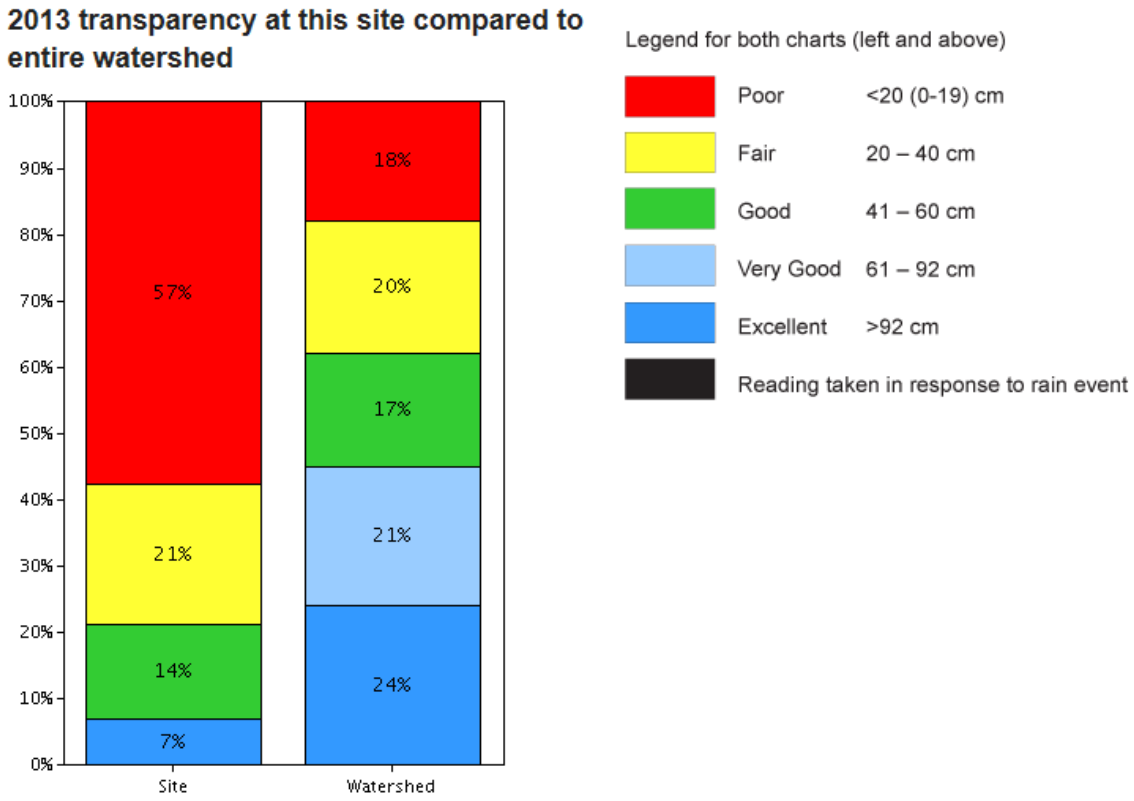

Figure 76. Transparency information from CSMP volunteer in 2013 at S001-639.

Between 2012 and 2013, 26 secchi tube transparencies were recorded and ranged from 9 cm to >100 cm with an average transparency of 25.6 cm. From 2000-2011, 565 60 cm transparency tube values were recorded. These values range from 2 cm to 60 cm with an average value of 25.4 cm, which is above the 65 mg/L equivalent for secchi tube (10 cm). Regardless, secchi/transparency values around 25 are pretty low and do not demonstrate clear water conditions.

There was not any TSS data available on this reach, but daily TSS values were calculated for the South Branch Middle Fork Zumbro (AUID 07040004-980; subshed 505) by the HSPF model from 1995-2009. These values ranged from 1.0-1741.7 mg/L with an average value of 15.9 mg/L. Overall, only 3.8% of the modeled values were above 65 mg/L.

In the South Branch-Middle Fork Zumbro, the macroinvertebrate metrics signal TSS stress (Table 32). There is consistent response seen with the elevated TSS index score, the lack of TSS intolerant taxa, and higher than average number and percentage of TSS tolerant taxa. The fish community, while not impaired, responds with 7 of the 10 metrics signaling TSS stress. Using data regarding fish community composition, there is only a 45% chance this reach meets the TSS standard. There is extensive channelization upstream of this reach, with some areas lacking riparian corridor. While TSS data is lacking, transparency information confirms that the stream is more turbid on a regular basis than most areas of the watershed, in addition to the existing turbidity listing on the AUID immediately downstream. The productivity of Rice Lake, which feeds this reach, may explain why collector-filterers are doing better than expected and may also be responsible for some turbidity issues. In 2012 there was a significant algae bloom which caused the stream to turn very green, as noted during biological sampling. Considering all of the information, TSS is a stressor to the fish and macroinvertebrate communities of the South Branch Middle Fork Zumbro.

Table 32. Macroinvertebrate metrics relevant to TSS for stations in the South Branch Middle Fork compared to statewide averages for southern streams GP and southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM052	**19.79**	**0.00**	**14.00**	**60.97**	35.19	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to TSS stress	↑	↓	↑	↑	↓	↓

Habitat

The South Branch Middle Fork Zumbro River (07040004-980) had a qualitative habitat assessment take place at site 12LM052 in 2012. The MSHA score for this site was 43.2 which is a poor score. Limiting the habitat conditions in this reach was the poor surrounding land use, bank erosion, lack of stream shading, silty substrates, moderate embeddedness, sparse fish cover, moderate channel stability, poor sinuosity, and fair channel development. Site 04LM043 was not sampled for fish, therefore, did not have a qualitative habitat assessment performed.

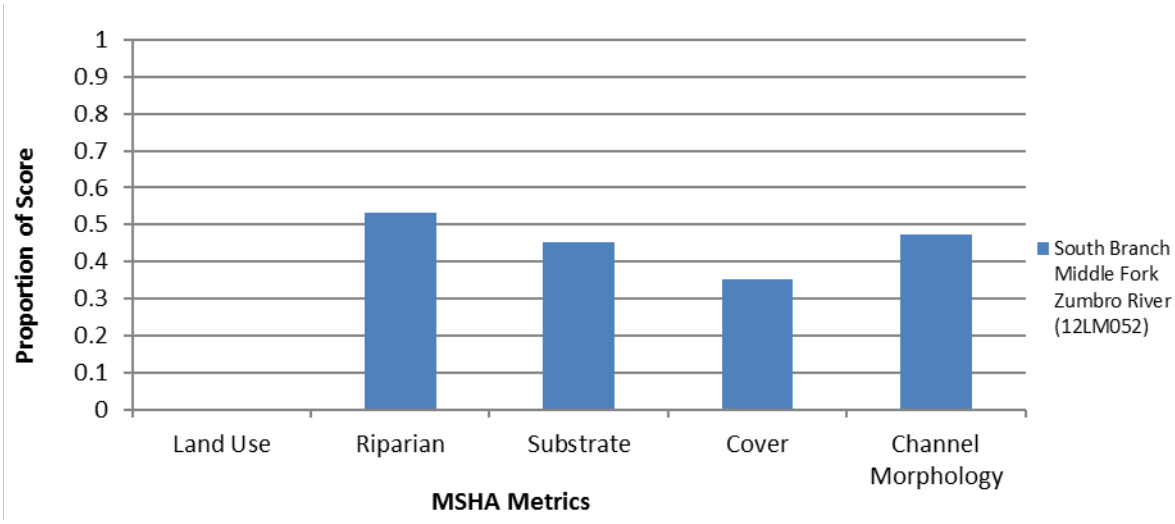

Figure 77. MSHA metric value scores at site 12LM052 along South Branch Middle Fork Zumbro River (07040004-980).

The macroinvertebrate sample at 12LM052 was taken from equal parts of riffle and overhanging vegetation habitats and site 04LM043 had the sample taken from overhanging vegetation and woody debris. This sample had an increased amount of burrower (21.29%) individuals, especially at site 04LM043 (34.87%). Burrower species are commonly found in silty substrates. This reach also had decreased numbers of climber (17.16%) and sprawler (15.18%) individuals, while also having an above average amount of legless (48.01%) individuals. These results reflect a macroinvertebrate assemblage being negatively impacted by the available habitat conditions.

The fish community along this reach also showed signs of stress caused by the habitat conditions. The fish assemblage had decreased amounts of benthic insectivore (8.47%) and darter/sculpin/round-bodied sucker (5.93%) individuals, while also having increased amounts of pioneer species (39.83%) and tolerant (72.88%) individuals.

In a summary of the habitat conditions in "Stream Survey Report, South Branch Middle Fork Zumbro River 2009" (MNDNR) noted that the habitat quality was poorest in the upper two stream reaches where agricultural land use was highest. This report also mentioned that habitat quality was the highest in the lower sections of their study reach, which corresponds to South Branch Middle Fork Zumbro River (07040004-976). Also noted was that "Instream cover is scarce throughout much of the river and lowered overall habitat quality scores. Depths are wadeable in all stream reaches and rarely exceed 4 ft. The underlying geology does not foster down cutting and the development of deep pools."

Based on the overwhelming poor response of the habitat related biological metrics for both fish and macroinvertebrate communities, the poor MSHA score, along with the observations from the MNDNR, the lack of habitat is a stressor in this portion of the South Branch Middle Fork Zumbro River.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 9.39-mile-long reach of South Branch Middle Fork Zumbro River (07040004-980) was 17.35% modified. Modified channels typically lead to reduced habitat conditions, eroded banks, and an overall reduction in diversity. Upstream of this reach is completely modified. At site 12LM052, some bank erosion was present, as well as silt substrates. The MSHA score also indicated that the sampling site had poor sinuosity, which is common in sites that have been modified. Channel stability was only moderate and channel development was fair. These two metrics often respond negatively when affected by channel alteration.

Downstream of this reach along the South Branch Middle Fork Zumbro River is a dam located in the town of Mantorville. Site 12LM052 did have an above average number of migratory fish individuals (23.73%) when compared statewide averages. Sites on the next downstream AUID (07040004-976), also contained a high amount of migratory fish individuals both upstream and downstream of the dam in Mantorville. Also, out of four MNDNR mussel survey sites upstream of the Mantorville Dam along the South Branch Middle Fork Zumbro River, two of the sites did not contain any living mussels. The other two sites had an average of eight mussels per site. Having sites without mussels may indicate issues regarding stream connectivity.

Based on the high degree of channel alteration upstream of the reach, at the sampling site (12LM052), as well as the many poor scoring MSHA metrics linked to flow and channel alteration; flow alteration is a stressor to this portion of the South Branch Middle Fork Zumbro River. The dam located in Mantorville does not appear to be negatively impacting fish migration. Sites upstream and downstream of the dam both had above average amounts of migratory fish individuals. Therefore, connectivity is not considered a stressor along this reach at this time.

Conclusions and recommendations

The macroinvertebrate community in the South Branch Middle Fork (980) is being stressed by elevated TSS, lack of habitat, and flow alteration (Table 33). There is extensive channelization upstream of this reach, with some areas lacking sufficient riparian corridor. While TSS data is lacking, transparency information confirms that the stream is more turbid on a regular basis than most areas of the watershed, in addition to the existing turbidity listing on the AUID immediately downstream. The productivity of Rice Lake may be responsible for some turbidity issues noted. However, tied to the suspended sediment is poor habitat. Embedded substrate, surrounding land use, and bank erosion

contributes to the degraded macroinvertebrate habitat conditions. MNDNR has documented poor habitat conditions in this area with little instream cover and depth variability. There is also channelization and a high density of tile drainage, both of which contribute to an altered flow regime and subsequent habitat loss.

Nitrate is considered inconclusive as a stressor due to the lack of connecting chemical data and wide mix of biological response. Additional chemical information would be helpful in understanding the potential concentrations in this reach including the duration of elevated nitrate concentrations and any temporal differences that may account for the varied biological response. In 2012 (when the biological sample took place) the concentrations may not have reached a typical peak, given the low flow year. Given that high concentrations have been observed (highest in 2015 was 22.5 mg/L), nitrate does seem like a probable stressor and should be reduced in the reach regardless. It's difficult to make the connection for stressor determination at this point, but additional biological monitoring (which would cover multiple years of sampling) in addition to better understanding of the corresponding seasonality of nitrate concentrations would be helpful in determining nitrate as a stressor.

DO levels were found to be sufficient in 2015 and biologically, there was little indication that DO was a likely stressor for both fish and macroinvertebrates. Addressing potential eutrophication problems in Rice Lake is needed to prevent possible DO related issues in this stream section. Additional monitoring is recommended to ensure DO levels remain normal and sufficient.

Table 33. Summary of stressor determinations for South Branch Middle Fork.

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
South Branch Middle Fork Zumbro (Downstream Rice Lake)	07040004-980	---	---	o	●	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.8.2 South Branch Middle Fork Zumbro (976)

Biological and background information

The South Branch Middle Fork Zumbro (07040004-976) has two biological stations: 12LM051 and 12LM084, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 5 (Southern Streams RR). The MIBI impairment threshold for this class is 37, with an average score per metric of 3.7 needed to achieve that threshold. 12LM051 has an MIBI score of 34.37, and 6 out of 10 metrics sore below the average needed. Site 12LM084 has an MIBI score of 56.92, which is above impairment threshold. Two metric scores are below average (HBI_MN, Trichoptera) but are relatively close to the average score needed. Interestingly, this site was one of the few Class 5 streams with a score other than zero for Plecoptera (score of 5), which is notable because they are a more sensitive taxa and not as commonly found.

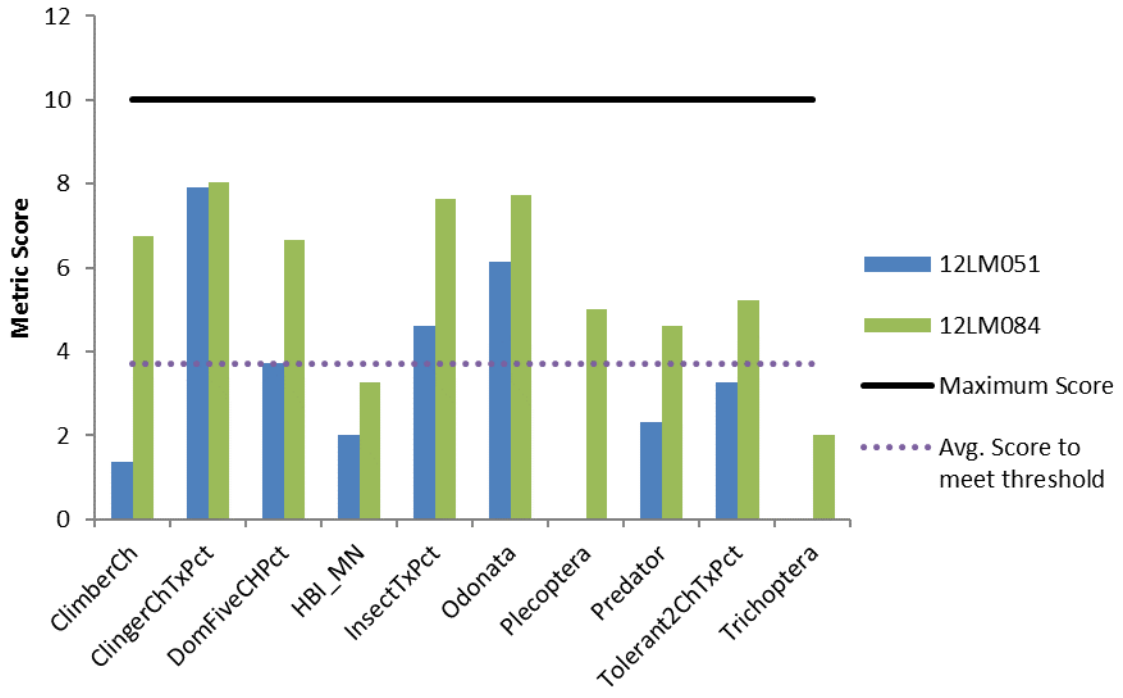

Figure 78. Macroinvertebrate IBI metrics for the South Branch Middle Fork (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

From 2003-2012, a total of 666 Do measurements were taken from this reach. These values ranged from 6.1-14.7 mg/L with no values falling below the 5 mg/L daily minimum standard. In 2015, continuous DO monitoring occurred at site 12LM051. This monitoring showed that the daily DO flux did not exceed the 4.5 mg/L maximum daily flux standard for the South nutrient region, and DO levels never fell below the 5 mg/L daily minimum standard.

Additionally, 42 phosphorus samples were taken along this stream reach from 2007-2015. These samples ranged from 0.067-1.22 mg/L with 25 (85%) above the 0.15 mg/L standard for phosphorus in the South nutrient region. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

The macroinvertebrate community in the South Branch Middle Fork of the Zumbro River at sites 12LM051 and 12LM084 averaged a high amount of DO intolerant species per site (10.5), while having a below average amount of DO tolerant individuals (7.49% average) when compared to all other macroinvertebrate Class 5 sites. The DO TIV score for this assemblage was also above average when compared across all Class 5 sites.

The fish assemblage along this reach had increased amounts of late maturing (46.43%) and sensitive (23.95%) individuals as well as decreased numbers of serial spawning (21.48%) and tolerant (48.95%) individuals when compared to all other fish Class 2 sites. These results reflect a stream that is not being negatively impacted by the DO conditions. Additionally, the DO TIV score was above average for Class 2 sites.

Based the very strong biological evidence as well as the continuous Do monitoring, low Do and eutrophication are not a stressor to the fish or macroinvertebrate assemblages in the South Branch

Middle Fork Zumbro River at this time. The high amounts of phosphorus measured may potentially lead to DO problems and will need to be monitored moving forward.

Nitrate

During biological sampling the nitrate concentration ranged from 2.2 mg/L-9.8 mg/L. On June 14, 2012 the nitrate concentration at 12LM084 was 6.4 mg/L, and on July 2, 2012 the nitrate concentration at 12LM051 was 9.8 mg/L. There were 38 additional samples collected in this reach in 2007 and 2008 at station S001-729. The average concentration was 5.6 mg/L, with a maximum of 13 mg/L collected in June of 2008. Only 3 of the 38 samples were above 10 mg/L. This station is located in-between the two biological stations, a few miles upstream of 12LM084.

The one macroinvertebrate sample taken at station 12LM051 had 78.6% nitrate tolerant species collected, and 12LM084 had only 65.7%. At 83.78% nitrate tolerant species, there is only a 10% probability of meeting the MIBI. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At these two stations, taxa richness was above average, at 37 for 12LM051 and 49 for 12LM084. Similarly, there were some Trichoptera taxa overall (4 and 5), but lacking in abundance (shown in the MIBI metric for Trichoptera). There were 6 generally intolerant taxa found at 12LM084, but only two at 12LM051. There were no nitrate intolerant taxa at station 12LM051, but 4 nitrate intolerant taxa found at 12LM084 (highest number in the Zumbro).

Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These trichoptera include all caddisflies that do not spin nets. The percentage at these stations was 1.1%-1.2%, while the average for sites in the LMB is 3.39%.

It's not clear if the concentrations in this reach vary or not. There are a few small tributaries that come in in-between the two stations, but the relative contribution of nitrate is unknown. The majority of nitrate data that has been taken on this reach is from the middle part of the reach at S001-729. It does seem probable that concentrations decrease when moving downstream in this watershed. There is some biological response evidence that suggests it may be a stressor at 12LM051 (the upper part of the reach) but not at 12LM084 (the lower part of the reach). Additional information should be collected to better understand the concentrations longitudinally. Given the lack of connecting information and uncertainty, nitrate is considered inconclusive as a stressor in this reach.

Suspended sediment

At the time of biological monitoring on July 2, 2012, a one-time chemistry sample was collected at 12LM051 and the TSS value recorded was 37 mg/L. At 12LM084 on June 14, the TSS value was 8 mg/L, then 33 mg/L on July 30, 2012. In early August, when macroinvertebrates were sampled, the stream was noted as looking like pea soup at both locations. During this time period, Rice Lake was having a significant algae bloom which contributed to the downstream conditions.

Since this reach was listed for turbidity, there were multiple samples taken for TMDL monitoring from 2007 and 2008. A total of 40 samples, mostly taken from 2007 and 2008, show an average concentration of 144 mg/L, with a maximum concentration of 870 mg/L collected on March 13th, 2007. Half of the samples collected were above the water quality standard of 65 mg/L, but these samples were also aimed at storm event sampling which does bias the results.

Daily TSS values were calculated for the South Branch Middle Fork Zumbro (AUID 07040004-976) subshed 502 by the HSPF model from 1995-2009. These values ranged from 2.09-2098.52 mg/L with an average value of 28.67 mg/L. additionally, 6.4% of the values were above 65 mg/L.

In the South Branch-Middle Fork Zumbro, the macroinvertebrate metrics do signal TSS stress (Table 34). There is consistent response seen with the elevated TSS index score, the lack of TSS intolerant taxa, and higher than average number and percentage of TSS tolerant taxa. Station 12LM051 had the highest TSS index score of any sites in the Zumbro Watershed, indicating a very TSS tolerant macroinvertebrate community is present. The fish community, while not impaired, signals TSS stress within the community present. Using data regarding fish community composition, there is only a 32% (12LM084) and 52% (12LM051) chance the reach meets the TSS standard. There is extensive channelization upstream of this reach, with some areas lacking riparian corridor. This is also supported by the current turbidity listing. All variables support that TSS is a stressor to the fish and macroinvertebrate communities of the South Branch Middle Fork Zumbro.

Table 34. Macroinvertebrate metrics relevant to TSS for stations in the South Branch Middle Fork compared to statewide averages for southern streams GP and southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM051	**20.52**	**0.00**	**12**	**57.04**	**21.42**	**0.00**
12LM084	**17.55**	3	**15**	**40.55**	**16.16**	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to TSS stress	↑	↓	↑	↑	↓	↓

Habitat

Qualitative habitat assessments took place during the fish sampling at both 12LM051 and 12LM084 in 2012. Site 12LM051 had an MSHA score of 77.5 (Good), and site 12LM084 had an average MSHA score from two visits of 64.35 (Fair) (Figure 79). Limiting the MSHA scores along this reach was the lack of stream shading, the presence of some sand and silt substrates, moderate to light embeddedness, sparse fish cover at 12LM084, moderate channel stability, and lack of a riffle at 12LM084.

The macroinvertebrate sample at site 12LM051 was taken from equal parts woody debris and riffle habitat, while site 12LM084 had samples taken from woody debris, riffles, overhanging vegetation and aquatic macrophytes. This sample showed that the macroinvertebrate community differed between the two sites. Site 12LM051 had a decreased amount of burrower individuals (5.9%), while site 12LM084 had an above average amount of burrower individuals (17.66%) when compared statewide. Burrowers are often more abundant in streams with degraded habitat conditions containing sand and silt substrates. A large difference was also observed in amounts of legless individuals. Site 12LM051 at 17.7% compared to 54.49% at 12LM084. High amounts of legless individuals can often be associated

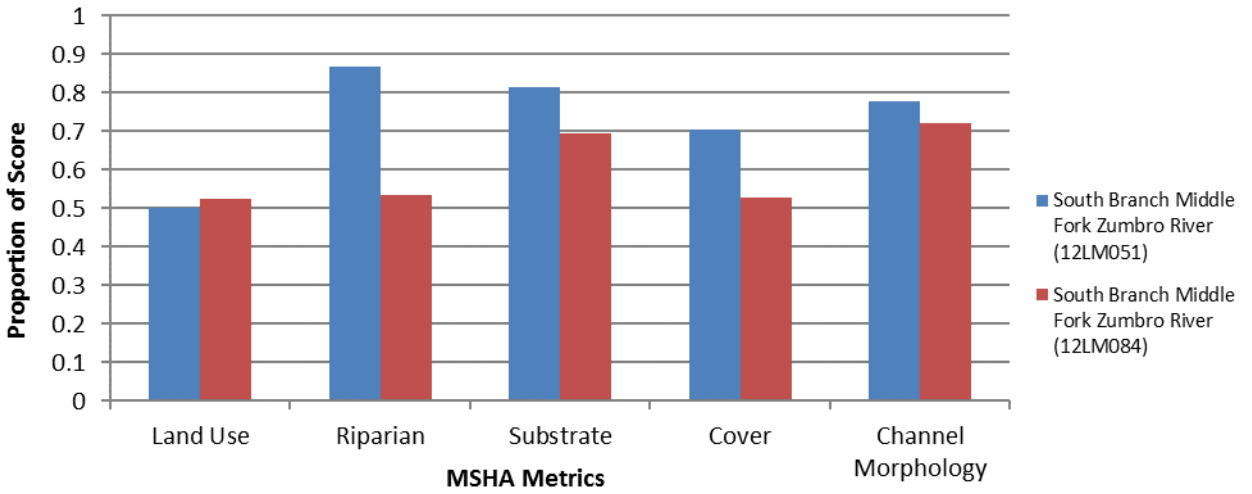

Figure 79. MSHA metric value scores at two sites along South Branch Middle Fork Zumbro River (07040004-976).

with poor habitat conditions. Site 12LM051 had a high amount of clinger (74.53%) but a decreased amount of climber (8.07%) individuals, while site 12LM084 had elevated numbers of climbers (31.44%) and a slightly above average amount of clingers (37.43%).

The fish assemblage was fairly similar at both sites along this reach. These sites had increased numbers of benthic insectivore (32.47%), darter/sculpin/round-bodied sucker (29.78%), riffle dwelling (48.11%), and simple lithophilic spawning (49.34%) individuals. These results all indicate good habitat conditions. A few notable differences in the fish communities were the difference in pioneering individuals at each site as site 12LM051 had an increased amount (34.2%) compared to site 12LM084 (8.22%). Pioneering species are able to thrive in unstable environments and are usually the first to invade after a disturbance. Site 12LM051 also had more tolerant individuals (66.67%) than 12LM084 (40.1%).

Despite the lower scoring habitat related macroinvertebrate metrics and the lower MSHA score, site 12LM084 had an MIBI score above the Class 5 threshold. The MIBI at site 12LM051 was below the Class 5 threshold leading to the macroinvertebrate impairment; however, the habitat related metrics and MSHA scored very well at this site. Additionally, the fish metrics scored fairly well at both sites, suggesting that the lack of habitat is not a stressor in the South Branch Middle Fork Zumbro River (07040004-976) at this time.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 19.36-mile-long reach of South Branch Middle Fork Zumbro River (07040004-976) was 24.16% modified. Modified channels typically lead to reduced habitat conditions, eroded banks and an overall reduction in diversity. The far headwaters of this reach are completely modified.

This reach includes a dam located in the town of Mantorville. However, the dam does not appear to be a stressor as the site located upstream of the dam along this reach (12LM051), had similar numbers of migratory fish individuals (46.96%) to site 12LM084 (47.4%) located downstream of Mantorville along the same reach. Further upstream in this watershed, site 12LM052, also had an above average amount of migratory fish individuals (23. 73%).As opposed to South Branch Middle Fork Zumbro River (07040004-980), this reach seems to be much less impacted by the modified headwaters. The MSHA scores along this reach are much improved and metrics potentially impacted by flow alteration have much higher scores than the upstream AUID. Therefore, based on the habitat and high presence of

migratory fish species; flow alteration and connectivity is not a stressor to the biological communities in this portion of the South Branch Middle Fork Zumbro River (07040004-976) at this time.

Conclusions and recommendations

The macroinvertebrate community in the South Branch Middle Fork (976) is being stressed by elevated TSS (Table 35). The existing turbidity listing is further corroborated with the biological response showing many TSS tolerant taxa (both fish and macroinvertebrates). The upstream station (12LM051) has demonstrated the most stress; however, TSS stress is documented throughout this reach. Currently, the health of both the fish and macroinvertebrates are fairly good at 12LM084 (Oxbow Park) but any further degradation could reduce IBI scores there as well.

Nitrate concentrations are moderately elevated, but it is not clear if nitrate is having a large impact on the macroinvertebrate community. There is some biological response evidence that suggests it may be a stressor at 12LM051 (the upper part of the reach) but not at 12LM084 (the lower part of the reach). Additional information, including biological and chemical, should be collected to better understand the concentrations longitudinally and seasonally. Regardless, it would be helpful to reduce nitrate concentrations in this reach.

Habitat and DO were ruled out as potential stressors in this reach. High phosphorus was noted on the reach and needs to be reduced, even though DO levels do not appear to be affected. Overall, the habitat and DO levels are suitable, as evidenced by biological and chemical information.

The main stress on this reach is in the upper end (12LM051; near Dodge Center Creek). Farther downstream, stress is not as apparent (12LM084). The upstream land use and heavy channelization are likely contributing factors to the issues seen in this reach. The upstream reach (980, discussed in previous section) was also stressed by habitat issues and flow alteration. As noted by MNDNR reports, the geology of this area changes, with more gradient and bedrock when moving downstream. These conditions allow for sediment to continue to be transported downstream instead of settling out and impacting habitat and this also suggests this reach is not as impacted by flow and channelization issues as is the case in the upstream reach.

Table 35. Summary of stressor determinations for South Branch Middle Fork.

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
South Branch Middle Fork Zumbro (Dodge Center Creek to Oxbow)	07040004-976	---	---	o	●	---	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.9 Dodge Center Creek Watershed

The Dodge Center Creek Watershed is a warmwater stream in Dodge County, and flows to the South Branch Middle Fork Zumbro. This subwatershed drains a total of 56,960 acres, 83% of which is in agricultural use. Section 4.9 will discuss four streams with biological impairments in this watershed (Figure 80).

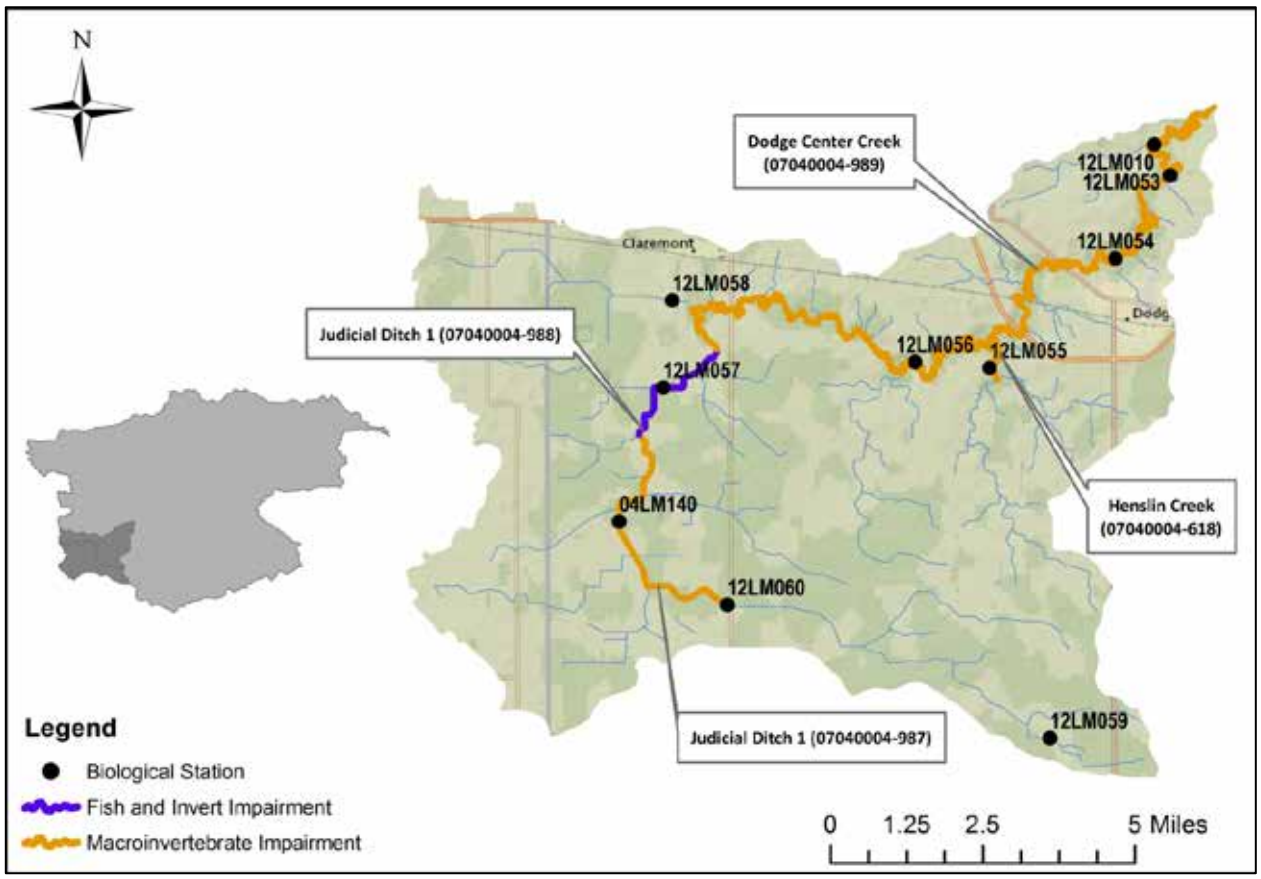

Figure 80. Map of the Dodge Center Creek Watershed, biological stations, and impaired AUIDs.

4.9.1 Dodge Center Creek (989)

Biological and background information

Dodge Center Creek (07040004-989) has four biological monitoring sites: 12LM053, 12LM056, and 12LM010 and 12LM054. Site 12LM010 has no data recorded and no MIBI score, due to a missing sample. Two of the three assessed sites along Dodge Center Creek (12LM053, 12LM056) are designated macroinvertebrate Class 5 (Southern Streams RR). For streams designated macroinvertebrate Class 5 the MIBI impairment threshold is 37, with an average score per metric of 3.7 needed to achieve that threshold. One station on the reach, 12LM054, was designated macroinvertebrate Class 6 (Southern Forest Streams, GP). This data resulted in a macroinvertebrate impairment on this reach.

Site 12LM053 had an MIBI score of 41.1, which is above impairment threshold. Seven out of 10 metrics at site 12LM053 scored at or above the average score needed. The taxa at this site are diverse and not overly dominated by any particular taxa. Site 12LM056 had an MIBI score of 38.86 which is also above impairment threshold. Climber taxa are abundant at this location, but overall the metrics show diverse taxa are present. Both sites however, had zero Plecoptera taxa. Both sites have below the average metric score for Trichoptera taxa (Trichoptera) and are below the average metric score for the Hilsenhoff Biotic Index (HBI_MN) score. HBI_MN is a measure of pollution based tolerance values assigned to each individual taxon.

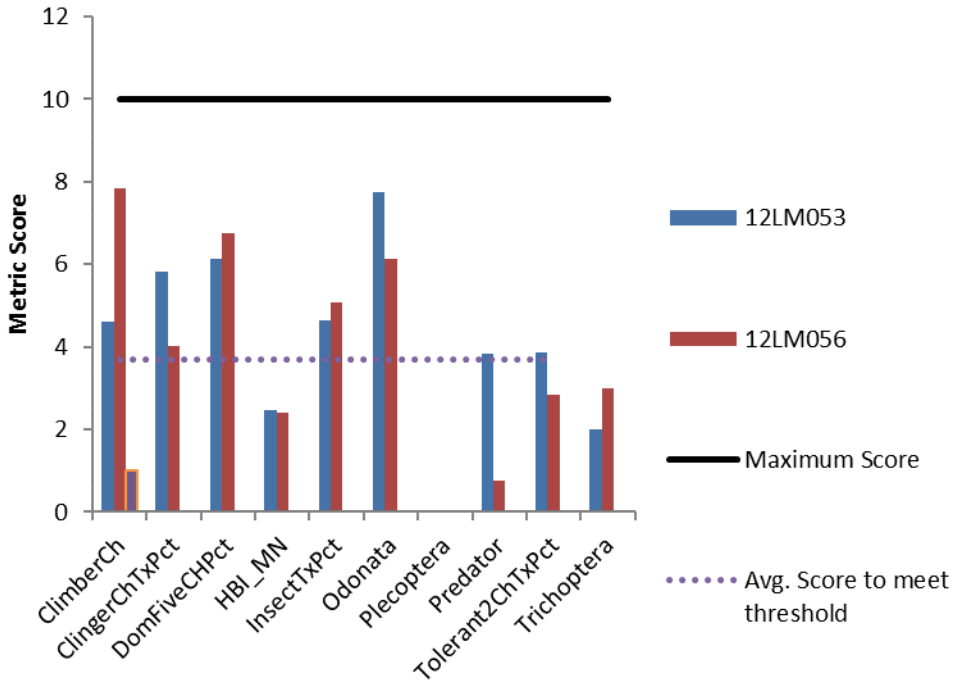

Figure 81. Macroinvertebrate IBI metrics for Dodge Center Creek (Class 5; Southern Streams Riffle/Run).

Station 12LM054 has an MIBI score of 30.2, which is below the impairment threshold of 43. An average metric score of 4.3 is needed to meet that threshold. The site scores poorly on most of the MIBI metrics. The taxa richness of intolerant individuals (Intolerant2CH) scores zero. This site is closest to the ditched portion of Dodge Center Creek, where the other two stations on Dodge Center Creek are father downstream. This may indicate potential longitudinal improvement or may be simply site specific differences.

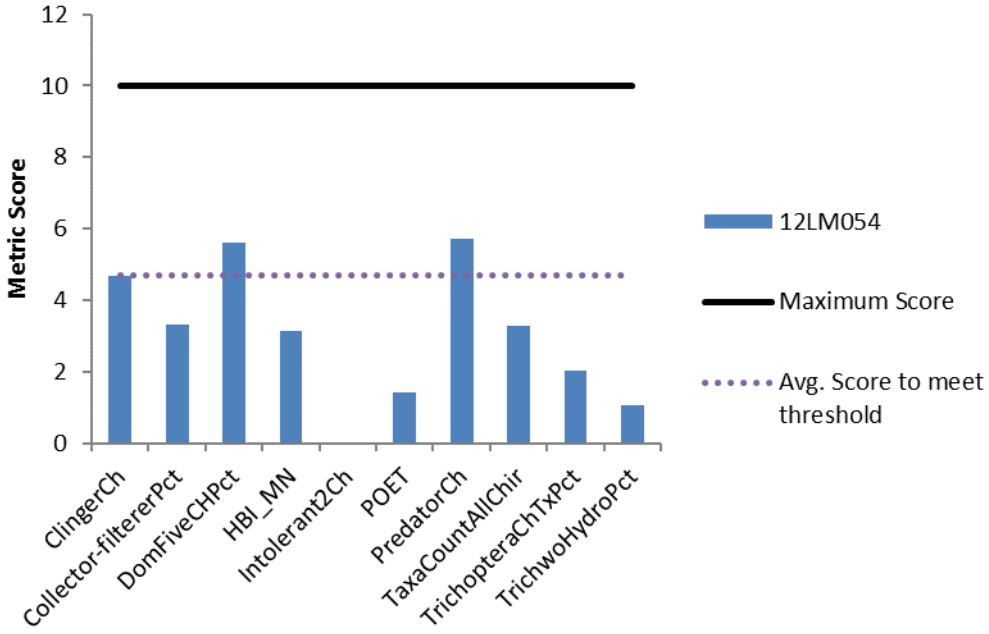

Figure 82. Macroinvertebrate IBI metrics for Dodge Center Creek (Class 6; Southern Streams Glide/Pool).

Dissolved oxygen and eutrophication

Dodge Center Creek had continuous DO monitoring take place in July 2014 (Figure 83). DO values in this reach did not fall below the 5 mg/L daily minimum standard, or did the daily exceed the 4.5 mg/L standard in the South nutrient region. Flux in excess of 4.5 mg/L can often signal stress due to the DO conditions.

Additionally, 20 of the 43 phosphorus samples collected from 2012-2014 were above the 0.15 mg/L standard for phosphorus. Excess phosphorus can lead to eutrophication, which can alter the DO conditions in the stream. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

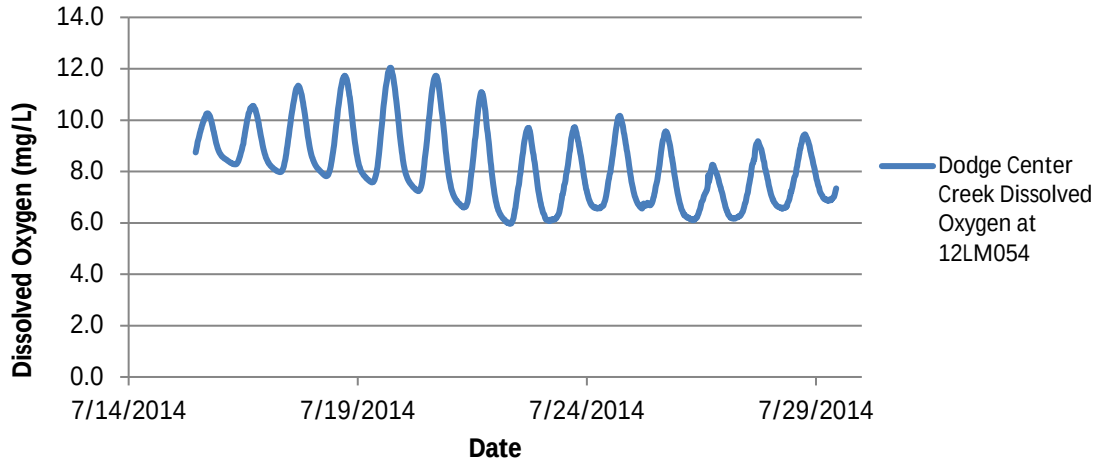

Figure 83. Continuous DO monitoring at site 12LM054 along Dodge Center Creek (07040004-989).

Biologically, the macroinvertebrate community in Dodge Center Creek averaged 4.67 low DO intolerant taxa per sample at the three biological stations along this reach. This average is low when compared to all other sites within the watershed. The most downstream station with a macroinvertebrate sample, 12LM053 had 8. This site also had a high amount of EPT individuals (44.51%). Collectively, these sites

also averaged a high amount of dissolved oxygen tolerant individuals (17.77%) when compared statewide, which was primarily driven by site 12LM034 (38% DO tolerant individuals). The two Class 5 macroinvertebrate sites (12LM053, 12LM056) had a slightly below average DO TIV score for their respective class, while the Class 6 site, 12LM054, had a below average DO TIV score.

The fish assemblage in this reach had a high amount of late maturing individuals (43.95%) such as golden redhorse (24 individual average per site). This stream also had few sensitive (3.51%), few serial spawning individuals (16.16%) and a high amount of tolerant (80.41%) individuals. Collectively, the biological stations along this reach had a slightly above average dissolved oxygen TIV score when compared to all other Class 2 sites.

The continuous DO monitoring never exceeded the dissolved oxygen minimum standard, and did not have any instances in which the daily flux was above 4.5 mg/L and had mixed biological metric scores. It is likely that the biological metrics are being negatively impacted by other stressors. The high levels of phosphorus may eventually lead to DO issues in this stream; but at this time, low DO and eutrophication are not stressors to the impaired macroinvertebrate community in Dodge Center Creek.

Nitrate

During fish sample, the nitrate concentrations measured on this reach ranged from 6.9 to 13 mg/L (June 2 and 3, 2012). The concentrations decreased when moving longitudinally downstream. There were 39 nitrate values taken on this reach, from multiple locations, in 2012 and 2014. The average nitrate concentration collected from these samples was 11.39 mg/L, the maximum concentration occurred on June of 2014 and measured 20 mg/L. Thirty percent of the samples collected were above 15 mg/L, all of which were collected in either May or June.

Daily nitrate values were calculated for Dodge Center Creek (AUID 07040004-989) subsheds 52 and 53 by the HSPF model from 1995-2009. These values ranged from 1.73-24.84 mg/L with an average value of 5.5 mg/L. In addition, for the entire 07040004-989 reach, 4% of the values were above 10 mg/L and less than 1% were above 20 mg/L.

The macroinvertebrate communities in Dodge Center Creek show a mixed response to elevated nitrate. Taxa Count or species richness were above class averages for two of the three stations (Table 36). Trichoptera taxa were below average at only one station, 12LM054. This station, along with 12LM053 both were lacking intolerant macroinvertebrate taxa (non-hydropsychid Trichoptera and nitrate intolerant taxa). However, station 12LM056 had an above average percentage of non-hydropsychid Trichoptera and nitrate intolerant taxa. All of the sites had some nitrate tolerant individuals present, but they weren't overly abundant, with percentages near the average for the respective stream classes. The macroinvertebrate community nitrogen index score also varied from 2.8- 3.2, while the average for warmwater stations meeting impairment threshold is 2.9. Interestingly, the lower score of 2.8 (which suggests more sensitivity) was seen at 12LM054, where the other nitrate metrics were more consistently responding.

Overall, the biological response evidence doesn't overwhelmingly support nitrate stress throughout the AUID. There is more response seen with the macroinvertebrate community at 12LM054, which is where nitrate is lower comparatively (concentrations decrease when moving downstream). Other stressors are likely playing a role in the varied response between stations. Nitrate concentrations are elevated here, but biological response and duration of elevated nitrate is unknown. At this time, nitrate is considered inconclusive as a stressor to Dodge Center Creek.

Table 36. Nitrate relevant metrics comparison for Dodge Center Creek

Nitrate Relevant Metrics	Taxa Count (TaxaCountAllChir)	Trichoptera Taxa	% Non-hydropsychid tricoptera	Nitrate Intolerant Taxa	% Nitrate Tolerant Individuals
12LM053 (Class 5)	37	4	**1.8**	**0**	67
12LM056 (Class 5)	46	5	4.4	3	64
12LM054 (Class 6)	**30**	**1**	**0.3**	**0**	53
Expected response with increased Nitrate stress	↓	↓	↓	↓	↑
Class 5 Averages	***37.76***	***4.3***	***3.39***	***1.49***	***69.8***
Class 6 Averages	***33***	***2.2***	***2.21***	***1.49***	***69.8***

Suspended sediment

At the time of biological monitoring in 2012, as part of a one-time chemistry sample, TSS values were recorded at sites 12LM010, 12LM053, 12LM054 and 12LM056. These TSS values were 4.4, 6.8, 15 and 4.4 mg/L, respectively. Additionally, 39 TSS values were collected from April through September of 2012 and 2014. These values ranged from 3.2-190 mg/L with an average value of 38.6 mg/L. Of the 39 values, 9 were above the 65 mg/L standard for designated warm water streams. This reach also has an existing turbidity impairment.

Daily TSS values were calculated for Dodge Center Creek (AUID 07040004-989) subsheds 52 and 53 by the HSPF model from 1995-2009. These values ranged from 1.68-1935.48 mg/L with an average value of 20.42 mg/L. In addition, 4.6% of the values from Dodge Center Creek were above 65 mg/L.

In Dodge Center Creek, the macroinvertebrate metrics signal TSS stress (Table 36). There is consistent response seen with the elevated TSS index score, the lack of TSS intolerant taxa and higher than average number and percentage of TSS tolerant taxa. The fish community, while not impaired, responds with 6 of the 10 metrics signaling TSS stress at all stations (Table 36). There is extensive channelization upstream of this reach, with some areas lacking riparian corridor; this corroborates the macroinvertebrates stress which seems more prominent in the upstream reaches. TSS is a stressor to the fish and macroinvertebrate communities of Dodge Center Creek.

Table 37. Macroinvertebrate metrics relevant to TSS for stations in Dodge Center Creek compared to statewide averages for southern streams GP and southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Stations upstream to downstream (Macroinvertebrate Class)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM053 (RR)	18.9	0.0	9.0	54.1	15.5	0.0
12LM056 (RR)	17.35	3	14	42.2	36.1	0.0
12LM054 (GP)	15.6	1.0	7.0	19.9	12.8	0.0
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Station	BenFdFrimPct	Centr-TolPct	HerbvPct	Percfm-TolPct	RiffePct	SensitivePct	SLithopPct	IntolerantPct	Longlived Pct	TSS Index Score (RA)
12LM053	68.86	1.90	5.19	3.81	63.15	1.56	67.30	0.69	2.77	16.2
12LM054	44.68	3.34	0.61	11.25	32.22	5.17	39.21	0.61	6.69	20.9
12LM056	57.54	1.71	5.60	14.46	49.14	4.20	50.70	0.16	1.09	17.3
12LM010	46.70	1.59	13.84	9.47	37.95	3.10	42.32	0.95	0.08	16.6
Statewide average for Southern Streams that are meeting the FIBI Threshold (45)	**34.08**	**4.63**	**7.72**	**19.37**	**28.32**	**14.81**	**35.19**	**3.32**	**12.86**	**18.03**
Expected response to TSS stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Habitat

The four biological stations along Dodge Center Creek (07040004-989) had qualitative habitat assessments performed during the fish sampling events in 2012. The MSHA scores at these sites ranged from 56.55-66.7, with an average score of 63.9 which is considered fair (Figure 84). Limiting the MSHA at these sites was poor surrounding land use, a limited riparian buffer; moderate to light embeddedness, moderate channel stability, reaches lacking riffles and fair channel development.

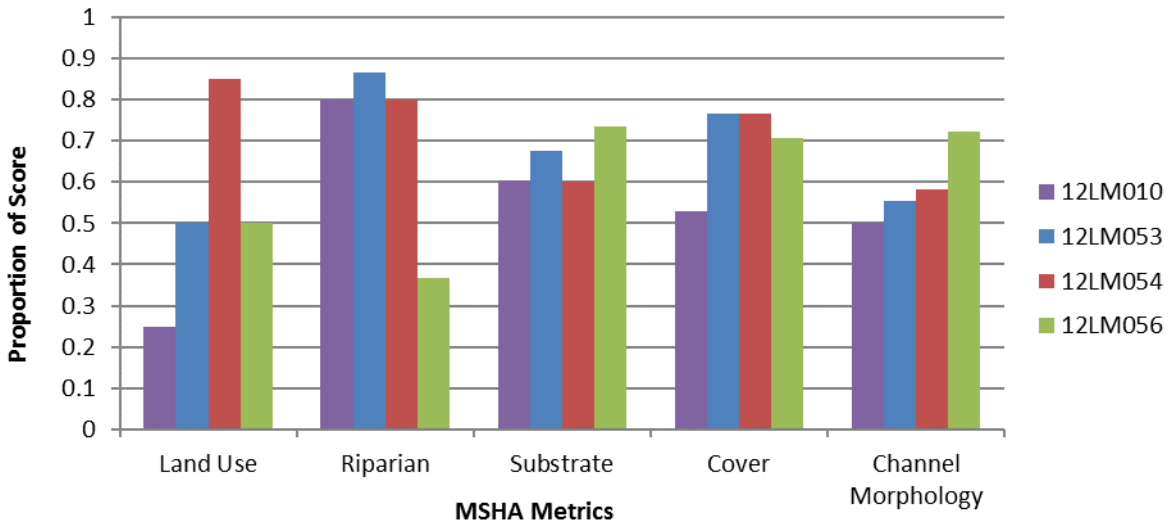

Figure 84. MSHA metric value scores for sites located along Dodge Center Creek (07040004-989).

The macroinvertebrate sample at sites 12LM053, 12LM054 and 12LM056 was taken from the riffle, woody debris and overhanging vegetation habitat available. The macroinvertebrate community in Dodge Center Creek averaged few burrower (8.03%) and a high amount of clinger (60.49%) individuals. Burrower species prefer abundant fine sediments, while clingers prefer habitats abundant with rocks and woody debris. These results are common in streams with good habitat conditions. This reach did have a low amount of climber individuals (17.62%). These species prefer areas abundant with overhanging vegetation. This reach also averaged a low amount of EPT individuals (24.03), which was primarily due to the very low amount present at 12LM054 (0.61%). EPT taxa are a sensitive group of macroinvertebrates commonly used to assess the overall health of an ecosystem.

The fish assemblage in this reach averaged higher numbers of benthic insectivore (16.48%), simple lithophilic spawning (49.88%), riffle dwelling (45.61%) and darter/sculpin/round-bodied sucker (12.37%) individuals when compared statewide. These results all signal a reach with good habitat conditions. Additionally, this reach did have a high amount of tolerant (80.41%) and pioneering (30%) individuals. These metrics tend to be higher in streams with limiting habitat.

MNDNR Summary for Biological Station 12LM054

Dodge Center Creek near station 12LM054 is classified as a C5c stream type with a sand bed. Water surface slope of 0.00018 is very flat. Width to depth ratio is 15.91 with an adjusted entrenchment ratio of 2.22. The low entrenchment ratio suggests incision and recent succession from an F to a C stream type. A poor Pfankuch rating was given with deposition being a large factor. The bank-height ratio is right on the border of being moderately and deeply incised.

A total of 9 banks were observed in this 590 ft. survey. An average erosion rate of 0.07 tons/yr/ft, with the worst bank rate of 0.17 tons/yr/ft or 10.3 tons/yr. Exposed banks were common throughout the survey; however, where present, tree roots acted as armor protecting the bank and reducing erosion.

Similar to the other reach surveyed on this creek, this reach is in recovery. The buildup of sand point bars is an indication of aggradation, which is the stream developing a floodplain within an incised and over widened channel. Local stressors may be driving conditions observed on site. A cattle crossing was noted just above the geomorphology site that was very wide and shallow, causing excess sediment and instability. Another issue is downstream meander migration (Figure 85).

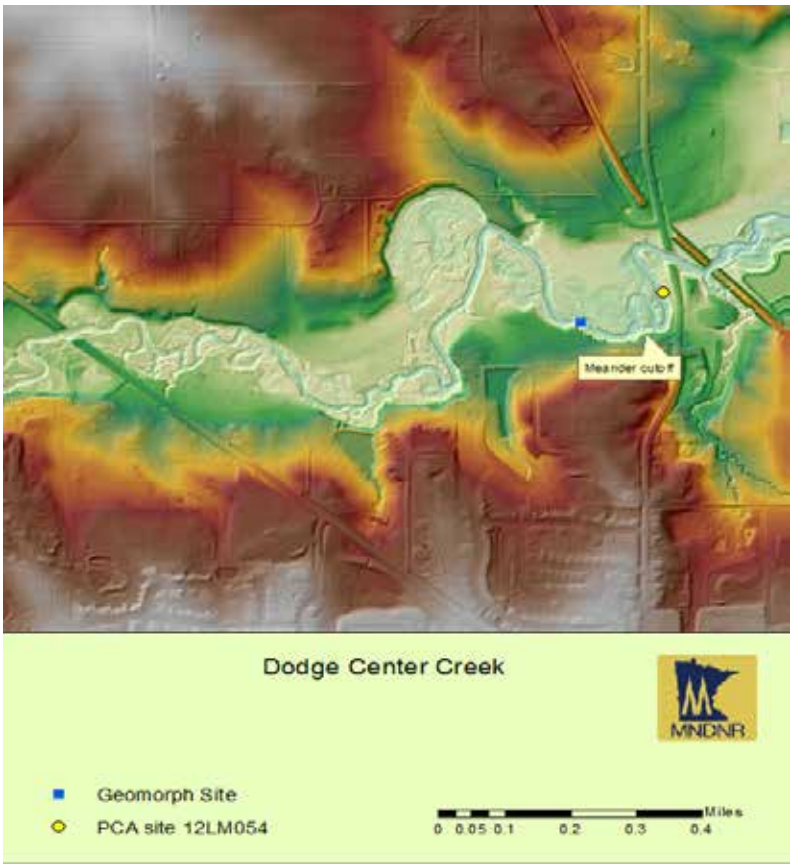

Figure 85. Survey locations and meander cutoff from MNDNR geomorphology survey.

There was a recent meander cutoff of 670 feet just above the SID site. As seen in the field, this cutoff is now dry and the channel is routed through a narrow area that will erode more in the future.

Dodge Center Creek (07040004-989) is impaired for aquatic life due to its poor macroinvertebrate community. Many MSHA habitat related metrics in the IBI scored low; this likely due to the predominantly fair habitat conditions observed across Dodge Center Creek. The lack of channel development, poor land use, and presence of fine sediment was found to be limiting this assemblage. The fish assemblage in this reach also showed some stress with the high presence of tolerant and pioneering individuals. Therefore, the lack of habitat is a stressor to the macroinvertebrate assemblage at this time.

Flow alteration and connectivity

The biologically impaired reach, 07040004-989, is considered to be 99.32% natural or unaltered according to the Altered Watercourses GIS layer. However, there are highly altered tributaries to this system that will be addressed in their respective sections. Currently, there are no dams or perched culverts along this portion of Dodge Center Creek that would suggest connectivity to be a stressor.

While there are minimal channel alterations, and a lack of dams and perched culverts to this portion of Dodge Center Creek, the highly altered tributaries to Dodge Center Creek appear to be having a negative effect in the upper reaches of the AUID observed nearest the channelized/modified tributaries. However, there is not enough evidence to conclude flow alteration as a stressor in Dodge Center Creek at this time. Therefore, flow alteration is inconclusive as a stressor to the macroinvertebrate community.

Conclusions and recommendations

The macroinvertebrate community of Dodge Center Creek (989) is being stressed by elevated TSS and poor habitat (Table 38). The existing turbidity impairment is validated with a dominance of macroinvertebrates that are tolerant of high TSS and a lack of TSS intolerant taxa. There is extensive channelization upstream of this reach, with some areas lacking riparian corridor. This corroborates the macroinvertebrate stress which seems more prominent in these upstream reaches, nearest the channelized areas. Similarly, habitat issues are limiting the macroinvertebrates. There is a lack of channel development, poor land use and presence of fine sediment all of which contribute to the degraded community. The fish community, while not impaired, is also signaling TSS and habitat stress.

Nitrate is inconclusive as a stressor, even though the concentrations are elevated in this watershed. The maximum concentration in 2014 was 20 mg/L (June). The percentage of tile drainage and channelization in this watershed contributes to the high nitrate concentrations observed. The macroinvertebrate response to elevated nitrate was mixed in this reach, with the most response seen where the concentrations were lower (nitrates appear to decrease in concentration when moving downstream through the watershed). Due to this unexpected trend, nitrate could not be confirmed as a stressor.

DO was ruled out as a potential stressor due to a mixed biological response and sonde data that confirmed concentrations were adequate. High levels of phosphorus were documented and should be reduced but do not appear to be impacting the DO regime at this time. Flow alteration is inconclusive as a stressor given lack of biological evidence to support it, even though there are highly altered tributaries in the upstream watershed. There also doesn't appear to be any issues with connectivity at this time.

Table 38. Summary of stressor determinations for Dodge Center Creek

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Dodge Center Creek	07040004-592	---	---	o	●	●	o

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.9.2 Judicial Ditch (987)

Biological and background information

Judicial Ditch 1 (07040004-987) has two biological stations, 04LM140 and 12LM060, which resulted in a macroinvertebrate impairment. These sites are located on a reach that is a designated macroinvertebrate Class 6 (Southern Forest Stream GP) stream. For streams in this class the MIBI "modified" use impairment threshold is 30, with an average score per metric of 3.0 needed to achieve that threshold. In 2012, the MIBI was 18.48, and all of the metrics received very poor scores below the average metric score needed. However, site 04LM140 sampled in August had an MIBI score of 33.20, which is above the modified use threshold. This site scored above the average metric of 4.3 in 4 out of 7 metrics.

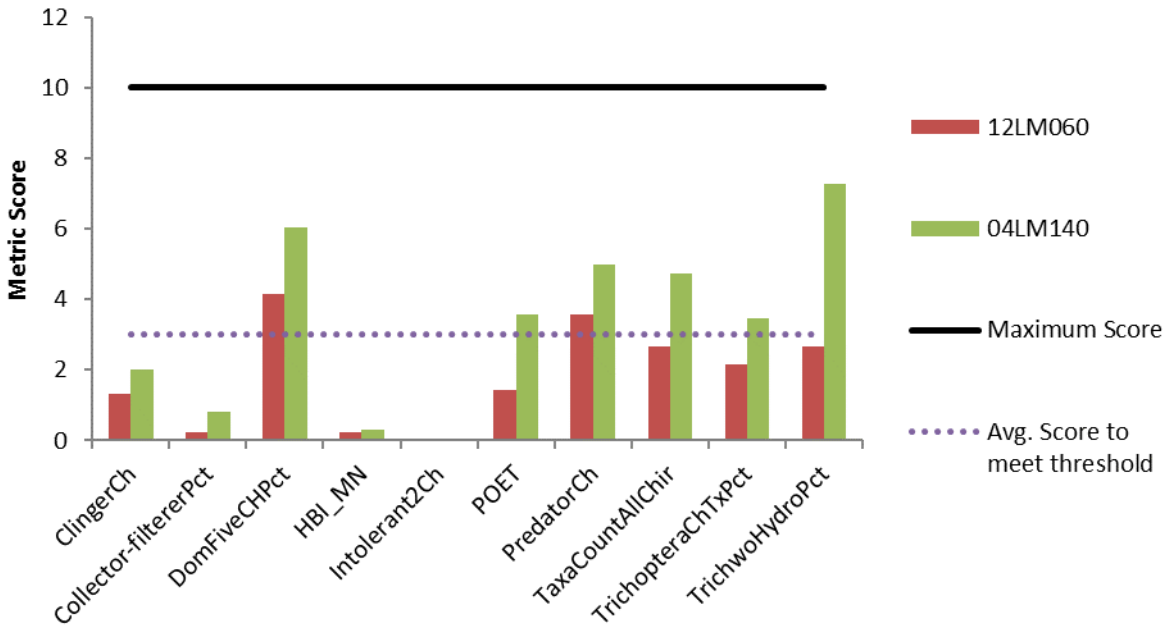

Figure 86. Macroinvertebrate IBI metrics for JD1 (Class 6; Southern Streams Glide/Pool)

Dissolved oxygen and eutrophication

Judicial Ditch 1 had a total of 7 DO readings taken from 2012-2014. These readings ranged from 6.74-15.17 mg/L. Continuous DO monitoring was performed along Judicial Ditch 1 at site 12LM060 (S001-488) during July 2014, (Figure 88). Daily DO values frequently fell below the 5 mg/L daily minimum standard. The daily flux often exceeded 16 mg/L. Flux in excess of 4.5 mg/L in the South nutrient region can often signal stress due to the poor DO conditions.

Figure 87: Excessive algae growth causing eutrophication at site 12LM060.

Additionally, six phosphorus samples were taken along this stream section from 2012-2014, with values ranging from 0.037-0.491 mg/L with three values well above the 0.15 mg/L phosphorus standard in the South nutrient region. The high levels of phosphorus seem to have caused eutrophication (Figure 87) in Judicial Ditch 1 and led to a high flux in DO and prolific algae growth. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts. The temperature at this site also reached 32.64 degrees C during a sonde deployment. When water temperatures are high, the water cannot hold as much oxygen.

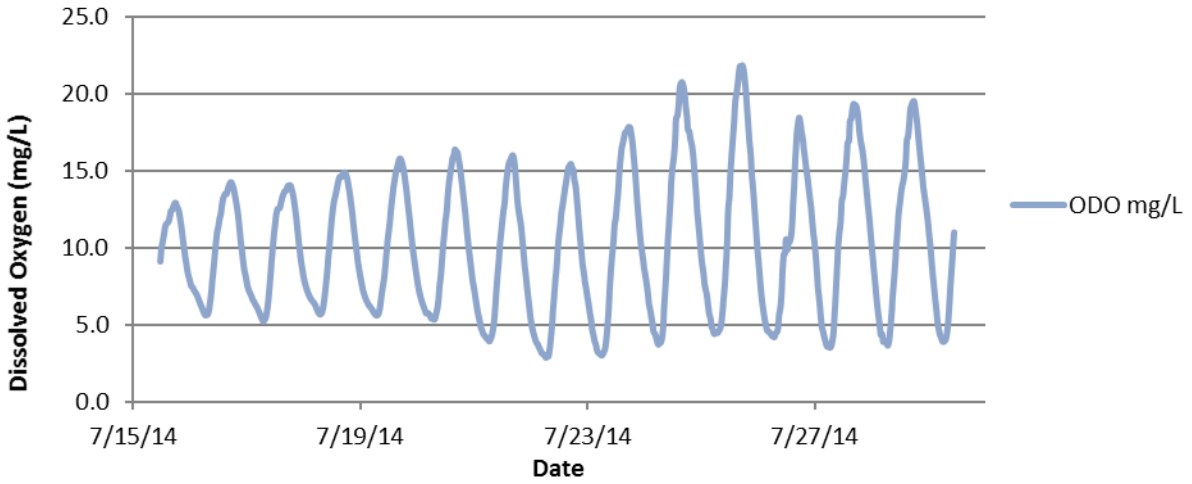

Figure 88. Continuous DO Data at site 12LM060 along Judicial Ditch 1 (07040004-987) in 2014.

The macroinvertebrate community in Judicial Ditch 1 had many DO tolerant species (10) and individuals (70.99%), which is above the class average. This site also only had one DO intolerant taxa present. This reach also had few EPT individuals (4.67%), which is common in streams negatively impacted by low DO conditions. Site 12LM060 also had a low DO TIV score compared to all other Zumbro Watershed sites, which indicates the community is comprised of species tolerant to low DO.

The fish assemblage in Judicial Ditch 1 had high amounts of serial spawning (33.64%) and tolerant (70.99%) species individuals, while also having few late-maturing (6.79%) and sensitive (0.62%) species individuals. These metric results are common in streams impacted by low DO conditions. Site 12LM060 also had a below average DO TIV score when compared to all other sites within the Zumbro River Watershed. The fish sample had a high amount of bigmouth (49) and common (43) shiner individuals. These species are tolerant to low DO conditions.

The DO conditions consistently fall below 5 mg/L and have a daily flux that greatly exceeds 4.5 mg/L. The DO related biological metrics as well as the very high levels of phosphorus and algae growth also strongly suggest that eutrophication and subsequent low DO is negatively impacting both the fish and macroinvertebrate communities. Therefore, low DO and eutrophication are stressors to the biological communities in Judicial Ditch 1.

Nitrate

During fish sample, the nitrate concentration at 12LM060 was 28 mg/L on June 25, 2012 and 25 mg/L on June 21, 2004 at 04LM140. There were five additional samples taken on this reach in 2014, from June through July. In June there were three samples taken, with a range of concentration from 13 to 30 mg/L. The concentration dropped to 10 mg/L in mid-July, to less than 1 mg/L at the end of July.

Daily nitrate values were calculated for Judicial Ditch 1 (07040004-987, 55) by the HSPF model from 1995-2009. The values ranged from 1.95-40.0 mg/L with an average value of 5.74 mg/L. Of 5474 values, 207 were above 10 mg/L and 10 were above 20 mg/L. In addition, in March 2000 one calculated value was 40.0 mg/L, the highest predicted for this AUID.

In 2012, station 12LM060 had poor taxa richness with a taxa count of 28 (TaxaCountAllChir). The average taxa count for macroinvertebrate Class 6 (Southern Forest Streams GP) is 33. Conversely, station 04LM140 had a taxa count of 35, which is above average. Trichoptera are also found to be generally sensitive to elevated nitrate concentrations. There was only one Trichoptera taxon at 12LM060 and 2 at 04LM140, which is below the average for the Class 6 stations of the LMB (2.2).

Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. Non-hydropsychid trichoptera are all caddisflies that do not spin nets. Station 12LM060 had only 0.9% non-hydropsychid trichoptera. This is below average compared to all biological sites in the LMB (3.39%) and of this stream class (2.21%). However, station 04LM140 had 5% non-hydropsychid Trichoptera which is above average.

The macroinvertebrate visits at station 12LM060 had only 39% nitrate tolerant individuals, which is actually lower than most sites in the watershed. This low percentage may be explained because of dominance of *Coenagrionidae,* a damselfly found in degraded stream conditions but not considered overly tolerant to high nitrate. It's possible the reason this damselfly exists in JD1 was due to adults coming from a nearby wetland and laid eggs in this stagnant ditch. At the time the ditch became stagnant, nitrate concentrations were generally lower compared to the late spring when concentrations were at their peak. It's likely these damselflies will not be able to tolerate the high nitrates in this ditch later on in their life cycle.

Contrast this with nearby 04LM140 (sampled a different year), which had 86% nitrate tolerant individuals and was dominated by *Pseudocloeon* (a tolerant mayfly) and *Physa* (snails). At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Class 6 MIBI. There were no nitrate intolerant taxa, or generally intolerant macroinvertebrate taxa present at either station. Overall, both communities reflect nitrate degradation and multiple stressors are likely producing the dramatic response seen. The difference in stream conditions between the two years (i.e., in terms of total precipitation; 2012 had less precipitation and thus likely lower concentrations) also corroborates the community composition differences between the two stations and potential differences in nitrate concentration.

Overall, the chemical concentrations and biological response confirm that nitrate is a stressor to the biological community in JD1.

Suspended sediment

At the time of biological monitoring in 2004 as part of a one-time chemistry sampling, the TSS value recorded at site 04LM140 was 20 mg/L. Then during one-time chemistry sampling again in 2012, at site 12LM060 the TSS value recorded was 4.4 mg/L. Additionally, 5 TSS values were collected from June and July of 2014. These values range from 1.6-230 mg/L with an average value of 49.9 mg/L.

Daily TSS values were calculated for Judicial Ditch 1 (AUID 07040004-987) subshed 55 by the HSPF model from 1995-2009. These values ranged from 1.17-1556.18 mg/L with an average value of 15.9 mg/L. Additionally, 3.27% of the values were above 65 mg/L.

Overall, the macroinvertebrate metrics seem to signal TSS stress (Table 39). This reach is a judicial ditch, with many areas lacking a sufficient riparian corridor, but the ditch itself is fairly stable without much erosion contributing to elevated TSS. There is macroinvertebrate response which indicates elevated TSS is a probable stressor, but there is a lack of connecting chemical information from a very small chemical dataset. Modeled chemical data also does not give a strong signal for TSS as a stressor. Other cumulative stressor impacts may explain the biological response. TSS is inconclusive as a stressor to the fish and macroinvertebrate communities of JD1.

Table 39. Macroinvertebrate metrics relevant to TSS for stations in JD1 compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
04LM140	**17.21**	**0.00**	5.00	**31.48**	**3.45**	**0.00**
12LM060	**17.61**	**0.00**	8.00	**42.57**	**1.25**	**0.00**
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Judicial Ditch 1 had a qualitative habitat assessment take place at site 12LM060 during its fish sampling event in 2012. The resulting MSHA score for this site was 50, which is considered to be a fair score. Limiting the habitat at this site was the poor surrounding land use (Figure 89), narrow riparian buffer, no stream shading, light embeddedness, as well as poor sinuosity and channel development.

Figure 89: Channelization and land use at site 12LM060.

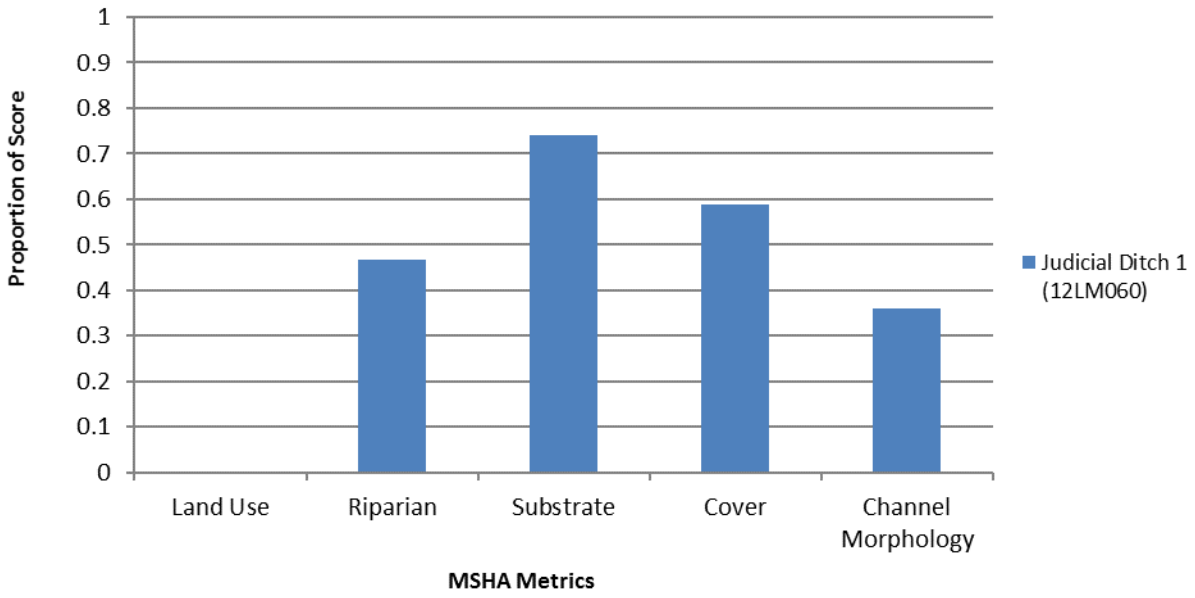

Figure 90. MSHA metric value scores at site 12LM060 along Judicial Ditch 1 (07040004-987).

The macroinvertebrate sample at 12LM060 was taken from equal parts aquatic macrophytes and overhanging vegetation. This sample found that the macroinvertebrate community in Judicial Ditch 1 had a low amount of burrower individuals (6.54%). Burrowers tend to be more abundant in streams with more fine sediment available. This site also had low amounts of EPT (4.67%), clinger (12.15%) and swimmer (4.05%) individuals. Ditches and channelization of streams often leads to reduced habitat complexity, which is demonstrated with a lack of EPT and clinger individuals, both of which require course substrates and/or woody debris. The abundant overhanging vegetation present did lead to a high amount of climber individuals (54.21%), which is also common in channelized streams.

The fish assemblage in this reach had a high amount of benthic insectivore (17.9%) and simple lithophilic spawning (59.88%) individuals. Site 12LM060 did have few individuals classified as darters/sculpins/round-bodied suckers (2.4%), riffle dwelling (14.51%) and pioneering species (14.2%), while also having a high amount of tolerant individuals (70.99%).

Based on the fair MSHA score, many poor scoring habitats related biological metrics and many poor scoring habitat attributes, the lack of habitat is a stressor to the macroinvertebrate community in Judicial Ditch 1.

Flow alteration and connectivity

Figure 91: Channelization at site 12LM060.

The vast majority of the minor watershed (14-digit HUC) containing Judicial Ditch 1 (07040004-987) has been modified according the Altered Watercourses GIS layer for Minnesota streams. This includes the entire sampling site, 12LM060, and the impaired stream reach (Figure 91). The channelization of streams often leads to bank erosion and instability, and this along with the presence of undercut banks are site evidence that flow alteration is a potential stressor. Flow alteration also leads to the reduction of habitat by limiting a streams ability to push fine sediment through a system, which can cover the coarse substrates. Additionally, this changes stream depth variability, which reduces the numbers of

riffles and pools present, which are vital for some less tolerant fish and macroinvertebrate species to survive.

With the significant degree of channel modification present along this reach in conjunction with the poor habitat observed in Judicial Ditch 1, flow alteration is a stressor to the impaired biological communities in this reach.

Conclusions and recommendations

The macroinvertebrates community of Judicial Ditch 1 (987) is being stressed by low DO, elevated nitrate, poor habitat and flow Alteration (Table 40). The DO levels consistently fall below 5 mg/L and have a daily flux of greater than 3.5 mg/L. There are high levels of phosphorus, which are present during many different flow conditions. The abundance of nutrients promotes a stream with high productivity resulting in high DO flux, and low DO. Some factors that contribute to these issues include: a small point source discharge (Hayfield), low summer baseflow, and low slope. Nutrients are abundant throughout JD1, including the highest nitrate concentrations measured in the watershed, at 30 mg/L, which are degrading the biological communities. Further adding to the stress are the poor habitat conditions, which are characteristic channelized reaches, including poor substrates and surrounding land use and a lack of cover/woody debris. All of these limitations do not allow biology to thrive in JD1. It would take many large scale changes in this watershed and within the stream channel to see any improvement in the biology.

There is some macroinvertebrate response to elevated TSS, but a lack of connecting chemical information and small chemical dataset make it difficult to confirm this stressor. It's possible that the response seen is due to other stressors, therefore, TSS is considered inconclusive until further information can be collected.

Table 40. Summary of stressor determination for JD1

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Judicial Ditch 1	07040004-987	---	●	●	o	●	●

4.9.3 Judicial Ditch 1 (988-modified)

Biological and background information

Judicial Ditch 1 (07040004-988) has one biological site, 12LM057, which resulted in a macroinvertebrate and fish impairment on this reach. This site is designated macroinvertebrate Class 6 (Southern Streams GP). For streams in this class the MIBI "modified" use impairment threshold is 30, with an average score per metric of 3.0 needed to achieve that threshold. 12LM057 has a low MIBI score of 24.62. The DomFiveCHPct metric is the highest scoring metric. Most of the other metrics scores are near or below the average, and HBI_MN and Intolerant2Ch both received score of zero. The HBI_MN metric is a

measure of pollution based tolerance values assigned to each individual taxon, and the Intolerant2Ch metric represents taxa richness of macroinvertebrates that are very intolerant to poor water quality conditions.

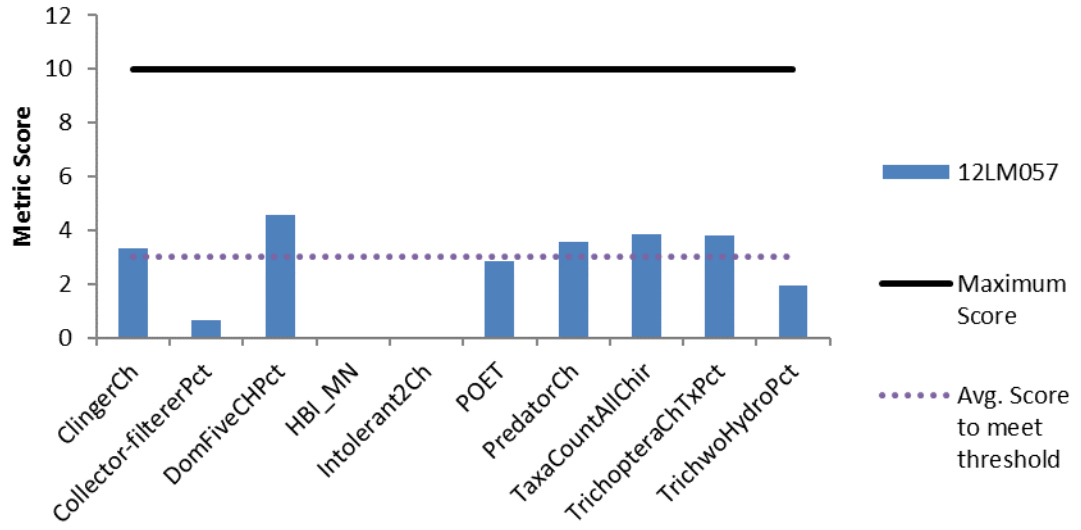

Figure 92. Macroinvertebrate IBI metrics for JD1 (Class 6; Southern Streams Glide/Pool)

Site 12LM057 is a designated fish Class 2 (Southern Streams). The "modified" FIBI threshold for this class is 35, with an average score per metric of 4.3 needed to achieve that threshold. 12LM057 has an FIBI score 32, the lowest FIBI score for all of the Class 2 sites on the South Branch Middle Fork. This site scores below all the other SBMF sites on most metrics, showing a degraded fish community.

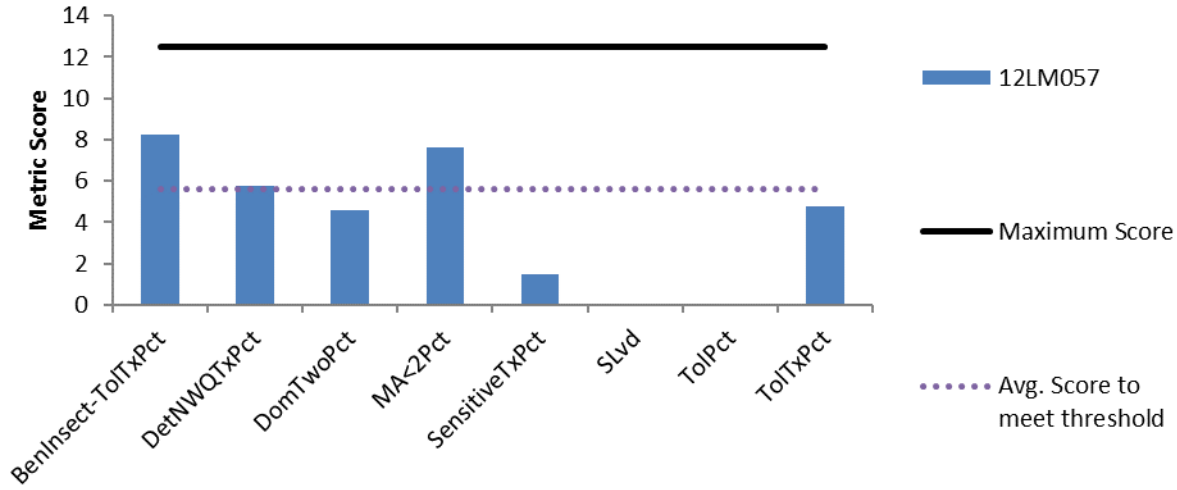

Figure 93. Fish IBI metrics for JD1 (Class 2; Southern Streams).

Dissolved oxygen and eutrophication

Judicial Ditch 1 (07040004-988) had a total of six DO measurements take place from 2012-2014. These observations ranged from 6.89-20.72 mg/L, with no values falling below the 5 mg/L minimum standard for DO, but no values were collected before 9 a.m., when DO values are typically the lowest. (Table 41).

Additionally, five phosphorus samples were taken during this same time period. These values ranged from 0.041-0.478 mg/L, with one sample above the 0.15 mg/L Phosphorus standard for the South

nutrient region. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

Table 41. DO data at site 12LM057 along Judicial Ditch 1 (07040004-988)

Sample Location	Sample Date and Time	Result (mg/l)	Daily Minimum Standard (mg/l)
12LM057	6/25/2012 11:39 AM	9.07	5
12LM057	8/7/2012 3:23 PM	20.72	5
12LM057	4/30/2014 1:35 PM	11.96	5
12LM057	6/18/2014 11:55 AM	6.89	5
12LM057	6/24/2014 9:45 AM	7.26	5
12LM057	7/16/2014 12:00 PM	11.53	5

The macroinvertebrate community in Judicial Ditch 1 had an increased amount of DO tolerant individuals (40.13%), completely lacked any dissolved oxygen intolerant taxa and had a below average DO TIV score when compared to all other Minnesota streams, as well as all Class 6 sites.

Given the poor scoring macroinvertebrate community, the fish assemblage along this reach surprisingly had an increased amount of late maturing individuals (35.7%). These species typically are not found in streams experiencing poor DO conditions. Site 12LM057 did have very few sensitive individuals (0.37%) and also had an increased amount of serial spawning individuals (30.22%). These results more accurately reflect a stream being stressed by the DO conditions present. The DO TIV score was slightly above average when compared to all other Class 2 fish stations.

While no measured values fell below the daily minimum standard for DO, very high values were observed, which can often indicate a high level of daily flux. The two phosphorus exceedances may also allude to a high daily flux of DO. Nearby, Judicial Ditch 1 (07040004-987) experienced a high level of daily flux and low DO when measured with a sonde. Low DO is inconclusive as a stressor due to the mixed response of the fish community as well as lack of definitive chemical information. Additional continuous DO monitoring with a sonde and additional phosphorus monitoring is recommended to determine if DO and eutrophication are indeed negatively impacting the impaired biological communities.

Nitrate

During fish sample, the nitrate concentration at 12LM057 was 4.3 mg/L (June 25, 2012). There were four additional samples taken on this reach in 2014, from April through July. In April the concentration was elevated, at 10 mg/L. In June, there were two samples; 13 mg/L on the 18th and 20 mg/L on the 24th. Then on July 16, the concentration fell back to 9.3 mg/L.

Daily nitrate values were calculated for Judicial Ditch 1 (07040004-988, 54) by the HSPF model from 1995-2009. The values ranged from 1.87-24.86 mg/L with an average value of 5.75 mg/L. Out of 5479 values, 223 were above 10 mg/L (4%) and 13 were above 20 mg/L (<1%).

Station 12LM057 had worse than average taxa count (TaxaCountAllChir; 32). The average taxa count for this macroinvertebrate Class 6; (Southern Forest Streams GP) is 33. Trichoptera are found to be generally sensitive to elevated nitrate concentrations. There were 2 Trichoptera taxa, which is just below the average for the Class 6 stations of the LMB (2.2). However, the percentage of Trichoptera individuals was above the average, at 6.25% (average is 5.3%). This site had 57% nitrate tolerant individuals, which is in the moderate range. There was one nitrate intolerant taxon found. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. Non-hydropsychid trichoptera are all caddisflies that do not spin nets. Station 12LM057 had only 0.62% non-hydropsychid trichoptera. This is below average compared to all biological sites in the LMB (3.39%) and of this stream class (2.21%). The macroinvertebrate community nitrogen index score was 3.2, while the average for warmwater stations meeting impairment threshold is 2.9. This suggests that overall the community is made up of individuals tolerant to high nitrate concentrations.

The macroinvertebrate visits at this station had only a moderate amount of nitrate tolerant taxa; less than expected for a ditch which generally has higher nitrate concentrations. This lower percentage of nitrate tolerant individuals may be explained because of dominance of *Coenagrionidae,* a damselfly found in degraded stream conditions, which is not considered overly tolerant to high nitrate. A similar phenomenon is found at 12LM060, another reach of JD1. It's possible the reason this damselfly exists in JD1 was due to adults coming from a nearby wetland and laid eggs in this stagnant ditch. At the time of the ditch being stagnant, nitrate concentrations were likely generally lower than during the late spring when concentrations typically peak. It's likely these damselflies will not be able to tolerant the high nitrates later on in their life cycle and would die off. Overall, the biological metrics including taxa count and reduced Trichoptera, with elevated concentrations, confirm that nitrate is a stressor to this reach.

Suspended sediment

At the time of biological monitoring a one-time chemistry sample was collected at 12LM057 and the TSS value recorded was 9.2 mg/L. Additionally, 4 TSS values were collected from April through July of 2014. These values are 7.6, 8.4, 11, and 440 mg/L. Three measurements were collected during this time period using a secchi tube and one measurement with a transparency tube. The 3 secchi values were 3, 46 and 100 cm, and the transparency value was 80 cm.

Daily TSS values were calculated for Judicial Ditch 1 (AUID 07040004-988) subshed 54 by the HSPF model from 1995-2009. These values ranged from 1.01-1617.35 mg/L with an average value of 15.9 mg/L. Additionally, 3.85% of the values were above 65 mg/L.

In JD1, the macroinvertebrate metrics signal TSS stress (Table 42). There is consistent response seen with all of the TSS metrics. The fish community, however, doesn't show a strong response to TSS issues. This reach is a judicial ditch, with many areas lacking riparian corridor, but for the most part, the ditch system is intact. There is strong macroinvertebrate response which indicates elevated TSS is a probable stressor, but there is a lack of connecting chemical information. Modeled chemical data also does not give a strong signal for TSS as a stressor. Other cumulative

Table 42. Macroinvertebrate metrics relevant to TSS for stations in JD1 compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
12LM057	**18.40**	**1.00**	**11.00**	**37.12**	**2.80**	**0.00**
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to TSS stress	↑	↓	↑	↑	↓	↓

Habitat

Judicial Ditch 1 (07040004-988) had a qualitative habitat assessment take place at site 12LM057 during its fish sampling event in 2012. The resulting MSHA score for this site was 38, which is considered to be a poor score (Figure 94). Limiting the habitat at this site was the poor surrounding land use, narrow riparian area, lack of stream shading, a primarily sand substrate, moderate embeddedness, sparse fish cover, poor channel development and sinuosity and few different velocity types.

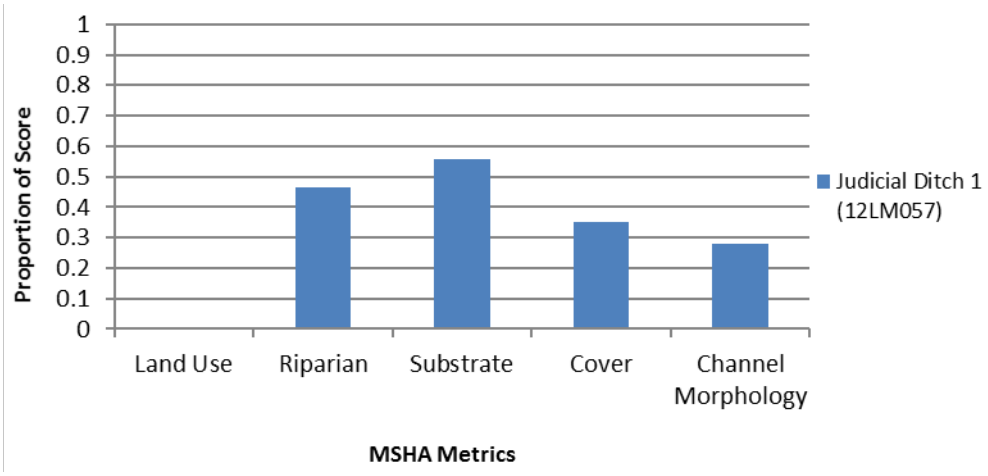

Figure 94: MSHA metric value scores at site 12LM057 along Judicial Ditch 1 (07040004-988).

The macroinvertebrate sample at 12LM057 was collected entirely from the overhanging vegetation habitat present. This sample had a decreased amount of burrower (6.21%) and an increased amount of climber (55.59%) individuals. These results can indicate that there is good habitat present. However, the macroinvertebrate community also had an increased amount of legless (49.07%), while having a decreased amount of sprawler (9.01%) individuals. These results can indicate a potential habitat stressor.

The fish assemblage in Judicial Ditch 1 had increased numbers of both riffle dwelling (43.03%) and simple lithophilic spawning (40.55%) individuals. These results often indicate adequate habitat. However, this reach also had decreased amounts of benthic insectivore (10.32%) and

darter/sculpin/round-bodied sucker (7.71%) individuals, while also have increased amounts of tolerant (90.17%) and pioneer species (38.06%) individuals. These results commonly signal a community being negatively impacted by the habitat conditions.

MNDNR summary for biological station 12LM057

Dodge Center Creek near Station 12LM057 is classified as an F stream type with a sand bed. The channel is deeply entrenched and with little floodplain. Ditch segments are normally a G stream type; however, the stream has widened to an F and is likely moving to a stable C or E type. Evidence of this progression to stability includes a lack of bank erosion and the formation of a small floodplain within the channel (Figure 95).

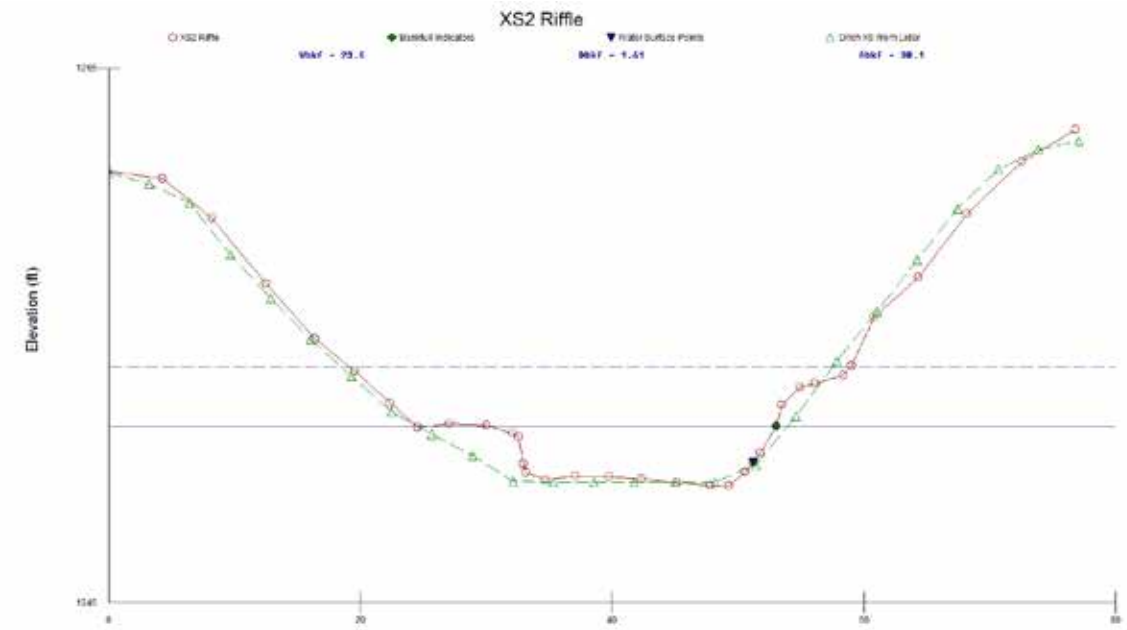

Figure 95. Riffle cross section (red) with LiDAR (2011) overlay (green).

The current width to depth ratio is 14.65, considered good for a C stream type. Riffle lengths are short, less than a channel width, and pool to pool spacing is eight times bankfull width. The stream has a mostly homogenous distribution of particles with little distinction between facets, typical of an F stream type. Flat slope (0.00018) is typical of stream with little facet diversity and a contributor to the deposition of fine sediment within the stream channel. Vegetated banks and low debris jam potential are helping maintain stable banks and result in a Pfankuch stability rating of fair.

Overall the stream is in recovery to a more stable form. Aggradation of material is expected to accumulate within the channel until a floodplain is established. Until then, there is little pool and riffle habitat for invertebrates and fish species. In time, riffle and pool habitat may develop, but there might remain a fine silt deposition, which may need to be addressed.

Based on the poor MSHA score, MNDNR geomorphology data, as well as the majority of the habitat related biological metrics of both the fish and macroinvertebrate assemblages, the lack of habitat is a stressor to the impaired biological communities in Judicial Ditch 1.

Flow alteration and connectivity

Judicial Ditch 1 (07040004-988) is completely modified (Figure 96) according to the Altered Watercourses GIS layer for Minnesota streams. Additionally, all upstream portions of Judicial Ditch 1 and tributaries are also entirely channelized. The channelization of streams often leads to bank erosion and instability and undercut banks present are site evidence that flow alteration is a potential stressor. Flow alteration also leads to the reduction of habitat by limiting a streams ability to push fine sediment through a system, which can cover the coarse substrates. Additionally, it changes stream depth variability, which reduces the numbers of riffles and pools present, which are vital for some less tolerant fish and macroinvertebrate species to survive.

Figure 96. Channelization at site 12LM057.

The poor habitat, likely caused by channelization, was evident at site 12LM057 along this reach. High amounts of sand dominated the substrate, low sinuosity, poor channel development, limited depth variability and very few velocity types were present. With the significant degree of channel modification present along this reach, in conjunction with the poor habitat observed in Judicial Ditch 1, flow alteration is a stressor to the impaired biological communities in this reach.

Conclusions and recommendations

The fish and macroinvertebrate communities of Judicial Ditch 1 (988) are being stressed by elevated nitrate, poor habitat and flow alteration (Table 43). Nitrate concentrations are elevated and showing stress to the macroinvertebrates, even though the concentrations are not as high as nearby JD1 (987). Further adding to the stress are the poor habitat conditions, which are characteristic of a channelized reach; poor substrate, land use and lack of cover/woody debris. All of these limitations do not allow the biology to thrive in JD1.

While no measured DO values fell below the daily minimum standard for DO, very high values were observed, which can often indicate a high level of daily flux. Nearby, Judicial Ditch 1 (07040004-987) experienced a high level of daily flux, had low DO levels, and a matching biological response to this reach. Low DO is inconclusive as a stressor due to the mixed response of the fish community as well as lack of definitive chemical information. Additional continuous DO monitoring with a sonde and additional phosphorus monitoring is recommended to determine if DO and eutrophication are indeed negatively impacting the impaired biological communities

There is some macroinvertebrate response to elevated TSS, but a lack of connecting chemical information and small chemical dataset make it difficult to confirm this stressor. It's possible that the response seen is due to other stressors; therefore, TSS is considered inconclusive until further information can be collected.

Table 43. Summary of stressor determinations for JD1

Stream Name	AUID	Stressors: Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Judicial Ditch 1	07040004-988	---	o	●	o	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.9.4 Henslin Creek (618)

Biological and background information

Henslin Creek (07040004-618) has one biological monitoring site, 12LM055, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 5 (Southern Streams RR). For streams designated macroinvertebrate Class 5 the MIBI impairment threshold is 37, with an average score per metric of 3.7 needed to achieve that threshold. The MIBI score at 12LM055 is 30.41, and 7 out of 10 metrics were below the average metric score needed. The three metrics that scored well were the percentage of taxa adapted to cling to substrate or woody debris in swift flowing water (ClingerChTxPct), the relative abundance of dominant five taxa (DomFiveCHPct) and Odonata taxa richness (Odonata). All other metrics scored poorly, especially the Plecoptera taxa (Plecoptera) and Trichoptera taxa (Trichoptera), both scored zero. These taxa include macroinvertebrates that are generally sensitive to pollution and degradation.

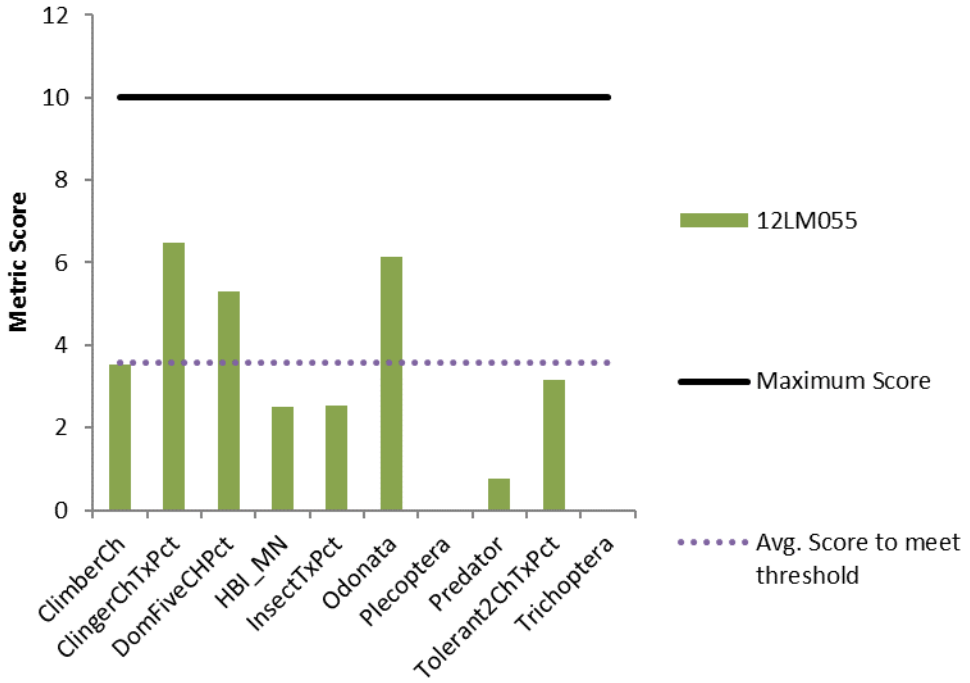

Figure 97. Macroinvertebrate IBI metrics for Henslin Creek (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

Henslin Creek had a total of 9 DO readings taken from 2012-2014. These values ranged from 5.53-12.96 mg/L with no values below the 5 mg/L DO standard.

Additionally, Henslin Creek had nine Phosphorus samples taken from 2012-2014 with values ranging from 0.018-.649 mg/L. Of these values, one was above the 0.15 mg/L standard for phosphorus in the South nutrient region. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

Biologically, the macroinvertebrate assemblage in Henslin Creek had few EPT individuals (12.46%), but site 12LM055 had 8 DO intolerant taxa, while having only 8.33% DO tolerant individuals. While low numbers of EPT individuals can signal stress, the high number of intolerant species and presence of few tolerant individuals indicate the macroinvertebrate community is not being negatively impacted by the DO conditions.

The fish community in this reach had an increased number of serial spawning (24.56%) individuals, while also having decreased number of sensitive (6.43%) and late maturing (7.21%) species individuals. These results can be common in streams impacted negatively by the DO conditions. The DO TIV score for this site was above average when compared to all other Class 3 sites statewide; however, this site scored below average when compared to all other sites within the Zumbro River Watershed.

Based on the DO measurements and the many DO intolerant macroinvertebrates, low DO and eutrophication are not stressors to the impaired macroinvertebrate community in Henslin Creek at this time. Other stressors are likely negatively impacting the impaired macroinvertebrate assemblage. The fish community in Henslin Creek is not impaired at this time; it is likely that other stressors are responsible for lower DO related metric scores.

Nitrate

During the fish sample, the nitrate concentration was measured at 14 mg/L (June of 2012). There were 8 additional nitrate samples taken at this site in 2014. The nitrate concentration ranged from 9.8 mg/L in September up to 24 mg/L in June. The average concentration was 14.85 mg/L.

The one macroinvertebrate sample taken at station 12LM055 had 72.20% nitrate tolerant species collected. At 83.78%, there is only a 10% probability of meeting the MIBI. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At this station, taxa richness was just above average at 38. There were few Trichoptera taxa overall (only 2), but only three generally intolerant taxa, but no nitrate intolerant taxa. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These trichoptera include all caddisflies that do not spin nets. The percentage at this station was 0%, while the average for sites in the LMB is 3.39%.

The biological response is mixed but generally indicates nitrate related stress. There is a fairly high percentage of nitrate tolerant taxa, and while there are three generally intolerant taxa, none of them are considered intolerant to high nitrate. In addition, there is a lack of Trichoptera taxa and non-hydropsychid Trichoptera which are both sensitive to high nitrate. There is a lack of sensitive fish species (6%) and higher percentage of tolerant fish species (75%) which also can be consistent with nitrate stress, in addition to fairly high nitrate concentrations documented in 2014. Nitrate is a stressor to Henslin Creek and concentrations need to be reduced.

Suspended sediment

At the time of biological monitoring a one-time chemistry sample was collected at 12LM055 and the TSS value recorded was 4.8 mg/L. Additionally, 8 TSS values and 7 secchi tube values were collected from April through July of 2014. The TSS values ranged from 2.4-620 mg/L, and the secchi values range from 3 to 100 cm. The only TSS value to exceed 13 mg/L was the one value of 620 mg/L. The high TSS value was from June 18, 2014 and appears to be a result of high precipitation in the region. The State Climatology Office recorded a total rainfall of 3.57 inches on the previous day in the Dodge Center/Byron area.

In Henslin Creek, the macroinvertebrate metrics show a mixed response to TSS stress (Table 44). The lack of response is indicated by a lack of TSS intolerant taxa, a higher than average percentage of TSS tolerant taxa and lack of plecoptera taxa. It's possible that the response seen is due to other stressors. The fish community, while not impaired, responds with 7 of the 10 metrics signaling TSS stress. The chemical information on this reach is limited, and there is a lack of understanding on the potential duration of high TSS values. TSS is inconclusive as a stressor to the fish and macroinvertebrate community of Henslin Creek.

Table 44. Macroinvertebrate metrics relevant to TSS for stations in Henslin Creek compared to statewide averages for southern streams RR stations meeting impairment threshold (35.9). Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM055	16.68	**0.00**	7.00	**40.58**	28.04	**0.00**
Statewide average	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Henslin Creek had a qualitative habitat assessment take place at site 12LM055 during the fish sampling event in 2012. The resulting MSHA score for this site was 63.35, which is considered fair (Figure 98). Limiting the habitat at this site was the presence of sand substrates, sparse fish cover, and moderate channel stability, as well as excess sedimentation present in the run and pool sections of the stream reach.

Figure 98. Pastured land use along Henslin Creek (12LM055).

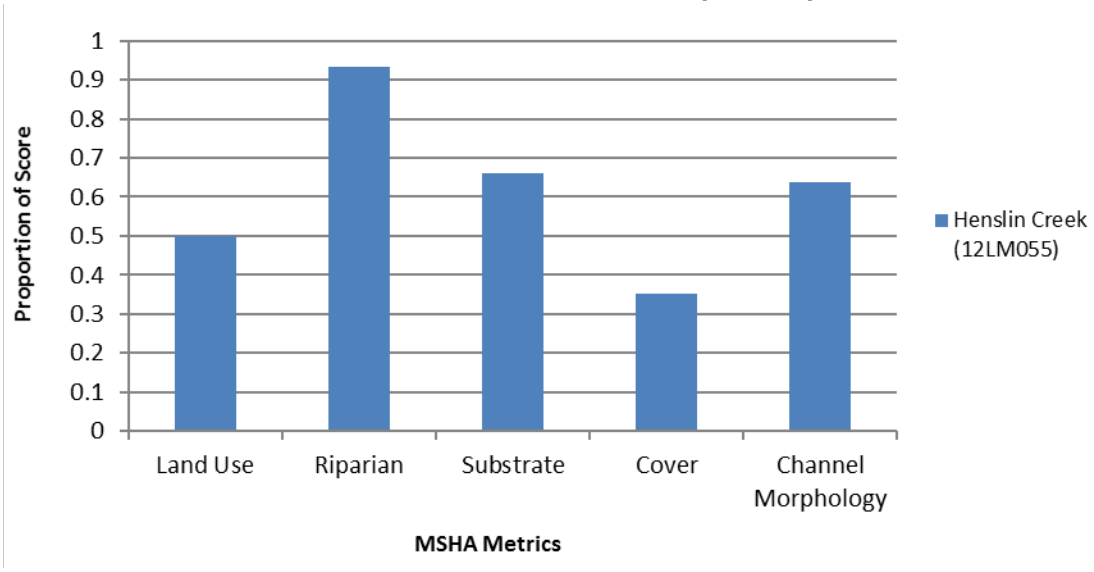

Figure 99: MSHA metric value scores for site 12LM055 along Henslin Creek (07040004-618).

Biologically, the macroinvertebrate sample was taken from equal parts of the present riffles and woody debris. It is important to note that the water levels were low at the time of sampling, which made it difficult to effectively sample some of the habitat types at site 12LM055. The sample had a high amount of climber individuals (42.68%) and an average amount of clinger individuals (42.37%) when compared to all other Class 5 sites statewide. Numbers of Clinger taxa tend to be reduced in streams stressed by poor habitat conditions as they prefer to attach themselves to rocks or woody debris. Site 12LM055 also had very few burrower individuals (3.74%). Burrowers tend to be much more abundant in streams with high amounts of fine substrates. Additionally, *Polypedilum* (a very tolerant climbing midge) did comprise over 25.55% of the macroinvertebrate sample and the amount of legless individuals (72.47%) was above average for a Class 5 site. Legless individuals tend to be more abundant in streams with degraded habitat.

The fish community along Henslin Creek had a below average amount of riffle dwelling individuals (14.04%) when compared to statewide averages. Riffle dwelling fish species and individuals tend to be less abundant in streams with poor habitat. However, this reach also had a high amount of benthic insectivore (33.33%), simple lithophilic spawning (37.43%) and darters/sculpins/round-bodied sucker (20.86%) individuals. These results are indicative of a community not stressed by present habitat conditions.

The majority of the habitat related biological metrics indicate a system that is not negatively impacted by the habitat conditions present. The MSHA score at site 12LM055 reflects the biological response observed. While habitat conditions could certainly be improved along this reach, the lack of habitat is not a stressor to the impaired macroinvertebrate assemblage in Henslin Creek at this time.

Flow alteration and connectivity

Henslin Creek Watershed has a minimal amount of altered streams. The altered stream sections are located upstream in the far headwaters of this system and likely have minimal impact on the biological communities at 12LM055.

During the macroinvertebrate sample, it was noted that water levels were low making it difficult to sample some habitat types. However, the stream does not appear to go dry or be disconnected, despite a fair amount of tile drainage in the upper reaches. Therefore, flow alteration and connectivity are not stressors to the impaired macroinvertebrate assemblage in Henslin Creek at this time.

Conclusions and recommendations

The macroinvertebrate community of Henslin Creek is being stressed by elevated nitrate (Table 45). The chemical concentrations are quite elevated with a matching biological response. Tile drainage is believed to be rather high in this area, which contributes to the higher concentrations observed (Maximum of 24 mg/L in June of 2014). Tile drainage in the headwater area is likely a large source of these seasonally high concentrations.

TSS is considered inconclusive at this time due to a mixed biological response and limited chemical information. Habitat conditions, which could be improved, do not appear to be the driving stress. Similarly, DO levels appear normal, and a fair number of DO intolerant species further confirm that DO stress is unlikely. Flow alteration and connectivity were also ruled out as potential stressors given a minimal amount of altered streams in this watershed; and despite the fair amount of tile drainage, there is no evidence showing the stream goes dry or is disconnected.

Table 45. Summary of stressor determinations for Henslin Creek

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Henslin Creek	07040004-618	---	---	●	o	---	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.10 South Fork Zumbro Watershed

The South Fork Zumbro Watershed is a warmwater stream in Olmsted County and flows north to Lake Zumbro. The entire large subwatershed drains a total of 218,496 acres, 60% of which are in agricultural use and 17% which are developed. This section will discuss two stream reaches with biological macroinvertebrate impairments in this watershed. The first is a macroinvertebrate impairment on 07040004-507, which flows through the city of Rochester to Lake Zumbro (Figure 100). The other reach is a macroinvertebrate impairment upstream of Rochester on 07040004-536 (Figure 116). The other subwatersheds of the South Fork Zumbro (Bear Creek, Willow Creek, Cascade Creek, Salem Creek) will be addressed separately in the subsequent sections.

4.10.1 South Fork Zumbro (507) *Cascade Creek to Lake Zumbro*

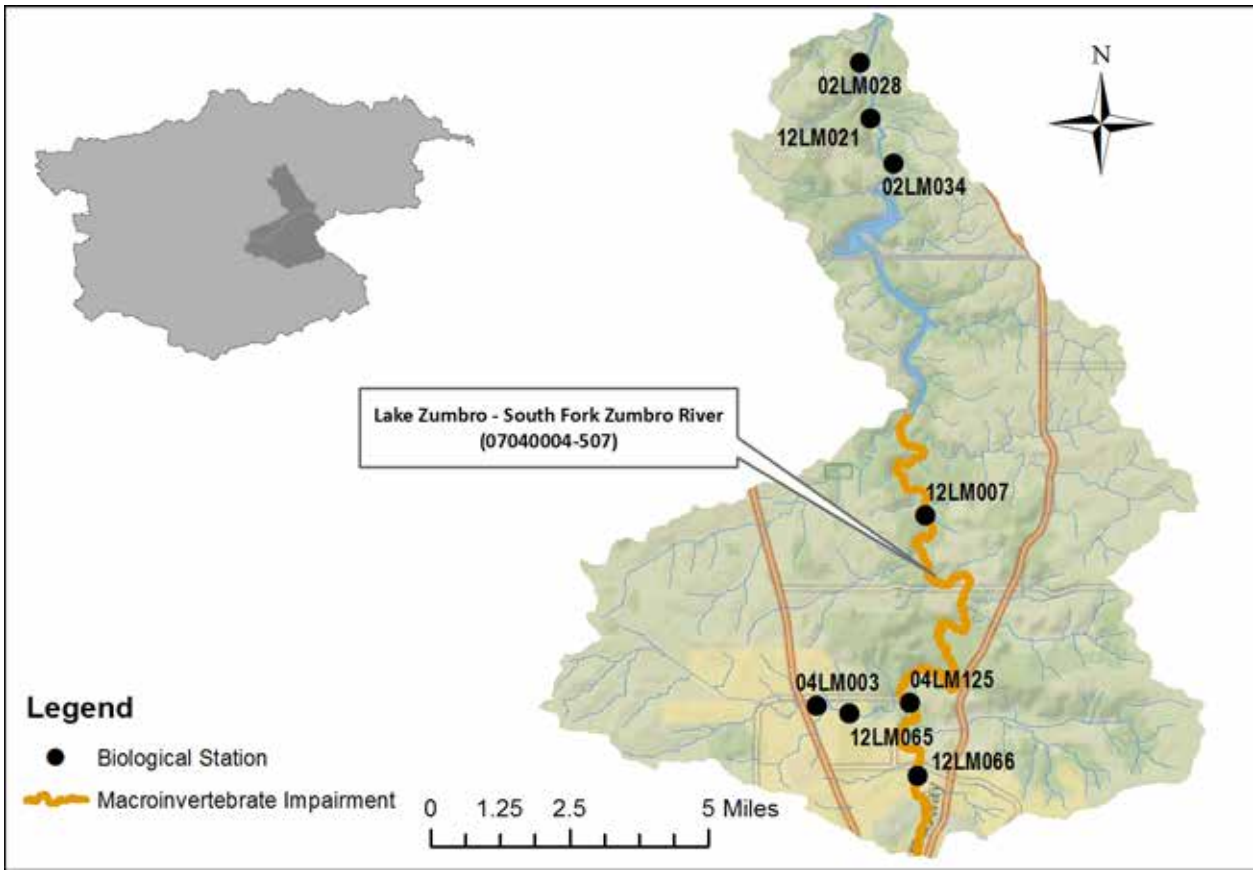

Figure 100. The South Fork Zumbro (507) with biological stations, and impaired AUIDs.

Biological and background information

The South Fork Zumbro (07040004-507) has three biological stations: 12LM066, 12LM007, and 04LM125, which resulted in a macroinvertebrate impairment on this reach. Station 12LM066 is designated macroinvertebrate Class 5 (Southern Streams RR), and the farthest upstream on this reach. The MIBI threshold for this class is 37, with an average score per metric of 3.7 needed to achieve that threshold. Station 12LM066 had an MIBI score of 21.46 and only two metrics scored above the average score needed to meet the threshold (Figure 101). This is somewhat unusual because most of the low scores ranged from 2.45 to 0, with three metrics scoring a zero; while at the same time the highest metric (ClingerChTxPct) scored the maximum of 10. The DomFiveCHPct metric received a score of zero suggesting that this community is not very diverse and dominated by few species. The most abundant macroinvertebrate sampled was a rather tolerant net-spinning caddisfly, *Cheumatopsyche (48% of total community)*, which is also a clinger.

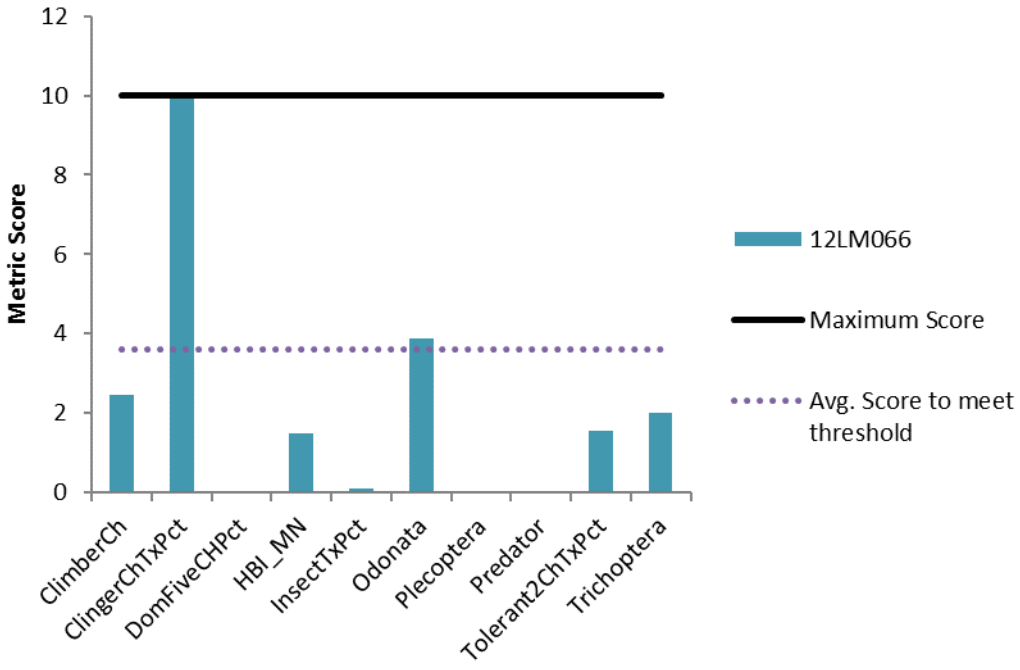

Figure 101. Macroinvertebrate IBI metrics for South Fork Zumbro (Class 5; Southern Streams Riffle/Run).

Moving downstream, stations 12LM007 and 04LM125 are designated macroinvertebrate Class 6 (Southern Forest Streams GP). The MIBI impairment threshold for this class is 43, with an average score of 4.3 per metric needed to achieve that threshold. Station 12LM007 had an MIBI score of 54, while 04LM125 had a score of 52; both above impairment threshold for macroinvertebrate Class 6. Both stations showed a similar response and scored below the average needed on only 3 out of 10 IBI metrics (Figure 102). The metrics that did not score well indicate low taxa richness overall, (TaxaCountAllChir) and had a lack of intolerant and predator species.

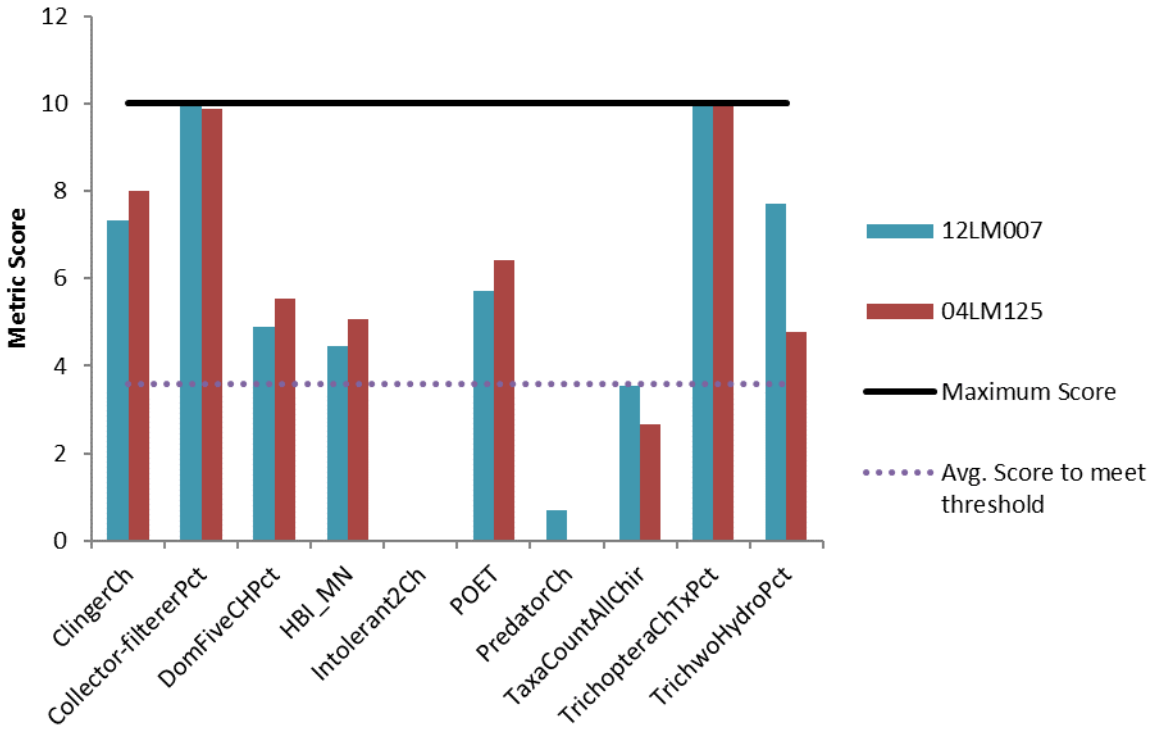

Figure 102. Macroinvertebrate IBI metrics for South Fork Zumbro (Class 6; Southern Streams Glide/Pool).

Dissolved oxygen and eutrophication

From 2000-2014 there were 123 DO measurements on this stream reach, most taken at either S003-802 or S000-268 (75th St/90th St). The average concentration measured was 9.8 mg/L. The maximum concentration measured was 17.8 mg/L, and a minimum of 4.9 mg/L. Only two measurements (one in 2001, the other in 2008) were below the 5 mg/L standard. A total of five of them were taken before 9 am, when low DO conditions are most common.

Continuous DO monitoring took place along the South Fork Zumbro River at two stations: 12LM066 in 2014 (Figure 102) and 12LM007 in 2012. As the 2014 graph shows, the DO level in this reach stays above the 5 mg/L standard and the daily flux of DO does exceed the 3.5 mg/L standard some days. The 2012, graph (Figure 104) shows a more dramatic flux (up to 9 mg/L) at 12LM007. However, there is no indication the DO level goes below the standard of 5 mg/L.

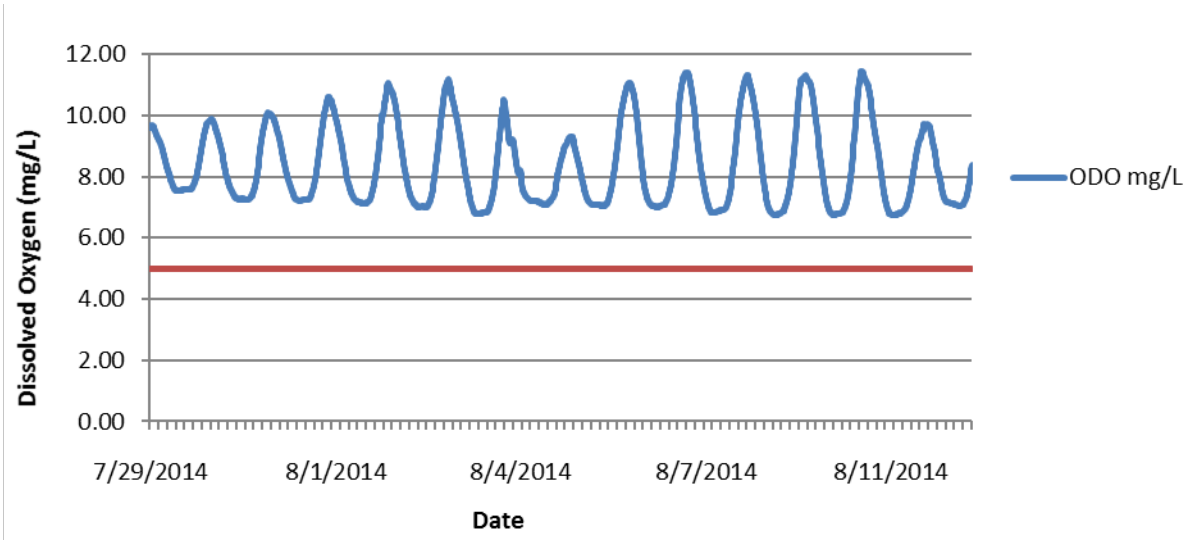

Figure 103. Continuous DO monitoring data at site 12LM066 on the South Fork Zumbro River in 2014, (07040004-507).

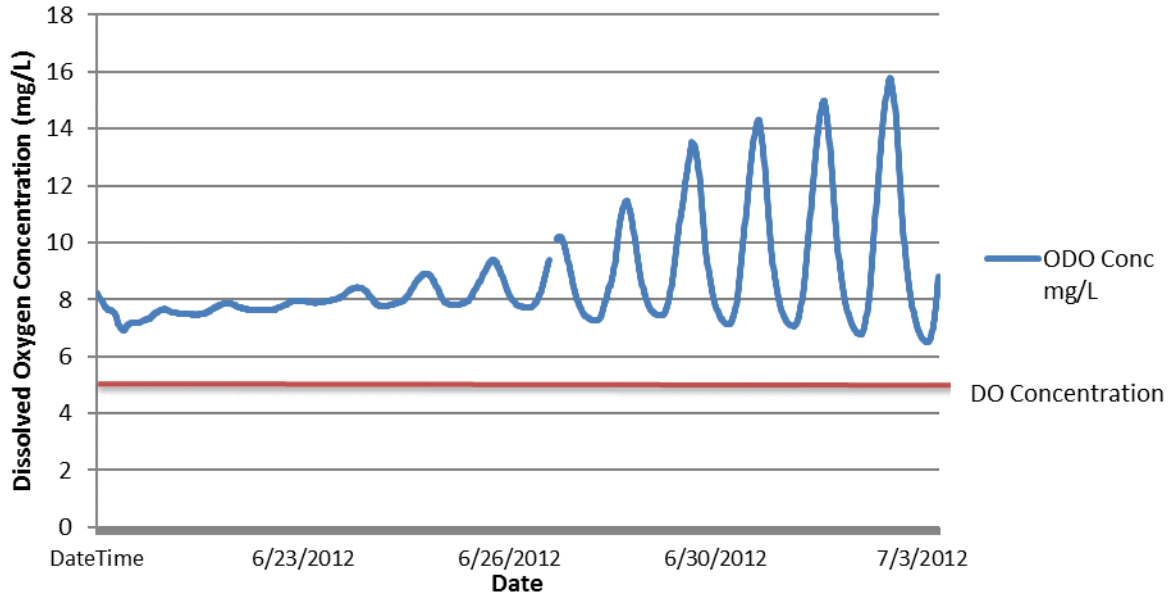

Figure 104. Continuous DO monitoring at 12LM007, in 2012 (07040004-507).

The DO regime at 12LM007 does look inconsistent, but is explained by a rain event which took place aound June 20, and increased the flow in this reach close to 500 cfs (Figure 105). As the flow receded, DO flux steadily increased until the end of the deployment on 7/3/12 (Figure 105). When large DO swings are observed in a stream, there is a higher likelyhood of low DO as well. While this reach does show a slight increase in DO flux, there were never any exceedences of the low DO standard during sonde deployment.

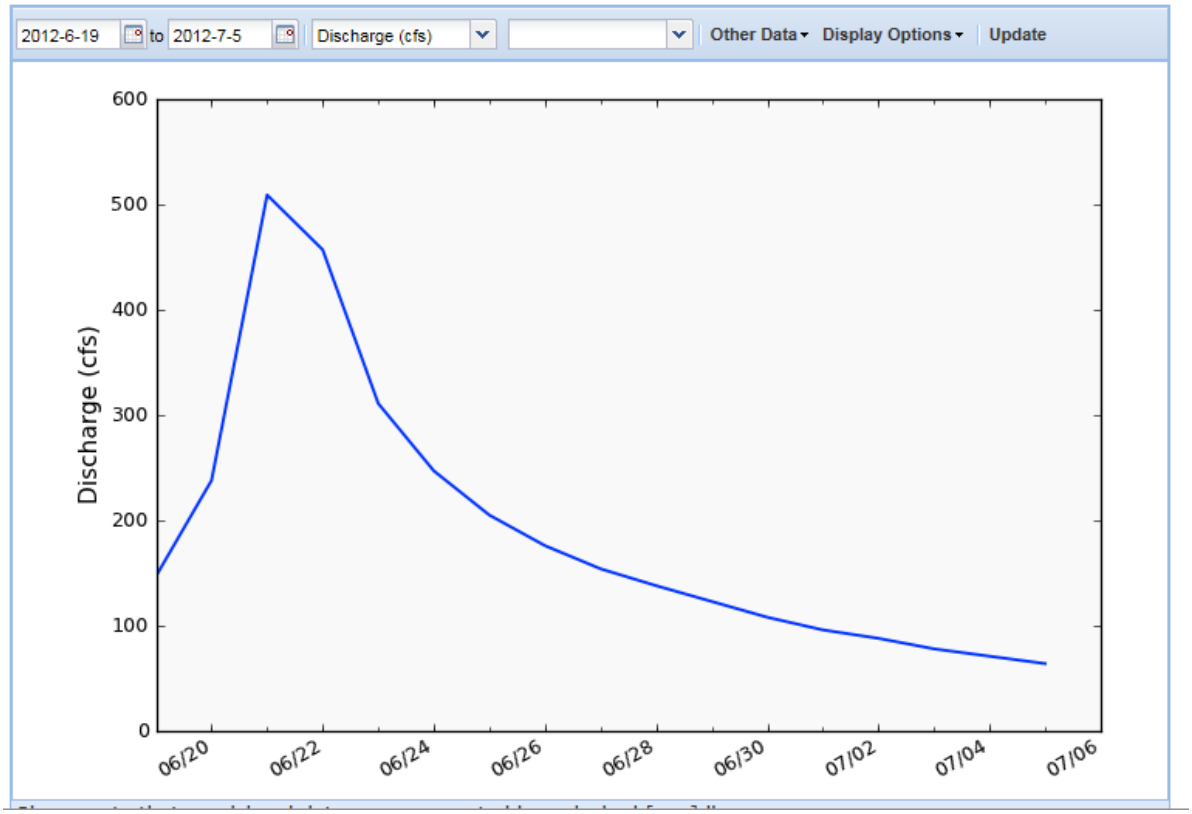

Figure 105. Discharge data from the South Fork Zumbro at Rochester (41063001) showing storm event in late June of 2012, which impact the DO regime at 12LM007. (MNDNR/USGS)
http://www.dnr.state.mn.us/waters/csg/site_report.html?mode=get_site_report&site=41063001**.**

High DO flux readings can often be an indication of elevated phosphorus concentrations resulting excess stream productivity or algae growth. A total of 206 phosphorus samples were taken along this portion of the South Fork Zumbro River. These values ranged from 0.014-1.12 mg/L, with 188 (91.3%) samples at or above the 0.10 mg/L phosphorus standard. The relationship of TSS to TP is shown in Figure 106 . The data shows multiple instances where the TP is elevated with TSS (assumed storm events) and also without events (assumed baseflow conditions). The consistency of elevated phosphorus is likely attributed to the influence of the wastewater treatment facility which may have more of an impact on stream phosphorus concentrations during baseflow conditions. There are also other smaller point source discharges that may be influencing phosphorus concentrations as well. Another important factor associated with algae and nutrient inputs to the South Fork Zumbro is potentially Silver Lake, a small reservoir on the South Fork just upstream end of this reach. Silver Lake captures the drainage from the entire South Fork Watershed, which also includes multiple flood control reservoirs. The cumulative impact of all of these reservoirs on nutrient concentrations and potential algae growth is not known exactly.

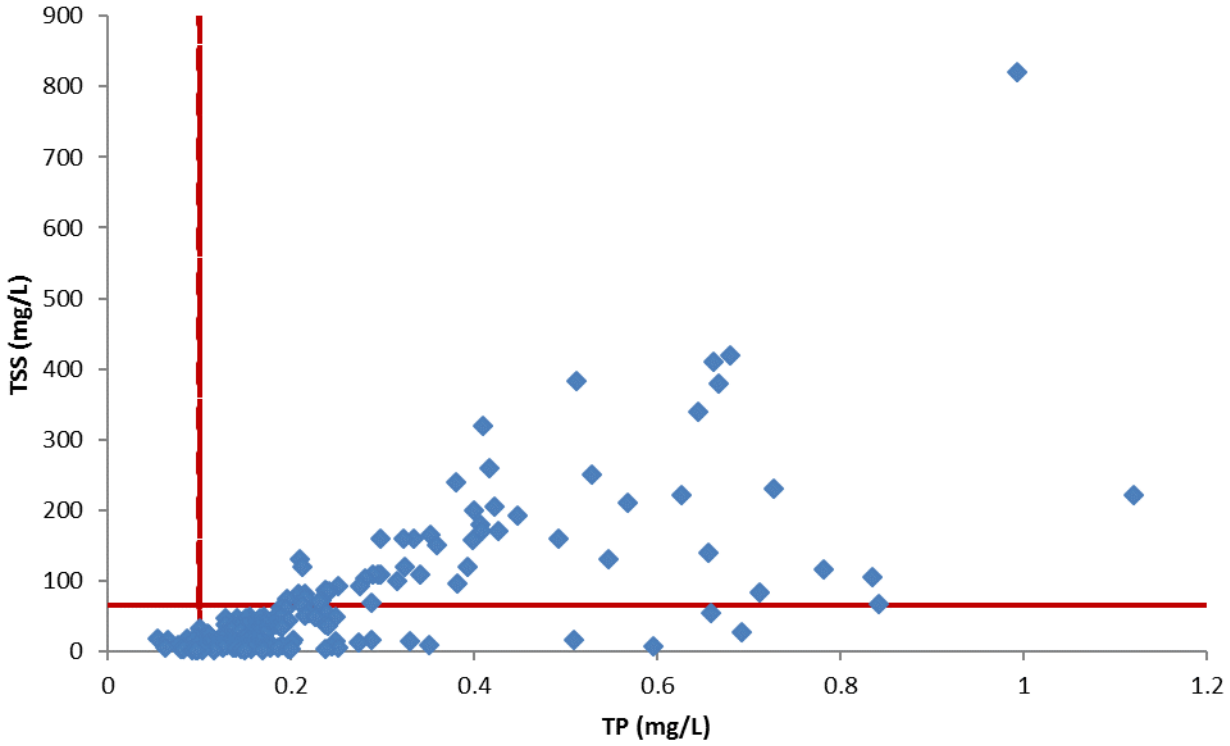

Figure 106. TSS and TP relationship in the South Fork Zumbro -507 (2007-2014). The points that exceed both the TSS and TP standards (red lines) are showing samples with phosphorus likely tied to sediment. Those that are below the TSS standard, but greater than the TP standard are more likely not tied to sediment.

When TP is elevated during multiple flow conditions, there is a potential for biological stress related to river eutrophication and additional variables are analyzed to determine if the elevated phosphorus concentrations are leading to stress. The DO flux that was measured in 2014, did exceed the recommended daily flux of 3.5 mg/L. Similarly, station 12LM007 also exceeded the daily flux, but more dramatically, with a daily flux max of almost 9 mg/L in 2012, which was a very low flow year. Chlorophyll-*a* data was available (44 samples from 2002-2012). Nine of those samples (20%) were greater than the chlorophyll a standard for the central region (18 µg/L) and seemed to correlate to low flow years. Additionally, there were 15 samples for BOD on this reach, ranging from 1.2-5.3 mg/L. Almost half (7) exceeded the 2 mg/L BOD standard. Many biological metrics indicate a negative shift in biological condition at about 2-3 mg/L for BOD (MPCA 2013). These variables all indicate increased stream productivity in the South Fork Zumbro.

On June 13, 2015 several MPCA staff completed a kayak reconnaissance survey on the majority of the 07040004-507 reach. During the survey intensive vegetation was noted downstream of the wastewater treatment plant outfall. The extent of vegetation was more localized, as it did not extend farther than ~1/2 mile downstream of the outfall (Figure 107). The available nutrients, baseflow condition, as well lack of shading and clear water provide optimal conditions for plant and macrophyte growth in this particular area. There was not an abundance of algae, macrophytes, or periphyton noted during the survey in most other locations on the reach, which may support little impact in terms of productivity downstream of the outfall. However, the turbidity issues noted in the reach may be also making an impact on the amount of productivity taking place.

Figure 107. Photo of aquatic vegetation downstream of wastewater treatment plant outfall

Biologically, the macroinvertebrate community at site 12LM066 had few tolerant DO taxa, while also containing multiple taxa that are intolerant to low DO levels (Table 46). The DO TIV score for the macroinvertebrate community was above average when compared to all other Class 5 sites within Minnesota, indicating the community is not dominated by low DO tolerant taxa.

While these metrics do not indicate the biology are stressed by low dissolved oxygen particularly, the high DO flux and chlorophyll-*a* observed points to other related issues with eutrophication, which can have a different impact to the biological community. The percentages of collector-filterer macroinvertebrate taxa are quite high in this reach (Table 46). They are much more abundant than the statewide averages for similar stations meeting the impairment threshold, and also more abundant than most stations in this stream class. Typically, we expect these stream classes have between 15-25% collector-filterers. Collector filterers gather their food by filtering particles out of the water column. It seems possible that somewhere upstream algae are growing and are transferred downstream to this reach during low flow conditions. It is also possible that some algae production is happening within the stream reach itself. The result of increased algal growth upstream and within the stream is a change in the macroinvertebrate community structure, to favor taxa that are collector-filterers as food in the water column is readily available. All stations show increased collector filterers, yet it seems more apparent with the 2012, stations, which may or may not be a function of the year sampled since 2012 was a lower flow year and more algae was potentially available. An increase in collector-gatherer taxa would indicate the potential for the abundance of food on substrates which is not the case here. Again, high turbidity and lack of light penetration to create food on substrate may be to blame. Taxa count is

reduced at all stations which is also a metric which often responds to stress related to eutrophication, among other stressors.

The fish assemblage along this reach had an increased amount of late maturing individuals except at 12LM007 (Table 46) Late maturing fish are often indicative of a stream with suitable DO levels. However, this reach also had an increased amount of serial spawning individuals at 12LM007 and a decreased amount of sensitive fish individuals at all stations (5.59%-14.57%). These results can often be a sign of DO stress. All sites also had increased percentages of simple lithophilic spawners, which show a relationship with multiple eutrophication variables. Further, all stations had increased generalists (ranging from 32%-43%) and omnivores (ranging from 15%-28%) both of which correlate to increased stress related to eutrophication. However, as already noted, fish are not impaired in this reach, but can serve as indicators for certain stressors in a stream.

Table 46. Fish and macroinvertebrate metrics relevant to DO for stations in the South Fork Zumbro. Bold and highlighted indicates the metric score is higher or lower than average, depending on the expected response with increased stress. *indicates metric with relationship to river eutrophication variables (DO flux, TP, BOD or Chl-a).

Station (Year sampled)	MA>3 years	Sensitive Fish Percentage*	Serial Spawning Percentage	Simple Lithophilic Percentage*	Macroinvertebrate Low DO TIV Community Score	Percentage Low DO Tolerant Macroinvertebrate Taxa	Low DO Intolerant Macroinvertebrate Taxa	Taxa Count (TaxaCountAllChir)*	EPT Macroinvertebrate Taxa*	Collector-Gatherer Ch*	Collector Filterer Pct*
12LM066 (2012)	36.52	**14.57**	24.35	36.09	7.43	0	5	22	7	6	55.97
04LM125 (2004)	45.81	**10.89**	37.15	37.71	7.50	0	10	28	11	8	37.5
12LM007 (2012)	**31.34**	**5.59**	49.44	33.31	7.30	2.47	4	31	9	11	58.28
Statewide average for Class 1 (fish) stations meeting the FIBI threshold	***36.50***	***16.33***	***37.88***	***29.11***	---	---	---	---	---	---	
Statewide average for Class 5 meeting the MIBI threshold	---	---	---	---	***7.24***	***8.84***	***9.41***	***37.7***	***10.7***	***14.8***	***25.3***
Statewide average for Class 6 meeting the MIBI threshold	---	---	---	---	***7.04***	***13.99***	***6.51***	***33.0***	***8.8***	***15.0***	***24.7***
Expected response to stress	↓	↓	↑	↑	↓	↑	↓	↑	↓	↑	↑

The South Fork Zumbro River is impaired for aquatic life due to its poor scoring macroinvertebrate assemblage. The related low DO biological metrics for this community score reasonably well as few DO tolerant individuals were present. The continuous DO monitoring for the most part did exceed the 3.5 mg/L daily flux standard, but all values were above the low DO standard of 5 mg/L. Low DO does not appear to be an issue in this reach according to the available data. Phosphorus values in this reach frequently exceed the standard, which can lead to further eutrophication and subsequent DO problems. The chlorophyll a data shows that during low flow years, high suspended algae is present in this reach,

and the macroinvertebrate community composition also reflects this; with a dominance of collector filterer individuals. It's not known how this varies each year, but the data suggests it is variable. Given the worst scoring macroinvertebrate station is 12LM066, which is the farthest upstream in the reach, it appears there could be sources of algae upstream in the South Fork, and the algae are being transferred downstream. Additional inputs of phosphorus to this reach can also play a role in the responses observed, but the longitudinal differences are not well understood at this time in addition to the role that turbidity may be playing. While low DO has not been observed regularly and does not appear to be causing biological stress at this time, this reach remains susceptible. If phosphorus continues to increase, or other variables (climate and flow) contribute to the production of additional algae in this reach, low DO could become a problem. The fish community, while not impaired, is beginning to show potential signs that dissolved oxygen could become an issue. Both low DO and eutrophication cannot be confirmed at this time due to the spatial disconnect of biological stress and chemical information. Additional chemical data at 12LM066 would be helpful in determining phosphorus and chlorophyll concentrations as they relate to downstream (where the majority of the samples have been collected in years past). This, in addition to continuous DO monitoring may be warranted at multiple locations throughout this reach, especially in low flow years.

Nitrate

During biological sampling the nitrate concentration in this reach ranged from 4.9 to 10 mg/L (samples taken in 2004 and 2012). There were 208 additional nitrate samples available on this reach, taken from 1999 and 2014 (Figure 108). The average concentration of the samples collected was 6.0 mg/L, with the maximum of 13.4 mg/L, collected in June of 2014. Longitudinally, there is more information in the middle and lower parts of this reach, with only a handful of samples in the upper reaches (near 12LM066). On 6/28/2012, a sample at 12LM066 had a concentration of 7.8 mg/L and on 6/27/2012; a sample at 12LM007 had a concentration of 10 mg/L. This limited data does suggest slightly increasing nitrate concentrations when moving downstream; additional information would help understand the longitudinal or seasonal differences.

Daily nitrate values were calculated for the South Fork (AUID 07040004-507) subsheds 600, 601, 602, 603, and 604 by the HSPF model from 19995-2009. These values ranged from 1.23-19.37 mg/L with an average value of 4.59 mg/L. In addition, 1.83% of the values were above 10 mg/L.

The macroinvertebrate communities in the South Fork show a mixed response to elevated nitrate. Taxa Count or species richness are below class averages for all stations in this reach (Table 47). Trichoptera taxa numbers are less than average for one visit at 12LM066. This station also had a higher percentage of nitrate tolerant taxa, compared to the other two stations. There were no nitrate intolerant taxa present at any site. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These Trichoptera include all caddisflies that do not spin nets. The percentage at these three stations was above average for sites in the LMB (3.39%). There is a lack of sensitive fish species (5%-14%) and higher percentage of tolerant fish species (44-72%) which also can be consistent with nitrate stress but may be related to other stressors as well.

The biological response evidence doesn't strongly support a nitrate stress due to the inconsistent results among stations and metrics. The macroinvertebrate response seen may or may not be due to other stressors. There is very little chemical data that provides an understanding of the potential variations in nitrate concentrations in this reach and whether or not nitrates are consistently higher or lower at

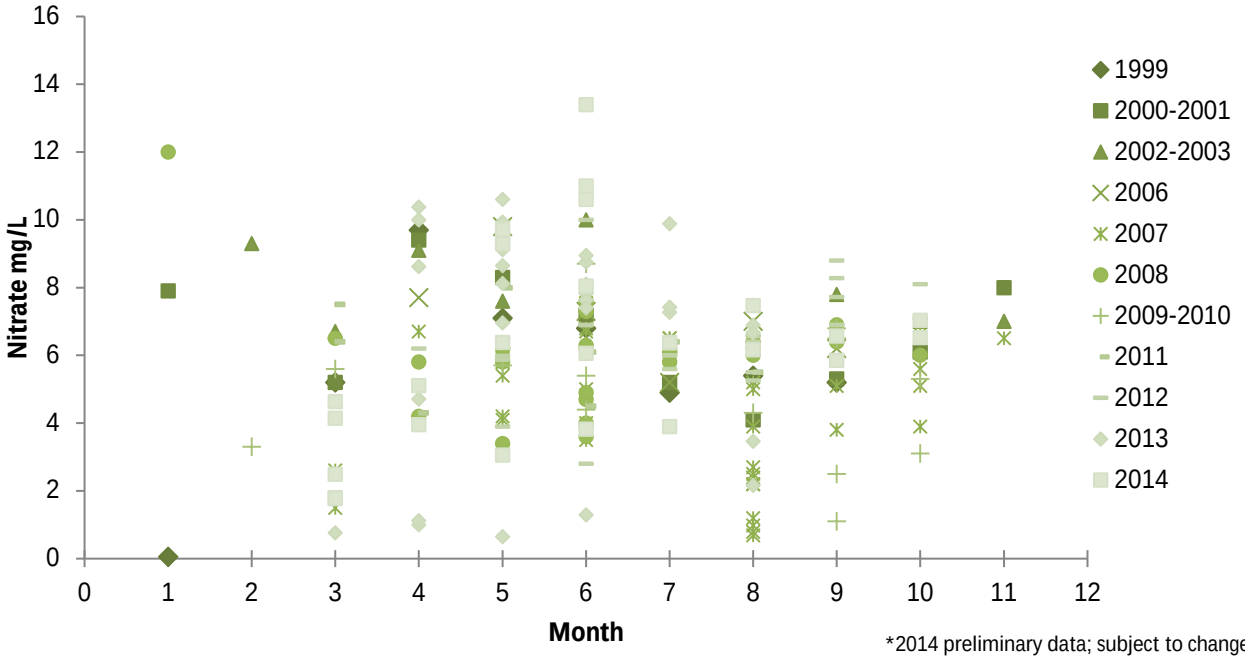

Figure 108. Nitrate concentrations for the South Fork Zumbro (507). The majority of the samples taken are from the middle (S000-268) and lower parts of the reach (S003-802).

12LM066. There may be seasonal or other longitudinal differences in nitrate concentration that are currently not understood and need to be explored further. Because of the inconsistency with the biological data and lack of understanding in nitrate concentrations throughout this reach, nitrate is inconclusive as a stressor. Additional information on longitudinal dynamics (more information specifically at 12LM066) would be helpful.

Table 47. Nitrate relevant macroinvertebrate metrics on the South Fork Zumbro compared to statewide averages for Class 5 and 6 streams meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Nitrate Relevant Metrics	Taxa Count (TaxaCountAllChir)	Trichoptera Taxa	% Non-hydropsychid tricoptera	Nitrate Intolerant Taxa	% Nitrate Tolerant Individuals
12LM066 (Class 5)	**22**	**4**	3.45	**0**	**90.9**
12LM007 (Class 6)	**31**	6	5.73	**0**	67.4
04LM125 (Class 6)	**28**	6	2.24	**0**	69.8
Expected response with increased Nitrate stress	↓	↓	↓	↓	↑
Class 5 Averages	***37.76***	***4.3***	***3.39***	***1.49***	***69.8***
Class 6 Averages	***33***	***2.2***	***2.21***	***1.49***	***69.8***

Suspended sediment

At the time of biological monitoring in 2004 as part of a one-time chemistry sample at site 04LM125 the TSS value recorded was 13 mg/L. During one-time sampling during 2012 at site 12LM007 two samples were collected, on June 27, the TSS value was 18 mg/L and on July 31 the TSS value was 13 mg/L. Finally, in 2012 at site 12LM066, one-time chemistry was collected and the TSS value was 24 mg/L. Additionally, 222 TSS values were recorded from 2000-2014. The TSS values range from 1.6-820 mg/L with an average value of 59.54 mg/L. Many of these samples were directed at load monitoring due to the turbidity listing in 2002. Therefore, much of the data is biased high to due to the sampling directed towards storm events.

From all the samples taken on this reach (2002-2014), it appears that any flows above ~500 cfs, were almost always greater than 65 mg/L TSS concentration (N=77). Normal events during the summer often produce flows >500 cfs, but often for shorter durations; i.e., anywhere from 1 to 12 days depending on the event and conditions. For example, a June event in 2014, had sustained flows above 500 cfs for nine continuous days and had an average concentration of 320 mg/L from four samples; all above the TSS standard. Similarly, June of 2013, produced similar results, with 12 consecutive days of flows above 500 cfs and three samples during that time period that had an average of 123 mg/L. While the TSS benchmark used here is 65 mg/L (current WQ standard), stress to biology is believed to occur before this concentration is reached and especially at longer durations of elevated TSS.

Daily TSS values were calculated for the South Fork Zumbro River (AUID 07040004-507) subsheds 600, 601, 602, 603, and 604 by the HSPF model from 1995-2009. These values ranged from 2.01-2087.53 mg/L with an average value of 28.61 mg/L. There were 8.4% of the values above the proposed TSS standard of 65 mg/L.

In the South Fork, the macroinvertebrate metrics signal TSS stress (Table 48). There is consistent response seen with the very elevated TSS index score, the lack of TSS intolerant taxa and higher than average number and percentage of TSS tolerant taxa at all three stations. The collector filterer percent was above average for all three stations. Filtering organisms can benefit from increases in suspended organic matter and algae. Silver Lake, just upstream of this reach may provide a source of food for filtering organisms, thus increasing their abundance in this reach. The fish community, while not impaired, responds with 6 of the 10 metrics signaling TSS stress as well. The fish community is made up of tolerant to TSS fish species (sand shiner, white sucker) with a TSS index score ranging from 21.06 to 25.9, values higher than most reaches in the Zumbro Watershed. Using data from the fish community, there is only a 12%-35% chance the reach meets the TSS standard because of more TSS tolerant fish species present. There is a large drainage area to this reach, and it is dominated by a shifting sand stream bed. Bank erosion, substrate and instability are further characterized in the habitat section. The chemical and biological response from both fish and macroinvertebrates confirms TSS is a stressor to aquatic life in the South Fork Zumbro.

Table 48. Macroinvertebrate metrics relevant to TSS for stations in the South Fork Zumbro compared to statewide averages for southern streams GP and southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Class)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM066 (RR)	**19.99**	**0.00**	10.00	**77.02**	55.97	**0.00**
12LM007 (GP)	**18.67**	**0.00**	9.00	**61.13**	58.28	**0.00**
04LM125 (GP)	**20.36**	**0.00**	**12**	**46.45**	37.5	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

The South Fork Zumbro River (07040004-507) had qualitative habitat assessments take place at each of its three biological monitoring stations, 12LM066, 12LM007 and 04LM125. These MSHA scores ranged from 63.9 (Fair) to 70.1 (Good). Limiting the habitat at these sites was a poor surrounding land use (particularly at 04LM125), a sometimes limited riparian buffer, sand/silt substrates, light embeddedness, moderate channel stability and fair channel development. (Figure 109).

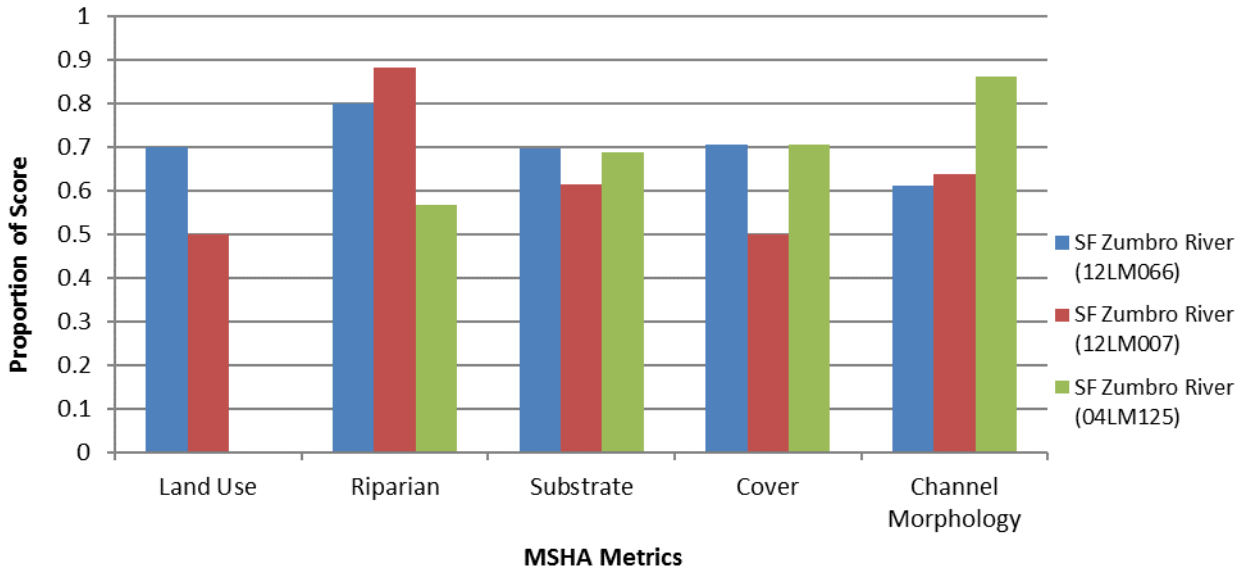

Figure 109. MSHA metric value scores at sampling sites along South Fork Zumbro River (07040004-507).

The majority of the habitats sampled during the macroinvertebrate collections were from woody debris, with a few riffle areas sampled from 12LM066. This sample had an increased amount of clinger (66.87%) individuals, which is not surprising given the amount of woody debris sampled. Cheumatopsyche, a very tolerant clinger caddisfly, dominates the community found at both 12LM066 and 12LM007 (47% and 42% respectively). The dominance of the community by one species, not only signals problems but also skews metric percentages. This reach also had decreased amounts of burrower (10.11%) and legless (31.84%) individuals, which may be due to the sample coming mostly from woody debris. If more of the sand covered riffle areas were sampled, an increase in burrower and legless individuals are expected, especially with sedimentation issues. Taxa count is also below average for all stations, which means the community is not as rich as expected, and this can also skew the community percentages.

The fish assemblage in this section of the South Fork Zumbro River was one that does not appear to be stressed by the lack of habitat. This reach had increased numbers of benthic insectivore (28.66%), darter/sculpin/round-bodied sucker (25.13%), riffle dwelling (28.18%) and simple lithophilic spawning (35.16%) individuals. Additionally, this reach had a decreased amount of pioneer species individuals (19.76%).

In July of 2015, a float trip on the majority of the AUID was conducted to analyze the varying habitat conditions throughout this reach. Substrate was documented as being unstable along the reach. While some courser substrates were observed in the upper reaches, when moving downstream, sand became the prominent substrate. Some bank erosion was observed, but when moving downstream, most of the reach had a decent riparian area.

Furthermore, the MNDNR did a geomorphology assessment along this reach at biological station 12LM007. This work determined that the stream section was classified as an F stream type with a sand bed. The water surface slope is 0.00073 with a width to depth ratio of 35.05 and entrenchment ratio of 1.4. A steep terrace runs along the right bank at the survey site (near 12LM007), while the left bank has a small floodplain. Both sides of the bank have at least 300 feet of vegetated buffer on each side. A Pfankuch rating of poor was observed within the reach, due in large part to deposition seen throughout the reach.

Using a reference reach found in the Little Cannon for comparison, potential stability issues at this location were determined. The information in Table 49 shows the key ratio comparisons of the reference reach and this impaired reach.

Table 49. Geomorphic comparison of impaired and reference reaches (MNDNR)

Site Name	Ratios			
	Pool length to riffle width	**Pool slope to average slope**	**Max pool depth to mean riffle depth**	**Riffle length to riffle width**
S. F. Zumbro	1.1	0.85	1.63	0.49
Reference C	2.2	0.18	2.9	1.42

The ratio comparison reveals the impaired reach has short and shallow pools. The pools also have a steep water slope, indicative of instability within the reach. Riffle lengths are also short in the impaired reach. Unfortunately, competence analysis could not be completed to show suspected aggradation, as sand bed streams are assumed to be mobile at bankfull discharge. At the time of the survey, point bars and side bars were developing within the floodplain, showing aggradation and potential succession towards stability. Pools and riffles are likely filling with excess sediment from upstream sources, as the stream banks in this location are not predicted to contribute large amounts of sediment.

Identified from aerial photographs, there appears to be multiple sources contributing sediment upstream (Figure 110). One source of sediment could be a quarry 1.5 miles upstream. The quarry runs for about 0.7 miles along the river, which may be contributing sediment.

Figure 110. Potential sediment sources. Bing Maps 2015. MPCA photo (right) showing access from quarry.

Despite the fairly good MSHA scores and high scoring habitat related biological metrics, it is likely that these scores do not accurately reflect the limited habitat conditions currently present in the South Fork Zumbro River. The additional observations made along this reach show a stream system that is being heavily impacted by the flashy flows that are common in close proximity to urban areas and the high abundance of impervious surfaces. The resulting eroded banks present (Figure 111) deposit fine sediments on top of course substrates as well as other potential habitat features. This limits the reproductive suitability for many high quality fish and macroinvertebrate species. The physical habitat conditions associated with urbanization often include a change in streambed substrate composition, channel enlargement, and reduced habitat complexity (Caddis). Throughout this reach, these characteristics have been documented well with the dominance of sand substrates, areas of channel widening/instability and a lack of habitat complexity including: increased length of runs, decreased riffle segments and decreased pool depths. Without improvements, expect habitat conditions along the South Fork Zumbro to continue to degrade and provide stress to the biotic communities. Therefore, lack of habitat is a stressor to the impaired macroinvertebrate assemblage at this time.

Figure 111. Massive bank erosion on 07040004-507.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 13.65-mile-long reach of South Fork Zumbro River (07040004-507) was 85.51% a natural stream channel. A couple stretches within the city of Rochester were altered as well as two smaller sections located downstream of the city.

Both historical and recent flow information was available for the section of the South Fork Zumbro River. According to the MNDNR report from 1965, "Above Zumbro Lake, the South fork has a baseflow of 31 cfs during the middle part of the summer. At this point the maximum daily average for between 1952 and 1960 was about 9000 cfs, the average flow about 100 cfs and the minimum was 8.4 cfs. The baseflow is primarily derived from numerous springs and seepage areas which are about 300 ft higher and several miles upstream from the lower end of the watershed."

MNDNR completed some detailed hydrologic analysis on the South Fork Zumbro, which highlighted that both high flows and low flows have been increasing over time.

Also, Figure 112 is a hydrograph of the 2014 discharge along the South Fork Zumbro River.

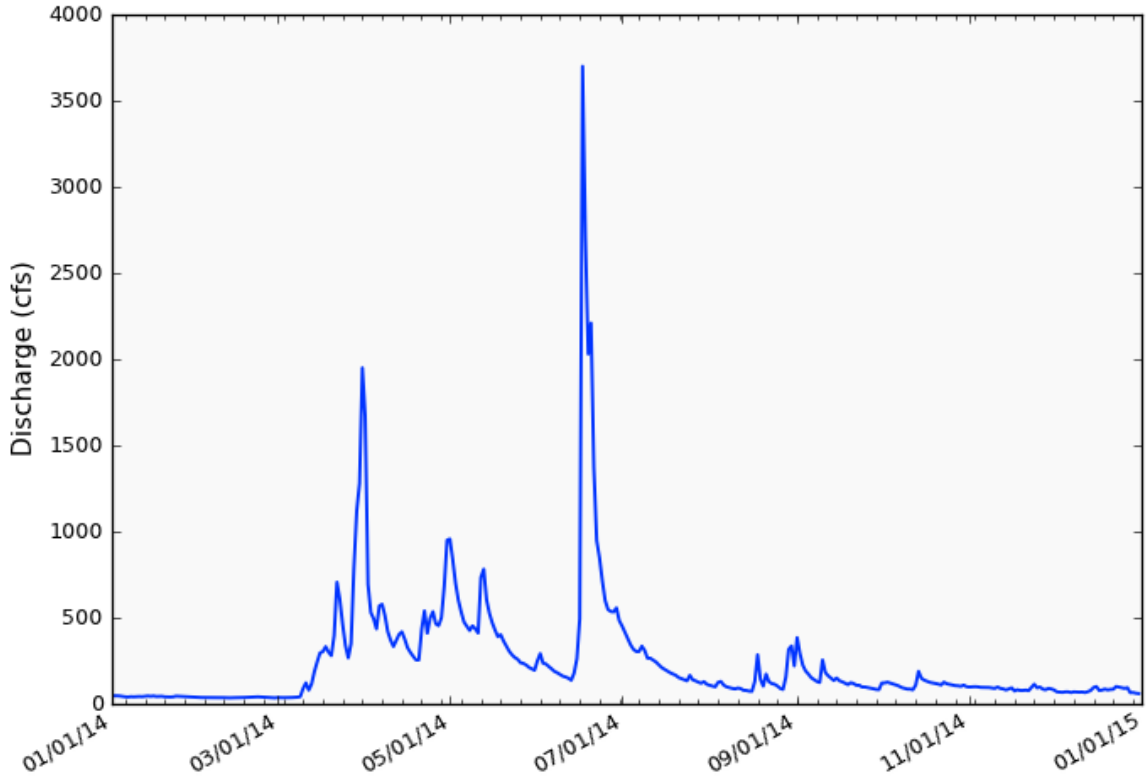

Figure 112. Hydrograph of the South Fork Zumbro from 2014.

In both instances, the flows of the South Fork Zumbro River can often become very high. This leads to heavily eroded banks and aggradation, as previously mentioned in the habitat section that covers many of the course substrates needed by the fish and macroinvertebrate communities.

Furthermore, according to Booth et al (2004), sites with greater than or equal to 54% urban land cover tend to have poor macroinvertebrate conditions due to the flashiness of these systems, that can be attributed to the high amount of impervious surfaces present nearby. Flowing through the city of Rochester, urbanization and impervious surfaces are abundant and are likely contributing to the flashiness of the stream.

This particular section of the South Fork Zumbro River does not have concerns with connectivity, but flow alteration and is a large concern with the sometimes high flow conditions resulting in eroded banks, aggradation and reduced habitat conditions. Therefore, flow alteration is a stressor to the impaired biological communities in South Fork Zumbro River (07040004-507).

Chloride and conductivity

This AUID is particularly susceptible to influences from due to nearby urbanized areas, which prompted additional analysis of chloride and conductivity data. Specific conductance is an indication of the amount of dissolved minerals or total dissolved solids in the water. Elevated conductivity can be toxic to biological organisms through effects on osmoregulation.

After data examination, the highest conductivity and chloride readings in the entire Zumbro Watershed occurred on this AUID, so this dataset went through further examination. A few instances of elevated conductivity have been documented, from 2003-2012. There were seven occasions when conductivity was greater than 900 µS/cm and 3 when the conductivity was greater than 1,000 µS/cm. Only one of those conductivity readings had a paired chloride reading, which was elevated at 132 mg/L but did not exceed the standard (230 mg/L). Elevated conductivity may not be caused by only elevated chloride but can serve as a surrogate or indicator for ions in the water, such as chloride. The chloride data from this stream reach did not once exceed the standard (Figure 113), and the highest numbers measured were during the later summer months when stream baseflow is reduced. However, the samples during the winter months were minimal compared to other times of the year.

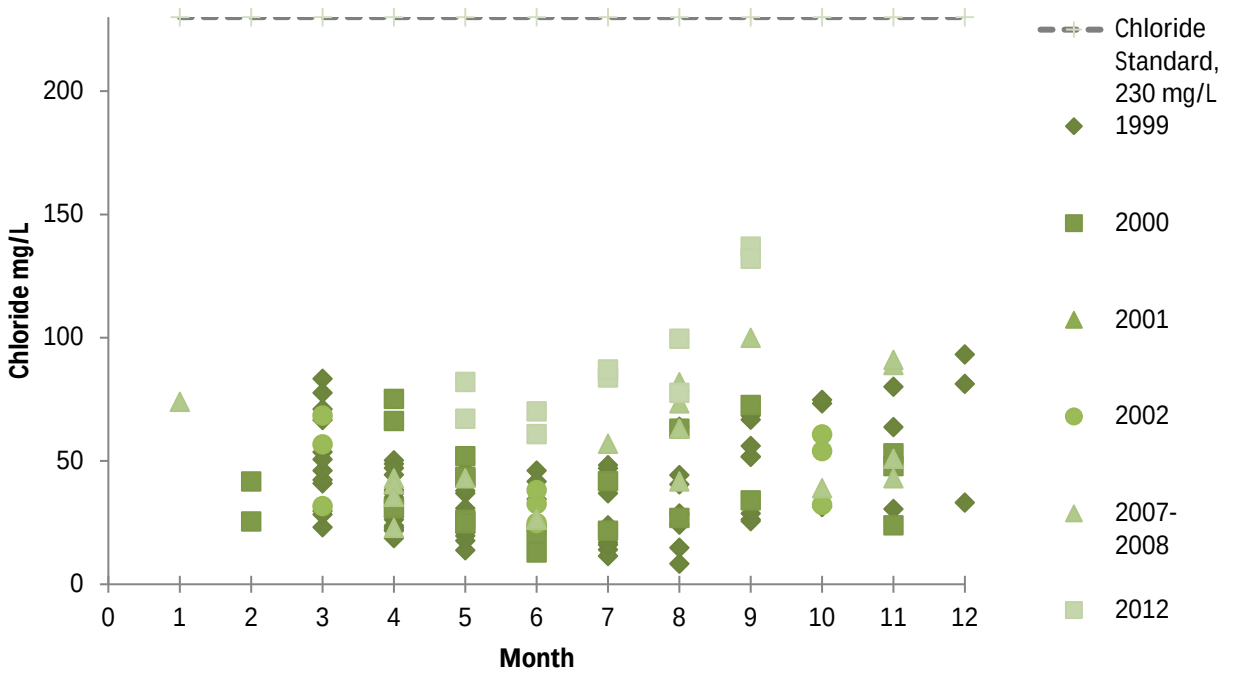

Figure 113. Chloride data from the South Fork Zumbro by month for AUID 507, from 1999-2012.

The Rochester WWTP discharges to this AUID and paired chloride data has been collected for a number of years upstream and downstream of the wastewater treatment plant (Figure 114). The samples that were taken upstream of the wastewater treatment discharge showed lower results than those collected downstream of the plant on the same sampling day. On average, the chloride concentration in the stream doubled after receiving the treatment plant discharge.

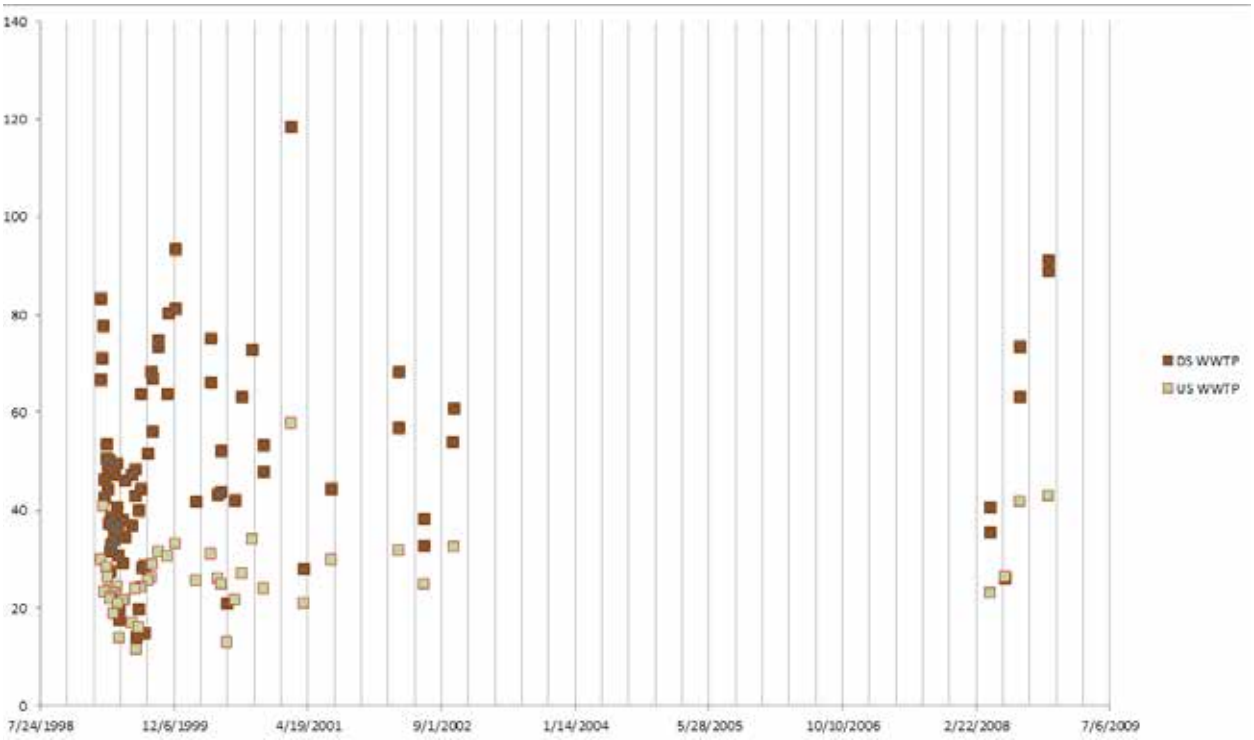

Figure 114. Chloride samples taken on the same day comparing concentrations upstream and downstream of the wastewater treatment plant.

From a biological standpoint, sunfish based assemblages can increase due to elevated chloride levels (Centrarchidae). Across the state, the average percentage of sunfish for Class 1 fish stations meeting impairment threshold is 9.3%. Two of the three stations had higher than average sunfish populations (04LM125; 15.08% and 12LM066; 20.22%) However, downstream station 12LM007 had 6.29% in June and 3.37% in July. In this example, the highest percentage of sunfish is actually at the biological station farthest upstream (upstream of the WWTP discharge point) and therefore doesn't correlate to the higher concentrations generally. This may speak to the possibility that other factors play into the higher percentages or may indicate that data in this location is not sufficient. Additional information may be needed.

Chloride and conductivity related stress can also result in reduced overall taxa richness, decreases in mayfly (Ephemeroptera) percentages, mayfly taxa richness and EPT taxa. Response is seen among most of these metrics (Table 50) which may be suggestive of chloride related stress but could also be a result of other stressors. The response seen in this table seems fairly consistent across sites, with similar response throughout the entire reach.

Table 50. Biological metrics related to chloride and conductivity in the South Fork Zumbro.

Station, organized upstream to downstream (Stream Class)	TaxaCountAllChir	EphemeropteraCh	EphemeropteraPct	EPT Taxa
12LM066 (Class 5)	22	3	15.40	7
04LM125 (Class 6)	28	5	23.07	11
12LM007 (Class 6)	31	4	7.32	9
Statewide Class 5 Averages for streams meeting impairment threshold	*42.4*	*6*	*22.4*	*10.7*
Statewide Class 6 Averages for streams meeting impairment threshold	*41.2*	*5.1*	*18*	*8.8*
Expected response to stress	↓	↓	↓	↓

Olmsted County had a chloride budget study done in 2007, which indicated there were three major sources of chloride in the county: road salt, softener salt and potassium fertilizer. These sources account for over 90% of the inventoried load in the county. The highest chloride loads were found on this reach of the South Fork Zumbro, which is subject to wastewater effluent as previously stated. The study found that the chloride in the effluent is attributed largely to commercial and residential softener use, chloride in raw water and ferric chloride used at the treatment facility for phosphorus removal. The chloride loads upstream and downstream of the plant were also compared and suggest that chloride below the plant is about 19% higher than would be predicted by the sum of the stream load above the plant and the treatment plant load. The vast majority of the chloride load at treatment plant is attributable to water softening.

The Shingle Creek (not Shingle Creek in the Zumbro) Chloride TMDL indicated that specific conductivity readings above 1000 µS/cm showed that chloride levels were high enough to cause toxicity problems for aquatic organisms. There have been three instances where conductivity has been measured above this level on this reach (all of them downstream of the treatment plant, none upstream). While this may be episodic in nature, and may or may not be linked to elevated chloride, additional information should be collected to better understand its potential effects.

The biological response information, while limited, does not signal more issues at the downstream sites compared to the upstream site in terms of chloride/conductivity stress. The observed conductivity values >1000 are concerning. While some chloride data was elevated, the data has not yet exceeded the standard. The biological station that resulted in biological impairment in this reach, with an MIBI score significantly lower than the others, was upstream of the wastewater treatment plant discharge. However, this station also may be subjected to other impacts of related urbanization and/or may be responding to cumulative stressor effects. Conductivity/chloride is inconclusive in this reach due to the lack of connecting biological information, but it should continue to be monitored to ensure that both

chloride and conductivity are at suitable levels in this reach upstream and downstream of the WWTP during all seasons.

Conclusions and recommendations

The impaired macroinvertebrate community of the South Fork Zumbro (507) is being stressed by elevated TSS, poor habitat conditions and flow alteration/connectivity (Table 51). The existing turbidity impairment on this reach has an abundance of biological response which validates the impairment. All stations on this reach show an elevated macroinvertebrate TIV index score which indicates that the majority of the taxa present are tolerant of high TSS. There is also a complete lack of intolerant to elevated TSS macroinvertebrate taxa. Collector filterer taxa which often can respond negatively to increases in TSS are actually higher than average, which is not expected. There are likely upstream sources providing a source of food for these filtering organisms, thus increasing their abundance. The fish community is made up of tolerant TSS fish species (sand shiner, white sucker) with a TSS index score ranging from 21.06 to 25.9, values higher than most reaches in the entire Zumbro Watershed. Using data probability from the fish community, there is only a 12%-35% chance that the reach meets the TSS standard because more TSS tolerant fish species present. There is a large drainage area to this reach, and it is dominated by a shifting sand stream bed. Bank erosion, substrate and instability are part of the reason TSS is an issue and ultimately play into the habitat stress observed. Observations made along this reach show a stream system that is being heavily impacted by the flashy flows that are common in close proximity to urban areas and the high abundance of impervious surfaces. The eroding banks and fine sediment limits the reproductive suitability for many high quality fish and macroinvertebrate species. The physical habitat conditions associated with urbanization often include a change in streambed substrate composition, channel enlargement and reduced habitat complexity. Throughout this reach, these characteristics have been documented well with the dominance of sand substrates, areas of channel widening/instability, and lack of habitat complexity including: increased length of runs, decreased riffle segments, and decreased pool depths. The alteration of flows and channelization in the urban area of Rochester is a contributing factor to this habitat degradation.

Nitrate and Chloride/Conductivity are both considered inconclusive as stressors at this time. The biological response was very inconsistent among biological stations and the nitrate concentrations throughout this reach are variable and may be exhibiting seasonal differences that are not completely understood. In terms of chloride and conductivity, the biological response information does not signal more issues at the downstream sites compared to the upstream site as expected. The observed conductivity values >1000µS/cm downstream are concerning and some chloride data was elevated, but the data has not yet exceeded the standard. The biological station that resulted in biological impairment in this reach, with an MIBI score significantly lower than the others, was upstream of the wastewater treatment plant, which is a likely source of some of the elevated chloride/conductivity. However, this station upstream of the plant may also be subjected to other impacts of urbanization and may be responding to cumulative stressor effects not yet understood. Additional monitoring would be useful to ensure both chloride and conductivity are at suitable levels in this reach upstream and downstream of the treatment plant during all seasons and flows.

Low DO and eutrophication are inconclusive as stressors to this reach due to the spatial disconnect of biological response and chemical information. Continuous DO monitoring supported adequate oxygen levels with no violations of the 5 mg/L standard, but the daily flux did exceed the 3.5 mg/L standard, which suggests eutrophication may be occurring in this reach. This also indicates that low DO could be problem and this stream is susceptible to low DO, but further information is needed to validate. In addition, other variables support the eutrophication impacts including, high chlorophyll-*a*, BOD, and phosphorus. The fish community, while not impaired, does signal the potential for DO issues. Monitoring

for DO over time to ensure suitable levels throughout this reach is recommended. The station with the worst scoring macroinvertebrate community is 12LM066, but without additional information at that specific location, it's difficult to confirm if the stress is related to DO and eutrophication, and how that compares to downstream (where all of the chemical information exists). Other stressor impacts could also explain the response seen at 12LM066, including poor habitat. Additional chemical data at 12LM066 would be helpful in determining phosphorus and chlorophyll concentrations as they relate to downstream (where the majority of the samples have been collected). This, in addition to continuous DO monitoring may be warranted throughout this reach, especially in low flow years.

Additional monitoring on this reach, at multiple locations, will help in the understanding of the complexities and differences. One of the other unknowns about this reach is the impact of multiple point sources. The wastewater treatment plant is a large point source discharge, but there are additional point source discharges on this reach, and that cumulative impact is not well known (Figure 115). Also, there are many discharges in the City of Rochester that are not displayed in the map that should also be considered as potential impacts to this reach. Additional monitoring at multiple locations will aid in further understanding.

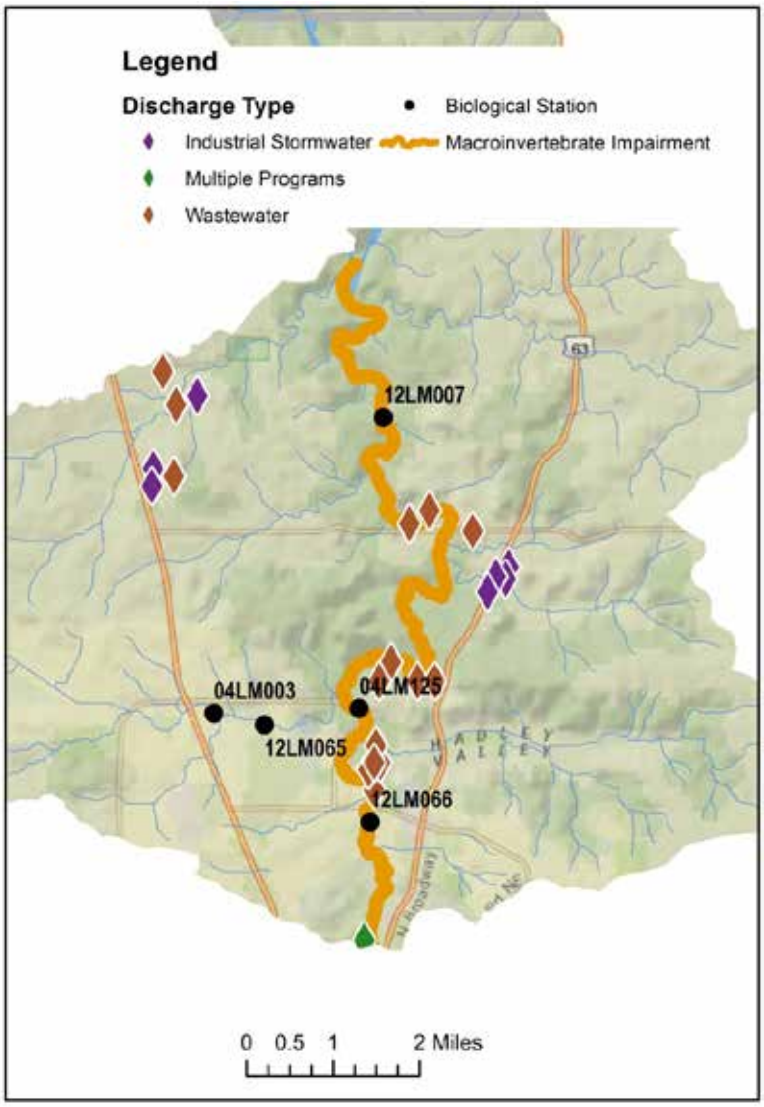

Figure 115. Map of multiple point source discharges in relation to biological monitoring stations in the South Fork Zumbro.

Table 51. Summary of stressor determinations for the South Fork Zumbro

Stream Name	AUID	Stressors: Temperature	Dissolved Oxygen / Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity	Chloride/Conductivity
South Fork Zumbro	07040004-507	---	o	o	●	●	●	o

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.10.2 South Fork Zumbro (536) *Salem Creek to Bear Creek*

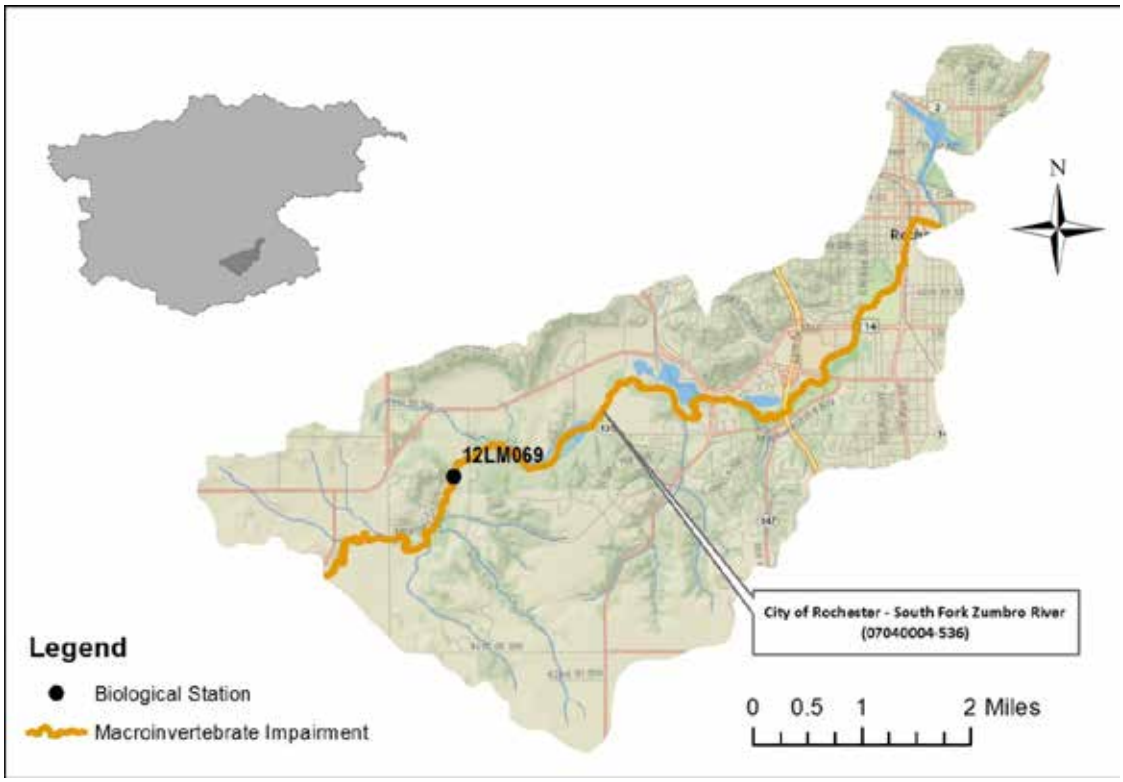

Figure 116. The South Fork Zumbro (536), biological station and impaired AUID.

Biological and background information

The South Fork Zumbro (07040004-536) has one biological station, 12LM069, which resulted in a macroinvertebrate impairment. This site is designated macroinvertebrate Class 6 (Southern Forest Streams GP). Station 12LM069 is located upstream of the City of Rochester. The MIBI impairment threshold for this class is 43, with an average score of 4.3 per metric needed to achieve that threshold. 12LM069 has an MIBI score of 38.51 and scored below the average needed on 5 out of 10 metrics. The 5 metrics that scored well did not score exceptionally higher than the average metric needed, scores

ranged from 4.6 to 6.4. The worst scoring metrics indicate low taxa richness of intolerant species (Intolerant2Ch) and a lack of Trichoptera individuals and taxa (TrichopteraChTxPct and TrichwoHydroPct).

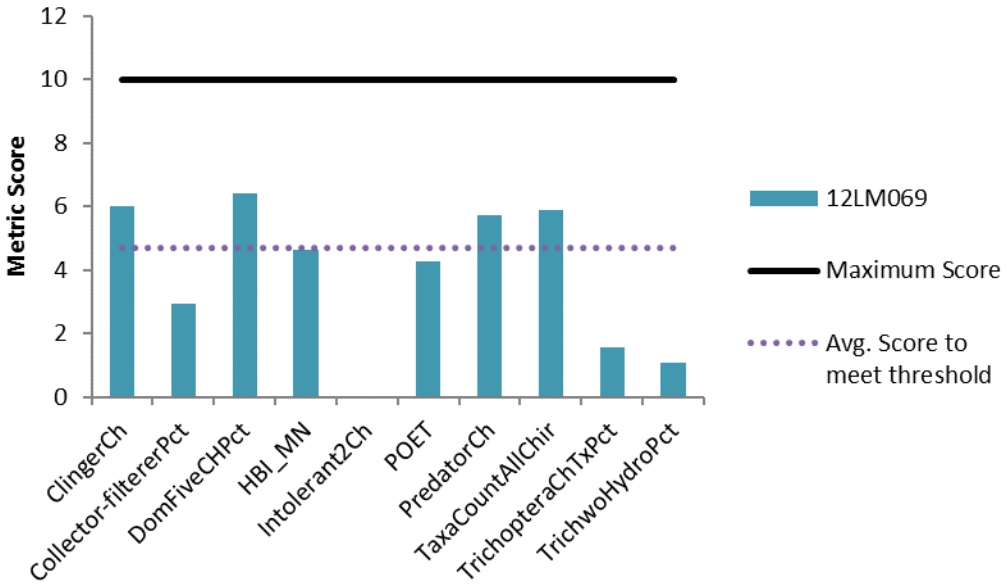

Figure 117. Macroinvertebrate IBI metrics for South Fork Zumbro (Class 6; Southern Streams Glide/Pool).

Dissolved oxygen and eutrophication

The South Fork Zumbro River (07040004-536) had continuous DO monitoring take place downstream of the County Road 104 crossing (S007-956). The results of this monitoring show that the DO conditions stayed above 7.3 mg/L, while the daily flux maxes out at 3.9 mg/L. These results do not indicate any issues regarding low DO conditions or problems with daily Do flux as the results did not exceed the 4.5 mg/L standard for flux in the South nutrient region.

Additionally, 7 phosphorus samples were taken along this reach from 2012-2014. These values ranged from 0.018-0.279 mg/L, with one value above the 0.15 mg/L phosphorus standard for the South nutrient region. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

The macroinvertebrate assemblage at site 12LM069 had a decreased amount of Do tolerant individuals (13.96%). This site contained just three DO intolerant taxa, while having an increased amount of tolerant taxa (7). The DO TIV score for this assemblage was slightly above average when compared to all other Class 6 sites within Minnesota.

The fish community along this portion of South Fork Zumbro River had an increased amount of late maturing in (28.01%), while also having a decreased amount of serial spawning individuals (13.32%). The DO TIV score for the fish community was slightly above average when compared to all other Class 2 sites. All of these results signal that low DO is not negatively impacting the fish assemblage.

Based on the observed dissolved oxygen data from the continuous monitoring, the low phosphorus values, as well as the agreement of the majority of the related biological metrics from communities, low DO and eutrophication are not stressors to this portion of the South Fork Zumbro River at this time.

Nitrate

During fish sample, the nitrate concentration at 12LM069 was measured at 5.1 mg/L (June of 2012). There were 35 additional samples taken on this reach from 2007-2014. The nitrate concentration ranged from 0.42 mg/L up to 14 mg/L. The average concentration was 5.4 mg/L; only three samples were over 10 mg/L.

Daily nitrate values were calculated for the South Fork Zumbro River (AUID 07040004-536) subsheds 608 and 609 by the HSPF model from 1995-2009. These values ranged from 1.03-23.43 mg/L. In addition, 3.8% of the values were above 10 mg/L and less than 1% were above 20 mg/L.

Station 12LM069 had an above average taxa count (TaxaCountAllChir; 39). The average taxa count for this macroinvertebrate Class 6; (Southern Forest Streams GP) is 33. Trichoptera are found to be generally sensitive to elevated nitrate concentrations. There was one Trichoptera taxon, which is just below the average for the Southern Forest Streams GP stations of the LMB (2.2). Similarly, the percentage of Trichoptera individuals was below the average, at 2.56% (Average is 5.3%). However, this site had only 69% nitrate tolerant individuals, which is in the moderate range, but still below average for the LMB. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (Class 6) MIBI. There were two nitrate intolerant taxa found as well. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. Non-hydropsychid trichoptera are all caddisflies that do not spin nets. Station 12LM069 had only 3.45% non-hydropsychid trichoptera. This is above average compared to all biological sites in the LMB (3.39%) and of this stream class (2.21%).

There is a minor response to elevated nitrate in this reach, which is likely due to other stressors present. The presence of sensitive species (nitrate intolerant and non-hydropsychid Trichoptera) indicate nitrate is probably not driving stress. Given the lack of strong biological response, presence of sensitive species and chemical data, nitrate is not considered a stressor to this reach at this time.

Suspended sediment

At the time of biological monitoring a one-time chemistry sample was collected at 12LM069 and the TSS value recorded was 29 mg/L. Additionally, 36 TSS values were recorded on this reach from 2007 to 2014. The TSS values range from 2.4-790 mg/L with an average value of 83.43 mg/L. Of the 36 TSS values, 12 were above the 65 mg/L TSS standard for designated warm water streams. However, most of these values were taken downstream, after the reach is impacted by the city, so the samples may not be 100% representative of the biological sampling location which is on the upstream portion of the AUID. There were six TSS values taken in 2014, that correspond to the area of the biological station. Those values had a maximum concentration of 150 mg/L, taken during a storm event in June 18, 2014. The average concentration of the six samples was 37 mg/L.

There is an existing turbidity listing on this reach from 2006. This reach is also impacted by Mayowood lake which was constructed via a dam on the river in 1911. The biological station is upstream of this lake. Olmsted County collected TSI (trophic status index) data and concluded that "Mayowood Lake is essentially a small bay within the Zumbro River system that has become so full of sediment that it can hardly be considered a lake anymore. The TSI Map shows that the lake is eutrophic with hypereutrophic areas in the narrower, shallow zones of the river."

Daily TSS values were calculated for the South Fork Zumbro River (AUID 07040004-536) subsheds 608 and 609 by the HSPF model from 1995-2009. These values ranged from 1.25-2412.2 mg/L with an average value of 23.1 mg/L. Additionally, about 5.3% of the values were above 65 mg/L, the standard for warmwater streams in the southern region.

There is very weak indication that the biological community is being impacted by TSS (Table 52). There is also very little chemical information that corresponds to the biological station. A good amount of chemical data was collected downstream, but the system changes between the two locations and is not likely representative of the whole system, with the influence of Mayowood Lake. Additional TSS data and analysis should be done in order to understand TSS dynamics in this reach, especially given the turbidity listing and sedimentation documented in Maywood Lake. TSS as a stressor is inconclusive at this time.

Table 52. Macroinvertebrate metrics relevant to TSS for stations in the South Fork Zumbro compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
12LM069	16.2	**1.00**	9.00	23.47	**11.38**	**0.00**
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

South Fork Zumbro River (07040004-536) had a qualitative habitat assessment take place at its biological station, 12LM069, during the fish sampling event in 2012. The MSHA score for this site was 75.1 (Good). Limiting the habitat at 12LM069 was a narrow riparian buffer on one side, the presence of sand and silt substrates, light embeddedness, and moderate/high channel stability.

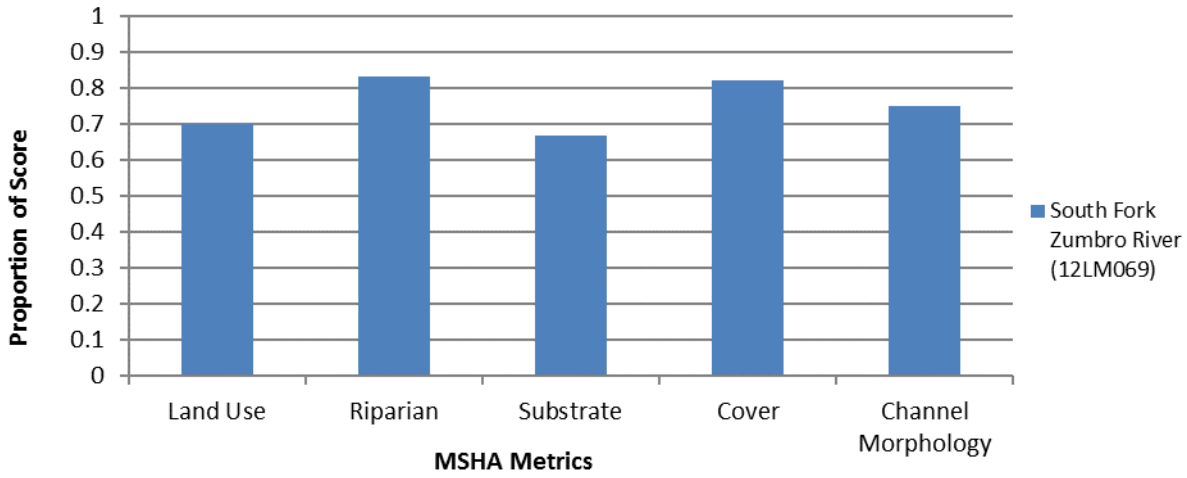

Figure 118. MSHA metric value scores at site 12LM069 along South Fork Zumbro River (07040004-536).

The macroinvertebrate sample at 12LM069 along the South Fork Zumbro River was taken from equal parts of aquatic macrophytes and overhanging vegetation. The macroinvertebrate community had a low amount of burrower (8%) individuals and had a high amount of climber (36.62%) individuals, which is

probably a result of the habitat types sampled. This site did have a low amount of EPT (4.31%), while also having a high amount of legless (63%) and sprawler individuals (24.92%), which can often signal degraded habitat conditions and poor substrate conditions.

The fish community had a high amount of benthic insectivore (18.53%), simple lithophilic spawning (61.8%), riffle-dwelling (41.06%) and darter/sculpin/round-bodied sucker (15.02%) individuals. These results all reflect a stream with suitable habitat conditions for fish.

Fine sediment in the South Fork Zumbro River has been noted historically (1965) and during the fish sampling event in 2012. The abundance of sand and silt present seems to be negatively impacting the macroinvertebrate community more so than the fish as evidenced by the high amount of legless and sprawler individuals, with few EPT individuals, while the fish community had very good scoring metrics. This reach has rip-rap on the banks and many mid channel bars, which are evidence for instability and excess sediment supply which is impacting habitat. The lack of habitat is indeed a stressor to the macroinvertebrate assemblage in this reach.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 9.54-mile-long reach of South Fork Zumbro River (07040004-536) was 89.87% a natural stream channel. The rest of the stream reach was partially impounded (9.6%) in the city of Rochester as well as by Mayowood Lake. A small percentage (0.53%) was determined to be altered.

Upstream of the dam at Mayowood Lake is site 12LM069. This site had an above average amount of migratory fish individuals (35.58%) when compared statewide. Additionally, MNDNR mussel surveys upstream found live mussels in Salem Creek as well as in the headwaters of the South Fork Zumbro River.

One potential concern with the dam on Mayowood Lake is the amount of fine sediment deposited. A historic MNDNR report from 1965 mentions, “Mayowood Lake which was originally a fairly deep impoundment having a dam of 14 feet high but not in the last states of being filled in with silt. Silt and sand deposits caused by the impoundment extend beyond the mouth of Salem Creek, three miles upstream and are found eight feet above the pool elevation.” “extensive sand deposits which extend at least three miles upstream from the waters impounded by the mayowood dam. Apparently floodwaters are slowed sufficiently to deposit a portion of the streams bedload”

With the minimal channelization occurring along this portion of the South Fork Zumbro River and the presence of many migratory fish individuals and mussels upstream of Mayowood Lake; flow alteration and connectivity are not stressing the impaired biological community at this time. Further monitoring of the potential habitat impacts resulting from the dam may be needed in the future.

Conclusions and recommendations

The impaired macroinvertebrate community of the South Fork (536) is being stressed by lack of habitat (Table 53). Fine sediment in the South Fork Zumbro River has been noted historically (1965) and during the fish sampling event in 2012. The abundance of sand and silt present seems to be negatively impacting the macroinvertebrate community more so than the fish as evidenced by the high amount of legless individuals and few EPT individuals, while the fish community had very good scoring metrics and do not appear to be impacted by the current habitat conditions.

There is a very weak indication that the biological community is being impacted by TSS and is therefore inconclusive. There is also very little chemical information that corresponds to the biological station. A good amount of chemical data was collected downstream, but the system changes between the two

locations and is not likely representative of the whole system, due to the influence of Mayowood Lake. Additional TSS data and analysis should be done in order to understand TSS dynamics in this reach, especially given the turbidity listing and sedimentation documented in Maywood Lake.

DO, Nitrate and Flow Alteration/Connectivity were all ruled out as potential stressors. Continuous DO data, low phosphorus values and biological metrics for both assemblages do not signal DO stress at this time. Nitrate concentrations were found to be generally low to moderate, but nitrate intolerant species were present which indicates that nitrate concentrations are not driving stress in this reach. While the lower reaches of this watershed are highly altered within the city of Rochester, the biological station was upstream of these areas, and therefore is not considered a driver of stress for this location. In addition, Mayowood Lake is not driving any connectivity issues in this reach, as evidenced by a fair number of migratory fish individuals in the biological station upstream. Therefore, flow alteration/connectivity was also ruled out as a stressor in this reach.

Table 53. Summary of stressor determinations for the South Fork Zumbro

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
South Fork Zumbro (Upstream of City)	07040004-536	---	---	---	o	●	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.11 Bear Creek Watershed

The Bear Creek Watershed is a warmwater stream in Olmsted County and flows through the city of Rochester and meets the South Fork Zumbro. This subwatershed drains a total of 3,456 acres, 55% of which is in agricultural use and 18% of which is developed. Section 4.10 will discuss two streams with biological (fish) impairments in this watershed. The first is a tributary to Bear Creek, Unnamed Creek 07040004-621 (Figure 119) and the second is Badger Run 07040004-620 (Figure 120).

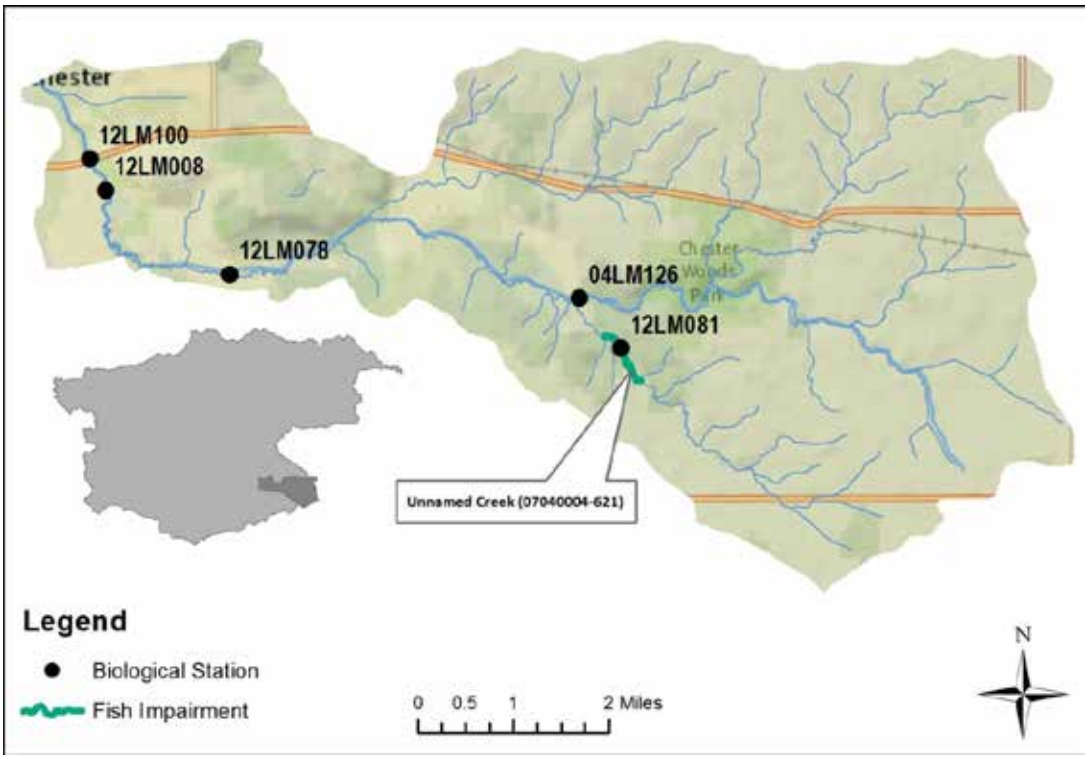

Figure 119. Map of the Bear Creek Watershed, biological stations, and impaired AUIDs.

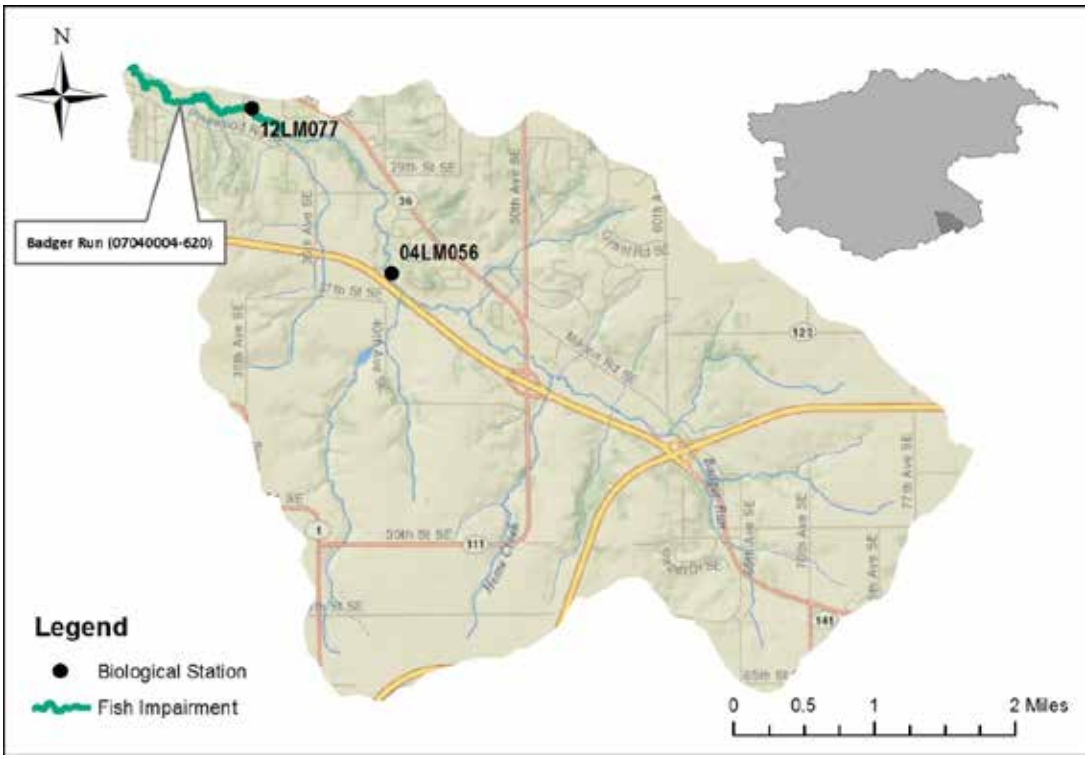

Figure 120. Map of Badger Run (Bear Creek Tributary), biological stations, and impaired AUIDs.

4.11.1 Unnamed Creek (621)

Biological and background information

Bear Creek Tributary (07040004-621) has one biological station, 12LM081, sampled on June 12th, 2012. This is a designated fish Class 3 (Southern Headwaters) stream. The FIBI impairment threshold for this

class is 55, with an average score per metric of 8.5 needed to achieve that threshold. Station 12LM081 has an FIBI score of 19, which led to a fish impairment on this reach. The most abundant fish captured was brook stickleback (23) followed by creek chub (5) and blacknose dace (2). Three out of six metrics score below the average needed, one (Sensitive) scored a zero. In addition, the other metrics that scored poorly (GeneralTxPct, and SLvdPct) and indicates the majority of species are generalists. Generalists can inhabit a wide range of environments and are short lived. The fish community metrics that scored well were: detritivores taxa (DetNWQTxPct), individuals that are serial spawning species (SSpnPct), and taxa that are very tolerant species (VtolTxPct).

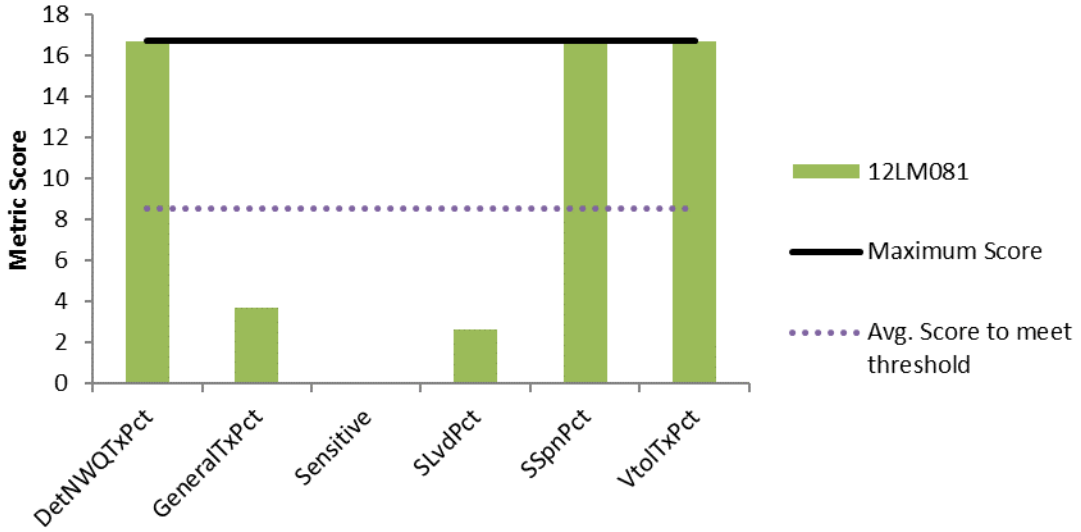

Figure 121. Fish IBI metrics for Unnamed Creek (Fish Class 3; Southern Headwaters).

Dissolved oxygen and eutrophication

Unnamed Creek had four DO measurements taken from 12LM081 (S004-309) from 2012-2015. These values ranged from 8.95-10.49 mg/L. One of these samples was taken before 9 AM. Continuous DO monitoring also took place in 2015. This data showed that the DO levels stayed between 6-7 mg/L during the two-week time period. This indicates that there does not seem to be any issues with DO flux or general DO regime at this time.

Additionally, three phosphorus samples were taken from this reach. The phosphorus levels ranged from 0.048-0.108 mg/L, with one value above the 0.10 mg/L phosphorus standard. If high levels were present, it may indicate problems with eutrophication and dissolved oxygen flux. However, the available data does not indicate flux is an issue. There was no chlorophyll-*a* nor BOD data available to further assess potential eutrophication impacts.

The macroinvertebrate community in Unnamed Creek had a low amount of EPT individuals (16.72%). EPT taxa tend to be intolerant of low DO conditions. However, the macroinvertebrate sample contained many DO intolerant taxa (10), while also having few DO tolerant individuals (3.87%). The DO TIV score at site 12LM081 was above average of the biological sites within the Zumbro River Watershed.

The fish assemblage in this reach consisted of mainly brook sticklebacks (23 of 30 individuals sampled). Brook sticklebacks (Figure 122) are known to be very tolerant of low DO conditions. The fish sample also contained zero late maturing and sensitive species. The DO fish TIV score at site 12LM081 was poor and the second worst score within the watershed.

Figure 122: **Brook Stickleback (Photo Credit: Konrad Schmidt).**

Based on the measured DO values, low DO flux, low phosphorus values, and high scoring macroinvertebrate TIV score, it is likely that the impaired fish community is being impaired by other stressors instead of low DO.

Nitrate

During fish sample at 12LM081, the nitrate concentration was measured at 11 mg/L (June 2012). One additional sample was taken in October of 2014, with a value of 12 mg/L and one in July of 2015, at 11 mg/L. All samples were taken during periods of low flow.

The fish metrics at 12LM081 consist of 0% sensitive fish and 100% tolerant fish. These two metrics can respond in this way (few sensitive, many tolerant) to elevated nitrate. However, macroinvertebrates which are generally more responsive to high nitrate concentrations do not show a response. The community consisted of only 40% nitrate tolerant macroinvertebrates which is relatively low when comparing to similar stream types. The percentage of non-hydropsychid Trichoptera is well above average, at 13%, in addition to 4 Trichoptera taxa (making up 10% of the total community). These Trichoptera are sensitive of elevated nitrate. There were also four generally intolerant macroinvertebrate taxa and one nitrate intolerant taxon, which further demonstrate sensitivity of the community.

Macroinvertebrate metrics related to nitrate stress look reasonable even though the concentrations are high. Nitrate should be reduced and not allowed to increase and cause further stress to aquatic life. While the fish appear to show response to nitrate, given the health of the macroinvertebrates, the alleged response can be attributed to other stress that is more specifically impacting the fish community. Nitrate is not a stressor to the impaired fish community of Unnamed Creek.

Suspended sediment

At the time of biological monitoring a one-time chemistry sample was collected at 12LM081 and the TSS value recorded was 5.6 mg/L. One additional TSS sample was taken in 2015 on July 29, with a result of 42 mg/L.

The macroinvertebrate community, which is not impaired, has metrics that do not suggest elevated TSS is a stressor. The index score, tolerant taxa and percentage, collector filterer and plecoptera, are all better than average and do not signal stress (Table 54). The fish community, which is impaired, shows a response among all metrics. However, its more probable that the metrics a response from another stressor, as the fish community is so degraded. It is not likely that elevated TSS would only impact the fish community and not the macroinvertebrate community. It's more likely that the fish are responding to a stressor which is more specific to their needs/requirements. That does not mean that sediment should not be reduced in this watershed to prevent habitat degradation. Therefore, TSS is not considered a probable stressor to the fish community of Unnamed Creek at this time.

Table 54. Macroinvertebrate metrics relevant to TSS for stations in Unnamed Creek compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
12LM081	14.28	**1.00**	5.00	7.74	58.51	1.24
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***

Habitat

Unnamed Creek had a qualitative habitat assessment take place at site 12LM081 during its fish sampling event in 2012. The resulting MSHA score for this site was 64.65, which is considered to be a fair score (Figure 124). Limiting the habitat at this site was the high presence of sand substrate (Figure 123), light embeddedness, limited substrate variety, sparse fish cover, and moderate channel stability. Outside of the biological monitoring sampling reach, eroded banks were also present.

Figure 123: Sand substrate at site 12LM081.

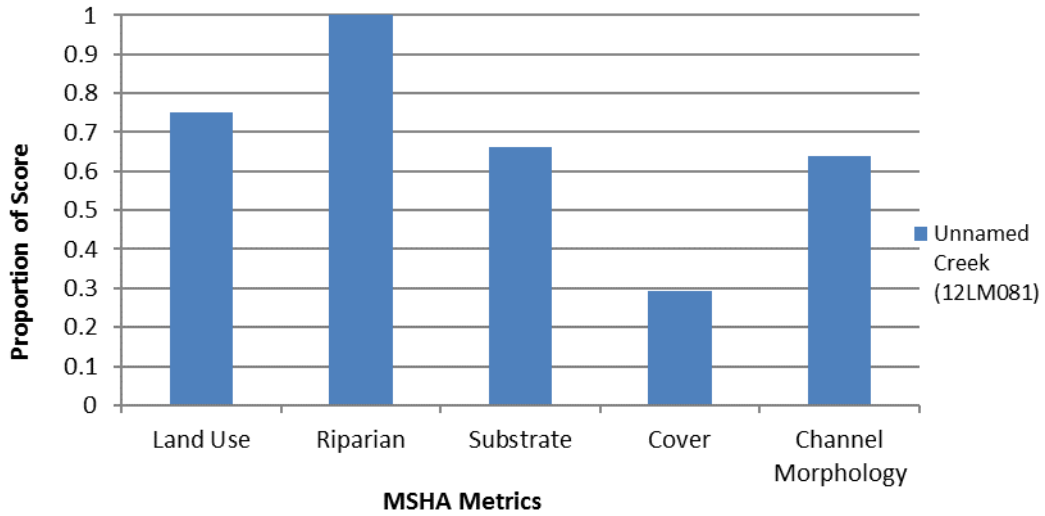

Figure 124: MSHA metric value scores at site 12LM081 along Unnamed Creek (07040004-621).

The macroinvertebrate sample at site 12LM081 along Unnamed Creek (07040004-621) was taken from the woody debris habitat available. The macroinvertebrate community contained few burrower individuals (1.55%), which is expected given the sampling of woody debris. This assemblage also had an increased amount of clinger (56.35%) individuals, which is expected with the amount of woody debris present and sampled. This site did have lower numbers of EPT (16.72%), while also having an increased amount of legless (74.3%) individuals. These results signal that the macroinvertebrate community, while not impaired, is being negatively impacted by the present habitat conditions.

Figure 125: Rock Dam located at site 12LM081.

The fish assemblage along this reach completely lacked any benthic insectivore and darter/sculpin/round-bodied sucker species, while having a decreased amount of simple Lithophilic spawning individuals (6.67%). The community also consisted of 100% tolerant taxa. This assemblage strongly suggests habitat problems in this reach.

Based on the fair MSHA score, photographic evidence, as well as the majority of the habitat related biological metrics (especially the fish community); the lack of habitat is a stressor to the impaired fish community in this reach. The macroinvertebrate assemblage, while not impaired, is also showing signs of being stressed by the current habitat conditions.

Conclusions and recommendations

The fish community of Unnamed Creek (621) is being stressed by poor habitat and connectivity issues (Table 55). A large rock dam at the culvert on County Road 23 (Figure 125) is a complete barrier to fish and limit their ability to migrate upstream. It's not clear what impact that has on reproductive potential of the fish or if they are able to find other suitable locations/habitat elsewhere in this stream. It also may be contributing to some of the sediment transport and instability seen within the reach and be tied to the poor habitat observed. The sampling site has a dominant sand substrate, little depth variability, cover, and was very wide and shallow for a stream of its size. Some eroded banks exist in the reach, but the riparian area is quite good, which contributes to a decent amount of woody debris to the channel and a fair macroinvertebrate IBI score. Without that habitat, it's likely the macroinvertebrates would also be impaired, due to little available habitat variability throughout the reach.

Nitrate, DO and TSS are not considered stressors to the impaired fish community. While the fish appear to show response to nitrate, given the health of the macroinvertebrates, the alleged response is attributed to the poor habitat that is more specifically impacting the fish community. However, nitrate is becoming elevated (~11 mg/L) and should be reduced and not allowed to increase and cause further stress to aquatic life in this watershed.

Table 55. Summary of stressor determinations for Unnamed Creek

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Unnamed Creek (Bear Creek Tributary)	07040004-621	---	---	---	---	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.11.2 Badger Run (620)

Biological and background information

Badger Run (07040007-620) has one biological station, 12LM077, sampled on June 12th, 2012 which led to a fish impairment listing on this reach. This site is a designated fish Class 3 (Southern Headwaters) stream. The FIBI threshold for this class is 55, with an average score per metric of 9.17 needed to achieve that threshold. Figure 126 shows the metrics for 12LM077 compared to 04LM056, which is on an upstream AUID (07040004-619). 12LM077 has an FIBI score of 36 (below impairment threshold) and 04LM056 has an FIBI score of 57 (just above impairment threshold). The fish community at 12LM077 signals stress with 4 out of 6 metrics scoring below the average score needed, and the sensitive fish metric scores zero. The best scoring metric is the relative abundance of individuals that are serial spawning species (SSpnPct), which is similar to 04LM056.

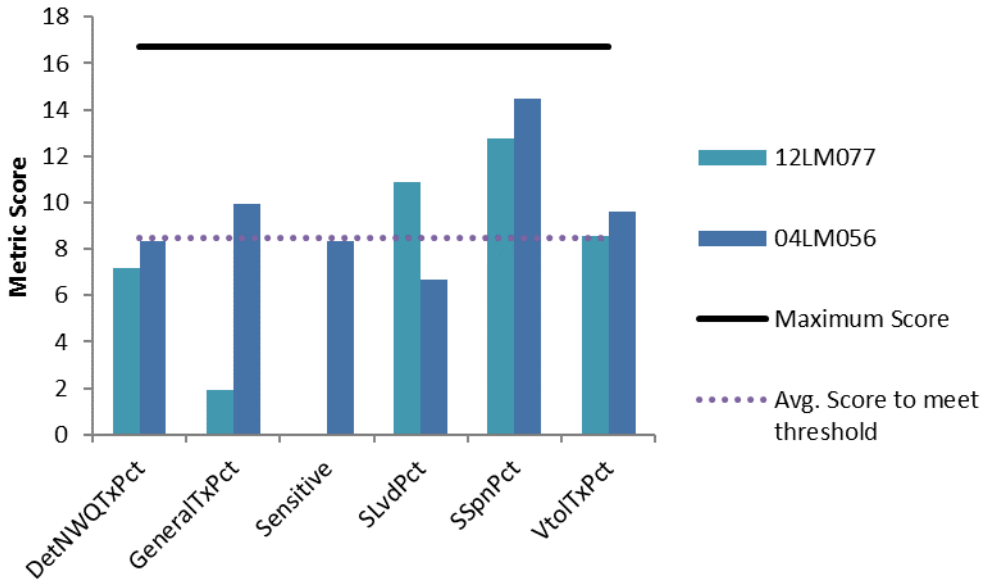

Figure 126. Fish IBI metrics for Badger Creek (Fish Class 3; Southern Headwaters). Station 04LM056 is included for comparison.

Dissolved oxygen and eutrophication

Badger Run had continuous Do monitoring take place in 2014 (Figure 127). As the figure shows, DO levels did not fall below 7 mg/L and had a relatively minimal daily flux that did not exceed 3.5 mg/L. One phosphorus sample was taken on this reach during biological sampling, with a result of 0.093 mg/L. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

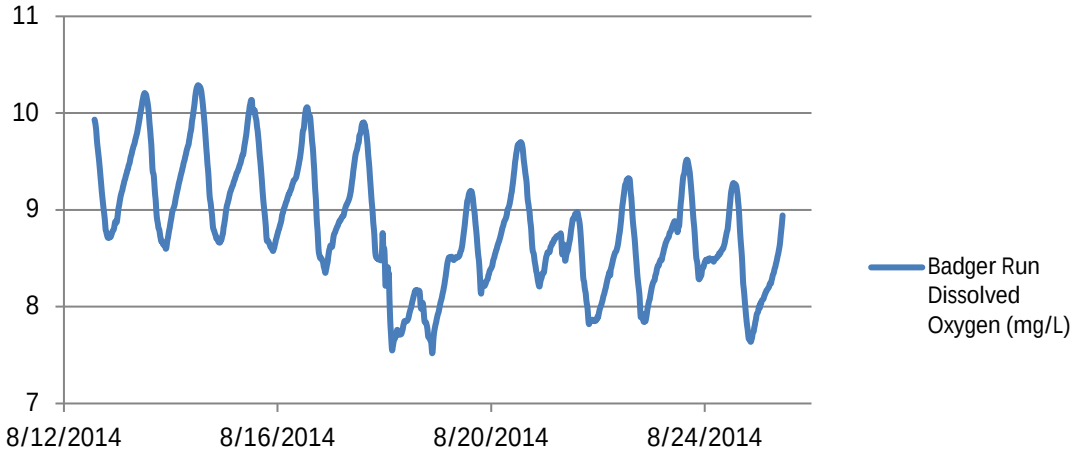

Figure 127. Continuous DO monitoring at site 12LM077 along Badger Run (07040004-620).

Site 12LM077 along Badger Run had a macroinvertebrate assemblage containing a very high number of dissolved oxygen intolerant taxa (11), while also having a decreased amount of DO tolerant individuals (0.65%). The DO TIV score for this community was also much higher than the state average.

The fish community in Badger Run had a decreased amount of late maturing fish species (16.36%), but did have a below average amount of serial spawning individuals (18.18%). Serial spawning fish species are typically found in much higher numbers in streams impacted by low DO conditions. The DO TIV score for the fish community was slightly above average when compared to all other Minnesota streams,

which indicates the fish community is not made up of species typically found in low DO situations. The available data do not provide any indication of a potential for eutrophication related issues.

Based on the observed continuous DO monitoring, as well as the TIV scores and related biological metrics, low DO and eutrophication are not stressors to the impaired fish assemblage in Badger Run at this time.

Nitrate

During fish sample at 12LM077, the nitrate concentration was measured at 6 mg/L (June 2012). Five additional samples were taken in 2014. The nitrate concentration ranged from 5.6 mg/L in September to 9.1 mg/L in June. The average concentration was 6.84 mg/L.

Daily nitrate values were calculated for Badger Creek (AUID 07040004-620) subshed 74 by the HSPF model from 1995-2009. These values ranged from 0.84-16.65 mg/L with an average value of 2.53 mg/L. In addition, less than 1% of the values were above 10 mg/L.

There is a lack of sensitive fish species (0%) and higher percentage of tolerant fish species (60%) which also can be consistent with nitrate stress. However, these metrics often respond to other stress as well. Macroinvertebrates which are generally more responsive to high nitrate concentrations do not show a response. The community consisted of 60% nitrate tolerant macroinvertebrates which is just below the average for this stream class. The percentage of non-hydropsychid Trichoptera is above average at 8%, in addition to 6 Trichoptera taxa, both above average for this stream class. Trichoptera and non-hydropsychid Trichoptera often disappear as nitrate concentrations increase.

Macroinvertebrate metrics related to nitrate stress look reasonable even though the concentrations are moderate. While the fish appear to show response to nitrate, given the health of the macroinvertebrates, the alleged response can be attributed to other stress that is more specifically impacting the fish community. Nitrate is not a stressor to Badger Run.

Suspended sediment

During biological monitoring in 2012 at site 12LM077 TSS concentration was 19 mg/L. In 2014, there were 5 TSS samples taken from May through September. Two of the five samples were greater than 60 mg/L (TSS standard); both taken during a June storm event. The maximum concentration was 190 mg/L from 6/18/14. Then later on 6/24/14, the concentration was 66 mg/L. The samples from May, July, and September were 21 mg/L, 37 mg/L and 4 mg/L, respectively.

Daily TSS values were calculated for Badger Creek (AUID 07040004-620) subshed 74 by the HSPF model from 1995-2009. These values ranged from 1.08-906.72 mg/L with an average value of 13.95 mg/L. About 4% of the values were above 65 mg/L.

The macroinvertebrate metrics show a mixed response to TSS. The index score, tolerant taxa and percentage, are all just above normal for 12LM077 (Table 56). Overall, this doesn't provide a strong indication regarding the macroinvertebrate response to TSS. Fish metrics that often respond to TSS do show a consistent response, with 8 of the 10 metrics signaling potential stress (Table 56). The response between the two communities doesn't seem consistent enough to be confident the response is due to TSS and not some other stressor. Often time's macroinvertebrates will show impacts from TSS, which is not evident here. A more probable cause of fish impairment in this reach is something making a more direct impact on the fish community only. In addition, the limited chemical dataset makes confirming TSS a stressor difficult at this time. TSS is inconclusive as a stressor to the fish community of Badger Creek. Additional chemical data on TSS would be useful in understanding sediment dynamics in this reach.

Table 56. Fish metrics relevant to TSS stress for Badger Run compared to statewide averages for Southern Headwaters streams meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	BenFdFrimPct	Centr-TolPct	HerbvPct	Percfm-TolPct	RifflePct	SensitivePct	SLithopPct	Intolerant Pct	Longlived Pct	TSS Index Score (RA)
12LM077	56.36	**0.00**	**0.00**	40.00	**16.36**	**0.00**	**18.18**	**0.00**	**0.00**	**16.3**
Statewide average for Southern Headwaters that are meeting the FIBI Threshold (51)	**34.47**	**1.18**	**12.27**	**13.13**	**25.44**	**6.82**	**31.25**	**1.04**	**4.25**	**15.09**
Expected response to TSS stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Table 57. Macroinvertebrate metrics relevant to TSS for stations in Badger Run compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
12LM077	**16.84**	**0.00**	10.00	**35.50**	50.31	0.63
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***

Habitat

Badger Run (07040004-620) had qualitative habitat assessments take place at sites 12LM077 and 04LM056 during their respective fish sampling events in 2012 and 2004. The MSHA scores for these sites were 47.5 (Fair) at site 12LM077 and 57.15 (Fair) at site 04LM056 (Figure 129). Limiting the MSHA at 12LM077 was the sand substrate (Figure 128), the lack of coarse substrates and riffles, fair sinuosity, poor channel development, and moderate channel stability. At site 04LM056, the habitat was limited due to the poor surrounding land use, eroded banks, moderate embeddedness and channel stability, sand substrates and restricted depth variability.

Figure 128. Sand substrate at site 12LM077

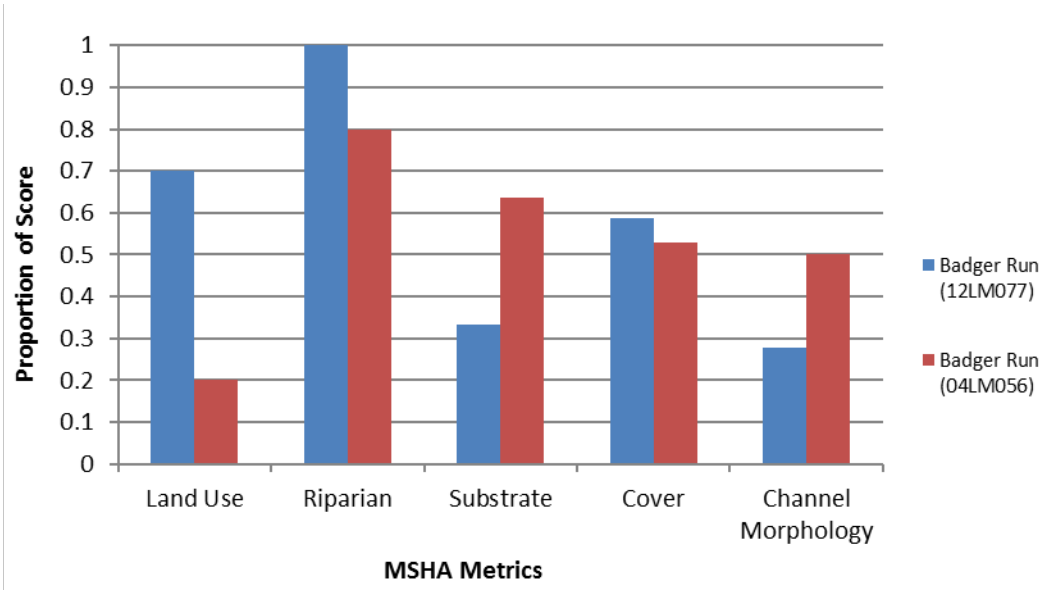

Figure 129: MSHA metric value scores at sites 12LM077 and 04LM056 along Badger Run (07040004-620).

The macroinvertebrate sample along Badger Run was taken from overhanging vegetation and woody debris. This sample showed that the macroinvertebrate community had a decreased amount of burrower (4.69%) and had an above average amount of clinger (52.81%) individuals. These are often signs of good habitat, but it is not surprising given woody debris were the primary habitat sampled. However, site 12LM077 also had decreased numbers of both climber (18.44%) and sprawler (12.81%) individuals, while also having many legless individuals (50.31%). These results can indicate stress from the habitat conditions, even though the macroinvertebrates are not impaired at this site.

The fish assemblage along Badger Run had increased amounts of benthic insectivore (40%) and darter/sculpin/round-bodied sucker (40%) individuals, but also had increased numbers of pioneer species (67.27%) and tolerant (60%) individuals. Pioneer species are able to thrive in unstable conditions and are frequently the first to invade after disturbance. Site 12LM077 also had fewer numbers of riffle dwelling (16.36%) and simple lithophilic spawning (18.18%) individuals. These fish species are limited by the absence of riffle habitat and coarse substrates.

The Minnesota MNDNR did an extensive geomorphologic assessment along Badger Run at site 12LM077. This work concluded that the reach is classified as an E stream type with a sand bed. Compared to a reference E channel, Badger Creek is much more entrenched and has a higher width to depth ration. This stream also had a poor Pfankuch stability rating and was largely influenced by scouring and deposition.

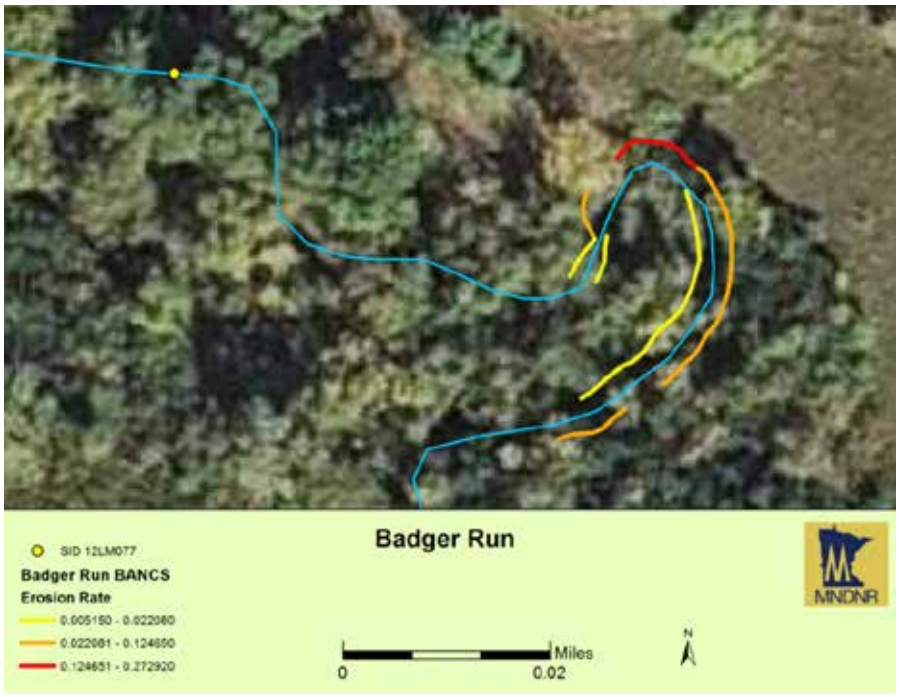

Figure 130. Erosion rates of Badger Run near site 12LM077.

A total of 10 banks were observed in this 270 ft. reach. Exposed banks were seen on both sides of the channel (Figure 130). An average of 0.10 tons/yr/ft of sediment was estimated to be eroding from the banks, estimates were as high as 0.28 tons/yr/ft.

This reach is in the beginning stages of stream succession and is predicted to move towards instability based on the comparison to a reference E. E stream types are very efficient at transporting sediment. Eroding banks on both sides of the stream combined with entrenchment and width to depth ratios indicate a succession to a C channel. Channel instability is increased by moderate to heavy amounts of trees and branches within in the stream causing debris jams and scouring. The stream is predicted to widen, lose power and accumulate sediment.

The overall effect of instability and sediment accumulation has led to embedded riffles and pool filing, resulting in the loss of habitat and lowering of habitat quality. Systemic implementation would need to be addressed in this instance to aid in the stability of this reach. Although issues upstream are the main cause of instability, the crossing just downstream may be a local stressor. The crossing is an over-wide box culvert with three openings. The over wide crossing could have caused the stream to over widen. The result was a loss of stream power and decrease in sediment capacity leading to deposition near the crossing. Two of the culverts have now been partly filled (Figure 131); possibly improving the crossing by acting as floodplain culverts and improving power and capacity.

Based on the fair MSHA scores, the majority of the habitat related biological metrics, the photographic evidence depicting poor habitat conditions and the geomorphology assessment from the MNDNR, the lack of habitat is a stressor to the impaired fish community in Badger Run.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that Badger Run (07040004-620) was 51.2% modified. Many small tributaries upstream and in the headwaters of Badger Run are all or partially channelized. As noted in the habitat section, the MNDNR identified high erosion rates along this section of Badger Run. Additionally, the road crossing immediately downstream of site 12LM077 has an over-wide box culvert. This culvert has three openings with two of them filled with deposited sediment. This site is also in a highly expanding urban area in the City of Rochester, which results in flashy stormwater runoff leading to overall stream instability.

Figure 131. Culverts that have been partially filled with sediment at Site 12LM077 along Badger Run.

Based on the high degree of channelization present on the impaired reach in the upstream portions of Badger Run, the high erosion rates and the geomorphic findings of the MNDNR, flow alteration is a stressor to the impaired fish community along Badger Run. The flow alteration issues also play into the habitat stress which is currently observed in the fish community.

Conclusions and recommendations

The fish community of Badger Run (620) is being stressed by poor habitat and flow alteration (Table 55). The sand substrate and absence of both good riffle habitat and coarse substrate lead to a fish community that has a high percentage of pioneer fish species and a lack of riffle dwelling and simple lithophilic spawning species. MNDNR has also documented instability in this reach. The overall effect of instability and sediment accumulation has led to embedded riffles and pool filling, resulting in the loss of habitat quality. Systemic implementation would need to be addressed in this instance to aid in the stability of this reach. Although issues upstream are the main cause of instability, the culvert crossing just downstream of 12LM077 may also be a local stressor. Resulting in a loss of stream power and decrease in sediment transport capacity leading to deposition near the crossing. Additionally, this watershed is in a highly expanding urban area in the City of Rochester, which may have resulted in some of the channelization observed and flashy stormwater runoff leading to overall stream instability.

TSS is considered inconclusive as a stressor. A lack of connecting chemical information and a mixed response between the fish and macroinvertebrates, make it difficult to determine if TSS is truly impacting the biology, or if the response is due to a stressor specific to the fish community (habitat). Additional chemical information would be helpful in determining the magnitude and duration of TSS concentrations in this reach.

Nitrate and DO are not considered stressors to the impaired fish community. While nitrate concentrations are moderate, they do not appear to be reaching levels to be impacting the macroinvertebrate community, which typically are the first to respond to increased nitrate

concentrations. DO levels are also sufficient in this reach. Biologically, the majority of the fish present aren't typically found in low DO streams.

Table 58. Summary of stressor determinations for Badger Run

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Badger Run	07040004-620	---	---	---	o	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.12 Willow Creek Watershed

Willow Creek is a warmwater stream in Olmsted County and flows to the South Fork Zumbro. The subwatershed of Willow Creek that was considered impaired drains a total of 3,187 acres while the entire Willow Creek Watershed drains close to 15,000 acres, 51% of which is in agricultural use and 22% is developed. Section 4.11 will discuss one stream with biological impairment (fish and macroinvertebrates) in this watershed (Figure 132).

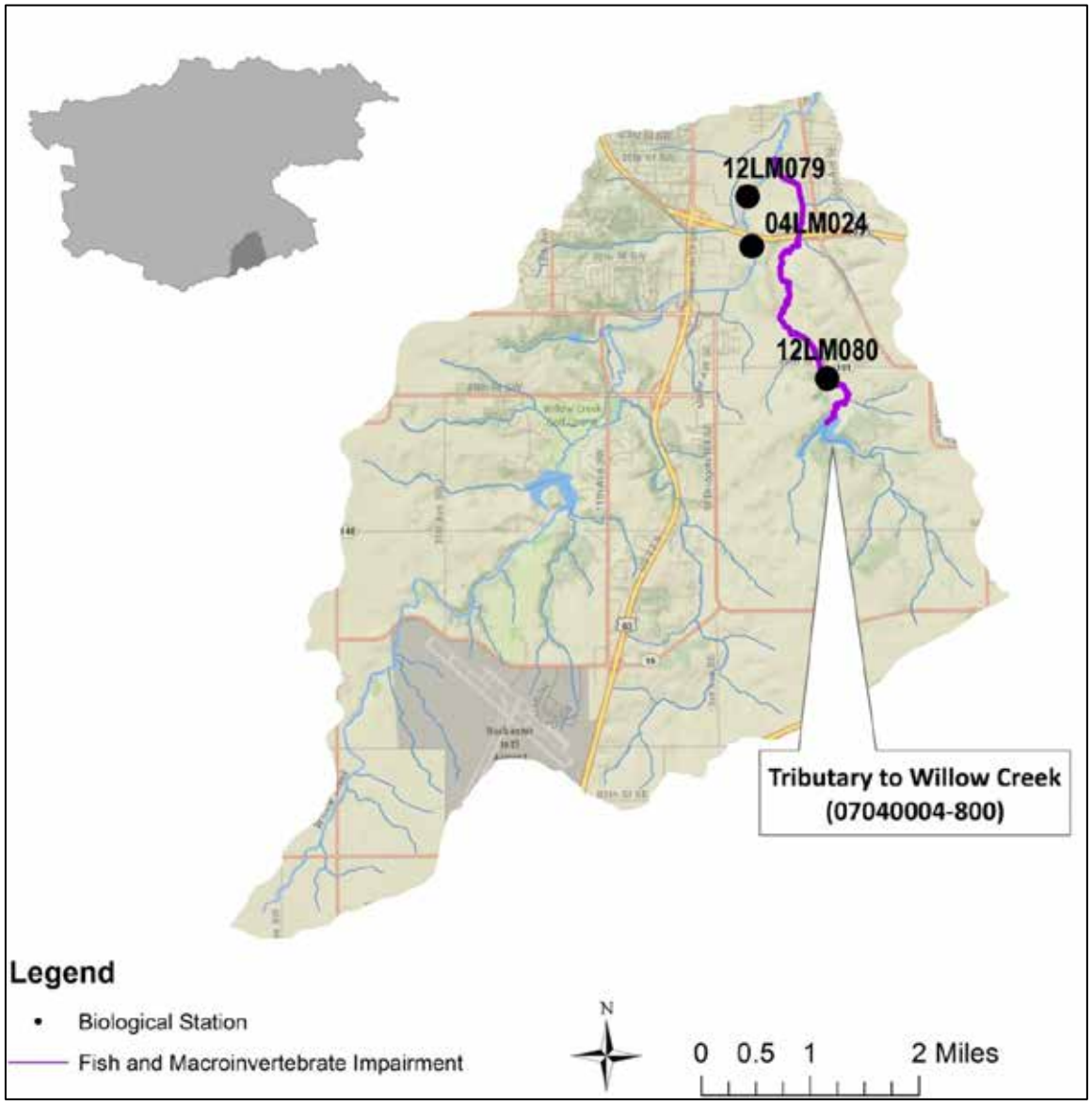

Figure 132. Map of the Willow Creek Watershed, biological stations, and impaired AUIDs.

4.12.1 Unnamed Creek (800)

Biological and background information

Willow Creek Tributary (07040004-800) has one biological station, 12LM080, sampled on June 12th, 2012 and led to a fish impairment on this reach. This is a designated fish Class 3 (Southern Headwaters) stream. The FIBI impairment threshold for this class is 55, with an average score per metric of 8.5 needed to achieve that threshold. Site 12LM080 has an FIBI score of 0 and had a low sample size because only 22 fish were captured. The most abundant fish captured was johnny darter (18), followed by blacknose dace (4). One out of six metrics score below the average needed; (Sensitive) scored a zero. Unusually, the 3 metrics that scored above the average needed all received the maximum score of 16.7, but this is likely due to the low sample size which skews the calculations. The fish community metrics that scored well were: detritivores taxa (DetNWQTxPct), individuals that are serial spawning species (SSpnPct) and taxa that are very tolerant species (VtolTxPct).

Willow Creek Tributary also has one macroinvertebrate sample collected at site 12LM080 on July 31, 2012. This site is designated macroinvertebrate Class 5 (southern streams RR). The MIBI threshold for this class is 37, with an average score per metric of 3.7 needed to achieve that level. 12LM080 has an MIBI score of 21.76 and scored below average on 7 out of 10 metrics, receiving a score of zero for 3 metrics. The three metrics that scored zeros are the taxa richness of climbers (ClimberCh), taxa richness of Odonata (Odonata) and taxa richness of Plecoptera (Plecoptera).

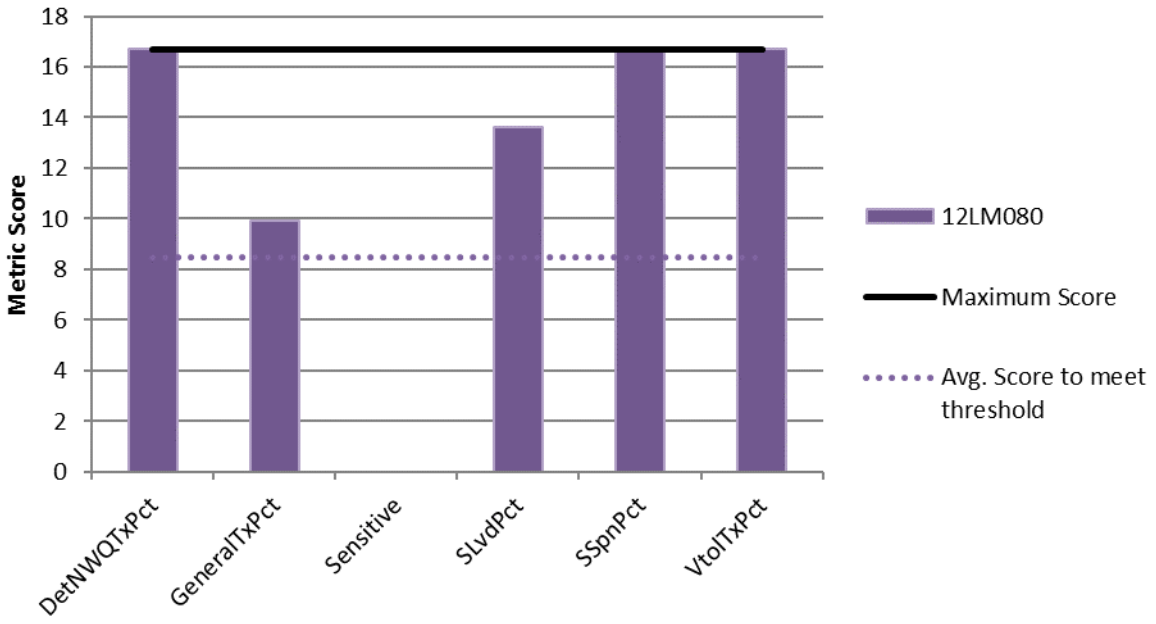

Figure 133. Fish IBI metrics for Unnamed Creek (Fish Class 3; Southern Headwaters).

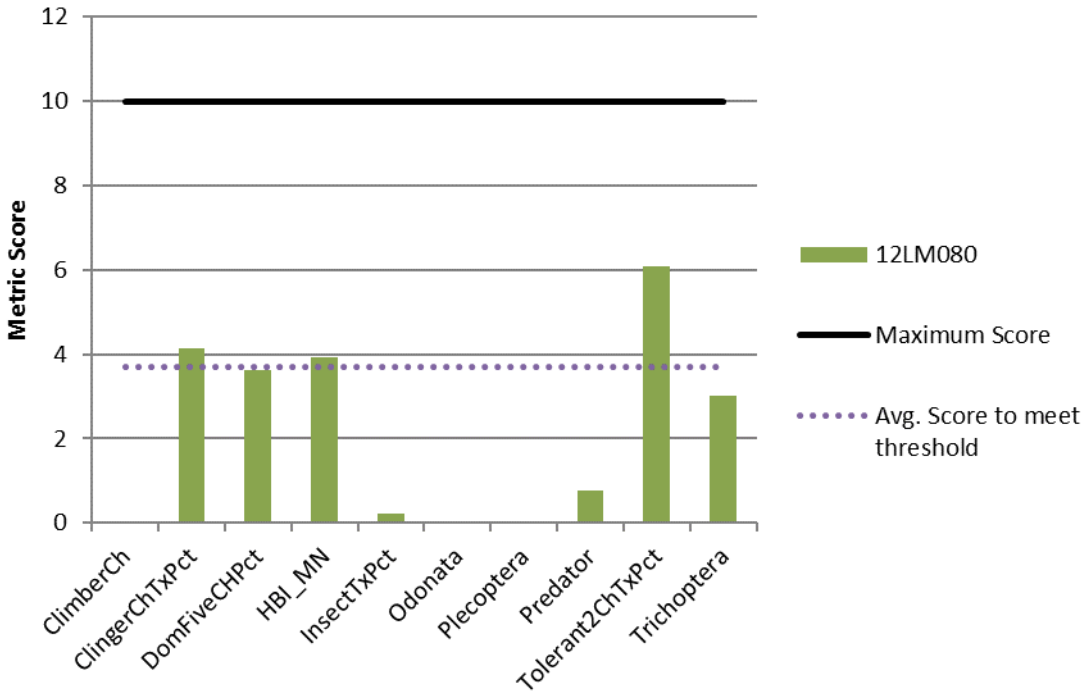

Figure 134. Macroinvertebrate IBI metrics for Unnamed Creek (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

In 2015, continuous monitoring along Willow Creek took place. This data showed that the DO levels rarely dropped below 6 mg/L and never below the daily minimum standard of 5 mg/L. The DO flux never exceeded 1 mg/L, which is below the 3.5 mg/L standard for daily DO flux.

Additionally, three phosphorus samples were collected from site 12LM080 from 2012-2015. These values ranged from 0.061 to 0.167 mg/L, with one value above the phosphorus standard of 0.10 mg/L. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

A likely source for the high phosphorus levels in Willow Creek is the Willow Creek reservoir (Gamehaven Lake), which is located upstream of the Willow Creek sampling location. Willow Creek reservoir is considered a eutrophic reservoir as demonstrated by TSI (trophic status index) work was done by Olmsted County in 2011. Willow Creek reservoir is "surrounded by several potential nutrient sources: dense residential housing, golf course, industrial facilities and agricultural fields. This reservoir has some large patches of dense aquatic vegetation that show up on the TSI Map as hypereutrophic."

Biologically, the macroinvertebrate community had many DO intolerant taxa (11), with seven species considered very intolerant. This reach also did not have any DO tolerant individuals or species. The DO TIV score for the macroinvertebrate assemblage was also above average when compared to all other Class 5 streams. These results all strongly signal that dissolved oxygen is not stressing the macroinvertebrate community.

The fish assemblage at site 12LM080 along Willow Creek only consisted of 22 individual fish. This community consisted of 18 johnny darter and five blacknose dace species (Figure 135)**.** These species are generally present in streams not experiencing DO issues. The low fish count may be a result of the fluctuating water levels in Willow Creek due to the reservoir or another undetermined cause.

Based on the continuous dissolved oxygen monitoring as well as the high amount of DO intolerant macroinvertebrate species, in addition to the complete absence of DO tolerant species; DO and eutrophication are not stressors in Willow Creek at this time. The fish and macroinvertebrate communities are likely being negatively impacted by other stressors. The highly eutrophic condition of the Willow Creek reservoir may eventually lead to DO flux issues and is worth additional monitoring moving forward, but do not seem to be causing issues at this time.

Figure 135. Photos of Johnny Darter (left) and Blacknose Dace (right).

Nitrate

During the fish sample, the nitrate concentration at 12LM080 was 1.8 mg/L (July 12, 2012). There was one additional nitrate sample taken in May of 2014, with a result of 2.5 mg/L. In 2015, four additional nitrate samples were taken (one each in May, June, July and August) which had results that ranged from 1.4 mg/L -3.5 mg/L.

The one macroinvertebrate sample taken at station 12LM080 had only 56.68% nitrate tolerant species collected, which is less than most sites in the watershed of this stream class. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At this station, taxa richness was below average, only 26. Trichoptera, which are sensitive to elevated nitrate concentrations were found above average with 5 trichoptera taxa, comprising 19.2% of the community. There was also one generally intolerant taxon. There were no nitrate intolerant taxa at station 12LM080. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These trichoptera include all caddisflies that do not spin nets. The percentage at this station was 1.8%, while the average for sites in the LMB is 3.39%.

The macroinvertebrates show a mixed response, but given the low concentrations and lack of nitrate tolerant species, in addition to the good Trichoptera abundance, nitrate is not considered a stressor at this time. There is a lack of sensitive fish species (0%) but a less than average percentage of tolerant fish species (18%). However, there was a small sample size for fish which may skew the overall percentages related to the fish community.

Suspended sediment

At the time of biological monitoring a sample was collected at 12LM080 and the TSS was 13 mg/L. One additional sample was taken in 2015 on July 29, with a result of 34 mg/L.

The macroinvertebrate metrics show very little response to TSS. The number of TSS intolerant taxa, collector filterer percent and plecoptera percent are not within expected ranges but could be a result of other stressors. (Table 59). Fish metrics that often respond to TSS do show a consistent response to elevated TSS, with 7 of the 10 metrics below average (Table 59). However, the TSS index scores for both fish and macroinvertebrates are much below average, indicating that overall both communities aren't dominated by taxa tolerant to TSS. It's likely that the metrics are responding to other stress. The lack of consistent response makes TSS an unlikely stressor to Unnamed Creek even despite the limited chemical data. TSS is not a stressor at this time, but additional chemical information would help in understanding any sediment dynamics in Unnamed Creek.

Table 59. Fish metrics relevant to TSS for Unnamed Creek compared to statewide Southern Headwaters averages. Bold and highlighted equals the metric score is higher or lower than average depending on expected response with increased stress.

Station	BenFdFrimPct	Centr-TolPct	HerbvPct	Percfm-TolPct	RiffIePct	SensitivePct	SLithopPct	Intolerant Pct	Longlived Pct	TSS Index Score (RA)
12LM080	81.82	**0.00**	**0.00**	81.82	**0.00**	**0.00**	**18.18**	**0.00**	**0.00**	11.4
Statewide average for Southern Headwaters that are meeting the FIBI Threshold (51)	**34.47**	**1.18**	**12.27**	**13.13**	**25.44**	**6.82**	**31.25**	**1.04**	**4.25**	**15.09**
Expected response to TSS stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Table 60. Macroinvertebrate metrics relevant to TSS for stations in Unnamed Creek compared to statewide averages for southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM080	14.60	**1.00**	4.00	27.71	25.3	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Unnamed Creek (07040004-800) had a qualitative habitat assessment take place at site 12LM080 during the fish sampling event in 2012. The MSHA score for this site was 58.9 (Figure 137), which is considered to be fair. Limiting the MSHA at 12LM080 was the moderate bank erosion (Figure 136), sand/silt substrates (Figure 136), sparse fish cover, and limited depth variability.

Figure 136. Silt and sand substrate (left) and bank erosion (right) at 12LM080.

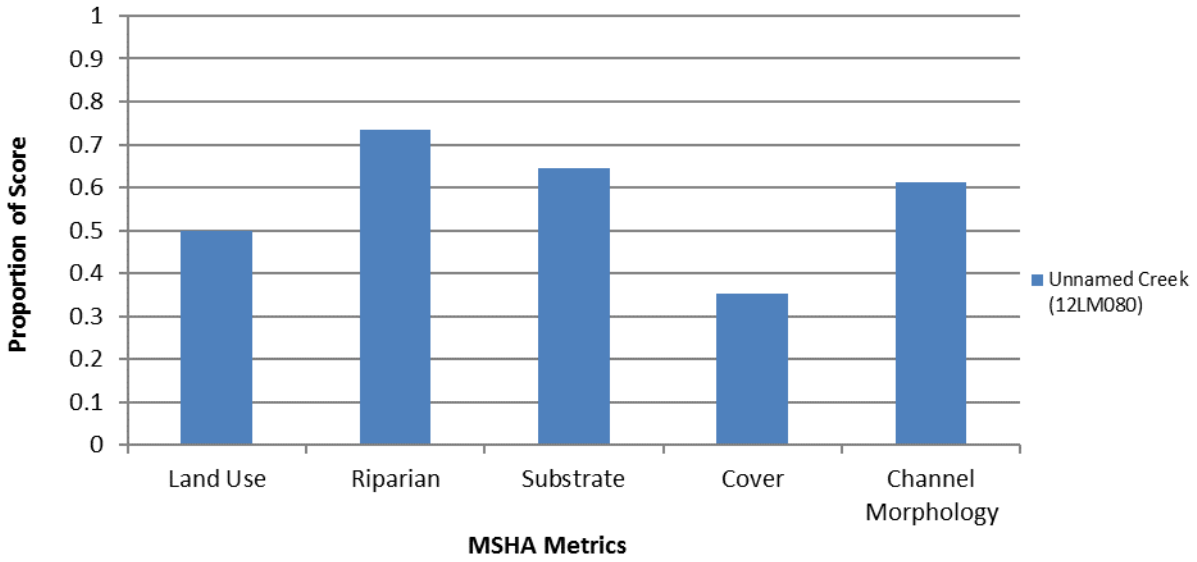

Figure 137: MSHA metric value scores at site 12LM080 along Unnamed Creek (07040004-800).

The macroinvertebrate sample along Unnamed Creek was taken from equal parts of woody debris and riffle habitats. This sample showed that the macroinvertebrate community had below average numbers of climber individuals (9.23%) despite half of the sample coming from preferred habitat for climbers, woody debris. Site 12LM080 also had a lower amount of burrower (5.54%) and legless (20.31%) individuals. However, there were a very high percentage of sprawlers (38%) comparatively. Sprawlers are macroinvertebrates which sprawl on top of fine sediments and correlate to poor substrate conditions in streams.

The fish community in Unnamed Creek was very sparse. With only 22 fish sampled, consisting of just two different species, it is difficult to properly assess the community. The overall lack of species and diversity is rather telling that conditions are not favorable for a thriving fish community.

To better evaluate the habitat conditions along this reach, stressor identification staff walked a portion of Unnamed Creek upstream of site 12LM080 and downstream of the Willow Creek reservoir. This stream section was found to be dominated by sand substrates with numerous eroded banks. Very few riffles and depth variability existed along this stretch. Sparse woody debris and overhanging vegetation were present to provide ample cover for a diverse biological assemblage. The high presence of fine substrates, completely embedded gravel and overall limited habitat conditions may be attributed to the unnatural flow conditions released from the reservoir. As a result of the flow conditions, it's possible the stream is not able to move sediment in a natural way that it's supposed to.

Based on the fair MSHA score, the lack of diversity in the fish and macroinvertebrate assemblages, in addition to the observed poor habitat conditions directly upstream of the sampling station; the lack of habitat is indeed a stressor to Unnamed Creek.

Flow alteration and connectivity

The condition of Unnamed Creek (07040004-800) is rather unique to the Zumbro River Watershed. The Altered Watercourses GIS layer for Minnesota streams indicated that Unnamed Creek was 49.74% modified. Channelized portions of streams may have led to some of the eroded banks mentioned in the habitat section.

Gamehaven Lake, located immediately upstream of the impaired reach, is a controlled reservoir that limits the natural flow regime of Unnamed Creek. The output of Gamehaven Lake seems to vary on an

annual basis dependent on the amount of precipitation. These outputs can have a large impact on the base flow of Unnamed Creek.

A couple observations of Unnamed Creek historically and more recent have also been made. Surber (1924) noted that Willow Creek, "during the latter part of the summer it becomes dry near its headwaters and only a feeble stream flowing from pool to pool in its lower course." Also, anecdotally, a landowner approximately 1 mile downstream of 12LM080 says the stream has dried up and seems to be more frequent in recent years. He said in 2013, which was a wetter year overall, the stream was dried up for two months.

Additionally, approximately one mile downstream of site 12LM080, a culvert (Figure 138) was noted as perched in May 2014. Perched culverts are a significant barrier to fish migration. Also, a culvert perched in May, when water levels tend to be higher, can often signal that the culvert likely becomes perched every year in the late summer and early fall when the water levels tend to be much lower.

Figure 138. Photo of perched culvert crossing approximately 1 mile downstream of 12LM080. MPCA photo, taken May 30, 2014.

The geology of the area may also explain the streams flow patterns. The confining layer which provides horizontal movement of water (Decorah Shale; see few mapped springs in the area) gives way to the conductive layer moving downstream in the watershed (St. Peter Sandstone and Shakopee formations) where water is able to move vertically. The St. Peter sandstone formation has a very high infiltration rate for groundwater recharge and therefore probable the stream is losing flow in those locations before it reaches Willow Creek.

Based on the overwhelming evidence of channelization, a perched culvert, eroded banks, a dam, as well as local observations; flow alteration and connectivity are stressors to Unnamed Creek.

Conclusions and recommendations

The impaired fish and macroinvertebrate community of Unnamed Creek (800) is being stressed by poor habitat conditions and flow alteration/connectivity issues (Table 61). The habitat conditions at the biological station were not favorable for a thriving macroinvertebrate community as they were dominated by sand substrates and eroding banks. There were few riffles, with little depth variability, which may be partially due to the unnatural flow regulation from Gamehaven reservoir. In addition, a perched culvert and evidence of the stream drying up are also contributing to the connectivity issues seen and may prevent fish from migrating upstream to 12LM080.

Gamehaven reservoir is considered a eutrophic reservoir, and the DO levels at biological sampling station at 12LM080 shows good oxygen dynamics, and a macroinvertebrate community that is intolerant of low DO levels. The fish community had few species overall, but those that were present are typically not present in streams with DO issues. The highly eutrophic condition of the reservoir may eventually lead to DO issues and is worth additional monitoring moving forward, even though the stream does not appear to be stressed at this time.

Both nitrate and TSS have been ruled out as potential stressors. Nitrate concentrations are low in this watershed and biologically, there was little indication that nitrate is a stressor. Similarly, the biological metrics related to TSS do not strongly support TSS as a stressor, even though chemical information was limited.

Table 61. Summary of stressor determinations for Unnamed Creek

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Unnamed Creek (Willow Tributary)	07040004-800	---	---	---	---	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.13 Cascade Creek Watershed

The Cascade Creek Watershed is a warmwater stream in Olmsted County and flows to the South Fork Zumbro. This subwatershed drains a total of 24,326 acres, 64% of which is in agricultural use and 17% is developed. Section 4.12 will discuss two streams with biological impairments in the Cascade Creek Watershed (Figure 139). The upstream AUID is impaired for fish (07040004-991) and the downstream AUID is impaired for macroinvertebrates (07040004-581).

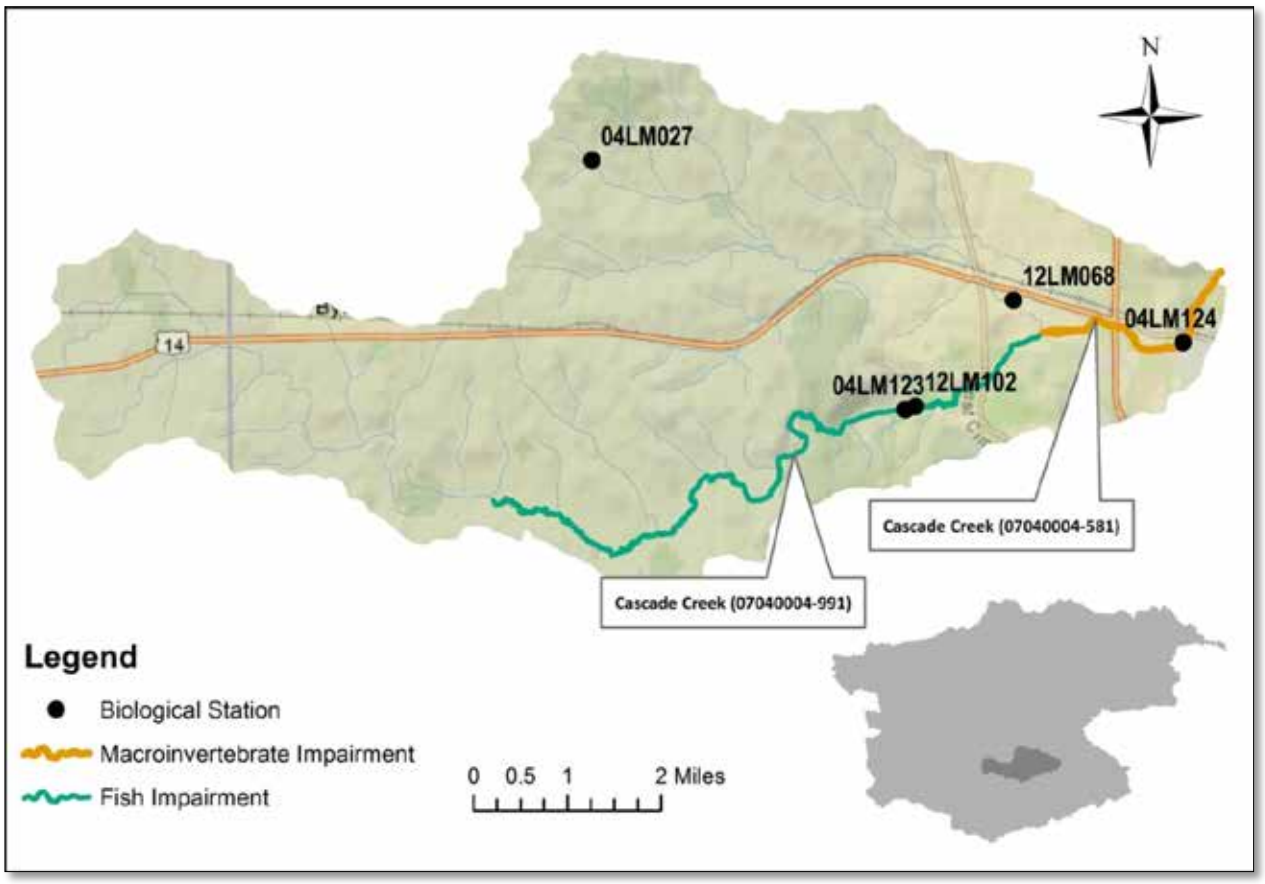

Figure 139. Map of the Cascade Creek Watershed, biological stations, and impaired AUIDs.

4.13.1 Cascade Creek (581)

Biological and background information

Cascade Creek (07040004-581) has one biological station, 04LM124, sampled in 2004, which led to a macroinvertebrate impairment on this reach. This site is designated macroinvertebrate Class 5 (Southern Streams RR). The MIBI impairment threshold for this class is 37, with an average score of 3.7 per metric needed to achieve that threshold (Figure 140). Station 04LM124 has an MIBI score of 34.36 and scores below the average for 7 out of 10 metrics. The three metrics that did score well were ClimberCh, DomFiveCHPct, and Odonata. Plecoptera taxa scored a zero at this site which is similar to many others in the Zumbro Watershed, meaning plecoptera (Stoneflies) were absent from the sample.

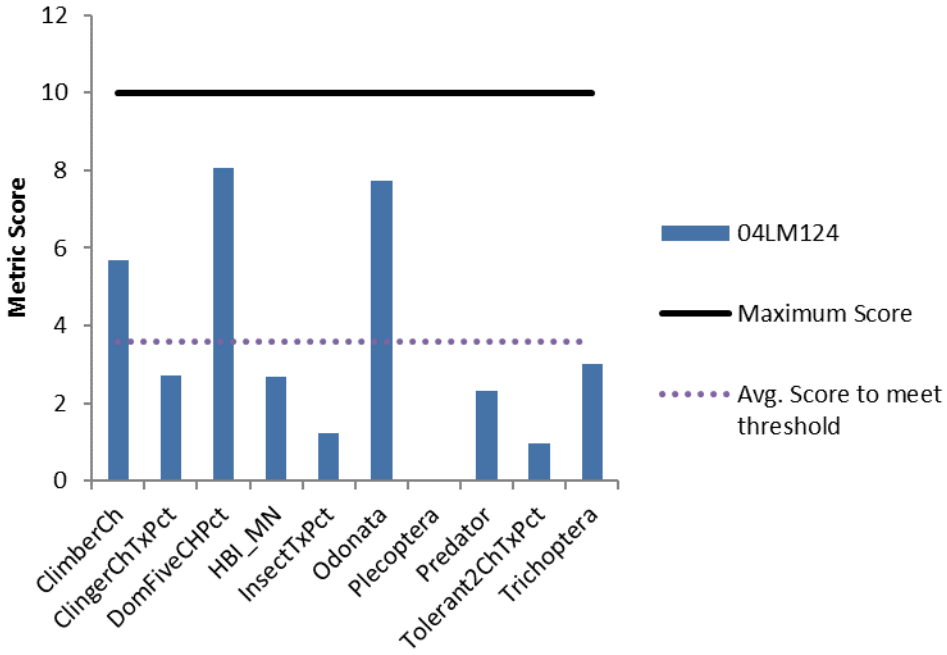

Figure 140. Macroinvertebrate IBI metrics for Cascade Creek (Class 5; Southern Streams Riffle/Run).

Dissolved oxygen and eutrophication

Cascade Creek (07040004-581) had a total of eight DO measurements taken from 2004-2014. These values ranged from 7.23-9.84 mg/L, with no values falling below the minimum standard for DO. There was also a continuous sonde at the site in 2014, which showed DO values were above 6 mg/L for the entire duration (August 12, 2014-August 25 2014). The daily DO flux was around 3.5 mg/L.

Additionally, 40 phosphorus samples were taken from Cascade Creek during the same time period. These values ranged from 0.018-.494 mg/L with 26 measurements above the 0.10 mg/L phosphorus standard. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

The macroinvertebrate community contained an increased amount of DO tolerant taxa (7) and DO tolerant individuals (12.02%) when compared to Class 5 sites. Site 04LM124 also had a below average Class 5 DO TIV score.

The fish assemblage along this reach of Cascade Creek had an increased amount of late maturing individuals (54.55%); however, site 04LM124 also had an above average amount of serial spawning individuals (27.27%). Serial spawning fish are much more common in streams with low DO conditions. This reach did have above average DO TIV scores for Class 2 streams.

The DO levels along Cascade Creek do not drop below 5 mg/L. The phosphorus levels along this reach frequently violated the phosphorus standard. The biological communities have fairly mixed results, making it difficult to conclude if DO and eutrophication are stressors in this reach or not. Therefore, DO and eutrophication are inconclusive as stressors. Continuous DO monitoring with a sonde is recommended to better determine if DO levels are negatively impacting the fish and/or macroinvertebrate assemblages.

Nitrate

During fish sample, the nitrate concentration was measured at 2 mg/L (June of 2004). There were 37 additional nitrate samples taken on this stream reach from 2007-2014. The average concentration of the samples collected was 2.3 mg/L, with the maximum of 5.7 mg/L, collected in June of 2014.

Daily nitrate values were calculated for Cascade Creek (AUID 07040004-581) subsheds 63, 64, 65 and 65 by the HSPF model from 1995-2009. The values ranged from 0.76-18.13 mg/L with an average value of 3.29 mg/L. In addition, 1.1% of the values were above 10 mg/L.

The one macroinvertebrate sample taken at station 04LM124 had 71.7% nitrate tolerant species collected. At 83.78%, there is only a 10% probability of meeting the MIBI threshold. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At this station, taxa richness was average, at 37. There were a decent number of Trichoptera taxa overall (5) and one generally intolerant taxon. There were no nitrate intolerant taxa at station 04LM124. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These trichoptera include all caddisflies that do not spin nets. The percentage at this station was 0.9%, while the average for sites in the LMB is 3.39%.

There is some macroinvertebrate response, but overall the concentrations are moderate and biological response is not strong. The response could be attributed to other stressors. There is a lack of connecting information; therefore, nitrate is not considered a stressor to this reach of Cascade Creek.

Suspended sediment

At the time of biological monitoring, a one-time chemistry sample was collected at 04LM124 and the TSS value recorded was 7.6 mg/L. Additionally, 38 TSS values were recorded from 2007 to 2014. The TSS values range from 5.6-300 mg/L with an average value of 58.88 mg/L. Of the 38 TSS values, 12 were above the 65 mg/L TSS standard for designated warm water streams. However, many of the samples were taken during turbidity TMDL monitoring in 2007 and 2008, which were biased towards storm event sampling.

Daily TSS values were calculated for Cascade Creek (AUID 07040004-581) subsheds 63, 64, 65 and 66 by the HSPF model from 1995-2009. These values ranged from 1.39-1075.5 mg/L with an average value of 18.3 mg/L. Overall, 5.4% of the values were above 65 mg/L, the standard for warmwater streams in the southern region.

In Cascade Creek, the macroinvertebrate metrics signal TSS stress (Table 62). There is consistent response seen with the elevated TSS index score, the lack of TSS intolerant taxa, the higher than average taxa percentage of TSS tolerant taxa and the lack of plecoptera. Collector filterers were just above average, but this metric can actually increase downstream of lakes/reservoirs due to the increase in opportunities for food for filter feeding organisms. Cascade Lake may be a source of food for collector filterers in this reach. The fish community, while not impaired, responds with only 1 of the 10 metrics signaling TSS stress; therefore, TSS is not likely impacting the fish community. It's possible that the fish have the option to migrate to the South Fork given its close proximity. TSS is a stressor to the macroinvertebrate community in Cascade Creek.

Table 62. Macroinvertebrate metrics relevant to TSS for stations in Cascade Creek compared to statewide averages for southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
04LM124	**18.54**	**0.00**	**13.00**	**44.76**	26.89	**0.00**
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Cascade Creek had a qualitative habitat assessment take place at site 04LM124, during its fish sampling event in 2004. The resulting MSHA score for this site was 65.45, which is considered to be a fair score (Figure 141). Limiting the habitat at this site was the poor surrounding land use, a very narrow riparian buffer, moderate stream shading, light embeddedness and fair sinuosity.

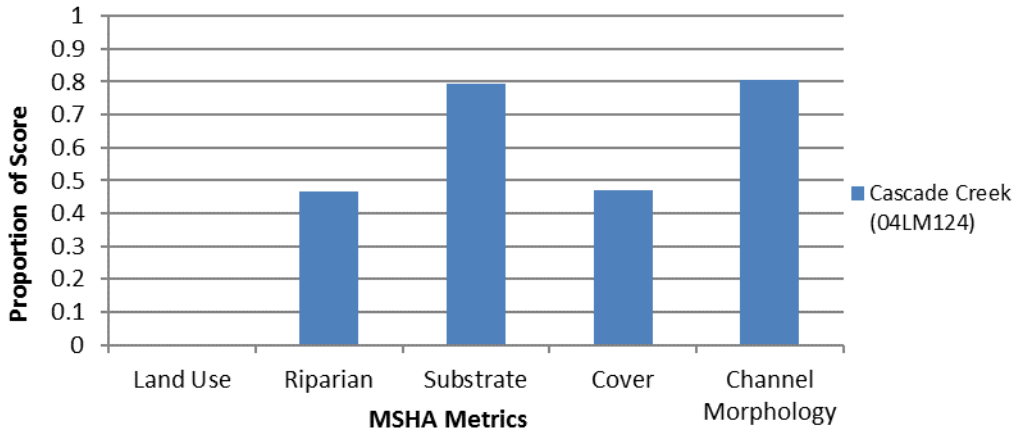

Figure 141. MSHA metric value scores at site 04LM124 along Cascade Creek (07040004-581).

The macroinvertebrate sample at site 04LM124 along Cascade Creek was collected from equal parts of riffle and overhanging vegetation habitats. This sample found that this reach had increased numbers of burrower individuals (18.69%). The increase in burrowers may be attributed to the layer of fine sediment observed. Site 04LM124 also had an increased amount of legless individuals (55.74%), while also having a decreased amount of sprawler individuals (15.74%) when compared to all other Minnesota streams. These results can signal a community being stressed by the habitat conditions.

The fish assemblage in this portion of Cascade Creek had increased numbers of both riffle dwelling (48.48%) and simple lithophilic spawning (42.42%) individuals. However, this stream also had decreased numbers of benthic insectivore (13.64%) and darter/sculpin/round-bodied sucker (6.06%) individuals,

while also having an above average amount of pioneer species individuals (27.27%). Pioneering fish species are able to thrive in unstable environments and are the first to invade following a disturbance.

Based on the fair MSHA score, as well as the majority of the habitat related fish and macroinvertebrate metrics, the lack of habitat is a stressor to the impaired macroinvertebrate community in Cascade Creek.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the three-mile-long reach of Cascade Creek (07040004-581) was 100% modified. Modified channels typically lead to reduced habitat conditions, eroded banks and an overall reduction in diversity. This portion of Cascade Creek flows through a very developed area of the city of Rochester. Highly developed areas have more impervious surfaces that allow storm water to quickly enter the stream with little water retention. Significant rain events can lead to a spike in stream velocity which results in eroded banks and destruction of available habitat.

There are a series of drop structures in the lower end of Cascade Creek where it enters the South Fork. At this point it doesn't appear to be an issue, given the health of the fish community, but it should be monitored over time to ensure fish are not impacted.

The MSHA at site 04LM124 showed some bank erosion, sand substrates, light embeddedness and fair channel sinuosity. With this portion of Cascade Creek located in a highly developed and densely populated area and the channel is completely modified resulting in many poor habitat metric scores; flow alteration is a stressor to the impaired macroinvertebrate community at this time.

Conclusions and recommendations

The impaired macroinvertebrate community of Cascade Creek (581) is being stressed by elevated TSS, poor habitat conditions and flow alteration (Table 63). The macroinvertebrate community is comprised of many TSS tolerant taxa and individuals. This reach also has an existing turbidity listing, which is validated by the chemistry and biological response information. The sediment issues in this reach are having a direct impact on the available habitat as well. This is reflected in metrics like burrowers and legless macroinvertebrates, which can thrive in the thin layer of sediment observed. Lack of riparian buffer and the surrounding urban land use can also be contributors to the suspended sediment and bedded sediment issues in this location in addition to the entire upstream watershed contributions. In addition, the fact that this entire reach is 100% modified and located in a highly developed area of the city of Rochester contributes to the habitat issues observed.

The nitrate concentrations in this reach are generally low, and little biological information exists to suggest nitrate stress; therefore, nitrate is not considered a stressor at this time. DO is considered inconclusive due to a lack of connecting information. There were no violations of the DO standard on this reach, which includes sonde measurements; but some biological response suggests that it's possible DO could be an issue (high percentage of DO tolerant taxa, higher phosphorus measurements etc.). It's not certain if the response is due to DO issues or other stressors in this reach; therefore, a DO stressor determination could not be made. Additional information should be collected to better understand potential DO impacts to this reach.

It would be helpful if this station were resampled for biology, as the biological information is from 2004 may or may not reflect current conditions. MNDNR information on Cascade Creek does not capture this reach and is concentrated in the areas upstream of this location.

Table 63. Summary of stressor determinations for Cascade Creek

Stream Name	AUID	Stressors: Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Cascade Creek (City of Rochester)	07040004-581	---	o	---	●	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.13.2 Cascade Creek (991)

Biological and background information

Cascade Creek (07040004-639) has two biological stations within close proximity to one another. Four biological samples were collected for fish at the two stations, which led to a macroinvertebrate impairment on this reach. Two samples were collected at site 04LM123 in 2004 (June and August). Additionally, two samples were collected at 12LM102 in 2012 (June and July). Both sites are designated fish Class 3 (Southern Headwaters). Station 12LM012 was added in order to capture the natural channel portion of this reach, while 04LM023 remains on an old channelized reach.

The FIBI impairment threshold for these stations is 55, with an average score per metric of 9.17 needed to meet that level. 04LM123 (June 2004) had an FIBI score of 54, and 04LM123 (August 2004) had an FIBI score of 65. In June of 2004, 3 out of 6 metrics scored below the average score needed to pass the FIBI (DetNWQTxPct, GeneralTxPct and Sensitive;). The sensitive fish metric, which is the taxa richness of sensitive fish species, scored low at all visits. Station 12LM012 scored 49 in June and 55 at the end of July. Overall, three of the four visits were at or below impairment threshold, which led to the fish impairment listing on this reach.

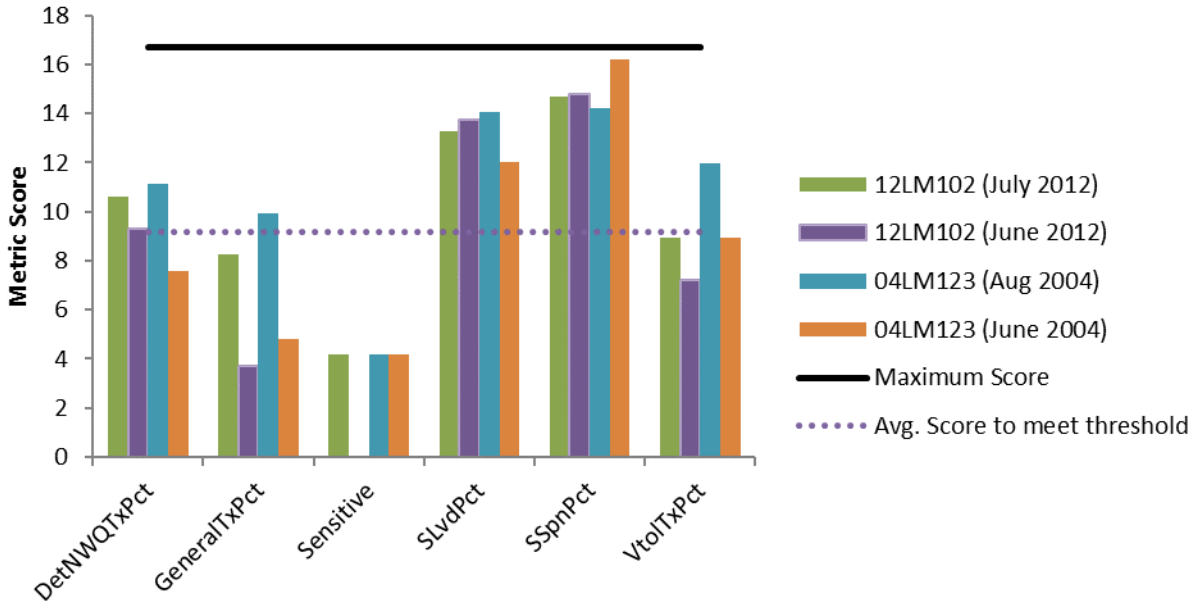

Figure 142. Fish IBI metrics for Cascade Creek (Fish Class 3; Southern Headwaters.

Dissolved oxygen and eutrophication

From 2004-2014, a total of 19 DO measurements were taken along Cascade Creek (07040004-991). These values ranged from 5.18-13.42 mg/L, with no values falling below the daily minimum standard for DO. In 2014, a sonde was placed along Cascade Creek at 45th Street (). The sonde also showed that the DO concentration did not fall below the 5 mg/L standard; however, the daily flux frequently exceeded the 3.5 mg/L standard. These results can potentially signal stress from eutrophication.

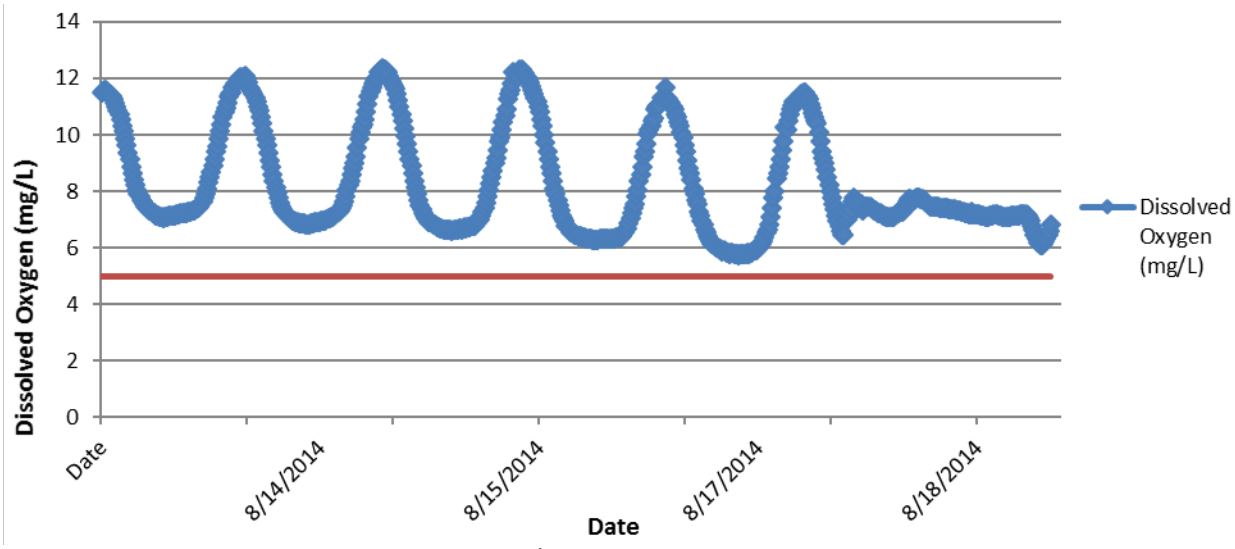

Figure 143. Continuous DO monitoring at the 45th St Crossing along Cascade Creek (0704004-991)

Additionally, 18 phosphorus samples were taken along this stream reach. These values ranged from 0.032-0.952 mg/L, with six of the values exceeding the 0.10 mg/L phosphorus standard. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

The macroinvertebrate community along this section of Cascade Creek had a decreased amount of DO tolerant individuals (3.98%), while also containing many DO intolerant taxa (9.5 average). There was an

average DO TIV score for this assemblage when compared to all other Class 5 sites throughout Minnesota.

The fish assemblage along this reach had a good number of late maturing individuals (33.99%), while also having decreased amounts of serial spawning individuals (8%). These results signal a stream that is not being negatively impacted by low DO levels. Furthermore, the DO TIV score for the fish community was above average when compared to all other Class 3 sites.

For now, the biological conditions do not seem to be negatively impacted by the high daily flux of DO and the elevated levels of phosphorus. DO and eutrophication are not stressors along Cascade Creek at this time, but frequent monitoring of DO and phosphorus is recommended to ensure that conditions do not worsen as it is likely that they will eventually stress the biological assemblages in this stream.

Nitrate

During the fish sample, the nitrate concentration was measured four different times on this reach and showed variable concentrations. At 12LM102 the concentration was 9.8 mg/L in June of 2012, and was 2.6 mg/L in July 2012. At 04LM123, the nitrate concentration was 11 mg/L in June of 2004, and fell to 4.6 mg/L in August of 2004. There were 14 paired nitrate samples collected from May – September in 2014, at two locations on the reach, one at the bio station and one upstream of County Road 3. Overall samples collected at CR 3 were slightly higher than the concentrations found near the biological stations. The average concentration of all the samples collected was 7.3 mg/L, with a maximum of 14 mg/L collected in June of 2014.

The two macroinvertebrate samples taken had 69% (12LM102) and 81% (04LM123) nitrate tolerant species collected. At 83.78%, there is only a 10% probability of meeting the MIBI threshold; however, the macroinvertebrates are meeting impairment threshold at both stations. The average taxa richness for Class 5 stations in the LMB is 37.76 (TaxaCountAllChir). At these stations, taxa richness was above average (43 at 12LM102 and 39 at 04LM123). There were a decent number of Trichoptera taxa at 12LM102 (7), with fewer at 04LM123 (3). There were no nitrate intolerant taxa at station 04LM123, but there were 2 found at 12LM102. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. These Trichoptera include all caddisflies that do not spin nets. The percentage at these two sites ranged from 1.7%-2.9%; below the average for sites in the LMB (3.39%).

With the macroinvertebrate community above impairment threshold, the presence of a fair number of intolerant taxa, total taxa and Trichoptera taxa, nitrates don't appear to be making a large impact to the biological community. While there are differences in metric response between the two stations in regards to nitrate, they are in close proximity to one another and at different temporal scales (2004 vs 2012). While nitrate is elevated and may be making some impacts on the biological communities, it is not likely the driving stressor. The slight metric response is more likely due to another stressor present (i.e., habitat condition differences between the two stations). Given the mix of response, and fish impairment, it cannot be concluded if nitrate is making a large impact on the communities in this reach. Nitrate is considered inconclusive as a stressor to this reach in Cascade Creek.

Suspended sediment

During biological sampling, the TSS concentration ranged from 4.4 mg/L to 16 mg/L at 12LM102 and 04LM123 (4 samples from 2 years). There were 14 additional chemistry samples taken in 2014, at two different locations on this reach from 6 different days. The maximum TSS recorded was 760 mg/L, from a storm event on June 24, 2014 (45th Ave/12LM102). The average concentration among the samples was

88 mg/L, but only two of the values exceeded the 65 mg/L TSS standard for warmwater streams in the southern region.

The macroinvertebrate community does not show a strong response to elevated TSS (Table 64). Both visits had low TSS index scores, few tolerant taxa and some plecoptera (stonefly) taxa present. However, intolerant taxa were generally low in addition to collector filterers, both of which can decrease with increases in TSS. Fish seem to show more response but a mix of response overall. It's unclear if the fish are responding to elevated TSS or another stressor and at this point it seems more likely that they are responding to another stressor given the lack of macroinvertebrate response (which would be expected if TSS were an issue).

Given the mixed biological response, it's difficult to conclude TSS is making a direct impact even though sediment generally may be an issue here (perhaps making habitat related impacts instead of staying suspended). TSS is considered inconclusive as a stressor at this reach.

Table 64. Nitrate relevant macroinvertebrate metrics for Cascade Creek compared to statewide averages for Class 5 streams meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
04LM123	14.62	**2**	5	7.39	**23.30**	0.97
12LM102	15.85	**1**	11	21.01	**24.19**	1.42
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Expected response to stress	↑	↓	↑	↑	↓	↓

Station	BenFdFrimPct	Centr-TolPct	HerbvPct	Percfm-TolPct	RiffllePct	SensitivePct	SLithopPct	Intolerant Pct	Longlived Pct	TSS Index Score (RA)
12LM102	45.30	0.55	9.39	8.29	38.67	1.10	43.65	0.00	0.55	15.46
12LM102	61.25	0.00	12.50	8.75	52.50	0.00	52.50	0.00	0.00	15.38
04LM123	76.79	0.00	25.16	19.31	63.77	8.68	45.34	0.00	0.00	15.24
04LM123	61.50	0.00	25.82	0.23	60.80	0.23	59.15	0.00	0.00	14.73
Statewide average for Southern Headwaters that are meeting the FIBI Threshold (51)	**34.47**	**1.18**	**12.27**	**13.13**	**25.44**	**6.82**	**31.25**	**1.04**	**4.25**	**15.09**
Expected response to TSS stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Habitat

Cascade Creek (07040004-991) had qualitative habitat assessments take place during both fish sampling events at each site, 04LM123 and 12LM102. These sites had average MSHA scores of 50.25 (04LM123) and 52.68 (12LM102) respectively. These scores are considered fair. Limiting MSHA scores at these sites were the poor surrounding land use, bank erosion, narrow riparian, moderate-severe embeddedness, poor sinuosity, moderate-sparse fish cover, low-moderate channel stability and fair channel development.

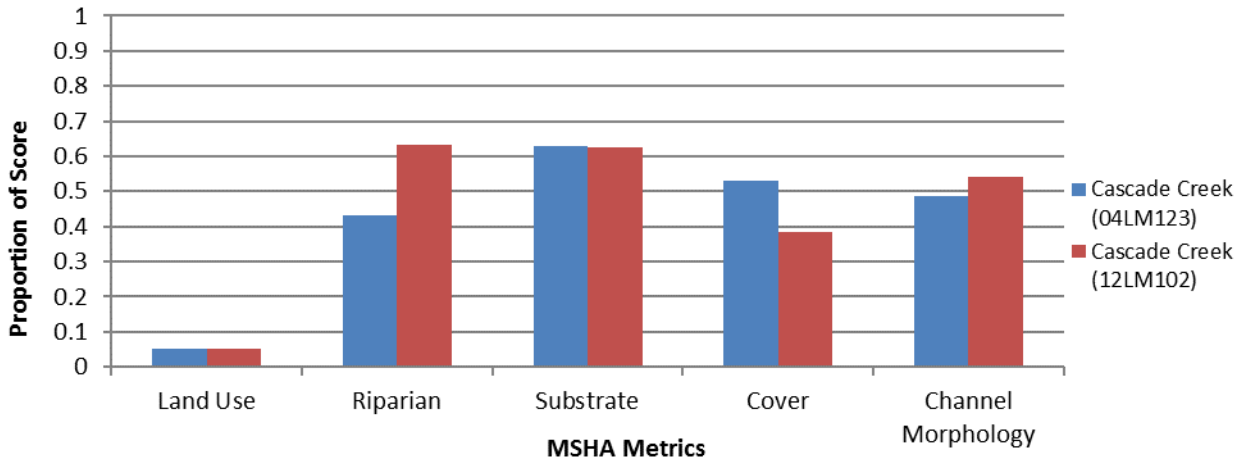

Figure 144: MSHA metric value scores for sites 04LM123 and 12LM102 along Cascade Creek (07040004-991).

The macroinvertebrate sample along Cascade Creek was taken from woody debris, riffles and overhanging vegetation. The community had an increased amount of burrower individuals (18.51%) at site 04LM123, which is likely due to the high degree of embedded substrate present. These sites also had an increased amount of legless individuals (59.29%), which can often signal stress from habitat conditions. In contrast to the poor scoring metrics, this reach did have an increased amount of climber (26.69%) and clinger (41.29%) individuals, which is more common in good habitat conditions.

The fish assemblage along this portion of Cascade Creek had increased amounts of riffle dwelling (53.94%) and simple lithophilic spawning (50.16%) individuals. This reach also had lower numbers of benthic insectivore (10.42%) and darter/sculpin/round-bodied sucker (9.01%) individuals, while also having increased amounts of pioneer species (26.63%) and tolerant (85.57%) individuals. These percentages often signal degraded habitat conditions.

A geomorphic assessment by MNDNR revealed that Cascade Creek (flowing through Meadow Lakes Golf Club) is actively incising and eroding the stream banks. This reach was contributing approximately three times more sediment per foot of stream than any other reach surveyed in the entire Cascade Creek Watershed. Specifically, the upstream part of the geomorphic reach (12LM102) has over widened and is considered unstable, contributing to habitat loss.

The majority of the habitat related metrics scored poorly for both assemblages, supporting habitat stress in this reach. This, along with further geomorphic information from MNDNR confirms excess sediment and erosion contributing to the degraded habitat conditions. Therefore, habitat is a stressor to the impaired fish assemblage in Cascade Creek.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 10.26-mile-long reach of Cascade Creek (07040004-991) was 34.29% modified. Modified channels typically lead to reduced habitat conditions, eroded banks and an overall reduction in diversity. This portion of Cascade Creek flows through a rural area just west of Rochester into the outskirts of the city.

Flows through Cascade Creek can be flashy at times. The MNDNR maintains a flow gaging station at 45th St. SW along Cascade Creek (Figure 145). In 2014, the hydrograph showed minimal flows during the early spring and winter months and dramatic increases during summer rain events. One rainfall event in late June 2014 led to a discharge in excess of 400 cfs. Stream discharges that increase quickly and that have poor surrounding land use with little riparian area, will likely result in eroded banks and habitat destruction.

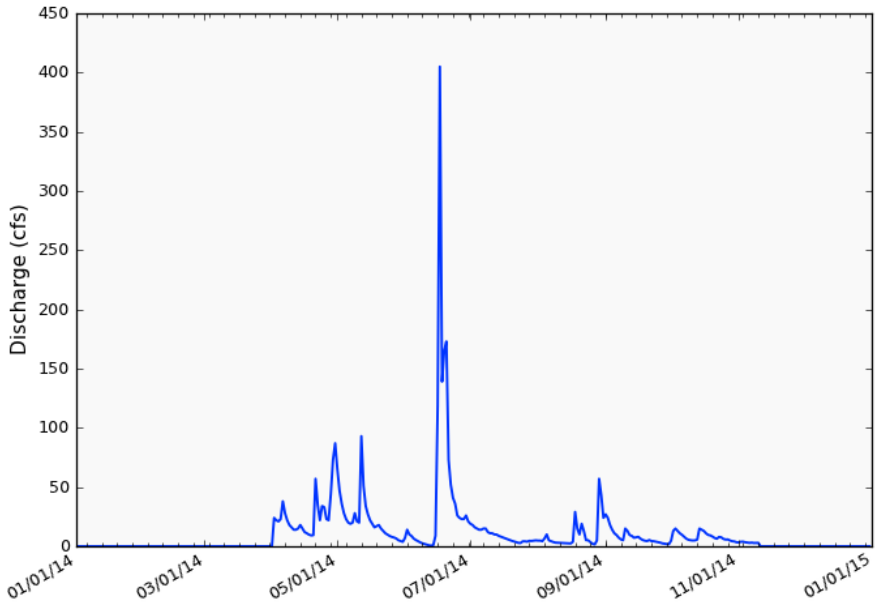

Figure 145. Stream discharge (cfs) along Cascade Creek at 45st SW in Rochester. (Courtesy MNDNR).

Connectivity in Cascade Creek is also an issue. A perched culvert was observed downstream of CR 22 (Figure 146 and Figure 147), which would prevent fish migration upstream from Cascade lake. The lake also has an outlet structure that can disconnect itself from the downstream portion of Cascade Creek.

Figure 146. Backed up flow (MPCA photo 2015) on upstream end of culverts at CR22/Cascade Creek intersection

Figure 147. Aerial photo of perched culvert (downstream end) on CR22 intersection of Cascade Creek (07040004-991).

Furthermore, more documented observations of stream flow and connectivity exist as follows:

According to MNDNR report from 1965, on the South Fork Watershed, "All the streams lose water at elevations somewhere between 1,000 ft and 1,040 ft above sea level, but this water plus some additional groundwater is gained between the elevations of 1,040 ft and 1,000 ft above sea level. Notable examples of this are Cascade Creek and Salem Creeks. Salem Creek loses water in its upper part of the large alluvial basin and regains water where the creek flows through in a narrow, deep and short valley located at the lower end of the basin. Cascade Creek is only a series of pools in the middle part of its course but is a flowing stream in the upper and lower parts of its course. It regains its water in the City of Rochester at an elevation higher than the top of the hard strata of rock. A similar outcrop can be observed in the bed of the South Fork of the Zumbro River above the power dam impoundment in Rochester."

Surber, 1924, who made many observations on Zumbro River streams noted that "during the latter part of the summer in dry seasons water ceases to flow between the sluggish pools, consequently the creek is unworthy of further consideration." This may be further evidence that historically the stream has not always had a predicable flow.

Based on the amount of channelization along Cascade Creek, the flashy flow conditions, structures limiting migration, as well as the observed periods of a dry stream bed both recently and historically, flow alteration and connectivity are indeed stressors to the impaired fish community in Cascade Creek.

Conclusions and recommendations

The impaired fish community in Cascade Creek (991) is being stressed by poor habitat conditions and flow alteration/connectivity (Table 65). Even though the macroinvertebrates are not currently impaired in this location, they are showing signs of habitat related stress relating back to the poor substrate and surrounding land use. A geomorphic assessment by MNDNR revealed that Cascade Creek (flowing through old Meadow Lakes Golf Club) is actively incising and eroding the stream banks. This reach was contributing approximately three times more sediment per foot of stream than any other reach surveyed in Cascade Creek. In terms of Connectivity, a perched culvert on CR22 and Cascade Lake completely blocks fish from migrating during certain flow regimes. In 2012, there were observed periods where the stream bed was completely dry. MNDNR intensive surveys on Cascade Creek also document habitat and flow alteration/connectivity as contributing issues to the impaired fish community.

Nitrate and TSS are inconclusive as stressors in this reach. It doesn't appear that TSS is making a direct impact to the biology even though sediment and erosion are issues in this watershed. It appears the sediment problems are revealed in the habitat issues seen, instead of suspended sediment. While nitrate is elevated and may be making some minor impact on the biology, it is not likely driving stress; the slight metric response is more likely due to another stressor present (i.e., habitat). Also, macroinvertebrates are not impaired and they would be expected to respond if nitrates were contributing to the stress observed; therefore, it cannot be concluded that nitrate is contributing to biological impairment.

DO measurements were within acceptable ranges, and the biological communities did not have an abundance of low DO tolerant species and had low numbers of DO intolerant taxa and late maturing fish, which signals communities that are not being negatively impacted by DO. Reductions in phosphorus may be needed to ensure DO levels stay adequate.

Table 65. Summary of stressor determinations in Cascade Creek

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Cascade Creek (Upstream of City)	07040004-991	---	---	o	o	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.14 Salem Creek Watershed

The Salem Creek Watershed is a warmwater stream originating in Dodge County and flows through Olmsted County to the South Fork Zumbro. This subwatershed drains a total of 35,526 acres, 81% of which is in agricultural use. Section 4.14 will discuss two streams with biological impairment in this watershed (Figure 148).

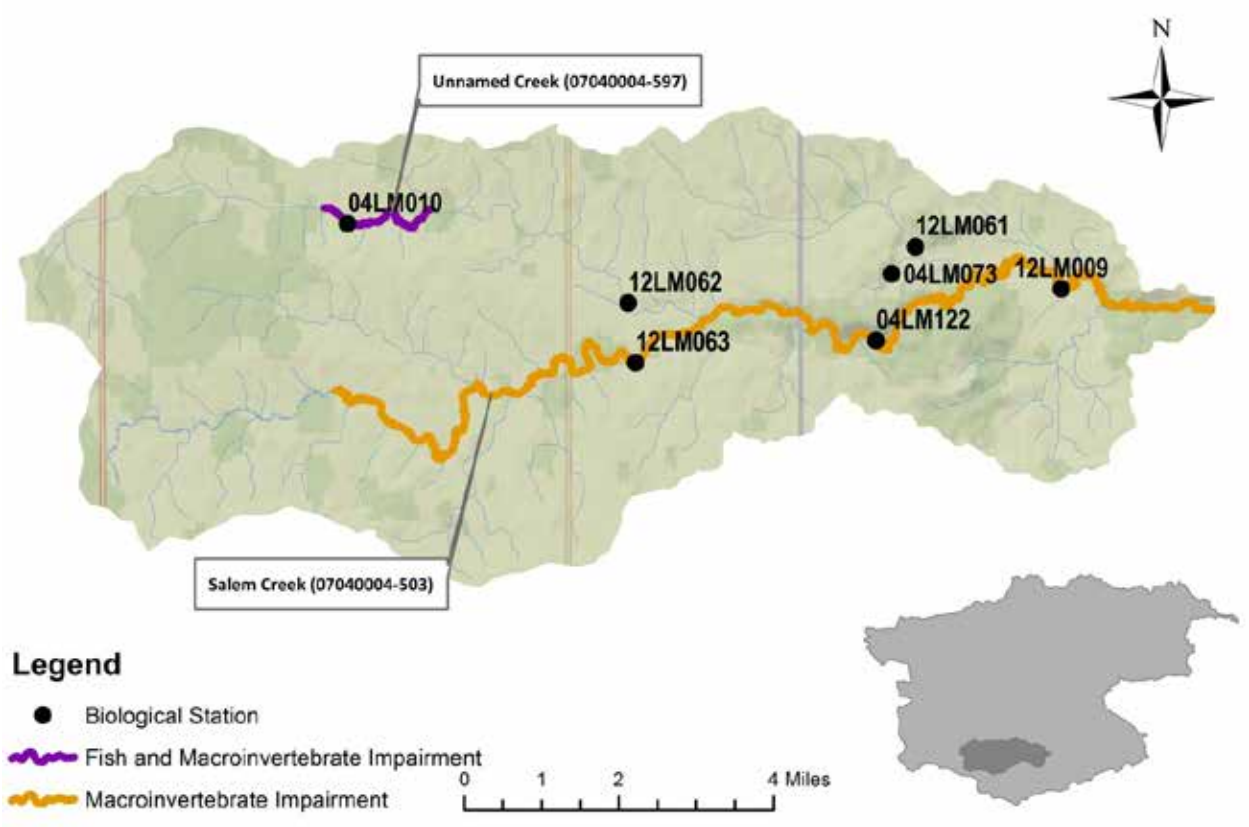

Figure 148. Map of the Salem Creek Watershed, biological stations, and impaired AUIDs.

4.14.1 Salem Creek (503)

Biological and background information

Salem Creek (07040004-503) has four macroinvertebrate samples collected at two different sites; two samples at 12LM063 on August 7, 2012, and two samples at 12LM009 on August 2, 2012, Samples from 12LM063 are designated Class 5 (Southern Streams RR), and samples 12LM009 are designated Class 6 (Southern Forest Streams GP). There was one additional site on this reach, 04LM122, but only fish were sampled in 2004. The result during assessment confirmed a macroinvertebrate impairment on this reach.

The MIBI threshold for Class 5 streams is 37, with an average score per metric of 3.7 needed to achieve that threshold. 12LM063 had two visits with MIBI results of 39.72 and 45.44, both above impairment threshold. Both samples have a relatively similar distribution with a metric score of zero for taxa richness of climbers (ClimberCh), taxa richness of Odonata (Odonata) and taxa richness of predators (Predator). Both visits scored below the average score needed for taxa richness of Trichoptera (Trichoptera), and both visits received the maximum score of 10 for the relative percentage of taxa that cling (ClingerChTxPct).

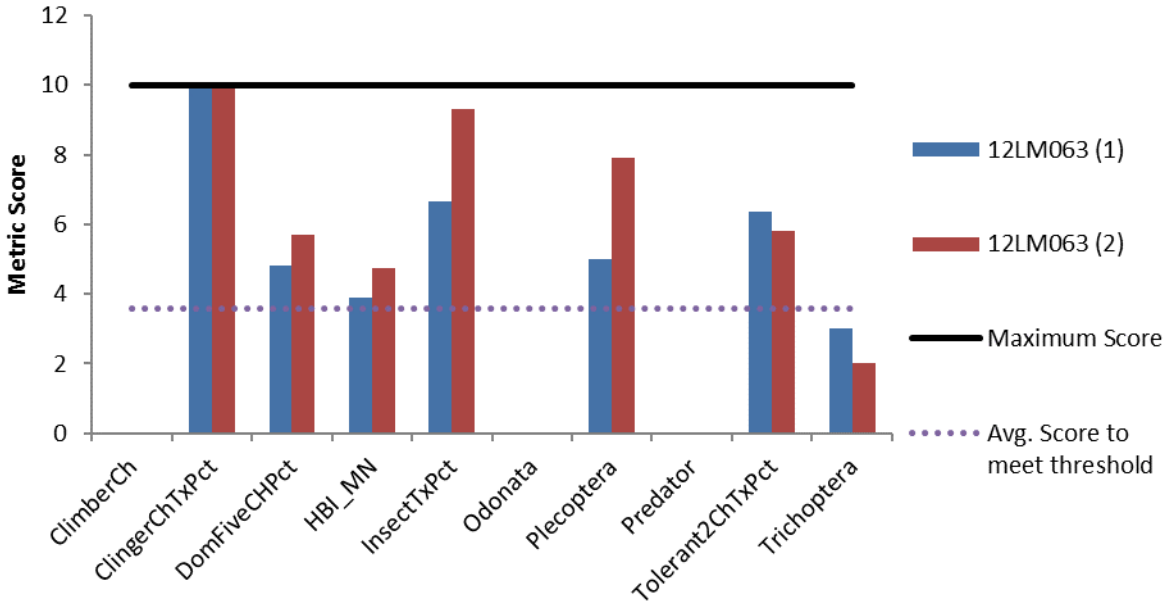

Figure 149. Macroinvertebrate IBI metrics for Salem Creek (Class 5; Southern Streams Riffle/Run).

For streams that are Class 6 the MIBI threshold is 43 with an average score per metric of 4.3 needed to achieve that threshold. Site 12LM009 had MIBI scores from its two visits of 40.70 and 39.99, both score just below impairment threshold. The 12LM009 site is located downstream of 12LM063; many tributaries join Salem Creek between sites 12LM063 and 12LM009. Both 12LM009 samples received a low metric score for the metrics of Collector-filtererPct, HBI_MN, PredatorCh and TrichwoHydroPct. The highest scoring metric from both samples is the taxa richness of clingers (ClingerCh) with a score of eight for both visits.

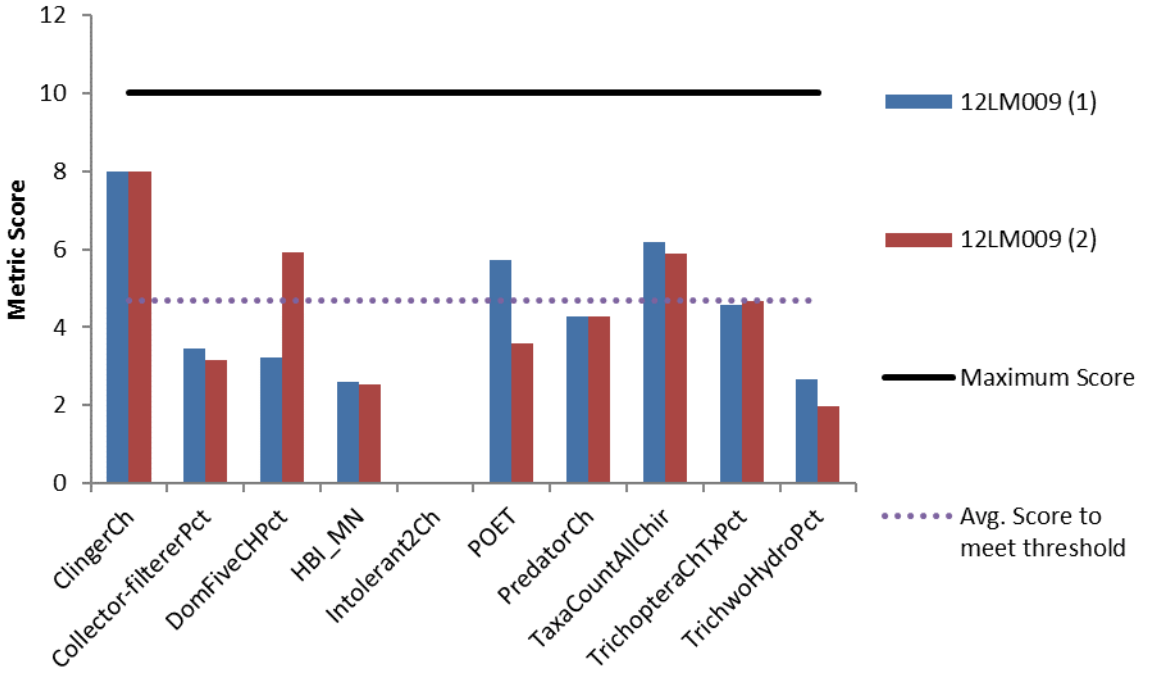

Figure 150. Macroinvertebrate IBI metrics for Salem Creek (Class 6; Southern Streams Glide/Pool).

Dissolved oxygen and eutrophication

Salem Creek had 12 DO measurements taken from 2012-2014. These measurements ranged from 7.4-14.04 mg/L with one reading taken before 9 a.m. Salem Creek also had continuous dissolved monitoring take place in 2012 at site 12LM009. During the continuous monitoring, the DO level never fell below 6 mg/L. The daily flux never exceeded the 4.5 mg/L standard for the South nutrient region.

Additionally, 24 phosphorus samples were taken from this section of Salem Creek. These values ranged from 0.029-0.498 mg/L with three samples above the 0.15 mg/L phosphorus standard for the South river nutrient region. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

Biologically, the macroinvertebrate community in Salem Creek had very few EPT individuals (8.87%) at site 12LM009, while site 12LM063, had a high amount of EPT individuals (57.67%). Site 12LM063 also averaged 10 DO intolerant taxa from its samples, while fewer (5.5 average) were sampled further downstream at site 12LM009. The DO TIV score was also much higher at 12LM063 than at 12LM009.

The fish assemblage in Salem Creek averaged a high amount of late maturing (26.94%) and sensitive (35.5%) individuals, while also having a low amount of serial spawning individuals (13%). These results reflect a stream that is not affected by the present DO conditions.

Based on the measured and continuous DO data at 12LM009, the increased amounts of EPT and intolerant macroinvertebrate species especially at site 12LM063, and the high scoring fish metrics concludes that low DO and eutrophication are not stressors at this time.

Nitrate

During biological sampling events the nitrate concentration in Salem Creek ranged from 5.3 to 15 mg/L (samples taken in 2004 and 2012). There were 21 additional nitrate samples available, taken from 2012 and 2014. The average concentration of the samples collected was 10.1 mg/L, with the maximum of 24 mg/L, collected on June 24, 2014, at 12LM063. On this same date at 12LM009, the nitrate concentration was 18 mg/L, suggesting slight longitudinal decrease when moving downstream. This was also observed during baseflow conditions, where the nitrate concentration upstream at 12LM063 was 8 mg/L compared to 12LM009 which was 5.4 mg/L in September 2014. A difference in bedrock geology in the upper portion of the watershed may be contributing to the higher stream nitrate concentrations observed.

Daily nitrate values were calculated for Salem Creek (AUID 07040004-503) subsheds 78, 79, 83 and 86 by the HSPF model from 1995-2009. These values ranged from 1.12-37.68 mg/L with an average value of 5.4 mg/L. In addition, for the entire 07040004-503 reach, 4.7% of the values were above 10 mg/L and less than 1% were above 20 mg/L.

The macroinvertebrate communities in Salem Creek show a mixed response to elevated nitrate. Taxa Count or species richness are below class averages for the two visits at 12LM063 but were above average for 12LM009 (Table 66). Trichoptera taxa numbers are less than average for one visit at 12LM063. However, 12LM063 had two visits with between 14% and 20% Trichoptera taxa, which is much higher than 12LM009 and its two visits, both with only 7% Trichoptera. Percentages of nitrate tolerant individuals were just above the average for the respective stream classes during all visits. Sensitive species (non-hydropsychid Trichoptera and nitrate intolerant taxa) demonstrate more of a response at 12LM063 compared to 12LM009. However, the opposite is true regarding generally intolerant taxa, with more present (5 and 3) at the two visits at 12LM063, compared to 12LM009 (0 and 3). Both sites have nitrate community index scores for macroinvertebrates (3.1 and 3.3) that are greater

than the average score of stations meeting the threshold (2.9). This indicates the communities present are likely stressed by nitrate.

The majority of the metrics show that nitrate is stressing the macroinvertebrate community in Salem Creek but more so at 12LM063 where the concentrations are comparatively higher (Table 66). The MIBI score is slightly worse farther downstream at 12LM009, where nitrate is likely having a combined impact with another stressor. Nitrate must be reduced in Salem Creek to prevent communities from further degradation. Nitrate is considered a stressor to the biological communities in Salem Creek.

Table 66. Nitrate relevant metrics for Salem Creek. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Nitrate Relevant Metrics	Taxa Count (TaxaCountAllChir)	Trichoptera Taxa	% Non-hydropsychid tricoptera	Nitrate Intolerant Taxa	% Nitrate Tolerant Individuals
12LM063 (Class 5)	**27**	**4**	**0.62**	**1**	**79.2**
12LM063 (Class 5)	**25**	5	**0.93**	**1**	**75.2**
12LM009 (Class 6)	40	3	3.65	2	**71.9**
12LM009 (Class 6)	39	3	4.62	NA	NA
Expected response with increased Nitrate stress	↓	↓	↓	↓	↑
Class 5 Averages	***37.76***	***4.3***	***3.39***	***1.49***	***69.8***
Class 6 Averages	***33***	***2.2***	***2.21***	***1.49***	***69.8***

Suspended sediment

At the time of biological monitoring in June and July of 2012, at sites 12LM009 (June and July 2012) and 12LM063 (June 2012), there were three TSS values recorded, all were less than 10 mg/L.

Daily TSS values were calculated for Salem Creek (AUID 07040004-503) subsheds 78, 79, 83 and 86 by the HSPF model from 1995-2009. These values ranged from 0.62-2171.75 mg/L with an average value of 16.3 mg/L. In addition, 3.9% of the values were above 65 mg/L, which is the TSS standard for warmwater streams in the southern region.

Paired TSS sampling between the two biological stations in 2014 shows generally increased suspended sediment concentrations when moving downstream (Table 67). The TSS samples were taken on the same day and very close to the same time.

Table 67. Paired TSS sampling data from 2014, at two biological stations of Salem Creek.

	S003-459 (12LM063; upstream)	S005-422 (12LM009; downstream)
9/25/2014	5.2	16
7/16/2014	9.2	6
6/24/2014	27	25
6/18/2014	160	210
4/30/2014	16	43

In addition to TSS data, there is a good amount of transparency data available at S005-422, which corresponds to 12LM009. The 2013, transparency information shows the site has better transparency than compared to other sites in the watershed. For further details see: http://cf.pca.state.mn.us/water/cmp/resultDetail.cfm?siteid=S005-422.

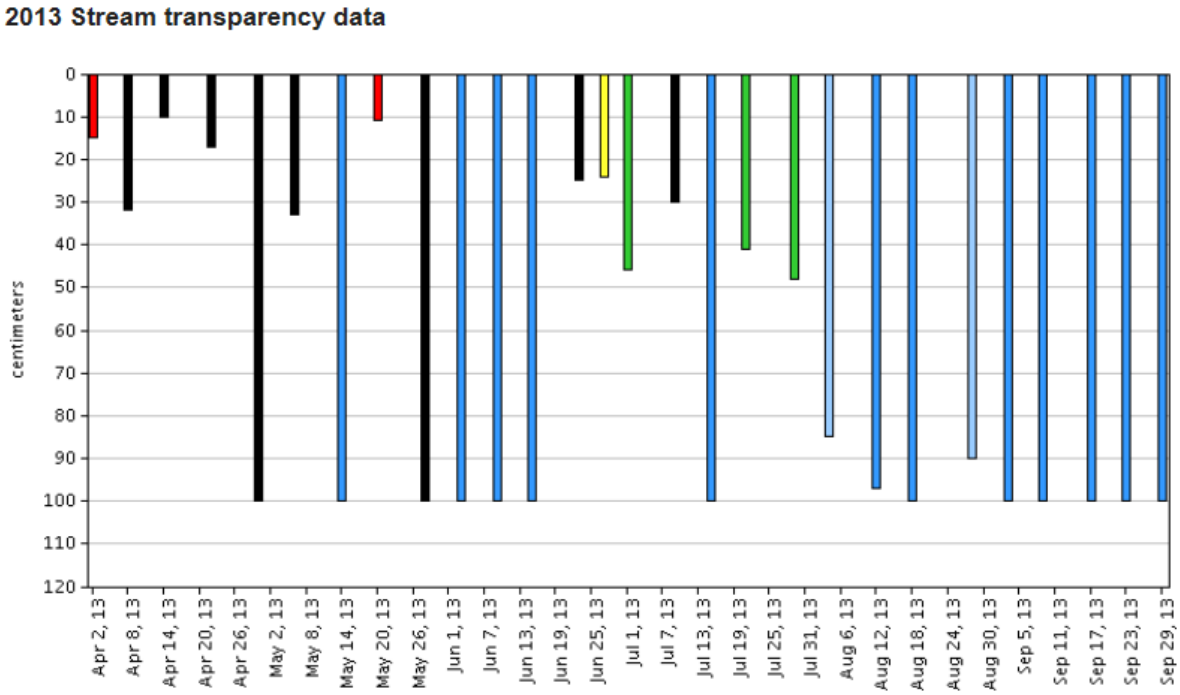

Figure 151: 2013 stream transparency data for S005-422 (12LM009)

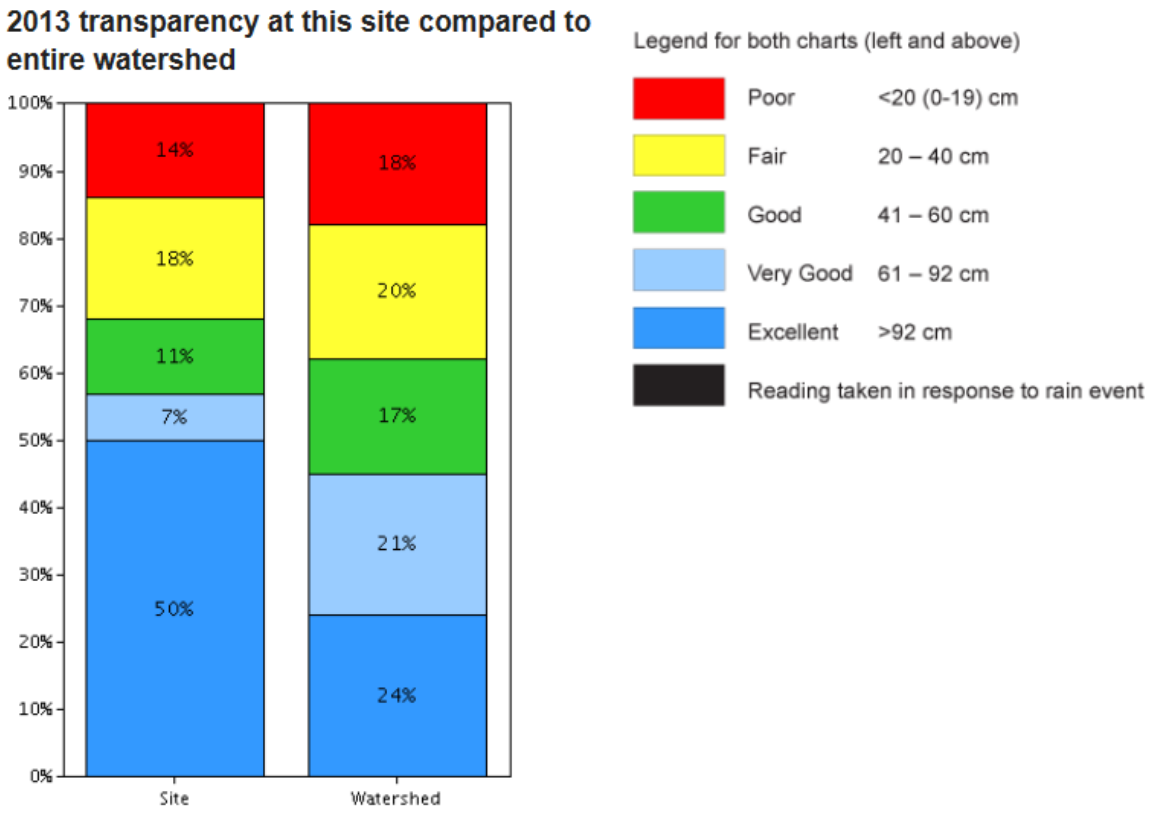

Figure 152. Transparency information displayed for S005-422, showing in 2013 comparison of the site to the watershed.

The fish communities at both stations do not have a strong signal towards TSS related stress. The macroinvertebrate communities show a drastic difference between the two stations. (Table 68) The macroinvertebrate community is showing a response at 12LM009, while little to no response was seen at 12LM063. There are some differences between the TSS concentrations between the two stations, but with the limited data available it's not clear if that difference is significant. Other stressors can be tied to the response seen between the two stations. Considering 2013, was a wet year, the 2013, transparency dataset shows good transparency through most of the year (monitoring station coincides with 12LM009).

Table 68. Macroinvertebrate metrics relevant to TSS for stations in Salem Creek compared to statewide averages for southern streams GP and southern streams RR stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plectoptera Pct
12LM063 (2012; RR)	16.81	2.00	6.00	46.18	28.27	1.22
12LM063 (2012; RR)	16.43	2.00	7.00	33.86	26.46	1.23
12LM009 (2012; GP)	16.82	1.00	11.00	38.51	13.35	0.00
12LM009 (2012; GP)	17.98	1.00	11.00	52.05	12.15	0.00
Statewide average for Southern Steams RR that are meeting the MIBI Threshold (35.9)	***17.1***	***2.6***	***11.3***	***34.0***	***25.3***	***0.6***
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Salem Creek (07040004-503) had qualitative habitat assessments performed at sites 12LM009 and 12LM063 during the fish sampling events in 2012 (Figure 153). Site 12LM009 had an average MSHA score of 63.05 (Fair) during its habitat assessments, while site 12LM063 had an MSHA score of 84.75 (Good). Site 12LM063 had the second highest MSHA score in the entire Zumbro River Watershed. Limiting the habitat scores at the two sites was the poor surrounding land use, a limited riparian buffer. Especially at site 12LM009, moderate to heavy bank erosion, the abundance of silt and sand substrates and moderate channel stability.

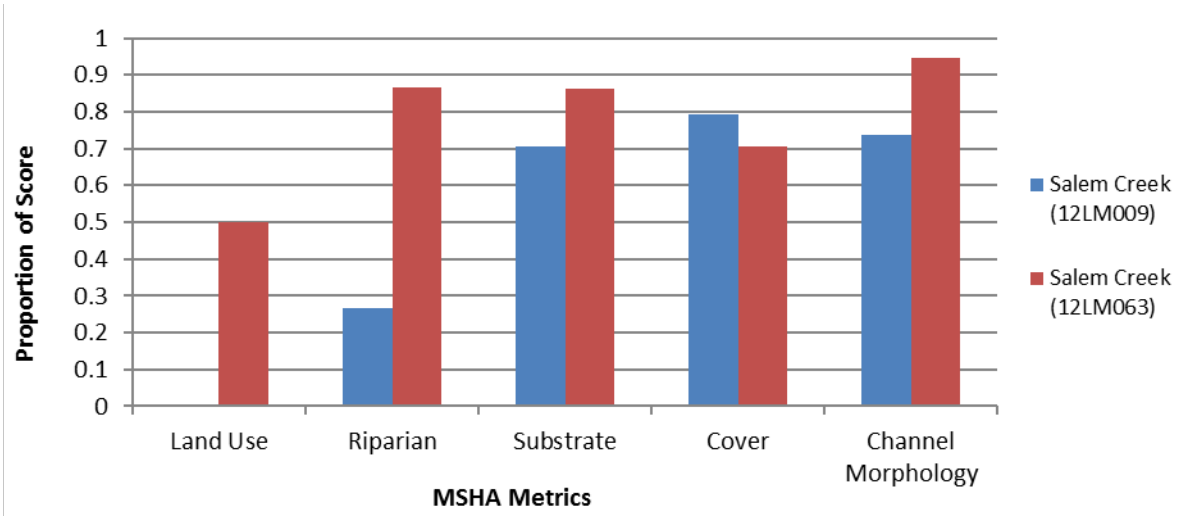

Figure 153: MSHA metric value scores at sites 12LM009 and 12LM063 along Salem Creek (07040004-503).

The macroinvertebrate samples taken along Salem Creek were taken from woody debris and overhanging vegetation at site 12LM009 and from riffles at site 12LM063. The macroinvertebrate communities reflect habitat conditions present at these sites. As expected, high amounts of climbers (51.77%) were sampled at 12LM009. These results are common given the types of habitat sampled. Site 12LM009, also high amounts of legless (81.96%) and few EPT (8.87%) individuals when compared to the lower amounts of legless (28.72%) and higher numbers of EPT (57.67%) at 12LM063. Legless macroinvertebrates (i.e., snails, worms) can tolerate poor habitat conditions. These results can be correlated to the differences in MSHA scores observed at these two sites and are likely related to available substrates. Station 12LM009 had substrates primarily of sand/gravel/silt with no riffles; as compared to station 12LM063, which had cobble and gravel substrates and abundant riffle habitat.

The fish assemblage along Salem Creek showed a slightly below average amount of benthic insectivore individuals (16.17%) when compared to all other Minnesota streams. This result can signal potential stress due to the habitat conditions, because these species require good coarse substrates and riffles. However, sites 12LM009 and 12LM063 did have above average amounts of darters/sculpin/round-bodied sucker (13.17%), riffle dwelling (50.61%) and simple lithophilic spawning (58.38%) individuals. Additionally, these sites had lower numbers of tolerant individuals (42.74%).

Based on the biological and MSHA data, habitat conditions related to substrate and surrounding land use along Salem Creek are stressing the macroinvertebrate assemblage at site 12LM009.

Flow alteration and connectivity

The Altered Watercourses GIS layer for Minnesota streams indicated that the 19.22-mile-long reach of Salem Creek (07040004-503) was 16.16% modified. The headwaters section of Salem Creek and its respective tributaries did show a fair amount of channelization as well. Modified channels typically lead to reduced habitat conditions, eroded banks and an overall reduction in diversity.

Another potential concern is the Mayowood Lake Dam located downstream of impaired reach on the South Fork Zumbro River. However, sites 12LM009 and 12LM063 had above average numbers of migratory fish individuals. Another indicator of potential connectivity stress is the absence of mussels. The MNDNR conducted mussel surveys upstream of the Mayowood Dam along Salem Creek and the South Fork Zumbro River. These surveys indicated that mussels were indeed present along these reaches. Notably, a site located on the upstream portion of this Salem Creek reach had a total of 71 individual mussels sampled, which included seven different species.

Based on the relatively low amount of channelization present along the impaired reach, the high abundance of migratory fish individuals, as well as the presence of a diverse mussel community; flow alteration and connectivity is not a stressor along Salem Creek (07040004-503) at this time.

Conclusions and recommendations

The impaired macroinvertebrate community of Salem Creek (503) is being stressed by elevated nitrate and poor habitat (Table 69). The MIBI impairment on this reach is not dramatic, as with the MIBI at 12LM009 scored only three points below impairment threshold. Station 12LM063 scored two points above impairment threshold. Nitrate concentrations appear to be highest in the upstream areas, and decrease when moving downstream. The majority of macroinvertebrate response to nitrate is seen upstream at 12LM063, where the concentrations are higher, but it is believed to be having a combined impact with another stressor at the downstream site, 12LM009. Nitrate must be reduced in this watershed to prevent further degradation of the biological community. The opposite response is seen in terms of habitat stress; the downstream station shows stress due to poor substrate and degraded habitat conditions, compared to 12LM063 which had fairly decent habitat conditions. Station 12LM009

had substrates primarily of sand, gravel and silt with no riffles, compared to 12LM063, which had cobble and gravel substrates and abundant riffle habitat. The nearby land use and riparian area also differs between the two stations, likely contributing to habitat degradation.

Overall, nitrate stress is more apparent in the upper end of the reach, and habitat related stress more apparent in the lower end of the reach. Both are believed to contribute to the degraded communities throughout. The headwater areas of Salem Creek, which have more channelization and tile drainage, are believed to be contributing to the increased nitrate concentrations and sedimentation observed. Improvements in riparian land use to include better buffers and management of pastures, would likely improve instream habitat and overall water quality. Nitrogen related BMPs will also be an important consideration to the restoration and reduction of nitrate in the watershed.

TSS and DO are not considered stressors to the macroinvertebrate community at this time. The biological metrics and chemical information do not strongly point toward stress from these parameters. If the watershed degrades further, these parameters may need to be re-evaluated as stressors.

Table 69. Summary of stressor determinations for Salem Creek

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen /Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Salem Creek	07040004-503	---	---	●	---	●	---

● = stressor; o = inconclusive stressor; --- = not an identified stressor

4.14.12 Unnamed Creek (597)

Biological and background information

Salem Creek Tributary (07040004-597) has one biological station sampled in 2004, 04LM010, which resulted in a macroinvertebrate impairment on this reach. This site is designated macroinvertebrate Class 6 (Southern Forest Streams GP). The MIBI impairment threshold for this class in 43, with an average score per metric of 4.3 needed to achieve that threshold. Station 04LM010 has an MIBI score of 36.21 and has a metric score above the average needed in only two metrics, while all of the others are below. The two metrics that scored well are DomFiveCHPct and Intolerant2ChPct, with scores of 7.07 and 7.92, respectively.

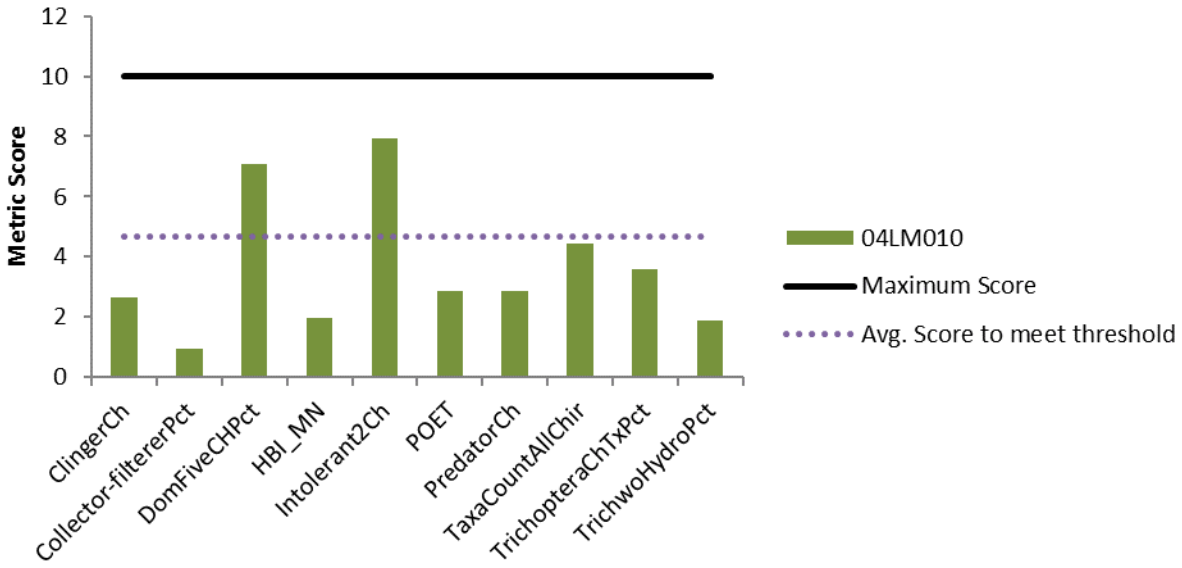

Figure 154. Macroinvertebrate IBI metrics for Unnamed Creek (Class 6; Southern Streams Glide/Pool).

Salem Creek Tributary also had one fish biological sample collected at site 04LM010 on June 22, 2004. This site is designated fish Class 3 (Southern Headwaters). The FIBI impairment threshold for this class is 55, with an average score per metric of 8.5 needed to achieve that level. Station 04LM010 has an FIBI score of 43 and scored below average on 4 out of 6 metrics. The two metrics that scored slightly above average are GeneralTXPct which is a measure of the relative abundance of taxa that are generalist feeders, and VtolTxPct, which is the relative abundance of taxa that are very tolerant species. Overall, there is a uniform poor response among the IBI metrics.

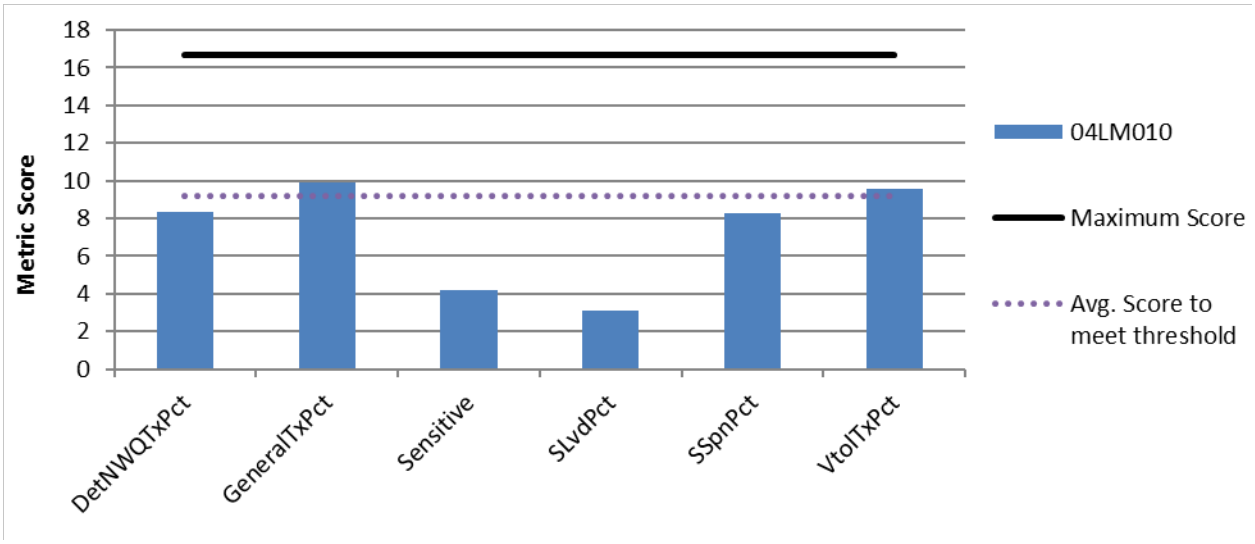

Figure 155. Fish IBI metrics for Unnamed Creek (Class 3; Southern Headwaters).

Dissolved oxygen and eutrophication

Unnamed Creek had a total of 8 DO readings taken from 2004-2014, from site 04LM010 (S007-915). These values ranged from 7.25-14.04 mg/L. Of these measurements, none were taken before 9 AM. In 2015, continuous DO monitoring took place at site 04LM010 (Figure 156). These results show that the DO levels in Unnamed Creek do not fall below the 5 mg/L daily minimum standard; however, there were instances in which the daily flux exceeded the 4.5 mg/L standard in the South nutrient region.

Additionally, 9 phosphorus samples were taken from Unnamed Creek from 2004-2014. These values ranged from 0.006-0.336 mg/L with only one value above the 0.15 mg/L Phosphorus standard in the South nutrient region. This high value may be correlated with a 1-inch rainfall event that took place on the day of sample. There was no chlorophyll-*a* nor BOD data available to further assess eutrophication impacts.

Biologically, the macroinvertebrate assemblage in Unnamed Creek had few EPT individuals (13.69%) but did have 4 DO intolerant taxa (4), while having a low amount of DO tolerant individuals (9.52%). The DO TIV score for the macroinvertebrate community at site 04LM010 was above average when compared to all other Class 6 sites.

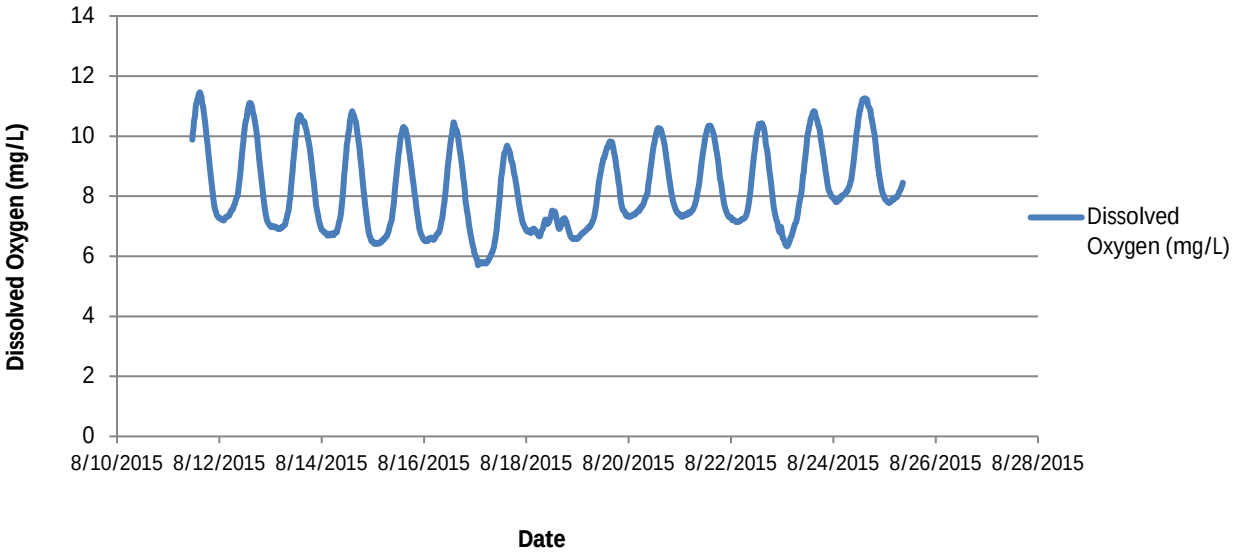

Figure 156. Continuous DO monitoring data from site 04LM010 in 2015 from Unnamed Creek (07040004-597).

The fish community in this reach had few late maturing (2.18%) and sensitive individuals (3.37%), while also having a high amount of serial spawning individuals (38.75%). These results can often signal a reach impacted by low DO conditions. Furthermore, site 04LM010 had a below average DO TIV score when compared to all other biological sites within the Zumbro River Watershed.

The biological metrics show a bit of a mixed response to the DO conditions. The continuous DO monitoring did show instances in which the daily flux exceeded 4.5 mg/L. However, the majority of the time it did not, and the daily value never fell below 5 mg/L. Also, the one high phosphorus value coincided with a significant rainfall event. It is likely that the impaired fish and macroinvertebrate communities are being stressed by other factors besides DO. Therefore, DO and eutrophication are not stressors in Unnamed Creek at this time.

Nitrate

During fish sample, the nitrate concentration was measured at 26 mg/L (June of 2004). There were eight additional nitrate samples taken at this site in 2014. In May and June, nitrate concentrations were above 15 mg/L consistently (samples over this time period) and fell to 12 mg/L by mid- July and again to 4.3 mg/L at the end of September when conditions were drier. One sample taken on 8/11/15 had a concentration of 13 mg/L. The maximum concentration was 27 mg/L in June, with a 2014, sample average of 15.6 mg/L.

Daily nitrate values were calculated for the Salem Creek Tributary (AUID 07040004-597) subshed 82 by the HSPF model from 1995-2009. The values ranged from 1.38-29.04 mg/L with an average value of 5.9 mg/L. Additionally, 5.45% of the values were above 10 mg/L and less than 1% were above 20 mg/L.

In 2004, station 04LM010 had a slightly better than average taxa count (TaxaCountAllChir; 34). The average taxa count for this macroinvertebrate Class 6; (Southern Forest Streams GP) is 33. Trichoptera are found to be generally sensitive to elevated nitrate concentrations. There were 2 Trichoptera taxa present, which is just below average for the Southern Forest Streams GP stations of the LMB (2.2). Additionally, the percentage of Trichoptera individuals was below the average, at only 0.5% (Average is 5.3%). There were also 76.3% nitrate tolerant individuals present, which is higher than many sites in the watershed. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (Class 6) MIBI. There were two nitrate intolerant taxa found during the visit, but they were not abundant. Increasing nitrate concentrations also correlate with a decrease in non-hydropsychid Trichoptera (sensitive caddisfly) individual percentages in warmwater streams. Non-hydropsychid trichoptera are all caddisflies that do not spin nets. This site had only 0.5% non-hydropsychid trichoptera present. This is below average compared to all biological sites in the LMB (3.39%) and of this stream class (2.21%).

The macroinvertebrates are dominated by midges/chironomids; individuals that are quite tolerant of high nitrate. There also is a lack of sensitive fish species (3%) and higher percentage of tolerant fish species (67%), which also can be consistent with nitrate stress. Overall, the high nitrate concentrations in May and June and biological response evidence (high % tolerant to nitrate; lack of Trichoptera) confirms nitrate is a stressor to the macroinvertebrate community in this reach.

Suspended sediment

At the time of biological monitoring in 2004, as part of a one-time chemistry sample at site 04LM010, the TSS value recorded was 3 mg/L. Additionally, eight values were recorded for TSS, six values were recorded for secchi transparency and one value was recorded with a 1 m transparency tube from April through July of 2014. The TSS values range from 1.6-170 mg/L with an average value of 28.3 mg/L. Only one TSS value exceeded the 65 mg/L standard for warm water streams and that was 170 mg/L on June 18, 2014. The secchi transparencies range from 5 to 100 cm with an average of 71.5 and the single t-tube value was 66 cm.

Daily TSS values were calculated for a Salem Creek Tributary (AUID 07040004-597) subshed 82 by the HSPF model from 1995-2009. These values ranged from 0.91-2003.3 mg/L with an average value of 16.0 mg/L. In addition, only about 3.5% of the values were above 65 mg/L, which is the TSS threshold for designated warmwater streams.

The biological response to TSS is not strong and is mixed between the fish and macroinvertebrate communities (Table 70 and Table 71). The metric response observed could be attributed to other stressors, but it is not clear. There is also a lack of chemical data to confirm that TSS is an issue in this reach; that along with a mixed biological response means TSS cannot be confirmed or ruled out and is considered inconclusive as a stressor

Table 70. Fish metrics relevant to TSS for stations in Unnamed Creek compared to statewide averages for southern headwaters stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station	BenFdFrimPct	Centr-TolPct	HerbvPct	Percfm-TolPct	RiffePct	SensitivePct	SLithopPct	Intolerant Pct	Longlived Pct	TSS Index Score (RA)
04LM010	36.97	**0.00**	25.37	**9.42**	**9.61**	**3.37**	66.70	**0.00**	**0.00**	12.9
Statewide average for Southern Headwaters that are meeting the FIBI Threshold (51)	**34.47**	**1.18**	**12.27**	**13.13**	**25.44**	**6.82**	**31.25**	**1.04**	**4.25**	**15.09**
Expected response to TSS stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Table 71. Macroinvertebrate metrics relevant to TSS for stations in Unnamed Creek compared to statewide averages for southern streams GP stations meeting impairment threshold. Bold and highlighted equals the metric score is higher or lower than average, depending on expected response with increased stress.

Station (Year sampled)	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct	Collector Filterer Pct	Plecoptera Pct
04LM010	16.47	2.00	6.00	29.05	3.87	0.00
Statewide average for Southern Forest Streams GP that are meeting the MIBI Threshold (46.8)	***16.2***	***2.0***	***10.2***	***27.2***	***24.7***	***0.4***
Expected response to stress	↑	↓	↑	↑	↓	↓

Habitat

Unnamed Creek (07040004-597) had a qualitative habitat assessment at site 04LM010 during the fish sampling event in 2004. The resulting MSHA score for this site was 67.4, which is considered good (Figure 157). Limiting the MSHA habitat score at this site was pasture in the surrounding land use, a very narrow riparian width, light stream shading, and the presence of sand and silt substrates and light embeddedness of coarse substrates.

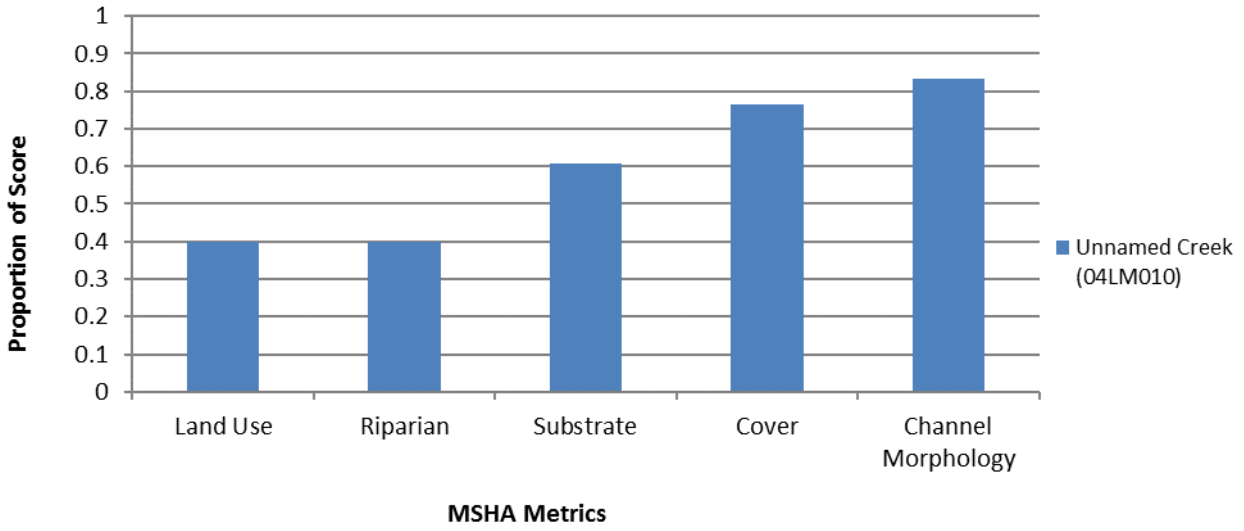

Figure 157. MSHA metric value scores at site 04LM010 along Unnamed Creek (07040004-597).

The macroinvertebrate sample from site 04LM010 came from equal parts of aquatic macrophytes and overhanging vegetation. This sample contained many burrower individuals (21.43%), which is expected in a stream with fine substrates like Unnamed Creek. This site also had a high amount of climber individuals (47.62%), which is likely due to the abundant overhanging vegetation. Few clinger (5.95%) and sprawler (10.71%) individuals were sampled, which is also expected given the limited amount of rocks and woody debris that clingers prefer. Furthermore, Unnamed Creek had a low amount of EPT individuals (13.69%) when compared to all other Minnesota streams.

The fish community in Unnamed Creek had a low amount of benthic insectivore (9.71%), riffle dwelling (9.61%) and darter/sculpin/round-bodied sucker (9.42%) individuals. This stream reach also had an above average amount of pioneer individuals (22.6%). Pioneer species are able to thrive in unstable conditions and are frequently the first to invade after a disturbance. These results are expected in streams affected by their habitat conditions. Site 04LM010 did have a very high amount of simple lithophilic spawning individuals (66.7%).

Despite the good MSHA score, the biological response of both the fish and macroinvertebrate communities strongly signal that the habitat conditions are a stressor to the biotic communities in Unnamed Creek.

Flow alteration and connectivity

Unnamed Creek (07040004-597) is 60% modified according to the Altered Watercourses GIS layer for Minnesota streams. This includes the majority of the sampling site, 04LM010. This layer also indicated that upstream of site 04LM010 is completely channelized. The channelization of streams often leads to bank erosion and instability. Flow alteration and channelization also lead to the reduction of habitat by limiting a streams ability to push fine sediment through a system, which can cover the coarse substrates. Additionally, it changes stream depth variability, which reduces the numbers of riffles and pools present, which are vital for some less tolerant fish and macroinvertebrate species to survive.

Figure 158. Upstream of 04LM010.

The MSHA at site 04LM010 noted little bank erosion, high channel stability, a lot of depth variability and the presence of some course substrates. However, like many altered stream systems a lack of channel development due to channelization can limit the habitat present. Site 04LM010 had only one small pool present, while the majority of the reach (90%) was a run. This lack of variety reduces biological diversity. Also, watersheds with a high degree of channelization can lead to streams with low flow conditions due to poor water retention on the landscape. (Figure 158).

Given the habitat stress found, it is likely that the channelization in portions of Unnamed Creek and in the headwaters is a source of this stress. Therefore, flow alteration and connectivity is a stressor to the impaired biological communities in Unnamed Creek.

Conclusions and recommendations

The impaired fish and macroinvertebrate communities of Salem Creek Tributary (597) are being stressed by elevated nitrate, poor habitat conditions, and flow alteration (Table 72). The nitrate concentrations on this reach are some of the highest observed in the entire Zumbro Watershed, with June having the highest seasonal concentration (June 2004, 26 mg/L; June 2014, 27 mg/L). High nitrate concentrations in May and June are consistent with the very tolerant macroinvertebrate and fish communities and an absence of sensitive species, including those macroinvertebrates most sensitive to high nitrate, like Trichoptera. These elevated seasonal nitrate concentrations are indicative of and correlate to the amount of tile drainage in this watershed. Similarly, habitat conditions at this site were limited and include poor substrates and limited riffle and woody debris habitat which provides cover for fish and are important macroinvertebrate habitat. The channelization in this reach (90% run), reduces habitat availability and complexity. Watersheds with a high degree of channelization and tile drainage, such as this one, often lead to very low flow conditions during baseflow, abnormally high seasonal nitrate concentrations, and limited habitat.

TSS is inconclusive as a stressor due to the mixed response between the fish and macroinvertebrate community which may or may not be due to other stressors. TSS may play into the habitat issues seen in this location but not enough information exists in order for TSS to be confirmed or ruled out as a stressor.

DO was ruled out as a stressor at this point. There were a decent number of intolerant to low DO macroinvertebrate taxa and a mixed DO response overall. More recent high resolution DO data also

does not give much indication that DO is responsible for biological impairment in this reach. Given the lack of consistent response to DO, it seems more probable other stressors are responsible for the responses observed. However, it is important to continue to monitor DO levels due to the high degree of channelization, elevated nutrients and potential flow issues, as these can all lead to future DO issues.

Overall, it would be beneficial if this biological station were resampled because the only assessment data available was from 2004. It's important to verify and determine if the biological condition has changed since this visit. Stressor determination is much less reliable in this instance because of the large gap in time that has elapsed between the sample (20014) and the assessment (2015). It's possible that the biological information relied on during the SID process may not be a complete representation of present day conditions.

Table 72. Summary of stressor determinations for Salem Creek Tributary

Stream Name	AUID	Stressors:					
		Temperature	Dissolved Oxygen (Eutrophication	Nitrate	Suspended Sediment	Habitat	Flow Alteration/Connectivity
Salem Creek Tributary	07040004-597	---	o	●	o	●	●

● = stressor; o = inconclusive stressor; --- = not an identified stressor

5. Conclusions and recommendations for the Zumbro Watershed

5.1 Summary of stressors

The stressors for the biological impairments in the Zumbro Watershed are listed in Table 73. The most common stressor in the watershed was habitat, followed by nitrate and flow alteration/connectivity. Temperature and DO stressors were identified in a few select locations. A more detailed version of this table with potential sources/pathways and locations where additional monitoring is needed can be found in the Appendix 7.3.

Table 73. Summary of probable stressors in the Zumbro Watershed

Stream Name	AUID	Biological Impairment	Stressors						
			Temperature	Dissolved Oxygen and Eutrophication	Nitrate	Total Suspended Solids	Lack of Habitat	Flow Alteration/Connectivity	Chloride/Conductivity
Spring Creek	07040004-568	Inverts	●	---	o	●	---	---	---
Spring Creek	07040004-570	Fish	---	---	o	●	●	---	---
Cold Creek	07040004-510	Inverts	---	---	o	---	●	---	---
Trout Brook (Mazeppa Creek)	07040004-515	Inverts	---	---	o	---	●	o	---
Trout Brook (Dumfries)	07040004-585	Fish	---	---	---	---	●	o	---
Unnamed creek	07040004-964	Inverts	---	o	●	---	●	o	---
Unnamed creek (Spring Creek Tributary)	07040004-605	Inverts	---	---	●	o		---	---
Spring Creek	07040004-606	Inverts	---	●	●	---	●	---	---
Shingle Creek	07040004-562	Inverts	---	---	●	o		---	---
Unnamed Creek	07040004-579	Inverts	---	---	---	---	●	---	---
North Fork Zumbro	07040004-971	Inverts	---	o	o	●	●	---	---
Unnamed Creek	07040004-578	Inverts	---	---	●	o	●	●	---
Middle Fork	07040004-973	Inverts	---	---	●	o	---	---	---
Dodge Center Creek	07040004-989	Inverts	---	---	o	●	●	o	---
Henslin Creek	07040004-618	Inverts	---	---	●	o	---	---	---
Judicial Ditch 1	07040004-987	Inverts	---	●	●	o	●	●	---
Judicial Ditch 1	07040004-988	Fish and Inverts	---	o	●	o	●	●	---
South Branch Middle Fork	07040004-976	Inverts	---	---	o	●	---	---	---
South Branch Middle Fork	07040004-980	Inverts	---	---	o	●	●	●	---
Salem Creek	07040004-503	Inverts	---	---	●	---	●	---	---
Salem Creek Trib	07040004-597	Fish and Inverts	---	o	●	o	●	●	---
Unnamed Creek (Trib to Willow)	07040004-800	Fish and Inverts	---	---	---	---	●	●	---
Badger Run	07040004-620	Fish	---	---	---	o	●	●	---
Unnamed Creek	07040004-621	Fish	---	---	---	---	●	●	---
South Fork Zumbro	07040004-507	Inverts	---	o	o	●	●	●	o
South Fork Zumbro	07040004-536	Inverts	---	---	---	o	●	---	---
Cascade Creek	07040004-581	Inverts	---	o	---	●	●	●	---
Cascade Creek	07040004-991	Fish	---	---	o	o	●	●	---

● = stressor; o = inconclusive stressor; --- = not a stressor

5.2 Recommendations and additional monitoring

In the Zumbro Watershed, the most common stressors identified are habitat and suspended sediment. These stressors are largely tied to land use activities in the watershed. Some sediment issues are related to poor riparian area management, while others are more systemic. Watersheds that have a high degree of human alterations seem most at risk for not only habitat and suspended sediment, but nitrate issues as well. Overall, the stressors will need to be addressed in various ways depending on the location in the watershed. The table in Appendix 7.3 shows not only more detail on potential sources and pathways, but also includes areas where additional monitoring is necessary to help understand stressors.

Table 74. Recommended prioritization of restoration activities relative to the stressors contributing to the biological impairment in the Zumbro Watershed.

Stressor	Priority	Comment
Suspended Sediment	High	Focus on reducing sediment input from riparian corridor (cattle pastures) and immediate stream channel (stream banks).
Habitat	High	Re-establish quality riparian corridor to increase woody debris, stream stability, and stream shading. Protect streambanks, reduce erosion and overall stream sedimentation
Nitrate	High	Utilize a variety of nutrient reducing BMP's including but not limited to: cover crops, nutrient management, saturated buffers, etc.
Flow Alteration	Medium	Increase storage and infiltration of water in locations with flow alteration stressors
DO and Eutrophication	Medium	Collect information as needed for streams that are lacking necessary DO and Eutrophication related information
Connectivity	Low	Solicit MNDNR recommendations for streams with existing connectivity stressors and/or determine if restoration is appropriate
Temperature	Low	Conduct additional monitoring in areas with questions regarding thermal regime

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Blacknose Dace photo
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Cascade gaging station
http://www.dnr.state.mn.us/waters/csg/site_report.html?mode=getsitereport&site=41065002

SF Zumbro gaging station
http://www.dnr.state.mn.us/waters/csg/site_report.html?mode=getsitereport&site=41063001

7. Appendix

7.1 Strength of evidence

Strength of Evidence scoring and analysis was completed for each AUID in the Zumbro Watershed and is available upon request.

Table A1. Values used to score evidence in the Stressor Identification Process.

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*	

Table A2. Strength of Evidence Scores for various types of evidence

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, -

7.2 MDA pesticide data in Zumbro River Watershed

Table 1. Zumbro River Watershed River and Stream Pesticide Sampling (1991-2015)

Pesticide Name	Pesticide Type	Detects	Total Samples	Detection Frequency (%)	Detection Concentration Distribution (ng/L)					Water Quality Standards and/or Reference Values (ng/L)[1]			
					Median	75th %-tile	90th %-tile	95th %-tile	Maxi-mum	MPCA Class 2Bd[5] Chronic Standard[3]	MPCA Maximum Standard[4]	EPA Acute Value Aquatic Life Benchmark (ng/L)[2]	EPA Chronic Value Aquatic Life Benchmark (ng/L)[2]
2,4-D	Herbicide	98	26	27	nd	P(<200)	134	281	719	70,000 H	--	12,075,000(f)	13,100 (v)
Acetochlor	Herbicide	138	86	62	P(<50)	90	424	822	5650	3,600 T	86,000 T	na	na
Acetochlor ESA	Degradate	21	21	100	303	601	1220	1420	1780	--	--	> 62,500,000(i)	9,900,000 (n)
Acetochlor OXA	Degradate	21	18	86	84	225	769	895	1120	--	--	--	--
Alachlor	Herbicide	154	14	9	nd	nd	nd	87	2280	4,200 H; 59,000 T	800,000 T	na	na
Alachlor ESA	Degradate	21	21	100	141	199	216	271	304	--	--	>52,000,000 (f)	—
Alachlor OXA	Degradate	21	3	14	nd	nd	44	47	61	--	--	>47,500,000 (i)	—
Atrazine	Herbicide	154	131	85	100	250	977	1498	3530	3,400 H; 10,000 T	323,000T	na	na
Azoxystrobin	Fungicide	21	4	19	nd	nd	14	20	47	--	--	130,000 (i)	44,000 (i)
Bentazon	Herbicide	21	3	14	nd	nd	1	5	5	--	--	>50,000,000(f)(i)	4,500,000(n)
Clopyralid	Herbicide	21	5	24	nd	nd	60	180	230	--	--	56,500,000 (i)	—
Clothianidin	Insecticide	16	4	25	nd	21	147	178	260	--	--	11,000 (i)	1,100 (i)
DEDI Atrazine	Degradate	21	2	10	nd	nd	nd	62	65	--	--	>50,000,000(f)(i)	—
Deisopropylatrazine	Degradate	148	6	4	nd	nd	nd	nd	168	--	--	8,500,000 (f)	2,500,000(n)
Desethylatrazine	Degradate	148	116	7	110	200	300	393	750	--	--	—	1,000,000(n)
Dicamba	Herbicide	98	7	7	nd	nd	nd	P(<180)	950	--	--	14,000,000 (f)	61,000 (n)
Dichlobenil	Herbicide	26	1	4	nd	nd	nd	nd	5	--	--	1,850,000 (i)	30,000 (v)
Dimethenamid	Herbicide	107	30	28	nd	P(<50)	41	107	680	--	--	3,150,000 (f)	5,100 (v)[6]
Dimethenamid ESA	Degradate	21	16	76	11	21	33	38	83	--	--	—	—
Dimethenamid OXA	Degradate	21	5	24	nd	nd	17	41	58	--	--	—	—
Flumetsulam	Herbicide	16	4	25	nd	22	213	257	279	--	--	127,000,000 (i)	3,100 (v)
Hydroxyatrazine	Degradate	21	21	100	49	61	133	157	166	--	--	> 1,500,000 (f)	>10,000,000(n)
Imazethapyr	Herbicide	21	8	38	nd	11	33	38	98	--	--	120,000,000 (f)	59,200,000(n)
Imidacloprid	Insecticide	21	1	5	nd	nd	nd	nd	27	--	--	34,500 (i)	1,050 (i)
MCPA	Herbicide	98	1	1	nd	nd	nd	nd	270	--	--	90,000 (i)	20,000 (v)
MCPP	Herbicide	98	1	1	nd	nd	nd	nd	190	--	--	>45,500,000(i)	14,000 (n)
Mesotrione	Herbicide	21	3	14	nd	nd	69	163	220	--	--	> 60,000,000(f)	9,800 (v)
Metalaxyl	Fungicide	21	4	19	nd	nd	19	30	34	--	--	14,000,000 (i)	100,000 (i)
Metolachlor	Herbicide	154	130	84	80	218	1222	3042	13000	23,000T	271,000T	na	na
Metolachlor ESA	Degradate	21	21	100	1820	2170	2880	2960	3410	--	--	24,000,000 (f)	>95,100,000(v)
Metolachlor OXA	Degradate	21	21	100	296	514	903	904	1020	--	--	7,700,000 (i)	57,100,000(n)
Metribuzin	Herbicide	154	1	1	nd	nd	nd	nd	111	--	--	2,100,000	8,700 (n)

Pesticide Name	Pesticide Type	Detects	Total Samples	Detection Frequency (%)	Detection Concentration Distribution (ng/L)					Water Quality Standards and/or Reference Values (ng/L)[1]			
					Median	75th %-tile	90th %-tile	95th %-tile	Maxi-mum	MPCA Class 2Bd[5] Chronic Standard[3]	MPCA Maximum Standard[4]	EPA Acute Value Aquatic Life Benchmark (ng/L)[2]	EPA Chronic Value Aquatic Life Benchmark (ng/L)[2]
												(i)	
Propazine	Herbicide	70	4	6	nd	nd	nd	nd	34	--	--	>2,660,000 (i)	24,800 (n)
Propiconazole	Fungicide	56	1	2	nd	nd	nd	nd	18	--	--	425,000 (f)	21,000 (n)
Saflufenacil	Herbicide	21	4	19	nd	nd	86	110	153	--	--	> 49,000 ,000(f)	42,000 (n)
Simazine	Herbicide	131	1	1	nd	nd	nd	nd	P (<80)	4,000 H	4,000 H	500,000 (i)	2,240 (n)
Tembotrione	Herbicide	21	1	5	nd	nd	nd	nd	129	--	--	24,450,000 (i)	5,200 (v)
Terbufos	Insecticide	84	1	1	nd	nd	nd	nd	P (<190)	--	--	100 (i)	30 (i)
Thiamethoxam	Insecticide	21	4	19	nd	nd	84	90	101	--	--	17,500 (i)	20,000,000 (f)
Triclopyr	Herbicide	98	2	2	nd	nd	nd	nd	448	--	--	125,000 (i)	19,000 (f)
Trifluralin	Herbicide	154	1	1	nd	nd	nd	nd	P (<170)	--	--	20,500 (f)	1,140 (f)

Key to value types and symbols in surface water reference values

– – For some analytes, reference values have not been identified or evaluated

na – not applicable

(f) –EPA/OPP benchmark value for fish.

(i) –EPA/OPP benchmark value for invertebrates.

(n) –EPA/OPP benchmark value for nonvascular plants

(v) –EPA/OPP benchmark value for vascular plants.

H – "H" Chronic Standard values are human health-based and protective for an exposure duration of 30 days.

T – "T" Chronic Standard values are toxicity-based for aquatic organisms and protective for an exposure duration of 4 days.

[1] **Reference Values** are given for all detected target and non-target analytes. They are also given for non-detected target analytes when a reference value is available. Other non-detected analytes do not have an available reference value from the sources listed below.

[2] **Aquatic Life Benchmarks** based on toxicity values derived from data available to the EPA OPP supporting registration of the pesticide are provided only when an MPCA value is not available. Current values posted by the EPA's OPP may differ from those of previous MDA reports. See EPA's website for more detailed information and definitions.

[3] **Chronic Standard** as defined in Minn. R. ch. 7050. "H" value is human health-based and is protective for an exposure duration of 30 days. Human health-based values are shown only when they are less than toxicity-based values. "T" value is toxicity-based for aquatic organisms and is protective for an exposure duration of 4 days.

[4] **Maximum Standard Value for Aquatic Life & Recreation** as defined on MPCA's website and Minn. R. ch. 7050. Values are the same for all classes of surface waters.

[5] **State Water Classification for aquatic life** (2B – sport and commercial; 2C – non-commercial; 2D – wetlands) & recreation (2B – all types; 2C,D – limited types). Not protected as drinking water sources.

[6] **For the Dimethenamid Chronic Value,** the MPCA has calculated a non-promulgated criterion for aquatic plants using two point estimates of toxicity to the vascular plant duckweed.

7.3 Expanded summary of stressor table

Key: ●=plausible/suspected source, ○=potential source — Stressor | Inconclusive | Not a Stressor

AUID	Stream Name	Biological Stations	Probable Sources/ Pathways
	SPRING CREEK		
568	Spring Creek	12LM018	M-IBI
570	Spring Creek	12LM001	F-IBI
	COLD CREEK		
510	Cold Creek/Cold Spring	12LM002	M-IBI
	TROUT BROOK (MAZEPPA CREEK)		
515	Trout Brook (Mazeppa Creek)	12LM011, 04LM134	M-IBI
	TROUT BROOK (Dumfries)		
585	Trout Brook	12LM012	F-IBI
	NORTH FORK ZUMBRO		
964	Unnamed creek	12LM037	M-IBI
605	Unnamed creek (Spring Creek Tributary)	12LM101	M-IBI
606	Silver Creek/Spring Creek	04LM087	M-IBI
562	Shingle Creek	12LM033	M-IBI
579	Unnamed Creek	04LM008	M-IBI
971	Zumbro River, North Fork	04LM088, 10EM139, 12LM034, 12LM032, 12LM106; 12LM003	M-IBI
	MIDDLE FORK ZUMBRO		
578	Unnamed Creek (*modified use)	04LM028	M-IBI
973	Middle Fork	04LM142, 07LM022, 12LM045, 12LM046, 12LM004	M-IBI
	SOUTH BRANCH MIDDLE FORK ZUMBRO		
989	Dodge Center Creek	12LM053, 12LM054, 12LM056, 12LM010	M-IBI
618	Henslin Creek	12LM055	M-IBI
987	Judicial Ditch 1	12LM060	M-IBI

Stressors

Temperature

AUID	Lack of Shading	Riparian	Sedimentation	Unidentified	Additional Monitoring?
568				●	ü
570					
510					ü
515					
585					ü
964					
605					
606					
562					
579					ü
971					ü
578					ü
973					ü
989					
618					
987					ü

DO/Eutroph

AUID	Wetland Influence	Excess Phosphorus	Algal/Plant Shift	Unidentified	Additional Monitoring?
568					ü
570					
510					ü
515					
585					
964					ü
605					
606				●	
562					
579					
971					ü
578			●		ü
973		●			ü
989					
618					
987		●			

Nitrate

AUID	Tile Drainage/Land Use	Karst Pathways/Springs	Point Sources	Additional Monitoring?
568				
570		●		
510		●		
515	○	●		ü
585				
964	●			
605	●			
606	●			
562	●			
579				
971	●			
578	●			
973	●			
989				
618	●			
987	●			

TSS

AUID	Flow Alteration/Connectivity	Streambank erosion	Altered	Urbanization	Local Land Use or Pasture	Additional Monitoring?
568		●			●	ü
570		●			●	ü
510						
515		●			●	
585		●				
964						
605						ü
606						
562						ü
579						
971	●	●	●			
578			●			ü
973			●			ü
989			●		●	
618			●			ü
987	○		○			ü

Habitat

AUID	Flow Alteration/Connectivity	Pasturing/Lack of Riparian	Altered	Bedded Sediment	Erosion	Lack of Cover/Other habitats	Additional Monitoring?
568							
570				●	●	●	
510				●	●		
515		●		●	●		
585			●	●		●	
964		●		●		●	
605							
606		●		●			
562							
579				●	●		
971				●	●	●	
578	●	●	●	●		●	
973							
989		●	●	●			
618							
987	●	●	●	●		●	

Flow/Connectivity

AUID	Dams/Impoundments	Road Crossings/Culverts	Water Withdrawal	Altered	Tile Drainage/Land Use	Additional Monitoring?
568						
570						
510	●					
515		●		●		ü
585				●		ü
964	●			●	●	
605				●	●	
606				●	●	
562						
579						
971				●	●	
578				●	●	
973						
989						ü
618						
987				●	●	

Chloride

AUID	Urbanization/Road Salt	Wastewater or industrial	Additional Monitoring?
568			
570			
510			
515			
585			
964			
605			
606			
562			
579			
971			
578			
973			
989			
618			
987			

Key

●=plausible/suspected source, ○=potential source | Stressor | Inconclusive | Not a Stressor

AUID	Stream Name	Biological Stations	Probable Sources/ Pathways	Temperature: Lack of Shading	Temperature: Riparian	Temperature: Sedimentation	Temperature: Unidentified	Temperature: Additional Monitoring?	DO/Eutroph: Wetland Influence	DO/Eutroph: Excess Phosphorus	DO/Eutroph: Algal/Plant Shift	DO/Eutroph: Unidentified	DO/Eutroph: Additional Monitoring?	Nitrate: Tile Drainage/Land Use	Nitrate: Karst Pathways/Springs	Nitrate: Point Sources	Nitrate: Additional Monitoring?	TSS: Flow Alteration/Connectivity	TSS: Streambank erosion	TSS: Altered	TSS: Urbanization	TSS: Local Land Use or Pasture	TSS: Additional Monitoring?	Habitat: Flow Alteration/Connectivity	Habitat: Pasturing/Lack of Riparian	Habitat: Altered	Habitat: Bedded Sediment	Habitat: Erosion	Habitat: Lack of Cover/Other habitats	Habitat: Additional Monitoring?	Flow/Connectivity: Dams/Impoundments	Flow/Connectivity: Road Crossings/Culverts	Flow/Connectivity: Water Withdrawal	Flow/Connectivity: Altered	Flow/Connectivity: Tile Drainage/Land Use	Flow/Connectivity: Additional Monitoring?	Chloride: Urbanization/Road Salt	Chloride: Wastewater or industrial	Chloride: Additional Monitoring?
988	JD 1	12LM057	F-IBI, M-IBI							●			ü	●				○		○			ü	●	●	●	●		●					●	●				
976	SMBF Zumbro (DC Creek to Oxbow)	12LM051, 12LM084	M-IBI							●				●			ü	●																				
980	SBMF Zumbro (DS rice lake)	12LM052, 04LM043	M-IBI										ü	●			ü	●		●					●	○	●	●	●					●	●				
	SOUTH BRANCH ZUMBRO																																						
503	Salem Creek	12LM063, 12LM009	M-IBI											●											●		●	●											
597	Salem Creek Trib	04LM010	F-IBI, M-IBI										ü	●						○			ü		●	●								●	●				
800	Unnamed Creek (Trib to Willow)	12LM080	F-IBI, M-IBI																					●			●				●			●	●				
620	Badger Run	12LM077, 04LM056(US AUID)	F-IBI																				ü				●	●	●			●		●	●				
621	Unnamed Creek	12LM081	F-IBI																					●	●	●	●	●	●			●							
507	Zumbro River, South Fork	12LM066, 12LM007, 04LM125	M-IBI							●	●		ü	●		●		●		○	○			●		●	●				●		○	●	●		●	●	ü
536	Zumbro River, South Fork	12LM069	M-IBI																				ü				●												
581	Cascade Creek	04LM124	M-IBI							●			ü					●		○	○				●	●	●							●	●				
991	Cascade Creek	12LM102, 04LM123	F-IBI							●			ü	●						○	○	○	ü		●		●	●	●			●	●		●	●				

Map disclaimer