Cannon River Watershed Stressor Identification Report

A study of local stressors limiting the biotic communities in the Cannon River Watershed.

Minnesota Pollution Control Agency

October 2015

wq-ws5-07040002a

Legislative charge

Minn. Stat. § 116.011 Annual Pollution Report

A goal of the Minnesota Pollution Control Agency (MPCA) is to reduce the amount of pollution that is emitted in the state. By April 1 of each year, the MPCA shall report the best estimate of the agency of the total volume of water and air pollution that was emitted in the state the previous calendar year for which data are available. The agency shall report its findings for both water and air pollution, etc., etc.

HIST: 1995 c 247 art 1 s 36; 2001 c 187 s 3

Authors

Kim Laing (MPCA)
Joe Magee (MPCA)

Contributors/acknowledgements

Jen Ender (MPCA)
Tiffany Schauls (MPCA)
Chuck Johnson (MPCA)
Justin Watkins (MPCA)
Brenda DeZiel (MPCA)
John Genet (MPCA)
Joel Chirhart (MPCA)
Ashley Ignatius (MPCA)
Mark Gernes (MPCA)
Paul Marston (MPCA)
Colton Cummings (MPCA)
Kelsey Budahn (MPCA)
Dave Tollefson (MDA)
Brent Beste (DNR)
Todd Kolander (DNR)
Nick Proulx (DNR)
Jon Lore (DNR)
Brooke Hacker (DNR)
Reid Northwick (DNR)
David DePaz (DNR)
Kevin Stauffer (DNR)
Randy Binder (DNR)

Editing and graphic design

Jinny Fricke
Cathy Rofshus

The MPCA is reducing printing and mailing costs by using the Internet to distribute reports and information to wider audience. Visit our website for more information.

The MPCA reports are printed on 100% post-consumer recycled content paper manufactured without chlorine or chlorine derivatives.

Contents

List of Tables

List of Figures

Key Terms & Abbreviations

AUID	Assessment Unit ID
BEHI	Bank Erosion Hazard Index
BHR	Bank Height Ratio
BOD	biological oxygen demand
CADDIS	Causal Analysis/Diagnosis Decision Information System
CBI	coldwater biotic index
CCSI	channel condition stability index
CL	confidence limits
cm	centimeter
DELT	Deformities, Eroded fins, Lesions, and Tumors
DO	Dissolved Oxygen
EDA	Environmental Data Access
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
FIBI	Fish Index of Biological Integrity
FWC	Flow weighted concentration
GP	Glide/Pool
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
IWM	Intensive Watershed Monitoring
LMB	Lower Mississippi Basin
MDA	Minnesota Department of Agriculture
MDH	Minnesota Department of Health
MDNR	Minnesota Department of Natural Resources
MIBI	Macroinvertebrate Index of Biological integrity
mg/L	milligrams per Liter
MPCA	Minnesota Pollution Control Agency
MSHA	MPCA Stream Habitat Assessment
N	Nitrate
NBS	near bank stress
NTU	Nephelometric Turbidity Units
PDSI	Palmer Drought Severity Index
RR	Riffle Run
SID	Stressor Identification
SOE	Strength of Evidence
SSURGO	Soil Survey Geographic Database
TIV	Tolerance Indicator Value
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
TSVS	Total Suspended Volatile Solids

USDA	United States Department of Agriculture
USGS	United States Geological Survey
W/D	width to depth ratio
WRAPS	Watershed Restoration and Protection Strategies
WWTP	Wastewater Treatment Plant

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. The SID 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 SID work in the Cannon River Watershed. There are 34 AUIDs currently impaired for a lack of biological assemblage. During the original assessment in 2013, three AUIDs were deferred due to uncertain flow and wetland conditions; a follow-up assessment was completed in 2015 which resulted in impairments for two of these AUIDs.

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

- Temperature
- Nitrate
- Phosphorus
- DO
- TSS
- Habitat
- Fish Passage
- Flow Alteration
- Chloride

1. Introduction

1.1. Monitoring and Assessment

Water quality and biological monitoring in the Cannon River Watershed have been ongoing. As part of the MPCA's Intensive Watershed Monitoring (IWM) approach, monitoring activities increased in rigor and intensity during 2011, 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 obtained prior to 2011, were used to identify stream reaches that were not supporting healthy fish and macroinvertebrate assemblages (Figure 1).

Once a biological impairment is discovered, the next step is to identify the source(s) of stress on the biological community. A 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.

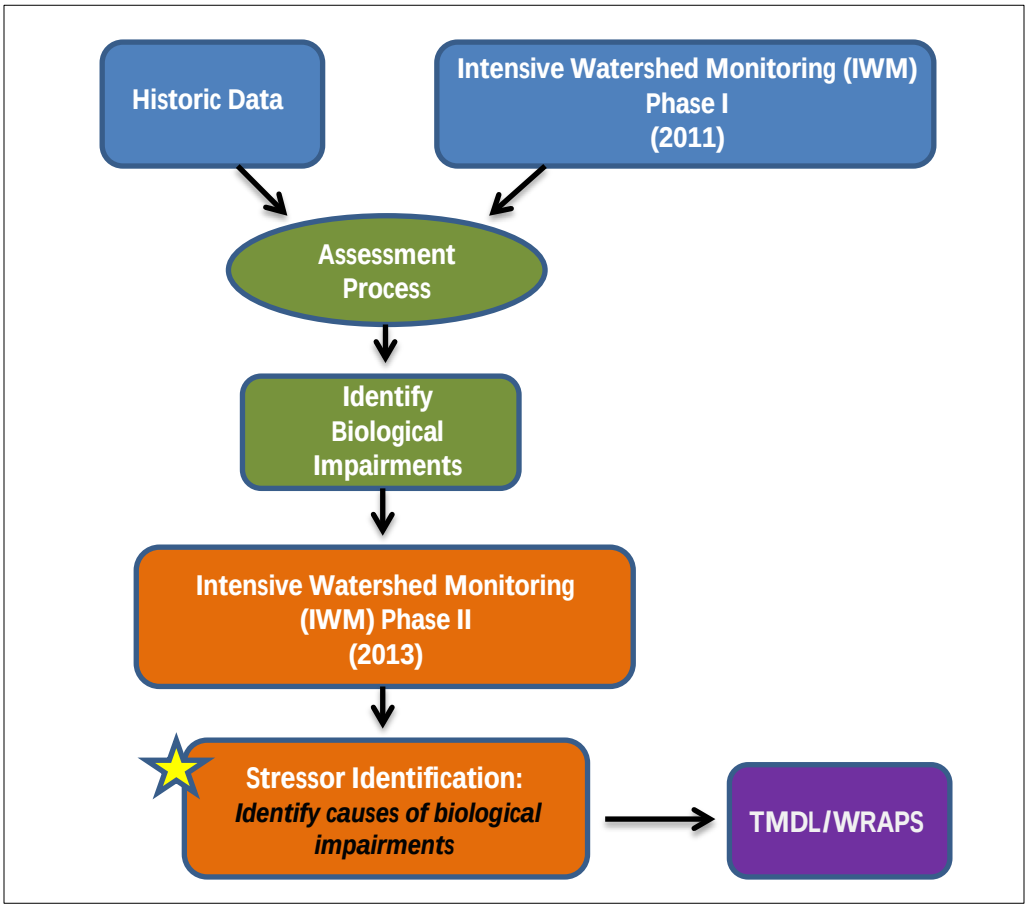


Figure 1. Process map of Intensive Watershed Monitoring, Assessment, Stressor Identification and TMDL processes.

1.2. Stressor Identification Process

The MPCA follows the EPA's process of identifying stressors that cause biological impairment, which has been used to develop the MPCA's guidance to SID (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/.

The 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.

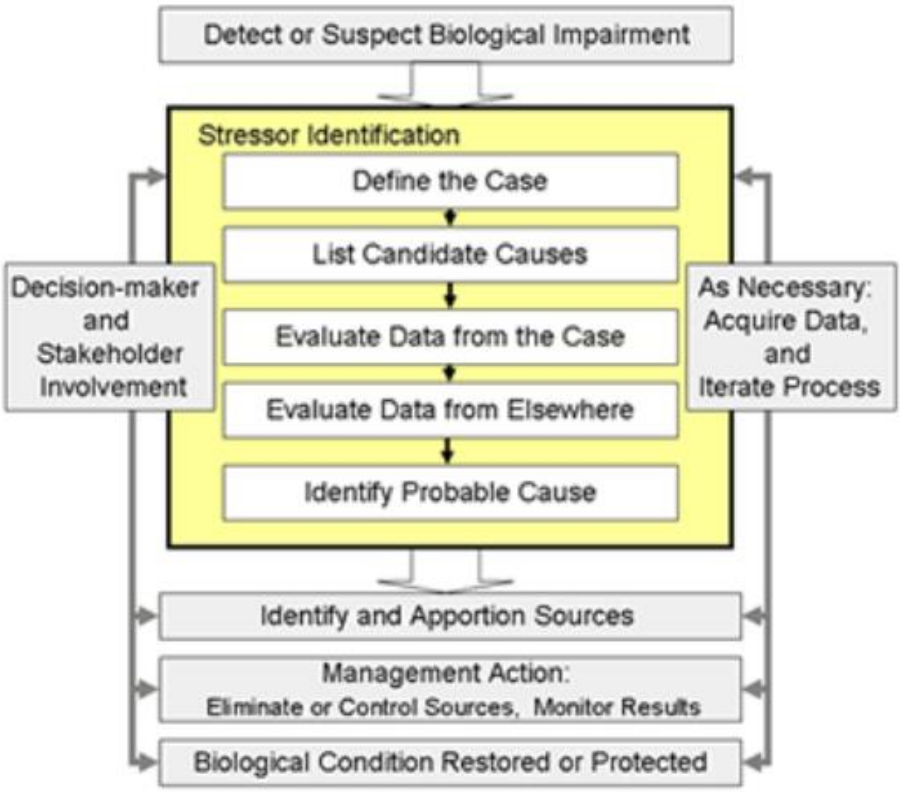


Figure 2. Conceptual model of Stressor Identification process (Cormier et al. 2000).

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 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. 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.
Water Chemistry	**Low Dissolved Oxygen Concentrations** **Elevated levels of Nutrients** · Increased nutrients from human influence · Widely variable DO levels during the daily cycle · Increased algal and or periphyton growth in stream · Increased nonpoint pollution from urban and agricultural practices · Increased point source pollution from urban treatment facilities	There is a loss of intolerant species and a loss of diversity of species, which tends to favor species that can breathe air or survive under low DO conditions. Biology tends to be dominated by a few tolerant species.
Stream Biology	Fish and macroinvertebrate communities are affected by all of the above listed stressors	If one or more of the above stressors are affecting the fish and macroinvertebrate community, the IBI scores will not meet expectations and the stream will be listed as impaired.

1.4. Report Format

This SID report follows a format to first summarize candidate causes of stress to the biological communities at the 8-digit HUC scale. Within the summary (Section 3), there is information about how the stressor relates broadly to the Cannon River Watershed, water quality standards and general effects on biology. Section 4 is organized by impaired AUID, grouped within 10 digit HUC watersheds, and discusses the available data and relationship to fish and macroinvertebrate metrics in more detail.

2. Overview of the Cannon River Watershed

2.1. Background

The Cannon River Watershed drains 946,440 acres (1460 mi^2) in southeastern Minnesota and consists of two river systems: the Cannon River and the Straight River (Figure 3). From west to east, the Cannon River travels 112 miles between Shields Lake and the Mississippi River north of Redwing. From south to north, the Straight River flows 56 miles through the cities of Owatonna and Medford before connecting with the Cannon River downstream of the dam in Faribault.

The Cannon River Watershed spans a portion of nine counties. The six counties with the largest land area in the watershed include Steele, Rice, Goodhue, Dakota, LeSueur, and Waseca while small portions of Scott, Blue Earth, and Freeborn dot the periphery of the watershed.

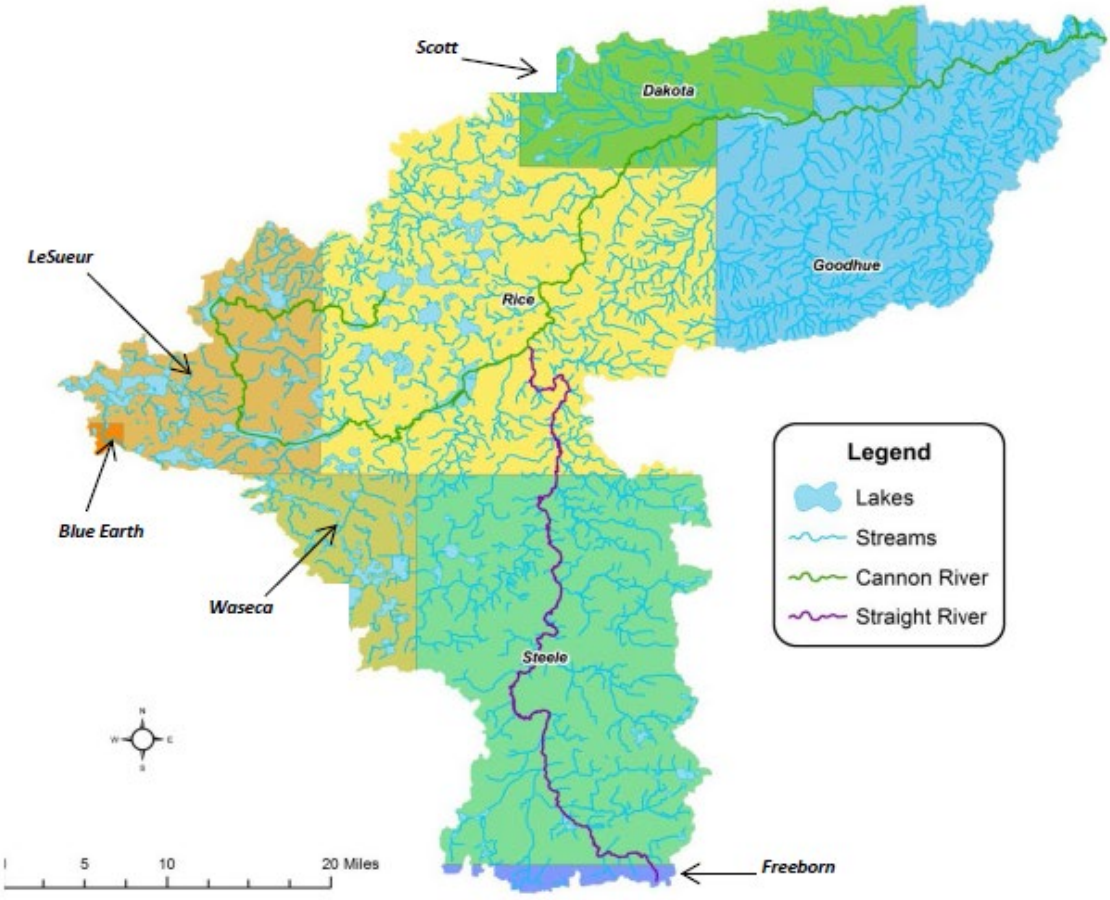


Figure 3. Counties and river courses within the Cannon River Watershed.

The Cannon River Watershed is comprised of three Level III ecoregions (Figure 4): North Central Hardwoods (NCH), Western Cornbelt Plains (WCBP) and Driftless Area (Omernik and Gallant 1988). The ecosystem framework attempts to characterize broad regional differences in geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (Omernik 1995) and consequent ecosystem

responses to disturbance (Bryce et al. 1999) in order to assist agencies and organizations in design and implementation of effective management strategies (Omernik et al. 2000).

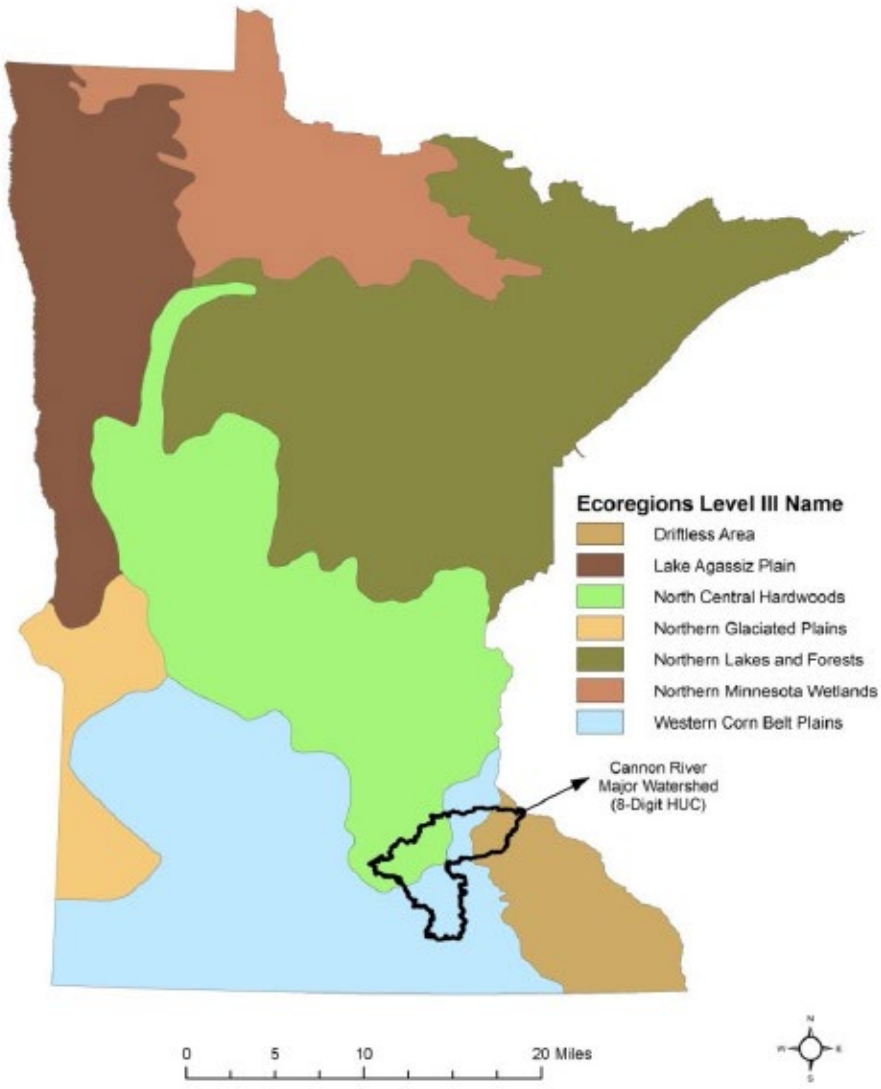


Figure 4. The Cannon River Watershed within the level III ecoregions of Minnesota.

The Level III ecoregions were recently further subdivided into Level IV ecoregions (EPA 2007). In the northwest corner of the watershed lies the southern extent of the NCH and includes the Big Woods. This region was once hardwood forests covering rolling plains dotted with lakes. Today the hardwood forests have largely been removed and the region is dominated by row-crop agriculture and residential development. The northern lobe of the WCBP runs through the south and central regions of the watershed, which includes the headwaters of the Straight River and central portion of the Cannon River. The portion along the Straight River lies within the eastern Iowa and Minnesota Drift Plains, which is described as an "older glacial till plain with mostly row crops and some pasture" while the Cannon River portion falls within the Lower St Croix and Vermillion Valleys which is described as a "dissected till plain and outwash valleys with a mix of row crops and pasture" (EPA 2007). On the eastern side lies the Blufflands and Coulees region of the Driftless Area. This region has steep hills and plateaus and was

densely forested. For a time, these steep hills were intensely farmed; however, today, many acres are now managed as forest with cropland and pasture in the valleys.

The Cannon River Watershed has three major land resource areas (Figure 5). The central Iowa and Minnesota Till Prairies covers the largest portion of the western and southern extent of the watershed including almost all of the Straight River Watershed, and all of the Upper Cannon, Wolf Creek, Heath Creek, and western side of the Middle Cannon Watershed. Part of the Des Moines Lobe of the Wisconsin ice sheet, the land is mostly a rolling glaciated plain of sand and gravel with higher hills formed by glacial meltwaters with lake plains in some areas. Consequently, the geology is predominantly glacial till, outwash and glacial lake deposits with clay, silt, sand, and gravel fill the bottoms of most of the major river valleys (NRCS 2006). Soils are generally very deep, loamy, and range from well drained to very poorly drained. The eastern Iowa and Minnesota Till Prairies encompasses land near Northfield and Cannon Falls and including the Byllesby Reservoir with small portions on the eastern side of the Straight River Watershed, lower Middle Cannon River, Prairie Creek, Chub Creek, and northern half of the Lower Cannon River subwatersheds. The topography is gently rolling with few lakes and ponds. The geology is a mix of glacial till and outwash deposits with clay, silt, sand, and gravel fills the major river valleys. Karst features exist in this area with shallow depth of soils and glacial material covering limestone. Soils are classified as well drained to very poorly drained. Subsurface drain tile is commonly used to lower water tables and increase crop production (NRCS 2006). Northern Mississippi Valley Loess Hills lies on the far eastern extent of the watershed and includes Belle Creek, the Little Cannon, and Spring Creek Watersheds. This region is part of what is known as the “Driftless Area” because it underwent limited landscape formation by glacial ice. The resulting landscape is mostly gently sloping to rolling summits that create scenic landscapes of deep valleys, abundant rock outcrops, high bluffs, caves, crevices, and sinkholes (NRCS 2006). Limestone and sandstone outcrops are observed along some streams and rivers in the area. Loess deposits cover bedrock in many areas. Some karst areas exist where carbonate rocks are near the surface. Soils are generally moderately deep to very deep, loamy, and well drained to moderately well drained.

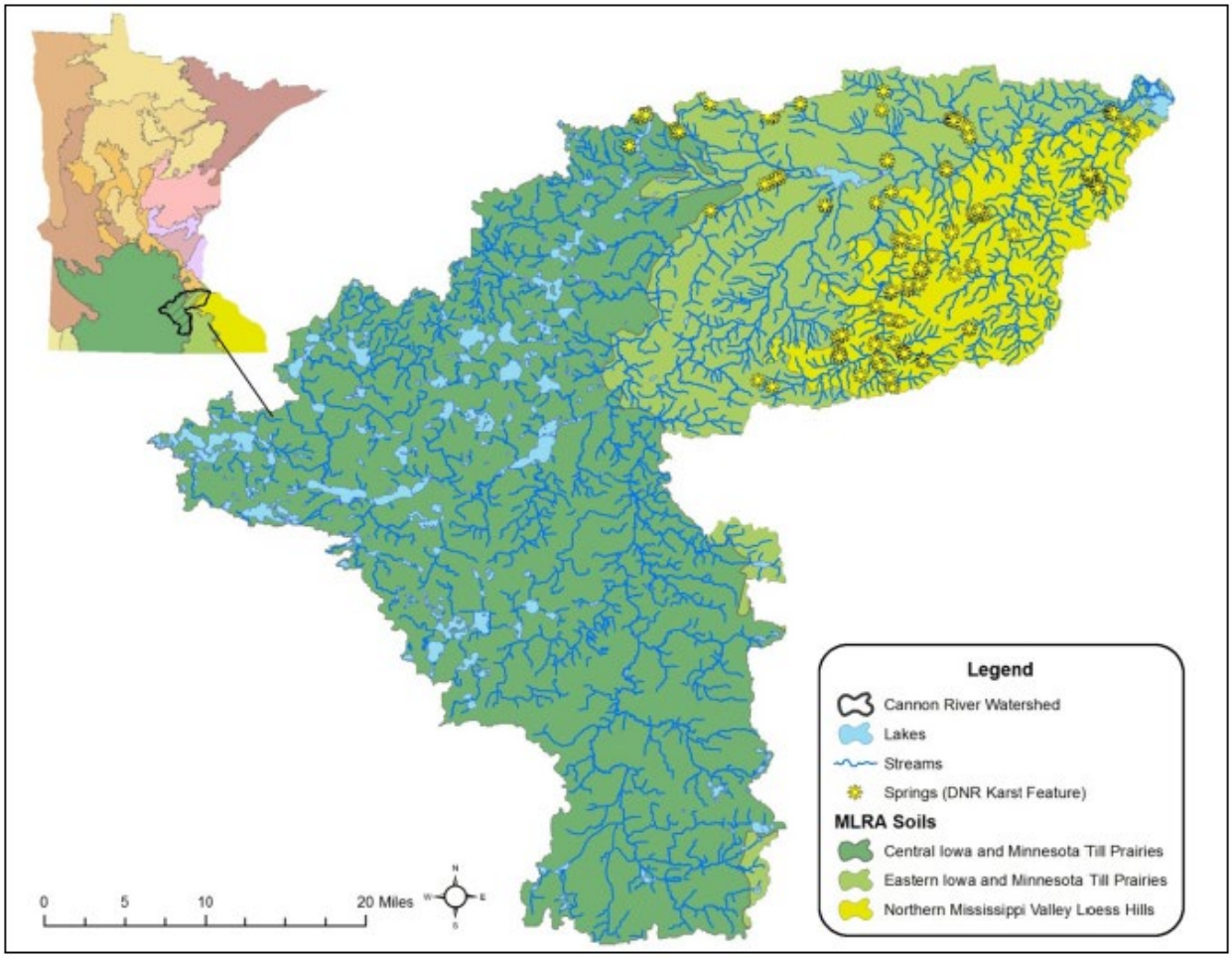


Figure 5. Major land resource areas and springs in the Cannon River Watershed.

Today, the Cannon River Watershed is comprised of a variable mix of agriculture, forest, and developed land (Figure 6). Agriculture is the dominant land use (76.3%), consisting of cropland (60.5%) and rangeland (15.7%). Cropland is used predominantly for growing corn and soybeans. Forest (9.4%) and wetland (3.1%) comprise 12.5%. Developed land (e.g., industrial land use, urban and rural housing, roads) is 8.4%. Open water (e.g., lakes, rivers, streams, ditches) accounts for 2.9%.

The total watershed population is approximately 194,000 people (NRCS 2007). The three largest cities stretch along the banks of the Straight and Cannon Rivers: Owatonna, Faribault, and Northfield. Smaller cities line the river banks and are scattered throughout agricultural areas: Waseca, Ellendale, Medford, Waterville, Morristown, Kilkenny, Lonsdale, Dundas, Cannon Falls, New Trier, Miesville, Randolph, Dennison, Nerstrand, and Welch. Several unincorporated communities dot the watershed as well.

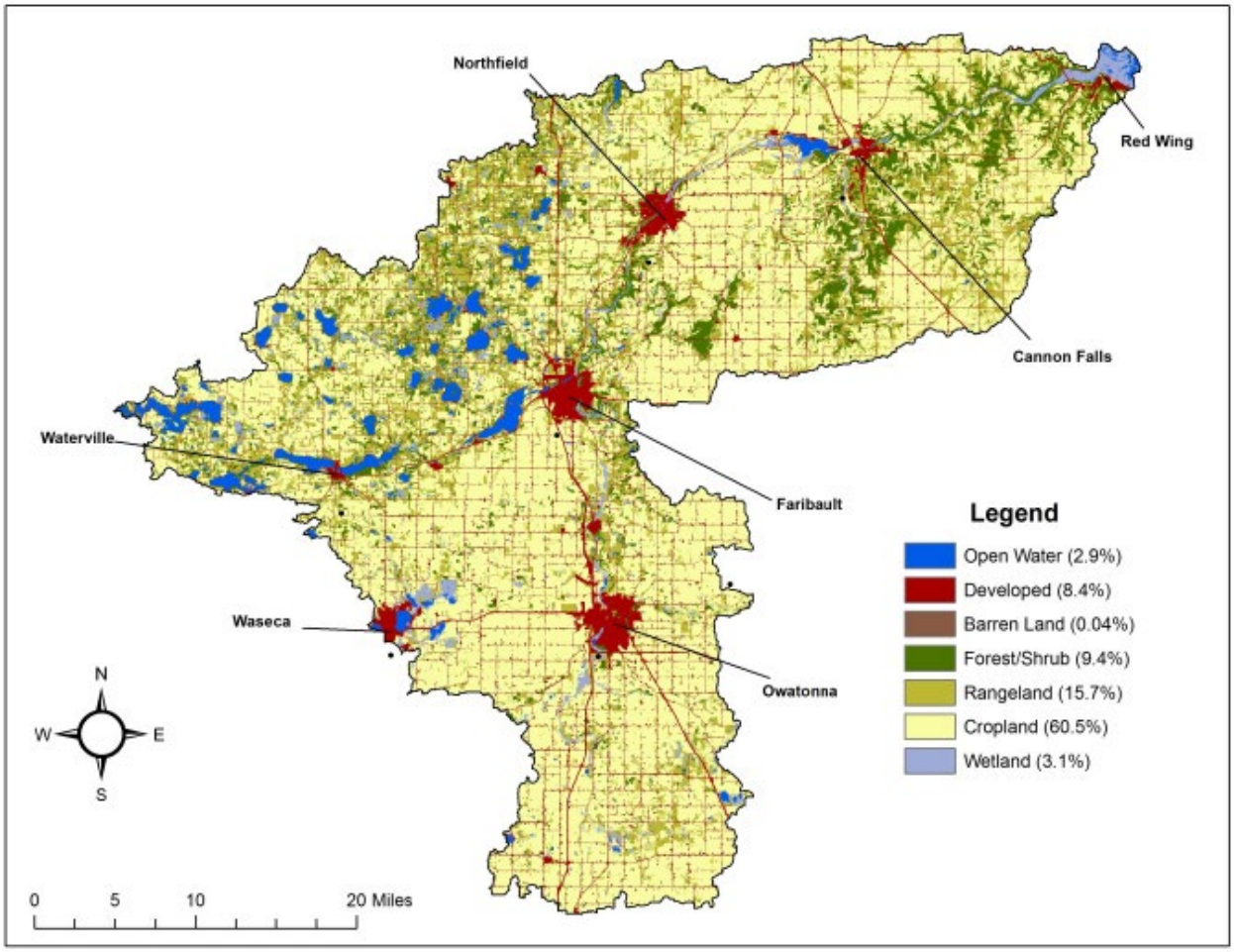


Figure 6. Land use in the Cannon River Watershed. The above map was taken from the Cannon River Watershed Monitoring and Assessment Report.

This SID report examines the biological impairments found during the 2013 watershed assessments, which are summarized in the Cannon River Watershed Monitoring and Assessment Report. The above background information was taken from the Monitoring and Assessment Report; additional background information can be found in that report.

2.2. Monitoring Overview

The Cannon River Watershed was sampled intensively for fish and macroinvertebrates in 2011 (Figure 7). Detailed information regarding the biological monitoring process and impairment decisions can be found in the Cannon River Watershed Monitoring and Assessment Report.

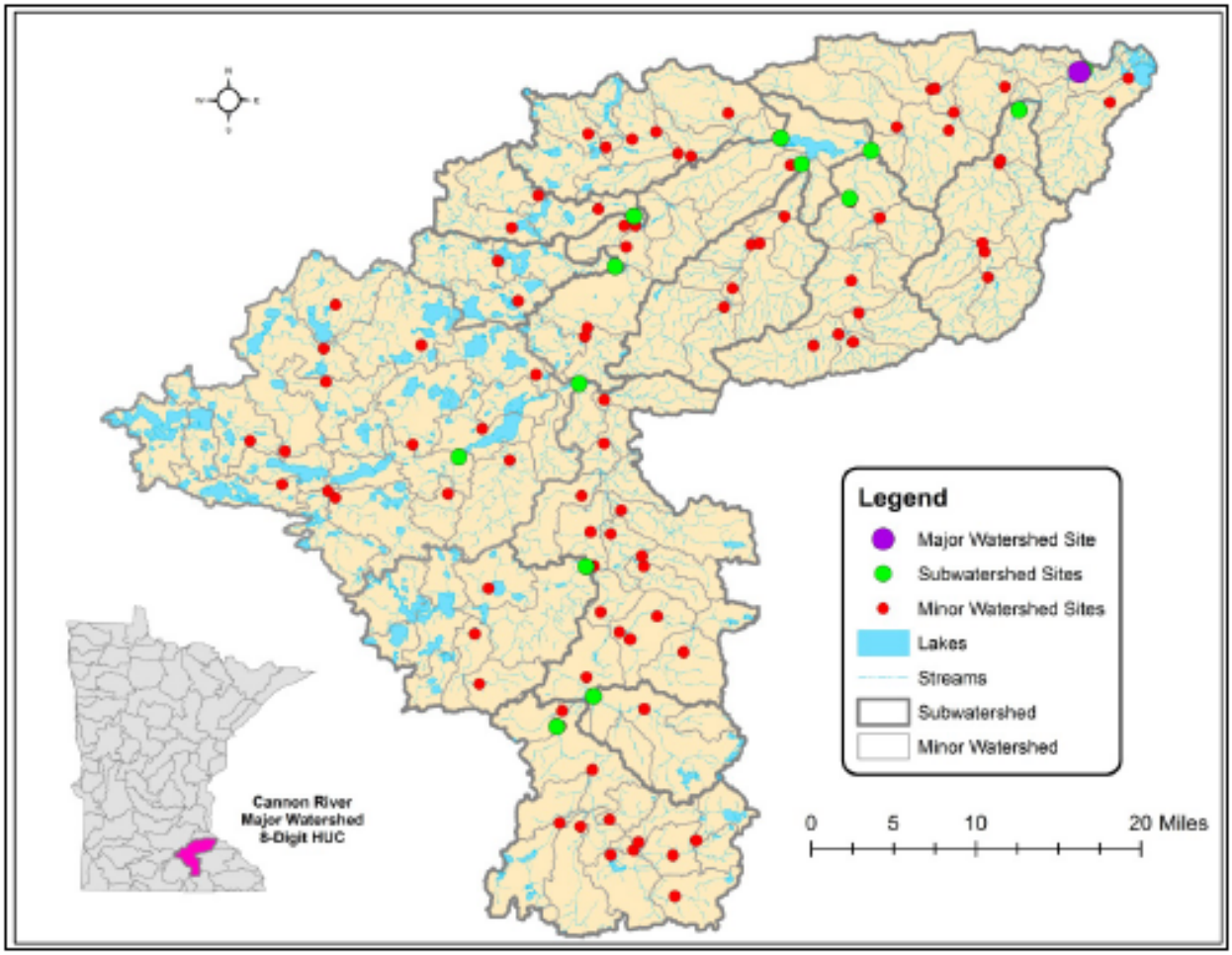


Figure 7. Intensive watershed monitoring sites for streams in the Cannon River Watershed. The above map was taken from the Cannon River Watershed Monitoring and Assessment Report.

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 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 (CL) 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 Cannon River Watershed, 34 AUIDs are currently impaired for a lack of biological assemblage (Table 2). During the original assessment in 2013, three AUIDs were deferred due to uncertain flow and wetland conditions; a follow-up assessment was completed in 2015 which resulted in impairments for two of these AUIDs.

Table 2. Biologically impaired AUIDs in the Cannon River Watershed.

			Impairments	
Stream Name	**AUID #**	**Reach Description**	**Biological**	**Water Quality**
Whitewater Creek	706	Unnamed cr to Waterville Cr	Macroinvertebrates	Bacteria
Waterville Creek	560	Hands Marsh to Upper Sakatah Lk	Fish and Macroinvertebrates	Bacteria
Devils Creek	577	Unnamed cr to Cannon R	Macroinvertebrates	Bacteria
Unnamed creek	705	Unnamed cr to Cannon R	Fish	Bacteria
MacKenzie Creek	576	T108 R21W S7, west line to Cannon Lk	Macroinvertebrates	Bacteria
Unnamed creek	638	Unnamed cr to Cannon R	Macroinvertebrates	
Cannon River	542	Headwaters to Cannon Lk	Macroinvertebrates	DO, Bacteria
Unnamed creek	731	Unnamed cr to Unnamed cr	Macroinvertebrates	
Medford Creek	547	Headwaters to Straight R	Fish and Macroinvertebrates	
Straight River	503	Maple Cr to Crane Cr	Macroinvertebrates	Turbidity, Bacteria
Straight River	536	Crane Cr to Rush Cr	Macroinvertebrates	Turbidity
Straight River	515	Rush Cr to Cannon R	Macroinvertebrates	Turbidity, Bacteria
Unnamed creek	732	Headwaters to Unnamed cr	Macroinvertebrates	
Chub Creek	528	Headwaters to Cannon R	Fish and Macroinvertebrates	Bacteria
Unnamed creek	587	Unnamed cr to Unnamed cr	Macroinvertebrates	
Unnamed creek	512	Headwaters to Prairie Cr	Macroinvertebrates	Turbidity, Bacteria
Unnamed creek	723	Unnamed cr to Prairie Cr	Macroinvertebrates	
Prairie Creek	504	Headwaters to Lk Byllesby	Macroinvertebrates	Turbidity, Bacteria
Unnamed creek (Spring Brook)	557	Unnamed cr to Cannon R	Macroinvertebrates	Turbidity, Bacteria, Nitrate
Spring Creek	591	Unnamed cr to Unnamed cr	Macroinvertebrates	
Cannon River	582	T110 R20W S19, NE1/4 line to Wolf Cr	Macroinvertebrates	Bacteria
Cannon River	507	Wolf Cr to Heath Cr	Macroinvertebrates	Turbidity,

				Bacteria
Cannon River	509	Northfield Dam to Lk Byllesby inlet	Fish and Macroinvertebrates	Turbidity, Bacteria
Cannon River	539	Byllesby Dam to Little Cannon R	Macroinvertebrates	
Unnamed ditch	555	T111 R22W S1, north line to Unnamed cr	Fish and Macroinvertebrates	
Unnamed creek (Little Cannon River Tributary)	670	T110 R18W S12, south line to Unnamed cr	Macroinvertebrates	
Unnamed creek (Little Cannon River Tributary)	639	T110 R18W S1, east line to Little Cannon R	Macroinvertebrates	
Butler Creek	590	Unnamed cr to Little Cannon R	Macroinvertebrates	Turbidity, Bacteria
Little Cannon River (Goodhue County)	589	T110 R18W S10, west line to T111 R18W S13, east line	Fish and Macroinvertebrates	Turbidity, Bacteria, Nitrate
Little Cannon River (Goodhue County)	526	T111 R17W S18, west line to Cannon R	Macroinvertebrates	Turbidity, Bacteria
Unnamed creek (Trib to Trout Brook)	580	Unnamed cr to Unnamed cr	Macroinvertebrates	
Unnamed creek (Trout Brook)	573	T113 R17W S27, west line to Unnamed cr	Macroinvertebrates	
Dutch Creek	572	Headwaters to Chub Cr	Fish and Macroinvertebrates	
Heath Creek	521	Headwaters (Union Lk 66-0032-00) to Cannon R	Fish and Macroinvertebrates	Bacteria

The IBI thresholds for stream classes sampled in the Cannon River Watershed can be found below in Table 3 and Table 4. Additional information can be found in the Cannon River Watershed Monitoring and Assessment Report.

Table 3. Fish classes with respective IBI thresholds and upper/lower CL found in the Cannon River Watershed.

Class	Class Name	IBI Thresholds	Upper CL	Lower CL
1	Southern Rivers	46	57	35
2	Southern Streams	45	54	36
3	Southern Headwaters	51	58	44
7	Low Gradient	40	50	30
10	Southern Coldwater	45	58	32

Table 4. Macroinvertebrate classes with respective IBI thresholds and upper/ lower CL found in the Cannon River Watershed.

Class	Class Name	IBI Thresholds	Upper CL	Lower CL
2	Prairie Forest Rivers	30.7	41.5	19.9
5	Southern Streams RR	35.9	48.5	23.3
6	Southern Forest Streams GP	46.8	60.4	33.2
9	Southern Coldwater	46.1	59.9	32.3

The purpose of SID 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. A summary of the macroinvertebrate and fish IBI scores can be found in the Cannon River Watershed Monitoring and Assessment Report.

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. Eliminated Causes

There were no causes eliminated from the Cannon River Watershed.

3.2. Inconclusive Causes (insufficient information)

Some candidate causes were unable to be considered further and therefore were determined inconclusive. These causes were inconclusive due to lack of information, lack of biological connection, and/or mixed results (water quality and/or biological). The potential causes that were inconclusive in the Cannon River Watershed were pesticides, ammonia, and pH. These causes are discussed in more detail below.

3.2.1. Pesticides

A pesticide 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 (ChE) 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 (USDA) (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 located at http://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 routinely analyzes for, three have been named a "surface water pesticide of concern" in Minnesota -- 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. To understand more about the MDA surface water monitoring program, visit: http://www.mda.state.mn.us/monitoring.

3.2.1.1. Water Quality Standards

Since 1985, the MDA and the 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 learn more about the MDA pesticide monitoring plan and results go to the following website, http://www.mda.state.mn.us/protecting/cleanwaterfund/pesticidemonitoring.aspx.

Surface water reference values (text from MDA, 2010)

The MPCA has developed toxicity-based (for aquatic life) or human health-based enforceable chronic standards for pollutants detected in surface water. The toxicity-based standard is designed to be protective of aquatic life exposure, and is typically based on exposure duration of four days. The human health-based standard (protective for drinking water plus fish consumption) is based on exposure duration of 30 days. For the most current MPCA water quality rules see Minn. R. ch. 7050: Standards for Protection of Waters of the State (https://www.revisor.mn.gov/rules/?id=7050). A summary of MPCA's chronic and maximum standard values for common pesticides used in Minnesota are shown in Table 5.

Table 5. Summary of MPCA surface water standards associated with target pesticides analytes.

Pesticide Analyte	Class 2A	Class 2B	Maximum Standard
Acetochlor	**3.6**	**3.6**	**86**
Alachlor	**59**	**59**	**800**
Atrazine	**10**	**10**	**323**
Chlorpyrifos	**0.041**	**0.041**	**0.083**
Metolachlor	**23**	**23**	**271**

1 Chronic standards are defined in Minn. R. ch. 7050 as toxicity-based for aquatic organisms and is protective for an exposure duration of 4 days

2 Maximum standard value for aquatic life & recreation as defined in Minn. R. ch. 7050. Values are the same for all classes of surfacewaters.

3 State water classification for coldwater streams and all recreation.

4 State water classification for cool and warmwater streams and all recreation.

3.2.1.2. Sources and Causal Pathways Model for Pesticides

For the background and to see the Conceptual Model for herbicides, follow this link: http://www.epa.gov/caddis/ssr_herb_int.html.

3.2.1.3. Overview of Pesticides in the Cannon River Watershed (provided by David Tollefson, MDA)

The 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.

The MDA has conducted a large amount of pesticide monitoring in the Cannon River Watershed. Since 1991, the MDA has collected and analyzed 220 pesticide samples from 15 different river and stream locations, and four samples from four different lakes since 2007. Most of the river and stream samples were collected from three locations: the Cannon River near Welch (S000-003), the Little Cannon River at CR-24 near Cannon Falls (S004-512), and the Straight River near Faribault (S003-557). The MDA continues to sample at these three locations. In addition to these locations, 12 additional river/streams were sampled over several years as part of MDA's tiered network or as part of a MPCA randomized survey (EMAP) in 2010. All samples were collected as grab samples. Pesticide monitoring locations in the Cannon River Watershed are presented in Figure 8. For more information about MDA's monitoring, please refer to: http://www.mda.state.mn.us/chemicals/pesticides/maace.aspx.

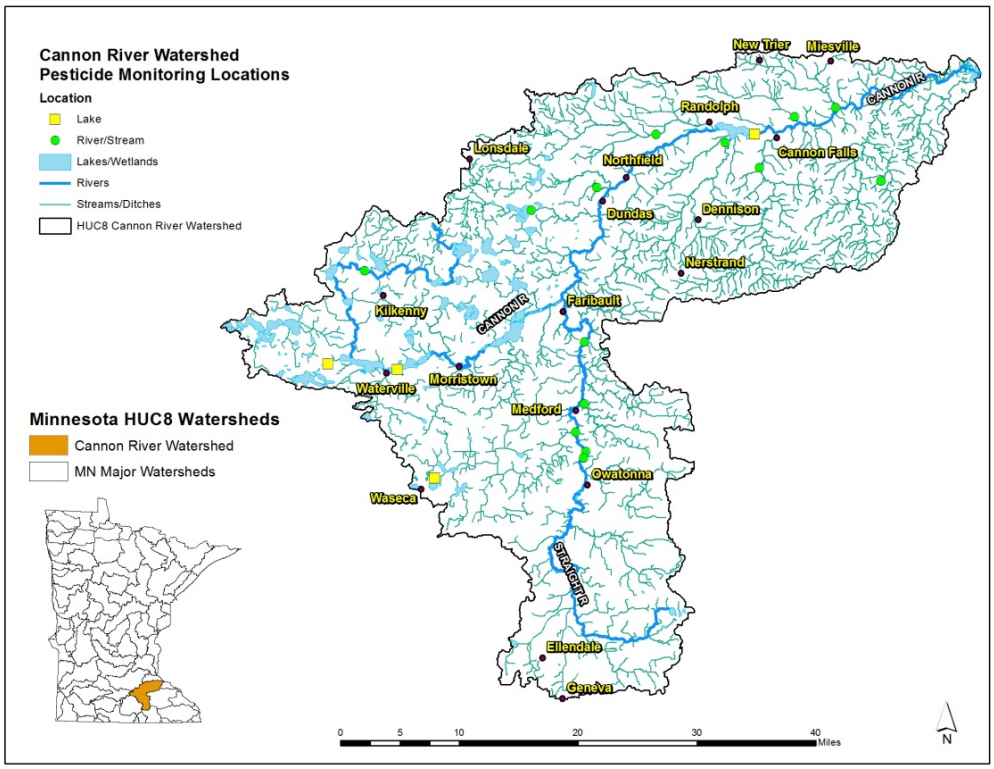


Figure 8. Map showing river, stream, and lake locations where pesticide data has been collected in the Cannon River Watershed.

Pesticides (including herbicides, fungicides, and insecticides) are considered potential stressors in the Cannon River Watershed due to the surrounding land use. Pesticide results are presented in Table 6 (river/streams) and Table 7 (lakes) below. Since 1991, a total of 30 different pesticides (19) or pesticide degradates (11) have been detected in rivers or streams, and since 2007, a total of 17 different pesticides (seven) or pesticide degradates (10) have been detected in lakes in the Cannon River Watershed. 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, the MPCA Class 2Bd Chronic Standards are developed with a duration exposure of four days. Therefore, concentration data cannot solely be used for assessment. All of the data collected by MDA is reviewed annually by the MPCA for the assessment of water quality standards. As of 2014, there is no water quality impairments related to pesticides in the Cannon River Watershed.

All of the detections in lakes were well below applicable water quality standards or reference values. For rivers and streams, 28 of the 30 detected pesticide compounds were well below applicable water quality standards or reference values. Many pesticides have low detection frequency, and many detections occur near the laboratory method reporting limit (MRL) and are extremely low when compared to applicable water quality reference values and standards (Table 6). Atrazine was detected in a single instantaneous grab sample once above the 30-day MPCA Class 2A Human Health Based Standard collected from the Little Cannon River at CR-24 near Cannon Falls (S004-512) in 2011. Also, dichlorvos was detected at "Present but below the MRL (15 ng/L)" from the Straight River near Faribault (S003-557), which may have been above the EPA Chronic Value Aquatic Life Benchmark. Neither samples

resulted in a water quality exceedance. In addition, the MDA has ongoing monitoring with increased pesticide monitoring intensity for these locations.

The 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.

Table 6. Cannon River Watershed River and Stream Pesticide Sampling (1991-2013)

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	4	7	57 %	12.1	27.4	643	1097	1550	70,000 H	--	12,075,000(f)	13,100 (v)
Acetochlor	Herbicide	127	204	62 %	P(<33)	90.8	417	538.5	2130	3,600 T	86,000 T	na	na
Acetochlor ESA	Degradate	7	7	100 %	242	270	316	348.9	381	--	--	> 62,500,000(i)	9,900,000 (n)
Acetochlor OXA	Degradate	5	7	71 %	99.9	124.5	127	129.2	131	--	--	--	--
Alachlor	Herbicide	3	220	1 %	nd	nd	nd	nd	1110	4,200 H; 59,000 T	800,000 T	na	na
Alachlor ESA	Degradate	7	7	100 %	155	226	296	333.5	371	--	--	52,000,000(f)(i)	–
Atrazine	Herbicide	194	220	88 %	60	180	650	930.3	3720	3,400 H; 10,000 T	323,000T	na	na
Bentazon	Herbicide	4	8	50 %	1.2	5.4	12.4	12.4	12.4	--	--	>50,000,000(f)(i)	4,500,000(n)
Cyanazine	Herbicide	1	188	1 %	nd	nd	nd	nd	40	--	--	--	–
DEDI Atrazine	Degradate	3	10	30 %	nd	82.5	161	165.5	170	--	--	>50,000,000(f)(i)	–
Deisopropylatrazine	Degradate	14	213	7 %	nd	nd	nd	P(<150)	P(<150)	--	--	8,500,000 (f)	2,500,000(n)
Desethylatrazine	Degradate	179	214	84 %	50	80	136	160	249.9	--	--	–	1,000,000(n)
Diazinon	Insecticide	1	214	<1 %	nd	nd	nd	nd	P(<30)	--	--	110 (i)	170 (i)
Dichlorvos	Insecticide	1	61	2 %	nd	nd	nd	nd	P(<15)			35 (i)	5.8 (i)
Dimethenamid	Herbicide	95	204	47 %	nd	P(<15)	87	167	1600	--	--	3,150,000 (f)	5,100 (v)[6]
Dimethenamid ESA	Degradate	6	7	86 %	33.8	38.7	39.3	39.7	40.1	--	--	–	–
Dimethenamid OXA	Degradate	4	7	57 %	11.7	14.1	16.5	16.6	16.6	--	--	–	–
Hydroxyatrazine	Degradate	7	7	100 %	74.8	121	200	246.1	292	--	--	> 1,500,000 (f)	>10,000,000(n)
Imazethapyr	Herbicide	1	7	14 %	nd	nd	2.7	4.8	6.8	--	--	>55,000,000(f)(i)	8,100 (v)
Metolachlor	Herbicide	180	220	82 %	19.5	190	642	1531	14000	23,000 T	271,000T	na	na

Metolachlor ESA	Degradate	7	7	100 %	940	2615	3340	3340	3340	--	--	24,000,000 (f)	>95,100,000(v)
Metolachlor OXA	Degradate	7	7	100 %	210	275	313	342.9	372	--	--	7,700,000 (i)	57,100,000(n)
Prometon	Herbicide	1	192	1 %	nd	nd	nd	nd	P(<100)	--	--	6,000,000(f)	98,000 (n)
Propazine	Herbicide	8	194	4 %	nd	nd	nd	nd	P(<25)	--	--	>2,660,000 (i)	24,800 (n)
Propiconazole	Fungicide	1	170	1 %	nd	nd	nd	nd	P(<200)	--	--	425,000 (f)	21,000 (n)
Saflufenacil	Herbicide	2	7	29 %	nd	9	18	18	18	--	--	> 49,000 ,000 (f)(i)	42,000 (n)
Simazine	Herbicide	4	178	2 %	nd	nd	nd	nd	120	4,000 H	4,000 H	500,000 (i)	36,000 (n)
Tebuconazole	Fungicide	1	170	1 %	nd	nd	nd	nd	P(<200)	--	--	1,135,000(f)	12,000 (f)
Tetraconazole	Fungicide	1	170	1 %	nd	nd	nd	nd	P(<150)	--	--	1,315,000(i)	190,000 (i)
Trifluralin	Herbicide	2	203	1 %	nd	nd	nd	nd	P(<50)	--	--	20,500 (f)	1,140 (f)

Table 7. Cannon River Watershed Lake Pesticide Sampling (2007-2011).

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	3	3	100 %	29.6	43.7	52.1	54.9	57.7	70,000 H	--	12,075,000(f)	13,100 (v)
Acetochlor	Herbicide	2	4	50%	nd	P(<50)	P(<50)	P(<50)	P(<50)	3,600 T	86,000 T	--	--
Acetochlor ESA	Degradate	3	4	75%	269.9	488	502.4	507.2	512	--	--	>62,500,000(i)	9,900,000(n)
Acetochlor OXA	Degradate	3	4	75%	176.3	321.3	350.5	360.3	370	--	--	--	--
Alachlor ESA	Degradate	2	4	50%	66.5	149.8	179.9	190	200	--	--	>52,000,000(f)(i)	--
Alachlor OXA	Degradate	1	4	25%	nd	15.5	43.3	52.6	61.9	--	--	> 47,500,000 (i)	--
Atrazine	Herbicide	4	4	100 %	25	70	106	118	130	3,400 H; 10,000 T	323,000T	na	na
Bentazon	Herbicide	1	3	33%	nd	0.8	1.3	1.5	1.7	--	--	>50,000,000(f)(i)	4,500,000(n)
Desethylatrazine	Degradate	3	4	75%	P(<50)	12.5	35	42.5	50	--	--	—	1,000,000(n)
Dimethenamid	Herbicide	1	4	25%	nd	nd	nd	nd	P(<50)	--	--	3,150,000 (f)	5,100 (v)[6]
Dimethenamid ESA	Degradate	1	4	25%	nd	10.3	28.9	35.1	41.3	--	--	--	--
Dimethenamid OXA	Degradate	1	4	25%	nd	4.9	13.7	16.6	19.5	--	--	--	--
Hydroxyatrazine	Degradate	3	3	100 %	79.3	88.1	93.3	95.1	96.8	--	--	> 1,500,000 (f)	>10,000,000 (n)
Imazethapyr	Herbicide	1	3	33%	nd	6.1	9.7	10.9	12.1	--	--	55,000,000 (f)(i)	8,100 (v)
Metolachlor	Herbicide	3	4	75%	P(<70)	50	140	170	200	23,000 T	271,000T	na	na
Metolachlor ESA	Degradate	4	4	100 %	491	965	1118	1169	1220	--	--	24,000,000 (f)	>95,100,000 (v)
Metolachlor OXA	Degradate	4	4	100 %	159.3	281.8	284.9	286	287	--	--	7,700,000 (i)	57,100,000 (n)

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 four 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 web site for more detailed information and definitions.

[3] **Chronic Standard** as defined in Minn. Rule Chap. 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 four days.

[4] **Maximum Standard Value for Aquatic Life & Recreation** as defined on MPCA's web site and Minn. Rule Chap. 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.

3.2.1.4. Pesticides as a Biological Stressor in Minnesota Watersheds (provided by David Tollefson, MDA)

The presence and concentrations of pesticides detected in a Minnesota watershed have been presented in the above tables. The presence and detection frequency of pesticides in surface waters is reason for concern. Although individual pesticide toxicity has been determined for many pesticides, there is concern that the biological effects of various combinations of pesticides under varying environmental conditions are less understood.

The results above indicate that at this time there are no pesticide concentrations exceeding an applicable standard for aquatic toxicity and therefor no direct evidence that concentrations are high enough to cause known impacts to sensitive aquatic life. This does not mean that pesticides aren't acting as stressors, only that the existing monitoring data does not implicate a pesticide as a likely stressor.

The MDA monitoring program targets agricultural watersheds and collects samples during storm flow periods when pesticide concentrations are likely to be highest. The MDA operates one of the largest state level pesticide monitoring efforts in the nation. With this said, in order to document the potential contribution of pesticides to stream biology impacts, one would have to design a site-specific study that, among other factors, simultaneously looked at pesticide application timetables while measuring pesticide concentration in adjacent water bodies, complete water chemistry (including the presence of other toxins), water temperature, and fluctuations in hydrology and biological diversity. The study would need to ascertain how the chemical is entering the water, the exposure time, and look for impacts to sensitive organisms. This work has not been performed and is not currently anticipated.

3.2.2. Ammonia

Ammonia (NH_3) is a common toxicant derived from animal waste, fertilizers, and natural processes. Ammonia nitrogen contains both the ionized form (ammonium, NH_4^+) and the unionized form (ammonia, NH_3). An increase in pH favors formation of the more toxic unionized ammonia (NH_3).

3.2.2.1 Water Quality Standards

Ammonia-N (NH_3) standard for Class 2A (coldwater) streams is 0.016 mg/L. For Class 2B (warmwater streams ammonia –N (NH_3) standard is 0.040 mg/L. Most of NH_3+NH_4 are in the NH_4form. But NH_3 increases with higher temperatures and pH concentrations.

3.2.2.2 Types of Ammonia Data

The concentration of ammonia in water is measured as total ammonia and is reported in mg/L. The fraction of unionized ammonia (NH_3) is not directly measured, but instead is calculated using measures of total ammonia, pH, temperature, and specific conductivity. The EPA CADDIS webpage has a calculator available for calculating unionized ammonia; it is located here.

3.2.2.3 Sources and Causal Pathways Model for Ammonia

Many human activities and associated sources can contribute to high ammonia concentrations in aquatic systems, which can lead to lethal and sub-lethal effects on aquatic organisms. Channel alteration can result in decreased nitrogen uptake within the stream, while decreases in riparian and watershed vegetation associated with agriculture and urbanization can reduce nitrogen uptake in the surrounding landscape. Channel alteration and water withdrawals can reduce ammonia volatilization due to changes in water velocities and depths. Sources associated with agriculture, urbanization, industry and aquaculture also can directly increase ammonia inputs to aquatic systems via four main transport pathways (or transport-defined sources): stormwater runoff, leakage or leachate into groundwater sources, atmospheric emissions and deposition, or direct effluent discharges (U.S.EPA, CADDIS Volume 2 Sources, Stressors & Responses, 2012). For a more detailed explanation of Ammonia sources and pathways visit EPA's CADDIS Ammonia webpage.

3.2.2.4. Overview of Ammonia in the Cannon River Watershed

Ammonia was only explored further in one AUID, where elevated concentrations were documented. Elevated ammonia concentrations were identified in the Straight River (just below Owatonna), but it's inconclusive if ammonia is a stressor in this AUID. The elevated concentrations were only observed in 2010; additional monitoring is recommended.

3.2.3. pH

The term pH is a measure of acidity or basicity, with a scale ranging from 0 to 14. As described by EPA, pH values are considered high when they are above 9 for a prolonged amount of time or frequency (CADDIS 2013). Photosynthesis from elevated rates of eutrophication creates an increase in pH values. High pH values also influence elevated ionic strength and the toxicity of other chemicals such as ammonia. As pH increases, unionized ammonia becomes the predominant form, which can lead to ammonia toxicity (CADDIS 2013). Values of pH outside the range of 6.5-9 or highly fluctuating values are stressful to aquatic life.

3.2.3.1 Water Quality Standards

The standard for Class 2B (warmwater) streams in the state of Minnesota for pH is 6.5 as a daily minimum and 9 as a daily maximum (Minn. Stat. ch. 7050.0222 subp. 4).

3.2.3.2 Sources and Causal Pathways Model for pH

The conceptual model for pH as a candidate stressor is modelled at EPA's CADDIS pH webpage. Human effects on pH values can result from agricultural runoff, urbanization, and industrial discharges. Some geology has naturally high hydrogen ions that can leach into surface water, but it would be rare for this to be the only cause. Photosynthesis of overabundant macrophytes and algae can remove carbon dioxide from the water, causing a higher pH. Effects on biology include decreased growth and reproduction, decreased biodiversity, and damage to skin, gills, eyes, and organs. Concentrations of nutrients (especially nitrogen) also play a significant part in pH dynamics, as nitrification and respiration both produce hydrogen ions (CADDIS 2013).

3.2.3.3 Overview of pH in the Cannon River Watershed

pH was determined inconclusive in two AUIDs in the Upper Cannon 10-digit HUC (Cannon River and Whitewater Creek). These stream reaches are located in the nutrient rich lakes region. Additional monitoring is recommended to better understand the pH dynamics in this area. The pH is described further in those reaches, but likely can be attributed to eutrophication.

3.3. Summary of Candidate Causes in the Cannon River Watershed

Twelve candidate causes were selected as possible drivers of biological impairments in the Cannon River Watershed. The initial list of candidate/potential causes was narrowed down after the initial data evaluation/data analysis resulting in nine for final analysis in this report. The nine remaining candidate causes are:

- Temperature
- Nitrate
- Phosphorus
- DO
- TSS
- Habitat
- Fish Passage
- Flow Alteration
- Chloride

3.3.1. Candidate Cause: Elevated Stream Temperature

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 dissolved oxygen, and higher water temperatures also affects the toxicity of numerous chemicals in the aquatic environment. Algal blooms often occur with temperature increases (EPA, 1986).

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 dissolved oxygen (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 invertebrates 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.

Fish in coldwater systems can suffer adverse effects due to increases in temperature (Raleigh et al. 1986). When temperatures rise near 21°C, other fish can have a competitive advantage over trout for the food supply (Behnke 1992). The temperature at which fish continue to feed and gain weight is considered their functional feeding temperatures. The limits for brown trout growth at 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 thermal window 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 ability to gain weight.

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).

3.3.1.1 Water Quality Standards

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

The state standard for temperature in Class 2A streams is “no material increase” (Minn. Stat. § 7050.0222 Specific Water Quality Standards for Class 2 Waters of the State; Aquatic Life and Recreation).

3.3.1.2 Types of Temperature Data

Both one time and continuous temperature data is available in the watershed.

3.3.1.3 Sources and Causal Pathways Model for Elevated Temperature

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

3.3.1.4 Overview of Temperature in the Cannon River Watershed

Temperature stress is very minimal in the Cannon River Watershed. Temperature was identified as a stressor in one AUID, contributing to a stressor in one AUID, inconclusive in three AUIDs, and was eliminated as a potential stressor in 28 AUIDs (Figure 9). The coldwater section of the Little Cannon River is the only reach where temperature was identified as a stressor. Temperature was also identified as contributing to a stressor (DO) in the Upper Cannon lakes region. Overall, temperature is not a big issue or concern in the Cannon River Watershed.

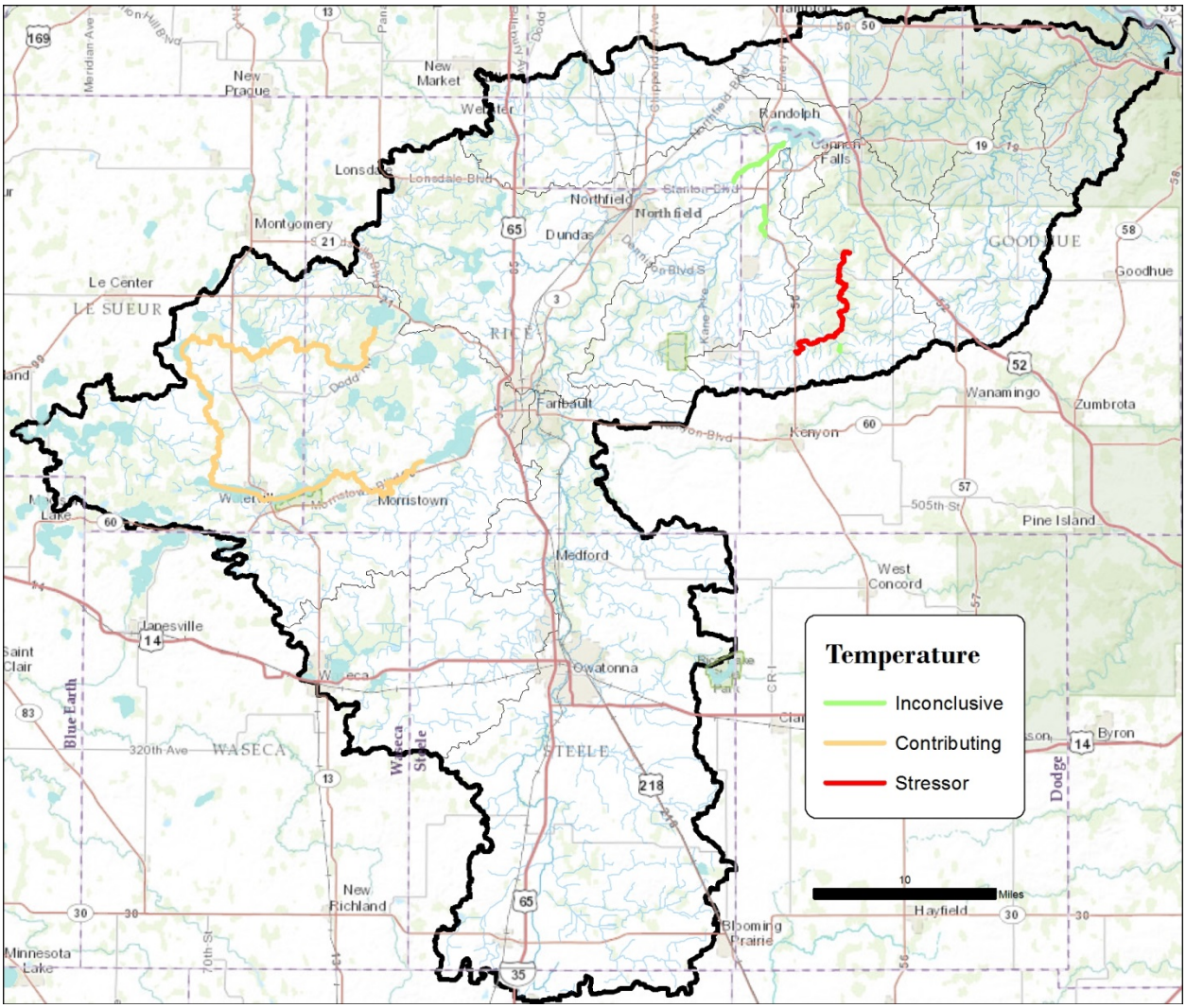


Figure 9. Stressor results for temperature in the Cannon River Watershed.

3.3.2. Candidate Cause: Nitrogen

Nitrate toxicity to freshwater aquatic life is dependent on concentration and exposure time, as well as the overall 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 2.0 mg/L nitrate-N as appropriate for protecting the most sensitive freshwater species and that NO3-N concentrations are under 10.0 mg/L to be protective of several sensitive fish and aquatic invertebrate taxa. The intake of nitrite and nitrate by aquatic organisms has been shown to convert 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

Streams classified as Class 1 waters of the state, designated for domestic consumption, in Minnesota have a nitrate water quality standard of 10.0 mg/L (Minn. Stat. § 7050.0222, subp. 3). Minnesota currently does not have a nitrate standard for other waters of the state except for Class 1; however an aquatic life nitrate standard is being drafted.

Types of Nitrate Data

Stream and river water samples are collected at various locations throughout the 8HUC. Samples are sent to a state certified laboratory and analyzed for a number of water quality parameters including nutrients. Laboratory analytical data is then stored in the EQuIS database and can be accessed via the MPCA webpage here.

Sources and Causal Pathways Model for Nitrate

The conceptual model for nitrogen 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, 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).

Overview of Nitrate in the Cannon River Watershed

Nitrate was determined a stressor in 22 AUIDs, inconclusive in 9 AUIDs, and was eliminated as a potential stressor in only two AUIDs (Figure 10). Nitrate is currently stressing the biota in the Little Cannon River (four AUIDs), Prairie Creek (four AUIDs), Straight River (six AUIDs), Lower Cannon (two AUIDs), Middle Cannon (three AUIDs), and the Upper Cannon (three AUIDs). Nitrate is a big issue and concern watershed wide. Agricultural tile drainage is prevalent throughout the Cannon River Watershed, and is likely a major source of the elevated nitrate concentrations. According to the report "Nitrogen in Minnesota Surface Waters" (MPCA 2013), cropland sources account for an estimated 89 – 95% of the nitrate load in the Lower Mississippi River basin, and tile drainage is the highest estimated cropland source pathway.

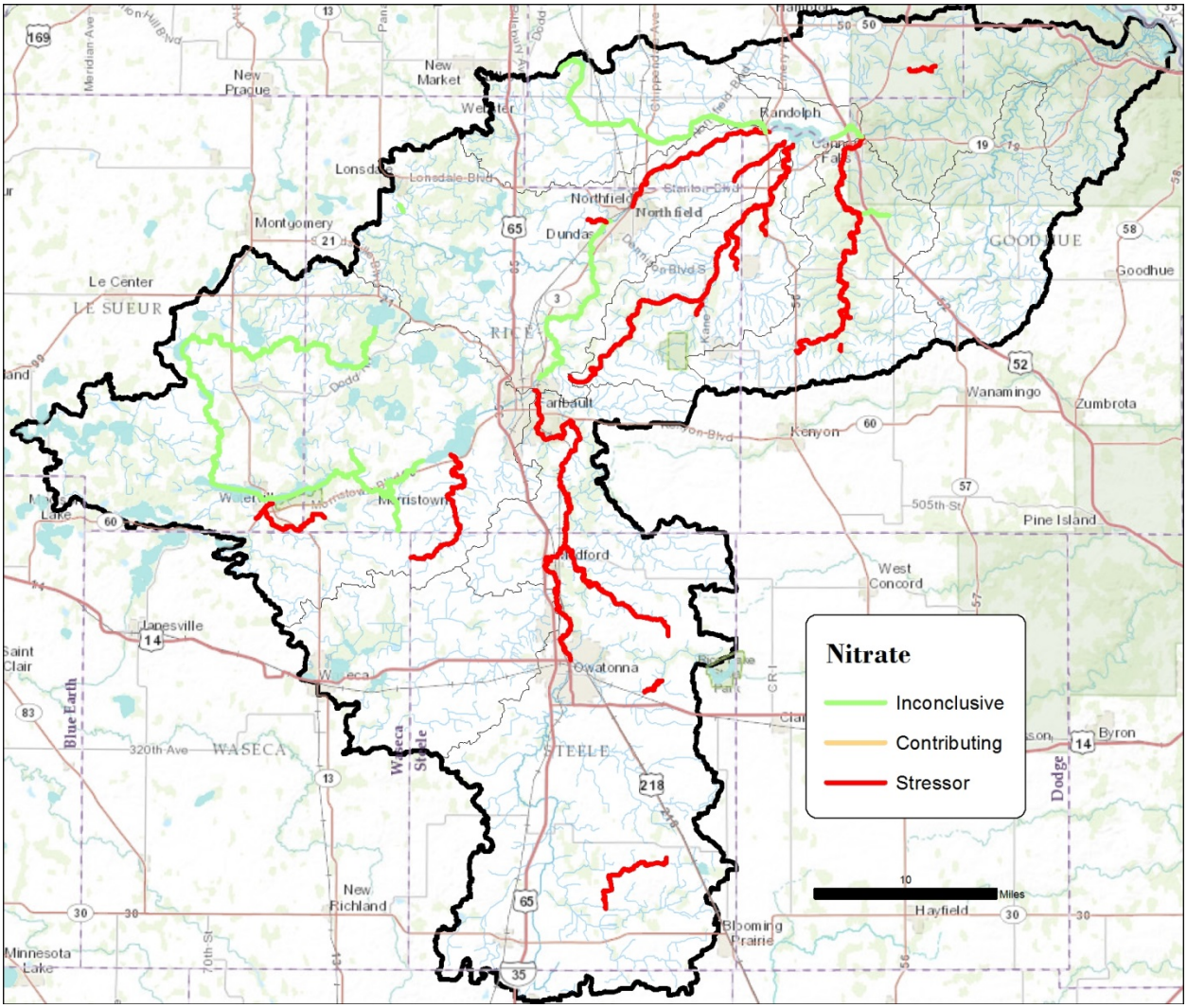


Figure 10. Stressor results for nitrate in the Cannon River Watershed.

3.3.3. Candidate Cause: Phosphorus

Phosphorus is an essential nutrient for all aquatic life, but elevated phosphorus concentrations can result in an imbalance which can impact stream organisms. Excess phosphorus results in indirect impacts to fish and macroinvertebrates, and direct impacts to aquatic communities from response variables such as DO flux, chlorophyll-a, and biological oxygen demand (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.

Water Quality Standards

There is currently no water quality standard for TP; however, there is a draft nutrient standard for rivers of Minnesota (Heiskary et al. 2013). The current draft standard for the central region of the state is a maximum concentration of 0.1 mg/L with at least one response variable out of desired range (BOD, DO flux, chlorophyll-a, and/or pH). The current draft standard for the south region of the state is 0.15 mg/L.

Sources and Causal Pathways Model for Phosphorus

Phosphorus is delivered to streams by wastewater treatment facilities, urban stormwater, agricultural runoff, and direct discharges of sewage. Phosphorus bound to sediments in the river channel could be contributing to concentrations; however there is no data available. Orthophosphorus is the form of phosphorus that is readily available for plant and algal uptake, and can influence excess algae growth. While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from waste water treatment plants, noncompliant septic systems, and fertilizers in urban and agricultural runoff. The causes and potential sources for excess phosphorus are modeled at EPA's CADDIS Phosphorus webpage.

Increased phosphorus levels 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).

Overview of Phosphorus in the Cannon River Watershed

Elevated total phosphorus (TP) concentrations are present throughout the Cannon River Watershed, and are extremely high in many cases. Response variable data (chl-a, DO flux, and BOD) is often limited or non-existent, which led to several inconclusive stressor determinations. TP was identified as a stressor in five AUIDs, inconclusive in 27 AUIDs, and was only ruled out as a stressor in one AUID (Figure11). The TP stressors are located in Chub Creek (1 AUID), the Middle Cannon (2 AUIDs), and the Upper Cannon (two AUIDs). Elevated TP is a watershed wide issue that is contributing to degraded water quality and biological conditions. One caveat regarding total phosphorus concentrations is that 2012 and 2013 samples may be biased low due to lab methodologies.

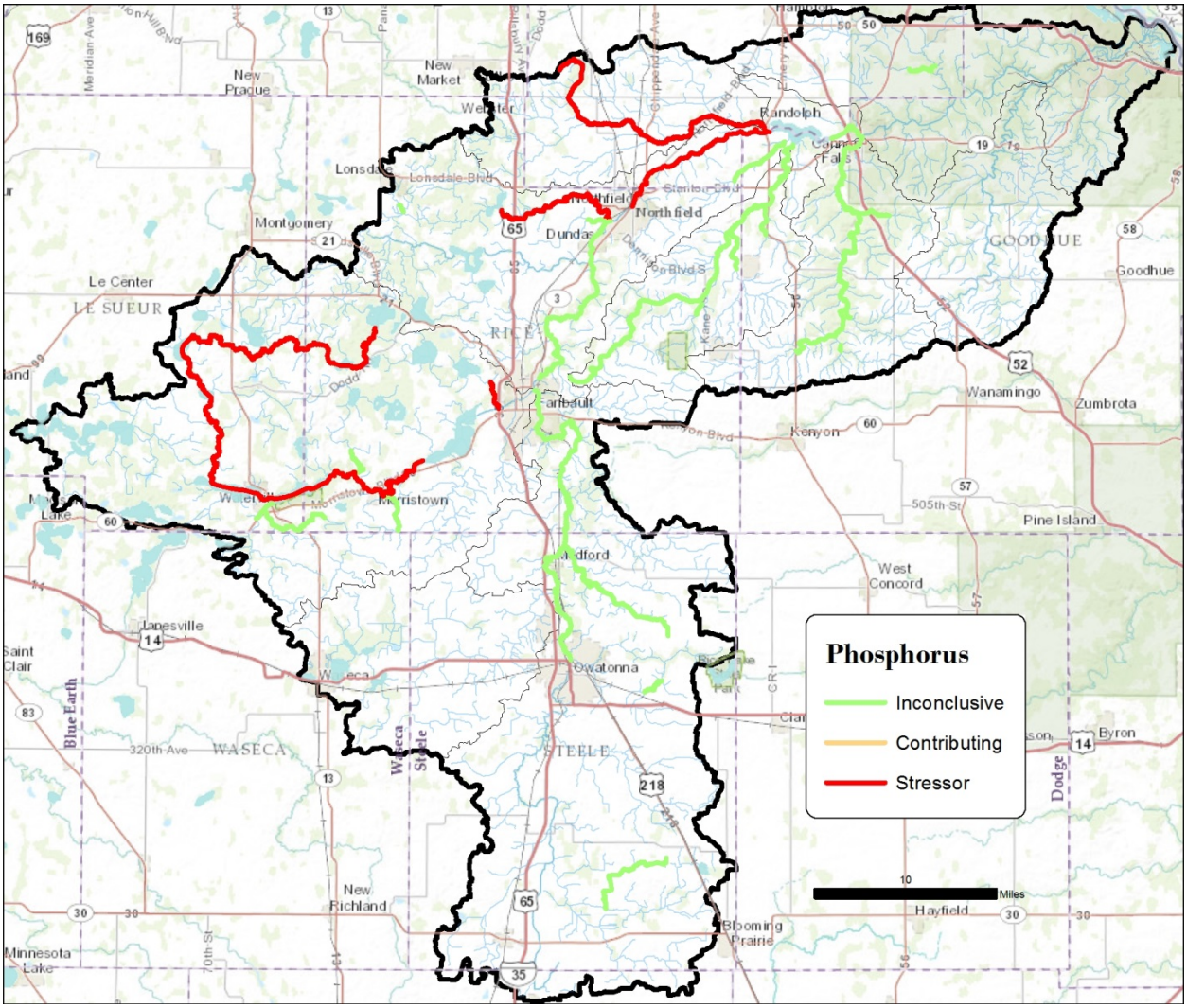


Figure 11. Stressor results for phosphorus in the Cannon River Watershed.

3.3.4. Candidate Cause: Dissolved Oxygen

DO refers to the concentration of oxygen gas within the water column. Low or highly fluctuating concentrations of DO can have detrimental effects on many fish and macroinvertebrate species ((Davis, 1975); (Nebeker, 1991)). DO concentrations change seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column. For more detailed information on DO go to the EPA Caddis webpage following this link. (U.S.EPA)

Fish require oxygen for respiration. If DO concentrations become limited or fluctuate dramatically, aerobic aquatic life can experience reduced growth or fatality (Allan 1995). Some macroinvertebrates that are intolerant to low levels of DO include mayflies, stoneflies and caddisflies (Marcy 2007). Many species of fish avoid areas where DO concentrations are below five 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, and/or high groundwater seepage (Hansen, 1975). Heiskary et al. (2013) observed several strong negative relationships between fish and macroinvertebrate metrics and DO flux.

3.3.4.1. Water Quality Standards

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. Additional stipulations have been recently added to this standard. The following is from the Guidance Manual for Assessing the Quality of Minnesota Surface Waters (MPCA, 2009).

> *Under revised assessment criteria beginning with the 2010 assessment cycle, the DO standard must be met at least 90 percent of the time during both the 5-month period of May through September and the 7-month period of October through April. Accordingly, no more than 10 percent of DO measurements can violate the standard in either of the two periods.*
>
> *Further, measurements taken after 9:00 in the morning during the 5-month period of May through September are no longer considered to represent daily minimums, and thus measurements of > 5 DO later in the day are no longer considered to be indications that a stream is meeting the standard.*
>
> *A stream is considered impaired if 1) more than 10 percent of the "suitable" (taken before 9:00) May through September measurements, or more than 10 percent of the total May through September measurements, or more than 10 percent of the October through April measurements violate the standard, and 2) there are at least three total violations.*

3.3.4.2. Types of Dissolved Oxygen Data

1. Point Measurements

Instantaneous DO data is available throughout the watershed and can be used as an initial screening for low DO. These measurements represent discrete point samples. Because DO concentrations can vary significantly with changes in flow conditions and time of sampling, instantaneous measurements need to be used with caution and are not completely representative of the DO regime at a given site.

2. Longitudinal (Synoptic)

A series of longitudinal synoptic DO surveys were conducted throughout the Cannon River Watershed. A synoptic monitoring approach gathers data across a large spatial scale and minimal temporal scale (as close to simultaneously as possible). In terms of DO, the objective was to sample a large number of sites from upstream to downstream under comparable ambient conditions. For the most part, the surveys took place in mid to late summer when low DO is most commonly observed. DO readings were taken at pre-determined sites in the early morning in an attempt to capture the daily minimum DO reading.

3. **Diurnal (Continuous)**

   YSI sondes were deployed at sites located in the Cannon River Watershed in late summer to capture the diurnal fluctuations. This data revealed the magnitude and pattern of diurnal DO flux at each site.

3.3.4.3. Sources and Causal Pathways Model for Low Dissolved Oxygen

DO concentrations in streams are driven by a combination of natural and anthropogenic factors. Natural background characteristics of a watershed, such as topography, hydrology, climate, and biological productivity can influence the DO regime of a waterbody. Agricultural and urban land uses, impoundments (dams), and point-source discharges are just some of the anthropogenic factors that can cause unnaturally high, low, or volatile DO concentrations. The conceptual model for low DO as a candidate stressor is shown in the EPA CADDIS website by following this link: Dissolved oxygen simple conceptual diagram | CADDIS: Sources, Stressors & Responses | US EPA.

3.3.4.4. Overview of Dissolved Oxygen in the Cannon River Watershed

Low DO was determined a stressor in five AUIDs, inconclusive in 12 AUIDs, and was eliminated as a potential stressor in 16 AUIDs (Figure 12). DO is currently stressing the biota in the Upper Cannon lakes region (three AUIDs), Middle Cannon (one AUID), and the middle – upper portions of Chub Creek (one AUID). Nutrient rich waters, including lakes and wetlands, are driving many of the low DO conditions. Low DO is not a huge issue watershed wide, but is an important factor in the Upper Cannon lakes region.

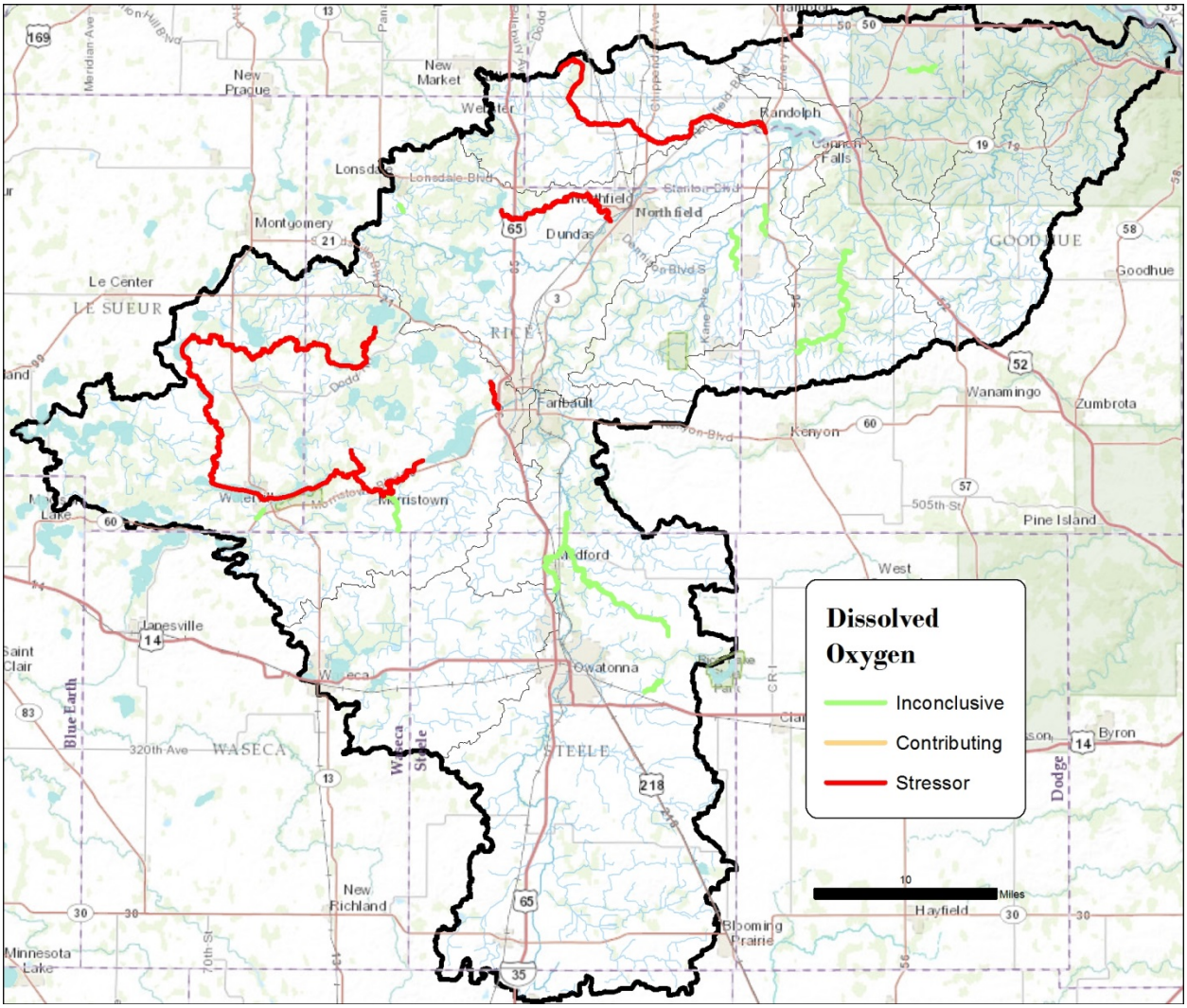


Figure 12. Stressor results for DO in the Cannon River Watershed.

3.3.5. Candidate Cause: Increased Sediment (Turbidity/TSS)

Increases in suspended sediment and turbidity within aquatic systems are now considered one of the greatest causes of water quality and biological impairment in the United States (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: (one) direct, physical effects on biota (i.e., abrasion of gills, suppression of photosynthesis, avoidance behaviors); and (two) 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 populations.

Whereas suspended solids and turbidity are potential stressors operating in the water column, bedded (= deposited) sediments impact the stream substrate. Excessive deposition of fine sediment can impair macroinvertebrate habitat quality and productivity (Rabeni et al. 2005). Quantitative field measurement of bedded sediment (bedload) is very difficult. However, a significant amount of data on substrate composition and embeddedness (the degree in which fine sediments surround coarse substrates on the surface of a stream bed) has been collected. These data will be used to determine whether or not natural coarse substrate (a very important habitat type) is being covered up or filled in by excess fine sediment. To learn more about sediment affects on stream organisms go to the EPA CADDIS webpage here.

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.

3.3.5.1 Water Quality Standards

The water quality standard for turbidity is 25 Nephelometric Turbidity Units (NTUs) for Class 2B waters. For Class 2A waters, the standard is 10 NTUs. TSS and transparency tube/Secchi tube measurements can be used as surrogate standard. A strong correlation exists between the measurements of TSS concentration and turbidity. In 2010, the MPCA released draft TSS standards for public comment (MPCA, 2009). The new TSS criteria are stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The draft TSS standard for the Cannon River Watershed (South and Central River Nutrient Regions) has been set at 65 mg/L. For assessment, this concentration is not to be exceeded in more than 10% of samples within a 10-year data window. There is no current standard for bedded sediment in Minnesota. There is currently no standard for TSVS

For the purposes of SID, TSS results will be relied upon to evaluate the effects of suspended solids and turbidity on fish and macroinvertebrate populations. TSS results are available for the watershed from state-certified laboratories, and the existing data covers a much larger spatial and temporal scale in the watershed.

3.3.5.2 Types of Sediment Data

Suspended sediment (TSS) data is collected by collecting a stream water sample and having the sample filtered and weighed to determine the concentration of TSS in the sample. Bedded sediment is visually estimated by looking at the fine material surrounding rock or woody substrate within the stream channel. Bedded sediment is also analyzed by conducting pebble counts in stream reaches and analyzing the D^{50} particle size in both the stream reach and the representative riffle site.

3.3.5.3 Sources and Causal Pathways Model for Sediment

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

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.

3.3.5.4. Overview of Sediment trends in the Cannon River Watershed

TSS was determined a stressor in 10 AUIDs, inconclusive in 20 AUIDs, and was eliminated as a potential stressor in only three AUIDs (Figure 13). TSS is currently stressing the biota in Chub Creek (one AUID), Little Cannon River (three AUIDs), Prairie Creek (two AUIDs), Straight River (three AUIDs), and the Middle Cannon (one AUID). The lower portion of the watershed, as well as the Straight River, is experiencing elevated TSS which is contributing to biota impairments. TSS impacts in the Upper Cannon are likely being mitigated by the lakes.

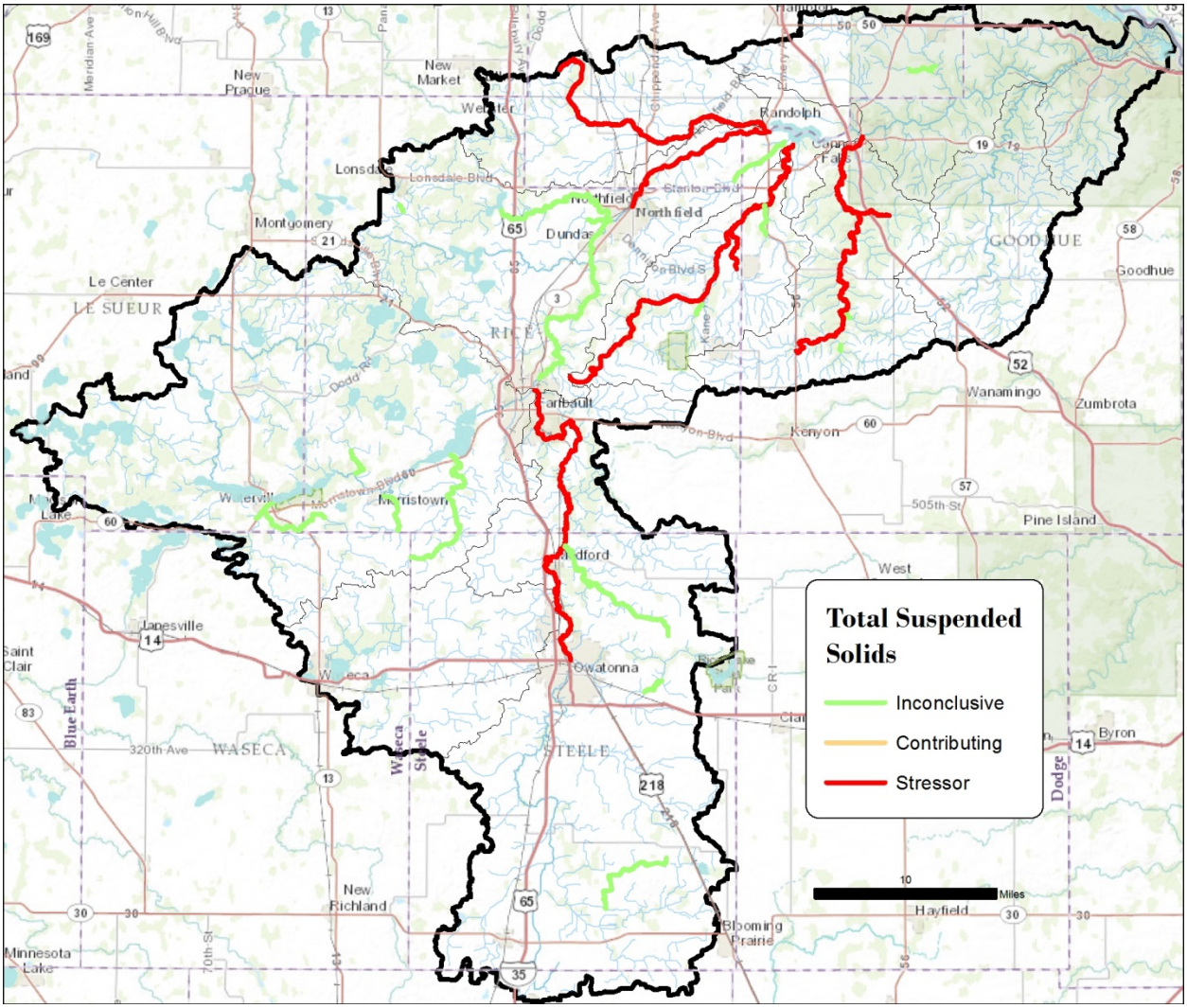


Figure 13. **Stressor results for TSS in the Cannon River Watershed.**

3.3.6. Candidate Cause: Lack of Physical 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, dissolved oxygen) and will be addressed separately.

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, refugia, and/or reproduction (Newcombe et al. 1991). Aquatic macroinvertebrates are generally affected in several ways: (one) loss of certain taxa due to changes in substrate composition (Erman and Ligon 1988); (two) increase in drift (avoidance) due to sediment deposition or substrate instability (Rosenberg and Wiens, 1978); and (three) changes in the quality and abundance of food sources such as periphyton and other prey items (Pekarsky 1984). Fish communities are typically influenced through: (one) a reduction in spawning habitat or egg survival (Chapman 1988); and (two) 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 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).

Degraded physical habitat is a leading cause of impairment in streams on 303(d) lists. According to the EPA CADDIS website six attributes are the main features 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.

3.3.6.1 Water Quality Standards

There are no State water quality standards for physical habitat.

3.3.6.2 Types of Physical Habitat Data

The MPCA biological survey crews conduct a qualitative habitat assessment using the MPCA Stream Habitat Assessment (MSHA) protocol for stream monitoring sites. The MSHA protocol can be found here. MSHA scores can be used to review habitat conditions at biological sampling locations and compare those conditions against similar size streams and a variety of IBI scores. The MPCA and MDNR partners are collecting stream channel dimension, pattern and profile data at select stream locations of various sizes and biological condition. This data can be used to compare channel departure from a reference condition. Habitat features can be analyzed to determine if a stream is lacking pool depth, pool spacing, adequate cross sectional area to convey discharge, and various other physical habitat features that are too numerous to list here. The applied river morphology method created by (Rosgen, 1996) is the accepted method for this data collection by the MPCA and MDNR.

3.3.6.3 Sources and Causal Pathways Model for Lack of Physical Habitat

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 and resource extraction, 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 (see the Sediment and Flow modules for more information on sediment- and flow-related stressors).

Direct alteration of streams channels also can influence physical habitat, by changing discharge patterns, changing hydraulic conditions (water velocities and 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 EPA CADDIS webpage here.

3.3.6.4. Overview of Lack of Physical Habitat in the Cannon River Watershed

Habitat was determined a stressor in 22 AUIDs, inconclusive in 11 AUIDs, and was not eliminated as a potential stressor in any AUIDs (Figure 14). Habitat is currently stressing the biota in Chub Creek (one AUID), Little Cannon River (three AUIDs), Prairie Creek (four AUIDs), Straight River (two AUIDs), Lower Cannon (two AUIDs), Middle Cannon (four AUIDs), and Upper Cannon (six AUIDs). In general, habitat conditions are degraded watershed wide, and contributing to degraded biological conditions.

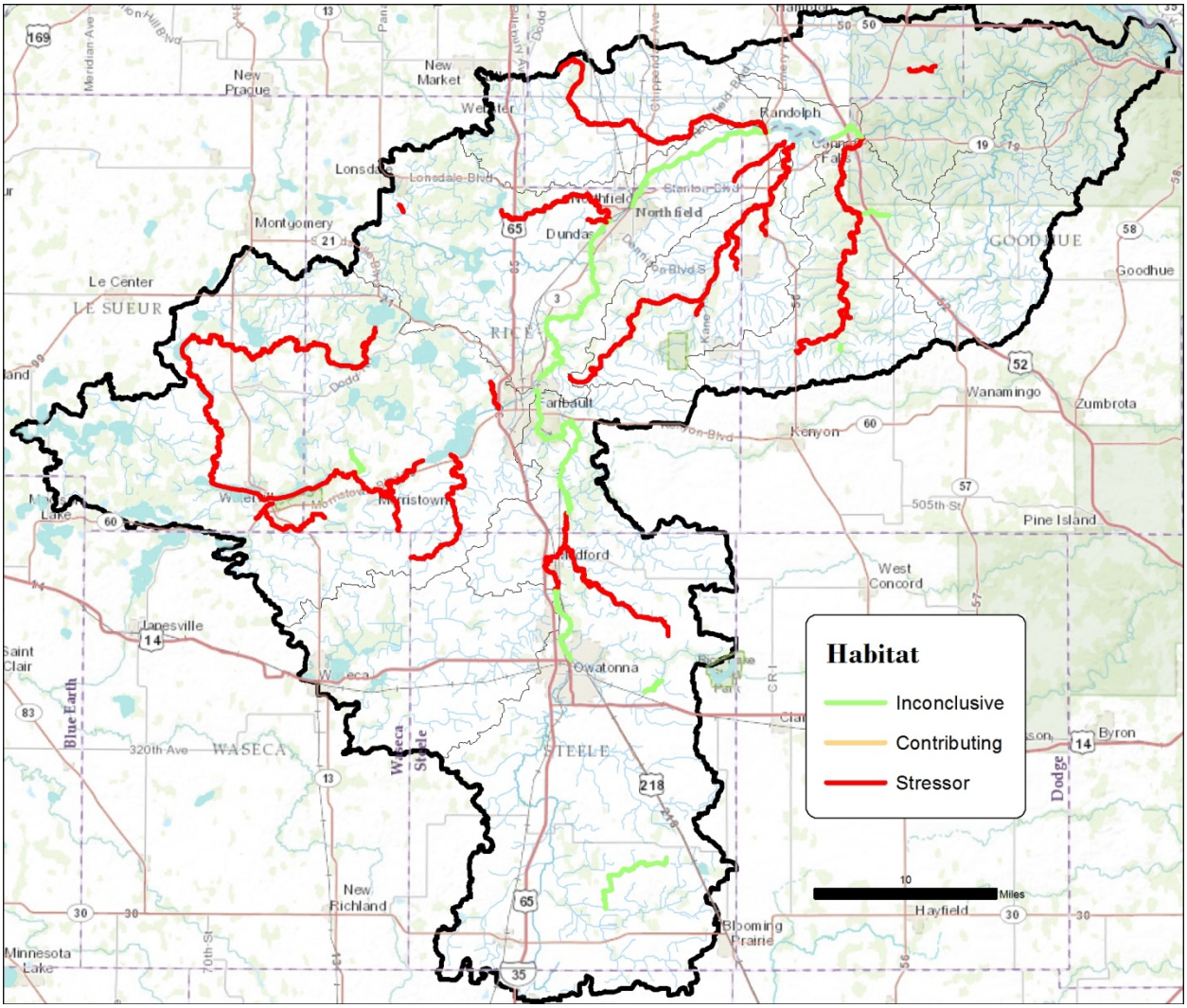


Figure 14. Stressor results for habitat in the Cannon River Watershed.

3.3.7. Candidate Cause: Physical Connectivity (referred to as fish passage in this report)

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).

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. Riparian connectivity provides habitat for terrestrial species as well as spawning and refuge habitat for fish during periods of flooding. 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 wash out down stream banks and vegetation.

Lateral connectivity represents the connection between a river and its floodplain. The dynamic relationship amongst terrestrial and aquatic components of a river's floodplain ecosystem comprises a spatially complex and interconnected environment (Ickes et al. 2005). The degree to which lateral connectivity exists is both a time-dependent phenomenon (Tockner et al. 1999) and dependent upon the physical structure of the channel. Rivers are hydrologically dynamic systems where their floodplain inundation relates to prevailing hydrologic conditions throughout the seasons. Riverine species have evolved life history characteristics that exploit flood pulses for migration and reproduction based on those seasonally predictable hydrologic conditions that allow systems to access their floodplains (Weclomme 1979, McKeown 1984, Scheimer 2000). When a system degrades to a point where it can no longer access its floodplain, the system's capacity to dissipate energy is lost. Without dissipation of energy through floodplain access, sheer stress on streambanks builds within the channel causing

channel widening. Channel widening reduces channel stability and causes loss of integral habitat that in turn reduces biotic integrity of the system until the stream can reach a state of equilibrium once again.

3.3.7.1. Water Quality Standards

There is no applicable water quality standard for connectivity impacts.

3.3.7.2 Sources and Causal Pathways Model for Physical Connectivity

The conceptual model for physical connectivity as a candidate stressor is found in Figure 15 below:

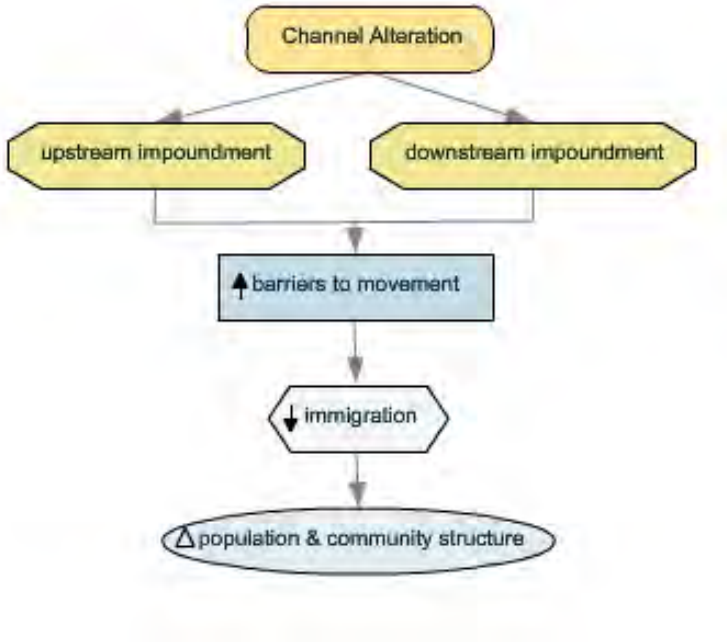


Figure 15. Conceptual Model for Connectivity.

3.3.7.3. Overview of Physical Connectivity in the Cannon River Watershed

Physical connectivity, referred to as fish passage in this report, was determined a stressor in two AUIDs, inconclusive in three AUIDs, and was eliminated as a potential stressor in 28 AUIDs (Figure1 6). Fish passage is currently a stressor in the upper end of the Little Cannon River, and the Middle Cannon just upstream of Lake Byllesby. Overall, fish passage is adequate across most of the watershed, and is not having significant direct effects on the biota. However, with that being said, there are multiple improperly sized and misaligned culverts in the watershed contributing to stream instability, habitat loss, stream bank erosion, and degrading overall stream health.

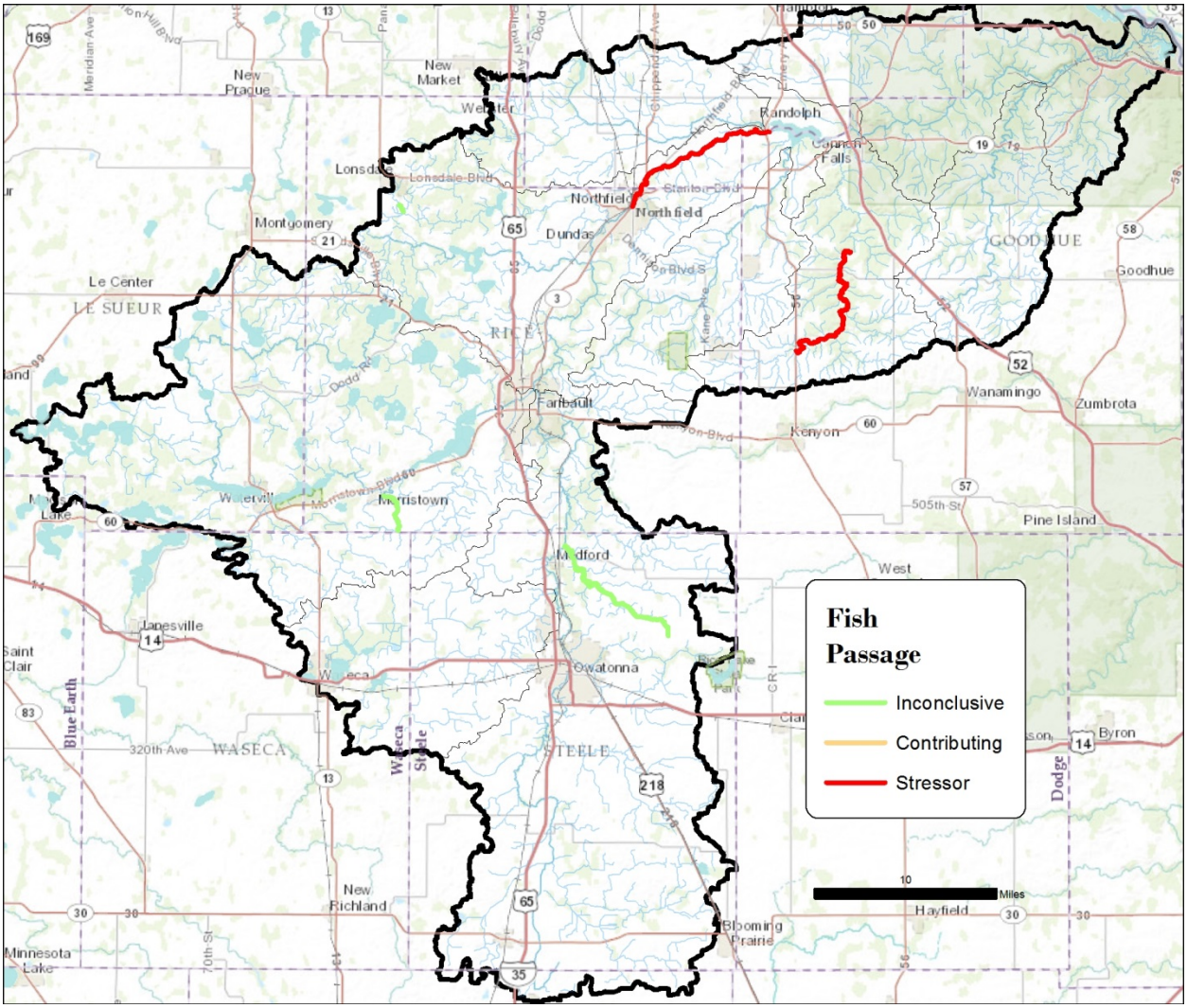


Figure 16. Stressor results for fish passage in the Cannon River Watershed.

3.3.8. Candidate Cause: Flow Alteration

Flow alteration is the change of the stream flow regime caused by anthropogenic sources. These sources can include channel alteration, water withdrawals, land cover alteration, agricultural tile drainage, and impoundment. To learn more about flow alteration go to the EPA CADDIS webpage here.

Across the conterminous U.S., Carlisle et al. (Carlisle, Wolcock, & Meador, 2010) 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 a decreased wetted width, cross sectional area, and water volume. Aquatic organisms require adequate living space and when flows are reduced beyond normal baseflow, competition for resources increases. Pollutant concentrations can increase when flows are lower than normal, making it more difficult for populations to maintain a healthy diversity. Often tolerant organisms that can outcompete others in such limiting situations 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, CADDIS Volume 2 Sources, Stressors & Responses, 2012).

Flow conditions can have an effect on the type of fish species that are present. When baseflows are reduced, fish communities respond with increases in nest guarding species rather than simple nesters (Carlisle et al. 2010). This life style adaptation increases the reproductive ability for nest guarders by protecting 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. 2010). Streamlined species have bodies that allow fish to reduce drag under high velocities (Blake 1983). Similarly, the macroinvertebrate communities exhibit changes with increasing swimming species and decreasing taxa with slow crawling rates. The EPA's CADDIS lists the response of low flow alteration with reduced total stream productivity, elimination of large fish, changes in taxonomic composition of fish communities, fewer species of migratory fish, fewer fish per unit area, and a greater concentration of some aquatic organisms (potentially benefiting predators).

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

3.3.8.1 Water Quality Standards

There currently is no applicable standard for flow alteration.

The standard for minimum streamflow, according to Minn. Stat. § 7050.0210, subp. 7 is:

> *Point and nonpoint sources of water pollution shall be controlled so that the water quality standards will be maintained at all stream flows that are equal to or greater than the $7Q_{10}$* [the lowest streamflow for 7 consecutive days that occurs on average once every 10 years] *for the critical month or months, unless another flow condition is specifically stated as applicable in this chapter*.

3.3.8.2 Sources and Causal Pathways Model for Flow Alteration

The conceptual model for flow alteration can be found on the EPA webpage. The causes and potential sources for altered flow are modeled at EPA's CADDIS Flow Alteration webpage.

3.3.8.3. Overview of Flow Alteration in the Cannon River Watershed

Flow alteration (altered hydrology) is a significant driver of many stressors in the Cannon River Watershed. Hydrology is affected by several components in the watershed, some of which include wetland drainage, tile drainage, channelization, ground water and surface water appropriation, precipitation, land use, dams, and impervious surface. All of these components alter stream and river flows, which in turn can negatively impact the biology and have direct or indirect effects on stressors such as temperature, nitrate, phosphorus, DO, TSS, habitat, and fish passage. Ultimately, flow alteration impacts several stressors and is a major contributor to the impaired biological communities in the Cannon River Watershed.

Wetland drainage plays an important role in the altered hydrology in the Cannon River Watershed. The following excerpt is from the Cannon River Watershed Monitoring and Assessment Report (MPCA 2014) as it pertains to wetlands:

> *"The Cannon River watershed has approximately 56,000 acres of wetlands, equivalent to ~6% of the watershed area. Wetlands with herbaceous emergent (i.e., marsh) vegetation are the most predominant wetland type in the watershed (Figure 17). The distribution of wetlands across the watershed is not uniform with the majority of wetland area occurring in the west-central region, corresponding to the Upper Cannon River, Wolf Creek, Heath Creek, Chub Creek, and Crane Creek subwatersheds. In addition, an extensive corridor of floodplain wetlands (forested, emergent, and shallow open) occurs along the lower reaches of the Cannon River as it empties into the Mississippi River. It should be noted that these estimates represent a snapshot of the location, type, and extent of wetlands occurring in the early 1980s, which is the time period that aerial imagery was acquired to develop National Wetlands Inventory (NWI) maps in this part of the state. Updated NWI maps are currently available for select counties in the watershed (Dakota, Scott, Rice, & Goodhue) that were included in a recent update of wetland spatial data for the East-Central region of Minnesota based on 2010 and 2011 aerial imagery."*

> *"Soil data can be used to estimate the extent of historic or pre-settlement wetlands that can serve as a baseline against which current wetland acreage can be compared. The Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database, based on a summation of "all hydric" map units, provides an estimate of approximately 294,000 acres of wetlands (~31% of watershed area) occurring in the Cannon River watershed prior to European settlement (Soil Survey Staff, NRCS 2013). Based on the National Wetlands Inventory the watershed currently has approximately 56,000 acres of wetlands, representing 6% of the watershed area. A comparison of these two time periods (i.e., pre-settlement vs early 1980s) yields an estimate of 81% wetland loss for the Cannon River watershed. Wetland loss is not uniformly distributed across the watershed with the greatest rates of loss occurring in the Upper Straight River (96%), Lower Straight River (94%), Turtle Creek (94%), and Little Cannon River (90%) subwatersheds (Figure 18). Due in large part to its topographic relief, the Lower Cannon River subwatershed had one of the lowest pre-settlement wetland acreage estimates and the lowest rate of wetland loss (43%) in the watershed."*

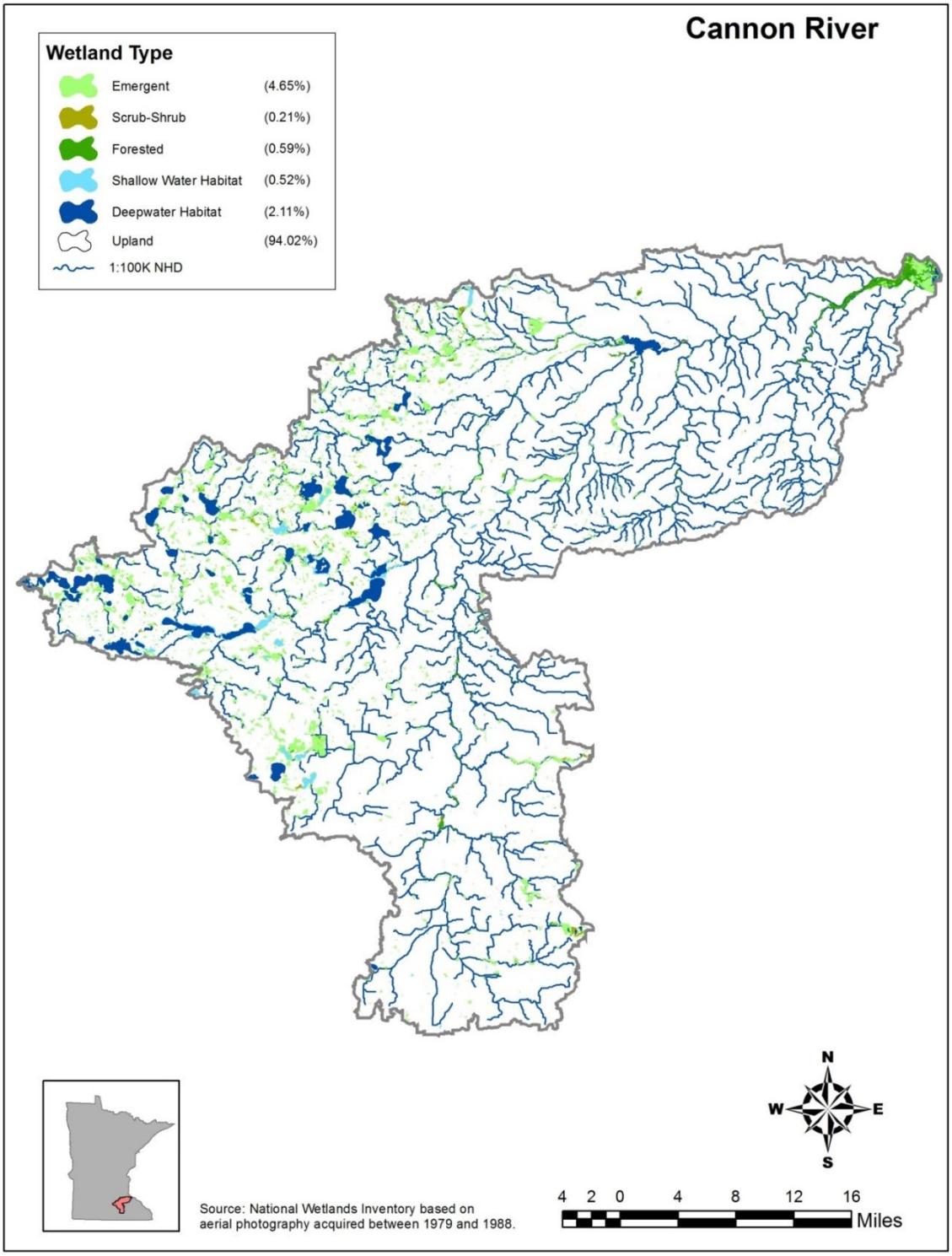


Figure 17. Wetland types and their distribution across the Cannon River Watershed. The above figure was taken from the Cannon River Watershed Monitoring and Assessment Report produced by the MPCA.

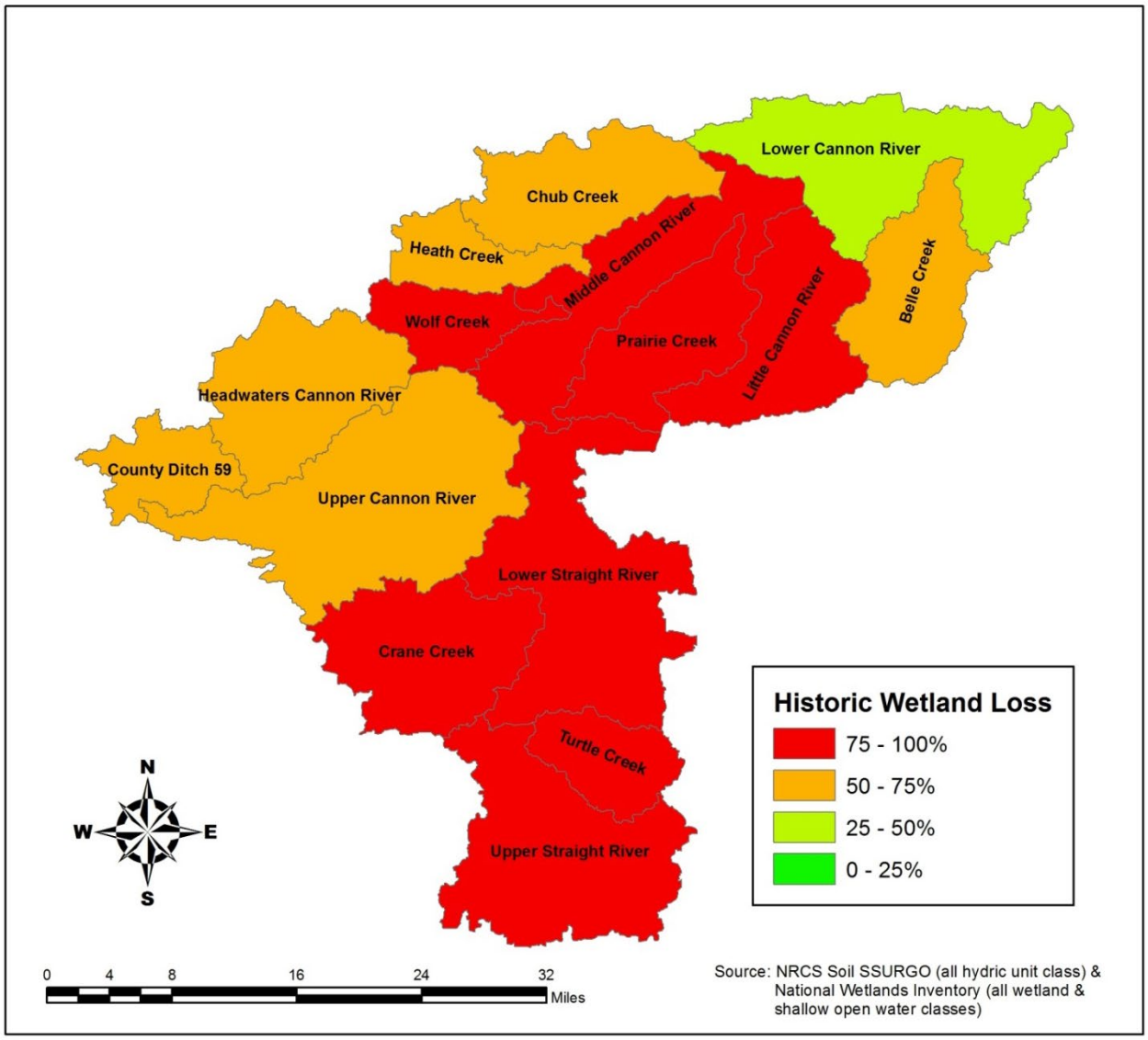


Figure 18. Estimated historic wetland loss in each subwatershed based on a comparison of "all hydric" soil types (SSURGO database) to wetland extent in the early 1980s (NWI). The above figure was taken from the Cannon River Watershed Monitoring and Assessment Report produced by the MPCA.

Agricultural tile drainage is a common practice used in the Cannon River Watershed (Figure 19). Although tile drainage can increase agricultural productivity, it has negative impacts on hydrology (increasing river flows) and water quality. A recent study comparing changes in hydrology for 21 southern Minnesota watersheds, which included the Cannon River, found that "artificial drainage is a major driver of increased river flow, exceeding the effects of precipitation and crop conversion" (Schottler et al. 2013) (Figure 20). It also noted that "twentieth century crop conversions and the attendant decreases in ET from depressional areas due to artificial drainage have combined to significantly alter watershed hydrology on a very large scale, resulting in more erosive rivers." Cannon River Watershed tile calculations, which were derived using the 2009 USDA crop data layer, USGS National Elevation Dataset, and SSURGO soil drainage class, estimate that roughly 16% (151,110 acres) of the watershed is tiled. Statistics were also calculated and broken down by 10-digit HUC, which identified spatial differences (Table 8). Crane Creek (which was not part of the SID process) and the Straight River had the highest percentages of estimated tile drainage.

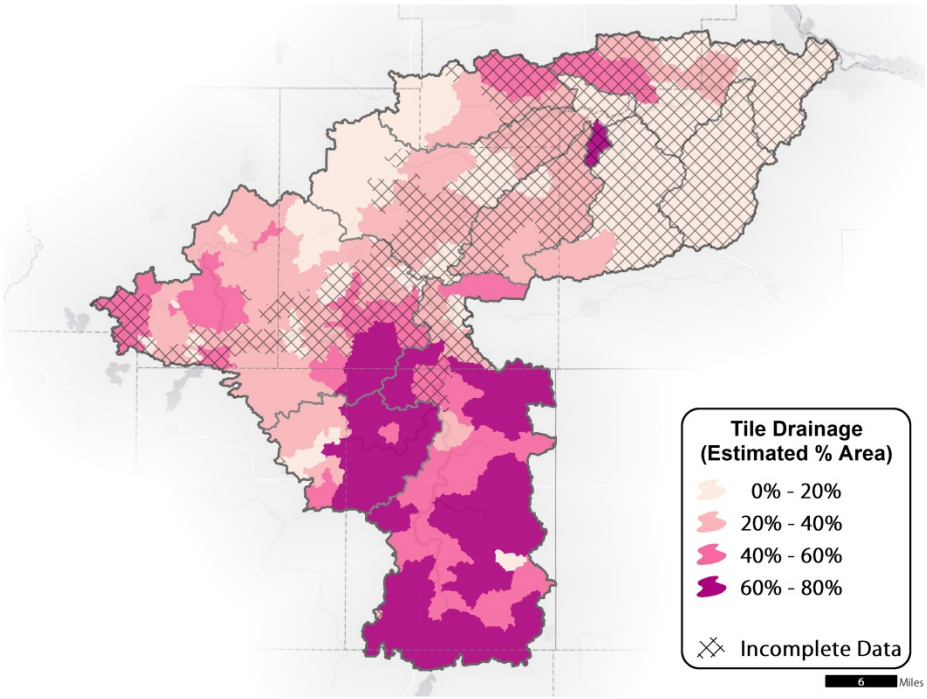


Figure 19. Tile drainage estimates in the Cannon River watershed.

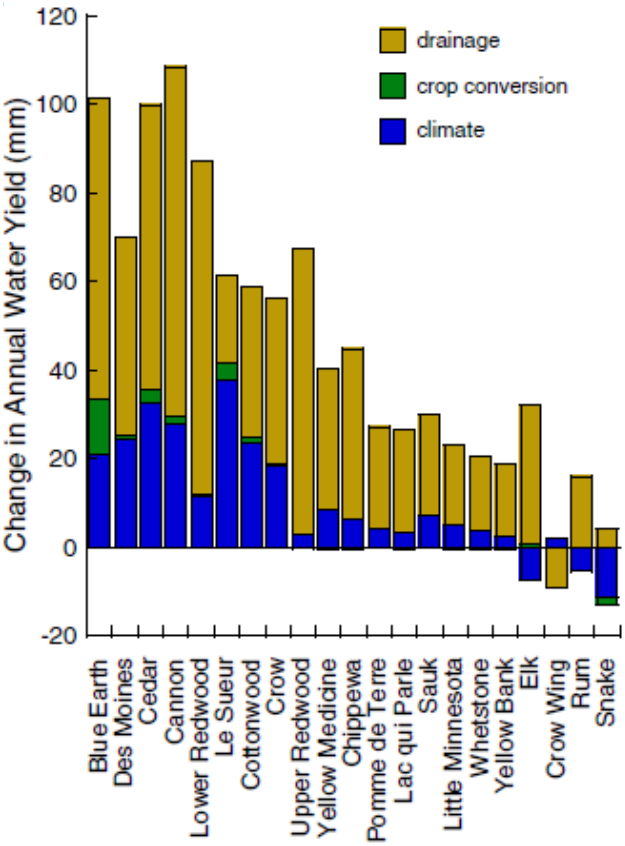


Figure 20. Apportionment of changes in mean annual water yield for each watershed. In rivers with significant changes in flow, climate and crop conversions account for less than half of the total change in water yield. Excess water yield is the portion that cannot be attributed to changes in crop ET and climate and is hypothesized to result from artificial drainage. The above figure was taken from the journal article titled "Twentieth century agricultural drainage creates more erosive rivers" (Schottler et al. 2013).

Table 8. Estimated tile drainage for the Cannon River Watershed by 10-digit HUC. Estimates were derived using the 2009 USDA crop data layer, USGS National Elevation Dataset, and SSURGO soil drainage class.

HUC 10 Name	*Total Area (ac)*	*No Tile Area (ac)*	*Percent No Tile*	*Tile Area (ac)*	*Percent Tile*
Chub Creek	54,664	18,042	33.0%	6,763	12.4%
Crane Creek	67,390	23,065	34.2%	24,066	35.7%
Middle Cannon River	126,049	31,938	25.3%	8,146	6.5%
Upper Cannon River	212,731	63,389	29.8%	32,262	15.2%
Straight River	227,973	50,463	22.1%	69,684	30.6%
Belle Creek	50,145	4,498	9.0%	148	0.3%
Prairie Creek	51,035	11,153	21.9%	5,411	10.6%
Little Cannon River	60,819	8,689	14.3%	2,535	4.2%
Lower Cannon River	89,737	8,527	9.5%	2,171	2.4%

Altered (channelized) watercourses are also common in the Cannon River Watershed (Figures 21 and 22). These channelized reaches have direct impacts on hydrology, as well as other variables (e.g. habitat). The Cannon River Watershed has approximately 929 altered stream miles (41%). Statistics were also calculated and broken down by 10-digit HUC, identifying spatial differences (Table 9). The greatest number of altered stream miles is located in the Straight River, while the highest percentage of altered stream miles is located in Crane Creek (which was not part of the SID process).

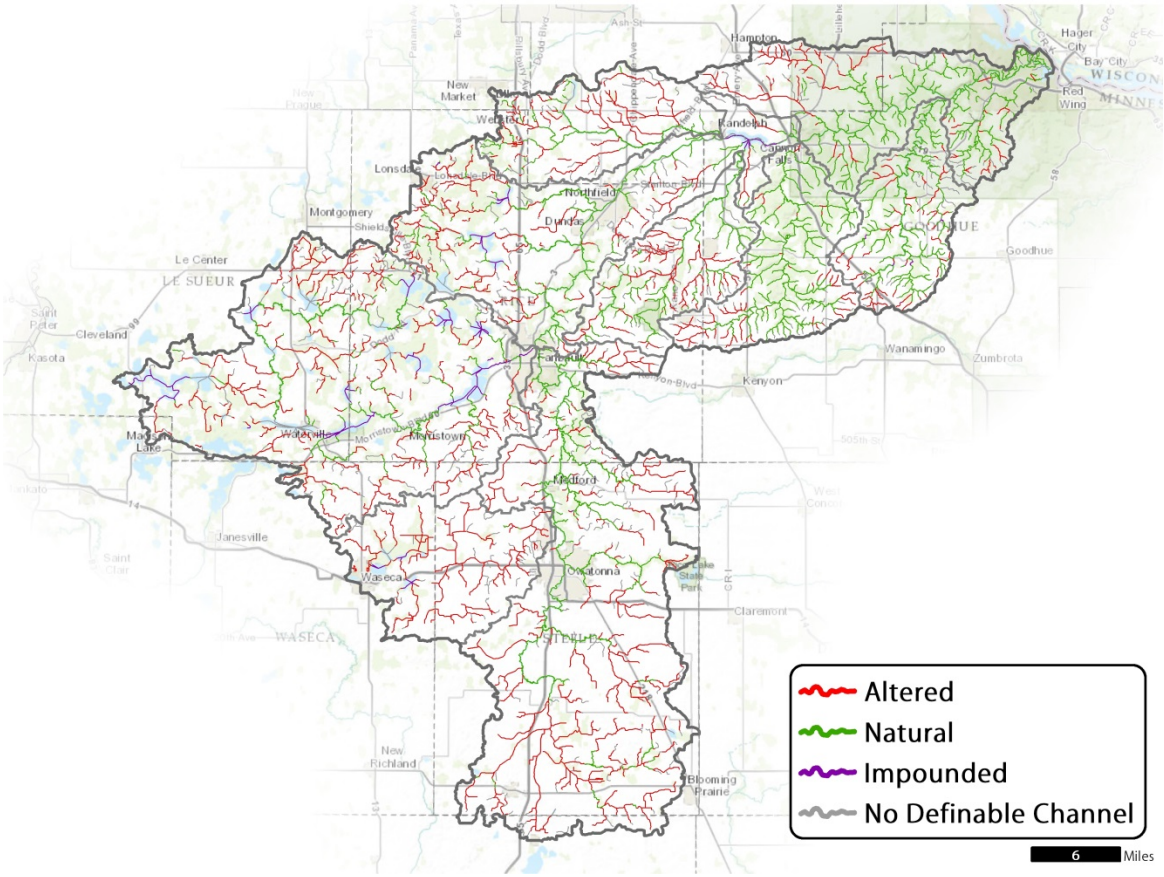


Figure 21. Altered, natural, impounded, and no definable channel watercourses in the Cannon River Watershed.

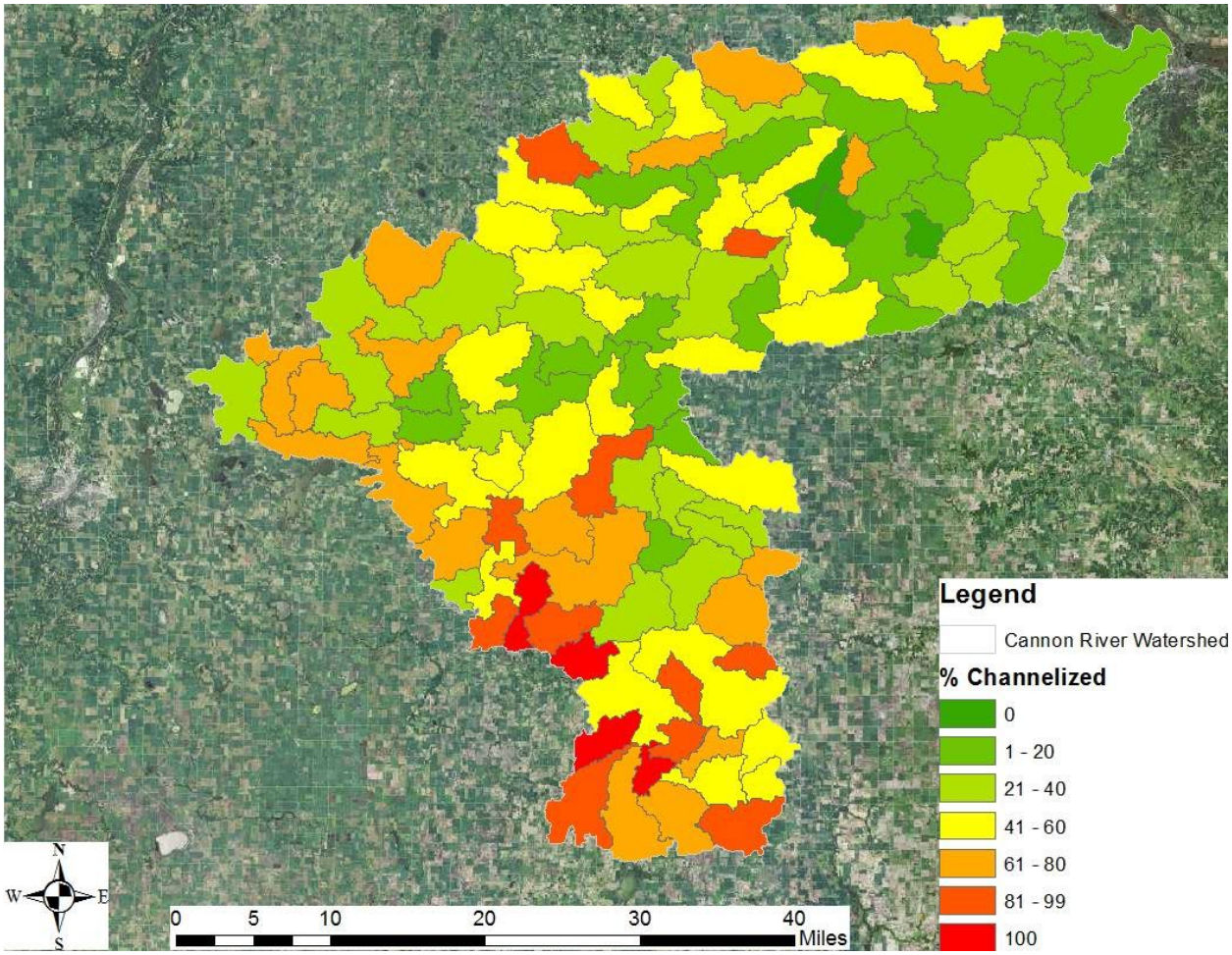


Figure 22. **Percent channelization of each sub-watershed within the Cannon River Watershed. The above figure was taken from the report titled "Upper Cannon River Watershed Geomorphology and Hydrology: A Report to DNR Fisheries" which was produced by the DNR.**

Table 9. **Altered, natural, impounded, and no definable channel stream miles in the Cannon River Watershed by 10 digit HUC.**

	Altered		Natural		Impounded		No Definable Channel	
HUC 10 Name	*Stream Miles*	*Percent of Total Miles*	*Stream Miles*	*Percent of Total Miles*	*Stream Miles*	*Percent of Total Miles*	*Stream Miles*	*Percent of Total Miles*
Belle Creek	34.6	20.8%	113.9	68.4%	2.1	1.3%	15.8	9.5%
Chub Creek	68.3	48.4%	43.9	31.1%	0	0.0%	29.0	20.5%
Crane Creek	98.3	73.9%	0.6	0.4%	4.6	3.5%	29.6	22.2%
Little Cannon River	34.7	18.4%	143.5	75.9%	0	0.0%	10.8	5.7%
Lower Cannon River	59.7	23.2%	162.4	63.2%	0	0.0%	35.0	13.6%
Middle Cannon River	116.1	37.8%	125.0	40.7%	15.3	5.0%	50.7	16.5%
Prairie Creek	59.1	38.0%	74.4	47.8%	0	0.0%	22.2	14.2%
Straight River	251.0	53.2%	154.3	32.7%	0.4	0.1%	66.1	14.0%
Upper Cannon River	209.3	45.3%	100.1	21.7%	48.1	10.4%	104.2	22.6%

Another factor impacting the hydrology in the Cannon River Watershed is groundwater and surface water appropriation (Figures 23 and 24). The following excerpt is from the DNR as it pertains to appropriation:

> *"Total water appropriation in the Cannon River Watershed is permitted for nearly 22.3 billion gallons per year (bgy). Actual water use is typically significantly lower. Reported water use for the most recent year of reported data is 2013, when nearly 6.46 billion gallons was appropriated from various aquifers and surface water resources in the Cannon River Watershed."*
>
> *"A majority of the permitted appropriations is from groundwater resources. This permitted appropriation totals nearly 17.2bgy. By contrast, surface water appropriations are only permitted at 5.1bgy. These appropriation numbers are only for the 301 active appropriations permits in the Cannon River Watershed. Many of the appropriators have more than one installation (well or intake) per permit for a total of 378 permitted installations. These are accounted for in total annual water use and the permitted appropriation is split between installations in the permit."*

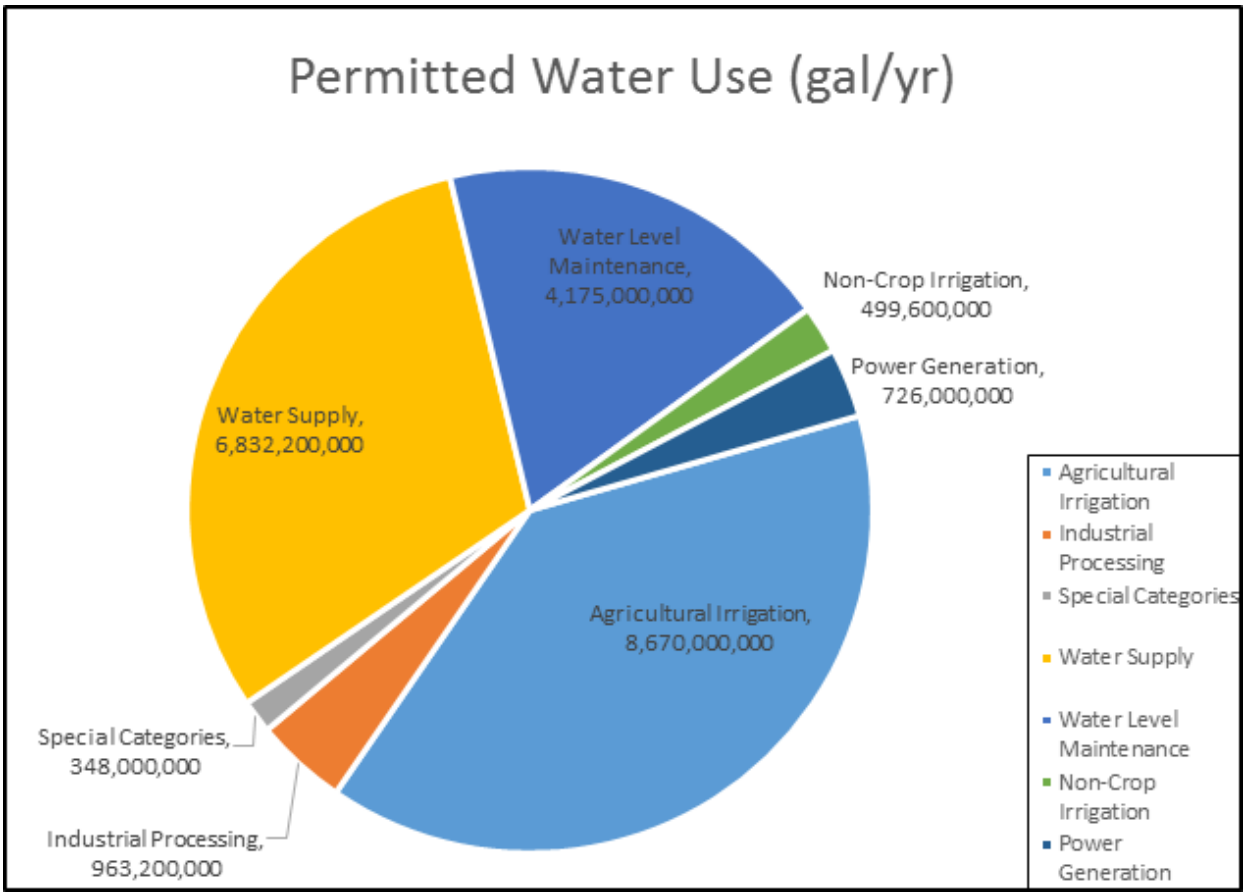
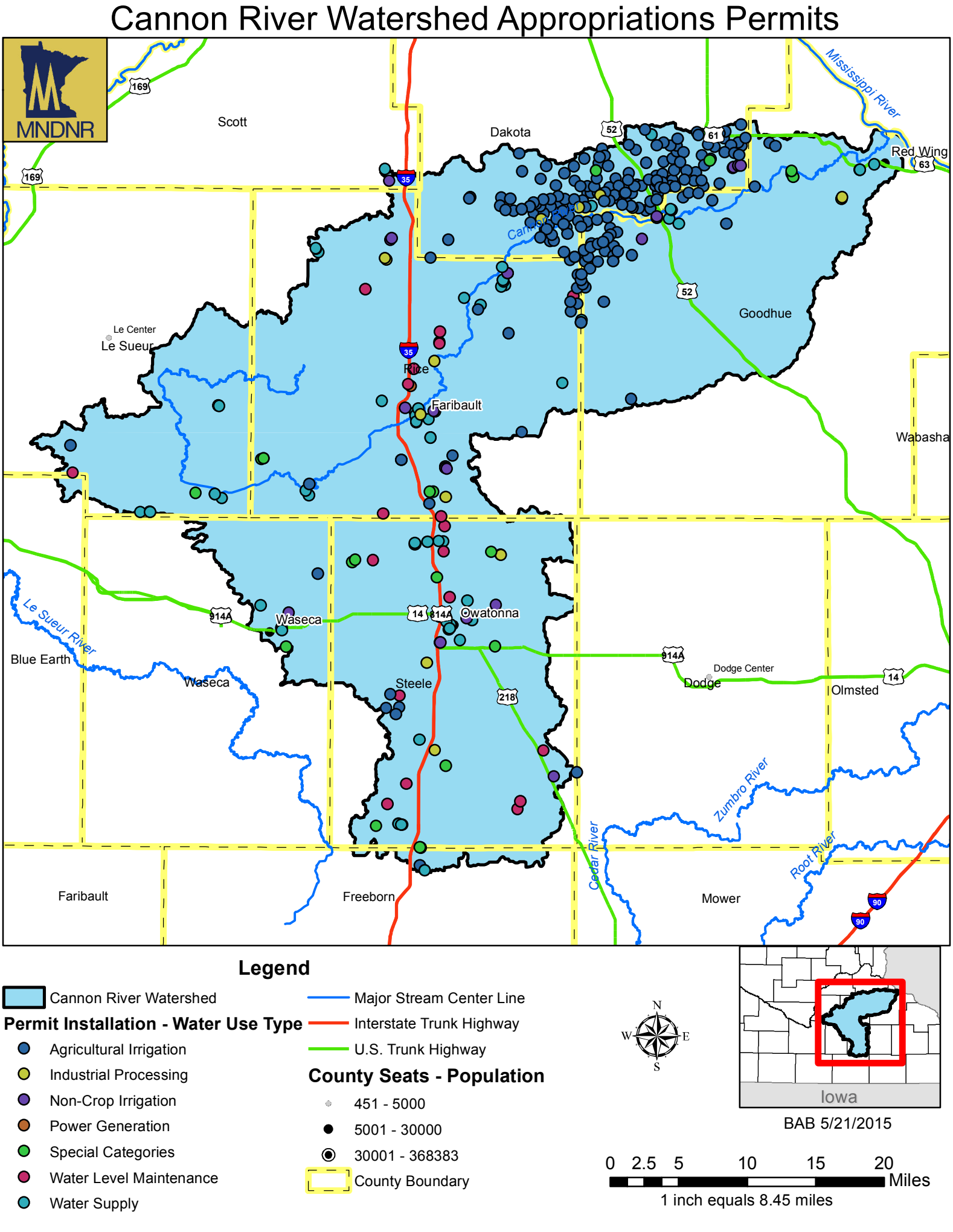


Figure 23. Permitted water use in the Cannon River Watershed. The above figure was provided by the DNR.

Figure 24. Appropriation permits in the Cannon River Watershed. The below figure was provided by the DNR



Land use in a watershed has significant impacts on the hydrology. Perennial cover, cropland, forest, wetlands, and developed (impervious) land affect hydrology in different ways, with some ultimately reducing runoff and river flows while others increase these flows. Agriculture is the dominant land use in the Cannon River Watershed; additional information regarding land use can be found in section 2.1 above as well as in the Cannon River Watershed Monitoring and Assessment Report.

The DNR has performed hydrologic analysis in the Cannon River Watershed, establishing that discharge and precipitation have been increasing. The following excerpt is from the report titled "Upper Cannon River Watershed Geomorphology and Hydrology: A Report to DNR Fisheries" which was produced by the DNR:

> *"Starting with the Cannon River (Welch) gage data, hydrological changes are definitely apparent over the period of time. Figure 25 shows that annual average discharge has been increasing throughout the period of record, along with increase precipitation. Along with an increase in average annual discharge, it also appears that the number of days with flows above Q10 (i.e. highest 10% of flows over a period of record) has increased (Figure 26). Breaking monthly average flows into two time periods, 1931-1971 and 1992-2013, shows that 1992-2013 has had considerably higher flows every month than previous; especially in spring (i.e. April-June) months when vegetation has not established on much of the agricultural lands (Figure 27)."*
>
> *"The Straight River gage in Faribault showed similar trends to the Cannon with discharge analyses. The period of record used for the Straight River was from 1965-2012 (2013 data had not been finalized at the time of analyses). Similar to the Cannon River gage, the Straight River has also shown an increasing trend in precipitation and discharge (Figure 28). Number of days above Q10 was relatively low in the 1960s, but since 1970 the trend has stayed similar throughout the period of record (Figure 29). Average monthly flows were broken up into two periods of time: 1966-1982 and 1983-2012. Average monthly flows follow similar trends to the Cannon where 1983-2012 are higher than 1966-1982 and the biggest change falls in spring months (Figure 30)."*

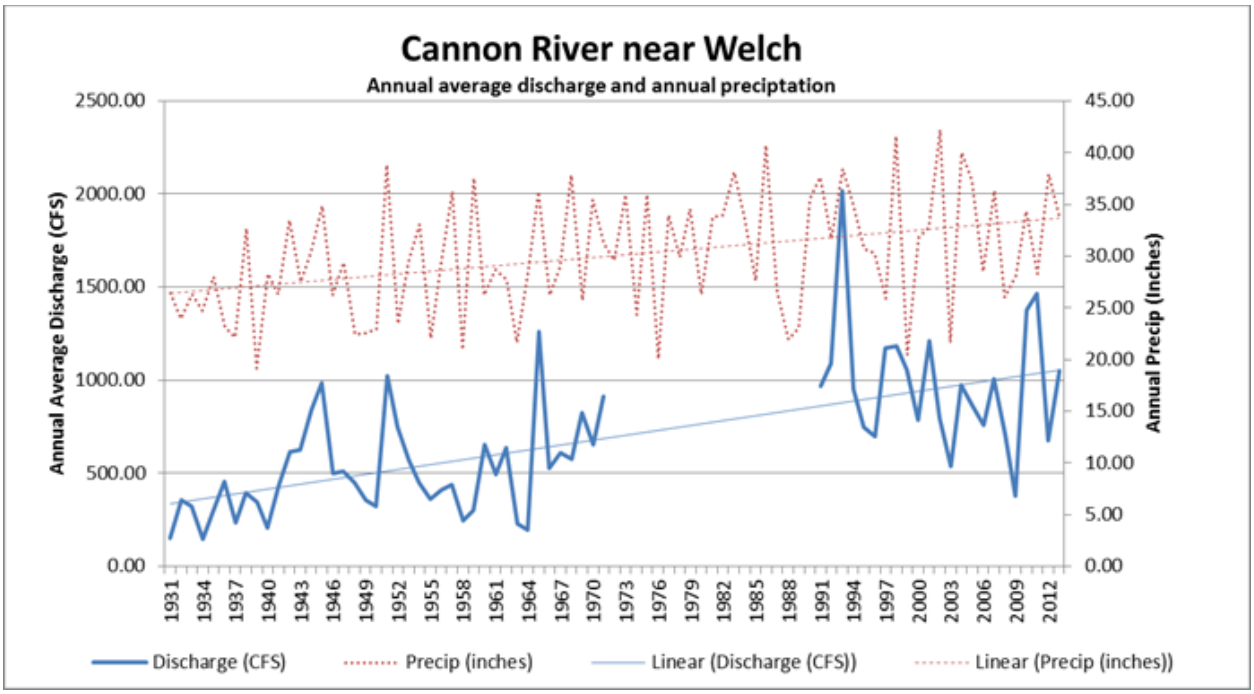


Figure 25. Average annual discharge plotted against annual precipitation for the Cannon River gage in Welch, Minnesota. The above figure was taken from the report titled "Upper Cannon River Watershed Geomorphology and Hydrology: A Report to DNR Fisheries", which was produced by the DNR.

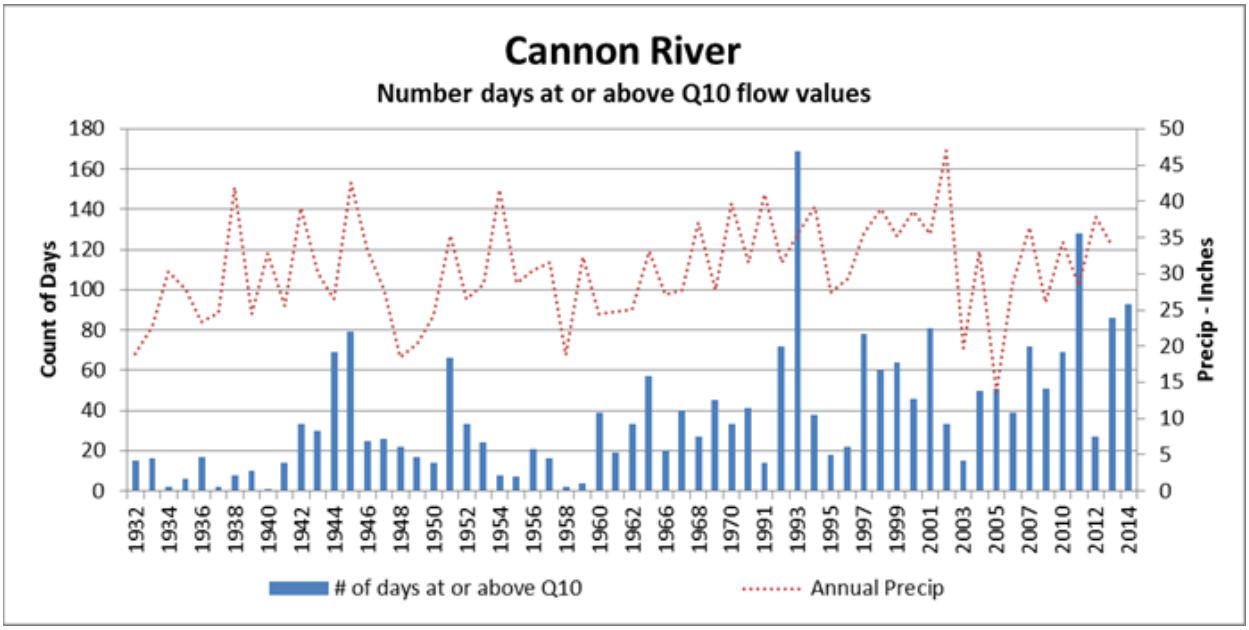


Figure 26. Number of days at or above the 10th percentile (Q10) high flows at the Cannon River gage in Welch, Minnesota. There is a data gap from 1972-1990. The above figure was taken from the report titled "Upper Cannon River Watershed Geomorphology and Hydrology: A Report to DNR Fisheries" which was produced by the DNR.

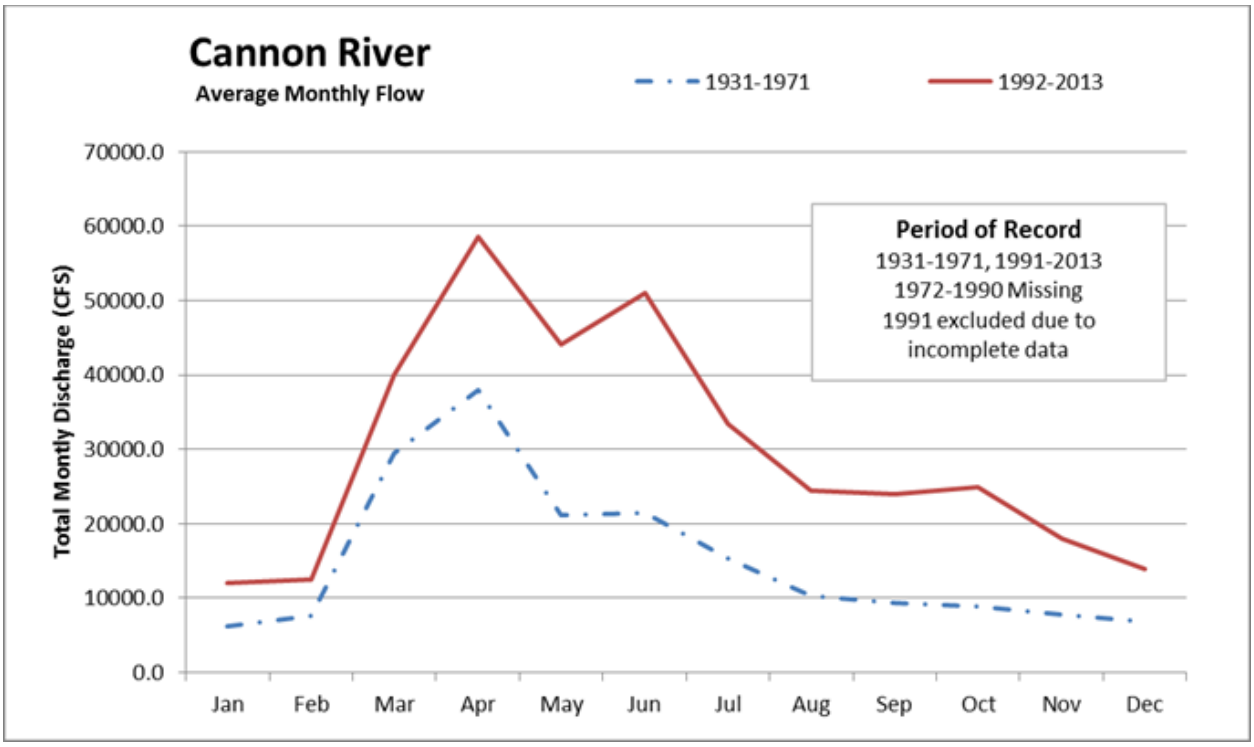


Figure 27. Change in average monthly flows in the Cannon River using two periods of record: 1931-1971 and 1992-2013. The above figure was taken from the report titled "Upper Cannon River Watershed Geomorphology and Hydrology: A Report to DNR Fisheries", which was produced by the DNR.

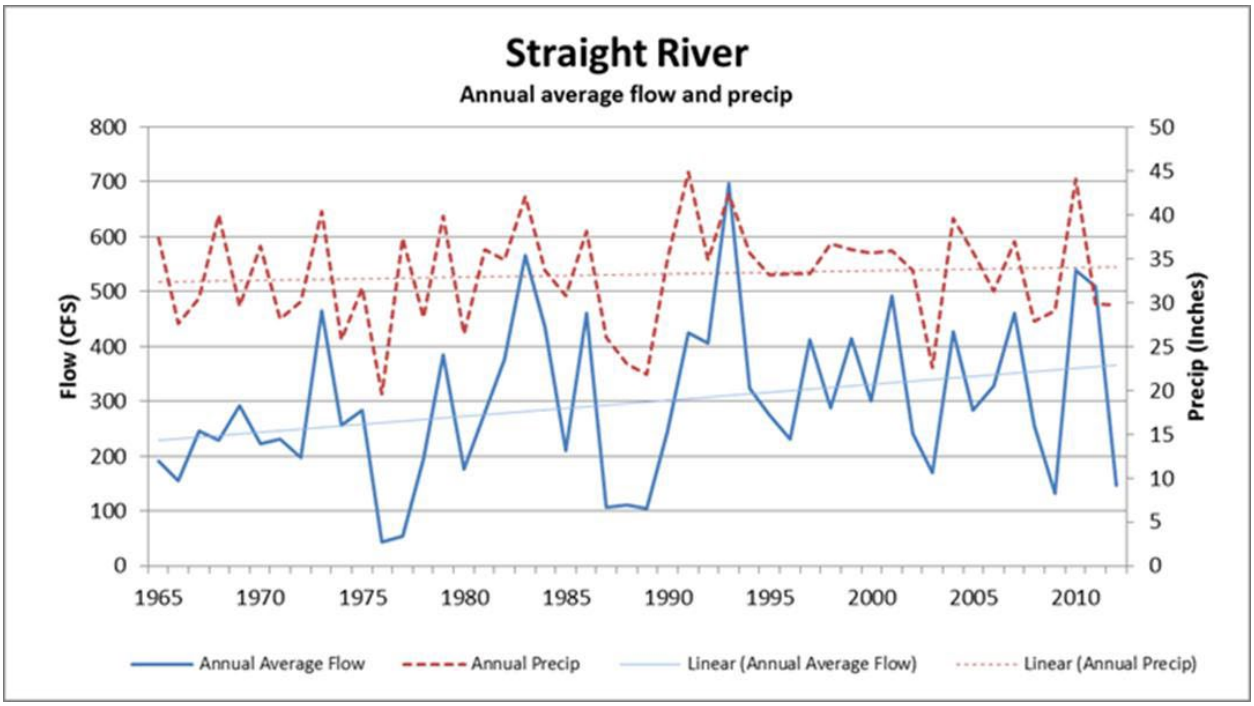


Figure 28. Average annual discharge plotted against annual precipitation for the Straight River gage in Faribault, Minnesota. The above figure was taken from the report titled "Upper Cannon River Watershed Geomorphology and Hydrology: A Report to DNR Fisheries", which was produced by the DNR.

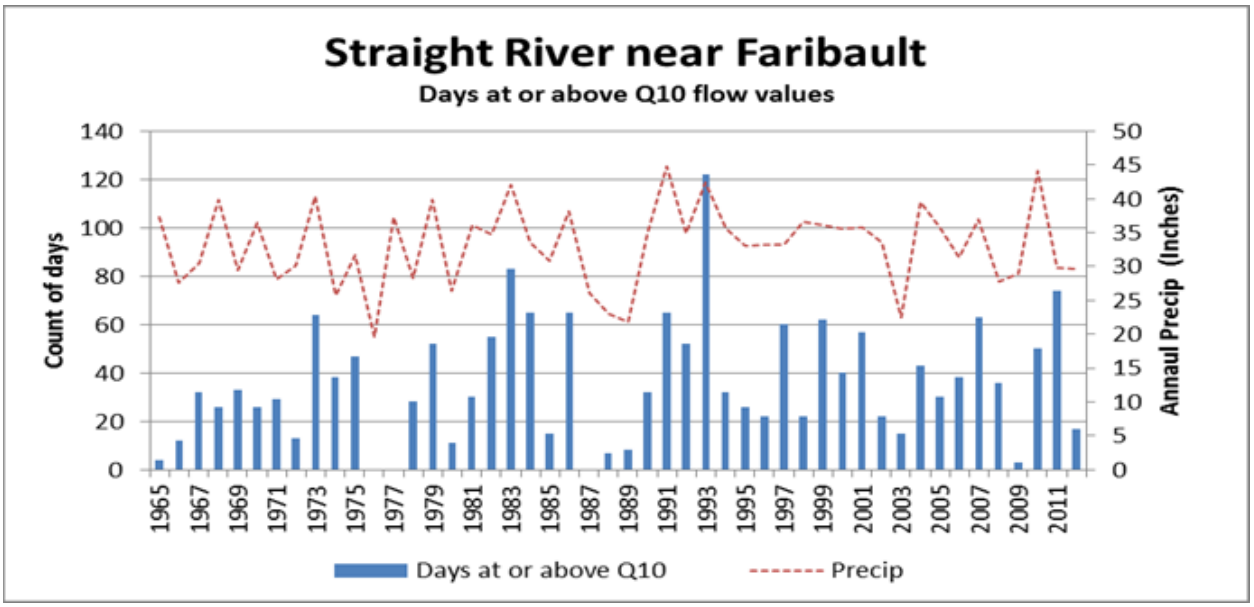


Figure 29. Number of days at or above the 10th percentile (Q10) high flows at the Straight River gage in Faribault, Minnesota from 1965-2012. The above figure was taken from the report titled "Upper Cannon River Watershed Geomorphology and Hydrology: A report to DNR Fisheries", which was produced by the DNR.

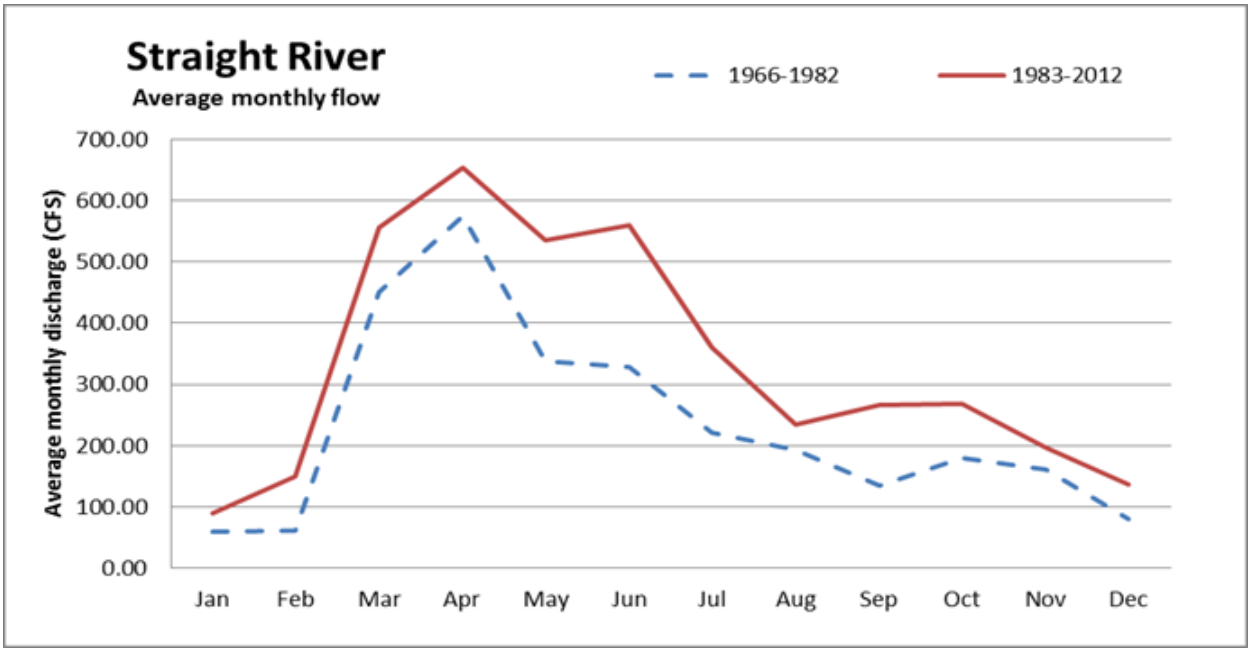


Figure 30. Change in average monthly flows on the Straight River using two periods of record: 1966-1982 and 1983-2012. The above figure was taken from the report titled "Upper Cannon River Watershed Geomorphology and Hydrology: A report to DNR Fisheries", which was produced by the DNR.

River flows have been increasing in the Cannon River Watershed, which are contributing to stream instability and degraded water quality and biological conditions. Many factors are playing a role in these increased flows, and their affects are accelerating the impacts of the identified stressors in this report. It's reasonable to assume that flow alteration is contributing (in part) to all (or most) of the stressors in the Cannon River Watershed; it's not the only driver but it affects multiple components of stream health. Many of the BMPs available for conventional pollutants (e.g. sediment and nutrients) also have positive impacts on hydrology, providing multiple benefits. Focusing these BMPs in the upper portions of

watersheds and tributaries (as opposed to the main channel) will provide necessary flow attenuation (in addition to other benefits) and improve hydrology.

3.3.9. Candidate cause: 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). The EPA recommended chronic criterion for aquatic life is a four-day average chloride concentration of 230 mg/L with an occurrence interval of once every three years, and the recommended acute criterion concentration for chloride is 860 mg/L (EPA 1988).

Water Quality Standards

The chronic standard for chloride in MN is 230 mg/L.

Sources and Causal Pathways Model for Chloride

The causes and potential sources for increases in chloride are modeled at EPA's CADDIS Ionic Strength webpage.

Overview of Chloride in the Cannon River Watershed

Elevated chloride has been documented in the Unnamed Ditch to Heath Creek (555); this is the only reach in the Cannon River Watershed where chloride was identified as a stressor. Chloride levels as high as 417 mg/L have been observed in this AUID.

4. Evaluation of Candidate Causes

Candidate causes were evaluated in the Cannon River Watershed by individual AUID. Each AUID is discussed below, and organized by 10-digit HUC.

4.1 Little Cannon River 10-digit HUC

This section encompasses biotic impairments in the Little Cannon River 10-digit HUC (Figure 31). There are five AUIDs with biotic impairments in the Little Cannon River 10-digit HUC; all impairments are for macroinvertebrates and there is also a fish impairment in the upper end of the Little Cannon River (AUID 589). Two of the impairments are located on the Little Cannon River, while the other three impairments are located on tributaries to the Little Cannon River. One of the tributaries is Butler Creek, and the other two are unnamed tributaries located in the upper end of the watershed. The upper end of the Little Cannon River is a coldwater (2A) stream, and the remaining AUIDs are warmwater (2B). This 10-digit HUC is the only one in the Cannon River Watershed where redside dace were collected; redside dace are considered a special concern species by the DNR.

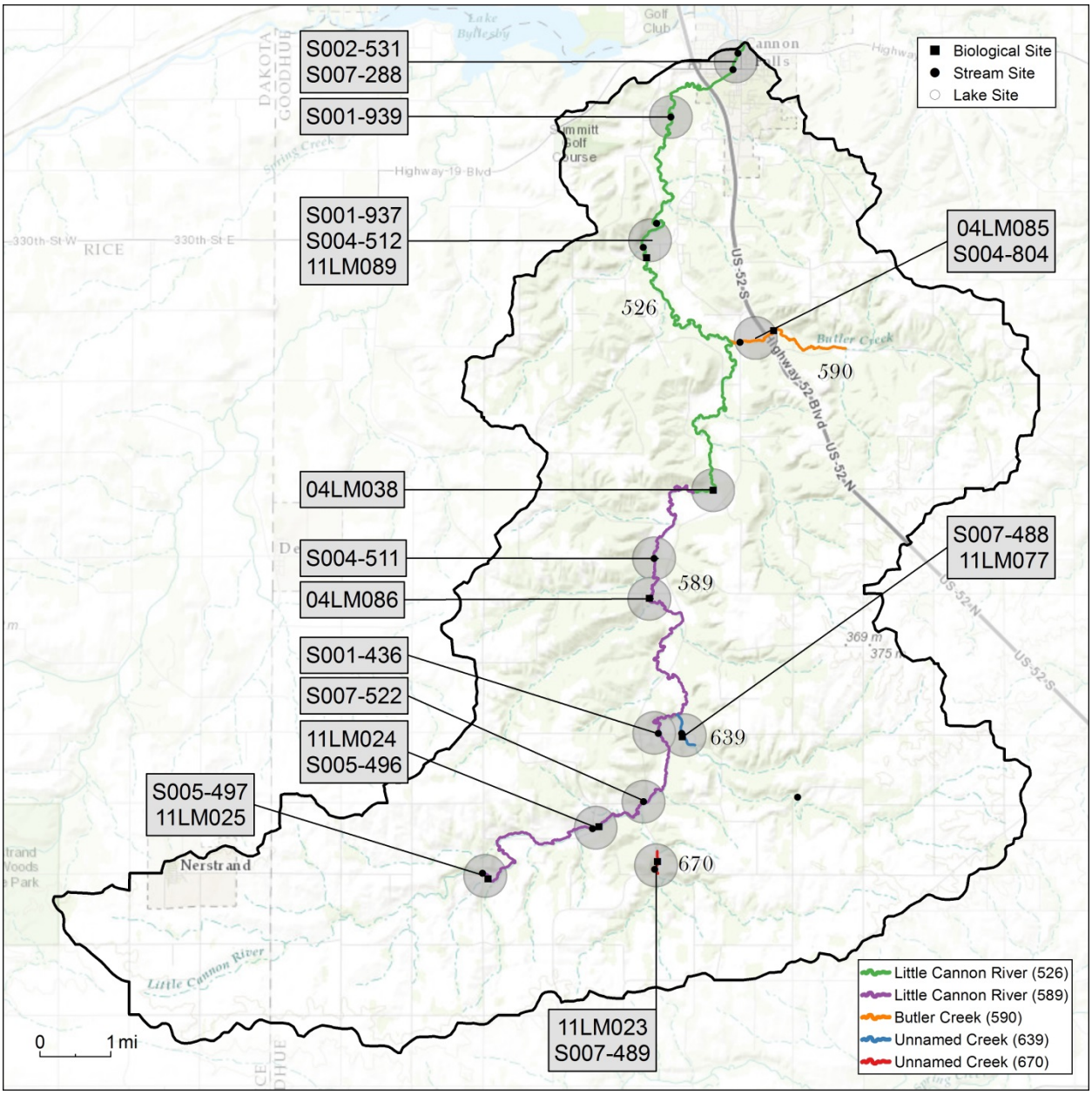


Figure 31. Map of the Little Cannon River 10 digit HUC including biota impairments with biological stations and chemistry stations used in report.

4.1.1. Little Cannon River (526)

Biological Communities

Little Cannon (07040002-526) is an 11.9 mile long stream segment in Goodhue County. This warmwater reach is located in the Driftless Area ecoregion. A majority of this reach flows through farm country and forest. The tail end of this AUID flows through Cannon Falls where it then drains into the Cannon River just below Lake Byllesby. Butler Creek is a tributary that drains into this AUID between the two biological monitoring stations. Little Cannon – 526 has a macroinvertebrate impairment, as well as turbidity and bacteria impairments. Butler Creek and the upstream AUID (Little Cannon – 589) also have turbidity and bacteria impairments. Station 04LM038 and 11LM089 are the two biological monitoring stations in this

AUID. Station 11LM089 is located near the middle of the reach, downstream of the confluence with Butler Creek. Station 04LM038 is on the upper end of the AUID, upstream of the confluence with Butler Creek. Station 11LM089 was sampled in 2011 for fish and macroinvertebrates, and station 04LM038 was sampled in 2004 for fish and macroinvertebrates.

The fish community in this AUID is "supporting" the aquatic life use, and not currently impaired. Both stations were above the FIBI impairment threshold of 45 (lower CL = 36, upper CL = 54) for the Southern Streams fish class. Station 11LM089 had a FIBI score of 47, and station 04LM038 had a FIBI score of 58. A total of 13 fish species were collected at station 11LM089, and 17 at station 04LM038. Although designated a warmwater stream, brown trout were collected at both stations and rainbow trout were collected at station 04LM038. The MPCA biologists noted that several sensitive species were collected in fair numbers, but the populations for both stations favor tolerant individuals. Blacknose dace (98), creek chub (62), and white sucker (41) were the three most abundant species at station 11LM089. There were two pollution intolerant species present and one game fish species (brown trout). The top three fish species at station 04LM038 were blacknose dace (200), white sucker (151), and bluntnose minnow (135). This station had three pollution intolerant species and two game fish species (brown trout and rainbow trout).

The macroinvertebrate community is impaired and "not supporting" the aquatic life use. The MIBI score for station 11LM089 is 42, which is below the impairment threshold (46.8) but above the lower confidence limit (33.2) for the Southern Forest Streams GP macroinvertebrate class. The MIBI score for station 04LM038 is 46, which is above the impairment threshold (35.9) but below the upper confidence limit (48.5) for the Southern Streams RR macroinvertebrate class. Station 11LM089 has several MIBI metric scores below average (Figure 33). DomFiveChPct, HBI_MN, POET, PredatorCh, TaxaCountAllChir, and TrichopteraChTxPct MIBI metric scores were all below the average metric score needed to meet the impairment threshold. ClimberCh, ClingerChTxPct, DomFiveChPct, InsectTxPct, Odonata, and Plecoptera MIBI metric scores were above the average metric score needed to meet the impairment threshold at station 04LM038, resulting in a MIBI score above the impairment threshold (Figure 32).

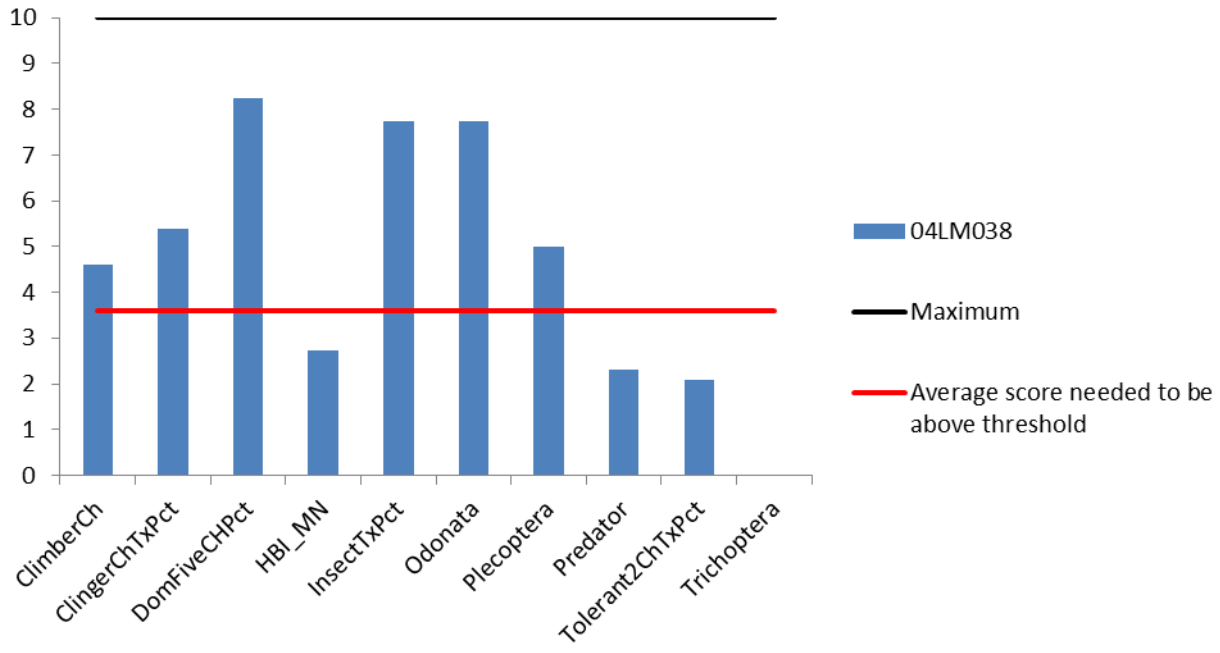


Figure 32. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for the Little Cannon River (07040002-526), station 04LM038.

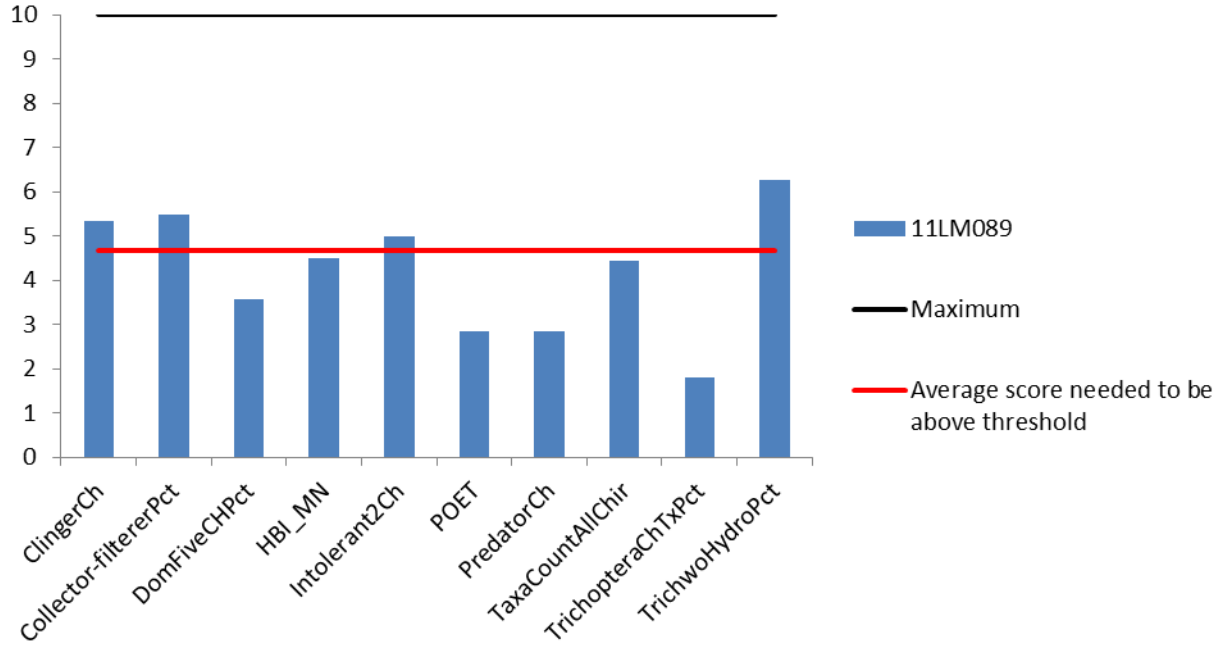


Figure 33. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for the Little Cannon River (07040002-526), station 11LM089.

Data Evaluation for each Candidate Cause

Temperature

The temperature data set for the Little Cannon River (07040002-526) spans from 2002 – 2013, and includes 223 samples. The minimum value recorded was -1.1 °C, and the maximum value was 25.0 °C (average of 13.4 °C). Temperature readings were collected at six monitoring stations (including the biological monitoring stations). A majority of the readings were collected at the mouth of the Little Cannon, and near the middle of the AUID (downstream of Butler Creek). The two stations with the greatest number of readings (S004-512 – 103 samples, and S002-531 – 37 samples) have good temporal coverage across seasons and years. Only one sample has been collected in the upper end of the AUID (above Butler Creek). In the future, it would benefit this data set to collect additional temperature readings on the upper end of this AUID. There were no measurements above 30 °C at any of the stations; temperature does not appear to be stressing the biological community at this time.

Nitrate

Nitrate concentrations, from 2004-2013, ranged from 1.2 mg/L to 11 mg/L (average of 4.0 mg/L) (Figure 34). Only one sample out of the 107 collected exceeded 10 mg/L. Six samples (6%) exceeded 8 mg/L. Sampling efforts were focused on the central portion of the AUID at station S004-512 (82 samples) and station S001-939 (23 samples). Samples collected at station S004-512 occurred in six different years, and 40% (33 samples) were collected from April through June. The only sample above 10 mg/L was collected at station S004-512 in June of 2008. There were no samples collected at the mouth of the Little Cannon, and only one sample collected in the upper end of the AUID. Improved spatial coverage (at the upper and lower end of the AUID) would assist with understanding the nitrate dynamics in this reach.

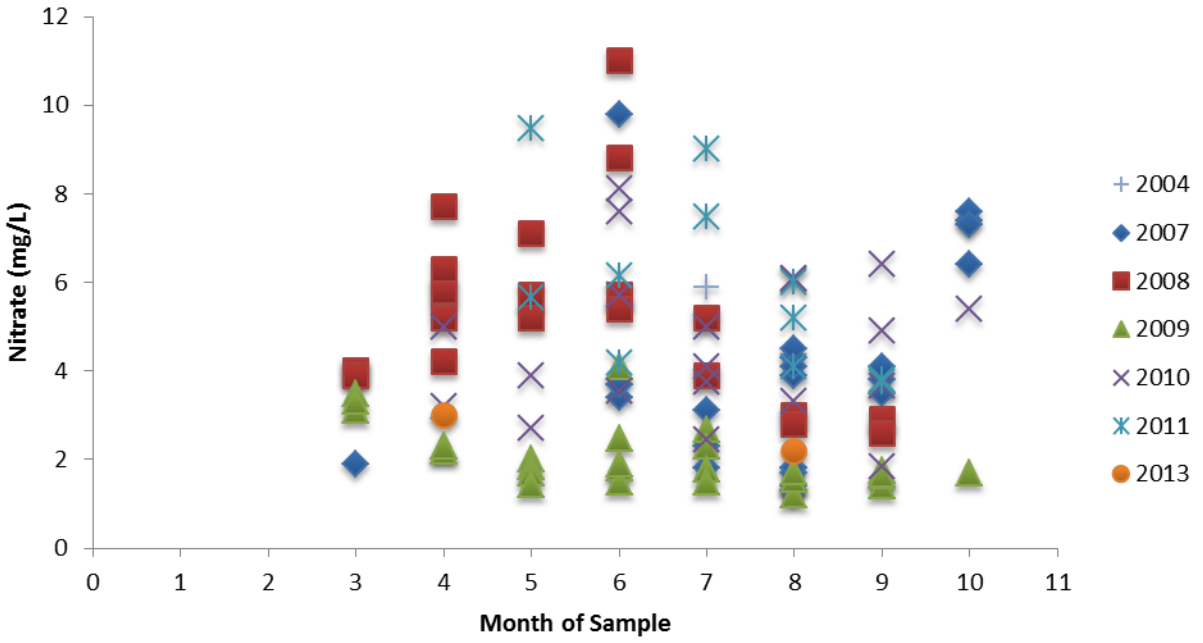


Figure 34. Nitrate concentrations in the Little Cannon River by month sampled.

Fish lack a strong biological response in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows a 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

Station 04LM038 has above average taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) (Table 10). Trichoptera taxa richness and abundance of non-hydropsychid Trichoptera individuals (TrichopteraCh and TrichwoHydroPct) were well below the state average. Two caddisfly taxa were present. Trichoptera taxa comprised 4% of the overall taxa found at station 04LM038, and Trichoptera individuals made up 8% of the community. The Trichoptera IBI metric score, which is one of the 10 metrics used to calculate the Southern Streams RR IBI, was zero and well below the average metric score (3.59) needed to meet the IBI threshold of 35.9. Station 11LM089 had below average Trichoptera taxa richness and abundance of non-hydropsychid Trichoptera individuals. Trichoptera taxa comprised 3% of the total taxa, and Trichoptera individuals were 4% of the community. The Trichoptera IBI metric scores used in the calculation of the Southern Forest Streams GP IBI were above and below the average metric score (4.68) needed to meet the threshold. The TrichopteraChTxPct metric score was 1.79 and the TrichwoHydroPct metric score was 6.27. There was one intolerant taxa present.

Station 04LM038 had two nitrate intolerant taxa and one nitrate very intolerant taxon present. Station 11LM089 had one nitrate intolerant taxon present. Station 04LM038 had 27 (78%) nitrate tolerant and 19 (40%) nitrate very tolerant taxa. There were 22 (75%) nitrate tolerant and 14 (63%) nitrate very tolerant taxa present at station 11LM089. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI, and at 83.8% nitrate tolerant individuals there is a 10% probability of meeting the MIBI. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. The nitrate index scores were 3.3 (04LM038) and 3.8 (11LM089), which are above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 10. Macroinvertebrate metrics that respond to nitrate stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
04LM038 (2004)	**2**	**0.0**	2	**3.3**	**2**	1	**27**	**19**	**78.3**	**40.3**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
11LM089 (2011)	**1**	**3.7**	1	**3.8**	**1**	**0**	**22**	**14**	**74.7**	**63.2**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

The nitrate chemistry data is good in terms of sample quantity, but is limited longitudinally throughout the reach. The concentrations are not consistently high, with only one sample greater than 10 mg/L in the past decade (average of 4.0 mg/L). Trichoptera taxa richness and IBI metric scores are worse than expected (with exception of the TrichwoHydroPct metric score at station 11LM089). There were nitrate intolerant taxa present at each station, which is not likely in nitrogen stressed streams, but there were also multiple nitrate tolerant and very tolerant taxa present. Tolerant individuals comprised a high percentage of the community. Also, the nitrate index scores were worse than the statewide average of stations meeting the MIBI threshold. Overall, it's not cut and dry, but it appears that nitrates are adversely impacting the macroinvertebrate community. Nitrate is not the only stressor in this AUID, but it is a stressor.

Phosphorus

The phosphorus data set contains 105 samples from 2004-2013 (minimum of 0.018 mg/L, maximum of 5.08 mg/L, and an average of 0.3 mg/L). Forty-seven samples (45%) were greater than 0.1 mg/L, the draft river eutrophication standard for the Central Region. At least one exceedance was observed in every month that was sampled (March through October), with the majority occurring in June and August (26% and 28% respectively). Many of the TP exceedances were associated with elevated TSS concentrations (Figure 35). This implies that much of the elevated phosphorus conditions are occurring during storm flows, where phosphorus is flushed through the system attached to sediment particles. Four different monitoring stations were sampled, but two of the stations (04LM038 and 11LM089) had only one sample. Station S004-512, downstream of Butler Creek near the middle of the AUID, has the most samples (80). These 80 samples were spread out across six different years, and included samples from various seasons (March through October). A majority of the samples (33) were collected from April through June. Station S001-939, in-between station S004-512 and the mouth of the Little Cannon, had 23 samples collected. The samples covered two different years, and had good seasonal coverage (April through September). Both of these stations had concentrations that exceeded the draft standard. The

existing data set shows elevated phosphorus concentrations, and has good temporal coverage. Collecting samples on the upper and lower ends of this AUID would bolster this data set.

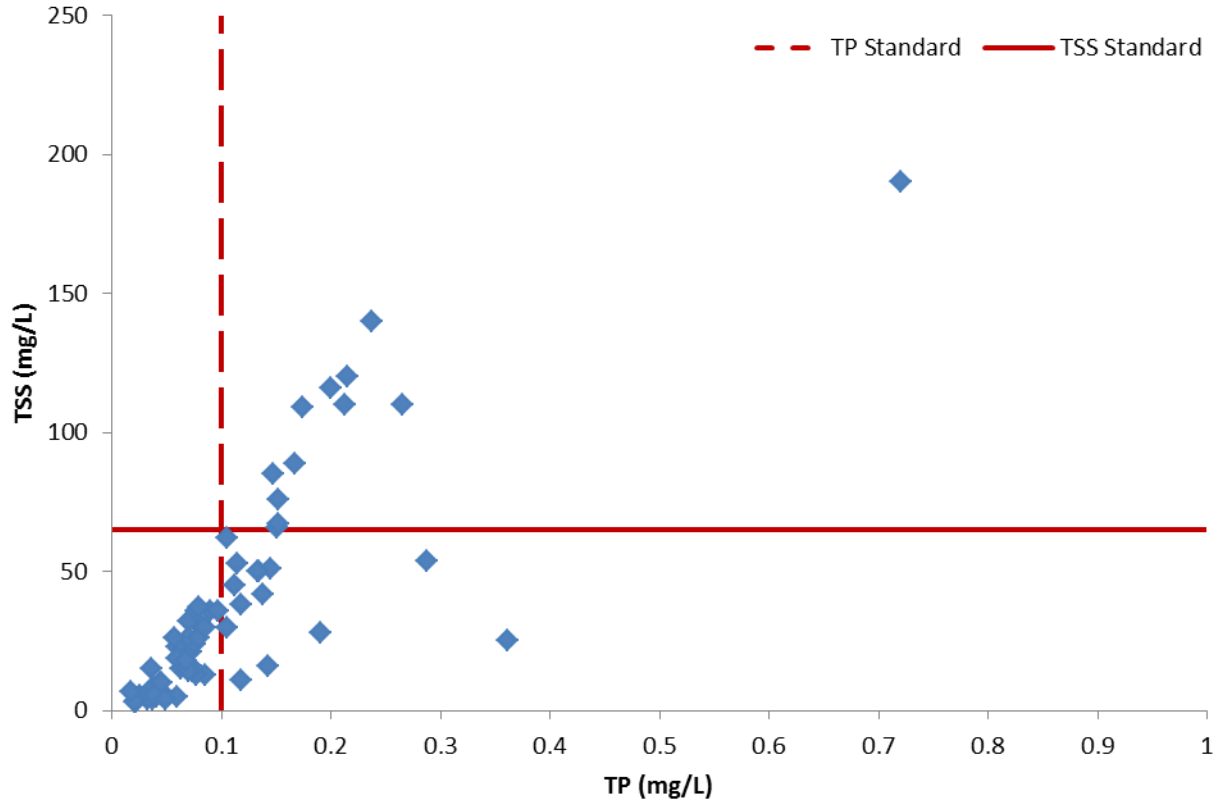


Figure 35. TSS and TP relationship in the Little Cannon - 526 (2004-2013). A few of the extremely elevated TSS and TP concentrations were excluded to enable finer resolution.

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired for excess nutrients. Chlorophyll-a samples were limited to 23 samples collected in 2009 and 2010 at station S001-939 (minimum of 1 µg/L, maximum of 11 µg/L, and an average of 4.7 µg/L). There were zero concentrations above the Central Region draft river eutrophication standard (18 µg/L). There was no BOD data available at the time of this report; BOD sampling should be included in future monitoring efforts. Sonde deployment in 2014 at station 04LM038 resulted in DO flux exceedances just above the Central Region standard of 3.5 mg/L; daily DO flux exceeded the standard two out of the six days, with a maximum of 3.58 mg/L. In August 2014, a longitudinal DO survey identified three DO flux exceedances. The exceedances were minimal (3.52 mg/L, 3.63 mg/L, and 3.56 mg/L), and located in the middle – upper portions of the AUID.

The macroinvertebrate metrics with strong relationships to phosphorus were better (for the most part) than the statewide average at station 04LM038 (Table 11). Four out of the six metrics (TaxaCountAllChir, Collector-filtererCh, Collector-gathererCh, and Intolerant2Ch) were better than the statewide average of stations meeting the MIBI threshold. Taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) and the percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) were worse than the average. Station 11LM089 had four metrics (TaxaCountAllChir, Collector-filtererCh, EPT, and Tolerant2ChTxPct) that were worse than average, and two metrics (Collector-gathererCh and Intolerant2Ch) that were better than average.

Table 11. Macroinvertebrate metrics that respond to TP stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
04LM038 (2004)	50	7	19	**9**	2	**84.0**
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
11LM089 (2011)	**34**	**2**	17	**5**	1	**76.5**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

This AUID has elevated phosphorus levels with multiple exceedances at various flows. However, there were no chlorophyll-a exceedances, and no BOD samples collected. DO flux exceedances were identified, but were just above the standard. The macroinvertebrate metrics were mixed between stations; a majority of the metrics at one station were better than average, while a majority at the other station were worse than average. Overall, it appears that phosphorus has the potential to be a stressor to the biology in this section of the Little Cannon River, but at this time it's inconclusive due to limited data for the response variables. Additional chl-a, BOD, and DO flux information is necessary in order to determine if the elevated phosphorus levels are leading to eutrophication issues. Although inconclusive at this time, reducing phosphorus in the Little Cannon River should be a priority in any future planning efforts. Phosphorus has the potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus loading should help (and/or protect from potential future impacts) the biology in the Little Cannon River, as well as downstream receiving waters.

Dissolved Oxygen

DO samples exist from 2003 – 2013, and include 83 samples with an average concentration of 9.9 mg/L (minimum of 6.46 mg/L and a maximum of 19.47 mg/L). There were zero samples below the warmwater standard (5.0 mg/L). Nineteen of the 83 samples (23%) were collected in the early morning hours (prior to 9:00 a.m.). However, of those early morning samples, only three were collected in July and one in August. July and August are critical months for low DO concentrations. Samples were collected at four monitoring stations throughout the reach, with station S004-512 and S002-531 having the most samples (63 and 18 respectively). These two stations had samples from March through October, and station S004-512 had samples from seven different years. The two biological monitoring stations (04LM038 and 11LM089) had one sample each.

There were zero low DO concentrations identified during a longitudinal DO survey in August 2014. Also, sonde deployment from August 5th – 11th, 2014 at station 04LM038 resulted in zero low DO concentrations.

Total taxa richness of the macroinvertebrate community (TaxaCountAllChir), the percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) were worse than the statewide average at both stations except for the total taxa richness at station 04LM038 (Table 12). TaxaCountAllChir and EPT are expected to decrease in response to stress while Tolerant2ChTXPct is expected to increase.

Station 04LM038 and station 11LM089 both had several DO intolerant and very intolerant macroinvertebrate taxa. Each station also had DO tolerant taxa, but in low numbers. Percentages of DO tolerant taxa range from 1% - 15%, and very tolerant from 0% - 1%. The number of DO intolerant and very intolerant taxa are greater than the number of DO tolerant and very tolerant taxa at both stations. The DO index scores were 7.0 (04LM038) and 7.4 (11LM089). The score for station 04LM038 was below the statewide average of stations meeting the MIBI threshold, while station 11LM089 was above. As the score decreases, so does the sensitivity of the community.

Table 12. Macroinvertebrate metrics that respond to low DO stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
04LM038 (2004)	50	**84.0**	**9**	**7.0**	**8**	6	**6**	**2**	**15.2**	1.2
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
11LM089 (2011)	**34**	**76.5**	**5**	7.4	10	5	2	0	0.7	0.0
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

At this time, DO is meeting the standard (no low DO values in data set, longitudinal DO survey, or sonde deployment) and is not currently stressing the biota. There are several DO intolerant and very intolerant macroinvertebrate taxa present at both stations and lower tolerant individuals.

TSS/Turbidity

This AUID (Little Cannon – 526) is currently impaired for turbidity. The immediate upstream AUID (Little Cannon – 589) and Butler Creek, a tributary to the Little Cannon – 526, are also impaired for turbidity. TSS data for this stream segment is available from 2004 – 2013, and contains 114 samples. The concentrations range from 2.8 mg/L to 4,900 mg/L (average of 298.9 mg/L). There were 38 exceedances (33%) of the Southern Region draft TSS standard, which is 65 mg/L. The most exceedances occurred in June (11 samples), with August not far behind (10 samples). Four stations (04LM038, 11LM089, S004-512, and S002-531) have been sampled, but station 04LM038 and 11LM089 were only sampled once during fish assessment. Station S004-512, near the middle of the AUID and downstream of Butler Creek,

has the most samples (99). Good temporal coverage exists at this station. Thirty-nine samples (39%) were collected from April through June, and 47 samples (48%) were collected from July through September. Multiple years (seven) were sampled at this station. Station S002-531, located in Cannon Falls near the mouth of the Little Cannon, has 13 samples. All of these samples were collected in 2004 as part of the Lower Cannon TMDL study. Both stations had multiple exceedances and extremely high maximum concentrations (S004-512 – 4,900 mg/L, S002-531 – 3,500 mg/L). Limited TSS data is available on the upper end of this AUID. Bedload sediment estimates near station 11LM089 suggest that 30% of the load is in excess; some of the riffles were comprised completely of sand substrate (Proulx 2015).

Transparency data for this AUID contains 566 samples from 2002-2013 (minimum of 1 cm, maximum of 100 cm, and an average of 55 cm). A total of 38 samples (7%) were less than 10 cm, which is the S-tube surrogate for the South Region TSS standard. Samples were collected at seven different stations along the AUID. Most stations contained samples from multiple years and seasons. Five of the stations had at least one sample below the standard, and the two stations that didn't were bio sites which were only sampled once during baseflow conditions. Station S001-939, located on the lower portion of the AUID, has the most samples (302). May and June combined for over half (53%) of the exceedances. Similar to the TSS data set, transparency data is limited on the upper end of this AUID.

A majority of the macroinvertebrate metrics with strong relationships to TSS were below the statewide average of stations meeting the MIBI threshold at station 04LM038 (Table 13). The relative abundance of collector-filterer individuals (Collector-filtererPct), and relative abundance of Plecoptera individuals (PlecopteraPct) are expected to decrease in response to stress. These metrics at station 04LM038 had values indicative of stress. Station 11LM089 had above average PlecopteraPct, and below average Collector-filtererPct.

There were two TSS intolerant taxa present at both stations. TSS very intolerant taxa were also present at both stations; there was one at station 04LM038 and two at station 11LM089. Multiple TSS tolerant and very tolerant taxa were also found, ranging from 7 – 16 and 4 – 7 respectively. TSS tolerant taxa comprised 20% of the macroinvertebrate community at station 04LM038, and 32% at station 11LM089. TSS very tolerant taxa comprised 6% of the macroinvertebrate community at station 04LM038, and 3% at station 11LM089. The macroinvertebrate TSS index scores were 16.2 (04LM038) and 17.1 (11LM089). Station 04LM038 was below the statewide average of stations meeting the MIBI threshold, while station 11LM089 was above average. As the score increases, so does the tolerance of the community.

Table 13. Macroinvertebrate metrics that respond to TSS stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
04LM038 (2004)	**19.8**	**0.0**	16.2	**2**	1	**16**	**7**	19.9	5.7
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
11LM089 (2011)	**21.0**	0.6	**17.1**	2	2	7	**4**	**31.8**	2.5
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it still has the potential to shed light on stressors. The relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are long-lived (LLvdPct), relative abundance of individuals that are sensitive species (SensitivePct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were all below the statewide average of stations meeting the FIBI threshold at both stations in this AUID (Table 14). The relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), and relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct) were above average at station 04LM038, and below average at station 11LM089. The relative abundance of individuals that are intolerant species (IntolerantPct) was above average at both stations. All of these metrics are expected to decrease in response to stress. The fish TSS index score, which is expected to increase with stress, was below average at both stations. Five out of the 10 metrics were worse than average at station 04LM038, and 8 out of the 10 metrics were worse than average at station 11LM089.

Table 14. Fish metrics that respond to TSS stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RiffflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
04LM038 (2004)	36.9	**0.0**	**14.9**	3.7	**0.2**	19.9	28.5	**14.3**	**14.7**	14.6
11LM089 (2011)	**23.7**	**0.0**	**18.0**	4.3	**1.8**	**5.8**	**19.4**	**6.8**	**14.7**	13.5
Southern Streams Average	*34.1*	*4.6*	*24.3*	*3.3*	*12.9*	*19.4*	*28.3*	*14.8*	*17.5*	*18.0*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

This AUID has multiple TSS and transparency exceedances, and is currently impaired for aquatic life for turbidity. The upstream AUID and Butler Creek are also impaired for turbidity. In addition, the DNR estimates that bedload sediment is in excess by approximately 30%, many of the macroinvertebrate metrics were worse than the statewide average, there were multiple TSS tolerant and very tolerant taxa, and the macroinvertebrate TSS index score was worse than the statewide average at station 11LM089. Although not impaired, a majority of the fish metrics were worse than the statewide average. TSS/turbidty is stressing the macroinvertebrate community.

Lack of Habitat

MSHA scores for station 04LM038 and station 11LM089 were "fair" (Table 15). The MPCA biologists noted unstable banks and streambed during fish assessment; geomorphology data generated from a Rosgen class at station 11LM089 confirms this instability. They also mentioned severe sedimentation problems based on SCSI observations and photos. Surrounding land use at the time of fish sampling for station 04LM038 was row crops. Station 11LM089 had row crops as well, but also had a natural (forest, wetland, prairie, and shrub) component. The riparian width at station 04LM038 was moderate (30 – 150 feet) to wide (150 – 300 feet), while station 11LM089 was extensive (>300 feet). Bank erosion at station 04LM038 was little (5 – 25%) to moderate (25 – 50%), while station 11LM089 had heavy (50 – 75%) to severe (75 – 100%) bank erosion. Riparian shade was moderate (25-50%) at station 04LM038, and substantial (50 - 75%) at station 11LM089.

Table 15. MSHA subcategory scores for the Little Cannon River.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
04LM038	29-Jul-04	0	9	18.3	13	25	65.3 (Fair)
11LM089	09-Aug-11	2.5	9.5	12.4	16	22	62.4 (Fair)

Channel features at station 04LM038 included pools (25%), riffles (25%), and runs (50%). Predominant pool substrates were gravel and sand, riffle substrates were gravel, and the run substrates were gravel and sand. Moderate embeddedness was observed, and more than four substrate types were present. Cover types present included undercut banks, overhanging vegetation, deep pools, woody debris, rootwads, and emergent macrophytes. Cover amount was moderate (25 – 50%). Channel sinuosity was good, channel stability was moderate, channel development was good, multiple velocity types were present (slow – fast including eddies), pool width was greater than riffle width, and depth variability was good (>4x shallow depth). Recent geomorphology work performed by the DNR near station 04LM038 identified a highly mobile stream bed, indicating excess sediment loads that can reduce habitat quality. Channel features at station 11LM089 included pools (60%), riffles (10%), and runs (30%). Predominant pool substrates were sand and silt, riffle substrates were gravel and sand, and the run substrate was gravel. Severe embeddedness was observed, and more than four substrate types were present throughout the station. Cover types included undercut banks, overhanging vegetation, deep pools, woody debris, rootwads, and emergent and submergent macrophytes. Cover amount was extensive (>50%). Channel sinuosity was excellent, channel stability was low, channel development was good, multiple velocity types were present (moderate – torrential including eddies), pool width was greater than riffle width, and depth variability was good (>4x shallow depth).

Macroinvertebrate burrowers and legless individuals are expected to increase in response to habitat stress. Both stations had well above average numbers of burrowers and legless individuals (Figure 36 and Figure 37). Legless individuals comprised 75% (station 04LM038) and 91% (station 11LM089) of the macroinvertebrate communities. Climbers and clingers are expected to decrease in response to habitat stress. Station 04LM038 had below average numbers for both metrics, while station 11LM089 had below average clingers but above average climbers. Interestingly enough, clinger and climber MIBI metric scores were above the average score needed to be at the threshold for both stations and their respective invertebrate class. Habitats sampled at station 04LM038 during assessment included riffles, overhead cover, and woody debris. The habitats sampled at station 11LM089 were overhead cover and woody debris.

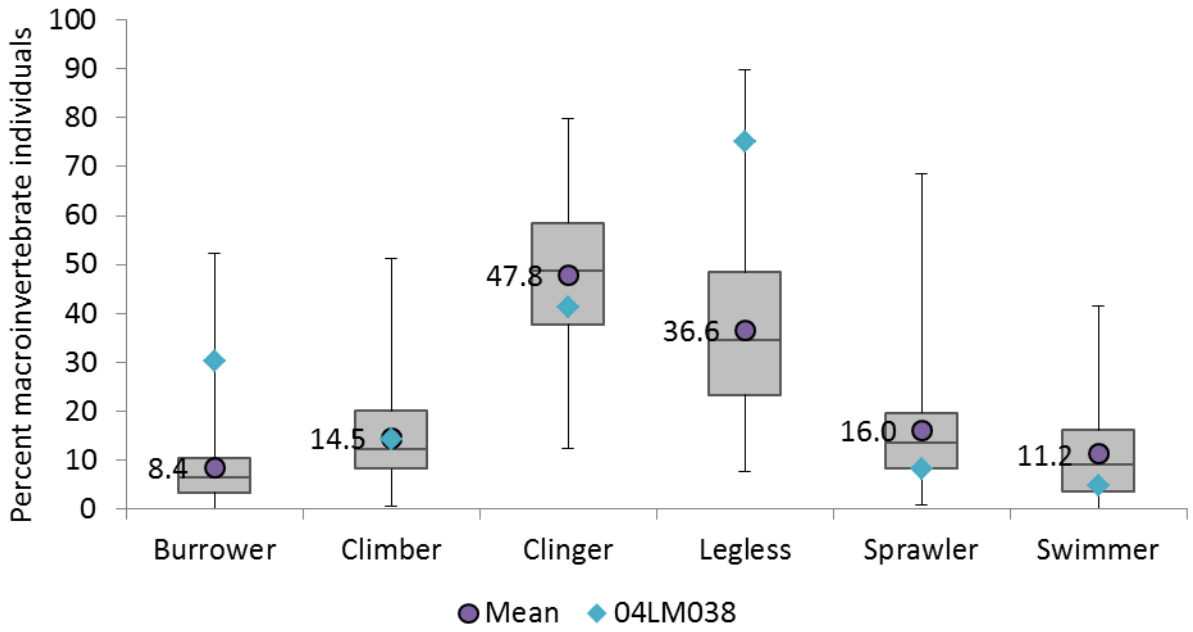


Figure 36. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Little Cannon Watershed stations.

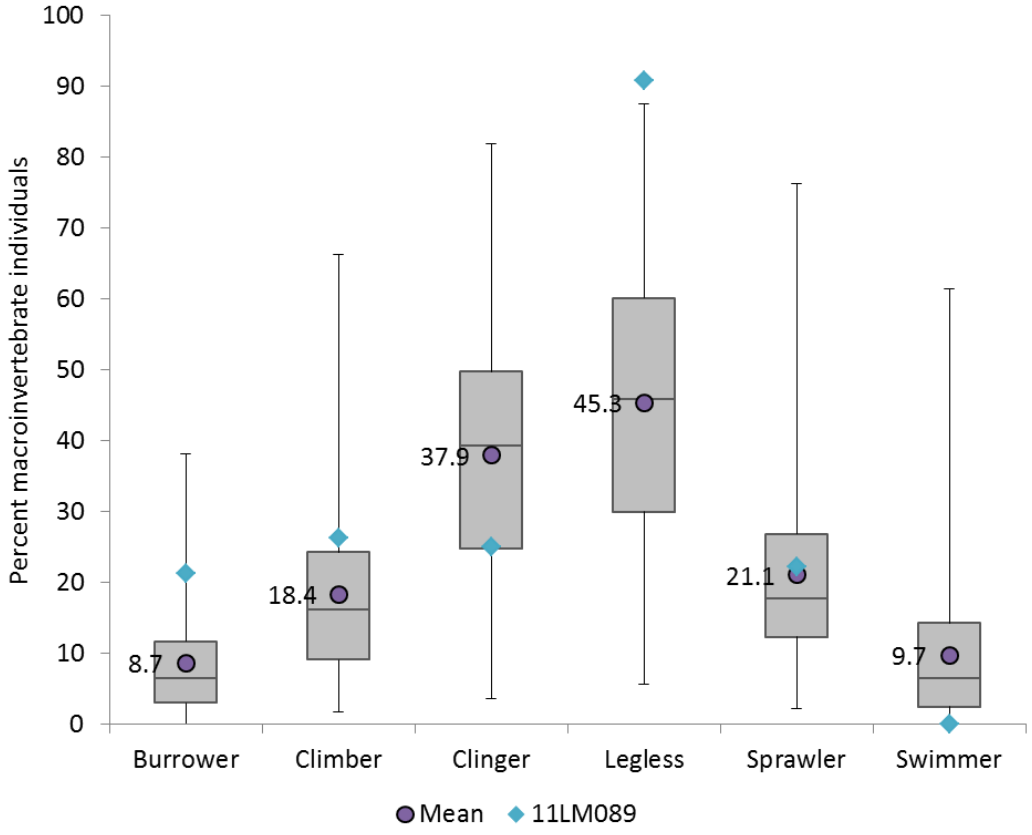


Figure 37. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Little Cannon Watershed stations.

This AUID had fair MSHA scores, little – severe bank erosion, moderate – severe embeddedness, elevated burrowers, below average clingers, and extremely elevated tolerant (legless) individuals. Although multiple habitats were sampled in this AUID, lack of habitat and fine substrate (embeddedness) is stressing the macroinvertebrate community.

Fish Passage

A migration barrier was identified during a connectivity survey in the summer of 2014 (Figure 38). This impasse is located in Cannon Falls near the mouth of the Little Cannon River (Mill Street West). Also, geomorphology work completed recently by the DNR in the lower portion of the Little Cannon identified several crossing issues (alignment, barriers, active erosion, and sizing). Although the fish community is not currently impaired, effort should be made to re-connect these sections of the river. At this time, fish passage does not appear to be stressing the macroinvertebrate community in this AUID.

Figure 38. Migration barrier near the mouth of the Little Cannon River (Mill Street West).

In general, in the Little Cannon River Watershed, there are numerous stream crossings being impacted by improperly aligned and sized culverts and bridges (Figure 39). These scenarios affect sediment supply, stream stability, habitat, and ultimately stream health and biological condition. Proper placement and sizing is critical to stream health, and concerted effort should be made watershed wide towards achieving this goal.

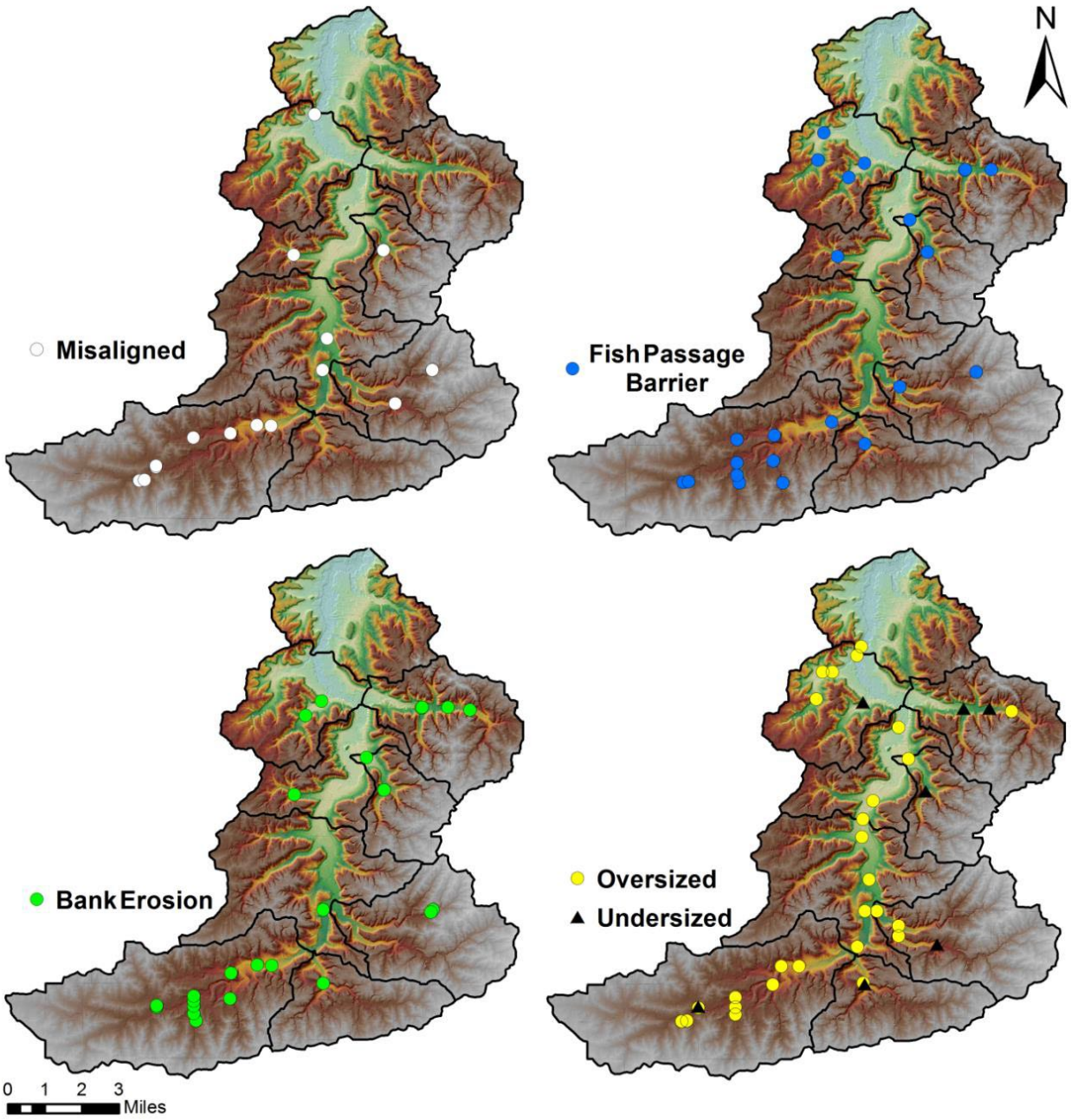


Figure 39. Assessment of stream crossing conditions affecting sediment supply and stability including whether the crossing is in proper alignment with the stream channel, acts as a barrier to the movement of fish, causes bank erosion, and if the crossing is the correct size compared to the bankfull width of the stream. The above figure was created by the DNR, and is included in their "Little Cannon River Watershed Geomorphology Assessment Report."

Conclusion

This portion of the Little Cannon River has multiple stressors at play, with the cumulative effects leading to an impaired macroinvertebrate community. Nitrate, TSS, and habitat are stressors in this AUID. Elevated phosphorus levels have been observed, but at this time it's inconclusive whether or not phosphorus is a stressor. Temperature, DO, and fish passage are not currently stressing the macroinvertebrate community. Reducing the nutrient and sediment loading to the Little Cannon River, and improving in-stream habitat should be priorities in future planning and implementation efforts.

4.1.2. Little Cannon River (589)

Biological Communities

Little Cannon (07040002-589) is a 12.1 mile long coldwater AUID in Goodhue County. This reach flows through farmland and forest in the Driftless Area ecoregion. This AUID has a macroinvertebrate impairment, and is also impaired for turbidity, bacteria, and nitrates. The three biological monitoring stations located within this reach are stations 11LM024, 11LM025, and 04LM086. Station 11LM024 and station 11LM025, which are located in the upper portion of the AUID, were sampled for fish and macroinvertebrates in 2011. Station 04LM086, located in the lower portion of the AUID, was sampled for fish and macroinvertebrates in 2004 and 2011.

The fish community in this AUID is impaired and "not supporting" the aquatic life use. All of the FIBI scores were below the Southern Coldwater impairment threshold of 45 (lower CL = 32, upper CL = 58), and at or below the lower confidence limit. The FIBI scores ranged from 21 – 32, with the two most upstream stations (11LM024 and 11LM025) having the lowest scores. Multiple fish species were sampled at each station, ranging from 12 – 17. Two game fish species, rainbow trout and brown trout, were present at stations 04LM086 and 11LM024; there were no game fish at station 11LM025. The number of rainbow trout ranged from 1-5 at station 04LM086, and only one was sampled at station 11LM024. The number of brown trout ranged from two to six at station 04LM086, and only one was sampled at station 11LM024. The most abundant species during all three visits at station 04LM086 were white sucker, while the most abundant species at stations 11LM024 and 11LM025 were central stoneroller and blacknose dace respectively. A majority of the FIBI metrics were below the average metric score needed to meet the threshold, resulting in low FIBI scores (Figure 40). The relative abundance of individuals that are sensitive in coldwater streams (CWSensitivePct_10DrgArea), taxa richness of tolerant species in coldwater streams (CWTol_10DrgArea), relative abundance of individuals that are native coldwater species (NativeColdPct), relative abundance of taxa that are native coldwater species (NativeColdTXPct_10DrgArea), and the relative abundance of taxa that are detritivorous (SdetTXPct_10DrgArea) were below average at all of the stations in this AUID. There were no deformities, eroded fins, lesions, or tumors (DELTs) present. The relative abundance of individuals that are herbivorous (HerbvPct), and the relative abundance of individuals that are pioneer species (PioneerPct) were the only FIBI metrics with above average scores. Currently, the DNR manages this reach as a trout stream, and stocks brown trout fingerlings and rainbow trout yearlings.

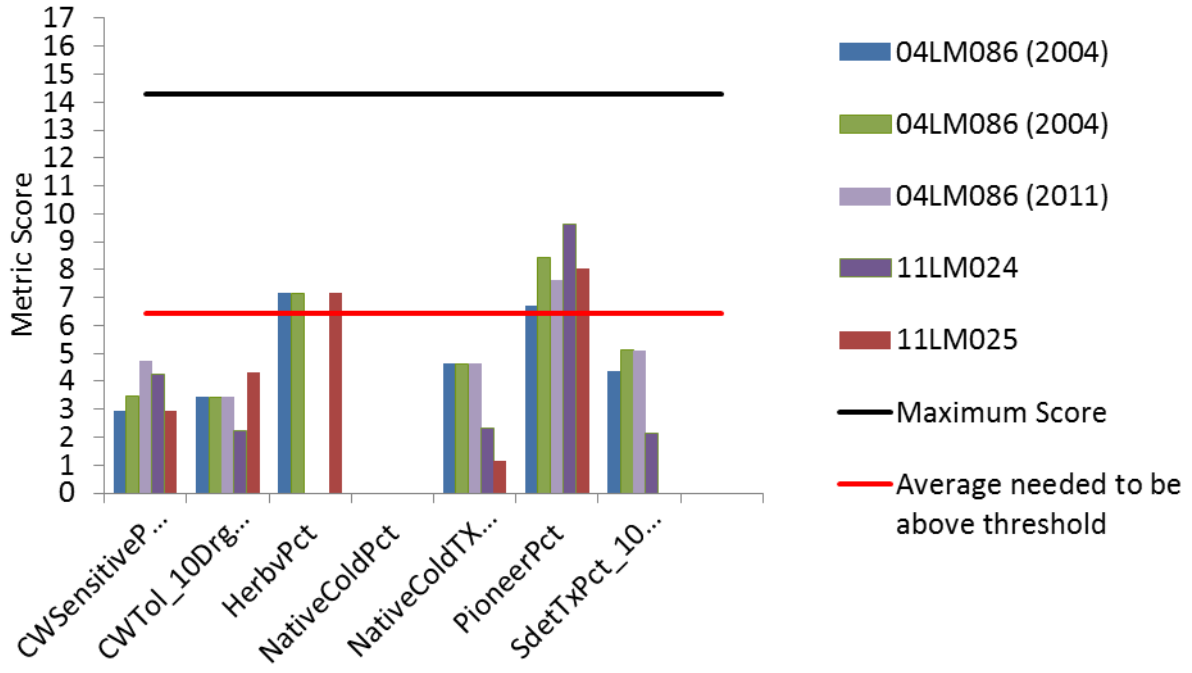


Figure 40. Fish metrics of the Southern Coldwater IBI for the Little Cannon River (07040002-589), stations 04LM086, 11LM024, and 11LM025.

The macroinvertebrate community is also impaired, and not supporting of the aquatic life use. All of the MIBI scores were well below the impairment threshold (46.1) and lower confidence limit (32.3) for Southern Coldwater Streams (Class 9). The MIBI scores ranged from 1.5 – 19.5; station 04LM086 had both the minimum and maximum scores. All of the MIBI metrics besides the relative abundance of collector-filterer individuals (Collector-filtererPct) at station 11LM025 were below the average metric score needed to meet the MIBI threshold (Figure 41). The Coldwater Biotic Index score (CBI), ratio of Chironomidae abundance to total Dipteran abundance (ChiroDip), a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch), relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct), and the relative abundance of macroinvertebrate individuals with tolerance values equal to or greater than eight using MN TVs (VeryTolerant2Pct) all had very low MIBI metric scores. These low metric scores resulted in low MIBI scores. Cricotopus (non-biting midge), Cheumatopsyche (net-spinning caddisfly), and Polypedilum (non-biting midge) were the most abundant taxa during the three visits at station 04LM086. Polypedilum was the most abundant at stations 11LM024 and 11LM025.

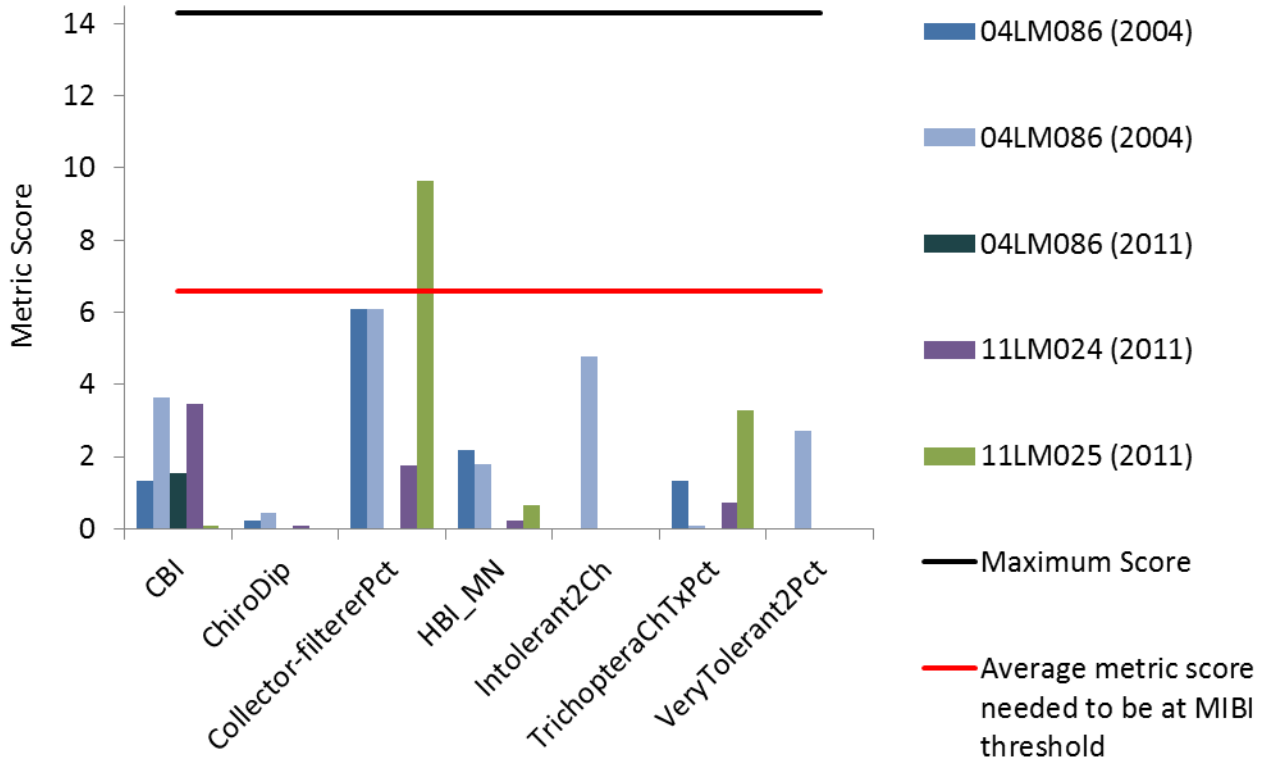


Figure 41. Macroinvertebrate metrics of the Southern Coldwater Streams (class 9) IBI for the Little Cannon River (07040002-589), stations 04LM086, 11LM024, and 11LM025.

Data Evaluation for each Candidate Cause

Temperature

Temperature data for the Little Cannon River (589) consists of 128 samples from 2000 – 2013 (minimum of 1.21°C, maximum of 28.3°C, and an average of 16.7°C). There were 17 samples (13%) above 22°C, and 40 samples (31%) above 20°C. Brown trout may be physiologically stressed from 19-22°C (Bell 2006). Most of these samples (123) were collected within the past 10 years (2004 – 2013), and therefore the statistics are very similar to the entire data set (minimum of 1.21°C, maximum of 28.3°C, and an average of 16.6°C). Sixteen samples (13%) were above 22°C, and 38 samples (31%) were above 20°C. Samples from 2004 – 2013 were collected from seven different monitoring stations, with fairly good coverage along the AUID. Four of these monitoring stations contained samples from multiple years and seasons. Station S001-436, near the middle of the AUID, has the greatest number of samples (70) as well as the highest reading (28.3°C). Elevated temperature values (> 22°C) were measured at four different stations and all parts of the AUID. Biological monitoring station 11LM024 had a temperature value of 22.2°C at the time of fish sampling. July and August accounted for 94% (15 samples) of the values greater than 22°C.

Continuous temperature data was also collected, which documented elevated temperatures. A continuous temperature logger (Hobo) was deployed from 4/10/14 – 9/29/14 at station 11LM024. The maximum temperature during this deployment was 33.2 °C, and there were 1,959 (12%) measurements above 22 °C. These exceedances occurred in July, August, and September. Sonde deployment at station

04LM086 from July 17, 2014 to July 23, 2014 also identified elevated temperatures. The maximum temperature during this deployment was 25.1 °C, and there were 163 (29%) readings above 22 °C.

The CBI MIBI metric scores, which are based on coldwater tolerance values derived from Minnesota taxa and temperature data, were 1.3, 3.7, and 1.5 (04LM086), 3.5 (11LM024), and 0.1 (11LM025). All of these scores are below the average metric score (6.6) needed to meet the MIBI threshold.

The relative abundance of individuals that are coldwater species (ColdPct) was extremely low at all stations. The percentages ranged from 0 – 0.5%, well below the statewide average (63%) of stations meeting the FIBI threshold. The relative abundance of individuals that are coldwater and coolwater species (ColdCoolPct) was also well below the statewide average (72%), ranging from 11 – 31%.

Multiple elevated temperature readings have been documented throughout this AUID. In addition to elevated temperature values, the macroinvertebrate and fish metrics are suggestive of stress. At this time, it appears that temperature is playing a role in stressing the biota.

Nitrate

The nitrate data set has 122 samples from 2004 – 2013 (minimum of 0.05 mg/L, maximum of 13.0 mg/L, and an average of 4.5 mg/L) (Figure 42). Five samples (4%) are greater than 10 mg/L, and 18 samples (15%) are greater than 8 mg/L. The 5 samples above 10 mg/L occurred in three different years (2007, 2008, and 2010) at two monitoring stations (S005-496 and S004-511) in June (4) and August (one). Seven different monitoring stations were sampled in all, with four of them sampled in multiple years and seasons. Stations S004-511, S005-496, and S001-436 have the highest sample counts at 69, 24, and 22 samples respectively. High nitrate concentrations occurred in all sections of the AUID. Biological monitoring station 11LM024 had a nitrate concentration of 8.2 mg/L during fish assessment.

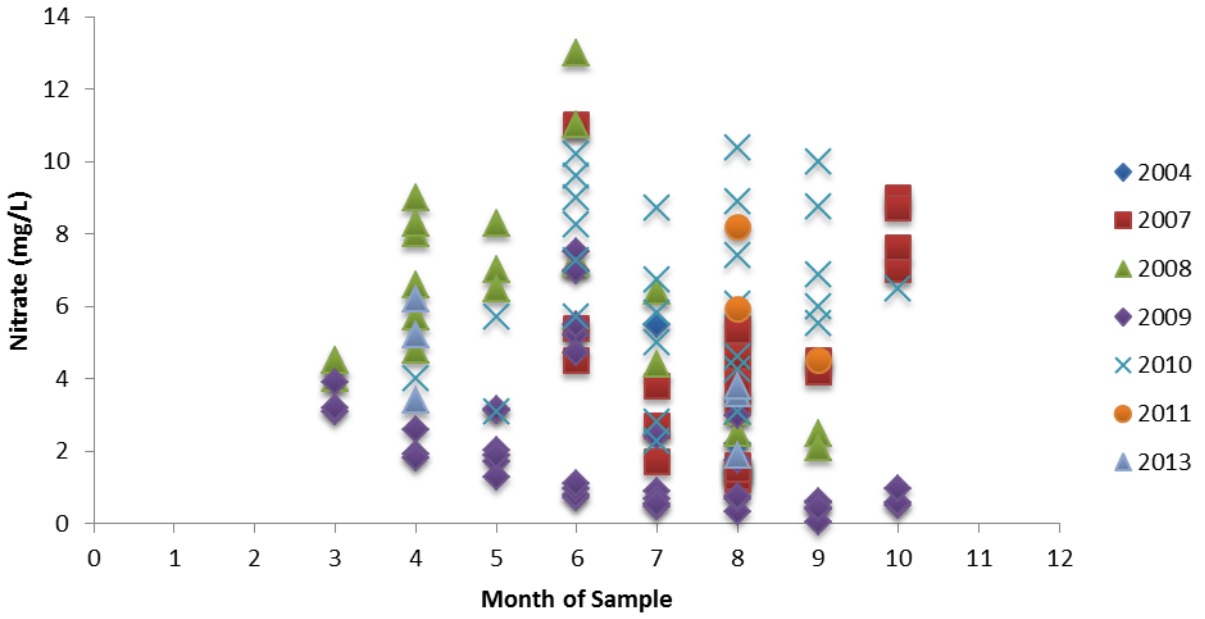


Figure 42. Nitrate concentrations in the Little Cannon River by month sampled.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of Southern Coldwater Macroinvertebrate stations in Minnesota shows a 75% confidence that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold. In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% confidence the MIBI score will be below the impairment threshold.

Taxa richness of Trichoptera (TrichopteraCh), relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct), relative abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch), and a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN) were all worse than the statewide average of stations meeting the MIBI threshold (Table 16). All of the metrics (at all three stations) have values suggestive of stress. The HBI_MN MIBI metric scores for all stations, which is one of the metrics used in determining the MIBI score, are below the average MIBI metric score needed to meet the MIBI threshold for Southern Coldwater Streams (class 9). The average MIBI metric score needed to meet the threshold is 6.59, and the HBI_MN MIBI metric scores for the stations in this reach ranged from 1.7 – 2.7. The HBI_MN values, which are expected to increase in response to stress, were above the statewide average (6.3) of stations meeting the MIBI threshold. The HBI_MN values ranged from 7.4 – 7.8. The TrichopteraChTxPct MIBI metric scores at all stations were also below the average metric score needed to meet the threshold (ranging from 0 – 3.3).

There were zero nitrate intolerant and very intolerant taxa present at all stations. Each station had numerous nitrate tolerant and very tolerant taxa present. Nitrate tolerant taxa comprised 65% - 89% of the macroinvertebrate community at the stations in this AUID. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern coldwater MIBI, and at 20.2 nitrate tolerant taxa there is only a 25% probability of meeting the Southern coldwater MIBI. The nitrate index scores were 3.4, 3.6, and 3.8 (04LM086), 3.5 (11LM025), and 3.7 (11LM024). All of these scores are above the statewide average (3.2) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 16. Macroinvertebrate metrics that respond to nitrate stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichopteraChTxPct	TrichwoHydroPct	Intolerant2Ch	HBI_MN	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
04LM086 (2004)	**3**	**7.9**	**0.0**	**0**	**7.5**	**3.4**	**0**	**0**	**22**	**13**	**89.4**	51.5
04LM086 (2004)	**3**	**6.4**	**0.0**	**1**	**7.5**	**3.6**	**0**	**0**	**23**	**15**	**82.4**	58.1
04LM086 (2011)	**0**	**0.0**	**0.0**	**0**	**7.8**	**3.8**	**0**	**0**	**25**	**14**	**81.2**	**65.9**
11LM024 (2011)	**2**	**7.1**	**1.6**	**0**	**7.6**	**3.7**	**0**	**0**	**16**	10	**85.1**	**80.3**
11LM025 (2011)	**4**	**10.3**	**1.2**	**0**	**7.4**	**3.5**	**0**	**0**	**25**	**18**	65.3	**59.8**
Southern Coldwater Streams Average	*4.6*	*16.8*	*11.6*	*1.2*	*6.3*	*3.2*	*1.1*	*0.2*	*14.8*	*11.3*	*66.2*	*58.3*
Expected response to stress	↓	↓	↓	↓	↑	↑	↓	↓	↑	↑	↑	↑

The chemistry results, which include elevated nitrate concentrations coupled with the worse than average macroinvertebrate metrics, lack of nitrate intolerant and very intolerant taxa, presence of several nitrate tolerant and very tolerant taxa, worse than average nitrate index scores, and the low HBI_MN and TrichopteraChTxPct MIBI metric scores indicate that nitrate is stressing the biology in this AUID.

Phosphorus

Phosphorus data for this AUID consists of 114 samples from 2004 – 2011 (minimum of 0.021 mg/L, maximum of 3.57 mg/L, and an average of 0.175 mg/L). A total of 36 samples (32%) exceeded the draft river eutrophication standard for the Central Region (0.100 mg/L). Samples were collected from six monitoring stations, three of which were the biological monitoring sites. Longitudinal coverage is good with adequate sample numbers in the upper, middle, and lower sections of the AUID. However, one station that could use some sampling is S005-497. This station is at the end of the AUID on the upstream side, above the biological monitoring station 11LM025. There have been zero samples collected at this station; sampling here would help inform the biological data at 11LM025. This is true for all parameters, not just phosphorus. The three stations with the greatest sample numbers (S004-511, S001-436, and S005-496) were sampled in multiple years and seasons, thus theoretically characterizing some of the various hydrologic and water quality conditions that occur over time. Exceedances of the draft standard occurred in the middle and lower end of Little Cannon (589) at stations S001-436 and S004-511. The number of exceedances for those stations is 4 and 32 respectively. Exceedances occurred from March – October, with August (12) and June (10) having the most. The remaining months have four or fewer exceedances. Most of the TP exceedances were associated with elevated TSS concentrations (Figure 43). This implies that much of the elevated phosphorus conditions are occurring during storm flows, where phosphorus is flushed through the system attached to sediment particles.

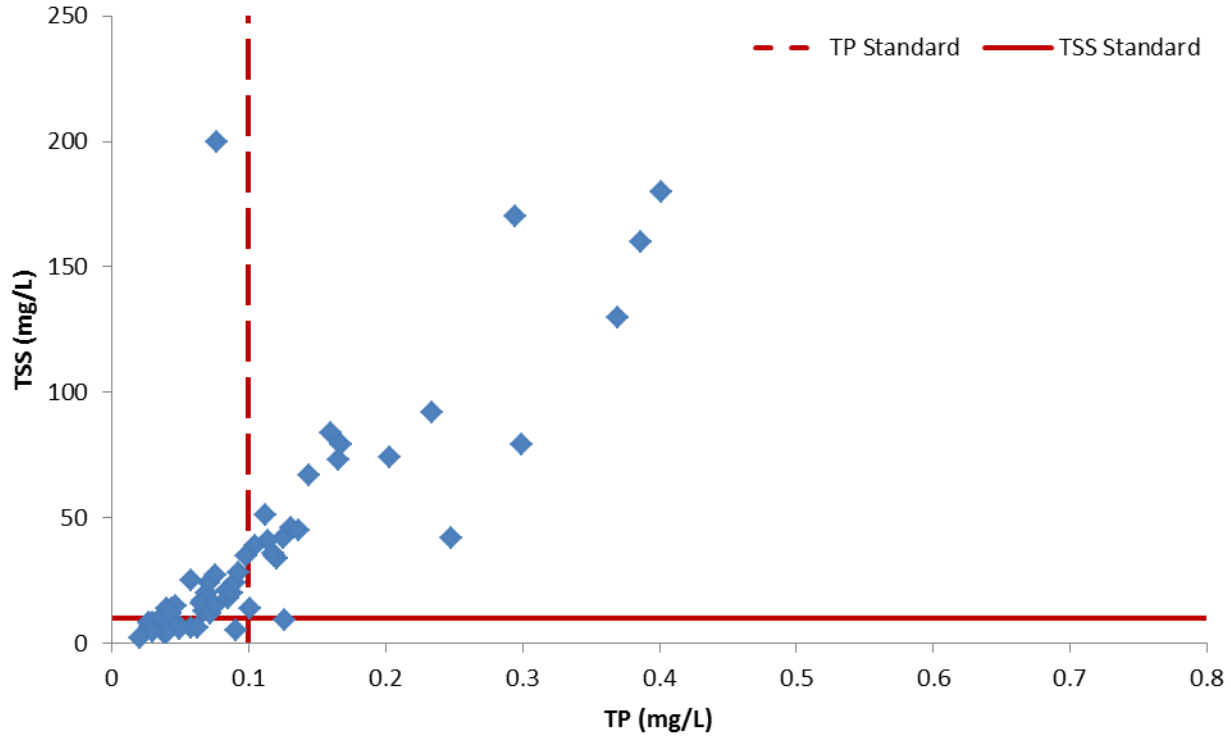


Figure 43. TSS and TP relationship in the Little Cannon - 589 (2004-2011).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. There were 43 chl-a samples collected in 2009 and 2010 (minimum of 1 µg/L, maximum of 24 µg/L, and an average of 4.2 µg/L). These samples included two exceedances (5%) of the draft standard for the Central Region (18 µg/L). There have been zero BOD samples collected at the time of this report; BOD should be included in future monitoring plans. Sonde deployment in 2014 at station 04LM086 (lower half of AUID) identified some DO flux exceedances (6 daily DO flux exceedances with a maximum of 4.6 mg/L), while deployment at station 11LM024 (upper end of AUID) had no DO flux exceedances. In August 2014, a longitudinal DO survey was completed, which resulted in DO flux exceedances at three stations in the middle – upper portions of the AUID (S001-436, S007-522, and the farthest upstream road crossing on County 44 Blvd.). The DO flux was 6.23 mg/L, 3.82 mg/L, and 3.57 mg/L respectively. The draft DO flux standard for the Central Region is 3.5 mg/L. Low DO, which is discussed in the DO section, was present in this AUID.

The total taxa richness of macroinvertebrates (TaxaCountAllChir), taxa richness of collector-gatherers (Collector-gathererCh), and the percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) were greater than the statewide average of stations meeting the MIBI threshold at all stations in this AUID (Table 17). Collector-gathererCh is expected to decrease in response to stress, while Tolerant2ChTxPct and TaxaCountAllChir are expected to increase. Intolerant taxa (Intolerant2Ch) were below average at all stations. There were zero macroinvertebrates with tolerance values less than or equal to two using MN TVs present at all stations except the September 2004 sample at station 04LM086. Intolerant2Ch is expected to decrease in response to stress. Taxa richness of collector-filterers (Collector-filtererCh) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) were worse than average at all stations in 2011, except for the collector-filterers at station 11LM025. The

2004 visits at station 04LM086 were above the statewide average (except for collector-filterers in one sample). Both metrics are expected to decrease in response to stress. TaxaCountAllChir, Intolerant2Ch, and Tolerant2ChTxPct were worse than the statewide average at all stations, and Collector-gathererCh was better than the statewide average at all stations. Overall, a majority of the macroinvertebrate metrics are worse than average and suggestive of stress.

Table 17. Macroinvertebrate metrics that respond to TP stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
04LM086 (2004)	**38**	**5**	18	7	**0**	**84.2**
04LM086 (2004)	**47**	8	20	8	**1**	**72.3**
04LM086 (2011)	**38**	**2**	22	**2**	**0**	**78.9**
11LM024 (2011)	**28**	**4**	12	**4**	**0**	**82.1**
11LM025 (2011)	**39**	6	17	**6**	**0**	**84.6**
Southern Coldwater Streams Average	*27.6*	*5.1*	*11.0*	*6.8*	*1.2*	*65.7*
Expected response to stress	↑	↓	↓	↓	↓	↑

Multiple exceedances have been documented in the lower – middle portion of this AUID, with a majority occurring during elevated flows. This segment of the Little Cannon also has chl-a and DO flux exceedances, in addition to low DO. No BOD samples have been collected. In addition to the chemistry exceedances, a majority of the macroinvertebrate metrics are suggestive of stress. Overall, it appears that phosphorus has the potential to be a stressor to the biology in this section of the Little Cannon River, but at this time it's inconclusive. Additional chl-a, BOD, and DO flux information is necessary in order to determine if the elevated phosphorus levels are leading to eutrophication issues. Although inconclusive at this time, reducing phosphorus in the Little Cannon River should be a priority in any future planning efforts. Phosphorus has the potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus loading should help (and/or protect from potential future impacts) the biology in the Little Cannon River, as well as downstream receiving waters.

Dissolved Oxygen

The DO data set has 40 samples from 2004 – 2013 (minimum of 6.22 mg/L, maximum of 18.69 mg/L, and an average of 9.85 mg/L). Four samples (10%) were below the coldwater standard of 7 mg/L. These low readings were observed on the upper portion of the AUID at station S007-522 (one), and the lower portion at station S004—511 (three). Three of the values below the standard occurred in August, and one in June. This data set has good early morning sample coverage, as over half (53%) of the samples were collected prior to 9:00 a.m. Spatial coverage, however, could be improved as most of the samples were taken near the downstream end of the AUID (34 of the 40 samples). Station S004-511 has the

highest sample count (31 samples) and good temporal coverage; there is at least one sample in the months of March – October and they were collected across five different years.

Continuous DO data was collected via sonde deployment in 2014 (Figure 44). Sonde deployment from July 17, 2014 through July 23, 2014 at station 04LM086 had low DO 18% of the time, with a minimum of 6.2 mg/L. Sonde deployment from August 22, 2014-August 28, 2014 at station 11LM024 resulted in low DO 20% of the time, with a minimum of 6.2 mg/L. A longitudinal DO survey was also completed in late August of 2014, which resulted in numerous low DO values.

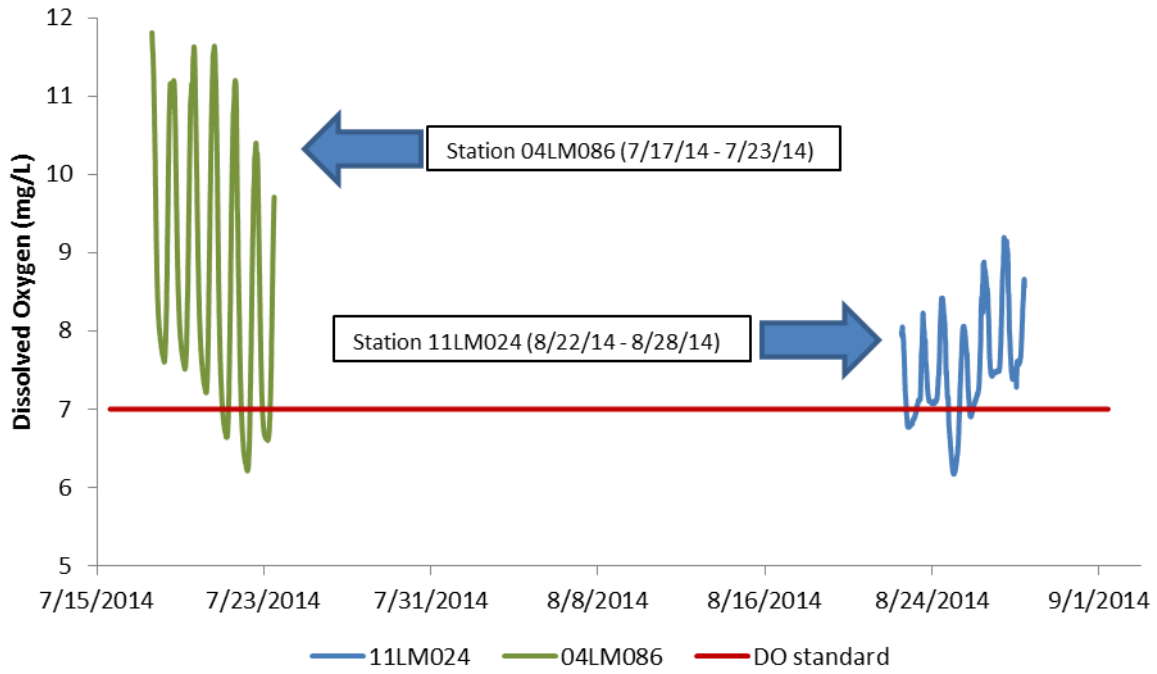


Figure 44. Diurnal DO at station 04LM086 and station 11LM024 in the Little Cannon River.

Total taxa richness of the macroinvertebrate community (TaxaCountAllChir), and a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN) were worse than the statewide average of stations meeting the MIBI threshold (Table 18). Taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) was worse than average at station 11LM024, station 11LM025, and the 2011 visit at station 04LM086. TaxaCountAllChir and HBI_MN are expected to increase in response to stress, while EPT is expected to decrease. Overall, a majority of the macroinvertebrate metrics are worse than the statewide average and suggestive of stress.

All of the stations in this AUID had multiple DO intolerant and very intolerant macroinvertebrate taxa, ranging from 6 – 13 and 3 – 9 respectively. Each station also had DO tolerant taxa, and most had at least one DO very tolerant taxon. DO tolerant individuals comprised 1 – 18% of the macroinvertebrate community, and DO very tolerant individuals comprised 0 – 7%. The macroinvertebrate DO index scores were 7.3, 7.0, and 7.0 (04LM086), 7.6 (11LM024), and 7.4 (11LM025). All of these scores are below the statewide average (7.9) of stations meeting the MIBI threshold. As the score decreases, so does the sensitivity of the community.

Table 18. Macroinvertebrate metrics that respond to low DO stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	HBI_MN	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
04LM086 (2004)	**47**	**7.5**	8	**7.3**	13	9	**7**	**2**	**8.0**	**1.9**
04LM086 (2004)	**38**	**7.5**	7	**7.0**	**6**	**5**	**3**	**1**	**18.0**	**0.9**
04LM086 (2011)	**38**	**7.8**	**2**	**7.0**	**9**	**3**	**3**	**1**	**10.0**	**6.6**
11LM024 (2011)	**28**	**7.6**	**4**	**7.6**	**8**	**4**	1	0	**1.3**	0.0
11LM025 (2011)	**39**	**7.4**	**6**	**7.4**	**9**	**5**	**5**	**1**	**3.4**	**0.3**
Southern Coldwater Streams Average	*27.6*	*6.3*	*6.8*	*7.9*	*10.3*	*7.5*	*1.6*	*0.5*	*1.2*	*0.2*
Expected response to stress	↑	↑	↓	↓	↓	↓	↑	↑	↑	↑

The fish DO index scores were 7.5, 7.4, and 7.5 (04LM086), 7.6 (11LM024), and 7.7 (11LM025). All of these scores are below the statewide average (8.7) of stations meeting the FIBI threshold. As the score decreases, so does the sensitivity of the community. In addition, the taxa richness of sensitive species (Sensitive) was the only metric to have better than average scores; all of the other metrics were worse than the statewide average of stations meeting the FIBI threshold (Table 19). However, there were a few rainbow and brown trout sampled at station 04LM086 and 11LM024, which are sensitive to low DO conditions. American brook lamprey, which are also sensitive to low DO conditions, were present at station 04LM086.

Table 19. Fish metrics that respond to low DO stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Sensitive	MA>3Pct	SSpnPct	TolPct	TaxaCount
04LM086 (2004)	6	**27.8**	**23.3**	**67.2**	**17**
04LM086 (2004)	6	**25.1**	**29.6**	**68.2**	**16**
04LM086 (2011)	6	**22.6**	**30.5**	**60.6**	**17**
11LM024 (2011)	5	**7.8**	**32.7**	**58.5**	**16**
11LM025 (2011)	**2**	**5.1**	**28.0**	**59.7**	**12**
Southern Coldwater Average	2.8	72.8	2.4	27.6	6.1
Expected response to stress	↓	↓	↑	↑	↑

This AUID has multiple DO readings below the standard, a majority of the macroinvertebrate and fish metrics were worse than the statewide average, and the macroinvertebrate and fish DO index scores

were worse than the statewide average. However, this AUID also had several DO intolerant and very intolerant macroinvertebrate taxa at all stations, and lower tolerant taxa. There were also a few DO sensitive fish species present. It's inconclusive if DO is a stressor due to the mixed biological response. Additional monitoring is recommended for stressor determination.

TSS/Turbidity

The TSS data set contains 85 samples from 2004 – 2013 (minimum of 2 mg/L, maximum of 3,500 mg/L, and an average of 178.8 mg/L). There are 58 samples (68%) above the draft coldwater standard of 10 mg/L. Samples were collected from seven monitoring stations, however, almost all were collected near the downstream end of the AUID at station S004-511 (69 samples). This station included samples from five different years and the months of March – October. Even though minimal samples were collected in the middle and upper portions of this reach, exceedances were still observed. Exceedances occurred at four of the monitoring stations; the three stations with no exceedances were the biological monitoring sites (11LM025, 11LM024, and 04LM086). There were two or more exceedances in each month from March – October. April, June, July, and August comprise 76% of the 58 exceedances. August has the most with 13 samples greater than 10 mg/L. There were 394 transparency samples collected from 1999 – 2013 (minimum of 2 cm, maximum of 100 cm, and an average of 42 cm). Geomorphology work performed by the DNR just upstream of station 04LM086 revealed that the sediment load has increased 30% at this location, resulting in a more destabilized channel (Proulx 2015).

The relative abundance of macroinvertebrate individuals in subsample with tolerance values less than or equal to two (IntolerantPct) was below the statewide average of stations meeting the MIBI threshold (Table 20). The relative abundance of longlived individuals in subsample (LongLivedPct) and relative abundance of collector-filterer individuals in subsample (Collector-filtererPct) were below the statewide average at station 04LM086 and station 11LM024, and above average at station 11LM025. All of these metrics are expected to decrease in response to stress. The farthest upstream station (11LM025) had two out of three metrics above the statewide average, but all of the metrics at the downstream stations were below average. Overall, a majority of the macroinvertebrate metrics are suggestive of stress.

There were no TSS intolerant or very intolerant taxa present at any of the stations in this AUID. There were, however, TSS tolerant and very tolerant taxa. TSS tolerant taxa ranged from 5 – 14 (13 – 37%), and TSS very tolerant taxa ranged from one to six (0 – 3%). There were no obvious longitudinal differences. The macroinvertebrate TSS index scores were 16.4, 15.2, and 17.1 (04LM086), 16.2 (11LM024), and 17.0 (11LM025). All of these scores are above the statewide average (14.7) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 20. Macroinvertebrate metrics that respond to TSS stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	IntolerantPct	LongLivedPct	Collector-filtererPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
04LM086 (2004)	**2.3**	**1.6**	**26.9**	**16.4**	**0**	**0**	**14**	**6**	**32.7**	**1.4**
04LM086 (2004)	**6.6**	**0.9**	**27.0**	**15.2**	**0**	**0**	**8**	1	**12.8**	0.4
04LM086 (2011)	**9.6**	**1.6**	**6.8**	**17.1**	**0**	**0**	**7**	**3**	**36.8**	**1.5**
11LM024 (2011)	**3.1**	**0.9**	**13.0**	**16.2**	**0**	**0**	**5**	1	**27.8**	0.3
11LM025 (2011)	**5.2**	6.4	38.4	**17.0**	**0**	**0**	**9**	**3**	**36.5**	**2.5**
Southern Coldwater Streams Average	*14.9*	*2.8*	*34.0*	*14.7*	*1.7*	*1.3*	*3.7*	*1.0*	*7.3*	*1.3*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

The fish TSS index scores were 13.9, 14.5, and 13.7 (04LM086), 13.9 (11LM024), and 12.5 (11LM025). All of these scores are worse than the statewide average (10.6) of stations meeting the FIBI threshold; as the score increases, so does the tolerance of the community.

This AUID is currently impaired for turbidity and has multiple TSS exceedances, a majority of the macroinvertebrate metrics are suggestive of stress, there are no TSS intolerant macroinvertebrate taxa and multiple TSS tolerant and very tolerant macroinvertebrate taxa, and the macroinvertebrate and fish TSS index scores were worse than the statewide average. Also, the geomorphology work performed by the DNR identified sediment issues. TSS/turbidity is a stressor in this AUID.

Lack of Habitat

The MSHA scores ranged from 54.5 ("fair") – 69.4 ("good") (Table 21). Station 04LM086 had "good" ratings in 2004 (68.5 and 66.6), but a "fair" rating in 2011 (54.5). This station is located on the lower end of the AUID. Station 11LM024 and 11LM025, on the upper end of the AUID, had "fair" (57.4) and "good" (69.4) scores respectively. The 2011 habitat scores get progressively worse as you move downstream.

Table 21. MSHA subcategory scores for the Little Cannon River.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
04LM086	01-Jul-04	2.5	8	18	13	27	68.5 (Good)
04LM086	19-Aug-04	0	7.5	15	13	31	66.6 (Good)
11LM025	14-Sep-11	0	6	21	13	29	69.4 (Good)
04LM086	09-Aug-11	2.5	6	13	13	20	54.5 (Fair)
11LM024	10-Aug-11	2.5	6.5	20	8	20	57.4 (Fair)

The surrounding land use at the time of sampling was classified as forest, wetland, prairie, shrub, and row crop. Riparian width ranged from none – extensive (>300 feet), and shade was moderate (25 – 50%) to substantial (50 – 75%). Bank erosion ranged from little (5 – 25%) to severe (75 – 100%).

Multiple habitat types were sampled for macroinvertebrates throughout this AUID. The habitats sampled at station 04LM086 were riffles, undercut banks/overhanging vegetation, and woody debris. Station 11LM024 had riffles and woody debris habitats sampled. Riffles, undercut banks/overhanging vegetation, and woody debris was sampled at station 11LM025. Pool features ranged from 10% - 30% of the station length. Pool substrates included cobble (two stations), gravel (one station), sand (three stations), bedrock (one station), and silt (one station). Riffle features were present in good numbers, ranging from 20% - 40%. Riffle substrates were cobble (three stations), gravel (three stations), and clay (one station). Run features dominated most stations, ranging from 40% - 55%. Run substrates were cobble (two stations), gravel (two stations), sand (two stations), and silt (one station). Embeddedness ranged from light – moderate. Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders, rootwads, and emergent and submergent macrophytes) were available, and cover amount ranged from sparse (5 – 25%) to moderate (25 – 50%). Channel sinuosity was good – excellent, channel stability was low – high, channel development was fair – excellent, multiple velocity types were present (slow – torrential including eddies), and the greatest depth was greater than four times the shallowest depth.

Burrowers, which are expected to increase in response to habitat stress, were significantly elevated in 2004 and 2011 at station 04LM086 (Figure 45). Legless, which are also expected to increase in response to habitat stress, were extremely high for all stations. However, all stations have elevated climbers, which are expected to decrease in response to habitat stress. The remaining metrics (clinger, sprawler, and swimmer) fall within the middle quartiles at station 11LM024 and station 11LM025, and the lower quartile for some of the assessments at station 04LM086.

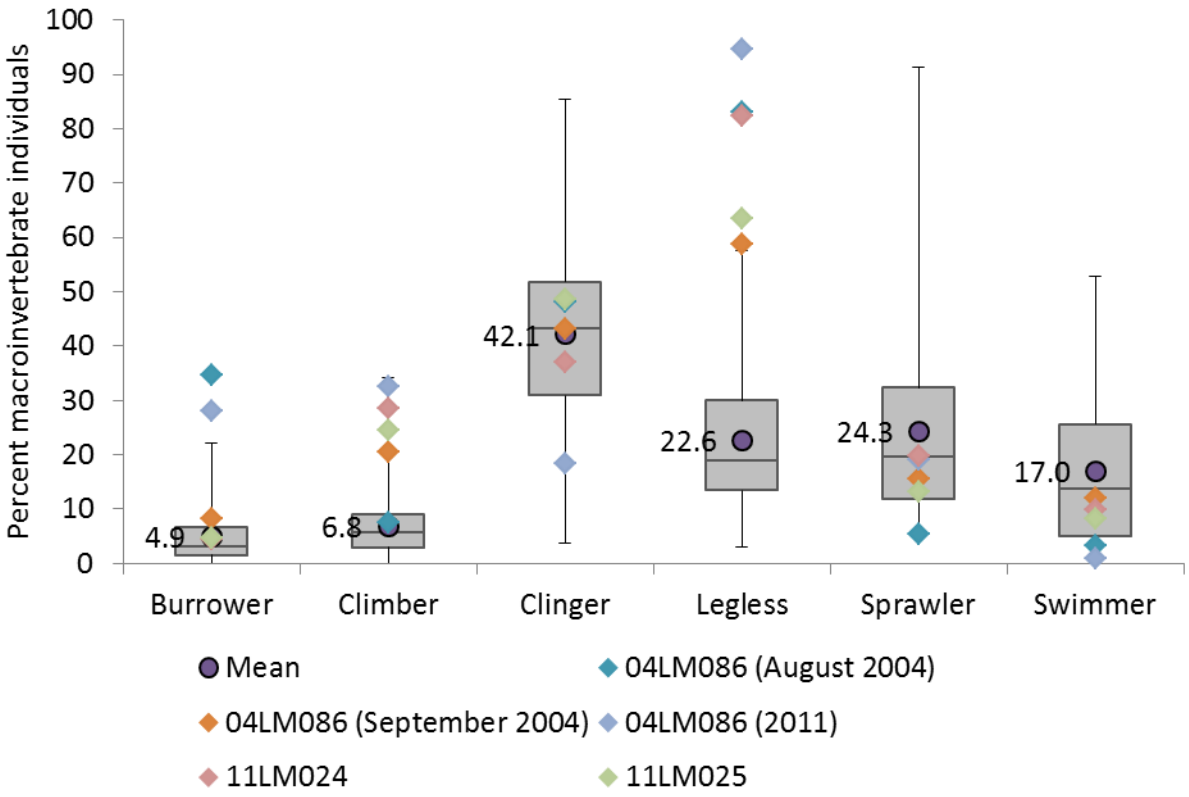


Figure 45. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Coldwater Streams (class 9) stations with MIBI greater than 46.1 (threshold), mean of those stations, and metric values from Little Cannon Watershed stations.

In general, the fish metrics displayed a mixed response in regards to habitat stress (Table 22). The relative abundance of individuals that are non-tolerant benthic insectivore species (BenInsect-TolPct) was worse than the statewide average of stations meeting the FIBI threshold at station 04LM086 in 2004. The relative abundance of individuals that are riffle-dwelling species (RifflePct) was worse than the statewide average at station 11LM025. The relative abundance of individuals that are pioneer species (PioneerPct) and relative abundance of individuals that are piscivore species (PiscivorePct) were worse than average at all stations. Piscivore percentages were extremely low, ranging from 0 – 0.5%. Relative abundance of individuals that are simple lithophilic spawners (SLithopPct) and relative abundance of individuals that are darter, sculpin, and round bodied sucker species (DarterSculpSucPct) were better than average at all stations. Half of the metrics were better than average and half were worse than average at station 04LM086 in 2004, and four out of six were better than average in 2011. Station 11LM024 also had four out of six metrics that were better than average, and station 11LM025 had three out of six.

Table 22. Fish metrics that respond to habitat stress in the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenInsect-TolPct	SLithopPct	DarterSculpSucPct	PioneerPct	PiscivorePct	RiffflePct
04LM086 (2004)	**19.5**	57.0	18.7	**22.6**	**0.5**	42.7
04LM086 (2004)	**19.7**	49.0	18.7	**29.3**	**0.5**	37.4
04LM086 (2011)	28.6	43.0	28.5	**25.6**	**0.5**	48.6
11LM024 (2011)	31.6	27.2	31.2	**18.0**	**0.1**	61.5
11LM025 (2011)	28.3	48.3	28.3	**24.0**	**0.0**	**31.7**
Southern Coldwater Average	*21.0*	*22.1*	*18.1*	*6.3*	*50.3*	*34.7*
Expected response to stress	↓	↓	↓	↑	↓	↓

This segment of the Little Cannon had fair – good MSHA scores, little – severe bank erosion, light – moderate embeddedness, elevated burrowers, and extremely elevated tolerant (legless) individuals. All of the legless and some of the burrowers were present in numbers above the maximum value seen in stations meeting the MIBI threshold. Legless are tolerant species (midges, snails, etc.) and burrowers burrow in fine sediment indicating potential siltation issues. Multiple habitat types were sampled, but lack of habitat and excess fine sediment are stressors in this AUID.

Fish Passage

There were no obvious barriers identified on the main channel during a brief connectivity survey in the summer of 2014, but it appeared as though fish passage could be limited during lower flows at a few crossings in the upper end of the AUID (Figure 46). A more rigorous inventory completed by the DNR noted that the very upper end of the Little Cannon Watershed had more crossing issues than any other catchment in the watershed. These crossing issue locations, which included 10 fish passage barriers, can be seen in Figure 46 located in the Fish Passage section of Little Cannon – 526. Coldwater and coolwater migratory fish species were present at stations 04LM086 and 11LM024, but were absent at station 11LM025 (Table 23). The fish barrier in the picture below is represented by the red line in Table 23; there were no migratory species above this crossing. Fish passage appears to be having a negative impact on the fish community, and is a stressor in this AUID. Effort should be made to fix these crossing issues and improve stream health.

Figure 46. Stream crossing at station 11LM024.

Table 23. Migratory fish species in the Little Cannon River above and below the stream crossing at station 11LM024.

	Upstream	Downstream	
Migratory Fish Species	Station 11LM025	Station 11LM024	Station 04LM086
American brook lamprey			x
black redhorse			
brook trout			
brown trout		x	x
rainbow trout		x	x

pH

There was a pH value of 9.8 at station S001-436 (near the middle of the AUID) in August of 2014. This is above the coldwater maximum pH standard of 8.5. This was the only exceedance in the data set; pH monitoring should be continued in the future to ensure the standard is being attained.

Conclusion

There are multiple stressors at play in this portion of the Little Cannon River, with the cumulative effects resulting in impaired macroinvertebrate and fish communities. Temperature, nitrate, TSS/turbidity, habitat, and fish passage are stressors in this AUID. Elevated phosphorus has been observed, but at this time it's inconclusive if it is acting as a stressor. DO is also inconclusive as a stressor. Reducing nutrient and sediment loading, improving in-stream habitat, protecting and/or lowering stream temperature, and improving fish migration capability (in the upper end) should be priorities in future planning and implementation efforts. It's highly unlikely that this reach will be able to support healthy coldwater fish and macroinvertebrate communities until stream temperatures are reduced.

4.1.3. Butler Creek (590)

Biological Communities

Butler Creek (07040002-590) is a 2.1 mile long AUID in Goodhue County. This warmwater reach flows through the Driftless Area ecoregion, and is a tributary to the Little Cannon River. The macroinvertebrate community is impaired, and turbidity and bacteria impairments also exist in Butler Creek. Station 04LM085 is the only biological monitoring station, and it is located in the middle of the AUID. This station was sampled in 2004 and 2011 for fish and macroinvertebrates.

The fish community is considered "supporting" of the aquatic life use. The FIBI scores were above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58) in 2004 and 2011. They were also above the upper confidence limit in both years. The FIBI scores were 66 (2004) and 78 (2011). Seven fish species were collected at station 04LM085 in 2004 and 2011, including a redside dace in 2004. Redside dace are sensitive species that require good water quality and habitat conditions. The MPCA biologists noted that Butler Creek may require additional protections if redside dace are collected in the future. The species collected in 2004 were blacknose dace, brown trout, creek chub, fathead minnow, johnny darter, redside dace, and white sucker. Creek chub were the most abundant (82). Fish species collected in 2011 were blacknose dace, bluegill, brown trout, central stoneroller, creek chub, johnny darter, and white sucker. Creek chub was again the most abundant (53).

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI scores were 40 (2004) and 22 (2011). The 2004 score is above the Southern Streams RR impairment threshold of 35.9 (lower CL = 23.3, upper CL = 48.5), but below the upper confidence limit. The 2011 score is below the impairment threshold and lower confidence limit. There were 15 total families collected in 2004, and 8 in 2011. The 2011 sample had below average ClimberCh, DomFiveChPct, Odonata, Plecoptera, Predator, Tolerant2ChTxPct, and Trichoptera MIBI metric scores, resulting in the low MIBI score (Figure 47).

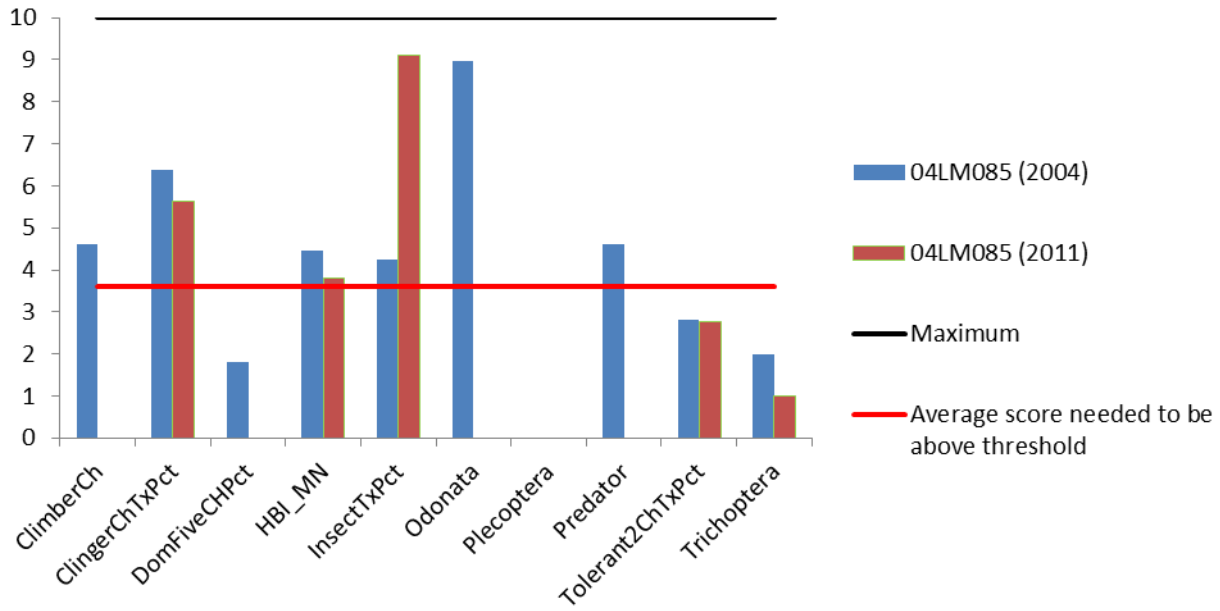


Figure 47. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for Butler Creek (07040002-590), station 04LM085.

Data Evaluation for each Candidate Cause

Temperature

Temperature data consists of 49 samples from 2004 – 2013 (minimum of 1.48 °C, maximum of 19.2 °C, and an average of 13.4 °C). Samples were collected at two stations, with the bulk (47 samples) being collected near the mouth of Butler Creek at station S004-804. Samples at this station covered three different years and the months of April – September. The remaining two samples were collected near the middle of the AUID at the bio site. No temperature data has been collected on the upper end of this AUID. Continuous temperature readings were also collected at station S004-804 from August 21, 2013 – September 4, 2013 and May 8, 2014- September 29, 2014; the maximum temperature was 23.3 °C and there were only 68 (0.4%) measurements above 22 °C. Temperature values are within the expected range, and not currently adversely affecting the fish and macroinvertebrate communities.

Nitrate

Nitrate concentrations from 2004 – 2013 ranged from 2.2 mg/L – 7.6 mg/L (average of 4.0 mg/L) (Figure 48). The data set consists of 37 samples from two different monitoring stations. A majority of the samples (35) were collected near the mouth of Butler Creek at station S004-804. The other two samples were collected in the middle of the AUID at the biological monitoring station (04LM085); these samples were collected during fish assessment in 2004 and 2011. The samples at station S004-804 took place across three different years and covered the months of April – October. Most of the samples were collected in 2008 and 2009; there were 15 collected in 2008 (minimum of 2.8 mg/L, maximum of 7.6 mg/L, and an average of 5.1 mg/L), and 18 collected in 2009 (minimum of 2.2 mg/L, maximum of 6.3 mg/L, and an average of 3.1 mg/L). Over half of the samples (51%) were collected between April and June. The three highest concentrations were 6.3 mg/L (August 8, 2011), 6.3 mg/L (April 14, 2009), and 7.6 mg/L (September 17, 2008).

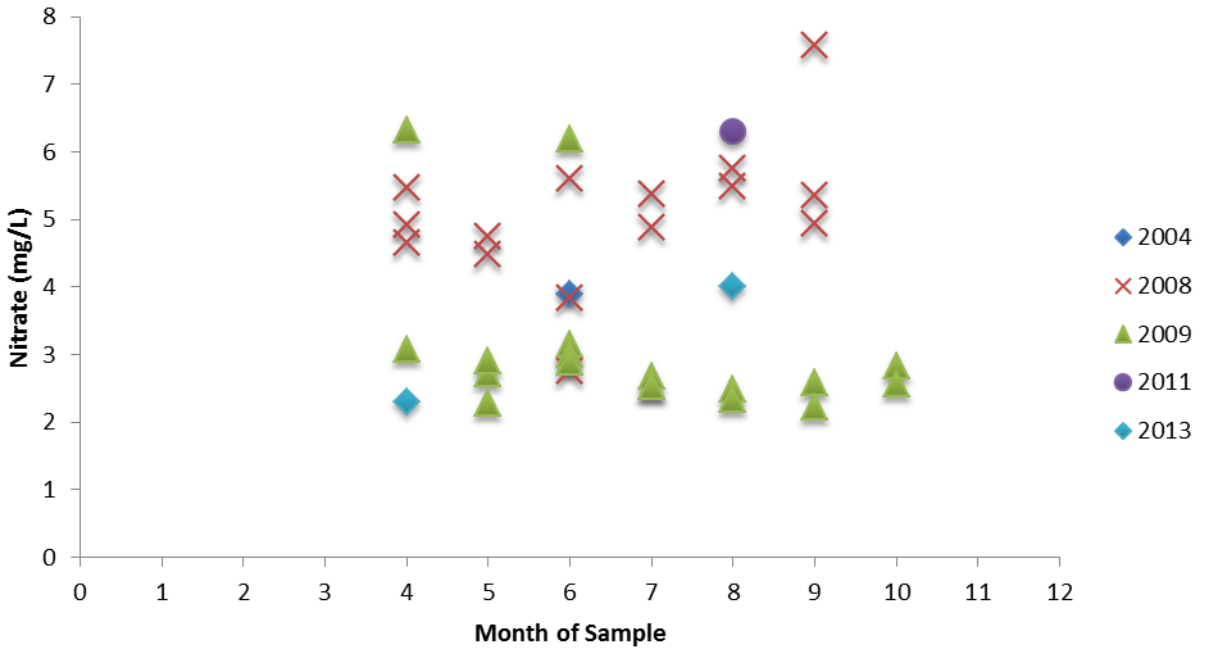


Figure 48. Nitrate concentrations in Butler Creek by month sampled.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class. Station 04LM085 is in the Southern Streams RR macroinvertebrate class.

Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide average at station 04LM085 (Table 24). This station was sampled in 2004 and 2011, and the results from the most recent sample in 2011 have declined since the 2004 sample. All of these metrics are expected to decrease in response to stress.

Station 04LM085 had zero nitrate intolerant and very intolerant taxa present. On the other hand, it did have several nitrate tolerant and very tolerant taxa present. In 2004 it had 18 (59%) nitrate tolerant taxa and 12 (53%) nitrate very tolerant taxa. In 2011, it had 25 (55%) nitrate tolerant taxa and 14 (44%) nitrate very tolerant taxa. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI. The nitrate index scores were 3.1 and 3.2, both of which are above the statewide average of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 24. Macroinvertebrate metrics that respond to nitrate stress in Butler Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
04LM085 (2004)	**4**	**3.4**	**0**	**3.1**	**0**	**0**	**25**	**14**	55.2	**44.1**
04LM085 (2011)	**3**	**0.0**	**0**	**3.2**	**0**	**0**	18	12	**58.8**	**52.9**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

The chemistry data set could use additional samples and doesn't include extremely high concentrations, but most of the macroinvertebrate metrics are worse than the statewide average, there are zero nitrate intolerant or very intolerant taxa present, there are several nitrate tolerant and very tolerant taxa present, and the nitrate index scores are worse than the statewide average. Nitrate may be adversely impacting the macroinvertebrate community, but at this time it's inconclusive if nitrate is a stressor. Additional monitoring is recommended for stressor determination.

Phosphorus

Total phosphorus concentrations ranged from 0.025 mg/L – 0.616 mg/L (average of 0.115 mg/L). Thirty-five samples were collected from 2004 – 2011. Nine of the samples (26%) exceeded 0.100 mg/L, the draft river eutrophication standard for the Central Region. The exceedances occurred in April (one), June (three), July (one), August (two), and October (two). Six of the nine exceedances were associated with low TSS concentrations (Figure 49). It appears that phosphorus exceedances are occurring during baseflow and stormflow conditions. Goodhue County SWCD collected 33 samples at station S004-804 in 2008 and 2009. Seventeen of these samples (52%) were collected in the spring between April and June, with the remainder collected between July and October. All of the nine exceedances were found at this station, and the maximum value (0.616 mg/L) occurred in June. Station 04LM085 was sampled twice during fish assessments; both concentrations were below the draft standard.

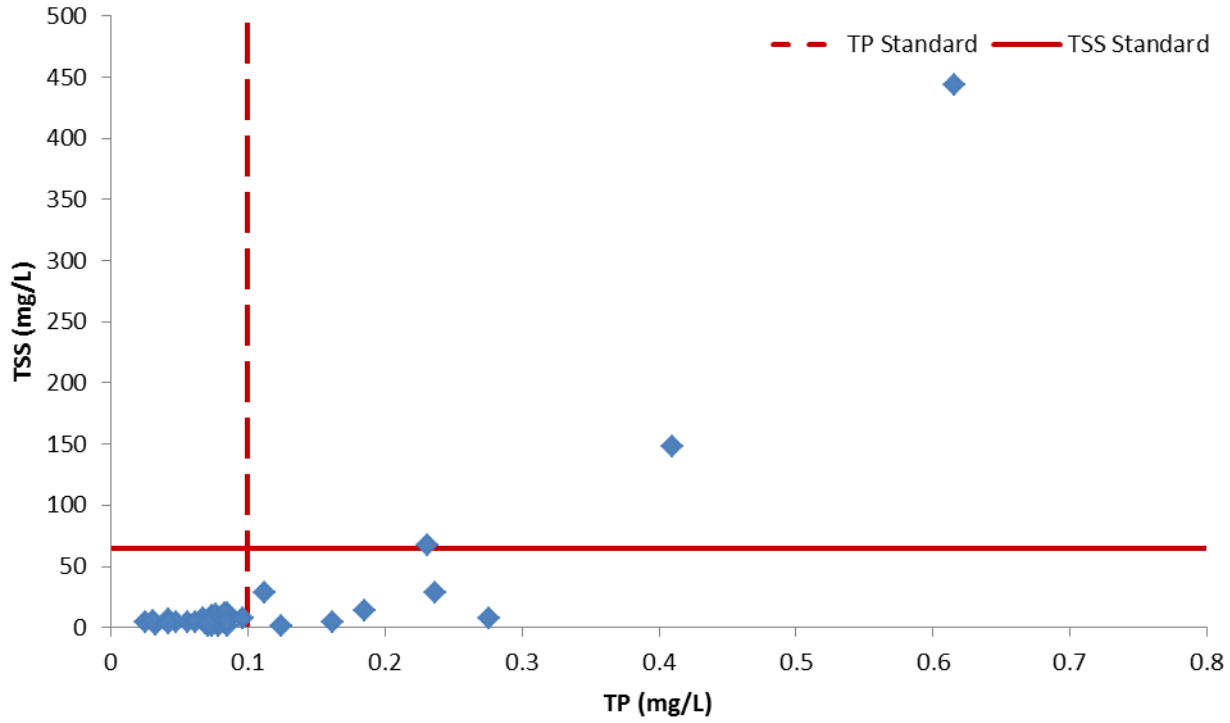


Figure 49. TSS and TP relationship in Butler Creek (2004-2011).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. There were no chl-a or BOD samples at the time of this report; both of these parameters should be included in future monitoring efforts. Sonde deployment in 2013 identified consistent DO flux exceedances at station S004-804; there were 14 daily DO flux exceedances with a maximum of 4.8 mg/L. A longitudinal DO survey completed in August 2014 resulted in no DO flux exceedances. Also, there has been no low DO identified in this AUID. Response variable data is limiting, but algal production was documented in September 2013 (Figure 50).

Figure 50. Algal production in Butler Creek (September 2013).

Total taxa richness of macroinvertebrates (TaxaCountAllChir), taxa richness of collector-gatherers (Collector-gathererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) at station 04LM085 were below the statewide average of stations meeting the MIBI threshold during both visits (2004 and 2011) (Table 25). The metrics mentioned above are expected to decrease in response to stress. Tolerant taxa (Tolerant2ChTxPct) were greater than the statewide average in 2004 and 2011; tolerant taxa are expected to increase in response to stress. Taxa richness of collector-filterers (Collector-filtererCh) was above average in 2004 and below average in 2011; collector-filterers are expected to decrease in response to stress. All metrics were worse than the statewide average in 2011.

Table 25. Macroinvertebrate metrics that respond to TP stress in Butler Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
04LM085 (2004)	**41**	7	**12**	**7**	**0**	**80.5**
04LM085 (2011)	**26**	**5**	**13**	**4**	**0**	**80.8**
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
Expected response to stress	↓	↓	↓	↓	↓	↑

Butler Creek includes multiple exceedances and elevated phosphorus concentrations during various flows. However, there is no chl-a and BOD data, and minimal DO flux information. The limited DO flux information does include exceedances, and the macroinvertebrate metrics are suggestive of stress. Also, algal production has been documented via photos. Overall, it appears that phosphorus has the potential to be a stressor to the biology in Butler Creek, but at this time it's inconclusive due to limited data for the response variables. Additional chl-a, BOD, and DO flux information is necessary in order to determine if the elevated phosphorus levels are leading to eutrophication issues. Although inconclusive at this time, reducing phosphorus in Butler Creek should be a priority in any future planning efforts. Phosphorus has the potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus loading should help (and/or protect from potential future impacts) the biology in Butler Creek, as well as downstream receiving waters.

Dissolved Oxygen

The DO data set contains 47 samples from 2008-2013 (minimum of 8.6 mg/L, maximum of 15.29 mg/L, and an average of 11.1 mg/L). There were zero samples below the warmwater standard of 5 mg/L. There were only eight samples collected before 9:00 a.m. Additional early morning data would help confirm the fact that DO is meeting the standard. All but one of the samples was collected at station S004-804. The samples at this station had good seasonal coverage (April – September), and covered parts of three

different years (2008, 2009, and one sample in 2013). The biological station (04LM085) was sampled once in 2011, and had a concentration of 8.6 mg/L.

There were zero low DO concentrations identified during a longitudinal DO survey in August 2014. Also, sonde deployment in August and September of 2013 at station S004-804 resulted in zero low DO concentrations.

Station 04LM085 had worse than average total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 26). This station was sampled in 2004 and 2011. All three metrics were worse in 2011. Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

Station 04LM085 had 9 DO intolerant macroinvertebrate taxa present in 2004 and seven in 2011. Several DO very intolerant taxa were also present in these years (Five and three respectively). Two DO tolerant taxa were sampled each visit, and one DO very tolerant taxa was found in 2011. DO tolerant and very tolerant taxa were present in very low numbers (< 2%). The DO index scores were 7.8 and 7.7, both are above the statewide average (7.2) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 26. Macroinvertebrate metrics that respond to low DO stress in Butler Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
04LM085 (2004)	**41**	**80.5**	**7**	7.8	**9**	**5**	2	0	1.4	0.0
04LM085 (2011)	**26**	**80.8**	**4**	7.7	**7**	**3**	2	1	0.6	0.3
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

Although some of the macroinvertebrate metrics are worse than the statewide average, there are zero DO readings below the warmwater standard of 5 mg/L (this includes the historical data set and the longitudinal DO survey and sonde deployment performed during SID fieldwork). In addition to the lack of low DO readings, there were DO intolerant and very intolerant taxa present and very few DO tolerant and very tolerant taxa. Also, the DO index scores were better than the statewide average. DO is not currently stressing the macroinvertebrate community in Butler Creek.

TSS/Turbidity

There have been 37 TSS samples collected between 2004 – 2013 (minimum of 1 mg/L, maximum of 3,300 mg/L, and an average of 113 mg/L). Four samples (11%) exceeded the South Region draft TSS standard (65 mg/L). During assessment, the MPCA staff noted that additional TSS data would help confirm (or refute) the current turbidity listing; it appears to be right at the standard. As with the rest of the parameters, most samples were collected near the mouth at station S004-804. A total of 35 samples were collected at this station over a three year time period and the months of April – October. Samples appear to have been distributed evenly among those months (18 samples in April – June, 15 samples in July – September), thus in theory characterizing the wide range of flow conditions that can occur each year. The maximum value (3,300 mg/L) was observed during an event in April of 2013. The two remaining samples were collected at biological monitoring station 04LM085. These samples were taken at or near baseflow conditions, and were both below the standard (4 and 12 mg/L).

There have been 52 transparency samples collected from 2004 – 2013 (minimum of 4 cm, maximum of 100 cm, and an average of 75 cm). Only one sample (2%) exceeded the s-tube surrogate standard for the South Region (10 cm). The exceedance occurred on April 9, 2013. Samples were collected from two different stations located in the lower – middle portion of the AUID; a majority of the samples were collected near the mouth of Butler Creek. Samples were collected from April – October, with June (12), July (10), and August (10) having the most samples.

Figure 51. Unstable stream bank at station 04LM085 in June 2004.

Macroinvertebrate samples were collected at station 04LM085 (Figure 51) in 2004 and 2011 (Table 27). The relative abundance of collector-filterer individuals (Collector-filtererPct) was above the statewide average of stations meeting the MIBI threshold during both visits, while the relative abundance of Plecoptera individuals (PlecopteraPct) was below average. Both of these metrics are expected to decrease in response to stress.

Station 04LM085 had zero TSS intolerant and very intolerant taxa present during both visits. This station, however, did have TSS tolerant (5 - 6) and very tolerant (0 - 2) taxa present. TSS tolerant and very tolerant taxa comprised 6% - 23% and 0% - 2% of the macroinvertebrate community respectively. The macroinvertebrate TSS index scores for station 04LM085 were 15.5 and 16.0, which are better than the statewide average (17.1) of stations meeting the MIBI threshold.

Table 27. Macroinvertebrate metrics that respond to TSS stress in Butler Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
04LM085 (2004)	42.2	**0.0**	15.5	**0**	**0**	6	2	6.4	1.7
04LM085 (2011)	41.1	**0.0**	16.0	**0**	**0**	5	0	22.8	0.0
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can still inform the SID process. All of the metrics at station 04LM085 in 2004 were worse than the statewide average of stations meeting the FIBI threshold except for the relative abundance of individuals that are herbivore species (HrbNWQPct) and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) (Table 28). In 2011, all of the metrics besides the relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct) and relative abundance of individuals that are long-lived (LLvdPct) were worse than the statewide average. The fish TSS index scores were 15.3 and 15.3, which are worse than the statewide average (15.1) of stations meeting the FIBI threshold. As this score increases, so does the tolerance of the community. Overall, a majority of the fish metrics were worse than average and suggestive of stress during both visits.

Table 28. Fish metrics that respond to TSS stress in Butler Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RiffflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
04LM085 (2004)	**26.2**	**0.0**	23.4	**0.7**	**1.4**	**2.8**	**23.4**	**2.1**	23.4	**15.3**
04LM085 (2011)	**22.1**	1.3	**10.4**	**0.0**	5.2	**13.0**	**10.4**	**3.9**	**3.9**	**15.3**
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Recent geomorphology work performed by the DNR in Butler Creek documented generally poor and unstable width to depth ratios in the lower to middle portions. These segments are also deeply incised and disconnected from the floodplain (likely due to landuse, channel straightening, and stream crossing issues) (Figure 52). These conditions increase stress on stream banks during high flows, and can increase sediment loading. Sediment supply estimates from WARSSS were calculated for multiple catchments in the Little Cannon River Watershed; the Butler Creek catchment had the lowest average sediment yield at 0.70 metric tons/acre. However, a fair amount of surface erosion is produced in this catchment compared to the other catchments (Proulx 2015).

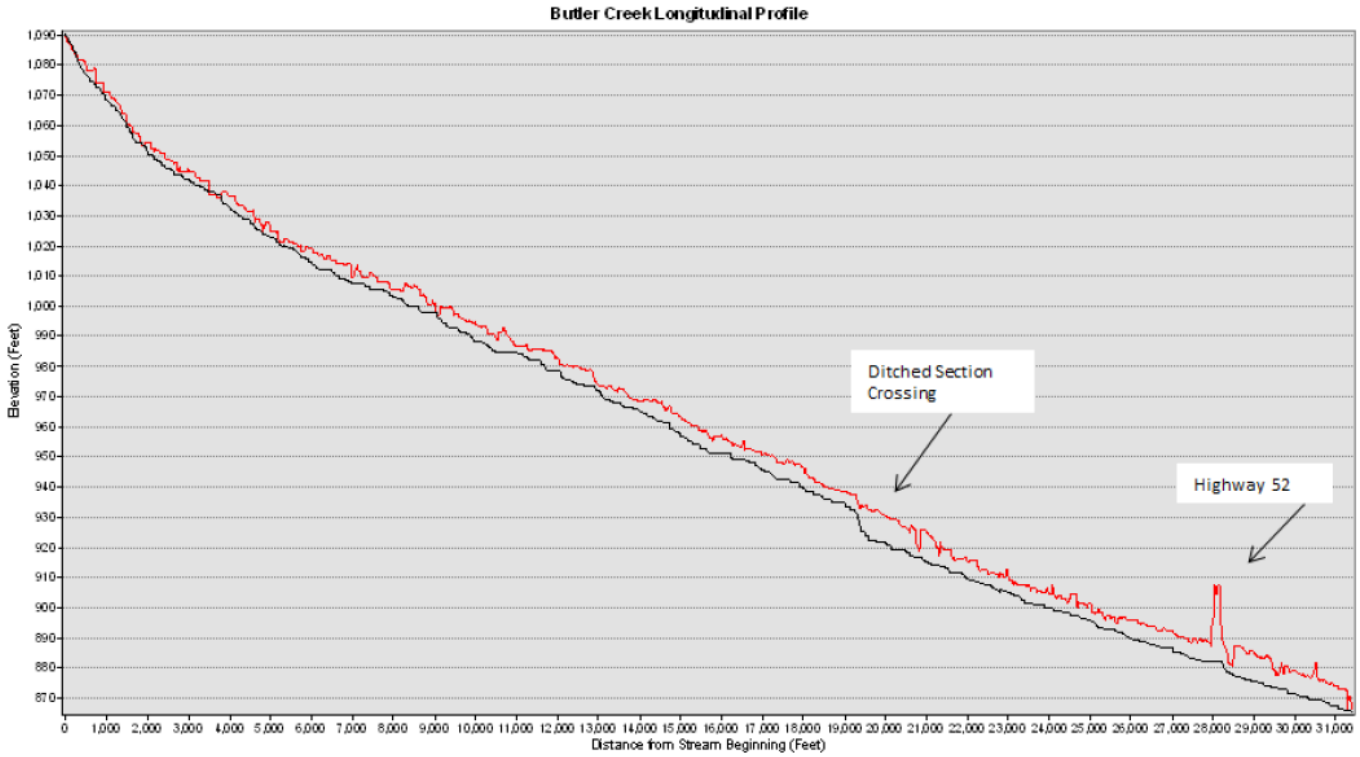


Figure 52. Longitudinal profile of Butler Creek (black) with low bank (red), illustrating a stable, not incised stream above the ditch crossing and incised stream below. The above figure was created by the DNR, and is included in their "Little Cannon River Watershed Geomorphology Assessment Report."

Butler Creek has TSS and transparency exceedances, but not in great number and additional sampling would be beneficial. The macroinvertebrate metrics were a little mixed, but there were no TSS intolerant taxa, and there were multiple TSS tolerant taxa. The TSS tolerant taxa, however, comprised a relatively small portion of the community, and the macroinvertebrate TSS index scores were better than the statewide average. Although not impaired, a majority of the fish metrics were below the statewide average, and the fish TSS index scores were worse than the statewide average. Also, the geomorphology work conducted by the DNR identified some stream instability and incision. Butler Creek is currently impaired for turbidity, and it appears as though TSS/turbidity is negatively impacting the macroinvertebrate community.

Lack of Habitat

The MSHA scores for Butler Creek were "good" in 2004 (67), and "fair" in 2011 (55.9) (Table 29). Riparian, substrate, and channel morphology scores were lower in 2011, resulting in a decreased overall score.

Table 29. MSHA subcategory scores for Butler Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
04LM085	24-Jun-04	2.5	11	18	7	29	67 (Good)
04LM085	08-Aug-11	2.5	9	17	8	19	55.9 (Fair)

The surrounding land use at the time of sampling was classified as forest, wetland, prairie, shrub, and row crop. The riparian width ranged from moderate (30 – 150 feet) to extensive (>300 feet), and shade was moderate (25 – 50%) to substantial (50 – 75%). There was no – little (5 – 25%) bank erosion in 2004, and heavy (50 – 75%) bank erosion in 2011.

Macroinvertebrate habitats sampled at station 04LM085 included riffles, undercut banks/overhanging vegetation, and woody debris. Pool features represented 15% of the station length in 2004, and 20% in 2011. Pool substrates were gravel (2004 only), sand, and detritus (2011 only). Riffles comprised 25% of the station length in 2004, and 40% in 2011. Riffle substrates included cobble (2011 only), gravel, and sand (2004 only). Run features ranged from 60% in 2004 to 40% in 2011. Run substrates consisted of gravel and sand. Light – moderate embeddedness was observed, and less than four substrate types were present in 2004 and more than four substrate types were present in 2011. Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, emergent macrophytes, and boulders) were available, but cover amount was sparse (5 – 25%). Channel sinuosity was fair, channel stability ranged from moderate – high, channel development was good, pool width was equal to or greater than riffle width, and multiple velocity types were present (slow – fast including eddies).

The macroinvertebrate habitat specific metrics, for the most part, are within an expected range (Figure 53). The percentage of most metrics falls within or near the middle quartiles. Clingers were slightly elevated in 2011. Sprawlers (2004) and swimmers (2011) comprised a slightly lower percentage of the community. The climber MIBI metric score was above the average metric score needed to meet the MIBI threshold in 2004, but below average in 2011. The clinger MIBI metric scores were above the average score needed to meet the MIBI threshold in 2004 and 2011.

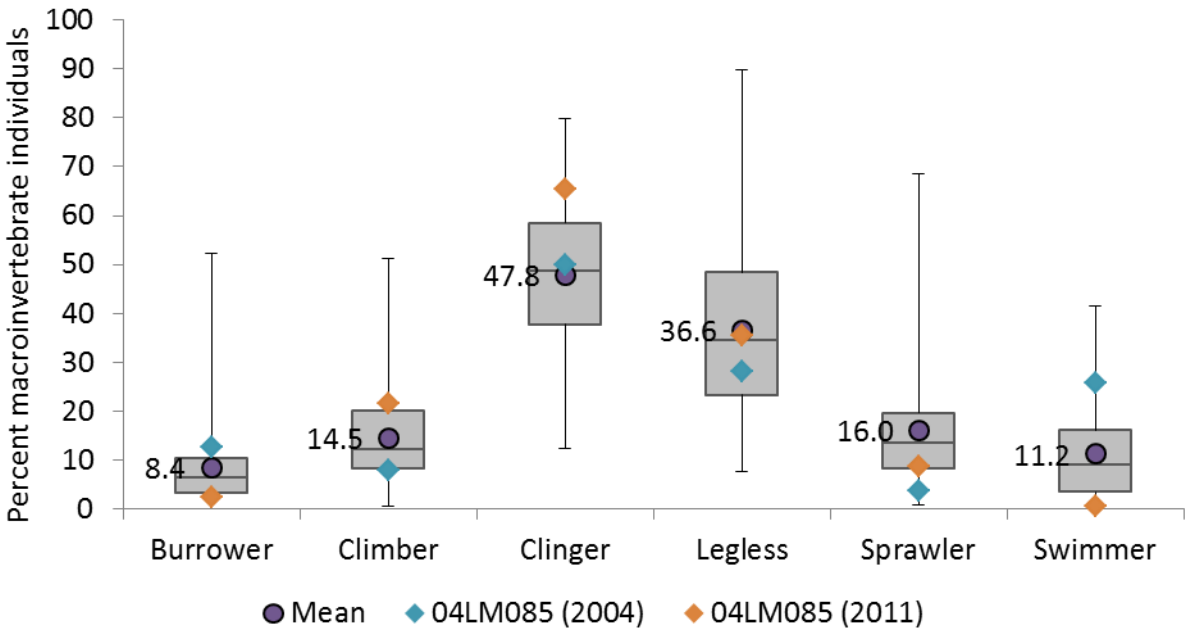


Figure 53. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Butler Creek Watershed stations.

As mentioned above in the TSS/Turbidity section, the DNR has documented instability, incision, and lack of floodplain connectivity in the lower portion of Butler Creek. The riffle cross section below depicts some of the incision/entrenchment observed in Butler Creek; bankfull flows in channels like this are confined and induce tremendous stress on the stream banks and habitat (Figure 54). All of these conditions can have a negative impact on habitat quality and availability.

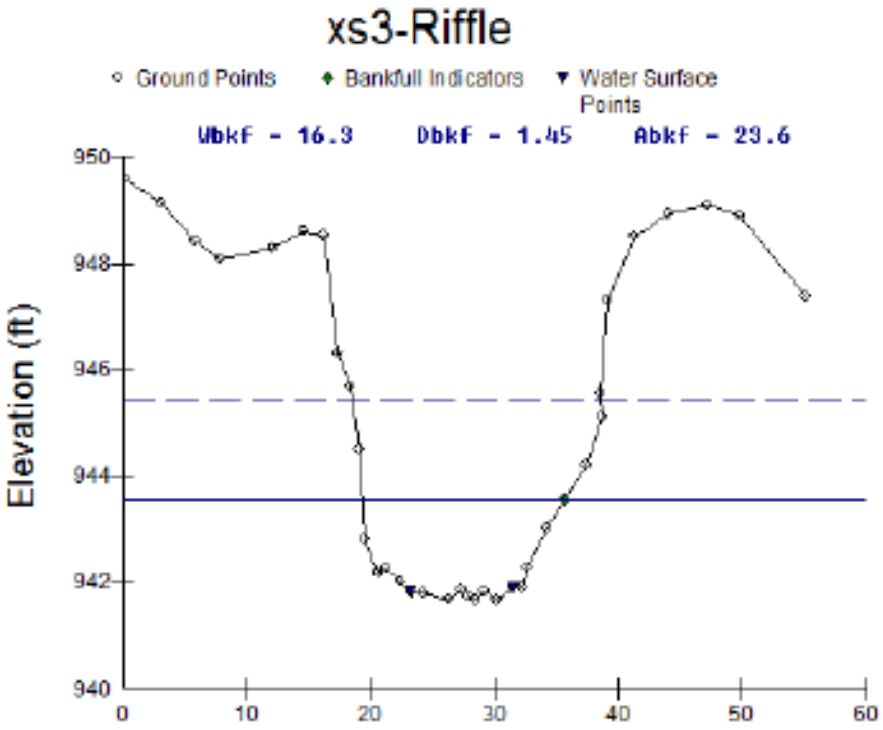


Figure 54. Riffle cross section profile in Butler Creek. The above figure was created by the DNR, and is included in their "Little Cannon River Watershed Geomorphology Assessment Report."

Butler Creek had fair – good MSHA scores, moderate – extensive riparian width, minimal bank erosion in 2004 (but heavy bank erosion in 2011), and light – moderate embeddedness. Multiple habitat types were sampled, and generally speaking the macroinvertebrate metrics specific to habitat had values consistent with a healthy system (i.e. not limited by habitat). However, the DNR has documented significant instability, incision, and floodplain disconnect in the lower portion of Butler Creek; these conditions can have severe impacts on habitat. Although lack of habitat does not appear to be greatly impacting the macroinvertebrate community at this time, it's inconclusive if it is a stressor.

Fish Passage

A recent stream crossing inventory completed by the DNR noted fewer stability issues in the Butler Creek catchment compared to other catchments in the watershed. However, there were a few crossings with multiple issues (two identified as fish passage barriers) (Figure 55). Results from the survey can be seen in Figure 39 located in the Fish Passage section of Little Cannon – 526. Although the fish community is not currently impaired, effort should be made to fix these crossing issues and improve stream health. At this time, fish passage does not appear to be a stressor in this AUID.

Figure 55. Fish barrier on a tributary to Butler Creek (Skunk Hollow Trail road crossing).

Conclusion

TSS is a stressor in Butler Creek, resulting in an impaired macroinvertebrate community. Elevated phosphorus levels have been observed, but at this time it's inconclusive whether or not phosphorus is a stressor. Nitrate and habitat are also inconclusive as stressors. Temperature, DO, and fish passage are not currently stressing the macroinvertebrate community. Reducing the nutrient and sediment loading to Butler Creek should be priorities in future planning and implementation efforts.

4.1.4. Tributary to Little Cannon River (639)

Biological Communities

Tributary to Little Cannon River (07040002-639) is a 0.6 mile long AUID in Goodhue County. This warmwater reach flows through the Drifless Area ecoregion, and joins the Little Cannon River in the upper part of the watershed. This AUID has a macroinvertebrate impairment. Station 11LM027 is the only biological monitoring station in the AUID, and it is located near the middle of the reach. This station was sampled for fish and macroinvertebrates in 2011.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI score was 74, which is above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58). This score is also above the upper confidence limit. There were 11 total

fish species collected, including two pollution intolerant species and zero game fish species. The three most abundant species were creek chub, fantail darter, and blacknose dace. The MPCA biologists noted the presence of several sensitive coolwater taxa, making this location a prime candidate for additional protections.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI score was 36, which is just above the Southern Streams RR impairment threshold of 35.9 (lower CL = 23.3, upper CL = 48.5). There were nine total families, including zero intolerant families. The three most abundant taxa were Polypedilum (non-biting midges), Oligochaeta (worms), and Rheotanytarsus (non-biting midges). ClimberCh, Plecoptera, Predator, Tolerant2ChTxPct, and Trichoptera MIBI metric scores were below the average metric score needed to meet the threshold (Figure 56). Plecoptera and Predator metrics received zero out of the possible 10 points; InsectTxPct received the maximum points available.

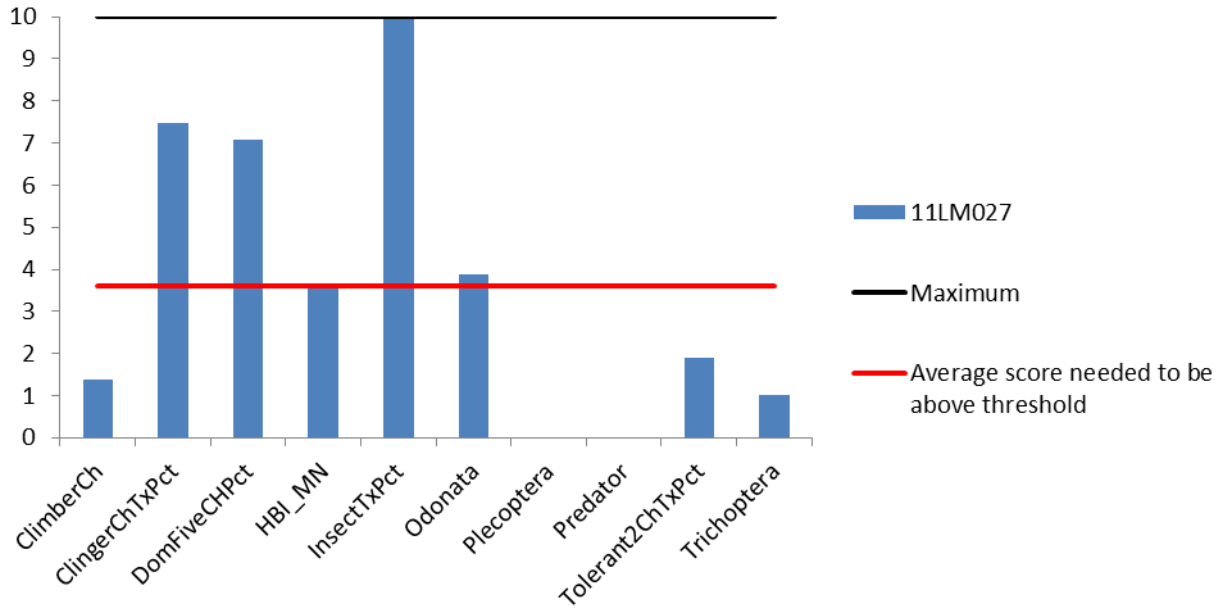


Figure 56. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for a tributary to the Little Cannon River (07040002-639), station 11LM027.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 2011 – 2014 ranged from 1.8 °C – 19.9 °C (average of 11.7 °C). Only seven samples have been collected, none of which were above 30 °C (the acute warmwater standard). These samples were collected from two stations (S007-488 and 11LM027) co-located at the County 49 Blvd. road crossing in April (three), June (one), and August (three). The highest temperature was observed on August 22, 2013 (19.9 °C).

A sonde was deployed at station 11LM027 from July 24, 2014 - July 31, 2014. All of the temperature readings during this timeframe were below 30° C (maximum of 24.1 °C).

The temperature data set for this AUID is limited in terms of sample numbers, but does include continuous data over a seven day period in the summer of 2014. There have been zero exceedances, and temperature does not appear to be a stressor in this AUID.

Nitrate

Nitrate concentrations from 2011 – 2014 ranged from 2.4 mg/L – 13 mg/L (average of 5.2 mg/L). The data set is limited in terms of sample numbers (7), and all of the samples were collected near the middle of the AUID just before it joins the Little Cannon River. The samples were collected at co-located stations (S007-488 and 11LM027). Samples were collected in April (three), June (one), and August (three). There was one sample that exceeded 10 mg/L, which was collected in June of 2014 and had a concentration of 13 mg/L. Additional sampling and seasonal coverage would benefit this data set.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class. Station 11LM027 is in the Southern Streams RR macroinvertebrate class.

Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide average of stations meeting the MIBI threshold (Table 30). All of these metrics are expected to decrease in response to stress.

Station 11LM027 had zero nitrate intolerant and very intolerant taxa present. This station, however, had several nitrate tolerant (77%) and very tolerant (65%) taxa present. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI, and at 83.8% nitrate tolerant individuals there is a 10% probability of meeting the MIBI. The nitrate index score was 3.6, which is above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 30. Macroinvertebrate metrics that respond to nitrate stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM027 (2011)	**3**	**0.6**	**0**	**3.6**	**0**	**0**	**21**	13	**77.0**	**64.5**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

The chemistry data set for this AUID is weak in terms of sample numbers and seasonal coverage, but does include some elevated concentrations. The three highest concentrations were 5.2 mg/L, 5.6 mg/L, and 13.0 mg/L. All but one of the macroinvertebrate metrics was worse than the statewide average, and there were zero nitrate intolerant and very intolerant taxa present. There were also several nitrate tolerant and very tolerant taxa present (comprising a high percentage of the community), and the nitrate index score was worse than the statewide average of stations meeting the MIBI threshold. Additional monitoring is recommended to get a better handle on the nitrate dynamics in this AUID, but the limited existing chemistry data (with elevated concentrations) and strong biological response provide enough confidence to conclude that nitrate is a stressor in this AUID.

Phosphorus

TP values from 2011 – 2014 ranged from 0.053 mg/L – 1.63 mg/L (average of 0.385 mg/L). Only six samples have been collected, but four of the six exceeded 0.100 mg/L, the draft river eutrophication standard for the Central Region. These samples were collected from two stations (S007-488 and 11LM027) co-located in the middle of the AUID in April (three) and August (three). The four exceedances occurred on august 26, 2014 (0.116 mg/L), April 25, 2014 (0.161 mg/L), April 3, 2014 (0.249 mg/L), and April 9, 2013 (1.63 mg/L). Three out of the four exceedances occurred in April, likely during high flows.

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. At this time, there have been zero chl-a and BOD samples collected; both of these parameters should be sampled in the future. There were zero DO flux exceedances identified during a longitudinal DO survey in August 2014. Sonde deployment from July 24, 2014 – July 31, 2014 at station 11LM027 resulted in minimal flux exceedances near the end of the deployment (there were two daily DO flux exceedances with a maximum of 4.0 mg/L). No low DO was identified in this AUID.

All of the macroinvertebrate metrics with strong relationships to phosphorus were worse than the statewide average of stations meeting the MIBI threshold, except for the taxa richness of collector-gatherers (Collector-gathererCh) (Table 31). The total taxa richness of macroinvertebrates (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of

Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are all below the statewide average and expected to decrease in response to stress. The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) was above average, and is expected to increase in response to stress.

Table 31. Macroinvertebrate metrics that respond to TP stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM027 (2011)	**33**	**5**	15	**4**	**0**	**84.8**
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
Expected response to stress	↓	↓	↓	↓	↓	↑

This AUID has very few TP samples, and zero chl-a and BOD samples. With that being said, elevated TP concentrations have been documented, and there were minimal DO flux exceedances during sonde deployment in 2014. Also, a majority of the macroinvertebrate metrics were worse than the statewide average. The potential for phosphorus stress seems to exist, but it's inconclusive whether or not phosphorus is stressing the macroinvertebrate community in this AUID due to limited data. Additional monitoring (TP, chl-a, BOD, and DO flux) is necessary for stressor determination.

Dissolved Oxygen

DO concentrations from 2011 – 2014 ranged from 5.85 mg/L – 12.24 mg/L (average of 9.1 mg/L). Only six samples have been collected, none of which were below the warmwater standard of 5 mg/L. These samples were collected from two stations co-located in the middle of this small AUID in April (two), June (one), and August (three). The lowest concentration was observed on August 22, 2013 (5.85 mg/L).

A longitudinal DO survey completed in August 2014 resulted in zero low DO concentrations. Also, a sonde was deployed at station 11LM027 from July 24, 2014 – July 31, 2014, which identified zero low DO concentrations.

Station 11LM027 had worse than average total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 32). Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

Station 11LM027 had eight DO intolerant macroinvertebrate taxa and four DO very intolerant taxa. DO tolerant and very tolerant taxa were also present (three and two respectively), but they comprised a very minimal portion of the overall community (2% and 1% respectively). The DO index score was 7.6,

which is above the statewide average (7.2) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 32. Macroinvertebrate metrics that respond to low DO stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM027 (2011)	**33**	**84.8**	**4**	7.6	**8**	**4**	3	**2**	1.5	1.1
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

This limited data set includes zero concentrations below the warmwater standard. Although limited overall, this AUID contains continuous data over an eight day span in July of 2014 that has zero low DO concentrations. Many of the macroinvertebrate metrics were worse than the statewide average, but there were multiple DO intolerant and very intolerant taxa. DO tolerant and very tolerant taxa were present in low numbers, and the DO index score was above the statewide average. Based on the existing information, DO does not appear to be stressing the macroinvertebrate community. Future monitoring is recommended to strengthen this data set.

TSS/Turbidity

TSS concentrations from 2011 – 2014 ranged from 4.8 mg/L – 2,000 mg/L (average of 342.6 mg/L). Only six samples have been collected in this AUID, and they were collected at two different monitoring stations (S007-488 and 11LM027) in the middle of this very small AUID. Samples were collected in April (three) and August (three). Of these six samples, only one was greater than the South Region draft TSS standard (65 mg/L). This exceedance took place at station S007-488 on April 4, 2013; the concentration was 2,000 mg/L.

Transparency values from 2011 – 2014 ranged from 4 cm – 100 cm (average of 49.6 cm). Only seven samples have been collected, but one of those samples exceeded the s-tube surrogate standard for the South Region (10 cm). Samples were collected from two stations (S007-488 and 11LM027) co-located near the mouth of the tributary in April (three), June (one), and August (three). The exceedance occurred on April 9, 2013 (4 cm). Figure 57 below shows an eroding stream bank upstream of station 11LM027.

Figure 57. Eroding stream bank upstream of AUID and station 11LM027.

The macroinvertebrate metrics with strong relationships to TSS were below the statewide average of stations meeting the MIBI threshold (Table 33). The relative abundance of collector-filterer individuals (Collector-filtererPct) and relative abundance of Plecoptera individuals (PlecopteraPct) are expected to decrease in response to stress. Both metrics had values indicative of stress.

Station 11LM027 had zero TSS intolerant and very intolerant taxa present. This station, however, did have TSS tolerant (seven) and very tolerant (two) taxa present. TSS tolerant and very tolerant taxa comprised a minimal percentage of the macroinvertebrate community at 18% and 2% respectively. The macroinvertebrate TSS index score for station 11LM027 was 15.6, which is better than the statewide average (17.1) of stations meeting the MIBI threshold.

Table 33. Macroinvertebrate metrics that respond to TSS stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM027 (2011)	**19.0**	**0.0**	15.6	**0**	**0**	7	2	17.8	1.7
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can still inform the SID process. The relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are herbivore species (HrbNWQPct), and relative abundance of individuals that are long-lived (LLvdPct) were the only metrics worse than the statewide average of stations meeting the FIBI threshold (Table 34). The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are intolerant species (IntolerantPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), relative abundance of individuals that are sensitive species (SensitivePct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were above the statewide average. All of these metrics are expected to decrease in response to stress. The fish TSS index score, which is expected to increase with stress, was below the statewide average. Centr-TolPct and LLvdPct were absent at station 11LM027. Centr-TolPct includes sight feeding species which can be adversely impacted by increased turbidity, and LLvdPct includes long lived species with long life histories that require more time to recover from disturbance. However, the station did have an abundance of intolerant species (IntolerantPct) and sensitive species (SensitivePct). Overall, a majority of the metrics were better than the statewide average.

Table 34. Fish metrics that respond to TSS stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
11LM027 (2011)	54.3	**0.0**	**22.0**	7.5	**0.0**	28.5	43.0	26.3	15.6	13.3
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Recent geomorphology work performed by the DNR in the catchment containing station 11LM027 noted that historic land use changes and farming practices may have altered the channel morphology, which produced high sediment loads, and reduced invertebrate habitat and food sources. They also identified a quarry on the upper end of the tributary (upstream of the AUID) which appears to be acting as a point source for sediment (Figure 58).

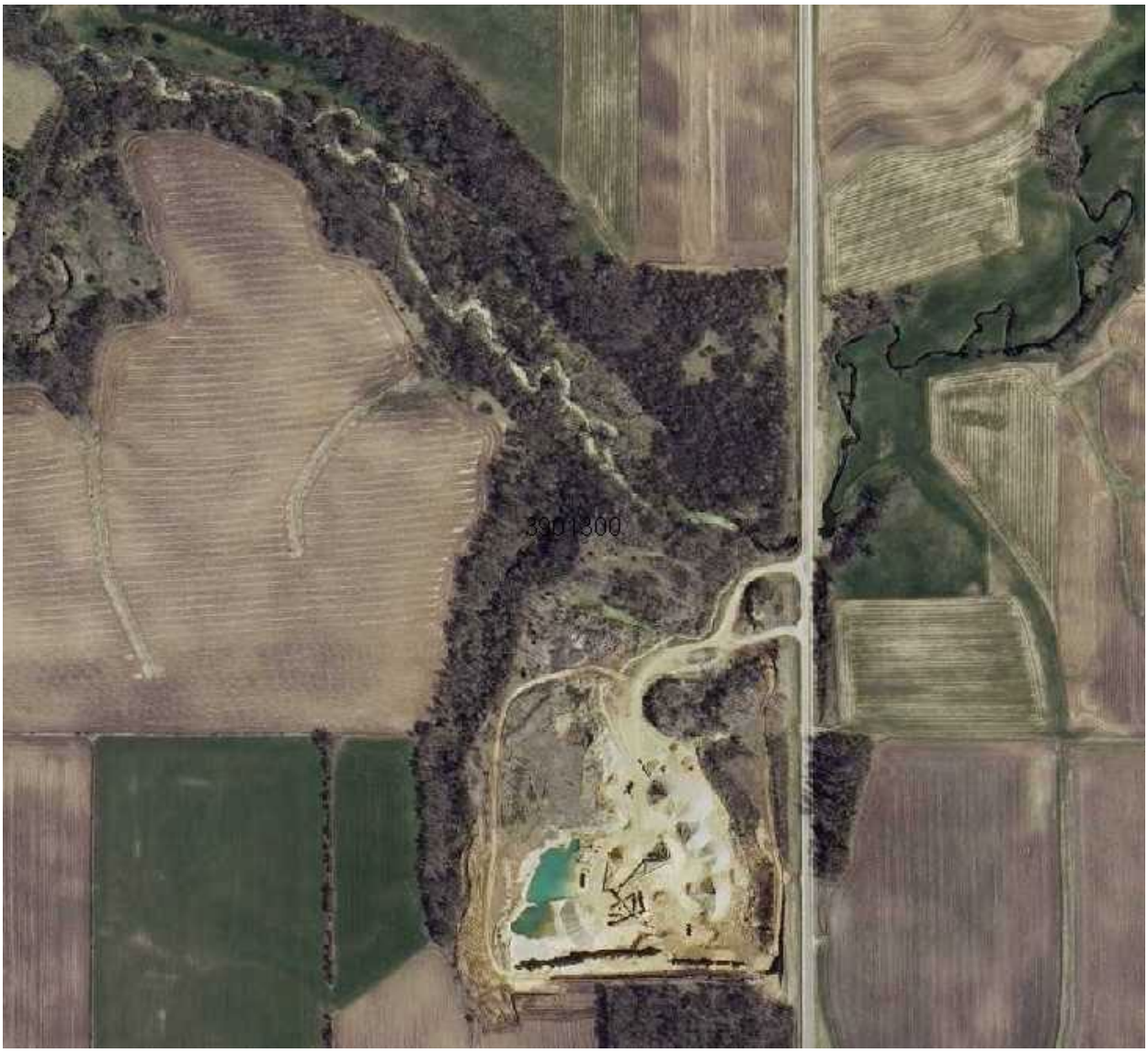


Figure 58. Quarry located upstream of station 11LM027; note the stream color change downstream of the quarry. This figure was produced by the DNR and is included in their "Little Cannon River Watershed Geomorphology Assessment Report."

There is very limited data available for this AUID, but it does include an elevated TSS concentration (2,000 mg/L) and low transparency value (4 cm). Both of these exceedances occurred in April of 2013. Many of the macroinvertebrate metrics were below the statewide average; there were zero TSS intolerant and very intolerant taxa, and multiple TSS tolerant and very tolerant taxa. Geomorphology work conducted by the DNR also documented sediment issues. However, the macroinvertebrate TSS index score was better than the statewide average, a majority of the fish metrics (although not impaired) were better than the statewide average, and at this time it's inconclusive as to whether or not TSS/turbidity is stressing the macroinvertebrate community. Signals of stress exist, but additional sampling is needed to verify that it is (or isn't) a stressor.

Lack of Habitat

The MSHA score for station 11LM027 was 68.15 or "good" (Table 35). Land use, riparian, substrate, cover, and channel morphology scores were all fairly decent.

Table 35. MSHA subcategory scores for the tributary to the Little Cannon River.

Station	Visit Date	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
11LM027	17-Aug-11	3.8	10.5	16.9	12	25	68.2 (Good)

The surrounding land use at the time of sampling was classified as forest, wetland, prairie, and shrub on the left bank, and forest, wetland, prairie, shrub and row crop on the right bank. The riparian width was extensive (> 300 feet) on both sides of the stream, bank erosion was heavy (50 – 75%) on both sides of the stream, and there was substantial (50% – 75%) – heavy (>75%) shade present.

Macroinvertebrate habitats sampled included riffles, undercut banks/overhanging vegetation, and woody debris. Pool features comprised 25% of the station length in 2011, and pool substrates included cobble and gravel. Riffles made up 20% of the station length. The substrate types found in riffles included cobble and gravel. Run features represented 55% of the station. Run substrates were gravel and sand. Moderate embeddedness was noted, and there were less than four substrate types present. Cover types included undercut banks, deep pools, logs or woody debris, boulders, and rootwads; the cover amount was considered moderate (25% - 50%). Channel sinuosity was excellent and channel stability moderate. This reach had good depth variability (greatest depth > 4x shallow depth) and multiple velocity types (slow – fast and eddies).

Burrowers, legless, and sprawlers were all elevated, and in the upper quartile (Figure 59). Burrowers and legless are expected to increase in response to habitat stress; sprawlers may also increase. Climbers and clingers, expected to decrease in response to habitat stress, are in the middle quartiles. Clingers are below the average of Southern Streams RR stations that are meeting the MIBI threshold. The MIBI metric score for climbers (1.37) was below the average metric score needed (3.59) to meet the MIBI threshold; the clinger MIBI metric score (7.47), however, was above the average score needed. Swimmers, which require low velocity water, were absent at station 11LM027. Multiple macroinvertebrate taxa (37) were present, and the three most abundant were Polypedilum (non-biting midges), Oligochaeta (worms), and Rheotanytarsus (non-biting midges); all three are considered tolerant taxa.

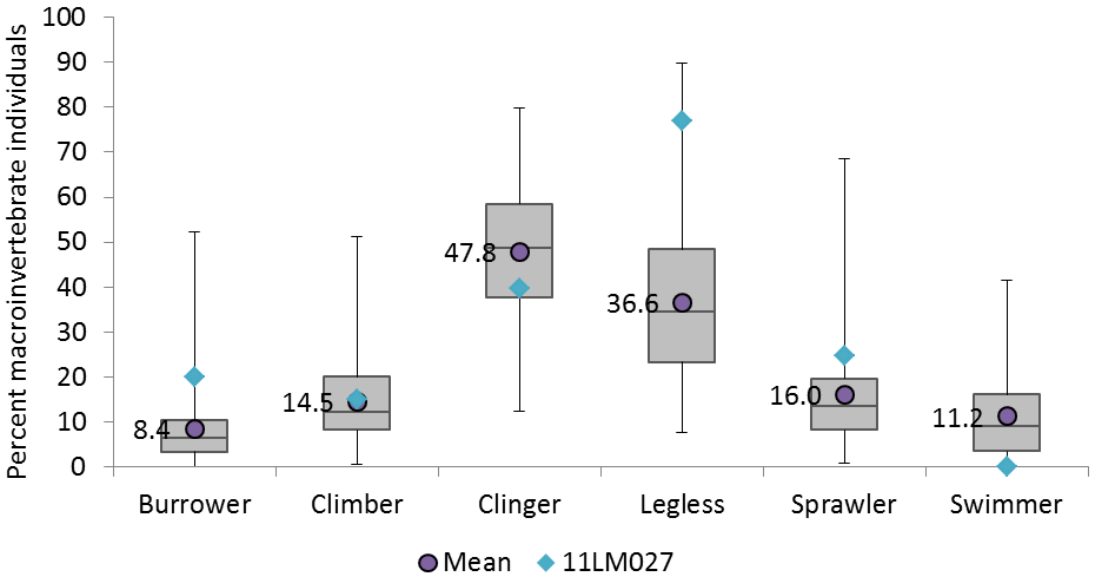


Figure 59. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Little Cannon Watershed stations.

The DNR conducted geomorphology sampling in the Little Cannon Watershed in 2014, and one of their survey sites was located at (or near) station 11LM027. This site was determined to be an E4 stream type that is transitioning to or from a C channel type; E4 stream types are channel systems with low to moderate sinuosity, gentle to moderately steep channel gradients, with very low channel width/depth ratios, and predominantly gravel sized bed materials (Rosgen 1996). Results from this survey indicated that "embedded sediments do not appear to be a direct stressor" and that wood and deep pool habitat were present (Proulx 2015). It appears that embeddedness was more significant in 2011 when the MSHA was completed (based on the moderate embeddedness observed at that time and the elevated burrowers). There are several possible explanations for this, one being that a high flow event(s) came through and "flushed" the system prior to the geomorphology sampling performed in 2014 by the DNR.

The MSHA score for station 11LM027 was good and multiple habitat types were present, but moderate embeddedness and heavy bank erosion were observed. Burrowers, legless, and sprawlers were all elevated, a response suggestive of stress. Burrowers can indicate fine sediment/siltation issues, legless are tolerant species, and sprawlers live on the surface of fine sediments. In addition, clingers were below average and the climber MIBI metric score was below average. At this time, habitat appears to be stressing the macroinvertebrate community.

Fish Passage

There were two perched culverts identified upstream of the AUID during a connectivity survey in the summer of 2014 (Figure 60 and Figure 61). Also, a detailed stream crossing inventory recently completed by the DNR in the catchment containing station 11LM027 identified two fish barriers (in addition to other issues). Results from the survey can be seen in Figure 39 located in the Fish Passage section of Little Cannon – 526. Although the fish community is not currently impaired, effort should be made to fix these crossing issues and improve stream health. At this time, fish passage does not appear to be a stressor in this AUID.

Figure 60. Perched culvert above AUID on 63rd Avenue.

Figure 61. Perched culvert above AUID on 408th Street Way.

Conclusion

This tributary to the Little Cannon River has nitrate and habitat stressors, with their impacts contributing to an impaired macroinvertebrate community. Elevated TSS and phosphorus levels have been documented, but at this time it's inconclusive whether or not they are stressors due to limited data. Although inconclusive at this time, reducing the concentrations of these parameters is still recommended. Also, a quarry upstream of this AUID has been identified as a potential sediment source. Temperature, DO, and fish passage are not currently stressing the macroinvertebrate community. Reducing the nutrient and sediment loading to this tributary, and improving in-stream habitat should be priorities in future planning and implementation efforts.

4.1.5. Tributary to Little Cannon River (670)

Biological Communities

Tributary to Little Cannon River (07040002-670) is a 0.4 mile long AUID in Goodhue County. This warmwater reach flows through the Driftless Area ecoregion, and joins the Little Cannon River in the upper part of the watershed. This AUID has a macroinvertebrate impairment. Station 11LM023 is the only biological monitoring station in this AUID, and it is located in the upper end of the tributary. This station was sampled for fish and macroinvertebrates in 2011.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI score was 83, which is above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58). This score is also above the upper confidence limit. There were 14 total fish species collected, including two pollution intolerant species and one game fish species. The three most abundant species were central stoneroller, fantail darter, and creek chub. The only game fish sampled was brown trout, and only one was collected. The MPCA biologists noted the presence of several sensitive coolwater taxa, making this location a prime candidate for additional protections.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI score was 29, which is below the Southern Streams RR impairment threshold of 35.9 (lower CL = 23.3, upper CL = 48.5). There were 15 total families, including zero intolerant families. The three most abundant taxa were Polypedilum (non-biting midges), Baetis (mayflies), and Simulium (black flies). In general, MIBI metric scores were lower, resulting in the low MIBI score (Figure 62). ClimberCh, Plecoptera, Predator, Tolerant2ChTxPct, and Trichoptera MIBI metric scores were below the average metric score needed to meet the threshold. Plecoptera and Predator metrics received zero out of the possible 10 points.

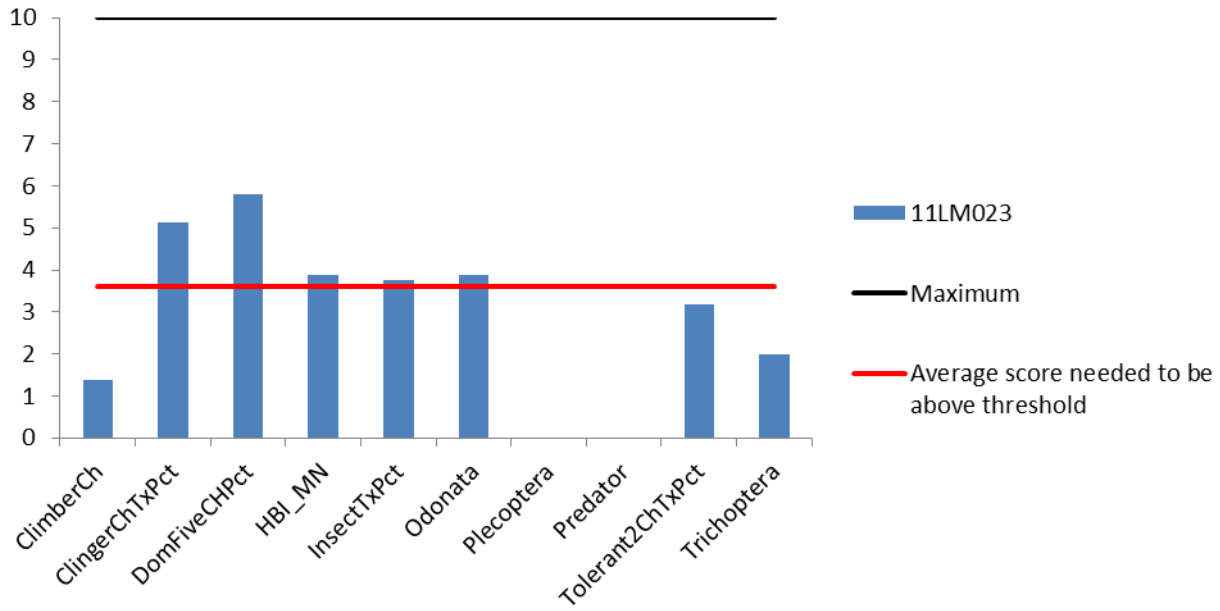


Figure 62. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for a tributary to the Little Cannon River (07040002-670), station 11LM023.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 2011 – 2014 ranged from 0.8 °C – 19.8 °C (average of 12.8 °C). Only six samples have been collected, none of which were above 30 °C (the acute warmwater standard). These samples were collected from two stations (11LM023 and S007-489) co-located at the County 14 Blvd. road crossing in April (two), June (one), and August (three). The highest temperature was observed on August 17, 2011 (19.8 °C).

Also, temperature was recorded as part of a longitudinal DO survey in August 2014 at station 11LM023. The two readings from this survey were 17.41 °C and 20.68 °C. At this time, there is no continuous temperature data available for this AUID. Continuous data would provide a better understanding of the temperature regime in this AUID.

It's inconclusive at this time if temperature is stressing the macroinvertebrate community due to limited data. There have been zero exceedances to this point, but additional monitoring (preferably continuous) is necessary to eliminate temperature as a potential stressor.

Nitrate

Nitrate concentrations from 2011 – 2014 ranged from 3.5 mg/L – 14 mg/L (average of 6 mg/L). Only seven samples have been collected in this AUID, and they were collected at two different monitoring stations (S007-489 and 11LM023) in the middle – upper portion of this very small AUID. Samples were collected in April (three), June (one), and August (three). The three highest concentrations were 6.1 mg/L (April 25, 2014), 6.7 mg/L (August 17, 2011), and 14 mg/L (June 2, 2014). Additional sampling with good temporal coverage is recommended and would strengthen this data set.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class. Station 11LM023 is in the Southern Streams RR macroinvertebrate class.

Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide average of stations meeting the MIBI threshold (Table 36). All of these metrics are expected to decrease in response to stress.

Station 11LM023 had zero nitrate intolerant and very intolerant taxa present. This station, however, had several nitrate tolerant (22) and very tolerant (17) taxa present. Nitrate tolerant and very tolerant taxa comprised a high percentage of the macroinvertebrate community at 67% and 56% respectively. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI, and at 83.8% nitrate tolerant individuals there is a 10% probability of meeting the MIBI. The nitrate index score was 3.3, which is above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 36. Macroinvertebrate metrics that respond to nitrate stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM023 (2011)	**4**	**0.6**	**0**	**3.3**	**0**	**0**	**22**	**17**	**66.6**	**55.8**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

This AUID has some elevated nitrate concentrations, all the macroinvertebrate metrics are worse than the statewide average, there are zero nitrate intolerant and very intolerant taxa present, nitrate tolerant and very tolerant taxa are abundant, and the nitrate index score is worse than the statewide average of stations meeting the MIBI threshold. Additional monitoring is recommended to get a better handle on the nitrate dynamics in this AUID, but the limited existing chemistry data (with elevated concentrations) and strong biological response provide enough confidence to conclude that nitrate is a stressor in this AUID.

Phosphorus

TP concentrations from 2011 – 2014 ranged from 0.059 mg/L – 0.165 mg/L (average of 0.099 mg/L). Only five samples have been collected, but two out of the five exceeded 0.100 mg/L, the draft river eutrophication standard for the Central Region. These samples were collected from two co-located stations (S007-489 and 11LM023) in April (two) and August (three). The two exceedances occurred on August 26, 2014 (0.109 mg/L) and April 3, 2014 (0.165 mg/L).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. At this time, there have been zero chl-a and BOD samples collected; both of these parameters should be sampled in the future. There were zero DO flux exceedances identified during a longitudinal DO survey in August 2014.

All of the macroinvertebrate metrics with strong relationships to phosphorus were worse than the statewide average of stations meeting the MIBI threshold, except for the taxa richness of collector-gatherers (Collector-gathererCh) (Table 37). The total taxa richness of macroinvertebrates (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are all below the statewide average and expected to decrease in response to stress. The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) was above average, and is expected to increase in response to stress.

Table 37. Macroinvertebrate metrics that respond to TP stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM023 (2011)	**33**	**5**	15	**6**	**0**	**78.8**
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
Expected response to stress	↓	↓	↓	↓	↓	↑

This AUID has very few TP samples, zero chl-a and BOD samples, and minimal DO flux information. With that being said, elevated TP concentrations have been documented. Also, a majority of the macroinvertebrate metrics were worse than the statewide average. At this time, it's inconclusive whether or not phosphorus is stressing the macroinvertebrate community in this AUID due to limited data. Additional monitoring (TP, chl-a, BOD, and DO flux) is necessary in order to formulate a conclusion.

Dissolved Oxygen

DO concentrations from 2011 – 2014 ranged from 7.68 mg/L – 12.62 mg/L (average of 10.0 mg/L). Only six samples have been collected, none of which were below the warmwater standard of 5 mg/L. These samples were collected from two stations co-located near the upper end of this small AUID in April

(two), June (one), and August (three). The lowest concentration was observed on August 22, 2013 (7.68 mg/L).

Station 11LM023 had worse than average total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 38). Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

Station 11LM023 had 10 DO intolerant macroinvertebrate taxa and six DO very intolerant taxa. One DO tolerant taxon was also present, comprising a very minimal portion of the overall community (0.3%). The macroinvertebrate DO index score was 7.7, which is above the statewide average (7.2) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 38. Macroinvertebrate metrics that respond to low DO stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM023 (2011)	**33**	**78.8**	**6**	7.7	10	6	1	0	0.3	0.0
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

The DO data set for this AUID includes zero concentrations below the warmwater standard, but is very weak in terms of sample numbers. Some of the macroinvertebrate metrics are worse than the statewide average, but there are several DO intolerant and very intolerant taxa. DO tolerant taxa comprise a very small portion of the macroinvertebrate community, and the DO index score was above the statewide average. At this time, it's inconclusive whether or not DO is a stressor due to limited data. It seems unlikely that DO is a stressor, but future monitoring is needed in order to confirm this inkling.

TSS/Turbidity

TSS concentrations from 2011 – 2014 ranged from 4 mg/L – 19 mg/L (average of 10.4 mg/L). Only six samples have been collected in this AUID, and they were collected at two different monitoring stations (S007-489 and 11LM023) in the middle – upper end of this very small AUID. Samples were collected in April (three) and August (three). Of these six samples, zero were greater than the South Region draft TSS standard of 65 mg/L.

Transparency values from 2011 – 2014 ranged from 26 cm – 99 cm (average of 61 cm). Only six samples have been collected, and zero of those samples were below the s-tube surrogate standard for the South

Region (10 cm). Samples were collected from two co-located stations (S007-489 and 11LM023) in April (two), June (one), and August (three). The three lowest readings were 26 cm (June 2, 2014), 46 cm (August 26, 2014), and 50 cm (August 22, 2013). Figure 63 below shows an eroding stream bank at station 11LM023.

Figure 63. Eroding stream bank at station 11LM023.

The relative abundance of collector-filterer individuals (Collector-filtererPct) was above the statewide average of stations meeting the MIBI threshold, while the relative abundance of Plecoptera individuals (PlecopteraPct) was below the statewide average (Table 39). There were no stoneflies (Plecoptera) present during sampling. Both of the metrics mentioned above are expected to decrease in response to stress.

Station 11LM023 had zero TSS intolerant and very intolerant taxa present. This station, however, did have TSS tolerant (six) and very tolerant (three) taxa present. TSS tolerant and very tolerant taxa comprised a relatively minimal percentage of the macroinvertebrate community at 27% and 1% respectively. The macroinvertebrate TSS index score for station 11LM023 was 15.6, which is better than the statewide average (17.1) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS.

Table 39. Macroinvertebrate metrics that respond to TSS stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM023 (2011)	27.5	**0.0**	15.6	**0**	**0**	6	3	26.8	1.3
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can still inform the SID process. The relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are long-lived (LLvdPct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were the only metrics worse than the statewide average of stations meeting the FIBI threshold (Table 40). Centr-TolPct and LLvdPct were very low at 0.0% and 0.3% respectively. The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are intolerant species (IntolerantPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), and relative abundance of individuals that are sensitive species (SensitivePct) were well above the statewide average. All of these metrics are expected to decrease in response to stress. The fish TSS index score, which is expected to increase with stress, was below the statewide average. Overall, a majority of the fish metrics were better than the statewide average.

Table 40. Fish metrics that respond to TSS stress in the tributary to the Little Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
11LM023 (2011)	69.2	**0.0**	36.6	7.8	**0.3**	30.1	58.6	29.6	**8.0**	13.3
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

There is very limited data available for this AUID, which includes zero TSS or transparency exceedances. There were zero TSS intolerant and very intolerant taxa, and multiple TSS tolerant and very tolerant taxa. However, the macroinvertebrate TSS index score was better than the statewide average, and a majority of the fish metrics (although not impaired) were better than the statewide average. At this time

it's inconclusive as to whether or not TSS/turbidity is stressing the macroinvertebrate community. Additional sampling is needed to determine the impact of TSS/turbidity in this AUID.

Lack of Habitat

The MSHA score at station 11LM023 was 68.75 ("good") (Table 41). All of the sub-category scores received well over half of the available points, except land use, which received only 25% of the points available.

Table 41. MSHA subcategory scores for the tributary to the Little Cannon River.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
11LM023	17-Aug-11	1.3	9.5	20	13	25	68.8 (Good)

The surrounding land use at the time of sampling was classified as forest, wetland, prairie, shrub, and row crop. The riparian width was moderate (30 – 150 feet) to extensive (>300 feet), and shade was substantial (50 – 75%) to heavy (>75%). Bank erosion was heavy (50 – 75%).

Macroinvertebrate habitats sampled at station 11LM023 were riffles, undercut banks/overhanging vegetation, and woody debris (Figure 64). Pool features represented 25% of the station length. Pool substrates were cobble and gravel. Riffles comprised 15% of the reach, and substrates were also cobble and gravel. Run features were the most dominant at 60%. As with the pool and riffle substrates, run substrates were cobble and gravel. Embeddedness was light, and less than four substrate types were present. Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, rootwads, and submergent macrophytes) were available, and cover amount was moderate (25 – 50%). Channel sinuosity was excellent, channel stability was moderate, channel development was good, multiple velocity types were present (slow – fast), pool width was equal to riffle width, and the greatest depth was greater than four times the shallowest depth.

Figure 64. Habitat and riffle feature at station 11LM023 (August 17, 2011).

Burrowers, climbers, clingers, and legless were all within a relatively expected range (Figure 65). They fell right at, or within the middle quartiles of Southern Streams RR stations meeting the MIBI threshold. Sprawlers were in the upper quartile, while swimmers were in the lower quartile. Overall, these macroinvertebrate habitat specific metrics have "good" values and are not showing responses expected with habitat stress. The climber MIBI metric score was below the average metric score needed to meet the MIBI threshold, while the clinger MIBI metric score was above average.

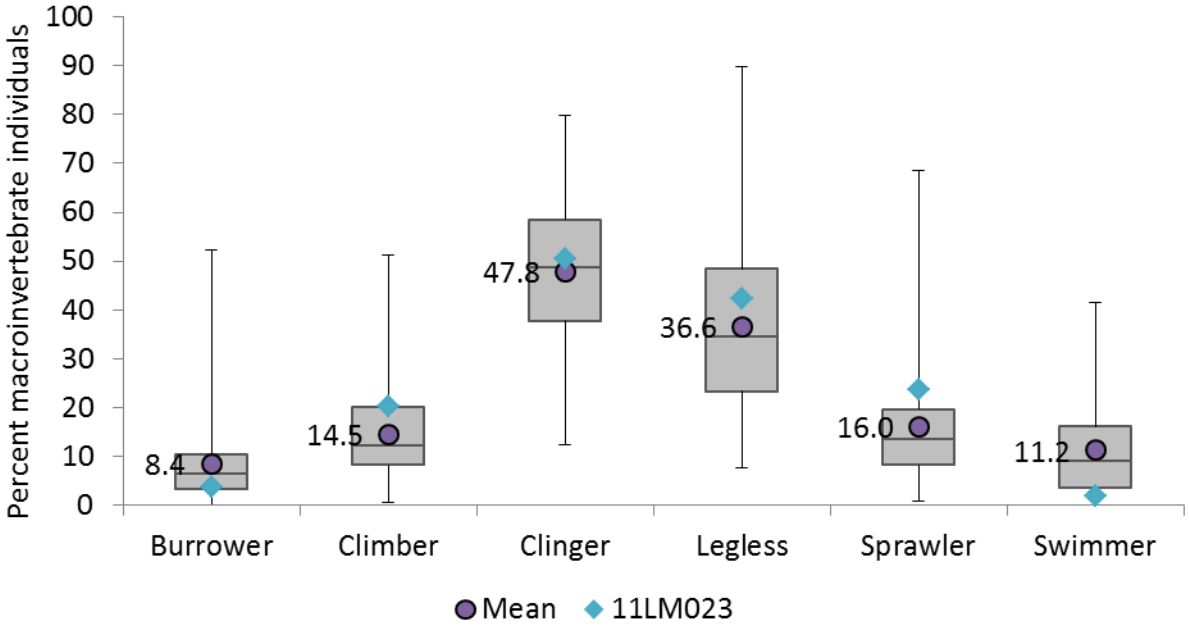


Figure 65. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Little Cannon Watershed stations.

Recent geomorphology work conducted by the DNR classified the upper portion of the catchment as primarily a stable E channel, and the downstream portion (where station 11LM023 is located) as primarily an unstable F channel (Figure 66). The following excerpt is from the "Little Cannon River Watershed Geomorphology Assessment Report" produced by the DNR as it pertains to station 11LM023:

> *The biological survey site is located downstream of the geomorphic survey and in a different stream type. Similar conditions to 11LM025 and LC12-02 occur at this location, where channel stability changes rapidly due to localized stressors. In this case the road, road crossings and inadequate buffers are responsible for causing the entrenched channel. Much like the other F channels, this one has over-widened and loss sinuosity. The channel instability has direct impacts to the invertebrate community in the form of increased bank erosion rates due to lateral meander migration. However, the channel is recovering when compared to historical aerial photographs. Once the channel has stabilized by either active or passive restoration directed at localized stressors, the biggest obstacle for the invertebrate community will be recruitment. The main channel invertebrate community near the confluence of this tributary is also impaired so source populations may take quite a while to reach this area unless active reintroductions were to take place.*

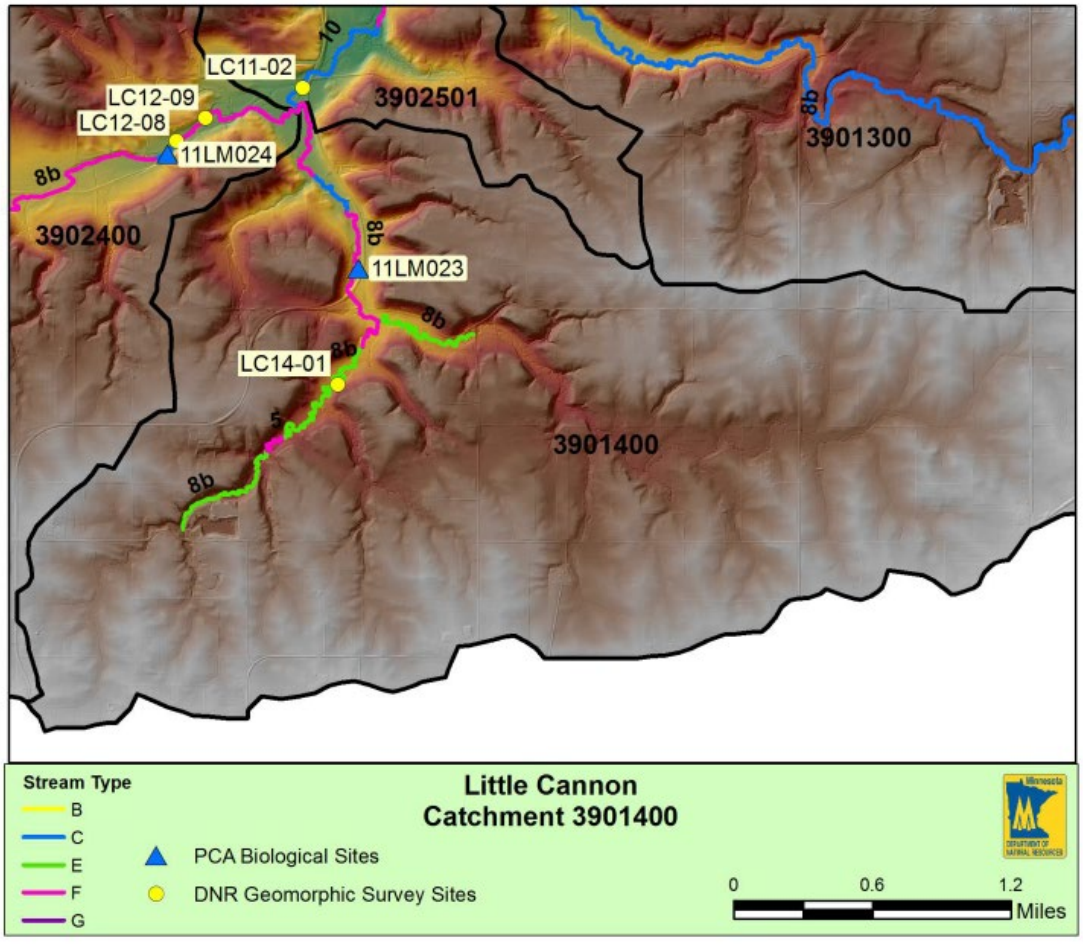


Figure 66. Little Cannon catchment 3901400 with survey locations and stream and valley types. The above figure was created by the DNR, and is included in their "Little Cannon River Watershed Geomorphology Assessment Report."

The good MSHA score, light embeddedness, lack of response from the habitat specific macroinvertebrate metrics, adequate composition of channel features (pools, riffles, and runs), and multiple habitats suggest that lack of habitat is not currently impacting the macroinvertebrate community in this AUID. However, the channel instability identified by the DNR is likely adversely affecting habitat, and therefore it's inconclusive if habitat is a stressor.

Fish Passage

One low flow fish barrier was identified in the upper end of the AUID (upstream of station 11LM023) during a connectivity survey in the summer of 2014 (Figure 67). A stream crossing inventory completed by the DNR noted this same issue, and also mentioned that County 14 Blvd. is having the biggest impact as it cuts into the floodplain. Although the fish community is not currently impaired, effort should be made to fix this crossing issue and improve stream health. At this time, fish passage does not appear to be a stressor in this AUID.

Figure 67. Stream crossing near station 11LM023 (County 14 Blvd.).

Conclusion

Nitrate is the only stressor currently identified in this tributary to the Little Cannon River. Temperature, phosphorus, DO, TSS, and habitat are inconclusive due to limited data or mixed response. It's possible that one or more of these parameters is stressing the macroinvertebrate community, but additional sampling is needed for stressor determination. Fish passage is not currently stressing the macroinvertebrate community. Reducing the nitrogen loading to this tributary should benefit the macroinvertebrate community.

Little Cannon River 10-Digit HUC Summary

Nitrate, TSS, and habitat were the dominant stressors in the Little Cannon River 10-digit HUC (Table 42). Temperature and fish passage were also stressors in the upper end of the Little Cannon River. Elevated phosphorus has been measured throughout the 10-digit HUC, but in all cases it's inconclusive if phosphorus is a stressor. In summary, nitrate was identified as a stressor in four AUIDs, TSS and habitat were identified as stressors in three AUIDs, and temperature and fish passage were identified as stressors in one AUID.

Table 42. Little Cannon River 10-digit HUC stressor summary (• = stressor, ○ = inconclusive stressor, blank = not a stressor).

Reach	AUID	Biological Impairment	Class	Stressors						
				Temperature	Nitrate	Phosphorus	DO	TSS	Habitat	Fish Passage
Little Cannon River	526	Macroinvertebrates	2B		●	○		●	●	
Little Cannon River	589	Fish and Macroinvertebrates	2A	●	●	○	○	●	●	●
Butler Creek	590	Macroinvertebrates	2B		○	○		●	○	
Trib to Little Cannon River	639	Macroinvertebrates	2B		●	○		○	●	
Trib to Little Cannon River	670	Macroinvertebrates	2B	○	●	○	○	○	○	

4.2. Prairie Creek 10-digit HUC

This section encompasses biotic impairments in the Prairie Creek 10 – digit HUC (Figure 68). There are four AUIDs with biotic impairments, all of which are for lack of a healthy macroinvertebrate assemblage. The AUIDs include Prairie Creek (from headwaters to mouth), and three unnamed tributaries to Prairie Creek. All of these reaches are warmwater streams.

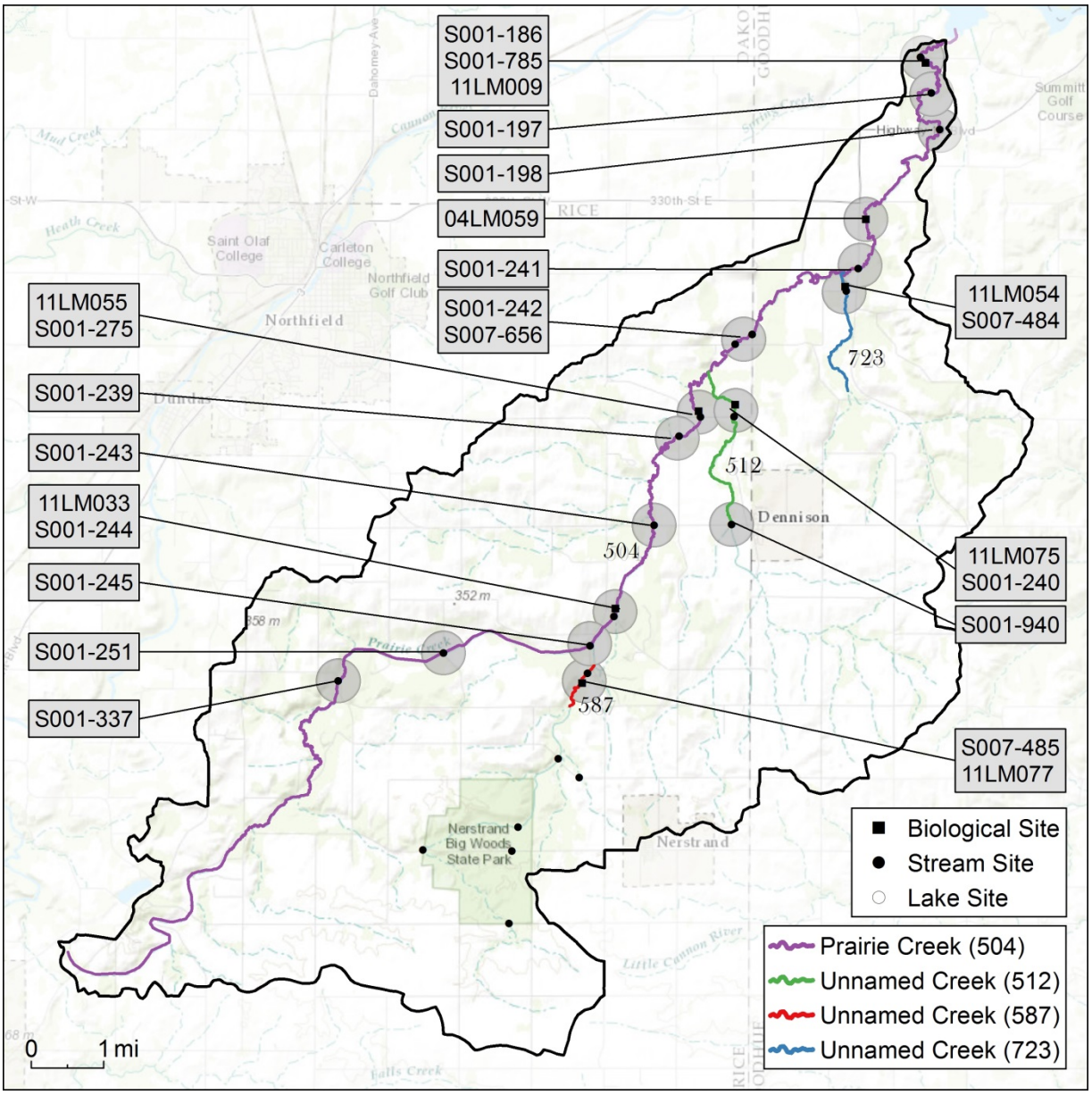


Figure 68. Map of the Prairie Creek 10 digit HUC including biota impairments with biological stations and chemistry stations used in report.

4.2.1. Prairie Creek (504)

Biological Communities

Prairie Creek (07040002-504) is a 28.8 mile long AUID in Rice and Goodhue counties, running from the headwaters to Lake Byllesby. This warmwater reach flows through the Driftless Area, North Central Hardwood Forests, and Western Corn Belt Plains ecoregions. Prairie Creek enters Lake Byllesby on the south side of the lake. The macroinvertebrate community is impaired, and turbidity and bacteria impairments also exist in Prairie Creek. The biological monitoring stations in this AUID include 11LM009, 04LM059, 11LM055, and 11LM033. These stations are located in the lower – middle portions of Prairie Creek. Station 04LM059 was sampled for fish and macroinvertebrates in 2004, and the remaining stations were sampled in 2011 for fish and macroinvertebrates.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI scores were above the Southern Streams impairment threshold of 45 (lower CL = 36, upper CL = 54) at stations 11LM009 (55 and 57), 04LM059 (49), and 11LM055 (50), and below the threshold at station 11LM033 (32). The number of total fish species per site ranged from 15 – 28, the number of pollution intolerant species ranged from zero to three, and the number of game fish species ranged from two to four. Some of the more abundant species included central stoneroller, white sucker, creek chub, common shiner, fathead minnow, bluntnose minnow, redhorse, spotfin shiner, and blacknose dace. The game fish species sampled included largemouth bass, green sunfish, bluegill, white bass, walleye, smallmouth bass, rock bass, and channel catfish.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI scores were 31 and 45 (11LM009), 63 (04LM059), 30 (11LM055), and 45 (11LM033). Station 11LM009 had one score above the Southern Streams RR threshold of 35.9 (lower CL = 23.3, upper CL = 48.5), and one score below. Station 11LM055 was below the Southern Streams RR threshold. Station 04LM059 was above the Southern Forest Streams GP threshold of 46.8 (lower CL = 33.2, upper CL = 60.4), while station 11LM033 was below the threshold. The number of macroinvertebrate families per site ranged from 12 – 21, and the number of intolerant families ranged from one – 2. Station 11LM009 had below average ClimberCh and Trichoptera MIBI metric scores during both visits, and station 11LM055 had below average ClimberCh, InsectTxPct, Odonata, Plecoptera, Predator, and Trichoptera (Figure 69). Station 04LM059 had below average Intolerant2Ch and PredatorCh MIBI metric scores, and station 11LM033 had below average DomFiveCHPct, Intolerant2Ch, POET, PredatorCh, and TaxaCountAllChir (Figure 70).

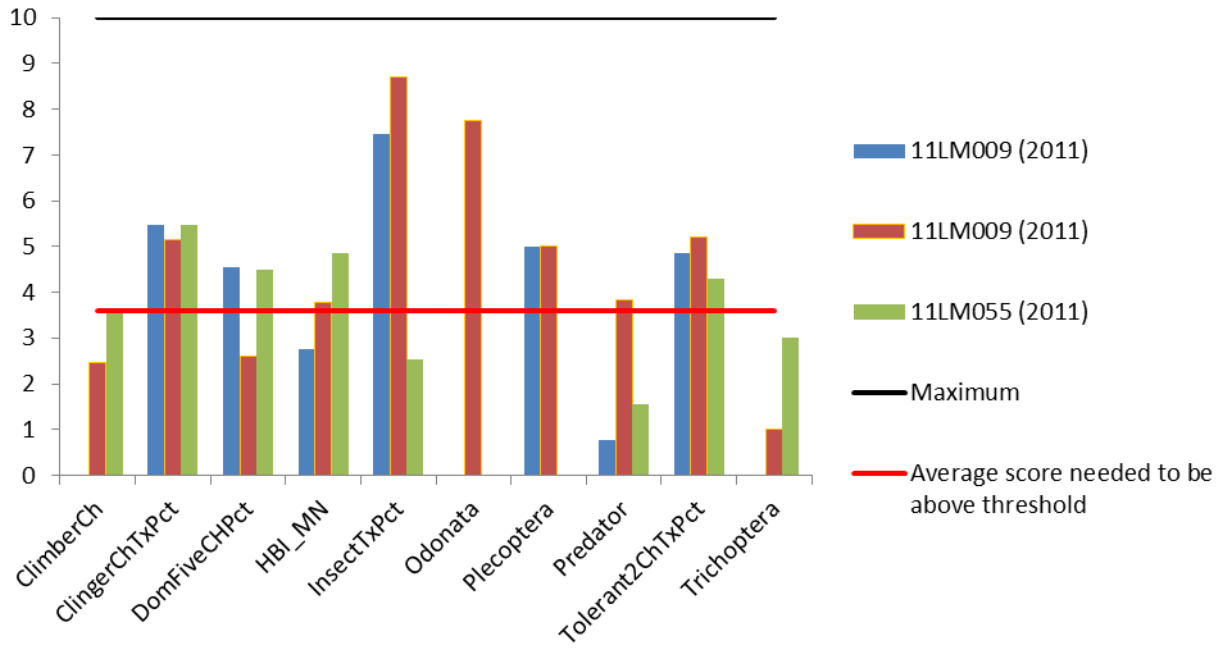


Figure 69. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for Prairie Creek (07040002-504), stations 11LM009 and 11LM055.

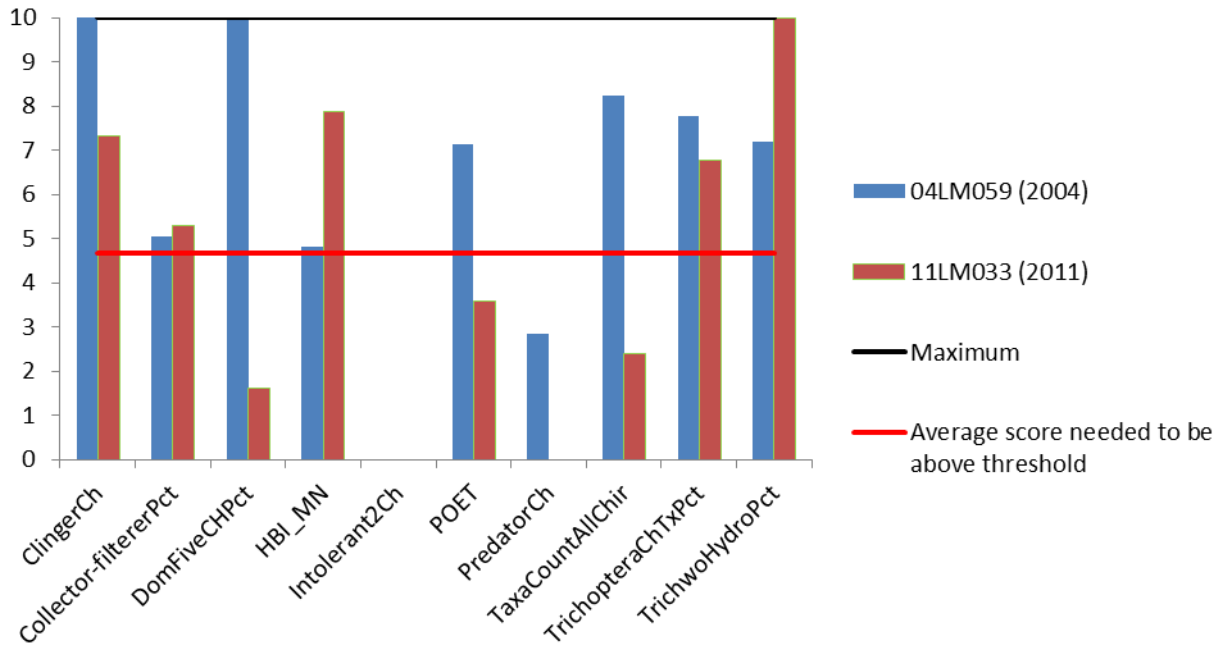


Figure 70. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for Prairie Creek (07040002-504), stations 04LM059 and 11LM033.

Data Evaluation for each Candidate Cause

Temperature

Temperature data for this AUID exists from 1989 – 2013 (minimum of -0.8° C, maximum of 29.8° C, and an average of 16.2° C). A total of 766 samples have been collected over this time period. A majority of the samples have been collected within the past decade (2004 – 2013). The 575 samples collected in the past 10 years have similar statistics (minimum of 0° C, maximum of 29.8° C, and an average of 16.5° C). These samples were taken from 13 different monitoring stations along this 29 mile stream segment. Seven of these stations have two or fewer samples, but the remaining stations have a greater number of samples (ranging from 19 – 302) and provide good coverage longitudinally along the AUID. The highest number of samples were taken near the headwaters and mouth of Prairie Creek (302 and 170 samples respectively). Good spatial and temporal representation exists in this data set, and indicates that temperature is not currently stressing the fish or macroinvertebrate communities.

Nitrate

Nitrate concentrations from 1989 – 2013 range from 0.28 mg/L – 12.0 mg/L (average of 4.9 mg/L). A total of 154 samples were collected, and two (1%) of those samples were greater than 10 mg/L. Approximately 10% (16 samples) were greater than 8 mg/L. More recent data, from 2004 – 2013, has a range of 0.28 mg/L – 9.61 mg/L (average of 4.5 mg/L) (Figure 71). Zero of these 91 samples were greater than 10 mg/L, and seven (8%) samples were greater than 8 mg/L. The 91 samples were collected from 11 different stations, with most of the samples coming from the mouth and middle portion of the AUID. Only 3 of the 11 stations had more than three samples (22, 23, and 33 samples). These stations have good seasonal coverage, and include samples from two or more years. The upper end of the AUID is lacking samples and would benefit from future sampling in this area.

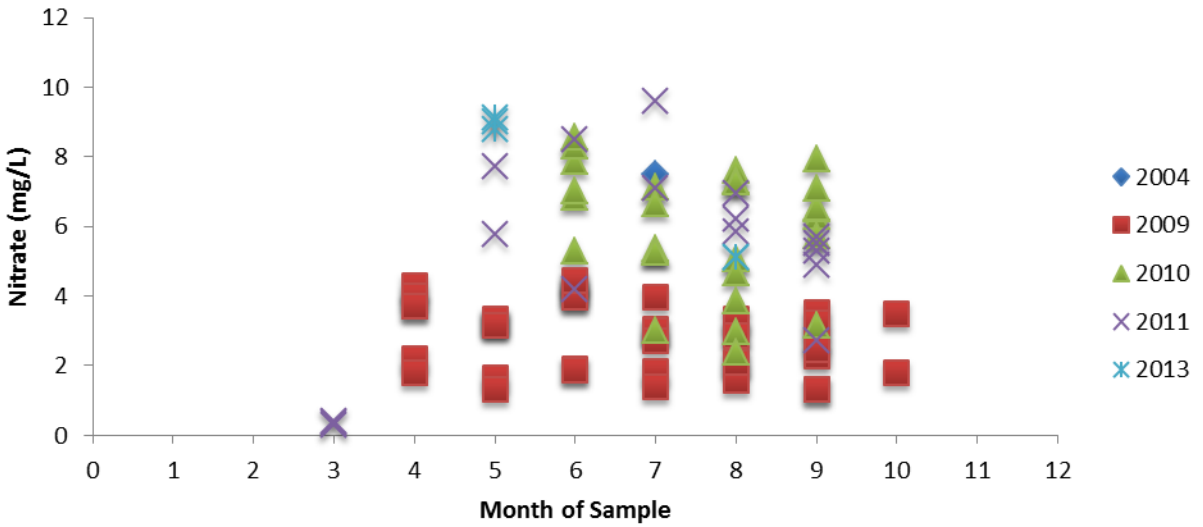


Figure 71. Nitrate concentrations in Prairie Creek by month sampled.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

Trichoptera taxa richness (TrichopteraCh) and abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) are below the statewide averages at station 11LM009 and 11LM055 (Table 43). Station 11LM009 had one taxa during one of its assessments with a tolerance value less than or equal to two using MN TVs (Intolerant2Ch), while station 11LM055 had zero. Station 04LM059 had above average Trichoptera taxa richness and abundance of non-hydropsychid Trichoptera individuals and below average taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs. Station 11LM033 had above average abundance of non-hydropsychid Trichoptera individuals and below average Trichoptera taxa richness and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs. All of the metrics discussed above are expected to decrease in response to stress.

There were nitrate intolerant taxa present at the downstream stations (04LM059 and 11LM009) near the mouth of Prairie Creek. Station 11LM009 also had one nitrate very intolerant taxa present. Station 11LM033 and 11LM055, near the middle of the AUID, had zero nitrate intolerant or very intolerant taxa present. All stations had multiple nitrate tolerant and very tolerant taxa. Nitrate tolerant taxa comprised 80% - 93% of the macroinvertebrate community, and nitrate very tolerant taxa comprised 59% - 88%. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI, and at 83.8% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. The nitrate index scores were 3.5 and 3.7 (11LM009), 3.6 (11LM055), 3.5 (04LM059),

and 3.7 (11LM033). All of these scores are above the statewide average (2.9) of stations meeting the MIBI threshold; as the score increases, so does the tolerance of the community.

Table 43. Macroinvertebrate metrics that respond to nitrate stress in Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM009 (2011)	**2**	**1.9**	1	**3.5**	**2**	1	**21**	**15**	**85.4**	**75.9**
11LM009 (2011)	**3**	**2.8**	**0**	**3.7**	**0**	**0**	**23**	**16**	**85.8**	**74.9**
11LM055 (2011)	**5**	**4.9**	**0**	**3.6**	**0**	**0**	**23**	**17**	**84.4**	**76.9**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
04LM059 (2004)	6	4.9	**0**	**3.5**	**1**	**0**	**27**	**20**	**79.6**	**58.5**
11LM033 (2011)	**3**	13.2	**0**	**3.7**	**0**	**0**	15	10	**92.5**	**88.2**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

The data set for this AUID has good sample numbers and contains elevated concentrations. A majority of the macroinvertebrate metrics are worse than the statewide average. There are nitrate intolerant and very intolerant taxa present in the lower half of the AUID, but there are also several nitrate tolerant and very tolerant taxa present at all stations (comprising a very high percentage of the community). Also, the macroinvertebrate nitrate index scores are worse than the statewide average of stations meeting the MIBI threshold. It appears that nitrates are playing a role in stressing the macroinvertebrate community in Prairie Creek.

Phosphorus

Phosphorus data for Prairie Creek contains 171 samples from 1989 – 2011 (minimum of 0.010 mg/L, maximum of 0.645 mg/L, and an average of 0.093 mg/L). There were 22 samples (13%) that exceeded the draft river eutrophication criteria for the South Region (0.150 mg/L). Condensing the data set to exclude "older" samples (prior to 2004) shows similar phosphorus values (minimum of 0.018 mg/L, maximum of 0.645 mg/L, and an average of 0.084 mg/L). There were 9 samples out of 91 (10%) that exceeded the draft standard. The greatest numbers of samples (38) were collected at station S001-785 near the mouth of Prairie Creek before it drains into Lake Byllesby. The middle portion of the AUID contains most of the remaining samples. Exceedances of the standard occurred in each segment of the AUID where samples were collected; there is no phosphorus data on the very upper end of Prairie Creek. Future sampling for phosphorus (and other parameters) should include stations in the upper end of Prairie Creek. There was at least one exceedance observed in each month from March – August. In all cases where TP and TSS were sampled simultaneously, the TP exceedances were associated with

elevated TSS concentrations (Figure 72). This implies that the exceedances took place during high flow conditions, as phosphorus is often transported attached to sediment particles. Based on the relatively small data set in Figure 72, elevated TP does not appear to be present during baseflow conditions.

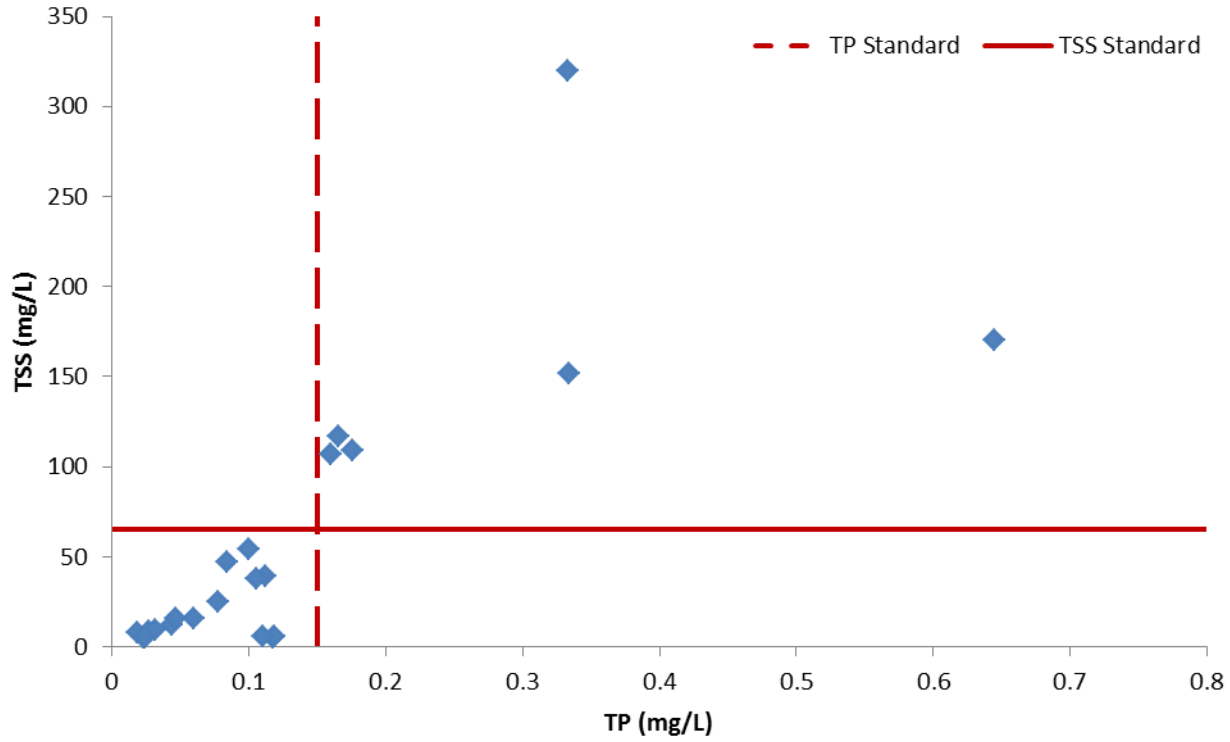


Figure 72. TSS and TP relationship in Prairie Creek (2004-2011).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. There have been 93 chl-a samples collected from 1989 – 2010 (minimum of 0.8 µg/L, maximum of 19.2 µg/L, and an average of 4.3 µg/L). There were zero exceedances of the draft standard for the South Region (35 µg/L). Only eight BOD samples have been collected (minimum of 0.5 mg/L, maximum of 2.2 mg/L, and an average of 1.3 mg/L). These samples were not collected recently (1990 – 1998), and there were zero exceedances of the draft standard for the South Region (3.0 mg/L). BOD, along with chl-a and TP, should be included in future monitoring efforts. A longitudinal DO survey was completed in July 2014, which identified two DO flux issues. There were DO flux exceedances of the draft standard for the South Region (4.5 mg/L) at station S001-245 (7.31 mg/L), and at the 180th Street road crossing (9.50 mg/L) (Figure 73). Station S001-245 is located near the middle portion of the AUID just upstream of station 11LM033, and 180th Street is located in the very upper end of Prairie Creek. Low DO, which is covered in the DO section, was also discovered during the survey in the very upper end of the AUID.

Figure 73. Prairie Creek stations where DO flux exceedances were observed (S001-245 and the 180th Street road crossing).

The macroinvertebrate metrics with strong relationships to phosphorus showed varying results across Prairie Creek (Table 44). Station 11LM009, near the mouth of Prairie Creek, had below average taxa richness of macroinvertebrates (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and below average percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct). TaxaCountAllChir, Collector-filtererCh, and EPT are expected to decrease in response to stress, while Tolerant2ChTxPct is expected to increase. Taxa richness of collector-gatherers (Collector-gathererCh) and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) were both above and below the statewide average in 2011; both metrics are expected to decrease in response to stress. Station 04LM059, on the lower end of Prairie Creek, had above average metric scores for all metrics except Collector-filtererCh and Intolerant2Ch. This was the only station sampled in 2004. Station 11LM055, near the middle of the AUID, had below average TaxaCountAllChir, Collector-gathererCh, EPT, and Intolerant2Ch. This station had above average Collector-filtererCh and Tolerant2ChTxPct. Station 11LM033, the farthest upstream station, had below average metric values for all metrics except Collector-filtererCh. Overall, the macroinvertebrate metrics display mixed results throughout Prairie Creek, and there does not appear to be any obvious longitudinal differences.

Table 44. Macroinvertebrate metrics that respond to TP stress in Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM009 (2011)	**38**	**4**	18	**7**	1	71.1
11LM009 (2011)	**36**	**5**	**13**	**8**	**0**	69.4
11LM055 (2011)	**38**	7	**14**	**7**	**0**	**73.7**
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
04LM059 (2004)	47	6	20	12	**0**	**85.1**
11LM033 (2011)	**27**	6	**10**	**6**	**0**	74.1
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

Although the fish community is not impaired in Prairie Creek, the fish metrics can still assist in stressor determination. The relative abundance of individuals that are sensitive species (SensitivePct), with the exception of one of the visits at station 11LM009, and the relative abundance of individuals that are darter species (DarterPct) were below the statewide average of stations meeting the FIBI threshold at all stations on Prairie Creek (Table 45). These metrics are expected to decrease in response to stress. The relative abundance of individuals that are tolerant species (TolPct) was well above the statewide average at all stations; tolerant individuals are expected to increase in response to stress. The abundance of individuals that are simple lithophilic spawners (SLithopPct) was above the statewide average at stations 04LM059, 11LM009, and 11LM055, and below the statewide average at stations 11LM009 and 11LM033. Simple lithophilic spawners, which require clean gravel or cobble, are expected to decrease in response to stress. The total taxa richness of fish species (TaxaCount), which is expected to decrease in response to stress, was above the statewide average at all stations besides station 11LM033. All of the fish metrics at station 11LM033 (the most upstream station) were worse than the statewide average and indicating stress. Overall, a majority of the fish metrics had values indicative of stress.

Table 45. Fish metrics that respond to TP stress in Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount
04LM059 (2004)	**2.4**	**4.0**	44.3	**71.3**	22
11LM009 (2011)	15.8	**10.7**	37.0	**68.4**	28
11LM009 (2011)	**12.8**	**8.7**	**23.1**	**75.0**	25
11LM055 (2011)	**9.8**	**8.3**	56.4	**86.3**	23
11LM033 (2011)	**2.0**	**11.0**	**28.4**	**87.1**	**15**
Southern Streams Average	*14.8*	*11.8*	*35.2*	*48.4*	*18.8*
Expected response to stress	↓	↓	↓	↑	↓

Prairie Creek has a fairly rich data set with approximately 10% exceedances over the past 10 years. The exceedances appear to be occurring during storm flow conditions. There have been exceedances in the lower and middle portions of the AUID, but there have been no phosphorus samples collected in the upper end of Prairie Creek. A substantial chl-a data set and weak BOD data set include zero exceedances. DO flux was identified at two locations (middle and upper portion of AUID). The macroinvertebrate and fish metrics provide mixed results, although the fish metrics do point to stress at the farthest upstream station (11LM033). Overall, it appears that phosphorus has the potential to be a stressor to the biology in Prairie Creek, but at this time it is inconclusive as to whether or not it is currently acting as such. Although inconclusive at this time, reducing phosphorus in Prairie Creek should be a priority in any future planning efforts. Phosphorus has the potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus loading should help (and/or protect from potential future impacts) the biology in Prairie Creek, as well as its downstream receiving water (Lake Byllesby).

Dissolved Oxygen

The DO data set for this AUID contains 105 samples from 1989 – 2013 (minimum of 6.8 mg/L, maximum of 13.8 mg/L, and an average of 9.5 mg/L). There were zero samples below the standard (5 mg/L). It should be noted that the data set is light on early morning (pre 9:00 a.m.) samples; bolstering this portion of the data set would increase confidence in the conclusion on DO's role as a stressor. Recent data from 2004 – 2013 has similar statistics as the entire data set, and consists of 49 samples (minimum of 7.34 mg/L, maximum of 12.82 mg/L, and an average of 9.1 mg/L). Samples over the past decade have been collected primarily from station S001-785 at the lower end of Prairie Creek. Samples at this station have been collected from 2010 – 2012, and occurred in April – October.

A longitudinal DO survey in July 2014 resulted in low DO values at the 180th Street East road crossing (2.8 mg/L), and the Cannon City Blvd road crossing (0.23 mg/L and 2.0 mg/L). Both of these exceedances were located in the very upper end of Prairie Creek, several miles upstream of the nearest biology station.

The total taxa richness of macroinvertebrates (TaxaCountAllChir) and the taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) were below the statewide average at all of the

stations except station 04LM059 in the lower portion of the AUID (Table 46). The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) were worse than average at station 11LM055 and 04LM059, while better than the average at station 11LM009 and 11LM033. TaxaCountAllChir and EPT are expected to decrease in response to stress, and Tolerant2ChTxPct is expected to increase. The farthest upstream station (station 11LM033) has the lowest total taxa richness and EPT taxa richness. The station just downstream (station 11LM055) has worse than average values for all three metrics.

All four stations had numerous DO intolerant and very intolerant taxa, and extremely low percentages of DO tolerant and very tolerant taxa. The number of DO intolerant taxa ranged from 8 – 13, and the DO very intolerant taxa ranged from four to eight. Conversely, the DO tolerant taxa ranged from one to three, and the DO very tolerant from zero to one. The DO index scores were 7.8 and 7.6 (11LM009), 7.8 (11LM055), 7.3 (04LM059), and 8.1 (11LM033). All of the scores were above the statewide average of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 46. Macroinvertebrate metrics that respond to low DO stress in Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM009 (2011)	**38**	71.1	**7**	7.8	11	6	1	0	1.3	0.0
11LM009 (2011)	**36**	69.4	**8**	7.6	13	7	3	0	1.5	0.0
11LM055 (2011)	**38**	**73.7**	**7**	7.8	12	8	1	1	0.3	0.3
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
04LM059 (2004)	47	**85.1**	12	7.3	13	7	2	1	1.2	0.4
11LM033 (2011)	**27**	74.1	**6**	8.1	8	4	2	1	0.9	0.3
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

This AUID has zero DO concentrations below the warmwater standard (5 mg/L) in the historical data set, however, there were low DO concentrations identified at two locations in the headwaters region during the longitudinal DO survey in the summer of 2014. These low DO values were found several miles upstream of the nearest biology site. Although some of the macroinvertebrate metrics were worse than the statewide average, there were several DO intolerant and very intolerant taxa present at all stations. Each station also had very low DO tolerant and very tolerant taxa, and the DO index scores were better than the statewide average. At this time, based on the existing chemistry and biology data, low DO does not appear to be stressing the macroinvertebrate community in Prairie Creek.

TSS/Turbidity

There have been 100 TSS samples collected from 1989 – 2013 (minimum of 2 mg/L, maximum of 320 mg/L, and an average of 42 mg/L). Sixteen of these samples (16%) exceeded 65 mg/L, the draft TSS standard for the South Region. More recent data from 2004 – 2013 contains 27 samples (minimum of 4.8 mg/L, maximum of 320 mg/L, and an average of 52 mg/L). There were six samples (22%) that exceeded the draft standard. The samples collected over the past decade were collected from nine different monitoring stations. Station S001-785, near the mouth of Prairie Creek, has the most samples (14). This station is also where the six exceedances occurred. The remaining stations have one to three samples. The current data set supports the existing turbidity impairment, but would benefit from additional samples and better spatial and temporal coverage.

There have been 842 transparency samples collected from 1999 – 2014 (minimum of 3 cm, maximum of 100 cm, and an average of 44 cm). There were 46 samples (6%) less than 10 cm, the S-tube surrogate for the South Region TSS standard. Data from 2004 – 2014 consists of 620 samples (minimum of 3 cm, maximum of 100 cm, and an average of 46 cm). There were 27 samples (4%) less than 10 cm. The exceedances occurred in March (two), April (one), May (three), June (6), July (7), August (7), and September (one), and they occurred in the lower and upper end of Prairie Creek. The data from 2004 – 2014 was collected from 14 stations, with good spatial and temporal coverage.

A majority of the macroinvertebrate metrics with strong relationships to TSS were worse than the statewide average of stations meeting the MIBI threshold (Table 47). The relative abundance of collector-filterer individuals (Collector-filtererPct) was below average at all of the stations in Prairie Creek. The relative abundance of Plecoptera individuals (PlecopteraPct) was below average at stations 11LM055, 04LM059, and 11LM033, and above average at station 11LM009. Both metrics are expected to decrease in response to stress. Overall, the metrics have values indicative of stress.

TSS intolerant and very intolerant taxa were present at station 11LM009 (during one visit) and station 11LM055. Station 11LM009 had three TSS intolerant taxa and one TSS very intolerant taxa, and station 11LM055 had one TSS intolerant taxa and one TSS very intolerant taxa. The other stations had zero TSS intolerant and very intolerant taxa. All of the stations had multiple TSS tolerant and very tolerant taxa, ranging from 5 – 13 and 3 – 7 respectively. TSS tolerant taxa comprised 13% - 50% of the macroinvertebrate community, and TSS very tolerant taxa comprised 1% - 38%. TSS tolerant and very tolerant taxa were more abundant in the lower portion of Prairie Creek, and decrease as you move upstream. The macroinvertebrate TSS index scores were 20.3 and 20.8 (11LM009), 15.7 (11LM055), 17.9 (04LM059), and 15.8 (11LM033). The scores at the two lower stations (11LM009 and 04LM059) were above the statewide average of stations meeting the MIBI threshold, while the two upper stations (11LM055 and 11LM033) were below the statewide average. As the score increases, so does the tolerance of the community.

Table 47. Macroinvertebrate metrics that respond to TSS stress in Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM055 (2011)	**13.6**	**0.0**	15.7	**1**	1	9	3	18.2	2.3
11LM009 (2011)	**5.0**	0.9	**20.3**	3	1	10	**6**	**49.7**	**37.7**
11LM009 (2011)	**7.1**	0.6	**20.8**	**0**	**0**	**13**	**7**	**41.2**	**31.0**
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
04LM059 (2004)	**19.3**	**0.0**	**17.9**	**0**	**0**	**11**	**6**	**28.6**	**17.9**
11LM033 (2011)	**20.2**	**0.0**	15.8	**0**	**0**	5	3	13.4	1.2
Southern Forest Streams Average	*24.4*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can help inform the SID process. The following stations are discussed going from downstream to upstream. Station 11LM009, near the mouth of Prairie Creek, was sampled twice in 2011 (Table 48). The relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are long-lived (LLvdPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were below the statewide average of stations meeting the FIBI threshold during both visits. The relative abundance of individuals that are sensitive species (SensitivePct) was below average during one visit and above average during the other. The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are intolerant species (IntolerantPct), and relative abundance of individuals that are riffle-dwelling species (RifflePct) were above average during both visits. All of the metrics besides HrbNWQPct and SLithFrimPct were below average at station 04LM059. Station 11LM055 had below average Centr-TolPct, IntolerantPct, LLvdPct, Percfm-TolPct, and SensitivePct. All of the metrics besides the TSS index score were worse than average at station 11LM033. Centr-TolPct, LLvdPct, and Percfm-TolPct were below the statewide average at all of the stations in Prairie Creek. Centr-TolPct includes sight feeding species which can be adversely impacted by increased turbidity; all stations had low values, ranging from 0.2% - 2.2%. The TSS index scores were better than average at all of the stations except 04LM059. Overall, there does not appear to be any obvious longitudinal differences, and a majority of the fish metrics were worse than the statewide average. Station 04LM059 in the lower portion of Prairie Creek, and station 11LM033 near the middle of Prairie Creek displayed the most signs of stress.

Table 48. Fish metrics that respond to TSS stress in Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RiffePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
04LM059 (2004)	**32.1**	**0.6**	24.8	**0.8**	**6.6**	**6.4**	**27.7**	**2.4**	29.1	**21.3**
11LM009 (2011)	59.6	**2.2**	46.5	5.8	**5.6**	**14.4**	58.4	15.8	**15.8**	15.7
11LM009 (2011)	47.4	**1.3**	37.2	6.1	**4.2**	**10.9**	45.2	**12.8**	**8.3**	18.0
11LM055 (2011)	64.1	**0.2**	53.1	**3.3**	**0.6**	**8.5**	62.3	**9.8**	42.2	14.8
11LM033 (2011)	**26.4**	**0.5**	**16.4**	**0.0**	**0.5**	**11.4**	**18.4**	**2.0**	**16.4**	16.7
Southern Streams Average	*34.1*	*4.6*	*24.3*	*3.3*	*12.9*	*19.4*	*28.3*	*14.8*	*17.5*	*18.0*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Prairie Creek, which is currently impaired for turbidity, has six (22%) TSS exceedances over the last decade; all of which occurred near the mouth. Transparency exceedances (4%) also occurred, and took place in the upper and lower end of the AUID. These elevated concentrations coupled with worse than average macroinvertebrate metrics, multiple tolerant and very tolerant taxa, worse than average macroinvertebrate TSS index scores (lower portion), and minimal sight feeding fish species suggest that TSS/turbidity is currently a stressor in Prairie Creek. It may be having a more profound impact in the lower portion; all of the TSS exceedances occurred there, and TSS tolerant and very tolerant taxa increase as you move downstream.

Lack of Habitat

MSHA scores ranged from 56.25 ("fair") – 67.45 ("good") (Table 49). All of the stations had "fair" scores except for station 11LM009. This station, which is located near the mouth of Prairie Creek, had a "good" score in September 2011; it also had a "fair" score in August 2011. The September 2011 sample had high substrate and channel morphology sub-category scores, which helped bring the overall score into the "good" category. All of the stations had fairly good sub-category scores for cover. Station 11LM055 and station 11LM009 (August 2011) received zero points in the land use subcategory; the surrounding land use was row crops during these visits.

Table 49. MSHA subcategory scores for Prairie Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
04LM059	06-Jul-04	4.3	7	16	13	16	56.3 (Fair)
11LM055	07-Sep-11	0	7.5	16.7	10	25	59.2 (Fair)
11LM033	14-Sep-11	2.5	9.5	10.3	14	20	56.3 (Fair)
11LM009	14-Sep-11	1.3	8	20.2	11	27	67.5 (Good)
11LM009	10-Aug-11	0	12	17.1	12	23	63.6 (Fair)

Multiple macroinvertebrate habitat types were sampled throughout Prairie Creek. Habitats sampled at station 04LM059 were riffles, undercut banks/overhanging vegetation, and woody debris. Station 11LM033 only had woody debris habitat available for sampling. Riffles and undercut banks/overhanging vegetation were sampled at station 11LM055. Habitat types sampled at station 11LM009 included riffles, undercut banks/overhanging vegetation, and woody debris.

The percentage of pool habitats ranged from 10% (station 04LM059) – 55% (station 11LM033). Pool substrates were gravel (two stations), sand (four stations), and silt (three stations). Riffle habitats ranged from 0% (station 04LM059) – 25% (station 11LM009). Substrate types found in the riffles included cobble (two stations), gravel (three stations), and sand (two stations). Run habitat types dominated in most cases, ranging from 40% (station 11LM033) – 90% (04LM059). Run substrates included gravel (three stations), sand (four stations), and silt (one station). Substrate embeddedness ranged from none – moderate throughout Prairie Creek, and there were less than four substrate types at all of the stations except station 11LM055. Bank erosion ranged from little (5% - 25%) – heavy (50% - 75%). Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders, rootwads, and macrophytes) were present, and cover amounts ranged from moderate (25% - 50%) – extensive (>50%). Channel sinuosity ranged from fair – excellent, channel stability ranged from low – moderate/high, and there were multiple velocity types present (slow – torrential as well as eddies).

Burrowers, climbers, clingers, legless, sprawlers, and swimmers are sensitive to habitat stress (Figure 74 and Figure 75). Station 11LM009 and station 11LM055 had below average burrowers, climbers, clingers, and legless, and above average sprawlers. Swimmers were above and below average at station 11LM009, and below average at station 11LM055. Burrowers and legless are expected to increase in response to habitat stress, while climbers and clingers are expected to decrease. Swimmers and sprawlers may increase or decrease. Station 04LM059 had above average burrowers, clingers, legless, and swimmers, and below average climbers and sprawlers. Station 11LM033 was below average in all metrics except sprawlers. Climber MIBI metric scores were below the average score needed to meet the MIBI threshold at station 11LM009 and station 11LM055. Clinger MIBI metric scores were above the average score needed to meet the MIBI threshold at all stations.

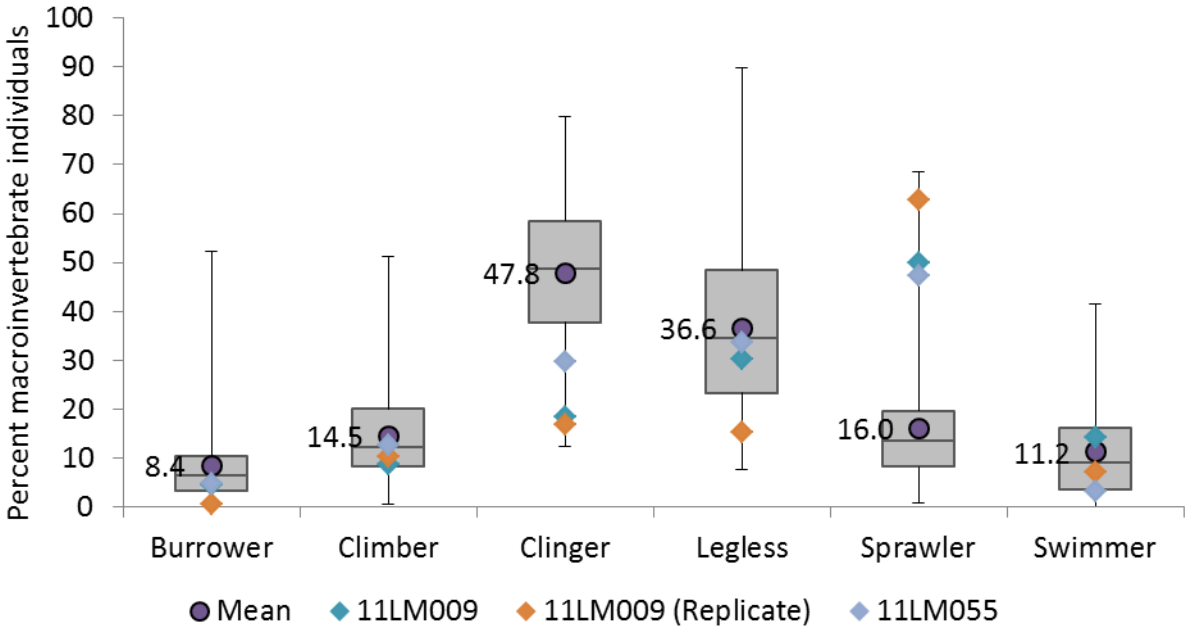


Figure 74. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Prairie Creek Watershed stations.

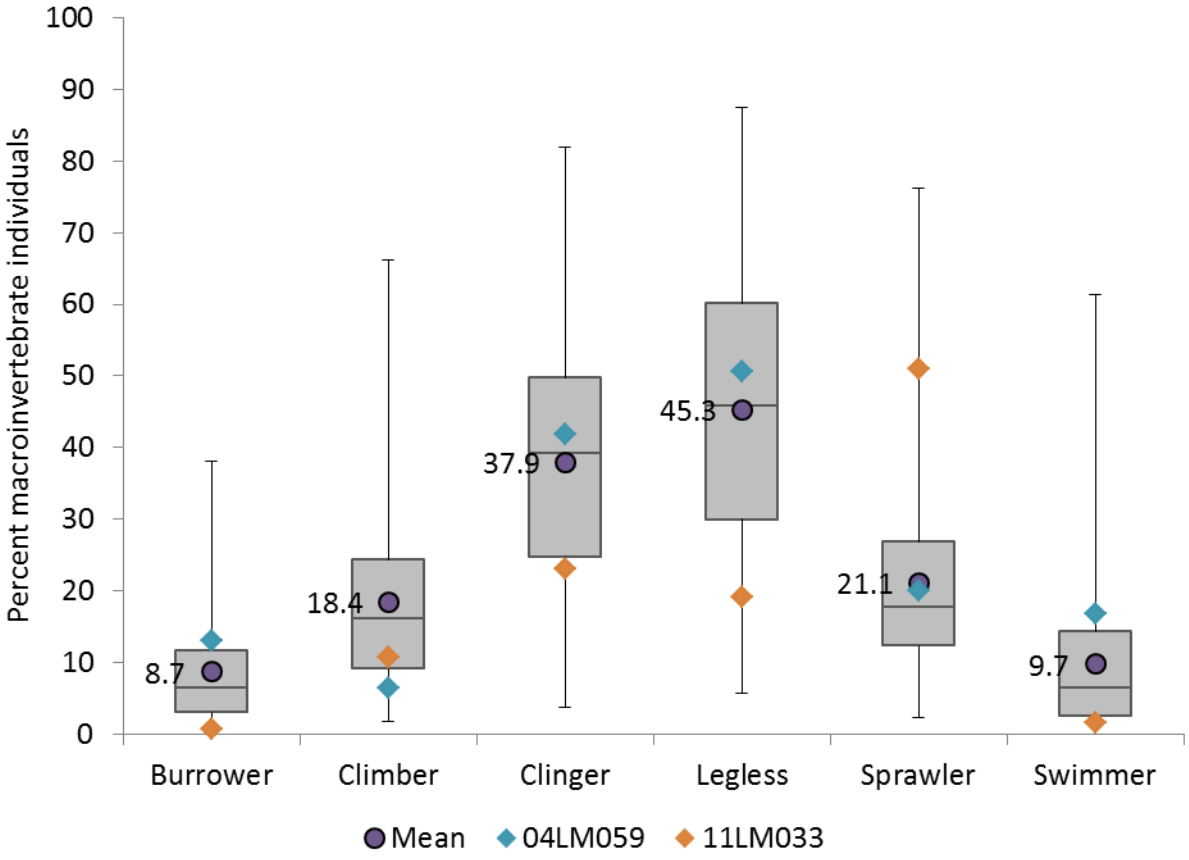


Figure 75. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Prairie Creek Watershed stations.

Prairie Creek had fair – good MSHA scores, no – moderate embeddedness, and little – heavy bank erosion. Although multiple habitat types were present, the below average climbers and clingers suggest that habitat is currently a stressor in this AUID.

Fish Passage

Culverts and bridges were examined for passage issues on July 22, 2014. Station S001-245 (Kane Avenue) seemed passable during the survey, but could potentially become a barrier during lower flows (Figure 76). In the very upper end of the AUID, there was a perched culvert at the 180th Street road crossing and a potential passage issue due to minimal flows and sediment at the Cannon City Blvd. road crossing. These two crossings are several miles upstream of the nearest biological station, and likely not impacting the IBI scores. Overall, passage seemed to be adequate, but should continue to be monitored throughout the years over various low flow conditions. Also, proper attention should be given to culvert and bridge placement and sizing and adjusted as necessary (e.g. perched culvert at 180th Street).

Figure 76. Station S001-245 (Kane Avenue) (left) and 180th Street (right) during connectivity survey.

pH

There was a pH value of 6.45 at station S001-198 (near the lower end of the AUID) in March of 2011. This is just below the minimum pH standard of 6.5. This was the only exceedance in the data set; pH monitoring should be continued in the future to ensure the standard is being attained.

Conclusion

Prairie Creek has multiple stressors at play, with the cumulative effects leading to an impaired macroinvertebrate community. Nitrate, TSS/turbidity, and habitat are stressors in Prairie Creek. The TSS impacts appear to be more significant in the lower portion. Elevated phosphorus levels have been observed, but at this time it's inconclusive whether or not phosphorus is a stressor. Reducing the nutrient and sediment loading to Prairie Creek, and improving in-stream habitat would benefit the macroinvertebrate community. Temperature, DO, and fish passage are not currently stressors.

4.2.2. Unnamed Creek (512)

Biological Communities

Unnamed Creek (07040002-512), a tributary to Prairie Creek, is a 3.0 mile long AUID in Rice County. The AUID begins in the headwaters and ends at the confluence with Prairie Creek. This warmwater reach flows through the Western Corn Belt Plains ecoregion, and has macroinvertebrate, turbidity, and bacteria impairments. Station 11LM075 is the only biological monitoring station in this AUID; it was sampled for fish and macroinvertebrates in 2011. Station 11LM075 is located near the confluence with Prairie Creek.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI score at station 11LM075 was 68, which is above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58). It is also above the upper confidence limit. There were 13 total fish species collected, including zero pollution intolerant species and zero game fish species. The three most abundant fish species were creek chub, white sucker, and blacknose dace.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI score was 17, which is below the Southern Forest Streams GP threshold of 46.8 (lower CL = 33.2, upper CL = 60.4). It is also below the lower confidence limit. There were 14 total families, one of which being intolerant. All of the MIBI metric scores except for HBI_MN were below the average score needed to meet the MIBI threshold; thus resulting in a low MIBI score (Figure 77). Some of the more abundant taxa included Gammarus (scuds), Polypedilum (non-biting midges), Baetis (mayflies), Brillia (non-biting midges), and Oligochaeta (worms).

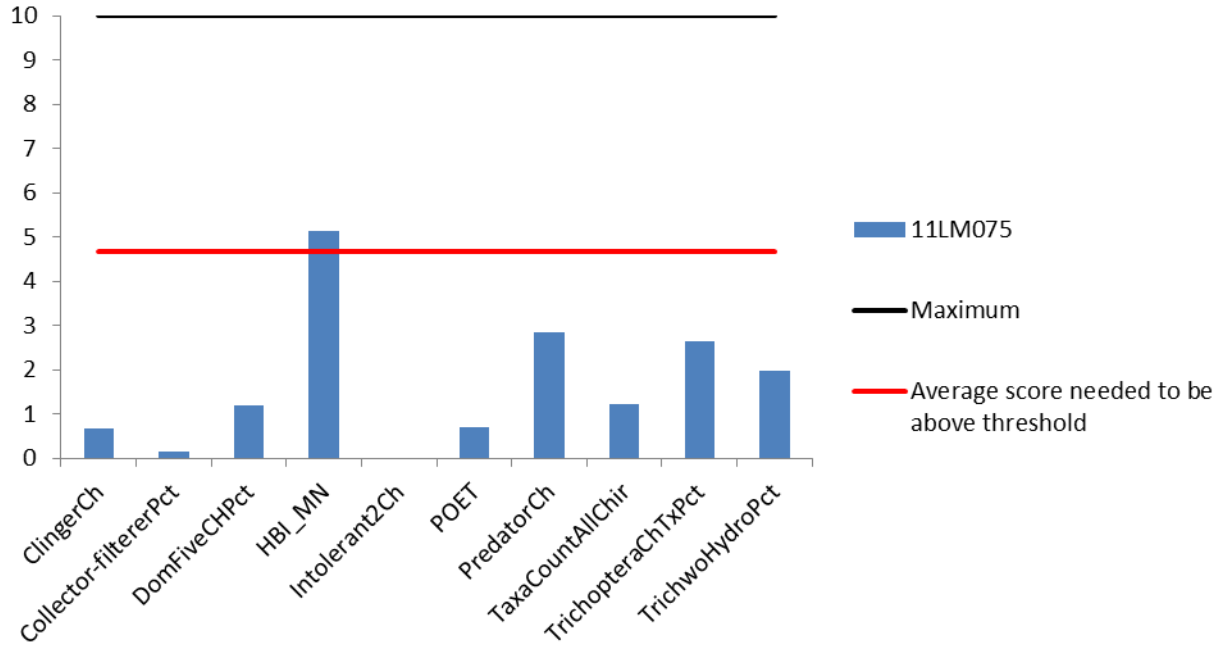


Figure 77. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for Unnamed Creek (07040002-512), station 11LM075.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 2002 – 2013 ranged from 0 °C – 24 °C (average of 13.9 °C). Of the 127 samples, zero were above 30 °C (the acute warmwater standard). These samples were collected from three stations (S001-940, 11LM075, and S001-240) throughout the AUID. A majority of the samples (106) were collected in the upper part of the AUID, and the remaining samples (21) were collected in the lower end. Seasonal coverage was good, with samples collected from March – October. The three highest sample months were June (54), July (20), and August (21). The three highest temperature values were 24 °C (July 24, 2005), 24 °C (June 26, 2005), and 23 °C (July 17, 2012).

Also, temperature was recorded as part of a longitudinal DO survey in July 2014 at station S001-240 and station S001-940. The four readings from this survey were 15.8 °C and 24.8 °C (S001-240), and 16.0 °C and 23.9 °C (S001-940). At this time, there is no continuous temperature data available for this AUID. Continuous data would provide a better understanding of the temperature regime in this AUID.

At this time, temperature is meeting water quality standards, and does not appear to be a stressor in this AUID. Future continuous monitoring would be beneficial, and strengthen this data set.

Nitrate

There have only been three3 nitrate samples collected in this AUID. These samples were collected on the lower portion of the AUID at stations 11LM075 and S001-240. Although minimal samples have been collected, elevated concentrations appear to be present. Nitrate concentrations were 11 mg/L (august 10, 2011), 7.4 mg/L (April 8, 2013), and 5.4 mg/L (August 22, 2013). Additional sampling with good spatial and temporal coverage is recommended.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide average of stations meeting the MIBI threshold (Table 50). All of these metrics are expected to decrease in response to stress.

Station 11LM075 had zero nitrate intolerant and very intolerant taxa present. This station, however, had several nitrate tolerant (15) and very tolerant (15) taxa present. Nitrate tolerant and very tolerant taxa comprised an extremely high percentage of the macroinvertebrate community at 96%. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI threshold, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the threshold. The nitrate index score was 4.0, which is above the statewide average (2.9) of stations meeting the MIBI threshold; as the score increases, so does the tolerance of the community.

Table 50. Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM075 (2011)	**1**	**0.6**	**0**	**4.0**	**0**	**0**	15	**15**	**96.0**	**96.0**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

Very few nitrate samples have been collected, but elevated nitrate concentrations were present. Most of the macroinvertebrate metrics are worse than the statewide average, and have values indicative of stress. The lack of nitrate intolerant and very intolerant taxa, the incredibly high percentage of nitrate tolerant and very tolerant taxa, and worse than average nitrate index score are also signs of stress. Additional monitoring is recommended to get a better handle on the nitrate dynamics in this AUID, but the limited existing chemistry data (with elevated concentrations) and strong biological response provide enough confidence to conclude that nitrate is a stressor in this AUID.

Phosphorus

TP concentrations from 2011 – 2013 ranged from 0.034 mg/L – 0.316 mg/L (average of 0.139 mg/L). Only three samples have been collected, but one was above the draft river eutrophication standard for the South Region (0.150 mg/L). These samples were collected from two stations (S001-240 and 11LM075) co-located in the lower portion of the AUID in April (one) and August (two). The highest concentration occurred on April 8, 2013 (0.316 mg/L).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. At this time, there have been zero chl-a and BOD samples collected; both of these parameters should be sampled in the future. There were zero DO flux exceedances identified during a longitudinal DO survey in July 2014; DO flux should also be monitored more extensively in the future.

All of the macroinvertebrate metrics with strong relationships to phosphorus were worse than the statewide average of stations meeting the MIBI threshold (Table 51). Station 11LM075 had below average total taxa richness (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of collector-gatherers (Collector-gathererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch). These metrics are expected to decrease in response to stress. The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct),

which is expected to increase in response to stress, was well above the statewide average. All of the macroinvertebrate metrics at station 11LM075 have values indicative of stress.

Table 51. Macroinvertebrate metrics that respond to TP stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM075 (2011)	**23**	**2**	**9**	**3**	**0**	**87.0**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

Although the fish community is not impaired, the fish metrics can still assist in stressor determination. The relative abundance of individuals that are sensitive species (SensitivePct), the relative abundance of individuals that are darter species (DarterPct), and the relative abundance of individuals that are tolerant species (TolPct) were worse than the statewide average of stations meeting the FIBI threshold (Table 52). TolPct was extremely high at 93%. The abundance of individuals that are simple lithophilic spawners (SLithopPct), and the total taxa richness of fish species (TaxaCount) were, however, above the statewide average.

Table 52. Fish metrics that respond to TP stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount
11LM075 (2011)	**2.0**	**5.0**	44.0	**93.0**	13
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*
Expected response to stress	↓	↓	↓	↑	↓

This AUID has very few TP samples, zero chl-a and BOD samples, and minimal DO flux information. An elevated TP concentration has been documented, and all of the macroinvertebrate metrics were worse than the statewide average. Also, a majority of the fish metrics were worse than the statewide average. At this time, it's inconclusive whether or not phosphorus is stressing the macroinvertebrate community in this AUID due to limited data. Additional monitoring (TP, chl-a, BOD, and DO flux) is necessary in order to formulate a conclusion.

Dissolved Oxygen

DO concentrations from 2011 – 2013 ranged from 6.26 mg/L – 12.74 mg/L (average of 9.2 mg/L). This data set includes 20 samples, none of which were below the warmwater standard of 5 mg/L. These samples were collected from two stations (11LM075 and S001-240) co-located near the lower end of the

AUID in June (six), July (five), and August (nine). The lowest concentration was observed on August 19, 2013 (6.26 mg/L). A longitudinal DO survey was completed in July 2014 which produced zero concentrations below the standard.

Station 11LM075 had worse than average total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 53). Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

Station 11LM075 had six DO intolerant macroinvertebrate taxa and three DO very intolerant taxa. Three DO tolerant taxa were also present, comprising a very minimal portion of the overall community (1.3%). The macroinvertebrate DO index score was 7.7, which is above the statewide average (7.0) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 53. Macroinvertebrate metrics that respond to low DO stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM075 (2011)	**23**	**87.0**	**3**	*7.7*	**6**	**3**	3	0	1.3	0.0
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

The data set for this AUID contains zero samples below the warmwater DO standard of 5 mg/L. This data set, however, is limited and does not include any continuous sonde data. Some of the macroinvertebrate metrics were worse than the statewide average, but there were multiple DO intolerant and very intolerant taxa present. Also, DO tolerant taxa comprised a very small portion of the macroinvertebrate community, and the DO index score was above the statewide average. At this time, it's inconclusive whether or not DO is stressing the macroinvertebrate community in this AUID due to limited data. It seems unlikely that DO is a stressor, but additional sampling is necessary to confirm this suspicion. Sonde deployment for an extended period (one to two weeks) during late summer would likely provide sufficient information.

TSS/Turbidity

TSS concentrations from 2011 – 2013 ranged from 24 mg/L – 330 mg/L (average of 127.7 mg/L). Only three samples have been collected, and they were collected at two different monitoring stations (S001-240 and 11LM075) in the lower portion of the AUID (just above the confluence with Prairie Creek). The sample dates and concentrations were August 10, 2011 (29 mg/L), April 8, 2013 (330 mg/L), and August

22, 2013 (24 mg/L). There was one sample that exceeded 65 mg/L, the draft TSS standard for the South Region. This AUID is currently impaired for turbidity.

Transparency values from 2002 – 2013 ranged from 2 cm – 100 cm (average of 32 cm). Of these 129 samples, 15 (12%) were below the s-tube surrogate standard for the South Region (10 cm). Samples were collected from three stations (11LM075, S001-240, and S001-940) from March – October. June (54), July (21), and August (22) were the three highest sample months. Most of the samples (108) were collected in the upper end of the AUID, and the remaining samples (21) were collected near the mouth of the tributary. The samples in the upper end were collected from 2002 – 2006, and the samples in the lower end were collected from 2011 – 2013. The exceedances occurred in April (one), May (two), June (nine), July (one), and August (two); all but one of the exceedances took place in the upper end at station S001-940.

The macroinvertebrate metrics with strong relationships to TSS were well below the statewide average of stations meeting the MIBI threshold (Table 54). The relative abundance of collector-filterer individuals (Collector-filtererPct) and relative abundance of Plecoptera individuals (PlecopteraPct) were extremely low at 0.9% and 0% respectively. Both of these metrics are expected to decrease in response to stress.

Station 11LM075 had zero TSS intolerant and very intolerant taxa present. This station, however, did have TSS tolerant (five) and very tolerant (two) taxa present. TSS tolerant and very tolerant taxa comprised 35% and 2% of the macroinvertebrate community, respectively. The macroinvertebrate TSS index score for station 11LM075 was 17.5, which is worse than the statewide average (16.2) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community.

Table 54. Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM075 (2011)	**0.9**	**0.0**	**17.5**	**0**	**0**	5	2	**35.2**	2.3
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can help inform the SID process. The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are intolerant species (IntolerantPct), relative abundance of individuals that are long-lived (LLvdPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), and

relative abundance of individuals that are sensitive species (SensitivePct) were below the statewide average of stations meeting the FIBI threshold (Table 55). The relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were above the statewide average. All of these metrics are expected to decrease in response to stress. Centr-TolPct were absent; this metric includes sight feeders which can be negatively impacted by increased turbidity and sedimentation. Station 11LM075, did however, have abundant RifflePct and SLithFrimPct, which require riffle habitat and clean gravel. Sedimentation and siltation can adversely impact these species. The TSS index score was better than the statewide average. Overall, a majority of the metrics have values indicative of stress.

Table 55. Fish metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
11LM075 (2011)	**32.0**	**0.0**	28.0	**0.0**	**1.0**	**6.0**	30.0	**2.0**	27.0	15.0
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

The data set for this AUID includes limited TSS samples but an adequate number of transparency samples; both included exceedances. In addition to the presence of exceedances, a majority of the macroinvertebrate metrics were worse than the statewide average, there were zero TSS intolerant and very intolerant taxa and multiple TSS tolerant and very tolerant taxa, the macroinvertebrate TSS index score is worse than the statewide average, and a majority of the fish metrics were below the statewide average. This AUID is currently impaired for turbidity, which is stressing the macroinvertebrate community.

Lack of Habitat

The MSHA score at station 11LM075 was 48.05 (“fair”) (Table 56). Land use, riparian, and substrate sub-category scores received less than half of the available points. Cover and channel morphology sub-category scores received more than half of the available points.

Table 56. MSHA subcategory scores for Unnamed Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
11LM075	10-Aug-11	1.3	6	10.8	11	19	48.1 (Fair)

The surrounding land use at the time of sampling was classified as row crop on the left bank, and forest, wetland, prairie, shrub, and row crop on the right bank. The riparian width was narrow (15 – 30 feet), and light (5% - 25%) shade was present. Moderate (25% - 50%) bank erosion was observed at station 11LM075.

Undercut banks/overhanging vegetation was the only macroinvertebrate habitat type sampled at station 11LM075 (Figure 78). Pool features were 30% of the station length, and included silt substrate. Minimal riffles were present (5%). Riffle substrates were gravel and sand. Run features comprised 65% of the station length, and had sand and silt substrate. Light embeddedness was observed, and less than four substrate types were present. Multiple cover types (undercut banks, overhanging vegetation, deep pools, and logs or woody debris) existed, and cover amount was considered moderate (25% - 50%). Channel sinuosity was good, channel stability was moderate, and stream velocity ranged from slow – moderate.

Figure 78. Station 11LM075 on 8/3/11.

Burrowers, climbers, legless, and sprawlers were above average, and clingers and swimmers were below average (Figure 79). Climbers and sprawlers were elevated and in the upper quartile. Clingers, which are expected to decrease in response to habitat stress, were very low in abundance and fell with-in the lower quartile. Swimmers were also in the lower quartile. The clinger MIBI metric score (0.67) was well below the average score needed (4.68) to meet the MIBI threshold. Gammarus (scuds) and Polypedilum (non-biting midges) dominated the macroinvertebrate community with 119 and 96 individuals respectively. The remaining taxa had 24 or fewer individuals, with most having three or less. Indicator values for suspended sediment and fine substrates for Gammarus and Polypedilum, developed by Carlisle et al (2007), are on the higher end indicating higher tolerance.

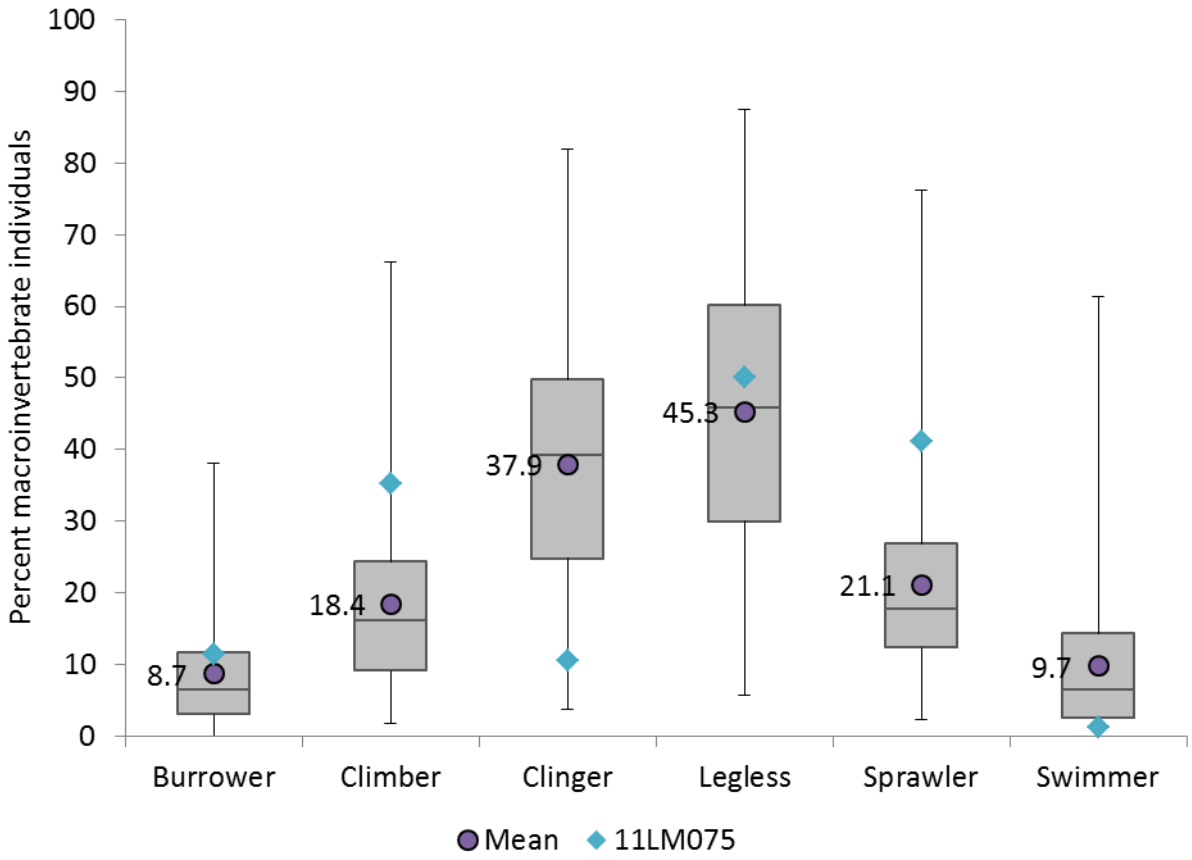


Figure 79. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Prairie Creek Watershed stations.

This AUID had a fair MSHA score that was close to the poor threshold, moderate bank erosion, and light embeddedness. Undercut banks/overhanging vegetation was the only habitat sampled, and the substrate was primarily sand and silt. Climbers appear to be doing well, which is expected given overhanging vegetation/undercut banks were the only habitat type sampled. Burrowers and sprawlers are above average, which could be caused by siltation (excess fine sediment). Also, clingers are very low, likely due to the lack of rock substrate and woody debris. The homogeneous habitat and substrate appear to be limiting the macroinvertebrates, resulting in an unbalanced community. Lack of habitat is a stressor in this AUID.

Fish Passage

There were no passage issues identified during the July 22, 2014 survey. There are only two road crossings located in this AUID, both of which were suitable for fish migration. Fish passage is not currently a stressor in this AUID.

Conclusion

This tributary to Prairie Creek has multiple stressors at play, with the cumulative effects leading to an impaired macroinvertebrate community. Nitrate, TSS/turbidity, and habitat are stressors in this AUID. It's currently inconclusive if phosphorus and DO are stressors, but temperature and fish passage do not appear to be stressing the macroinvertebrate community. Reducing nitrate and sediment loading, and improving in-stream habitat will benefit the macroinvertebrates. Also, in general, this AUID has limited chemistry data; additional sampling for most parameters is recommended and necessary (TP and DO) in some cases.

4.2.3. Unnamed Creek (587)

Biological Communities

Unnamed Creek (07040002-587), a tributary to Prairie Creek, is a 0.8 mile long AUID in Rice County. This warmwater reach flows through the Western Corn Belt Plains ecoregion, and has a macroinvertebrate impairment. Station 11LM077 is the only biological monitoring station in this AUID, and it was sampled for fish and macroinvertebrates in 2011. Station 11LM077 is located near the lower – middle portion of the AUID.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI score at station 11LM077 was 70, which is above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58). It is also above the upper confidence limit. There were eight fish species collected, including zero pollution intolerant species and zero game fish species. The fish species collected were bigmouth shiner, blacknose dace, brook stickleback, central stoneroller, creek chub, fantail darter, johnny darter, and white sucker.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI score at station 11LM077 was 31, which is below the Southern Streams RR impairment threshold of 35.9 (lower CL = 23.3, upper CL = 48.5). There were 12 total families, one of which was intolerant. Gammarus (scuds) dominated the macroinvertebrate community with 226 individuals; Baetis (mayflies), Polypedilum (non-biting midges), and Simulium (black flies) were the next most abundant with 17, 9, and 9 individuals respectively. ClimberCh, DomFiveCHPct, Predator, and Trichoptera MIBI metric scores were below the average score needed to meet the threshold, thus resulting in the low MIBI score (Figure 80). DomFiveCHPct, Predator, and Trichoptera received zero out of a possible 10 points.

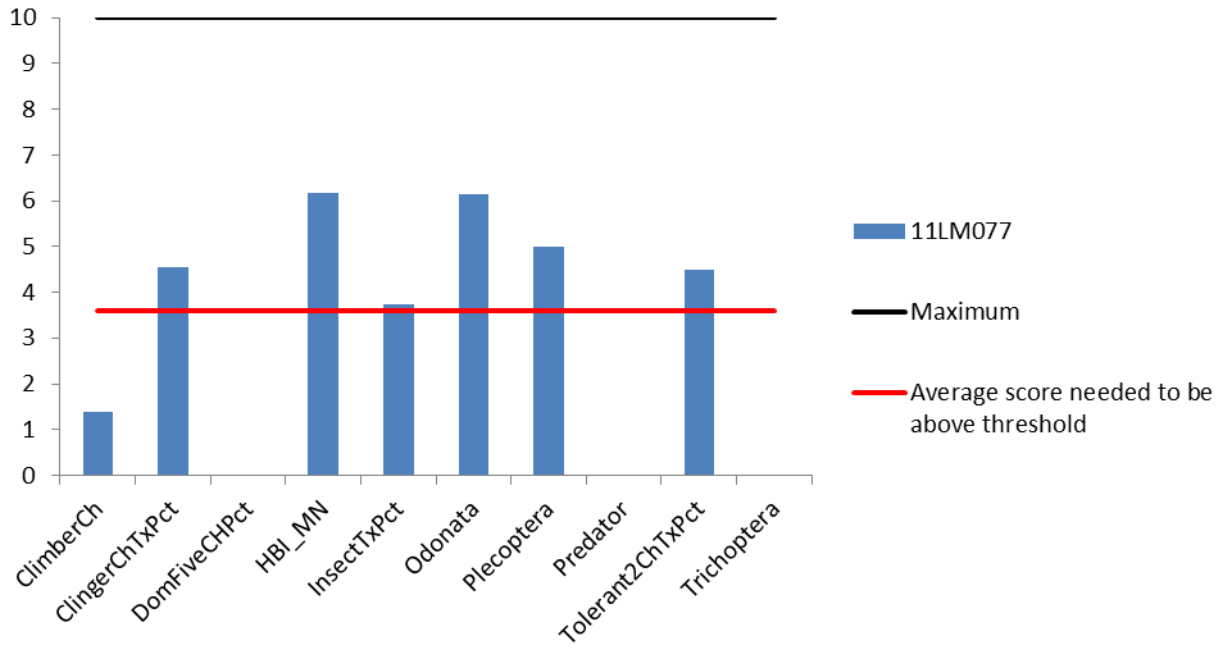


Figure 80. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for Unnamed Creek (07040002-587), station 11LM077.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 2011 – 2014 ranged from 0.7 °C – 17.7 °C (average of 10.8 °C). Only seven samples have been collected, none of which were above 30 °C (the acute warmwater standard). These samples were collected from two stations (S007-485 and 11LM077) co-located at the Jenkins Trail road crossing in April (three), June (one), and August (three). The highest temperature was observed on August 4, 2011 (17.7 °C).

Temperature was recorded as part of a longitudinal DO survey in July 2014 at station S007-485 and 11LM077. The temperature reading at station S007-485 was 18.5 °C. Temperature readings were taken above and below a beaver dam in station 11LM077; values above the beaver dam were 18.7 °C and 18.8 °C, and values below the beaver dam were 18.7 °C and 21.4 °C. Also, continuous temperature data was captured during sonde deployment from July 29, 2013 – August 12, 2013. There were zero exceedances during this timeframe (maximum temperature of 20.7 °C).

The temperature data set for this AUID is limited in terms of sample numbers, but does include continuous data over a 14 day period in the summer of 2013. There have been zero exceedances, and temperature does not appear to be a stressor in this AUID.

Nitrate

Nitrate concentrations from 2011 - 2014 ranged from 1.6 mg/L – 12 mg/L (average of 5.4 mg/L). Only seven samples have been collected, and they were collected at two stations (S007-485 and 11LM077) in the lower portion of this small AUID. Sampling occurred in April (three), June (one), and August (three). Although minimal samples have been collected, there are some elevated concentrations. The three

highest concentrations are 7.8 mg/L, 8.7 mg/L, and 12 mg/L. Additional sampling with good temporal coverage is recommended.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold. Station 11LM077 is in the Southern Streams RR macroinvertebrate class.

Trichoptera taxa richness (TrichopteraCh) and abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) were below the statewide average of stations meeting the MIBI threshold (Table 57). Taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) was above the statewide average. All of these metrics are expected to decrease in response to stress.

Station 11LM077 had one nitrate intolerant and very intolerant taxa present. This station had several nitrate tolerant (16) and very tolerant (12) taxa present. Nitrate tolerant and very tolerant taxa comprised a high percentage of the macroinvertebrate community at 92% and 90% respectively. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI, and at 83.8% nitrate tolerant individuals there is a 10% probability of meeting the MIBI. The nitrate index score was 3.8, which is above the statewide average (2.9) of stations meeting the MIBI threshold; as the score increases, so does the tolerance of the community.

Table 57. Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM077 (2011)	**1**	**0**	1	**3.8**	**1**	1	16	12	**91.8**	**89.5**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

The limited nitrate data set includes elevated concentrations, and a majority of the macroinvertebrate metrics have values indicative of stress. A nitrate intolerant and very intolerant taxon was present, but there were multiple nitrate tolerant and very tolerant taxa and they comprised an extremely high percentage of the community. Also, the nitrate index score was worse than the statewide average. Additional monitoring is recommended to get a better handle on the nitrate dynamics in this AUID, but

the limited existing chemistry data (with elevated concentrations) and strong biological response provide enough confidence to conclude that nitrate is a stressor in this AUID.

Phosphorus

TP concentrations from 2011 – 2014 ranged from 0.028 mg/L – 0.299 mg/L (average of 0.122 mg/L). Only six samples have been collected, but one was above the draft river eutrophication standard for the South Region (0.150 mg/L). These samples were collected from two stations (S007-485 and 11LM077) co-located in the lower end of the AUID in April (three) and August (three). The three highest concentrations were 0.129 mg/L (April 3, 2014), 0.139 mg/L (August 4, 2014), and 0.299 mg/L (April 8, 2013). Although not in this AUID, algal production was documented upstream (approximately two miles) at station S001-250 (Figure 81). The flow at this site was very minimal.

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. At this time, there have been zero chl-a and BOD samples collected; both of these parameters should be sampled in the future. There were zero DO flux exceedances identified during a longitudinal DO survey in July 2014. Sonde deployment from July 29, 2013 – August 12, 2013 at station 11LM077 resulted in some DO flux exceedances (there were eight daily DO flux exceedances with a maximum of 6.0 mg/L).

Figure 81. Algae growth at station S001-250 on 7/22/14.

Station 11LM077 had below average total taxa richness (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of collector-gatherers (Collector-gathererCh), and taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) (Table 58). These metrics are expected to decrease in response to stress. The taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch), which is expected to decrease in response to stress, was

above the statewide average. The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), which is expected to increase in response to stress, was below the statewide average. Four of the six metrics have values indicative of stress.

Table 58. Macroinvertebrate metrics that respond to TP stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM077 (2011)	**22**	**3**	**9**	**3**	1	72.7
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
Expected response to stress	↓	↓	↓	↓	↓	↑

Although the fish community is not impaired, the fish metrics can still assist in stressor determination. The relative abundance of individuals that are sensitive species (SensitivePct), the abundance of individuals that are simple lithophilic spawners (SLithopPct), the relative abundance of individuals that are tolerant species (TolPct), and the total taxa richness of fish species (TaxaCount) were worse than the statewide average of stations meeting the FIBI threshold (Table 59). The relative abundance of individuals that are darter species (DarterPct) was above the statewide average. Four out of the five metrics had values indicative of stress.

Table 59. Fish metrics that respond to TP stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount
11LM077 (2011)	**3.9**	18.6	**14.7**	**81.4**	**8**
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*
Expected response to stress	↓	↓	↓	↑	↓

This AUID has very few TP samples, and zero chl-a and BOD samples. With that being said, elevated TP has been documented, and there were DO flux exceedances during sonde deployment in 2013. Also, a majority of the macroinvertebrate and fish metrics were worse than the statewide average, and algal production was noted in an upstream AUID. The potential for phosphorus stress seems to exist, but due to limited data it's inconclusive whether or not phosphorus is stressing the macroinvertebrate community in this AUID. Additional monitoring (TP, chl-a, and BOD) is necessary to better understand the impacts that phosphorus may be having on the macroinvertebrate community.

Dissolved Oxygen

DO concentrations from 2011 – 2014 ranged from 5.21 mg/L – 12.44 mg/L (average of 9.3 mg/L). Only six samples have been collected, none of which were below the warmwater standard of 5 mg/L. These samples were collected from two stations (11LM077 and S007-485) co-located near the lower end of the AUID in April (two), June (one), and August (three). The lowest concentration was observed on August 22, 2013 (5.21 mg/L).

A longitudinal DO survey was completed in July 2014 which produced zero concentrations below the standard in the AUID, but a low value (4.79 mg/L) was found in an upstream AUID at station S001-250. A sonde was deployed for 14 days (July 29, 2013 – August 12, 2013), and zero low DO concentrations were identified (minimum of 6.5 mg/L).

Station 11LM077 had worse than average total macroinvertebrate taxa richness (TaxaCountAllChir) and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 60). This station had better than average percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct). Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa. Two out of these three macroinvertebrate metrics had values indicative of stress.

Station 11LM077 had 9 DO intolerant macroinvertebrate taxa and seven DO very intolerant taxa. One DO tolerant taxon was also present, comprising a very minimal portion of the overall community (0.3%). The macroinvertebrate DO index score was 8.1, which is above the statewide average (7.2) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community

Table 60. Macroinvertebrate metrics that respond to low DO stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM077 (2011)	**22**	72.7	**3**	8.1	**9**	7	1	0	0.3	0.0
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

This AUID includes zero concentrations below the warmwater DO standard of 5 mg/L. The data set contains minimal synoptic measurements, but does include continuous data over a two week period in late summer of 2013. A few of the macroinvertebrate metrics were worse than the statewide average, but several DO intolerant and very intolerant taxa were present. This AUID also had very few DO

tolerant taxa, and a DO index score above the statewide average. Based on the existing data set, low DO is not currently stressing the macroinvertebrate community.

TSS/Turbidity

TSS concentrations from 2011 – 2014 ranged from 6.4 mg/L – 180 mg/L (average of 61.6 mg/L). Only six samples have been collected, and they were collected at two different monitoring stations (S007-485 and 11LM077) in the lower – middle portion of the AUID. The samples were collected in April (three) and August (three). There were two samples that exceeded 65 mg/L, the draft TSS standard for the South Region. Both exceedances occurred at station S007-485 in April.

Transparency values from 2011 – 2014 ranged from 6 cm – 90 cm (average of 34 cm). Only eight samples have been collected, and they were collected from three stations (S007-485, 11LM077, and Kane Avenue road crossing) located in the lower end of the AUID in April (three), May (one), June (one), and August (three). One sample was below the s-tube surrogate standard for the South Region (10 cm). The three lowest values were 6 cm (April 8, 2013, 13 cm (June 2, 2014), and 13 cm (April 25, 2014). Figure 82 below shows an unstable and eroding bank at station 11LM077.

Figure 82. Unstable and eroding bank at station 11LM077 (August 2011).

The macroinvertebrate metrics with strong relationships to TSS were below the statewide average of stations meeting the MIBI threshold (Table 61). The relative abundance of collector-filterer individuals (Collector-filtererPct) and relative abundance of Plecoptera individuals (PlecopteraPct) were low at 6.5% and 0.3% respectively. Both of these metrics are expected to decrease in response to stress. Gammarus (scuds) dominated the macroinvertebrate community with 226 individuals; the remaining taxa had 17 or fewer individuals with most having five or fewer. Indicator values for suspended sediment and fine

substrates for Gammarus, developed by Carlisle et al (2007), are 10 and six respectively. The scoring system is based on a scale from one – 10, with 10 being the most tolerant.
Station 11LM077 had one TSS intolerant taxa and zero TSS very intolerant taxa present. This station also had TSS tolerant (three) and very tolerant (one) taxa present. TSS tolerant and very tolerant taxa comprised a very low percentage of the macroinvertebrate community at 4% and 1% respectively. The macroinvertebrate TSS index score for station 11LM077 was 15.0, which is better than the statewide average (17.1) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community.

Table 61. Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM077 (2011)	**6.5**	**0.3**	15.0	**1**	**0**	3	1	3.9	0.7
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can help inform the SID process. The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are intolerant species (IntolerantPct), relative abundance of individuals that are long-lived (LLvdPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), relative abundance of individuals that are sensitive species (SensitivePct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were below the statewide average of stations meeting the FIBI threshold (Table 62). The relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct) and TSS index score were better than the statewide average. All of these metrics besides the TSS index score are expected to decrease in response to stress. Centr-TolPct, HrbNWQPct, RifflePct, and SLithFrimPct were well below the statewide average, and can be negatively impacted by increased turbidity, sedimentation, and siltation. Overall, a majority of the fish metrics have values indicative of stress.

Table 62. Fish metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RiffePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
11LM077 (2011)	**26.4**	**0.0**	**7.8**	**0.0**	**0.0**	18.6	**11.6**	**3.9**	**3.9**	14.9
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Very limited data exists for this particular AUID; only six TSS samples and eight transparency samples have been collected. This small data set does include two TSS exceedances and one transparency exceedance. Some of the macroinvertebrate metrics were worse than the statewide average, and a majority of the fish metrics (although not impaired) were below the statewide average. Station 11LM077 did have a TSS intolerant taxon and the macroinvertebrate TSS index score was better than the statewide average, but also had TSS tolerant and very tolerant taxa. There are signs of TSS/turbidity stress (which seem likely to be contributing to the habitat degradation), but at this time it's inconclusive whether or not it's stressing the macroinvertebrate community. Additional sampling is needed for stressor determination.

Lack of Habitat

The MSHA score at station 11LM077 was 60.8 ("fair") (Table 63). All of the sub-category scores (land use, riparian, substrate, cover, and channel morphology) received 50% or more of the available points.

Table 63. MSHA subcategory scores for Unnamed Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
11LM077	04-Aug-11	2.5	8.5	16.8	12	21	60.8 (Fair)

The surrounding land use at the time of sampling was classified as forest, wetland, prairie, shrub, and row crop. The riparian width was moderate (30 – 150 feet) – wide (150 – 300 feet), and heavy (>75%) shade was documented. Also, severe (75 – 100%) bank erosion was observed.

Macroinvertebrate habitat types sampled at station 11LM077 were riffles and woody debris (Figure 83). Pool habitats represented 25% of the station length. Pool substrates were sand and clay. Riffle features comprised 10%, and contained cobble and gravel substrates. Run features dominated at 65%, and had

sand substrate. Moderate embeddedness was observed, and more than four substrate types were present. Available cover types included undercut banks, overhanging vegetation, deep pools, logs or woody debris, and rootwads; cover amount was moderate (25 – 50%). Station 11LM077 had excellent sinuosity, good depth variability, fair channel development, low channel stability, a range of velocity types (slow – fast including eddies), and the pool width was greater than the riffle width.

Figure 83. Woody debris, bank erosion, and substrate at station 11LM077 (8/11/11).

Burrowers, climbers, clingers, legless, and swimmers were below the average of Southern Streams RR stations meeting the MIBI threshold (Figure 84). Sprawlers, which can increase or decrease with habitat stress, were extremely high. Their abundance was greater than the maximum abundance observed in Southern Streams RR stations meeting the MIBI threshold. Legless, expected to increase with habitat stress, were very low in abundance. They were just above the minimum value observed in Southern Streams RR stations meeting the MIBI threshold. Clingers, however, did show signs typical of habitat induced stress. Clinger abundance was very low, near the bottom of the lower quartile. Gammarus (scuds) dominated the macroinvertebrate community with 226 individuals; the remaining taxa had 17 or fewer individuals with most having five or fewer. Indicator values for suspended sediment and fine substrates for Gammarus, developed by Carlisle et al (2007), are 10 and six respectively. The scoring system is based on a scale from 1 – 10, with 10 being the most tolerant.

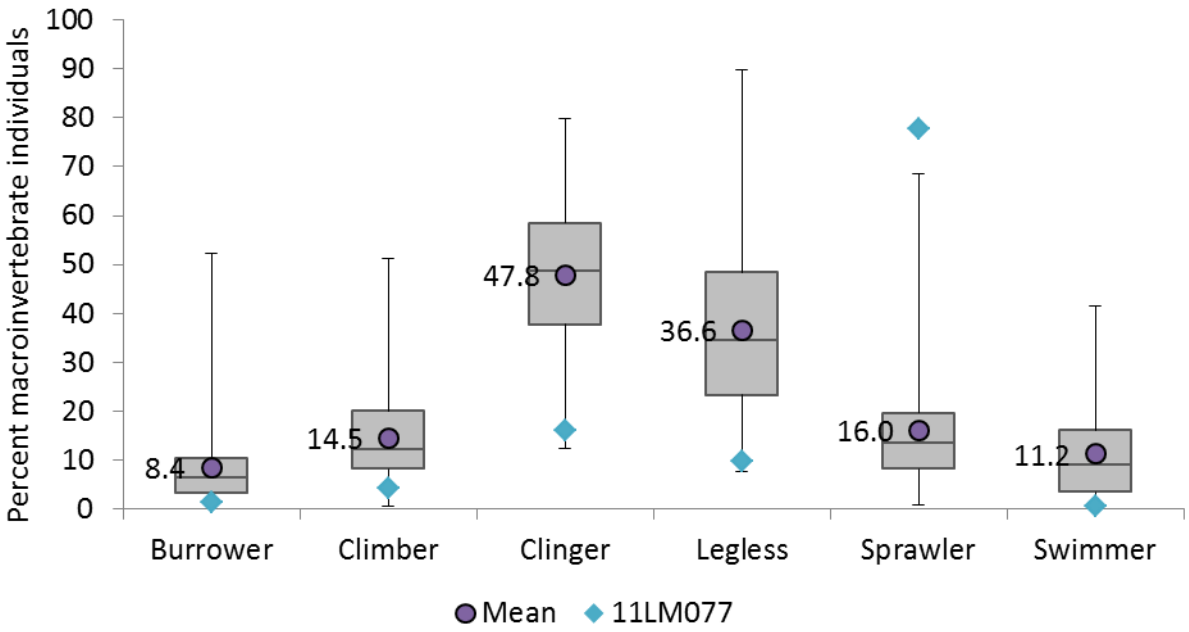


Figure 84. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Prairie Creek Watershed stations.

Also, worth noting, is that a beaver dam was present at station 11LM077 in the summer of 2014 (this is also discussed in the Connectivity section). This dam was causing very low flow conditions downstream and impacting habitat quality. The extent and frequency of beaver activity in this reach is unknown.

Although the MSHA score was fair, this AUID was dominated by sand substrate and moderate embeddedness was observed, there was severe bank erosion, and minimal climbers and clingers were sampled. With the rock and woody debris sampled in this reach, one would expect more climbers and clingers. Also, the extremely elevated sprawlers are indicative of excess fine sediments. Lack of habitat is stressing the macroinvertebrate community.

Fish Passage

During the survey in the late summer of 2014, a beaver dam was present near station 11LM077, causing very low flow conditions downstream (Figure 85). It is not known whether or not beavers are common in this AUID, but at the time of this survey, the beaver dam appeared to be prohibiting fish migration upstream and was creating low flow conditions downstream. Farther up the watershed, in a different AUID, a passage issue was identified at station S001-250. There was minimal flow at the time of the survey, but the flow that was present was flowing underneath the bridge. The extent of the effect on the macroinvertebrate community in AUID - 587 is unclear, but regardless, the elevation of this bridge appears to be too high.

Assuming that beaver dams are not typically an issue, and given the location in the watershed of the passage barrier at station S001-250 and the fact that fish are not impaired, indicate that fish passage is not a likely stressor. The passage/barrier issues identified, however, may be contributing to channel instability and habitat loss.

Figure 85. Beaver dam at station 11LM077 (left) and passage barrier in upstream AUID at station S001-250 (right).

Conclusion

Nitrate and habitat are currently stressing the macroinvertebrate community in this AUID. It's inconclusive at this time if phosphorus and/or TSS/turbidity are stressors, but temperature, DO, and fish passage do not appear to be stressors. Reducing nitrate loading and improving in-stream habitat will benefit the macroinvertebrate community. Also, in general, this AUID has limited chemistry data; additional sampling for most parameters is recommended and necessary (TP and TSS) in some cases.

4.2.4. Tributary to Prairie Creek (723)

Biological Communities

Tributary to Prairie Creek (07040002-723) is a small, warmwater AUID in Goodhue County. This tributary drains into the lower portion Prairie Creek. This AUID currently has a macroinvertebrate impairment. Station 11LM054 is the only biological monitoring station, which is located near the mouth of the tributary. This station was sampled for fish and macroinvertebrates in 2011.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI score at station 11LM054 was 57, which is above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58). There were 14 total fish species collected, including one pollution intolerant species and zero game fish species. The MPCA biologists noted that the fish community was diverse and well balanced. The three most abundant fish species were central stoneroller, creek chub, and blacknose dace.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI score at station 11LM054 was 23, which is below the Southern Forest Streams GP impairment threshold of 46.8 (lower CL = 33.2, upper CL = 60.4). It is also below the lower confidence limit. There were 14 total families, one of which was intolerant. Some of the more abundant taxa included Gammarus (scuds), Polypedilum (non-biting midges), Baetis (mayflies), Physa (snails), and Oligochaeta (worms). All of the MIBI metric scores except for HBI_MN were below the average metric score needed to meet the impairment threshold, which resulted in a low MIBI score (Figure 86).

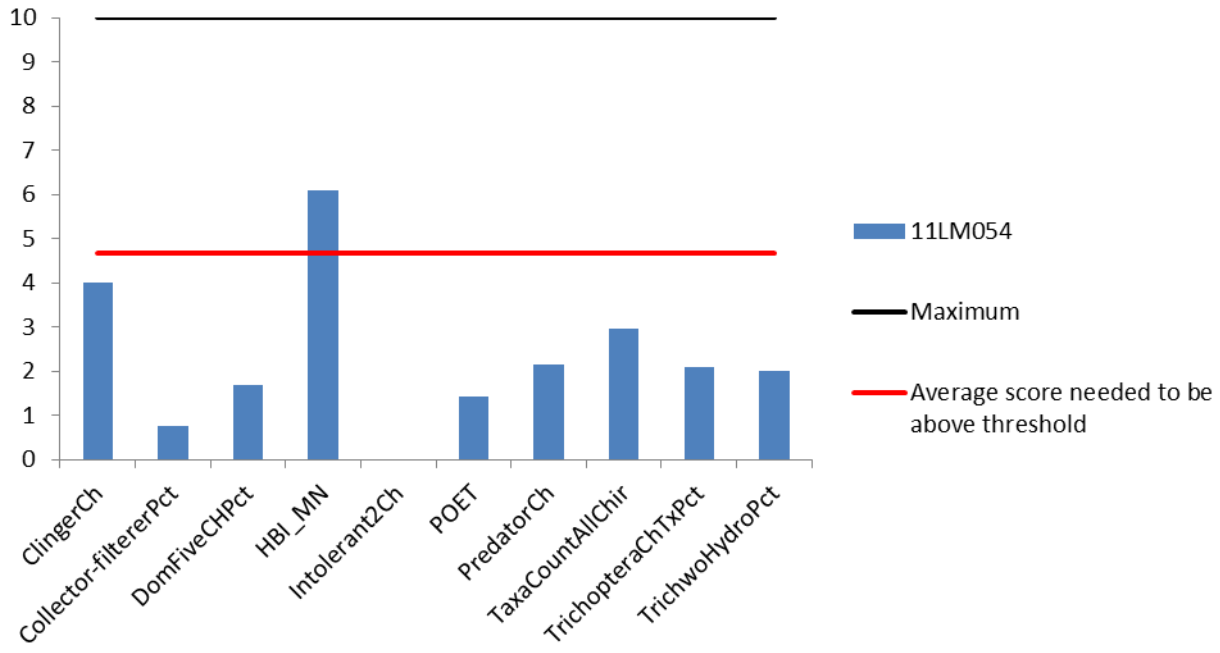


Figure 86. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for a tributary to Prairie Creek (07040002-723), station 11LM054.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 2011 – 2014 ranged from 1.4 °C – 19.0 °C (average of 10.7 °C). Only seven samples have been collected, none of which were above 30 °C (the acute warmwater standard). These samples were collected from two stations (S007-484 and 11LM054) co-located at the 342nd Street road crossing in April (three), June (one), and August (three). The highest temperature was observed on June 2, 2014 (19.0 °C).

Temperature was recorded as part of a longitudinal DO survey in July 2014 at station S007-484. The two temperature readings were 15.3 °C and 21.4 °C. At this time, there is no continuous temperature data available for this AUID. Continuous data would provide a better understanding of the temperature regime in this AUID.

It's inconclusive at this time if temperature is stressing the macroinvertebrate community due to limited data. There have been zero exceedances to this point, but additional monitoring (preferably continuous) is necessary to eliminate temperature as a potential stressor.

Nitrate

Nitrate concentrations from 2011 – 2014 ranged from 1.9 mg/L – 8.4 mg/L (average of 3.9 mg/L). Only seven samples have been collected, and they were collected at two stations (S007-484 and 11LM054) located just above the confluence with Prairie Creek. Sampling occurred in April (three), June (one), and August (three). There are zero samples above 10 mg/L, and only one sample above 8 mg/L. Additional sampling with good temporal coverage is recommended.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide average of stations meeting the MIBI threshold (Table 64). All of these metrics are expected to decrease in response to stress.

Station 11LM054 had two nitrate intolerant and zero nitrate very intolerant taxa present. This station had several nitrate tolerant (20) and very tolerant (13) taxa present. Nitrate tolerant and very tolerant taxa comprised a high percentage of the macroinvertebrate community at 93% and 87% respectively. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. The nitrate index score was 3.8, which is above the statewide average (2.9) of stations meeting the MIBI threshold; as the score increases, so does the tolerance of the community.

Table 64. Macroinvertebrate metrics that respond to nitrate stress in the tributary to Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM054 (2011)	**1**	**0.6**	**0**	**3.8**	**2**	**0**	**20**	**13**	**93.4**	**87.4**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

Little is known about the nitrate concentrations in this AUID, as only seven samples have been collected. The three highest concentrations were 3.6 mg/L, 4.1 mg/L, and 8.4 mg/L. The macroinvertebrate metrics do show signs of stress, as all are worse than the statewide average. Two nitrate intolerant taxa were present, but there were multiple nitrate tolerant and very tolerant taxa present (comprising an extremely high percentage of the community). Also, the nitrate index score was worse than the statewide average of stations meeting the MIBI threshold. Additional monitoring is recommended to get a better handle on the nitrate dynamics in this AUID. Although the limited existing chemistry data does not include extremely high concentrations, there are strong biological signals suggesting that nitrate is a stressor in this AUID.

Phosphorus

TP concentrations from 2011 – 2014 ranged from 0.027 mg/L – 0.185 mg/L (average of 0.074 mg/L). Only six samples have been collected, but one was above the draft river eutrophication standard for the South Region (0.150 mg/L). These samples were collected from two stations (S007-484 and 11LM054)

co-located near the mouth of the tributary in April (three) and August (three). The three highest concentrations were 0.051 mg/L (August 18, 2011), 0.108 mg/L (April 3, 2014), and 0.185 mg/L (April 8, 2013).

Although elevated TP has been documented, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. At this time, there have been zero chl-a and BOD samples collected; both of these parameters should be sampled in the future. There were zero DO flux exceedances identified during a longitudinal DO survey in July 2014; DO flux should also be monitored more extensively in the future.

All of the macroinvertebrate metrics with strong relationships to phosphorus were worse than the statewide average of stations meeting the MIBI threshold (Table 65). Station 11LM054 had below average total taxa richness (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of collector-gatherers (Collector-gathererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch). These metrics are expected to decrease in response to stress. The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), which is expected to increase in response to stress, was above the statewide average. All of the macroinvertebrate metrics at station 11LM054 have values indicative of stress.

Table 65. Macroinvertebrate metrics that respond to TP stress in the tributary to Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM054 (2011)	**29**	**3**	**10**	**2**	**0**	**75.9**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

Although the fish community is not impaired, the fish metrics can still assist in stressor determination. The relative abundance of individuals that are sensitive species (SensitivePct), the relative abundance of individuals that are tolerant species (TolPct), and the total taxa richness of fish species (TaxaCount) were above the statewide average of stations meeting the FIBI threshold (Table 66). SensitivePct and TaxaCount are expected to decrease in response to stress, while TolPct is expected to increase. The relative abundance of individuals that are darter species (DarterPct), and the abundance of individuals that are simple lithophilic spawners (SLithopPct) were below the statewide average. These metrics are expected to decrease in response to stress. Three out of the five metrics had values indicative of stress.

Table 66. Fish metrics that respond to TP stress in the tributary to Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount
11LM054 (2011)	11.4	**6.2**	**29.3**	**85.9**	14
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*
Expected response to stress	↓	↓	↓	↑	↓

This AUID has very few TP samples, zero chl-a and BOD samples, and minimal DO flux information. An elevated TP concentration has been documented, and all of the macroinvertebrate metrics were worse than the statewide average. Also, a majority of the fish metrics (although not impaired) were worse than the statewide average. At this time, it's inconclusive whether or not phosphorus is stressing the macroinvertebrate community in this AUID due to limited data. Additional monitoring (TP, chl-a, BOD, and DO flux) is necessary in order to formulate a conclusion.

Dissolved Oxygen

DO concentrations from 2011 – 2014 ranged from 5.34 mg/L – 10.78 mg/L (average of 8.3 mg/L). Only six samples have been collected, none of which were below the warmwater standard of 5 mg/L. These samples were collected from two stations (11LM054 and S007-484) co-located at the 342nd Street road crossing in April (two), June (one), and August (three). The lowest concentration was observed on August 26, 2014 (5.34 mg/L).

A longitudinal DO survey was completed in July 2014 which produced zero concentrations below the standard. Unfortunately, there was no sonde deployed in this AUID, and therefore no continuous data.

Station 11LM054 had worse than average total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 67). Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

Station 11LM054 had five DO intolerant macroinvertebrate taxa and three DO very intolerant taxa. DO tolerant and very tolerant taxa were also present (three and one respectively), but they comprised a very minimal portion of the overall community (1.3% and 0.3% respectively). The macroinvertebrate DO index score was 7.7, which is above the statewide average (7.0) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 67. Macroinvertebrate metrics that respond to low DO stress in the tributary to Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM054 (2011)	**29**	**75.9**	**2**	7.7	**5**	**3**	3	1	1.3	0.3
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

Although there are zero exceedances of the standard, multiple DO intolerant and very intolerant taxa, minimal DO tolerant taxa, and a DO index score above the statewide average it's inconclusive at this time whether or not DO is stressing the macroinvertebrate community due to limited data. It seems unlikely that DO is a stressor, but additional sampling is required to confirm this inkling; sonde deployment over an extended period of time during the late summer months would likely satisfy this gap.

TSS/Turbidity

TSS concentrations from 2011 – 2014 ranged from 8 mg/L – 72 mg/L (average of 28.8 mg/L). Only six samples have been collected, and they were collected at two monitoring stations (S007-484 and 11LM054) co-located just above the tributaries confluence with Prairie Creek. The samples were collected in April (three) and August (three). There was one sample that exceeded 65 mg/L, the draft TSS standard for the South Region. The exceedance occurred on August 22, 2013 (72 mg/L) at station S007-484.

Transparency values from 2011 – 2014 ranged from 23 cm – 86 cm (average of 53 cm). Only seven samples have been collected, and they were collected at station S007-484 and station 11LM054 in April (three), June (one), and August (three). There were zero samples below the s-tube surrogate standard for the South Region (10 cm). The three lowest values were 23 cm (April 8, 2013), 33 cm (August 22, 2013), and 37 cm (August 26, 2014).

The macroinvertebrate metrics with strong relationships to TSS were below the statewide average of stations meeting the MIBI threshold (Table 68). The relative abundance of collector-filterer individuals (Collector-filtererPct) and relative abundance of Plecoptera individuals (PlecopteraPct) were very low at 3.2% and 0%, respectively. Both of these metrics are expected to decrease in response to stress.

Station 11LM054 had zero TSS intolerant and very intolerant taxa present. This station, however, did have TSS tolerant (three) taxa present. There were zero TSS very tolerant taxa. TSS tolerant taxa comprised 25% of the macroinvertebrate community. The macroinvertebrate TSS index score for station

11LM054 was 16.5, which is worse than the statewide average (16.2) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community.

Table 68. Macroinvertebrate metrics that respond to TSS stress in the tributary to Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM054 (2011)	**3.2**	**0.0**	**16.5**	**0**	**0**	3	0	25.2	0.0
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can help inform the SID process. The relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are long-lived (LLvdPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were below the statewide average of stations meeting the FIBI threshold (Table 69). The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are intolerant species (IntolerantPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), and relative abundance of individuals that are sensitive species (SensitivePct) were above the statewide average. All of these metrics are expected to decrease in response to stress. Centr-TolPct, which includes sight feeding species that can be adversely impacted by increased turbidity, were absent at station 11LM054. However, BenFdFrimPct, HrbNWQPct, and RifflePct, all of which can be negatively impacted by sedimentation, were well above the statewide average. The TSS index score, which increases with stress, was better than the statewide average. Overall, a majority of the fish metrics were better than the statewide average.

Table 69. Fish metrics that respond to TSS stress in the tributary to Prairie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
11LM054 (2011)	52.4	**0.0**	39.5	6.7	**0.2**	**6.2**	50.9	11.4	**9.2**	15.0
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Very limited data exists for this AUID; only six TSS samples and seven transparency samples have been collected. This small data set does include one TSS exceedance, but zero transparency exceedances. A majority of the macroinvertebrate metrics were worse than the statewide average, but a majority of the fish metrics were better than the statewide average. Station 11LM054 had zero TSS intolerant and very intolerant taxa, but had three (25%) TSS tolerant taxa. Also, the macroinvertebrate TSS index score was worse than the statewide average. It is possible that TSS/turbidity is stressing the macroinvertebrate community in this AUID, but at this time it's inconclusive; additional sampling is needed to confidently conclude whether or not it's a stressor.

Lack of Habitat

The MSHA score at station 11LM054 was 67.25 ("good") (Table 70). All of the sub-category scores received greater than 50% of the available points except land use, which received 25%. Channel morphology received the highest percentage (78%) of available points.

Table 70. MSHA subcategory scores for the tributary to Prairie Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
11LM054	18-Aug-11	1.3	9	16	13	28	67.3 (Good)

The surrounding land use at the time of sampling was classified as row crop on the left bank, and forest, wetland, prairie, shrub, and row crop on the right bank. The riparian width on the left bank was narrow (15 – 30 feet), while extensive (>300 feet) on the right bank. Shade was determined light (5 – 25%) on the left bank, and substantial (50 – 75%) on the right bank. Bank erosion was moderate (25 – 50%).

The macroinvertebrate habitats sampled at station 11LM054 (Figure 87) were undercut banks/overhanging vegetation and woody debris. Pool habitats represented 20% of the station. Pool substrates were sand. Riffle features comprised 10%, and included cobble and gravel substrates. Run features dominated at 70%, and consisted of gravel and sand substrates. Moderate embeddedness was observed, and less than four substrate types were present. Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders, and rootwads) were available, and cover amount was moderate (25 – 50%). This AUID had excellent sinuosity, good depth variability, good channel development, moderate – high channel stability, multiple velocity types (slow – fast including eddies), and pool width was less than riffle width.

Figure 87. Station 11LM054 (8/18/11).

Burrowers, clingers, legless, and swimmers were below average, while climbers and sprawlers were above average (Figure 88). Burrowers, climbers, and legless are present in numbers you wouldn't expect in a stream where habitat is a stressor. The lower abundance of clingers, however, is a result one might see as a product of habitat stress. The clinger MIBI metric score was below the average metric score needed to meet the MIBI threshold. The three most abundant taxa were Gammarus (scuds) (110), Polypedilum (non-biting midges) (75), and Baetis (mayflies) (51).

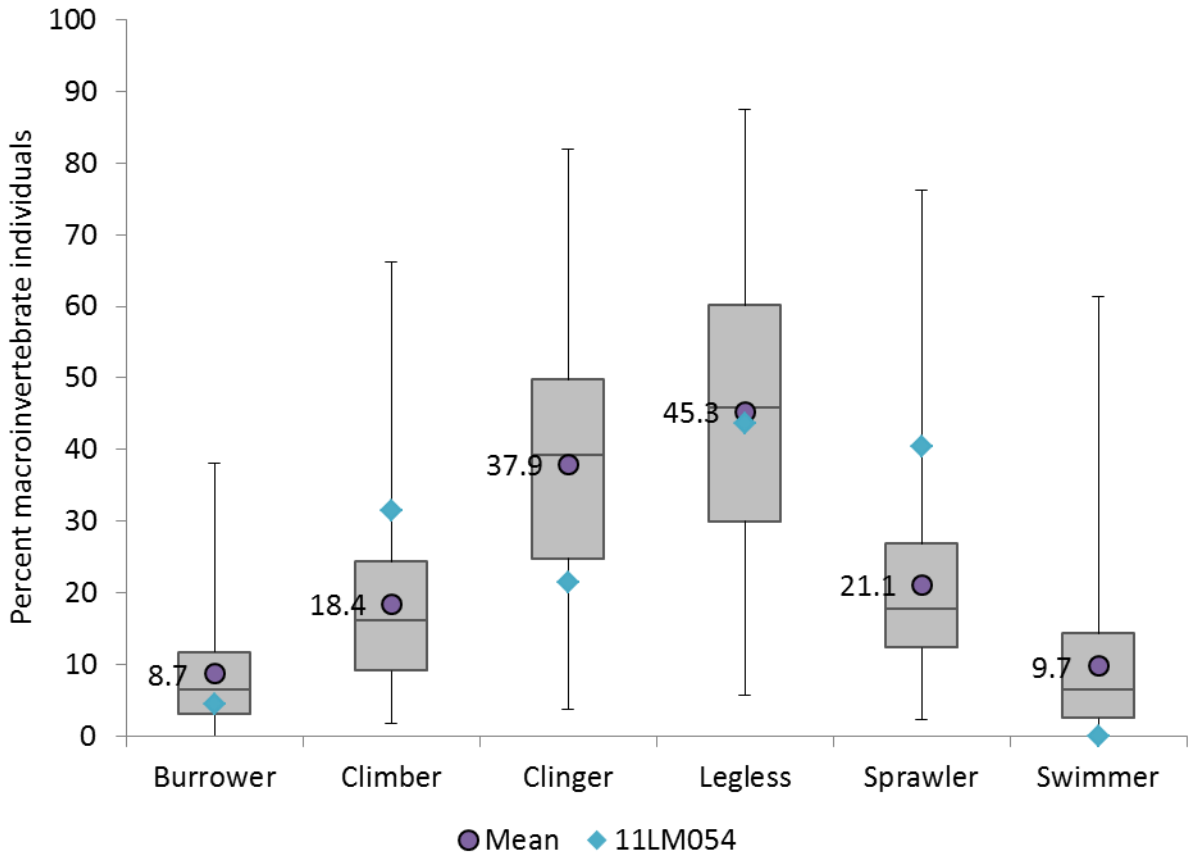


Figure 88. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Prairie Creek Watershed stations.

This AUID had a good MSHA score, moderate bank erosion, and moderate substrate embeddedness. The habitat related macroinvertebrate metrics were within an expected range for the most part, but clingers were below average and in the lower quartile. Also, the clinger MIBI metric score was below the average metric score needed to meet the MIBI threshold. This could be due to a lack of rock substrate. Sprawlers were elevated and in the upper quartile, which may be a sign of excess fine sediment as sprawlers live on the surface of fine sediments (in addition to floating macrophytes). Habitat is a stressor in this AUID.

Fish Passage

The survey during late summer of 2014 identified zero passage issues in this AUID. A culvert upstream of station 11LM054 at the 357th Street road crossing, however, has the potential to be a passage barrier at lower flows (Figure 89). At this time, fish passage does not appear to be stressing the macroinvertebrate community in this AUID.

Figure 89. Road culvert at the 357th Street crossing (upstream of AUID and station 11LM054).

Conclusion

At this time, nitrate and habitat are stressors in this AUID, with their impacts leading to an impaired macroinvertebrate community. It's inconclusive if temperature, phosphorus, DO, and/or TSS/turbidity are stressors due to limited data. Fish passage is not currently a stressor in this AUID. Reducing the nitrate loading to this AUID, and improving in-stream habitat will benefit the macroinvertebrate community. Also, in general, this AUID has limited chemistry data; additional sampling for all parameters is recommended and necessary (temperature, TP, DO, and TSS) in some cases.

Prairie Creek 10-Digit HUC Summary

Nitrate, TSS, and habitat are the identified stressors in the Prairie Creek 10-digit HUC (Table 71). Elevated phosphorus has been measured throughout the 10-digit HUC, but in all cases it's inconclusive if phosphorus is a stressor. Nitrate and habitat are stressors in all four AUIDs, and TSS was a stressor in two AUIDs.

Table 71. Prairie Creek 10-digit HUC stressor summary (• = stressor, ○ = inconclusive stressor, blank = not a stressor).

Reach	AUID	Biological Impairment	Class	Stressors						
				Temperature	Nitrate	Phosphorus	DO	TSS	Habitat	Fish Passage
Prairie Creek	504	Macroinvertebrates	2C		●	○		●	●	
Unnamed Creek	512	Macroinvertebrates	2B		●	○	○	●	●	
Unnamed Creek	587	Macroinvertebrates	2B		●	○		○	●	
Trib to Prairie Creek	723	Macroinvertebrates	2B	○	●	○	○	○	●	

4.3. Lower Cannon

The tributary to Trout Brook (07040002-580) and Trout Brook (07040002-573) are impaired reaches upstream of the confluence with each other and upstream of Trout Brook (07040002-567). All three of these reaches are coldwater streams, designated class 2A. The two upper reaches are impaired for aquatic life use, for lack of a coldwater macroinvertebrate assemblage. The lower reach of Trout Brook is impaired for aquatic life for turbidity and drinking water use for nitrate (Figure 90). This watershed had some of the highest nitrate levels in Minnesota trout streams. Studies to understand the nitrate dynamics have been undertaken by E. Calvin Alexander, Joel T. Groten, and Dakota County SWCD. The highest levels of nitrate were found in the west branch of Trout Brook. In June 2012, a large flood affected the watershed and damaged the bridge on the tributary to Trout Brook, along with moving large amounts of rock and debris.

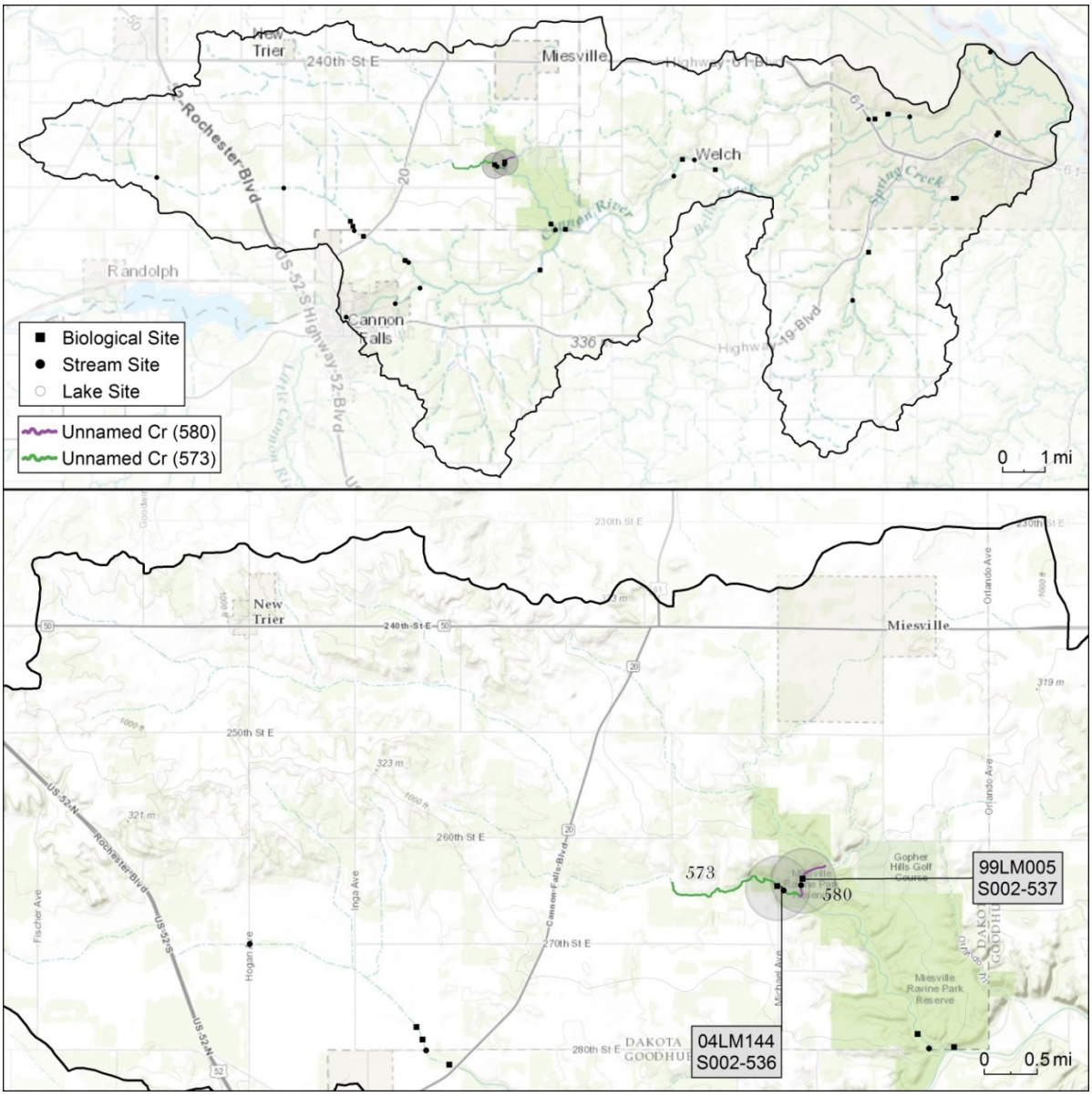


Figure 90. Map of Lower Cannon River 10 digit HUC including impaired reaches with biological stations and chemistry stations used in report

4.3.1 Biological Overview

Visits at stations 04LM144 and 99LM005 resulted in MIBI scores below the threshold (43), whereas the downstream station 99LM001 had a score 17 points greater than the threshold. Station 04LM144, in the upper reach of Trout Brook, had southern coldwater class macroinvertebrate IBI (MIBI) scores of 37.4 and 23.2 in 2004, and 30.1 in 2011. Station 99LM001, in the lower reach of Trout Brook, had an MIBI score of 60.16 in 2011. In the tributary to Trout Brook, station 99LM005 had a MIBI of 33.31 in 2011. Despite the differences in MIBI scores, some of the metrics that combine to make the IBI show similar trends between these four visits (Figure 91). The metrics that are similarly high are the CBI score based on coldwater tolerance values derived from Minnesota taxa and temperature data (CBI) and relative abundance (%) of macroinvertebrate individuals in subsample with tolerance values equal to or greater than eight, using Minnesota tolerance values (VeryTolerant2Pct). All four visits in the watershed resulted

in a reduced metric score for relative abundance (%) of collector-filterer individuals in subsample (Collector-filtererPct). Stations 04LM144 and 99LM005 also had low metric scores for ChiroDip, Intolerant2Ch, and TrichopteraChTxPct. Station 04LM144 dominant taxon was *Baetis*, a tolerant mayfly, followed by *Gammarus* (scud or sideswimmer) and *Physa* (snail) in 2011. In 2004, the dominant macroinvertebrate taxon was *Micropsectra* (a tolerant midge), followed by *Gammarus* (scud or sideswimmer) and *Simulium* (black flies).

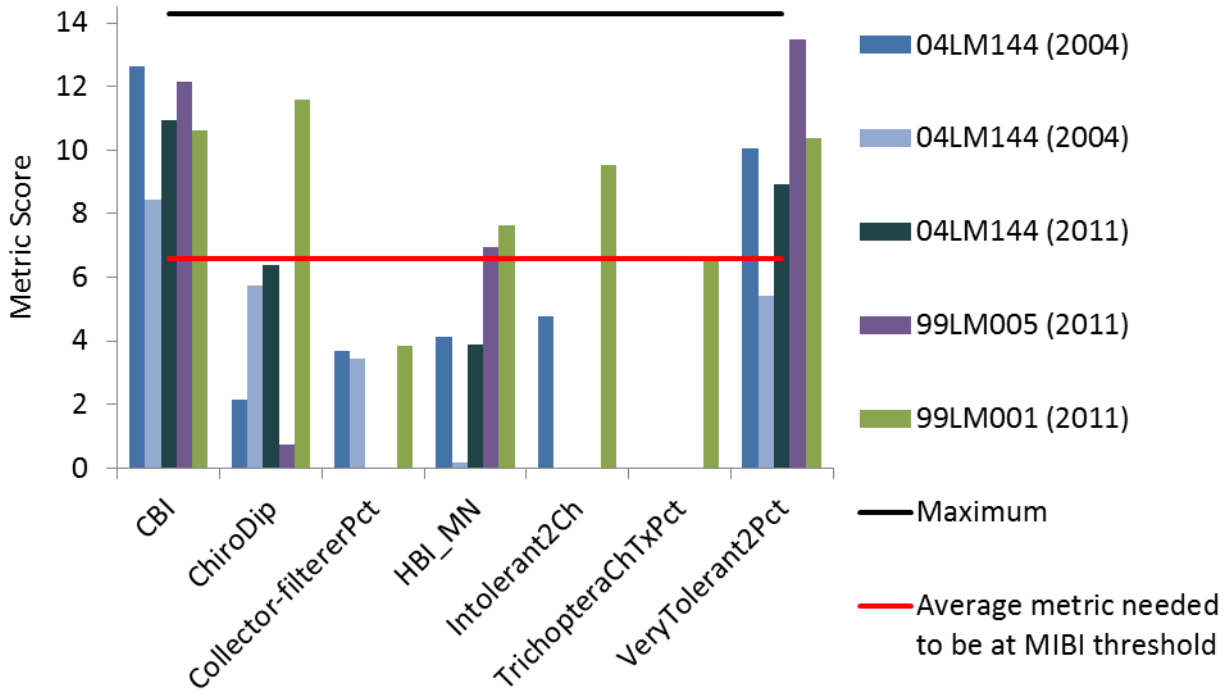


Figure 91. Macroinvertebrate metrics of the Southern Coldwater IBI for Trout Brook (04LM144 and 99LM001) and the Tributary to Trout Brook (99LM005).

The fish at station 04LM144 scored 97, 98, and 98 on Southern Coldwater fish IBI (FIBI) during the three visits in 2004 and 2011. The community was comprised of brook trout, and on August 18, 2004, brook stickleback were also sampled. Station 99LM005 had a fish IBI score of 93 in 1999 and 94 in 2011. The fish community was comprised of 70 brook trout and six brook stickleback on June 27, 1999. Similarly, on June 15, 2011, the community was comprised of 124 brook trout and one brook stickleback. At station 99LM001, at the downstream station in Trout Brook, the fish IBI in 1999 was 82, and in 2011 scores were 82 and 84. In 1999, station 99LM001 had dominant presence of brook trout and then brown trout, but also had American brook lamprey, brook stickleback, green sunfish, and creek chub. In 2011, the dominant fish was brown trout followed by brook trout. Other fish surveyed in 2011 included green sunfish, white sucker, creek chub, yellow perch, and longnose dace. This station is only approximately 0.4 miles from the Cannon River and may be why additional taxa are found at this station.

In 1977, the DNR sampled one brown trout, a likely migrant from the Cannon River. It was felt that further trout management was warranted based on stream temperatures. That survey also notes “Nine beaver dams were present between bridges one and two; three were small (1’ head) and new, six were large (4-6’ head) and old. Much of this stream length at present is impounded.” Stocking records

indicate 501 Brook Trout fingerlings were stocked in 1977, another 7,380 in 1978, and 18,029 Brook Trout fry were stocked in 1983. No stocking has occurred since. A 1983 survey indicated Brook Trout were successfully reproducing, but that "beaver impoundments were adversely affecting a large portion of the stream."

DNR annually monitors the fish population near the upper bridge (mile 2.8) on Trout Brook. Not much sampling has occurred in the lower reaches due to accessibility. The 2014 DNR report on Trout Brook includes some data on long-term trout populations at mile 2.8. The number of adult Brook Trout in this station has been highly variable between the visit dates.

4.3.2. Trout Brook (573)

The next sections will be by potential stressors in Trout Brook. Data summaries for each parameter, biological response and conclusion of the potential stressor(s) will be discussed.

Temperature

At the time of macroinvertebrate sampling on August 4, 2011, the temperature was 11.4°C. In 2004 and 2011, a temperature logger was deployed. The maximum of the daily average temperature for the summer was 10.7°C in 2004 and 12.9°C in 2011. The CBI scored fairly high for this station and there was a presence of brook trout. Temperature is not currently a stressor to the biotic communities at this time.

Nitrate

Nitrate has been sampled 29 times in this AUID of Trout Brook, at collocated stations S002-536 and 04LM144, spanning the years of 2004, 2006, 2010 to 2011, and 2013 to 2014 (Figure 92). The highest level of nitrate was 21 mg/L (April 8, 2014). Only two samples were 10 mg/L or lower. The rest of the data averaged 18.2 mg/L. The lowest concentration of nitrate was sampled after a rain event August 13, 2010.

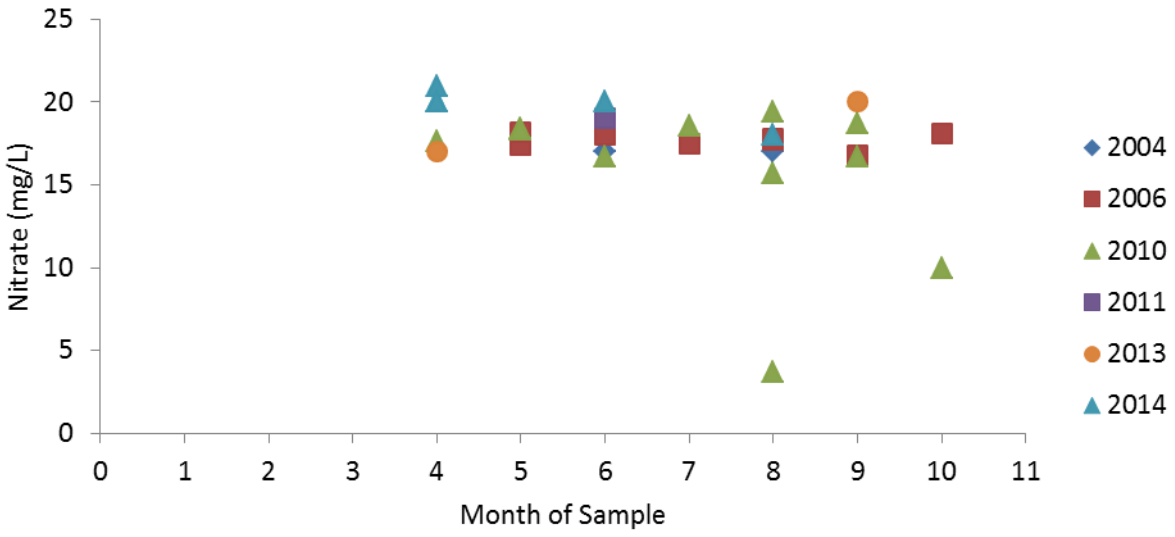


Figure 92. Nitrate concentrations in Trout Brook by month sampled, 2004, 2006, 2010-2011, and 2013-2014

A quantile regression analysis of Southern Coldwater macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below

the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate metrics that correspond with nitrate stress show a consistent response as expected. Station 04LM144 had two intolerant taxa in each survey in 2004 and one intolerant taxa in 2011. Trout Brook, station 04LM144, had no Trichoptera taxa in two of the visits and one Trichoptera taxon (*Limnephilus*) comprising 4.3% of the total taxa in the other visit (TrichopteraChTxPct; September 7, 2004; Table 72). The low or absent Trichoptera taxa resulted in metric scores of zero, lower than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold.

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 value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased nitrate. At station 04LM144, in Trout Brook, the metric scores were between 0.1 to 2.9 (in 2004 and 2011, out of 14.3), below the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At station 04LM144 the HBI_MN value was 7.07 and 7.52 in 2004 and 7.10 in 2011, both greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 04LM144 had 13 to 14 nitrate tolerant taxa (78.9 to 92.9% individuals); and 10 to 11 nitrate very tolerant taxa. At 16.6 nitrate tolerant taxa, there is a 50% probability of meeting the Southern Coldwater MIBI, and at 20.18 nitrate tolerant taxa there is a 25% probability of meeting the Southern Coldwater MIBI. There was one nitrate intolerant taxa (*Ephemerella*) present in the August 17, 2004 macroinvertebrate survey.

The elevated nitrate concentrations in Trout Brook are contributing stress on the macroinvertebrate community.

Table 72. Macroinvertebrate metrics that respond to nitrate stress in Trout Brook compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
04LM144 (2004)	**0**	**0**	**1**	**3.87**	**1**	13	**84.8**
04LM144 (2004)	**1**	**0.3**	**0**	**3.76**	**0**	14	**78.9**
04LM144 (2011)	**0**	**0**	**0**	**3.80**	**0**	14	**92.8**
Southern Coldwater Average	*4.6*	*11.6*	*1.2*	*3.23*	*1.10*	*14.77*	*66.22*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

In Trout Brook, at station S002-536, there were 28 samples of TP collected during 2004, 2006, 2010, 2011, 2013, and 2014. The maximum TP was 1.09 mg/L (August 13, 2010). Only three samples were greater than the draft river nutrient criteria for the central region (0.1 mg/L), two in 2010 and one in 2013. TSS was collected concurrently with the TP and the potential relationship was evaluated (Figure 93) and found that there was elevated TP with elevated TSS concentrations indicating that the TP is likely bound to the sediment. The 2013 TP data may be skewed low due to inaccurate lab methodologies.

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to be considered impaired. BOD and chlorophyll-a were not collected in this reach of Trout Brook. At station S005-536, DO was measured by an YSI sonde from August 7 – 21, 2013. DO was not lower than the 7 mg/L coldwater standard and there was low DO flux recorded. More information on the DO dynamics in Trout Brook can be found in the DO section. There is a fair amount of periphyton within this reach of Trout Brook (Figure 99), but it has not been quantified. Additional monitoring should be conducted to understand the prevalence of periphyton and if it is in excess.

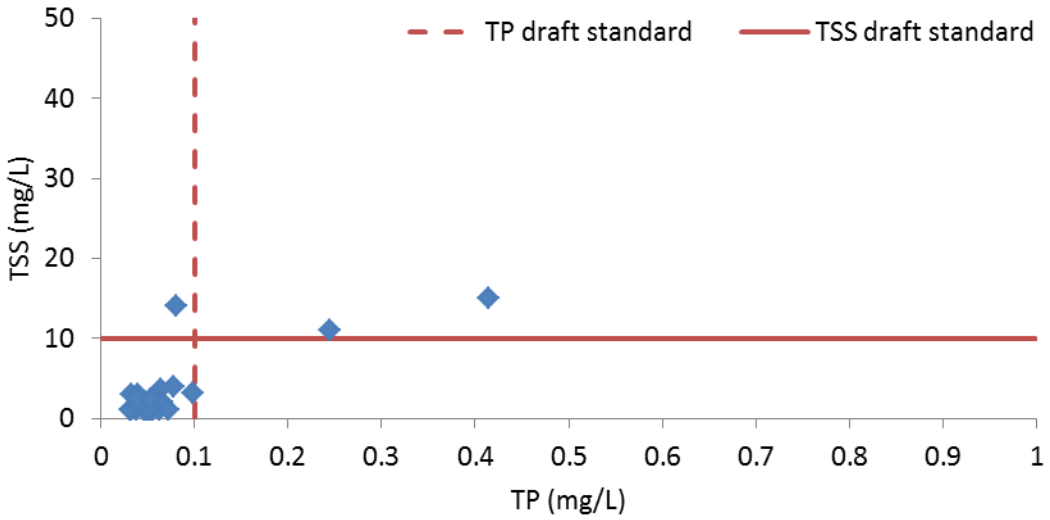


Figure 93. TSS and TP relationship in Trout Brook (2004, 2006, 2010, 2011, 2013 and 2014)

Coldwater biotic relationships with eutrophication have not been researched greatly in Minnesota. In warmwater systems, EPT communities are inversely correlated with chlorophyll-a, low DO, and high DO flux values. Only two EPT taxa were collected at station 04LM144, whereas the average of southern coldwater visits that are meeting the biocriteria is seven taxa. In 2004, the percentage of EPT individuals was low, 6.3 and 11.6%. In 2011, the percentage was greater at 38.9%, nearer the average of southern coldwater stations meeting the biocriteria (41.2%). Phosphorus is also positively correlated with the percentage of tolerant taxa. Tolerant taxa at station 04LM144 ranged from 65 – 69.6%, compared to the average of 65.7% found in southern coldwater stations meeting the biocriteria. The number of tolerant taxa collected was less than the average for the southern coldwater class

Functional feeding groups are likely to shift when stressed. An increase in collector-gatherers can indicate an increase in organics. Both the percentage of individuals and the taxa richness of collector-gatherers was elevated at two of the visits to station 04LM144 (Figure 94). There was only one taxon of collector-filterer macroinvertebrates at each of the visits, this resulted in percentages of collector-filters nearly half of the mean of visits meeting the biocriteria for southern coldwater stations. All three of the visits to station 04LM144 had macroinvertebrates that are considered scrapers in higher proportion than the mean of visits meeting the biocriteria, and two were in the highest quartile ranges.

The total phosphorus in this reach of Trout Brook is generally lower than the draft standard for the central region. Only three samples (out of 28) were elevated, and each of those samples was associated with an elevated TSS measurement. The macroinvertebrate community shows possible responses related to elevated phosphorus, but a lack of connecting data on eutrophication (elevated phosphorus, and response variables) it's difficult to conclude phosphorus is a stressor. This reach does have the presence of periphyton, but is not documented further than pictures. Further study should include quantifying the periphyton throughout the Trout Brook Watershed.

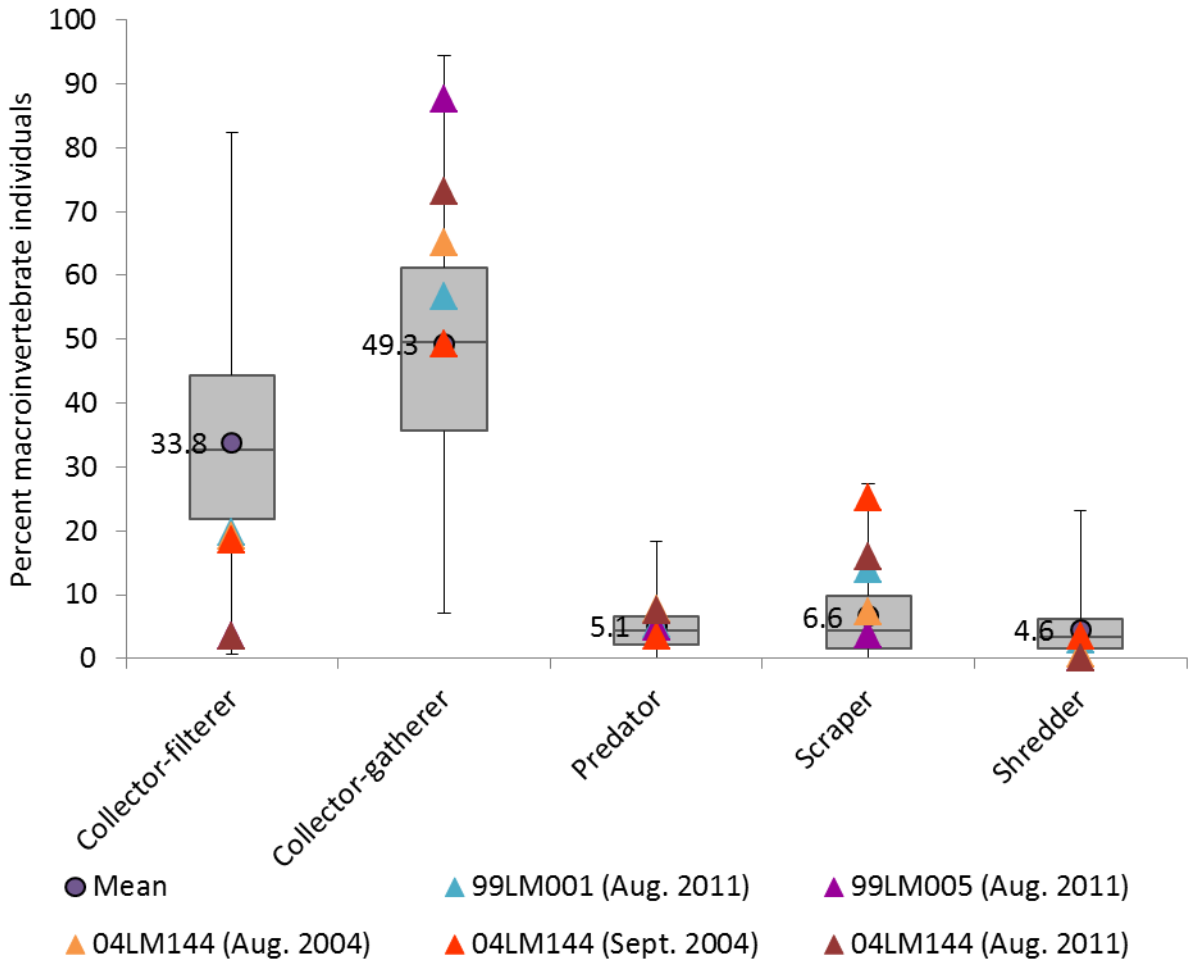


Figure 94. Percent macroinvertebrate individuals in functional feeding groups in the Trout Brook watershed

Dissolved oxygen

In 2010, there were two exceedances of the DO standard of 7 mg/L at station S002-536. The DO exceedances were 6.88 mg/L on June 23 at 9:20AM, and 6.85 mg/L on August 11 at 12:05PM. Both of these dates had rain, near a half an inch and over an inch, respectively (State Climatology Office). There were no other exceedances out of the 27 synoptic measures collected at station S002-536. Only one of the 27 measures was taken prior to 9AM. An YSI sonde was deployed in 2013 from August 7-21, with no measures below the standard and low flux of DO (approximately 2 mg/L). Under a half inch of rain was reported on August 7, 2013, but during the rest of the sonde deployment no rain was observed. The DO data range from the sonde was 8.39 to 10.64 mg/L. There was no BOD data available for this reach.

Station 04LM144 had 20-23 taxa during the three visits (Table 73). There were seven to 10 low DO intolerant taxa, six to eight low DO very intolerant taxa, and one to four tolerant low DO taxa (0.6-3.59% individuals). There were only two EPT taxa in two visits and one taxon in 2011 that comprised 6.3 and 11.6% in 2004, and 38.9% in 2011 of the individuals present. Stations within the Southern coldwater class that are meeting the biocriteria average 7.0 EPT taxa. The DO TIV station score was 7.07 to 7.52, below the average for stations meeting the MIBI (7.93), in the most tolerant quartile for the coldwater class.

It would be advantageous to collect additional DO information under summer storm flow conditions. There are limited DO values that exceed the standard, but there are indications of a community tolerant to low DO. It is inconclusive whether low DO is a stressor in this reach of Trout Brook.

Table 73. Macroinvertebrate metrics that respond to low DO stress in Trout Brook compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
04LM144 (2004)	20	**2**	**7.07**	**7.19**	**10**	**3**	**2.02**
04LM144 (2004)	23	**2**	**7.52**	**7.33**	**8**	1	0.6
04LM144 (2011)	23	**1**	**7.10**	**7.73**	**7**	**4**	**3.59**
Southern Coldwater Average	*27.6*	*7.0*	*6.3*	*7.93*	*10.32*	*1.59*	*1.17*
Expected response to stress	↑	↓	↑	↓	↓	↑	↑

TSS/Turbidity

TSS has been sampled 28 times at station S002-536, over 2004, 2006, 2010-2011, and 2013-2014. The highest TSS was during a rain event on August 13, 2010. There were four measurements (14%) greater than 10 mg/L (coldwater region TSS standard), two in 2010, one each in 2004 and 2013. There were 45 secchi tube or transparency measurements made in this section of Trout Brook. The transparency tube measurements were converted to secchi tube measurements, and seven measurements (15.6%) were less than the 55 cm surrogate standard of the coldwater TSS region. The duration of elevated TSS is unknown.

In April 2003, over 2 inches of rain fell over April 15-16 and then just over 0.5 inch from April 17-19. On April 17, 2003, transparency was 40.4 cm converted to secchi tube measures, and on April 19, 2003, transparency was at the maximum of the transparency tube used that day. On August 11 and 13, 2010, transparency remained low both days, but over an inch of rain fell on August 12 as well as rain prior to August 11th. The other four low transparency measurements did not have another follow up measurement for two weeks. The measurements two weeks later resulted in a very good transparency measurement of the maximum possible. Although there are indications of quick recovery from elevated suspended sediment, additional data should be collected to understand the duration of reduced transparency.

In 2011, station 04LM144 had a macroinvertebrate TSS station index score of 15.6 (Table 74), one taxon that was TSS intolerant (*Percoma*) and one taxon that was TSS tolerant (*Neoporus*). In 2004, the TSS index scores were at or lower than southern coldwater stations meeting the biocriteria. The one tolerant TSS taxon comprised of 1.6% of the community. The percentage of intolerant macroinvertebrate individuals was less than 1% in 2004 and no intolerant individuals were surveyed in

2011. Similarly, there were no long-lived macroinvertebrates in 2004 or 2011. The percentage of collector-filterers was low (ranging from 3.4 – 19.2%), resulting in a low metric score (Figure 91). The variability in the macroinvertebrate community may be explained by a rain event that occurred in 2011 which theoretically may have brought more sediment through the system. The macroinvertebrate community had differing precipitation conditions between the two years sampled, 2004 and 2011 (Figure 95). However, there is no TSS or secchi tube information during that time to aid in understanding.

There are indications of elevated suspended sediment with both TSS and secchi tube measurements, although somewhat limited. The biological data is somewhat mixed, particularly when looking at the specific TSS related index score and metrics. It may be playing a role in shaping the macroinvertebrate community, but most likely not a direct role as suspended sediment, but a source of sediment impacting the habitat quality in Trout Brook. TSS is inconclusive as a stressor in Trout Brook. Further discussion of habitat is available in the next section.

Table 74. Macroinvertebrate metrics that respond to TSS stress in Trout Brook compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	LongLivedPct	Intolerant2Pct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
04LM144 (2004)	**19.2**	**0**	**0.3**	12.7	**1**	0	0
04LM144 (2004)	**18.5**	**0**	**0**	14.7	**0**	0	0
04LM144 (2011)	**3.4**	**0**	**0**	**15.6**	**1**	1	1.62
Southern Coldwater Average	*34.0*	*2.8*	*2.5*	*14.7*	*1.7*	*3.75*	*7.35*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

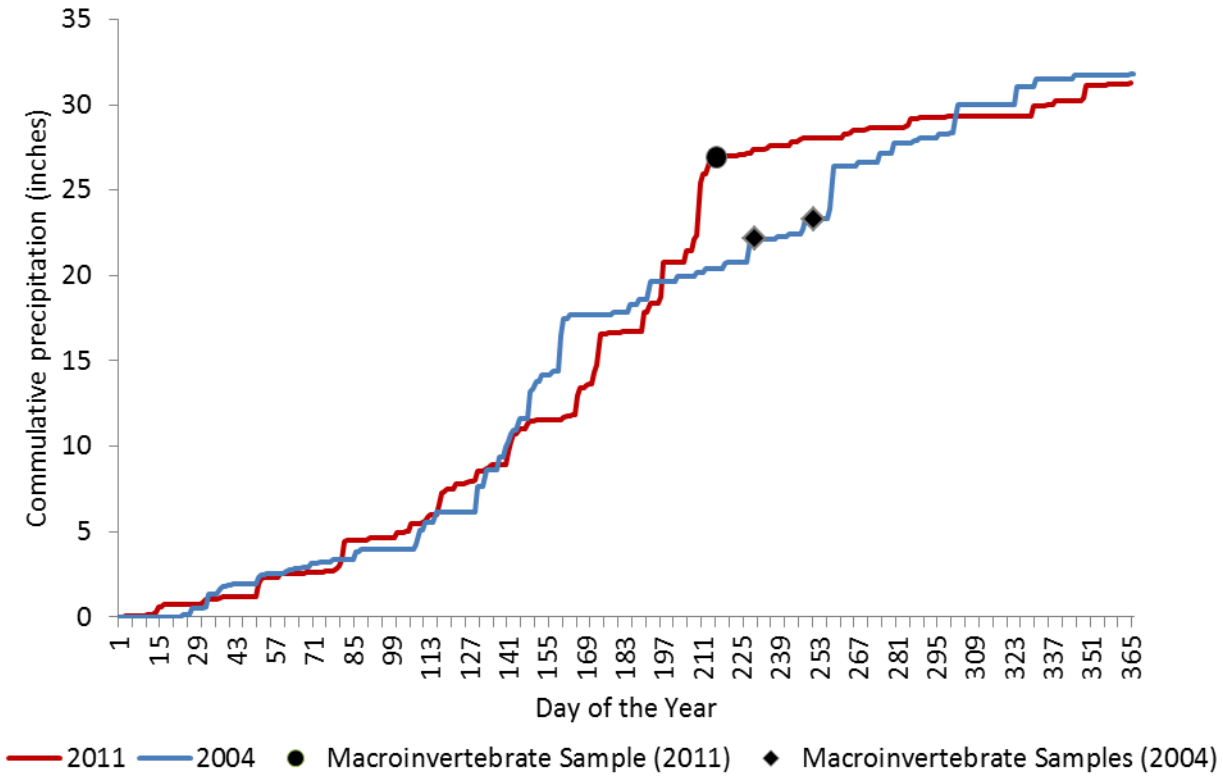


Figure 95. Cumulative precipitation near Trout Brook in 2004 and 2011 and day of macroinvertebrate sample (Dakota-Douglas-Miesville 113N 17W S26, 44.56590, -92.83118; State Climatology Office)

Habitat

At station 04LM144, the habitats sampled for macroinvertebrates in 2004 included: riffle, run, or rock; undercut banks or overhanging vegetation; snags, woody debris, or root wads; and leaf packs. In 2011, only two habitat types were sampled: riffle, run, or rock; and snags, woody debris, or root wads.

In 2004, the MSHA total score was 73.3 and 82.2 (out of 100). In 2011, the MSHA total score was 66.25. Of the three visits the subcategory scores for station 04LM144 were similar (Figure 96). The visit on June 24, 2004, had the highest subcategory scores and the visit in 2011 had the lowest subcategory scores, but near the 2004 scores. The DNR has been completing the MSHA for Trout Brook at mile 2.8. In 2014, the MSHA score was 59.9 and has declined slightly in recent years. The biggest change has been lower scores for the Instream Substrate subcategory, with more fine substrates present (Figure 97).

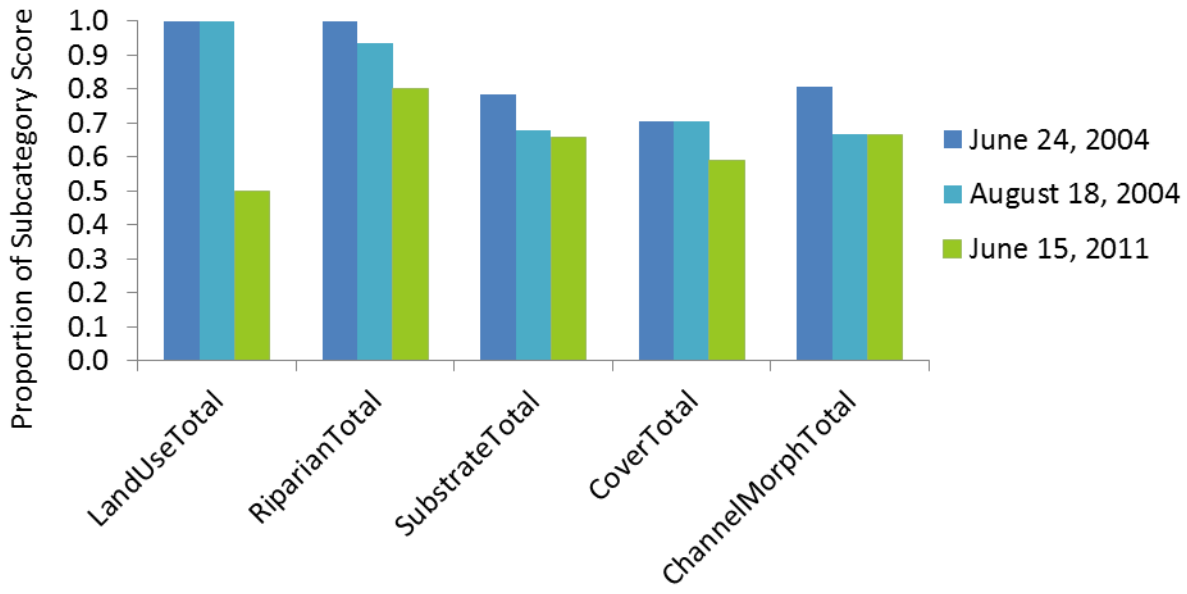


Figure 96. MSHA subcategory scores for station 04LM144, Trout Brook

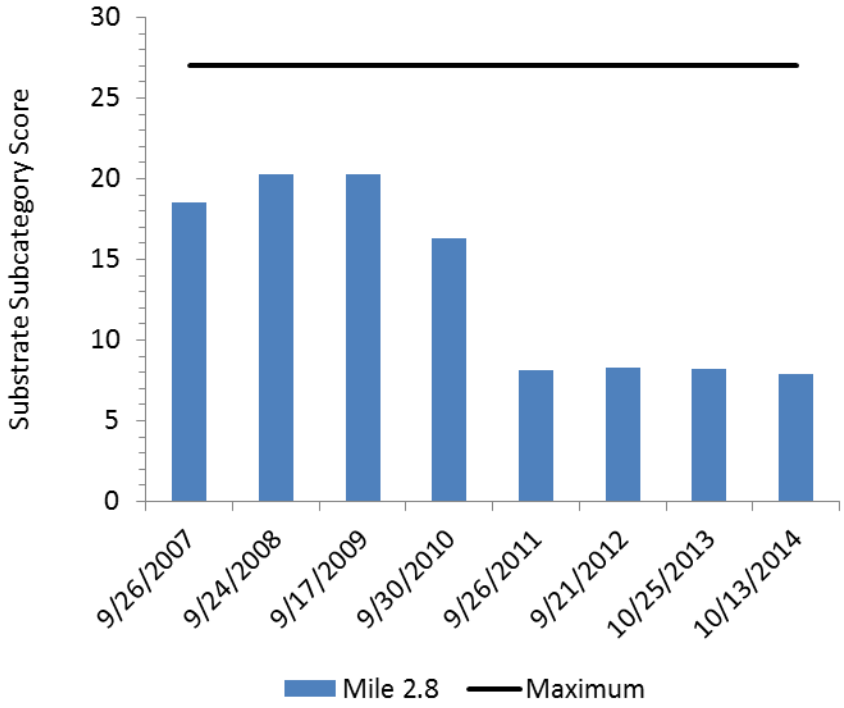


Figure 97. Instream substrate subcategory scores at Mile 2.8 from 2007 – 2014 visits (DNR, 2014)

Station 04LM144 is within Miesville Ravine Park Reserve. The immediate surrounding land use is dominated by deciduous forest with upland cultivated crop higher in the watershed. The riparian width is extensive with heavy shading present both in 2004 and 2011. In 2004, no to little bank erosion was observed. In 2011, heavy and moderate bank erosion was noted.

Greater than four substrate types were noted during each of the three visits. Embeddedness was light in June 2004, moderate in August 2004 and June 2011. In 2004, there were 5 to 10% riffle features in

station 04LM144, comprised of gravel and cobble (Figure 98). The pool and run features were comprised of sand, gravel and cobble. In 2011, riffle features made up 30% of the reach with sand and gravel substrate (Figure 99). In the pool and run features sand and gravel were the dominant substrate types. Cobble was not the dominating substrate in riffles in 2011 as it was in 2004. This shift may be indicative of stream stability changes.

Cover was noted as moderate (25-50%) during all three visits. In June 2004, undercut banks, overhanging vegetation and emergent macrophytes, deep pools, and woody debris were types of cover available. In August 2004, deep pools were not noted. Station 04LM144 had undercut banks, overhanging vegetation and submergent macrophytes in 2011.

In 2004, station 04LM144 had good depth variability with many velocity types found. The two visits also resulted in MSHA indicating high channel stability. Sinuosity was noted as poor in June 2004 and fair in August 2004. Channel development was excellent in August and fair in June. The pool width was equal to or greater than the riffle width. In June 2011, the station also had good depth variability, moderate channel stability (decreased from 2004), good sinuosity, good channel development and pool width greater than riffle width. In 2011, fast, moderate and slow velocity types were noted at the station. Wetted perimeter was observationally low (Figure 98 and Figure 99), with undercut banks and overhanging vegetation high and dry.

Figure 98. Photograph of station 04LM144, upstream looking downstream, with cobble evident (June 24, 2004)

Figure 99. Photograph of station 04LM144 (August 21, 2013)

At station 04LM144, there were slightly more burrowers than would be expected, ranging from 8.1-17.1%; and more climbers (20.6-39.9%; Figure 100). There were also an elevated percentage of legless (35.2-72%). The visit in 2011 also resulted in a high percentage of sprawlers (61.7%). All three visits resulted in lower percentages of clingers (4.4-19.1%), with the lowest percentage surveyed in August 2011.

Lack of physical habitat is impacting the macroinvertebrate community in Trout Brook. The excess burrowers suggest sedimentation with moderate embeddedness and bank erosion. The perched culvert downstream of this station may be playing a role in the stream attempting to find stability. Changes between 2004 and 2011 indicate that habitat is not the only stressor impacting the macroinvertebrate community in Trout Brook, but improved habitat would be beneficial.

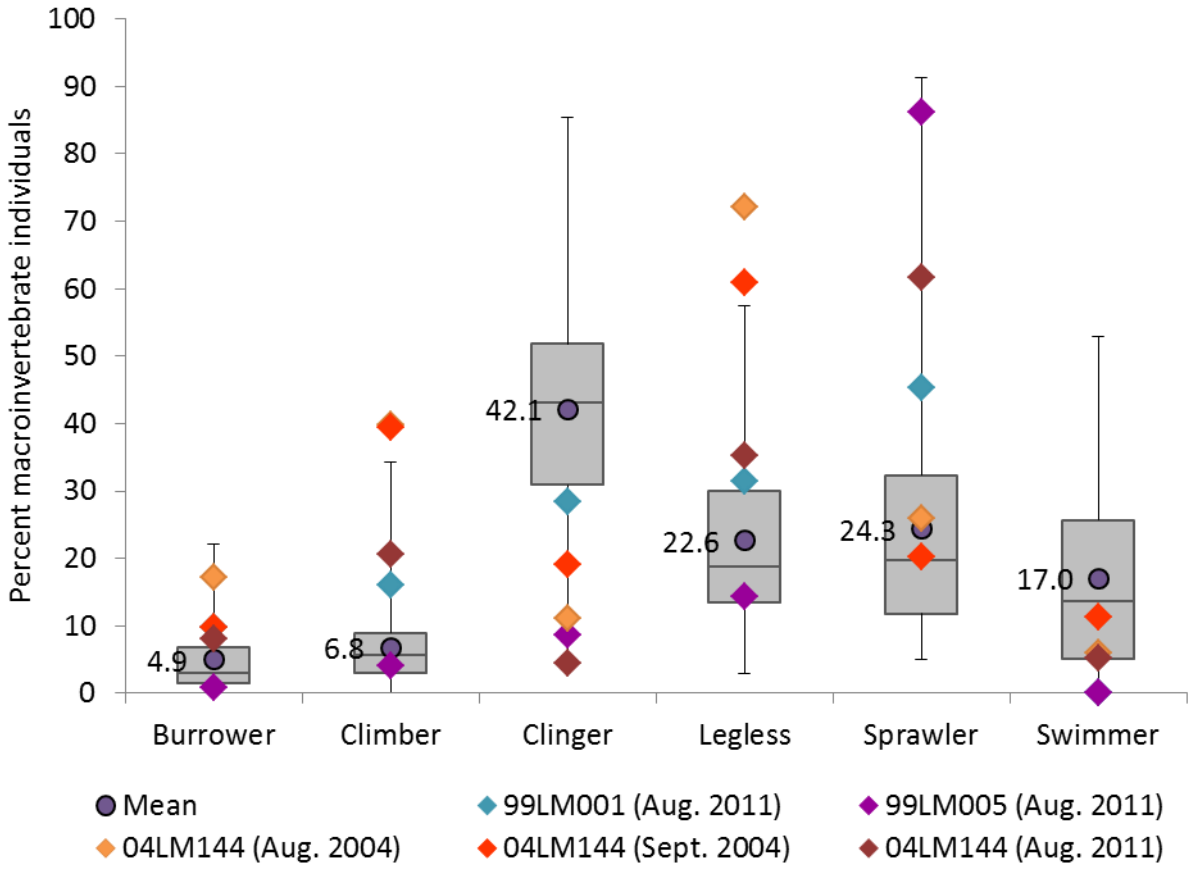


Figure 100. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Coldwater stations with MIBI greater than 46.1 (threshold), mean of those stations, and metric values from Trout Brook Watershed stations

Fish Passage

Miesville Trail, at Trout Brook, near station 04LM144, has a perched culvert (Figure 101). Currently there is presence of brook trout upstream of the perched culvert and may not be currently a barrier to fish migration. However, the perched culvert does pose a potential issue to passage as well as a potential indication of stream instability, as well as a cause of instability. The DNR staff report at times beaver dams have been numerous and large, easily 6' head on some. Beaver dams have been fairly persistent until the present time. They might not be as large anymore, but they are found frequently. There are no other known visible physical barrier issues in Trout Brook, and it is not currently a stressor.

It is recommended that the perched culvert be fixed before further issues develop. It is recommended that a geomorphic survey is conducted prior to fixing culvert to appropriately match the stream slope and bankfull width to help stabilize the upstream and downstream channel.

Figure 101. Photograph of perched culvert downstream of Miesville Trail., near station 04LM144 (April 8, 2014)

Conclusion

Trout Brook has very high concentrations of nitrate throughout much of the year. Nitrate is a stressor to the macroinvertebrate community, along with lack of physical habitat. Low DO and elevated TSS are inconclusive as stressors. Elevated phosphorus as a sign of eutrophication is not currently a stressor to the macroinvertebrates, but additional quantitative data should be collected regarding the periphyton. Fish passage is not an immediate concern; however the perched culvert maybe playing a negative role in the habitat degradation as well as cause future concerns to connectivity. Elevated temperature is also not a concern at this time.

Efforts should be put forth to reduce nitrate inputs to the stream as well as improve habitat conditions. A geomorphic survey should be conducted to analyze stream stability as it relates to decreased habitat availability as well as prior to fixing the perched culvert. A new culvert should take into account for the natural flows of the stream and geomorphic stability to further instability does not occur. Additional data should be collected to understand the episodes of low DO and elevated TSS, their frequency and magnitude, as well as impacts to the biotic community.

4.3.3. Tributary to Trout Brook (580)

The next sections will be by potential stressors in the tributary to Trout Brook. The Tributary to Trout Brook is impaired for lack of a coldwater macroinvertebrate assemblage. Data summaries for each parameter, biological response and conclusion of the potential stressor(s) will be discussed.

Temperature

At station 99LM005, at the time of macroinvertebrate sampling on August 4, 2011, the water temperature was 10.7°C. In 2012, a temperature logger was deployed and resulted in a maximum of the daily average temperature for the summer of 14.7°C. The CBI scored fairly high for this station and there was presence of brook trout. Temperature is not currently a stressor to the biotic communities at this time.

Nitrate

Nitrate has been sampled 28 times in the tributary to Trout Brook spanning the years of 2006, 2010-2011, and 2013-2014 (Figure 102). The highest level of nitrate was 21 mg/L (April 8, 2014). Only three samples were 10 mg/L or lower. The rest of the data averaged 12.9 mg/L. The lowest concentration of nitrate was sampled after a rain event August 13, 2010.

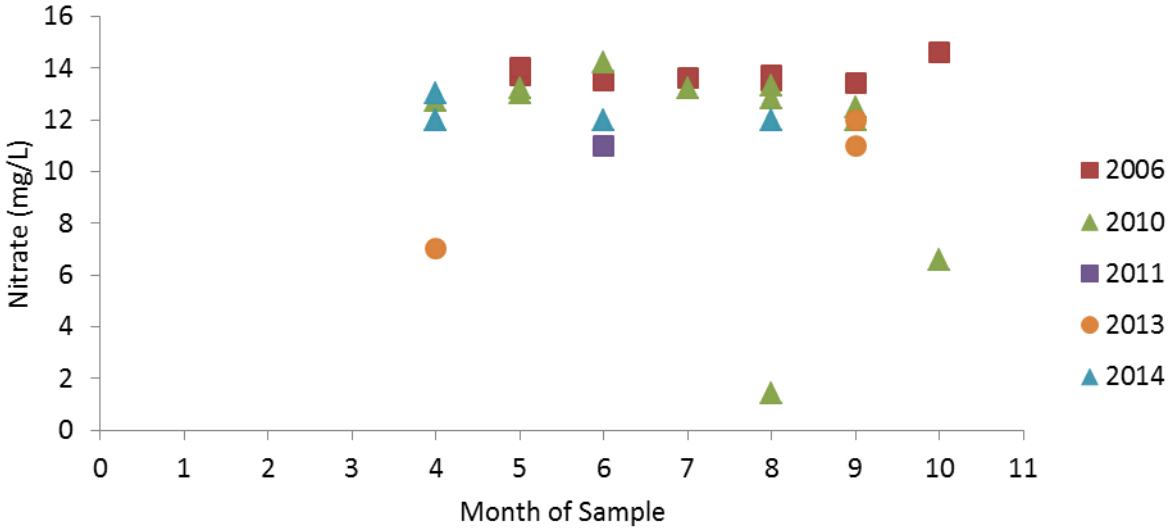


Figure 102. Nitrate concentrations in tributary to Trout Brook by month sampled, 2006, 2010-2011, and 2013-2014

A quantile regression analysis of Southern Coldwater macroinvertebrate stations in Minnesota show a 75% probability that if a stream has a nitrate reading of 12 mg/L or higher, the MIBI score will be below the threshold (46.1). In addition, if a stream has a nitrate reading of 6 mg/L or higher, there is a 50% probability the MIBI score will be below impairment threshold.

The macroinvertebrate metrics that correspond with nitrate stress show a consistent response as expected (Table 75).Tributary to Trout Brook, station 99LM005, had one Trichoptera taxon comprising of 6.5% of the total taxa (TrichopteraChTxPct). The low number of Trichoptera taxa resulted in a metric score of zero, lower than the average metric score needed to be at the Southern Coldwater MIBI threshold. Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a

significant changepoint at only 2.85 mg/L nitrate at time of fish sampling (p=0.006). At this level of nitrate there is less than a 50% probability of having a metric score for TrichopteraChTxPct greater than the average metric score needed for the MIBI to be at the threshold. Station 99LM005 had no intolerant taxa in 2011.

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 value and consequent metric score have a significant relationship with nitrate at the time of fish sampling. The HBI_MN metric score decreases with increased nitrate. At station 99LM005, in the Tributary to Trout Brook, the metric scores was 6.9 (in 2004 and 2011, out of 14.3), just above the average metric score needed to be at the Southern Coldwater MIBI threshold (6.6).

The HBI_MN value increases with increased nitrate. At station 99LM005 the HBI_MN value was 6.7 in 2011, greater than the average HBI_MN value for stations meeting the MIBI (6.27). Utilizing quantile regression analysis for stations in the Southern Coldwater class, there is a significant changepoint at 6.95 mg/L nitrate at time of fish sampling ($p \leq 0.001$). At that concentration there is a 50% probability that the HBI_MN will be less than or greater than 6.65. At a concentration of 10 mg/L nitrate at the time of fish sampling there is only a 25% probability that HBI_MN will be less than 6.57.

Station 99LM005 had 10 nitrate tolerant taxa (95.4% individuals); and eight nitrate very tolerant taxa (94.8% individuals). The percent individuals that were both tolerant to nitrate and very tolerant to nitrate were very high. There were no nitrate intolerant taxa present in the macroinvertebrate survey in 2011.

The elevated nitrate concentrations in the tributary to Trout Brook are contributing stress on the macroinvertebrate community.

Table 75. Macroinvertebrate metrics that respond to nitrate stress in the Tributary to Trout Brook compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
99LM005 (2011)	**1**	**0.3**	**0**	**3.71**	**0**	10	**95.4**
Southern Coldwater Average	*4.6*	*11.6*	*1.2*	*3.23*	*1.10*	*14.77*	*66.22*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

In the tributary to Trout Brook, at station S002-537, there were 27 samples of TP over 2006, 2010, 2011, 2013, and 2014. The maximum TP was 2.37 mg/L (April 8, 2013). Only two samples were greater than the draft river nutrient criteria for the central region (0.1 mg/L). TSS was collected concurrently with the TP and the potential relationship was evaluated (Figure 104) and found that there was elevated TP only with elevated TSS concentrations indicating that the TP is likely bound to the sediment. The 2013 data may be skewed low due to inaccurate lab methodologies.

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to consider the reach impaired for excess phosphorus. BOD and chlorophyll-a were not collected in this reach of Trout Brook. At station S005-537, DO was measured by an YSI sonde from August 7 – 21, 2013. DO was slightly below the 7 mg/L standard (low of 6.91 mg/L) on August 19, 2013. During the sonde deployment there was little DO flux recorded (greatest was 1.19 mg/L). More information on the DO dynamics in the tributary to Trout Brook can be found in the DO section. There is a fair amount of periphyton within this reach of the tributary to Trout Brook (Figure 105), but it has not been quantified. Additionally monitoring should be conducted to understand the prevalence of periphyton and if it is in excess.

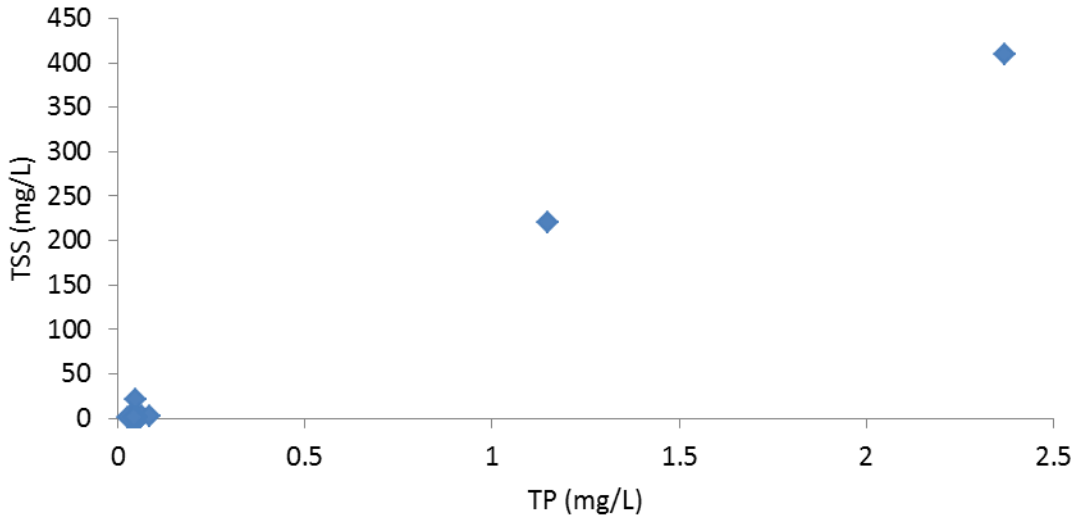


Figure 103. TSS and TP relationship in Tributary to Trout Brook (2006, 2010, 2011, 2013 and 2014)

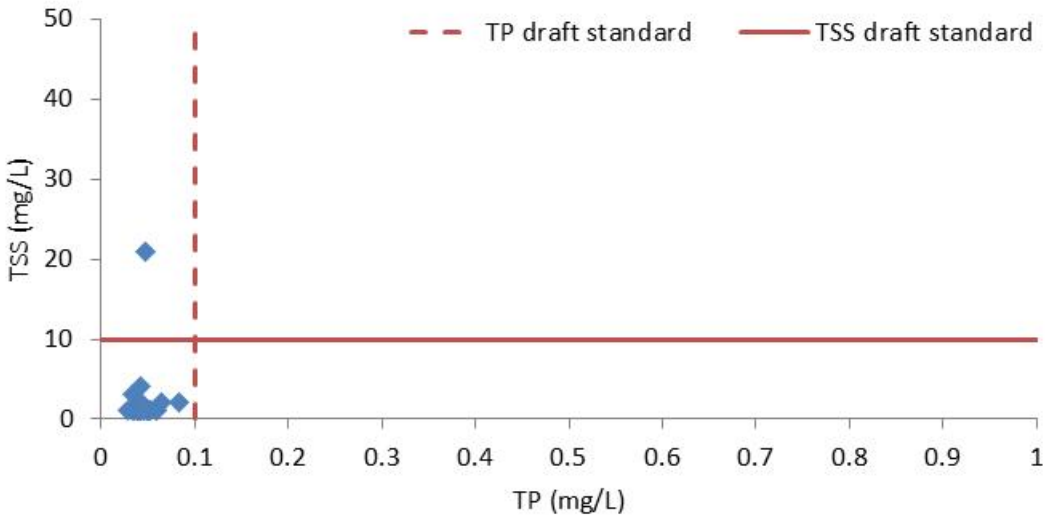


Figure 104. TSS and TP relationship in Tributary to Trout Brook (2006, 2010, 2011, 2013 and 2014) zoomed in

Figure 105. Photographs of station 99LM005 of extensive filamentous algae (August 7, 2013)

Coldwater biotic relationships with eutrophication have not been researched greatly in Minnesota. In warmwater systems, EPT communities are inversely correlated with chlorophyll-a, low DO, and high DO flux values. Two EPT taxa were collected at station 99LM005, whereas the average of southern coldwater visits that are meeting the biocriteria is seven taxa. In 2011, the percentage of EPT individuals was high, 62.2%, above the average of southern coldwater stations meeting the biocriteria (41.2%). Phosphorus is also positively correlated with the percentage of tolerant taxa. Tolerant taxa at station

99LM005 were 62.5%, compared to the average of 65.7% found in southern coldwater stations meeting the biocriteria. The number of tolerant taxa at station 99LM005 was less than the average.

Based on literature, functional feeding groups are likely to shift when stressed. An increase in collector-gatherers can indicate an increase in organics. The percentage of collector-gatherers individuals was very elevated at station 99LM005 (87.6%; Figure 94). There was only two taxa of collector-filterer macroinvertebrates, this resulted in percentages of collector-filters nearly a tenth of the mean of visits meeting the biocriteria for southern coldwater stations. Station 99LM005 had expected ranges of predators and scrapers, but low percentage of shredders. Across four of the five functional feeding groups, the taxa counts for each group were in the lowest quartile ranges.

The total phosphorus in the tributary to Trout Brook is generally lower than the draft standard for the central region. Only two samples (out of 27) were elevated, and each of those samples was associated with an elevated TSS measurement. The macroinvertebrate community shows possible responses related to elevated phosphorus, but a lack of connecting data on eutrophication (elevated phosphorus, and response variables) it's difficult to conclude phosphorus is a stressor. The macroinvertebrate community is suggestive of possible issues related to responses to elevated phosphorus, but without elevated phosphorus indicating eutrophication it is difficult to conclude on stressor status. This reach does have the presence of periphyton, but is not documented further than pictures. Further study should include quantifying the periphyton throughout the Trout Brook Watershed.

Dissolved Oxygen

In the tributary to Trout Brook, there were five exceedances of the DO standard of 7 mg/L at station S002-537, out of 26 synoptic measurements. Only two of the 27 measures were taken prior to 9AM. The DO exceedances occurred in 2006, 2010, and 2011. The lowest DO measurement was 6.26 mg/L on August 24, 2006 at 3:19PM. Three of the five dates of DO exceedances had rain reported (State Climatology Office).

An YSI sonde was deployed in 2013 from August 7-21, with one day with measurements just below the standard and a low flux. Under a half on inch rain was reported on August 7, 2013, but during the rest of the sonde deployment no rain was observed. The DO data range from the sonde was 6.91 to 8.12 mg/L. There was no BOD data available for this reach.

Station 99LM005 had 16 taxa during the 2011 visit (Table 76). There were six low DO intolerant taxa, five low DO very intolerant taxa, and zero tolerant low DO taxa (0% individuals). There were only two EPT taxa in 2011 that comprised 62.2% of the individuals present. Stations within the Southern coldwater class that are meeting the biocriteria average 7.0 EPT taxa. The DO TIV station score was 8.15, above the average for stations meeting the MIBI (7.93), in the most sensitive quartile for the coldwater class.

It would be advantageous to collect additional DO information under summer storm flow conditions as such as some of the exceedances occurred. Additional information regarding source water and DO levels would also be advantageous in understanding the DO dynamics in this system. There are limited DO

values that exceed the standard, but there are mixed indications of a community tolerant to low DO. It is inconclusive whether low DO is a stressor in this reach of Trout Brook.

Table 76. Macroinvertebrate metrics that respond to low DO stress in the tributary to Trout Brook compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
99LM005 (2011)	16	**2**	**6.70**	8.15	**6**	0	0
Southern Coldwater Average	*27.6*	*7.0*	*6.3*	*7.93*	*10.32*	*1.59*	*1.17*
Expected response to stress	↑	↓	↑	↓	↓	↑	↑

TSS/Turbidity

TSS has been sampled 27 times at station S002-537, over 2006, 2010-2011, and 2013-2014. The highest TSS was during a snowmelt sample April 8, 2013 (410 mg/L), followed by a rain event on August 13, 2010 (220 mg/L). There were three measurements (11%) greater than 10 mg/L (trout region TSS standard). There were 46 secchi tube or transparency measurements made in this reach. The transparency tube measurements were converted to secchi tube measurements, and five measurements (10.9%) were less than the 55 cm surrogate standard of the trout TSS region. The duration of elevated TSS is unknown. When low transparency has been measured, there has not been a follow-up measurement of transparency for two weeks. The measurement two weeks later has resulted in a very good transparency measurement of the maximum possible. Additional data should be collected to understand the duration of reduced transparency.

In 2011, station 99LM005 had a macroinvertebrate TSS station index score of 15.4, one taxon that was TSS intolerant (*Hesperophylax*) and no taxa that were TSS tolerant (Table 77). There were no intolerant macroinvertebrate individuals in 2011. Similarly, there were no long-lived macroinvertebrates. The percentage of collector-filterers was low (3.4%), resulting in a low metric score (Figure 91). Similar to Trout Brook station 04LM144, station 99LM005 was sampled after a rain event in 2011, which theoretically may have brought more sediment through the system. However, there is no TSS or secchi tube information during that time to aid in understanding.

There are indications of elevated suspended sediment with both TSS and secchi tube measurements, although somewhat limited. The biological data indicates tolerance to elevated TSS, but does not have TSS tolerant taxa present. Elevated TSS is inconclusive as a stressor to the macroinvertebrate community in the tributary to Trout Brook.

Table 77. Macroinvertebrate metrics that respond to TSS stress in the tributary to Trout Brook compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	LongLivedPct	Intolerant2Pct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
99LM005 (2011)	**3.4**	**0**	**0**	**15.4**	**1**	0	0
Southern Coldwater Average	*34.0*	*2.8*	*2.5*	*14.7*	*1.7*	*3.75*	*7.35*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Habitat

At station 99LM005, the habitat sampled for macroinvertebrates was the dominant habitat features of riffle, run, or rock. The MSHA was 79.15 (out of 100), quite good relatively. Station 99LM005 is within Miesville Ravine Park Reserve. The immediate surrounding land use is dominated by deciduous forest and grassland/pasture with upland cultivated crop higher in the watershed. The riparian width is extensive with heavy to substantial shading present. In 2011, no bank erosion was noted. Less than four substrate types were noted during the fish visit, with no embeddedness noted. In 2011, there were 15% riffle features in station 99LM005, dominated by gravel and cobble. The pool and run features were comprised of sand and cobble.

Cover was noted as moderate (25-50%) during the 2011 visit. Undercut banks, and overhanging vegetation, submergent macrophytes, deep pools, woody debris, and boulders were types of cover available. In 2011, station 99LM005 had good depth variability with moderate, slow, and interstitial velocity types found. The MSHA indicated high channel stability. Sinuosity was noted as good in June 2011. Channel development was good. The pool width was greater than the riffle width.

Station 99LM005 had low percentages of all habitat macroinvertebrate metrics except for sprawlers (Figure 100). Sprawlers comprised of 86.1% of the macroinvertebrate community in August 2011. The high number of sprawlers is likely driven both by habitat and presence of aquatic macrophytes and periphyton. Sprawlers like to “inhabit the surfaces of floating leaves of vascular hydrophytes or fine sediments” (Merritt and Cummins (1996) and Heino (2005) from Heino 2008).

Despite presence of riffles and rock, there was a lack of macroinvertebrates that cling, which is not expected. The over abundance of periphyton contributes to the habitat issues, in addition to interstitial spaces that are filled in with fine sediment. Physical habitat in this reach is not poor, but the abundance of periphyton is allowing sprawlers to be dominant and thus is a stressor to the macroinvertebrate community. Further geomorphic condition analysis would be beneficial to further understand the stream stability.

Fish Passage

Currently there are no connectivity concerns for the macroinvertebrate community between station 99LM005 and the Cannon River. Connectivity or physical barriers are not a current stressor to the biological communities.

Conclusion

The tributary to Trout Brook has very high concentrations of nitrate throughout much of the year. Nitrate is a stressor to the macroinvertebrate community, along with lack of physical habitat. The habitat issues stem from excess periphyton. Elevated TSS and low DO are inconclusive as stressors. Elevated phosphorus as a sign of eutrophication is not currently considered a stressor to the macroinvertebrate community. Fish passage and elevated temperatures are also not stressors to the macroinvertebrate communities at this time.

Efforts should be put forth to reduce nitrate inputs to the stream and improve habitat conditions by reducing nutrients and conditions that allow for excess periphyton growth. Additional quantitative data should be collected regarding the excess periphyton present within the reach. Data should also be collected to understand the episodes of low DO frequency and magnitude, as well as impacts to the biotic community.

4.3.4 Lower Cannon River 10 digit HUC Summary

Within the Lower Cannon River 10 digit HUC common stressors are nitrate and lack of habitat (Table 78). Phosphorus and the response variables, with DO, and TSS should be continued to be monitored as they are inconclusive as stressors. The periphyton in the reaches should also be monitored and further quantitative information may be beneficial to understanding the stream dynamics. Although fish passage is not a stressor, the perched culvert in Trout Brook should be replaced.

Table 78. Lower Cannon river 10-digit HUC stressor summary (• = stressor, ○ = inconclusive stressor, blank = not a stressor)

Reach	AUID	Biological Impairment	Class	Stressors						
				Temperature	Nitrate	Phosphorus	DO	TSS	Habitat	Fish Passage
Tributary to Trout Brook	580	Macroinvertebrates	2A		●	○	○	○	●	
Trout Brook	573	Macroinvertebrates	2A		●	○	○	○	●	

4.4. Chub Creek 10-digit HUC

This section encompasses biotic impairments in the Chub Creek 10-digit HUC (Figure 106). At the time of this report, only one AUID had biotic impairments. Chub Creek, from the headwaters to the mouth, has fish and macroinvertebrate impairments and is a warmwater (class 2B) stream.

Dutch Creek, a tributary to Chub Creek, also has fish and macroinvertebrate impairments but will not be addressed in this report. This AUID was initially not assessed due to insufficient information. In particular, it was inconclusive if this reach should be assessed against stream criteria because of potential wetland conditions. Follow-up assessment in 2015 determined Dutch Creek to be more indicative of stream conditions, which led to the impairment. Dutch Creek will be covered during the second cycle of the Watershed Approach.

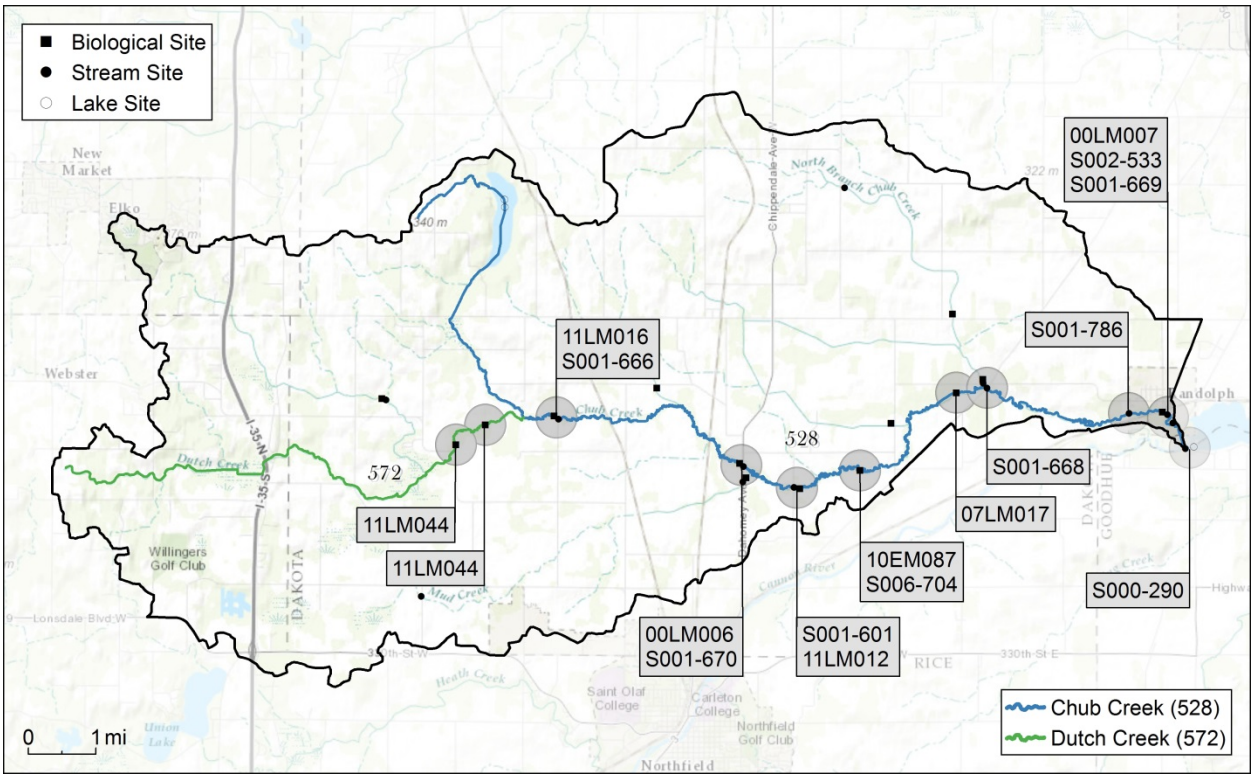


Figure 106. Map of Chub Creek 10 digit HUC including biota impairments with biological stations and chemistry stations used in report.

4.4.1 Chub Creek (528)

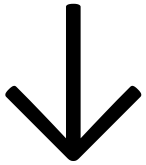
Biological Communities

Chub Creek (07040002-528) is a 24.7 mile long AUID in Dakota County. This warmwater AUID begins in the headwaters of Chub Creek (upstream of Chub Lake) and flows east to the city of Randolph where it joins the Cannon River. Just downstream of this confluence is Lake Byllesby. Chub Creek has fish and macroinvertebrate impairments, as well as bacteria. There are six biological monitoring stations (11LM016, 00LM006, 11LM012, 10EM087, 07LM017, and 00LM007) located along this AUID. Stations 11LM016, 11LM012, and 00LM007 were sampled for fish and macroinvertebrates in 2011. Station

00LM006 and 00LM007 were sampled for fish in 2000, station 10EM087 was sampled for fish and macroinvertebrates in 2010, and station 07LM017 was sampled for fish in 2007.

The fish community in Chub Creek is impaired, and not supporting of the aquatic life use. The FIBI impairment threshold for the Southern Streams fish class is 45 (lower CL = 36, upper CL = 54); four out of the six stations are below this threshold but at or above the lower confidence limit (Table 79). The four stations below the impairment threshold are 10EM087 (36), 00LM006 (39), 11LM016 (39), and station 07LM017 (44). Station 00LM007, near the mouth of Chub Creek, was above the impairment threshold during both visits (53 – 2000, 65 – 2011). The FIBI in 2000 was below the upper confidence limit, and the FIBI in 2011 was above the upper confidence limit. Station 11LM012 is above the impairment threshold and above the upper confidence limit (56). Spotfin shiner was the most abundant fish species at station 00LM007 during both visits. White sucker was the most abundant species at station 07LM017. Station 10EM087 had 20 bigmouth shiners, which was the most of any species sampled at that station. The most common fish species at station 11LM012 was common shiner. Green sunfish were the most abundant at station 00LM006, and the central mudminnow at station 11LM016. At all stations on Chub Creek the relative abundance of early-maturing individuals (MA<2Pct) FIBI metric scores were below the average metric score needed to meet the threshold (Figure 107). The relative abundance of sensitive taxa (SensitiveTXPct), taxa richness of short-lived species (SLvd) and relative abundance of individuals that are tolerant (TolPct) FIBI metric scores were also below average at most stations. Conversely, the relative abundance of taxa that are benthic insectivores excluding tolerant species (BenInsect-TolTXPct), relative abundance of taxa that are detritivorous (DetNWQTXPct), combined relative abundance of the two most abundant taxa (DomTwoPct), and relative abundance of tolerant taxa (TolTXPct) FIBI metric scores were above average at most stations.

Table 79. FIBI scores for the stations in Chub Creek.

Upstream	Station	Lower CL	Upper CL	Impairment Threshold	FIBI Score
	11LM016 (2011)	36	54	45	39
	00LM006 (2000)	36	54	45	39
	11LM012 (2011)	36	54	45	56
	10EM087 (2010)	36	54	45	36
	07LM017 (2007)	36	54	45	44
	00LM007 (2000)	36	54	45	53
Downstream	00LM007 (2011)	36	54	45	65

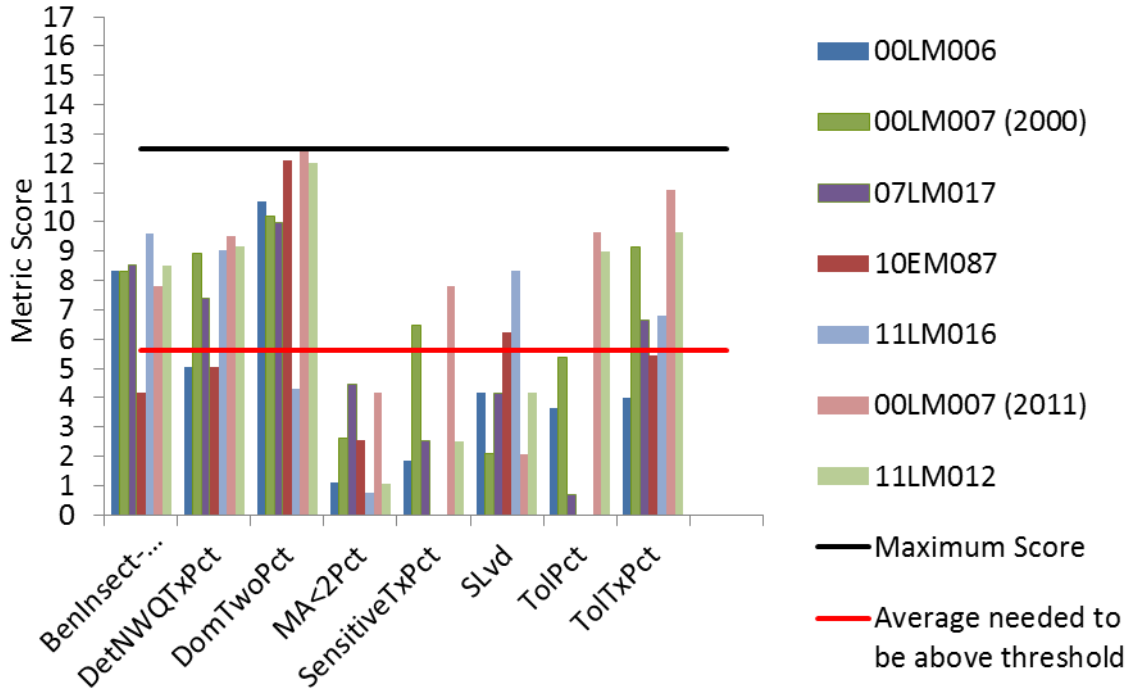


Figure 107. Fish metrics of the Southern Streams IBI for stations in Chub Creek.

The macroinvertebrate community is impaired, and not supporting of the aquatic life use. The MIBI scores were above the impairment threshold at all of the stations except station 11LM016, which is the farthest upstream station. This station scored 40 and 31 in 2011; one score was above the lower confidence limit and one was below. The MIBI impairment threshold for this station is 46.8 (lower CL = 33.2, upper CL = 60.4). Taxa richness of clingers (ClingerCh), relative abundance of dominant five taxa in subsample (DomFiveChPct), taxa richness of macroinvertebrates with tolerance values less than or equal to 2 using MN TVs (Intolerant2Ch), taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET), taxa richness of predators (PredatorCh), total taxa richness (TaxaCountAllChir), relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct), and relative abundance of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct) MIBI metric scores were below the average needed to meet the MIBI threshold at station 11LM016. The other three stations with invert samples (10EM087, 00LM007, and 11LM012) were above their respective impairment thresholds and scored 55, 51, and 36 respectively (Figure 108 and Figure 109). Station 11LM012 is just above the Southern Streams RR MIBI impairment threshold of 35.9 (lower CL = 23.3, upper CL = 48.5). Station 00LM007 is above this threshold and upper confidence limit. The relative percentage of taxa adapted to cling to substrate in swift flowing water (ClingerChTxPct), DomFiveChPct, a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), relative percentage of insect taxa (InsectTxPct), taxa richness of Odonata (Odonata), and relative percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) (station 00LM007) MIBI metric scores were above average and helped these stations meet the MIBI threshold. Both stations, however, had no stonefly taxa (Plecoptera) present during sampling. Station 10EM087 is above the MIBI impairment threshold for Southern Forest Streams GP (46.8), but below the upper confidence limit. This station had very high ClingerCh and DomFiveChPct MIBI metric scores.

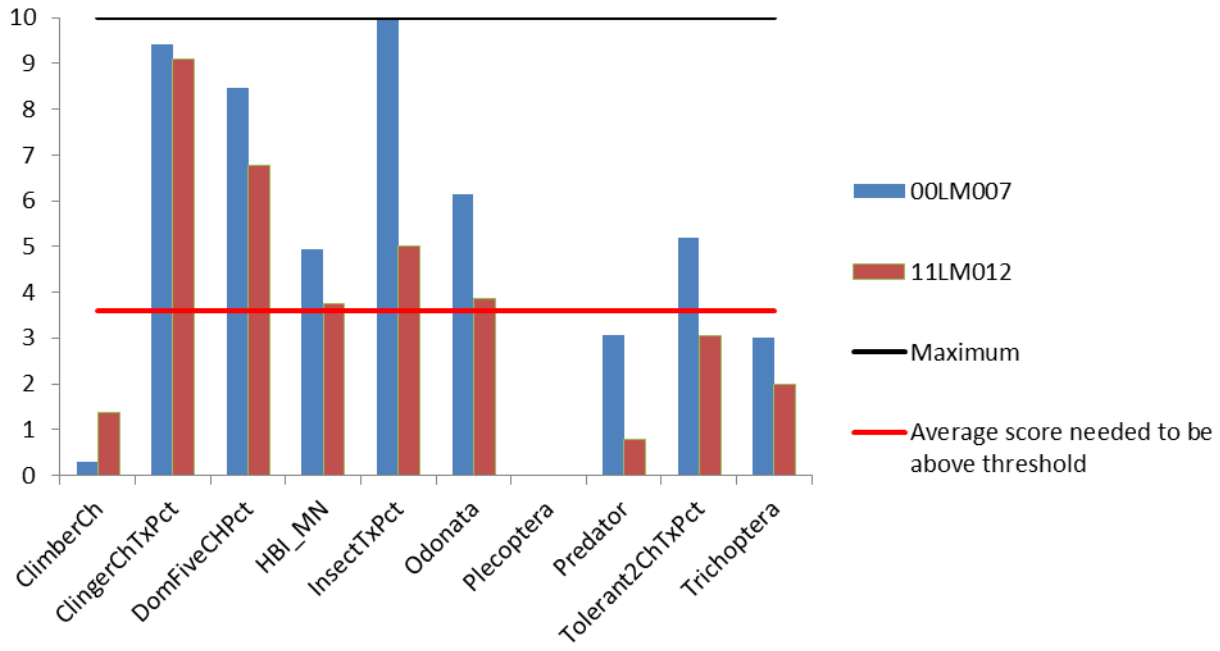


Figure 108. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for Chub Creek (07040002-528), stations 00LM007 and 11LM012.

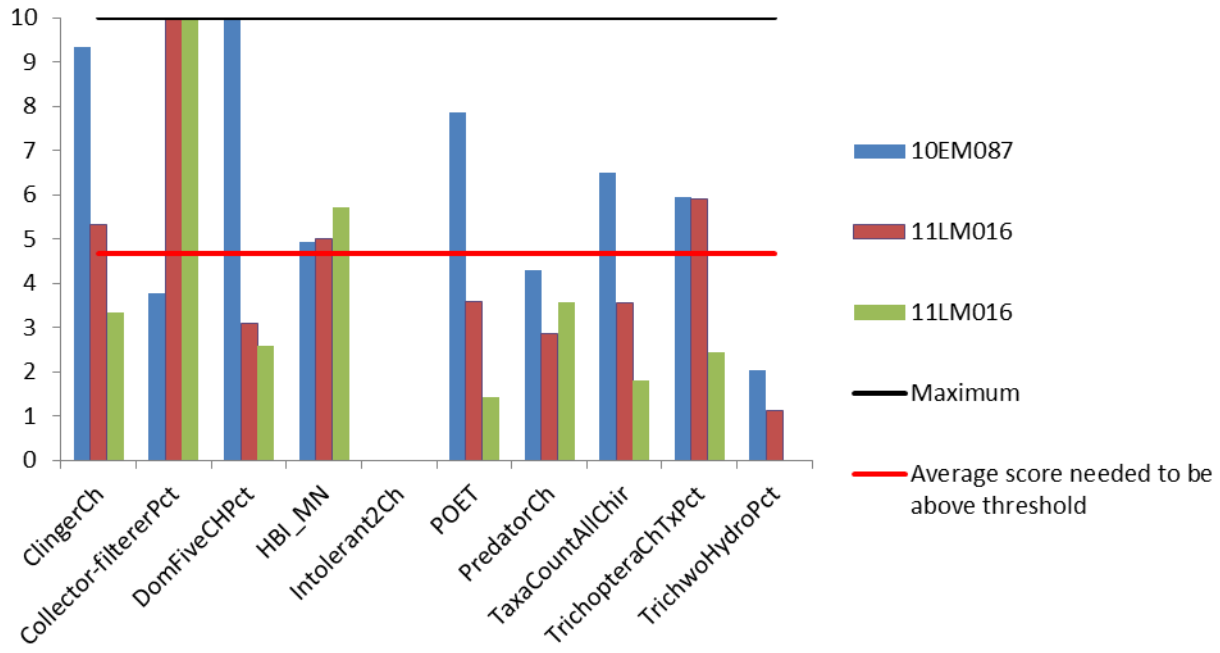


Figure 109. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for Chub Creek (07040002-528), stations 10EM087 and 11LM016.

Data Evaluation for each Candidate Cause

Temperature

Temperature data for Chub Creek exists from 1999 – 2013, and includes 445 samples (minimum of 0° C, maximum of 30.0° C, and an average of 17.0° C). Temperature data over the past decade (2004 – 2013) includes 288 samples (minimum of 1.1° C, maximum of 29.4° C, and an average of 17.0° C). The samples (2004 – 2013) were collected from 11 different stations, with most of the samples coming from the middle and lower portions of the AUID. The greatest coverage occurs at station S002-533, near the mouth of Chub Creek before it drains into Lake Byllesby. This station has 175 samples from March – October, spanning eight different years. The maximum temperature observed at this station is 26.7° C (July 2006). The maximum temperature observed in Chub Creek was 29.4°C at station S001-601 (near the middle of the AUID and downstream of the confluence with Mud Creek). The temperature data set is fairly extensive, and suggests that temperature is not currently stressing the biological communities in Chub Creek. Biota in warmwater streams generally don't experience temperature derived stress until values reach 30° C. The one station (S001-601) on Chub Creek is approaching this level, and monitoring should be continued to ensure that exceedances do not occur. In addition, future monitoring is recommended in the upper end of this AUID. Elevated temperature is currently not a stressor in Chub Creek.

Nitrate

Nitrate data for this AUID contains 28 samples from 2001 – 2012 (minimum of 0.05 mg/L, maximum of 7.46 mg/L, and an average of 3.8 mg/L) (Figure 110). This data set is limited spatially (and temporally in cases), and has minimal sample numbers. Sampling occurred from March – September, with the three highest sampling months being July (five), August (eight), and September (five). The three highest concentrations were 7.5 mg/L (September 13, 2011), 7.1 mg/L (September 18, 2001), and 7.0 mg/L (May 9, 2001). Most of the samples, including the three highest concentrations mentioned above, have been collected near the mouth of Chub Creek (24 samples at three different stations). Additional nitrate sampling across all sections of the AUID in multiple seasons and years would strengthen this data set, and provide opportunities to pin-point source areas.

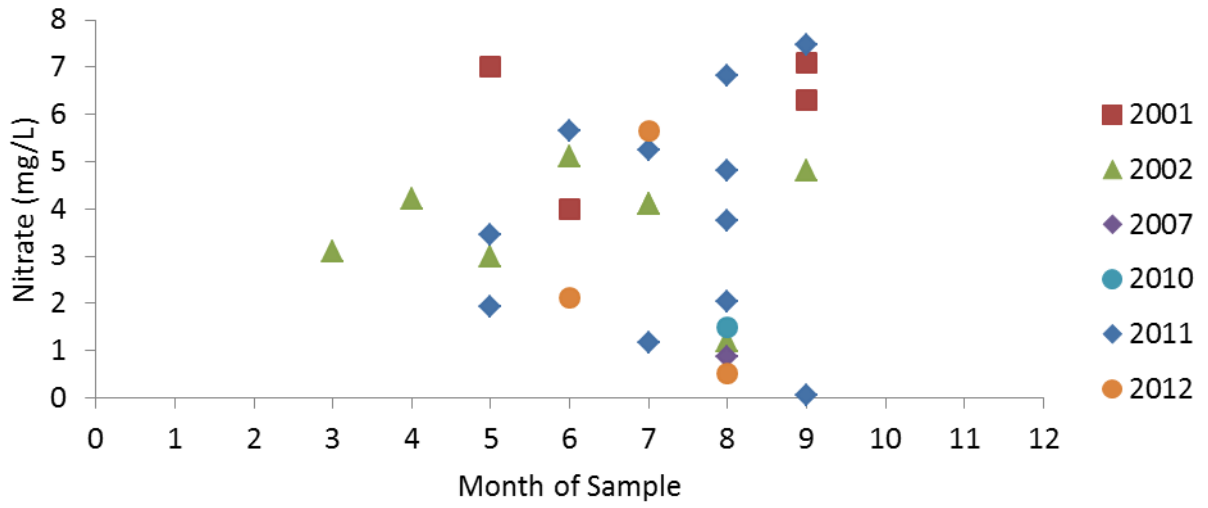


Figure 110. Nitrate concentrations in Chub Creek by month sampled.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide averages of similar stations meeting the biocriteria at all of the stations on Chub Creek (Table 80). Station 11LM016, the farthest upstream station, has the lowest values for all three metrics. All of these metrics are expected to decrease in response to stress.

Stations 00LM007, 11LM012, and 11LM016 had no nitrate intolerant and very intolerant taxa present. Station 10EM087 had one nitrate intolerant taxon present, and no nitrate very intolerant taxa. All stations had several nitrate tolerant and very tolerant taxa present. Station 11LM012, near the middle of the AUID, had the greatest number of nitrate tolerant and very tolerant taxa (21 and 14 taxa respectively). This station also had the highest percentages of nitrate tolerant and very tolerant taxa at 61% and 44% respectively. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. The macroinvertebrate nitrate index scores were 3.0 (00LM007), 2.9 (10EM087), 3.1 (11LM012), 3.0 (11LM016), and 2.9 (11LM016), all of which were at or above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community, suggesting a response to elevated nitrate stress.

Table 80. Macroinvertebrate metrics that respond to nitrate stress in Chub Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
00LM007 (2011)	**5**	**1.3**	**0**	**3.0**	**0**	**0**	18	13	51.0	42.4
11LM012 (2011)	**4**	**1.5**	**0**	**3.1**	**0**	**0**	**21**	**14**	61.2	43.7
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
10EM087 (2010)	**4**	**0.7**	**0**	2.9	**1**	**0**	18	**14**	58.4	43.2
11LM016 (2011)	**3**	**0.3**	**0**	2.9	**0**	**0**	14	9	44.4	28.4
11LM016 (2011)	**1**	**0.0**	**0**	**3.0**	**0**	**0**	12	7	43.8	31.1
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

The nitrate data set for this AUID is relatively small and limited spatially with most of the samples being collected from the mouth of Chub Creek. Although there hasn't been any extremely high concentrations observed, many of the macroinvertebrate metrics are worse than the statewide average and there were no nitrate intolerant and very intolerant taxa present at three of the four stations. All four stations have multiple nitrate tolerant and very tolerant taxa, and the nitrate macroinvertebrate index scores are equal to or worse than the statewide average. Nitrate has the potential to be a stressor in this reach, but at this time it's inconclusive if nitrate is a stressor. Additional chemistry and biological sampling is required to better understand the impact(s) of nitrate in Chub Creek.

Phosphorus

The phosphorus data set contains 207 samples from 1999 – 2013 (minimum of 0.01 mg/L, maximum of 0.703 mg/L, and an average of 0.189 mg/L). There were 111 samples (54%) that exceeded the draft river eutrophication standard for the South Region (0.150 mg/L). The more recent data (2004 – 2013) shows similar values (minimum of 0.02 mg/L, maximum of 0.703 mg/L, average of 0.187 mg/L, and a sample count of 104). The past 10 years also included several exceedances of the draft standard (57 samples, 55%) (Figure 111). These exceedances occurred from March – October, with May and June exceedances comprising 46% of the total. Although several exceedances took place during high flow periods (May and June), there were also exceedances during low flow periods (Figure 112). Several TP exceedances occurred at low TSS concentrations, which is indicative of lower non erosive stream flows. This implies that elevated phosphorus is not just being flushed through the system attached to sediment particles during storm flows, but that it is also available to the aquatic life and vegetation during low flow conditions. High phosphorus concentrations were located throughout the AUID, as 9 out of the 10 stations sampled had at least one exceedance of the standard. It should be mentioned that there were no samples collected on the very upper end of Chub Creek. Phosphorus concentrations at the time of fish sampling were above the draft standard at four of the five stations sampled (00LM007, 07LM017, 11LM012, and 11LM016).

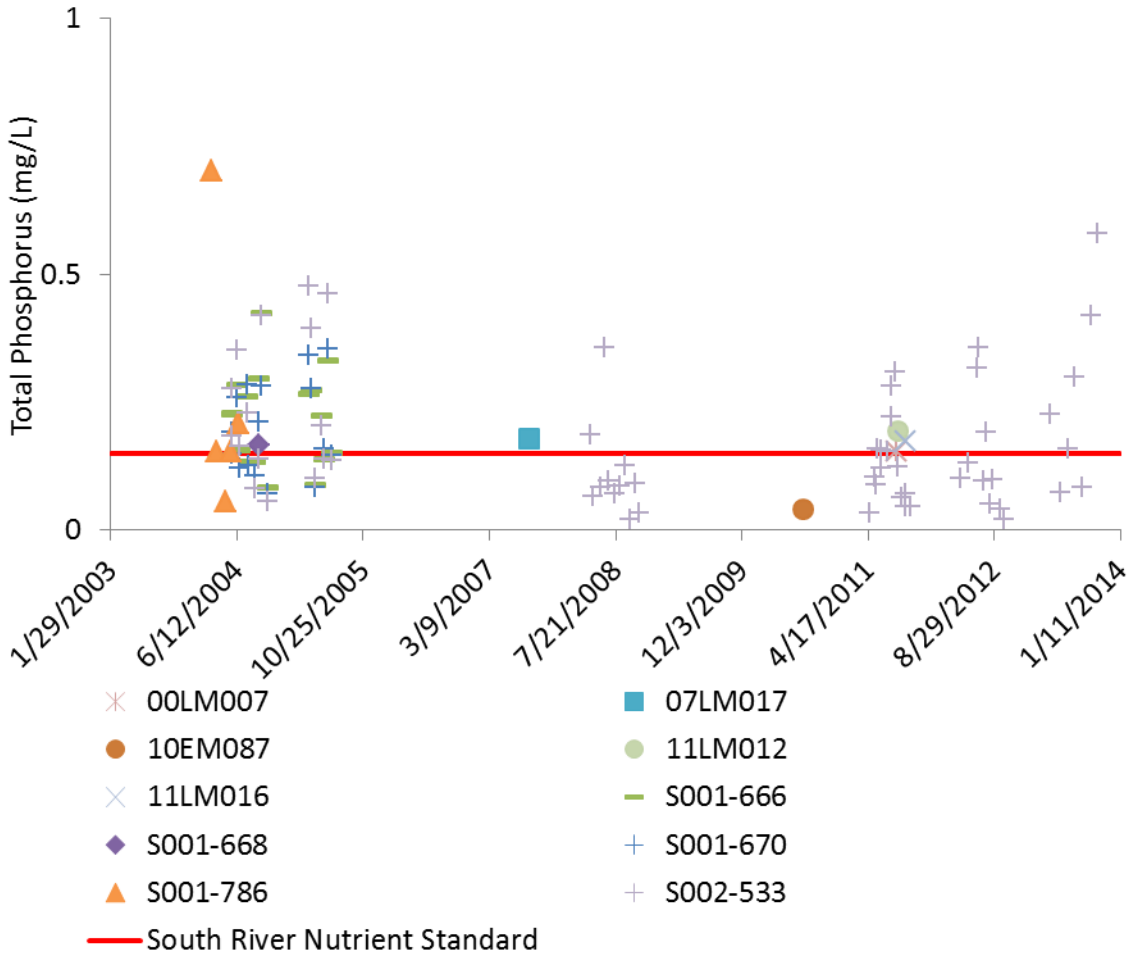


Figure 111. TP by station in Chub Creek.

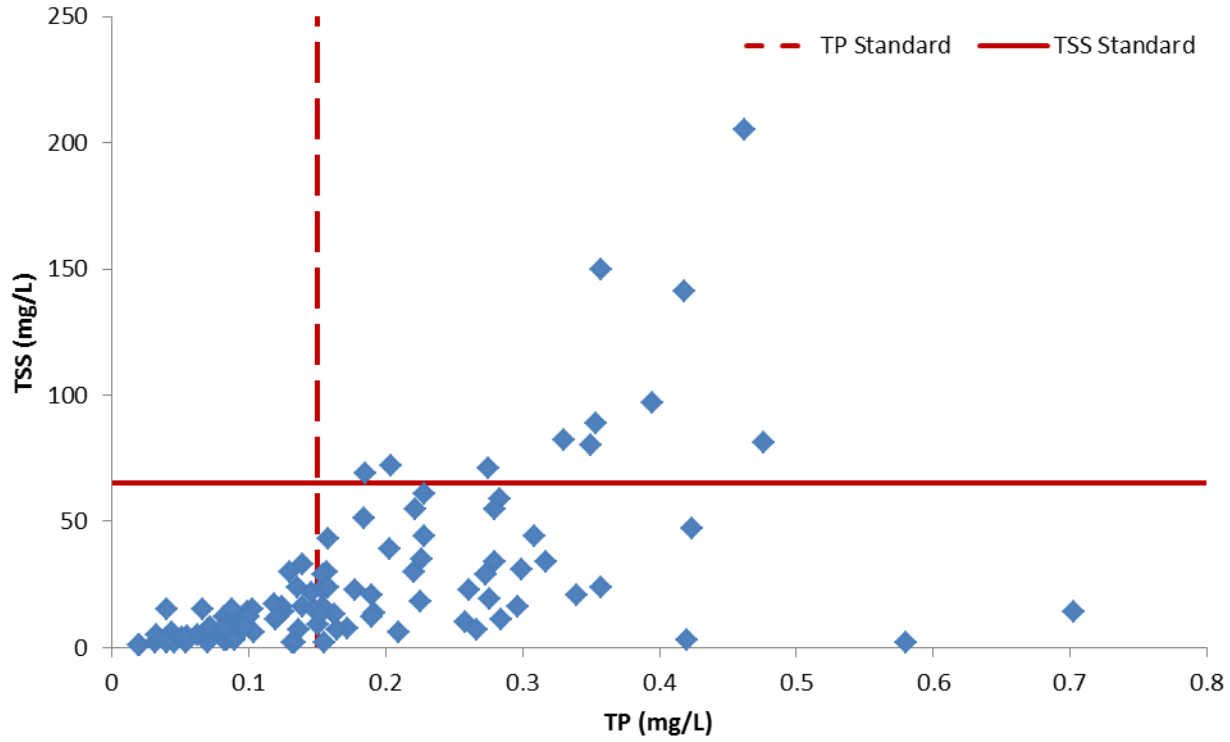


Figure 112. TSS and TP relationship in Chub Creek (2004-2013).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. There is no BOD or chl-a data available for this AUID; future monitoring efforts should include these parameters. There was low DO flux observed during 2014 sonde deployment at station 00LM007 (near the lower end of the AUID); however, elevated DO flux was observed at station 10EM087 (near the middle of the AUID). The daily DO flux exceeded the standard (4.5 mg/L) 3 out of the 11 days, with a max flux of 5.12 mg/L. Mud Creek joins Chub Creek just upstream of station 10EM087. Minimal DO flux exceedances were observed in the upper end of Chub Creek at station 11LM016; the daily DO flux exceeded the standard one out of the seven days, with a max flux of 4.73 mg/L. A longitudinal DO survey conducted in August 2014 resulted in one DO flux above the South Region standard of 4.5 mg/L; the DO flux just downstream of station 10EM087 (at the Arkansas Avenue road crossing) was 5.8 mg/L. Worth noting is that Mud Creek, a tributary to Chub Creek, had a DO flux of 7.0 mg/L just above the confluence with Chub Creek. Low DO, which is discussed in the DO section, was also present in Chub Creek.

Chub Lake, located in the upper end of this AUID, has a nutrient impairment. The lake and neighboring wetlands are potential sources of phosphorus to Chub Creek. Below is a picture of Chub Creek just as it leaves the lake; the picture is facing upstream towards the lake (Figure 113). Macrophytes were abundant at this location, as well as some of the other wetland areas in the upper end of this AUID.

Figure 113. Chub Creek just below Chub Lake in August 2014 (Grenada Avenue).

The macroinvertebrate metrics that respond to elevated phosphorus, and their expected response to stress, are displayed below in Table 81. The total taxa richness of macroinvertebrates (TaxaCountAllChir) was below the statewide average of stations meeting the MIBI threshold at all stations on Chub Creek; this metric is expected to decrease in response to stress. There were no intolerant taxa (Intolerant2Ch) present at all stations. The remaining metrics (collector-filtererCh, collector-gathererCh, EPT, and Tolerant2ChTxPct) had varying responses across the stations in Chub Creek; some were below the statewide average and some were above. Overall, a majority of the macroinvertebrate metrics were worse than the statewide average and suggestive of eutrophication stress.

Table 81. Macroinvertebrate metrics that respond to TP stress in Chub Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
00LM007 (2011)	**36**	**6**	**14**	13	**0**	69.4
11LM012 (2011)	**39**	**6**	15	**9**	**0**	**79.5**
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
10EM087 (2010)	**41**	8	16	11	**0**	70.7
11LM016 (2011)	**31**	**5**	**12**	**6**	**0**	**90.3**
11LM016 (2011)	**25**	**4**	**8**	**4**	**0**	**92.0**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

Sensitive fish individuals (SensitivePct) were below the statewide average at all of the stations besides one visit at station 00LM007 (Table 82). The abundance of darter species (DarterPct) were below the statewide average at stations 10EM087, 00LM007, and 11LM016. The abundance of simple lithophilic spawners (SLithopPct) were below the statewide average at all of the stations except station 00LM007 and 11LM012. The total taxa richness of fish species (TaxaCount) was below average at stations 10EM087, 00LM006, and 11LM016. All of the above mentioned metrics are expected to decrease in response to eutrophication stress. The percentage of tolerant individuals (TolPct), which are expected to increase in response to eutrophication stress, were above average at all of the stations except station 00LM007 and 11LM012. Station 10EM087 (near the middle of the AUID) and station 11LM016 (near the upper end of the AUID) were worse than the statewide average in all categories. Overall, a majority of the fish metrics were worse than the statewide average and suggestive of eutrophication stress.

Table 82. Fish metrics that respond to TP stress in Chub Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount
10EM087 (2010)	**0.0**	**11.4**	**25.7**	**79.1**	**15**
00LM006 (2000)	**1.2**	17.3	**23.9**	**61.3**	**15**
00LM007 (2000)	**8.2**	**10.4**	**22.8**	**54.7**	30
00LM007 (2011)	21.2	17.1	35.3	38.7	32
07LM017 (2007)	**0.6**	16.7	**27.4**	**72.4**	22
11LM012 (2011)	**5.9**	21.5	41.8	41.1	22
11LM016 (2011)	**0.0**	**8.7**	**13.0**	**79.4**	**13**
Southern Streams Average	*14.8*	*11.8*	*35.2*	*48.4*	*18.8*
Expected response to stress	↓	↓	↓	↑	↓

The robust data set includes numerous exceedances of the TP standard across multiple seasons and monitoring stations. This AUID is lacking BOD and chl-a data, but DO flux exceedances were identified during the 2014 field season. Low DO was also identified in Chub Creek. A majority of the macroinvertebrate and fish metrics are below average and suggestive of eutrophication stress. Phosphorus, which can be viewed as a proximate stressor, has the potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus in Chub Creek should be a priority in any future planning efforts. Reducing phosphorus loading should help the biology in Chub Creek, as well as its downstream receiving water (Lake Byllesby) which is impaired for aquatic recreation due to excess nutrients. Phosphorus appears to be playing a role, directly or indirectly, in the biota impairments in Chub Creek.

Dissolved Oxygen

DO data for Chub Creek contains 183 synoptic measures from 1999 – 2013 (minimum of 3.33 mg/L, maximum of 15.86 mg/L, and an average of 8.3 mg/L). Seven samples (4%) were below the warmwater standard of 5 mg/L. Condensing the data to look at the 96 samples over the most recent 10 years reveals similar results (minimum of 4.48 mg/L, maximum of 15.86 mg/L, and an average of 7.9 mg/L). Four

samples (4%) were below the standard. The data from 2004 – 2013 includes only five measurements that were collected prior to 9:00 a.m. Additional early morning measurements would increase the confidence in any conclusions made regarding DO as a stressor. The most recent decade of data is from nine different monitoring stations, with station S002-533 having the most measurements (64). Six of the stations had only one measurement. The exceedances occurred in June (two) and September (two), and were located in the middle and upper half of the AUID (stations S001-670 and S001-666). The upper end of this AUID contains Chub Lake and several wetland complexes likely impacting the DO levels downstream. The MPCA staff performed wetland monitoring in the Cannon River Watershed in 2014. Part of this monitoring included assessing natural background condition in regards to DO and the potential influence of wetlands. DO levels were monitored in a soil pit and the concurrent channel/wetland. The results for the site in the upper end of Chub Creek were 1.06 mg/L (soil pit) and 0.31 mg/L (channel/wetland). One of the general watershed wide conclusions from this work is that natural background influences from wetlands are not likely fully accounting for all of the low DO in the stream channel.

A longitudinal DO survey conducted in August 2014 resulted in five low DO values. Four of the values were located in the upper end of Chub Creek in or near wetland areas. The DO values in these locations ranged from 0.22 – 3.84 mg/L. The other low DO value (4.88 mg/L) was located near the middle of Chub Creek at the Arkansas Avenue road crossing (just downstream of station 10EM087).

There was no low DO observed during 2014 sonde deployment at station 00LM007 (near the mouth of Chub Creek). However, low DO was observed at station 10EM087 (near the middle of Chub Creek) approximately 26% of the time over an 11 day span with a minimum value of 2.3 mg/L. There was some rain that came through during the tail end of this deployment that appears to have resulted in an increase in flow and DO levels. There was no low DO observed in the upper end of Chub Creek at station 11LM016.

Total taxa richness of the macroinvertebrate community (TaxaCountAllChir) was below the statewide average at all of the stations in Chub Creek (Table 83). The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) was worse than average at station 11LM012 and 11LM016, and better than average at station 00LM007 and 10EM087. Taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) was below average at station 11LM012 and 11LM016, and above average at station 00LM007 and 10EM087. A measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN) was below average at station 00LM007, and at or above average at the remaining stations. TaxaCountAllChir and EPT are expected to decrease in response to stress while Tolerant2ChTxPct and HBI_MN are expected to increase.

There were multiple DO intolerant and very intolerant macroinvertebrate taxa present at all of the stations in Chub Creek. However, station 11LM016 near the upper end of the AUID, had no DO intolerant and very intolerant taxa during a replicate visit in 2011. Each station also had DO tolerant taxa present, ranging from one to five taxa. DO very tolerant taxa were present at all of the stations besides station 00LM007. The percentage of tolerant taxa ranged from 1 - 18%, and very tolerant ranged from 0 - 2%. The DO macroinvertebrate index scores were 7.5 (00LM007), 7.2 (11LM012), 7.1 (10EM087), 6.9

(11LM016), and 7.0 (11LM016). The scores for station 11LM012 and station 11LM016 were at or below the statewide average of stations meeting the MIBI threshold. As the score decreases, so does the low DO sensitivity of the community.

Table 83. Macroinvertebrate metrics that respond to low DO stress in Chub Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
00LM007 (2011)	**36**	69.4	13	6.7	7.5	15	7	1	0	0.7	0.0
11LM012 (2011)	**39**	**79.5**	**9**	7.1	7.2	**6**	**3**	4	1	3.9	0.3
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.1*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
10EM087 (2010)	**41**	70.7	11	**7.4**	7.1	8	4	4	2	12.0	1.7
11LM016 (2011)	**31**	**90.3**	**6**	**7.3**	**6.9**	**3**	**2**	4	2	**17.8**	1.3
11LM016 (2011)	**25**	**92.0**	**4**	7.1	7.0	**0**	**0**	5	1	11.0	1.8
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.1*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↑	↓	↓	↓	↑	↑	↑	↑

A majority of the fish metrics with strong relationships to DO were worse than the statewide average of stations meeting the FIBI threshold (Table 84). The taxa richness of sensitive species (Sensitive), relative abundance of individuals with a female mature age greater than three years (MA>3Pct), relative abundance of individuals that are serial spawning species (SSpnPct), relative abundance of individuals that are tolerant species (TolPct), and the total taxa richness of fish species (TaxaCount) were all worse than the statewide average at stations 10EM087, 00LM006, and 11LM016. Station 00LM007 had worse than average MA>3Pct, SSpnPct, and TolPct, and better than average sensitive species and overall taxa richness during the visit in 2000. In 2011, this station had worse than average MA>3Pct and SSpnPct, and better than average sensitive species, TolPct, and overall taxa richness. Station 07LM017 had worse than average sensitive species, SSpnPct, and TolPct, and better than average MA>3Pct and overall taxa richness. Station 11LM012 had worse than average sensitive species, MA>3Pct, and SSpnPct, and better than average TolPct and overall taxa richness. Sensitive species, MA>3Pct, and TaxaCount are expected to decrease in response to stress, while SSpnPct and TolPct are expected to increase. SSpnPct was worse than the statewide average at all of the stations in Chub Creek. In general, a majority of the fish metrics were worse than the statewide average throughout Chub Creek. The three stations where all of the metrics were worse than average are located in the middle – upper end of Chub Creek.

Table 84. Fish metrics that respond to low DO stress in Chub Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Sensitive	MA>3Pct	SSpnPct	TolPct	TaxaCount
10EM087 (2010)	**0**	**15.2**	**38.1**	**79.1**	**15**
00LM006 (2000)	**1**	**6.6**	**45.3**	**61.3**	**15**
00LM007 (2000)	7	**11.2**	**49.8**	**54.7**	30
00LM007 (2011)	9	**19.3**	**34.9**	38.7	32
07LM017 (2007)	**2**	25.8	**50.2**	**72.4**	22
11LM012 (2011)	**2**	**7.7**	**34.2**	41.1	22
11LM016 (2011)	**0**	**3.3**	**31.5**	**79.4**	**13**
Southern Streams Average	*4.6*	*22.6*	*29.5*	*48.4*	*18.8*
Expected response to stress	↓	↓	↑	↑	↓

In the synoptic measures dataset, longitudinal DO survey, and sonde deployments, there were low DO concentrations found in the middle and upper portions of Chub Creek. In addition, there was macroinvertebrate metric response corresponding to low DO stress in the middle and upper portions of the AUID (station 11LM012 and 11LM016), no DO intolerant macroinvertebrate species in the furthest upstream station (station 11LM016), and low DO tolerant macroinvertebrate percentages. Also, DO index scores at station 11LM012 and 11LM016, and a majority of the fish metrics were worse than average. Low DO is stressing the biological communities in the upper and middle reaches of Chub Creek. There are several wetland complexes in the headwaters portion of Chub Creek that are likely contributing to the lower DO concentrations observed in that part of the watershed.

TSS/Turbidity

The TSS data set has 207 samples from 1999 – 2013 (minimum of 1 mg/L, maximum of 205 mg/L, and an average of 28.3 mg/L). There are 25 samples (12%) that exceeded the South Region draft TSS standard of 65 mg/L. Similar values are present when looking at the data set from 2004 – 2013 (minimum of 1 mg/L, maximum of 205 mg/L, average of 26.2 mg/L, and a sample count of 104). Eleven of the samples (11%) during this timeframe were greater than the draft standard. Samples were collected from 10 different monitoring stations, with station S002-533 near the mouth having the highest number (60 samples). Samples from this station were collected from March – October in six different years. Nine of the eleven exceedances occurred at this station. Six stations had only one sample collected, and there were no samples collected on the very upper end of the AUID. June was the month with the greatest number of exceedances (five samples).

Transparency data for Chub Creek includes 517 samples from 1999 – 2013 (minimum of 5 cm, maximum of 100 cm, and an average of 53 cm). Four samples (0.8%) were less than 10 cm, the S-tube surrogate for the South Region TSS standard. As with TSS, transparency data from 2004 – 2013 has similar values (minimum of 5 cm, maximum of 100 cm, average of 56 cm, and a sample count of 334). There were four samples (1.2%) less than 10 cm. Samples were collected from 11 different monitoring stations. Station S002-533 has the greatest number of samples (218), and station S001-601 (near the middle of the AUID) has the second highest (71). Six of the stations had only one sample collected; a majority of these sites were the biological monitoring stations where one sample is collected during fish visits. Four of the

stations have samples from multiple years and seasons. Similar to TSS, June was the month with the greatest number of exceedances (four).

The macroinvertebrate metrics with strong relationships to TSS were both above and below the statewide average of stations meeting the MIBI threshold (Table 85). All of the stations except for the farthest upstream station (11LM016) had less than expected percentages of collector-filterers (Collector-filtererPct). There were no stoneflies (PlecopteraPct) present at any of the stations in Chub Creek. The percentage of collector-filterers and Plecoptera are reduced with increases in TSS stress. Overall, a majority of the macroinvertebrate metrics are suggestive of stress.

Although TSS intolerant taxa were present at all of the stations in Chub Creek (except for the replicate sample at station 11LM016), there were limited numbers of taxa ranging from 0-2. One TSS very intolerant taxa was also present at stations 00LM007, 11LM012, and 11LM016. All stations also had multiple TSS tolerant and very tolerant taxa, ranging from 6 – 15 and 2 – 7 respectively. TSS tolerant and very tolerant taxa comprised 24 - 47% and 2 - 28% of the macroinvertebrate community respectively. Station 11LM016, the farthest upstream station, had noticeably lower percentages of tolerant and very tolerant taxa. The macroinvertebrate TSS index scores were 18.6 (00LM007), 17.3 (11LM012), 18.6 (10EM087), 15.7 (11LM016), and 16.4 (11LM016); all of which (except for one of the visits at station 11LM016) were worse than the statewide average of stations meeting the MIBI threshold.

Table 85. Macroinvertebrate metrics that respond to TSS stress in Chub Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM012 (2011)	**24.9**	**0**	**17.3**	**1**	1	**12**	**7**	**40.1**	**21.0**
00LM007 (2011)	**16.9**	**0**	**18.6**	**2**	1	**13**	**7**	**45.4**	**28.0**
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
10EM087 (2010)	**14.6**	**0**	**18.6**	**1**	**0**	**15**	**5**	**46.5**	**17.2**
11LM016 (2011)	44.2	**0**	15.7	**1**	1	10	3	23.5	2.0
11LM016 (2011)	42.6	**0**	**16.4**	**0**	**0**	6	2	**29.0**	4.9
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

The fish metrics with strong relationships to TSS were above and below the statewide average of stations meeting the FIBI threshold (Table 86). Most of the metrics, however, were worse than the statewide average, and had values indicative of sediment related stress. This trend persists throughout Chub Creek, with the exception of the 2011 assessment at station 00LM007 near the mouth of Chub Creek. The relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), relative abundance of individuals that are sensitive species (SensitivePct), and relative abundance of individuals that are long-lived (LLvdPct) improved dramatically at this station from 2000 to 2011. All of the metrics at station 10EM087 and station 00LM006 were worse than the statewide average. Stations 00LM007 (2000), 11LM012, and 11LM016 had all but one metric that was worse than the statewide average. The relative abundance of individuals that are herbivore species (HrbNWQPct), and relative abundance of individuals that are riffle-dwelling species (RifflePct) were worse than average at all of the stations in Chub Creek. The fish TSS index scores were worse than the statewide average at all of the stations except 11LM016. A majority of the fish metrics have values suggestive of a stressed system.

Table 86. Fish metrics that respond to TSS stress in Chub Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
10EM087 (2010)	**21.9**	**0.0**	**15.2**	**0.0**	**2.9**	**12.4**	**15.2**	**0.0**	**14.3**	**19.5**
00LM006 (2000)	**9.5**	**0.0**	**4.1**	**1.2**	**0.0**	**17.3**	**4.1**	**1.2**	**6.6**	**21.8**
00LM007 (2000)	**21.0**	**0.6**	**8.8**	5.5	**5.3**	**11.4**	**14.1**	**8.2**	**10.8**	**24.1**
00LM007 (2011)	**23.1**	9.3	**12.3**	10.0	20.4	30.5	**16.7**	21.2	**10.0**	**20.8**
07LM017 (2007)	42.7	**0.0**	**22.6**	**0.6**	**4.0**	**16.7**	**22.8**	**0.6**	22.9	**20.1**
11LM012 (2011)	**12.9**	**0.3**	**8.9**	**0.7**	**6.9**	25.3	**9.2**	**5.9**	**4.5**	**18.1**
11LM016 (2011)	**9.8**	**0.0**	**1.1**	**0.0**	**0.0**	**8.7**	**1.1**	**0.0**	**3.3**	15.5
Southern Streams Average	*34.1*	*4.6*	*24.3*	*3.3*	*12.9*	*19.4*	*28.3*	*14.8*	*17.5*	*18.0*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Chub Creek has a fairly extensive TSS data set with approximately 11% exceedances of the draft standard over the past decade. Most of these exceedances occurred in the lower portion of Chub Creek. Transparency data is also abundant with minimal exceedances (approximately 1%). A majority of the macroinvertebrate metrics are worse than the statewide average. Both TSS tolerant and intolerant taxa are present, with good numbers of tolerant and very tolerant taxa in the middle - lower half of the AUID (stations 10EM087, 00LM007, and 11LM012). Also, the macroinvertebrate TSS index scores were worse than the statewide average at most stations. The fish metrics are suggesting stress, as most are worse than the statewide average. TSS is a stressor to the biota in Chub Creek, having more impact on the middle – lower portion.

Lack of Habitat

MSHA habitat scores for Chub Creek ranged from 44.3 (poor) – 72.4 (good) (Table 87). There were two poor scores (station 07LM017 and 11LM016), two fair scores (station 10EM087 and 11LM012), and one good score (station 00LM007). The habitat scores were poor – fair in the middle portion of Chub Creek, and good near the mouth. The two stations with poor scores had low land use scores, substrate scores, cover scores, and channel morphology scores.

Table 87. MSHA subcategory scores for Chub Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
07LM017	13-Aug-07	0	8.5	14	6	16	44.4 (Poor)
10EM087	02-Aug-10	0	13	20	13	20	66 (Fair)
11LM016	13-Sep-11	0	10	10	7	17	44.3 (Poor)
00LM007	10-Aug-11	3	13	19	13	24	72.4 (Good)
11LM012	11-Aug-11	1	3.5	20	13	21	58.4 (Fair)

The surrounding land use at the time of sampling varied between natural (forest, wetland, prairie, and shrub), residential/park, fenced pasture, and row crop. Riparian width ranged from none – extensive (>300 feet), and shade was none – heavy (>75%). Bank erosion ranged from none – moderate (25 – 50%). In general, there does not appear to be any obvious longitudinal differences in riparian width, shade, or bank erosion. However, the riparian width in the lower stations appears adequate, ranging from moderate – extensive.

During macroinvertebrate sampling, multiple habitats were sampled throughout Chub Creek. At station 10EM087, undercut banks, overhanging vegetation, and woody debris habitat types were sampled. Aquatic macrophytes and woody debris was sampled at station 11LM016. Habitat types at station 11LM012 included riffles, undercut banks, and overhanging vegetation. Station 00LM007 had riffles, undercut banks, overhanging vegetation, and woody debris habitat types. Undercut banks, overhanging vegetation, and macrophytes (emergent and submergent) were sampled at station 07LM017.

Station 11LM016 was 20% pool, 5% riffle, and 75% run (Figure 114). Pool substrates were sand and silt, riffle substrates were gravel and sand, and run substrates were sand and silt. There were more than four substrate types present, and substrate embeddedness was severe. Available cover types included overhanging vegetation, deep pools, logs or woody debris, and floating and submergent macrophytes; cover amount was sparse (5 – 25%). Channel sinuosity was good, channel stability was moderate, channel development was fair, pool width was greater than riffle width, and there were slow and moderate velocity types present.

Station 11LM012 was 20% pool, 10% riffle, and 70% run. Pool substrates were boulder and sand, riffle substrates were cobble and gravel, and run substrate was sand. There were more than four substrate types present, and substrate embeddedness was light. Available cover types included undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders, and submergent macrophytes; cover amount was moderate (25 – 50%). Channel sinuosity was excellent, channel stability was moderate, channel development was good, pool width was less than riffle width, and there were slow and moderate velocity types present (as well as eddies).

Station 10EM087 was 5% pool and 95% run; there were no riffle features present. Pool substrates were gravel and sand, and run substrates were also gravel and sand. There were more than four substrate types present, and substrate embeddedness was light. Available cover types included undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders, and rootwads; cover amount was moderate (25 – 50%). Channel sinuosity was good, channel stability was moderate, channel development was fair, and there were slow – fast velocity types present (as well as eddies).

Station 07LM017 was 10% pool, 5% riffle, and 85% run. Pool substrate was sand, riffle substrates were gravel and sand, and run substrates were gravel and sand. There were less than four substrate types present, and substrate embeddedness was severe. Available cover types included undercut banks, overhanging vegetation, and emergent and submergent macrophytes; cover amount was sparse (5 – 25%). Channel sinuosity was good, channel stability was moderate, channel development was fair, pool width was less than riffle width, and there were slow and moderate velocity types present (as well as eddies).

Station 00LM007 was 30% pool, 10% riffle, and 60% run. Pool substrates were gravel and clay, riffle substrates were gravel and sand, and run substrate was gravel. There were more than four substrate types present, and substrate embeddedness was light. Available cover types included undercut banks, overhanging vegetation, deep pools, logs or woody debris, rootwads, and emergent and submergent macrophytes; cover amount was moderate (25 – 50%). Channel sinuosity was excellent, channel stability was moderate, channel development was fair, pool width was greater than riffle width, and there were slow – fast velocity types present (as well as eddies).

Overall, minimal riffle features were present at the stations throughout this reach, ranging from 0% - 10%. Riffle substrates included cobble (one station), gravel (four stations), and sand (three stations). Run features dominated all sites, ranging from 60% - 95%. Run substrates were gravel (three stations), sand (three stations), and silt (one station). Pools were present at each station, ranging from 5% - 30%. Pool substrates included boulders (one station), gravel (two stations), sand (four stations), clay (one station), and silt (one station). Substrate embeddedness ranged from light – severe. Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders, rootwads, and macrophytes) were available, and cover amount was sparse (5 – 25%) to moderate (25 – 50%). Channel sinuosity was good – excellent, channel stability was moderate, channel development was fair – good, and multiple velocity types were present (slow – fast including eddies). In general, there was coarser substrate (gravel) and more cover (with the exception of station 07LM017) observed in the lower

stations. Substrate embeddedness (with the exception of station 07LM017) also appeared to decrease going downstream.

Figure 114. Station 11LM016 (9/13/11).

Macroinvertebrate metrics specific to habitat can help identify areas where habitat may be limiting the community (Figure 115 and Figure 116). Station 00LM007, near the mouth of Chub Creek, has burrowers, climbers, and clingers within an expected range. Legless and sprawlers are in the lower 25th percentile, while swimmers are in the upper 25th percentile. All of the habitat metrics at station 11LM012 are within the middle two quartiles except swimmers; swimmers are in the upper quartile. All the metrics at station 10EM087 are at or near the middle quartiles. Station 11LM016, near the upper end of Chub Creek, has an elevated percentage of legless and decreased sprawlers. Legless are expected to increase in response to habitat stress. Most of the other metrics are near or within the middle quartiles, with exception to clingers which were moderately elevated. The most abundant taxa at station 11LM016 included Rheotanytarsus (non-biting midges that are clingers), Polypedilum (non-biting midges that are climbers), Paratanytarsus (non-biting midges that are clingers), and Oligochaeta (worms that are burrowers); all of which are tolerant taxa. Station 00LM007 and station 11LM012 have below average climber MIBI metric scores, and station 11LM016 had a below average clinger MIBI metric score during one visit.

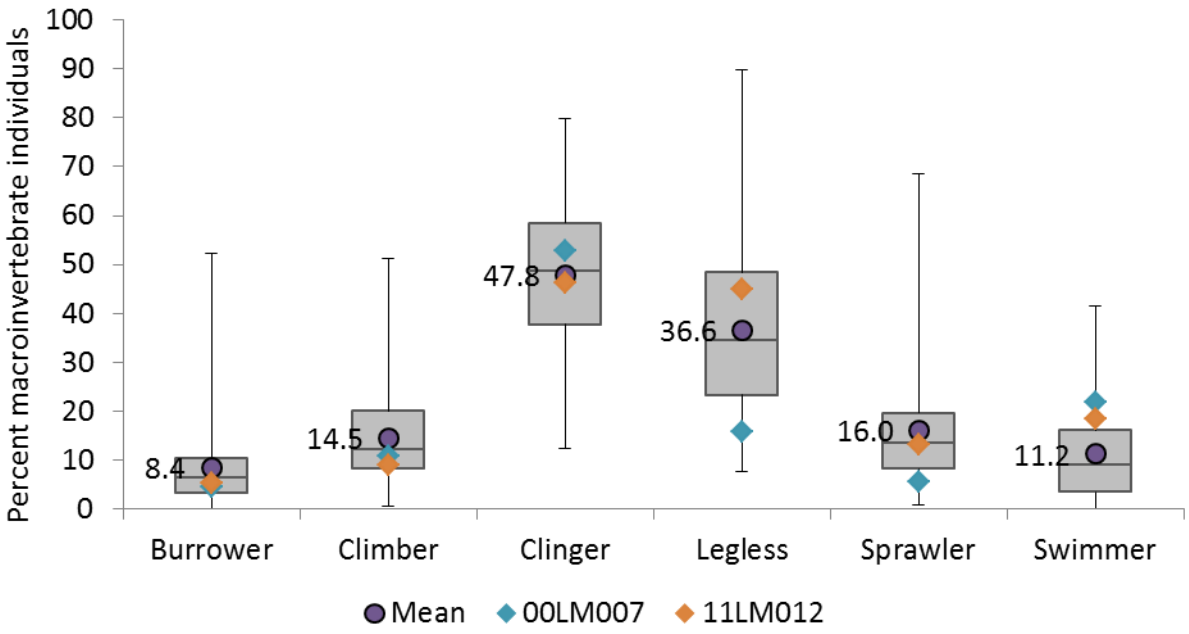


Figure 115. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Chub Creek Watershed stations.

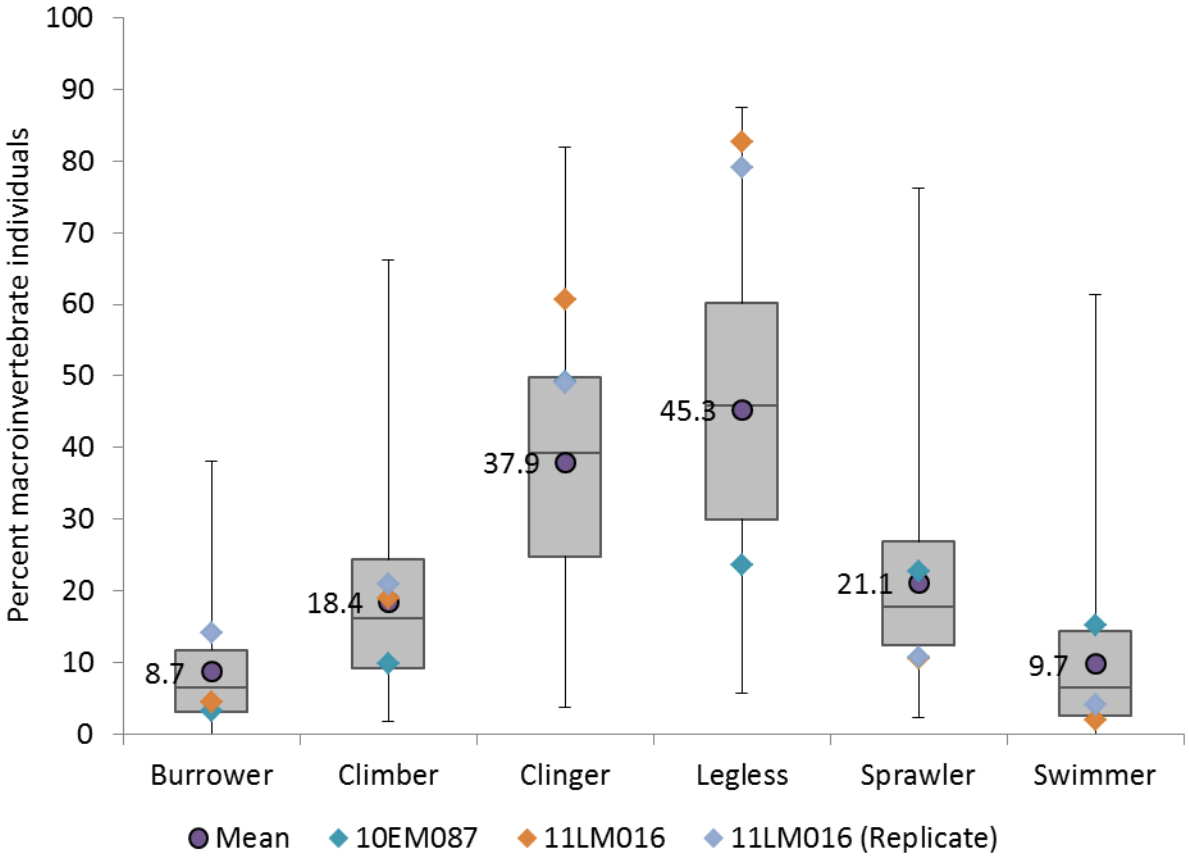


Figure 116. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Chub Creek Watershed stations.

Similar to the macroinvertebrate metrics, fish metrics can also help identify areas where habitat may be limiting. The following fish metrics for Chub Creek are discussed going from downstream – upstream (Table 88). During the 2000 fish visit, station 00LM007 had worse than average relative abundance of individuals that are tolerant species (TolPct), relative abundance of individuals that are benthic insectivore species (BenInsectPct), relative abundance of individuals that are lithophilic spawners (LithFrimPct), relative abundance of individuals that are darter, sculpin, and round bodied sucker species (DarterSculpSucPct), and relative abundance of individuals that are riffle-dwelling species (RifflePct). The relative abundance of individuals of the dominant two species (DomTwoPct) was better than the statewide average of stations meeting the FIBI threshold. For the 2011 fish visit, the only two metrics worse than the average at station 00LM007 were LithFrimPct and RifflePct. Station 07LM017 had worse than average TolPct, LithFrimPct, and RifflePct, and better than average BenInsectPct, DarterSculpSucPct, and DomTwoPct. Station 10EM087 had worse than average metric values for all metrics except BenInsectPct and DomTwoPct. Conversely, all of the metric values at station 11LM012 were better than average except for LithFrimPct and RifflePct. TolPct, LithFrimPct, and RifflePct were worse than the statewide average at station 00LM006, and all of the metrics at the farthest upstream station (11LM016) were worse than the statewide average. LithFrimPct and RifflePct were worse than the statewide average at all stations in Chub Creek; both are susceptible to siltation. Overall, the fish metrics had mixed results, but a majority of the metrics were worse than average at stations 00LM007 (2000), 10EM087, and 11LM016.

Table 88. Fish metrics that respond to habitat stress in Chub Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TolPct	BenInsectPct	LithFrimPct	DarterSculpSucPct	DomTwoPct	RifflePct
10EM087 (2010)	**79.1**	30.5	**42.9**	**11.4**	35.2	**15.2**
00LM006 (2000)	**61.3**	36.6	**30.0**	19.8	39.9	**4.1**
00LM007 (2000)	**54.7**	**19.6**	**24.7**	**13.7**	41.6	**14.1**
00LM007 (2011)	38.7	21.6	**42.4**	20.1	21.6	**16.7**
07LM017 (2007)	**72.4**	37.6	**29.3**	17.5	42.2	**22.8**
11LM012 (2011)	41.1	31.4	**48.5**	22.3	35.6	**9.2**
11LM016 (2011)	**79.4**	**19.6**	**13.0**	**10.9**	**60.9**	**1.1**
Southern Streams Average	*48.4*	*21.2*	*52.6*	*17.2*	*49.2*	*28.3*
Expected response to stress	↑	↓	↓	↓	↑	↓

Lack of habitat is a stressor in Chub Creek, and seems to be having greater impacts in the upper end (near station 11LM016). Station 11LM016 had a poor MSHA score, moderate bank erosion, primarily sand and silt substrate with severe embeddedness, elevated tolerant macroinvertebrates, and worse than average fish metric values.

Fish Passage

At this time, there are no known fish passage issues. A visual survey at all road crossings from the mouth of Chub Creek to just upstream of station 11LM016 (290th Street) was conducted on July 28, 2014, to confirm. Fish passage is not a stressor in Chub Creek.

pH

There was a pH value of 4.9 at station S001-668 (just below the North Branch Chub Creek confluence) in July of 2000. This is below the minimum pH standard of 6.5. This was the only exceedance in the data set; pH monitoring should be continued in the future to ensure the standard is being attained.

Conclusion

Chub Creek has many stressors at play, with the cumulative effects leading to impaired fish and macroinvertebrate communities. Elevated phosphorus, localized low DO (middle – upper portion), TSS (middle – lower portion), and habitat (upper portion) are stressors in Chub Creek. Phosphorus levels are extremely high (including during baseflows), and likely contributing to the low DO; the wetlands and Chub Lake are also likely contributing to the low DO conditions. It's inconclusive if nitrate is a stressor, and temperature and fish passage are not currently stressing the biota. Reducing nutrient and sediment loading in Chub Creek and improving in-stream habitat will benefit and improve the fish and macroinvertebrate communities.

Chub Creek 10-Digit HUC Summary

See Table 89 below for a stressor summary of the Chub Creek 10-digit HUC.

Table 89. Creek 10-digit HUC stressor summary (● = stressor, ○ = inconclusive stressor, blank = not a stressor).

Reach	AUID	Biological Impairment	Class	Stressors						
				Temperature	Nitrate	Phosphorus	DO	TSS	Habitat	Fish Passage
Chub Creek	528	Fish and Macroinvertebrates	2B		○	●	●	●	●	

4.5. Straight River 10-digit HUC

This section encompasses biotic impairments in the Straight River 10 – digit HUC (Figure 117). There are six AUIDs with biotic impairments; all AUIDs are impaired for lack of macroinvertebrate assemblage and Medford Creek also has a fish impairment. There are three AUIDs on the Straight River (which span from the mouth to Owatonna), and three AUIDs on tributaries. The tributaries include Medford Creek (from the headwaters to the mouth), an unnamed tributary to Maple Creek, and an unnamed tributary in the headwaters of the Straight River Watershed. All of these reaches are warmwater (2B) streams.

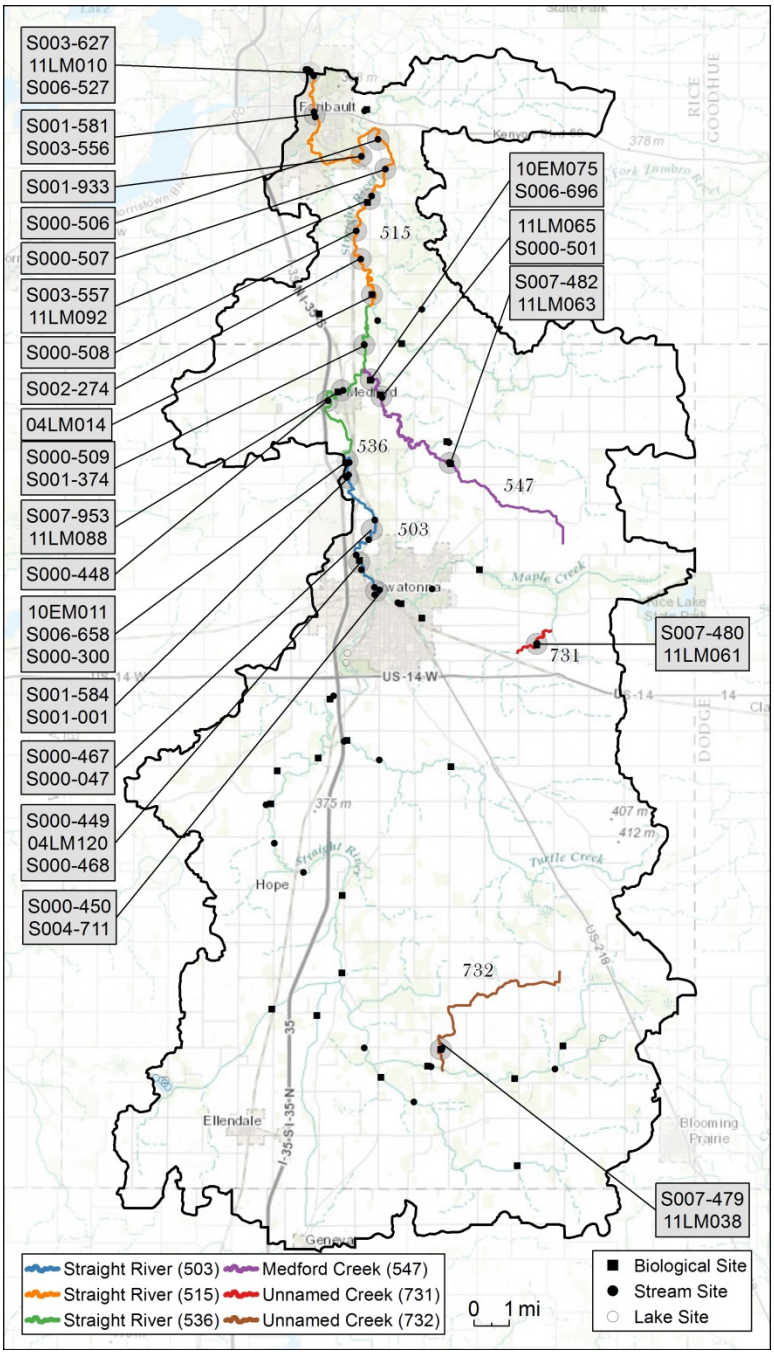


Figure 117. Map of the Straight River 10 digit HUC including biota impairments with biological stations and chemistry stations used in report.

4.5.1. Straight River (503)

Biological Communities

Straight River (07040002-503) is a 5.77 mile long stream segment starting in Owatonna at the mouth of Maple Creek, and ending just north of town at the confluence with Crane Creek. This is a warmwater reach with a macroinvertebrate impairment, as well as turbidity and fecal coliform. This AUID has two biological monitoring stations, 04LM120 and 10EM011. Station 04LM120 was sampled for fish and macroinvertebrates in 2004 and 2011. Station 10EM011 was sampled for fish and macroinvertebrates in 2010, and fish in 2011.

The fish community in this AUID is not currently impaired. The upstream and downstream AUIDs are also supporting for fish community assemblage. The fish IBI for station 04LM120 was 40 (2004) and 72 (2011), and station 10EM011 had scores of 45 (2010) and 69 (2011). The Southern Streams FIBI impairment threshold is 45 (lower CL – 36, upper CL – 54). There were 29 fish species collected at station 04LM120 in 2004 and 13 in 2011. The most abundant species collected in 2004 were green sunfish, white sucker, black bullhead, golden redhorse, and bluegill. The five most abundant species in 2011 were green sunfish, white sucker, northern hogsucker, common carp, and rock bass. Station 10EM011 had 26 fish species in 2010 and 2011. Fathead minnow, sand shiner, white sucker, johnny darter, and carmine shiner were the top five species in 2010, while northern hogsucker, carmine shiner, white sucker, sand shiner, and common carp were the top five in 2011. A complete list of the fish species collected can be found on the MPCA website.

The macroinvertebrate community is impaired, and not supporting the aquatic life use (Figure 118 and Figure 119). Macroinvertebrate IBI scores for station 04LM120 were 53.98 (2004) and 50.29 (2011), both above the Southern Forest Streams GP IBI impairment threshold (46.8). Clinger taxa richness, dominant five taxa relative abundance, Plecoptera, Odonata, Ephemeroptera, and Trichoptera taxa richness, total macroinvertebrate taxa richness, and the relative abundance of Trichoptera taxa had above average MIBI metric scores for both visits, which resulted in the good MIBI scores. Station 10EM011 scored 29.34 in 2010, below the Southern Streams RR IBI impairment threshold (35.9). This station had very poor taxa richness of climbers, stoneflies (Plecoptera), predators, and caddisflies (Trichoptera).

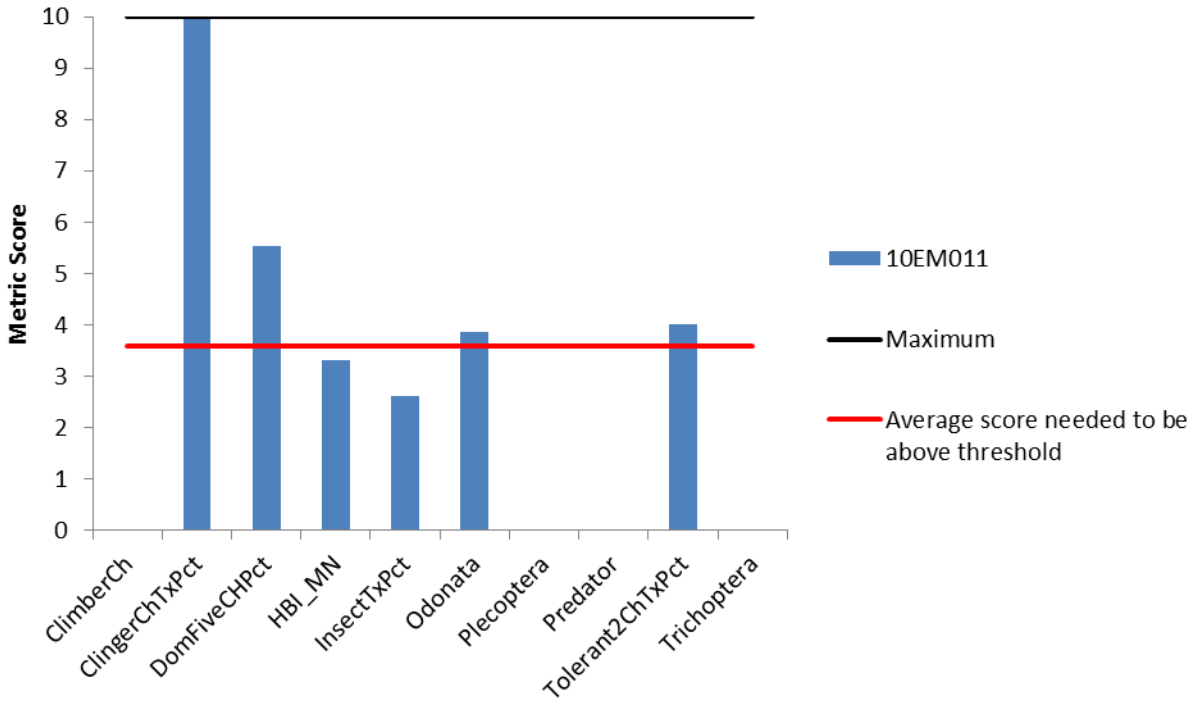


Figure 118. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for the Straight River (07040002-503), station 10EM011.

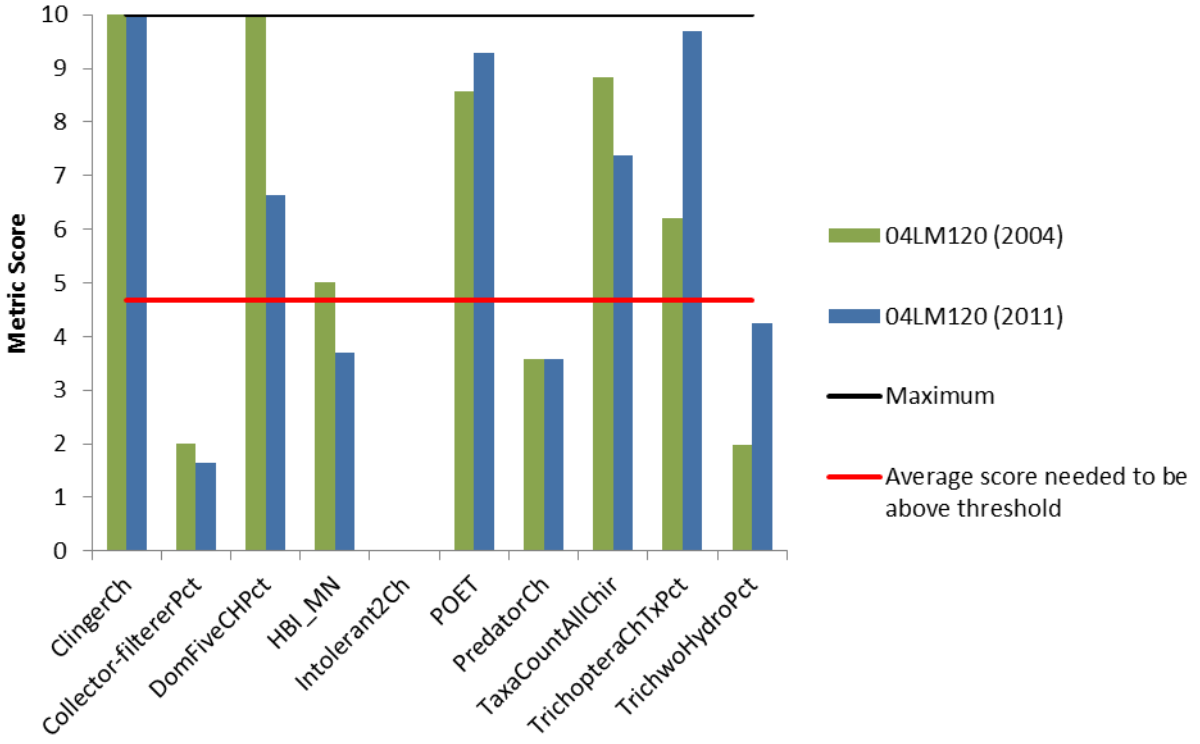


Figure 119. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for the Straight River (07040002-503), station 04LM120.

Data Evaluation for each Candidate Cause

Temperature

Temperature data for this AUID consisted of 934 records from 1955-2013. The maximum temperature recorded for this time period was 27.8 °C (average of 15.5 °C). Results for the previous 10 years (2004 – 2013) have similar values, with the highest temperature observed being 27.4 °C (average of 16.4 °C). These 582 samples over the last decade were collected from seven stations, with a majority taken in the middle – upper portion on the AUID. Biota in warmwater streams typically don't experience stress until temperatures approach 30 °C (acute warmwater standard). Temperature is not a stressor in this reach.

Nitrate

The nitrate data set contained 405 samples from 1976-2013 (minimum of 0.1 mg/L, maximum of 16.0 mg/L, and an average of 5.1 mg/L). Samples over the last decade (2004-2013) have similar results; these 195 samples ranged from 0.3 - 14.0 mg/L (average of 5.5 mg/L) (Figure 120). These samples were collected from six stations, with a majority taken in the middle – upper end of the AUID. There were 15 samples (8%) that exceeded 10 mg/L; these elevated concentrations occurred in April (five), May (five), June (four), and July (one). Approximately 22% (43 samples) of the samples collected from 2004-2013 were greater than 8 mg/L.

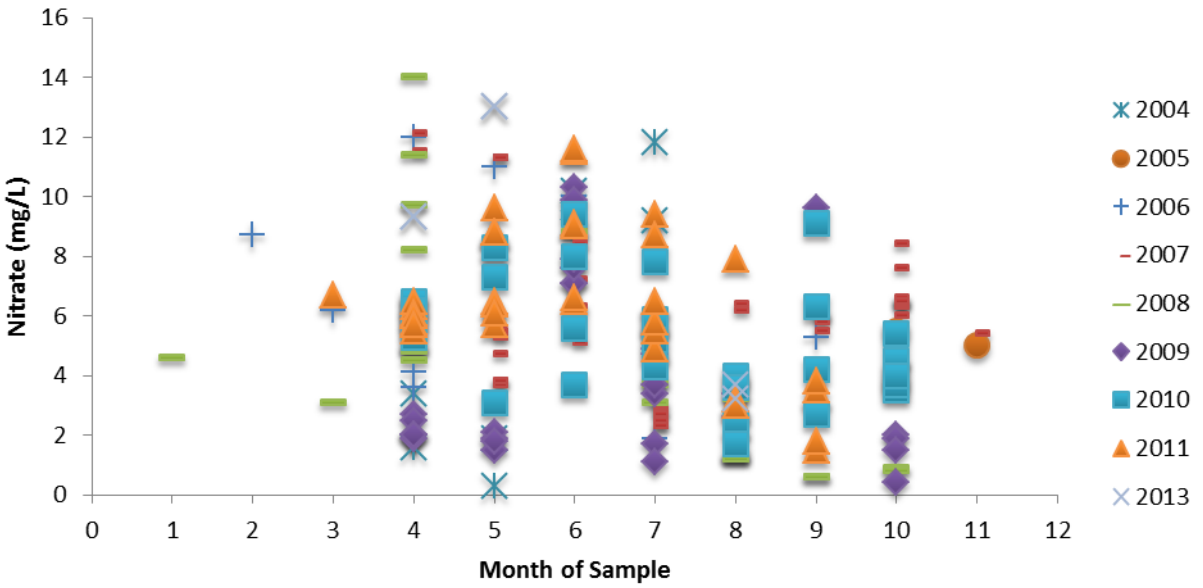


Figure 120. Nitrate concentrations in the Straight River by month sampled.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are all below the statewide average of stations meeting the MIBI

threshold at station 10EM011 (Table 90). Station 04LM120 had below average TrichwoHydroPct and Intolerant2Ch in 2004 and 2011. TrichwoHydroPct and Intolerant2Ch were below average at all stations. Trichoptera (caddisfly) taxa richness is greater at station 04LM120. All of these metrics are expected to decrease in response to stress. Overall, a majority of these metrics have values indicative of stress.

During two visits at station 04LM120, zero and one nitrate intolerant taxa were present. The same visits yielded 21 (70%) and 25 (58%) nitrate tolerant taxa, including 14 and 16 very tolerant taxa. Station 10EM011 had no nitrate intolerant taxa, and 12 nitrate tolerant taxa (68%). It also included nine very tolerant taxa. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. The nitrate index scores were 3.2 (10EM011), and 3.1 and 3.3 (04LM120), which are above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 90. Macroinvertebrate metrics that respond to nitrate stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
10EM011 (2010)	**2**	**0.0**	**0**	**3.2**	**0**	**0**	12	9	**68.1**	**50.7**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
04LM120 (2004)	5	**0.6**	**0**	**3.1**	***1***	***0***	***25***	***16***	***58.3***	*37.6*
04LM120 (2011)	6	**1.9**	**0**	**3.3**	***0***	***0***	***21***	***14***	***69.7***	***64.1***
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

This segment of the Straight River has elevated nitrate concentrations, a majority of the macroinvertebrate metrics are worse than average, and there are minimal nitrate intolerant taxa. In addition, there are multiple nitrate tolerant taxa that comprise a high percentage of the overall community, and the nitrate index scores were worse than the statewide average. Nitrate is stressing the macroinvertebrate community.

Phosphorus

The phosphorus (TP) data set for this AUID includes 557 samples from 1958 – 2013. The range of concentrations over this time period is 0.01-6.78 mg/L, with the average being 0.351 mg/L. The draft river eutrophication criterion for the South Region is 0.150 mg/L. The range for the 288 samples collected over the last decade (2004-2013) is 0.01-1.03 mg/L, with the average concentration being 0.230 mg/L. Most of these samples were collected in the middle – upper portion of the AUID. A total of

206 (72%) samples exceeded the draft standard over the past 10 years. Most of these exceedances were associated with low TSS concentrations, implying low flow conditions (Figure 121). The Owatonna WWTP, which discharges to the upper end of this AUID, recently implemented upgrades targeting phosphorus removal. The following statement was taken from the draft Byllesby Reservoir Phosphorus TMDL Report (2013): "The three most significant municipal point source dischargers of phosphorus (Faribault, Northfield and Owatonna) have completed capital improvements and taken on further maintenance costs to address phosphorus removal". Data from 2012 and 2013 (the years after the upgrades were implemented) included 74 (80%) samples that exceeded the draft standard. Similar to the pre-upgrade exceedances, most were associated with low TSS concentrations (Figure 122). This implies that elevated phosphorus is not just being flushed through the system attached to sediment particles during storm flows, but that it is also available to the aquatic life and vegetation during low flow conditions.

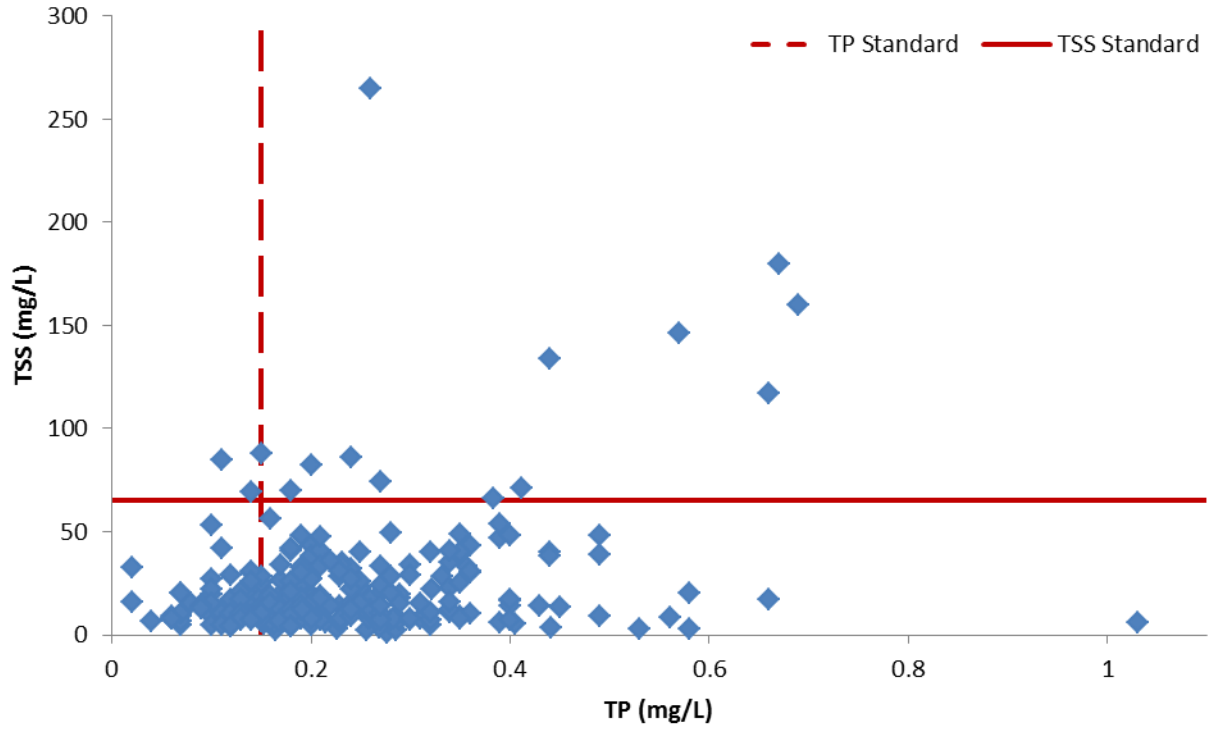


Figure 121. TSS and TP relationship in the Straight River - 503 (2004-2013).

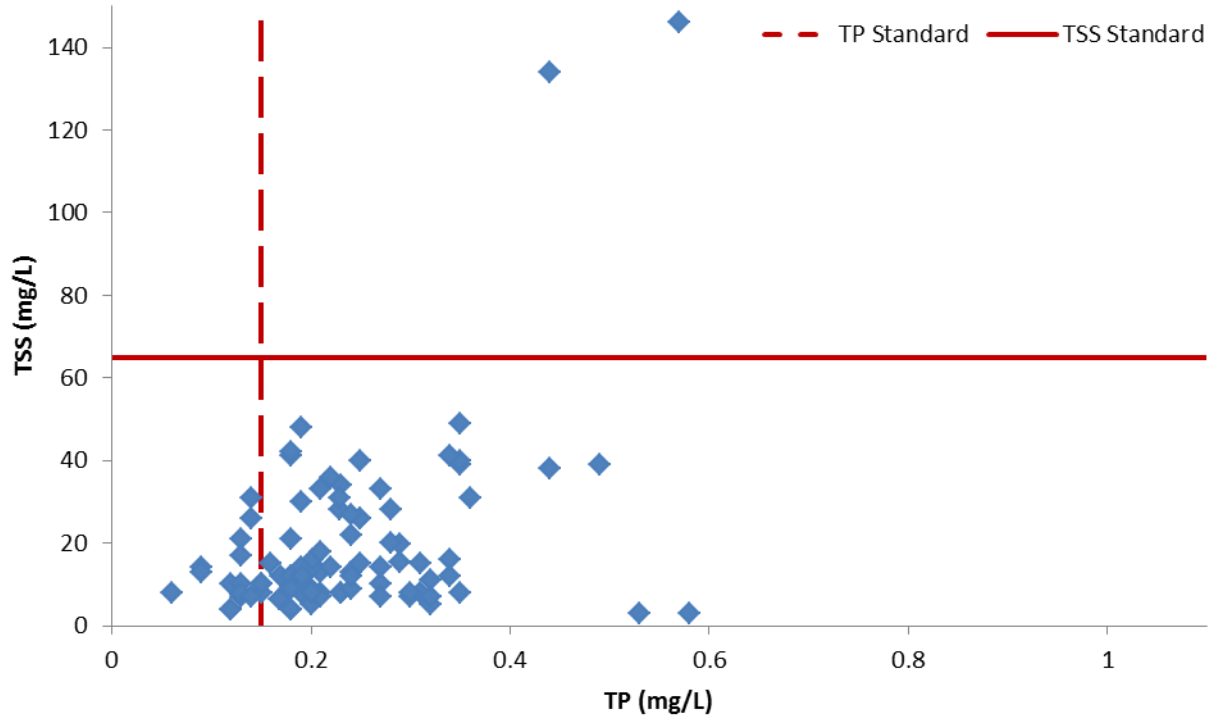


Figure 122. TSS and TP relationship in the Straight River – 503, post Owatonna WWTP upgrades (2012-2013).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. There have been 49 chlorophyll-a samples collected from 1977-2008 (minimum of 0.6 µg/L, maximum of 41.1 µg/L, and an average of 10.6 µg/L). Only one sample from this data set exceeded the South Region draft river eutrophication standard (35 µg/L); this sample was 41.1 µg/L (8/29/1984). Of the nine samples collected most recently (2006-2008), zero exceeded the standard (minimum of 1.9 µg/L, maximum of 10.7 µg/L, and an average of 4.7 µg/L). A total of 259 BOD samples have been collected from 1955 – 2008 (minimum of 0.5 mg/L, maximum of 32.0 mg/L, and an average of 4.2 mg/L). Approximately 51% (133 samples) of these samples exceeded the draft river eutrophication standard for the South Region (3.0 mg/L). The most recent BOD samples were collected in 2006 and 2008 (four samples each year), and the average value was 1.6 mg/L. One sample exceeded the draft standard on July 19, 2006 (6.4 mg/L). Limited DO flux information is available; there were no flux exceedances during a longitudinal DO survey in the summer of 2014. At this time, there is no continuous DO data available. Additional chl-a, BOD, and DO flux monitoring is recommended.

The total taxa richness (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of collector-gatherers (Collector-gathererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch), and the percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) were all worse than the statewide average of stations meeting the MIBI threshold at station 10EM011 (Table 91). Station 04LM120 had worse than average Intolerant2Ch and Tolerant2ChTxPct in 2004, and worse than average TaxaCountAllChir, Intolerant2Ch, and Tolerant2ChTxPct in 2011. Intolerant2Ch and Tolerant2ChTxPct were worse than average at all stations. All of these metrics besides Tolerant2ChTxPct are expected to decrease in response to stress. Overall,

the macroinvertebrate metrics are a little mixed, and there may be some longitudinal differences with regards to total taxa richness, collector-gatherers, and EPT.

Table 91. Macroinvertebrate metrics that respond to TP stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
10EM011 (2010)	**24**	**6**	**9**	**5**	**0**	**75.0**
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
04LM120 (2004)	44	7	18	11	**0**	**84.1**
04LM120 (2011)	**41**	7	16	10	**0**	**82.9**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

This robust data set includes extremely elevated phosphorus concentrations, with a majority exceeding the draft standard; exceedances occurred during various flows. Chlorophyll-a and BOD exceedances have been documented, but minimal samples have been collected recently. No DO flux exceedances have been documented, but the data set is limited and doesn't include any continuous data. All of the macroinvertebrate metrics at the downstream station (10EM011) were worse than the statewide average, but the metrics at the upstream station (04LM120) were a little more mixed. Overall, it appears that phosphorus has the potential to be a stressor in the Straight River, but at this time it's inconclusive due to limited recent data for the response variables. Additional chl-a, BOD, and DO flux information is necessary to determine if the elevated phosphorus levels are causing eutrophic conditions. Although inconclusive at this time, reducing phosphorus in the Straight River should be a priority in any future planning efforts. Phosphorus has the potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus loading should help (and/or protect from potential future impacts) the biology in the Straight River.

Dissolved Oxygen

DO data consists of 342 samples from 1955 – 2013 (minimum of 1.8 mg/L, maximum of 17.0 mg/L, and an average of 8.8 mg/L). Seventeen (5%) samples were below the warmwater standard of 5 mg/L. However, all results (45 samples) within the last 10 years were above the standard (minimum of 5.9 mg/L, maximum of 15.0 mg/L, and an average of 9.3 mg/L). Most of these samples were collected near the middle of the AUID, and they were collected from January – November.

There were no DO concentrations below 5 mg/L during a longitudinal DO survey in late summer of 2014. No sondes were deployed in this AUID, so there is no continuous data available.

The total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) were all worse than the statewide average at station 10EM011 (Table 92). This station is located at the downstream end of the AUID, just upstream of the Crane Creek confluence. This station, which was sampled in 2010, had very low overall taxa richness (24) and EPT taxa richness (5). Station 04LM120, located on the upper end of the AUID and just downstream of Owatonna, was sampled in 2004 and 2011. The macroinvertebrate metric results were similar in 2004 and 2011. TaxaCountAllChir was better than average in 2004, and just slightly below average in 2011. Tolerant2ChTxPct was worse than average in both years, while EPT was better than average in both years. Stressed streams often have reduced overall taxa richness and taxa richness of EPT, and increased tolerant taxa.

There were DO intolerant and very intolerant taxa present at both stations. Station 04LM120 had seven DO intolerant taxa present in 2004 and eight in 2011. There were four DO very intolerant taxa present both years. Station 10EM011 had seven DO intolerant taxa present in 2010, and three DO very intolerant taxa. Both stations had low numbers of DO tolerant taxa. Station 04LM120 had 7 – 8% DO tolerant taxa, and 1 – 3% DO very tolerant taxa. Station 10EM011 had zero DO tolerant or very tolerant taxa. The macroinvertebrate DO index score was 7.1 and 7.2 at station 04LM120, and 7.6 at station 10EM011. These scores are above the statewide average of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 92. Macroinvertebrate metrics that respond to low DO stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
10EM011 (2010)	**24**	**75.0**	**5**	7.6	**7**	**3**	0	0	0.0	0.0
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
04LM120 (2004)	44	**84.1**	11	7.1	7	4	4	1	8.4	1.2
04LM120 (2011)	**41**	**82.9**	10	7.2	8	4	4	1	7.2	**3.0**
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

There have been no low DO readings (< 5 mg/L) in the last decade, and no low DO was identified during the longitudinal DO survey in 2014. The macroinvertebrate metrics show more stress at the downstream station (10EM011), but that stress does not appear to be DO driven. There were several DO intolerant and very intolerant taxa present at all stations in various years (2004, 2010, and 2011). Both stations had

low DO tolerant and very tolerant percentages, and above average DO index scores. Based on the existing data, DO is not a stressor in this AUID.

TSS/Turbidity

This 5.77 mile long stream segment is currently listed for turbidity. A total of 554 TSS samples have been collected from 1956-2013 (minimum of 0.5 mg/L, maximum of 265 mg/L, and an average of 26.8 mg/L). Statistics on more recent data (2004-2013) include a range of concentrations from 1.2 – 265 mg/L (average of 24.2 mg/L). These samples were collected from seven stations, with a majority taken from the middle – upper sections of the AUID. Of the recent 276 samples, 16 (6%) were greater than 65 mg/L, the proposed draft TSS standard for the South Region. Exceedances have been documented in all portions of the AUID, and they occurred in March (one), May (one), June (ten), and July (four). Transparency values over that same 10-year span ranged from 3-100 cm (average of 48 cm). Approximately 2% of the 614 measurements fell below 10 cm, the South Region S-tube surrogate for the TSS standard. These exceedances occurred in the middle – upper portions of the AUID in April (two), May (two), June (five), July (two), and October (two).

The relative abundance of collector-filterer individuals (Collector-FiltererPct) at station 10EM011 was above the statewide average of stations meeting the MIBI threshold (Table 93). The relative abundance of Plecoptera individuals (PlecopteraPct) was below the statewide average. Station 04LM120 had below average Collector-FiltererPct and PlecopteraPct. Metric values were similar in 2004 and 2011. Both of these metrics are expected to decrease in response to stress. Collector-filterers were significantly more abundant in the lower portion of the AUID (station 10EM011), and very few stoneflies (Plecoptera) were present throughout the AUID. Overall, a majority of the macroinvertebrate metrics had values indicative of stress.

Station 10EM011 and 04LM120 had zero TSS intolerant and very intolerant taxa present. These stations, however, did have TSS tolerant (7 -15) and very tolerant (3 - 7) taxa present. TSS tolerant and very tolerant taxa comprised 37% - 68% and 8% - 34% of the macroinvertebrate community respectively. The macroinvertebrate TSS index scores were 17.7 (10EM011) and 19.4 and 20.1 (04LM120), which are above the statewide average of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 93. Macroinvertebrate metrics that respond to TSS stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
10EM011 (2010)	43.6	**0.0**	**17.7**	**0**	**0**	7	3	**36.8**	8.2
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
04LM120 (2004)	**7.8**	**0.3**	**19.4**	**0**	**0**	**15**	**7**	**51.9**	**34.3**
04LM120 (2011)	**6.5**	**0.0**	**20.1**	**0**	**0**	**12**	**6**	**68.1**	**20.4**
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can still help inform the SID process. Station 10EM011 was sampled in 2010 and 2011; metric values improved from 2010 to 2011. All of the metrics in 2010 were worse than the statewide average of stations meeting the FIBI threshold (Table 94). In 2011, the relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct) and TSS index score were the only metrics worse than the statewide average. Station 04LM120 was sampled in 2004 and 2011; metric values improved from 2004 to 2011. In 2004, all of the metrics besides the relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are long-lived (LLvdPct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were worse than the statewide average. In 2011, all of the metrics besides the relative abundance of individuals that are intolerant species (IntolerantPct) and the TSS index score were better than the statewide average. All of these metrics except for the TSS index score are expected to decrease in response to stress. The TSS index score was worse than average during all visits. Overall, a majority of metric values at both stations prior to 2011 were indicative of stress; conversely, a majority of metric values at both stations were indicative of a healthy system in 2011.

Table 94. Fish metrics that respond to TSS stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RiffflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
10EM011 (2010)	**14.2**	**1.7**	**13.9**	**1.3**	**2.2**	**9.6**	**11.5**	**9.9**	**7.1**	**20.9**
10EM011 (2011)	39.6	6.6	51.8	5.1	32.7	**14.6**	37.5	51.8	31.3	**20.8**
04LM120 (2004)	**26.4**	10.3	**16.3**	**2.4**	14.6	**12.5**	**14.4**	**7.7**	24.9	**21.1**
04LM120 (2011)	39.6	11.7	35.1	**2.6**	27.9	20.8	35.1	27.3	38.3	**20.2**
Southern Streams Average	*34.1*	*4.6*	*24.3*	*3.3*	*12.9*	*19.4*	*28.3*	*14.8*	*17.5*	*18.0*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

The DNR recently (2010) performed a geomorphic assessment of the Straight River, with one of the goals being able to provide a general estimate of bank erosion rates by reach (Figure 123). One of the reaches sampled for this assessment was from the Owatonna Dam to County Road 45. A majority of this AUID (Straight-503) is located within this reach. The following excerpt is from the geomorphology sampling summary document provided by the DNR as it pertains to this reach:

> *"The next reach below this site extends from the Owatonna Dam to county road 45. Through this 6.8 mile reach the stream channel varied in classification between a B4, C4 to an F4 channel classifications. The stream banks are generally well armored artificially or with a natural bedrock layer seen in various sections throughout this reach. This natural armoring has suppressed channel sinuosity allowing the channel classification to change depending on the stream slope, sinuosity, width/depth ratio, bank height and natural bedrock controls. The upper half of this reach has very limited bank erosion contribution sources and the channel is generally a B4 channel. The lower half of the reach has an old abandon mill site. The historical sediments created by the previous reservoir show considerable bank erosion from the fine silt soil deposits. Impacts of this mill extend for a considerable distance upstream of the site."*

The summary document also noted that "the upper part of this reach has considerable impacts from the city of Owatonna by confining the floodplain, storm water discharge, Maple Creek discharge, contracted bridge openings, and the city WWTP discharge." The pictures below were taken by the DNR during sampling, and depict some of the bank erosion issues (Figure 124).

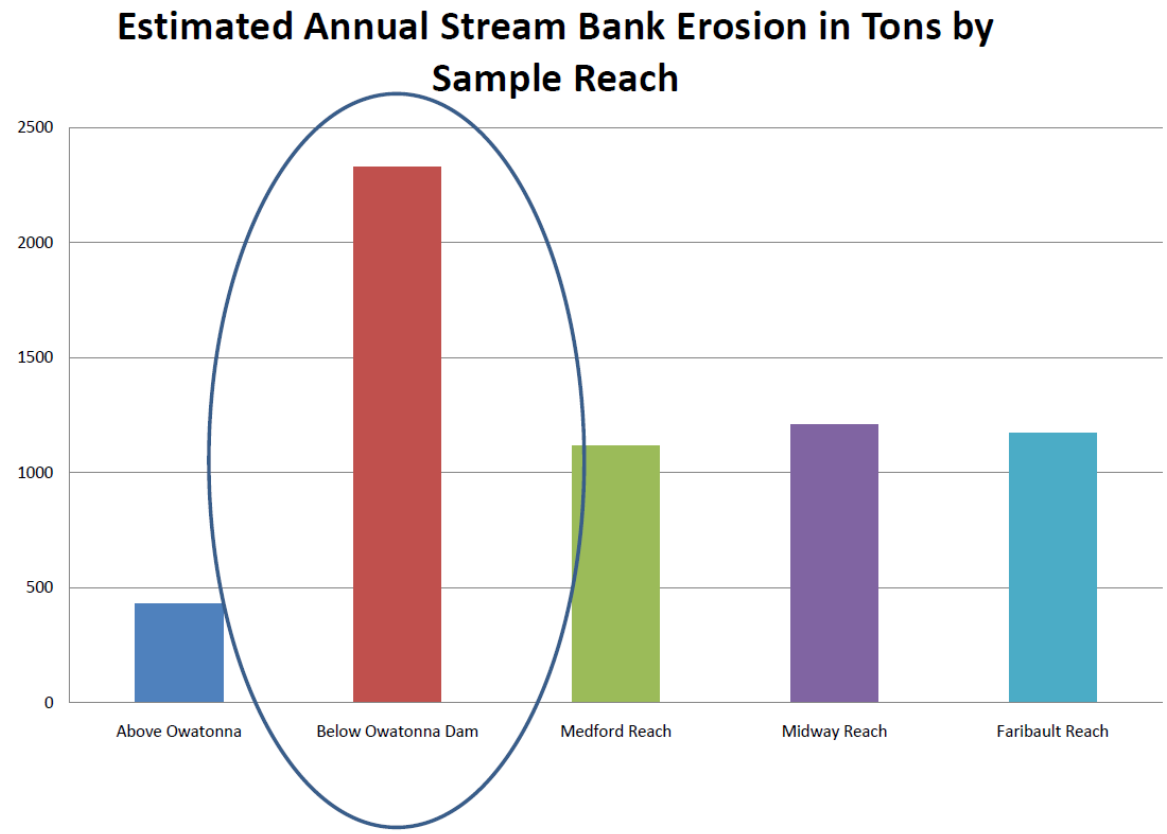


Figure 123. Annual stream bank erosion estimates by sample reach. The graph above was produced by the DNR.

Figure 124. Bank erosion in the Straight River (503). The photos above were taken from the Straight River Geomorphology Sampling Summary provided by the DNR.

This segment of the Straight River is currently impaired for turbidity. TSS and transparency exceedances have been documented throughout the AUID, but the number of exceedances is relatively low. A majority of the macroinvertebrate metrics were worse than average, but the fish metrics were a little mixed. There were no macroinvertebrate TSS intolerant taxa and multiple TSS tolerant and very tolerant taxa. Also, the macroinvertebrate and fish TSS index scores were worse than the statewide average. TSS/turbidity is not the only stressor at play in this AUID, but it is a stressor and contributing to the macroinvertebrate impairment.

Lack of Habitat

The MSHA is calculated by looking at five different categories (land use, riparian zone, substrate, cover, and channel morphology). MSHA scores for station 04LM120 were 53 (fair) in 2004 and 34.5 (poor) in 2011. The MPCA biologists noted that a major shift in substrate composition occurred between 2004 and 2011; from cobble and gravel to sand and silt. This change is evident in the substrate component scores of the MSHA (Table 95). Station 10EM011 scored 73.85 (good) in 2010 and 72.05 (good) in 2011. The MSHA scores were better at the downstream station (10EM011), and worse at the upstream station (04LM120) near the city of Owatonna. This is in large part due to the channel morphology scores.

Table 95. MSHA subcategory scores for the Straight River.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
04LM120	29-Jun-04	5	11	20	9	8	53 (Fair)
04LM120	16-Aug-11	5	8.5	10	6	5	34.5 (Poor)
10EM011	21-Jul-10	1.8	12.5	20.6	11	28	73.9 (Good)
10EM011	17-Aug-11	1.8	11	21.3	8	30	72.1 (Good)

The surrounding land use at the time of sampling for station 10EM011 was classified as residential/park and row crop on the left bank, and forest, wetland, prairie, shrub, and row crop on the right bank. Riparian width ranged from moderate (30 – 150 feet) to extensive (>300 feet), and shade was substantial (50 – 75%). Bank erosion ranged from none – moderate (25 – 50%). Habitats sampled for macroinvertebrates at station 10EM011 included riffles, woody debris, and overhanging cover. Pool habitats represented 10% - 15% of the station. Pool substrates were cobble, gravel, and sand. Riffle features comprised 30%, and included cobble and gravel substrates. Run features dominated at 55% - 60%, and consisted of cobble, gravel, and sand substrates. Light embeddedness was observed, and greater than four substrate types were present. Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders, and rootwads) were available, and cover amount was sparse (5 – 25%) to moderate (25 – 50%) (Figure 125). This AUID had good sinuosity, good depth variability, good – excellent channel development, moderate – high channel stability, multiple velocity types (slow – fast including eddies), and pool width was greater than riffle width.

The surrounding land use at the time of sampling for station 04LM120 was classified as forest, wetland, prairie, and shrub. Riparian width ranged from narrow (15 – 30 feet) to extensive (>300 feet), and shade was substantial (50 – 75%). Bank erosion ranged from moderate (25 – 50%) to heavy (50 – 75%). Habitats sampled for macroinvertebrates at station 04LM120 included rock and woody debris. Run features comprised the entire station length, and consisted of cobble and gravel substrate in 2004 and sand and silt in 2011. Moderate – severe embeddedness was observed, and greater than four substrate types were present. Multiple cover types (overhanging vegetation, logs or woody debris, and boulders) were available, and cover amount was sparse (5 – 25%) to moderate (25 – 50%). This AUID had poor sinuosity, poor channel development, moderate channel stability, and slow – moderate velocity types. The greatest depth was less than two times the shallowest depth in 2011, and two to four times the shallowest depth in 2004.

Figure 125. Station 04LM120 (August 16, 2011) and station 10EM011 (August 17, 2011).

Station 10EM011 had above average burrowers and clingers, and below average climbers, legless, sprawlers, and swimmers (Figure 126). Station 04LM120 had above average burrowers, clingers, and legless, and below average climbers, sprawlers, and swimmers in 2004 (Figure 127). In 2011, burrowers, climbers and legless were above average, and clingers, sprawlers, and swimmers were below average. In general, burrowers and legless are expected to increase in response to habitat stress, while climbers and clingers are expected to decrease. The climber MIBI metric score for station 10EM011 was zero, well below the average metric score (3.59) needed to meet the MIBI threshold. In contrast, the clinger MIBI metric score was 10, well above the average. The clinger MIBI metric scores at station 04LM120 were also 10, the maximum score possible. Station 10EM011 had good taxa diversity, with the top three taxa being Baetis (mayflies), Cheumatopsyche (caddisflies), and Pisidiidae (clams). The 2004 visit at station 04LM120 had good taxa diversity, while the 2011 visit was dominated by Polypedilum (non-biting midges).

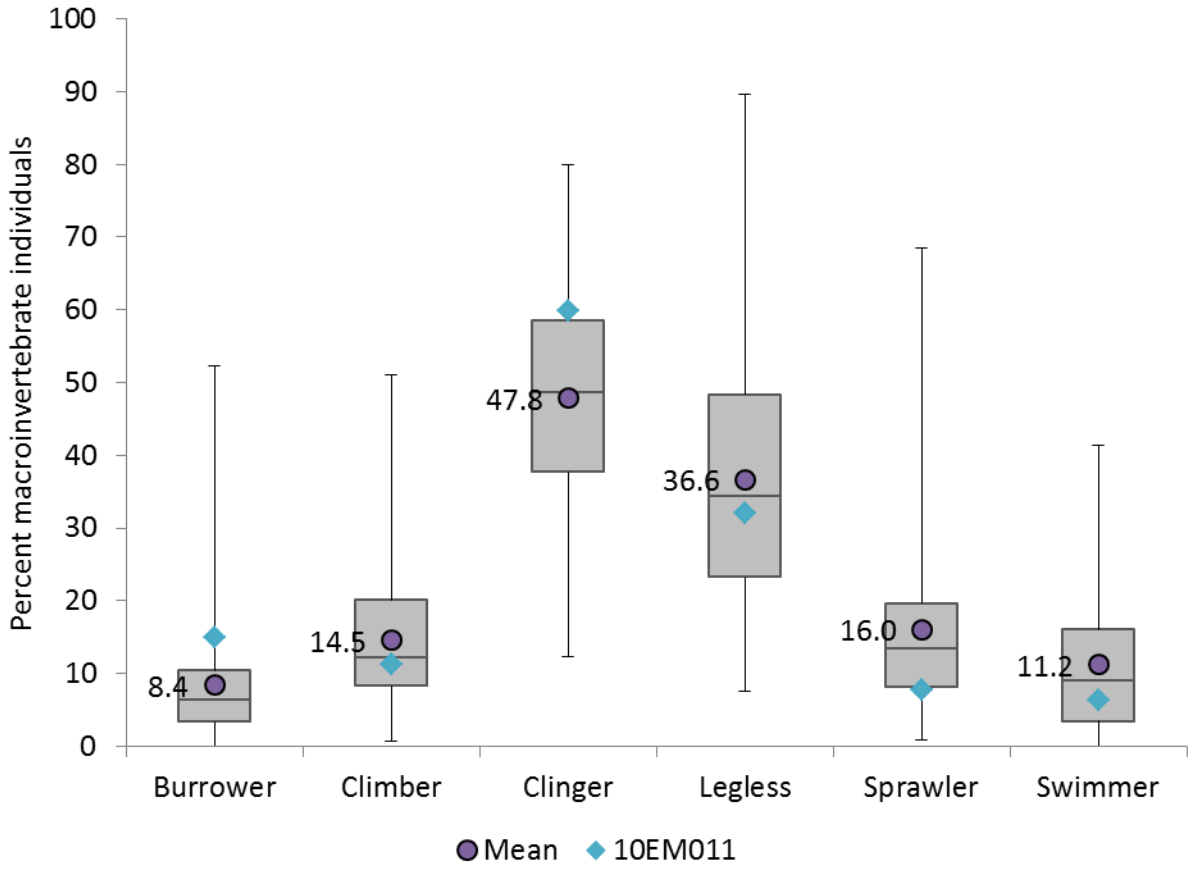


Figure 126. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Straight River Watershed stations.

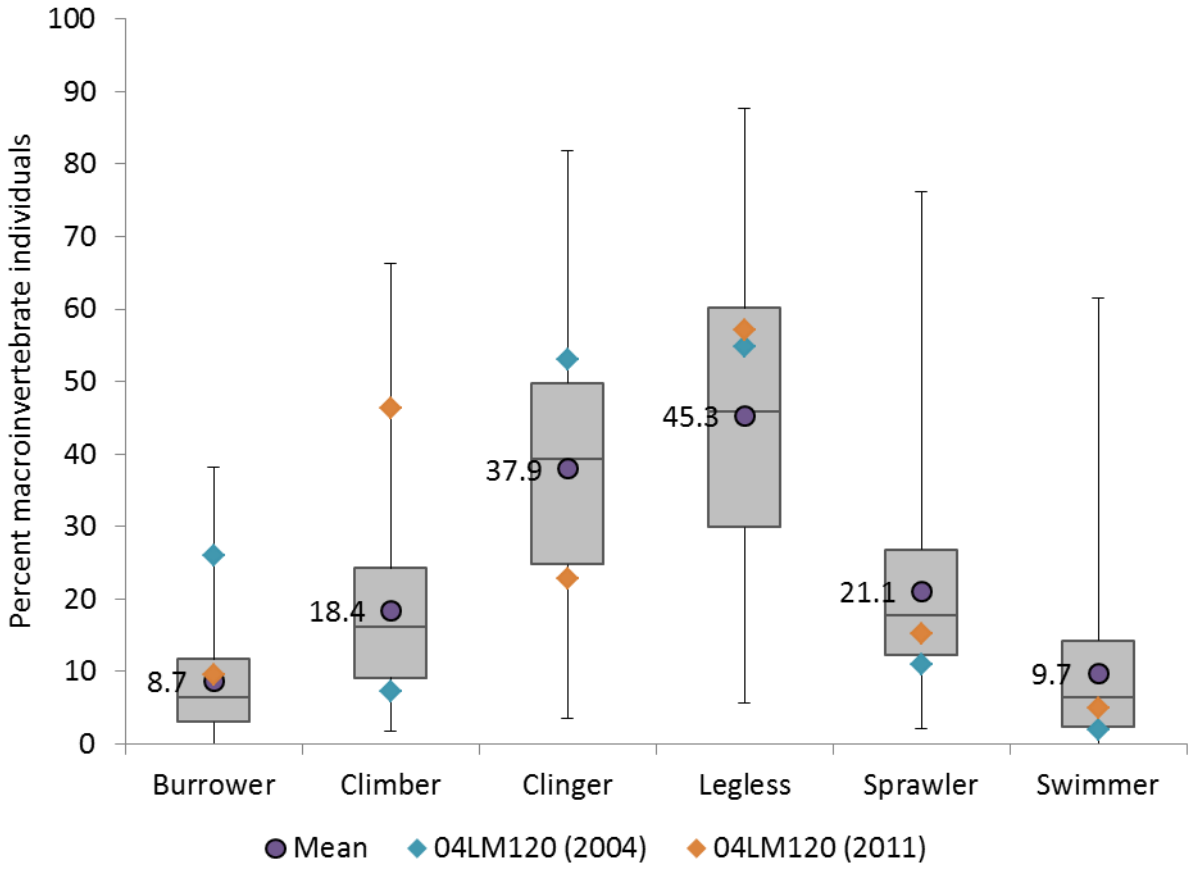


Figure 127. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Straight River Watershed stations.

This segment of the Straight River had poor – good MSHA scores, none – heavy bank erosion, and light – severe substrate embeddedness. The macroinvertebrate metrics related to habitat were a little mixed between stations and years. The lower station (10EM011), in general, had values atypical of habitat stress (although burrowers were slightly elevated). Station 04LM120 (just downstream from the city of Owatonna), however, did have values suggestive of habitat stress and there were noticeable differences between the 2004 and 2011 samples. In 2004, burrowers and climbers were in the upper and lower quartiles respectively. In 2011, clingers were in the lower quartile. Tolerant (legless) macroinvertebrates were above average both years. Habitat may be impacting the macroinvertebrate community, but at this time it's inconclusive if habitat is a stressor due to the mixed biological response.

Fish Passage

There were no passage barriers identified during the survey in the summer of 2014. The Morehouse Dam, which is just upstream of the AUID, was designed to allow fish passage (Figure 128). At this time, fish passage does not appear to be a stressor in this AUID.

Figure 128. Morehouse Dam with fish passage step-pool system (upstream of AUID).

Ammonia

Multiple ammonia exceedances occurred in 2010 in the upper end of this AUID at station S000-450. This station is just upstream of the Owatonna WWTP and just below the mouth of Maple Creek. There were 38 samples collected in 2010, ranging from 0 – 318 µg/L (average of 62.4 µg/L). Twenty-six of these samples were collected at station S000-450, which is where the 18 exceedances occurred. The warmwater standard for ammonia is 40 µg/L. The exceedances took place throughout the year, and there were nine samples greater than 100 µg/L. There were no exceedances during this same time period at station S000-047, which is only a few miles downstream. There were no samples collected in 2011, but results were drastically different in 2012 and 2013. There were 24 samples collected, ranging from 0 – 4 µg/L (average of 0.9 µg/L). Additional monitoring is recommended to keep an eye on the ammonia dynamics in this reach. Communication with Steele County staff at the time of this report indicated that Steele County has intentions of monitoring in the future. It's inconclusive if ammonia is a stressor.

pH

There was a pH value of 6.4 at station S000-047 (near the middle of the AUID) in April of 2010. This is below the minimum pH standard of 6.5. This was the only exceedance in the data set; pH monitoring should be continued in the future to ensure the standard is being attained.

Conclusion

This AUID has multiple stressors at play, with the cumulative effects leading to an impaired macroinvertebrate community. Nitrate and TSS/turbidity are stressors in this reach. Phosphorus levels are extremely elevated, but at this time it's inconclusive if phosphorus is a stressor due to limited data for the associated response variables (chl-a, BOD, and DO flux). Although inconclusive, reducing phosphorus levels is still recommended. Habitat and ammonia are also inconclusive as stressors.

Temperature, DO, and fish passage do not appear to be stressing the macroinvertebrate community. Reducing nutrient and sediment loading in the Straight River will benefit and improve the macroinvertebrate community. Additional monitoring for chl-a, BOD, DO flux, and ammonia is also recommended.

4.5.2. Straight River (515)

Biological Communities

Straight River (07040002-515) is a 13.33 mile long stream segment from Rush Creek to the Cannon River. The upper end of this AUID flows through farm country, while the lower end flows along the east side of Faribault. This is a warmwater reach with a macroinvertebrate impairment. It also includes a turbidity and fecal coliform impairment. There are three biological monitoring stations (04LM014, 11LM092, and 11LM010) located with-in this AUID. Station 04LM014, near the upper end of the AUID, was sampled for fish and macroinvertebrates in 2004. Station 11LM092, located downstream of the Straight River Golf Course, was sampled for fish and macroinvertebrates in 2011. Station 11LM010, located near the mouth of the Straight River just below the Faribault WWTP effluent, was also sampled for fish and macroinvertebrates in 2011.

The fish community in this AUID is considered "supporting" of the aquatic life use, and therefore not currently impaired. The fish IBI scores were above the impairment threshold at station 11LM010 (54) and station 11LM092 (61). Station 04LM014 had an IBI score of 39, which is below the threshold but above the lower confidence limit. The Southern Rivers IBI impairment threshold is 46 (lower CL – 35, upper CL – 57). There were 27, 19, and 28 fish species collected at stations 04LM014, 11LM092, and 11LM010 respectively (MPCA EDA). At station 04LM014 the most abundant species collected was the sand shiner. There were 255 collected, with a minimum length of 30 mm and a maximum length of 76 mm. Johnny darters were the next most abundant species collected (86). Game fish sampled at this site included black crappie (three), bluegill (20), green sunfish (28), hybrid sunfish (one), northern pike (two), rock bass (three), smallmouth bass (three), and yellow perch (one). The most abundant species collected at station 11LM092 were white sucker (15). Rock bass (12) and green sunfish (11) had the next highest sample counts. Near the mouth of the Straight (station 11LM010), sand shiner (75), spotttail shiner (62), and spotfin shiner (43) were the most abundant species sampled. Additional game fish sampled at this location (that were not collected at the upstream stations) included largemouth bass, orangespotted sunfish, walleye, and white bass. A complete list of the fish species collected can be found on the MPCA website.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. Macroinvertebrate IBI scores for station 04LM014 (40.25) and station 11LM092 (45.09) are above the impairment threshold, but station 11LM010 (26.80) is below the threshold. The IBI impairment threshold for Southern Streams RR is 35.9 (lower CL – 23.3, upper CL – 48.5). Both stations above the threshold are with-in the upper confidence limit. Climber, HBI_MN, predator, and trichoptera IBI metric scores were below the average needed to meet the threshold for all stations (Figure 129). Station 11LM010 also had reduced DomFiveCHPct, Odonata, and Plecoptera metric scores. This station, which is located near the mouth, had the lowest MIBI score and was the only station below the threshold.

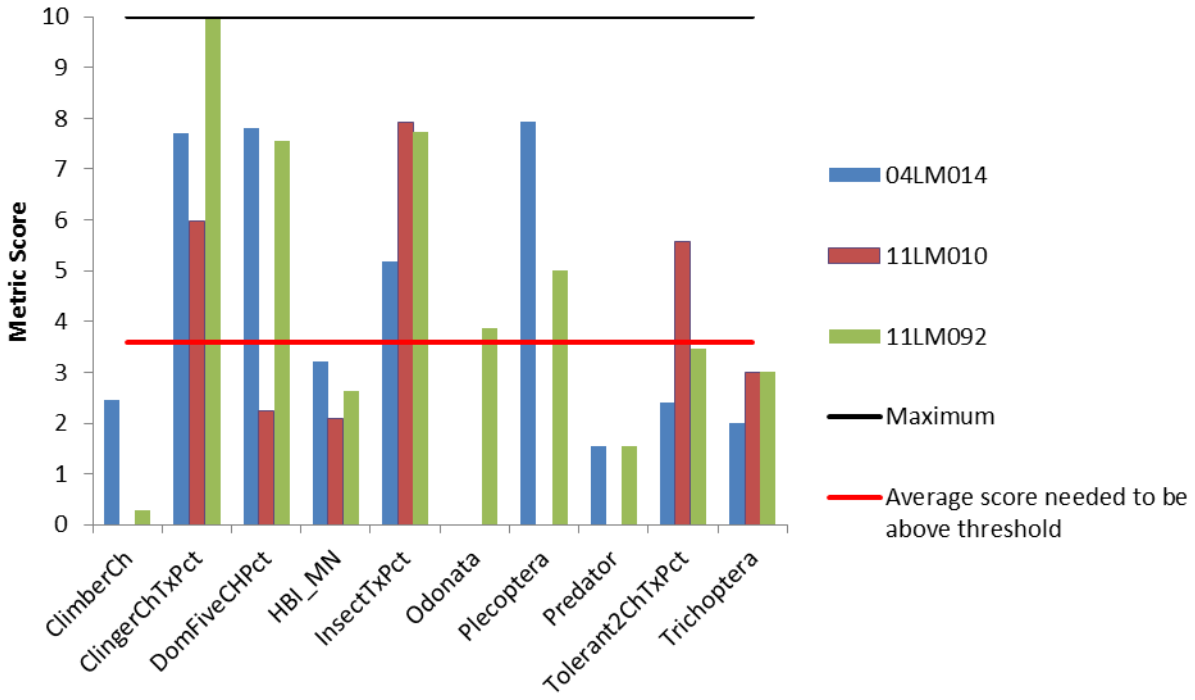


Figure 129. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for the Straight River (07040002-515), stations 04LM014, 11LM010, and 11LM092.

Data Evaluation for each Candidate Cause

Temperature

This particular stream segment in the Straight River (07040002-515) has 875 temperature readings from 1978 – 2013 (minimum of -0.98 °C, maximum of 30 °C, and average of 17.03 °C). There were 72 readings between 25 – 30 °C; samples approaching 30 °C were observed throughout this reach. These "higher" samples occurred from June – September. A majority of the samples (686) were collected during the last 10 years, with the average temperature being 16.83 °C. Spatial sampling coverage is good, as six stations (excluding the biological stations) spread out along this stream segment have been sampled. This intensive data set, with only one sample at 30°C, suggests that temperature is not currently stressing the biota in this reach. However, due to the presence of values approaching 30 °C, continued monitoring is recommended in the summer months to keep tabs on the temperature dynamics in this AUID.

Nitrate

Nitrate concentrations, from 264 samples, ranged from 0.96 – 18.0 mg/L (1978 – 2013). The average concentration is 6.46 mg/L. Approximately 17% of the samples exceeded 10 mg/L, and approximately 34% exceeded 8 mg/L. A majority of these samples (225) have been collected recently (2004 – 2013), and have similar statistics (minimum of 0.96 mg/L, maximum of 18.0 mg/L, and average of 6.75 mg/L) (Figure 130). The percentage of concentrations greater than 10 mg/L is slightly higher over the past decade (19%), as well as the percentage greater than 8 mg/L (37%). These samples were collected at three monitoring stations, with a bulk (212) coming from station S003-557 near the middle of the AUID (downstream of the Straight River Golf Course). There have also been a few samples collected upstream of the golf course, and a few near the mouth of the Straight (just upstream of the Faribault WWTP). The maximum concentrations were greater than 10 mg/L at all three stations, and the maximum values

occurred in May or June. Approximately 81% (35 samples) of the concentrations greater than 10 mg/L occurred in May or June, with March, April, and July comprising the other exceedance months. This extensive data set, as noted by the MPCA biologists, may indicate that elevated nitrates are adversely affecting the macroinvertebrate community in the lower parts of this AUID. It should be mentioned that none of these statistics include the 1X chemistry samples collected during fish assessments. Nitrate concentrations at the time of fish sampling were 4.8 mg/L (station 04LM014), 1.9 mg/L (station 11LM092), and 2.8 mg/L (station 11LM010).

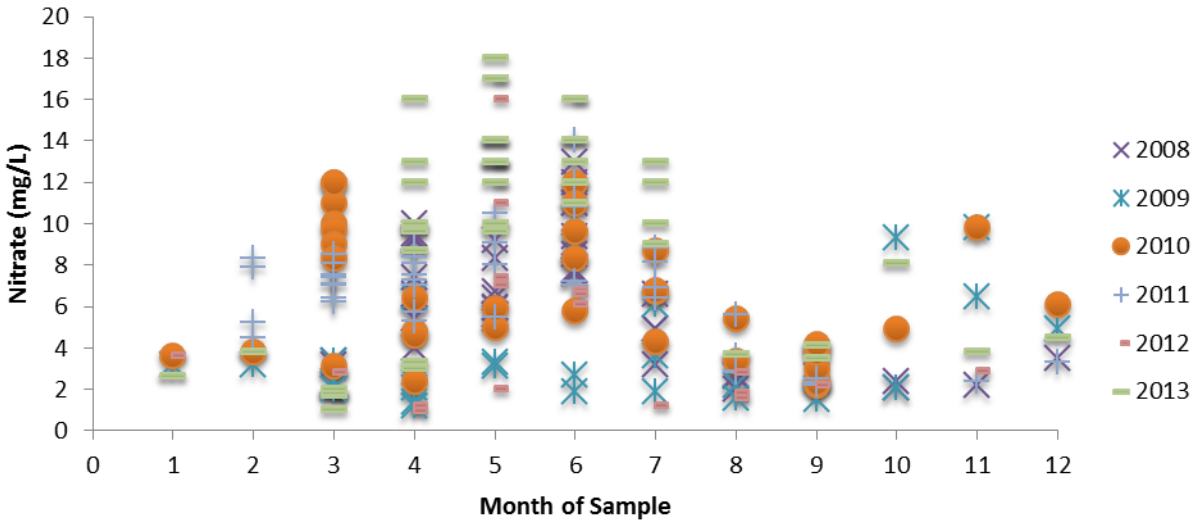


Figure 130. Nitrate concentrations in the Straight River by month sampled.

This AUID has a Watershed Pollutant Load Monitoring Network (WPLMN) station located near the middle of the reach at station S003-557. These sites are designed to obtain spatial and temporal pollutant load information and track water quality trends. The graph below (Figure 131) depicts the nitrate and nitrite concentrations and discharge across the 2012 calendar year. This graph is a product from the FLUX32 load estimation software. Sample concentrations are represented by the yellow triangles, and discharge by the green triangles. The nitrate and nitrite concentrations at this station are typically lower during baseflow conditions and then increase (substantially in some cases) during stormflow conditions. This is often the case in heavily tiled warmwater sytems. Nitrogen rich tile water contributes to these higher concentrations observed during stormflows; lower concentrations are often observed later in the summer as tile lines run dry and baseflow conditions set in. Concentrations during 2012 were as low as 0.96 mg/L (low flow time period in April), and as high as 17 mg/L (high flow time period in May). The duration of elevated concentrations for this particular year was approximately two months (May and June). Baseflow accounted for 61% of the total flow volume in 2012, and stormflow accounted for 39% (this was calculated using the flow separation tool in FLUX32).

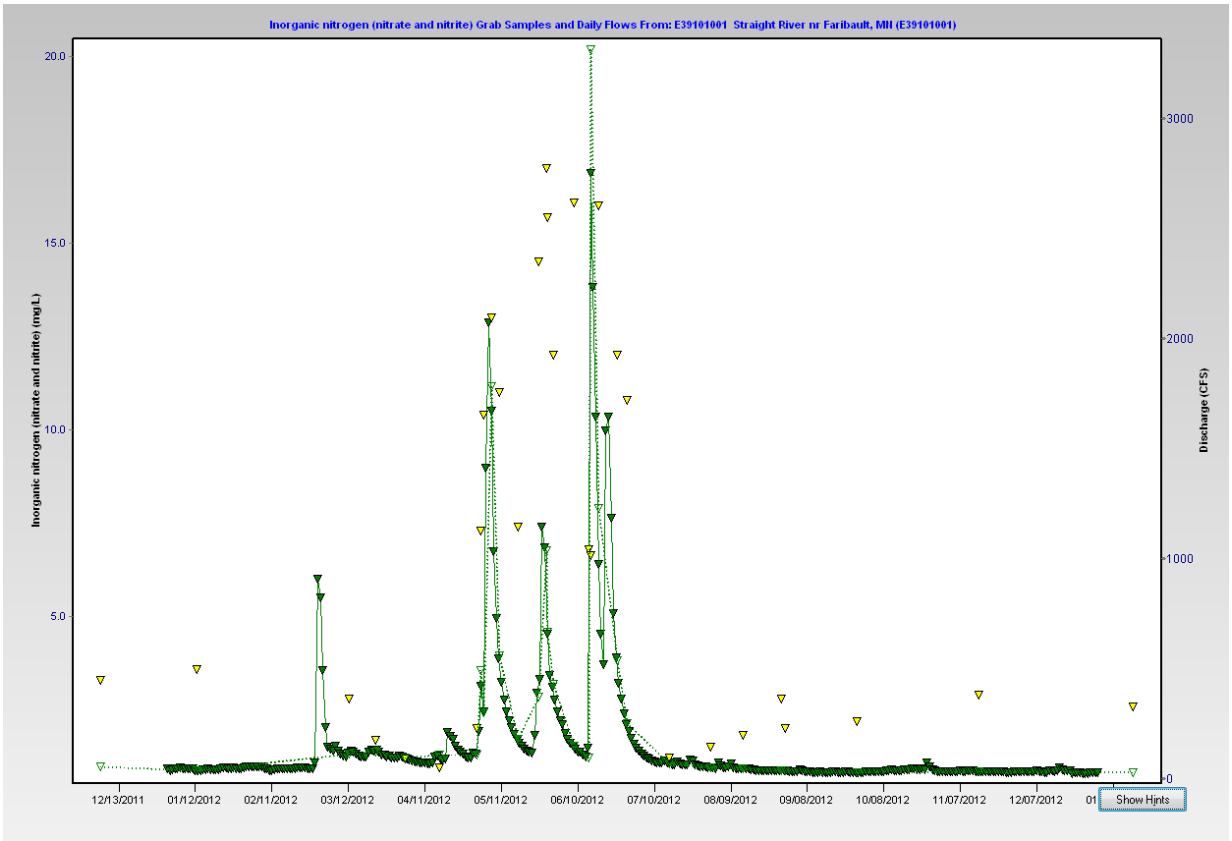


Figure 131. Nitrate and nitrite concentrations and discharge in 2012 at the Watershed Pollutant Load Monitoring Network (WPLMN) station near the middle of the AUID. Sample concentrations are represented by the yellow triangles, and discharge by the green triangles.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class. All stations (04LM014, 11LM010, and 11LM092) in this AUID are Southern Streams RR.

Trichoptera taxa richness (TrichopteraCh and TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two (Intolerant2Ch), were below the statewide average at all stations (Table 96). Trichoptera taxa comprised 10% (station 04LM014), 13% (station 11LM092), and 16% (station 11LM010) of the overall taxa (TrichopteraChTxPct). It should also be mentioned that the Trichoptera IBI metric scores for all three stations were below the average metric score needed to meet the Southern Streams RR MIBI threshold. Trichoptera are recognized to be very sensitive to pollution (Barbour et al. 1999). There were zero intolerant taxa present at all stations.

At all three stations, zero nitrate intolerant taxa were collected. However, each station had several nitrate tolerant taxa. Station 04LM014 had 23 (72%) nitrate tolerant taxa, and 15 (49%) nitrate very tolerant taxa. Station 11LM092 had 18 (62%) nitrate tolerant taxa, and 15 (43%) nitrate very tolerant taxa. The highest percentage of nitrate tolerant (74%, 17 taxa) and very tolerant (58%, 13 taxa) taxa was observed near the end of the AUID at station 11LM010. The nitrate index scores were 3.3 (11LM092),

3.4 (04LM014), and 3.4 (11LM010), which are above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 96. Macroinvertebrate metrics that respond to nitrate stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
04LM014 (2004)	**4**	**0.9**	**0**	**3.4**	**0**	**0**	**23**	**15**	**72.1**	**49.0**
11LM092 (2011)	**5**	**2.8**	**0**	**3.3**	**0**	**0**	18	**15**	**62.3**	**42.8**
11LM010 (2011)	**5**	**2.1**	**0**	**3.4**	**0**	**0**	17	13	**73.7**	**58.1**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

The extensive chemistry data set showing elevated nitrate levels, coupled with the lack of nitrate intolerant taxa, presence of nitrate tolerant taxa, worse than average nitrate index scores, poor Trichoptera taxa richness, absence of intolerant taxa, and below average Trichoptera IBI metric scores indicate that nitrate is playing a role in diminishing the macroinvertebrate community. Nitrate is a stressor, and reducing the nitrogen loading to this entire AUID should be a priority.

Phosphorus

Phosphorus data from 1978 – 2013 consists of 311 samples, with an average concentration of 0.260 mg/L (minimum of 0.014 mg/L, maximum of 2.12 mg/L). A total of 235 samples (76%) exceeded 0.150 mg/L, the draft river eutrophication criterion for the South Region. Many of the samples from this data set were collected from 2004-2013. The 247 samples collected over this time span averaged 0.240 mg/L (minimum of 0.014 mg/L, maximum of 1.22 mg/L), and 181 samples (73%) exceeded 0.150 mg/L. These statistics make use of many data collected for use in load computations; as such they are biased toward runoff event flows and conditions. Similar to Figure 131 in the Nitrate section above, Figure 132 below depicts phosphorus concentrations and discharge at station S003-557 throughout the 2011 calendar year using the FLUX32 load estimation software. Phosphorus is primarily transported attached to sediment particles, which is why concentrations are often highest during storm flows. There were four monitoring stations (S000-508, S003-557, S001-581, and S006-527) at which samples were collected. Similar to the nitrate data set, a majority of the samples (86%) were collected from station S003-557 near the middle of the AUID (just downstream of station 11LM092). There were three samples collected upstream of S003-557, and 31 samples collected (at two different stations) downstream near the mouth of the Straight River. All stations had a maximum phosphorus concentration above the draft standard. The majority of exceedances (19%) occurred in June, and approximately 76% occurred from March – July. Exceedances occurred at both high and low TSS concentrations, thus implying high and low flow conditions (Figure 133). Not included in the statistics mentioned above are the 1X samples collected

during fish sampling (station 11LM092 – 0.145 mg/L, station 11LM010 – 0.372 mg/L, and station 04LM014 – 0.252 mg/L).

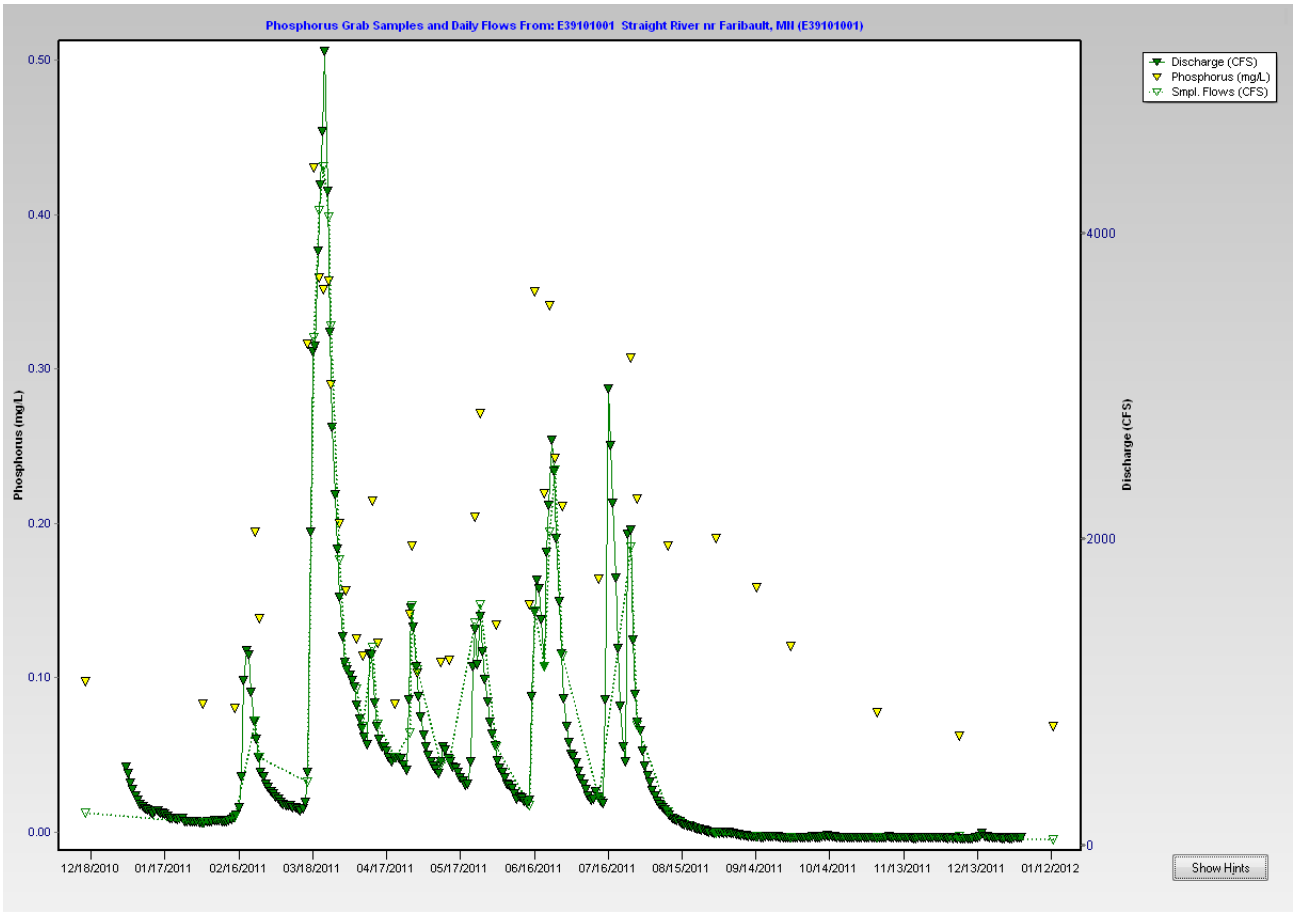


Figure 132. TP concentrations and discharge in 2011 at the Watershed Pollutant Load Monitoring Network (WPLMN) station near the middle of the AUID. Sample concentrations are represented by the yellow triangles, and discharge by the green triangles.

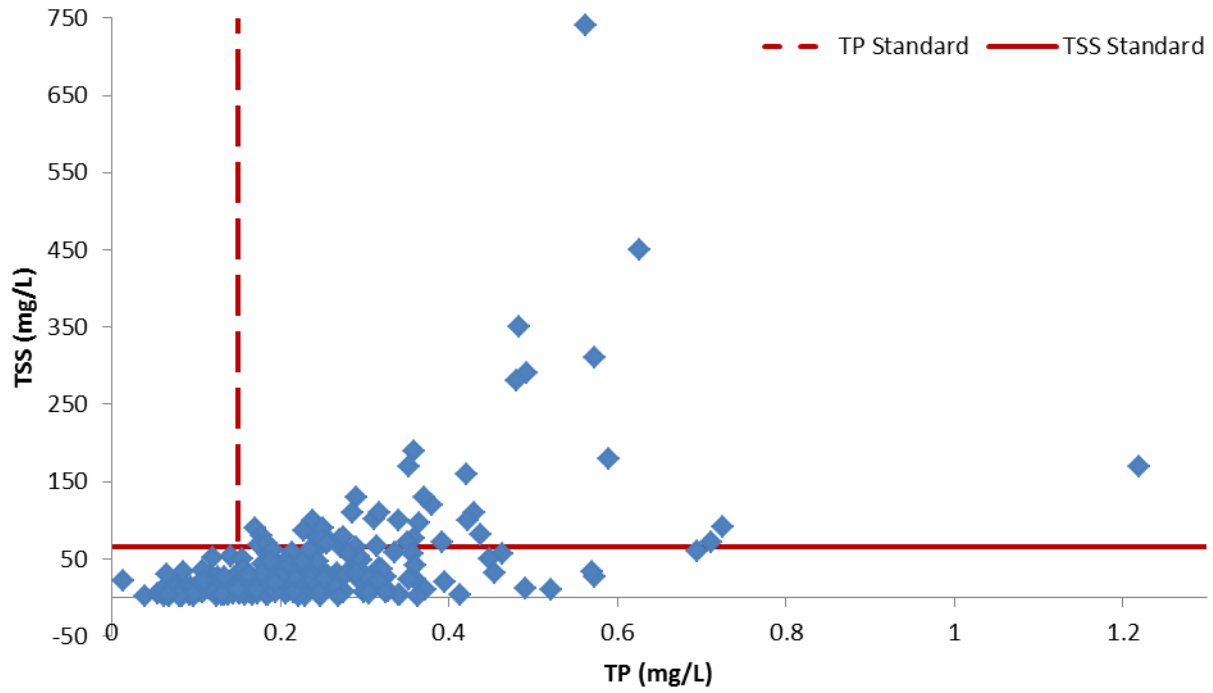


Figure 133. TSS and TP relationship in the Straight River - 515 (2004-2013).

The Faribault WWTP discharges to this AUID near the mouth of the Straight River, and recently implemented upgrades targeting phosphorus removal (Byllesby Reservoir Phosphorus TMDL Report, 2013).

Chlorophyll-a samples were limited for this AUID. A total of 21 samples were collected from 1978 – 2013 (minimum of 0.96 µg/L, maximum of 107 µg/L, and an average of 13.0 µg/L). There were two samples in 2002, collected from station S001-581 (downstream of MN-60), that exceeded the South Region draft river eutrophication standard (35 µg/L). Only six samples have been collected in the past decade, all of which were below the standard and collected from 2011-2013. They were all also collected from the same monitoring station (S003-557) near the middle of this AUID. The maximum concentration was 17.1 µg/L (September 2012). Due to this limited data set, it's hard to determine whether or not chlorophyll-a is indicating a response to the elevated phosphorus levels. Additional chlorophyll-a samples should be collected at multiple sites throughout this AUID in the subsequent years following this report.

Similar to chlorophyll-a, the BOD data set is limited to 18 samples from 1978-2002 (minimum of 0.5 mg/L, maximum of 15 mg/L, and an average of 1.9 mg/L). Two samples (11%) collected in May and June of 2002 at station S001-581 exceeded the draft river eutrophication standard for the South Region (3.0 mg/L). Four different monitoring stations were sampled throughout this timeframe. Again, similar to chlorophyll-a, the limited BOD data does not yield the opportunity to determine the response (if any) of BOD to the elevated phosphorus levels witnessed in this AUID. BOD samples should be collected throughout this reach in the years following this report, as the last sample taken was in 2002.

A longitudinal DO survey conducted in the summer of 2014 resulted in no DO flux exceedances of the draft standard for the South Region (4.5 mg/L). No sondes were deployed in this AUID, and therefore no

continuous DO data is available at this time. DO, which is discussed further in the DO section, ranged from 5.1 – 25.8 mg/L. This range suggests that DO flux exceedances may persist in this reach, which may be caused by excessive algal production. Continuous DO monitoring is recommended during the summer months to gain a better understanding of the DO flux dynamics in this segment of the Straight River.

The macroinvertebrate metrics with strong relationships to phosphorus were above and below the statewide average of stations meeting the MIBI threshold (Table 97). Station 11LM010, near the mouth of the Straight River, had worse than average total taxa richness (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of collector-gatherers (Collector-gathererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch). It had better than average percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct). The two stations in the upper end of the AUID, station 04LM014 and 11LM092, had worse than average TaxaCountAllChir, Collector-filtererCh, Intolerant2Ch, and Tolerant2ChTxPct. These stations had better than average Collector-gathererCh and EPT. All of the metrics besides Tolerant2ChTxPct are expected to decrease in response to stress. TaxaCountAllChir, Collector-filtererCh, and Intolerant2Ch were worse than the statewide average at all stations. Overall, a majority of the macroinvertebrate metrics at each station had values indicative of stress, and no obvious longitudinal differences appear to be present.

Table 97. Macroinvertebrate metrics that respond to TP stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
04LM014 (2004)	**40**	**5**	16	11	**0**	**82.5**
11LM092 (2011)	**40**	**6**	15	13	**0**	**77.5**
11LM010 (2011)	**31**	**6**	**13**	**9**	**0**	67.7
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
Expected response to stress	↓	↓	↓	↓	↓	↑

This segment of the Straight River has extremely high phosphorus concentrations and numerous exceedances during various flows and seasons, and most of the macroinvertebrate metrics were worse than the statewide average. Elevated phosphorus is present in this AUID, but it's not clear if it's adversely impacting the macroinvertebrate community. Limited data is available for chlorophyll-a, BOD, and DO flux. However, the limited data for these response variables does include two chlorophyll-a and BOD exceedances in 2002, and the existing DO data set does suggest the potential for flux issues. Overall, it appears that phosphorus has the potential to be a stressor in this AUID, but at this time it's inconclusive if phosphorus is a stressor due to limited data. Additional chlorophyll-a, BOD, and DO flux data is needed to determine if the elevated phosphorus levels are leading to eutrophication. Although

inconclusive at this time, reducing phosphorus in the Straight River should be a priority in any future planning efforts. Phosphorus has the potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus loading should help (and/or protect from potential future impacts) the biology in the Straight River.

Dissolved Oxygen

DO concentrations from 1978-2013 ranged from 5.1 – 25.76 mg/L, with an average of 10.1 mg/L. This data set consists of 184 samples, none of which fell below the warmwater standard of 5 mg/L. Most of the samples (178) were collected within the past 10 years (2004-2013), and showed similar statistics (minimum of 6.16 mg/L, maximum of 25.76 mg/L, and an average of 10.2 mg/L). Six stations (including the three biology stations) were sampled throughout this stream segment, with most samples (156) coming from station S003-557. The next station with the highest number of samples collected (17) is S006-527. The remaining stations (04LM014, S000-508, 11LM092, and 11LM010) had one or two samples collected. Several of the samples (51) were collected in the early morning hours (prior to 9:00 a.m.) in an attempt to capture low DO values, which provides reasonable assurance that "worse case" scenarios were sampled. Also, a longitudinal DO survey conducted in the summer of 2014 identified zero low DO concentrations.

The total macroinvertebrate taxa richness (TaxaCountAllChir) was below the statewide average for Southern Streams RR that are meeting the MIBI threshold at all three stations (Table 98). Station 11LM010, near the mouth of the Straight River, had the lowest overall taxa richness (31). The two upper stations (04LM014 and 11LM092) had worse than average taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), while station 11LM010 had better than average. Taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT) was above average at station 04LM014 and 11LM092, and below average at station 11LM010. Often times a stressed stream will see reductions in overall taxa richness and EPT taxa richness, and increases in tolerant taxa.

All three stations along this AUID have high numbers of DO intolerant and very intolerant taxa. DO intolerant taxa ranged from 9 – 15, and DO very intolerant taxa ranged from six to eight. DO intolerant taxa are sensitive to low DO, and not likely found in oxygen limited conditions. All three stations also had very low numbers of DO tolerant and very tolerant taxa. DO tolerant taxa ranged from one to two, and DO very tolerant taxa ranged from zero to one. The macroinvertebrate DO index scores were 7.5 (04LM014), 7.5 (11LM010), and 7.6 (11LM092). These scores are above the statewide average (7.2) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 98. Macroinvertebrate metrics that respond to low DO stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
04LM014 (2004)	**40**	**82.5**	11	7.5	11	8	1	0	0.4	0.0
11LM092 (2011)	**40**	**77.5**	13	7.6	15	8	2	1	0.9	0.6
11LM010 (2011)	**31**	67.7	**9**	7.5	**9**	6	2	1	0.6	0.3
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

There are no low DO (<5 mg/L) readings in the data set, and all samples collected in 2014 as part of a longitudinal DO survey were above the warmwater standard. A majority of the macroinvertebrate metrics were better than the statewide average. There were several DO intolerant and very intolerant taxa, and very low numbers of DO tolerant and very tolerant taxa. Also, the DO index scores were above the statewide average. At this time, DO is meeting water quality standards and does not appear to be stressing the biota in this AUID.

TSS/Turbidity

This AUID currently has a turbidity impairment, and the AUIDs immediately upstream (Straight River – 536 and Rush Creek – 505) are also impaired for turbidity. There were 353 TSS samples collected from 1978-2013 (minimum of 1 mg/L, maximum of 1500 mg/L, and an average of 51.4 mg/L). Approximately 20% (72 samples) were greater than 65 mg/L, the draft TSS standard for the South Region. Samples collected recently, from 2004 – 2013, had an average TSS concentration of 49.4 mg/L (minimum of 1 mg/L, maximum of 740 mg/L, and a sample count of 300); this average includes load monitoring samples which are biased towards runoff events. This time period also had numerous exceedances of the draft standard (65 samples, 22%), supporting the current turbidity impairment on this reach. Similar to the parameters discussed in the previous sections, station S003-557 is where most samples (246) were collected. Station S001-581 had 38 samples, which was the second highest. Seven stations, including the biology stations, had at least one TSS sample. Only two of the seven stations (S003-557 and S001-581) had at least one exceedance, but this is likely due to the limited number and/or timing of samples at the other stations. For example, the three biology stations were only sampled once during fish assessment, which was during baseflow conditions. In general, elevated TSS concentrations are typically associated with stormflow. This relationship makes it critical to sample all flow conditions to accurately characterize the water quality conditions. Depending on the year, one or two runoff events can carry a majority of the annual sediment load, and the duration at which a stream remains turbid can have large impacts on fish and macroinvertebrates.

Transparency values from 2000 – 2013 ranged from 2 – 100 cm, and averaged 49 cm (1128 samples). Approximately 7% (83 samples) were below 10 cm, the S-tube surrogate for the South Region TSS standard. Statistics from 884 samples collected over the last decade (2004-2013) indicate similar results (minimum of 2 cm, maximum of 100 cm, average of 49 cm, and 8% less than 10 cm). Spatial and temporal coverage is good, with multiple sites (seven) having samples across various years and seasons. Four of the seven sites have more than 100 samples, two of which have greater than 300. Five of the seven sites had at least one sample below the South Region S-tube surrogate. A majority of the exceedances documented occurred in the month of June.

The macroinvertebrate metrics with strong relationships to TSS were above and below the statewide average of stations meeting the MIBI threshold (Table 99). The following stations are discussed going from downstream to upstream. Station 11LM010, near the mouth of the Straight River, had above average relative abundance of collector-filterer individuals (Collector-filtererPct) and below average relative abundance of Plecoptera individuals (PlecopteraPct). Station 11LM092 had below average Collector-filtererPct and PlecopteraPct. Station 04LM014, near the very upper end of the AUID, had below average PlecopteraPct and above average Collector-filtererPct. Both of these metrics are expected to decrease in response to stress. Very few stoneflies (Plecoptera) were present throughout the AUID. Overall, a majority of the metrics had values indicative of stress.

Station 04LM014 had zero TSS intolerant and very intolerant taxa present, while station 11LM010 and 11LM092 had both. Station 11LM010 had one TSS intolerant taxa and very intolerant taxa, and station 11LM092 had two and one respectively. All stations also had multiple TSS tolerant (10 – 16) and very tolerant (4 – 8) taxa. TSS tolerant and very tolerant taxa comprised 35% - 68% and 16% - 31% of the macroinvertebrate community respectively. The macroinvertebrate TSS index scores were 20.0 (11LM092), 18.2 (04LM014), and 21.3 (11LM010), which are worse than the statewide average (17.1) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community.

Table 99. Macroinvertebrate metrics that respond to TSS stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
04LM014 (2004)	26.1	**0.3**	**18.2**	**0**	**0**	**12**	**7**	**34.6**	**15.9**
11LM010 (2011)	33.5	**0.0**	**21.3**	**1**	1	10	4	**68.2**	**28.4**
11LM092 (2011)	**24.8**	**0.3**	**20.0**	**2**	1	**16**	**8**	**62.6**	**30.8**
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can still assist in SID. The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are intolerant species (IntolerantPct), relative abundance of individuals that are long-lived (LLvdPct), and relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct) at station 11LM010 were below the statewide average of stations meeting the FIBI threshold (Table 100). The relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), relative abundance of individuals that are sensitive species (SensitivePct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were above the statewide average. Station 11LM092 was better than the statewide average in all metric categories except for LLvdPct. Station 04LM014 was worse than the statewide average in all metric categories except for HrbNWQPct and the TSS index score. HrbNWQPct and the TSS index score were better than average at all stations, and LLvdPct was worse than average at all stations. The fish metrics are mixed among stations; a majority of the metrics at the upstream station (04LM014) had values worse than the statewide average, while a majority of the metrics at the downstream stations (11LM092 and 11LM010) were better than the statewide average.

Table 100. Fish metrics that respond to TSS stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
04LM014 (2004)	**19.5**	**4.2**	15.4	**1.6**	**6.7**	**20.4**	**13.1**	**14.3**	**5.4**	22.9
11LM010 (2011)	**24.3**	7.8	15.0	**4.2**	**19.8**	**15.6**	16.5	30.8	36.5	23.7
11LM092 (2011)	41.8	23.1	28.6	13.2	**33.0**	33.0	29.7	39.6	37.4	17.4
Southern Rivers Average	*24.6*	*7.2*	*10.9*	*8.2*	*38.4*	*21.6*	*16.2*	*16.3*	*24.0*	*28.8*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Geomorphology sampling in this AUID was completed by the DNR in 2010 as part of a larger geomorphology assessment in the Straight River Watershed. The following excerpt is from the geomorphology sampling summary document provided by the DNR as it pertains to this AUID:

> *"The flowing reach downstream extends 8.1 miles between 270th street and 220th street. This reach accounted for nearly half the stream bank erosion that we estimated for the Straight River that was assessed. This reach was also classified as a F4 channel. Considerable instability as evident in the channel by the frequent mid-channel bars, traverse bars, high undercut banks, sandy loam soils and stratified bank materials. Bedrock control does exist at the lower end of this reach extending intermittently downstream to the Cannon River. The bedrock controlling feature has stopped the down cutting in the channel but at the same time increased the near bank sheer stress in those same reaches."*

"The final reach we assessed extends 8.4 miles from 220th street to the confluences with Cannon River. This was a geologically controlled reach for most of the upper 5 miles. Limestone outcrops and natural bedrock control features have kept the stream channel an F4/1. The upper section in this reach has a much higher stream gradient as characterized by steep frequent riffles, numerous traverse bars and a wide shallow channel. The lower 3 miles expresses a higher degree of bank erosion. The channel in the lower reach is wide, shallow with high stream banks. The bed material in this lower end of the reach is almost exclusively sand."

This AUID is currently impaired for turbidity and has 22% TSS exceedances and 9% transparency exceedances over the last decade. Although the fish metrics are a little mixed and there are TSS intolerant and very intolerant taxa, the elevated TSS concentrations coupled with worse than average macroinvertebrate metrics, elevated macroinvertebrate TSS tolerant and very tolerant taxa, worse than average macroinvertebrate TSS index scores, and the geomorphology findings (high stream bank erosion, high undercut banks, and channel instability) suggest that TSS/turbidity is playing a role in stressing the macroinvertebrate community.

Lack of Habitat

The MSHA scores were "good" at station 04LM014 (68.5) and station 11LM092 (70.8) (Table 101). Station 11LM010 had a "fair" MSHA score (62). The surrounding land use at the time of fish sampling for station 04LM014 was predominantly "natural" (forest, wetland, prairie, and shrub). Station 11LM092 had a mix of natural and row crop land use. Surrounding land use at station 11LM010 was predominantly urban and industrial, and also included a park.

Table 101. MSHA subcategory scores for the Straight River.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
04LM014	13-Sep-04	5	10.5	20	12	21	68.5 (Good)
11LM092	17-Aug-11	2.5	10.5	20.8	9	28	70.8 (Good)
11LM010	18-Aug-11	1	6	18	13	24	62 (Fair)

The riparian width in the three stations in this AUID ranged from narrow (15 – 30 feet) to extensive (>300 feet), and shade ranged from moderate (25 – 50%) to substantial (50 – 75%). Bank erosion ranged from little (5 – 25%) to severe (75 – 100%).

Station 04LM014 had two stream features (85% run, 15% riffle), while station 11LM092 and station 11LM010 had three stream features. Station 11LM092 was 80% run, 10% riffle, and 10% pool, and

station 11LM010 was 55% run, 30% pool, and 15% riffle. Riffle and run channel types in station 04LM014 had gravel and sand substrates. Pools in station 11LM092 consisted of boulders and sand, riffles were cobble and gravel, and run features were boulders and gravel. Station 11LM010 had pool substrate of sand, riffle substrate of cobble and gravel, and run substrate of gravel and sand. Substrate embeddedness ranged from light – moderate, and there were greater than four substrate types present.

Cover types included overhanging vegetation, deep pools, woody debris, boulders, and rootwads for all three stations. Undercut banks were also sampled at station 11LM092 and station 11LM010. Cover amount ranged from sparse (5 – 25%) to moderate (25 – 50%). Channel sinuosity was good, channel stability ranged from moderate – moderate/high, channel development ranged from fair – good, and multiple velocity types were present (slow – fast as well as eddies).

Station 11LM010 and station 11LM092 had well below average burrowers in 2011, but station 04LM014 had well above average burrowers in 2004 (Figure 134). Burrower species "burrow" in fine sediment (indicating potential siltation in riffles), and typically increase with habitat stress. Riffle habitats were sampled at all three stations. Legless invertebrates are tolerant species that also increase with habitat stress. Results for legless species were the same as they were for burrowers; station 11LM010 and station 11LM092 were below average while station 04LM014 was above average. Climbers and clingers are expected to decrease with habitat stress. All stations are slightly above or below the average for Southern Streams RR stations meeting or exceeding the MIBI. Overhanging vegetation and woody debris were sampled, and would be expected to have a diversity of climbers. Also, all climber MIBI metric scores are below the average score needed to be at the threshold. Conversely, all clinger MIBI metric scores are above the average score needed to be at the threshold. Station 11LM092 received the maximum MIBI metric score for clingers (10).

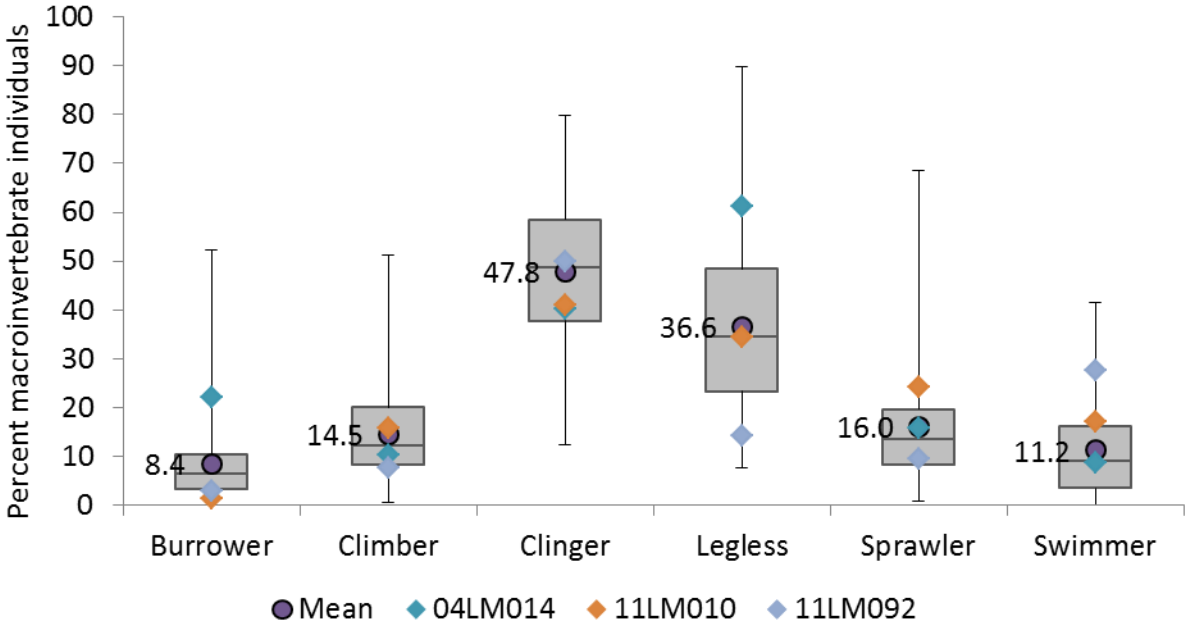


Figure 134. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Straight River Watershed stations.

As mentioned in the TSS/Turbidity section above, geomorphology work completed by the DNR classified this reach as an F channel. These channel types are entrenched and dis-connected from the floodplain, creating stress on the stream banks and increasing the width to depth ratio. The instability of F channels has direct impacts on the quantity and quality of habitat available. This reach, however, also has several bedrock controls providing some stability.

This AUID had fair – good MSHA scores, multiple habitat types, little – severe bank erosion, and substrate embeddedness ranged from light – moderate. Burrowers and legless were elevated in 2004 at station 04LM014, and climbers and clingers were below average at multiple stations. The DNR also documented channel instability. Habitat may be impacting the macroinvertebrate community, but at this time it's inconclusive if habitat is a stressor due to mixed biological response.

Fish Passage

There were no passage barriers identified in this AUID. At this time, fish passage is not currently a stressor.

Conclusion

This AUID has multiple stressors at play, with the cumulative effects leading to an impaired macroinvertebrate community. Nitrate and TSS/turbidity are stressors in this reach. Phosphorus levels are extremely elevated, but at this time it's inconclusive if phosphorus is a stressor due to limited data for the associated response variables (chl-a, BOD, and DO flux). Although inconclusive, reducing phosphorus levels is still recommended. Habitat is also inconclusive as a stressor. Temperature, DO, and fish passage do not appear to be stressing the macroinvertebrate community. Reducing nutrient and sediment loading in the Straight River will benefit and improve the macroinvertebrate community. Additional monitoring for chl-a, BOD, DO flux, and temperature (continuous data in summer months) is also recommended.

4.5.3. Straight River (536)

Biological Communities

Straight River (07040002-536) is a 6.7 mile long AUID in Steele and Rice Counties. This segment of the Straight River begins at the confluence with Crane Creek, and ends at the confluence with Rush Creek. This warmwater reach flows through the Western Corn Belt Plains ecoregion, and has macroinvertebrate and turbidity impairments. Station 11LM088 is the only biological monitoring station in this AUID. This station is located near Medford, and was sampled for fish and macroinvertebrates in 2011.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI scores at station 11LM088 were 46 and 63, which are at or above the Southern Rivers impairment threshold of 46 (lower CL = 35, upper CL = 57). There were 18 – 22 total fish species collected, including 1-2 pollution intolerant species and four to six game fish species. Some of the more abundant fish species included northern hogsucker, carmine shiner, green sunfish, white sucker,

blackside darter, rock bass, and common carp. The game fish species sampled were walleye, smallmouth bass, rock bass, northern pike, largemouth bass, and green sunfish.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI score at station 11LM088 was 37, which is below the Southern Forest Streams GP impairment threshold of 46.8 (lower CL = 33.2, upper CL = 60.4). There were 20 total families, including two intolerant families. Some of the more abundant taxa included Tricorythodes (mayflies), Dubiraphia (beetles), Nectopsyche (caddisflies), Gammarus (scuds), Coenagrionidae (damselflies), and Caenis (mayflies). ClingerCh, Collector-filtererPct, DomFiveCHPct, HBI_MN, Intolerant2Ch, and TrichopteraChTxPct MIBI metric scores were below the average score needed to meet the MIBI threshold, which resulted in a low MIBI score (Figure 135).

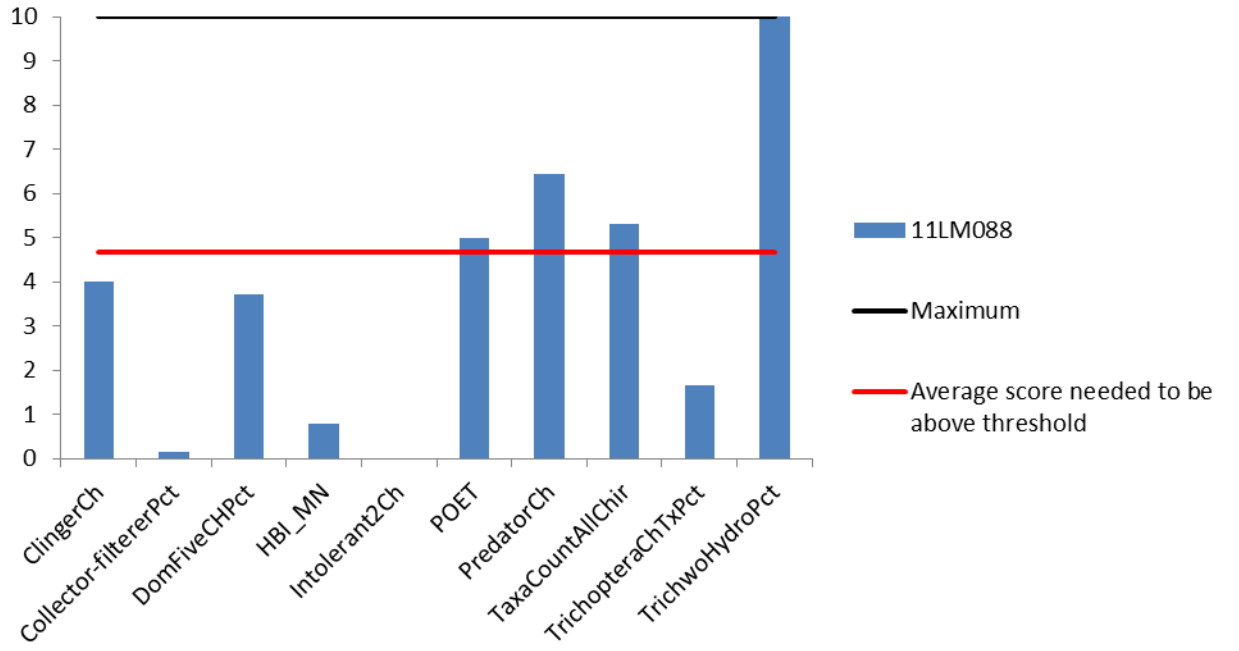


Figure 135. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for the Straight River (07040002-536), station 11LM088.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 1977 – 2014 ranged from 0 °C – 27.2 °C (average of 17.1 °C). Numerous samples (192) have been collected, none of which were above 30 °C (the acute warmwater standard). These samples were collected from five stations (11LM088, S000-448, S000-509, S001-374, and S007-953) in the lower – middle portion of the AUID. A majority of the samples (179) were collected in the lower portion of the AUID, while the remaining samples (13) were collected in the middle portion. There have been zero samples collected in the very upper end of the AUID. Seasonal coverage is good, with at least one sample collected from February – November. The three highest sample months were June (38), August (35), and May (32). The three highest temperature values were 27.2 °C (7/29/2008), 26.7 °C (7/21/2005), and 26.1 °C (8/21/2003). It should also be mentioned that 149 of the samples in this data set were collected from 2004 – 2014.

Temperature was recorded as part of a longitudinal DO survey in late summer 2014 at station S000-509 and station S007-953. Temperature readings from this survey were 20.6 °C and 21.4 °C, and 19.8 °C and 22.3 °C respectively. At this time, there is no continuous temperature data available for this AUID. Continuous data would provide a better understanding of the temperature regime in this AUID.

At this time, temperature is meeting water quality standards, and does not appear to be a stressor in this AUID. Future continuous monitoring would be beneficial, and strengthen this data set.

Nitrate

Nitrate concentrations from 1977 – 2014 ranged from 0.96 mg/L – 15 mg/L (average of 4.9 mg/L). Only 15 samples have been collected during this time period, and they were collected at four different monitoring stations. Thirteen of the samples were collected in the middle – upper portion of the AUID, and the other two samples were collected in the lower portion of the AUID. There were two samples greater than 10 mg/L and three samples greater than 8 mg/L. Recent samples, collected from 2011 – 2014, range from 2.4 mg/L – 15 mg/L (average of 7.1 mg/L). These nine recent samples were collected at three different monitoring stations in the middle – upper portion of the AUID in April (three), May (one), June (one), August (three), and September (one). The three highest concentrations were 9.9 mg/L, 14 mg/L, and 15 mg/L. Additional sampling with good spatial and temporal coverage is recommended.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. Trichoptera taxa richness (TrichopteraCh) and taxa richness of macroinvertebrates with tolerance values less than or equal to two using Minnesota TVs (Intolerant2Ch) were below the statewide average of stations meeting the MIBI threshold (Table 102). Abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct) was above the statewide average. All of these metrics are expected to decrease in response to stress; two out of these three metrics have values indicative of stress.

Station 11LM088 had zero nitrate intolerant and very intolerant taxa present. This station, however, had several nitrate tolerant (19) and very tolerant (13) taxa present. Nitrate tolerant and very tolerant taxa comprised a high percentage of the macroinvertebrate community at 86% and 66% respectively. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. The nitrate index score was 3.4, which is above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 102. Macroinvertebrate metrics that respond to nitrate stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM088 (2011)	**1**	10.8	**0**	**3.4**	**0**	**0**	19	**13**	**85.8**	**65.8**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although minimal samples have been collected, elevated nitrate concentrations have been observed. For the most part, the macroinvertebrate metrics are worse than the statewide average, and there are zero nitrate intolerant and very intolerant taxa present. Nitrate tolerant taxa are abundant and comprise a very high percentage of the macroinvertebrate community. Also, the nitrate index score was worse than the statewide average of stations meeting the MIBI threshold. Additional monitoring is recommended to get a better handle on the nitrate dynamics in this AUID, but the limited existing chemistry data (with elevated concentrations) and strong biological response provide enough confidence to conclude that nitrate is a stressor in this AUID.

Phosphorus

TP concentrations from 1977 – 2014 ranged from 0.126 mg/L – 0.735 mg/L (average of 0.341 mg/L). Only 12 samples have been collected, but 11 were above the draft river eutrophication standard for the South Region (0.150 mg/L). Four of the samples were collected in 1977 and 1978, and the remaining eight samples were collected from 2011 – 2014. Concentrations are higher in the older samples (ranging from 0.518 mg/L – 0.735 mg/L), and lower in the more recent samples (ranging from 0.126 mg/L – 0.319 mg/L). Although lower, the samples from 2011 – 2014 are still high, with seven out of the eight above the draft standard. These seven exceedances occurred in April (two), May (one), August (three), and September (one), and were all located near the middle of the AUID. Samples from this data set were collected from four stations (S000-448, S000-509, S007-953, and 11LM088) in the lower – middle portion of the AUID in February (two), April (three), May (one), August (four), and September (two). The three highest concentrations, when looking at the 2011 – 2014 samples, were 0.232 mg/L (April 15, 2013), 0.233 mg/L (August 26, 2014), and 0.319 mg/L (April 8, 2014).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. There have been zero recent chl-a or BOD samples collected, but there were a few samples collected in 1977 and 1978. There were six BOD samples collected (ranging from 1.7 mg/L – 3.3 mg/L), and four chl-a samples collected (ranging from 1 µg/L – 37.2 µg/L). There were exceedances of the current draft standards for the South Region for both parameters. The draft BOD standard of 3.0 mg/L was exceeded three times, and the draft chl-a standard of 35 µg/L was exceeded once. BOD and

chl-a should be sampled in the future. There were zero DO flux exceedances identified during a longitudinal DO survey in the summer of 2014; DO flux should also be monitored more extensively in the future.

All of the macroinvertebrate metrics with strong relationships to phosphorus were worse than the statewide average of stations meeting the MIBI threshold (Table 103). Station 11LM088 had below average total taxa richness (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of collector-gatherers (Collector-gathererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch). These metrics are expected to decrease in response to stress. The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), which is expected to increase in response to stress, was above the statewide average. All of the macroinvertebrate metrics at station 11LM088 have values indicative of stress.

Table 103. Macroinvertebrate metrics that respond to TP stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM088 (2011)	**37**	**3**	**14**	**6**	**0**	**81.1**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

This segment of the Straight River has limited phosphorus samples, but a majority of the samples exceed the draft standard. There have been no recent chl-a or BOD samples collected, but there were a few exceedances of each in the late 1970's. DO flux exceedances have not been identified, but data is limited and there is no continuous data. All of the macroinvertebrate metrics were worse than the statewide average, suggesting stress. Overall, it appears that phosphorus has the potential to be a stressor in this AUID, but at this time it's inconclusive if phosphorus is a stressor due to limited data. Additional chlorophyll-a, BOD, and DO flux data is needed to determine if the elevated phosphorus levels are leading to eutrophication. Although inconclusive at this time, reducing phosphorus in the Straight River should be a priority in any future planning efforts. Phosphorus has the potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus loading should help (and/or protect from potential future impacts) the biology in the Straight River.

Dissolved Oxygen

DO concentrations from 1977 – 2014 ranged from 5.0 mg/L – 11.17 mg/L (average of 7.8 mg/L). Only 14 samples have been collected over this time frame. None of the samples were below the warmwater standard of 5 mg/L, but there was one sample right at the standard. The three lowest concentrations were 5.0 mg/L (February 2, 1978), 5.2 mg/L (February 2, 1978), and 5.9 mg/L (February 24, 1978).

Samples were collected from four stations (S000-448, S000-509, S007-953, and 11LM088) near the lower – middle portion of the AUID in February (four), April (two), May (one), June (one), August (four), and September (two). Eight of the samples in this data set were collected from 2011 – 2014, and the remaining six samples were collected in 1977 and 1978. The eight recent samples range from 7.46 mg/L – 11.17 mg/L (average of 9.2 mg/L).

There were zero DO concentrations below 5 mg/L during a longitudinal DO survey in late summer of 2014. Unfortunately, no sondes were deployed in this AUID, so there is no continuous data available.

Station 11LM088 had worse than average total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 104). Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

Station 11LM088 had five DO intolerant macroinvertebrate taxa and three DO very intolerant taxa. DO tolerant and very tolerant taxa were also present (four and one respectively), but they comprised a minimal portion of the overall community (9.8% and 5.4% respectively). The macroinvertebrate DO index score was 7.1, which is above the statewide average (7.0) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 104. Macroinvertebrate metrics that respond to low DO stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM088 (2011)	**37**	**81.1**	**6**	7.1	**5**	**3**	4	1	9.8	**5.4**
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

The DO data set for this AUID has no exceedances, but is limited in terms of sample numbers and is lacking continuous data. Many of the macroinvertebrate metrics were worse than the statewide average, but there were multiple DO intolerant and very intolerant taxa. Also, DO tolerant taxa comprised a small percentage of the macroinvertebrate community and the DO index score was above the statewide average. Due to the limiting data set, it's inconclusive whether or not DO is stressing the macroinvertebrate community. It appears unlikely that DO is a stressor, but additional monitoring is needed to verify this inkling. Sonde deployment over an extended period of time during the late summer months would likely provide this necessary data.

TSS/Turbidity

This AUID is currently impaired for turbidity. TSS concentrations from 1977 – 2014 ranged from 4 mg/L – 35 mg/L (average of 15.4 mg/L). Only 14 samples have been collected during this time period, and they were collected at four different monitoring stations (S000-448, S000-509, S007-953, and 11LM088). Most of the samples (12) were collected near the middle of the AUID; the remaining two samples were collected in the lower (downstream) portion. More recent samples (2011 – 2014) ranged from 4.4 mg/L – 32 mg/L (average of 15.2 mg/L). These eight samples were collected during April (three), May (one), August (three), and September (one) at three different monitoring stations near the middle of the AUID. There were zero samples greater than 65 mg/L, the draft TSS standard for the South Region.

Transparency values from 1999 – 2014 ranged from 4 cm – 100 cm (average of 50 cm). Of these 212 samples, 10 (5%) were below the s-tube surrogate standard for the South Region (10 cm). Samples were collected from four stations (11LM088, S000-448, S001-374, and S007-953) from March – November. June (43) and August (40) were the top two sample months. Most of the samples (203) were collected in the lower end of the AUID, and the remaining samples (nine) were collected in the middle portion of the AUID. The exceedances occurred in March (one), June (five), July (two), and August (two); all of the exceedances took place in the lower end at station S001-374.

The relative abundance of collector-filterer individuals (Collector-filtererPct) and relative abundance of Plecoptera individuals (PlecopteraPct) were well below the statewide average of stations meeting the MIBI threshold (Table 105). Both were extremely low at 0.9% and 0% respectively. Both of these metrics are expected to decrease in response to stress.

Station 11LM088 had one TSS intolerant and very intolerant taxa present. This station also had TSS tolerant (15) and very tolerant (nine) taxa present. TSS tolerant and very tolerant taxa were abundant, comprising 61% and 52% of the macroinvertebrate community respectively. The macroinvertebrate TSS index score for station 11LM088 was 24.6, which is worse than the statewide average (16.2) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community.

Table 105. Macroinvertebrate metrics that respond to TSS stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM088 (2011)	**0.9**	**0.0**	**24.6**	**1**	1	**15**	**9**	**61.4**	**51.9**
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can help inform the SID process. Station 11LM088 was sampled twice in 2011. The relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are intolerant species (IntolerantPct), and relative abundance of individuals that are long-lived (LLvdPct) were below the statewide average of stations meeting the FIBI threshold (Table 106). Centr-TolPct was only below average during one visit, while IntolerantPct and LLvdPct were below average during both visits. The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), relative abundance of individuals that are sensitive species (SensitivePct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were at or above the statewide average. The TSS index scores were also better than the statewide average. Overall, a majority of the fish metrics were better than the statewide average.

Table 106. Fish metrics that respond to TSS stress in the Straight River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
11LM088 (2011)	40.2	**5.4**	40.9	**7.7**	**26.6**	21.6	30.9	39.8	29.0	19.3
11LM088 (2011)	30.3	14.8	24.6	**5.7**	**27.0**	27.9	21.3	29.5	27.0	19.0
Southern Rivers Average	*24.6*	*7.2*	*10.9*	*8.2*	*38.4*	*21.6*	*16.2*	*16.3*	*24.0*	*28.8*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Geomorphology sampling in this AUID was completed by the DNR in 2010 as part of a larger geomorphology assessment in the Straight River Watershed. The following excerpt is from the geomorphology sampling summary document provided by the DNR as it pertains to this AUID:

> *"The next reach downstream extends 6.1 miles from County Road 45 to 270th street. The stream channel in this reach remains an F4 entrenched channel. Flood flows do get out of the channel and on to the flood plain but the bankfull flow remain trapped increasing bank sheer stress and stream bank erosion. This reach has considerably more stream bank instability and bank erosion than sites upstream. Sand and gravel stratification is common in the banks in the lower end of this reach as evident by the frequent gravel mining operation in the adjacent flood plain. This stratification layer adds increased bank instability and erosion potential."*

This section of the Straight River is currently impaired for turbidity. The TSS data set has limited sample numbers and includes zero exceedances; additional TSS sampling is recommended for this AUID. The transparency data set has adequate sample numbers with minimal exceedances (5%). All but one of the

macroinvertebrate metrics were worse than the statewide average. Station 11LM088 had one TSS intolerant and very intolerant taxon, but several TSS tolerant and very tolerant taxa were present and comprised a high percentage of the community. Also, the macroinvertebrate TSS index score was well above the statewide average, indicating a TSS tolerant community. Geomorphology sampling identified stream bank instability and stream bank erosion. Although the existing chemistry data is limited, the macroinvertebrates are experiencing TSS/turbidity induced stress. TSS/turbidity is a stressor in this AUID.

Lack of Habitat

The MSHA scores for station 11LM088 were 48.3 ("fair") in August 2011, and 49.25 ("fair") in September 2011 (Table 107). The two visits had very similar scores, with the biggest difference occurring in the channel morphology sub-category.

Table 107. MSHA subcategory scores for the Straight River.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
11LM088	13-Sep-11	1	6	16.3	6	20	49.3 (Fair)
11LM088	17-Aug-11	3.5	7.5	15.3	8	14	48.3 (Fair)

The surrounding land use at the time of sampling was classified as forest, wetland, prairie, shrub, and residential/park in August, and row crop and residential/park in September. Riparian width varied from none – moderate (30 – 150 feet), and shade was light (5 – 25%) to moderate (25 – 50%). There was little (5 – 25%) to moderate (25 – 50%) bank erosion (according to the MSHA). The DNR identified substantial bank erosion during their geomorphology work (Figure 136).

Figure 136. ***"Significant sand and gravel deposits exist in this reach and are reflected in the stream banks and bedload estimates."*** **The caption and photo above were taken from the Straight River Geomorphology Sampling Summary provided by the DNR.**

Woody debris was the only macroinvertebrate habitat sampled at station 11LM088 (Figure 137). Pool habitat ranged from 5% - 20% of the station length during the two 2011 visits. Pool substrates were cobble and sand. Minimal riffles were present, ranging from 5% - 10%. Riffle substrates were cobble, gravel, and sand. Run features dominated, ranging from 75% - 85%. Run substrates were comprised of gravel and sand. Moderate – severe embeddedness was observed, and more than four substrate types were present in August and less than four substrate types were present in September. Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, and boulders) were available, and cover amount was sparse (5 – 25%). Channel sinuosity ranged from fair – good, channel stability was moderate, channel development was fair, and slow – moderate velocity types were present. Pool width was equal to or greater than riffle width.

Figure 137. Station 11LM088 (9/13/11).

Burrowers, climbers, and swimmers are near or within the middle quartiles (Figure 138). Clingers and legless fall within the lower quartile, and sprawlers are in the upper quartile. The lower abundance of clingers is an anticipated response from habitat stress; however, the very low number of legless is a result atypical of habitat stressed streams. Legless invertebrates are tolerant species like midges and snails. The top three taxa present were Tricorythodes (mayflies) (111), Dubiraphia (beetles) (56), and Nectopsyche (caddisfly) (30). Indicator values for suspended sediment and fine substrates for Tricorythodes, Dubiraphia, and Nectopsyche, developed by Carlisle et al (2007), are nine and nine, nine and eight, and eight and nine respectively. The scoring system is based on a scale from 1 – 10, with 10 being the most tolerant.

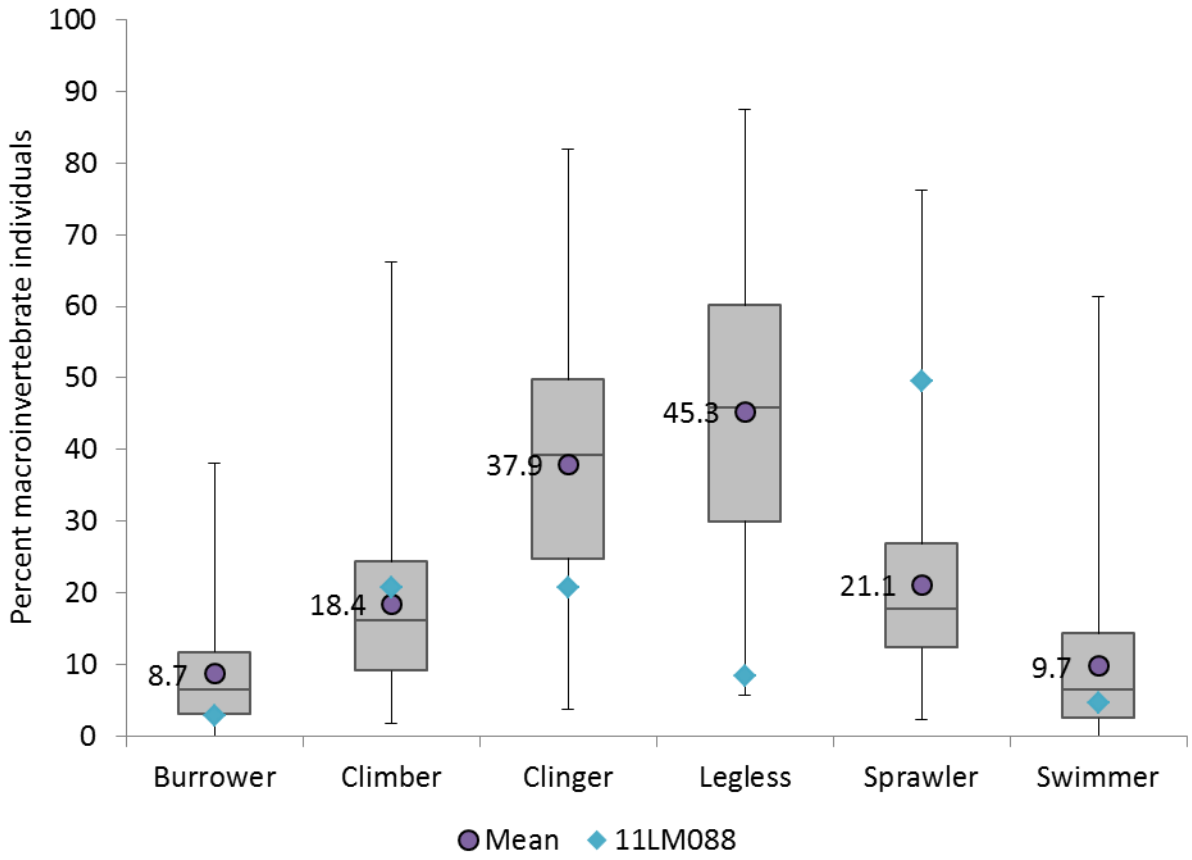


Figure 138. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Straight River Watershed stations.

This AUID had fair MSHA scores, little – moderate bank erosion (according to the MSHA), woody debris was the only habitat sampled, moderate – severe embeddedness was observed, and lower clingers and elevated sprawlers were sampled. Clingers attach to rock or woody debris, and sprawlers live on the surface of floating aquatic plants or fine sediments. Also, the top three macroinvertebrate taxa are very tolerant to suspended sediment and fine substrate. It appears that lack of habitat and fine substrates (embeddedness) are negatively impacting the macroinvertebrate community, and are stressors in this reach.

Fish Passage

There were no passage barriers identified in this AUID. At this time, fish passage is not currently a stressor.

Conclusion

This AUID has multiple stressors at play, with the cumulative effects leading to an impaired macroinvertebrate community. Nitrate, TSS/turbidity, and habitat are stressors in this reach. Phosphorus levels are elevated, but at this time it's inconclusive if phosphorus is a stressor due to limited data for the associated response variables (chl-a, BOD, and DO flux). Although inconclusive, reducing phosphorus levels is still recommended. DO is also inconclusive due to limited data; continuous monitoring is recommended. At this time, temperature and fish passage do not appear to be stressing

the macroinvertebrate community. Reducing nutrient and sediment loading in the Straight River, and improving in-stream habitat will benefit and improve the macroinvertebrate community. Additional monitoring for most parameters is also recommended.

4.5.4. Medford Creek (547)

Biological Communities

Medford Creek (07040002-547) is a 12.1 mile long AUID in Steele County. This warmwater reach flows through the Western Corn Belt Plains ecoregion, and joins the Straight River just downstream of Medford. Medford Creek has fish and macroinvertebrate impairments. Biological monitoring stations in this AUID include station 10EM075, station 11LM065, station 11LM063, and station 13LM002. These stations are located in the lower – middle portion of Medford Creek. Station 10EM075 was sampled in 2010 for fish and macroinvertebrates, and stations 11LM065 and 11LM063 were sampled in 2011 for fish and macroinvertebrates. Station 13LM002 was sampled for fish and macroinvertebrates in 2013.

The fish community in Medford Creek is impaired, and "not supporting" the aquatic life use. The FIBI scores were 70 and 73 (10EM075), 69 (11LM065), 39 and 58 (11LM063), and 41 (13LM002). Stations 10EM075, 11LM063 (2013), and 11LM065 were above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58), while stations 11LM063 (2011) and 13LM002 were below the threshold. Stations 11LM063 and 13LM002 are the farthest upstream stations. Also, all stations were above or below the CL, except station 11LM063 (2013) which was right at the upper confidence limit. There were 8 – 17 total fish species collected per station, including zero – one pollution intolerant species and zero to two game fish species. Some of the more abundant fish species collected included creek chub, white sucker, central stoneroller, bigmouth shiner, longnose dace, johnny darter, and blacknose dace. The game fish collected were largemouth bass and green sunfish. The relative abundance of taxa that are detritivorous (DetNWQTxPct), relative abundance of taxa that are generalist feeders (GeneralTxPct), taxa richness of sensitive species (Sensitive), and relative abundance of taxa that are very tolerant (VtolTxPct) at stations 11LM063 (2011) and 13LM002 had FIBI metric scores below average (with the exception of DetNWQTxPct at 13LM002) (Figure 139). These low scores resulted in low FIBI scores, which led to the fish impairment in Medford Creek.

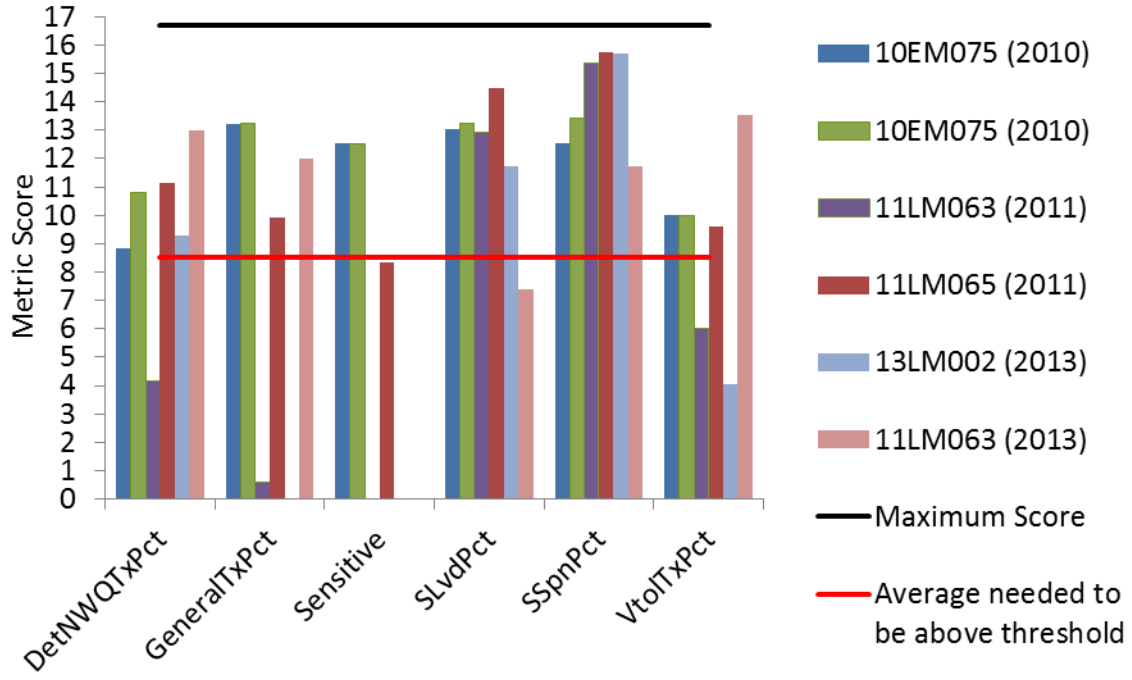


Figure 139. Fish metrics of the Southern Headwaters IBI for Medford Creek (07040002-547), stations 10EM075, 11LM063, 11LM065, and 13LM002.

The macroinvertebrate community is also impaired, and "not supporting" the aquatic life use. The MIBI scores were 45 (10EM075), 37 and 39 (11LM065), 31 (11LM063), and 27 (13LM002). Station 10EM075 and station 11LM065 are above the Southern Streams RR impairment threshold of 35.9 (lower CL = 23.3, upper CL = 48.5); all scores are below the upper confidence limit. Stations 11LM063 and 13LM002 were below the Southern Forest Streams GP impairment threshold of 46.8 (lower CL = 33.2, upper CL = 60.4); both are also below the lower confidence limit. Some of the more abundant taxa included Ceratopsyche (caddisflies), Cheumatopsyche (caddisflies), Gammarus (scuds), Calopterygidae (damselflies), Dubiraphia (beetles), and Oligochaeta (worms). In general, a majority of the MIBI metric scores were higher at stations 10EM075 and 11LM065, and lower at stations 11LM063 and 13LM002 (Figure 140 and Figure 141). All of the MIBI metrics except for DomFiveCHPct at station 11LM063 were below the average metric score needed to meet the MIBI threshold; thus resulting in the low MIBI score. Similarly, station 13LM002 only had one MIBI metric score (ClingerCh) above average.

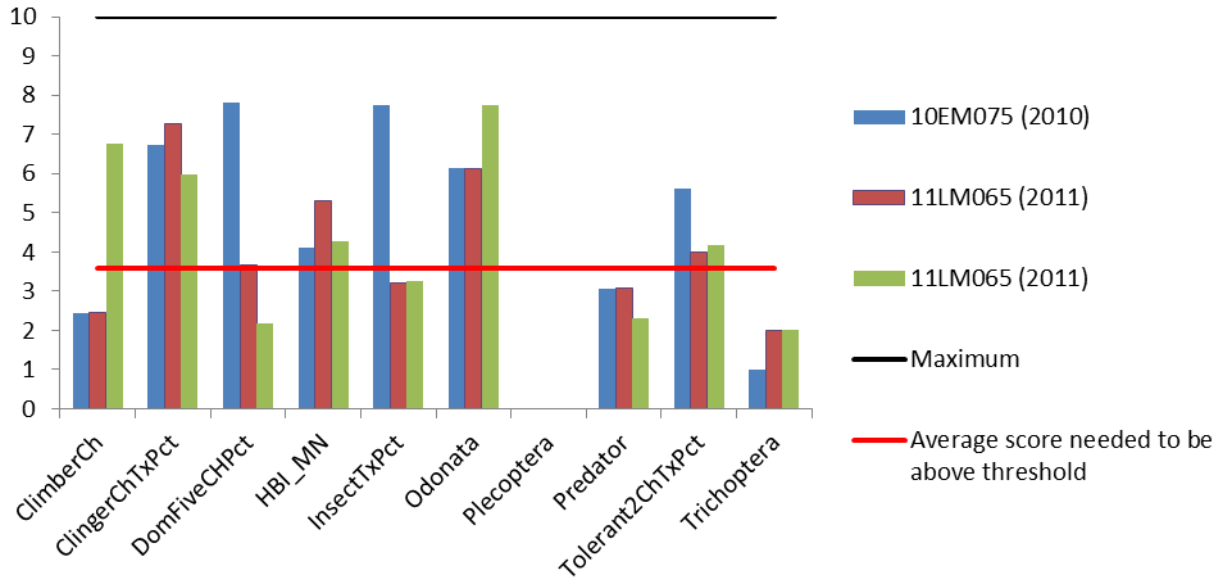


Figure 140. Macroinvertebrate metrics of the Southern Streams RR (class 5) IBI for Medford Creek (07040002-547), stations 10EM075 and 11LM065.

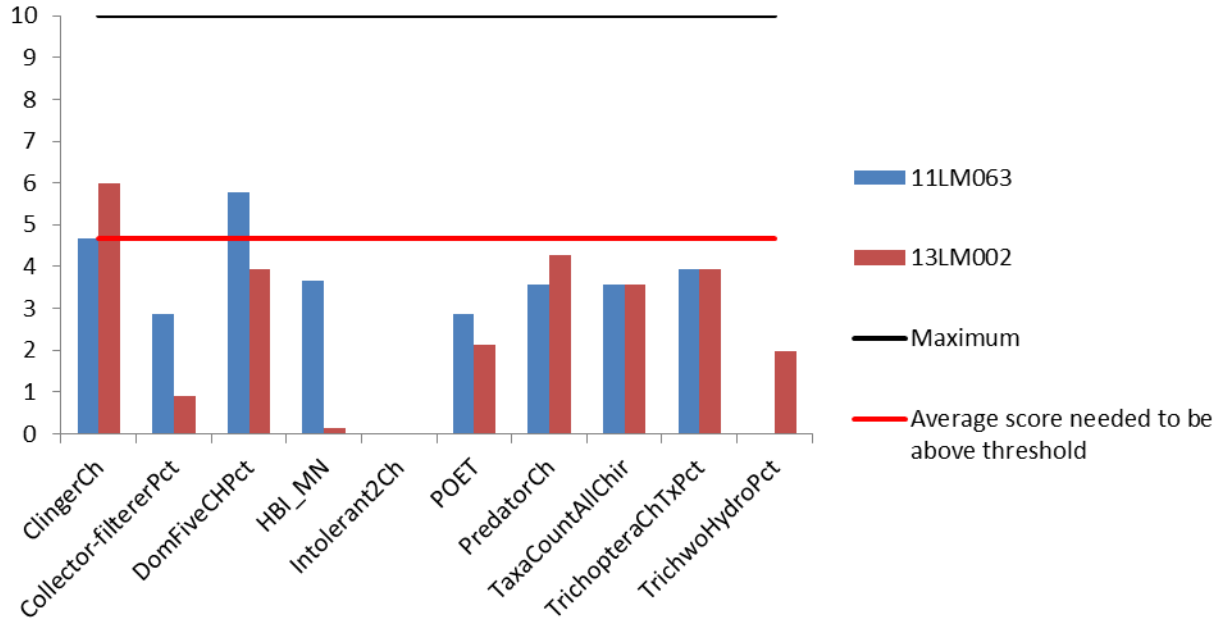


Figure 141. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for Medford Creek (07040002-547), stations 11LM063 and 13LM002.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 1978 – 2014 ranged from 0 °C – 22.9 °C (average of 12.6 °C). Only 15 samples have been collected, none of which were above 30 °C (the acute warmwater standard). Thirteen of the samples were collected from 2010 – 2014. Samples were collected from six stations (S000-501, S007-482, 10EM075, 11LM063, 11LM065, and 13LM002) in the lower – middle portion of Medford Creek in

February (two), April (three), May (one), June (one), July (one), and August (7). The highest temperature was observed on August 2,2011 (22.9 °C).

Temperature was recorded as part of a longitudinal DO survey in late summer 2014 throughout Medford Creek. A total of 14 measurements were taken, ranging from 15.3 °C – 22.7 °C. Also, a sonde was deployed from August 5, 2014 – August 11, 2014 at station 11LM063; during this time period there were zero samples above 30 °C (maximum temperature of 17.9 °C).

The temperature data set for this AUID is limited in terms of sample numbers, but does include continuous data over a six day period in the summer of 2014. There have been zero exceedances, and temperature does not appear to be a stressor in this AUID.

Nitrate

Nitrate concentrations from 1978 – 2014 ranged from 4.2 mg/L – 24 mg/L (average of 10.9 mg/L). Only 16 samples have been collected during this time period, and they were collected at six different monitoring stations in the lower – middle portion of Medford Creek. There were several elevated concentrations; eight samples were greater than 10 mg/L, and 13 samples were greater than 8 mg/L. Recent samples, collected from 2010 – 2014, range from 5.9 mg/L – 24 mg/L (average of 11.8 mg/L). These 14 recent samples were collected at five different monitoring stations in the lower – middle portion of the AUID in April (four), May (one), June (one), July (one), and August (Seven). There were eight samples greater than 10 mg/L and 13 samples greater than 8 mg/L. The samples greater than 10 mg/L occurred in April (one), May (one), June (one), July (one), and August (four), with seven out of the eight located in the middle of the AUID. Elevated nitrate concentrations are present in Medford Creek, but additional sampling with good spatial and temporal coverage is still recommended to bolster the data set.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate class 5 (Southern Streams RR) streams in Minnesota shows with 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class.

Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide average at all of the stations on Medford Creek (Table 108). All of these metrics are expected to decrease in response to stress. Intolerant2Ch was zero at all four stations. Station 11LM063, the farthest upstream station, had the lowest values for all three metrics.

Stations 11LM063, 11LM065, and 13LM002 had zero nitrate intolerant and very intolerant taxa present. Station 10EM075 had one nitrate intolerant taxa present, and zero nitrate very intolerant taxa. All stations had several nitrate tolerant and very tolerant taxa present, ranging from 20 – 25 and 12 – 16 respectively. Nitrate tolerant and very tolerant taxa comprised a high percentage of the

macroinvertebrate community at all stations, ranging from 60% - 92% and 40% - 81% respectively. At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI, and at 83.8% nitrate tolerant individuals there is a 10% probability of meeting the MIBI. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. The nitrate index scores were 3.1 (10EM075), 3.6 and 3.4 (11LM065), 3.6 (11LM063), and 4.0 (13LM002), all of which are above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 108. Macroinvertebrate metrics that respond to nitrate stress in Medford Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
10EM075 (2010)	**3**	**0.0**	**0**	**3.1**	**1**	**0**	**23**	**15**	**59.9**	39.5
11LM065 (2011)	**4**	**0.3**	**0**	**3.6**	**0**	**0**	20	12	**84.1**	**71.7**
11LM065 (2011)	**4**	**0.9**	**0**	**3.4**	**0**	**0**	**25**	**16**	**80.8**	**59.1**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.9*	*2.4*	*0.9*	*20.2*	*13.1*	*57.6*	*40.1*
11LM063 (2011)	**2**	**0.0**	**0**	**3.6**	**0**	**0**	**22**	**15**	**87.1**	**62.6**
13LM002 (2013)	**2**	**0.6**	**0**	**4.0**	**0**	**0**	**20**	**14**	**91.7**	**81.0**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the nitrate data set is limited in terms of sample numbers, it's apparent that elevated concentrations exist. In addition to elevated nitrate concentrations, most of the macroinvertebrate metrics are worse than the statewide average, several nitrate tolerant and very tolerant taxa are present throughout Medford Creek, and the nitrate index scores were worse than the statewide average. There is also a lack of nitrate intolerant taxa. Additional monitoring is recommended to strengthen the data set, but it appears that nitrate is a stressor to the biota in Medford Creek.

Phosphorus

TP concentrations from 1978 – 2014 ranged from 0.075 mg/L – 0.292 mg/L (average of 0.124 mg/L). Only 13 samples have been collected, but two samples were above the draft river eutrophication standard for the South Region (0.150 mg/L). One of the samples in this data set was collected in 1978, and the remaining samples were collected from 2010 – 2014. Samples were collected from six stations (10EM075, 11LM063, 11LM065, 13LM002, S000-501, and S007-482) in the lower to middle portion of Medford Creek in February (one), April (three), May (one), July (one), and August (seven). There were zero samples collected in the upper end of Medford Creek. The two exceedances occurred on April 8,

2014 (0.212 mg/L) and April 9, 2013 (0.292 mg/L); both at station S007-482 (near the middle of the AUID).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. There have been zero recent chl-a or BOD samples collected, but there were two BOD samples collected in 1978. Both were well below the draft standard for the South Region (3.0 mg/L) at 0.6 mg/L and 0.8 mg/L. BOD and chl-a should be sampled in the future. There were zero DO flux exceedances identified during a longitudinal DO survey in the summer of 2014, and zero DO flux exceedances during sonde deployment at station 11LM063 from August 5, 2014 – August 11, 2014.

All of the macroinvertebrate metrics with strong relationships to phosphorus were worse than the statewide average of stations meeting the MIBI threshold at stations 11LM065, 11LM063, and 13LM002 (Table 109). These stations had below average total taxa richness (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of collector-gatherers (Collector-gathererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch). These metrics are expected to decrease in response to stress. The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), which is expected to increase in response to stress, was above the statewide average. Station 10EM075, near the mouth of Medford Creek, had worse than average metric values for four out of the six metrics. TaxaCountAllChir, Collector-filtererCh, EPT, Intolerant2Ch, and Tolerant2ChTxPct were below the statewide average, and Collector-gathererCh was above the statewide average. Overall, most of the macroinvertebrate metrics at the stations throughout Medford Creek have values indicative of stress.

Table 109. Macroinvertebrate metrics that respond to TP stress in Medford Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
10EM075 (2010)	**40**	**6**	16	**7**	**0**	67.5
11LM065 (2011)	**36**	**5**	**13**	**6**	**0**	**75.0**
11LM065 (2011)	**31**	**3**	**10**	**7**	**0**	**74.2**
Southern Streams Average	*42.2*	*6.3*	*14.8*	*10.7*	*0.7*	*73.1*
11LM063 (2011)	**31**	**3**	**11**	**3**	**0**	**90.3**
13LM002 (2013)	**31**	**3**	**10**	**4**	**0**	**87.1**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

The fish metrics had varying results across the stations in Medford Creek (Table 110). Station 10EM075 was sampled twice for fish in 2010 (July and August). A majority of the metric values during both visits

were atypical of a stressed stream. All of the metric values for the August visit were better than the statewide average of stations meeting the FIBI threshold. Station 11LM065, just upstream of station 10EM075, had four out of five metric values that were better than the statewide average. The only metric that had a value indicative of stress was the abundance of darter species (DarterPct), which was below the statewide average. Stations 11LM063 and 13LM002, near the middle of Medford Creek, displayed more signs of stress than the other two stations. All of the metrics at station 11LM063 in 2011 were worse than the statewide average. There were an incredibly high number of tolerant individuals (TolPct) at approximately 96%, and 0% sensitive individuals (SensitivePct). The 2013 assessment had higher DarterPct, abundance of simple lithophilic spawners (SLithopPct), and total taxa richness (TaxaCount), but still had 0% sensitive individuals and three out of the five metrics had values indicative of stress. All of the metrics at station 13LM002 besides SLithopPct were worse than the statewide average. The fish metrics seem to identify some stress in the middle portion of Medford Creek.

Table 110. Fish metrics that respond to TP stress in Medford Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount
10EM075 (2010)	6.8	**9.1**	32.6	**75.5**	17
10EM075 (2010)	13.9	17.0	36.3	63.3	17
11LM065 (2011)	35.2	**7.7**	53.9	50.6	12
11LM063 (2011)	**0.0**	**2.0**	**30.6**	**95.9**	**8**
11LM063 (2013)	**0.0**	14.5	35.3	**84.7**	**10**
13LM002 (2013)	**0.0**	**0.0**	47.7	**89.8**	**9**
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*
Expected response to stress	↓	↓	↓	↑	↓

Medford Creek has minimal TP samples, zero recent chl-a and BOD samples, and minimal DO flux information. Elevated TP concentrations have been documented, and a majority of the macroinvertebrate metrics were worse than the statewide average. Also, the fish metrics were suggestive of stress in the middle portion of the AUID. At this time though, it's inconclusive whether or not phosphorus is stressing the fish and macroinvertebrate communities in Medford Creek due to limited data. Additional monitoring (TP, chl-a, BOD, and DO flux) is necessary for stressor determination.

Dissolved Oxygen

DO concentrations from 1978 – 2014 ranged from 7.5 mg/L – 12.8 mg/L (average of 9.4 mg/L). Only 14 samples have been collected over this time frame, none of which were below the warmwater standard of 5 mg/L. The samples were collected from six stations (10EM075, 11LM063, 11LM065, 13LM002, S000-501, and S007-482) near the lower – middle portion of Medford Creek in February (two), April (two), May (one), June (one), July (one), and August (seven). Twelve of the samples in this data set were collected from 2010 – 2014, and the remaining two samples were collected in 1978. The lowest concentration was observed on August 28, 2013 (7.5 mg/L).

A longitudinal DO survey completed in late summer 2014 identified a low DO value (4.72 mg/L) at the Northeast 50th Street road crossing just upstream of station 11LM063. Also, sonde deployment at station 11LM063 from August 5, 2014 – August 11, 2014 resulted in low DO concentrations approximately 18% of the time (minimum of 3.9 mg/L).

The total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) were worse than the statewide average of stations meeting the MIBI threshold at all of the stations in Medford Creek (Table 111). The exception to this was Tolerant2ChTxPct at station 10EM075, which was better than the statewide average. Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

All of the stations in Medford Creek had multiple DO intolerant and very intolerant macroinvertebrate taxa, ranging from 6 – 15 and three to eight respectively. All stations also had DO tolerant taxa, ranging from one – 3. DO tolerant taxa, however, comprise a very small portion of the macroinvertebrate community (0.3% - 6.1%). DO very tolerant taxa were present at two out of the four stations, but at very low percentages (1.1% and 1.3%). The macroinvertebrate DO index scores were 7.5 (10EM075), 7.0 (11LM063), 7.6 (11LM065), 7.7 (11LM065), and 6.9 (13LM002). All of these scores, except for station 13LM002, are at or above the statewide average of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 111. Macroinvertebrate metrics that respond to low DO stress in Medford Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
10EM075 (2010)	**40**	67.5	**7**	7.5	15	8	3	**2**	2.3	1.3
11LM065 (2011)	**36**	**75.0**	**6**	7.6	15	8	1	0	0.3	0.0
11LM065 (2011)	**31**	**74.2**	**7**	7.7	11	**5**	1	0	1.2	0.0
Southern Streams Average	*42.2*	*73.1*	*10.7*	*7.2*	*9.4*	*5.1*	*4.2*	*1.5*	*8.8*	*1.8*
11LM063 (2011)	**31**	**90.3**	**3**	7.0	7	**3**	3	1	6.1	1.1
13LM002 (2013)	**31**	**87.1**	**4**	**6.9**	**6**	**3**	3	0	3.8	0.0
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

The fish metrics with strong relationships to DO were above and below the statewide average of stations meeting the FIBI threshold (Table 112). The following stations are discussed going from downstream to upstream. Station 10EM075 was sampled twice in 2010. During the July visit, the relative

abundance of individuals with a female mature age ≥ 3 (MA>3Pct), relative abundance of individuals that are serial spawning species (SSpnPct), and relative abundance of individuals that are tolerant species (TolPct) were worse than the statewide average. The taxa richness of sensitive species (Sensitive) and total taxa richness of fish species (TaxaCount) were better than the statewide average. The August visit produced worse than average MA>3Pct and SSpnPct, and better than average sensitive species, TolPct, and overall taxa richness. Station 11LM065 had worse than average MA>3Pct, and better than average sensitive species, SSpnPct, TolPct, and overall taxa richness. All of the metrics at station 13LM002 were worse than the statewide average except for SSpnPct. Station 11LM063, the farthest upstream station, was sampled in 2011 and 2013. All of the metrics besides SSpnPct in 2011 were worse than the statewide average. Sensitive species, MA>3Pct, and TaxaCount are expected to decrease in response to stress, while SSpnPct and TolPct are expected to increase. MA>3Pct was below the statewide average during all visits at all stations. The fish metrics in the lower end of Medford Creek are a little mixed, but the metrics in the middle of the AUID are suggestive of stress. The fish DO TIV scores, however, were all above the statewide average (7.1) of stations meeting the FIBI threshold (scores ranged from 7.2 – 7.5). As these scores increase, so does the sensitivity of the community.

Table 112. Fish metrics that respond to low DO stress in Medford Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Sensitive	MA>3Pct	SSpnPct	TolPct	TaxaCount
10EM075 (2010)	3	**13.3**	**19.1**	**75.5**	17
10EM075 (2010)	3	**6.2**	**15.1**	63.3	17
11LM065 (2011)	2	**4.4**	4.4	50.5	12
11LM063 (2011)	**0**	**12.2**	6.1	**95.9**	**8**
11LM063 (2013)	**0**	**2.8**	**22.9**	**84.7**	**10**
13LM002 (2013)	**0**	**12.5**	4.5	**89.8**	**9**
Southern Headwaters Average	*1.7*	*13.5*	*14.9*	*74.3*	*11.3*
Expected response to stress	↓	↓	↑	↑	↓

DO data in Medford Creek is minimal, but does include continuous data from 2014 sonde deployment, which identifies low DO near the middle of Medford Creek. The accompanying biological data is a little mixed overall. Some of the macroinvertebrate metrics were worse than the statewide average, but there were several DO intolerant and very intolerant taxa present at all stations. Also, DO tolerant taxa comprised a very small portion of the macroinvertebrate community and the DO index scores were at or above the statewide average (except for station 13LM002). The fish metrics were a little mixed, but did show signs of stress near the middle of the AUID. The fish DO index scores, however, were all better than the statewide average. At this time, it's inconclusive if DO is a stressor due to mixed biological response. Additional monitoring is recommended for stressor determination.

TSS/Turbidity

TSS concentrations from 1978 – 2014 ranged from 1.6 mg/L – 31 mg/L (average of 12.6 mg/L). Only 15 samples have been collected during this timeframe, and they were collected at six different monitoring

stations (S000-501, S007-482, 10EM075, 11LM063, 11LM065, and 13LM002) in the lower – middle portion of the AUID. More recent samples (2010 – 2014) ranged from 1.6 mg/L – 31 mg/L (average of 13.7 mg/L). These 13 samples were collected during April (four), May (one), July (one), and August (seven) at five different monitoring stations in the lower – middle portion of Medford Creek. There were no samples collected in the upper end of Medford Creek. There were zero samples greater than 65 mg/L, the draft TSS standard for the South Region.

Transparency values from 2010 – 2014 ranged from 14 cm – 100 cm (average of 79 cm). Only 19 samples have been collected, and they were collected from 11 stations throughout Medford Creek in April (three), May (seven), June (one), July (one), and August (seven). There were zero exceedances of the s-tube surrogate standard for the South Region (10 cm). Six of these samples were collected on May 20, 2014 as part of a longitudinal secchi tube survey; values from this survey ranged from 80 cm – 100 cm. The three lowest values in this data set are 14 cm (June 2, 2014), 20 cm (April 9, 2013), and 35 cm (April 8, 2014).

All but one of the macroinvertebrate metrics with strong relationships to TSS were below the statewide average of stations meeting the MIBI threshold (Table 113). Station 10EM075, near the mouth of Medford Creek, had above average relative abundance of collector-filterer individuals (Collector-filtererPct). Collector-filtererPct and relative abundance of Plecoptera individuals (PlecopteraPct) were below average at all of the other stations. There were no stoneflies (Plecoptera) sampled in Medford Creek, and very few collector-filterer individuals were present in the middle portion of Medford Creek. Both of these metrics are expected to decrease in response to stress.

Stations 10EM075, 11LM063, 11LM065, and 13LM002 had zero TSS intolerant and very intolerant taxa present. These stations, however, did have TSS tolerant (ranging from three to eight) and very tolerant (ranging from one – 2) taxa present. TSS tolerant taxa comprised 11 -35% of the macroinvertebrate community, and TSS very tolerant taxa comprised 0 – 5%. The macroinvertebrate TSS index scores for stations 10EM075 and 11LM065 (two) were 16.5, 16.2, and 15.8 respectively, which is better than the statewide average (17.1) of stations meeting the MIBI threshold. These two stations are located in the lower end of Medford Creek. The two stations near the middle of the AUID (13LM002 and 11LM063) had TSS index scores of 17.5 and 16.4 respectively, which are worse than the statewide average (16.2) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community.

Table 113. Macroinvertebrate metrics that respond to TSS stress in Medford Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
10EM075 (2010)	45.3	**0.0**	16.5	**0**	**0**	8	2	**34.9**	4.6
11LM065 (2011)	**23.5**	**0.0**	16.2	**0**	**0**	7	1	23.3	2.2
11LM065 (2011)	**23.1**	**0.0**	15.8	**0**	**0**	6	2	20.2	1.9
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*0.8*	*11.3*	*4.9*	*34.0*	*13.0*
11LM063 (2011)	**11.1**	**0.0**	**16.4**	**0**	**0**	6	1	20.5	0.4
13LM002 (2013)	**3.8**	**0.0**	**17.5**	**0**	**0**	3	1	11.1	0.4
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

The following fish metrics for Medford Creek are discussed going from downstream to upstream. Station 10EM075, near the mouth of Medford Creek, was sampled twice in 2010. The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are long-lived (LLvdPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were worse than the statewide average of stations meeting the FIBI threshold during at least one of the visits (Table 114). Station 11LM065 had worse than average Centr-TolPct, HrbNWQPct, LLvdPct, Percfm-TolPct, and SLithFrimPct. Station 13LM002 was worse than average in all metric categories except for SLithFrimPct and the TSS index score. Station 11LM063, near the middle of Medford Creek, was sampled in 2011 and 2013. All of the metrics in 2011 were worse than the statewide average. In 2013, all of the metrics besides Percfm-TolPct and the TSS index score were worse than the statewide average. All of the metrics except the TSS index score are expected to decrease in response to stress. Centr-TolPct and LLvdPct were below the statewide average at all of the stations in Medford Creek. The fish TSS index scores were equal to or better than the statewide average at all of the stations except for one of the visits at station 11LM063. The lower the score, the more sensitive the community is to TSS. Overall, a majority of the fish metrics were worse than the statewide average. Also, the metrics seem to be more significantly affected near the middle of Medford Creek (station 13LM002 and 11LM063).

Table 114. Fish metrics that respond to TSS stress in Medford Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RiffePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
10EM075 (2010)	**30.8**	**0.2**	25.4	2.1	**0.2**	**9.3**	27.3	6.8	14.5	15.1
10EM075 (2010)	40.9	**0.4**	**18.5**	12.0	**0.4**	17.4	30.9	13.9	**6.6**	14.2
11LM065 (2011)	51.7	**0.0**	**17.6**	31.9	**0.0**	**7.7**	46.2	35.2	**4.4**	13.0
11LM063 (2011)	**14.3**	**0.0**	**12.2**	**0.0**	**0.0**	**2.0**	**12.2**	**0.0**	**12.2**	**15.4**
11LM063 (2013)	**18.1**	**0.0**	**3.2**	**0.0**	**0.0**	14.5	**3.2**	**0.0**	**3.2**	13.9
13LM002 (2013)	**14.8**	**0.0**	**12.5**	**0.0**	**0.0**	**0.0**	**12.5**	**0.0**	14.8	14.9
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Medford Creek has zero TSS or transparency exceedances, but minimal samples have been collected. Many of the macroinvertebrate metrics were worse than the statewide average. There were zero macroinvertebrate TSS intolerant and very intolerant taxa present at all stations in this AUID, but the macroinvertebrate TSS index scores were better than the statewide average at the two lower stations. All stations had multiple TSS tolerant taxa and one to two very tolerant taxa. A majority of the fish metrics were below the statewide average, but five out of six fish TSS index scores were as good as or better than the statewide average. Due to the limited chemistry data and mixed biological response, it's inconclusive if TSS/turbidity is acting as a stressor to the fish and macroinvertebrate communities. Additional monitoring with good spatial and temporal coverage is recommended.

Lack of Habitat

The MSHA scores in Medford Creek ranged from 46.5 ("fair") – 69.6 ("good") (Table 115). The only "good" score occurred near the mouth of Medford Creek (station 10EM075) in 2010. The two lowest scores occurred in 2011 and 2013 at station 11LM063, the most upstream station. Station 11LM063 had very poor land use, substrate, and channel morphology sub-category scores. The cover score was also very low in 2013.

Table 115. MSHA subcategory scores for Medford Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
10EM075	14-Jul-10	2.5	13	20.1	11	23	69.6 (Good)
10EM075	25-Aug-10	2.5	11.5	18.1	5	25	62.1 (Fair)
11LM063	02-Aug-11	0	10	9	15	15	49 (Fair)
11LM065	02-Aug-11	0	11	17.8	9	24	61.8 (Fair)
11LM063	05-Aug-13	1.5	13	10	6	16	46.5 (Fair)
13LM002	06-Aug-13	2.5	12	16	8	23	61.5 (Fair)

The surrounding land use at the time of sampling at the four stations in Medford Creek was classified as natural (forest, wetland, prairie, and shrub), row crop, and old field. Riparian width varied from moderate (30 -150 feet) to extensive (>300 feet), and shade was substantial (50 – 75%) to heavy (>75%). There was no to moderate (25 – 50%) bank erosion.

The two downstream stations had multiple macroinvertebrate habitats sampled. Macroinvertebrates were sampled in riffles, undercut banks/overhanging vegetation, and woody debris at station 10EM075. Habitats sampled at station 11LM065 included riffles and woody debris. The two upstream stations, station 11LM063 and station 13LM002, had only one habitat type sampled (woody debris) (Figure 142).

Pool habitat types ranged from 10% - 25% of the station length. Pool substrates included gravel (two stations), sand (four stations), and silt (one station). Riffles ranged from 0% - 25%, and contained cobble (two stations), gravel (three stations), and sand (one station) substrates. Run features were the dominant feature at all stations, ranging from 65% - 90%. Run substrates consisted of gravel (two stations), sand (four stations), and silt (one station). Substrate embeddedness ranged from light – no course substrate. Multiple cover types (undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders, and rootwads) were available, and cover amount ranged from sparse (5 – 25%) to extensive (>50%). Channel sinuosity was poor – excellent, channel stability was low – moderate/high, channel development was fair – good, and multiple velocity types were present (slow – fast including eddies). The pool width was greater than the riffle width at the three lower stations, and there were no riffles at the upstream station. Depth variability was good, with the greatest depth greater than four times the shallowest depth.

Figure 142. Habitat at station 11LM063 (8/2/11).

The habitat specific metrics for station 10EM075 and station 11LM065 were present at levels not typical for habitat stressed streams (Figure 143). Burrowers and legless are expected to increase in response to habitat stress; these metrics were below the average of Southern Streams RR stations meeting the MIBI threshold. Climbers and clingers are expected to decrease in response to habitat stress; most of these metrics were above the average of Southern Streams RR stations meeting the MIBI threshold. Station 11LM063, however, did show some signs typical of habitat stressed streams (Figure 144). Burrower and legless percentages were elevated, and in the upper quartile. Station 13LM002 also had elevated legless percentages. Climber MIBI metric scores were below the average metric score needed to meet the MIBI threshold at station 10EM075 and one of the visits at station 11LM065. Clinger MIBI metric scores were above the average metric score at stations 10EM075, 11LM065, and 13LM002, and just below the average metric score at station 11LM063.

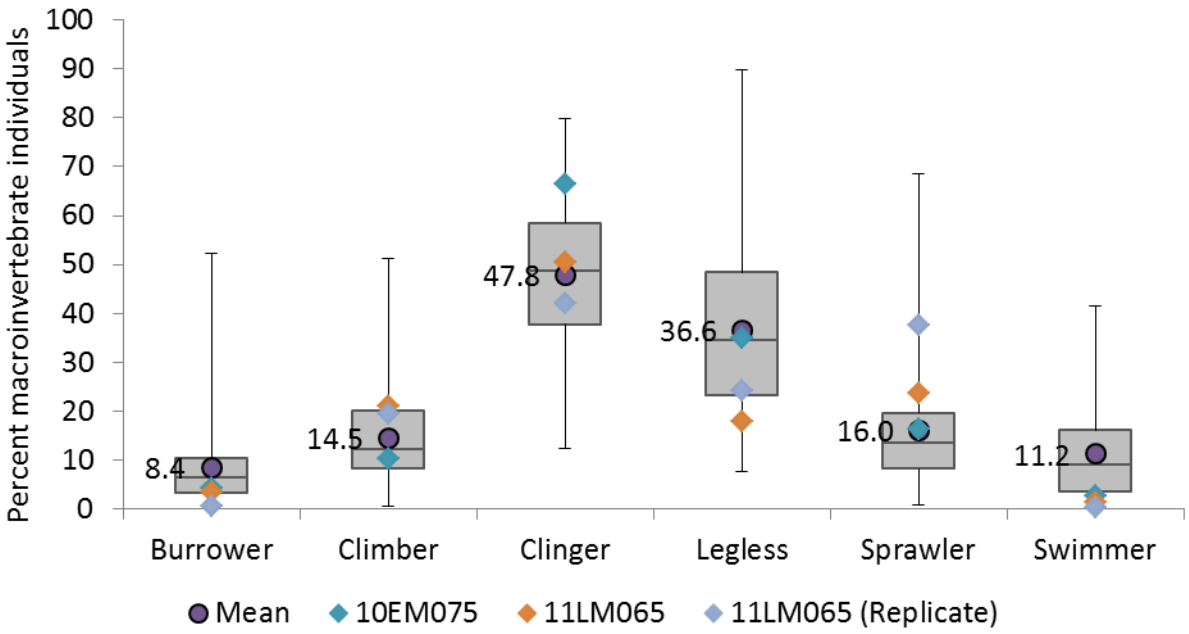


Figure 143. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR (class 5) stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from Medford Creek Watershed stations.

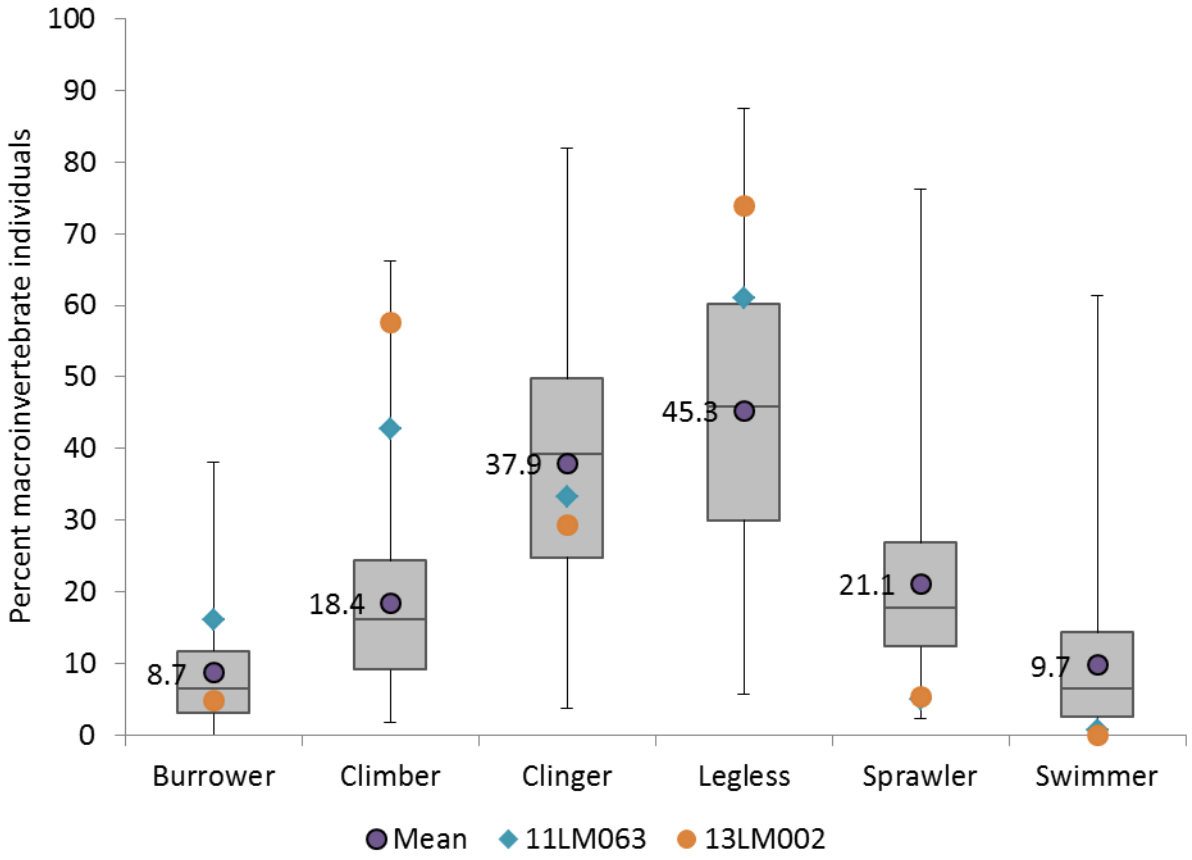


Figure 144. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Medford Creek Watershed stations.

During one visit in 2010, station 10EM075 had worse than average relative abundance of individuals that are tolerant species (TolPct) and relative abundance of individuals that are darter, sculpin, and round bodied sucker species (DarterSculpSucPct), and better than average relative abundance of individuals that are benthic insectivore species (BenInsectPct), relative abundance of individuals that are lithophilic spawners (LithFrimPct), relative abundance of individuals of the dominant two species (DomTwoPct), and relative abundance of individuals that are riffle-dwelling species (RifflePct) (Table 116). During the other visit in 2010, all of these metrics were better than the statewide average of stations meeting the FIBI threshold. All of the metrics at station 11LM065 besides DarterSculpSucPct were better than the statewide average. Station 11LM063, in 2011, had worse than average metric values for all metrics except LithFrimPct. In 2013, half of the metrics were better than average and half were worse than average. All of the metrics at station 13LM002 besides LithFrimPct were worse than average. In general, a majority of the habitat related fish metrics were better than the statewide average of stations meeting the FIBI threshold in the lower portion of Medford Creek, and worse than average in the middle portion.

Table 116. Fish metrics that respond to habitat stress in Medford Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TolPct	BenInsectPct	LithFrimPct	DarterSculpSucPct	DomTwoPct	RiffePct
10EM075 (2010)	**75.5**	18.7	78.6	**9.1**	47.3	27.3
10EM075 (2010)	63.3	34.4	74.5	17.0	37.8	30.9
11LM065 (2011)	50.6	44.0	87.9	**7.7**	56.0	46.2
11LM063 (2011)	**95.9**	**4.1**	91.8	**2.0**	**77.6**	**12.2**
11LM063 (2013)	**84.7**	34.9	**62.7**	14.5	58.6	**3.2**
13LM002 (2013)	**89.8**	**1.1**	90.9	**0.0**	**68.2**	**12.5**
Southern Headwaters Average	*74.3*	*14.3*	*64.1*	*11.2*	*60.4*	*25.4*
Expected response to stress	↑	↓	↓	↓	↑	↓

The MSHA scores in Medford Creek ranged from fair – good, with the lowest scores occurring in the upper end at station 11LM063. Conditions varied throughout the AUID, including bank erosion (none – moderate) and substrate embeddedness (light – no course substrate). Multiple habitat types were available and sampled throughout Medford Creek, but the only habitat sampled at station 11LM063 and station 13LM002 was woody debris. The macroinvertebrate habitat specific metrics were within an expected range for the most part, but the elevated burrowers and legless in the upper end suggest stress. Similar to the macroinvertebrate metrics, the fish metrics were generally satisfactory in the lower end, but displayed signs of stress in the upper stations. Lack of habitat and excess fine sediment (embeddedness) is a stressor in Medford Creek, particularly in the upper end.

Fish Passage

One potential fish passage issue and a perched culvert were identified during a survey on July 31, 2014 (Figure 145). Both occurred in the very upper end of Medford Creek at the two farthest upstream road crossings (County Road 8 and Northeast 36th Street). The passage at County Road eight appeared that it may prohibit certain fish from migrating upstream (especially at lower flows than those encountered during the survey). The Northeast 36th Street crossing had a perched culvert which prohibited migration. While these barriers are located within the impaired reach, they are miles upstream from the sampling locations with low FIBI scores. Fish passage has the potential to be a stressor in Medford Creek, but at this time it's inconclusive if it is a stressor. Effort should be made to properly place the culvert at the Northeast 36th Street crossing.

Figure 145. Passage at County Road 8 crossing (left) and perched culvert at NE 36th Street crossing (right).

Conclusion

At this time, based on the existing data set, nitrate and habitat are stressors in Medford Creek. Extremely elevated nitrate concentrations have been documented, and appear to be playing a significant role in the fish and macroinvertebrate impairments. Habitat seems to be inducing more localized stress in the upper end of Medford Creek. It's inconclusive if phosphorus, DO, TSS/turbidity, and/or fish passage are stressors due to limited data; additional monitoring is recommended to enable stressor determination. Temperature is not currently a stressor. Reducing the nitrate loading to Medford Creek should be a priority, as well as improving in-stream habitat and properly placing and designing culverts and bridges to allow water conveyance and biota passage.

4.5.5. Unnamed Creek (731)

Biological Communities

Unnamed Creek (07040002-731) is a tributary to Maple Creek (which joins the Straight River in Owatonna) in Steele County. This warmwater AUID currently has a macroinvertebrate impairment. Station 11LM061 is the only biological monitoring station in this AUID, and it is located in the upper end of the tributary. This station was sampled for fish and macroinvertebrates in 2011.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI scores at station 11LM061 were 62 and 72, which are above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58). Both scores are also above the upper confidence limit. There were 17 – 20 total fish species collected, including zero pollution intolerant species and one game fish species. Creek chub and white sucker were the most abundant species during both visits. Green sunfish was the only game fish sampled.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI score at station 11LM061 was 44, which is below the Southern Forest Streams GP impairment threshold of 46.8 (lower CL = 33.2, upper CL = 60.4). There were 23 total families, including zero intolerant families. The three most abundant taxa were Rheotanytarsus (non-biting midges), Physa (snails), and Dubiraphia (beetles). HBI_MN, Intolerant2Ch, PredatorCh, TrichopteraChTxPct, and TrichwoHydroPct MIBI metric

scores were below the average metric score needed to meet the threshold, which resulted in the low MIBI score (Figure 146).

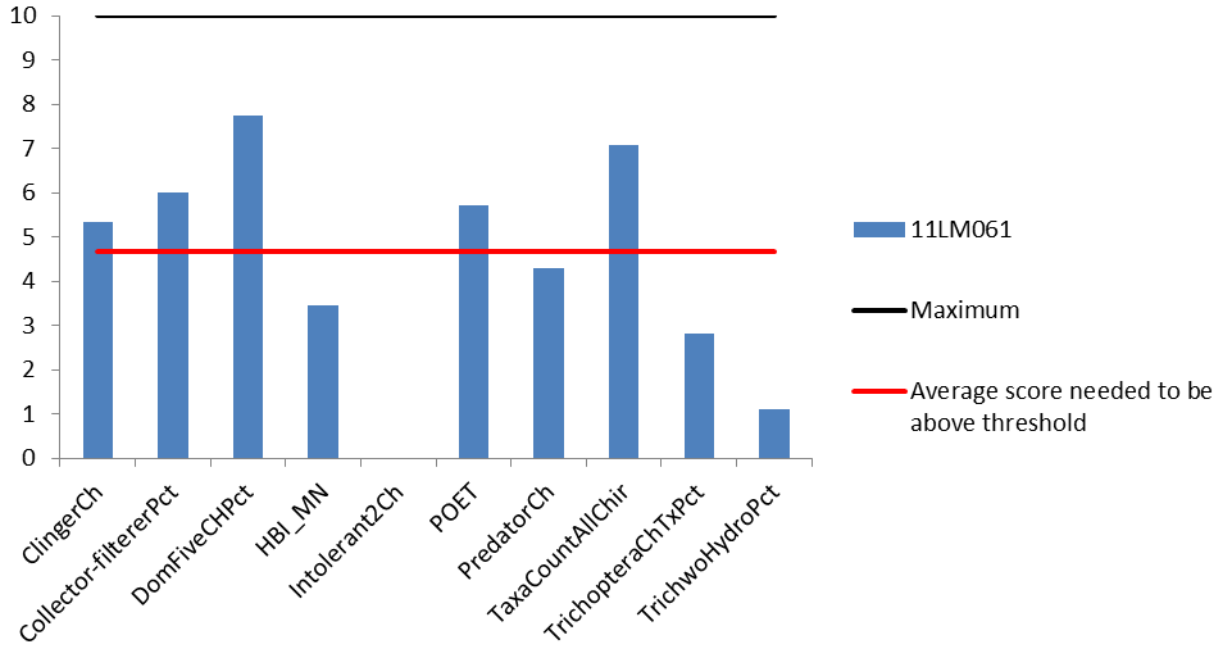


Figure 146. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for Unnamed Creek (07040002-731), station 11LM061.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 2011 – 2014 ranged from 1.4 °C – 27.0 °C (average of 13.8 °C). Only nine samples have been collected, none of which were above 30 °C (the acute warmwater standard). Samples were collected from two stations (S007-480 and 11LM061) co-located at the Havana Road crossing in April (three), May (one), June (one), and August (four). The highest temperature was observed on August 22, 2011 (27 °C).

A sonde was deployed from July 25, 2013 – August 7, 2013 at station 11LM061, and there were zero readings above 30 °C (maximum temperature of 21.8 °C). A sonde was also deployed at this station from August 5, 2014 – August 11, 2014, and there were zero readings above 30 °C (maximum temperature of 27.7 °C).

The temperature data set for this AUID is limited in terms of sample numbers, but does include continuous data in 2013 and 2014. There have been zero exceedances, and temperature does not appear to be a stressor in this AUID.

Nitrate

Nitrate concentrations from 2011 – 2014 ranged from 0.23 mg/L – 20 mg/L (average of 8.6 mg/L). Only nine samples have been collected in this AUID, and they were collected at two different monitoring stations in essentially the same location in the upper end of the tributary (Havana Road). These samples

were collected in April (three), May (one), June (one), and August (four). Elevated concentrations were present, as there were two samples greater than 10 mg/L and four samples greater than 8 mg/L. The three highest concentrations were 10 mg/L (April 24, 2014), 17 mg/L (May 20, 2013), and 20 mg/L (June 2, 2014). Albeit just a small snapshot during only two years, seasonal variability appears in the 2013 and 2014 samples. Nitrate concentrations in 2013 were 7.7 mg/L (April 9, 2013), 17 mg/L (May 20, 2013), and 3.3 mg/L (August 28, 2013); 2014 concentrations were 5.2 mg/L (April 3, 2014), 10 mg/L (April 24, 2014), 20 mg/L (June 2, 2014), and 4.2 mg/L (August 26, 2014). This pattern is often seen in heavily tiled warmwater systems. Additional sampling is recommended to build and strengthen this data set.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide average of stations meeting the MIBI threshold (Table 117). All of these metrics are expected to decrease in response to stress.

Station 11LM061 had one nitrate intolerant and zero nitrate very intolerant taxa present. This station had several nitrate tolerant (25) and very tolerant (16) taxa present. Nitrate tolerant and very tolerant taxa comprised a high percentage of the macroinvertebrate community at 65% and 56% respectively. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. The nitrate index score was 3.2, which is above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 117. Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM061 (2011)	**2**	**0.3**	**0**	**3.2**	**1**	**0**	**25**	**16**	**65.2**	**56.1**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

Elevated nitrate concentrations are present in the limited data set for this AUID, and all of the macroinvertebrate metrics are worse than the statewide average. Nitrate tolerant taxa are present in high numbers, and comprise a substantial portion of the overall community. Also, the nitrate index score is worse than the statewide average of stations meeting the MIBI threshold. Additional monitoring is recommended to get a better handle on the nitrate dynamics in this AUID, but the limited existing

chemistry data (with elevated concentrations) and strong biological response provide enough confidence to conclude that nitrate is a stressor in this AUID.

Phosphorus

TP concentrations from 2011 – 2014 ranged from 0.093 mg/L – 0.552 mg/L (average of 0.304 mg/L). Only eight samples have been collected, but six of the samples were above the draft river eutrophication standard for the South Region (0.150 mg/L). Samples were collected from two stations (S007-480 and 11LM061) co-located in the upper end of the AUID in April (three), May (one), and August (four). The six exceedances occurred in April (two), May (one), and August (three), and the three highest concentrations were 0.377 mg/L, 0.544 mg/L, and 0.552 mg/L. Algae and duckweed were observed just upstream of station 11LM061 in September 2014 (Figure 147).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. At this time, there have been zero chl-a and BOD samples collected; both of these parameters should be sampled in the future. Sonde deployment at station S007-480 from July 25, 2013 – August 7, 2013 resulted in DO flux exceedances (there were five daily DO flux exceedances with a maximum of 6.0 mg/L), and significant DO flux exceedances also occurred during sonde deployment from August 5, 2014 – August 11, 2014 (there were six daily DO flux exceedances with a maximum of 11.2 mg/L). Low DO, which is discussed in the DO section, was also present in this AUID.

Figure 147. Algae and duckweed just upstream of station 11LM061 at the 44th Avenue road crossing (9/18/14).

Four out of the six macroinvertebrate metrics with strong relationships to phosphorus were worse than the statewide average of stations meeting the MIBI threshold (Table 118). Station 11LM061 had below average taxa richness of collector-filterers (Collector-filtererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch). These metrics are expected to decrease in response to stress. The total taxa richness (TaxaCountAllChir), taxa richness of collector-gatherers (Collector-gathererCh), and the percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) were above the statewide average. TaxaCountAllChir and Collector-gathererCh are expected to decrease in response to stress, while Tolerant2ChTxPct is expected to increase.

Table 118. Macroinvertebrate metrics that respond to TP stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM061 (2011)	43	**4**	20	**7**	**0**	**88.4**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

Although the fish community is not impaired, the fish metrics can still assist in stressor determination. Station 11LM061 was sampled twice in August of 2011. The first visit resulted in four out of the five metrics with values indicative of stress (Table 119). The relative abundance of individuals that are sensitive species (SensitivePct), the abundance of darter species (DarterPct), and the abundance of simple lithophilic spawners (SLithopPct) were below the statewide average of stations meeting the FIBI threshold. These metrics are expected to decrease in response to stress. The relative abundance of individuals that are tolerant species (TolPct), and the total taxa richness (TaxaCount) were above the statewide average. TolPct was very high at approximately 92%. TolPct is expected to increase in response to stress, while TaxaCount is expected to decrease. The second visit resulted in two out of the five metrics with values indicative of stress. SensitivePct was below the statewide average, while DarterPct, SLithopPct, TolPct, and TaxaCount were above the statewide average.

Table 119. Fish metrics that respond to TP stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount
11LM061 (2011)	**3.3**	**5.3**	**30.3**	**91.5**	17
11LM061 (2011)	**1.9**	15.2	35.5	**81.3**	20
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*
Expected response to stress	↓	↓	↓	↑	↓

Although this data set has weak sample numbers, extremely elevated TP concentrations have been documented during various months throughout the year. There are no chl-a or BOD samples, but DO flux (as well as low DO) exceedances occurred in 2013 and 2014. In addition, algal production was documented in 2014 and most of the macroinvertebrate metrics were worse than the statewide average. Elevated phosphorus may be impacting the macroinvertebrate community, but at this time it's inconclusive if phosphorus is a stressor. Additional monitoring for TP, chl-a, BOD, and DO flux is recommended to strengthen this data set and enable stressor determination. Although inconclusive at this time, reducing phosphorus should be a priority in any future planning efforts. Phosphorus has the

potential to drive stressors such as low DO, eutrophication, feeding shifts, and habitat degradation. Reducing phosphorus loading should help (and/or protect from potential future impacts) the biology in this AUID.

Dissolved Oxygen

DO concentrations from 2011 – 2014 ranged from 4.89 mg/L – 10.28 mg/L (average of 7.8 mg/L). Only eight samples have been collected, but one of the samples was below the warmwater standard of five mg/L (4.89 mg/L). These samples were collected from two stations (S007-480 and 11LM061) co-located at the Havana Road crossing in April (two), May (one), June (one), and August (four). The three lowest concentrations were 4.89 mg/L (August 28, 2013), 6.41 mg/L (August 2, 2011), and 6.58 mg/L (August 26, 2014).

DO exceedances were observed at station 11LM061 during sonde deployment in 2013 and 2014. Sonde deployment in 2013, from July 25, 2013 – August 7, 2013, had DO exceedances approximately 4% of the time (minimum of 3.28 mg/L). Sonde deployment in 2014, from August 5, 2014 – August 11, 2014, had DO exceedances approximately 20% of the time (minimum of 4.41 mg/L).

Station 11LM061 had worse than average percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct) and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 120). The total macroinvertebrate taxa richness (TaxaCountAllChir) was better than the statewide average. Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

Station 11LM061 had six DO intolerant macroinvertebrate taxa and three DO very intolerant taxa. DO tolerant and very tolerant taxa were also present (six and two respectively), but they comprised a very minimal portion of the overall community (3.5% and 1.9% respectively). The macroinvertebrate DO index score was 7.1, which is above the statewide average (7.0) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 120. Macroinvertebrate metrics that respond to low DO stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM061 (2011)	43	**88.4**	**7**	7.1	**6**	**3**	**6**	2	3.5	1.9
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

Although there have been low DO concentrations observed in this AUID and half of the macroinvertebrate metrics are worse than the statewide average, it's inconclusive if DO is stressing the macroinvertebrate community. There are multiple DO intolerant and very intolerant taxa, and DO tolerant taxa comprise a very small portion of the community. Also, the DO index score was above the statewide average. Additional monitoring is needed for stressor determination.

TSS/Turbidity

TSS concentrations from 2011 – 2014 ranged from 4 mg/L – 47 mg/L (average of 18.0 mg/L). Only eight samples have been collected in this AUID, and they were collected at two different monitoring stations on the upper end of the tributary. The samples were collected in April (three), May (one), and August (four). There were zero samples greater than 65 mg/L, the draft TSS standard for the South Region.

Transparency values from 2011 – 2014 ranged from 26 cm – 100 cm (average of 66 cm). Only 11 samples have been collected, and they were collected at four stations (S007-480, 11LM061, 44th Avenue, and Havanna Road) in April (three), May (three), June (one), and August (four). There were zero samples below the s-tube surrogate standard for the South Region (10 cm). The three lowest values were 26 cm (August 22, 2011), 32 cm (August 26, 2014), and 34 cm (May 20, 2013).

The relative abundance of collector-filterer individuals (Collector-filtererPct) and relative abundance of Plecoptera individuals (PlecopteraPct) were below the statewide average of stations meeting the MIBI threshold (Table 121). There were no stoneflies (Plecoptera) present. Both of these metrics are expected to decrease in response to stress; both metrics had values indicative of stress.

Station 11LM061 had zero TSS intolerant and very intolerant taxa present. This station, however, did have TSS tolerant (17) and very tolerant (seven) taxa present. TSS tolerant and very tolerant taxa comprised 24% and 6% of the macroinvertebrate community respectively. The macroinvertebrate TSS index score for station 11LM061 was 17.2, which is worse than the statewide average (16.2) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community.

Table 121. Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM061 (2011)	**22.9**	**0.0**	**17.2**	**0**	**0**	**17**	**7**	24.2	5.5
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can help inform the SID process. Station 11LM061 was sampled on two different days in August of 2011. The relative abundance of individuals that are exclusively benthic feeders (BenFdFrimPct), relative abundance of individuals that are non-tolerant Centrarchidae (Centr-TolPct), relative abundance of individuals that are intolerant species (IntolerantPct), relative abundance of individuals that are long-lived (LLvdPct), relative abundance of individuals of the Order Perciformes excluding tolerant individuals (Percfm-TolPct), and relative abundance of individuals that are sensitive species (SensitivePct) were below the statewide average of stations meeting the FIBI threshold (Table 122). BenFdFrimPct and Percfm-TolPct were below average during one visit, while the other metrics were below average during both visits. There were no non-tolerant centrarchids, intolerant species, or long-lived individuals during either visit. The relative abundance of individuals that are herbivore species (HrbNWQPct), relative abundance of individuals that are riffle-dwelling species (RifflePct), and relative abundance of individuals that are simple lithophilic spawners (SLithFrimPct) were above the statewide average during both visits. All of these metrics are expected to decrease in response to stress. The TSS index score, which increases with stress, was above average during both visits. Overall, a majority of the fish metrics were worse than the statewide average.

Table 122. Fish metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RifflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
11LM061 (2011)	**31.6**	**0.0**	30.9	**0.0**	**0.0**	**5.3**	30.9	**3.3**	23.7	**15.8**
11LM061 (2011)	34.6	**0.0**	28.2	**0.0**	**0.0**	15.2	28.1	**1.9**	23.6	**15.8**
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

This AUID has minimal samples with zero exceedances. A majority of the macroinvertebrate metrics were worse than the statewide average, there were zero TSS intolerant and very intolerant taxa and multiple TSS tolerant and very tolerant taxa, and the macroinvertebrate TSS index score was worse than the statewide average. A majority of the fish metrics, although not impaired, were suggestive of stress. TSS/turbidity could potentially be stressing the macroinvertebrate community, but at this time it's inconclusive due to the limited chemistry data. Additional monitoring is necessary to determine if TSS/turbidity is a stressor.

Lack of Habitat

MSHA scores for station 11LM061 were "fair" in 2011 (48 and 55.75) (Table 123). Substrate sub-category scores were very low during both visits; the substrate sub-category has 27 possible points. Land use scores were also low during both visits, receiving 50% or less of the possible points. Riparian and cover scores were good, receiving more than 50% of the available points. Channel morphology scores received 42% and 67% of the available points.

Table 123. MSHA subcategory scores for Unnamed Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
11LM061	02-Aug-11	0	9	12	12	15	48 (Fair)
11LM061	22-Aug-11	2.5	11	4.3	14	24	55.8 (Fair)

The surrounding land use at the time of sampling was classified as forest, wetland, prairie, shrub, and row crop. Riparian width was moderate (30 – 150 feet) too extensive (>300 feet), and shade was light (5 – 25%) to moderate (25 – 50%). There was no – little (5 – 25%) bank erosion observed.

Macroinvertebrate habitats sampled at station 11LM061 included macrophytes, undercut banks/overhanging vegetation, and woody debris. Pool habitat ranged from 20% - 75% of the station length in 2011. Pool substrate was silt. Riffle habitat was minimal, ranging from 0% - 5%. Riffle substrate was sand. Run features ranged from 25% - 75%, and included sand and silt substrate (Figure 148). Embeddedness was severe to no course substrate present, and there were less than four substrate types. Multiple cover types (undercut banks, overhanging vegetation, deep pools, submergent and emergent macrophytes, and logs or woody debris) were available, and cover amount was moderate (25 – 50%) to extensive (>50%). Channel sinuosity was good – excellent, channel stability was moderate – moderate/high, channel development was fair – good, and velocity types included interstitial, slow, and moderate.

Figure 148. Sand/silt substrate at station 11LM061 (8/22/11).

For the most part, the habitat related macroinvertebrate metrics are within an expected range (Figure 149). Burrowers, clingers, legless, sprawlers, and swimmers are within the middle quartiles of Southern Forest Streams GP stations meeting the threshold. Climbers are slightly elevated and fall in the upper quartile; climbers use habitat such as overhanging vegetation or woody debris and are expected to decrease in response to habitat stress. The clinger MIBI metric score was above the average score needed to meet the MIBI threshold. Taxa diversity was good with 48 present, and the top three were Rheotanytarsus (non-biting midges) (52), Physa (snails) (44), and Dubiraphia (beetles) (32). Indicator values for suspended sediment and fine substrates for Rheotanytarsus, Physa, and Dubiraphia, developed by Carlisle et al (2007), are nine and nine, five and eight, and nine and eight respectively. The scoring system is based on a scale from 1 – 10, with 10 being the most tolerant.

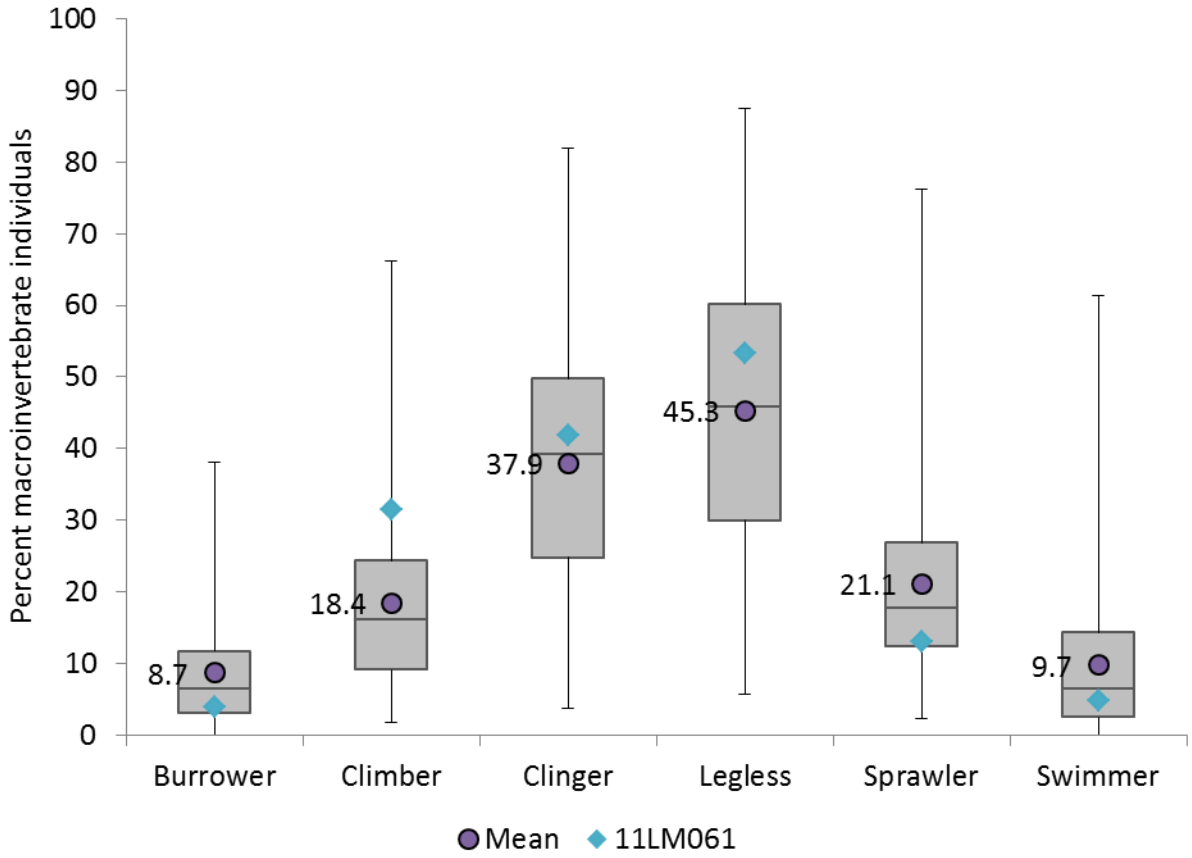


Figure 149. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Straight River Watershed stations.

This AUID had fair MSHA scores and minimal bank erosion. Multiple habitat types were sampled, but substrate was more or less homogeneous (sand and silt), embeddedness was a significant issue, and the top three taxa are moderately – highly tolerant to suspended sediment and fine substrate. However, with that being said, the macroinvertebrate habitat metrics were within an expected range. It's inconclusive if habitat is a stressor at this time, but a proactive approach with habitat improvement (and sediment reduction) would be a good idea in this reach.

Fish Passage

There were no passage barriers identified in this AUID during the September 18, 2014, survey. At this time, fish passage does not appear to be a stressor.

Conclusion

This AUID is a small headwaters tributary to Maple Creek, and is the only biota impairment in the Watershed. Nitrate is a stressor in this AUID, resulting in an impaired macroinvertebrate community. Additional sampling is recommended to strengthen this data set. At this time, it's inconclusive if phosphorus, DO, TSS/turbidity, and/or habitat are stressors; additional sampling is required for stressor determination. Although inconclusive, reducing phosphorus levels is still recommended. Temperature and fish passage do not appear to be stressors. Reducing nutrient loading to this AUID should be a priority. Although not deemed stressors at this point, it's recommended to take a proactive approach in regards to in-stream habitat improvement and sediment reduction.

4.5.6. Unnamed Creek (732)

Biological Communities

Unnamed Creek (07040002-732) is a small tributary in the upper end of the Straight River Watershed. This warmwater AUID is in Steele County, and has a macroinvertebrate impairment. Station 11LM038 is the only biological monitoring station in this reach, and it is located in the lower end of the tributary. This station was sampled for fish and macroinvertebrates in 2011.

The fish community is considered "supporting" of the aquatic life use, and therefore not currently impaired. The FIBI score for station 11LM038 was 70, which is above the Southern Headwaters impairment threshold of 51 (lower CL = 44, upper CL = 58). This score is also above the upper confidence limit. There were 13 total fish species collected, including zero pollution intolerant species and one game fish species. The three most abundant species were creek chub, blacknose dace, and green sunfish.

The macroinvertebrate community is impaired, and "not supporting" the aquatic life use. The MIBI score was 32, which is below the Southern Forest Streams GP impairment threshold of 46.8 (lower CL = 33.2, upper CL = 60.4). This score is also below the lower confidence limit. There were 13 total families, including zero intolerant families. The three most abundant taxa were Cheumatopsyche (caddisflies), Polypedilum (non-biting midges), and Dubiraphia (beetles). All of the MIBI metric scores, except for ClingerCh and Collector-filtererPct, were below the average metric score needed to meet the threshold (Figure 150). These below average metric scores resulted in a low MIBI score. Intolerant2Ch and TrichwoHydroPct received zero out of the possible 10 points.

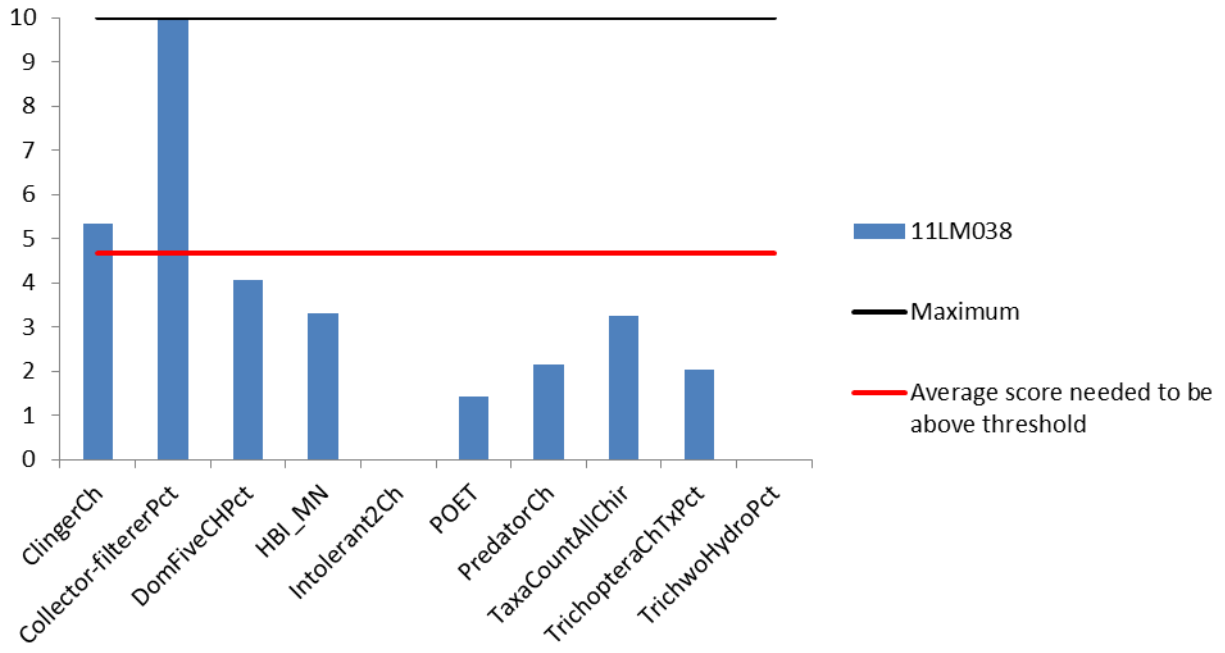


Figure 150. Macroinvertebrate metrics of the Southern Forest Streams GP (class 6) IBI for Unnamed Creek (07040002-732), station 11LM038.

Data Evaluation for each Candidate Cause

Temperature

Temperature values from 2011 – 2014 ranged from 2.0 °C – 24.4 °C (average of 12.8 °C). Only eight samples have been collected, none of which were above 30 °C (the acute warmwater standard). Samples were collected from two stations (S007-479 and 11LM038) co-located in the lower end of the AUID in April (three), May (one), June (one), July (one), and August (two). The highest temperature was observed on July 27, 2011 (24.4 °C).

A sonde was deployed from July 25, 2013 – August 7, 2013 at station 11LM038, and there were zero readings above 30 °C (maximum temperature of 19.7 °C).

The temperature data set for this AUID is limited in terms of sample numbers, but does include continuous data over a 13 day period in the summer of 2013. There have been zero exceedances, and temperature does not appear to be a stressor in this AUID.

Nitrate

Nitrate concentrations from 2011 – 2014 ranged from 1.6 mg/L – 16 mg/L (average of 6.3 mg/L). Only nine samples have been collected in this AUID, and they were collected at two different monitoring stations in essentially the same location in the lower end of the tributary (128th Street SE). These samples were collected in April (three), May (one), June (one), July (one), and August (three). There was one sample greater than 10 mg/L and three samples greater than 8 mg/L. The three highest concentrations were 8.2 mg/L (April 8, 2014), 9.4 mg/L (April 24, 2014), and 16 mg/L (May 20, 2013). Additional sampling is recommended to build and strengthen this data set.

Fish lack strong biological response evidence in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. Trichoptera taxa richness (TrichopteraCh), abundance of non-hydropsychid Trichoptera individuals (TrichwoHydroPct), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch) are below the statewide average of stations meeting the MIBI threshold (Table 124). All of these metrics are expected to decrease in response to stress.

Station 11LM038 had zero nitrate intolerant and very intolerant taxa present. This station, however, had several nitrate tolerant (17) and very tolerant (11) taxa present. Nitrate tolerant and very tolerant taxa comprised a high percentage of the macroinvertebrate community at 93% and 75% respectively. At 76.8% nitrate tolerant individuals, there is only a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI, and at 85.6% nitrate tolerant individuals there is only a 10% probability of meeting the MIBI. The nitrate index score was 3.7, which is above the statewide average (2.9) of stations meeting the MIBI threshold. As the score increases, so does the tolerance of the community.

Table 124. Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Very Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Very Tolerant Taxa	Nitrate Tolerant Pct	Nitrate Very Tolerant Pct
11LM038 (2011)	**1**	**0.0**	**0**	**3.7**	**0**	**0**	17	11	**93.4**	**74.8**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.9*	*2.6*	*0.9*	*19.4*	*12.7*	*55.5*	*39.6*
Expected response to stress	↓	↓	↓	↑	↓	↓	↑	↑	↑	↑

Elevated nitrate concentrations are present in the limited data set, most of the macroinvertebrate metrics are worse than the statewide average, there are zero nitrate intolerant and very intolerant taxa present, nitrate tolerant and very tolerant taxa are abundant and dominate the community, and the nitrate index score is worse than the statewide average of stations meeting the MIBI threshold. Additional monitoring is recommended to get a better handle on the nitrate dynamics in this AUID, but the limited existing chemistry data (with elevated concentrations) and strong biological response provide enough confidence to conclude that nitrate is a stressor in this AUID.

Phosphorus

TP concentrations from 2011 – 2014 ranged from 0.131 mg/L – 0.435 mg/L (average of 0.256 mg/L). Only seven samples have been collected, but six of those samples were above the draft river eutrophication standard for the South Region (0.150 mg/L). Samples were collected from two co-located stations (S007-479 and 11LM038) in April (three), May (one), July (one), and August (two). The six exceedances occurred in April (two), May (one), July (one), and August (two), and the three highest

concentrations were 0.278 mg/L, 0.308 mg/L, and 0.435 mg/L. Algae were documented in the stream in September 2014 just upstream of station 11LM038 at the 118th Street road crossing (Figure 151).

Although TP is elevated, there needs to be an elevated response variable of chl-a, DO flux, and/or BOD to be considered impaired. At this time, there have been zero chl-a and BOD samples collected; both of these parameters should be sampled in the future. Sonde deployment at station S007-479 from July 25, 2013 – August 7, 2013 resulted in zero DO flux exceedances. Also, there were zero low DO values (< 5mg/L).

Figure 151. Algae upstream of station 11LM038 at the 118th Street road crossing (9/18/14).

All of the macroinvertebrate metrics with strong relationships to phosphorus were worse than the statewide average of stations meeting the MIBI threshold (Table 125). Station 11LM038 had below average total taxa richness (TaxaCountAllChir), taxa richness of collector-filterers (Collector-filtererCh), taxa richness of collector-gatherers (Collector-gathererCh), taxa richness of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and taxa richness of macroinvertebrates with tolerance values less than or equal to two using MN TVs (Intolerant2Ch). These metrics are expected to decrease in response to stress. The percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), which is expected to increase in response to stress, was above the statewide average. All of the macroinvertebrate metrics at station 11LM038 have values indicative of stress.

Table 125. Macroinvertebrate metrics that respond to TP stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM038 (2011)	**30**	**5**	**11**	**2**	**0**	**80.0**
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*8.8*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

Although the fish community is not impaired, the fish metrics can still assist in stressor determination. A majority of the fish metrics at station 11LM038 were atypical of a stressed stream (Table 126). Only one out of the five metrics, the relative abundance of individuals that are tolerant species (TolPct), had a value indicative of stress. The remaining metrics (SensitivePct, DarterPct, SLithopPct, and TaxaCount) were at or above the statewide average; these metrics are expected to decrease in response to stress. Overall, the fish metrics don't seem to identify any stress.

Table 126. Fish metrics that respond to TP stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount
11LM038 (2011)	10.1	10.9	41.1	**77.5**	13
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*
Expected response to stress	↓	↓	↓	↑	↓

Although this data set has weak sample numbers, extremely elevated TP concentrations have been documented during various months throughout the year. There are no chl-a or BOD samples, and the available DO flux data includes zero exceedances. A fair amount of algae were documented in 2014 and all of the macroinvertebrate metrics were worse than the statewide average. The fish metrics were suggestive of healthy conditions, but the fish community in this AUID is not impaired. The possibility of phosphorus being a stressor in this AUID definitely exists, but at this time it's inconclusive if phosphorus is a stressor. Additional monitoring for TP, and chl-a, BOD, and DO flux in particular, is necessary for stressor determination.

Dissolved Oxygen

DO concentrations from 2011 – 2014 ranged from 6.41 mg/L – 10.6 mg/L (average of 8.02 mg/L). Only seven samples have been collected, none of which were below the warmwater standard of 5 mg/L. Samples were collected from two stations (S007-479 and 11LM038) co-located at the 128th Street Southeast road crossing in April (two), May (one), June (one), July (one), and August (two). The lowest

concentration was observed on August 26, 2014 (6.41 mg/L). Also, sonde deployment at station 11LM038 from July 25, 2013 – August 7, 2013 identified zero low DO concentrations.

Station 11LM038 had worse than average total macroinvertebrate taxa richness (TaxaCountAllChir), percentage of taxa with tolerance values equal to or greater than six using MN TVs (Tolerant2ChTxPct), and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) (Table 127). Stressed streams will often have lower overall taxa richness and taxa richness of EPT, and higher tolerant taxa.

Station 11LM038 had eight DO intolerant macroinvertebrate taxa and four DO very intolerant taxa. One DO tolerant taxon was also present, but comprised a very minimal portion of the overall community (2.8%). The macroinvertebrate DO index score was 7.3, which is above the statewide average (7.0) of stations meeting the MIBI threshold. As the score increases, so does the sensitivity of the community.

Table 127. Macroinvertebrate metrics that respond to low DO stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	TaxaCountAllChir	Tolerant2ChTxPct	EPT	Low DO Index Score	Low DO Intolerant Taxa	Low DO Very Intolerant Taxa	Low DO Tolerant Taxa	Low DO Very Tolerant Taxa	Low DO Tolerant Pct	Low DO Very Tolerant Pct
11LM038 (2011)	**30**	**80.0**	**2**	7.3	8	4	1	0	2.8	0.0
Southern Forest Streams Average	*41.3*	*75.2*	*8.8*	*7.0*	*6.5*	*3.4*	*5.6*	*2.2*	*14.0*	*2.7*
Expected response to stress	↓	↑	↓	↓	↓	↓	↑	↑	↑	↑

Although the data set is limited in terms of quantity, there have been zero DO exceedances and the data set includes continuous data spanning 13 days during late summer of 2013. Some of the macroinvertebrate metrics were worse than the statewide average, but there were multiple DO intolerant and very intolerant taxa. DO tolerant taxa comprise a very small percentage of the community, and the DO index score was above the statewide average. Based on this information, DO is not currently stressing the macroinvertebrate community in this AUID.

TSS/Turbidity

TSS concentrations from 2011 – 2014 ranged from 6.8 mg/L – 65.0 mg/L (average of 19.4 mg/L). Only eight samples have been collected in this AUID, and they were collected at two different monitoring stations (S007-479 and 11LM038) in essentially the same location (near the 128th Street Southeast road crossing on the lower end of the tributary). The samples were collected in April (three), May (one), July (one), and August (three). There were zero samples greater than 65 mg/L, the draft TSS standard for the South Region. One of the samples, however, was right at 65 mg/L (May 20, 2013).

Transparency values from 2011 – 2014 ranged from 12 cm – 100 cm (average of 73 cm). Only 13 samples have been collected, and they were collected from seven stations (S007-479, 11LM038, 128th Street, 118th Street, 34th Avenue, 44th Avenue, and 54th Avenue) in April (three), May (6), June (one), July (one), and August (two). There were zero samples below the s-tube surrogate standard for the South Region (10 cm). Five of the samples were collected on May 20, 2014 as part of a longitudinal secchi tube survey; values from this survey were all greater than 100 cm. The three lowest values in this data set are 12 cm (May 20, 2013), 23 cm (April 8, 2014), and 47 cm (April 24, 2014).

The macroinvertebrate metrics with strong relationships to TSS were above and below the statewide average of stations meeting the MIBI threshold (Table 128). The relative abundance of collector-filterer individuals (Collector-filtererPct) was well above average at 48%. The relative abundance of Plecoptera individuals (PlecopteraPct) was below average; there were no stoneflies (Plecoptera) present. Both of these metrics are expected to decrease in response to stress.

Station 11LM038 had one TSS intolerant and very intolerant taxon present. This station also had TSS tolerant (four) and very tolerant (one) taxa present. TSS tolerant and very tolerant taxa comprised 57% and 2% of the macroinvertebrate community respectively. The macroinvertebrate TSS index score for station 11LM038 was 18.4, which is worse than the statewide average (16.2) of stations meeting the MIBI threshold. The lower the score, the more sensitive the community is to TSS, as the score increases so does the TSS tolerance of the community.

Table 128. Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Very Intolerant Taxa	TSS Tolerant Taxa	TSS Very Tolerant Taxa	TSS Tolerant Pct	TSS Very Tolerant Pct
11LM038 (2011)	48.0	**0.0**	**18.4**	**1**	1	4	1	**56.9**	1.9
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*0.7*	*10.2*	*3.9*	*27.2*	*7.9*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑	↑	↑

Although the fish community is not impaired, it can help inform the SID process. All of the metrics except for the relative abundance of individuals that are sensitive species (SensitivePct) were worse than the statewide average of stations meeting the FIBI threshold (Table 129). There were no non-tolerant centrarchids (Centr-TolPct), intolerant individuals (IntolerantPct), or long-lived individuals (LLvdPct). Also, the TSS index score was worse than the statewide average. Overall, the fish metrics are suggestive of stress, with many of them well below the statewide average.

Table 129. Fish metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year Sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LLvdPct	Percfm-TolPct	RiffflePct	SensitivePct	SLithFrimPct	TSS Index Score (RA)
11LM038 (2011)	**5.4**	**0.0**	**8.5**	**0.0**	**0.0**	**10.9**	**5.4**	10.1	**1.6**	**15.6**
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.2*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

This AUID has minimal samples with zero exceedances, and mixed biological response. Collector-filterers were well above the statewide average, and there was one TSS intolerant and very intolerant taxon present at station 11LM038. However, there were also TSS tolerant and very tolerant taxa present, and the macroinvertebrate TSS index score was worse than the statewide average. The fish community, although not impaired, was suggestive of stress. It's inconclusive at this time if TSS/turbidity is a stressor in this AUID due to limited data; additional monitoring is required for stressor determination.

Lack of Habitat

The MSHA score at station 11LM038 was "poor" (41.3) in 2011 (Table 130). Land use and riparian sub-category scores received zero points. The surrounding land use was row crops, and there was little (5 – 25%) bank erosion and heavy (>75%) shade in the riparian corridor. The riparian width was narrow (15 – 30 feet) to moderate (30 – 150 feet). Substrate, cover, and channel morphology scores were also mediocre.

Table 130. MSHA subcategory scores for Unnamed Creek.

Station	VisitDate	LandUseTotal (5)	RiparianTotal (15)	SubstrateTotal (27)	CoverTotal (17)	ChannelMorphTotal (36)	TotalScore (Max=100)
11LM038	27-Jul-11	0	0	12.3	9	20	41.3 (Poor)

Woody debris was the only macroinvertebrate habitat type sampled at station 11LM038. This might explain why climbers and clingers comprised a higher percentage of the macroinvertebrate community. Pool habitat was 20% of the station length in 2011. Pool substrates were sand and silt. There were very few riffles (5%), and substrates consisted of gravel and sand. Run features dominated at 75%, and substrates were sand and silt. Light embeddedness was observed, and less than four substrate types were present. Deep pools and logs or woody debris were the available cover types, and the cover amount was moderate (25 – 50%). Channel sinuosity was good, channel stability was moderate, channel

development was fair, pool width was greater than riffle width, and slow – moderate velocity types were present.

Burrowers, legless, sprawlers, and swimmers were below the average of Southern Forest Streams GP stations meeting the MIBI threshold (Figure 152). Climbers and clingers were above average, and the clinger MIBI metric score was above the average metric score needed to meet the MIBI threshold. Most of the metrics have values atypical of a stream stressed by habitat. Swimmers, which require low velocity water, were absent at station 11LM038. Cheumatopsyche (caddisflies) dominated the sample with 145 individuals; Polypedilum (non-biting midges) and Dubiraphia (beetles) were the next most abundant with 29 and 21 individuals respectively. Cheumatopsyche and Polypedilum are clingers, and Dubiraphia are clingers/climbers.

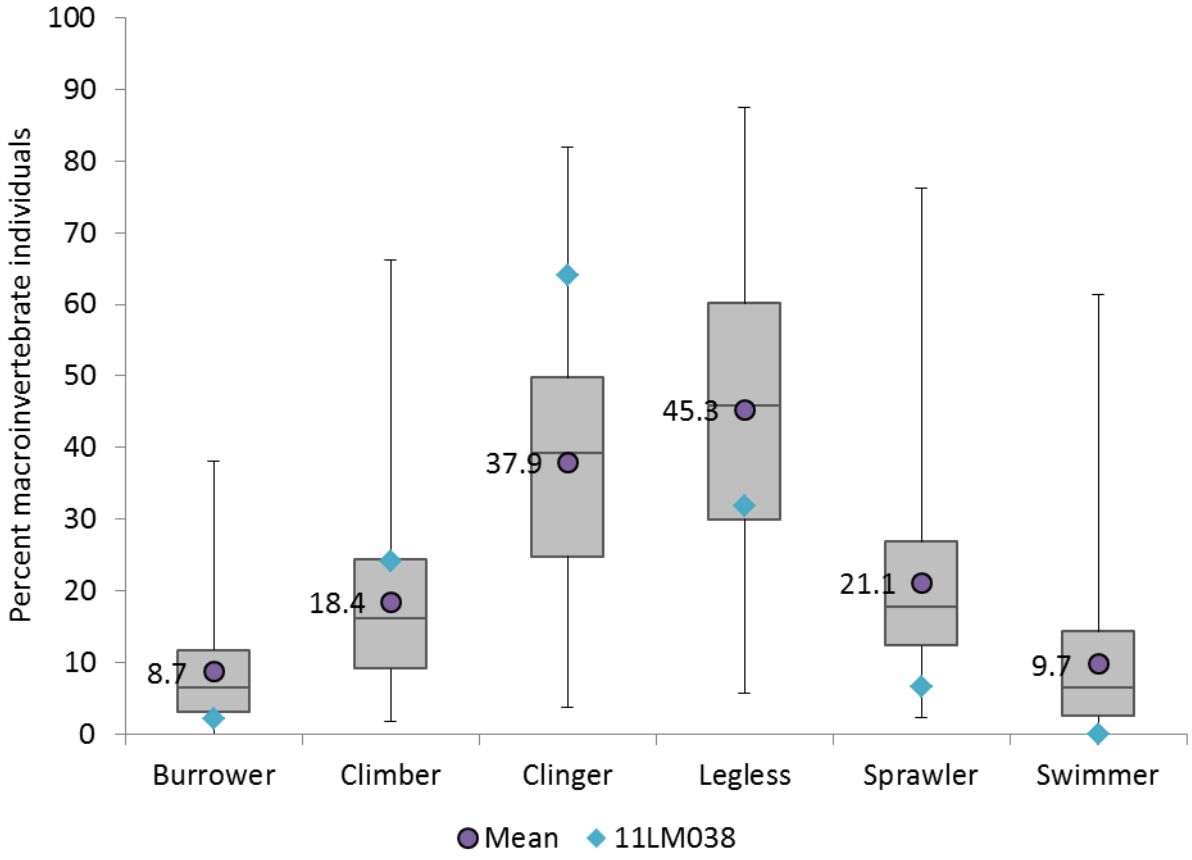


Figure 152. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP (class 6) stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from Straight River Watershed stations.

This AUID had a poor MSHA score, substrates were primarily sand and silt, and woody debris was the only habitat type fit for sampling. Minimal bank erosion and embeddedness were observed, and the macroinvertebrate habitat metrics (for the most part) were at levels typically not seen in habitat stressed streams. At this time, it's inconclusive if habitat is a stressor.

Fish Passage

There were no passage barriers identified in this AUID during the September 18, 2014 survey. At this time, fish passage does not appear to be a stressor.

Conclusion

Nitrate is the only stressor currently identified in this AUID; additional monitoring would strengthen the existing data set and provide a better understanding of the nitrate dynamics. It's inconclusive if phosphorus, TSS/turbidity, and/or habitat are stressors due to limited data; additional monitoring is required for stressor determination. At this time, temperature, DO, and fish passage do not appear to be stressing the macroinvertebrate community. Reducing the nitrogen loading to this AUID should be a priority.

Straight River 10-Digit HUC Summary

Nitrate, TSS, and habitat were the identified stressors in the Straight River 10-digit HUC (Table 131). Nitrate is a stressor in all of the AUIDs. Elevated phosphorus has been measured throughout the 10-digit HUC, but in all cases it's inconclusive if phosphorus is a stressor. In summary, nitrate was identified as a stressor in six AUIDs, TSS was identified as a stressor in three AUIDs, and habitat was identified as a stressor in two AUIDs. There were several inconclusive determinations due to limited data and/or mixed biological response.

Table 131. Straight River 10-digit HUC stressor summary (● = stressor, ○ = inconclusive stressor, blank = not a stressor).

Reach	AUID	Biological Impairment	Class	Stressors							
				Temperature	Nitrate	Phosphorus	DO	TSS	Habitat	Fish Passage	Ammonia
Straight River	503	Macroinvertebrates	2B		●	○		●	○		○
Straight River	515	Macroinvertebrates	2B		●	○		●	○		
Straight River	536	Macroinvertebrates	2B		●	○	○	●	●		
Medford Creek	547	Fish and Macroinvertebrates	2B		●	○	○	○	●	○	
Unnamed Creek	731	Macroinvertebrates	2B		●	○	○	○	○		
Unnamed Creek to Unnamed Creek	732	Macroinvertebrates	2B		●	○		○	○		

4.6. Middle Cannon

This section encompasses biotic impaired reaches in the Middle Cannon River 10 digit HUC (Figure 153). Small tributaries to the Cannon River will be discussed first followed by the mainstem reaches of the Cannon River, from upstream to downstream. The small tributaries will be discussed from upstream on the Cannon River to downstream confluences with the Cannon River. The small tributaries include Unnamed Creek (Spring Brook; and also known as Rice Creek), Unnamed Ditch to Heath Creek, Heath Creek, and Spring Creek. Spring Brook is the only coldwater reach in this 10 digit HUC, the remaining are warmwater reaches.

Rice Creek and Spring Creek are impaired for macroinvertebrate assemblage. Unnamed Ditch to Heath Creek and Heath Creek reaches are impaired for both macroinvertebrate and fish assemblages. Three of the four AUIDs on the Cannon River are impaired for macroinvertebrates only, while AUID 07040002-509, downstream of Northfield, is impaired for both assemblages.

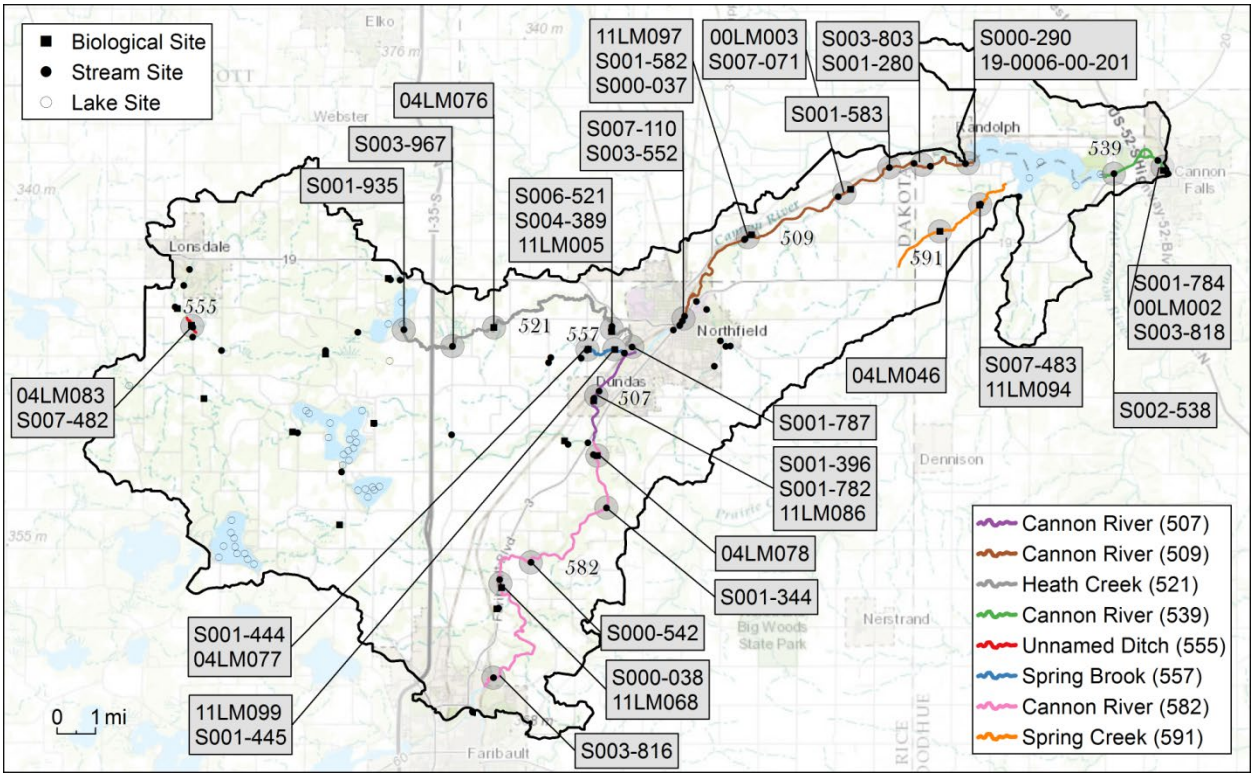


Figure 153. Map of Middle Cannon River 10 digit HUC including impaired reaches with biological stations and chemistry stations used in report

4.6.1. Unnamed Creek (Spring Brook/Rice Creek) (557)

Unnamed Creek (AUID 07040002-557) is a small coldwater tributary to the Cannon River, near Northfield, Minnesota. This reach is also known as Spring Brook and Rice Creek. For ease of reading, this reach will be referred to as Rice Creek in this document. The reach is impaired for lack of macroinvertebrate assemblage. It is also impaired for nitrate and turbidity, which will be discussed in terms of potential stressors to the macroinvertebrate community. Additionally, it is impaired for *E. coli*, which will not be addressed in this report. There are two biological stations in Rice Creek, upstream

station 04LM077 and downstream station 11LM099. Station 04LM077 was sampled in 2004 and 2011 for fish and macroinvertebrates. Station 11LM099 was sampled in 2011 for fish and macroinvertebrates.

The Cannon River Watershed Partnership collected and analyzed a wealth of data over 2011 and 2012. They reported the results in their Rice Creek Assessment Project Resources Investigation report in 2013. With that information, they have identified priorities for management actions that compliment this section of the report covering Rice Creek.

The fish community at station 04LM077 was dominated by brook trout in 2004, with blacknose dace, johnny darter, and brook stickleback. In 2011, station 04LM077 had a similar community with the majority brook trout, but also had presence of johnny darter, brook stickleback, creek chub, and green sunfish. Both visits to station 04LM077 resulted in FIBI scores above impairment threshold for the Southern Coldwater stream class (80.1 and 68.2). Station 11LM099 had a FIBI score of 65 in 2011. There were greater numbers of brook trout, but also presence of creek chub, johnny darter, white sucker, black bullhead, and green sunfish.

Station 04LM077, the macroinvertebrate community is impaired, receiving IBI scores of 47.9 in 2004 and 38.3 in 2011, on the macroinvertebrate IBI for Southern Coldwater class. Only the 2011 visit was below the threshold (43), but both results were within the confidence limit. Station 11LM099 had an MIBI of 56.1, better than both visits at the upstream station. The macroinvertebrates most dominant in 2004 at station 04LM077 were *Gammarus* (scud or sideswimmer) then *Simulium* (black flies). In 2011, at both stations, *Gammarus* and *Baetis* (a tolerant swimming mayfly) dominated the communities.

Looking at the metrics in the macroinvertebrate southern coldwater IBI, all three macroinvertebrate visits resulted in low scores for relative abundance of collector-filterer individuals in subsample (Collector-filtererPct) and taxa richness of macroinvertebrates with tolerance values less than or equal to 2, using MN TVs (Intolerant2Ch; Figure 154). Station 04LM077 also had low metric scores at both visits for relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct). In 2011, the metric score for HBI_MN (a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart) was also low for station 04LM077.

The MPCA biologists noted in 2011 that the downstream station with the higher IBI score had better riparian habitat than the upstream station. This pattern suggests that impairment may be localized near the upstream station due to poor habitat; however excessive algae, extremely high nitrate concentrations, and erosion/sedimentation at the lower station suggest otherwise.

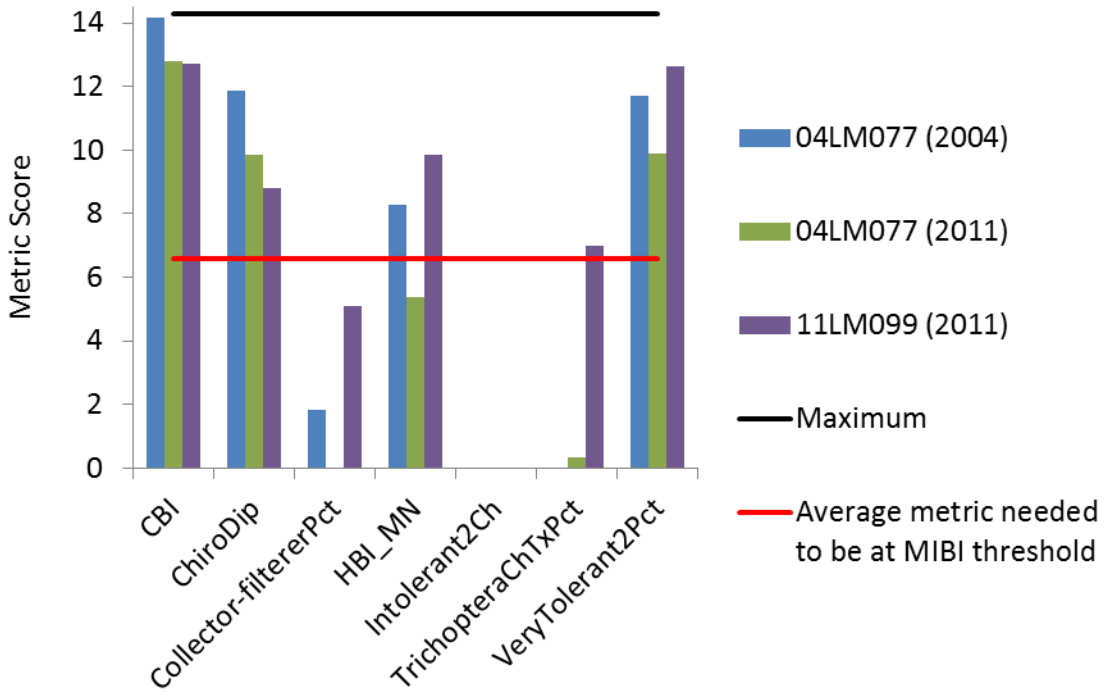


Figure 154. Macroinvertebrate metrics of the Southern Coldwater IBI for Rice Creek

Temperature

From 1999 to 2009, and 2011 to 2013, there have been 548 synoptic measures of temperature at stations 04LM077, 11LM099, S001-444, and S001-445. The data ranges from 0.3-27.8°C. The synoptic temperature measurements were greater than 18.3°C in 80 measurements (14.6%) and greater than 22.2°C in eight measurements (1.5%).In 2004, a temperature logger was deployed at station 04LM077. The maximum of the daily average temperature for the summer was 16.51°C. In 2011, both biological stations had temperature loggers. The maximum of the daily average temperature for the summer was 17.48°C at station 04LM077, and 17.42°C at station 11LM099. From April 10 – September 29, 2014, a HOBO temperature logger collected temperature data in 15 minute intervals. The data ranged from 1.16 to 21.2°C. No measurements were greater than 22.2°C over that time period in 2014, and 3.5% of the time measurements were greater than 18.3°C. Three days during data collection was the daily average temperature greater than 18.3.

The macroinvertebrate CBI scored fairly high for all three visits on this AUID and there was a presence of brook trout; however there were additional species that are not coldwater (johnny darter, brook stickleback, creek chub, and green sunfish) that may indicate warming. Temperature is not currently a stressor to the biotic communities; however, temperature should be closely monitored and activities that promote shading and maintain coldwater should be continued.

Dissolved Oxygen

In Rice Creek, DO was measured synoptically eight times, once in 2004 at the time of fish sampling and seven times in 2011. Only one of the measurements was made before 9AM, at station 04LM077 at

8:15AM on June 14, 2011 (6.86 mg/L). At station 04LM077, DO was measured by an YSI sonde from July 24-31, 2014. DO was not lower than the 7 mg/L standard and there was no excess DO flux. The DO data from that time ranged from 7.14 – 9.9 mg/L.

The macroinvertebrate metrics that correspond to low DO show mixed results (Table 132). There was a lack of EPT taxa as well as a lack of low DO intolerant taxa; however there still was presence of low DO intolerant taxa and low percentages of low DO tolerant individuals. It is unlikely that the metric responses are due to low DO due to the inconsistency of evidence. Low DO is not a stressor to the macroinvertebrate community in Rice Creek.

Table 132. Macroinvertebrate metrics that respond to low DO stress in Rice Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
04LM077 (2004)	21	**1**	**6.46**	8.0	**7**	**2**	0.35
04LM077 (2011)	15	**2**	**6.79**	7.98	**4**	**2**	0.63
11LM099 (2011)	27	**6**	6.30	8.08	**10**	1	0.33
Southern Coldwater Average	*27.6*	*7.0*	*6.30*	*7.93*	*10.32*	*1.59*	*1.17*
Expected response to stress	↑	↓	↑	↓	↓	↑	↑

Phosphorus

In Rice Creek, at stations S001-444, 04LM077, 11LM099, and S001-445, there were 106 samples of TP over 2004, 2006 - 2008, 2011, and 2012 (Figure 155). The maximum TP was 1.77 mg/L (May 6, 2012), but it was associated with an elevated TSS sample of 1045 mg/L. Many samples were greater than the river nutrient criteria for the central region (0.1 mg/L) and many were associated with elevated TSS levels. TSS was collected concurrently with the TP and the potential relationship was evaluated (Figure 156 and Figure 157). The elevated TP with elevated TSS concentrations indicate that the TP is likely bound to the sediment, but there were also elevated TP levels without elevated TSS levels.

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to result in an aquatic life impairment based on elevated nutrients. BOD and chlorophyll-a were not collected in this reach of Rice Creek. At station 04LM077, DO was measured by an YSI sonde from July 24-31, 2014. DO was not lower than the 7 mg/L standard and there was low DO flux recorded. More information on the DO dynamics in Rice Creek can be found in the DO section.

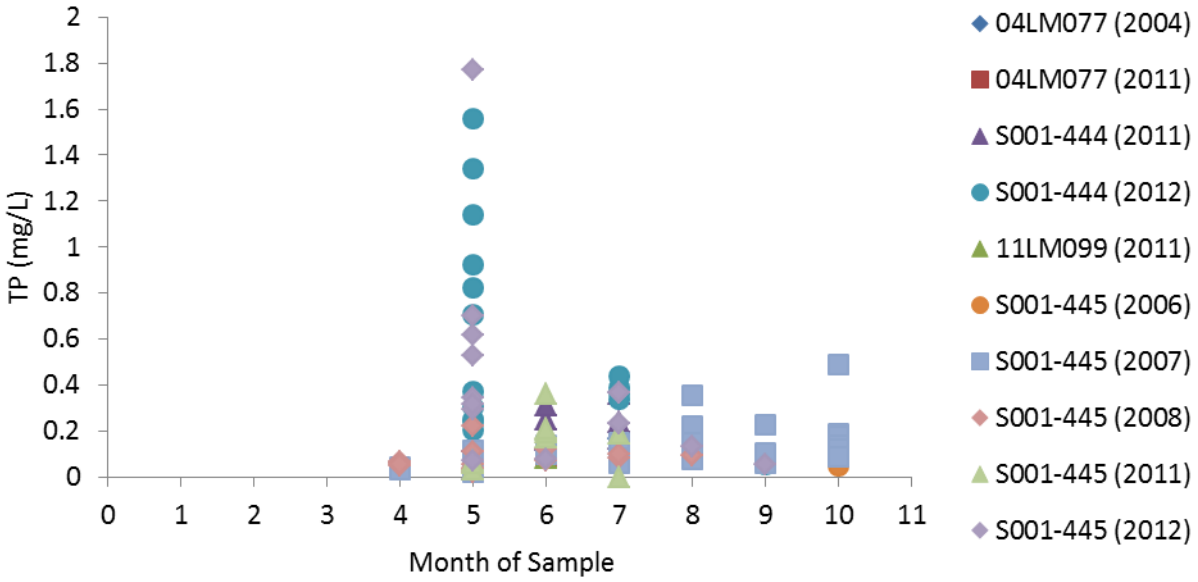


Figure 155. Total phosphorus concentrations in Rice Creek by month sampled

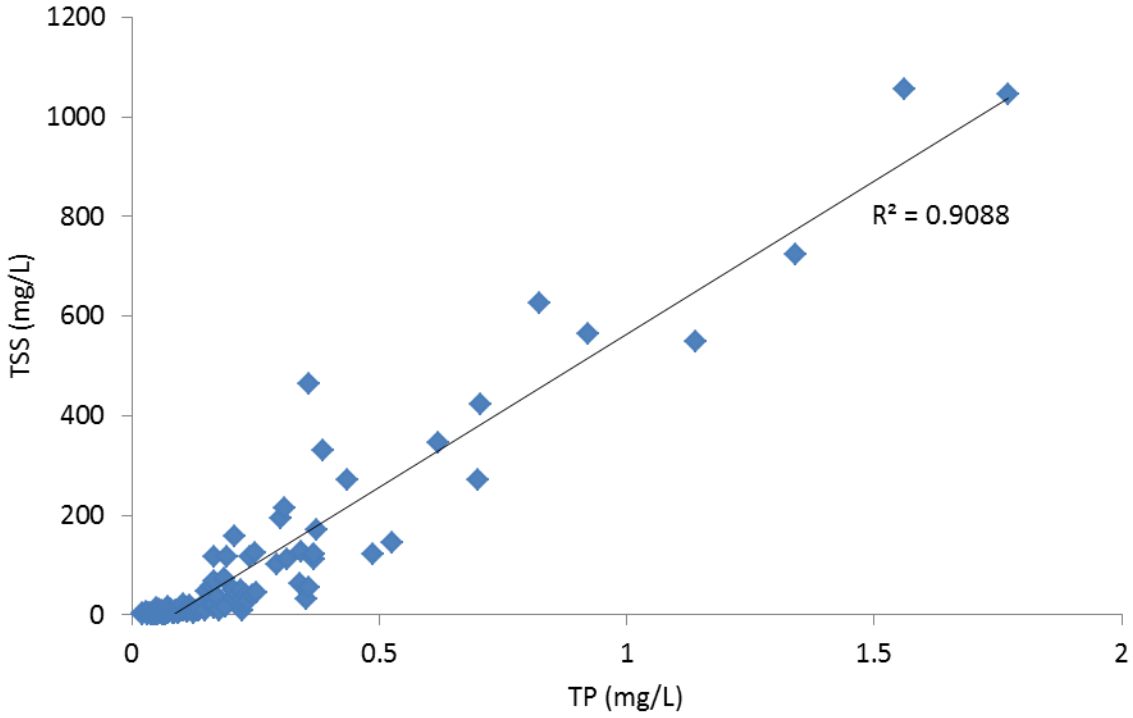


Figure 156. TSS and TP relationship in Rice Creek

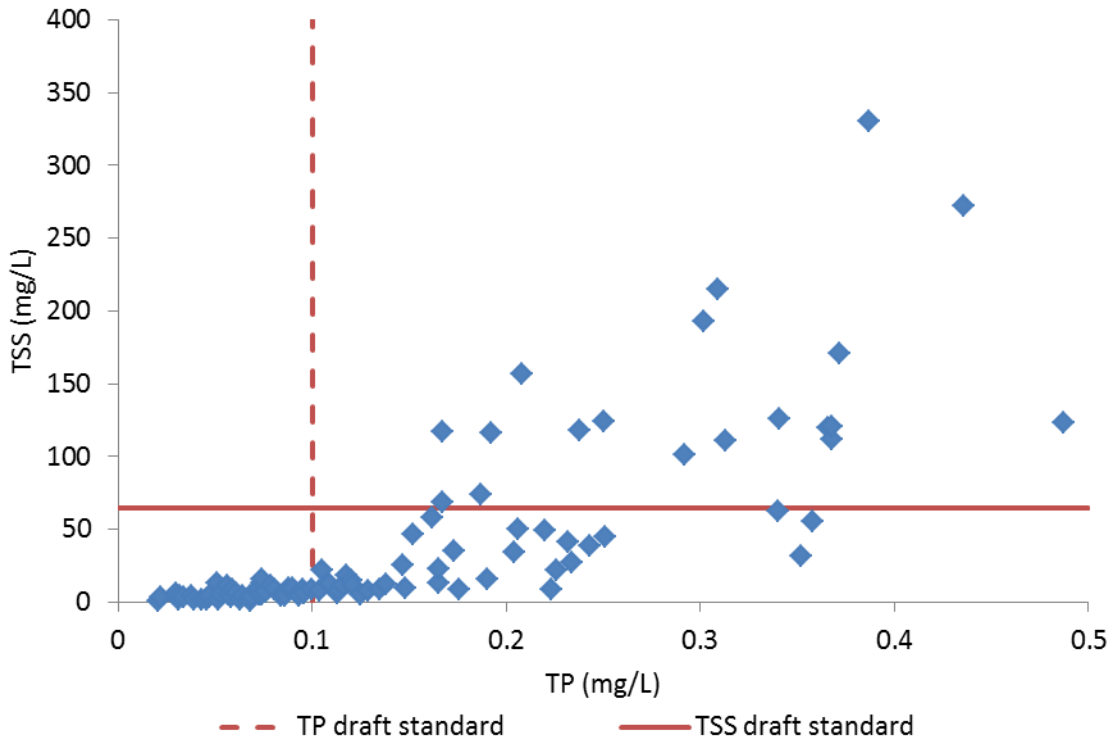


Figure 157. TSS and TP relationship in Rice Creek (zoomed in extent)

Coldwater biotic relationships with eutrophication have not been researched greatly in Minnesota. In warmwater systems, EPT communities are inversely correlated with chlorophyll-a, low DO, and high DO flux values. Six EPT taxa were the highest collected at station 11LM099 and two taxa at station 04LM077, whereas the average of southern coldwater visits that are meeting the biocriteria is seven taxa.

The percentage of EPT individuals was below the average of southern coldwater stations meeting the biocriteria (41.2%) for all three visits, ranging from 9.5 – 31.3%. Phosphorus is also positively correlated with the percentage of tolerant taxa. Tolerant taxa ranged from 70.4 - 80%, compared to the average of 65.7% found in southern coldwater stations meeting the biocriteria. The number of tolerant taxa was both less than and greater than the average (13). The visit at station 11LM099 had the highest number of tolerant taxa (15).

Functional feeding groups are likely to shift when stressed. An increase in collector-gatherers can indicate an increase in organics. The percentage of collector-gatherer individuals was elevated at all three visits in Rice Creek (Figure 158). There was not however a large number of collector-gatherer taxa, station 04LM077 had seven and eight taxa and station 11LM099 had 11 taxa, same as the average of southern coldwater stations meeting the biocriteria. There was only two and three taxa of collector-filterer macroinvertebrates at station 04LM077, this resulted in percentages of collector-filters nearly half of the mean of visits meeting the biocriteria for southern coldwater stations. Station 11LM099 had seven collector-filterer taxa and resulted in a greater proportion of individuals, but still less than the average of stations meeting the biocriteria. Station 04LM077 had macroinvertebrates that are considered scrapers in higher proportion than the mean of visits meeting the biocriteria. The abundance

of scrapers can be indicative of excess periphyton. At the time of macroinvertebrate sampling in 2011, firmly attached algae or submerged vegetation was noted as sparse. Other visits also did not note any exceedance of periphyton.

The phosphorus in Rice Creek is elevated. Much of the time it is elevated in response to elevated TSS, but there are also times when there is not elevated TSS, and could be related to instream productivity such as algae. Elevated TP may also be coming from the substrate when suspended sediments are low, particularly with low DO. If so, the problem may still be linked to the TSS problem. However, no elevated DO flux or low DO has been found in Rice Creek. The two response variables of BOD and chlorophyll-a have not been measured in Rice Creek to date. The macroinvertebrate community does exhibit stress that may be due to elevated TP and its associated response variables, but it is difficult to separate from other stressors present such as elevated TSS. At this time, TP and the response variables are inconclusive as stressors in Rice Creek. Efforts should be made to better understand the nutrient dynamics in Rice Creek as well as reduce excess loading of TP and TSS.

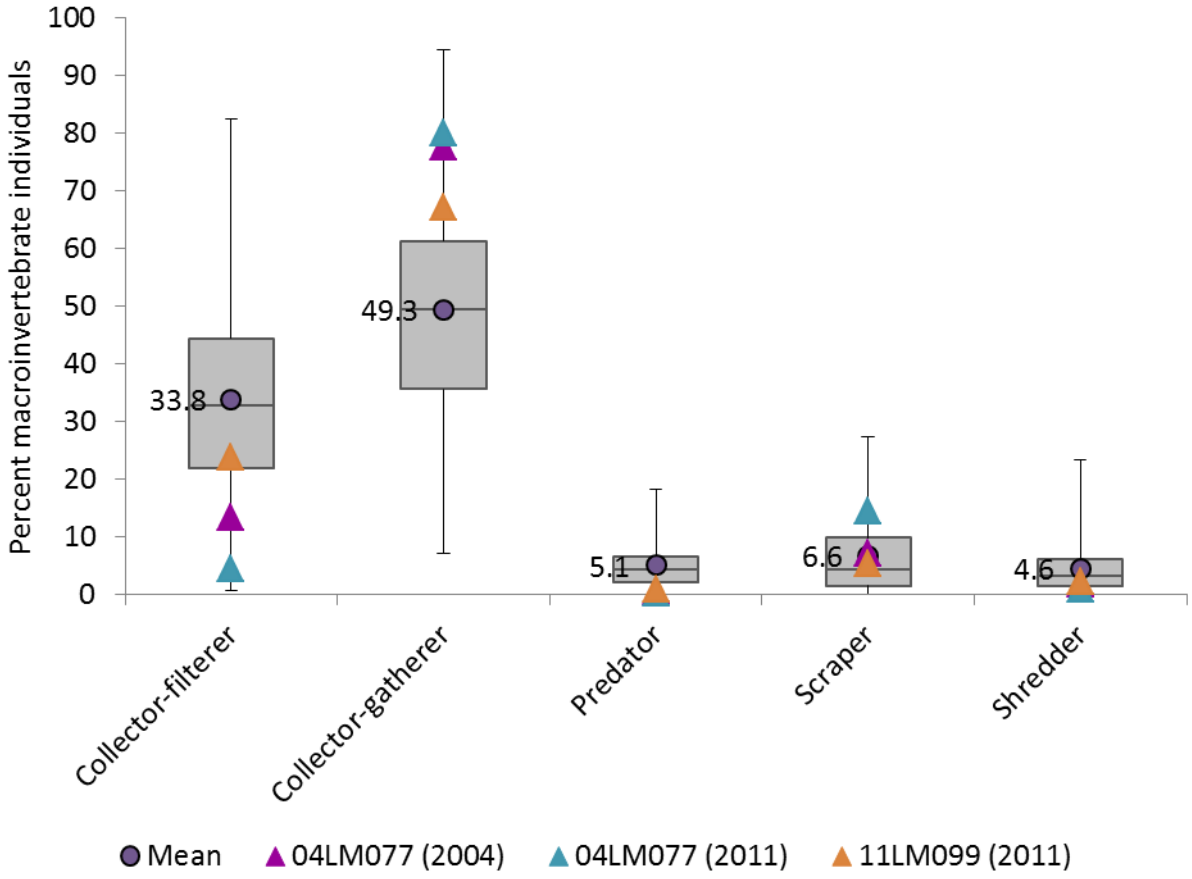


Figure 158. Percent macroinvertebrate individuals in functional feeding groups in Rice Creek

Nitrate

Nitrate has been sampled 69 times in this AUID of Rice Creek spanning the years of 2004, 2008, 2011-2012 (Figure 159). Of the 69 samples, 48 were greater than 10 mg/L (69.6%). However, some of these samples were targeted event samples, so may be slightly inflated to actual percentage. The highest level of nitrate was 70.8 mg/L (May 6, 2012; Figure 160). This incredibly high nitrate was sampled during a

rain event that also resulted in the highest TSS measurement in Rice Creek (1056 mg/L). On May 5, 2012, there was 0.45 inches of rain, and then on May 6, 2012, there was 1.65 inches (Figure 160). Unlike other coldwater fed systems that may decrease in nitrate with rain events, Rice Creek appears to have both elevated nitrate from events and elevated groundwater during baseflow.

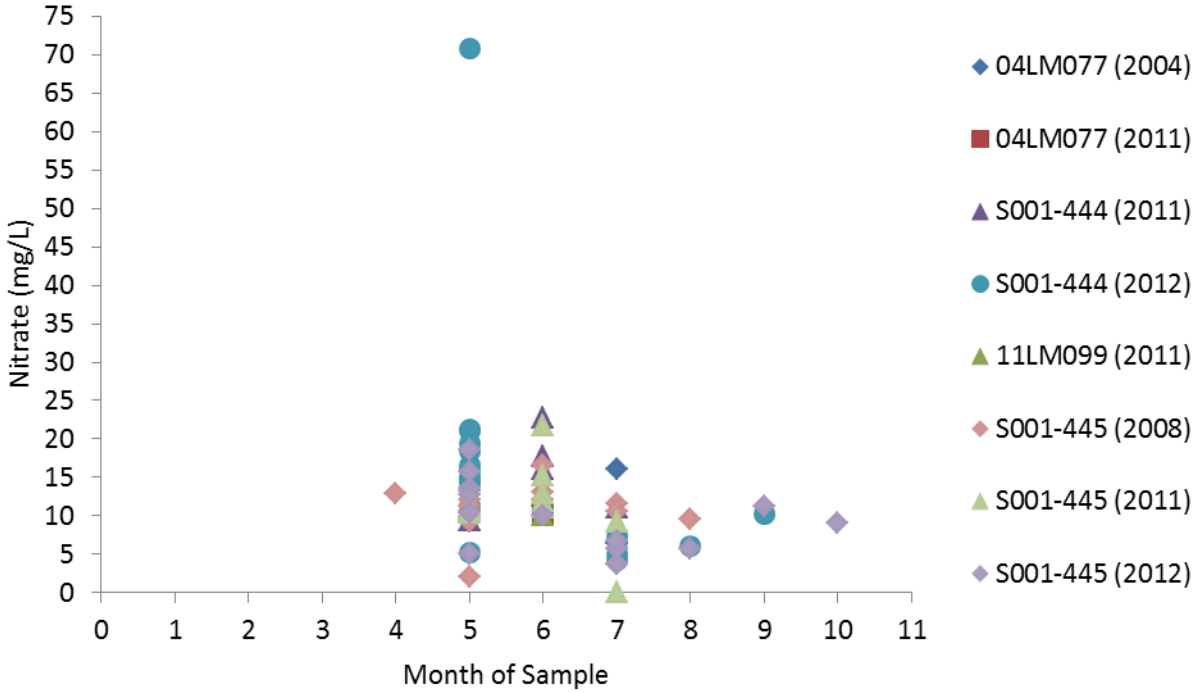


Figure 159. Nitrate concentrations by year and month in Rice Creek

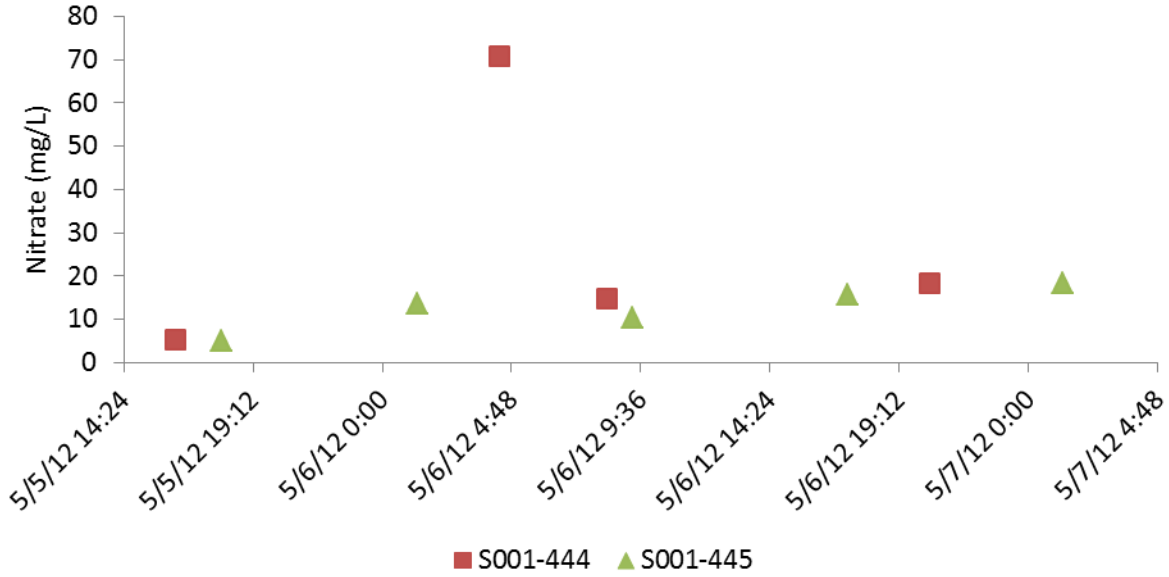


Figure 160. Nitrate concentrations in Rice Creek through a rain event in May 2012

The macroinvertebrate metrics that correspond with nitrate stress show a fairly consistent response as expected (Table 133). There was a lack of caddisflies (Trichoptera) across all visits as well as intolerant

taxa. The percentage of non-hydropsychid caddisflies was low at station 04LM077, but the taxa counts were also lower. Utilizing the nitrate specific metrics, the station index scores were elevated, indicative of nitrate stress. Similarly, there were no nitrate intolerant taxa and high percentage of nitrate tolerant individuals.

Nitrate is elevated at times within Rice Creek and the macroinvertebrate community exhibits characteristics of nitrate stress. Nitrate is a stressor in Rice Creek. Cannon River Watershed Partnership already has identified priority areas to reduce nitrate in Rice Creek (CRWP, 2013).

Table 133. Macroinvertebrate metrics that respond to nitrate stress in Rice Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
04LM077 (2004)	**0**	**0**	**0**	**3.86**	**0**	9	**94.7**
04LM077 (2011)	**1**	**0.3**	**0**	**3.70**	**0**	12	**85.1**
11LM099 (2011)	**4**	12.2	**0**	**3.59**	**0**	**15**	**85.5**
Southern Coldwater Average	*4.6*	*11.6*	*1.2*	*3.23*	*1.10*	*14.77*	*66.22*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

TSS

Rice Creek is currently impaired for turbidity. In Rice Creek, at stations S001-444, 04LM077, 11LM099, and S001-445, there were 106 samples of TSS over 2004, 2006 - 2008, 2011, and 2012 (Figure 161 and Figure 162). The highest TSS, 1056 mg/L, was during the rain event on May 6, 2012. There were 65 individual measurements (61.3%) greater than 10 mg/L (coldwater stream TSS draft standard). Some of those samples were targeted to rain events and on the same day. If you average the TSS samples by date for the entire dataset, independent of stations, there was data collected on 76 dates. Of those 76 dates, 38 (50%) had average TSS values greater than 10 mg/L. Rice Creek is a very flashy system with often high levels of TSS quickly moving through. One example of this is at 6AM on July 24, 2012, TSS was 330 mg/L after a 2.4 inch event, and was receded to 62 mg/L by 8PM. There was an extensive amount (630) of secchi tube or transparency measurements made in this section of Rice Creek, over 14 years of data at two stations. The transparency tube measurements were converted to secchi tube measurements, and 275 measurements (43.7%) were less than the 55 cm surrogate standard of the trout TSS region. There is not a strong longitudinal pattern in the dataset.

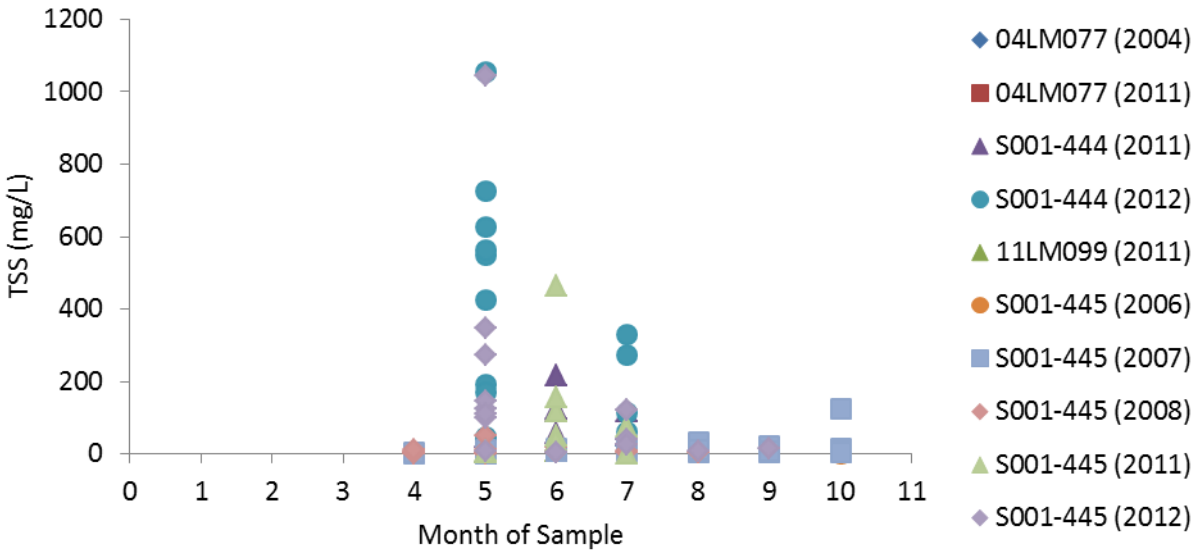


Figure 161. TSS concentrations in Rice Creek by month sampled

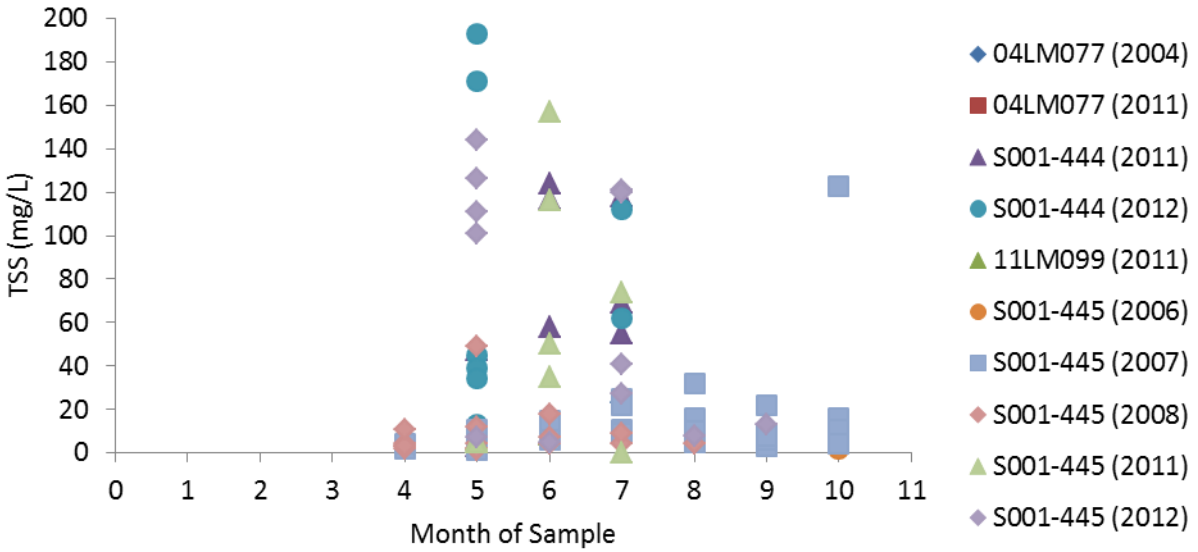


Figure 162. TSS concentrations in Rice Creek by month sampled (zoomed in)

Most of the macroinvertebrate metrics that correspond with elevated TSS show corresponding degradation (Table 134). There were a lack of collector-filterer individuals, long-lived individuals, and no generally intolerant macroinvertebrates in Rice Creek. The macroinvertebrate TSS index score ranges from 14.9 to 15.6, and all three visits had no TSS intolerant taxa. There were three to four TSS tolerant taxa in Rice Creek, with less than 2% of the individuals being TSS tolerant.

Although there are not many TSS tolerant individuals, there are no intolerant individuals and other metrics show that elevated TSS is contributing stress to the macroinvertebrate community. Elevated TSS is inconclusive as a direct stressor in Rice Creek. Sediment via fine sediment and embeddedness of substrates is discussed further in the next habitat section.

Table 134. Macroinvertebrate metrics that respond to elevated TSS stress in Rice Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	LongLivedPct	Intolerant2Pct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
04LM077 (2004)	**13.3**	**0.4**	**0**	**15.0**	**0**	**4**	1.4
04LM077 (2011)	**4.4**	**0.6**	**0**	**15.6**	**0**	3	1.3
11LM099 (2011)	**23.8**	**2.5**	**0**	**14.9**	**0**	3	2.0
Southern Coldwater Average	*34.0*	*2.8*	*2.5*	*14.7*	*1.7*	*3.75*	*7.35*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Habitat

Cannon River Watershed Partnership conducted longitudinal habitat assessments in 2011 and in 2012 after the flood. Specifics can be found in their 2013 Rice Creek Assessment Project Resources Investigation report. The CRWP reported that the difference in the MSHA scores had shifted, with good sites in 2011 receiving decreased scores in 2012 and the opposite. Sites with better scores had greater vegetative cover and those with poor scores were where sediment had been deposited.

Station 04LM077 had two samples of riffle run (RR) rock and 20 samples of undercut bank and overhanging vegetation sampled in 2004. In 2011, the habitat sampled was only undercut bank and overhanging vegetation. In 2004, station 04LM077 had a good MSHA score of 67.4. Similarly in 2011, it had a MSHA score of 76.15. In 2004, station 04LM077 was a fenced pasture. In 2011, the station was noted as having forest, wetland, prairie or shrub. Other differences include increases in the riparian total subcategory score between the two years (Figure 163). In 2004 there was no riparian width observed with moderate shade. In 2011 there was an extensive riparian width (greater than 300ft) with moderate to substantial shade. There was light and no erosion observed during both visits. Station 04LM077 had moderate embeddedness in 2004 and 2011, and less than or equal to four substrate types in 2011. In 2011, riffle features made up 15% and in 2004, riffle features comprised of 20% of the reach with cobble and gravel present. The riffle substrates shifted from cobble and gravel in 2004 to gravel in 2011, which is why the riffle habitat was not sampled in 2011. Moderate cover was available in both visits to station 04LM077. Channel morphology also scored quite well, with good depth variability, pool to riffle width, channel stability and development.

Station 11LM099 had habitat types of riffle, run, and rock, aquatic macrophytes, undercut banks and overhanding vegetation, and snags, woody debris and root wads sampled. Station 11LM099 had a good MSHA score of 71.2. The visit in 2011 had a low land use score due to both areas dominated by row crop. There was no riparian width with moderate erosion; however there was substantial shade available. There was moderate embeddedness with cobble and gravel in the riffle features. The cover

available was extensive with multiple type's available (overhanging vegetation, deep pools, logs or woody debris, boulders, root wads, and submergent macrophytes). Channel morphology also scored quite well, with good depth variability, pool to riffle width, channel stability and development.

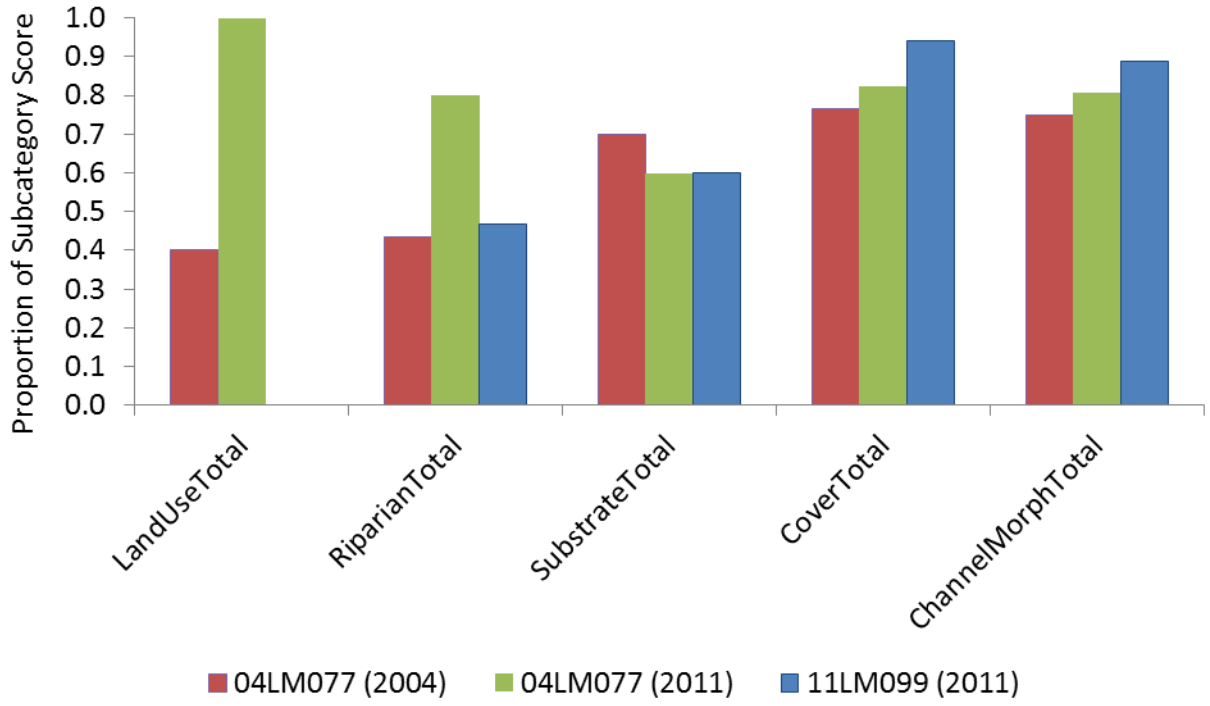


Figure 163. MSHA subcategory scores for Spring Brook

All visits on Rice Creek had fewer macroinvertebrates that cling compared to coldwater streams that meet the biocriteria (Figure 164). Sprawlers were present at fairly high percentages and climbers were present at moderate percentages. At station 04LM077 in 2004, *Gammarus* (a sprawling scud or sideswimmer) and *Simulium* (a clinging black fly) were the dominant taxa. In 2011, at stations 11LM099 and 04LM077, the most dominant taxa in the samples were *Gammarus* (a sprawling scud or sideswimmer) and *Baetis* (a swimming mayfly).

Lack of habitat quality is a stressor in Rice Creek. The macroinvertebrate community is lacking those that cling and has an abundance of tolerant individuals. The embeddedness could be reduced to enable better habitat. The lack of habitat is likely connected to the excess sediment being delivered to the stream as exhibited by the elevated TSS. Additional resources should be placed to minimize delivery of excess sediment to Rice Creek. CRWP already has recommendations to improve habitat in Rice Creek. Their collection of data is pivotal to understanding the dynamics in this system. More information on the work CRWP has done is available in their Rice Creek Assessment Project Resources Investigation report.

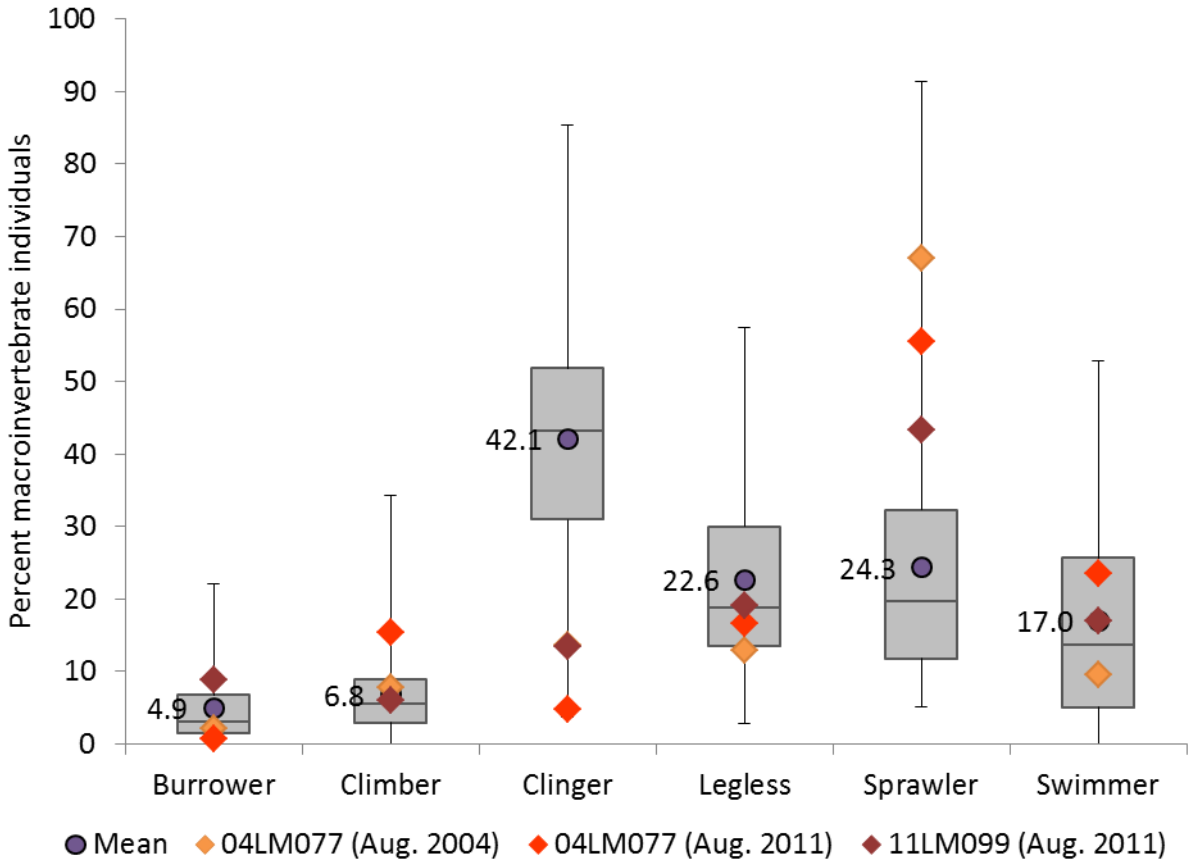


Figure 164. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Coldwater stations with MIBI greater than (threshold), mean of those stations, and metric values from Rice Creek Watershed stations

Conclusion

In Rice Creek, nitrate and habitat are stressors to the macroinvertebrate community. TSS is inconclusive as a stressor, but the sediment in the stream via habitat is problematic. Cannon River Watershed Partnership has done work to identify these stressors to the creek as well as set priority areas for habitat and nitrate; as well as flows and upland erosion which affect these stressors. Temperature and low DO are not stressors in Rice Creek. Temperature should be closely monitored and activities that promote shading and maintaining coldwater should be continued.

The phosphorus in Rice Creek is elevated. Much of the time it is elevated in response to elevated TSS, but there are also times when there is not elevated TSS. Two response variables of BOD and chlorophyll-a have not been measured in Rice Creek to date. There was no elevated DO flux or low DO. The macroinvertebrate community does exhibit stress that may be due to elevated TP and response stressors, but it is difficult to separate from other stressors present. At this time, TP and the response variables are inconclusive as stressors in Rice Creek. Efforts should be made to better understand the nutrient dynamics in Rice Creek as well as minimize excess loading of nutrients and sediment.

4.6.2. Unnamed Ditch to Heath Creek (555)

Unnamed ditch to Heath Creek (AUID 07040002-555) is a class 2B reach, downstream of a class 7 reach (AUID 07040002-530). Station 04LM083 on unnamed ditch to Heath Creek was sampled in 2004 and 2011 for fish and 2004 for macroinvertebrates. Unnamed ditch to Heath Creek is impaired for aquatic life due to lack of fish and macroinvertebrate assemblages. There are no other current impairments on this reach.

The fish community was dominated by black bullheads and brook stickleback in 2004, and fathead minnows, white suckers, and green sunfish in 2011. Both years the fish IBI was below the impairment threshold for the fish Southern Headwaters class IBI (44 in 2004 and 32 in 2011). In a comparison with both fish samples at station 04LM083 and upstream station 11LM031 (on class 7 upstream AUID), all visits show a general pattern in the fish IBI metrics (Figure 165). All metric scores in 2011 were below the average metric score needed to be at or above the IBI threshold. In 2004, taxa richness of sensitive species (Sensitive) and the percentage of taxa that are very tolerant species (VtolTxPct) metrics scored very low. The fish community in the Unnamed Ditch to Heath Creek is dominated by tolerant generalists.

The macroinvertebrate community is impaired, receiving a 44.8 on the macroinvertebrate IBI for Southern Forest Streams GP class in 2004. The lowest scoring metrics were taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch), taxa richness of Plecoptera, Odonata, Ephemeroptera, & Trichoptera (baetid taxa treated as one taxon, POET), relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct) and percentage of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct; Figure 166). The dominant macroinvertebrate was a non-biting midge, *Rheotanytarsus*. Tolerant taxa dominate this station at 95%. The community has a similar composition to a wetland macroinvertebrate community.

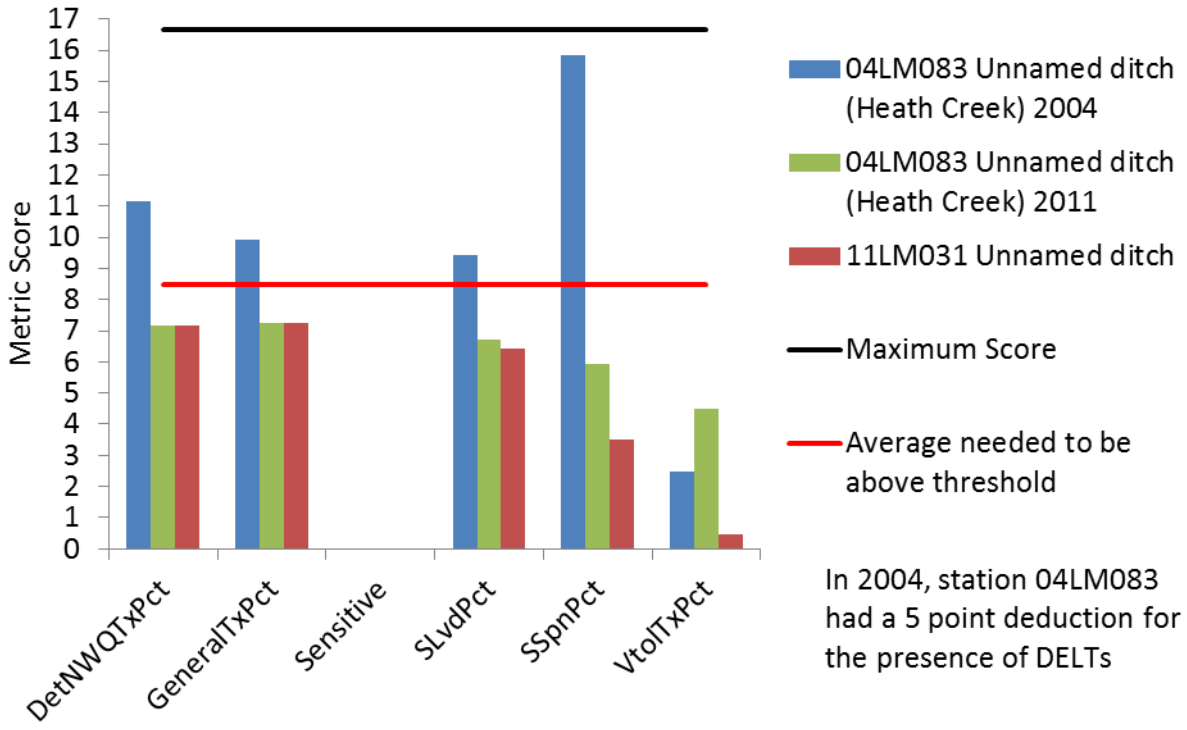


Figure 165. Fish metrics of the Southern Headwaters IBI for Unnamed Ditch, station 04LM0803 and 11LM031

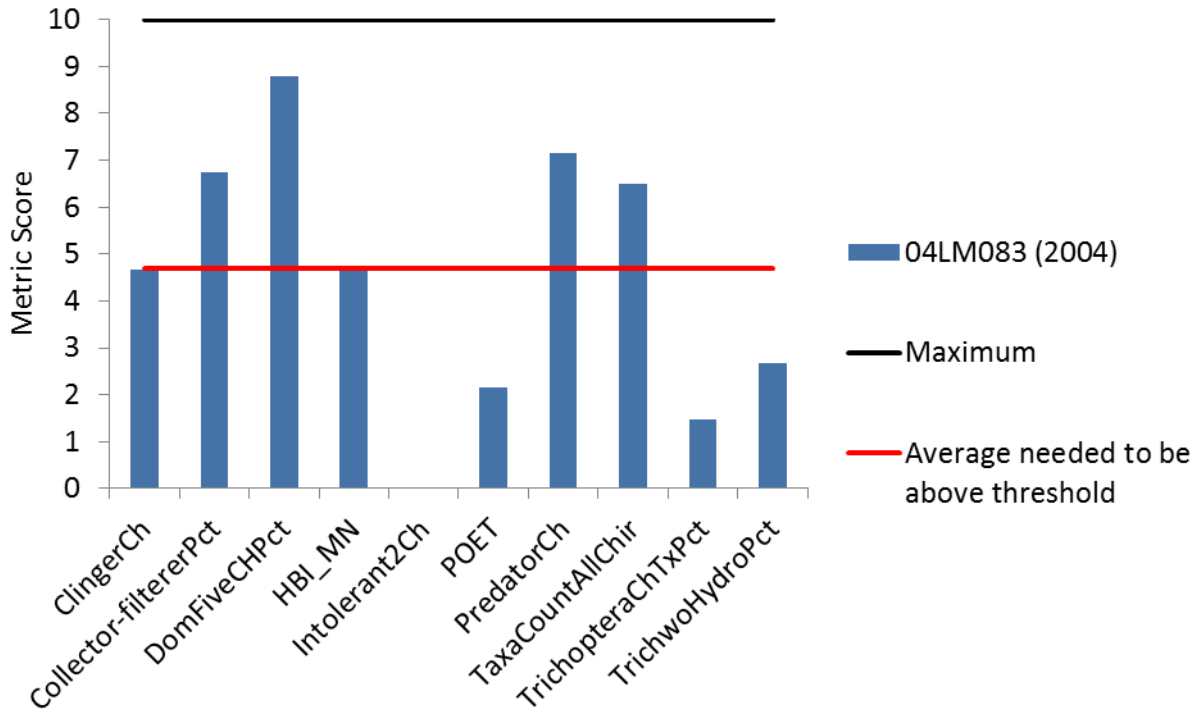


Figure 166. Macroinvertebrate metrics of the Southern Forest Streams GP IBI for Unnamed Ditch to Heath Creek, station 04LM083

Temperature

Chemistry station S007-487 is co-located with biological station 04LM083 on Unnamed Ditch. An YSI sonde was deployed from July 17 – 23, 2014. In 2014, the minimum temperature during that time was 16.87°C with a maximum temperature of 26.13°C. Thirteen synoptic measurements were taken at S007-487 from 2004, 2011, 2013, and 2014. The maximum temperature recorded was 25.2°C (August 15, 2011). Unnamed Ditch is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in Unnamed Ditch.

Chloride/Conductivity

During baseflow sampling in August of 2013, elevated levels of specific conductance were measured at the co-located stations of 04LM083 and S007-487. Follow-up monitoring longitudinally began September 9, 2013, and continued into 2014 under a variety of flow conditions. The stations that were monitored for chloride were stations S007-658, S007-659, and S007-487 (upstream to downstream). Stations S007-658 and S007-659 are on the upstream AUID (07040002-530) and station S007-487 is on the impaired AUID (07040002-555). Elevated chloride levels have been found at station S007-487 as high as 417 mg/L, well over the chronic standard of 230 mg/L (Figure 167). During times of increased stream flow, the chloride concentration is not as high, but during baseflow or lower flow times the two downstream stations exhibit elevated chloride concentrations.

Field measurements only were collected at additional stations downstream to follow the elevated specific conductivity measurements (Figure 168). During longitudinal surveys of conductivity, the highest conductivity was found at station S007-659 on July 24, 2014. The elevated conductivity may not be caused by the elevated chloride alone, but is a surrogate for issues such as chloride.

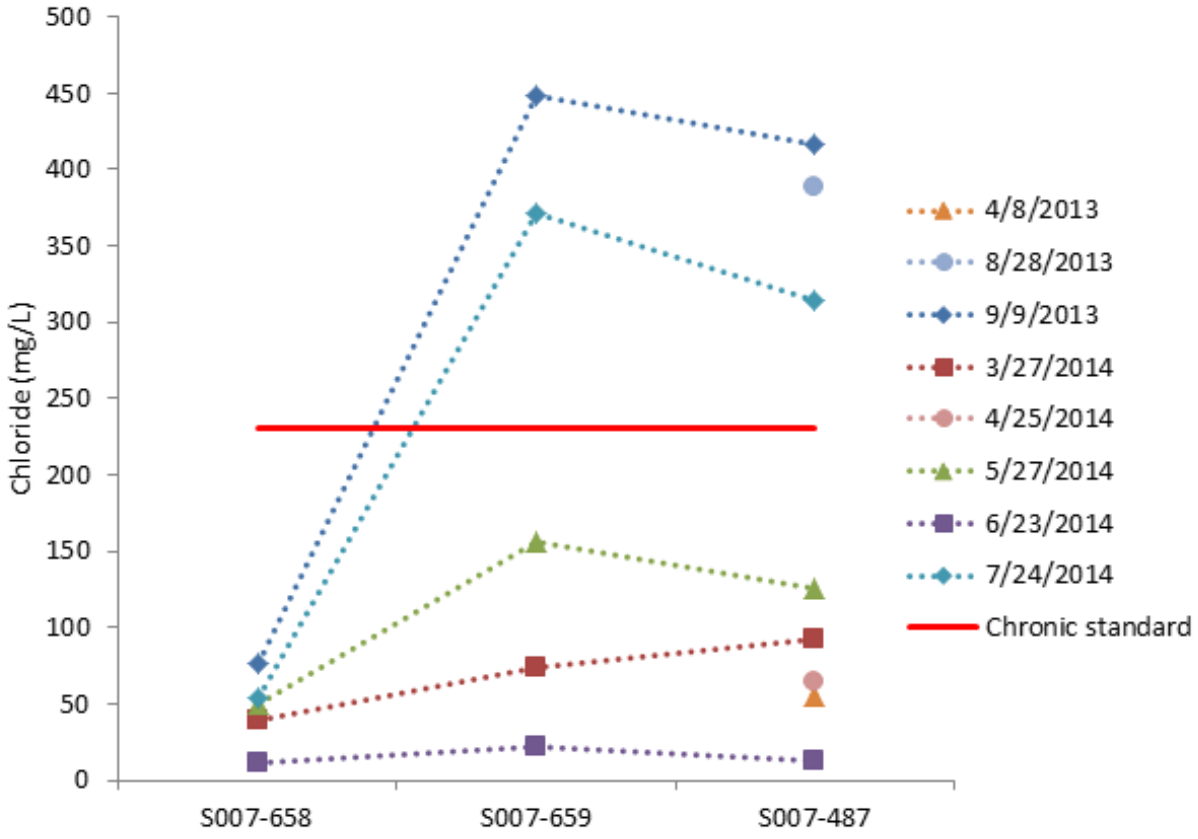


Figure 167. Chloride concentrations at three stations in Unnamed Ditch to Heath Creek

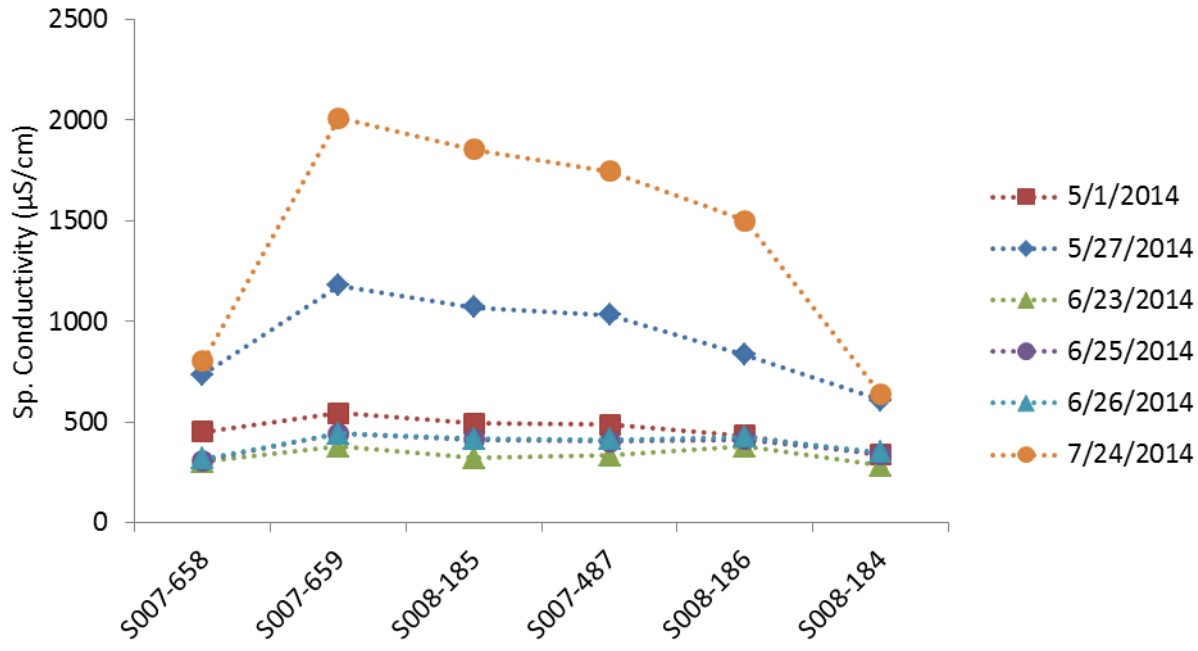


Figure 168. Specific conductivity readings longitudinally in Unnamed Ditch to Heath Creek on select dates in 2014

Chloride stress can result in reduced macroinvertebrate taxa richness, reduced density, and decreased mayfly richness (Roy et al. 2003 and Stranko et al. 2013). Additionally, increases in conductivity can result similarly in reduced taxa richness, decreases in mayfly (Ephemeroptera) percentages as well as

mayfly taxa richness and EPT (Piscart et al. 2005 and Echols et al. 2009). Both the upstream station 11LM031 and station 04LM083 had reductions in mayfly taxa, mayfly individual relative abundance, and EPT richness (Table 135). The taxa richness was very low at station 11LM031, but just below the average of Southern Forest Stream GP stations that are meeting the biocriteria. The macroinvertebrate community is dominated by tolerant individuals (over 90% at both sites) while lack in any intolerant individuals.

Elevated chloride can also lead to increases in sunfish based assemblages. The average percentage of Centrarchidae (sunfish) at stations in the Southern Headwaters fish class that are meeting the biocriteria is 3.5%. In 2004, station 04LM083 had just above that with 3.9%, and in 2011, it was greater with 15.1%.

Chloride and the surrogate measure of specific conductance are high at times in the Unnamed Ditch. Both the decrease in mayflies expected and the increase in sunfish are likely responses from the elevated chloride. Chloride is a stressor to the biological community. One likely source is the WWTP in Lonsdale, although background levels above the WWTP at station 5007-658 suggest that there are other small sources as well.

Table 135. Macroinvertebrate metrics that respond to elevated chloride and conductivity stress in Unnamed Ditch compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EphemeropteraCh	EphemeropteraPct	EPT
11LM031 (2011)	**20**	**2**	**2.2**	**4**
Southern Steams Average	*42.4*	*6*	*22.4*	*10.7*
04LM083 (2004)	**41**	**2**	**3.7**	**3**
Southern Forest Streams Average	41.2	5.1	18	8.8
Expected response to stress	↓	↓	↓	↓

Nitrate

Nitrate has been sampled 10 times in Unnamed Ditch at co-located stations S007-487 and 04LM083 spanning the years of 2004, 2011, 2013, and 2014 (Figure 169). The highest level of nitrate was 12 mg/L (July 24, 2014), baseflow conditions. There is no strong pattern in the data set showing seasonality to the elevated nitrate concentrations. The duration of elevated nitrate is unknown. It would be beneficial to collect samples across various flow conditions to understand the duration of elevated nitrate.

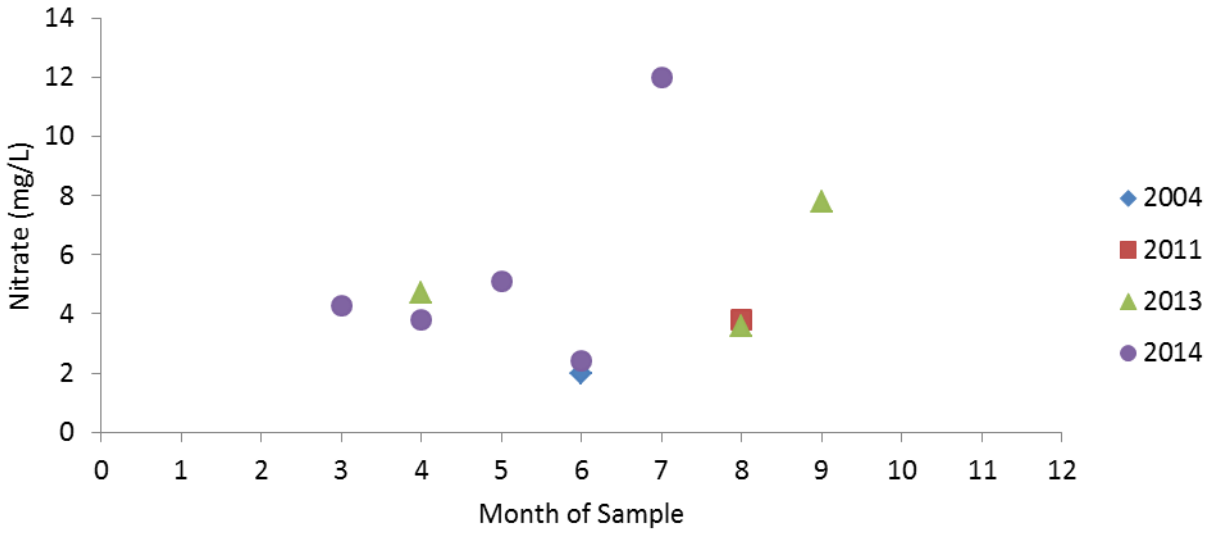


Figure 169. Nitrate concentrations by year and month in Unnamed Ditch (555)

The macroinvertebrate metrics that correspond with nitrate stress show a fairly consistent response as expected (Table 136). Station 04LM083 had only one Trichoptera taxon, and 0.9% non-hydropyschid caddisflies present. There was no intolerant taxa present, resulting in a low metric score (Figure 166). There were 57.0% nitrate tolerant individuals (22 taxa) and no nitrate intolerant taxa. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI threshold.

There is not a strong data set indicating sustained elevated nitrate conditions, yet there has also been nitrate measured as high as 12 mg/L. Similarly, the macroinvertebrate community generally is indicative of nitrate stress. Over half of the macroinvertebrate taxa and individuals are nitrate tolerant, but there is still moderate overall richness. Nitrate may be impacting the macroinvertebrate communities, but the chemical data is not strong. At this time, nitrate is inconclusive as a stressor. Additional nitrate data should be collected to help understand the dynamics in this system.

Table 136. Macroinvertebrate metrics that respond to nitrate stress in Unnamed Ditch to Heath Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM031 (2011)	**2**	**0**	**0**	**3.14**	**0**	12	**70**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.91*	*2.45*	*20.18*	*57.63*
04LM083 (2004)	**1**	**0.9**	**0**	**3.17**	**0**	**22**	**57**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.88*	*2.58*	*19.4*	*55.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

In Unnamed Ditch, at co-located stations S007-487 and 04LM083, there were 10 samples of TP over 2004, 2011, 2013, and 2014 (Figure 170). The maximum TP was 0.495 mg/L (March 27, 2014). The average TP of the 10 samples was 0.293 mg/L, and all of the samples were over the river nutrient criteria for the central region (0.1 mg/L). Although only 10 data points existed with both TSS and TP analyzed, the potential relationship was evaluated (Figure 171) and found that there was elevated TP with low TSS concentrations. The 2013 data may be skewed low due to inaccurate lab methodologies. The 2013 samples, although reported potentially lower than actual conditions, were still greater than the central region nutrient criteria.

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to be related to biological stress. BOD was only collected once, on July 24, 2014. The BOD sample result was 1.3 mg/L, but a replicate sample was taken with a result of 19 mg/L, confounding the results as one is above the draft standard (2.0) and one below. An YSI sonde was deployed from July 17 – 23, 2014. DO was greater than the 5 mg/L standard during the deployment. In 2014 there was flux as great as 3.6 mg/L, but the average DO flux was 2.85 mg/L. The DO flux should not exceed 3.5 mg/L for the central region. More information on the DO dynamics in Unnamed Ditch can be found in the DO section. Chlorophyll-a and periphyton has not been sampled in this reach of the Unnamed Ditch.

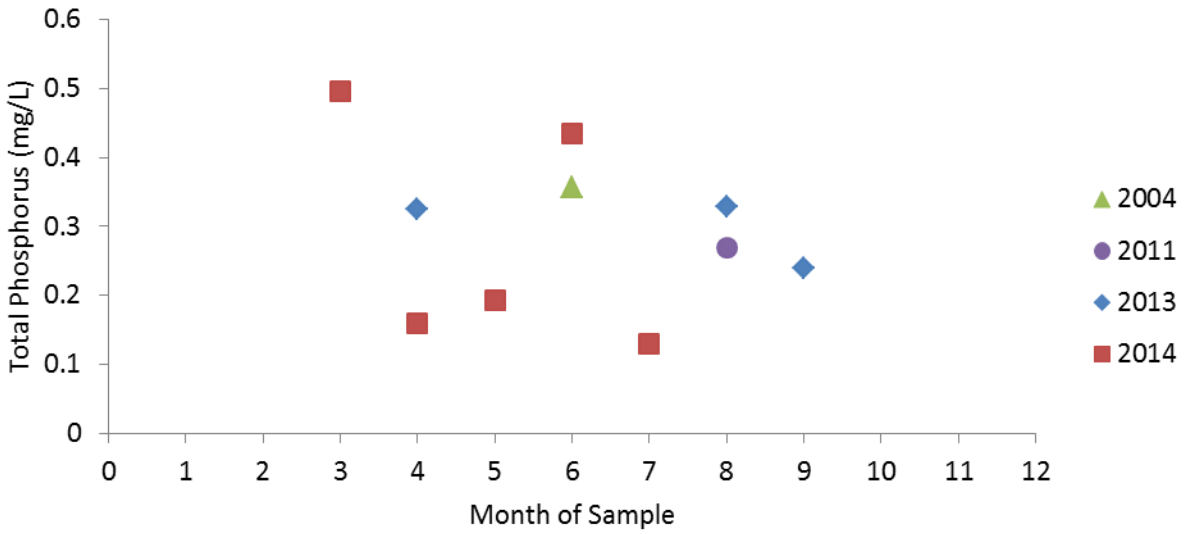


Figure 170. Total phosphorus concentrations in Unnamed Ditch to Heath Creek by month sampled (2004, 2011, 2013-2014)

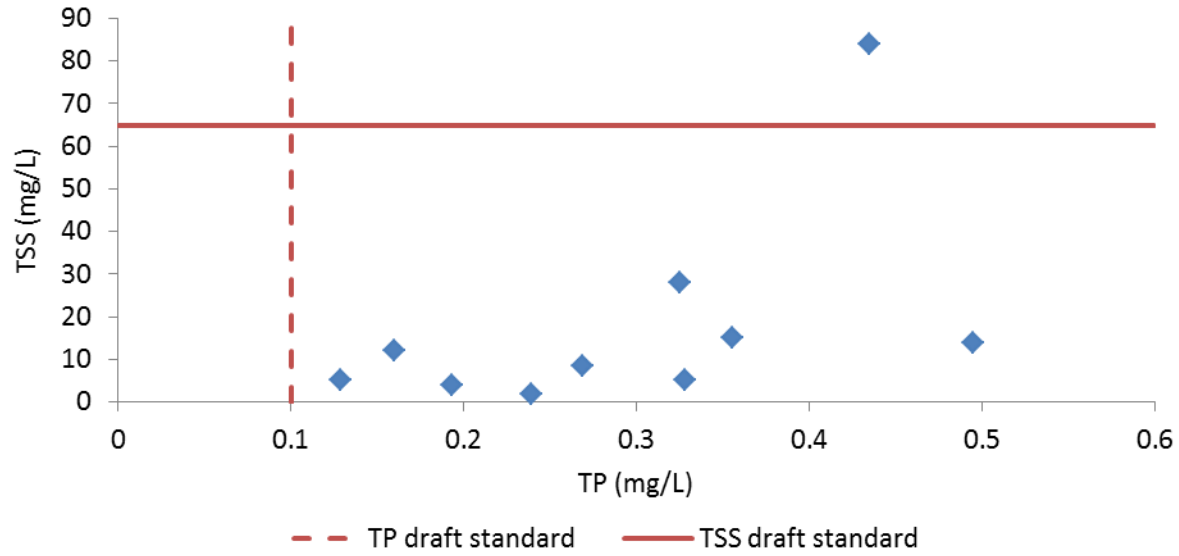


Figure 171. TSS and TP relationship in Unnamed Ditch to Heath Creek (2004, 2011, 2013-2014)

At station 11LM031, all of the six macroinvertebrate metrics responded negatively as expected with river eutrophication stress, and at station 04LM083, five of the six metrics responded negatively (Table 137). The macroinvertebrate taxa count was considerably lower at station 11LM031, but near average at station 04LM083 compared to similar stations that are meeting the biocriteria. Both stations had a high percentage of taxa that are tolerant (Tolerant2ChTxPct) and a lack of intolerant taxa. At station 04LM083, collector-gatherer taxa were just above the average of stations meeting the biocriteria.

Similar to the macroinvertebrate community, in each of the three visits, all of the fish metrics responded negatively as expected with river eutrophication (Table 138). There was a complete lack of sensitive, darter, and intolerant individuals in the Unnamed Ditch to Heath Creek. The lowest percentage of tolerant fish individuals was 98%. The percentage of simple lithophilic spawners was greatly reduced as well as the total taxa count at all three visits.

The response variables from TP are inconclusive as stressors in Unnamed Ditch to Heath Creek. All of the measures of TP were elevated and most without elevated TSS. Both biological communities responded as expected with eutrophication stress. Further data collection of the response variables would be beneficial in understanding the system dynamics.

Table 137. Macroinvertebrate metrics that respond to TP and response variables in Unnamed Ditch compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM031 (2011)	**20**	**3**	**7**	**4**	**0**	**95**
Southern Streams Average	*42.4*	*6.4*	*14.8*	*10.7*	*0.7*	*72.9*
04LM083 (2004)	**41**	**4**	16	**3**	**0**	**95.1**
Southern Forest Streams Average	41.2	5.9	15.0	8.8	0.5	74.9
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 138. Fish metrics that respond to TP and response variables in Unnamed Ditch compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
11LM031 (2011)	**0**	**0**	**11**	**99.3**	**7**	**0**
04LM083 (2004)	**0**	**0**	**0**	**98**	**6**	**0**
04LM083 (2011)	**0**	**0**	**16.3**	**99.7**	**7**	**0**
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*	*1.4*
Expected response to stress	↓	↓	↓	↑	↓	↓

Dissolved Oxygen

Twelve synoptic DO measurements were made over the years of 2004, 2011, 2013 and 2014, at station S007-487 and co-located station 04LM083. There were no measurements below the DO standard of 5 mg/L. The DO data ranged from 7.6-10.12 mg/L. Only one of the twelve measurements was taken prior to 9AM. Additionally in 2014, an YSI sonde was deployed from July 17 to 23, at station 04LM083. There were no violations of the standard, with DO ranging from 6.28 to 10.83 mg/L. Longitudinal surveys were conducted throughout part of 2014, which included reaches above and below the impaired AUID. Only one survey was collected prior to 9AM, on June 26 (Figure 172). Low DO was observed upstream and downstream of station S007-487.

Additionally, at station 04LM083, some elevated DO flux was observed two of the days in 2014 when a sonde was deployed (minimum of 1.96 mg/L, average of 2.85 mg/L, and maximum of 3.6 mg/L). As a response variable to the eutrophication standard, DO flux should not exceed 3.5 mg/L daily for the central region.

The macroinvertebrate community at station 04LM083 had low abundance of EPT taxa as well as a low number of DO intolerant taxa despite having a near average taxa richness (Table 139). Similarly the macroinvertebrate low DO index score was lower than average indicating more tolerance to low DO. The HBI_MN was also slightly elevated indicating potential organic enrichment. There was abundance of low DO tolerant taxa compared to similar stations meeting the biocriteria, and there was an elevated percentage of low DO tolerant individuals.

Fish abundance can decrease with low DO levels. In 2004, only 51 fish individuals were surveyed. The average number of fish per meter in the Southern headwaters fish class is 1.72. In 2011, the number of fish per meter was greater (2.2) than in 2004 (0.31). The abundance of fish that mature later in life (MA>3) was 0% in 2004, and 16.3% in 2011 but were all tolerant fish. The fish community has moderate fish tolerance to DO with DO TIV scores of 5.4 in 2004 and 6.2 in 2011. The scores fall below the median (7.08) for warmwater stations in the Cannon River Watershed, indicating communities generally moderately tolerant of low DO conditions.

The biological metrics indicate stress due to low DO, but the response is not co-located with the measured and known stress spatially. Both upstream and downstream had measurements of low DO; however not within this AUID. Without data showing that the stressor and response are co-occurring spatially, it is difficult to link low DO concentrations to the impaired biological communities. Currently, low DO is inconclusive as a stressor in Unnamed Ditch to Heath Creek.

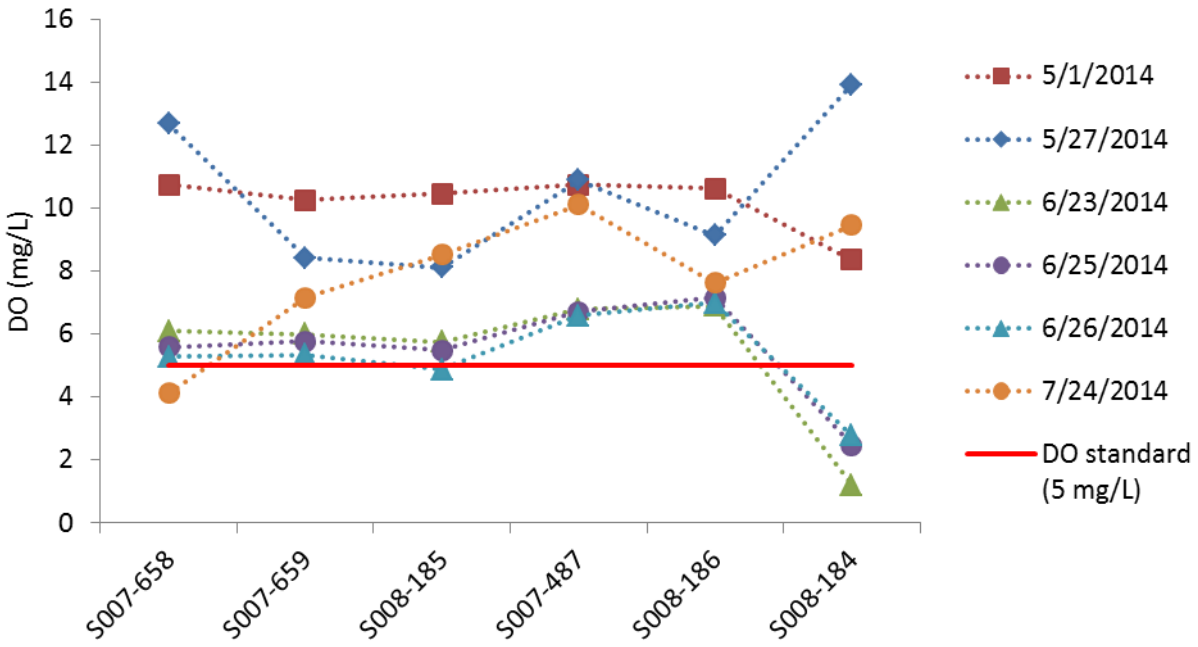


Figure 172. Longitudinal DO surveys in Unnamed Ditch in 2014

Table 139. Macroinvertebrate metrics that respond to low DO stress in Unnamed Ditch compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
04LM083 (2011)	**41**	**3**	**7.44**	**6.8**	**2**	**7**	**22.9**
Southern Forest Streams Average	*41.3*	*10.2*	*7.1*	*7.04*	*6.51*	*5.57*	*13.99*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

TSS

TSS has been sampled 10 times at station S007-659, over 2004, 2011, 2013, and 2014. TSS ranged from 2 to 84 mg/L. The highest TSS was during the rain event on June 23, 2014, which was the only sample greater than 65 mg/L (draft south region TSS standard). There were 10 secchi tube measurements paired with the TSS samples. The lowest measure was during the June 2014 rain event sample measured at 10 cm, others ranged from 19 to 100cm. No measurements were less than the 10cm surrogate standard of the south TSS region.

At station 04LM083, the metrics that correspond with elevated TSS were not consistent with TSS stress (Table 140). At the station upstream, 11LM031, there was observed stress consistent with elevated TSS. At station 04LM083, there was a lack of stoneflies (Plecoptera), and no taxa that are intolerant to TSS. The TSS index score was below the average of similar stations meeting the biocriteria. The TSS tolerant taxa were not relatively high and the percent individuals that are tolerant to TSS were not high at station 04LM083.

The fish community had a negative response to elevated TSS (Table 141). Nearly all of the metrics at all three visits, both upstream station 11LM031 and station 04LM083 had metric values that indicate TSS stress. Non-tolerant Centrarchidae were not recorded during any of the fish sampling visits. Relative abundance was equivalently low for herbivores, riffle dwellers, and simple lithophilic spawners. The only metric that did not have a negative response was simple lithophilic spawners in 2011 at station 04LM073. All three of the TSS index scores were greater than the average of similar stations meeting the biocriteria, indicating more tolerance to elevated TSS.

Unnamed Ditch to Heath Creek has limited data and little suggesting sustained concentrations of elevated TSS. The fish community indicates a negative response to elevated TSS stress, but the macroinvertebrate community at station 04LM083 does not show stress to elevated TSS. Based on limited data suggesting stress, as well as the lack of macroinvertebrate response, it is inconclusive if elevated TSS is a stressor to the biological communities in Unnamed Ditch. However, it would be in the best interest of this small stream, if additional monitoring is conducted to further the understanding of sediment within this system.

Table 140. Macroinvertebrate metrics that respond to elevated TSS stress in Unnamed Ditch compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM031 (2011)	**20.2**	**0**	**18.3**	**0**	7	**47.7**
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*11.3*	*34.0*
04LM083 (2004)	25.7	**0**	15.2	**0**	6	4.5
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*10.2*	*27.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 141. Fish metrics that respond to elevated TSS stress in Unnamed Ditch compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RifflePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM031 (2011)	**11.7**	**0**	**11**	**0**	**0**	**0**	**11**	**0**	**11**	**20.9**
04LM083 (2004)	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**20.1**
04LM083 (2011)	**16.6**	**0**	**16.3**	**0**	**0**	**0**	**16.3**	**0**	16.3	**19.8**
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.3*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

In 2004, at station 04LM083, the total MSHA score was poor (35.5 out of 100) and in 2011, the score was fair (50.65). The MSHA subcategory scores that were particularly low were the land use and riparian subcategory scores (Figure 173). The surrounding land use was row crop in 2004 and pasture and old field in 2011. There was no riparian width in 2004 and 2011, with heavy bank erosion and light to no shade.

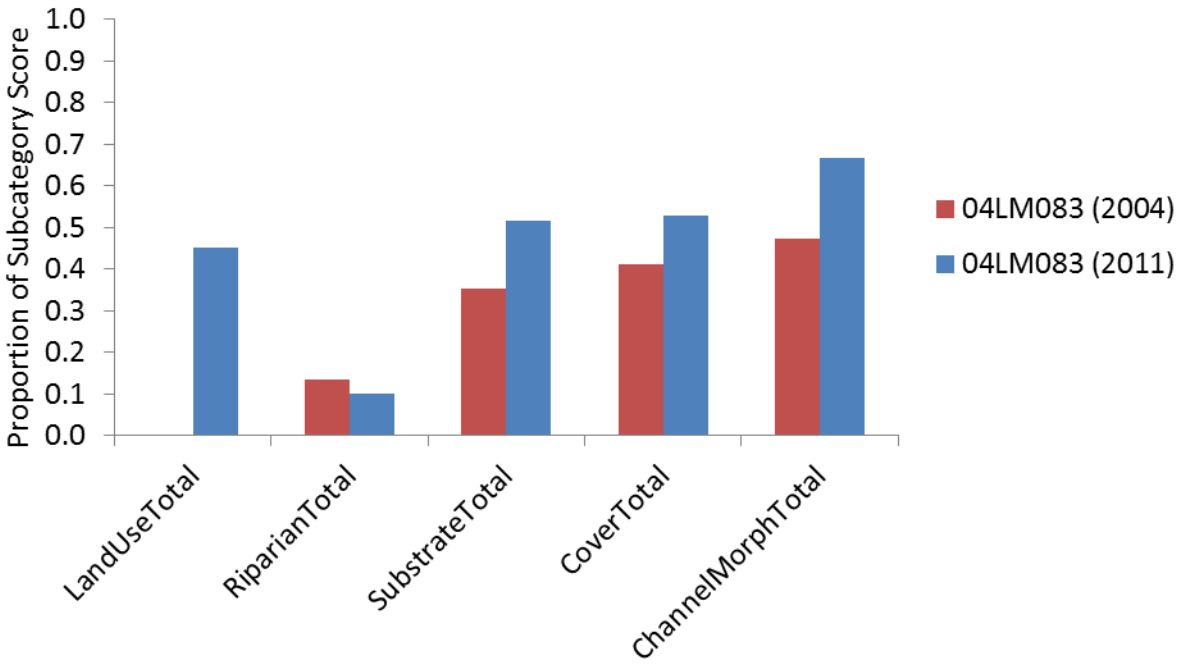


Figure 173. MSHA subcategory score for Unnamed Ditch to Heath Creek, station 04LM083

There were less than or equal to four substrate types in 2004, but greater than four in 2011. In 2004, sand and silt dominated the substrate in the run (70%), riffle (10%), and pool (20%) features. There was no course substrate and the water at the time of fish sampling was stained and brown with clarity of 46 cm. In 2011, there was some gravel in the riffle features that comprised 15% of the reach. Pool features accounted for 65% and run features 20% of the reach, with sand and silt substrate. The water color was also brown in 2011.

Cover was sparse (5-25%), with undercut banks, overhanging vegetation (including emergent macrophytes), and deep pools, in 2004. In 2011, the cover was noted also as sparse and additionally to the 2004 survey, included cover types of logs or woody debris, boulders, and submergent macrophytes.

In 2004, there was good depth variability, pool to riffle width, and sinuosity. The channel stability was low with fair channel development. Moderate and slow velocity types were noted during a time of above normal water level. In 2011, during normal water level, the pool width was less than the riffle width and there was moderate channel stability with good channel development. Fast, moderate and slow velocity types were noted in 2011.

Additionally in 2013, habitat was surveyed longitudinally in Unnamed Ditch by Cannon River Watershed Partnership, employing the MSHA protocol (Figure 174). The MSHA ranged from fair to good; 49.5 to 80.25. In the stations surveyed there was generally little erosion with a couple of sites with little to moderate erosion. Most of the reaches had moderate cover with one having extensive and a couple with sparse cover. Six of the eight reaches had few substrate types available, with two having greater than four substrate types. The percentage of riffle habitat varied throughout the reaches with some having no riffle habitat and the most upstream reach having 30% riffle habitat available.

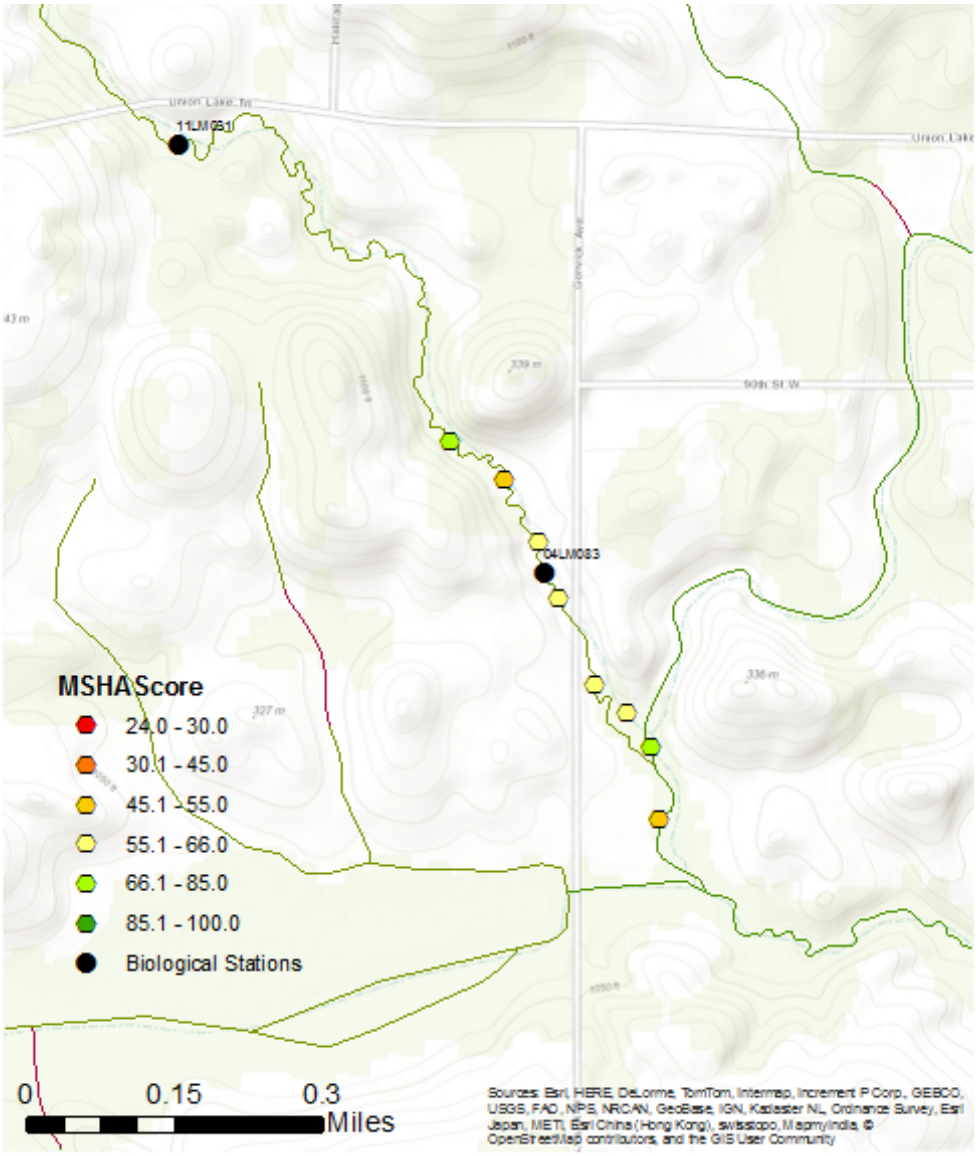


Figure 174. MSHA longitudinally in Unnamed Ditch to Heath Creek, 2013

In 2004, the macroinvertebrate samples were collected on undercut banks and overhanging vegetation. Station 04LM083 had slightly more burrowers and legless than expected (Figure 175). Increased burrowers can indicate increased fine sediments. The metric for taxa richness of clingers (ClingerCh) scored 4.7, near the average metric score needed to be at or above the threshold. The percentage of clingers was just above the mean and median of the natural channel Southern Forest Streams GP stations meeting the biocriteria.

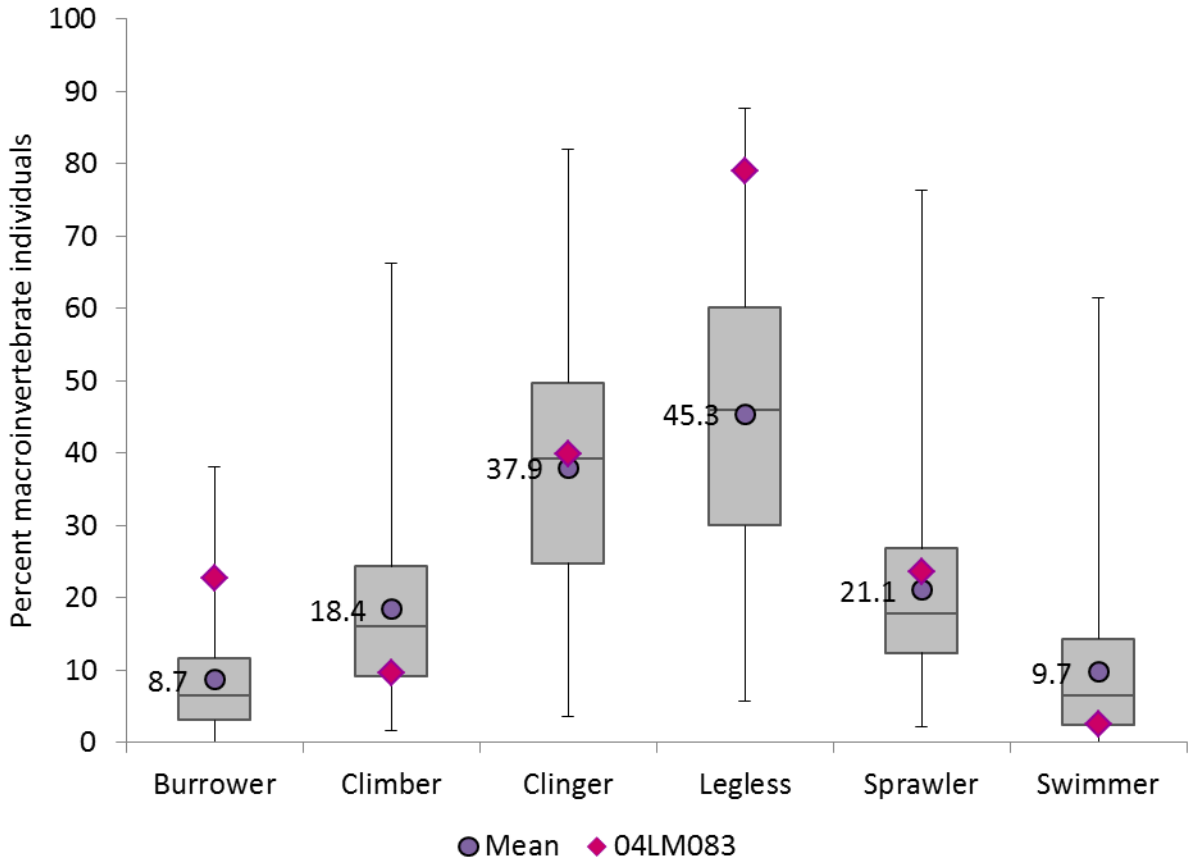


Figure 175. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP with MIBI greater than 46.8 (threshold), mean of those stations, and station 04LM083 in Unnamed Ditch to Heath Creek

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat quality is diminished. The fish community had no fish that prefer riffles at station 04LM083 in 2004 and only one taxon in 2011, white sucker, which is fairly tolerant and considered a generalist feeder. Similarly, there were no simple lithophilic spawners in 2004 and white suckers were the only taxon found in 2011, comprising 16.3% of the community. The average percentage of simple lithophilic spawners at Southern Headwater fish class stations in the Cannon River Watershed was 27.3%. In 2004 and 2011, station 04LM083 had less than 2% benthic insectivores (one tadpole madtom individual in each survey). There were no darter, sculpin, and round bodied suckers at station 04LM083 in 2004 or 2011.

Lack of adequate habitat is a stressor to the macroinvertebrate community and fish community. Although there may have been some improvement between 2004 and 2011, the fish community indicates that there is still room for further improvement. There are notes from the MPCA biologists indicating severe habitat degradation due to animal trampling in 2004 and 2011 at biological station 04LM083 (Figure 176).

Figure 176. Photograph of Station 04LM083, August 15, 2011

Fish Passage

Upstream of this AUID, there is a perched culvert at Union Lake Trail near stations S008-185 and 11LM031 (Figure 177). Additionally, downstream, there is a dam at the outlet of Union Lake. It is unknown if the dam is affecting fish passage from the downstream Health Creek to reaches upstream of the lake. The fish data is inconclusive at showing longitudinal differences (Table 142). The culvert and dam may be limiting fish mobility, but it is inconclusive as a stressor to the fish community.

Figure 177. Perched culvert downstream of Union Lake Trail

Table 142. Fish data from Heath Creek Watershed (station 11LM020 on Knowles Creek)

Station	11LM031	04LM083	04LM083	(11LM020)	Union Lake	04LM076	04LM076	13LM001	11LM005
Year	2011	2004	2011	2011		2004	2013	2013	2011
bigmouth shiner									4
black bullhead	18	25		1		4			
blacknose dace						1			38
bluntnose minnow									85
brook stickleback	1	21	33	30		1	2	1	
central mudminnow	13		20	3		3		9	2
central stoneroller									140
common carp						12	2		9
common shiner							3	2	263
creek chub			10	1					236
fantail darter									16
fathead minnow	87	1	163	112		18	17	4	109
green sunfish	9	2	50	74				1	55
hornyhead chub								1	240
hybrid sunfish		1		5					
johnny darter									58
longnose dace									22
northern hogsucker									1
northern pike								1	1
tadpole madtom	1	1	1	1			2	10	10
white sucker	16		54	54		1	35	40	273
yellow perch				4					5

Conclusion

Lack of habitat and elevated chloride are stressors in the Unnamed Ditch to Heath Creek. Many other stressors were inconclusive (nutrients, DO, TSS and fish passage). Elevated temperature is not a stressor.

Chloride and specific conductance, a surrogate measure of chloride, are high at times in the Unnamed Ditch. Chloride is a stressor to the biological community. The likely source is the WWTP in Lonsdale, although not all is sourced from there as seen by the background levels above the WWTP, at station S007-658.

Lack of adequate habitat is a stressor to the macroinvertebrate community and fish community. There are notes from the MPCA biologists indicating severe habitat degradation of the stream due to animal trampling in 2004 and 2011 at the biological station 04LM083.

The biological metrics indicate stress due to low DO, but the response is not co-located with the measured and known stress spatially. Both upstream and downstream had measurements of low DO; however not within this AUID. Without data showing that the stressor and response are co-occurring spatially, it is difficult to conclude. Currently, low DO is inconclusive as a stressor in Unnamed Ditch to Heath Creek.

Additional nitrate and phosphorus data should be collected to help understand the dynamics in this system. The fish passage should be monitored to see if it is limiting, particularly the dam on Union Lake. The culvert at Union Lake Trail should be replaced. A geomorphic survey should be conducted prior to the replacement as well as ensuring adequate size and placement of replacement culverts.

4.6.3. Heath Creek (521)

Heath Creek (AUID 07040002-521) is a tributary to the Cannon River, near Northfield, Minnesota. The reach is impaired for aquatic life use due to lack of macroinvertebrate assemblage and lack of fish assemblage. It is also impaired for *E. coli*, which will not be addressed in this report. There are three stations in Heath Creek, 04LM076, 13LM001, and 11LM005. The most upstream station 04LM076 was sampled for fish and macroinvertebrates in 2004 and replicated in 2013. The middle station 13LM001 was sampled for biology in 2013, and the downstream station 11LM005 was sampled in 2011.

This reach was previously listed as impaired due to turbidity and not supporting aquatic life in 2008. However, it was determined that water chemistry data at monitoring station S001-935 were influenced by algal conditions within Union Lake, due to its close proximity to the lake outflow, and were not representative of Heath Creek. As such, those data were removed from the assessment dataset and a new assessment showed that Heath Creek (-521) meets the water quality standard for turbidity.

For macroinvertebrates, the downstream station 11LM005 fell within the Southern Streams RR class and was above the threshold with a MIBI score of 43.2. Station 11LM005 was one of only two locations in the Cannon River Watershed where the pollution-sensitive, turtle shell case-maker caddisfly larvae, *Glossosoma sp*., was collected. The other two stations are in the Southern Forest Streams GP class. All three of the visits to these stations were below the threshold with MIBI scores ranging from 26 to 35. Many MIBI metric scores were below the average metric score needed to be at the threshold (Figure 178). All three visits resulted in a metric score of zero for taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch) and relative abundance of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct).

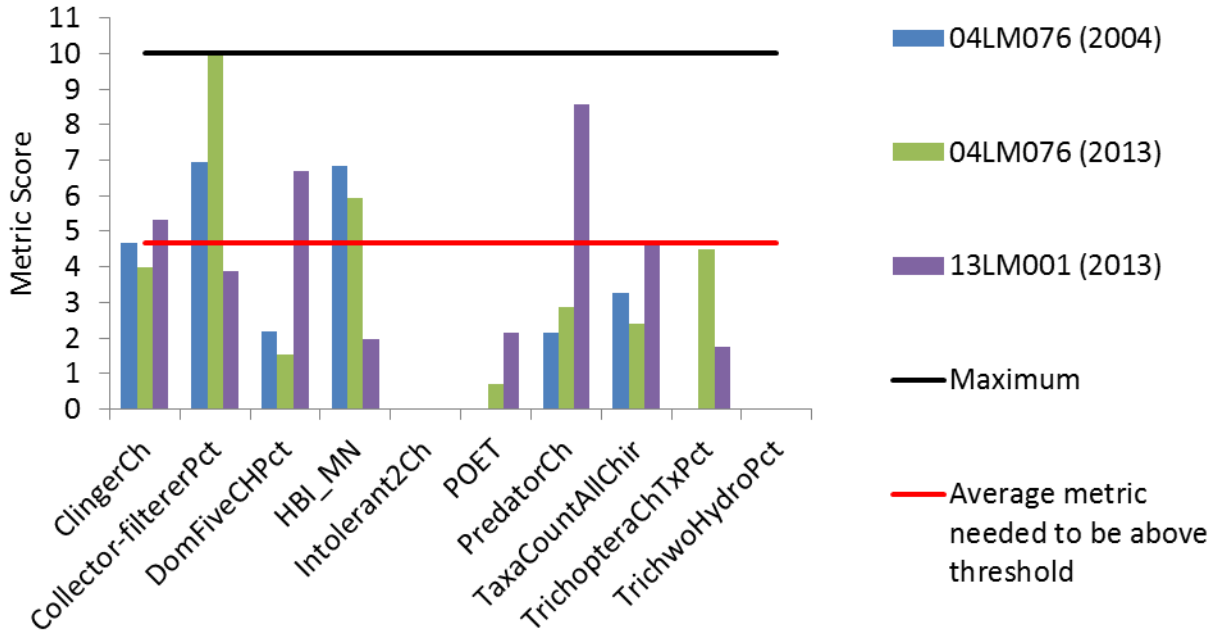


Figure 178. Macroinvertebrate metrics of the Southern Forest Streams GP IBI for Heath Creek, stations 04LM076 and 13LM001

The fish community showed similar poor condition at stations 04LM076 and 13LM001. The downstream station 11LM055 scored much higher on the Southern Streams class IBI (58), compared to upstream visits (11.6 – 43.8) which were below the threshold. Station 04LM076 was dominated by fathead minnows and common carp in 2004, and in 2013, white sucker and fathead minnow. Station 13LM001 was dominated by white sucker and tadpole madtom. The dominance in the surveys results in a low metric score of relative abundance of individuals of the dominant two species (DomTwoPct; Figure 179). Station 11LM005 also had a dominance of white sucker, but the percent dominance was not as strong. The fish communities at both stations were dominated by tolerant individuals, resulting in metric scores of zero for TolPct.

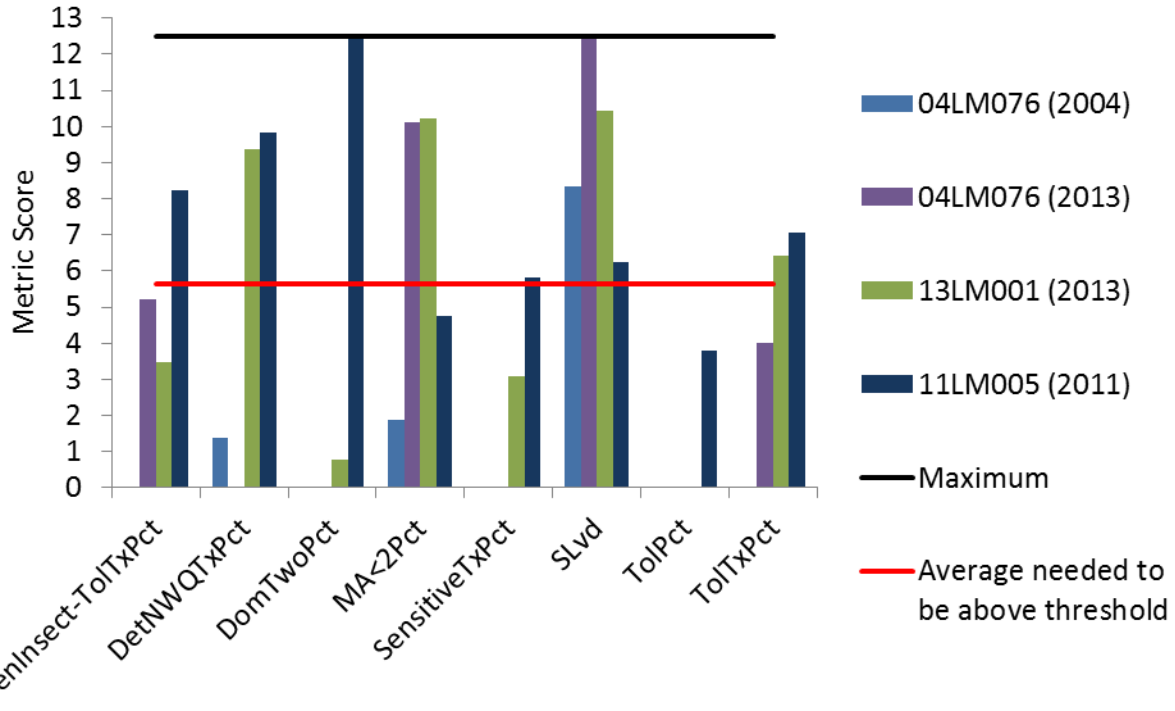


Figure 179. Fish metrics of the Southern Streams IBI for Heath Creek, stations 04LM076, 13LM001, and 11LM005

Temperature

There are five chemistry stations on Heath Creek, plus the three biological stations. From 2002 to 2013, there were 221 data points collected at these eight stations. The maximum temperature recorded was 29.8°C at station S006-521 on July 19, 2011. This station is located near biological station 11LM005. An YSI sonde was deployed in 2014 from August 11 to 22 at station 04LM076. The minimum temperature during that time was 18.6°C with a maximum temperature of 27.4°C. Heath Creek is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in Heath Creek.

Nitrate

Nitrate has been sampled 23 times in Heath Creek at the three biological stations, station S004-389 and station S006-521, spanning the years of 2004, 2010, 2011, and 2013 (Figure 180). The highest level of nitrate was 3.2 mg/L (June 21, 2011). There is no strong pattern in the data set showing seasonality to the elevated nitrate concentrations. The duration of elevated nitrate is unknown. It would be beneficial to collect samples during various flow conditions to understand the duration of elevated nitrate.

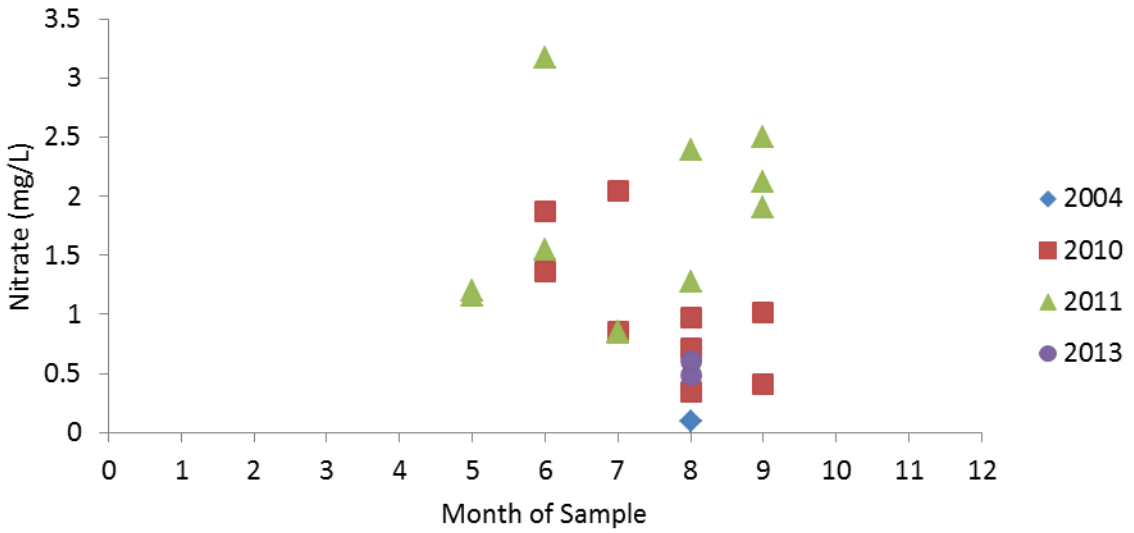


Figure 180. Nitrate concentrations by year and month in Heath Creek

The macroinvertebrate metrics that correspond with nitrate stress show a mixed response as expected (Table 143). In the upper two stations there were not as many caddisflies as expected, but at the downstream station 11LM005 there was a greater richness. Also in the upstream two stations there were no intolerant taxa present, resulting in a low metric score. Although there were indications of stress with other metrics, the nitrate specific metrics do not show the same response, with lower nitrate index scores and lower percentages of nitrate tolerant individuals.

The chemical nitrate data only has a maximum of 3.2 mg/L. The macroinvertebrate community is not strongly indicative of nitrate stress. At this time, nitrate is not a stressor, as there are more likely other stressors indicative of the response in the macroinvertebrate community. However, additional nitrate data should be collected to help understand the dynamics in this system and ensure that it does not increase.

Table 143. Macroinvertebrate metrics that respond to nitrate stress in Heath Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
04LM076 (2004)	**0**	**0**	**0**	2.33	**0**	13	36.2
04LM076 (2013)	**2**	**0**	**0**	2.66	**0**	13	28.9
13LM001 (2013)	**1**	**0**	**0**	**3.04**	**0**	16	29.6
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.88*	*2.58*	*19.4*	*55.5*
11LM005 (2011)	7	**1.5**	1	2.73	**0**	**23**	46
Southern Steams Average	*5.3*	*5.3*	*0.7*	*2.91*	*2.45*	*20.18*	*57.63*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

Throughout Heath Creek, 23 samples of TP were collected at five stations (Figure 181). The two highest measurements of TP were taken on August 5, 2013, at station 04LM076 and 13LM001 (0.799 and 0.684 mg/L respectively). All of the samples collected in Heath Creek were over the river nutrient criteria for the central region (0.1 mg/L). Thirteen samples in Heath Creek had both TSS and TP collected. The potential relationship with TSS was evaluated (Figure 182) and found that although some elevated TP coincides with elevated TSS, there was elevated TP with low TSS concentrations. Heath Creek flows out of Union Lake which is impaired by excess nutrients.

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to be linked to a biological stressor. Chlorophyll-a was sampled nine times at station S004-389, co-located with station 11LM005, during 2010. The highest level was 40 ug/L on September 28, 2010. The next highest sample was only 8 ug/L. Only one sample was above the standard of 35 ug/L. BOD has not been collected in Heath Creek. At station 04LM076, DO was measured by an YSI sonde from August 11-22, 2014. DO was lower than the 5 mg/L standard and the greatest flux was 5.89 mg/L. The DO flux should not exceed 3.5 mg/L for the central region. More information is available in the DO section.

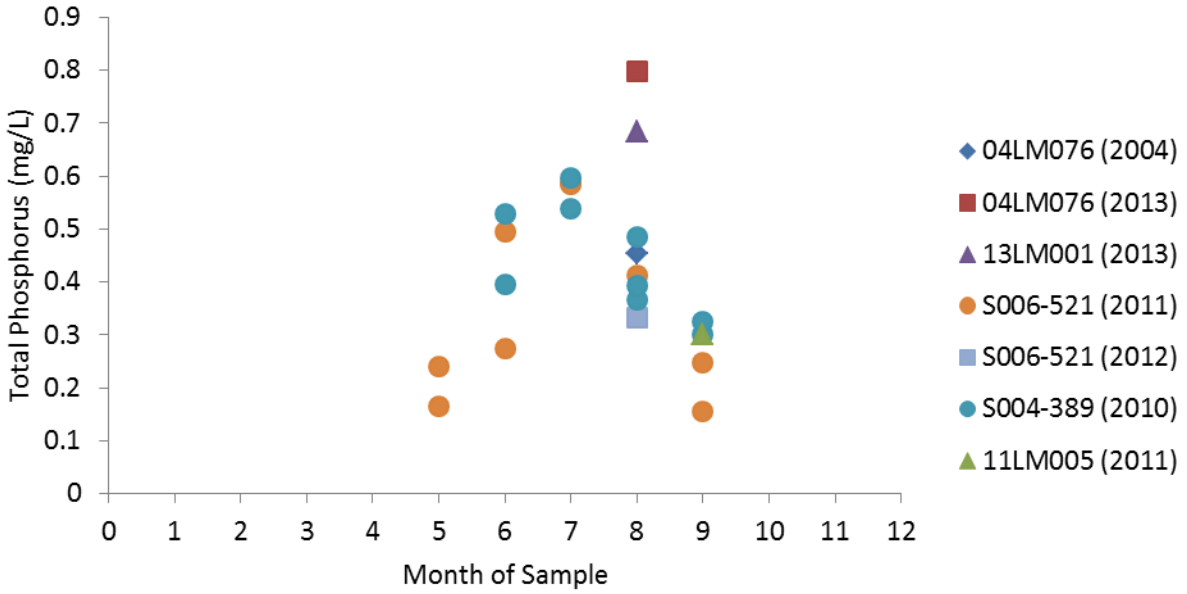


Figure 181. Total phosphorus concentrations in Heath Creek by month sampled

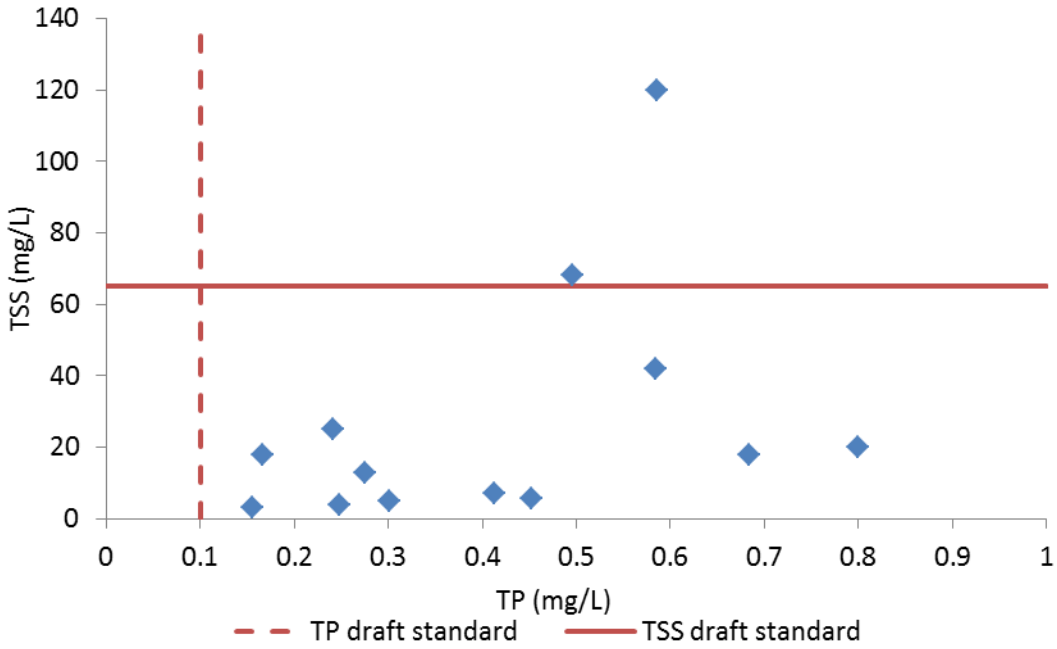


Figure 182. TSS and TP relationship in Heath Creek

Within Heath Creek, all of the six metrics responded negatively as expected with river eutrophication stress at stations 04LM076 and 13LM001 (Table 144). Station 11LM005 only had three metrics respond as expected with eutrophication stress, but the metric values were near the statewide averages for the Southern Streams RR class.

Similar to the macroinvertebrate community, at stations 04LM076 and 13LM001, almost all of the metrics responded negatively as expected with river eutrophication (Table 145). There was a complete lack of darter, and intolerant individuals in the two upstream stations in Heath Creek. The percentage of simple lithophilic spawners was high in 2013. All of the fish visits resulted in high percentages of tolerant individuals.

The response variables of DO flux with low DO, related to TP, are stressors in Heath Creek. All of the measures of TP were elevated and most without elevated TSS. Both communities responded as expected with eutrophication stress in the upper two stations of Heath Creek. Further data collection of the response variables would be beneficial in understanding the system dynamics.

Table 144. Macroinvertebrate metrics that respond to TP and response stressors in Heath Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
04LM076 (2004)	**30**	**2**	**12**	**2**	**0**	**93.3**
04LM076 (2013)	**27**	**5**	**9**	**3**	**0**	**88.9**
13LM001 (2013)	**35**	**3**	**8**	**4**	**0**	**97.1**
Southern Forest Streams Average	*41.2*	*5.9*	*15.0*	*8.8*	*0.5*	*74.9*
11LM005 (2011)	**41**	7	17	**10**	1	**75.6**
Southern Steams Average	*42.4*	*6.4*	*14.8*	*10.7*	*0.7*	*72.9*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 145. Fish metrics that respond to TP and response stressors in Heath Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
04LM076 (2004)	**0**	**0**	**5**	**100**	**7**	**0**
04LM076 (2013)	**0**	**0**	62.3	**91.8**	**6**	**0**
13LM001 (2013)	**1.5**	**0**	60.9	**79.7**	**9**	**0**
11LM005 (2011)	17.5	**4.7**	38.1	**60.7**	19	**1.4**
Southern Streams Average	*14.8*	*11.8*	*35.2*	*48.4*	*18.8*	*3.3*
Expected response to stress	↓	↓	↓	↑	↓	↓

Dissolved Oxygen

In Heath Creek, 35 synoptic DO measurements were made over the years of 2004, and 2010 – 2013. There were no measurements observed prior to 9AM, yet there were four measurements below the standard of 5 mg/L. The measurements below the standard were observed at stations 04LM076 (2004 and 2013) and S006-521 (2011 and 2012). The synoptic DO data ranged from 2.95-10.21 mg/L. Additionally in 2014, an YSI sonde was deployed from August 11 to 22, at station 04LM076, with exceedances of the standard each day (Figure 183). The DO ranged from 3.27 to 9.36 mg/L and the exceedance rate was 46.9% of the duration deployed.

Additionally, at station 04LM076, elevated DO flux was observed (minimum of 3.15, average of 4.84, and maximum of 5.89). As a response variable to the eutrophication standard, DO flux should not exceed 3.5 mg/L daily for the central region. While Heath Creek is influenced by some wetlands which naturally

experience DO fluctuations, DO flux values between 2.0 to 4.0 are typical in a 24-hour period (Heiskary et al, 2010).

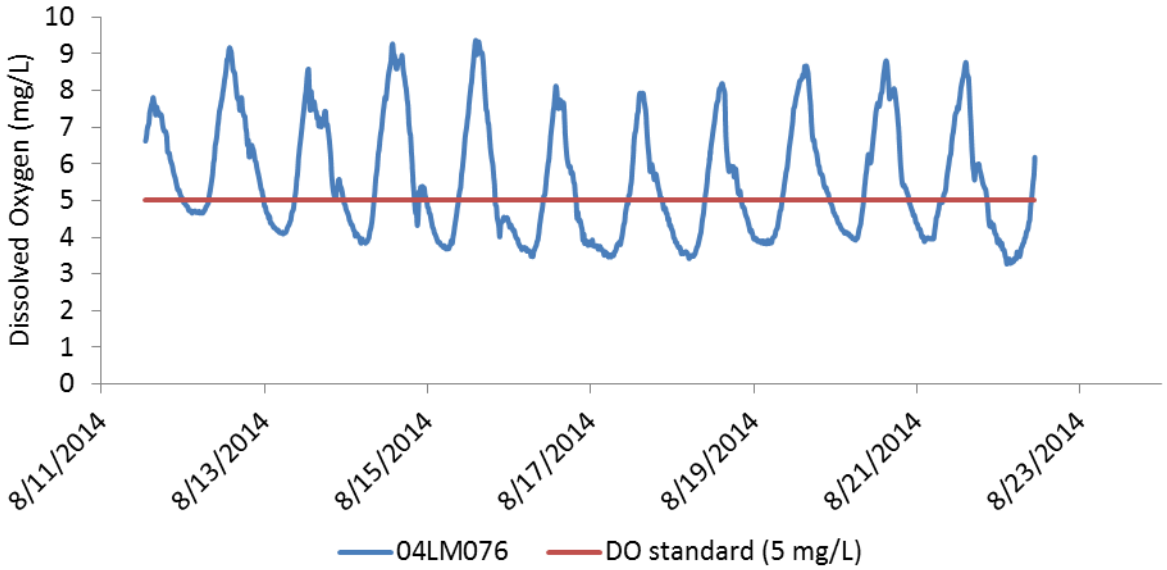


Figure 183. Diurnal dissolved oxygen at station 04LM076 in Heath Creek

Throughout Heath Creek there was a low abundance of EPT taxa as well as a low number of DO intolerant taxa (Table 146). Nearly all the macroinvertebrate metrics at stations 04LM076 and 13LM001 responded as expected with low DO stress. Additionally, the macroinvertebrate low DO index score was lower than average indicating more tolerance to low DO. Station 11LM005 did not have a similar response as the two upstream stations.

Fish abundance can decrease with low DO levels. In the upstream stations, the number of fish individuals was less than 70, whereas the downstream station had 1567 individuals. The average number of fish per meter in the Southern Streams fish class is 1.94. The three upstream visits resulted in 0.22 – 0.45 fish per meter, and station 11LM005 had 5.59 fish per meter. The abundance of fish that mature later in life (MA>3) was low only at station 04LM076 in 2004 (2.5%). Although the other visits resulted in a greater abundance of fish that mature later, they were nearly all tolerant except 0.4% at station 11LM005. The fish community has moderate intolerance to DO with the DO TIV index. The scores for stations 04LM076 and 13LM001 fell below the median (7.08) for warmwater stations in the Cannon River Watershed, indicating communities generally more tolerant of low DO conditions. Station 11LM005 had a fish community a little less tolerant to low DO.

Both synoptic measurements of DO and diurnal measurements indicated that Heath Creek violates the low DO standard of 5 mg/L. Additionally, high DO flux was observed when diurnal DO was measured. The macroinvertebrate and fish communities responded as expected with low DO stress at stations 04LM076 and 13LM001. It is likely that the DO may be recovering once it reaches station 11LM005. Low DO is a stressor to both biotic communities at stations 04LM076 and 13LM001.

Table 146. Macroinvertebrate metrics that respond to low DO stress in Heath Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
04LM076 (2004)	**30**	**2**	6.79	**6.45**	**1**	**10**	**38**
04LM076 (2013)	**27**	**3**	7.06	**6.95**	**1**	4	13
13LM001 (2013)	**35**	**4**	**8.27**	**6.51**	**1**	**12**	**33.3**
Southern Forest Streams Average	*41.2*	*10.2*	*7.1*	*7.04*	*6.51*	*5.57*	*13.99*
11LM005 (2011)	**41**	**11**	7.05	7.27	11	2	1.29
Southern Steams Average	*42.4*	*12.1*	*7.1*	*7.24*	*9.41*	*4.17*	*8.84*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

TSS

TSS has been sampled 14 times in Heath Creek; 10 times at station S006-521 in 2011, and at each of the biological stations when surveyed for fish in 2004, 2011, and 2013 (four total samples). TSS ranged from 3 to 120 mg/L. The highest TSS was on July 5, 2011, which was one of two samples greater than 65 mg/L (14.3% exceedance of the 14 samples, draft south region TSS standard). There were 218 measurements of transparency within Heath Creek. Converted to secchi measurements, the data ranged from 6.4 to 108 cm. Only three measurements from 218 (1.4%) were less than the 10cm surrogate standard of the south TSS region.

At station 04LM076, the metrics that correspond with elevated TSS were not consistent with TSS stress (Table 147). At station 13LM001, there was observed stress consistent with TSS stress. At station 13LM001, there was a lack of collector-filterers, but it was the only station to exhibit the missing individuals. Stations 04LM076 and 13LM001, in 2013, and station 11LM005, in 2011, had elevated TSS index scores, indicating more tolerance to elevated TSS. All of the stations lacked adequate taxa that are intolerant to TSS stress. Stations 13LM001 and 11LM005 also exhibited an excess of TSS tolerant individuals.

The fish community had a mixed response to elevated TSS stress (Table 148). All visits had no non-tolerant Centrarchidae. Relative abundance was equivalently low for herbivores, riffle dwellers, and simple lithophilic spawners only at station 04LM076 in 2004. The long-lived fish were reduced in the 2011 and 2013 visits. The TSS index score was elevated in 2004, but not in 2011 or 2013.

The biological data show mixed response to elevated TSS stress. The TSS data is limited and additional data would be beneficial. The secchi tube dataset is greater and not suggestive of stress. It is inconclusive if TSS is contributing stress to the biological communities in Heath Creek. Additional data should be collected throughout the AUID to understand magnitude and duration of any exceedances.

Table 147. Macroinvertebrate metrics that respond to elevated TSS stress in Heath Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
04LM076 (2004)	26.4	**0**	15.3	**0**	10	8.2
04LM076 (2013)	62.7	**0**	**16.3**	**0**	8	17.5
13LM001 (2013)	**15**	**0**	**18.4**	**0**	**16**	**36.2**
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*10.2*	*27.2*
11LM005 (2011)	49.5	**0**	**17.6**	**2**	9	**54.4**
Southern Steams Average	*25.3*	*0.6*	*17.1*	*2.6*	*11.3*	*34.0*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 148. Fish metrics that respond to elevated TSS stress in Heath Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LIvdPct	Percfm-TolPct	RiffePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
04LM076 (2004)	**2.5**	**0**	**2.5**	**0**	30.0	**0**	**2.5**	**0**	**2.5**	**25.1**
04LM076 (2013)	60.7	**0**	57.4	**0**	**3.3**	**0**	57.4	**0**	57.4	17.2
13LM001 (2013)	72.5	**0**	59.4	**0**	**1.5**	**0**	59.4	**1.5**	58	14.4
11LM005 (2011)	**33.2**	**0**	41.7	**1.4**	**1.0**	**5.0**	44.2	17.8	17.5	15.4
Southern Streams Average	*34.1*	*4.6*	*24.3*	*3.3*	*12.9*	*19.4*	*28.3*	*14.8*	*17.5*	*18.0*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

Habitat, as measured by the MSHA, was considered fair throughout the four visits in Heath Creek. In 2004, the MSHA subcategories of land use and substrate were particularly low (Figure 184). Land use was low through most of the visits, receiving no more than half of the available points. In stream habitat was low with low cover in 2013 at station 04LM076. Although close in proximity to each other, station 13LM001 had better cover (moderate) than the nearby upstream station 04LM076 (sparse cover). Station 04LM076 also lacked deep pools in 2013, but did not in 2004.

At station 04LM076, shade was substantial to heavy. In 2004, the bank erosion was noted as none with a wide riparian width, and in 2013, there was a narrow width with moderate erosion (Figure 186 and Figure 187). Substrate was comprised of gravel and sand, with only 10% riffle, and less than four types available. At station 13LM001, there was no riffle features present at the time of fish sampling, with a lack of diverse substrate types. At station 11LM005, cobble riffle habitat and a fairly stable channel was present in 2011.

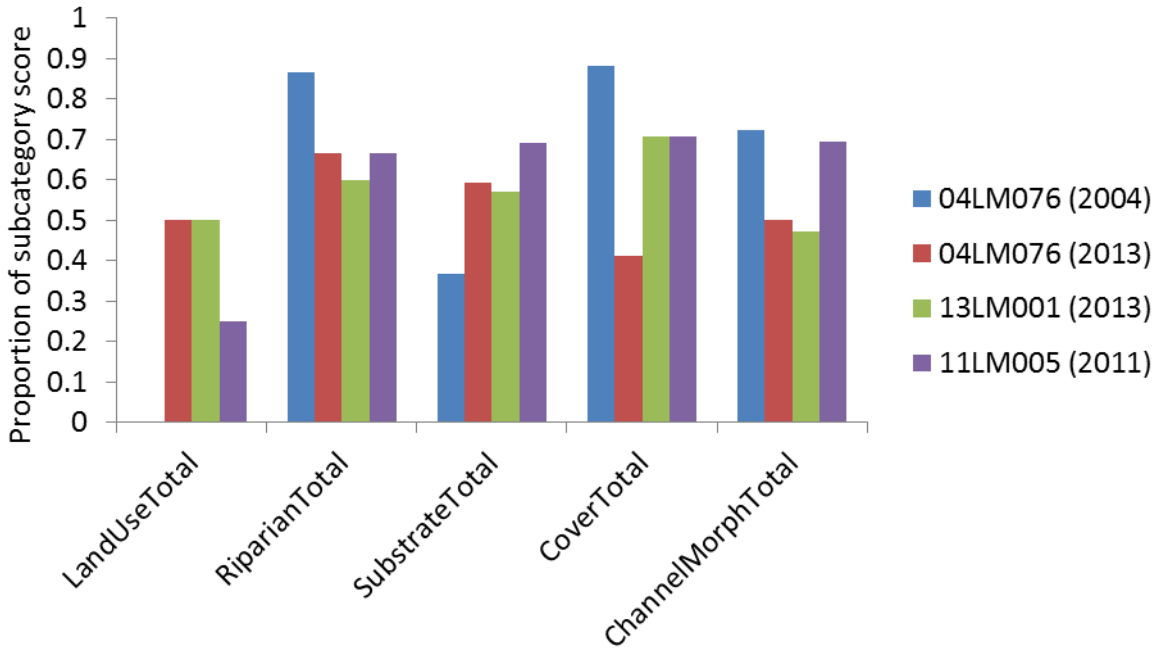


Figure 184. MSHA subcategory scores for Heath Creek

At stations 04LM076 and 13LM001, the macroinvertebrate samples were collected on instream macrophytes; undercut banks and overhanging vegetation; and snag, woody debris, and root wads. Station 04LM076 had considerably more burrowers than expected in 2004 (Figure 185). Increased burrowers can indicate increased fine sediments. The metric for taxa richness of clingers (ClingerCh) scored near the average metric score needed to be at or above the threshold for the three visits on station 04LM076 and 13LM001. The percentage of clingers had a great range for the three visits. Station 04LM076 had low percent of clingers in 2004, but the 2013 visit was just above the mean and median of the natural channel Southern Forest Streams GP stations meeting the biocriteria. All three visits resulted in a high percentage of legless macroinvertebrates.

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat is diminished. The fish community had only one taxon that prefers riffles at station 04LM076 in both 2004 and 2013, white sucker, which is fairly tolerant and considered a generalist feeder. Station 13LM001 also only had two species that are riffle dwellers, whereas station 11LM005 had six riffle dwelling taxa. Similarly, there were two taxa that are simple lithophilic spawners at each of the visits at station 04LM076 and 13LM001. Downstream there were a greater number of simple lithophilic spawners (five). The average percentage of simple lithophilic spawners at Southern Streams fish class stations in the Cannon River Watershed was 35.2%. Although there were few taxa, the percentages of individuals were above the average except the 2004 visit at station 04LM076. All four visits in Heath Creek had less non-tolerant benthic insectivores than expected. Darter, sculpin, and round bodied suckers were absent except station 11LM005.

Lack of adequate habitat is a stressor to the macroinvertebrate community and fish communities in Heath Creek. The stress is most severe at station 04LM076 and decreases downstream. Restoration activities to improve substrate and stability would benefit the biotic communities.

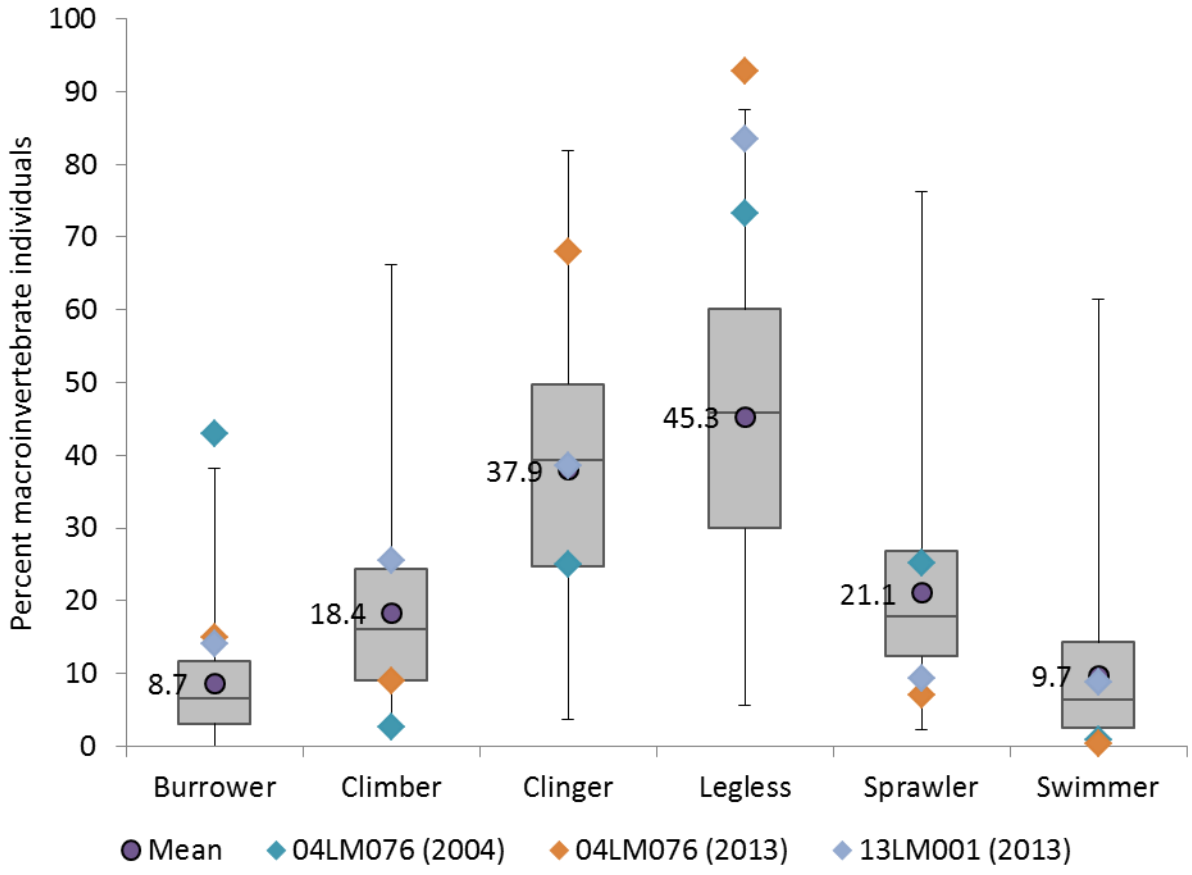


Figure 185. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP with MIBI greater than 46.8 (threshold), mean of those stations, and stations 04LM076 and 13LM001 in Heath Creek

Figure 186. Photograph of station 04LM076, May 18, 2004

Figure 187. Photograph of station 04LM076, August 5, 2013

Connectivity

There is no known immediate connectivity or physical barrier issues in Heath Creek. There is a dam on Union Lake which may truncate the ability of fish to migrate further up in the system.

Conclusion

Low DO, elevated DO flux via high phosphorus, and lack of habitat are stressors in Heath Creek. Elevated TSS is inconclusive as a stressor. Elevated temperature and nitrate are not stressors currently in Heath Creek.

Both synoptic measurements of DO and diurnal measurements indicated that Heath Creek violates the low DO standard of 5 mg/L. Additionally, high DO flux was observed when diurnal DO was measured. It is likely that the DO may be recovering once it reaches station 11LM005. Low DO is a stressor to both biotic communities at stations 04LM076 and 13LM001.

DO flux via elevated TP is a stressor in Heath Creek. All of the measures of TP were elevated and most without elevated TSS. Both communities responded as expected with eutrophication stress in the upper two stations of Heath Creek. Further data collection of the response variables would be beneficial in understanding the system dynamics.

Lack of adequate habitat is a stressor to the macroinvertebrate community and fish communities in Heath Creek. The stress is most severe at station 04LM076 and decreases downstream. Restoration activities to improve substrate and stability would benefit the biotic communities.

The biological data show mixed response to elevated TSS stress. The TSS data is limited and would require additional sample collection to verify as a stressor. The secchi tube data is greater in amount and not suggestive of stress. It is inconclusive if TSS is contributing stress to the biological communities in Heath Creek. Additional data should be collected to understand magnitude and duration of any exceedances.

4.6.4. Spring Creek (591)

Spring Creek (AUID 07040002-591) is a small warmwater tributary to Lake Byllesby, south of Randolph, Minnesota. Station 04LM046 was sampled in 2004 for fish and macroinvertebrates and station 11LM094 was sampled for fish and macroinvertebrates in 2011. Station 11LM094 is approximately 1.3 miles downstream of station 04LM046. Spring Creek is impaired for aquatic life due to lack of macroinvertebrate assemblages. There are no other current impairments on this reach. The fish community at station 04LM046 was dominated by creek chub, blacknose dace, and white suckers, and the IBI score (63.1) was above the impairment threshold for the Southern Headwaters fish class. Creek chub, johnny darter, and white sucker where the most dominant species at station 11LM094. The fish community at station 11LM094 scored above the impairment threshold as well with a FIBI of 70.1.

The macroinvertebrate community is impaired, station 11LM094 received a Macroinvertebrate IBI score of 36.8 for Southern Forest Streams GP class, and station 04LM046 had a MIBI score of 39.3. The macroinvertebrate community had low EPT richness, high percentage of tolerant taxa, and no sensitive taxa. As shown in Figure 188, many metric scores were below the average metric score needed to be at the threshold. Metrics that were particularly low were in some cases different for the two stations, likely

due to spatial and temporal variability. Station 04LM046 had the lowest metrics scores for relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct) and relative abundance of collector-filterer individuals in subsample (Collector-filtererPct). Station 11LM094 had metric scores of zero for taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch) and taxa richness of predators (PredatorCh).

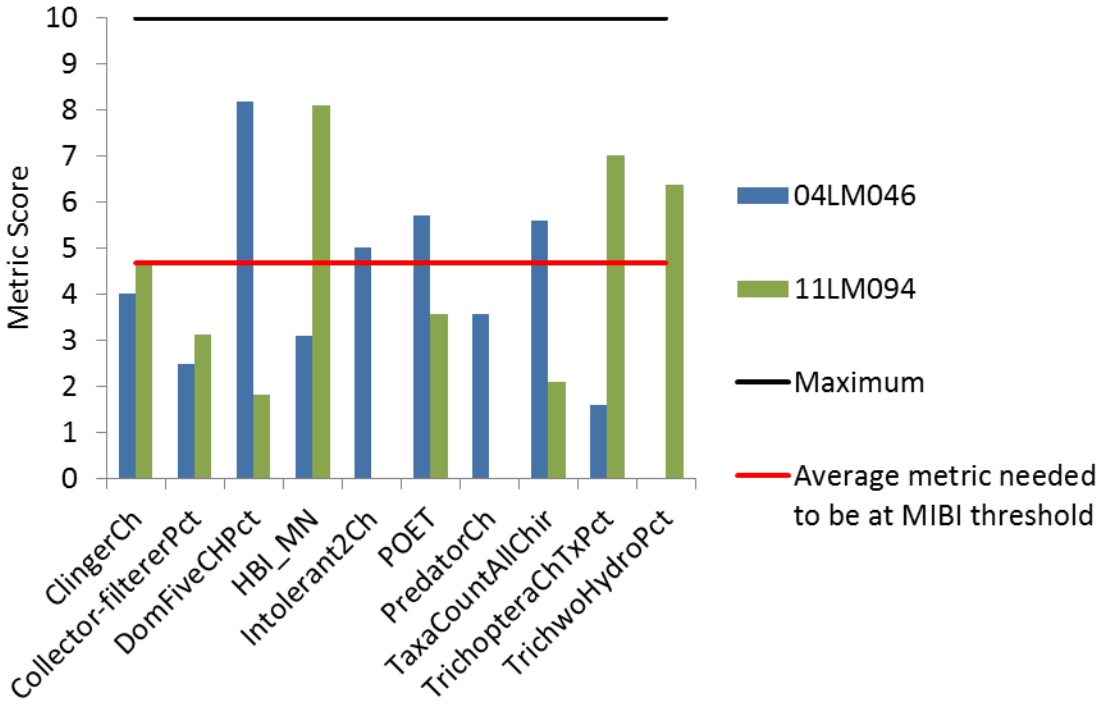


Figure 188. Macroinvertebrate metrics of the Southern Forest Streams GP IBI for Spring Creek, stations 04LM046 and 11LM094

Temperature

Within Spring Creek there have only been nine synoptic measures of temperature (2.17 – 17.9°C). Six of the measurements were at S007-483, in 2013 and 2014. Station 11LM094 is co-located with station S007-483 and had two measurements during each biological survey in 2011. Additionally, station 04LM046 had one measurement at the time of fish sampling in 2004. From July 24 – 31, 2014 an YSI sonde collected temperature data in 15 minute intervals. The data ranged from 14.8 to 24.8°C, well under the 30°C stress level for warmwater species. Spring Creek is a warmwater reach and is well within expected temperature ranges. Elevated temperature is not a stressor currently in Spring Creek. The daily fluctuation of temperature is high; at times reach to 10°C difference. It is unknown if that fluctuation is causing stress to the biotic communities.

Dissolved oxygen

In Spring Creek, only eight synoptic DO measurements were made over the years of 2004, 2011, and 2013 – 2014, at the biological stations 04LM046 and 11LM094 and station S007-483. There were no measurements observed prior to 9AM, and there were no measurements below the standard of 5 mg/L. The synoptic DO data ranged from 7.45 – 11.51 mg/L. Additionally in 2014, an YSI sonde was deployed from July 24 to 31, at station 04LM046, with no exceedances of the standard each day (Figure 189). The

DO ranged from 7.29 to 11.3 mg/L. At station 04LM046, elevated DO flux was observed one day of deployment (minimum of 1.38, average of 2.53, and maximum of 3.62). As a response variable to the eutrophication standard, DO flux should not exceed 3.5 mg/L daily for the central region.

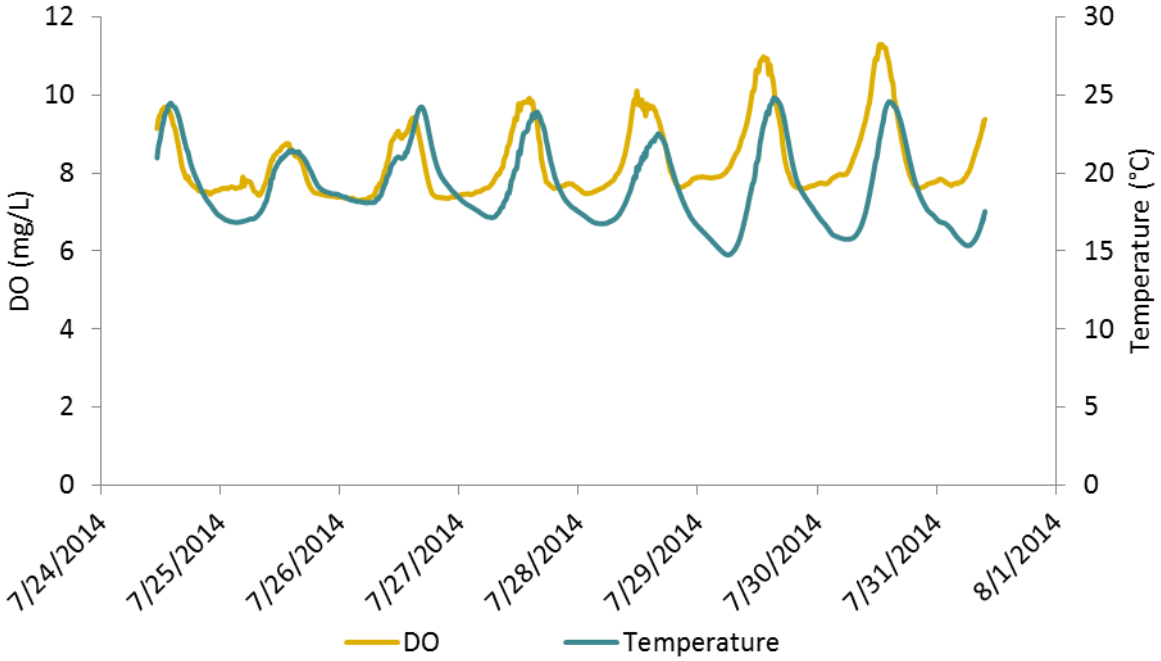


Figure 189. Diurnal dissolved oxygen and temperature measurements in Spring Creek station 04LM046

At station 04LM046, there is some evidence in the macroinvertebrate community suggestive of low DO stress, including lower taxa count, low EPT taxa, elevated HBI_MN, and low value of the low DO index score for the station (Table 149). However, both stations had seven low DO intolerant taxa and few to no low DO tolerant taxa. Station 11LM094 had low taxa count and low EPT, but no other metric values corresponded to low DO stress.

At this time, low DO is not a stressor in Spring Creek. Low DO has not been observed in Spring Creek and the macroinvertebrate associated metric values can be attributed to other stressors. Continued monitoring of the DO values plus temperature would be valuable for this stream.

Table 149. Macroinvertebrate metrics that respond to low DO stress in Spring Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
04LM046 (2004)	**38**	**7**	**7.93**	**6.9**	7	3	3.7
11LM094 (2011)	**26**	**5**	6.40	8.0	7	0	0
Southern Forest Streams Average	*41.3*	*10.2*	*7.1*	*7.04*	*6.51*	*5.57*	*13.99*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

Phosphorus

At station S007-483, there were five samples of TP from 2013 and 2014 (Figure 190). Additionally, there was a TP sample at the time of fish sampling at each of the biological stations, 04LM046 (2004) and 11LM094 (2011). The maximum TP was 0.190 mg/L (April 3, 2014). The average TP of the seven samples was 0.108 mg/L, less than the draft river nutrient criteria for the south region (0.15 mg/L). Only two samples were greater than the draft standard at station S007-483, both in the month of April in 2013 and 2014. Seven data points existed with both TSS and TP. The potential relationship was evaluated (Figure 191) and found that there was little elevated TSS; however the timing of the elevated TP is not suggestive of eutrophication. The 2013 data may be skewed low due to inaccurate lab methodologies. The 2013 samples may be higher than reported.

In addition to elevated TP, a response variable of DO flux, chlorophyll-a, or BOD would also need to be elevated to be related to a biological stress. BOD and chlorophyll-a were not collected in this reach of Spring Creek. At station 04LM046, DO was measured by an YSI sonde from July 24-31, 2014. DO was not lower than the 5 mg/L standard and only one day of elevated DO flux was recorded. More information on the DO dynamics in Spring Creek can be found in the DO section.

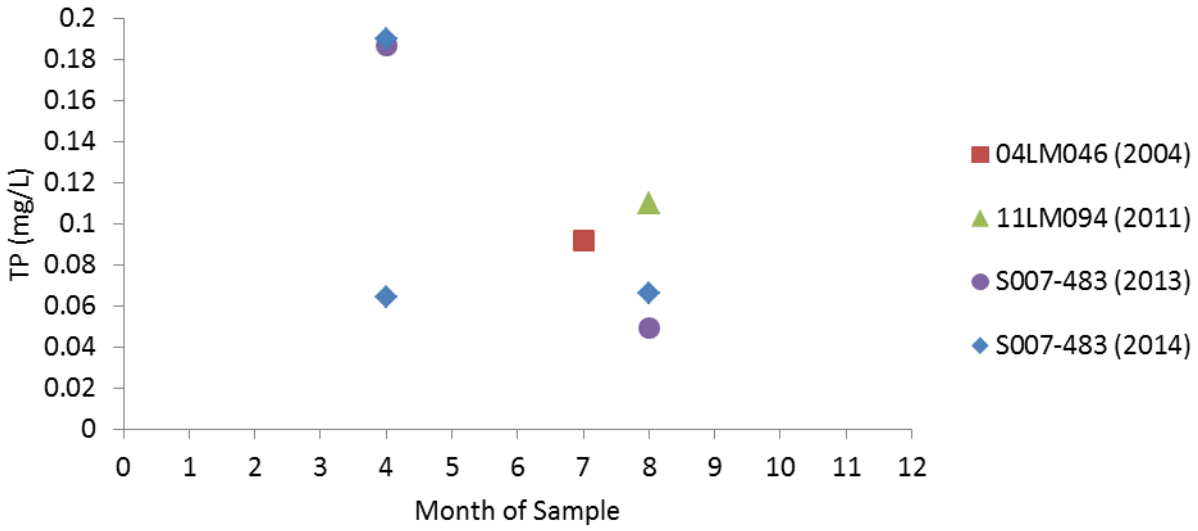


Figure 190. Total phosphorus concentrations in Spring Creek by month sampled

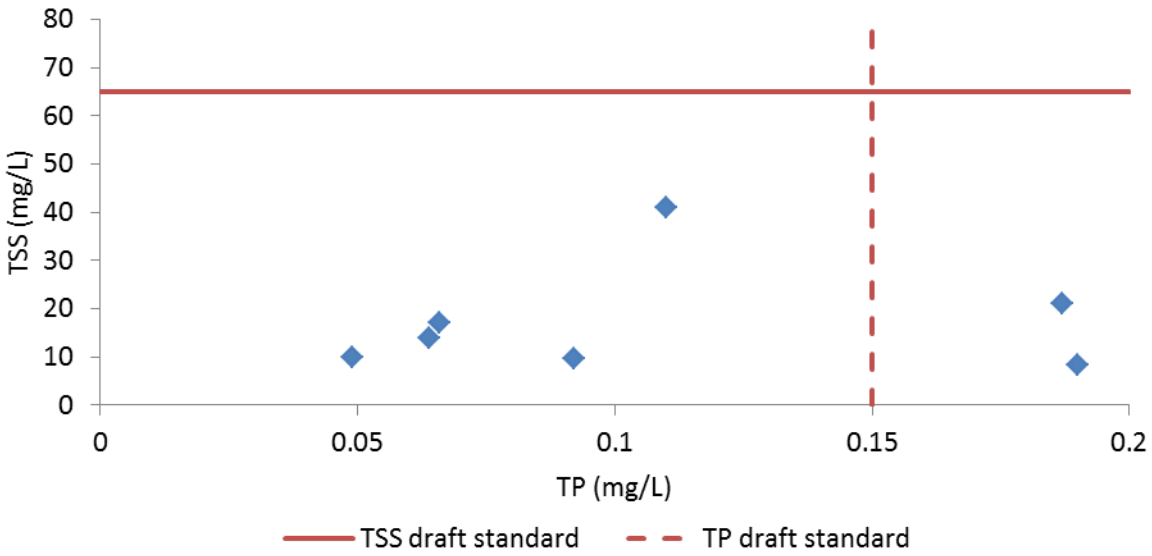


Figure 191. TSS and TP relationship in Spring Creek

The macroinvertebrate community has a mixed response to elevated TP and associated response stressors in Spring Creek (Table 150). At station 04LM046, four of six metrics responded in a way corresponding with elevated TP stress, and at station 11LM094, five of six metrics responded similarly. The stations do not have agreement between metric responses. The fish community, although not impaired, shows a similarly mixed response, but leaning towards exhibiting stress from elevated TP (Table 151). Due to the lack of TP and associated response variable data, as well as the mixed response from the biota, TP is inconclusive as a stressor in Spring Creek. The biological communities do indicate plausible stress, although not consistently and therefore additional monitoring should be conducted to further understand the nutrient dynamics in Spring Creek.

Table 150. Macroinvertebrate metrics that respond to TP and response stressors in Spring Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
04LM046 (2004)	**38**	**3**	19	**6**	1	**84.2**
11LM094 (2011)	**26**	6	**12**	**5**	**0**	**80.8**
Southern Forest Streams Average	*41.2*	*5.9*	*15.0*	*8.8*	*0.5*	*74.9*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 151. Fish metrics that respond to TP and response stressors in Spring Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	InsectPct	PiscivorePct	TaxaCount	IntolerantPct
04LM046 (2004)	**1.5**	**3.4**	37.1	**94.7**	**13.6**	**0**	**9**	**0**
11LM094 (2011)	**0.5**	16.2	**22.8**	**83.3**	27.4	**0**	**7**	**0**
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*15.7*	*1.8*	*11.3*	*1.4*
Expected response to stress	↓	↓	↓	↑	↓	↓	↓	↓

Nitrate

Nitrate has been sampled eight times in Spring Creek, six at S007-483 (2013 and 2014) and one each at stations 04LM046 (2004) and 11LM094 (2011; Figure 192). The highest level of nitrate was 13 mg/L (June 2, 2014). June 2, 2014, had a total of 0.7 inches of rain and the previous day had 1.4 inches of rain as recorded in Faribault. The duration of elevated nitrate is unknown. It would be beneficial to collect samples across various flow conditions to understand the duration of elevated nitrate.

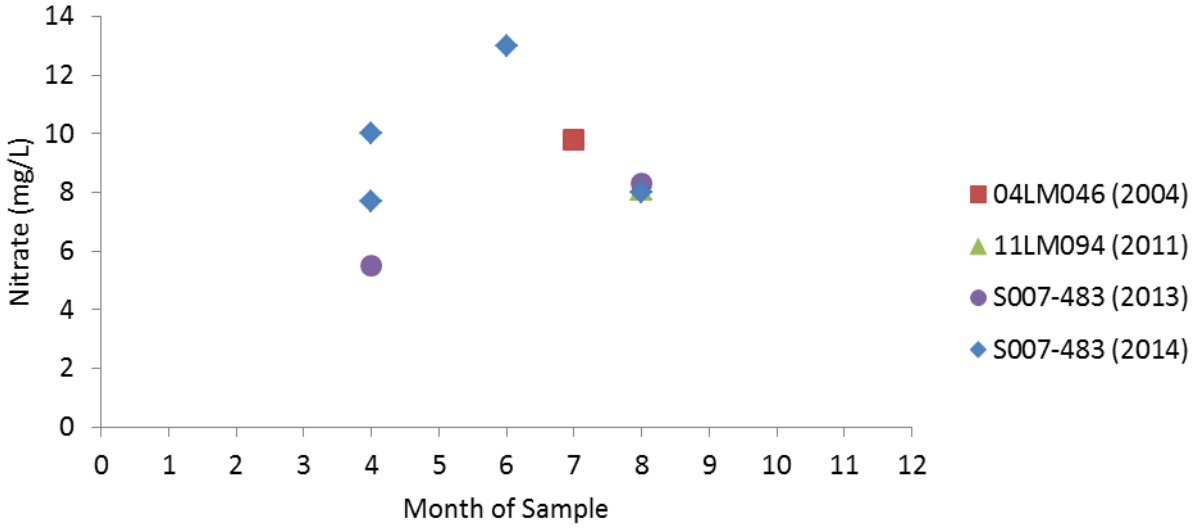


Figure 192. Nitrate concentrations by year and month in Spring Creek

The macroinvertebrate metrics that correspond with nitrate stress show a fairly consistent response as expected (Table 152). Station 04LM046 had only one Trichoptera taxon, and 0% non-hydropyschid caddisflies present. Station 11LM094 had three Trichoptera taxa with only 3.8% as non-hydropsychid caddisflies. There was no intolerant taxa present, resulting in a low metric score (Figure 166). There were over 88% nitrate tolerant individuals at both stations. Also they had elevated nitrate index scores. Station 04LM046 had elevated nitrate tolerant taxa. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI.

There is not a strong data set indicating sustained elevated nitrate conditions, yet there has also been nitrate as high as 13 mg/L. The macroinvertebrate community is indicative of nitrate stress. Over half of

the macroinvertebrate taxa and individuals are nitrate tolerant, but there is still moderate overall richness. At this time, nitrate is a stressor; however additional nitrate data should be collected to help understand the dynamics in this system.

Table 152. Macroinvertebrate metrics that respond to nitrate stress in Spring Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
04LM046 (2004)	**1**	**0**	1	**3.48**	**1**	**26**	**88.7**
11LM094 (2011)	**3**	**3.8**	**0**	**3.73**	**0**	14	**89.2**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.88*	*2.58*	*19.4*	*55.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

TSS

In Spring Creek there were 5 TSS samples at station S007-483 in 2013 and 2014, and one TSS sample at each of the biological stations (04LM046 in 2004 and 11LM094 in 2011). The seven samples ranged from 8.4 - 41 mg/L TSS, all below the draft South region TSS standard of 65 mg/L. There have only been six transparency measures on Spring Creek, with the lowest 20 cm, above the 10 cm draft standard. There are some indications that sediment may be impacting via habitat and that is discussed further in the Habitat section. The limited water chemistry data is not suggestive of stress, but additional data would help understand the sediment dynamics within Spring Creek.

The macroinvertebrate community in Spring Creek lacked collector-filterers and stoneflies at both stations (Table 153). The TSS index score was worse than average at station 04LM094, but better than average at station 11LM094. There were few TSS intolerant taxa at both stations, but there were also few TSS tolerant taxa and percent TSS tolerant individuals. The fish community in Spring Creek resulted in a similar response to the macroinvertebrates (Table 154). There was a complete lack of non-tolerant Centrachids, intolerant and long-lived individuals in the two visits. Similarly, herbivores and riffle dwellers were considerably reduced. Yet, there were a greater percentage of simple lithophilic spawners and the TSS index scores were better than the average for stations meeting the biocriteria.

The macroinvertebrate community indicates a mixed response, with a lack of evidence pointing to TSS as a stressor or not. The fish community is more indicative of a TSS stressed community, but still mixed. Additional chemical data should be collected to help understand the sediment dynamics in the creek. Elevated TSS is inconclusive as a stressor in Spring Creek.

Table 153. Macroinvertebrate metrics that respond to TSS stress in Spring Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
04LM046 (2004)	**9.7**	**0**	**16.7**	**1**	9	18.8
11LM094 (2011)	**12.1**	**0**	15.2	**0**	5	4.9
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*10.2*	*27.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 154. Fish metrics that respond to TSS stress in Spring Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RiffePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
04LM046 (2004)	**17.8**	**0**	**14**	**0**	**0**	**3.4**	**14**	**1.5**	15.9	14.5
11LM094 (2011)	**32**	**0**	**15.7**	**0**	**0**	16.2	**15.7**	**0.5**	16.2	15
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.3*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Habitat

In Spring Creek, habitat quality rated poor at the upstream station (04LM046) but rated good at the downstream station (11LM094). Similarly, four of the five subcategories resulted in lower scores in station 04LM046 (Figure 193). Images from sampling indicate the upstream station is in a pasture with slumping banks (Figure 195) while the downstream station has an intact riparian zone but may be incised with moderate bank instability (Figure 196). Row crop was the predominant land use surrounding station 04LM046. There was no riparian width with light shade and little erosion present in 2004. The habitat features within the reach were 95% run and 5% pool. There was no riffle present. There was no course substrate within the reach, leading to less than four substrate types. There was moderate cover (25-50%), with undercut banks, overhanging vegetation, emergent macrophytes, and deep pools. There was moderate depth variability and channel stability, with fair channel development. Under high water level during the survey, there was only the presence of slow velocity water.

Station 11LM094 had surrounding land use of forest, wetland, prairie, and/or shrub, along with row crop. There was an extensive riparian width with heavy shade. Moderate bank erosion was noted at station 11LM094. There was little riffle (only 5% of the reach), with gravel and sand as the dominant substrate types. Pool features accounted for 30% of the reach and also had gravel and sand. Run

features dominated the reach at 65% with sand as the dominate substrate. There was less than or equal to four substrate types available in 2011. The water color at the time of surveying on August 18, 2011 was brown. There was moderate cover with overhanging vegetation, deep pools, logs or woody debris, and boulders. The station had good depth variability, moderate/high channel stability, and fair channel development. The pool width was greater than riffle width and had fast, moderate, and slow velocity types present under the normal flow conditions.

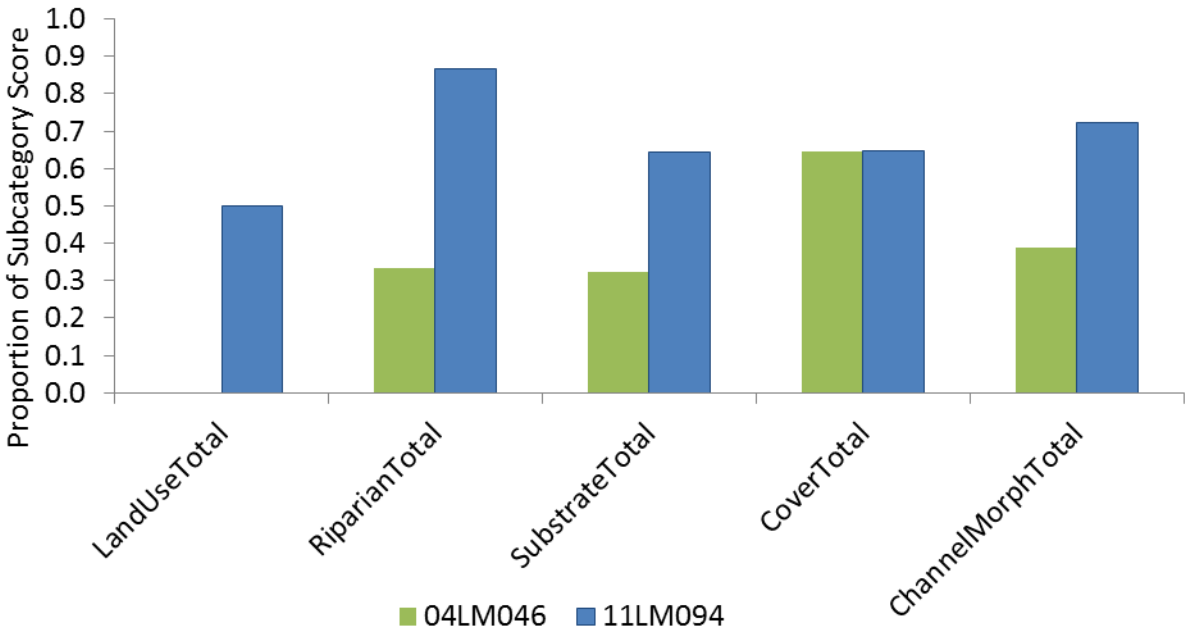


Figure 193. MSHA subcategory scores for Spring Creek

At station 04LM046, the macroinvertebrate samples were collected on undercut banks and overhanging vegetation. Station 11LM094 macroinvertebrate samples were collected on snags, woody debris, and root wads. There was a very elevated percentage of sprawler macroinvertebrates at station 11LM094 (Figure 194). The percentage of clinging macroinvertebrates is lower than expected. The taxa count of clingers was slightly low resulting in a low metric score in the MIBI. At station 04LM046, the most dominant taxa were *Caenis* (a very tolerant sprawling mayfly) and Branchiobdellida (leech-like clitellates that are mostly exoparasites of crayfish). At station 11LM094 Gammarus (a tolerant sprawling scud or sideswimmer) comprised of a large proportion of the sample (63%) and *Rheotanytarsus* (a tolerant clinging midge) was the second most common. Tolerant macroinvertebrates dominated the communities; 86.1% at station 04LM046 and 91.1% at station 11LM094.

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat is diminished. Although the fish are not impaired, they can provide additional information about potential stressors. The fish community had one taxon that have a preference for riffles at each station (white sucker). There were three species that are simple lithophilic spawners present at station 04LM046 and two species at station 11LM094. The average percentage of simple lithophilic spawners at Southern Headwater fish class stations in the Cannon River Watershed was 27.3%. Station 04LM046 had greater than average simple lithophilic spawners with 37.12%, and station 11LM094 had below average with 22.84%. In 2011, station 11LM094 had 23.86%

benthic insectivores and in 2004, station 04LM046 had 6.06%. There was one taxon of darter, sculpin, or round bodied fish at each of the stations in Spring Creek (johnny darter).

The macroinvertebrate community is stressed due to a lack of diverse habitats available including riffles. The fish community shows a mixed response to habitat. The lack of pools and riffles may be caused by excess bed sediment. The banks are eroding in the upstream station that erosion may be filling the channel causing the high amount of run.

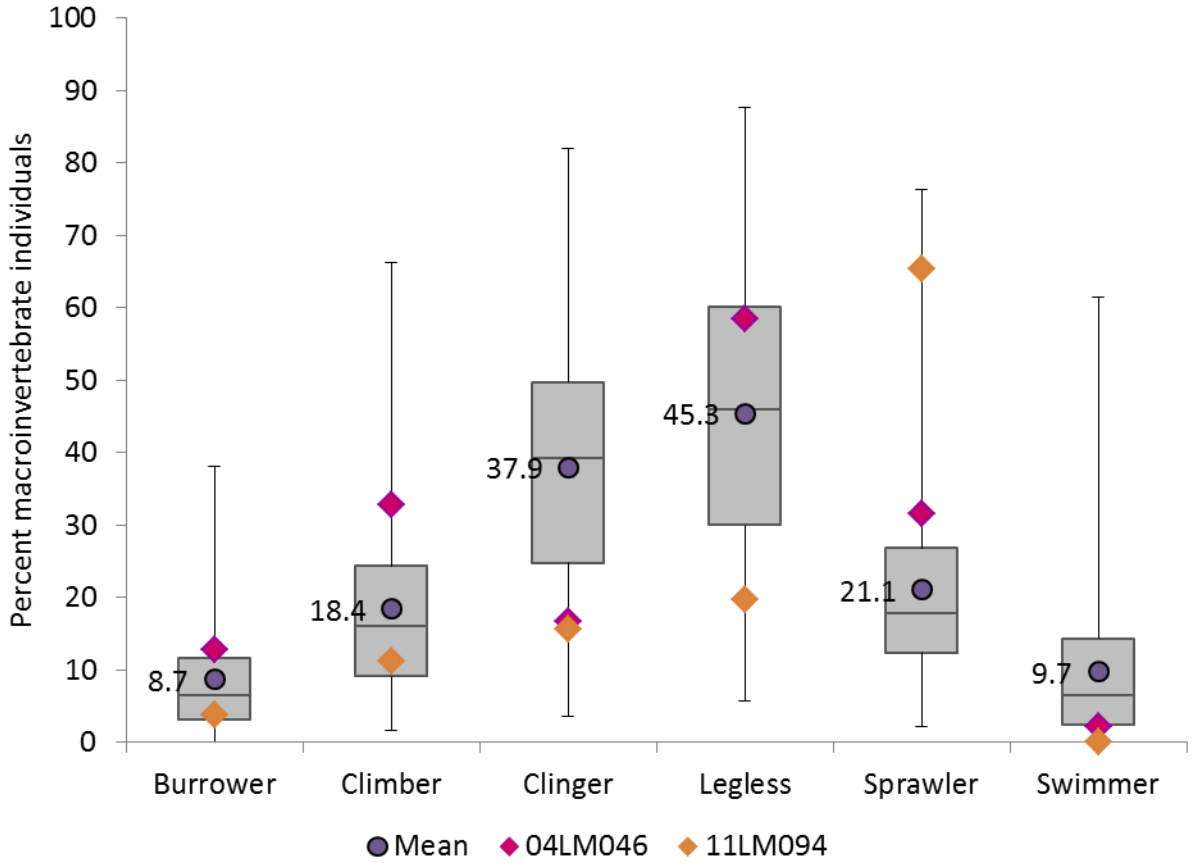


Figure 194. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP with MIBI greater than 46.8 (threshold), mean of those stations, and station 04LM046 and 11LM094 in Spring Creek

Figure 195. Photograph of station 04LM046, May 19, 2004

Figure 196. Photograph of station 11LM094, August 18, 2011

Fish Passage

There is a perched culvert at 23rd Avenue on Spring Creek (Figure 197). The fish community is sufficient upstream of the culvert, but it is unknown if the indirect effects are causing instability and habitat issues. To prevent any future stress it is recommended the perched culvert be replaced. Prior to replacement a geomorphic survey should be collected to ensure that it is placed at the correct slope and accounting for natural stream features.

Figure 197. Perched culvert at 23rd Avenue

Conclusion

Elevated nitrate and lack of habitat are stressors in Spring Creek. Elevated temperature fluctuation, phosphorus, and TSS are inconclusive as stressors. Low DO is not a stressor.

Nitrate has been measured as high as 12 mg/L. Over half of the macroinvertebrate taxa and individuals are nitrate tolerant, but there is still moderate overall richness. Nitrate is a stressor. Additional nitrate data should be collected to help understand the dynamics in this system.

The macroinvertebrate community is stressed due to a lack of diverse habitats available including riffles. The fish community shows a mixed response to habitat. There is a perched culvert at 23rd Avenue on Spring Creek (Figure 197). The fish community is sufficient upstream of the culvert, but it is unknown if

the indirect effects are causing instability and habitat issues. To prevent any future stress it is recommended the perched culvert be replaced.

Elevated temperature is not a stressor currently in Spring Creek. The daily fluctuation of temperature is high; at times reaching 10°C difference. It is unknown if that fluctuation is causing stress to the biotic communities.

At this time, low DO is not a stressor in Spring Creek. Due to the lack of TP and associated response variables as well as the mixed response from the biota, TP is inconclusive as a stressor in Spring Creek. Additional monitoring should be conducted to further understand the nutrient dynamics in Spring Creek. Elevated TSS is inconclusive as a stressor in Spring Creek. Additional chemical data should be collected to help understand the sediment dynamics in the creek.

Overview of Cannon River (AUIDs 582, 507, 509, 539)

This is the start of the Middle Cannon River section from Faribault to near Cannon Falls. All four reaches are impaired for macroinvertebrate assemblage and AUID -509 is impaired for fish as well. To aid in the longitudinal pattern of the data some figures are presented in the first AUID and referenced back to in preceding sections. The macroinvertebrate community in 2011, generally increased in MIBI scores from station 11LM068 to 11LM090, and dipped slightly at station 02LM017 (Figure 198). Upstream reaches of the Cannon play a large role in the water quality and response in these reaches of the Cannon River.

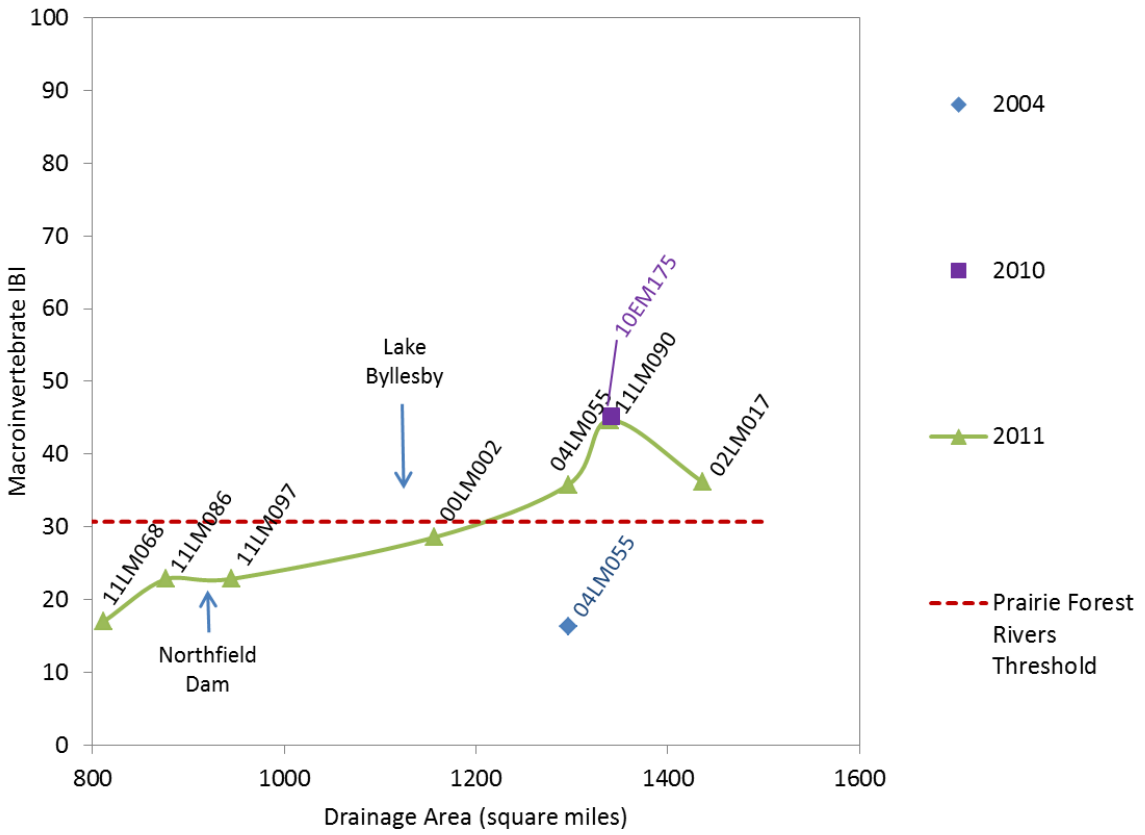


Figure 198. Macroinvertebrate IBI scores longitudinally in the Cannon River for stations in the Prairie Forest Rivers class

4.6.5. Cannon R. (582)

This reach of the Cannon River (AUID 07040002-582) begins just outside of Faribault to the confluence with Wolf Creek. This reach is impaired for aquatic life due to lack of macroinvertebrate assemblage. Additionally there are aquatic consumption (Mercury) and aquatic recreation (E.coli) impairments. This report will only address the aquatic life impairment. There are two biological stations within this reach of the Cannon River, station 11LM068 and downstream station 04LM078. Station 04LM078 was sampled for fish in 2004. There was a poor FIBI score in 2004, but the visit was thought to be impacted by high flows in 2004. In 2011, station 11LM068 was sampled for both fish and macroinvertebrates. The fish IBI score (47.3) was only one point above the impairment threshold for the southern rivers fish class, and due to weight of evidence this reach was not considered impaired for aquatic life due to fish assemblage. The fish community at station 11LM068 was dominated by spotfin shiners, sand shiners, and common shiners.

Only station 11LM068 within this reach has been sampled for macroinvertebrates. In 2011, station 11LM068 scored a 17 on the Prairie Forest Rivers IBI, well below the threshold. The sample was dominated by net-spinning caddisflies, *Cheumatopsyche* and *Hydropsychidae*. The IBI metric scores for station 11LM068, followed a similar pattern as those stations downstream of it on the Cannon River (Figure 199). Station 11LM068 had no Odonata and low percentage of non-Hydropsychid Trichoptera, resulting in metric scores of zero (Odonata and TrichwoHydroPct).

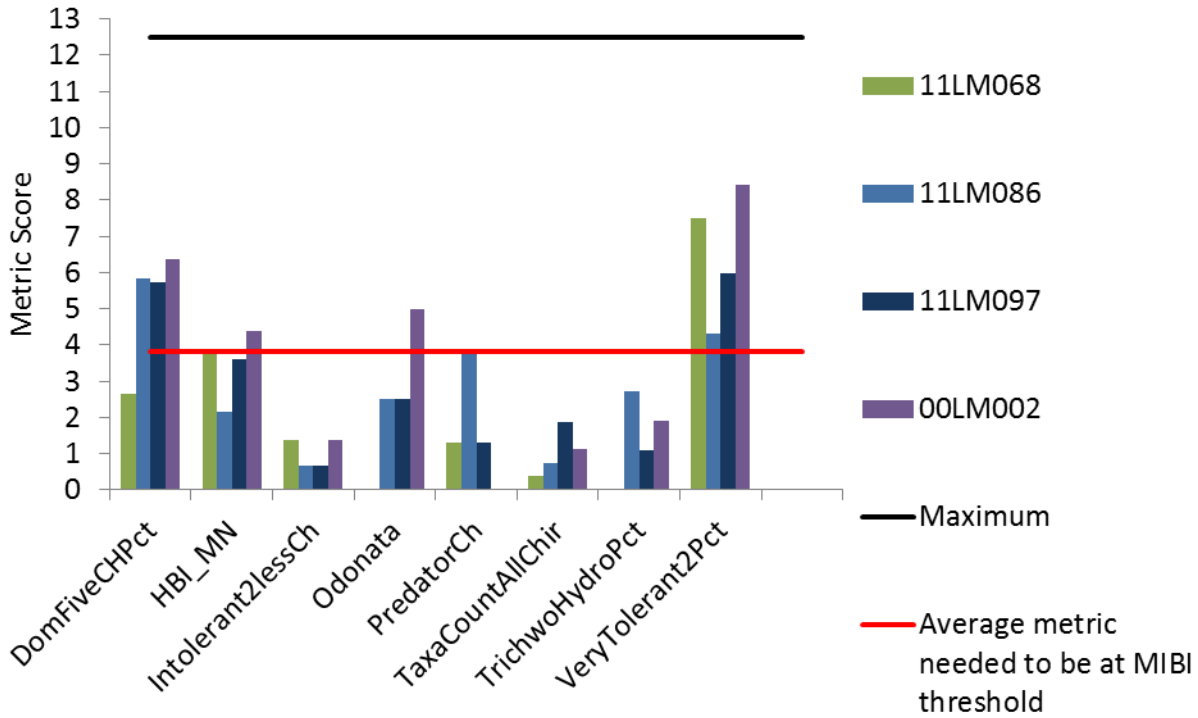


Figure 199. Macroinvertebrate metrics of the Prairie Forest Rivers GP IBI for the Cannon River, stations 11LM068, 11LM086, 11LM097, and 00LM002

Temperature

Within this reach of the Cannon River, there have been 134 synoptic measurements made of temperature ranging from 0 to 27.69°C, including data from the 1950's and 1960's. Since 2000, there have been 64 synoptic temperature measurements. An YSI sonde was deployed in 2013 from August 21 to September 4 at station S000-038. The minimum temperature during that time was 18.13°C with a maximum temperature of 28.76°C. The Cannon River is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in this reach of the Cannon River.

Nitrate

In this AUID of the Cannon River, nitrate has been measured 27 times at station S000-038 and once each at the two biological stations 04LM078 and 11LM068. The highest concentration was 12 mg/L at station S000-038 on May 21, 2013, after a rain event (Figure 200). The second highest concentration was 7.75 mg/L in 2010. It would be beneficial to collect more nitrate samples under spring and summer elevated flows (April – June) to further characterize the magnitude and duration of elevated nitrate levels.

The macroinvertebrate metrics that correspond with nitrate stress show a fairly consistent response as expected (Table 155). Station 11LM057 had only one Trichoptera taxon (Hydropsychid), and no non-hydropyschid caddisflies present. There was no intolerant taxa present, resulting in a low metric score (Figure 199). There were 60.9% nitrate tolerant individuals (18 taxa) and one nitrate intolerant taxon (prong-gilled mayfly, Leptophlebiidae) which comprised less than 1% of the individuals in the sample. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI.

There is limited data suggesting nitrate is elevated under wet conditions. The macroinvertebrate community at station 11LM068 has metric responses in an expected direction with nitrate stress. Further chemical data could be collected to refine the understanding in this reach. Nitrate is inconclusive as a stressor to the macroinvertebrate community.

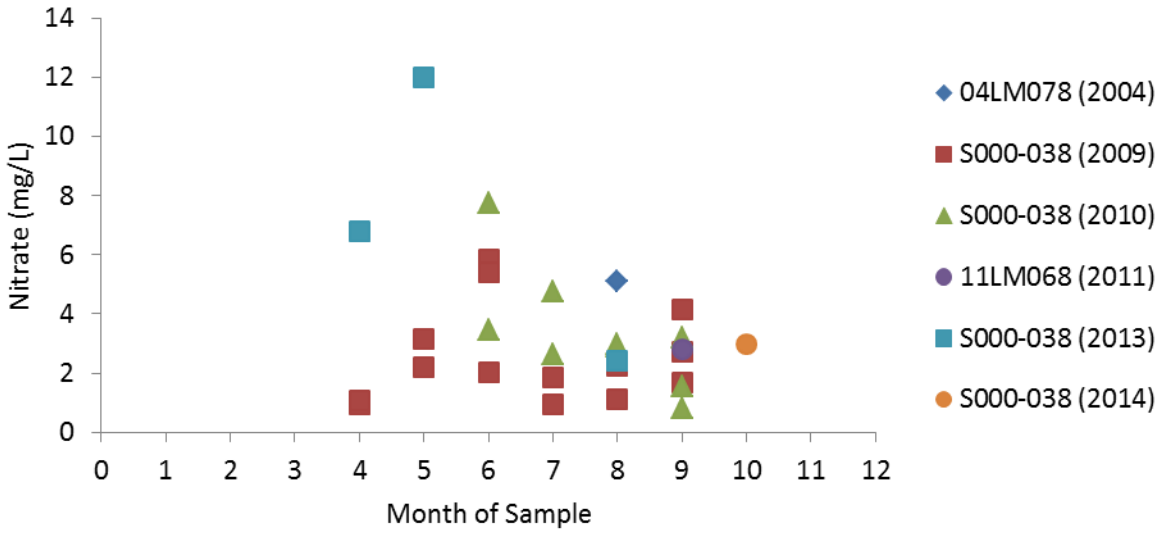


Figure 200. Nitrate concentrations in the Cannon River by month sampled, 2004, 2009 – 2011, 2013 and 2014

Table 155. Macroinvertebrate metrics that respond to nitrate stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM068 (2011)	**3**	**0**	**0**	**3.12**	**1**	10	**65.3**
Prairie Forest Rivers Average	*5.8*	*8.8*	*0.9*	*2.72*	*3.23*	*16.9*	*52.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

At station S000-038, there were 28 samples of TP from 2004, 2009-2010, and 2013-2014 (Figure 201). Additionally there was one TP sample at the time of fish sampling at the biological station 11LM068 (2011). The maximum TP was 0.772 mg/L (September 29, 2009). All but one of the 29 samples was greater than the draft river nutrient criteria for the south region (0.15 mg/L). Five data points existed with both TSS and TP. The relationship was evaluated (Figure 202) and found that there was little elevated TSS when TP was elevated. The 2013 data may be skewed low due to inaccurate lab methodologies. The 2013 samples may be higher than reported.

In addition to elevated TP, a response variable of DO flux, chlorophyll-a, or BOD would also need to be elevated to show the complete pathway. There was BOD data from the 1950's and 1960's but no recent data was available. Chlorophyll-a was collected 23 times over 2009 and 2010. The maximum chlorophyll-a sample was 33 µg/L, just below the 35 µg/L standard. DO was measured by an YSI sonde from August 21 to September 4, 2013, at station S000-038, with no exceedances of the standard each day. The DO ranged from 5.59 to 10.46 mg/L. At station S000-038, elevated DO flux was observed two times during

deployment (minimum of 1.33, average of 3.49, and maximum of 4.68). As a response variable to the eutrophication standard, DO flux should not exceed 4.5 mg/L daily for the south region. More information on the DO dynamics in the Cannon River can be found in the DO section.

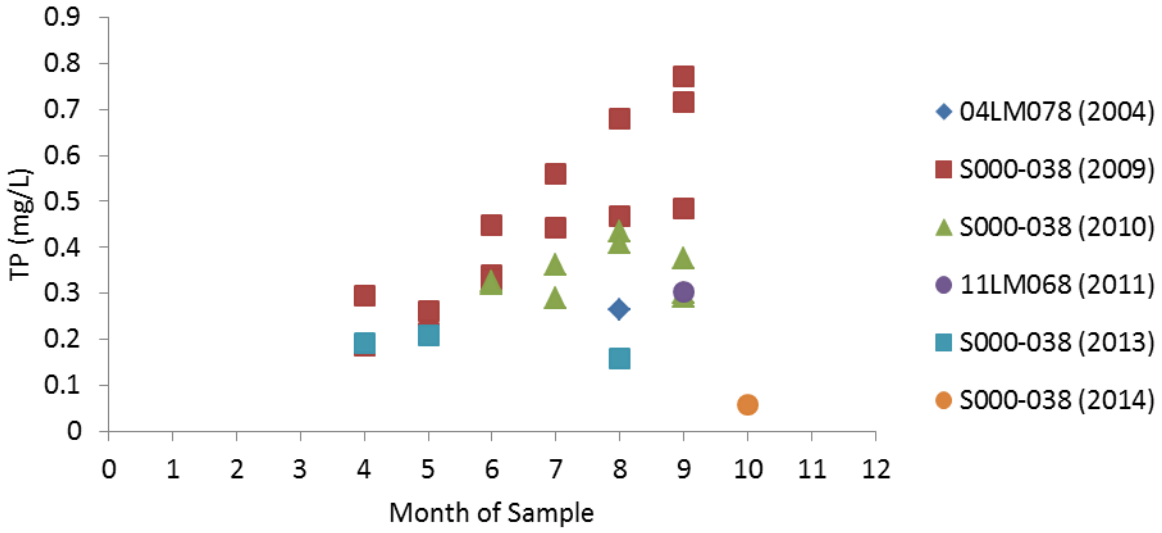


Figure 201. Total phosphorus concentrations in the Cannon River by month sampled

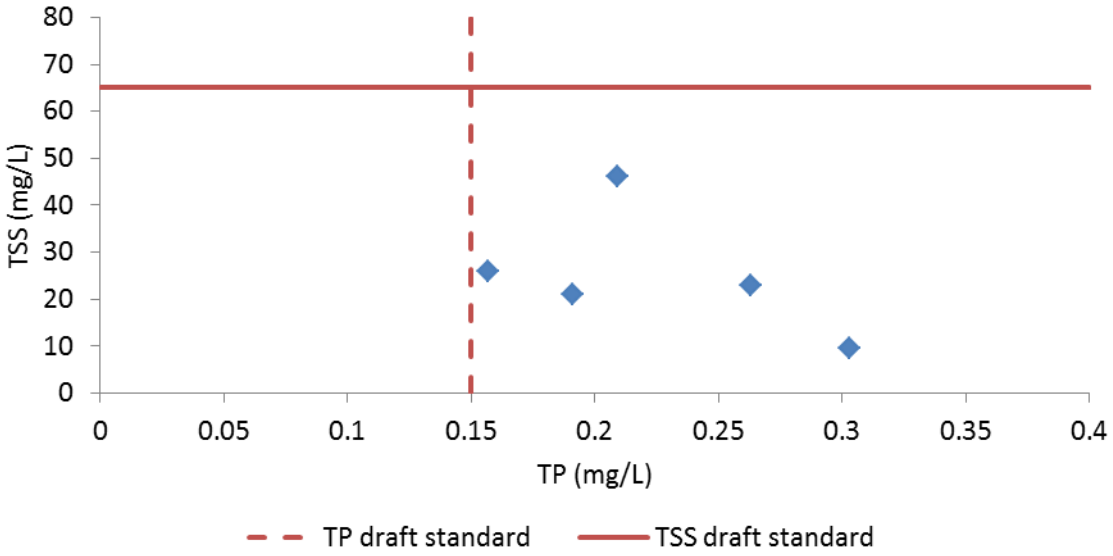


Figure 202. TSS and TP relationship in the Cannon River

The macroinvertebrate community has a mixed signal to potential stress from eutrophication (Table 156). The taxa count, EPT and intolerant taxa were all low, along with an elevated percentage for tolerant taxa. However the number of collector-filterer taxa was the same as the average of similar stations meeting the biocriteria. Similarly, the number of collector-gatherer taxa was greater than the average of similar stations meeting the biocriteria. Although the fish community is not impaired within this reach of the Cannon River, they also do not signal strongly toward stress from eutrophication (Table 157).

There is elevated TP within this reach, as well as an intermittent response variable of elevated DO flux. However, the biological community lacks consistency in confirming the response to elevated TP through river eutrophication. Additional data should be collected including TP, chlorophyll-a, BOD, and continued DO monitoring. At this time, although there is elevated TP, it is inconclusive as a stressor.

Table 156. Macroinvertebrate metrics that respond to TP and response stressors in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM068 (2011)	**25**	6	10	**7**	**0**	**88**
Prairie Forest Rivers Average	*39.4*	*6.0*	*8.6*	*12.2*	*0.9*	*73.6*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 157. Fish metrics that respond to TP and response stressors in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	InsectPct	PiscivorePct	TaxaCount	IntolerantPct
11LM068 (2011)	17.3	**2.2**	**27.2**	5.2	66.9	15.1	24	**3.5**
04LM078 (2004)	**4.2**	**0.9**	**27.6**	11.7	63.8	**0**	**18**	**0**
Southern Rivers Average	*16.3*	*6.1*	*29.1*	*25.4*	*63.8*	*13.8*	*23.0*	*8.2*
Expected response to stress	↓	↓	↓	↑	↓	↓	↓	↓

Dissolved Oxygen

In the 1950's and 1960's, DO was measured 36 times with a few measurements below the 5 mg/L standard. However, utilizing data collected more recently, 38 synoptic DO measurements have been collected at station S000-038 and the biological stations 11LM068 and 04LM078. There was only one measurement observed prior to 9AM, and there were no measurements below the standard of 5 mg/L. The synoptic DO data ranged from 5.38 – 12.05 mg/L. Additionally in 2013, an YSI sonde was deployed from August 21 to September 4, at station S000-038, with no exceedances of the standard each day (Figure 203). The DO ranged from 5.59 to 10.46 mg/L. At station S000-038, elevated DO flux was observed two times during deployment (minimum of 1.33, average of 3.49, and maximum of 4.68). As a response variable to the eutrophication standard, DO flux should not exceed 4.5 mg/L daily for the south region.

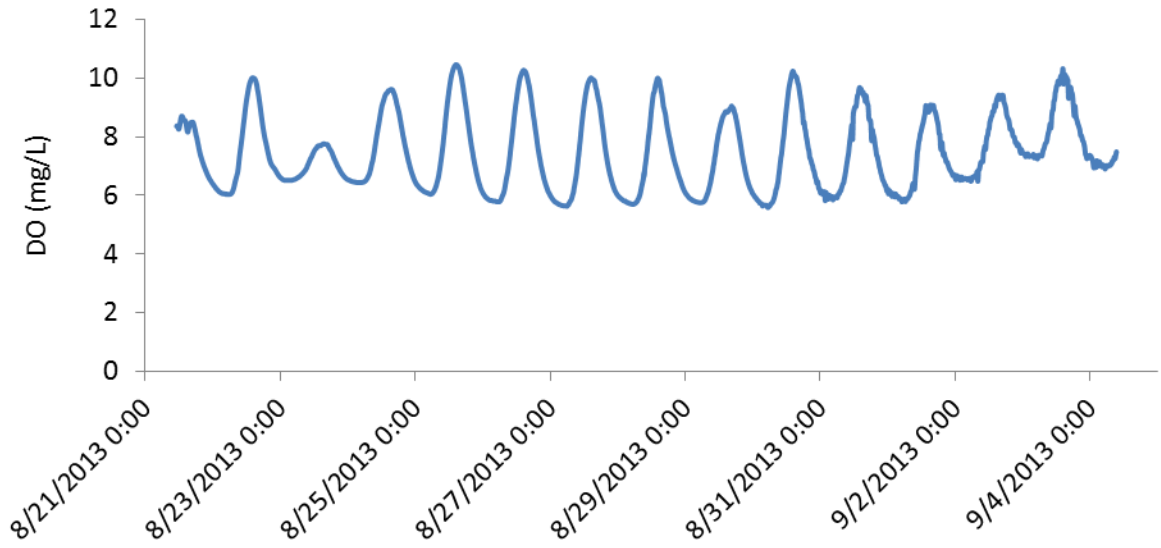


Figure 203. Diurnal DO measurements at station S000-038, August 21 – September 4, 2013

Within this reach of the Cannon River, station 11LM068 had low EPT taxa as well as low overall taxa richness (Table 158). The low DO index score was better than the average of similar stations meeting the biocriteria. Although there were a low number of low DO intolerant taxa, there were also a low number of low DO tolerant taxa and percent tolerant individuals. The mixed response by the macroinvertebrate community may be due to other stressors present.

Fish abundance can decrease with low DO levels. At station 11LM068 the number of fish individuals was 405. The average number of fish per meter in the Southern Rivers fish class 0.68. Station 11LM068 had a greater density at 0.81 fish per meter. The abundance of fish that mature later in life (MA>3) was 35.3%, lower than the average of stations meeting the biocriteria (72.7%). The fish community has moderate fish intolerance to low DO with DO TIV index. The scores for station 11LM068 fell above the median (7.08) for warmwater stations in the Cannon River Watershed, indicating communities generally less tolerant of low DO conditions.

In this reach of the Cannon River, there were no exceedances of the DO standard in synoptic measurements and diurnal measurements. High DO flux was observed twice during diurnal monitoring. The macroinvertebrate and fish communities had mixed response to potential low DO stress. It is likely that other stressors are contributing to the response seen in the communities and it is not attributed to low DO due to the lack of consistent evidence. At this time, low DO is not a stressor to the biological communities.

Table 158. Macroinvertebrate metrics that respond to low DO stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
11LM068 (2011)	**25**	**7**	**7.5**	7.48	**4**	2	3.1
Prairie Forest Rivers Average	*39.4*	*14.6*	*7.2*	*7.18*	*7.5*	*7.4*	*9.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

TSS

TSS has been sampled five times in this reach of the Cannon River; three times at station S000-038 in 2013, and at each of the biological stations when surveyed for fish in 2004 and 2011. TSS ranged from 9.6 to 46 mg/L. No samples were greater than 65 mg/L (draft south region TSS standard). There were 241 measurements of transparency within this reach of the Cannon River. Converted to secchi measurements, the data ranged from 5.2 to 74 cm. Only six measurements from 241 (2.5%) were less than the 10cm draft standard of the south TSS region.

The macroinvertebrate community in this reach of the Cannon River lacked stoneflies at station 11LM068 (Table 159). The TSS index score was better than average. The number of TSS tolerant taxa was low, but the percentage of TSS tolerant individuals was high. Overall the macroinvertebrate community signaled a mixed response to potential elevated TSS stress. The fish community at stations 11LM068 and 04LM078 resulted in a similar mixed response as the macroinvertebrates (Table 160). There was a low percentage of benthic feeders, non-tolerant Centrachids, intolerant and long-lived individuals in the two visits. Similarly, non-tolerant Perciformes and simple lithophilic spawners were reduced. Yet, there were a greater percentage of herbivores, riffle dwellers, sensitive individuals, and the TSS index scores were better than the average for stations meeting the biocriteria.

The macroinvertebrate community results in a mixed response, with a lack of evidence pointing to either side of TSS as a stressor or not. The fish community is more indicative of a TSS stressed community, but still mixed. The available chemical data is not suggestive of elevated TSS stress. Elevated TSS is inconclusive as a stressor in this reach of the Cannon River.

Table 159. Macroinvertebrate metrics that respond to TSS stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM068 (2011)	76.5	**0**	18.96	**0**	11	**62.23**
Prairie Forest Rivers Average	*23.7*	*0.6*	*19.23*	*2.67*	*13.7*	*47.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 160. Fish metrics that respond to TSS stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RifflePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM068 (2011)	**20**	**4.4**	22.2	**3.5**	**27.7**	**8.6**	18.3	17.3	**19**	28.5
04LM078 (2004)	**6.8**	**0.1**	**7.8**	**0**	**4.5**	**1.2**	**7.7**	**4.2**	**6.3**	26.0
Southern Rivers Average	*24.6*	*7.3*	*10.9*	*8.2*	*38.4*	*21.7*	*16.3*	*16.3*	*24.0*	*28.8*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

Station 11LM068 on the Cannon River received a fair MSHA score (64.2) in 2011. Station 04LM078 also received a fair MSHA score (51). Station 04LM078 was a little different in the MSHA subcategory scores than station 11LM068, with better land use but worse cover (Figure 204).

Station 11LM068 is the furthest upstream station in the series of Cannon River AUIDs in the Middle Cannon 10 digit HUC. It received at least half of the points for each subcategory of the MSHA. Station 11LM068 had a surrounding land use of forest, wetland, prairie or shrub with row crop. The riparian width was moderate to wide with moderate shading and little bank erosion. The substrate in the reach had more than four types available. The reach was comprised of 20% pool, 10% riffle, and 70% run features. There was light embeddedness noted. Cover within the reach was moderate with deep pools, logs or woody debris, boulders, and rootwads available. The reach had good depth variability, but the pool width was observed to be narrower than the riffle width. Channel stability was moderate, with good channel development, and fair sinuosity. Many velocity types were available to the biota in 2011.

Station 04LM078 had good surrounding land use with forest, wetland, prairie, or shrub, thus receiving all of the points for the subcategory. The riparian width was moderate, with light shade, and little bank erosion. The reach had 100% run features and was comprised of bedrock with sand substrates. There was no riffle within the reach. There was moderate embeddedness noted with greater than four

substrate types available. Cover was nearly absent with minimal deep pools, logs and woody debris, and boulders. The reach had good depth variability with excellent sinuosity. Channel stability was moderate and channel development was fair. There were fast, moderate, eddies, and torrential velocity types.

At station 11LM068, the macroinvertebrate samples were collected on rocks in riffles and runs as well as snags, woody debris, and root wads. There was a very elevated percentage of clinging macroinvertebrates at station 11LM068 (Figure 205). At station 11LM068, the most dominant taxa were tolerant net-spinning caddisflies (*Cheumatopsyche* and Hydropsychidae). The five most abundant taxa made up 73.7% of the community. Tolerant macroinvertebrates dominated the community (98.5%).

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat is diminished. Although the fish are not impaired, they can provide additional information about potential stressors. The fish community had three taxa at each station that have a preference for riffles, just below the average of similar stations meeting the biocriteria (3.6). Similarly, there were fewer numbers of simple lithophilic spawning taxa (six and seven) than the Southern Rivers stations meeting the biocriteria (8.1). The average percentage of simple lithophilic spawners in the Southern Rivers fish class stations meeting the biocriteria were 29.1%. Station 11LM068 had just below the average simple lithophilic spawners with 27.2%, and station 04LM078 was similar with 27.6%.The percentage of benthic insectivores was relatively low in comparison to the average of Southern River stations meeting the biocriteria, less than half. There were four taxa of darter, sculpin, or round bodied fish at each of the stations in this reach of the Cannon River. The average for similar stations meeting the biocriteria is 5.3 taxa.

The macroinvertebrate community exhibits mixed response to lack of habitat stress. The community is dominated by clinging individuals, but they are nearly all tolerant. The fish community response shows a community slightly depressed, but just slightly below similar stations meeting the biocriteria. The habitat could be improved including more cover and reducing sedimentation in the pools, as well as better riparian management. Lack of quality habitat is inconclusive as a stressor in this reach of the Cannon River.

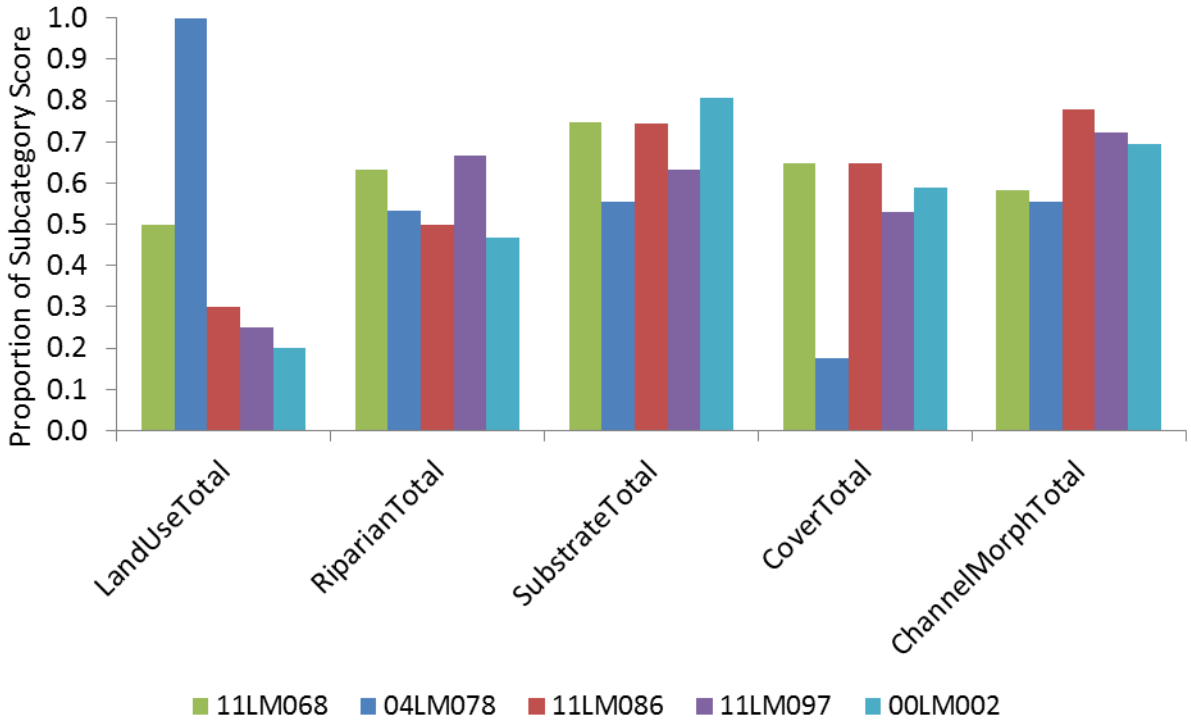


Figure 204. MSHA subcategory scores for the Cannon River

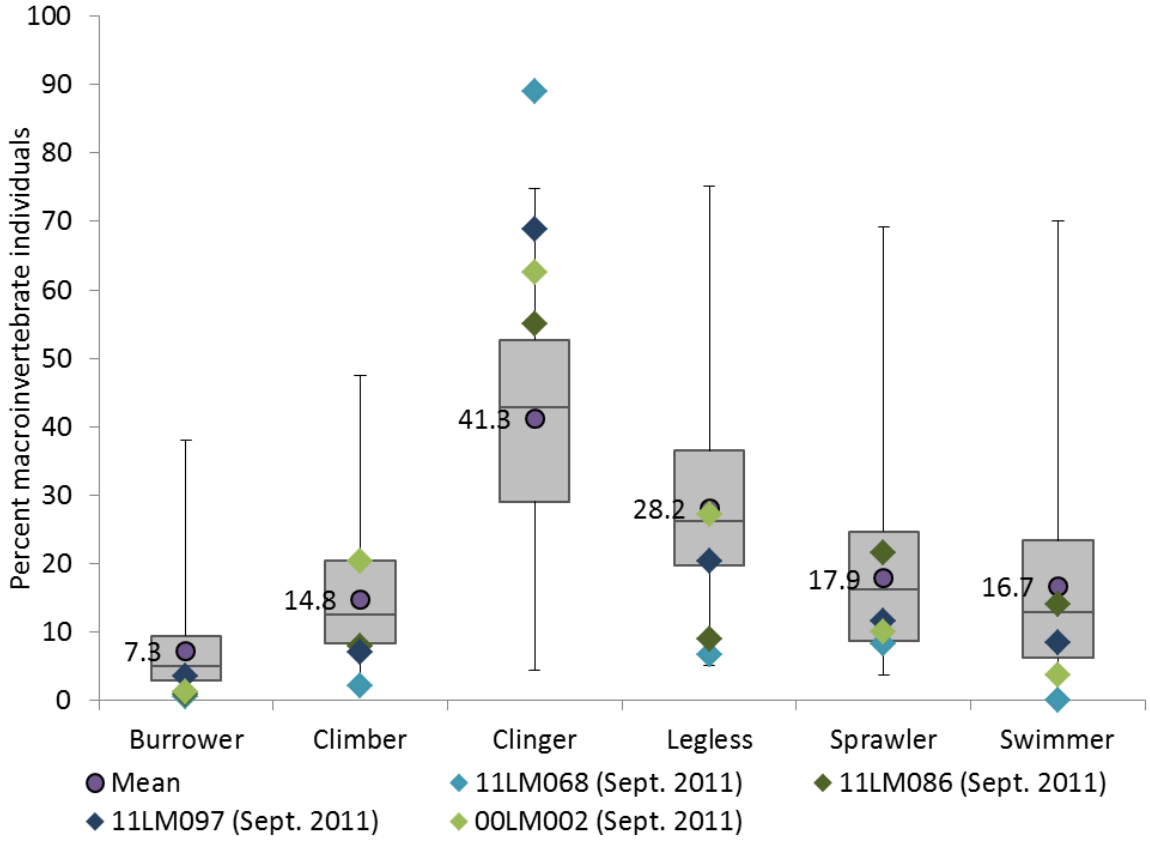


Figure 205. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Prairie Forest Rivers stations with MIBI greater than 30.7 (threshold), mean of those stations, and stations on the Cannon River within the Middle Cannon River 10 digit HUC

Fish Passage

There are dams located upstream and downstream of this reach on the Cannon River. The fish community is sufficient within this reach, but it is unknown if the indirect effects are causing instability and habitat issues. The lack of longitudinal connectivity maybe indirectly affecting the biological communities, but it is not directly.

Conclusion

Within this reach of the Cannon River, there were no clearly identified stressors. Nutrients, TSS and lack of habitat were inconclusive as stressors. Temperature and low DO are not stressors to the macroinvertebrate community.

There is limited data suggesting nitrate is elevated under wet conditions. Further chemical data could be collected to refine the understanding in this reach. Nitrate is inconclusive as a stressor to the macroinvertebrate community.

There is elevated TP within this reach, as well as an intermittent response variable of elevated DO flux. However, the biological community lacks consistency in confirming the response to elevated TP through river eutrophication. Additional data should be collected including TP, chlorophyll-a, BOD, and continued DO monitoring. At this time, although there is elevated TP, it is inconclusive as a stressor. Elevated TSS is also inconclusive as a stressor in this reach of the Cannon River.

The macroinvertebrate community exhibits mixed response to lack of habitat stress. The community is dominated by clinging individuals, but they are nearly all tolerant. The fish community response shows a community slightly depressed, but just slightly below similar stations meeting the biocriteria. The habitat could be improved including more cover and reducing sedimentation in the pools, as well as better riparian management.

4.6.6. Cannon R. (507)

This nearly three mile reach of the Cannon River (AUID 07040002-507) begins at the confluence with Wolf Creek to the confluence with Heath Creek in Northfield. This reach is impaired for aquatic life due to a lack of macroinvertebrate assemblage and elevated turbidity. Additionally, there are impairments for aquatic consumption (Mercury) and aquatic recreation (*E.coli*). This report will only address the aquatic life impairment. There is one biological station within this reach of the Cannon River, station 11LM086. In 2011 and 2013, station 11LM086 was sampled for both fish and macroinvertebrates. The fish IBI scores (79.7 and 59.3) were above the impairment threshold for the southern rivers fish class. The fish community at station 11LM086 was dominated by white sucker both years followed by northern hogsucker in 2011 and green sunfish in 2013. There was a good abundance of fish species both years, 25 and 21 respectively.

Station 11LM086 was sampled twice for macroinvertebrates and scored 22.8 in 2011 and _ in 2013 on the Prairie Forest Rivers IBI, both scores were below the threshold. In 2011, the sample was dominated by net-spinning caddisfly, *Cheumatopsyche* and mayfly, *Tricorythodes*. The IBI metric scores for station 11LM086 followed a similar pattern as the station upstream and stations downstream of it on the

Cannon River. Station 11LM086 had low metric scores for taxa richness of macroinvertebrates with tolerance values less than or equal to four, using MN TVs (Intolerant2lessCh) and total taxa richness of macroinvertebrates (TaxaCountAllChir; Figure 199).

Temperature

Within this reach of the Cannon River, there have been 363 synoptic measurements made of temperature ranging from 2.35 to 30.6°C, from 1999 to 2013 (Figure 206). An YSI sonde was deployed in 2013 from August 21 to September 4 at station S001-782. The minimum temperature during that time was 16.95°C with a maximum temperature of 29.37°C. The Cannon River is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. There was only one temperature greater than 30°C. Additional temperature monitoring should be continued within this reach to ensure that it maintains temperature dynamics for a healthy biological community. Elevated temperature is not a stressor currently in this reach of the Cannon River.

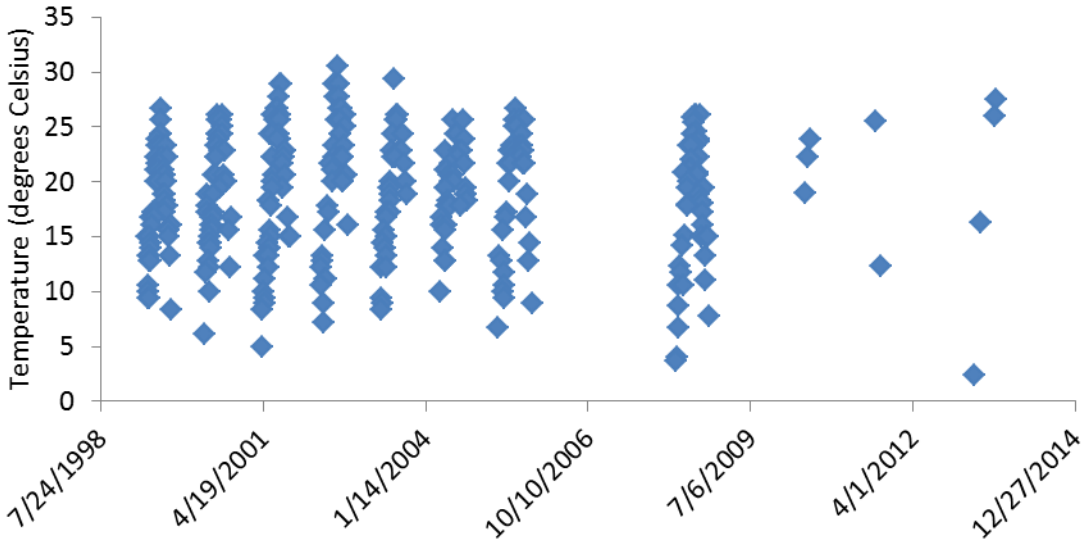


Figure 206. Synoptic temperature measurements in the Cannon River

Nitrate

In this AUID of the Cannon River, nitrate has been measured 23 times at station S001-396, three times at station S001-782 and once at each of the fish visits at station 11LM086. The highest concentration was 12 mg/L at station S001-782 on May 21, 2013, after a rain event (Figure 207). The second highest concentration was 7.53 mg/L in 2010. It would be beneficial to collect more nitrate samples under spring and summer elevated flows (April – June) to further characterize the magnitude and duration of elevated nitrate levels.

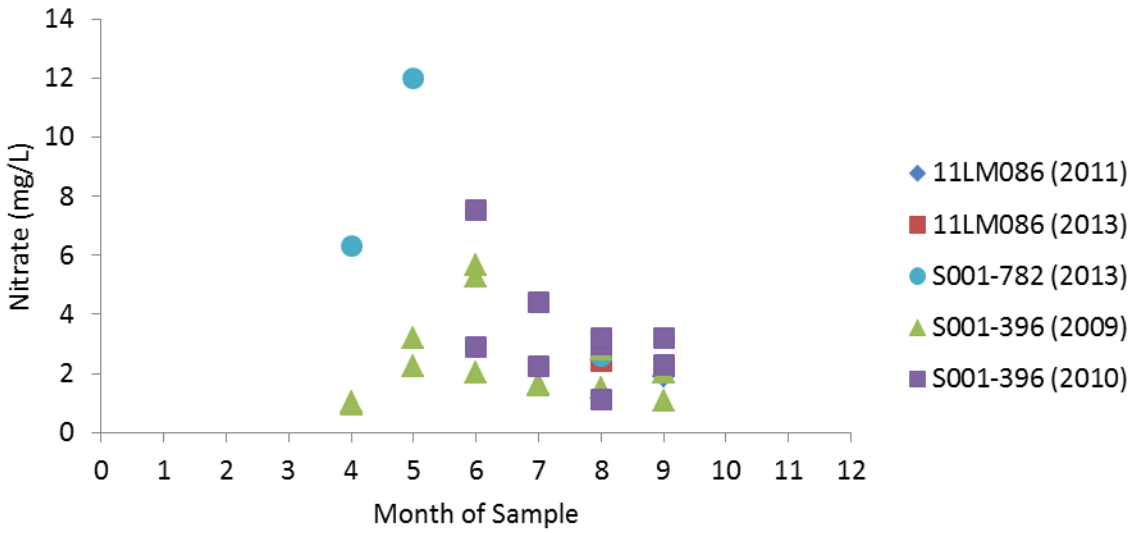


Figure 207. Nitrate concentrations in the Cannon River by month sampled, 2009 – 2011, and 2013

The macroinvertebrate metrics that correspond with nitrate stress show a fairly consistent response as expected (Table 161). Station 11LM086 was above and below the average of similar stations meeting the biocriteria; however, the percentage of individuals that are not Hydropsychids was quite low. There was no intolerant taxa present, resulting in a low metric score. There were a high percentage of nitrate tolerant individuals, but less nitrate tolerant taxa.

There is limited data suggesting nitrate is elevated under wet conditions. The macroinvertebrate community at station 11LM086 has metric responses in an expected direction with nitrate stress. Further chemical data could be collected to refine the understanding in this reach. Nitrate is inconclusive as a stressor to the macroinvertebrate community.

Table 161. Macroinvertebrate metrics that respond to nitrate stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM086 (2011)	**4**	**1**	**0**	**2.89**	**0**	13	**54.5**
11LM086 (2013)	6	**0.3**	**0**	**3.12**	**0**	11	**58.1**
Prairie Forest Rivers Average	*5.8*	*8.8*	*0.9*	*2.72*	*3.23*	*16.9*	*52.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

At station S001-396, there were 23 samples of TP from 2009-2010 (Figure 208). Additionally, there were two TP samples at station 11LM086 at the time of fish sampling (2011 and 2013). In 2013, three TP samples were taken at station S001-782. The maximum TP was 0.508 mg/L (September 29, 2009). All but two of the 28 samples were greater than the draft river nutrient criteria for the south region (0.15 mg/L). Only five data points existed with both TSS and TP. The TSS was relatively low during each of those five samples (Figure 209). The 2013 data may be skewed low due to inaccurate lab methodologies. The 2013 samples may be higher than reported.

In addition to elevated TP, a response variable of DO flux, chlorophyll-a, or BOD would also need to be elevated to show the complete pathway. There was no BOD data available. Chlorophyll-a was collected 21 times over 2009 and 2010. The maximum chlorophyll-a sample was 46 µg/L, above the 35 µg/L standard (August 31, 2010). It was the only chlorophyll-a to measure greater than the standard. DO was measured by an YSI sonde from August 21 to September 4, 2013, at station S001-782, with exceedances of the DO standard. The DO ranged from 4.59 to 12.43 mg/L. At station S001-782, elevated DO flux was observed eight times during deployment (minimum of 0.86, average of 4.71, and maximum of 6.27). As a response variable to the eutrophication standard, DO flux should not exceed 4.5 mg/L daily for the south region. More information on the DO dynamics in the Cannon River can be found in the DO section.

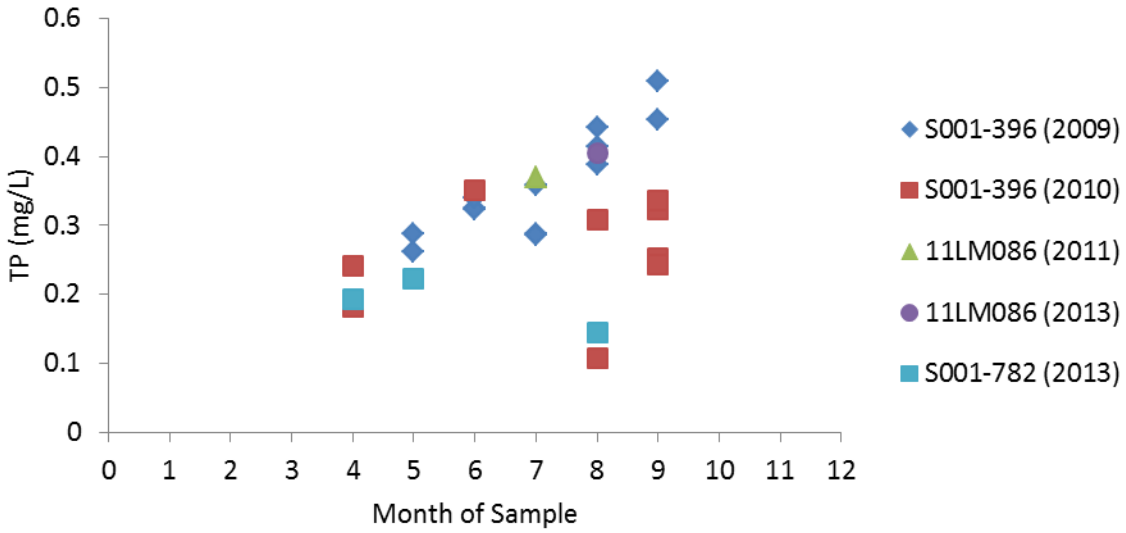


Figure 208. Total phosphorus concentrations in the Cannon River by month sampled

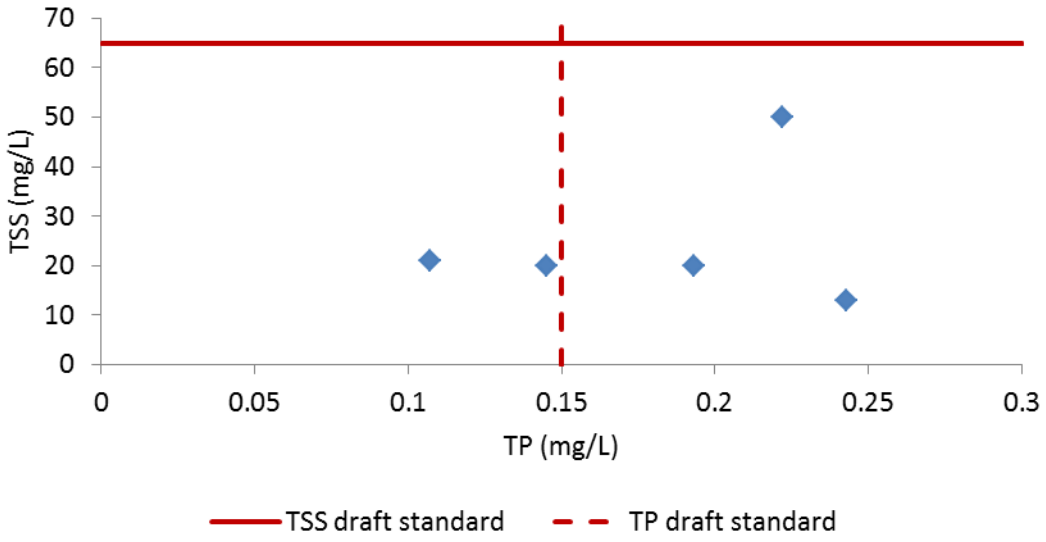


Figure 209. TSS and TP relationship in the Cannon River

The macroinvertebrate community has a mixed signal to potential stress from eutrophication (Table 162). The taxa count, EPT and intolerant taxa were all low, along with an elevated percentage for tolerant taxa. However the number of collector-filterer taxa was the same as the average of similar stations meeting the biocriteria. Similarly, the number of collector-gatherer taxa was greater than the average of similar stations meeting the biocriteria. The macroinvertebrate response at station 11LM086 is similar to the upstream AUID as well. Although the fish community is not impaired within this reach of the Cannon River, they also do not signal strongly toward stress from eutrophication (Table 163).

There is elevated TP within this reach, as well as the response variable of elevated DO flux and low DO. However, the biological community lacks consistency in confirming the response to elevated TP through river eutrophication. Additional data should be collected including TP, chlorophyll-a, BOD, and continued DO monitoring. At this time, although there is elevated TP, it is inconclusive as a stressor.

Table 162. Macroinvertebrate metrics that respond to TP and response stressors in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM086 (2011)	**33**	7	12	**11**	**0**	**81.8**
11LM086 (2013)	**27**	6	9	**8**	**0**	**74.1**
Prairie Forest Rivers Average	*39.4*	*6.0*	*8.6*	*12.2*	*0.9*	*73.6*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 163. Fish metrics that respond to TP and response stressors in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	InsectPct	PiscivorePct	TaxaCount	IntolerantPct
11LM086 (2011)	33.1	**5.8**	46.5	**35.3**	**55**	**7.6**	25	**6.1**
11LM086 (2013)	**11.5**	**5.4**	51.7	**54.1**	**39.5**	**5.1**	**21**	**3.0**
Southern Rivers Average	*16.3*	*6.1*	*29.1*	*25.4*	*63.8*	*13.8*	*23.0*	*8.2*
Expected response to stress	↓	↓	↓	↑	↓	↓	↓	↓

Dissolved Oxygen

DO has been synoptically measured 32 times within this reach. Measurements were collected at stations 11LM086, S001-782, and S001-396. There were only three measurements observed prior to 9AM, and there were no synoptic measurements below the standard of 5 mg/L. The synoptic DO data ranged from 7.09 – 13.05 mg/L. DO was measured by an YSI sonde from August 21 to September 4, 2013, at station S001-782, with violations of the DO standard (Figure 210). The DO ranged from 4.59 to 12.43 mg/L. At station S001-782, elevated DO flux was observed eight times during deployment (minimum of 0.86, average of 4.71, and maximum of 6.27). As a response variable to the eutrophication standard, DO flux should not exceed 4.5 mg/L daily for the south region.

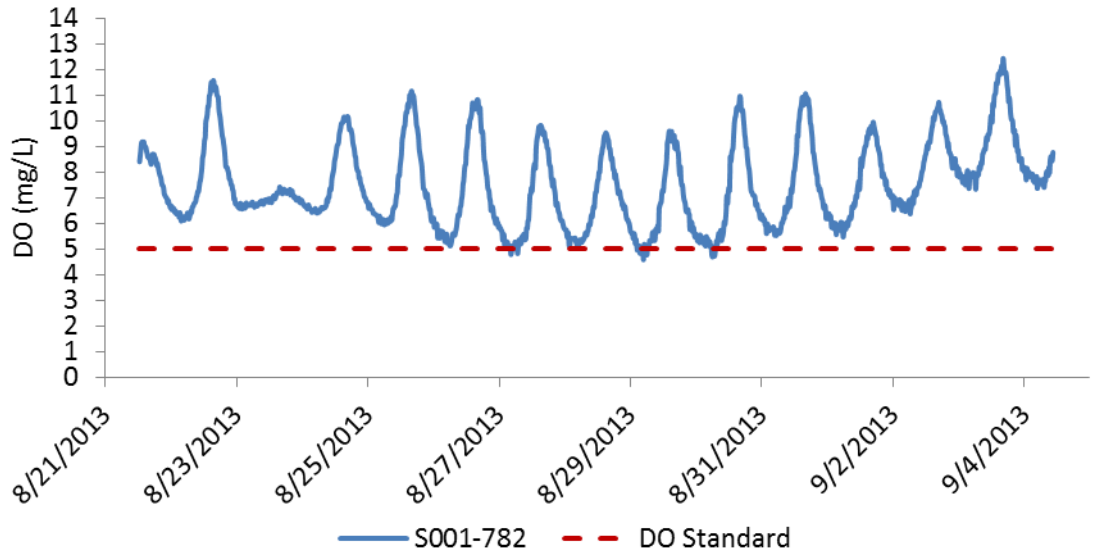


Figure 210. Diurnal DO measurements for the Cannon River station S001-782 from August 21 – September 4, 2013

Within this reach of the Cannon River, station 11LM068 had low overall taxa count, EPT taxa and elevated HBI_MN (Table 164). The low DO index scores were better than the average of similar stations meeting the biocriteria. The number of low DO intolerant taxa was on either side of the average of stations meeting the biocriteria. There was a slight increase of low DO tolerant individuals in 2011, but considerably lower in 2013. The mixed response by the macroinvertebrate community may be due to other stressors present.

Table 164. Macroinvertebrate metrics that respond to low DO stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
11LM086 (2011)	**33**	**13**	**7.84**	7.29	**7**	3	**16.2**
11LM086 (2013)	**27**	**9**	**7.33**	7.3	8	2	3.65
Prairie Forest Rivers Average	*39.4*	*14.6*	*7.2*	*7.18*	*7.5*	*7.4*	*9.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

Fish abundance can decrease with low DO levels. At station 11LM086 the number of fish individuals was 329 and 296 (2011 and 2013). The average number of fish per meter in the Southern Rivers fish class 0.68. Station 11LM086 had slightly less density at 0.66 and 0.59 fish per meter. The abundance of fish that mature later in life (MA>3) was 45.3% (both years), lower than the average of stations meeting the biocriteria (72.7%). The fish community has moderate fish intolerance to low DO with DO TIV index. The scores for station 11LM086 fell above the median (7.08) for warmwater stations in the Cannon River Watershed, indicating communities generally less tolerant of low DO conditions.

In this reach of the Cannon River, there were no exceedances of the DO standard in synoptic measurements; however, there were some exceedance of the DO standard from the diurnal measurements. High DO flux was observed eight times during diurnal monitoring. The macroinvertebrate and fish communities had mixed response to potential low DO stress. It is likely that other stressors are contributing to the response seen in the communities and it is not attributed to low DO due to the lack of consistent evidence. At this time, low DO is not a stressor to the biological communities.

TSS

TSS has only been sampled five times in this reach of the Cannon River; three times at station S001-782 in 2013, and station 11LM086 when surveyed for fish in 2011 and 2013. TSS ranged from 13 to 50 mg/L (Figure 211). No samples were greater than 65 mg/L (draft south region TSS standard). This reach of the Cannon River is listed for turbidity due to transparency tube measurements. There were 514 measurements of transparency within this reach of the Cannon River. Converted to secchi measurements, the data ranged from 0.7 to 92.7 cm. There were exceedances of the 10cm draft standard of the south TSS region, but dependent on the year collected. The exceedances appear to be prior to 2007, but the richness of the dataset differs between years as well. There was less frequent sampling in recent years. It is uncertain if transparency remains problematic in this reach. Additional data should be collected along the hydrograph to further understand the sediment dynamics within this reach of the Cannon River.

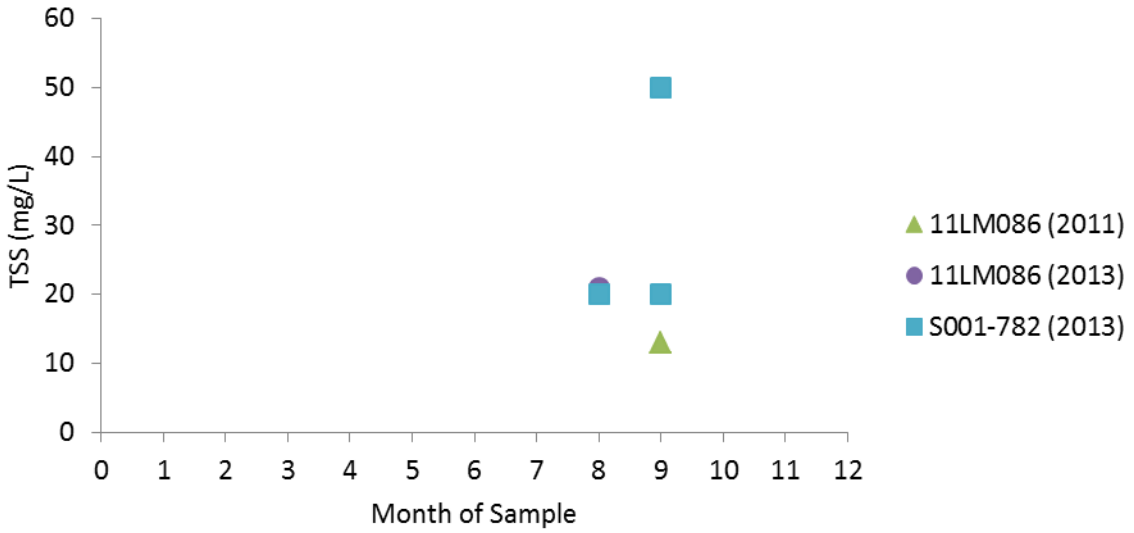


Figure 211. TSS by month in the Cannon River

The macroinvertebrate community in this reach of the Cannon River lacked stoneflies (Table 165). The TSS index score was better than average in 2013, but worse in 2011. The number of TSS tolerant taxa was low, but the percentage of TSS tolerant individuals was high. Overall the macroinvertebrate community signaled a mixed response to potential elevated TSS stress. The fish community at stations 11LM086 did not respond similarly to those with elevated TSS stress (Table 166). There were a low percentage of intolerant both years. In 2013, there were low percentages of long-lived and sensitive. All other metrics were better than the average of similar stations meeting the biocriteria.
The macroinvertebrate community results in a mixed response, with a lack of evidence pointing to either side of TSS as a stressor or not. The fish community is not indicative of a TSS stressed community. The available chemical data is variable depending on the year and quantity of data. Elevated TSS is inconclusive as a stressor in this reach of the Cannon River.

Table 165. Macroinvertebrate metrics that respond to TSS stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM086 (2011)	29.7	**0**	**22.8**	**0**	11	**63.5**
11LM086 (2013)	70.1	**0.3**	18.28	**1**	8	**51.1**
Prairie Forest Rivers Average	*23.7*	*0.6*	*19.23*	*2.67*	*13.7*	*47.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 166. Fish metrics that respond to TSS stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RifflePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM086 (2011)	42.3	19.8	45.3	**6.1**	40.4	29.2	47.4	33.1	38	18.1
11LM086 (2013)	43.6	13.5	40.5	**3**	**31.7**	22.3	41.9	**11.5**	41.2	19.7
Southern Rivers Average	*24.6*	*7.3*	*10.9*	*8.2*	*38.4*	*21.7*	*16.3*	*16.3*	*24.0*	*28.8*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

Station 11LM086 had a good MSHA score (68.1) in 2011, and fair in 2013 (53.4). Station 11LM086 received less than half of the land use subcategory score and half of the riparian subcategory score (Figure 204). The surrounding land use was residential, park, and/or urban. The riparian width was narrow with little to no bank erosion. There was light shade (5-25%) in 2011 and moderate shade (25-50%) noted in 2013. The majority of the reach was comprised of run type habitats (80%) with only 5% riffle habitats. There was cobble and gravel in the riffle but not many substrate types available in 2011. In 2013, similar channel types were noted with greater than four substrate types available. There was no noted embeddedness in 2011, and moderate embeddedness in 2013. The water color was noted as green in 2011 and brown in 2013. In 2011, there was moderate cover (25-50%) with overhanging vegetation, deep pools, logs or woody debris, and boulders. In 2013, only sparse cover was noted (5-25%). The depth variability was good along with good pool to riffle width. In 2011, the sinuosity was good, with good channel development and moderate to high channel stability. In 2013, the sinuosity was fair, with fair channel development that differed from 2011. There were also many velocity types available both years.

At station 11LM086, the macroinvertebrate samples were collected on rocks in riffles and runs, undercut banks and overhanging vegetation, aquatic macrophytes, as well as snags, woody debris, and root wads. There was a very elevated percentage of clinging macroinvertebrates at station 11LM086 (Figure 205). At station 11LM086, in 2011, the most dominant taxa were tolerant net-spinning caddisfly and sprawling mayfly (*Cheumatopsyche* and *Tricorythodes*) and in 2013, both of the dominant taxa were net-spinning caddisflies (*Cheumatopsyche* and *Ceratopsyche*). Tolerant macroinvertebrates dominated the community (95% both years).

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat is diminished. Although the fish are not impaired, they can provide additional information about potential stressors. The fish community had six and five taxa that have a preference for riffles, above the average of similar stations meeting the biocriteria (3.6). Similarly, there were decent numbers of simple lithophilic spawning taxa (10 and 8) compared to the Southern Rivers stations meeting the biocriteria (8.1). Station 11LM086 had above average simple lithophilic spawners both years. The percentage of benthic insectivores was relatively low in 2013, but

above the average of Southern River stations meeting the biocriteria in 2011. There were five taxa of darter, sculpin, or round bodied fish in 2013 and three taxa in 2011. The average for similar stations meeting the biocriteria is 5.3 taxa.

The macroinvertebrate community exhibits limited response to reduced habitat stress. The community is dominated by clinging individuals, but they are nearly all tolerant. The fish community does not correspond with reduced habitat. Currently, the habitat is not a stressor to the biological communities. Efforts should be made to protect and further enhance habitat within this reach.

Fish Passage

There are dams located upstream and downstream of this reach on the Cannon River. The fish community is sufficient within this reach, but it is unknown if the indirect effects are causing instability and habitat issues. The lack of longitudinal connectivity maybe indirectly affecting the biological communities, but it is not directly.

Conclusion

Within this reach of the Cannon River, there were no clearly identified stressors. Nutrients, TSS and lack of habitat were inconclusive as stressors. Temperature and low DO are not stressors to the macroinvertebrate community.

There is limited data suggesting nitrate is elevated under wet conditions. The macroinvertebrate community at station 11LM086 has metric responses in an expected direction with nitrate stress. Further chemical data could be collected to refine the understanding in this reach. Nitrate is inconclusive as a stressor to the macroinvertebrate community.
There is elevated TP within this reach, as well as the response variable of elevated DO flux and low DO. However, the biological community lacks consistency in confirming the response to elevated TP through river eutrophication. Additional data should be collected including TP, chlorophyll-a, BOD, and continued DO monitoring. At this time, although there is elevated TP, it is inconclusive as a stressor.

In this reach of the Cannon River, there were violations of the DO standard from the diurnal measurements. High DO flux was observed eight times during diurnal monitoring. The macroinvertebrate and fish communities had mixed response to potential low DO stress. It is likely that other stressors are contributing to the response seen in the communities and it is not attributed to low DO due to the lack of consistent evidence. At this time, low DO is not a stressor to the biological communities.

The macroinvertebrate community results in a mixed response to TSS stress, with a lack of evidence point to either side of TSS as a stressor or not. The fish community is not indicative of a TSS stressed community. The available chemical data is variable depending on the year and quantity of data. Elevated TSS is inconclusive as a stressor in this reach of the Cannon River.

The macroinvertebrate community exhibits limited response to reduced habitat stress. The macroinvertebrate community is dominated by clinging individuals, but they are nearly all tolerant. The fish community does not correspond with reduced habitat. Currently, the habitat is not a stressor to the biological communities. Efforts should be made to protect and further enhance habitat within this reach.

Within this reach of the Cannon River, there was only one temperature greater than 30°C. Additional temperature monitoring should be continued within this reach to ensure that it maintains temperature dynamics for a healthy biological community. Elevated temperature is not a stressor currently in this reach of the Cannon River.

4.6.7. Cannon R. (509)

This 11.5 mile reach of the Cannon River (AUID 07040002-509) begins at the Northfield Dam to Lake Byllesby inlet. It is impaired for lack of both fish and macroinvertebrate assemblages. This reach is also impaired for aquatic life due to turbidity. Additionally there are aquatic consumption (Mercury) and aquatic recreation (Fecal coliform) impairments. This report will only address the aquatic life impairments. There are two biological stations within this reach of the Cannon River, station 11LM097 and downstream station 00LM003. Station 00LM003 was sampled for fish in 2000 by DNR resulting in a FIBI score of 34.7 in the Southern Rivers class. In 2011, station 11LM097 was sampled for both fish and macroinvertebrates. The fish IBI score (42.1) was below the impairment threshold for the southern rivers fish class. The fish communities both years were comprised of a high relative abundance of taxa that are serial spawners (SSpnTxPct), low taxa richness of Piscivores (Piscivore), low relative abundance of sensitive taxa (SensitiveTxPctGR1) and taxa richness of simple lithophilic spawning species (SLithopGR1; Figure 212).

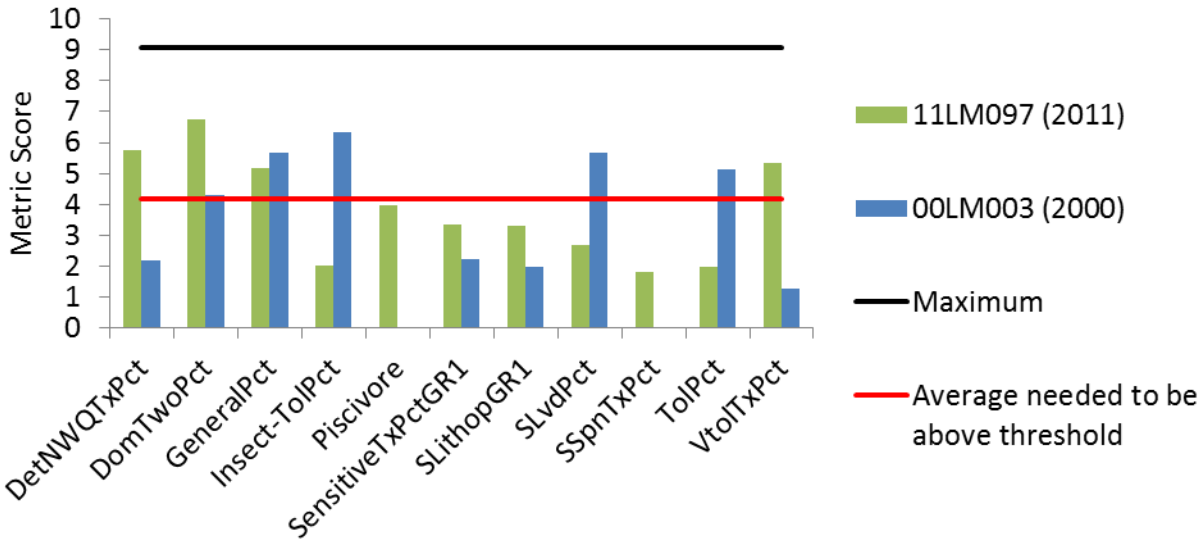


Figure 212. Fish metrics of the Southern Rivers IBI for the Cannon River, stations 11LM097 and 00LM003

Only station 11LM097 within this reach has been sampled for macroinvertebrates. In 2011, station 11LM097 scored a 22.8 on the Prairie Forest Rivers IBI, well below the threshold. The sample was dominated by net-spinning caddisfly, *Cheumatopsyche* and blackfly, *Simulium*. The IBI metric scores for station 11LM097 followed a similar pattern as those stations upstream and downstream of it on the Cannon River. Station 11LM097 had low taxa richness of macroinvertebrates with tolerance values less than or equal to four, using MN TVs, and low percentage of non-Hydropsychid Trichoptera, resulting in very low metric scores (Intolerant2lessCh and TrichwoHydroPct; Figure 199).

Temperature

Temperature data on this reach of the Cannon River begins in 1955. There was data collected from 1955 to 1963, and 1974 to 1979. Since 2000, there have been 210 synoptic measurements made of temperature ranging from 2.27 to 29.5°C. An YSI sonde was deployed in 2013 from August 21 to September 4 at station S001-582. The minimum temperature during that time was 17.42°C with a maximum temperature of 28.74°C. The Cannon River is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Additional temperature monitoring should be continued within this reach to ensure that it maintains its temperature dynamics for a healthy biological community. Elevated temperature is not a stressor currently in this reach of the Cannon River.

Nitrate

In this AUID of the Cannon River, nitrate has been measured 38 times in the late 1970's. Utilizing more recent data, nitrate has been analyzed 85 times since 2001. It has been collected once at station 11LM097, three times at S000-290, 12 times at S007-110, and 69 times S001-582 (Figure 213). The highest concentration was 12 mg/L at station S001-582 on May 21, 2013, after a rain event. The second highest concentration was 11.7 mg/L earlier in May 2013. It would be beneficial to collect more nitrate under spring and summer elevated flows (April – June) to further characterize the magnitude and duration of elevated nitrate levels.

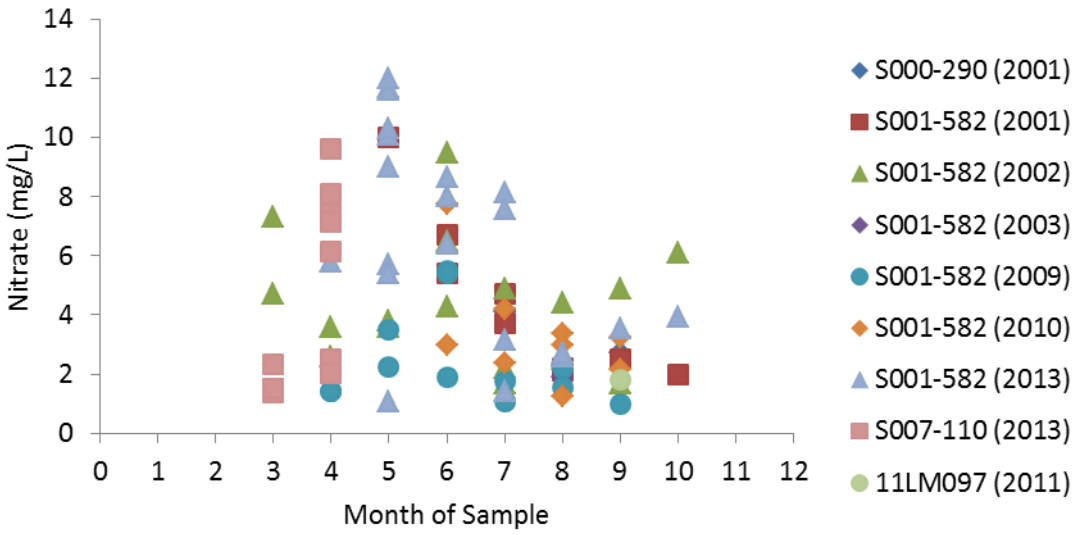


Figure 213. Nitrate concentrations in the Cannon River by month sampled, 2001 – 2003, 2009 – 2011, and 2013

The macroinvertebrate community had nearly every metric respond as expected with nitrate stress (Table 167). Station 11LM097 had fewer caddisfly taxa than the average of similar stations meeting the biocriteria and the percentage of individuals that are not Hydropsychids was quite low. There was no intolerant taxa present, resulting in a low metric score. There were a high percentage of nitrate tolerant individuals, but less nitrate tolerant taxa.

Nitrate is elevated under wet conditions and the macroinvertebrate community at station 11LM097 has metric responses in an expected direction with nitrate stress. In particular, there was a high percentage of nitrate tolerant individuals. Nitrate is currently a stressor to the macroinvertebrate community.

Table 167. Macroinvertebrate metrics that respond to nitrate stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM097 (2011)	**3**	**0.3**	**0**	**3.35**	**0**	15	**74.6**
Prairie Forest Rivers Average	*5.8*	*8.8*	*0.9*	*2.72*	*3.23*	*16.9*	*52.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

Since 2001, there have been 132 TP samples analyzed within this reach of the Cannon River. There is existing older data, but that was not considered at this time. The maximum TP was 1.61 mg/L (June 3, 2002). All but eight of the 132 samples were greater than the draft river nutrient criteria for the south region (0.15 mg/L). The relationship with TSS and TP was explored and found that there is some elevated TP in relationship to elevated TSS, but not all of it (Figure 214 and Figure 215). The 2013 data may be skewed low due to inaccurate lab methodologies. The 2013 samples may be higher than reported.

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD. There is historic BOD data from the 1950's and 1970's, but not used due to the age of the data. In 2002, BOD was measured from 1.4 to 14 mg/L, with 5 of the 13 samples greater than river nutrient standard for BOD (3 mg/L). Chlorophyll-a was analyzed in 2001, 2002, 2009, and 2010. Concentrations ranged from 3 to 148 µg/L. Of the 37 chlorophyll-a samples, six (16.2%) were above the 35 µg/L chlorophyll-a response variable threshold.

DO was measured by an YSI sonde from August 28 to September 4, 2013, at station S001-582, with no exceedances of the DO standard (Figure 216). The DO ranged from 6.21 to 12.83 mg/L. At station S001-582, elevated DO flux was observed five times during deployment (minimum of 3.12, average of 5.04, and maximum of 6.45). As a response variable to the eutrophication standard, DO flux should not exceed 4.5 mg/L daily for the south region. DO is discussed further in the DO section for this AUID.

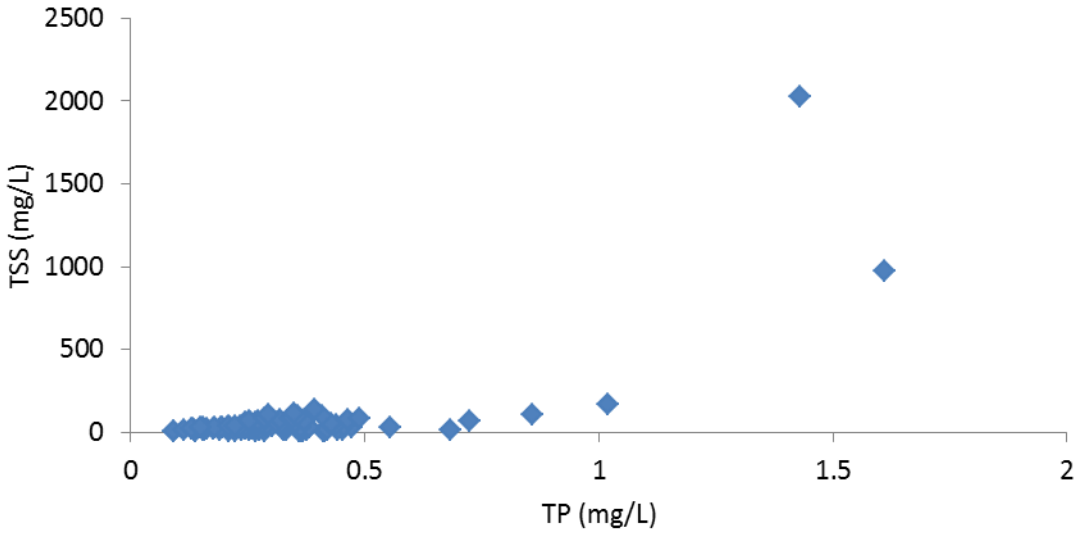


Figure 214. TSS and TP relationship in the Cannon River

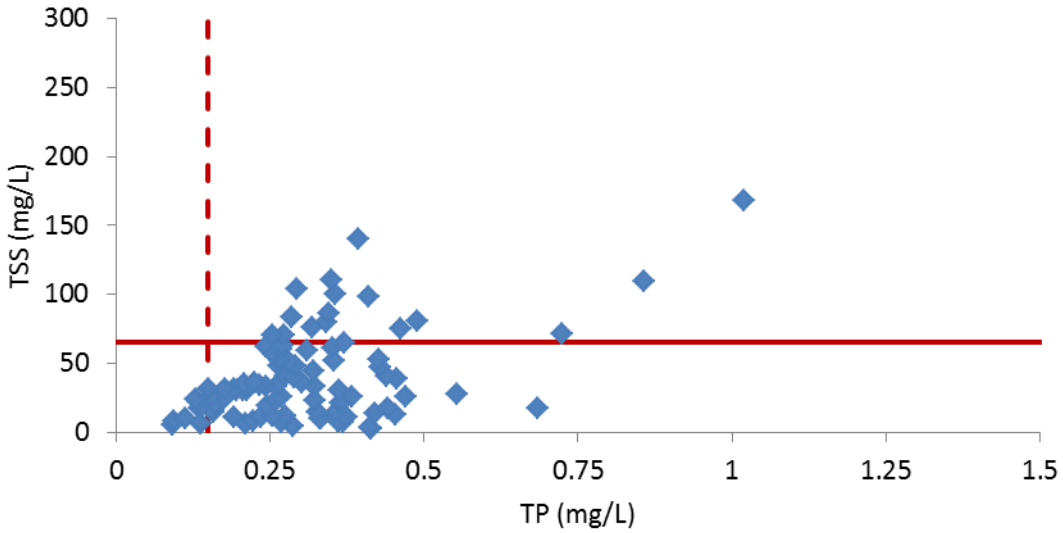


Figure 215. TSS and TP relationship in the Cannon River (zoomed in)

The macroinvertebrate community has a mixed signal to potential stress from eutrophication (Table 168). The taxa count, collector-filterer taxa, EPT and intolerant taxa were all low. The number of collector-gather taxa was high and the relative number of tolerant taxa was near that of the stations in the Prairie Forest Rivers class that are meeting the biocriteria. The fish community has a fairly consistent response to elevated TP stress (Table 169). Nearly all of the metrics at both stations indicated eutrophication stress.

There is elevated TP within this reach, as well as three response variables of elevated DO flux, BOD, and chlorophyll-a. The biological community also indicated stress from eutrophication. Eutrophication from TP is a stressor to the biotic communities in this reach of the Cannon River.

Table 168. Macroinvertebrate metrics that respond to TP and response stressors in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM097 (2011)	**29**	**5**	12	**6**	**0**	72.4
Prairie Forest Rivers Average	*39.4*	*6.0*	*8.6*	*12.2*	*0.9*	*73.6*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 169. Fish metrics that respond to TP and response stressors in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	InsectPct	PiscivorePct	TaxaCount	IntolerantPct
11LM097 (2011)	**9.1**	**5.9**	**10.5**	**65.7**	**57.3**	**5.9**	24	**2.5**
00LM003 (2000)	**2.5**	**0.5**	29.4	**39**	72.1	**0.2**	**17**	**0.4**
Southern Rivers Average	*16.3*	*6.1*	*29.1*	*25.4*	*63.8*	*13.8*	*23.0*	*8.2*
Expected response to stress	↓	↓	↓	↑	↓	↓	↓	↓

Dissolved Oxygen

DO has been synoptically measured 98 times within this reach. Measurements were collected at stations 11LM097, S001-582, S007-071, and S007-110. There were only four measurements observed prior to 9AM, and there were no synoptic measurements below the standard of 5 mg/L. The synoptic DO data ranged from 6.6 – 13.8 mg/L. DO was measured by an YSI sonde from August 28 to September 4, 2013, at station S001-582, with no exceedances of the DO standard (Figure 216). The DO ranged from 6.21 to 12.83 mg/L. At station S001-582, elevated DO flux was observed five times during deployment (minimum of 3.12, average of 5.04, and maximum of 6.45). As a response variable to the eutrophication standard, DO flux should not exceed 4.5 mg/L daily for the south region.

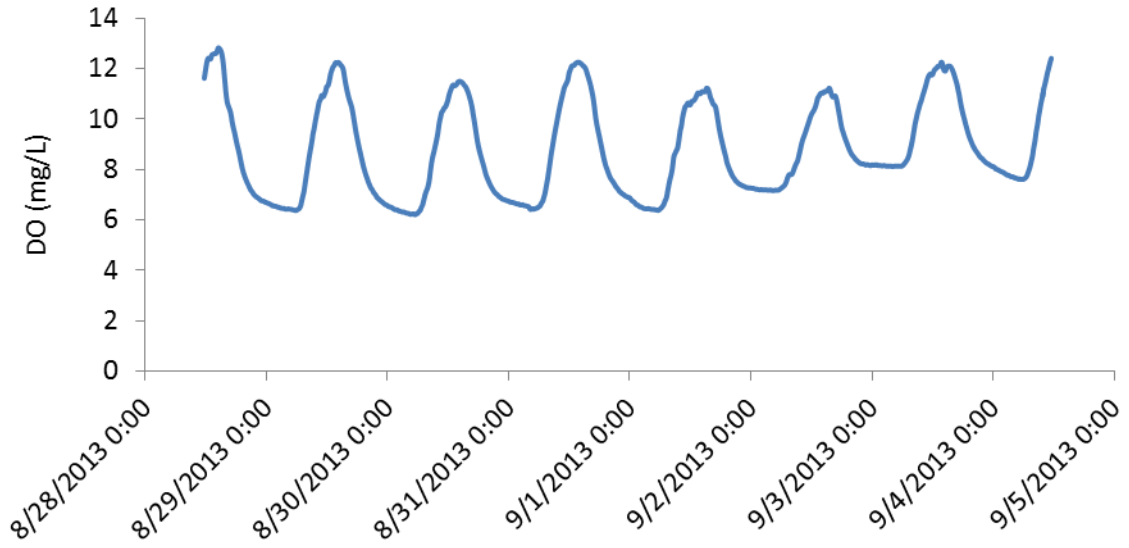


Figure 216. Diurnal DO measurements for the Cannon River station S001-582 from August 28 – September 4, 2013

Within this reach of the Cannon River, station 11LM097 had low overall taxa count, EPT taxa and elevated HBI_MN (Table 170). The low DO index score were better than the average of similar stations meeting the biocriteria. The number of low DO intolerant taxa was greater than the average of stations meeting the biocriteria and very few low DO tolerant taxa and individuals were present. The mixed response by the macroinvertebrate community is likely due to other stressors present.

Fish abundance can decrease with low DO levels. At station 11LM097 the number of fish individuals was 286. The average number of fish per meter in the Southern Rivers fish class 0.68. Station 11LM097 had slightly less density at 0.57 fish per meter. The abundance of fish that mature later in life (MA>3) was 12.9%, lower than the average of stations meeting the biocriteria (72.7%). The fish community has moderate intolerance to low DO when looking at the DO TIV index. The scores for station 11LM097 fell below the median (7.08) for warmwater stations in the Cannon River Watershed, indicating communities generally more tolerant of low DO conditions.

In this reach of the Cannon River, there were no exceedances of the low DO standard; however, there were exceedances of DO flux associated with river eutrophication. The macroinvertebrate community had mixed response to potential low DO stress. The fish community does indicate potential DO stress with nearly consistent response. It is likely that other stressors are contributing to the response seen in the communities and it is not attributed to low DO due to the lack of consistent evidence. At this time, low DO is not a stressor to the biological communities.

Table 170. Macroinvertebrate metrics that respond to low DO stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
11LM097 (2011)	**29**	**9**	**7.51**	7.55	8	2	1.3
Prairie Forest Rivers Average	*39.4*	*14.6*	*7.2*	*7.18*	*7.5*	*7.4*	*9.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

TSS

This reach of the Cannon River is currently listed for turbidity. TSS has been sampled 98 times in this reach of the Cannon River; three times at station S000-290 in 2001, 12 times at station S007-110 in 2013, 82 times at station S001-582 in 2001-2004 and 2013, and at the biological stations when surveyed for fish in 2011. TSS ranged from 2.4 to 2024 mg/L. Of the 98 samples, 19 (19.4%) were greater than 65 mg/L (draft south region TSS standard). There were 296 measurements of transparency within this reach of the Cannon River, from 2000-2006, 2008-2010, and 2012-2013. Converted to secchi measurements, the data ranged from 0.04 to 107 cm. Only 16 measurements from 296 (5.4%) were less than the 10cm draft standard of the south TSS region. Utilizing only the most recent 95 data points from 2012 and 2013, there were only seven exceedances with a 7.4% exceedance rate.

The macroinvertebrate community in this reach of the Cannon River lacked stoneflies (Table 171). The TSS index score was better than average. The number of TSS tolerant taxa was low, but the percentage of TSS tolerant individuals was high. Overall, the macroinvertebrate community signaled a mixed response to potential elevated TSS stress, similar to the upstream reach. The fish community at stations 11LM097 and 00LM003 indicates a potential for elevated TSS stress (Table 172). Both stations had five metrics score poorly in comparison with the average of stations in the Southern Rivers class that are meeting the biocriteria. However, the TSS index score is better than the average of similar stations meeting the biocriteria, indicating less tolerance to elevated TSS.

The macroinvertebrate community results in a mixed response, with a lack of evidence pointing to either side of TSS as a stressor or not. The fish community is more indicative of a TSS stressed community. The available chemical data does indicate elevated TSS conditions. Elevated TSS is a stressor in this reach of the Cannon River.

Table 171. Macroinvertebrate metrics that respond to elevated TSS stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM097 (2011)	52.6	**0**	**19.5**	**1**	11	**60.4**
Prairie Forest Rivers Average	*23.7*	*0.6*	*19.23*	*2.67*	*13.7*	*47.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 172. Fish metrics that respond to elevated TSS stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RiffIePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM097 (2011)	**15**	9.4	11.2	**2.5**	**21.7**	**16.1**	**14.3**	**9.1**	**8.4**	25.2
00LM003 (2000)	30	**0**	**4**	**0.4**	**17.2**	**0.9**	**7.8**	**2.5**	29	28
Southern Rivers Average	*24.6*	*7.3*	*10.9*	*8.2*	*38.4*	*21.7*	*16.3*	*16.3*	*24.0*	*28.8*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

Station 11LM097 had qualitative habitat completed in 2011. Station 00LM003 does not have any habitat information associated with the station. Station 11LM097 had a MSHA total score of 63.3 (fair). The surrounding land use was row crop with some forest, wetland, prairie, or shrub. The riparian width was wide with moderate shade and little bank erosion. The reach was comprised of 25% pool, 15% riffle, and 60% run features. There were greater than four substrate types available with moderate embeddedness. The cover was moderate with deep pools and logs or woody debris available.

At station 11LM097, the macroinvertebrate samples were collected on rocks in riffles and runs, and snags, woody debris, and root wads. There was a very elevated percentage of clinging macroinvertebrates at station 11LM097 (Figure 205). At station 11LM097, in 2011, the most dominant taxa were tolerant net-spinning caddisfly and black fly (*Cheumatopsyche* and *Simulium*). Tolerant macroinvertebrates dominated the community (89%).

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat is diminished. The fish community had six taxa that have a preference for riffles, above the average of similar stations meeting the biocriteria (3.6). There was just a taxa lower of simple lithophilic spawning taxa (seven) compared to the Southern Rivers stations meeting the biocriteria (8.1). Station 11LM097 had below average simple lithophilic spawners. The

percentage of benthic insectivores was also relatively low in 2011. There were five taxa of darter, sculpin, or round bodied fish. The average for similar stations meeting the biocriteria is 5.3 taxa.

The macroinvertebrate community exhibits limited response to reduced habitat stress. The community is dominated by clinging individuals, but they are nearly all tolerant. The fish community has mixed response to potentially reduced habitat. Currently, the habitat is inconclusive a stressor to the biological communities. Efforts should be made to protect and further enhance habitat within this reach.

Fish Passage

There are dams located upstream and downstream of this reach on the Cannon River. The fish community is sufficient both upstream and downstream of this reach. The fish communities that are within this AUID are locked in by Northfield dam on the upstream side and Byllesby Lake dam on the downstream side. Dams are known to limit fish passage. Taxa such as quillback and spottail shiner have been identified on the upstream of Northfield dam and downstream of Byllesby Lake dam (Table 173). Brown trout, sauger, silver redhorse, slenderhead darter, and white bass are present downstream of Byllesby dam, but have not been found in the Cannon River between Woolen Mill's dam and Byllesby Lake dam. Additional effects of dams are the potential for causing instability and habitat issues. The dams affect the stream channel slope which would affect the substrate composition and the channel width and riffle spacing and pool spacing which would have an effect on the biology. The lack of longitudinal connectivity is affecting the fish community within this reach and potentially indirectly the macroinvertebrate community.

Table 173. Migratory fish presence and absence below Woolen Mill's dam on the Cannon River

Station (date)	blackside darter	brown trout	central stoneroller	golden redhorse	greater redhorse	quillback	sauger	shorthead redhorse	silver redhorse	slenderhead darter	spottail shiner	walleye	white bass	white sucker
Woolen Mill's Dam														
11LM068 (2011)	x			x		x					x	x		x
04LM078 (2004)	x			x										x
11LM086 (2011)	x		x	x	x	x						x		x
11LM086 (2013)	x			x								x		x
Northfield Dam														
11LM097 (2011)	x		x	x				x						x
00LM003 (2000)				x				x				x		x
Byllesby Lake Dam														
00LM002 (2000)		x		x		x		x		x				
00LM002 (2011)				x				x		x	x			
04LM055 (2004)				x			x	x		x		x		x
04LM005 (2011)				x		x	x	x	x	x	x			x
00LM001 (2000)	x							x		x		x		x
11LM090 (2011)				x		x	x	x				x		x
10EM175 (2010)				x				x		x			x	x
11LM098 (2011)				x				x	x			x	x	

Conclusion

Nutrients, TSS, and lack of fish passage are stressors in this reach of the Cannon River. Lack of habitat is inconclusive as a stressor. Elevated temperature and low DO are not stressors to the biological communities.

Nitrate is elevated under wet conditions and the macroinvertebrate community at station 11LM097 has metric responses in an expected direction with nitrate stress. Nitrate is currently a stressor to the macroinvertebrate community.

There is elevated TP within this reach, as well as three response variables of elevated DO flux, BOD, and chlorophyll-a. The biological community also indicated stress from eutrophication. Eutrophication from TP is a stressor to the biotic communities in this reach of the Cannon River.

The fish community is more indicative of a TSS stressed community than the macroinvertebrate communities. The available TSS data does indicate elevated TSS conditions. Elevated TSS is a stressor to the fish in this reach of the Cannon River.

There are dams located upstream and downstream of this reach on the Cannon River. The lack of longitudinal connectivity is affecting the fish community within this reach and potentially indirectly the macroinvertebrate community.

The macroinvertebrate community exhibits limited response to reduced habitat stress. The community is dominated by clinging individuals, but they are nearly all tolerant. The fish community has mixed response to potentially reduced habitat. Currently, the habitat is inconclusive a stressor to the biological communities. Efforts should be made to protect and further enhance habitat within this reach.

4.6.8. Cannon River (539)

This nearly three mile reach of the Cannon River (AUID 07040002-539) starts at the Byllesby Dam to the confluence with Little Cannon River, near Cannon Falls. This reach is impaired for aquatic life due to lack of macroinvertebrate assemblage. There is also an impairment for aquatic consumption (PCBF). This report will only address the aquatic life impairments. There is one biological station within this reach of the Cannon River, station 00LM002.

Station 00LM002 was sampled for fish in 2000 by DNR resulting in a FIBI score of 68 in the Southern Rivers class. In 2011, station 00LM002 was sampled for both fish and macroinvertebrates. The fish IBI score (75.7) was above the impairment threshold for the Southern Rivers fish class. The fish communities where dominated by emerald shiner both years sampled, and had 21 and 25 taxa respectively.

Station 00LM002 was sampled for macroinvertebrates in 2011 and scored 28.6 on the Prairie Forest Rivers IBI, below the threshold. In 2011, the sample was dominated by non-biting midge (*Polypedilum)* and net-spinning caddisfly (*Ceratopsyche)*. The IBI metric scores for station 00LM002 followed a similar pattern as the stations upstream of it on the Cannon River. Station 00LM002 had low metric scores for taxa richness of predators (PredatorCh) and total taxa richness of macroinvertebrates (TaxaCountAllChir; Figure 199).

Temperature

Within this reach of the Cannon River, since 2000, there have been 293 synoptic measurements made of temperature ranging from -1.1 to 28°C. The maximum temperature was observed in July 2012. The Cannon River is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in this reach of the Cannon River.

Nitrate

In this AUID of the Cannon River, nitrate has been measured 34 times. The highest concentration was 8.25 mg/L at station S003-818 on June 21, 2011 (Figure 217). The second highest concentration was 7.6 mg/L in 2002. It would be beneficial to collect more nitrate samples under spring and summer elevated flows (April – June) to further characterize the magnitude and duration of elevated nitrate levels.

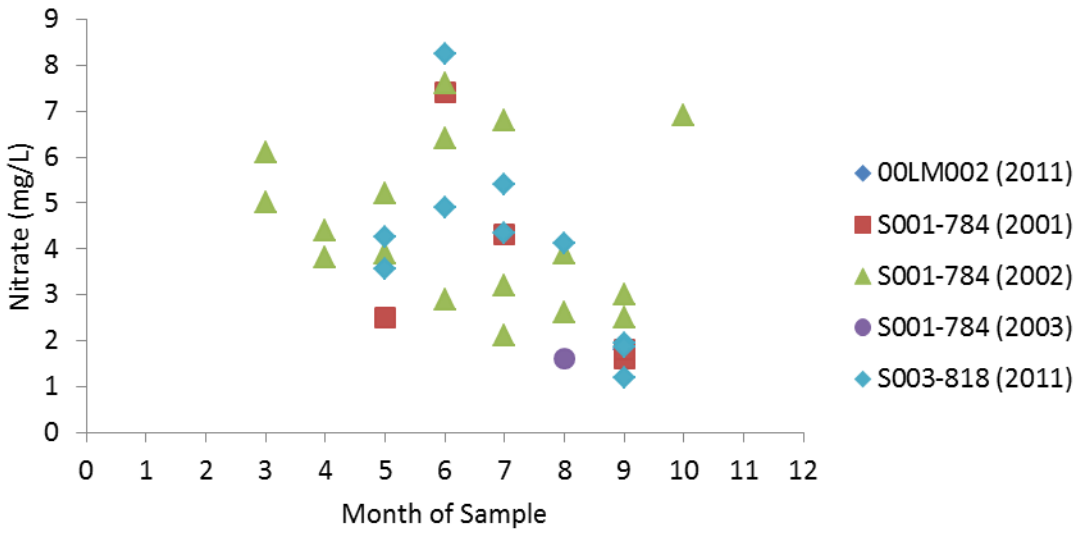


Figure 217. Nitrate concentrations in the Cannon River by month sampled, 2001 – 2003, and 2011

The macroinvertebrate community had nearly every metric respond as expected with nitrate stress (Table 174). Station 00LM002 had fewer caddisfly taxa than the average of similar stations meeting the biocriteria and the percentage of individuals that are not Hydropsychids was quite low. There were two intolerant taxa present, which was better than average but still resulted in a low metric score. The nitrate index score was a little higher than the average of similar stations meeting the biocriteria. There were no nitrate intolerant taxa and 17 nitrate tolerant taxa.

There is limited data suggesting nitrate is elevated under wet conditions. The macroinvertebrate community at station 00LM002 has metric responses in an expected direction with nitrate stress. Nitrate is currently inconclusive as a stressor to the macroinvertebrate community.

Table 174. Macroinvertebrate metrics that respond to nitrate stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
00LM002 (2011)	**4**	**0.6**	2	**2.96**	**0**	**17**	47.8
Prairie Forest Rivers Average	*5.8*	*8.8*	*0.9*	*2.72*	*3.23*	*16.9*	*52.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

Within this reach of the Cannon, TP has been analyzed 77 times; 10 times at station S003-818 in 2011, once at the time of fish sampling at station 00LM002 in 2011, and 66 times at station S001-784(Figure 218). The maximum TP was 0.553 mg/L (August 2, 2011). All but 13 of the 77 samples were greater than the draft river nutrient criteria for the south region (0.15 mg/L). The relationship with TSS and TP was explored and found that the elevated TP did not occur with elevated TSS (Figure 219).

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD. In 2002, BOD was measured from 1.5 to 5.1 mg/L, with two of the eight samples greater than river nutrient standard for BOD (3 mg/L). Chlorophyll-a was analyzed in 2002, with the BOD. Concentrations ranged from 4.13 to 78.9 µg/L. Of the eight chlorophyll-a samples, one (12.5%) were above the 18 µg/L chlorophyll-a response variable threshold. DO flux has not been measured within this reach.

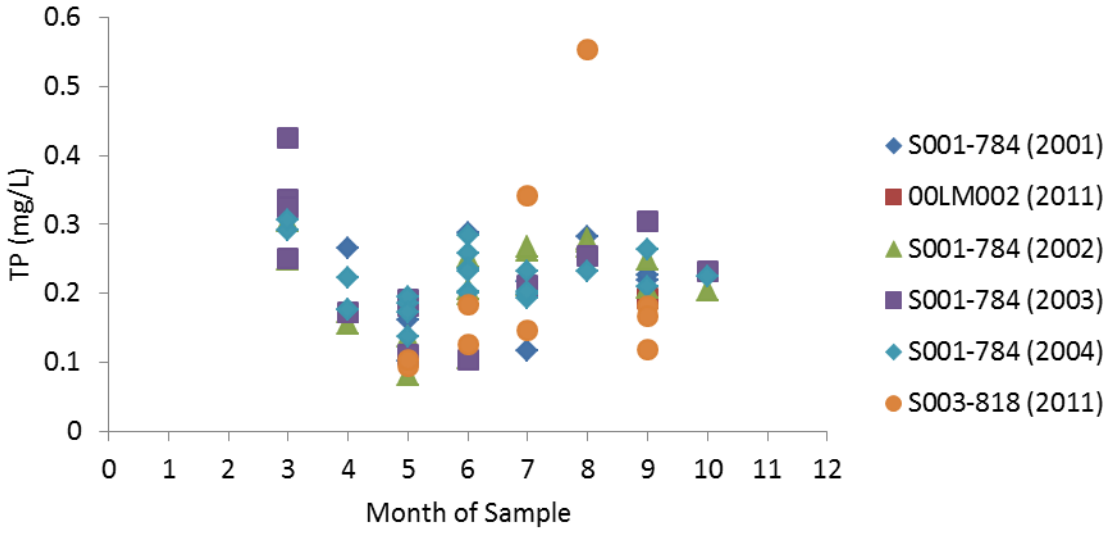


Figure 218. Total phosphorus concentrations in the Cannon River by month sampled

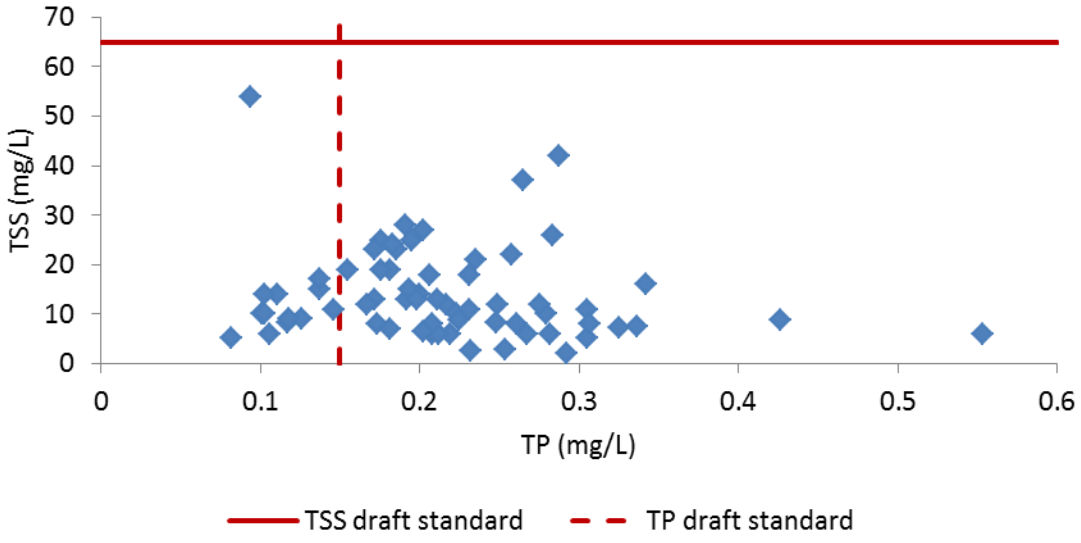


Figure 219. TSS and TP relationship in the Cannon River

The macroinvertebrate community has a consistent signal to potential stress from eutrophication (Table 175). The taxa count, collector-filterer taxa, EPT and intolerant taxa were all low. The number of collector-gather taxa was high compared to the stations in the Prairie Forest Rivers class that are meeting the biocriteria. The fish community did not have a consistent response to elevated TP stress (Table 176). Nearly all of the metrics at both stations contradicted eutrophication stress.

There is elevated TP within this reach, as well as response variables of elevated BOD and chlorophyll-a, although limited data. It would be beneficial to add to the TP, BOD, chlorophyll-a and DO flux dataset in the near future. The macroinvertebrate community indicated stress from eutrophication, although the fish did not. Eutrophication from TP is inconclusive as a stressor to the macroinvertebrate community in this reach of the Cannon River. This reach is downstream of Lake Byllesby. Reductions of TP to the lake will also likely be beneficial to this reach of the Cannon River.

Table 175. Macroinvertebrate metrics that respond to TP and response stressors in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
00LM002 (2011)	**27**	**4**	13	**6**	**0**	**74.1**
Prairie Forest Rivers Average	*39.4*	*6.0*	*8.6*	*12.2*	*0.9*	*73.6*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 176. Fish metrics that respond to TP and response stressors in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	InsectPct	PiscivorePct	TaxaCount	IntolerantPct
00LM002 (2000)	**0**	9.5	39	3.2	91.6	**4.2**	**21**	41.1
00LM002 (2011)	**0**	18.3	**13**	6.3	75.5	18.3	25	31.7
Southern Rivers Average	*16.3*	*6.1*	*29.1*	*25.4*	*63.8*	*13.8*	*23.0*	*8.2*
Expected response to stress	↓	↓	↓	↑	↓	↓	↓	↓

Dissolved Oxygen

There is limited DO data in this reach of the Cannon River. DO has been measured 23 times, with none collected prior to 9AM. Additional data would benefit the understanding of DO within this reach.

Within this reach of the Cannon River, station 00LM002 had low overall taxa count, EPT taxa and elevated HBI_MN (Table 177). The low DO index score were better than the average of similar stations

meeting the biocriteria. The number of low DO intolerant taxa was greater than the average of stations meeting the biocriteria, and very few low DO tolerant taxa and individuals were present. The mixed response by the macroinvertebrate community is likely due to other stressors present, similar to the upstream AUID.

Fish abundance can decrease with low DO levels. At station 00LM002 the number of fish individuals was 95 and 208 (2000 and 2011). The average number of fish per meter in the Southern Rivers fish class is 0.68. Station 00LM002 had considerably less density in 2000 at 0.19 fish per meter, and a bit better in 2011 with 0.43 fish per meter. The abundance of fish that mature later in life (MA>3) was 40 and 30.8% (2000 and 2011), lower than the average of stations meeting the biocriteria (72.7%). The fish community has moderate intolerance to low DO when looking at the DO TIV index. The scores for station 00LM002 fell above the median (7.08) for warmwater stations in the Cannon River Watershed, indicating communities generally less tolerant of low DO conditions.

In this reach of the Cannon River, there were no exceedances of the low DO standard; however, there was little data. The macroinvertebrate community had mixed response to potential low DO stress, but can likely be explained by other stressors. The fish community does indicate potential DO stress, except the DO index score, which is better than expected. It is likely that other stressors are contributing to the response seen in the communities, and it is not attributed to low DO due to the lack of consistent evidence. At this time, low DO is not a stressor to the biological communities.

Table 177. Macroinvertebrate metrics that respond to low DO stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
00LM002 (2011)	**27**	**9**	**7.39**	7.49	9	4	6.9
Prairie Forest Rivers Average	*39.4*	*14.6*	*7.2*	*7.18*	*7.5*	*7.4*	*9.0*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

TSS

TSS has been sampled 67 times in this reach of the Cannon River; 10 times at station S003-818 in 2011, 56 times at station S001-784 in 2001-2004, and one time at the biological station when surveyed for fish in 2011. TSS ranged from 2 to 54 mg/L. None of the samples were greater than 65 mg/L (draft south region TSS standard). There were 346 measurements of transparency within this reach of the Cannon River, from 2001-2013. Converted to secchi measurements, the data ranged from 9 to 107 cm. Only one measurement from 346 (0.2%) was less than the 10cm draft standard of the south TSS region.

The macroinvertebrate community in this reach of the Cannon River lacked stoneflies and TSS intolerant taxa (Table 178). The remaining metrics that respond to elevated TSS stress were better than the average of similar stations meeting the biocriteria. The fish community at station 00LM002 indicates a

more mixed response to elevated TSS stress (Table 179). Both visits had elevated TSS index scores in comparison with the average of stations in the Southern Rivers class that are meeting the biocriteria, indicating more tolerance to elevated TSS. The other metrics were inconsistent over the two visits and only a few responded poorly.

The chemical data is not suggestive of TSS as a potential stressor. Similarly, there is a lack of consistent evidence in both biological communities. Elevated TSS is not a stressor in this reach of the Cannon River.

Table 178. Macroinvertebrate metrics that respond to elevated TSS stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
00LM002 (2011)	56.6	**0**	17.2	**2**	9	40.3
Prairie Forest Rivers Average	*23.7*	*0.6*	*19.23*	*2.67*	*13.7*	*47.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 179. Fish metrics that respond to elevated TSS stress in the Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LIvdPct	Percfm-TolPct	RiffePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
00LM002 (2000)	42.1	**2.1**	41.1	41.1	**36.3**	**12.6**	26.3	52.6	33.7	**35**
00LM002 (2011)	34.1	47.1	**1**	31.7	61.5	66.8	23.1	42.3	**13**	**33.7**
Southern Rivers Average	*24.6*	*7.3*	*10.9*	*8.2*	*38.4*	*21.7*	*16.3*	*16.3*	*24.0*	*28.8*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

At the time of fish sampling in 2011, station 00LM002 scored fair on the MSHA (64.8). The riparian area was narrow to very narrow with little erosion. There was light to moderate shade available. There was cobble, gravel, and sand substrates, but less than four substrate types available. The reach had 40% run, 40% pool and 20% riffle features, with moderate cover. No embeddedness was noted in 2011. The depth variability was good with moderate to high stability.

At station 00LM002, the macroinvertebrate samples were collected on rocks in riffles and runs, and undercut banks and overhanging vegetation. There was a very elevated percentage of clinging macroinvertebrates at station 00LM002 (Figure 205). At station 00LM002, in 2011, the most dominant

taxa were non-biting midges and tolerant net-spinning caddisfly (*Polypedilum* and *Ceratopsyche*). Tolerant macroinvertebrates dominated the community (93%).

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat is diminished. Both years, the fish community had six taxa that have a preference for riffles, above the average of similar stations meeting the biocriteria (3.6). There were seven and eight taxa of simple lithophilic spawners compared to the Southern Rivers stations meeting the biocriteria (8.1). Station 00LM002 had above average simple lithophilic spawner individuals. The percentage of benthic insectivores was also very good both years. There were six and seven taxa of darter, sculpin, or round bodied fish, in 2000 and 2011 respectively. The average for similar stations meeting the biocriteria is 5.3 taxa.

The macroinvertebrate community exhibits limited response to reduced habitat stress. The community is dominated by clinging individuals, but they are nearly all tolerant. The fish community has a community not indicative of reduced habitat. Currently, the habitat is inconclusive a stressor to the biological communities. Efforts should be made to protect and further enhance habitat within this reach.

Fish Passage

There are dams located upstream of this reach on the Cannon River. The fish community is sufficient within this reach, but it is unknown if the indirect effects are causing instability and habitat issues. The lack of longitudinal connectivity maybe indirectly affecting the biological communities, but it is not directly.

Conclusion

Within this reach of the Cannon River, there were no clearly identified stressors. Nutrients and lack of habitat were inconclusive as stressors. Temperature, TSS, and low DO are not stressors to the macroinvertebrate community.

Nitrate is somewhat elevated under wet conditions and the macroinvertebrate community at station 00LM002 has metric responses in an expected direction with nitrate stress. Nitrate is inconclusive as a stressor to the macroinvertebrate community.

There is elevated TP within this reach, as well as response variables of elevated BOD and chlorophyll-a, although limited data. It would be beneficial to add to the TP, BOD, chlorophyll-a and DO flux dataset in the near future. The macroinvertebrate community indicated stress from eutrophication, although the fish did not. Eutrophication from TP is inconclusive as a stressor to the macroinvertebrate community in this reach of the Cannon River. This reach is downstream of Lake Byllesby. Reductions of TP to the lake will also likely be beneficial to this reach of the Cannon River.

The macroinvertebrate community exhibits limited response to reduced habitat stress. The community is dominated by clinging individuals, but they are nearly all tolerant. The fish community has a community not indicative of reduced habitat. Currently, the habitat is inconclusive a stressor to the biological communities. Efforts should be made to protect and further enhance habitat within this reach.

Elevated temperature is not a stressor currently in this reach of the Cannon River. The chemical data is not suggestive of TSS as a potential stressor, and there is a lack of consistent evidence in both biological communities. Elevated TSS is not a stressor in this reach of the Cannon River. In this reach of the Cannon River, there were no exceedances of the low DO standard, but the biological communities are not suggestive of low DO stress.

Middle Cannon River 10 digit HUC Summary

Within the Middle Cannon River 10 digit HUC common stressors are lack of habitat and nitrate (Table 180). Other stressors in this watershed include elevated TP with response variables, low DO, TSS, fish passage, and chloride. Three reaches on the Cannon River are inconclusive for the identification of stressors. There was a lack of connecting data to the remaining inconclusive stressors. Additive effects may be prevalent which is why one stressor did not come out as conclusive. Additional sampling should be utilized to see if the inconclusive reaches of the Cannon River have similar datasets to Cannon River (509), which had more connecting data for nitrate, TP, and TSS.

Table 180. Middle Cannon river 10-digit HUC stressor summary (● = stressor, ○ = inconclusive stressor, blank = not a stressor)

Reach	AUID	Biological Impairment	Class	Stressors							
				Temperature	Nitrate	Phosphorus	DO	TSS	Habitat	Fish Passage	Chloride
Unnamed - Spring Brook (Rice Creek)	557	Macroinvertebrates	2A		●	○		○	●		
Unnamed Ditch - Heath Creek	555	Fish and Macroinvertebrates	2B		○	○	○	○	●	○	●
Heath Creek	521	Fish and Macroinvertebrates	2B			●	●	○	●		
Spring Creek	591	Macroinvertebrates	2B	○	●	○		○	●		
Cannon River	582	Macroinvertebrates	2B		○	○		○	○		
Cannon River	507	Macroinvertebrates	2B		○	○		○	○		
Cannon River	509	Fish and Macroinvertebrates	2B		●	●		●	○	●	
Cannon River	539	Macroinvertebrates	2B		○	○			○		

4.7. Upper Cannon River

This section encompasses biotic impaired reaches in the Upper Cannon River 10 digit HUC (Figure 220). Small tributaries to the Cannon River will be discussed first followed by the headwaters reach of the Cannon River. The small tributaries will be discussed from upstream on the Cannon River to downstream confluences with the Cannon River. The small tributaries include Whitewater Creek, Waterville Creek, Devils Creek, Unnamed Creek (Dixon Creek), MacKenzie Creek, and Unnamed Creek (from Roberds Lake). All of the reaches within this section are warmwater, class 2B streams.

The Unnamed Creek (Dixon Creek) is impaired for fish assemblage only (macroinvertebrates were not assessed). All other reaches are impaired for lack of macroinvertebrate assemblage. Only Waterville Creek is impaired for lack of fish assemblage along with the lack of macroinvertebrate assemblage.

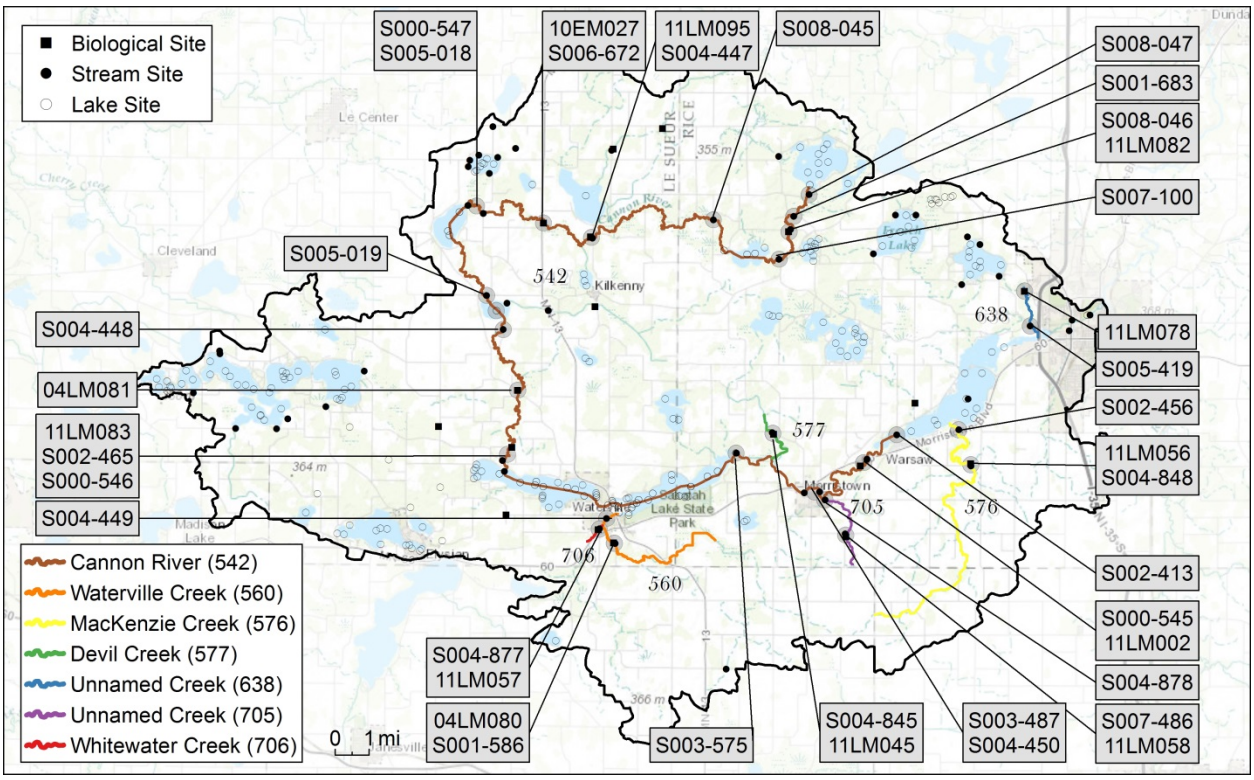


Figure 220. Map of Upper Cannon River 10 digit HUC including impaired reaches with biological stations and chemistry stations used in report

4.7.1 Whitewater Creek (706)

Whitewater Creek (AUID 07040002-706) is a small tributary to Waterville Creek, near Waterville, Minnesota. The reach is impaired for lack of macroinvertebrate assemblage. It is also impaired for *E. coli*, which will not be addressed in this report. Station 11LM057 was sampled in 2011 for fish and macroinvertebrates. The fish community was dominated by creek chub, mudminnows, and white suckers, and the FIBI of 66 was above the Southern Headwaters FIBI impairment threshold (55).

The macroinvertebrate community is impaired, receiving a MIBI score of 27.5 for the Southern Forest Streams GP class (threshold of 43). The macroinvertebrate community had very poor EPT and total taxa richness with a high proportion of tolerant individuals and no sensitive taxa. As shown in Figure 221, the only metric score in the MIBI that was greater than the average metric score needed to be at the threshold was the relative abundance (%) of dominant five taxa in subsample (chironomid genera treated individually; DomFiveCHPct). The lowest scoring metrics (scoring zero) were taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch) and relative abundance (%) of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct).

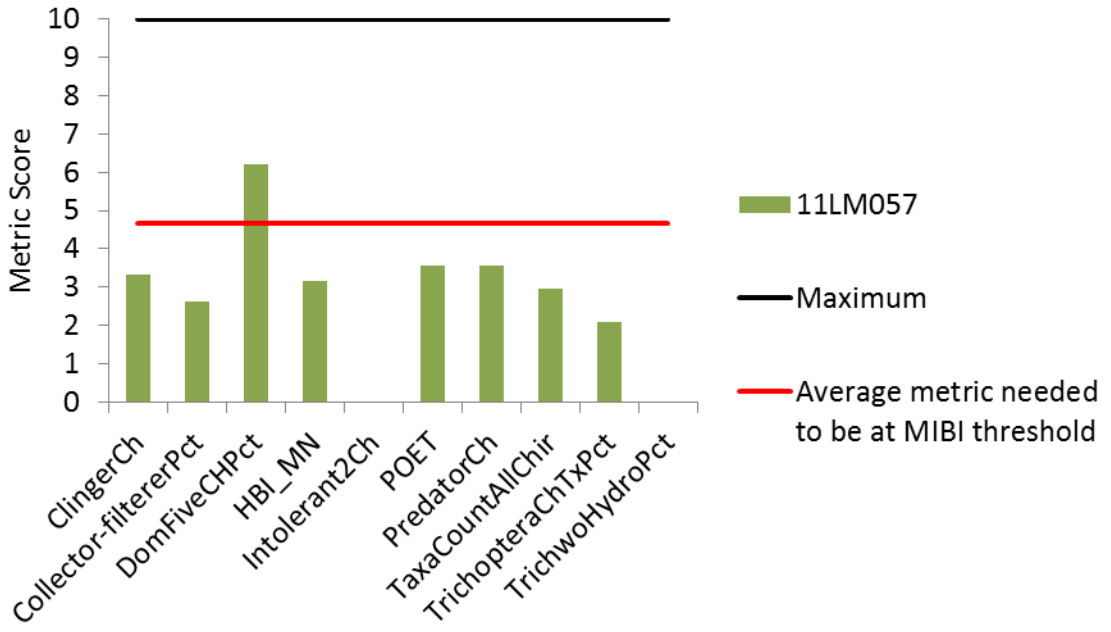


Figure 221. Macroinvertebrate metrics of the Southern Forest Streams GP IBI for Whitewater Creek, station 11LM057

Temperature

Chemistry station S004-877 is co-located with the biological station 11LM057 on Whitewater Creek. An YSI sonde was deployed in 2013 from July 25 to August 7. The minimum temperature during that time was 14.9°C with a maximum temperature of 20.6°C. Forty-two synoptic measurements were taken at station S004-877 from 2008 to 2013. The maximum temperature recorded was 23.8°C (August 3, 2010). Whitewater Creek is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in Whitewater Creek.

Nitrate

Nitrate was sampled 25 times over the years of 2009 to 2011 and 2013 at station S004-877, with the majority of the samples collected in 2009 and 2010 (Figure 222). The maximum value was 13 mg/L (May 20, 2013), during a rain event. The two highest measurements were in the months of May and June.

In 2009 the nitrate concentrations were consistently lower than that of 2010. Within the area of Whitewater Creek, 2009 was a dry precipitation year compared to normal (DNR State Climatology Office). 2010 was a wet year in comparison, with more precipitation than normal during the calendar

year. The wetter season likely influenced the nitrate delivery to the stream. Whitewater Creek does not have any flow information but by looking at the 2009 and 2010 hydrographs on the mainstem Cannon River. The flows in 2009 are much lower than they are in 2010, reflective of the precipitation in 2010. Precipitation amounts have a pronounced effect on nitrate loads. During a dry year, loads may drop by 49% compared to an average year; however during a wet year, overall loads may increase by 51% (MPCA 2013).

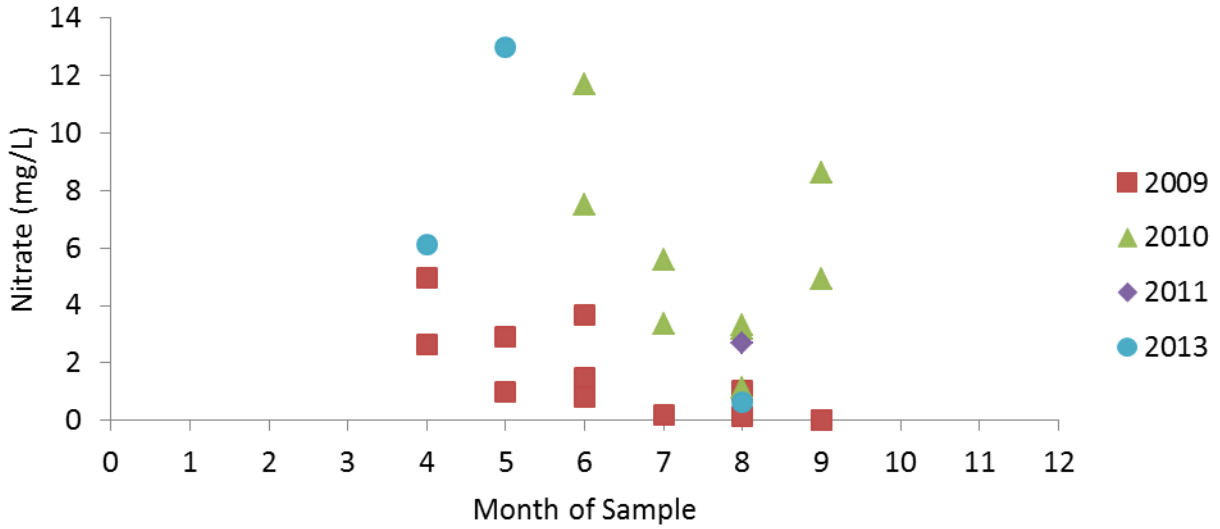


Figure 222. Nitrate concentrations in Whitewater Creek by month sampled, 2009 – 2011 and 2013

The macroinvertebrate metrics that correspond with nitrate stress show a fairly consistent response as expected (Table 181). Station 11LM057 had only one Trichoptera taxon (Hydropsychid), and no non-hydropyschid caddisflies present. There were no intolerant taxa present, resulting in a low metric score (Figure 221). There were 60.9% nitrate tolerant individuals (18 taxa) and one nitrate intolerant taxon (prong-gilled mayfly, Leptophlebiidae) which comprised of less than 1% of the individuals in the sample. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP MIBI. Elevated nitrate is a stressor to the impaired biological community in Whitewater Creek.

Table 181. Macroinvertebrate metrics that respond to nitrate stress in Whitewater Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM057 (2011)	**1**	**0**	**0**	**3.01**	**1**	18	**60.9**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.88*	*2.58*	*19.4*	*55.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Dissolved Oxygen

In July 2009, there were two midday DO measurements below the standard of 5 mg/L at station S004-877. The DO exceedances were 4.48 mg/L on July 14 at 11:55AM, and 4.94 mg/L on July 28 at 11:30AM. There were no other exceedances out of the 24 synoptic measures collected at station S004-877. There were some elevated DO measurements in April and early May of 2009, however temperatures were cool (less than 17°C) enabling for higher amounts of dissolved oxygen. An YSI sonde was deployed in 2013 from July 25 to August 7, with no measures below the standard (7.55-9.06 mg/L) and a daily DO flux of approximately 1 mg/L. As stated in the nitrate section, 2009 was a dry year compared to normal. The dates that the DO was below the standard the Cannon River in Morristown (station 39091001) was less than one cfs. Dry conditions and low flow likely influenced the July 2009 data points. There was no BOD data available for this reach.

Station 11LM057 had 29 macroinvertebrate taxa collected in the 2011 sample. There were three low DO intolerant taxa, two low DO very intolerant taxa, and four tolerant low DO taxa (2.2% individuals; Table 182). There were six EPT taxa that comprised of 47.9% of the individuals present. Stations within the Southern Forest Streams GP class that are meeting the biocriteria average 10.2 EPT taxa. The DO TIV station score was 6.8, just above the median for the class (6.75), and below the average for stations meeting the MIBI (7.04). Similarly, although the fish are not impaired, the DO TIV score was 6.5, also in the least sensitive quartile to low DO for warmwater stations in the Cannon River Watershed.

It would be advantageous to collect additional DO information under low flow and low precipitation conditions similar to that of July 2009. With the presence of very DO intolerant macroinvertebrate taxa and metrics indicating potential DO stress along with other metrics indicating sufficient DO, low DO and DO flux are inconclusive as stressors to the macroinvertebrate community.

Table 182. Macroinvertebrate metrics that respond to low DO stress in Whitewater Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
11LM057 (2011)	**29**	**6**	**7.9**	**6.8**	**3**	4	2.2
Southern Forest Streams Average	*41.3*	*10.2*	*7.1*	*7.04*	*6.51*	*5.57*	*13.99*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

Phosphorus

At station S004-877, there were 27 samples of TP from 2009 to 2011 and 2013. The maximum TP was 0.669 mg/L (August 25, 2009). The average TP of the 27 samples was 0.276mg/L, over double the draft river nutrient criteria for the central region (0.1 mg/L). Of the 27 samples, 24 were greater than the draft standard (88.9%). The highest TP measured was in the late summer months (Figure 223). Although only

three data points existed with both TSS and TP analyzed, the potential relationship was evaluated (Figure 224) and found that there was elevated TP with low TSS concentrations. In 2009, TP concentrations were much higher than samples taken during the other years, likely due to the low flow conditions. The 2013 TP data may be skewed low due to inaccurate lab methodologies. The 2013 samples, although reported potentially lower than actual conditions, were still greater than the central region draft nutrient criteria.

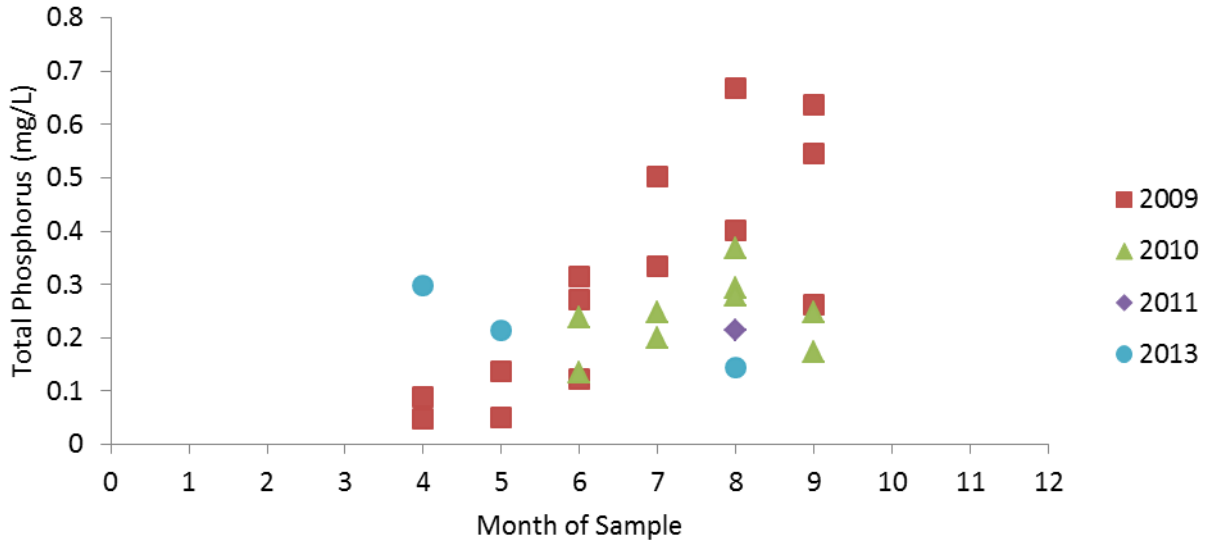


Figure 223. Total phosphorus concentrations in Whitewater Creek by month sampled, 2009 – 2011 and 2013

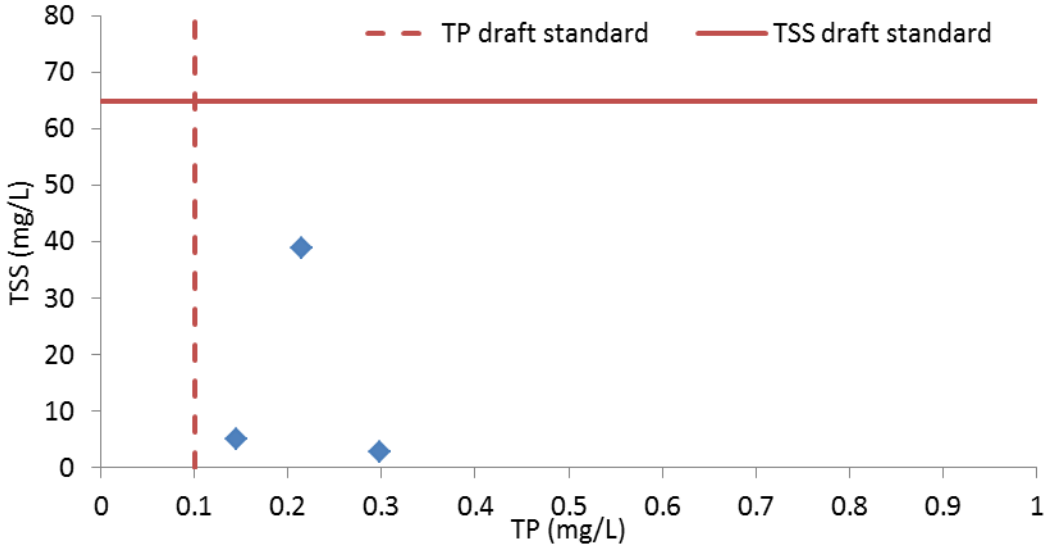


Figure 224. TSS and TP relationship in Whitewater Creek (2013)

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to be considered impaired for excess nutrients. There was no BOD collected on this reach and there was no record of elevated DO flux. Chlorophyll-a was sampled 23 times in 2009 and 2010. The range in concentrations was from less than 1 µg/L to 29 µg/L. The draft river nutrient criterion for chlorophyll-a is 18 µg/L. There were four samples greater than the criteria all taken in 2009 (May 5, June 2, July 28, and

September 29). The average chlorophyll-a in 2010 was slightly greater than 2 µg/L (nine samples). The average in 2009 was 11.6 µg/L.

At station 11LM057, four of the six metrics responded negatively as expected with river eutrophication stress (Table 183). The macroinvertebrate taxa count was considerably lower at station 11LM057 compared to similar stations that are meeting the biocriteria. There was only one less collector-gatherer taxon than that found in the similar stations meeting the biocriteria. The number of intolerant taxa and the percentage of tolerant taxa metrics performed better than similar stations. There were two taxa of scrapers which comprised of 10.5% of the sample. The average of similar station meeting the biocriteria is 4.4 scraper taxa and 10.2%. The scraper abundance is not suggestive of excess periphyton.

Although the fish community is not impaired, it still responds to stressors and can inform the SID process. Similar to the macroinvertebrate community, four of the six metrics responded negatively as expected with river eutrophication (Table 184). The percentage of darters and the percentage of simple lithophilic spawners were reduced compared to similar fish communities that are meeting the biocriteria. The percentage of sensitive fish individuals was reduced in Whitewater Creek, but was near the average of similar stations meeting the biocriteria. Fish taxa count and the percentage of intolerant individuals was greater than the average of similar stations meeting the biocriteria.

Table 183. Macroinvertebrate metrics that respond to TP and response variables in Whitewater Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPTCh	Intolerant2Ch	Tolerant2ChTxPct
11LM057 (2011)	**29**	**3**	**14**	**6**	3	65.5
Southern Forest Streams Average	*41.3*	*6.0*	*15.0*	*10.2*	*0.5*	*75.2*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 184. Fish metrics that respond to TP and response variables in Whitewater Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
11LM057 (2011)	**6.1**	**7.9**	**20.2**	**87.7**	12	6.1
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*	*1.4*
Expected response to stress	↓	↓	↓	↑	↓	↓

With elevated TP and some elevated chlorophyll-a, in-stream productivity changing the algal dynamics and food resources may be playing a role in the biological communities in Whitewater Creek. Although with a lack of BOD data and measured DO flux response uncertainty exists whether the elevated TP is leading to changes in aquatic life. However there are some indications that this may not be a consistently present stressor, but rather potentially episodic during low flow situations. Currently elevated TP and response variables are inconclusive as stressors in Whitewater Creek. Elevated TP is high enough to cause an increase in algal growth which can affect aquatic life through changes in the DO regime and food resources. Currently this does not appear to be happening; however the conditions are right to cause this chain reaction. Efforts should be undertaken to reduce TP throughout Whitewater Creek Watershed. Toners Lake, in the upstream portion of Whitewater Creek, is impaired for nutrients and may be one source of TP. Other influences of TP may include ditches with stagnant or slow moving water, and some remaining wetlands. The sources of excess TP should be further identified in Whitewater Creek.

pH

The standard for class 2B streams is 9.0 as a maximum for pH. At station S004-877, 2 out of 24 field measurements were above the standard, 9.01 (May 12, 2009) and 9.30 (April 21, 2009). A YSI sonde was deployed in 2013 and had pH levels ranging from 7.84 to 8.16. EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. An increase in pH can lead to higher susceptibility to other stressors (CADDIS, 2014). Elevated pH can arise due to eutrophication and increased productivity.

Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (CADDIS 2103). In Whitewater Creek, there were seven Perciformes taxa present (17.5% of the individuals), which was above average for the watershed.

Levels of pH between 9.5 and 10 causes reduced emergence of some stoneflies. At station 11LM057, there were no stoneflies (Plecoptera), but the lack of stoneflies in the sample could also be due to other factors, such as regional differences. It is difficult to pinpoint pH as a stressor in Whitewater Creek, but pH should be monitored to ensure that there are not further excursions above the standard. Elevated pH could be due to eutrophication; however the dates of the excursions above the standard are early in the year. It is difficult to know the cause of the elevated pH without further information. Elevated pH is inconclusive as a stressor in Whitewater Creek.

TSS/Turbidity

TSS has only been sampled four times at station S004-877; at the time of fish sampling in 2011 and during snowmelt, a rain event, and baseflow in 2013. TSS ranged from 2.8 to 39 mg/L. The highest TSS concentration was during the rain event on May 20, 2013. No samples were greater than the draft south region TSS standard of 65 mg/L. There were three secchi tube measurements paired with the TSS samples in 2013. The rain event sample measured at 34 cm and the other two measures were 100. From 2008 – 2011, the lowest transparency tube measurement was 21 cm out of 39 measurements, converted to secchi tube measurements; no measurement was less than the 10 cm standard of the draft south TSS region. Overall, the limited data does not support elevated TSS.

The macroinvertebrate metrics indicate a negative response to elevated TSS stress (Table 185). There was a lack of stoneflies (Plecoptera) and a low relative abundance of collector-filterer individuals. The TSS index score was above the average of similar stations meeting the biocriteria. The TSS index score for Whitewater Creek was in the most tolerant quarter of the Southern Forest Streams GP stations. Additionally there were no taxa that are intolerant to TSS. The TSS tolerant taxa were not relatively high, but the TSS tolerant individuals comprised of 40.1% of the community, above that of the average of similar stations meeting the biocriteria.

The fish metrics that respond to elevated TSS showed a mixed response at TSS, leaning toward stress (Table 186). There were lower than expected percentages of benthic feeders, herbivores, and riffle dwelling fish. The percent of non-tolerant Perciformes and sensitive fish were slightly lower than the average of similar stations meeting the biocriteria. The TSS index score for the station (16.4) was also slightly more tolerant than that of similar stations meeting the biocriteria, but less than the average of all stations in the Southern Headwaters class (15.9). There were higher percentages of carnivores, non-tolerant Centrarchidae, intolerant and long lived fish. Overall, the fish community does not point strongly at TSS stress.

Whitewater Creek has limited data with few of the chemical data suggesting sustained concentrations of elevated TSS. The fish community, although not impaired, does not indicate TSS stress. The macroinvertebrate community indicates some potential stress, with no intolerant taxa and relatively high tolerance to elevated TSS. There are indications of sediment issues in the amount of embeddedness that was surveyed in 2011. Further discussion of physical habitat related sediment can be found in the next section, Lack of Habitat. At this time, elevated TSS cannot be concluded as a stressor to the macroinvertebrate community, but it also cannot be ruled out as a stressor making it inconclusive. Additional monitoring is needed to understand the suspended sediment dynamics in Whitewater Creek.

Table 185. Macroinvertebrate metrics that respond to TSS stress in Whitewater Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM057 (2011)	**10.2**	**0**	**18.1**	**0**	8	**40.1**
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*10.2*	*27.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 186. Fish metrics that respond to TSS stress in Whitewater Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RifflePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM057 (2011)	**21.1**	2.6	**13.2**	6.1	8.8	**12.3**	**13.2**	**6.1**	14.9	**16.4**
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.3*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Physical Habitat

At station 11LM057, the macroinvertebrates were sampled on undercut banks and overhanging vegetation; and snags, woody debris, and root wads. The total MSHA score was fair (54.3). The subcategory scores that received less than half of the available scores were land use, substrate, and channel morphology (Figure 225).

The surrounding land use was row crop. The left riparian width was wide and the right riparian width was narrow. There was heavy bank erosion at the time of fish sampling. Heavy shading was also noted. The reach had predominately run features (75%) with sand and silt substrate. Only 5% of the reach features were riffle with gravel and sand. There were greater than four substrate types available. There was moderate embeddedness noted during the assessment, and the water color was brown. There was evidence of excess sedimentation with predominantly silt banks. Cover was extensive with undercut banks, overhanging vegetation, deep pools, logs or woody debris, boulders and rootwads available. The reach had good depth variability, sinuosity, and pool to riffle width. Channel stability was low with fair channel development, with some indications of channel incision.

In 2013, CRWP conducted a longitudinal survey of habitat utilizing the MSHA, from the confluence with Waterville Creek upstream to nearly Minnesota State Hwy 60 (Figure 226). The results of the survey indicated better conditions than those found in 2011. Four of the five subcategory scores were lower in 2011 than any of the eight reaches that were surveyed in 2013. One possibility is that a high flow event could have flushed the system making some of the fine sediments that were present as bedded sediment move further downstream, as there was a considerable amount of fines in 2011, that do not appear present in 2013. There were also a greater percentage of riffle habitats in 2013 than in 2011. There may be excess stream bed instability, as indicated by these changes.

The percentage of macroinvertebrate clingers is within an expected range; however the number of clinger taxa (ClingerCh) was less than expected (Figure 227). There were seven taxa that cling in Whitewater Creek; less than the average number of clinger taxa in Southern Forest GP stations that scored greater than the biocriteria (12.9). Similarly the percentage of macroinvertebrate habitat groups were within expected ranges. Yet, there were only four taxa that sprawl (SprawlerCh). Similar stations that meet the biocriteria have an average of 10 taxa that sprawl. Taxa count overall was lower in Whitewater Creek, which may be in part due to lack of diverse habitat.

Although the fish community is not impaired, they can still inform us regarding present stressors. There was only one taxon that prefers riffles at station 11LM057, white sucker, which is fairly tolerant and considered a generalist. Out of 115 fish sampled, the number of simple lithophilic spawners was low, walleye (two), white sucker (15), and logperch (six) which comprised 20% of the fish community (31.3% is the average of similar stations meeting the biocriteria).

Despite the presence of woody debris (Figure 228), which was sampled, there remains a lack of clinger taxa. Embeddedness changed from 2011 to 2013, indicating moving bed sediment and likely instability. The lack of riffle habitat and stream bed instability for macroinvertebrates that cling is a stressor. The fish community compliments the macroinvertebrate community indicating that the quality of habitat is a stressor to the biological community.

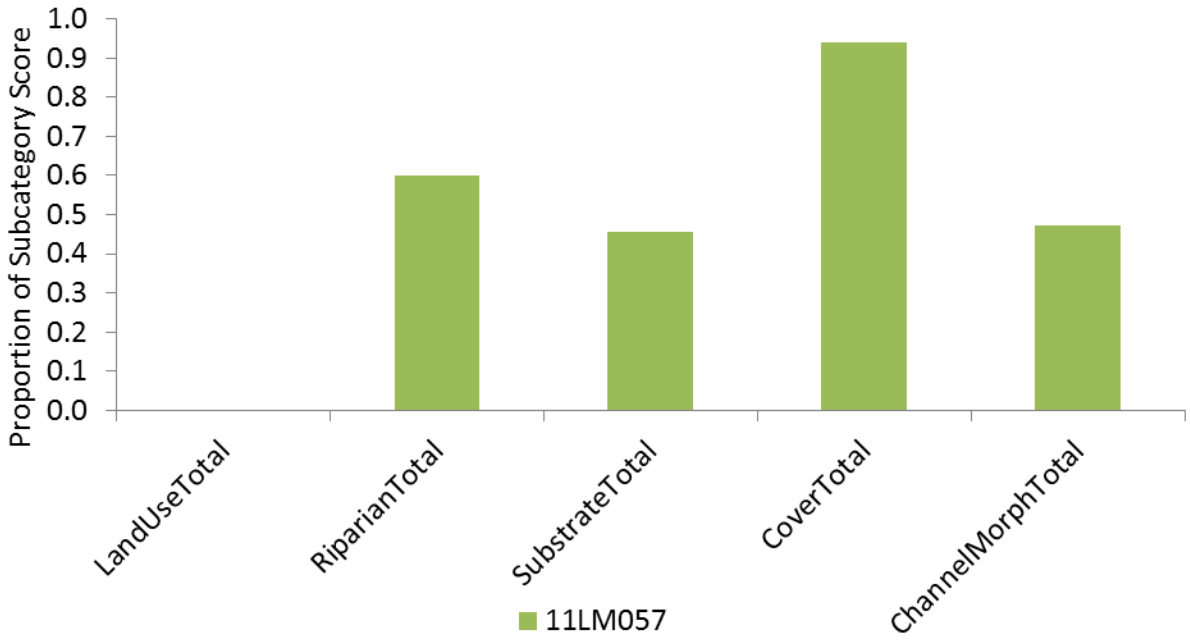


Figure 225. MSHA subcategory scores for station 11LM057, Whitewater Creek

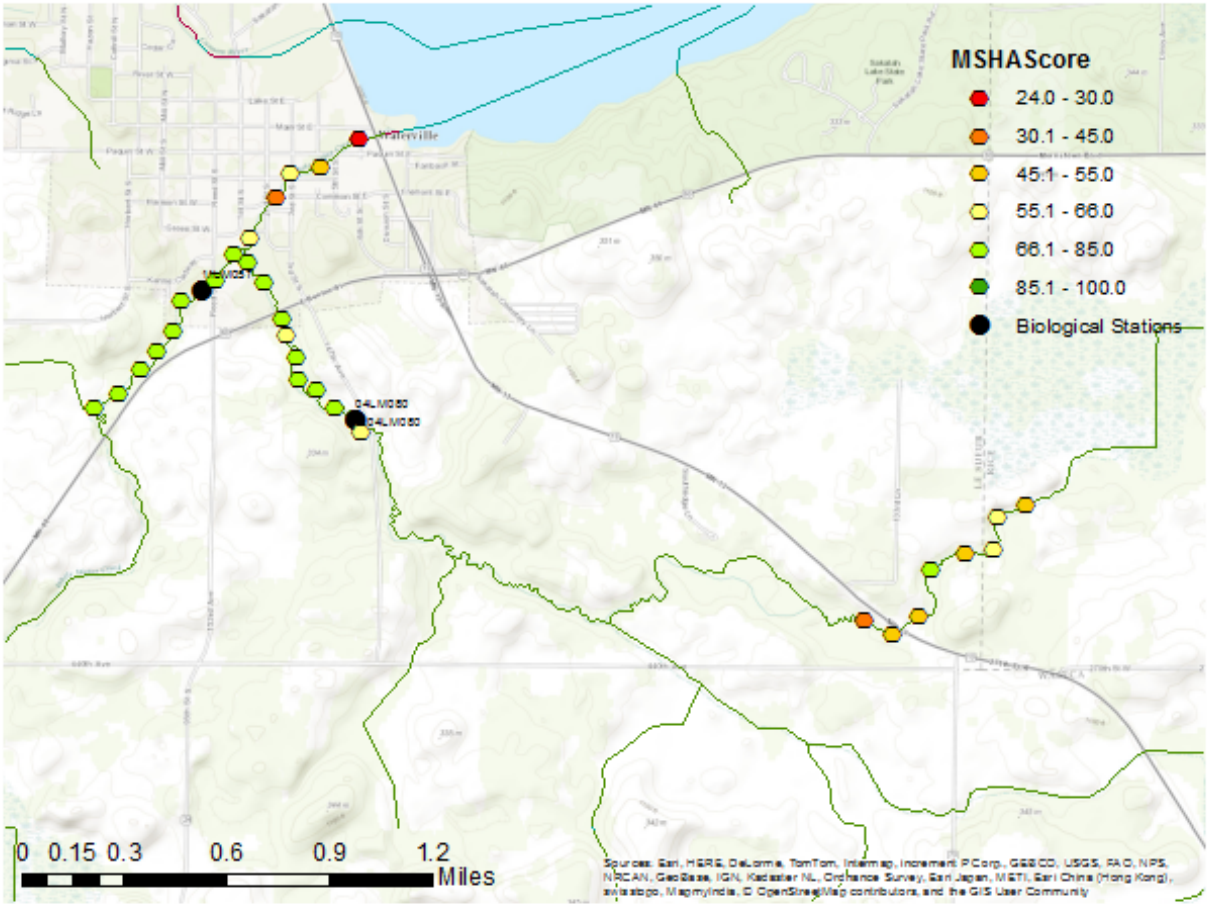


Figure 226. MSHA longitudinally in Whitewater Creek and Waterville Creek, 2013

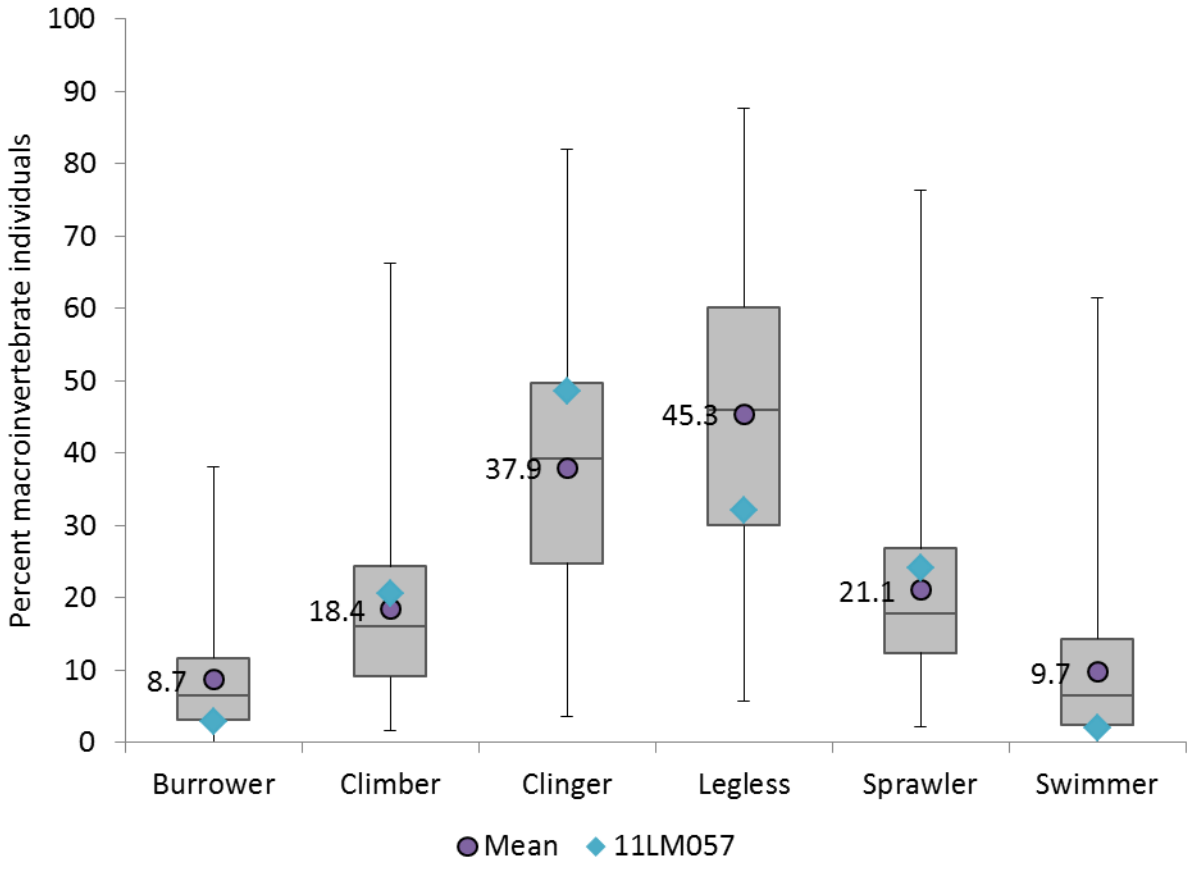


Figure 227. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP stations with MIBI greater than the threshold (46.8) mean of those stations, and metric values from station 11LM057

Figure 228. Photograph of station 11LM057 on August 23, 2013 showing woody debris

Fish Passage

Currently, there are no physical barrier concerns for the macroinvertebrate community. Of note, there is a culvert that may be too wide for low flow conditions at South Reed St. in Waterville, particularly on the downstream side of the culvert (Figure 229). It is uncertain if this is affecting fish passage under lower flows, but the fish community is not currently impaired. Additional observations may be warranted along with consideration of proper culvert placement for stream health in the future.

Figure 229. Fish swimming upstream through culvert on May 28, 2013

Conclusion

Whitewater Creek is impaired for lack of macroinvertebrate assemblage. In this highly altered watershed, the stressors contributing to the degradation of the macroinvertebrate community include nitrate and lack of habitat, in particular riffle habitat. Response variables associated with elevated TP, low DO and TSS are inconclusive as stressors. Elevated temperature is not a stressor.

The substrate and channel morphology could be improved in Whitewater Creek. Changes in hydrologic regime are likely contributing to the fair condition of the habitat. The lack of riffle habitat for macroinvertebrates that cling is a stressor, with only 5% riffle habitat available.

There is elevated TP during all flow conditions, with some elevated chlorophyll-a. There are some indications that this may not be a consistently present stressor, but rather potentially episodic during low flow conditions. Currently, elevated TP and response variable (chlorophyll-a) are inconclusive as a stressor.

There is some evidence during drought conditions, that low DO may be problematic, but the presence of very intolerant macroinvertebrate taxa and other metrics indicate sufficient DO. At this time, low DO and DO flux are not stressors to the macroinvertebrate community.

There were two measures of elevated pH in Whitewater Creek. This may indicated eutrophication and support potential changes in algal dynamics. It is difficult to pinpoint pH as a stressor in Whitewater Creek, but pH should be monitored to ensure that there are not further excursions above the standard.

Whitewater Creek has limited TSS data with few data points suggesting sustained concentrations of elevated TSS. The fish community, although not impaired, does not indicate TSS stress. The macroinvertebrate community indicates some potential stress, with no intolerant taxa and relatively high tolerance to elevated TSS. There are indications of sediment issues in the amount of embeddedness that was surveyed in 2011. At this time, elevated TSS is inconclusive as a stressor. Additional monitoring is needed to understand the suspended sediment dynamics in Whitewater Creek.

Currently, there are no physical barrier concerns for the macroinvertebrate community. Of note, there is a culvert that may be too wide for low flow conditions at South Reed St. in Waterville, particularly on the downstream side of the culvert. It is uncertain if this is affecting fish passage under lower flows, but the fish community is not currently impaired. Additional observations may be warranted along with consideration of proper culvert placement for stream health in the future.

Resources should be allocated towards improving habitat within Whitewater Creek, as well as reducing nutrient loading. Improvements to contributing waterways would also improve habitat and nutrient dynamics, ultimately improving the biological condition in Whitewater Creek.

4.7.2 Waterville Creek (560)

Waterville Creek (AUID 07040002-560) is a small tributary to the Cannon River near Waterville, Minnesota and is impaired for lack of macroinvertebrate assemblage and lack of fish assemblage. It is also impaired for *E. coli*, which will not be addressed in this report. Station 04LM080, in Waterville Creek, had two macroinvertebrate visits and two fish visits (2004 and 2011). On August 25, 2004, the macroinvertebrate IBI (MIBI) was 18 for the Southern Streams RR class. On August 4, 2004, the fish IBI (FIBI) was 35 for the Southern Headwaters class. On August 18, 2011, the MIBI score was 39.6, above the threshold (35.9) but within the confidence interval. On August 9, 2011, the FIBI score was 55 (threshold of 51). The 2011 samples for macroinvertebrates and fish resulted in better communities than the 2004 samples. The 2004 sample may have been impacted by the spring 2004 drought that affected much of Minnesota.

In 2004, the fish community sample collected only 13 individuals comprised of only four taxa (johnny darter, creek chub, northern pike, and white sucker). In 2011, the fish community sample collected many more fish and seven taxa. The sample was dominated by creek chub (78), with less than 10 fish each of white sucker, logperch, brassy minnow, fathead minnow, green sunfish, and johnny darter. There were no DELTs either sample. In 2004, the sample had low IBI metric scores for three metrics; although due to low numbers of individuals it may be indicative of the recovering drought conditions and adds noise to the anthropogenic stress on the fish community. In 2011, three IBI metrics were low: relative abundance of taxa that are detritivorous (NAWQA database; DetNWQTxPct), relative abundance of taxa that are generalists (GeneralTxPct), and taxa richness of sensitive species (Sensitive; Figure 230). Whitewater Creek had metric scores with a similar pattern as the 2011 sample of station 04LM080 in Waterville Creek, yet the scores were proportionally better in those three metrics.

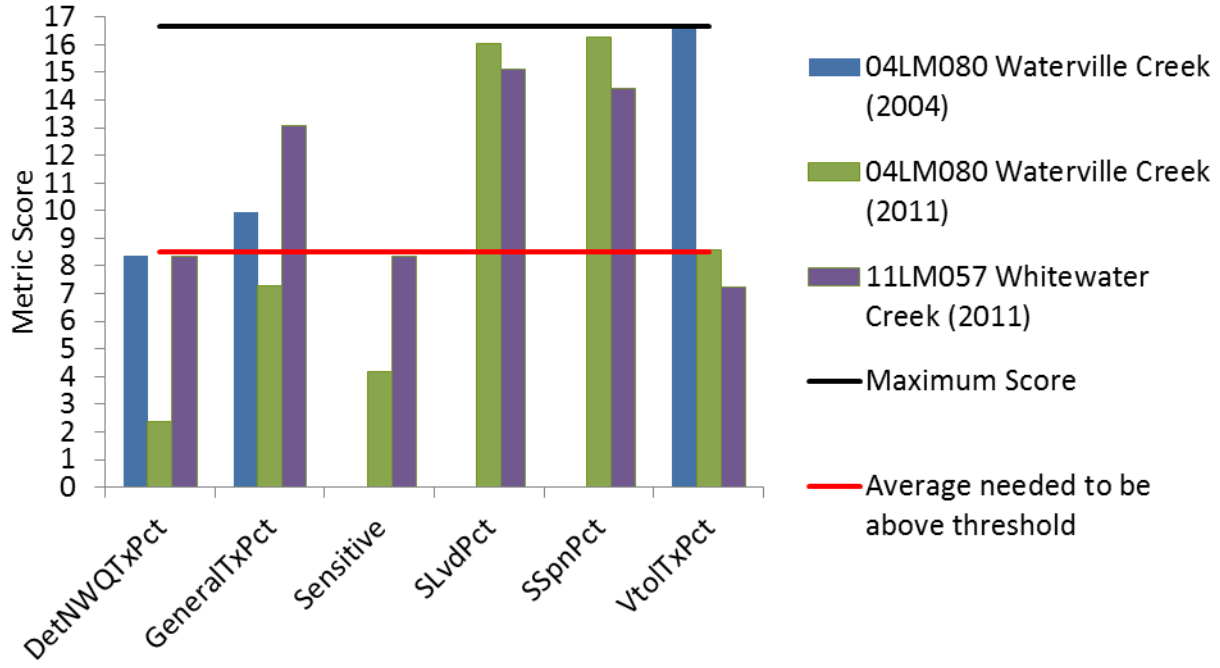


Figure 230. Fish metrics of the Southern Headwaters IBI for Waterville Creek, station 04LM080 and Whitewater Creek, station 11LM057

For the macroinvertebrate community, the dominant taxa in 2004 at station 04LM080 were both mayflies (*Heptagenia* and *Baetis*). In 2011, the dominant two taxa were midges and net-spinning caddisflies (*Rheotanytarsus* and *Cheumatopsyche*). All of the dominant taxa during both years were tolerant, with Minnesota tolerance values greater than six. In the Southern Streams RR IBI, the metrics that were consistently low both years were HBI-MN (a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart),taxa richness of Plecoptera (Plecoptera), taxa richness of predators (excluding chironomid predator taxa; Predator), relative percentage of taxa with tolerance values equal to or greater than six, using MN TVs (Tolerant2ChTxPct), and taxa richness of Trichoptera (Trichoptera; Figure 231).

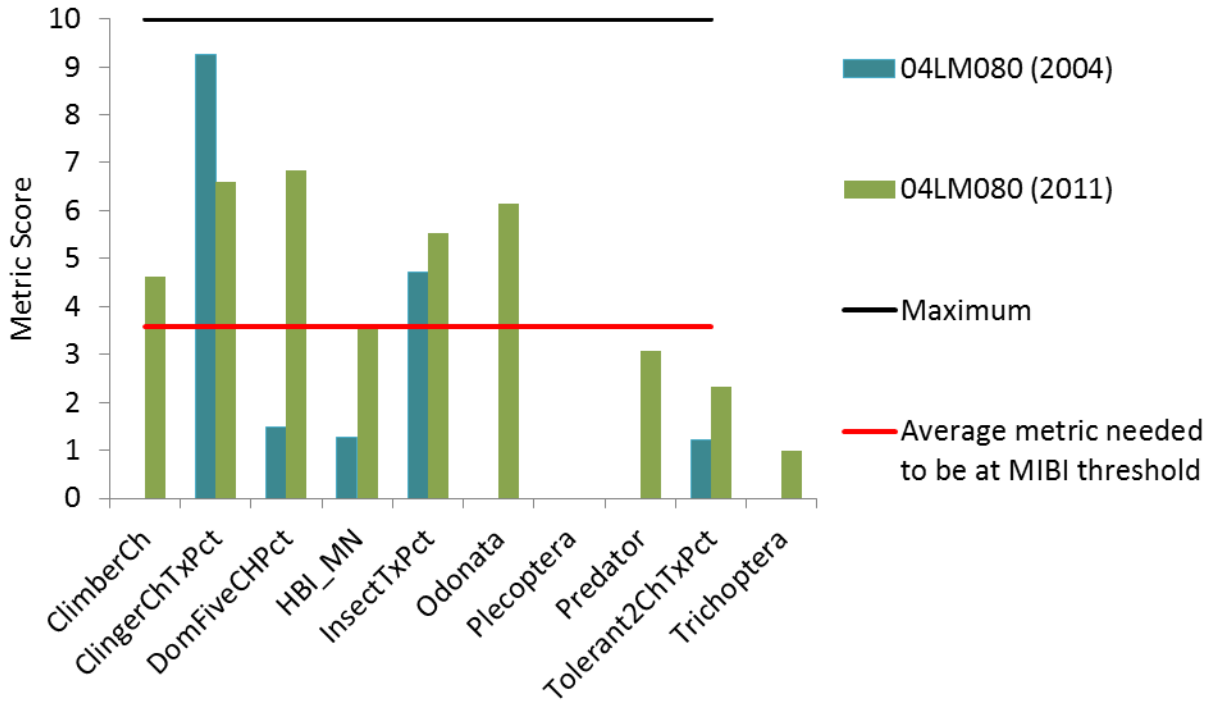


Figure 231. Macroinvertebrate IBI metrics of the Southern Streams RR class for Waterville Creek, station 04LM080

Temperature

Chemistry station S001-586 is co-located with the biological station 04LM080 on Waterville Creek. An YSI sonde was deployed in 2014 from August 11 - 22. The minimum temperature during that time was 16.6°C with a maximum temperature of 23.3°C. Seventy-four synoptic measurements were taken at stations S001-586 and S004-449 (downstream of confluence with Whitewater Creek at Hoosac Street) from dates in 2000, 2004, and 2007 – 2011. The maximum temperature recorded was 23.9°C (July 2, 2008). Waterville Creek is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in Waterville Creek.

Nitrate

Nitrate has been sampled 72 times in Waterville Creek spanning the years of 2004, and 2007-2011 (Table 187). The highest level of nitrate was 12.8 mg/L (April 13, 2008), but at the downstream station S004-449. At station S001-586, co-located with the biological station 04LM080, the highest nitrate level was 8.46 mg/L (June 22, 2010). There is no strong pattern in the data set showing seasonality to the elevated nitrate concentrations (Figure 232). The duration of elevated nitrate is unknown. It would be beneficial to collect samples throughout rain events (rising limb, peak, and falling limb) to understand the duration of elevated nitrate. Also, the sampling was done at two stations along Waterville Creek, but both stations were never sampled on the same day. It would be beneficial to sample longitudinally to understand the nitrate dynamics in Waterville Creek.

Table 187. Nitrate Data summary in Waterville Creek

Station	Year	Minimum	Average	Maximum	Number of Samples
S001-586	2004	8.2	8.2	8.2	1
S001-586	2009	<0.03	2.3	7.36	14
S001-586	2010	0.42	3.3	8.46	9
S001-586	2011	5.4	5.4	5.4	1
S004-449	2007	0.86	5.3	10.4	22
S004-449	2008	<0.2	6.2	12.8	15
S004-449	2009	0.22	3.6	12.5	10
All	All	<0.03	4.5	12.8	72

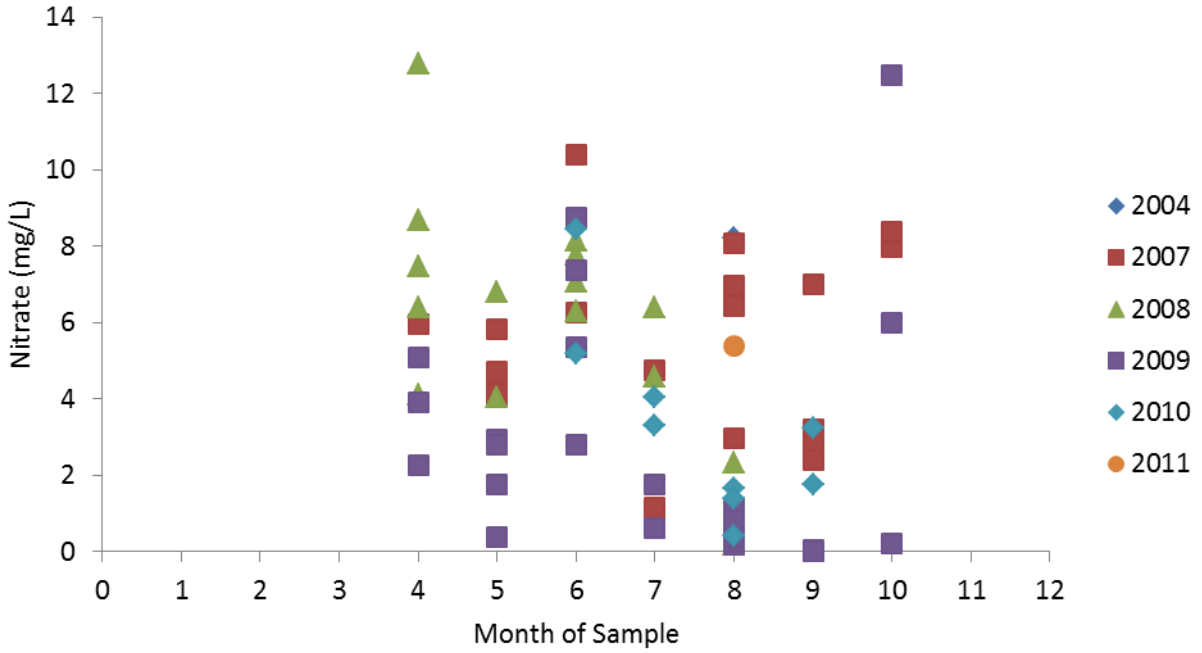


Figure 232. Nitrate concentrations by year and month in Waterville Creek

Fish lack a strong biological response in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. A quantile regression analysis of macroinvertebrate Southern Forest RR stations in Minnesota shows a 75% probability that if a stream has a nitrate reading of 18.1 mg/L or higher, the MIBI score will be below the threshold for that respective class. Waterville Creek has not had a nitrate sample that high to date.

Station 04LM080 had no intolerant taxa present (Table 188). The station had two and three Trichoptera taxa, which is reduced compared to expectations shown in Figure 231. Station 04LM080, each visit, had one nitrate intolerant taxon (prong-gilled mayfly, *Leptophlebiidae*). There were 13 and 21 nitrate

tolerant taxa, and nitrate tolerant macroinvertebrate individuals comprised 73.6 and 62.4% of the samples (2004 and 2011 respectively). At 78.2% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Streams RR (class 5) MIBI, and at 68.7% nitrate tolerant individuals there is a 50% probability of meeting the MIBI.

Nitrate is elevated in Waterville Creek, and further data collection could help understand the dynamics in this reach. The biological metrics indicate stress by nitrate including high percentages of nitrate tolerant macroinvertebrates. Nitrate is a stressor to the macroinvertebrate community.

Table 188. Macroinvertebrate metrics that respond to nitrate stress in Waterville Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
04LM080 (2004)	**2**	**1.2**	**0**	**3.87**	**1**	13	**73.6**
04LM080 (2011)	**3**	**0.7**	**0**	**3.11**	**1**	**21**	**62.4**
Southern Streams Average	*5.3*	*5.3*	*0.7*	*2.91*	*2.45*	*20.18*	*57.63*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

In Waterville Creek, there were 70 samples of TP collected from three stations: station S004-449 in 2007-2009, from station S001-586 in 2009-2010, and station 04LM080 in 2004 and 2011. Stations 04LM080 and S001-586 are collocated above the confluence with Whitewater Creek and station S004-449 is downstream of the confluence with Whitewater Creek. The maximum TP was 0.965 mg/L (August 26, 2009). The average TP of the 49 samples was 0.245mg/L, over double the draft river nutrient criteria for the central region (0.1 mg/L). Of the 70 samples, 57 were greater than the standard (81.4%). The highest TP is in the late summer months (Figure 233). Orthophosphate (OP) ranged from 0.018 to 0.699 mg/L in Waterville Creek. The highest OP was on the same date as the highest TP. The TSS and TP relationship was analyzed (Figure 234) and found that there was elevated TP with low TSS concentrations. In 2009, TP concentrations were much higher than samples taken during the other years, likely due to the low flow conditions. The summer month average for 2009 was 0.573 mg/L TP. The June through September averages were still high in 2007 and 2008 (0.326 and 0.201 mg/L).

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to result in an aquatic life impairment based on elevated nutrients. Chlorophyll-a was sampled 23 times during 2009 and 2010. The highest level was 22 µg/L on May 5, 2009, but TP was quite low at 0.077 mg/L on the same date, likely bound up in the algal community. All other levels of chlorophyll-a were well below the draft standard of 18 ug/L. BOD was at or above 2.0 mg/L in 14 of 37 samples collected during 2007 and 2008. DO was measured by an YSI sonde from August 11 – 22, 2014, with no

DO less than 5 mg/L and DO flux was less than 2 mg/L. The elevated BOD without low DO or DO flux may be due to the data collecting in differing years.

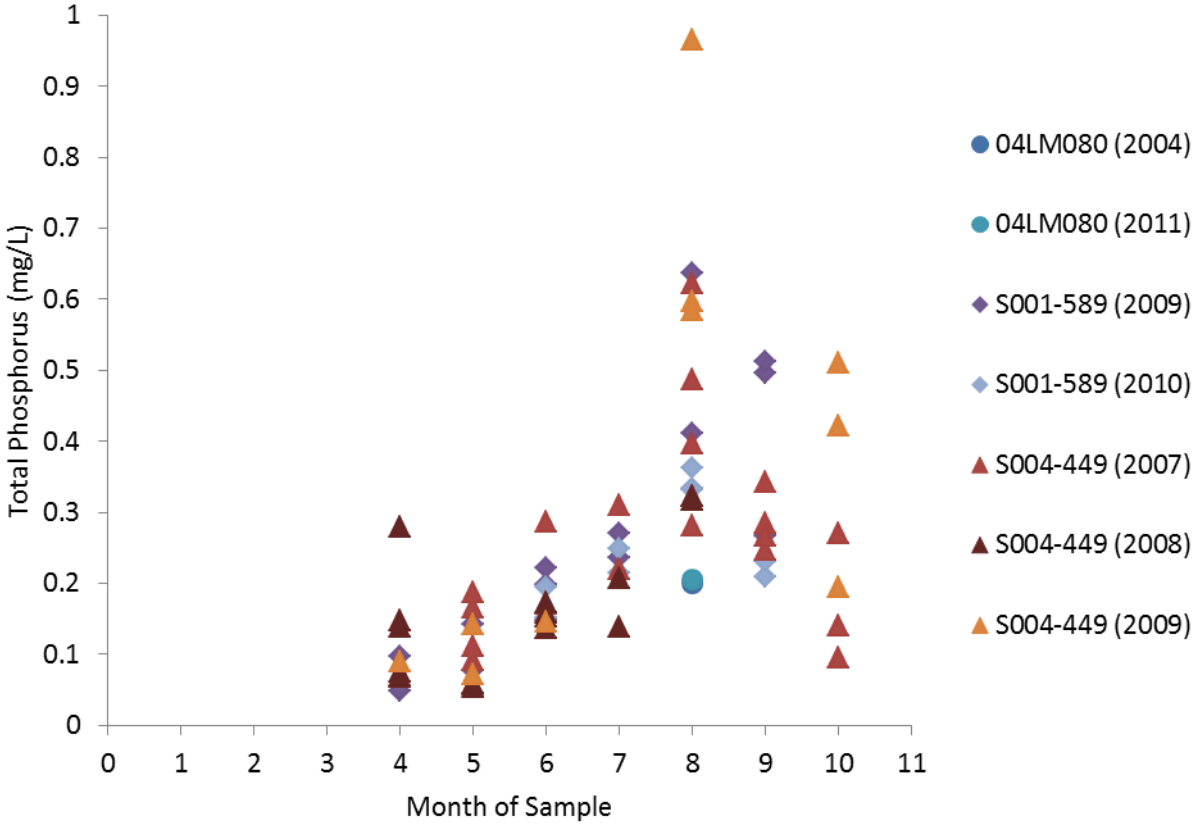


Figure 233. Total phosphorus concentrations in Waterville Creek by month sampled, 2004, 2007 – 2009 and 2011

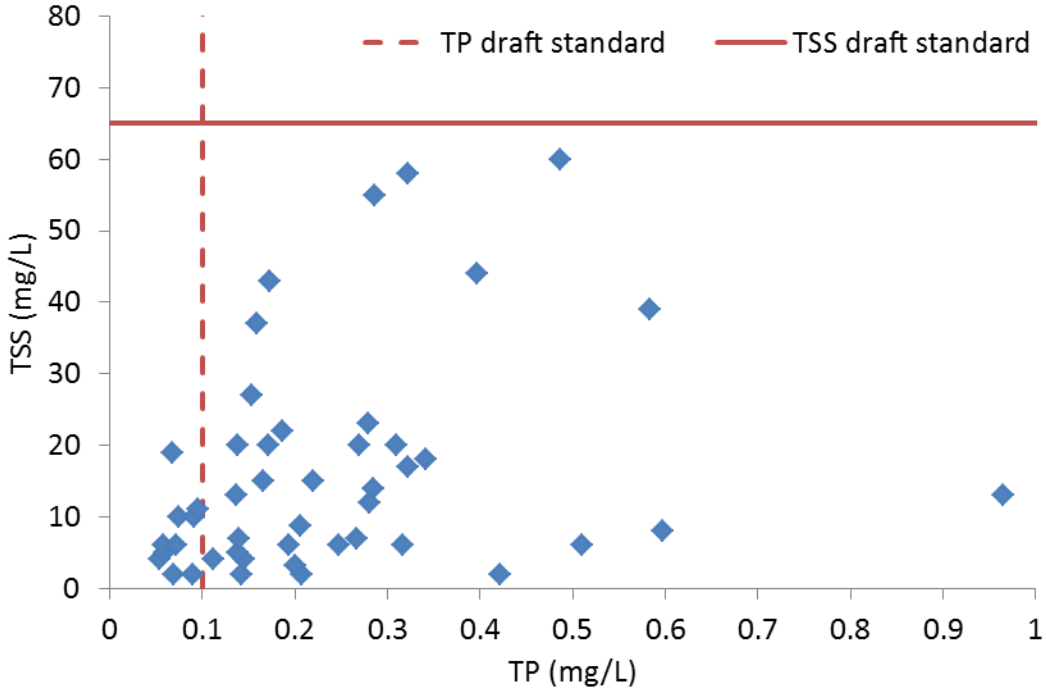


Figure 234. TSS and TP relationship in Waterville Creek (2004, 2007-2009, 2011)

In Waterville Creek, five of the six metrics responded negatively as expected with river eutrophication stress in 2011 and all six showed expected response to stress in 2004 (Table 189). The macroinvertebrate taxa count was considerably lower compared to similar stations that are meeting the biocriteria, particularly low in 2004. The number of collector-gatherer taxa was slightly above average of similar stations meeting the biocriteria in 2011. The percentage of tolerant taxa was considerably higher in Waterville Creek, with both visits resulting in no intolerant taxa.

Similar to the macroinvertebrate community, four of six fish metrics responded negatively as expected with river eutrophication (Table 190). In 2004, there were only 13 individuals surveyed which likely skews the percentages, potentially inflating or reducing percentages due to the limited total fish. In 2011, the total number of fish individuals was greater (100). During the 2011 visit, both the percentages of intolerant and sensitive were greater than similar stations meeting the biocriteria. However, taxa count was still reduced, and the percentages of darters and simple lithophilic spawners were reduced, whereas the percentage of tolerant individuals was high, 92%.

TP and BOD are elevated in Waterville Creek. One chlorophyll-a sample was elevated, but under low flow conditions. Although there was elevated BOD, there was not elevated DO flux or low DO, which may be due to the temporal difference in datasets. The macroinvertebrate community is suggestive of nutrient stress and the fish community was comprised of fish found under elevated nutrient conditions. The nutrient levels in Waterville Creek should be reduced, particularly under low flow conditions. Elevated TP and associated response variables are inconclusive as stressors in Waterville Creek. There is a high potential to see effects in the aquatic life. Currently the biological station is in heavy shade. If this shading is lost, the stream may show algal growth quickly. It is important reduce TP in this watershed.

Table 189. Macroinvertebrate metrics that respond to TP and response variables in Waterville Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
04LM080 (2004)	**25**	**4**	**11**	**8**	**0**	**88**
04LM080 (2011)	**35**	**4**	15	**8**	**0**	**82.9**
Southern Streams Average	*42.4*	*6.4*	*14.8*	*10.7*	*0.7*	*72.9*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 190. Fish metrics that respond to TP and response variables in Waterville Creek compared to the statewide average of visits meeting the biocriteria (*only 13 individuals were sampled skewing percentage results). Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
04LM080 (2004)*	**0**	38.5	**7.7**	38.5	**4**	**0**
04LM080 (2011)	7	**8**	**15**	**92**	**7**	7
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*	*1.4*
Expected response to stress	↓	↓	↓	↑	↓	↓

Dissolved Oxygen

There is limited DO data in Waterville Creek. In the years of 2004, and 2009 – 2011, DO was measured 16 times, with only one measurement prior to 9AM. None of the 16 measurements were below 6 mg/L. A longitudinal DO survey was completed August 11 and 12, 2014 with DO measurements ranging from 7.15 to 8.00 mg/L in the afternoon and 6.63 to 7.74 mg/L in the morning, prior to 9AM. Additionally, an YSI sonde was deployed at station 04LM080 from August 11 – 22, 2014 with DO that ranged from 6.33 to 9.2 mg/L; with no DO less than 5 mg/L and DO flux was less than 2 mg/L. BOD was at or above 2.0 mg/L in 14 of 37 samples collected during 2007 and 2008. The elevated BOD without low DO or DO flux may be due to the data collecting in differing years. It is unknown if the DO levels would have been different in 2007 and 2008 than in 2014.

The macroinvertebrate community had good DO station index scores of 7.6 and 7.3, in 2004 and 2011 respectively (Table 191). In 2004, there were eight low DO intolerant taxa, and in 2011 there were 11. There was even a higher presence of very intolerant to low DO taxa (five and seven taxa for 2004 and 2011). Less than 1% of the macroinvertebrate individuals were tolerant to low DO, with one taxon in 2004 and two taxa in 2011. Both overall taxa count and EPT taxa were reduced in Waterville Creek. In 2004, the percentage of EPT individuals was quite high (72.8%), but lower than average in 2011 (31.6%).

Table 191. Macroinvertebrate metrics that respond to low DO stress in Waterville Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
04LM080 (2004)	**25**	**10**	**7.91**	7.62	**8**	1	0.29
04LM080 (2011)	**35**	**8**	**7.14**	7.25	11	2	0.35
Southern Streams Average	*42.4*	*12.1*	*7.1*	*7.24*	*9.41*	*4.17*	*8.84*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

Fish abundance can decrease with low DO levels. In 2004, only 13 fish individuals were surveyed. In 2011, the number of fish per meter was greater (0.63) than in 2004 (0.08), but still less than the average of stations in the Southern Headwaters fish class (1.72). The abundance of fish that mature later in life (MA>3) was 7.7% in 2004 and 8.0% in 2011, but they were comprised of tolerant fish. The fish community has moderate fish intolerance to DO with DO TIV scores of 6.9 in 2004 and 7.1 in 2011. The scores fall on either side of the median (7.08) for warmwater stations in the Cannon River Watershed.

DO is currently not a stressor in Waterville Creek. There is no chemical evidence and mixed biological evidence to suggest DO related stress. BOD is elevated and it may be important to monitor BOD with DO to ensure that no exceedances or stress are incurred in Waterville Creek.

TSS/Turbidity

In Waterville Creek, there were 46 samples of TSS at station S004-449 averaging 21.5mg/L (2007-2009), but only two at station S001-586 (co-located with the biological station 04LM080), both less than 10 mg/L (2004 and 2011). Only two of the samples at station S004-449 were greater than the draft TSS standard of 65 mg/L for the south region (4.2%). Transparency data was collected during 2000, 2007 – 2011 at both chemistry stations in Waterville Creek, but never on the same date. The lowest transparency tube measurement was 13.7 cm out of 84 measurements, converted to secchi tube measurements, no measurements were less than the 10cm draft standard of the south TSS region. Overall, the chemical data does not strongly suggest TSS as a stressor; however there is limited data near the biological station. Both fish visit TSS analysis resulted in low values 3.2 mg/L (2004) and 8.8 mg/L (2011) and were noted as having normal flows.

The macroinvertebrate metrics that respond to elevated TSS stress show mixed results, particularly between the two years (Table 192). There was a lack of stoneflies (Plecoptera) both years, and reduced collector-filterer individuals in 2004. In 2004, the TSS index score was above the average of similar stations meeting the biocriteria, and below average in 2011. Both visits resulted in no taxa that are intolerant to TSS. The TSS tolerant taxa were not relatively high, but the TSS tolerant individuals comprised 36.6 and 50.1% of the community, above the average of similar stations meeting the biocriteria. The 2004 survey also had 30.1% TSS very tolerant macroinvertebrates.

The fish community also has a mixed response to elevated TSS stress and was variable between the two years (Table 193). Only 13 individuals were sampled in 2004 which may explain some of the differences in the percentages between the years. Both visits had no non-tolerant Centrarchidae. Relative abundance was equivalently low for herbivores, riffle dwellers, and simple lithophilic spawners. The remaining metrics that respond to elevated TSS had responses that differed between visit years. In 2011, there were an absence of long lived and a low abundance of non-tolerant Perciformes. In 2004, the TSS index score was less than the average of similar stations meeting the biocriteria, indicating more sensitivity to elevated TSS. In 2011, the TSS index score was greater than that same average. Overall, the fish community does not point strongly at TSS stress.

Waterville Creek has limited data with few of the chemical data near the biological station 04LM080 suggesting sustained concentrations of elevated TSS. Elevated TSS does appear to be an issue at the downstream station S004-449. The fish community indicates mixed response to elevated TSS stress. The

macroinvertebrate community is also mixed with no intolerant taxa and relatively high tolerance to elevated TSS in 2004. Additionally, the temporal aspect of the mixed biological results also further complicates, as the macroinvertebrate community has a higher TSS index score in 2004, but the fish community has a higher TSS index score in 2011. At this time, elevated TSS cannot be concluded as a stressor to the macroinvertebrate and fish communities, but it also cannot be ruled out as a stressor. Additional monitoring is needed to understand the suspended sediment dynamics in Waterville Creek.

Table 192. Macroinvertebrate metrics that respond to TSS stress in Waterville Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
04LM080 (2004)	**11.0**	**0**	**23.5**	**0**	6	**50.1**
04LM080 (2011)	39.6	**0**	16.8	**0**	7	**36.6**
Southern Streams Average	*25.3*	*0.6*	*17.1*	*2.6*	*11.3*	*34.0*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 193. Fish metrics that respond to TSS stress in Whitewater Creek compared to the statewide average of visits meeting the biocriteria (*only 13 individuals were sampled skewing percentage results). Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RifflePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
04LM080 (2004)*	46.2	**0**	**7.7**	**0**	23.1	38.5	**7.7**	**0**	**7.7**	14.1
04LM080 (2011)	**16.0**	**0**	**8**	7	**0**	**8**	**8**	7	**8**	**16.0**
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.3*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

At station 04LM080, the MSHA total score was fair in 2004 and 2011 (65.8 and 57.65). The subcategory scores were similar between the two years as well, with low land use and reduced substrate, cover, and channel morphology scores (Figure 235). Both years the macroinvertebrate samples were collected from riffle, run, and rock, and snag, woody debris, and root wad habitats.

At the time of both fish visits, the surrounding land use was a mixture of forest, wetland, prairie, or shrub and row crop. The left side of the stream had an extensive riparian width while the right had a moderate or narrow width. In 2004, there was little bank erosion noted, and in 2011, there was little to moderate bank erosion. Both years had presence of heavy shade.

In 2004, 50% of the reach was comprised of run features with sand and gravel substrate. The riffle features, 10% of the reach, had gravel and cobble substrates and the pool features, 40% of the reach, had sand substrate. In 2011, riffle features comprised 15% of the reach and run features 65%. Gravel was only noted in the riffle features, other features had sand, or sand and silt. There was moderate embeddedness noted both years and greater than four substrate types available. In 2004 at the time of fish sampling the water was clear, and in 2011, the water was stained. Although there was a variety of cover types, they were sparse both years. Undercut banks were present in 2011 and were not in 2004. The reach had good depth variability and pool to riffle width. The sinuosity was fair - good with moderate channel stability and good channel development.

In general, the macroinvertebrate metric percentages are within an expected range for the habitat metrics (Figure 236). In 2004, the number of taxa considered climbers was low (with a MIBI metric score of zero), but moderate in 2011 (above the average metric score needed to be at the threshold; Figure 231). The most dominant taxa in the two samples were *Heptagenia* (a very tolerant clinging mayfly) and *Baetis* (a tolerant swimming mayfly) in 2004, and *Rheotanytarsus* (a tolerant clinging midge) and *Cheumatopsyche* (a very tolerant clinging net-spinning caddisfly) in 2011. In other words, clingers appear decent, but are tolerant. Tolerant macroinvertebrates dominated the communities at station 04LM080 in 2004 and 2011 (98.3 and 82.2%).

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat is diminished. The fish community had only one taxon that prefers riffles at station 04LM080 in both 2004 and 2011, the white sucker, which is fairly tolerant and considered a generalist. There was only one white sucker in 2004, while in 2011 there were eight white sucker and seven logperch. These fish were the simple lithophilic spawners found at the station, comprising 7.7 and 15% of the community respectively. The average percentage of simple lithophilic spawners at Southern Headwater fish class stations in the Cannon River Watershed was 27.3%. In 2004, station 04LM080 had 38.46% benthic insectivores (johnny darters), but only due to the low number of total fish caught in 2004 (13 fish). In 2011, there were only 8% benthic insectivores (seven logperch and one johnny darter). Each year, the abundance of darter, sculpin, and round bodied suckers were the same as the benthic insectivores at station 04LM080.

Generally it appears this reach has some bed and bank instability, excess sedimentation, and channel over widening (Figure 237). Upstream of the station there are active pastures with significant bank erosion on the outside bends (Figure 238) and minimal vegetation to hold the banks stable (Figure 239). The lack of habitat is a stressor to the fish and macroinvertebrate communities. Additional efforts could be made to quantify the amount of erosion occurring in the upstream reaches of Waterville Creek that are contributing to the bed instability and excess sedimentation.

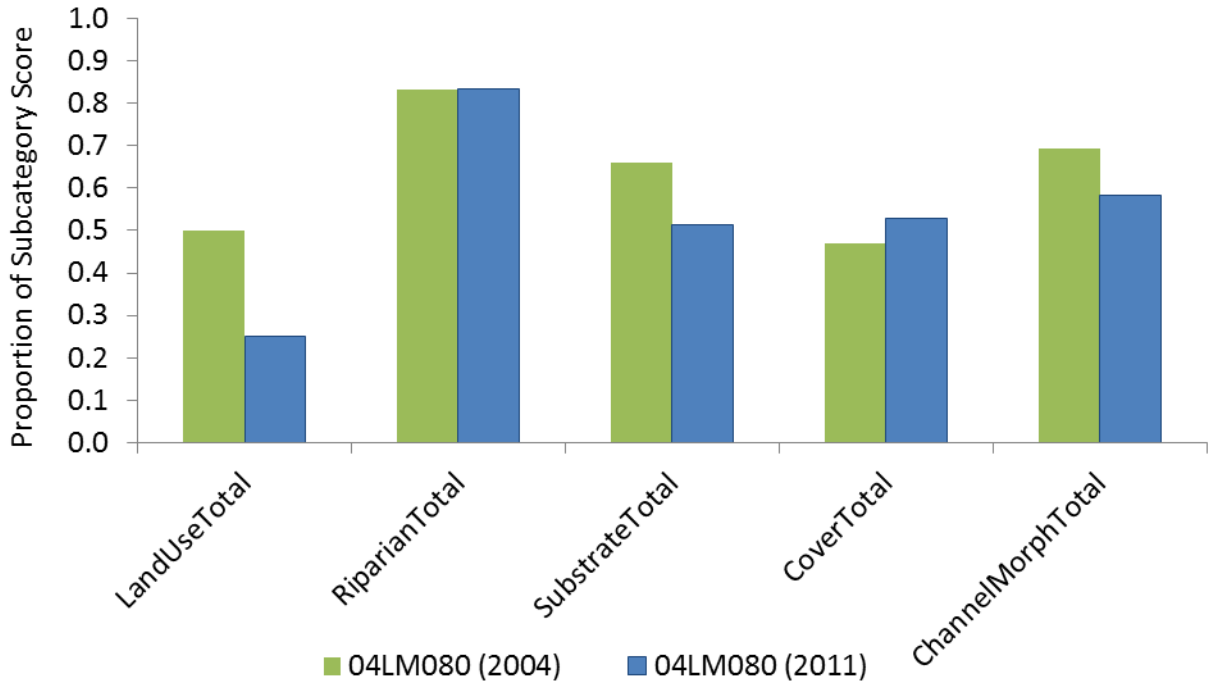


Figure 235. MSHA subcategory scores for station 04LM080, Waterville Creek

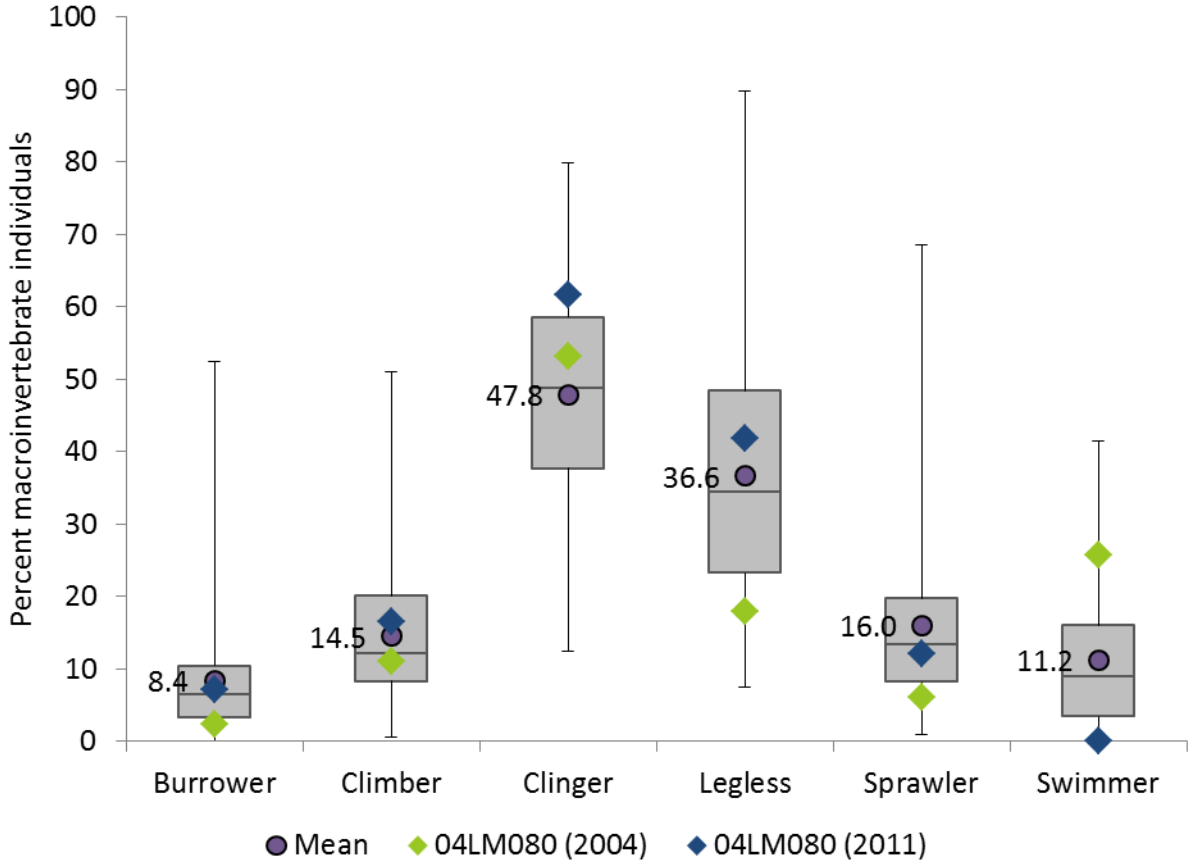


Figure 236. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Streams RR stations with MIBI greater than 35.9 (threshold), mean of those stations, and metric values from station 04LM080

Figure 237. Station 04LM080, middle of station looking downstream, August 9, 2011

Figure 238. Riparian corridor along Waterville Creek upstream of station 04LM080 from 147th Ave., April 23, 2014

Figure 239. Upstream (left) and downstream (right) at State Highway 13, April 23, 2014

Fish Passage

Currently, there are no known physical barrier concerns for the biological community.

Conclusion

Waterville Creek is impaired for lack of fish and macroinvertebrate assemblages. Stressors in Waterville Creek include nitrate and lack of habitat. The watershed is also highly altered likely contributing to the lack of habitat conditions and elevated nutrients.

Nitrate is elevated in Waterville Creek. Further data collection could help understand the dynamics. There are biological indications that nitrate is stressing the macroinvertebrate community.

Total phosphorus is elevated in Waterville Creek with the highest concentrations in the late summer months. BOD is also elevated as a response variable to TP. One chlorophyll-a sample was elevated, but under low flow conditions. Of the macroinvertebrate data, five of the six metrics responded negatively as expected with river eutrophication stress in 2011, and all six showed expected response to stress in 2004. The nutrient levels in Waterville Creek could be reduced and it is ripe for stress, particularly under low flow conditions. Elevated TP and associated response variables are stressors in Waterville Creek.

DO is currently not a stressor in Waterville Creek. There is no chemical evidence and mixed biological evidence to suggest stress, but BOD is elevated and may be important to monitor BOD with DO to ensure that no exceedances or stress are incurred in Waterville Creek.

Waterville Creek has limited TSS data near the biological station 04LM080 suggesting sustained concentrations of elevated TSS. Elevated TSS does appear to be an issue at the downstream station S004-449. The fish community indicates mixed response to elevated TSS stress. The macroinvertebrate community is also mixed with no intolerant taxa and relatively high tolerance to elevated TSS in 2004. At this time, elevated TSS cannot be concluded as a stressor to the macroinvertebrate and fish communities, but it also cannot be ruled out as a stressor. Additional monitoring is needed to understand the suspended sediment dynamics in Waterville Creek.

Generally it appears this reach has some bed and bank instability, excess sedimentation, and channel over widening. The lack of habitat is a stressor to the fish and macroinvertebrate communities. Currently, there are no known physical barrier concerns for the biological community.

Improvements to contributing altered waterways would also improve habitat and nutrient dynamics ultimately improving biological condition in Waterville Creek.

4.7.3 Devils Creek (577)

Devils Creek (AUID 07040002-577) is a small tributary to the Cannon River. The small creek is downstream of Cedar and Caron Lakes, both of which are impaired for nutrients. Devils Creek is impaired for lack of macroinvertebrate assemblage. It is also impaired for *E. coli*, which will not be addressed in this report.

Station 11LM045 had two samples in 2011, with very similar results. The MIBI scores were 20.4 and 29.8 for the Southern Forest Streams GP class. The macroinvertebrate community is a mix of wetland and stream species. The majority of metrics in the MIBI scored lower than the average metric score needed to be at the threshold. Only two metrics scored above the average score for one of the samples

(Collector-filtererPct and TrichopteraChTxPct). The lowest scoring metrics were (DomFiveCHPct), (Intolerant2Pct), (POET), (PredatorCh), (TaxaCountAllChir), and (TrichwoHydroPct). The five dominant taxa were *Polypedilum* (non-biting midges), *Simulium* (blackflies), *Rheotanytarsus* (non-biting midges), Oligochaeta (worms), and Hydropsychidae (net-spinning caddisflies) or *Micropsectra* (non-biting midges).

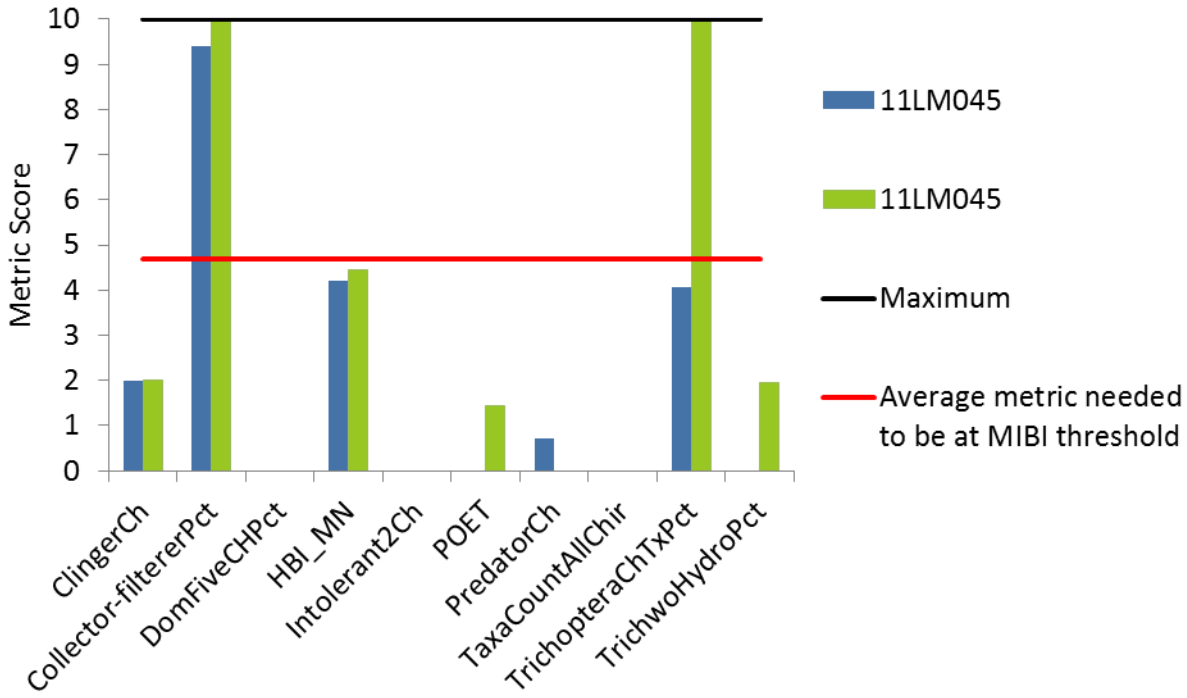


Figure 240. Macroinvertebrate metrics of the Southern Forest Streams GP IBI for Devils Creek, station 11LM045

Temperature

Chemistry station S004-845 is co-located with the biological station 11LM045 on Devils Creek. An YSI sonde was deployed in 2013 from August 7-21 and in 2014 from August 5-11. The minimum temperature during that time was 16.8°C (2013) and 20.7°C (2014), with a maximum temperature of 23.7°C (2013) and 24.5°C (2014). Thirty-one synoptic measurements were taken at station S004-845 from 2008, 2010, 2011, and 2014. The maximum temperature recorded was 23.5°C (August 31, 2010). Devils Creek is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in Devils Creek.

Nitrate

At collocated stations S004-845 and 11LM045, nitrate has been sampled a total of 22 times in Devils Creek spanning the years of 2009-2011, and 2014. The highest level of nitrate was 6.2 mg/L (April 3, 2014; Figure 241). There is no strong pattern in the data set showing seasonality to the elevated nitrate concentrations. The duration of elevated nitrate is unknown. It would be beneficial to collect samples throughout rain events (rising limb, peak, and falling limb) to understand the duration of elevated nitrate.

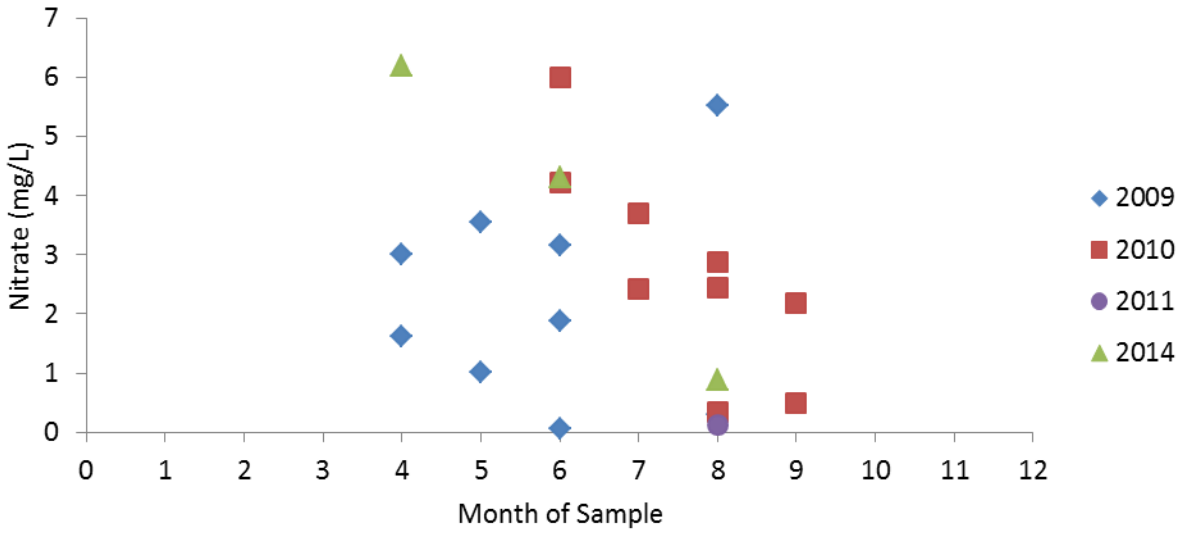


Figure 241. Nitrate concentrations by year and month in Devils Creek

The macroinvertebrate metrics that correspond with nitrate stress show a fairly consistent response as expected (Table 194). Station 11LM045 had four Trichoptera taxa and one Trichoptera taxon (Hydropsychid) in each of the samples. In Devils Creek, there was less than 1% non-hydropyschid caddisflies present in the sample with the greater Trichoptera richness. There were no intolerant taxa present, resulting in a low metric score (Figure 240). There were 60.1% and 57.7% nitrate tolerant individuals (five taxa) and no nitrate intolerant taxa. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. Over 50% of the survey was comprised of nitrate very tolerant individuals.

Elevated nitrate may be contributing to the impaired biological condition in Devils Creek. The chemical data is not particularly strong, but the biological data is suggestive of nitrate stress. At this time it is inconclusive if elevated nitrate is a stressor.

Table 194. Macroinvertebrate metrics that respond to nitrate stress in Devils Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM045 (2011)	**1**	**0**	**0**	**3.33**	**0**	5	**60.1**
11LM045 (2011)	**4**	**0.6**	**0**	**3.29**	**0**	5	**57.7**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.88*	*2.58*	*19.4*	*55.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

At collocated stations S004-845 and 11LM045, there were 22 samples of TP from 2009 to 2011 and 2014. The maximum TP was 0.580 mg/L (June 30, 2009). The average TP of the 22 samples was 0.302 mg/L; over triple the draft river nutrient criteria for the central region (0.1 mg/L). Only one sample was below the draft standard. The highest TP is in the late summer months (Figure 242).The summer month TP average for 2009 was 0.340 mg/L TP and for 2010 was 0.375 mg/L. Although only four data points existed with both TSS and TP analyzed, the potential relationship was evaluated (Figure 243) and found that there was elevated TP with low TSS concentrations. Additionally, Cedar Lake and Caron Lake upstream of this reach of Devils Creek are both impaired for excess nutrients.

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to result in an aquatic life impairment based on elevated nutrients. Chlorophyll-a was sampled 18 times during 2009 and 2010. The highest level was 77 µg/L on June 8, 2010. Two other samples of chlorophyll-a were elevated at 36 and 52 µg/L in 2009. The averages of the five samples in 2009 (13.2 ug/L) and nine in 2010 (11.2 ug/L) were below the draft standard of 18 µg/L. BOD has not been collected in Devils Creek. DO was measured by an YSI sonde from August 7-21, 2013 and August 5-11, 2014. In 2013, DO was not recorded below the standard and DO flux was less than 2 mg/L, but there was an orange-brown color to the water and filamentous algae present in 2013 when the sonde was deployed and retrieved. In 2014, DO was lower than the 5 mg/L standard and the greatest flux was 1.25 mg/L. For more information on DO please see the next section, Dissolved Oxygen.

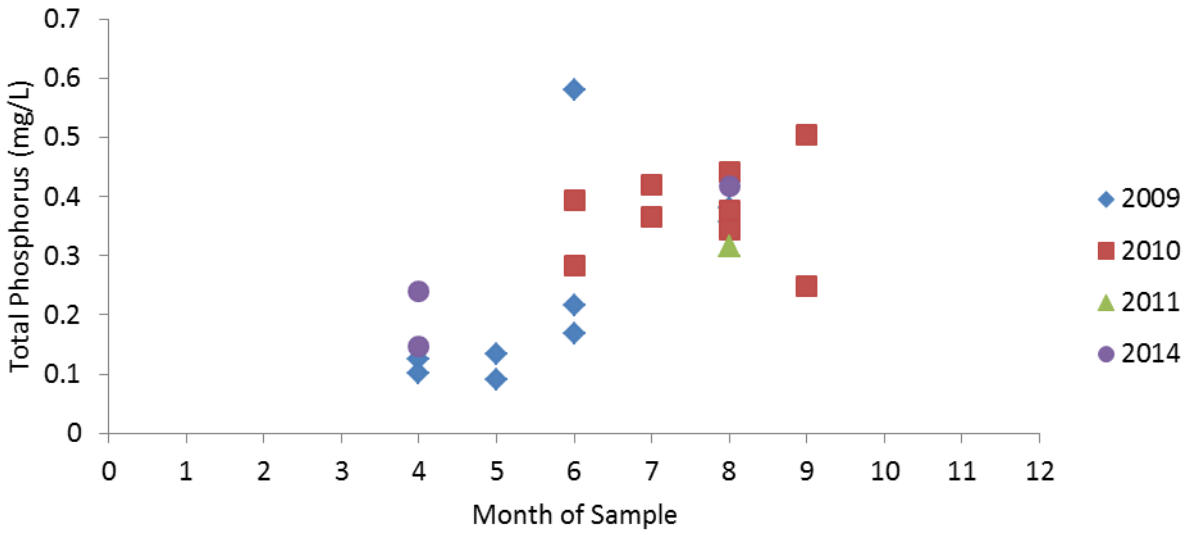


Figure 242. Total phosphorus concentrations in Devils Creek by month sampled, 2009-2011 and 2014

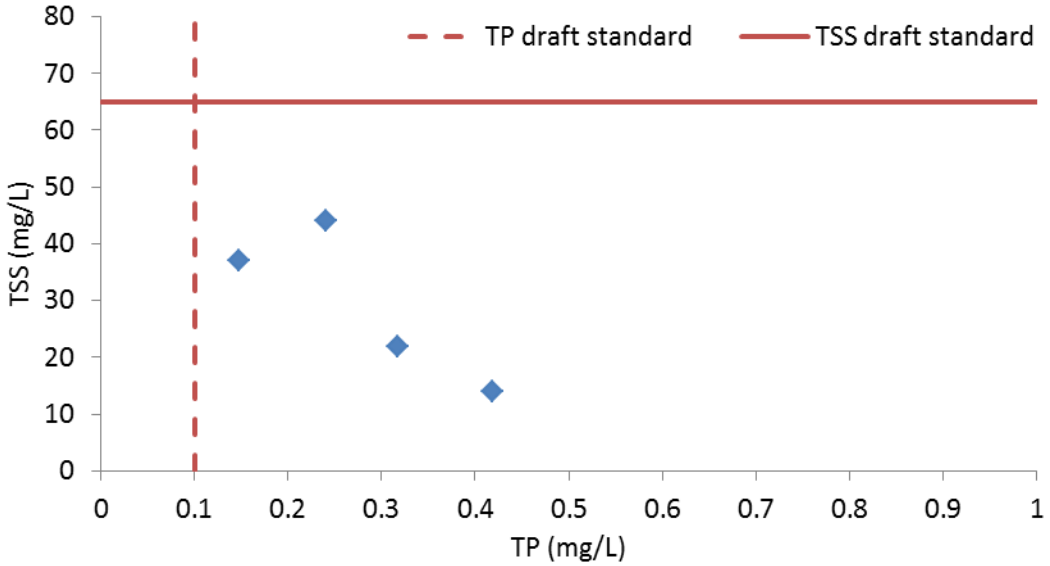


Figure 243. TSS and TP relationship in Devils Creek (2011 and 2014)

In Devils Creek, all six of the metrics responded negatively as expected with river eutrophication stress in 2011 (Table 195). The macroinvertebrate taxa count was considerably lower compared to similar stations that are meeting the biocriteria. The number of collector-filterer taxa was close to the average of those similar stations, and the number of collector-gatherer taxa was only near one third of that found in similar stations. The macroinvertebrate metrics all correspond with eutrophication.

Although the fish community is not impaired it still responds to stressors and can inform regarding those stressors. Similar to the macroinvertebrate community, five of six fish metrics responded negatively as expected with river eutrophication (Table 196). During the 2011 visit, there was a lack of sensitive, darter, simple lithophilic spawners and intolerant individuals, resulting in 0% for each of the respective metrics. However, taxa count was near the average for similar stations meeting the biocriteria, and the percentage of tolerant individuals was low (42.9%).

Phosphorus in Devils Creek is elevated, with some elevated chlorophyll-a, but a lack of BOD data. DO flux was relatively low, but DO was found to be below the standard in 2011 and 2014. In-stream productivity changing the algal dynamics and food resources may be playing a role in the biological communities in Devils Creek. Nearly all the biological community metrics responded in the expected direction with increased in stream eutrophication. With upstream Cedar Lake and Caron Lake impairments for nutrients, in addition to the data in Devils Creek, the evidence suggests that eutrophication driven by increases in TP are negatively impacting the biological communities in Devils Creek. Due to the lack of response variable data, elevated TP and response variables are inconclusive as a stressor in Devils Creek.

Table 195. Macroinvertebrate metrics that respond to TP and response variables in Devils Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM045 (2011)	**9**	**4**	**5**	**1**	**0**	**86.7**
11LM045 (2011)	**15**	**5**	**6**	**4**	**0**	**88.2**
Southern Forest Streams Average	*41.2*	*5.9*	*15.0*	*8.8*	*0.5*	*74.9*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 196. Fish metrics that respond to TP and response variables in Devils Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
11LM045 (2011)	**0**	**0**	**0**	42.9	**10**	**0**
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*	*1.4*
Expected response to stress	↓	↓	↓	↑	↓	↓

Dissolved Oxygen

In August 2011, there were two morning measurements that were below the DO standard of 5 mg/L at station S004-845, coinciding with each of the biological surveys. The DO exceedances were 3.38 mg/L on August 9 at 8:00AM, and 4.39 mg/L on August 17 at 9:59AM. In 2010, there were nine measurements of DO, all above the standard, but none prior to 9AM. DO was measured by a YSI sonde from August 7-21, 2013, and August 5-11, 2014. In 2013, DO ranged from 6.26 to 9.51 mg/L, was not recorded below the standard, and flux was less than 2 mg/L. In 2014, DO ranged from 3.9 to 5.15 mg/L, was lower than the 5 mg/L standard and the greatest flux was 1.25 mg/L (Figure 244). There was no BOD data available for this reach.

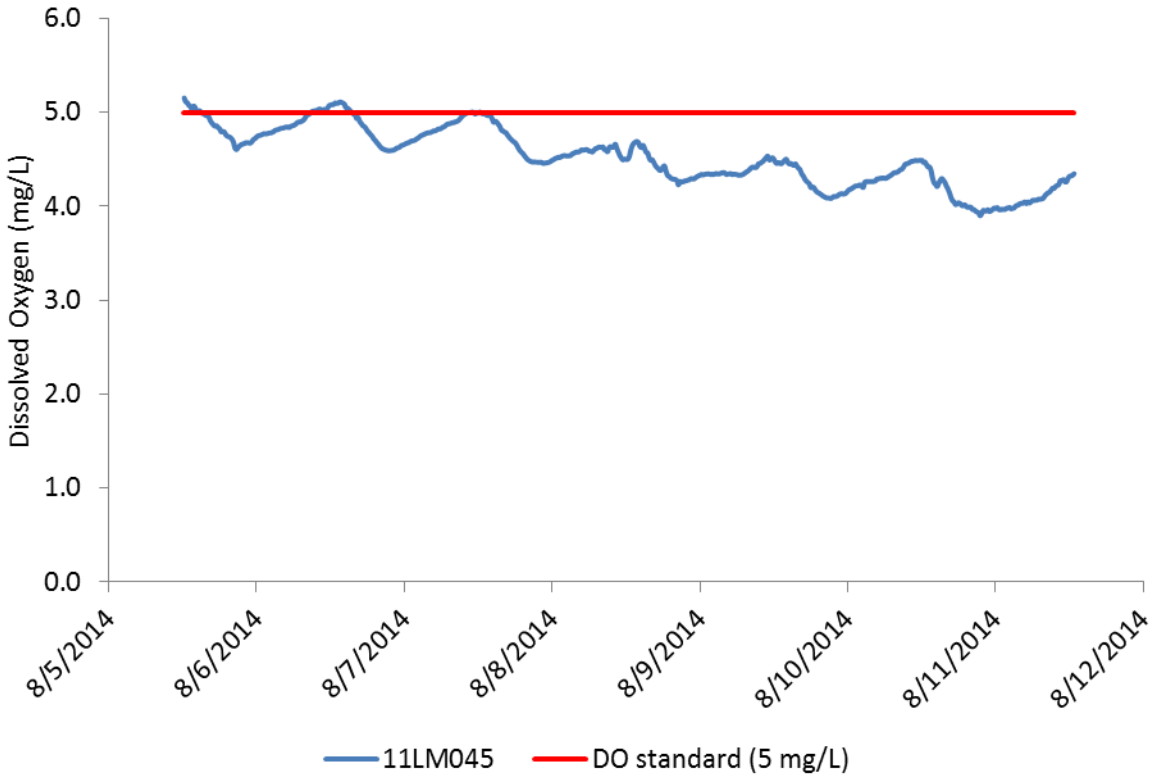


Figure 244. Dissolved oxygen measurements from August 5 to 11, 2014 at station 11LM045

Station 11LM045 had low numbers of taxa (15 and 17) during the 2011 samples (Table 197). There were zero and one low DO intolerant taxa, zero and one low DO very intolerant taxa, and zero and two tolerant DO taxa (<1% individuals). There were one and four EPT taxa that comprised 0.6 and 2.5% of the individuals present. Stations within the Southern Forest Streams GP class that are meeting the biocriteria average 10.2 EPT taxa. The DO TIV station score was 7.3 for both samples, just greater than the median (indicating moderate sensitivity to low DO). Although the fish are not impaired, the DO TIV score was 5.6, in the most tolerant quartile to low DO for warmwater stations in the Cannon River Watershed.

Table 197. Macroinvertebrate metrics that respond to low DO stress in Devils Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
11LM045 (2011)	**15**	**1**	**7.59**	7.34	**0**	0	0
11LM045 (2011)	**17**	**4**	**7.51**	7.29	**1**	2	0.99
Southern Forest Streams Average	*41.3*	*10.2*	*7.1*	*7.04*	*6.51*	*5.57*	*13.99*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

There is low DO in Devils Creek along with biological response indicative of low DO stress. The macroinvertebrate metrics do not strongly suggest low DO as a stressor, with the presence of one taxon very intolerant to low DO (*Ceratopsyche*); however only one individual was found in the subsample. The taxa count is very low which may account for some variation in metrics. The fish community does show a response to low DO. Low DO is a stressor to the degraded macroinvertebrate community.

TSS/Turbidity

TSS has only been sampled four times at station S004-845, at the time of fish sampling in 2011 and during snowmelt, a rain event, and baseflow in 2014. TSS ranged from 14 to 44 mg/L. The highest TSS was during snow melt on April 3, 2014. On April 24, 2014, after a rain event another elevated TSS sample at 37 mg/L was collected. None of the samples were greater than the 65 mg/L draft south region TSS draft standard.

There were three secchi tube measurements paired with the TSS samples in 2014. The lowest was the snowmelt sample, measured at 27 cm. Transparency tube data was collected in 2008 and 2010, but neither year covers the entire season. The lowest transparency tube measurement was 35 cm out of 26 measurements, converted to secchi tube measurements, no measurements were less than the 10 cm draft standard of the south TSS region. Overall, the limited data does not support elevated TSS.

The macroinvertebrate metrics that respond to elevated TSS stress show response corresponding to elevated TSS (Table 198). There was a lack of stoneflies (Plecoptera), but there was a decent relative abundance of collector-filterers. The TSS index score was above the average of similar stations meeting the biocriteria, indicating higher tolerance to elevated TSS. Both visits resulted in no taxa that are intolerant to TSS. The TSS tolerant taxa were not relatively high, but the TSS tolerant individuals comprised more than 56% of the community, above the average of similar stations meeting the biocriteria.

Although not impaired, the fish can sometimes help identify stressors. The fish community had a response consistent with elevated TSS stress (Table 199). In 2011, there was an absence of intolerant, riffle, sensitive and simple lithophilic spawners in Devils Creek. There was a greater proportion of long-lived fish within the station than that found at similar stations meeting the biocriteria. The TSS index score was greater than the average of similar stations meeting the biocriteria, indicating more tolerance to elevated TSS. Overall, the fish community is showing a mixed response to elevated TSS stress.

With the lack of chemical data supporting an elevated TSS stressor, but macroinvertebrate metrics consistent with elevated TSS, currently elevated TSS is inconclusive as a stressor. It may be contributing to stress that the macroinvertebrate community is experiencing, but there is not enough data to conclude that it is a stressor. Additional chemical sampling should be conducted within Devils Creek to help understand the suspended sediment dynamics and impacts on the biotic communities.

Table 198. Macroinvertebrate metrics that respond to TSS stress in Devils Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM045 (2011)	35.7	**0**	**18.0**	**0**	3	**58.7**
11LM045 (2011)	40.6	**0**	**17.9**	**0**	4	**56.5**
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*10.2*	*27.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 199. Fish metrics that respond to TSS stress in Devils Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RiffePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM045 (2011)	**25.7**	8.6	**2.9**	**0**	34.3	**11.4**	**0**	**0**	**0**	**18.8**
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.3*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

Station 11LM045 received a fair MSHA score in 2011 (64.3). The subcategory scores were also fair with most receiving at least 50% of the available score, but land use did not receive any points due to row crop upstream of the station (Figure 245). The riparian width was narrow to moderate, with moderate bank erosion and moderate shading. There was only 5% riffle habitat available in August 2011; however there were more than four substrate types available, but likely in small amounts. Run habitat was the most predominant for 85% of the reach and had gravel and cobble substrate. At the time of fish sampling the water color was noted as brown with light embeddedness of substrate. Numerous types of cover were available in moderate amounts (25-50%). The channel morphology category had moderate depth variability, good sinuosity, and numerous velocity types noted at the time of fish sampling. Channel stability was moderate/high with fair channel development. For both years the macroinvertebrate samples were collected from undercut banks and overhanging vegetation; and snag, woody debris, and root wad habitat (Figure 247).

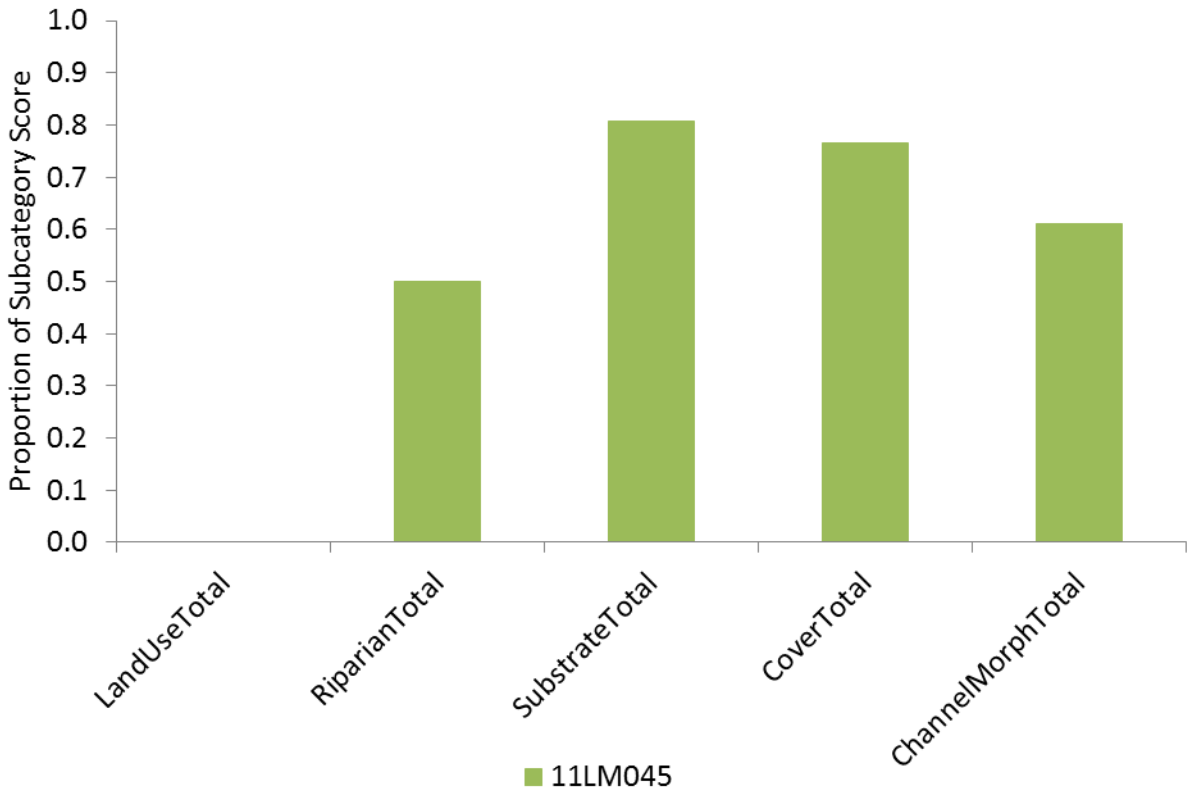


Figure 245. MSHA subcategory scores for station 11LM045, Devils Creek

There is an elevated percentage of macroinvertebrates that are climbers and legless, while there is a lack of sprawlers and swimmers (Figure 246). Although the percentage of clinging macroinvertebrates is very close to the mean of Southern Forest Streams GP stations meeting the biocriteria, the taxa count of clingers was low resulting in a low MIBI metric score. The most dominant taxa in the two samples were *Polypedilum* (a very tolerant climbing midge) and *Simulium* (a tolerant clinging black fly). Tolerant macroinvertebrates dominated both samples at station 11LM045 in 2011 (99% for both samples).

Reductions in riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers often occur when habitat is diminished. Although the fish community is not impaired, the composition of the community can provide additional information about potential stressors. The fish community had no taxa that have a preference for riffles at station 11LM045. Similarly, there were no simple lithophilic spawners present at station 11LM045. The average percentage of simple lithophilic spawners at Southern Headwater fish class stations in the Cannon River Watershed was 27.3%. In 2011, station 11LM045 had 25.7% benthic insectivores (tadpole madtom, nine fish). There were no darter, sculpin, or round bodied suckers at the station in Devils Creek.

There may be some loss of optimal habitat, but overall the habitat is decent. Habitat as a stressor is inconclusive, due to holes in lines of evidence. There is an abundance of climbers and legless, and a near absence of sprawlers and swimmers, but it is unknown if this is due to other stressors or habitat features.

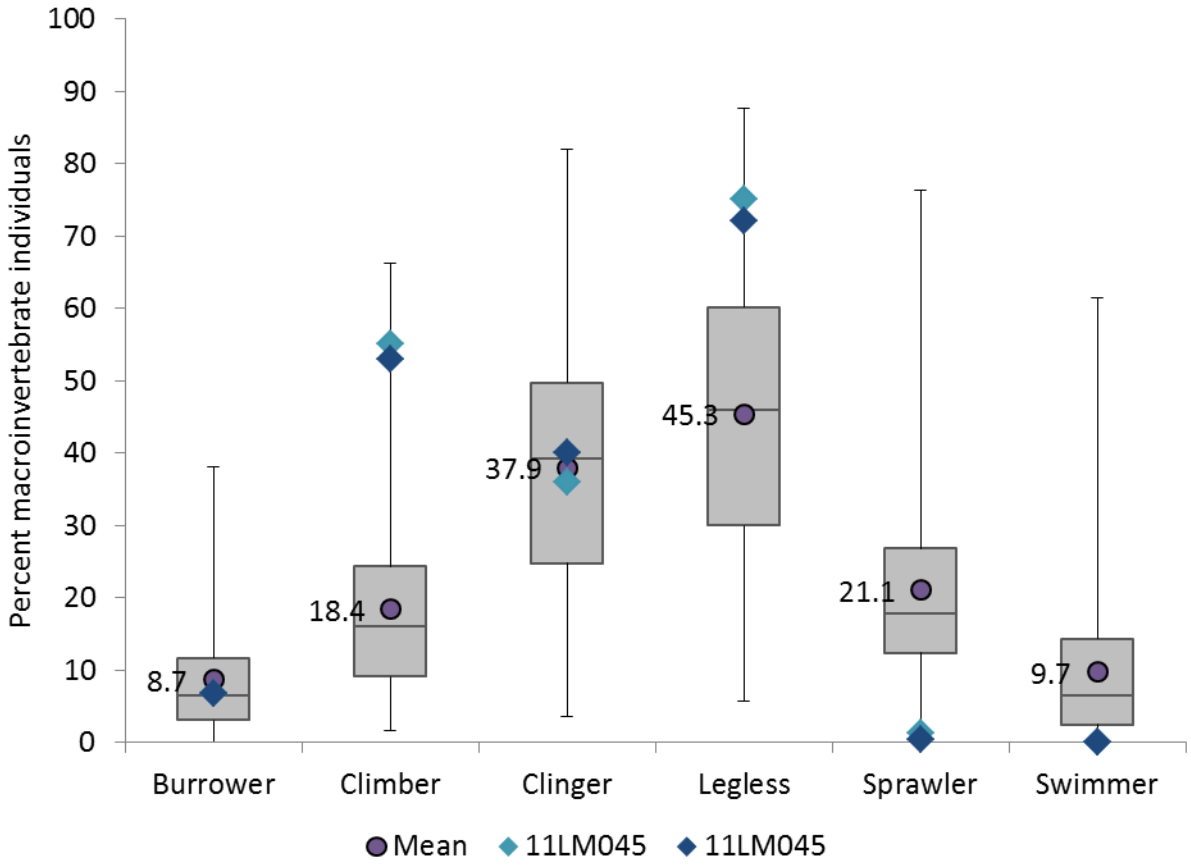


Figure 246. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from station 11LM045

Figure 247. Station 11LM045 August 9, 2011

Fish Passage

Currently, there are no known physical barrier concerns for the biological community.

Conclusion

Devils Creek is impaired for lack of macroinvertebrate assemblage. The stressor to the macroinvertebrate community is low DO. Elevated nutrients, TSS, and habitat are inconclusive as stressors at this time.

There is low DO in Devils Creek along with biological response indicative of low DO stress. Low DO is a contributing stressor to the degraded macroinvertebrate community.

Phosphorus in Devils Creek is elevated, with some elevated chlorophyll-a, but a lack of BOD data. DO flux was relatively low, but DO was found to be below the standard in 2011 and 2014. In-stream productivity may be changing the algal dynamics and food resources. There was not enough connecting data with response variables to conclude that TP and response variables in stream were contributing stress. The upstream lake impairments for nutrients in addition to the data in Devils Creek maybe one source of both elevated TP and low DO.

Nitrate has been measured as high as 6.2 mg/L. Elevated nitrate may be contributing to the impaired biological condition in Devils Creek; however the chemical data is not particularly strong, but the biological data is suggestive of nitrate stress. At this time it is inconclusive if elevated nitrate is a stressor.

With the lack of data supporting an elevated TSS stressor, but macroinvertebrate metrics consistent with elevated TSS, currently elevated TSS is inconclusive as a stressor. It may be contributing to the macroinvertebrate community, but there is not enough data to conclude. Additional sampling should be conducted within Devils Creek to help understand the suspended sediment dynamics and impacts on the biotic communities.

There may be some loss of optimal habitat, but overall the habitat is decent. Habitat as a stressor is inconclusive, due to holes in lines of evidence.

4.7.4. Unnamed Creek (Dixon Creek) (705)

Unnamed Creek, AUID (07040002-705), flows into the Cannon River in Morristown. This AUID is also known as Dixon Creek. The reach is impaired for lack of fish assemblage. It is also impaired for *E. coli*, which will not be addressed in this report. The macroinvertebrate community was not assessed because there was no perceptible stream flow at the time of sampling, and the stream is intermittent according to USGS topo, which led to concerns about natural intermittency of the stream and timing of sample collection. Data collected at station S004-878 on Dixon Creek was not used in analysis due to concerns of backwater effects from the Cannon River.

In 2011, at station 11LM058, the fish community scored 40 on the Southern Headwaters class FIBI (threshold of 55). The fish that dominated the community were blacknose dace and creek chub. In 2013, the fish were sampled again with the result of very few fish; five northern pike and two creek chub, resulting in an IBI of zero. All metric scores were zero in 2013, and all metrics except the percentage of serial spawners (SSpnPct) was below the average metric score needed to be above the threshold in 2011 (Figure 248). There were no deductions for DELTs in either of the samples.

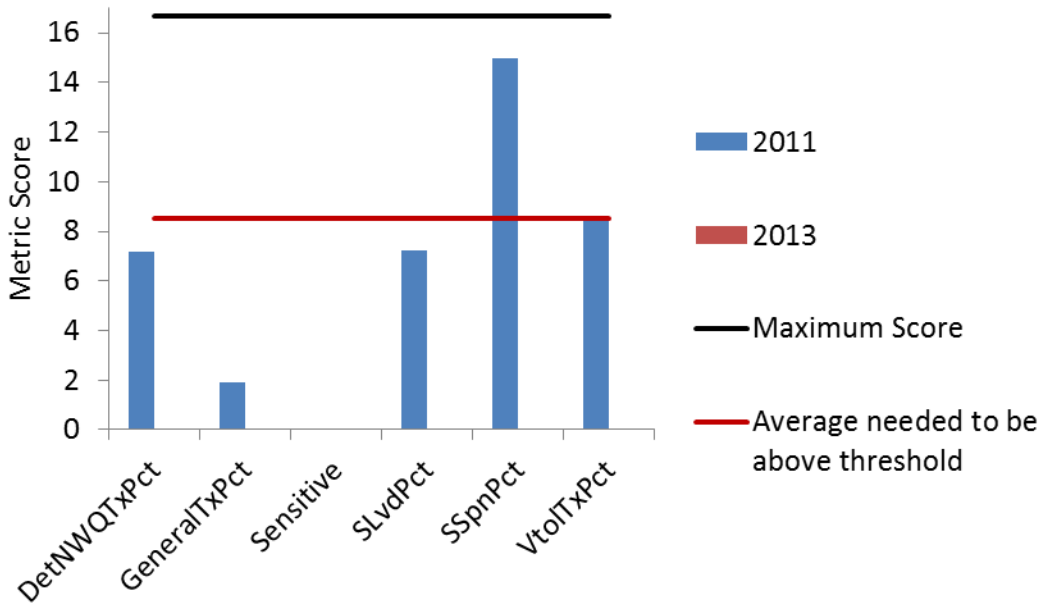


Figure 248. Fish metrics of the Southern Headwaters IBI for Dixon Creek, station 11LM058

Temperature

Chemistry station S007-486 is co-located with the biological station 11LM058 on Dixon Creek. An YSI sonde was deployed in 2013 from July 23 to August 7 at the biological station. The minimum temperature during that time was 13.3°C with a maximum temperature of 19.8°C. Similarly, an YSI sonde was deployed from July 17-23, 2014, with a maximum temperature of 23.2°C. Dixon Creek is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in Dixon Creek.

Nitrate

At station S007-486, co-located with the biological station 11LM058, there were only two samples of nitrate. The nitrate level was 14 mg/L (August 6, 2013) and 8.8 mg/L (August 3, 2011). There is no ability to understand the seasonality or the duration of the elevated nitrate in Dixon Creek with the limited data. It would be beneficial to collect samples throughout various flows and seasons to understand the duration of elevated nitrate.

Fish lack a strong biological response in relation to elevated nitrate. Better relationships have been made with respect to macroinvertebrate impairment and nitrate concentration. However, since there is no reliable macroinvertebrate data, the fish community was explored further with regards to potential nitrate stress. In 2013, there was simply a lack of an abundant fish community, with only seven individuals surveyed. The average station score based on nitrate tolerance values for southern headwater stations that meet the biocriteria is 3.9. Utilizing tolerance values, the fish community had nitrate station scores of 3.8 and 2.3 (in 2011 and 2013 respectively). These lower values indicated that the community is generally more sensitive to elevated nitrate than the average meeting the biocriteria. However, at the same time there is a complete lack of sensitive fish in Dixon Creek.

There are some indications in the fish community that nitrate may be influencing, either directly or indirectly, the biological health of Dixon Creek. There were elevated nitrate levels in Dixon Creek, but they were limited and duration of these concentrations is unknown. It would be beneficial to collect additional data to understand the nitrate dynamics as well as the flow regime to understand if the flow is the ultimate limiting factor over other potential stressors present. At this time, nitrate is inconclusive as a stressor to the fish community in Dixon Creek.

Phosphorus

At the time of fish sampling in 2011 and 2013, TP was sampled at station 11LM058 (0.134 mg/L and 0.112 mg/L respectively). TSS was very low so it is unlikely that the phosphorus was bound to suspended sediment. It would be beneficial to have additional TP data as well as paired TP and TSS measurements for additional analysis. Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to result in an aquatic life impairment based on elevated nutrients. Chlorophyll-a and BOD were not sampled in Dixon Creek. DO was measured by an YSI sonde from July 23 - August 7, 2013 and from July 17 – 23, 2014, with no exceedances of 5 mg/L and DO flux was less than two mg/L.

Many of the fish metrics responded negatively as expected with river eutrophication (Table 200). In 2013, there were only seven individuals surveyed, which likely skews the percentages, potentially inflating or reducing percentages due to the limited total fish. In 2011, the total number of fish individuals was greater (50). During the 2011 visit, the taxa count was lower than similar stations meeting the biocriteria. Simple lithophilic spawners were present in higher abundance than expected, but it was due to the presence of 16 blacknose dace and five white suckers. The percentages of darters, intolerant, and sensitive fish individuals were reduced; and the percentage of tolerant individuals was high (98%).

There is elevated TP in Dixon Creek, but there is very limited data. There was no available chlorophyll-a or BOD data and DO flux was not elevated. The fish metrics responded as expected in most cases, but there was limited fish collected, particularly in 2013. It is likely that TP and related response variables are stressors to the fish community in Dixon Creek, but there is a need for additional information, and therefore inconclusive at this time. Additional data should be collected to further evaluate TP and the response variables.

Table 200. Fish metrics that respond to TP and response variables in Dixon Creek compared to the statewide average of visits meeting the biocriteria (*only seven individuals were sampled skewing percentage results). Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
11LM058 (2011)	**0**	**2**	42	**98**	**7**	**0**
11LM058 (2013)*	**0**	**0**	**0**	28.6	**2**	**0**
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*	*1.4*
Expected response to stress	↓	↓	↓	↑	↓	↓

Dissolved Oxygen

DO was measured at the time of fish sampling, both dates DO was above 8 mg/L, with one of the measurements taken prior to 9AM. DO was measured by an YSI sonde from July 23 - August 7, 2013 and from July 17 – 23, 2014 with no excursions below 5 mg/L and DO flux was less than 2 mg/L.

Fish abundance can decrease with low DO levels. In 2013, only seven fish individuals were surveyed. In 2011, the number of fish per meter was greater (0.33) than in 2013 (0.04), but still less than the average of stations in the Southern Headwaters fish class (1.72). The abundance of fish that mature later in life (MA>3) was 10% in 2011 and 0% in 2013. The 2011 late to mature fish were tolerant. There was a lack of fish that are generally sensitive. The fish community has moderate tolerance to DO with DO TIV scores of 6.99 in 2011 and 6.49 in 2013. The scores fell just below the median (7.08) for warmwater stations in the Cannon River Watershed.

Although the fish community is plausibly indicative of low DO conditions, without the presence of low DO data it is difficult to conclude that low DO is a stressor in Dixon Creek. Additional data should be

collected to provide a greater understanding of the DO regime in Dixon Creek. Low DO is inconclusive as a stressor in Dixon Creek.

TSS/Turbidity

The TSS and transparency data is very limited in Dixon Creek. The only TSS samples were at the time of fish sampling in 2011 and 2013, with less than 5 mg/L TSS. It is uncertain the longitudinal differences that may exist in Dixon Creek and the duration of potential reduced transparency. There was no additional transparency measurements made either.

The fish community responded as expected with TSS stress for most of the metrics (Table 201). However the TSS index scores for both samples was lower than the average for similar streams meeting the biocriteria, indicating a generally more sensitive community to elevated TSS. As mentioned previously the lack of fish individuals, particularly in 2013, may skew results.

Although the fish community appears to respond with some metrics to potential elevated TSS, there is a lack of connecting data. Additional chemistry data should be collected under a range of flows with additional biological monitoring. Currently, the potential stressor of TSS is inconclusive in Dixon Creek.

Table 201. Fish metrics that respond to TSS stress in Dixon Creek compared to the statewide average of visits meeting the biocriteria (*only seven individuals were sampled skewing percentage results). Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RifflePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM058 (2011)	**12**	**0**	**10**	**0**	**0**	**2**	**10**	**0**	**10**	14.6
11LM058 (2013)*	**0**	**0**	**0**	**0**	73.4	**0**	**0**	**0**	**0**	14.9
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.3*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

In 2011, at station 11LM058, the MSHA total score was fair (49.1). Four of the five subcategories received half or less of the available scoring (Figure 249). The surrounding land use was row crop. The riparian width was moderate (30-150') with moderate shading (25-50%). Heavy bank erosion was noted in 2011 (50-75%). The reach was comprised mostly of run habitat with sand and clay substrates. Riffle and pool habitats comprised 10% each. There was gravel present in the riffles; however embeddedness throughout the reach was noted as moderate. There was a lack of substrate types available (with equal to or less than four types). Cover scored proportionally the best of the subcategories. There were moderate amounts of cover (25-50%) with five different types of cover available. The channel stability was low with fair channel development, despite having good depth variability, sinuosity, and pool to riffle width ratio. In 2013, the MPCA resurveyed the MSHA for a total score similar to 2011 (52.25). The riparian habitat scored better and cover scored worse in 2013. Cover was only found to be sparse (5-25%). Less bank erosion was noted in the MSHA in 2013.

Additionally in 2013, habitat was surveyed longitudinally in Dixon Creek by Cannon River Watershed Partnership, employing the MSHA protocol (Figure 250). The MSHA scores ranged from 24 (poor) to 75.1 (good), with an average of 60.2 (fair). The cover subcategory had the widest range of differences throughout the stream (Figure 251). Of the 34 reaches surveyed, 28 had moderate to severe or no coarse substrate (82%). Fifteen of the 34 reaches had 10% or less riffle habitat available and much of that was between the biological station 11LM058 and the confluence with the Cannon River.

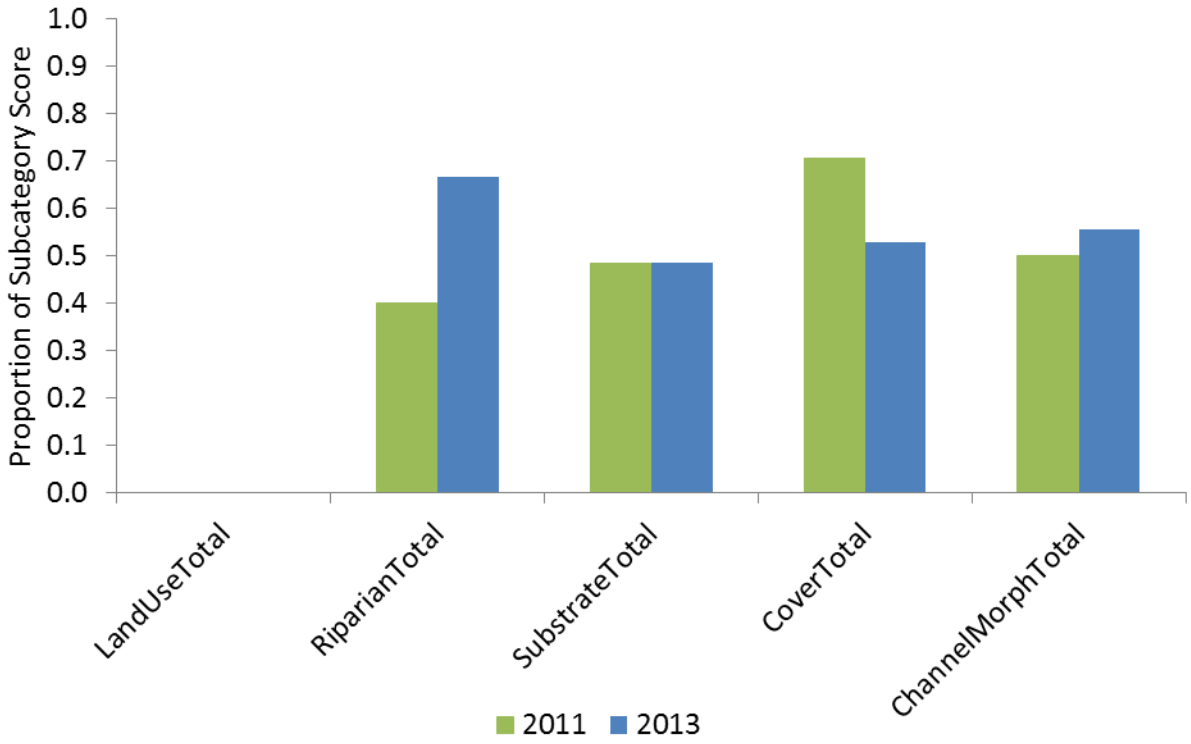


Figure 249. MSHA subcategory scores for station 11LM058, Dixon Creek

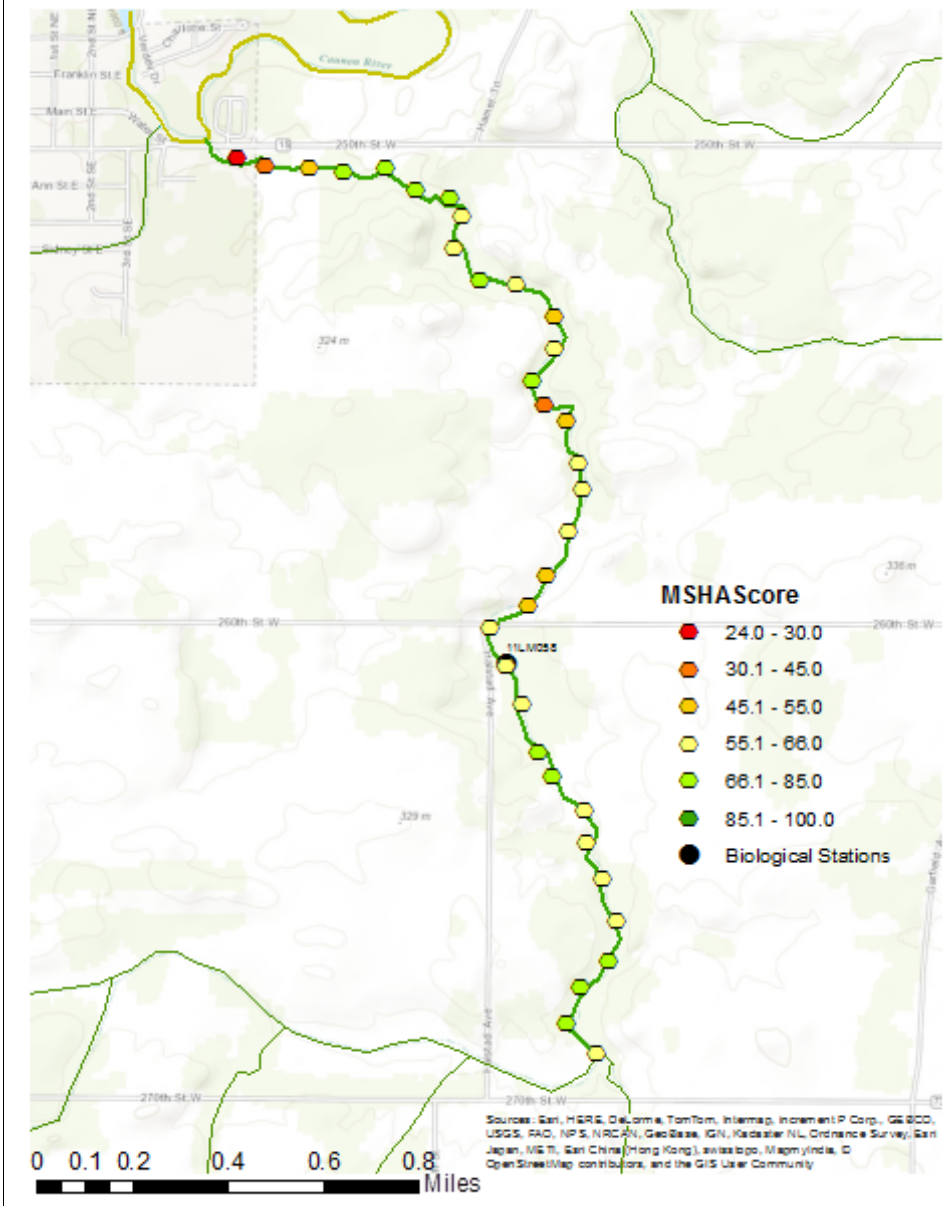


Figure 250. MSHA longitudinally through Dixon Creek

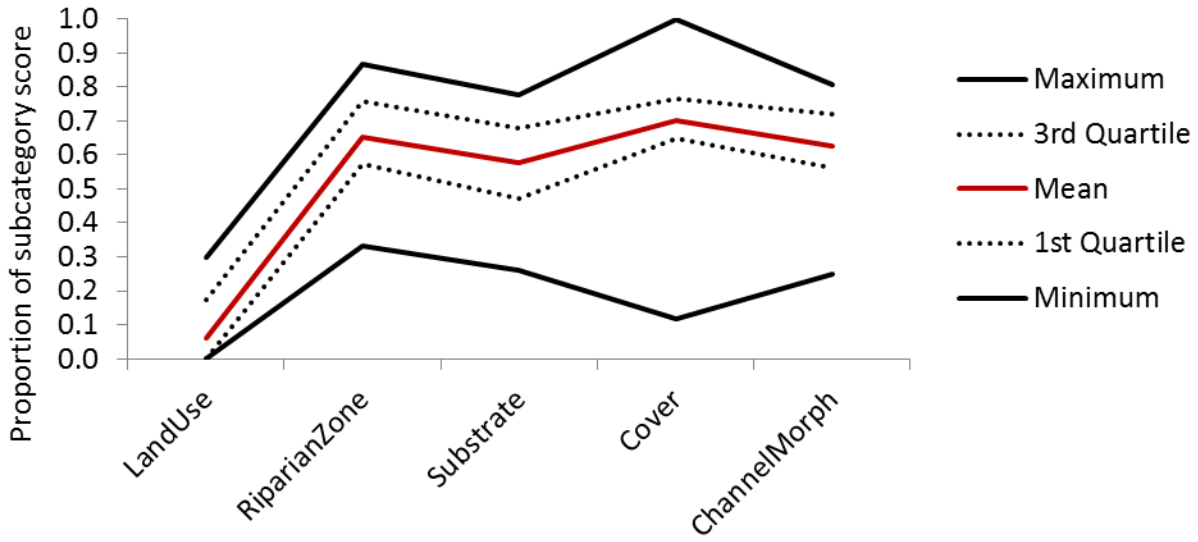


Figure 251. Range of MSHA subcategory Scores in Dixon Creek, 2013

When habitat quality is diminished, riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced. The fish community had one taxon that have a preference for riffles in 2011, but none in 2013. There were only five northern pike and two creek chub surveyed in 2013. There were two simple lithophilic spawners present at station 11LM058 in 2011 (blacknose dace and white sucker) comprising 42% of the fish community, with no simple lithophils in 2013. The average percentage of simple lithophilic spawners at Southern Headwater fish class stations in the Cannon River Watershed was 27.3%. In 2011, station 11LM058 had 2% benthic insectivores (johnny darter; one fish), and none in 2013. Similarly, the only darter, sculpin, or round bodied fish was the one individual johnny darter in 2011, and none in 2013. Blacknose dace and creek chub were the dominant fish species in 2011. There is also simply a lack of fish within this reach. The average number of fish per meter in Southern Headwater stations is 1.29. In 2011, station 11LM058 had 0.33 fish per meter and in 2013, 0.04 fish per meter.

The reach is mostly run features with sand and clay substrates, leading to homogenous habitat. The bank erosion is heavy and notes from the macroinvertebrate sampling suggest the reach is over widened. Lack of quality habitat is a stressor to the fish community. It is strongly intertwined with flow. The lack of diverse habitats is symptomatic of altered flow conditions.

Fish Passage

Fish passage at the major road crossings does not appear to be problematic. A field road culvert was thought to be a potential issue, but was found to be able to support fish passage by the DNR staff. In August 2012, Google Earth shows this location potentially backing up water and LiDAR imagery shows a blown out stream channel downstream, potentially indicating an improperly placed or sized culvert (Figure 252 and Figure 253).

Figure 252. Field road culvert downstream of 260th St. W, SE of Morristown

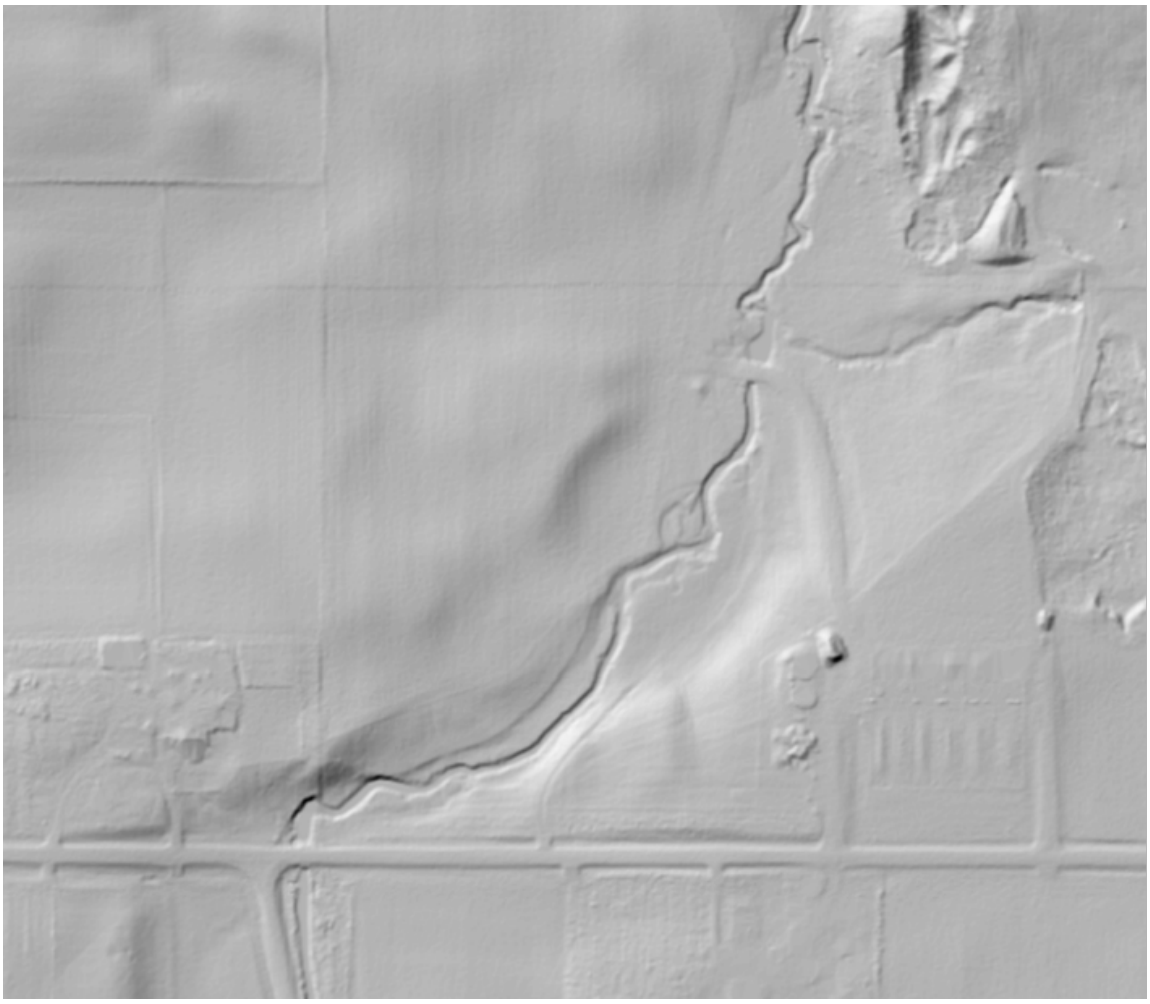


Figure 253. LiDAR imagery of downstream of 260th St W, SE of Morristown

Flow alteration

Dixon Creek (07040002-705) is entirely natural channel, but upstream there is significant alteration/addition to the stream channel. Within the Dixon Creek Watershed, there are approximately six miles of altered watercourses, or 59.5% of the contributing watercourses in the watershed. There is no flow information collected on Dixon Creek. However, HSPF modeling simulates flows in the Cannon River Watershed including the reach of Dixon Creek. Daily discharge values were calculated from 1996 through 2012. Just over 30% of the time calculated Dixon Creek was less than two cfs (Figure 254).

Dixon Creek is intermittent according to USGS topo. The drainage area upstream of the station is 6.32 square miles. When the macroinvertebrate community was attempted to be sampled, there was no perceptible stream flow (August 16, 2011). The macroinvertebrate community was not assessed due to concerns about natural intermittency of the stream and flow conditions at time of sample collection. It is unknown if there are issues with lack of baseflow, but may be plausible with the increase in drainage in the watershed of Dixon Creek. Flow alteration is a stressor to the biological communities in Dixon Creek.

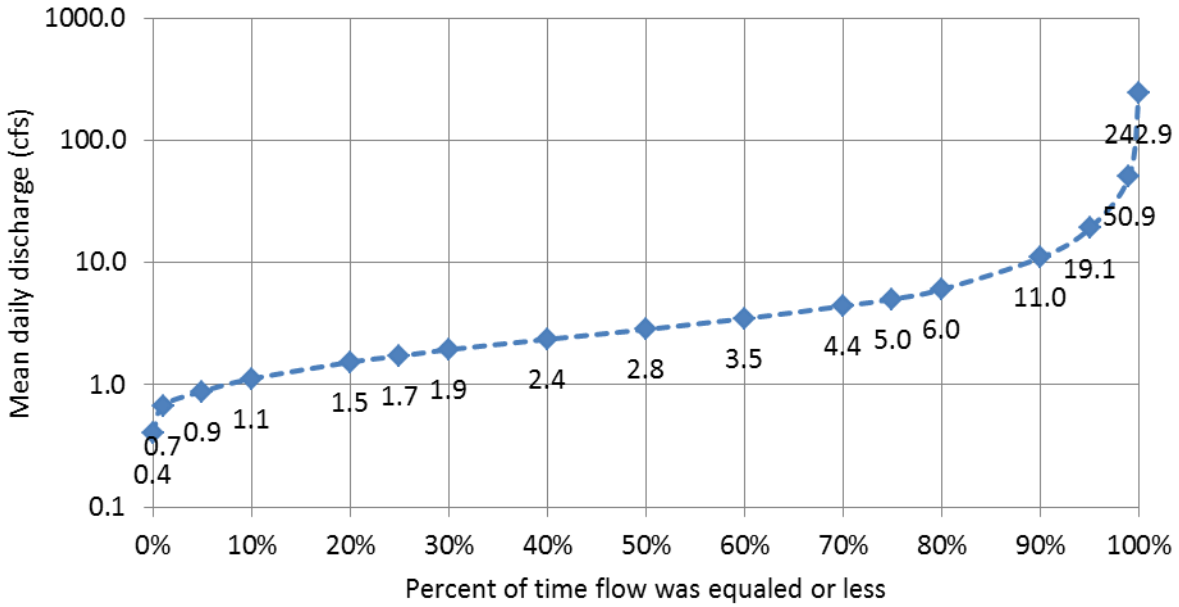


Figure 254. Flow duration curve for Dixon Creek, from HSPF

Conclusion

Dixon Creek is impaired for lack of fish assemblage. The only confirmed stressors impacting the fish community are lack of habitat and altered flow.

There are some indications in the fish community that nitrate may be influencing, either directly or indirectly, the biological health of Dixon Creek. There were elevated nitrate levels in Dixon Creek, but limited and duration of these concentrations is unknown. It would be beneficial to collect additional data to understand the nitrate dynamics as well as the flow regime to understand if flow is the ultimate limiting factor over other potential stressors present. At this time, nitrate is inconclusive as a stressor to the fish community in Dixon Creek.

There is elevated TP in Dixon Creek, but there is very limited data. There was no available chlorophyll-a or BOD data and DO flux was not elevated. The fish metrics responded as expected in most cases, but there was limited fish collected, particularly in 2013. It is likely that TP and related response variables are stressors to the fish community in Dixon Creek, but additional data is required to confirm.

Although the fish community may indicate low DO conditions, without the presence of low DO data it is difficult to conclude that low DO is the stressor in Dixon Creek. Additional data should be collected to provide a greater understanding of the DO regime in Dixon Creek.

Although the fish community appears to respond with some metrics to potential elevated TSS, there is a lack of data linking it as a stressor. Additional chemistry data should be collected under a range of flows with additional biological monitoring. Currently, it is inconclusive whether or not TSS is a potential stressor in Dixon Creek.

The lack of quality habitat at locations along Dixon Creek is stressing the fish community. Connectivity at the major road crossings does not appear to be problematic.

Dixon Creek is intermittent according to USGS topo. The drainage area upstream of the station is 6.32 square miles. When the macroinvertebrate community was attempted to be sampled, there was low flow conditions at the time of sampling (August 16, 2011). The macroinvertebrate community was not assessed due to concerns about natural intermittency of the stream and timing of sample collection. It is unknown if there are issues with lack of baseflow, but could also be related to increased drainage within the watershed to Dixon Creek.

There are many inconclusive stressors for Dixon Creek including nitrate, phosphorus, low DO, TSS, and lack of flow. Lack of adequate habitat is a stressor to the fish community in Dixon Creek.

4.7.5 MacKenzie Creek (576)

MacKenzie Creek (AUID 07040002-576) is a small warmwater tributary to Cannon Lake on the Cannon River. Station 11LM056 was sampled in 2011 for fish and macroinvertebrates. The reach is impaired for lack of macroinvertebrate assemblage. It is also impaired for *E. coli*, which will not be addressed in this report. The fish community scored 76 with the Southern Headwaters class FIBI, the dominant species being creek chub, logperch, and blacknose dace. The fish community is not currently impaired in MacKenzie Creek.

MacKenzie Creek at station 11LM056 scored below threshold (43) with an MIBI score of 42.4 for the Southern Forest Streams GP class. The metrics in the Southern Forest Streams GP macroinvertebrate IBI that scored low were percentage of collector-filterer individuals in subsample (Collector-filtererPct), a measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart (HBI_MN), taxa richness of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch), relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct), and relative abundance of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct; Figure 255).

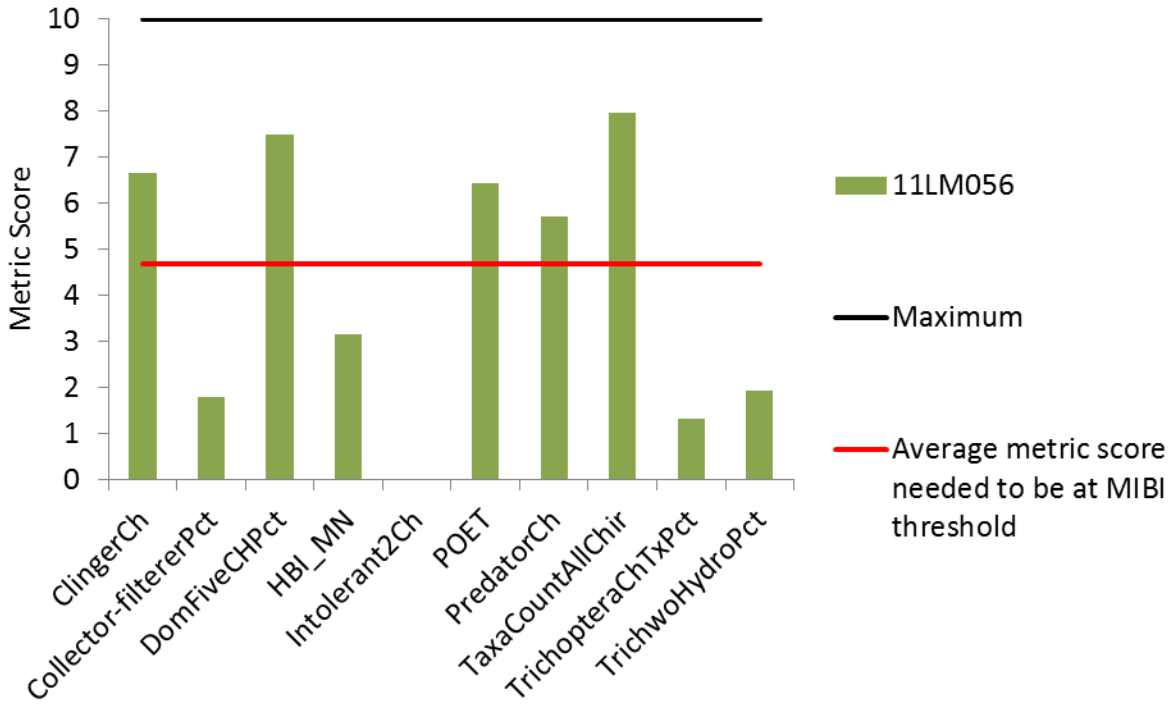


Figure 255. Macroinvertebrate metrics of the Southern Forest Streams GP IBI for MacKenzie Creek, station 11LM056

Temperature

Chemistry station S004-848 is co-located with the biological station 11LM056 on MacKenzie Creek. An YSI sonde was deployed in 2014 from August 5 to 11 at the biological station. The minimum temperature during that time was 18.3°C with a maximum temperature of 21.5°C. Thirty-nine synoptic measurements were taken at station S004-848 from 2008 to 2011, and 2013. The maximum temperature recorded was 24.4°C (July 29, 2008). MacKenzie Creek is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor in MacKenzie Creek.

Nitrate

Nitrate has been sampled 20 times in MacKenzie Creek spanning the years of 2009 to 2011, and 2013 (Figure 256). The highest level of nitrate was 14 mg/L (May 20, 2013) taken after a rain event. There is no strong pattern in the data set showing seasonality to the elevated nitrate concentrations. The duration of elevated nitrate is unknown. It would be beneficial to collect samples throughout rain events (rising limb, peak, and falling limb) to understand the duration of elevated nitrate.

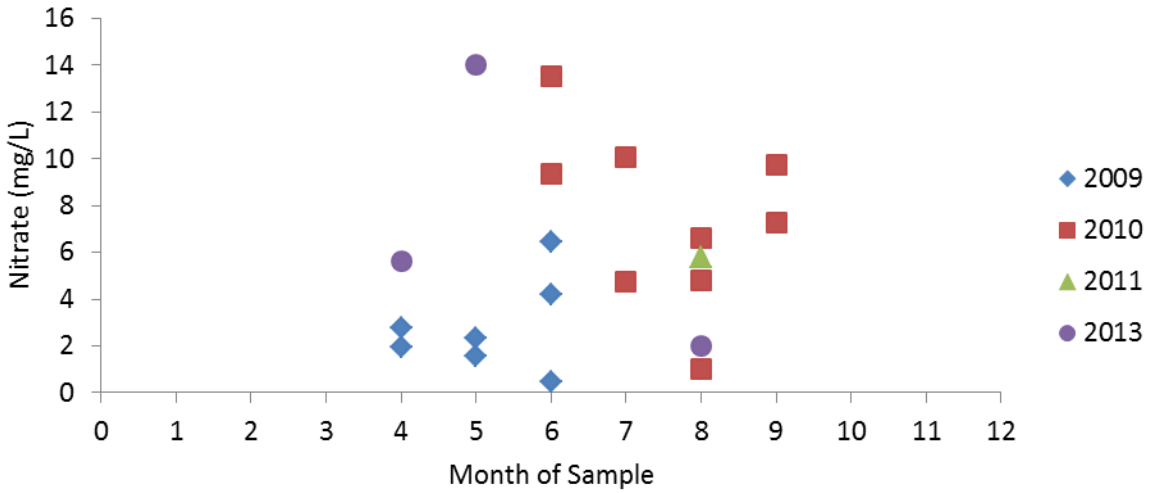


Figure 256. Nitrate concentrations by year and month in MacKenzie Creek

The macroinvertebrate metrics that correspond with nitrate stress show a fairly consistent response as expected (Table 202). Station 11LM056 had one Trichoptera taxon. In MacKenzie Creek, there was less than 1% caddisflies present in the sample. There was no intolerant taxa present, resulting in a low metric score (Figure 255). There were 72.2% nitrate tolerant individuals (27 taxa) and one nitrate intolerant taxon (prong-gilled mayfly, *Leptophlebiidae*). At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. Over 53% of the macroinvertebrate individuals were very tolerant to elevated nitrate.

Nitrate is a stressor to the biological community. Additional data should be collected to characterize the elevated nitrate conditions.

Table 202. Macroinvertebrate metrics that respond to nitrate stress in MacKenzie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM056 (2011)	**1**	**0.6**	**0**	**3.75**	**1**	**27**	**72.2**
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.88*	*2.58*	*19.4*	*55.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

At station S004-848 there were 17 samples of TP from 2009 to 2011. The maximum TP was 0.311 mg/L (September 28, 2010). The average TP of the 17 samples was 0.176 mg/L, over the draft river nutrient

criteria for the south region (0.15 mg/L). Of all 17 samples, nine were over the standard (52.9%). Of the data collected in the summer, June – September, 8 of 13 samples were over the standard (61.5%). In 2009, the data was only collected April through June and in 2010, June through September. The highest TP differed seasonally depending on the year, but much of late summer 2009 is unknown (Figure 257).The 2010 TP summer month average (June through September) was 0.190 mg/L. Only one sample in 2011 had both TSS and TP collected. The potential relationship between TSS and TP could not be evaluated at this time with the limited data.

Although TP is elevated, there needs to also be an elevated response variable of DO flux, chlorophyll-a, or BOD to result in an aquatic life impairment based on elevated nutrients. Chlorophyll-a was sampled 16 times during 2009 and 2010. The highest level was 29 ug/L on May 5, 2009. The next highest sample was only 4 ug/L. All samples were below the draft standard of 35 ug/L. BOD has not been collected in MacKenzie Creek. DO was measured by an YSI sonde from August 5-11, 2014. DO was lower than the 5 mg/L standard and the greatest flux was 5.4 mg/L, but most daily fluxes were less than 2.5 mg/L. More information is available in the DO section.

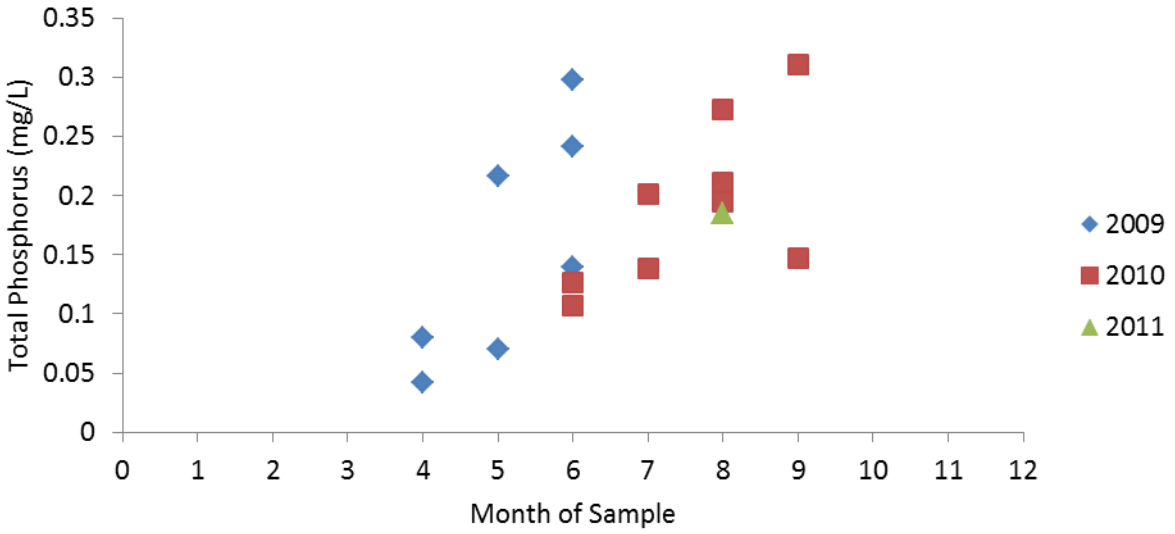


Figure 257. Total phosphorus concentrations in MacKenzie Creek by month sampled, 2009-2011

In MacKenzie Creek, three of six macroinvertebrate metrics responded negatively as expected with river eutrophication stress in 2011 (Table 203). There were numerous collector-gatherer taxa as well as total taxa in 2011. There was a lack of intolerant taxa as well as a high relative abundance of tolerant taxa. The macroinvertebrate response is mixed to a plausible eutrophication stressor.

Although the fish community is not impaired it still responds to stressors and can inform regarding those stressors. Only one metric, taxa count, responded negatively as expected with river eutrophication for the fish community in MacKenzie Creek (Table 204). The other metrics were considerably better than would be expected with eutrophication, including a presence of sensitive and darter individuals.

Although there was elevated TP in MacKenzie Creek, there was only one elevated DO flux and no other measurements of elevated response variables. The macroinvertebrate data had mixed indications of eutrophication stress and the fish community (although not impaired) did not exhibit strong eutrophication stress symptoms. The potential is high for eutrophication stress in MacKenzie Creek, but

it is not currently a stressor to the biological communities. Continued monitoring would be beneficial to ensure that the elevated TP does not become problematic. Additionally, efforts should be made to reduce TP delivery to the stream, not only for MacKenzie Creek, but also downstream waterbodies.

Table 203. Macroinvertebrate metrics that respond to TP and response variables in MacKenzie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM056 (2011)	46	**2**	21	9	**0**	**82.6**
Southern Forest Streams Average	*41.2*	*5.9*	*15.0*	*8.8*	*0.5*	*74.9*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 204. Fish metrics that respond to TP and response variables in MacKenzie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
11LM056 (2011)	22.4	28.4	49.3	64.2	**7**	22.4
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*	*1.4*
Expected response to stress	↓	↓	↓	↑	↓	↓

Dissolved Oxygen

DO was measured synoptically 17 times in 2009 and 2010, twice in 2011 at the time of biological sampling, and twice in 2013. None of the measurements were made before 9AM. One measurement was just below the standard on August 31, 2010 (4.89 mg/L at 10:15AM).This measurement was taken at low flow in comparison to the gage on the Straight River near Faribault. Another measurement made at the time of baseflow sampling on August 28, 2013 at 13:50 was just under the standard at 4.96 mg/L. DO was measured by an YSI sonde from August 5-11, 2014. DO was lower than the 5 mg/L standard and the greatest flux was 5.4 mg/L (August 6, 2014), but most daily fluxes were less than 2.5 mg/L (Figure 258). There was no flow information available on MacKenzie Creek to pair with the low DO measurements, so the nearby Straight River USGS station was used for comparison (Figure 259). Similar to the point measure in 2010, the low DO data in 2014 was captured during low flow conditions, and rebounded with a relatively small pulse of precipitation on August 5, 2014 (Figure 260).

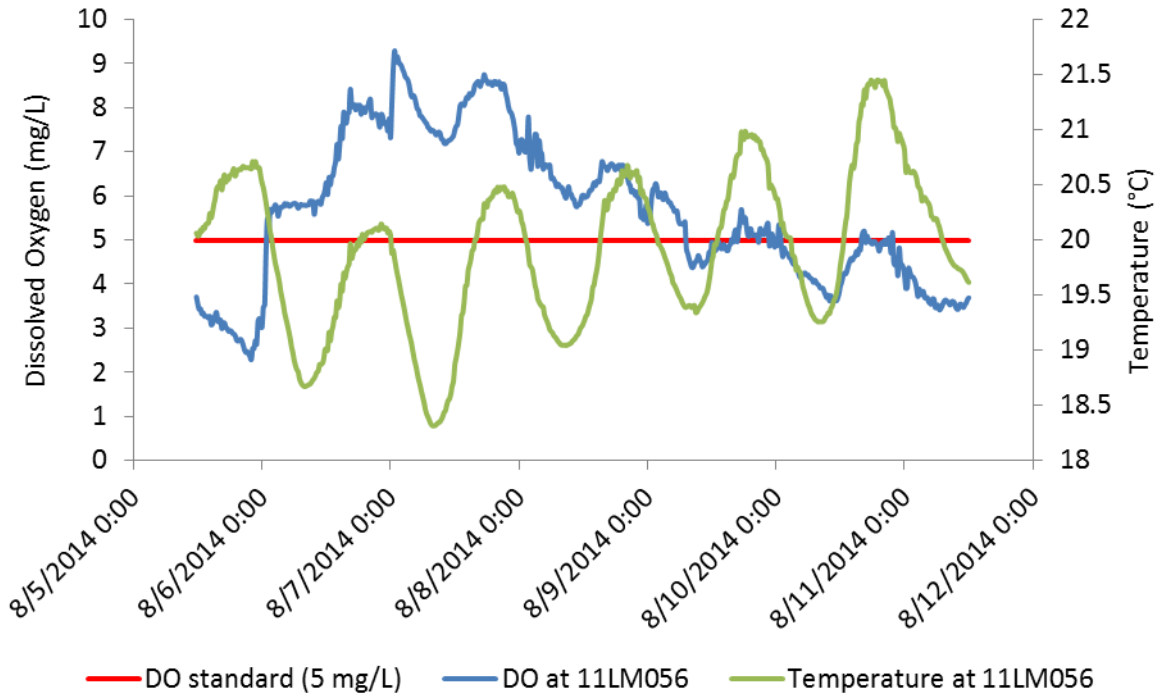


Figure 258. Dissolved oxygen and temperature measurements at station 11LM056 from August 5 – 11, 2014

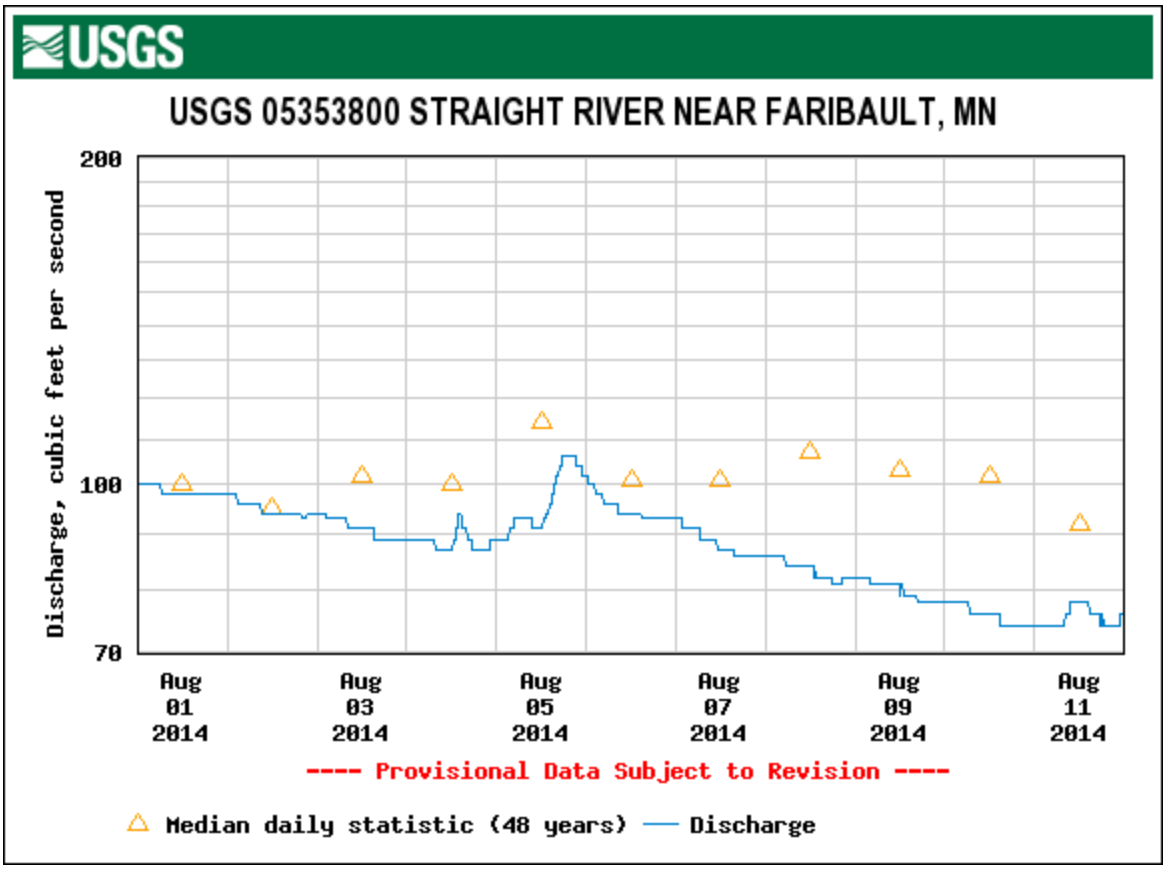


Figure 259.Discharge conditions on the Straight River from August 1-11, 2014 (USGS)

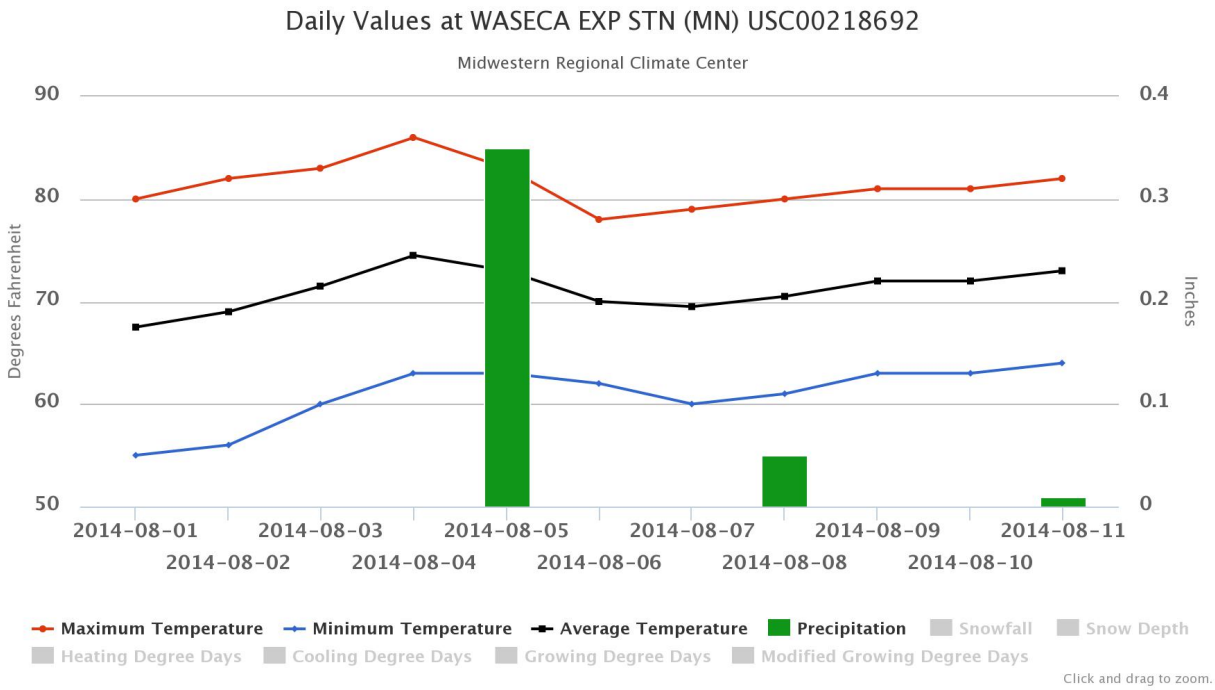


Figure 260. Temperature and precipitation at Waseca from August 1-11, 2014 (Midwestern Regional Climate Center)

Station 11LM056 had a high number of macroinvertebrate taxa (46) during the 2011 sample (Table 205). There were nine low DO intolerant taxa, four low DO very intolerant taxa, and four tolerant DO taxa (2.6% individuals).There were 11 EPT taxa that comprised 24.2% of the individuals present. Stations within the Southern Forest Streams GP class that are meeting the biocriteria average 10.2 EPT taxa. The DO TIV station score was 7.16, below the median (indicating moderate tolerance to low DO). Although the fish are not impaired, the DO TIV score was 7.23, greater than the median (indicating moderate sensitivity to low DO) for warmwater stations in the Cannon River Watershed.

MacKenzie Creek has exhibited low DO in 2010 and 2014. The lowest measured DO was 2.29 mg/L. The biological data collected in 2011 does not appear to exhibit stress from low DO. Potentially, there are yearly differences, with flow, and conditions were different in 2011 than in 2010 or 2014, leading to better biological response to metrics that correspond with low DO. The biological information does not connect to low DO stress. The presence of low DO should be evaluated further to understand the recurrence of low DO in MacKenzie Creek and the potential impacts to the biological communities. Low DO is not a stressor to the biological communities.

Table 205. Macroinvertebrate metrics that respond to low DO stress in MacKenzie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPT	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
11LM056 (2011)	46	11	**7.9**	7.16	9	4	2.6
Southern Forest Streams Average	*41.3*	*10.2*	*7.1*	*7.04*	*6.51*	*5.57*	*13.99*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

TSS/Turbidity

In MacKenzie Creek, at station S004-848, there were 35 transparency tube measurements collected from 2008 - 2010, with the lowest measurement of 9.5cm. Converted to secchi tube measurements, none were less than the 10cm standard of the south TSS region. Additionally there were five transparency tube measurements at station S002-456, in 2003, that were all greater than 60cm. There were four TSS samples taken on MacKenzie Creek. The one TSS sample was taken at the time of fish sampling in 2011, 32 mg/L TSS, and was less than the draft TSS standard for the south region (65 mg/L). The other three were targeted samples during snowmelt, a rain event and baseflow in 2013. The highest TSS was during at the rain event sample with 41 mg/L. It is uncertain if any longitudinal differences exist in MacKenzie Creek and the duration of reduced transparency.

The macroinvertebrate metrics that respond to elevated TSS show response corresponding to elevated TSS stress (Table 206). There was a lack of collector-filterer and stonefly (Plecoptera) individuals in 2011. The TSS index score was above the average of similar stations meeting the biocriteria, indicating higher tolerance to elevated TSS. There were no taxa that are intolerant to TSS and the number of TSS tolerant

taxa was slightly high, but the TSS tolerant individuals comprised more than 51% of the community, above that of the average of similar stations meeting the biocriteria.
Although not impaired, the fish can help sometimes identify stressors. The fish community had minimal response to elevated TSS stress (Table 207). In 2011, there was an absence of non-tolerant Centrarchidae fish, and lower than expected herbivores, riffle dwellers and simple lithophilic spawners. The remainder of the metrics had responses that would not indicate TSS stress. The TSS index score was less than the average of similar stations meeting the biocriteria, indicating greater sensitivity to elevated TSS. Overall, the fish community is not suggestive of elevated TSS stress.

The macroinvertebrate community does appear stressed from a plausible elevated TSS stressor. However, there is no documented elevated TSS or indicators of reduced transparency in MacKenzie Creek. The fish community (though not impaired) also does not corroborate with the macroinvertebrate results. At this time, elevated TSS is inconclusive as a stressor to the macroinvertebrate community. Additional data should be collected to better understand the sediment dynamics in MacKenzie Creek.

Table 206. Macroinvertebrate metrics that respond to TSS stress in MacKenzie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM056 (2011)	**7.1**	**0**	**20.9**	**0**	**11**	**51.4**
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*10.2*	*27.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 207. Fish metrics that respond to TSS stress in MacKenzie Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RifflePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM056 (2011)	40.3	**0**	**11.9**	22.4	7.5	31.3	**11.9**	22.4	**11.9**	12.7
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.3*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

Station 11LM056 had a poor MSHA score in 2011 (30.8). Four of the five subcategories in the MSHA received less than half of the available points (Figure 261). The surrounding land use was row crop on

both sides of the stream. The riparian width was moderate (30-150') with heavy shade. Erosion on the banks was noted as severe (75-100%). The channel was mostly comprised of run habitat with sand and silt as the primary substrates. There was only 5% riffle habitat with sand and gravel substrates. Pool habitats had silt substrate. There was a lack of diverse substrate types available. The entire reach had severe embeddedness. Cover in the reach was sparse (5-25%) with only the presence of logs/woody debris and rootwads. Station 11LM056 had moderate depth variability, good sinuosity, and decent pool to riffle width. The only velocity type noted at time of fish sampling was slow. The channel stability was low and channel development was poor, resulting in no points for those two categories. The biologists noted that there was excess sediment and mid channel bars present, indicating instability. Macroinvertebrates were sampled on snag, woody debris, and root wad habitats.

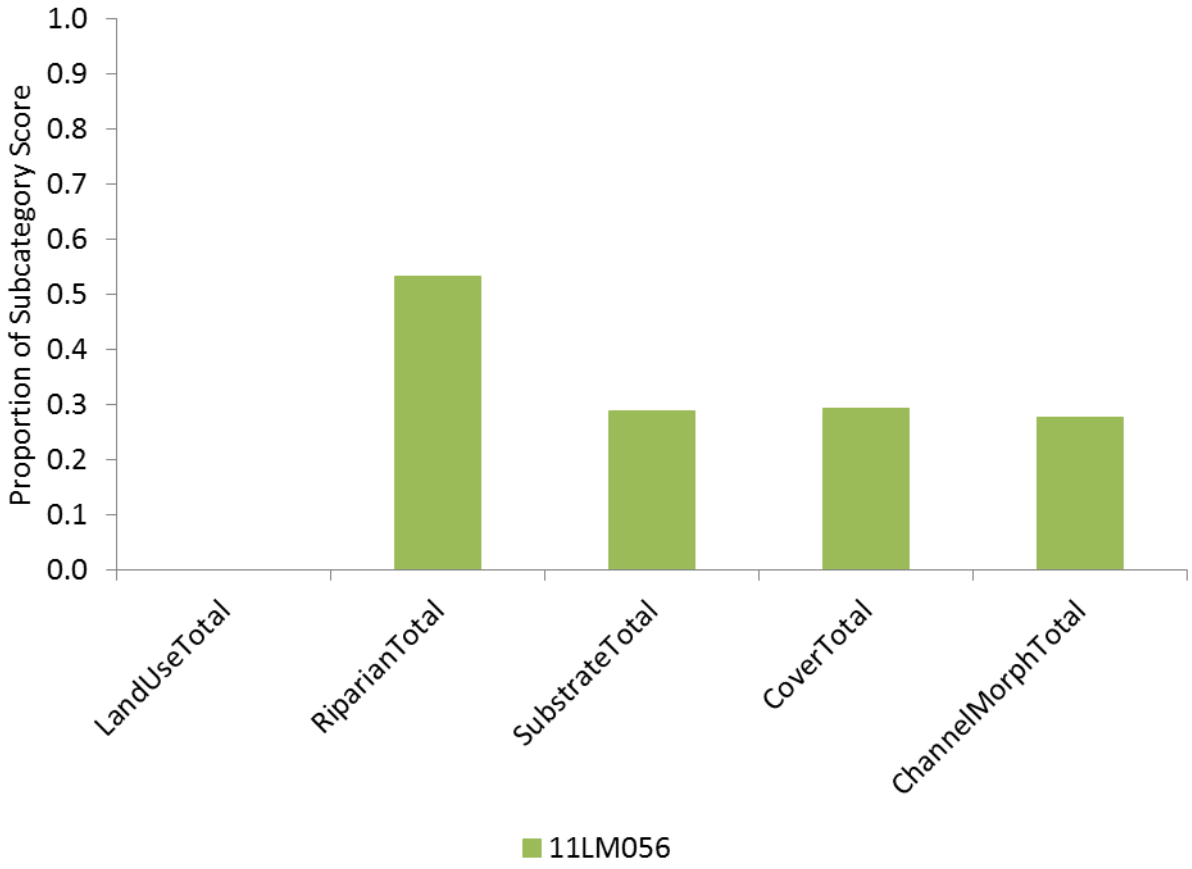


Figure 261. MSHA subcategory scores for station 11LM056, MacKenzie Creek

At station 11LM056, the percentages of habitat specific macroinvertebrate metrics were within a fairly expected range, except the percentages of burrowers and legless were elevated (Figure 262). Sprawlers and swimmers comprised a little less of the community. The clinger taxa count was moderate at station 11LM056 resulting in an MIB metric score greater than the average metric score needed to meet the biocriteria. The most dominant taxa in the sample were *Polypedilum* (a very tolerant climbing midge) and *Heptagenia* (a very tolerant clinging mayfly). Tolerant macroinvertebrates dominated the communities at station 11LM056 in 2011 (95%).

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat quality is diminished. Although the fish community is not impaired, they can provide additional information about potential stressors. The fish community had one taxon that has a preference for riffles at station 11LM056 (white sucker). There were three taxa present at 11LM056 that are simple lithophilic spawners, comprising 49.3% of the fish collected. The average percentage of simple lithophilic spawners at Southern Headwater fish class stations in the Cannon River Watershed was 27.3%. In 2011, station 11LM056 had 28.4% benthic insectivores (johnny darter and logperch). Those same fish were also the two darter, sculpin, or round bodied fish taxa at station 11LM056. Although these percentages seem good, there was also simply a lower number of fish within this reach. The average number of fish per meter in Southern Headwater stations in the Cannon River Watershed is 1.29. In 2011, station 11LM056 had 0.38 fish per meter.

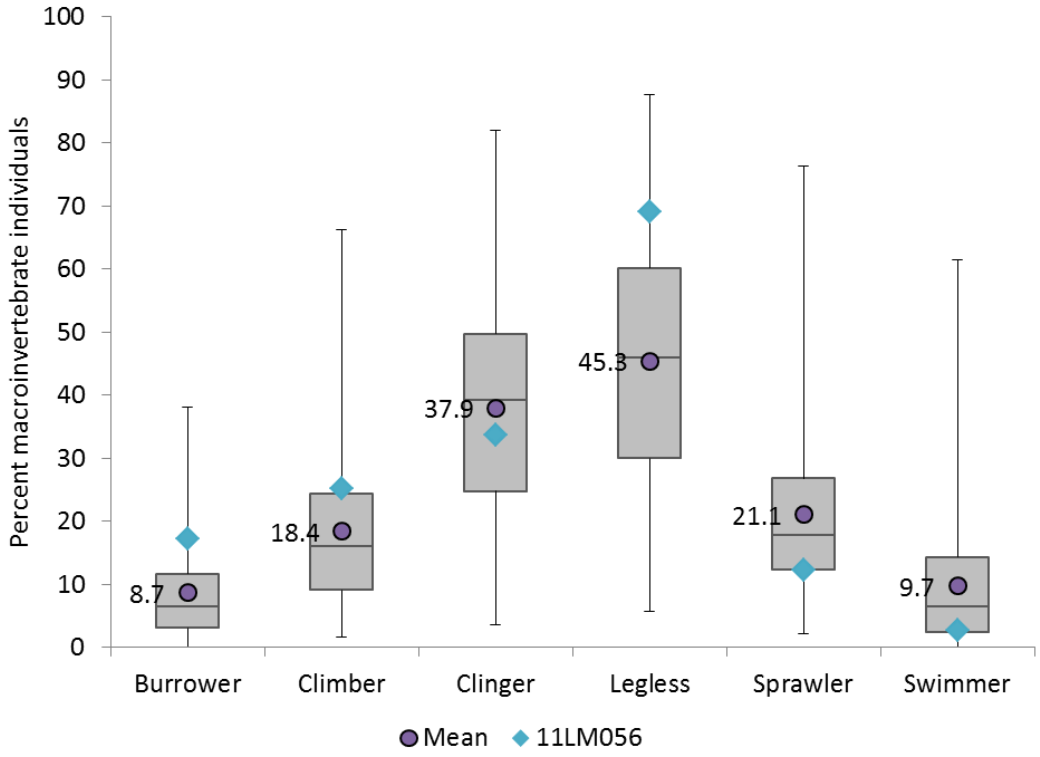


Figure 262. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from station 11LM056

The habitat available is quite poor in MacKenzie Creek. Despite the poor habitat, there were still healthy taxa of clinging macroinvertebrates. The lower number of fish per meter, along with an increase in macroinvertebrates that burrow (even though woody habitats were sampled), suggest that lack of quality habitat is playing a role in shaping the biological communities.

The MPCA biologists noted evidence of extreme stream flow during flooding in spring of 2011, which had blown out banks and left large piles of woody debris in numerous places. Additionally, silt deposition was apparent everywhere (Figure 263). Alteration of flow can cause flashiness in a system, and geomorphic instability such as incision, and lead to issues that directly affect the biological communities.

Figure 263. Photograph of station 11LM056, August 11, 2011

Fish Passage

Currently, there are no known physical barrier concerns for the biological community.

Conclusion

MacKenzie Creek is impaired for lack of macroinvertebrate assemblage. The stressors in MacKenzie Creek are elevated nitrate and lack of habitat. TSS is inconclusive as a stressor, but sediment leading to embeddedness is a major issue.

Nitrate is elevated and playing a role in shaping the macroinvertebrate community. Additional data should be collected to characterize the elevated nitrate conditions as well as sources.

Although there was elevated TP in MacKenzie Creek, there was only rain driven DO flux as a response variable, but no others. The macroinvertebrate data had mixed indications of eutrophication stress, and the fish community did not exhibit strong signals of eutrophication stress. The potential is high for eutrophication stress in MacKenzie Creek, but it is not currently a stressor to the biological communities. Continued monitoring would be beneficial to ensure that the elevated TP does not become problematic. Additionally, efforts should be made to reduce TP delivery to the stream, not only for MacKenzie Creek, but also downstream waterbodies.

MacKenzie Creek has exhibited low DO in 2010 and 2014. The lowest measured DO was 2.29 mg/L. The biological data collected in 2011 does not appear to exhibit stress from low DO. Potentially, there are yearly differences with flow, and conditions were different in 2011 than in 2010 or 2014, leading to better biological response. The biological information does not connect to low DO stress. Low DO is inconclusive as a stressor currently. The presence of low DO should be evaluated further to understand the recurrence of low DO in MacKenzie Creek and the potential impacts to the biological communities.

The macroinvertebrate community does appear stressed from a plausible elevated TSS stressor. However, there is no documented elevated TSS or indicators of reduced transparency in MacKenzie Creek. The fish community also does not corroborate with the macroinvertebrate results. At this time, elevated TSS is inconclusive as a stressor to the macroinvertebrate community. Additional data should be collected to better understand the sediment dynamics in MacKenzie Creek.

The habitat available is quite poor in MacKenzie Creek. Despite the poor habitat, there were still healthy taxa of clinging macroinvertebrates. The lower number of fish per meter, along with an increase in macroinvertebrates that burrow (even though woody habitats were sampled), suggest that lack of quality habitat is playing a role in shaping the biological communities, but it is also likely not the only stressor present in the stream.

Nitrate delivery and degraded habitat may be due in part to the altered hydrology in the watershed. Over half of the stream miles in the watershed are altered. The evidence at the station of extreme flows is evident.

Continued monitoring of TP, DO and TSS is recommended to understand the stream dynamic further, particularly TSS which is currently inconclusive as a stressor. Efforts to reduce nitrate and improve the habitat would be beneficial to the macroinvertebrate community.

4.7.6 Unnamed Creek (638)

This small warmwater AUID (07040002-638) on Unnamed Creek is 1.96 miles and located downstream of French and Roberds lakes. There is another small AUID (07040002-637) that outlets from Roberts Lake directly, this is the next AUID downstream. Data from both AUIDs were considered in the analysis of chemistry. Unnamed Creek outlets into Wells Lake on the Cannon River. Station 11LM078, on Unnamed Creek, was sampled for macroinvertebrates and fish in 2011. Through the sampling it was found to be impaired for the use of aquatic life due to lack of macroinvertebrate assemblage. There are currently no other impairments on this AUID.

The fish community was not listed as impaired, with an IBI score of 58 on the Southern Headwaters class. There were many lake species in the sample, in part due to the proximity to lakes both upstream and downstream of Unnamed Creek. The dominant fish were yellow perch, bluegill, and emerald shiner.

Station 11LM078 received a 38.2 on the Southern Forest Streams GP class MIBI. The community was dominated by *Rheotanytarsus*, *Polypedilum*, *Cheumatopsyche*, *Hyalella*, and *Stenochironomus*. Station 11LM078 had relatively low metric scores for taxa richness of clingers (ClingerCh), relative abundance of dominant five taxa in subsample (chironomid genera treated individually; DomFiveCHPct), taxa richness

of macroinvertebrates with tolerance values less than or equal to two, using MN TVs (Intolerant2Ch), taxa richness of Plecoptera, Odonata, Ephemeroptera, & Trichoptera (baetid taxa treated as one taxon; POET), total taxa richness of macroinvertebrates (TaxaCountAllChir), and relative abundance of non-hydropsychid Trichoptera individuals in subsample (TrichwoHydroPct; Figure 264).

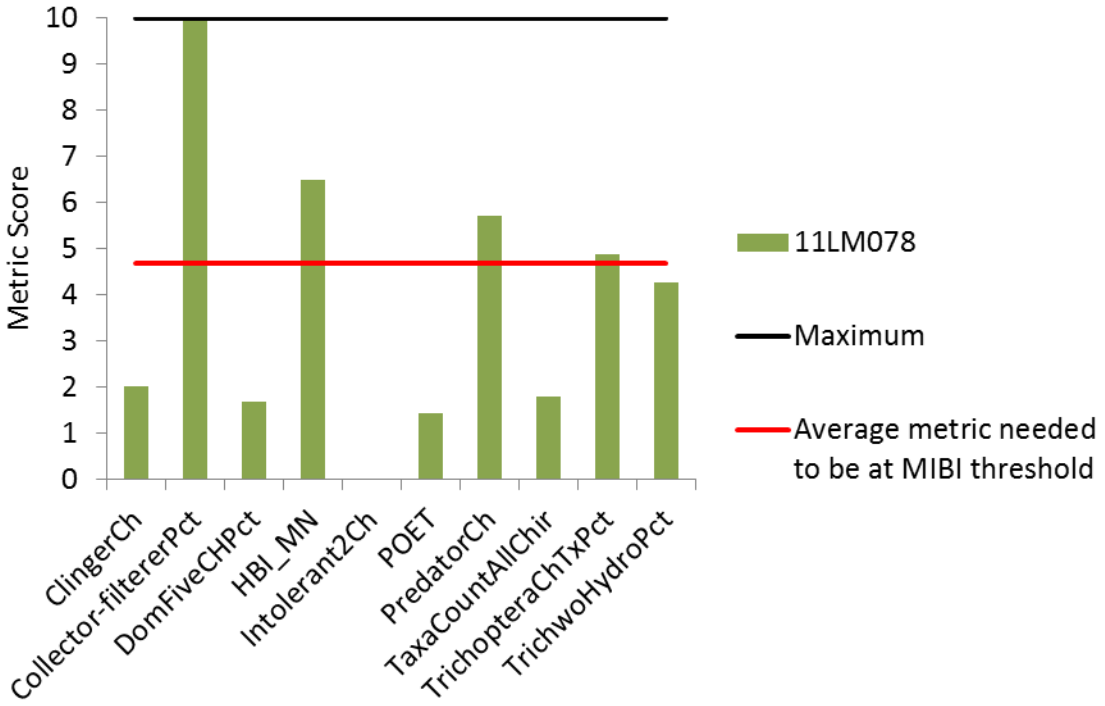


Figure 264. Macroinvertebrate metrics of the Southern Forest Streams GP IBI for Unnamed Creek, station 11LM078

Temperature

Chemistry station S005-419 is downstream of biological station 11LM078 on Unnamed Creek. An YSI sonde was deployed from August 13 – 26, 2013, and July 17-23, 2014, at the downstream station. In 2013, the minimum temperature during that time was 16.31°C with a maximum temperature of 27.51°C. In 2014, the minimum temperature during that time was 19.58°C with a maximum temperature of 26.24°C. Twelve synoptic measurements were taken along the creek from 2011, 2013, and 2014. The maximum temperature recorded was 26.29°C (August 26, 2013). Unnamed Creek is a warmwater reach and is well within expected temperature ranges, and does not show elevated daily fluctuations of temperature at this time. Elevated temperature is not a stressor currently in Unnamed Creek.

Nitrate

Nitrate has been measured 11 times over 2011, 2013, and 2014. The highest measure was 1.4 mg/L (August 28, 2013, baseflow). The majority of the samples were less than 1 mg/L (63.6%).

The macroinvertebrate metrics that correspond with nitrate stress show a mixed response as expected (Table 208). Station 11LM078 had two Trichoptera taxa, and 1.9% non-hydropyschid caddisflies present. There was no intolerant taxa present, resulting in a low metric score (Figure 264). There were 28.9% nitrate tolerant individuals (12 taxa) and no nitrate intolerant taxa. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI.

The macroinvertebrate community appears to have a mixed response to potential nitrate stress. There were very few nitrate tolerant individuals present. There were also relatively low nitrate values of those collected. It is likely that the response seen in the macroinvertebrate community is due to other stressors since it is lacking consistency amongst the metrics. Nitrate is not a stressor to the biological community at this time.

Table 208. Macroinvertebrate metrics that respond to nitrate stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM078 (2011)	**2**	**1.9**	**0**	2.67	**0**	12	28.9
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.88*	*2.58*	*19.4*	*55.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

In Unnamed Creek, there were 10 samples of TP over 2011, 2013, and 2014. The maximum TP was 0.296 mg/L (August 26, 2013). The average TP of the 10 samples was 0.168 mg/L, and 8 out of 10 samples were over the draft river nutrient criteria for the central region (0.1 mg/L). The highest TP is in the late summer months (Figure 265). Although only 10 data points existed with both TSS and TP analyzed, the potential relationship was evaluated (Figure 266) and found that there was elevated TP with low TSS concentrations. The 2013 data may be skewed low due to inaccurate lab methodologies. The 2013 samples, although reported potentially lower than actual conditions, were still greater than the central region draft nutrient criteria.

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to result in an aquatic life impairment based on elevated nutrients. BOD was only collected once, on August 26, 2013, at station S005-418 and S005-419 (8.5 and 2.7 mg/L respectively). Although this is very limited data, both were above the draft standard for the central region (2.0 mg/L). At station S005-419, DO was measured by an YSI sonde from August 13 – 26, 2013, and July 17-23, 2014. DO was lower than the 5 mg/L standard during both deployments. In 2013 there was very little flux, and in 2014 there was flux as great as 4.6 mg/L. More information on the DO dynamics in Unnamed Creek can be found in the DO section. Similarly, chlorophyll-a was only collected at the same time as the BOD samples, with 74.2 µg/L at station S005-418 (upstream) and 3.0 µg/L at station S005-419 (downstream). Only the upstream station had elevated chlorophyll-a, greater than the draft eutrophication standard of 18 µg/L. At the time of fish sampling in 2013, the water color was noted as green (Figure 267). The upstream lakes have a large influence on the quality of the water moving through this small creek. The upstream lakes, Roberds and French, are both impaired for elevated nutrients.

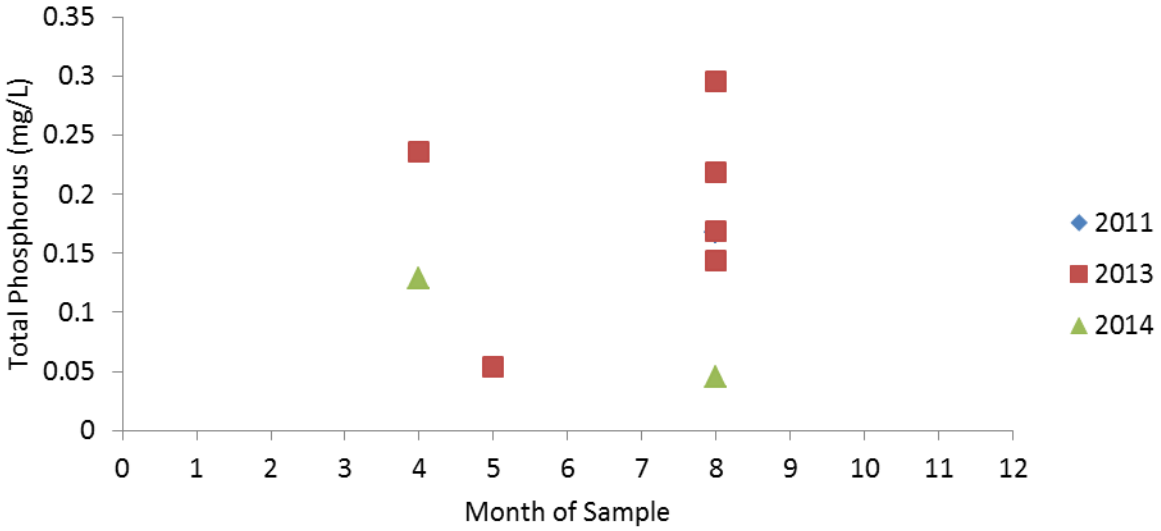


Figure 265. Total phosphorus concentrations in Unnamed Creek by month sampled, 2011, 2013, and 2014

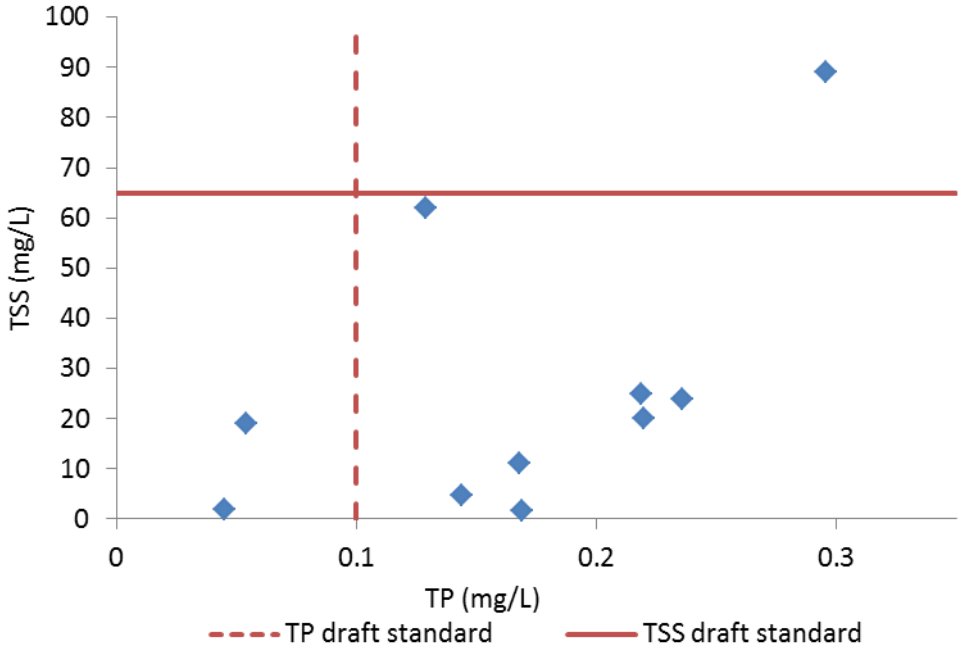


Figure 266. TSS and TP relationship in Unnamed Creek (2011, 2013 and 2014)

In Unnamed Creek, all six of the metrics responded negatively as expected with river eutrophication stress in 2011 (Table 209). The macroinvertebrate taxa count was considerably lower compared to similar stations that are meeting the biocriteria. Intolerant taxa were absent from the survey at station 11LM078, along with reduced numbers of collector-filterer, collector-gatherer, and EPT taxa. The macroinvertebrate metrics all correspond with eutrophication.

Although the fish community is not impaired it still responds to stressors and can inform regarding those stressors. Similar to the macroinvertebrate community, five of six fish metrics responded negatively as expected with river eutrophication in 2011, and three of six metrics in 2013 (Table 210). During the 2011 visit, there was a lack of sensitive, darter, and intolerant individuals, resulting in 0% for each of the respective metrics, and only 0.6% for simple lithophilic spawners. However, taxa count was near the

average for similar stations meeting the biocriteria, and the percentage of tolerant individuals was low (19.1%). In 2013, there were a greater abundance of sensitive and simple lithophilic individuals.

TP is elevated in Unnamed Creek, and although limited data exists, there is evidence of elevated response variables in the creek (BOD, DO flux and low DO). All of the macroinvertebrate metrics responded as expected with increased eutrophication stress, and most of the fish metrics also responded similarly. Elevated TP and the associated response variables are indicative of eutrophication and are stressors to the biological communities in Unnamed Creek.

Table 209. Macroinvertebrate metrics that respond to TP and response variables in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM078 (2011)	**25**	**3**	**6**	**3**	**0**	**84**
Southern Forest Streams Average	*41.2*	*5.9*	*15.0*	*8.8*	*0.5*	*74.9*
Expected response to stress	↓	↓	↓	↓	↓	↑

Table 210. Fish metrics that respond to TP and response variables in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
11LM078 (2011)	**0**	**0**	**0.6**	19.1	**11**	**0**
11LM078 (2013)	44.5	**0**	48.6	24.7	**10**	**0**
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*	*1.4*
Expected response to stress	↓	↓	↓	↑	↓	↓

Figure 267. Photograph of station 11LM078, August 6, 2013

Dissolved Oxygen

DO was measured synoptically 10 times in 2011, 2013, and 2014. Three measurements on the stream were below the 5 mg/L standard, two of them at separate locations on the same day and all in late August 2013. None of the measurements were made before 9AM. At station S005-419, DO was measured by an YSI sonde from August 13 – 26, 2013 and July 17-23, 2014. DO was lower than the 5 mg/L standard during both deployments. In 2013, DO was always below 5 mg/L and there was very little flux (Figure 268). In 2014, DO fluctuated daily both above and below the standard with flux as great as 4.6 mg/L (Figure 269). On August 26, 2013, DO was 3.23 mg/L out of lake, and at downstream station S005-419 DO was 3.22 mg/L. In 2014, blue green algae were present at the station. BOD was measured on August 26, 2013. At station S005-418, just downstream of the lake BOD was 8.5 mg/L, and at station S005-419, BOD was 2.7 mg/L.

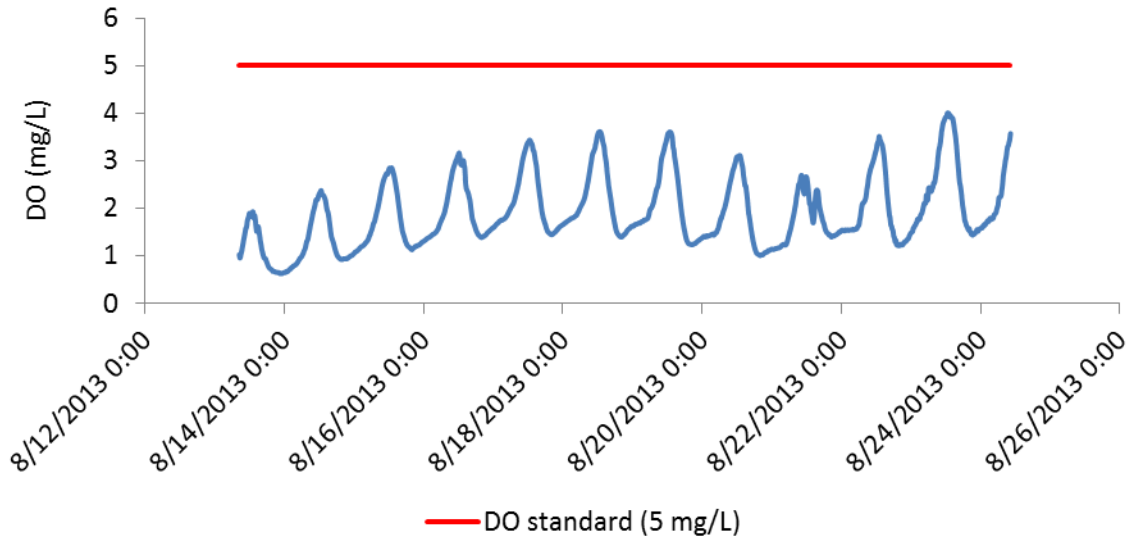


Figure 268. DO at station S005-419 in 2013

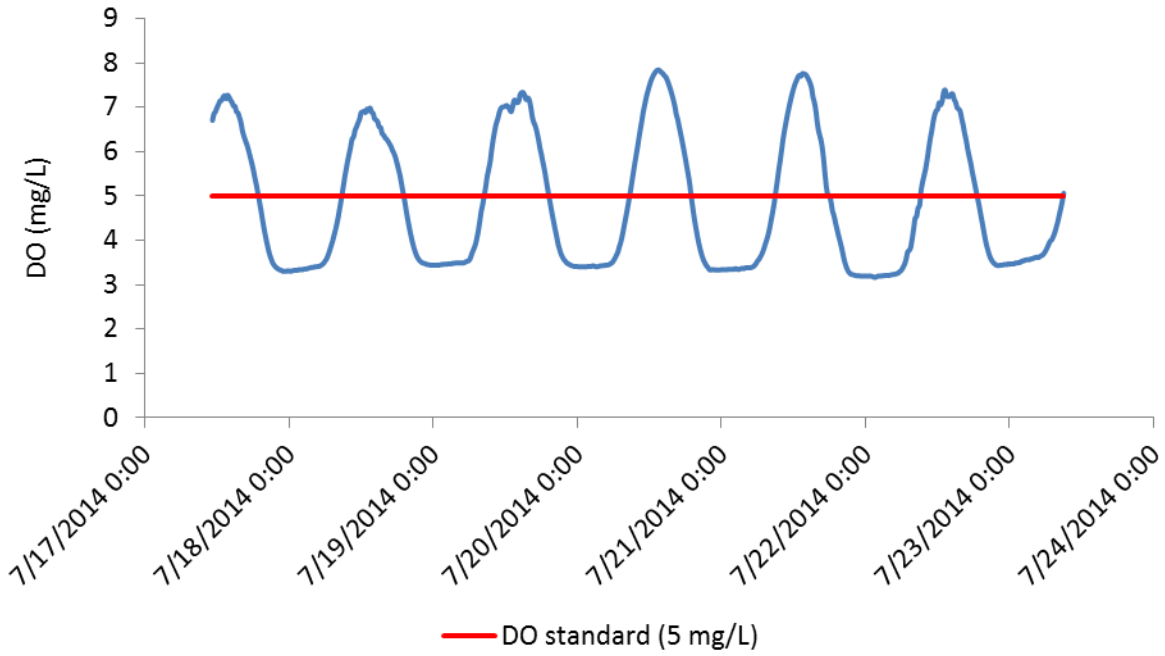


Figure 269. DO at station S005-419 in 2014

Station 11LM078 had low numbers of macroinvertebrate taxa (25) during the 2011 sample (Table 211). There were no low DO intolerant taxa, no low DO very intolerant taxa, and three tolerant DO taxa (8.1% individuals). There were three EPT taxa that comprised 11.8% of the individuals present. Stations within the Southern Forest Streams GP class that are meeting the biocriteria average 10.2 EPT taxa. The macroinvertebrate DO TIV station score was 7.07, below the median and above the first quartile (indicating moderate tolerance to low DO). Although the fish are not impaired, the DO TIV score was 6.49 (2011), in the most tolerant quartile to low DO for warmwater stations in the Cannon River Watershed.

In the Unnamed Creek DO has been below the standard. The creek also has had elevated BOD, although very limited data exists. The creek is greatly influenced by the conditions of the upstream lakes. The biological communities both responded as expected with low DO stress. Low DO is a stressor to the biological communities in Unnamed Creek.

Table 211. Macroinvertebrate metrics that respond to low DO stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPT	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
11LM078 (2011)	**25**	**3**	6.89	7.07	**0**	3	8.1
Southern Forest Streams Average	*41.3*	*10.2*	*7.1*	*7.04*	*6.51*	*5.57*	*13.99*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

TSS/Turbidity

In Unnamed Creek, there were 10 samples of TSS; one at station S005-418, two at station 11LM078, and seven at station S005-419. The samples were collected over 2011, 2013, and 2014. One of the samples was greater than the draft TSS standard of 65 mg/L for the south region (10%). There were 22 measurements of transparency collected during 2008, 2013, and 2014. Converted to secchi tube measurements, no measurements were less than the 10 cm draft standard of the south TSS region. Overall, the chemical data does not strongly suggest TSS as a stressor. Although the chemical data is not strong, habitat problems may suggest sediment is moving in this system.

The macroinvertebrate metrics that respond to elevated TSS stress do not show results consistent with TSS stress (Table 212). There was an abundance of collector-filterers, but lacked stoneflies (Plecoptera). The macroinvertebrate TSS index score was better than the statewide average of similar stations meeting the biocriteria. Additionally there were no taxa that are intolerant to TSS. The TSS tolerant taxa were not relatively high, and the TSS tolerant individuals comprised of 26% of the community, just below that of the average of similar stations meeting the biocriteria.

The fish community, although not impaired, had a mixed to little response to elevated TSS stress (Table 213). The percent of intolerant (both years) and sensitive fish (2011 only) were absent. There was an abundance of long lived fish as well as non-tolerant Perciformes. The TSS index score for the station was more tolerant than that of similar stations meeting the biocriteria, and greater than the average of all stations in the Southern Headwaters class (15.9). There were higher percentages of carnivores, non-tolerant Centrarchidae, non-tolerant Perciformes, and long lived fish. Overall, the fish community does not point strongly at TSS stress. TSS is not a stressor to the biological community in Unnamed Creek.

Table 212. Macroinvertebrate metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM078 (2011)	61.7	**0**	15.7	**0**	4	26
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*10.2*	*27.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Table 213. Fish metrics that respond to TSS stress in Unnamed Creek compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	BenFdFrimPct	Centr-TolPct	HrbNWQPct	IntolerantPct	LlvdPct	Percfm-TolPct	RifflePct	Sensitive Pct	SLithFrimPct	TSS Index Score (RA)
11LM078 (2011)	**0.6**	26.2	**0.6**	**0**	87.4	76.2	**0.6**	**0**	**0.6**	**18.7**
11LM078 (2013)	**14.8**	5.5	**14.8**	**0**	32.9	29.5	**14.8**	44.5	22.7	**23.0**
Southern Headwaters Average	*34.5*	*1.2*	*22.1*	*1.4*	*4.3*	*13.1*	*25.4*	*6.8*	*14.4*	*15.1*
Expected response to stress	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑

Lack of Habitat

Station 11LM078 received a fair MSHA score in 2011 (50.25) and in 2013 (55.8). The Unnamed Creek received low subcategory scores in substrate and land use (Figure 270). The surrounding land use was row crop and forest, wetland, prairie, or shrub. In 2011, the riparian width was moderate on the left and extensive on the right, with heavy and severe bank erosion. Shade was substantial and heavy. The substrate in 2011 was dominated by sand and silt with only 5% riffle habitat available. There were few substrate types available with severe embeddedness. Cover was moderate with many types of cover available. There was good depth variability, excellent sinuosity, and good pool to riffle width. Channel stability was low and channel development was fair. Moderate and slow velocity types were available. Macroinvertebrates were sampled on snag, woody debris, and root wad habitats.

In 2013, the MPCA repeated fish sampling and conducted habitat assessment utilizing the MSHA at station 11LM078. There were many similarities in the existing habitat, but there were some differences. Bank erosion was noted as only little (5-25%). Gravel was present in the still minimal riffle habitats available. Embeddedness was noted as moderate rather than severe.

Additionally in 2013, habitat was surveyed longitudinally in the Unnamed Creek by Cannon River Watershed Partnership, employing the MSHA protocol (Figure 271). The MSHA scores ranged from poor

to good (26 – 74.15), with an average of 47.75 (fair). There was very little riffle habitat in the 30 reaches that were surveyed. Additionally, there was very little coarse material, and when present, it was lightly to moderately embedded.

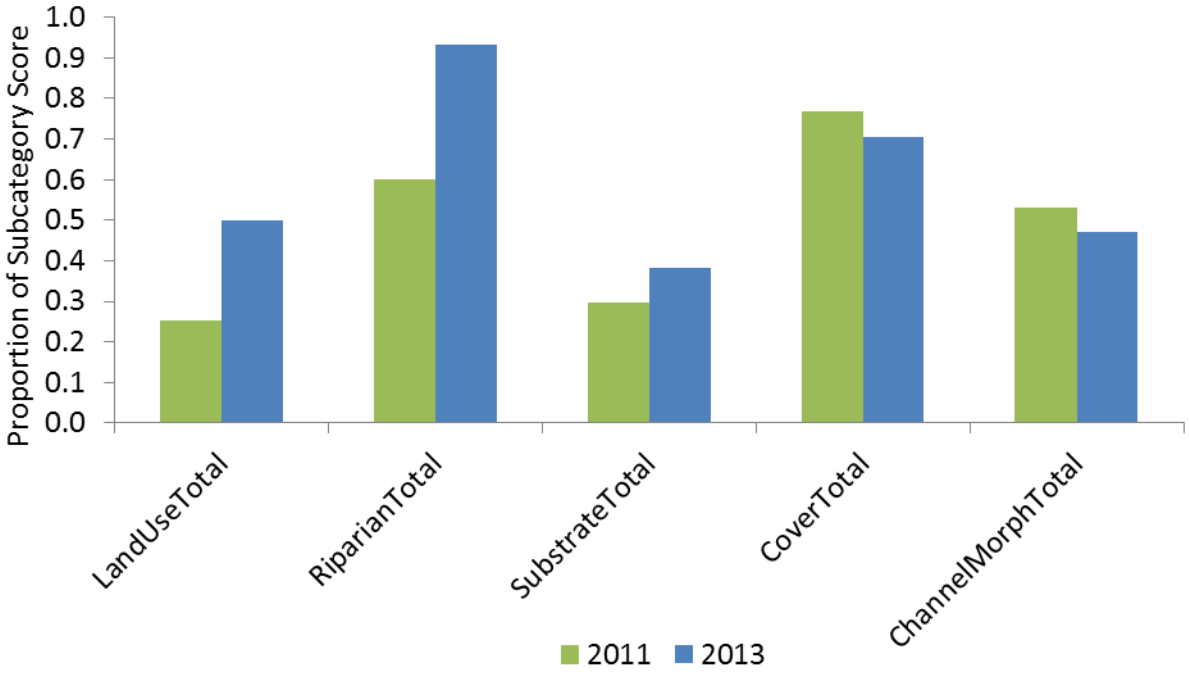


Figure 270. MSHA subcategory scores for station 11LM078, Unnamed Creek

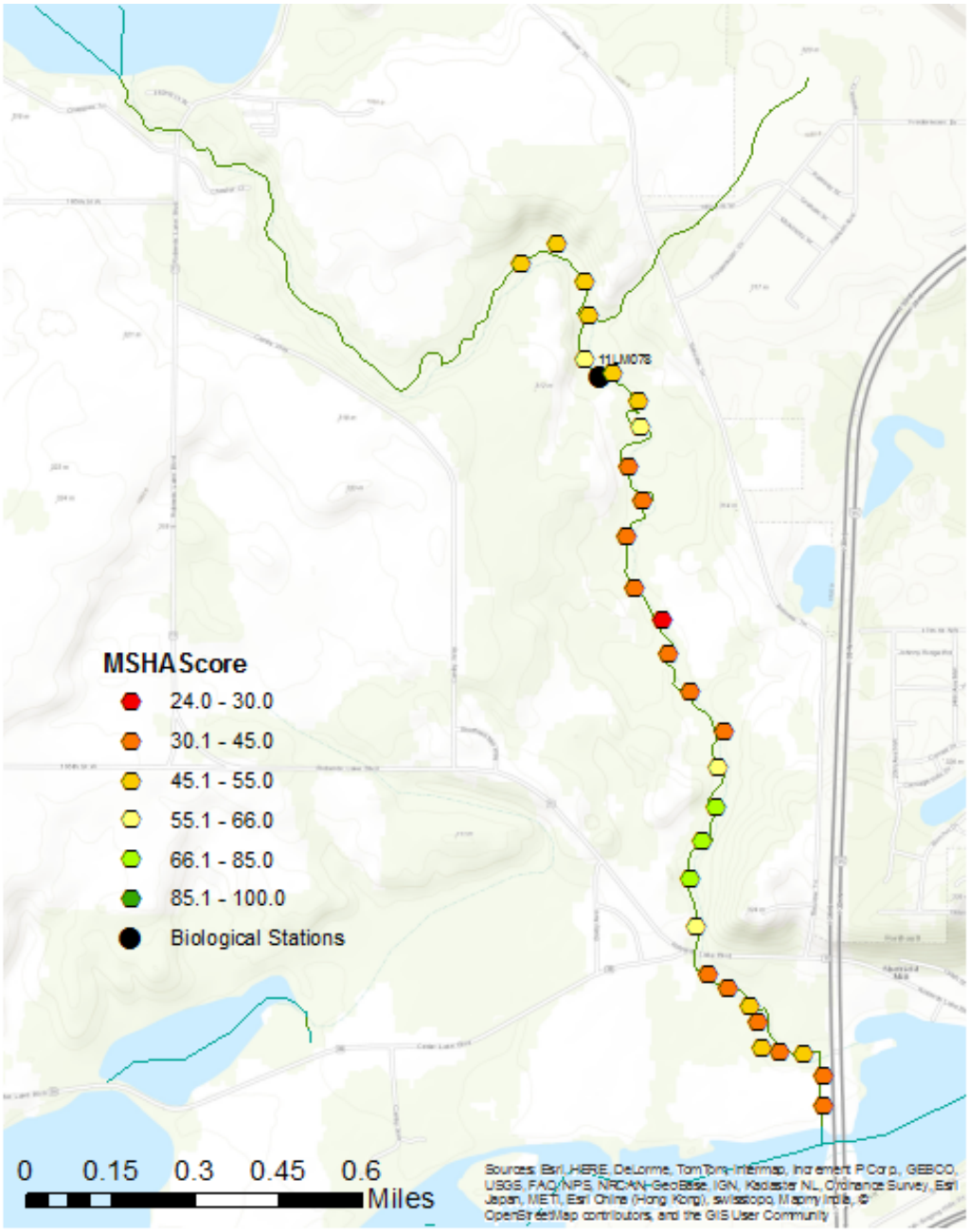


Figure 271. MSHA longitudinally through Unnamed Creek.

At station 11LM078, the percentages of macroinvertebrate habitat specific metrics were within a fairly expected range, except the percentages of clingers and legless were a little elevated (Figure 272). Sprawlers and swimmers comprised a little less of the community. Although the percentage of clingers was high, the clinger taxa count was low resulting in a low metric score in the MIBI. The most dominant taxa in the sample were *Rheotanytarsus* (a tolerant clinging midge) and *Polypedilum* (a very tolerant climbing midge). Tolerant macroinvertebrates dominated the communities at station 11LM078 in 2011 (97%).

Riffle dwelling fish, simple lithophilic spawners, benthic insectivores, and darter, sculpin, and round bodied suckers are often reduced when habitat quality is diminished. Although the fish are not impaired, they can provide additional information about potential stressors. The fish community had one taxon that has a preference for riffles at station 11LM078 (white sucker), in both 2011 and 2013. There were

two taxa that are simple lithophilic spawners present, comprising less than 1% in 2011, and 48.6% in 2013 (emerald shiner and white sucker). The average percentage of simple lithophilic spawners at Southern Headwater fish class stations in the Cannon River Watershed was 27.3%. Station 11LM078 had no benthic insectivores or darter, sculpin, or round bodied fish taxa in 2011 or 2013.

The lack of diverse habitat is a stressor to the biotic community in the Unnamed Creek. Reduced habitat availability is affecting both the macroinvertebrates as well as the fish community.

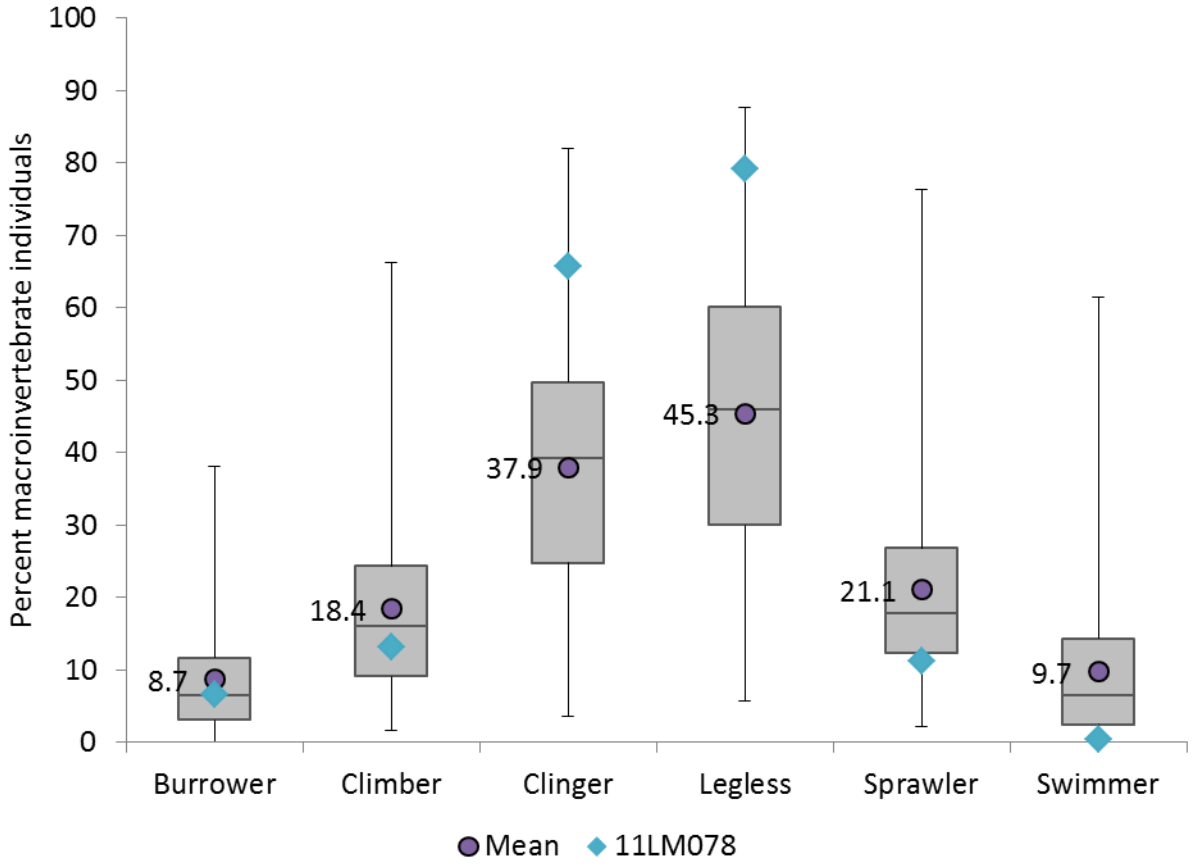


Figure 272. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from station 11LM078

Fish Passage

There is an outlet structure at both French and Roberds Lakes, and the stream flows into Wells Lake. There are many lake fish species present in the community. Although it is not understood very well in this area, there may be some limiting of the fish community due to the lack of available connections to additional river miles. Currently, connectivity for the macroinvertebrate community is not a concern.

Conclusion

Unnamed Creek is impaired for the use of aquatic life due to lack of macroinvertebrate assemblage. Elevated TP and associated response variables are indicators of eutrophication stress present in Unnamed Creek, connected to the low DO stress. Additionally, lack of quality habitat is a stressor.

Elevated temperature, nitrate, and TSS are not stressors to the macroinvertebrate community at this time.

TP is elevated in Unnamed Creek, and evidence of elevated response variables in the creek. All of the macroinvertebrate metrics responded as expected with increased eutrophication stress and most of the fish metrics also responded similarly. Elevated TP and the associated response variables are indicative of eutrophication and are stressors to the biological communities in Unnamed Creek.

In the Unnamed Creek DO has been below the standard. The creek also has had elevated BOD, although very limited data exists. The creek is greatly influenced by the conditions of the upstream lakes. The biological communities both responded as expected with low DO stress. There were not as many DO tolerant individuals, but there was a complete lack of intolerant taxa as well as low EPT taxa. Low DO is a stressor to the biological communities in Unnamed Creek.

The lack of diverse habitat is a stressor to the biotic community in the Unnamed Creek. Reduced habitat quality is affecting both the macroinvertebrates as well as the fish community.

Allocating resources to reduce nutrient loads to the upstream lakes would help Unnamed Creek that is fed by Roberds Lake. Eutrophication and low DO are stressors likely linked to the condition of the lake. Additionally, habitat could be greatly improved as it currently has minimal riffle habitat with a great deal of embeddedness.

While the impaired AUID of Unnamed Creek (07040002-638) is primarily a natural channel, except the downstream furthest section, there are some altered watercourses that are inputs to French and Roberds Lakes, as well as dams on both lakes which may have some negative impact. The lakes also provide a buffer to increased flows due to channelization. In the Unnamed Creek Watershed, there are approximately 8.1 miles of altered watercourses or 27.75% of the contributing watercourses in the watershed. There is no flow information on Unnamed Creek. It is unknown if the manipulated flows by dams and altered watercourses are negatively influencing the biology.

4.7.7. Cannon River (542)

This large warmwater reach of the Cannon River (AUID 07040002-542) starts at the headwaters and goes through a series of lakes to Cannon Lake. The reach is impaired for lack of macroinvertebrate assemblage and dissolved oxygen. It is also impaired for aquatic recreation (*E. coli*), which will not be addressed in this report. There are currently six biological stations on this reach. Station 04LM081 was sampled for macroinvertebrates in 2004, station 10EM027 in 2010, stations 11LM082, 11LM095 and 11LM083 in 2011, and station 11LM002 in 2012.

The MIBI scores ranged from 5 to 14.77 in the upper five stations, and the MIBI was 66.54 at station 11LM002. Many of the metrics in the Southern Forest Streams GP class were greatly reduced for the upper five stations (Figure 273). In general the macroinvertebrate communities were comprised of low DO tolerant individuals in the upper five stations. Many of the stations were dominated by oligochaetes. The fish community was not impaired at this time, and had a strong presence of lake species.

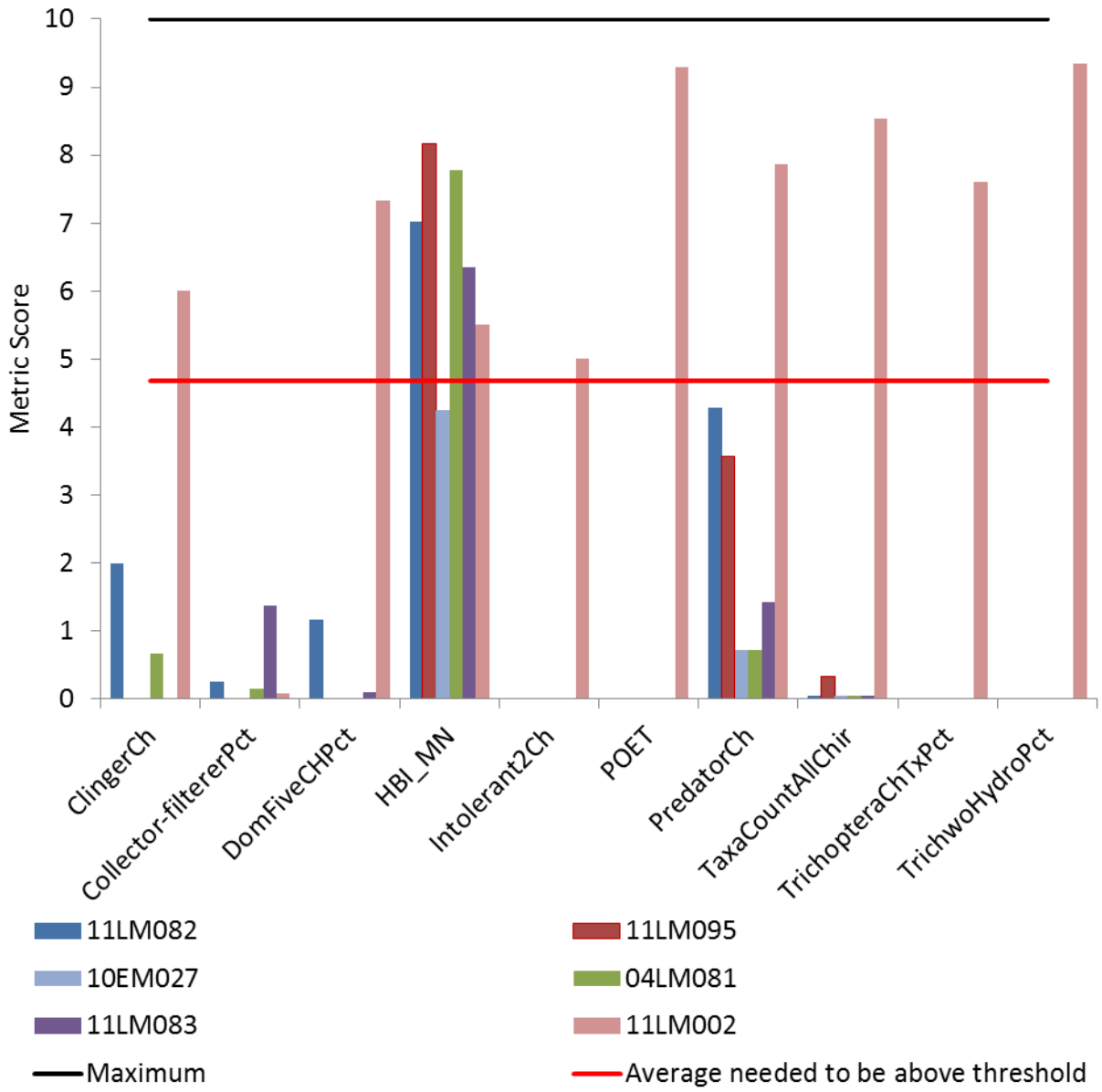


Figure 273. Macroinvertebrate metrics of the Southern Forest Streams GP IBI for Cannon River

Temperature

Temperature has been measured on this AUID as high as 31°C; there have been 265 measurements from 2002-2013 (Figure 274). Two stations have had measurements at or above 30°C, stations S001-683 and S000-545 (Figure 275). Station S001-683 is in the headwaters, is the upper most station on the AUID, and is downstream of Shields Lake. Station S000-545 is near Warsaw, before entering Cannon Lake. At station S001-683, a measurement of 31°C was made on May 29, 2002. Observationally, this data point is an outlier as it does not fit the seasonal pattern to this river reach. The other two measurements that are 30°C and 30.1°C are within the seasonal pattern, with one measured on August 20, 2003, and the other on July 20, 2011. It is difficult to compare longitudinally due to the different times that temperature measurements were taken. In 2011, a HOBO temperature logger was deployed at station 11LM002 to capture continuous temperature measurements. The average daily maximum temperature for the month of July was 27.4°C. Two YSI sondes were deployed from August 22 to 28, 2014. At station

S002-456 temperature measurements ranged from 21.72 -26.6°C. Temperature measurements during sonde deployment ranged from 20.58 -27.08°C at station S006-672.

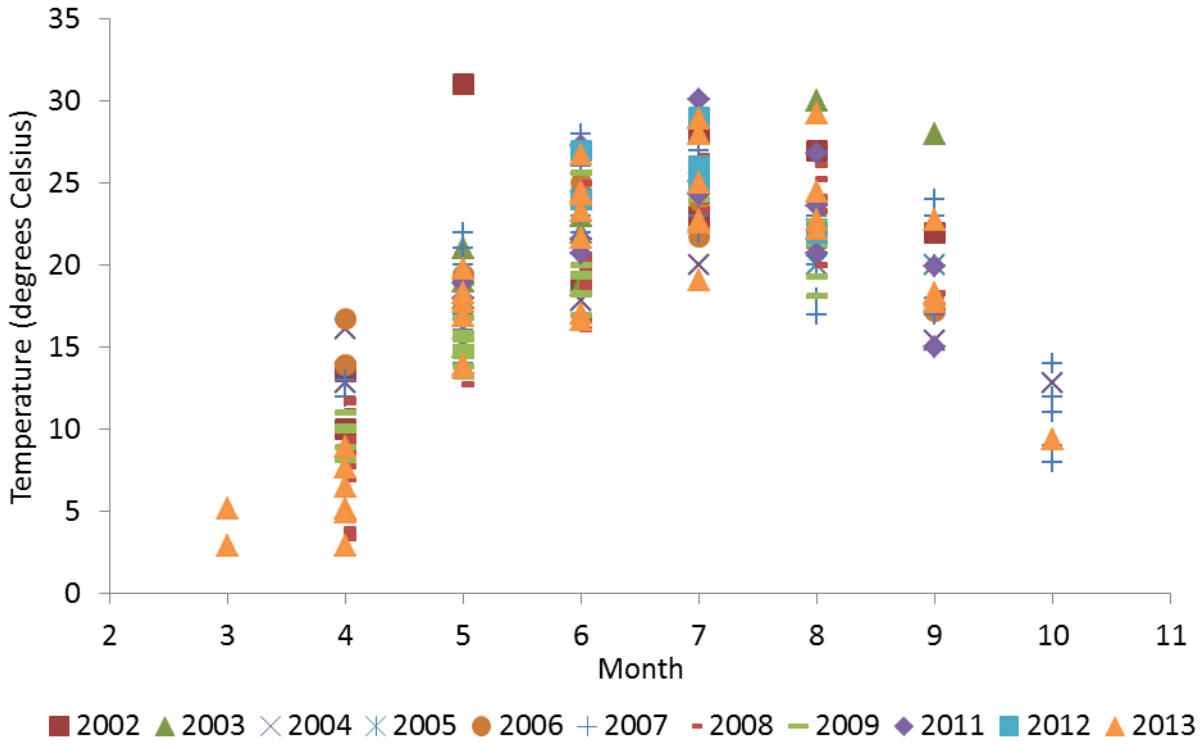


Figure 274. Temperature in the Upper Cannon River by year and month

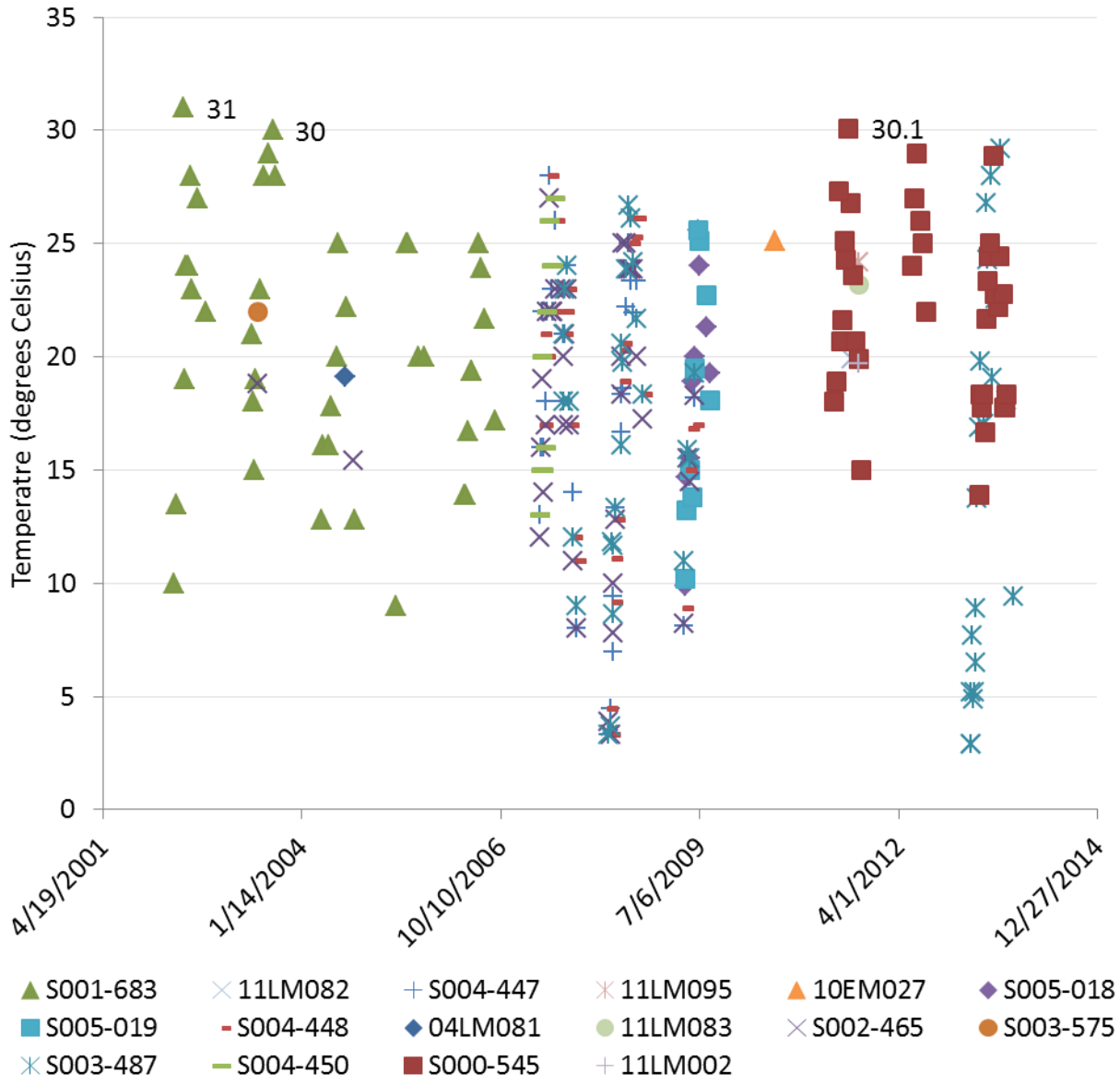


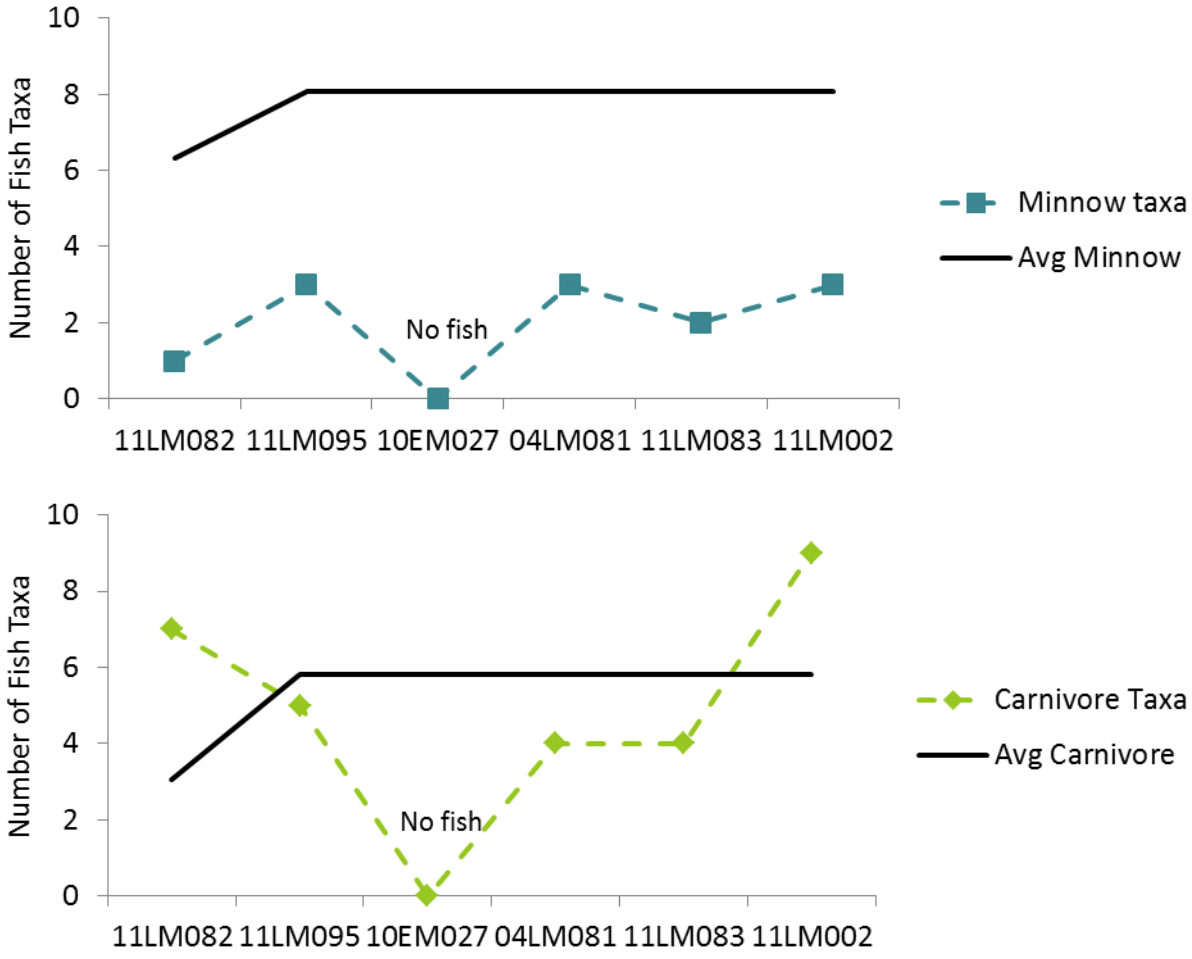
Figure 275. Temperature measurements in the Upper Cannon River by station

Temperature effects on aquatic communities in warmwater systems are not as clear as in coldwater systems. CADDIS (2012) describes changes in growth and thermal stress, and impaired fish and macroinvertebrate assemblages. A publication by the EPA (1986) shows a maximum weekly temperature of 28°C for optimum white sucker growth and 29°C for optimum smallmouth bass growth. In a study in the Minnesota River basin, Feist and Niemela (2005) found significant relationships between increased temperatures and temperature fluctuations, and a decrease in top carnivores and sucker species and an increase in the number of minnow species. In this reach of the Cannon River, those relationships aren't seen when compared to average number of fish taxa (Figure 276).

The EPA's CADDIS cites a decrease in abundance, richness, or diversity with increases in temperature for both fish and macroinvertebrates. Macroinvertebrate taxa richness was considerably reduced in the five upstream stations, with 19 to 20 taxa (Figure 273). The fish taxa richness was not as notably decreased,

but was less than the average of similar stations meeting the biocriteria in the five upstream stations, with a range of 8 to 11 taxa present at those stations.

The capacity of water to retain DO as temperature increases may be the direct stressor, with increased temperature playing an indirect role when it comes to increased macroinvertebrate mortality. There is limited evidence for temperature as a stressor on its own, but it is likely contributing with other stressors. It is a factor, but not a confirmed direct stressor at this time.



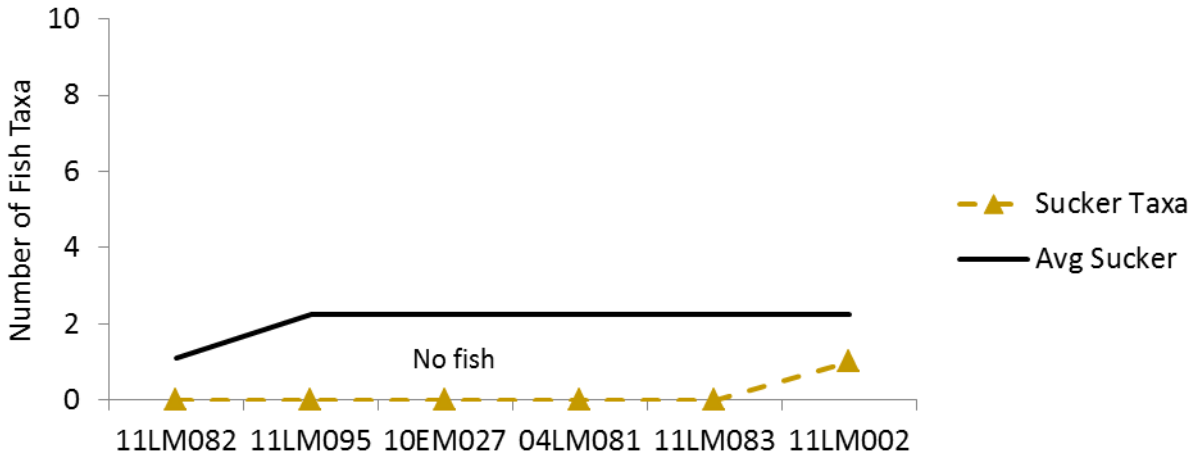


Figure 276. Comparisons of minnow, carnivore, and sucker taxa in the upper Cannon River to statewide fish class averages

Nitrate

Of 269 measurements, the highest nitrate measured on the reach was 16.7 mg/L, and only three data points were greater than 10mg/L (Figure 277). The highest concentration from 2009-2013 is 4.15 mg/L; however, there were different stations sampled different years which may contribute to some of the yearly inconsistency. Of the data collected, nitrate appears highest in the upper reaches of this AUID and highest after large rain events (Figure 278).

The macroinvertebrate metrics that correspond with nitrate stress show a mixed response as expected (Table 214). Station 11LM002 had six Trichoptera taxa present, whereas the upstream stations had none present at the time of sampling. Additionally, in the upstream stations, there were no intolerant taxa present resulting in low metric scores (Figure 273). There were 2 - 46% nitrate tolerant individuals at all stations, but some taxa were not included such as oligochaetes. At 76.8% nitrate tolerant individuals, there is a 25% probability of meeting the Southern Forest Streams GP (class 6) MIBI. Two stations had one nitrate intolerant taxon present (04LM081 and 11LM083) and station 11LM002 had four nitrate intolerant taxa. These three stations are the furthest downstream stations.

The elevated nitrate is most prominent in the upstream stations, similarly, the upstream stations is where there was a lack of nitrate intolerant taxa. Elevated nitrate may be contributing stress, but it is inconclusive as a stressor. It would be advantageous to understand the longitudinal differences of nitrate with samples collected on the same day. Inconclusive

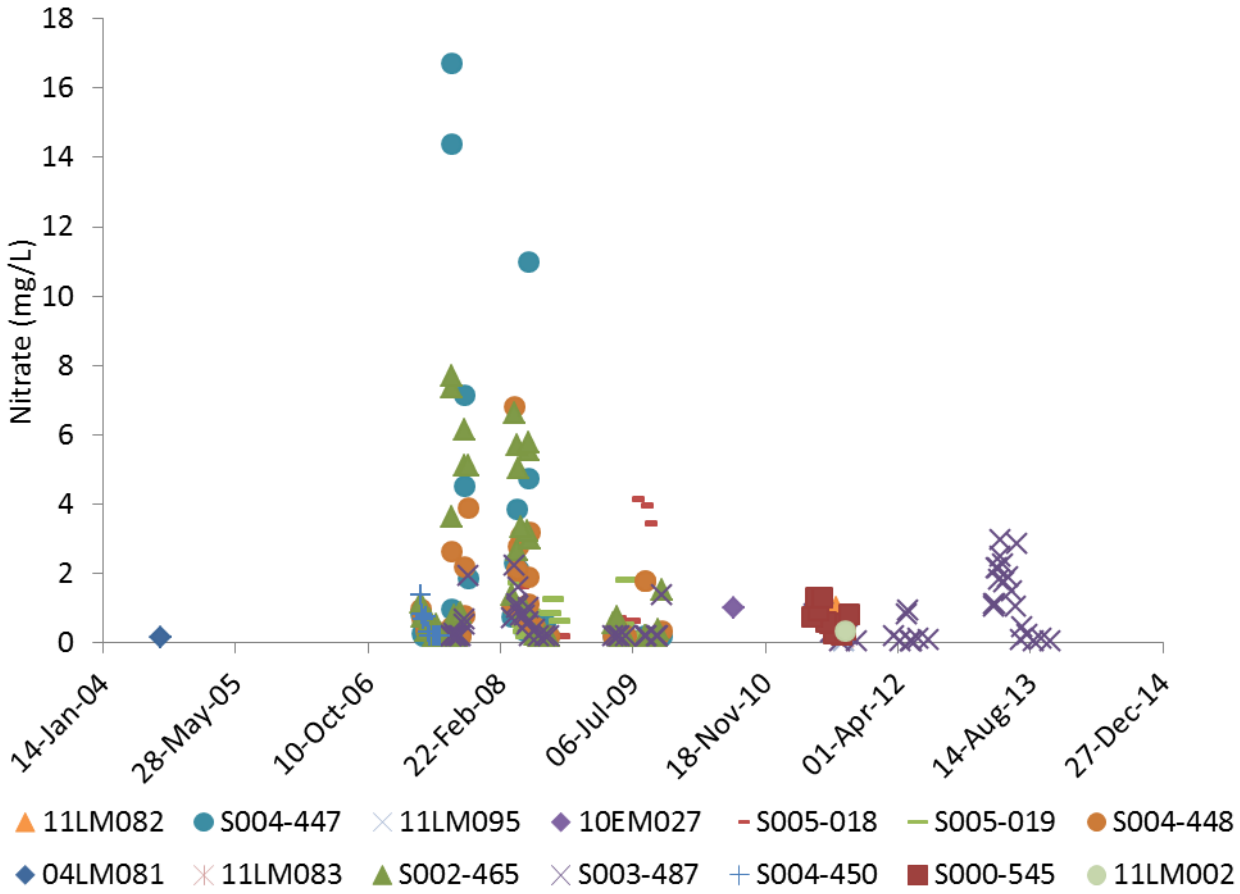


Figure 277. Nitrate concentrations by station in the Upper Cannon River from 2004 - 2013

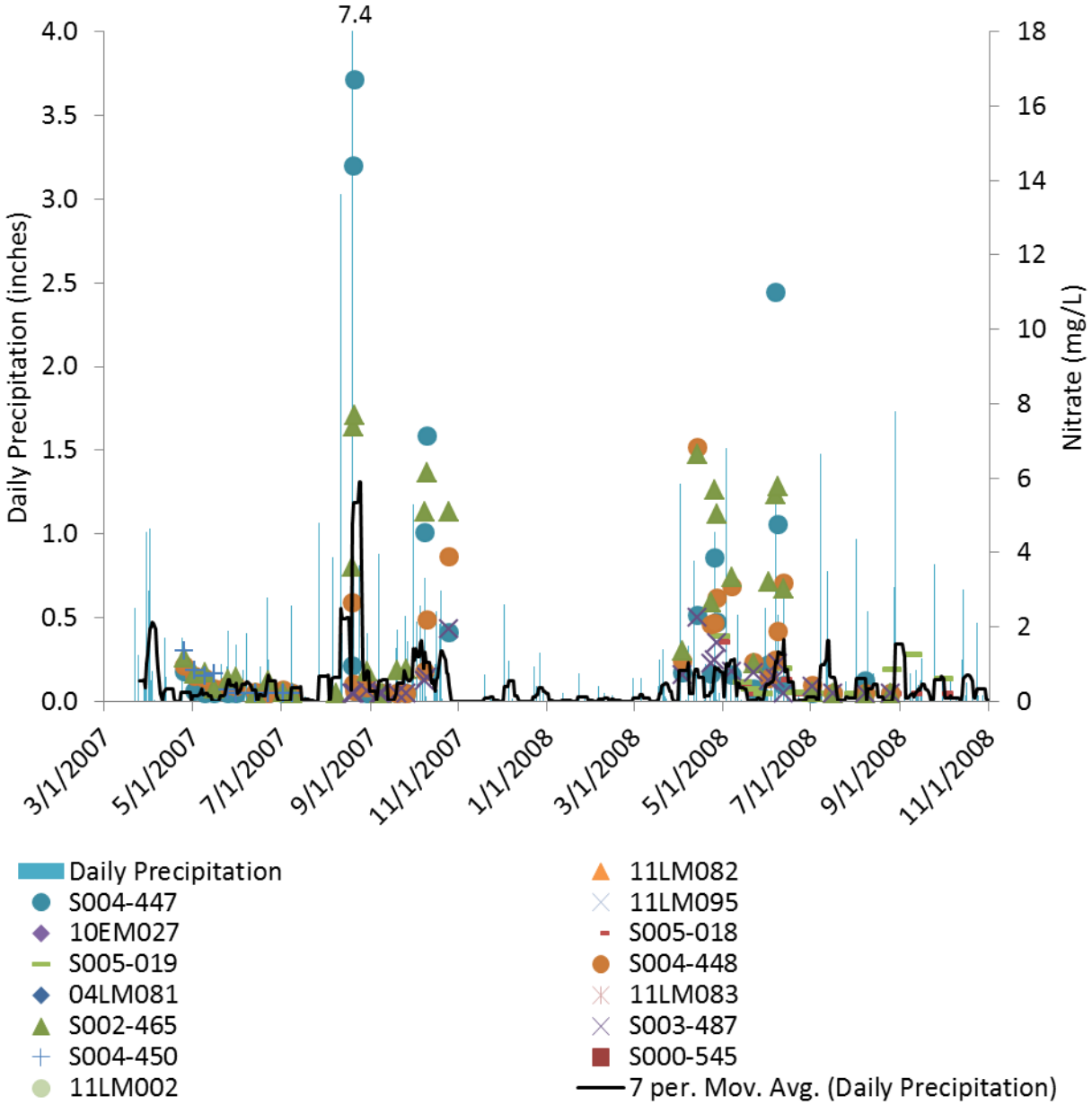


Figure 278. Daily precipitation and nitrate concentrations by station in the Upper Cannon River during 2007 and 2008 (MN State Climatology Center; Montgomery station: 215571)

Table 214. Macroinvertebrate metrics that respond to nitrate stress in the upper Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TrichopteraCh	TrichwoHydroPct	Intolerant2Ch	Nitrate Index Score	Nitrate Intolerant Taxa	Nitrate Tolerant Taxa	Nitrate Tolerant Pct
11LM082 (2011)	**0**	**0**	**0**	1.98	**0**	5	26.7
11LM095 (2011)	**0**	**0**	**0**	2.05	**0**	5	26.4
10EM027 (2010)	**0**	**0**	**0**	1.46	**0**	5	5.6
04LM081 (2004)	**0**	**0**	**0**	1.67	**1**	7	16.2
11LM083 (2011)	**0**	**0**	**0**	1.58	**1**	2	2.8
11LM002 (2012)	6	9.1	1	2.27	4	**24**	46.6
Southern Forest Streams Average	*4.7*	*4.4*	*0.5*	*2.88*	*2.58*	*19.4*	*55.5*
Expected response to stress	↓	↓	↓	↑	↓	↑	↑

Phosphorus

Total phosphorus has been sampled for 288 times from 2003 to 2013, with 277 (96%) of those samples measuring greater than the draft central river eutrophication standard (0.1 mg/L; Figure 279). The average TP was 0.513 mg/L and the maximum was 7.13 mg/L. The potential relationship with TSS was evaluated (Figure 280) and found that although some elevated TP coincides with elevated TSS, there was also elevated TP with low TSS concentrations. Additional evidence for eutrophication of the river reaches between the Upper Cannon lakes is that all of the inline lakes are impaired for excess nutrients, from Shields Lake through Lower Sakatah Lake. Also, many of the small connections to this reach of the Cannon River originate from nutrient impaired lakes (e.g. Dora Lake and Hunt Lake).

Although TP is elevated there needs to be an elevated response variable of DO flux, chlorophyll-a, or BOD to result in an aquatic life impairment based on elevated nutrients. This reach has elevated BOD and chlorophyll-a. BOD has been measured from less than 2 to 23 mg/L, in 2007 and 2008 (Table 215). At individual stations throughout the reach, a large percentage of the BOD samples were greater than the response variable river nutrient standards (32 – 100%). Chlorophyll-a concentrations ranged from 1.35 to 84.9 µg/L in 2003 and 2004. Only 2 of the 10 chlorophyll-a samples were above the 18 µg/L chlorophyll-a response variable threshold, June 2003. pH is also linked to eutrophication and there were a few elevated pH measures in 2009 that coincide with elevated TP measurements. Elevated pH is discussed further in the pH section for this AUID.

Two YSI sondes were deployed from August 22 to 28, 2014. The response variable, DO flux, standard is 3.5 mg/L for the central nutrient region. Station S002-456 exhibited DO flux just greater than the standard (3.6 mg/L). At station S006-672, the maximum DO flux while deployed was 2.88 mg/L. Low DO is present throughout the reach and is discussed further in the DO section for this AUID.

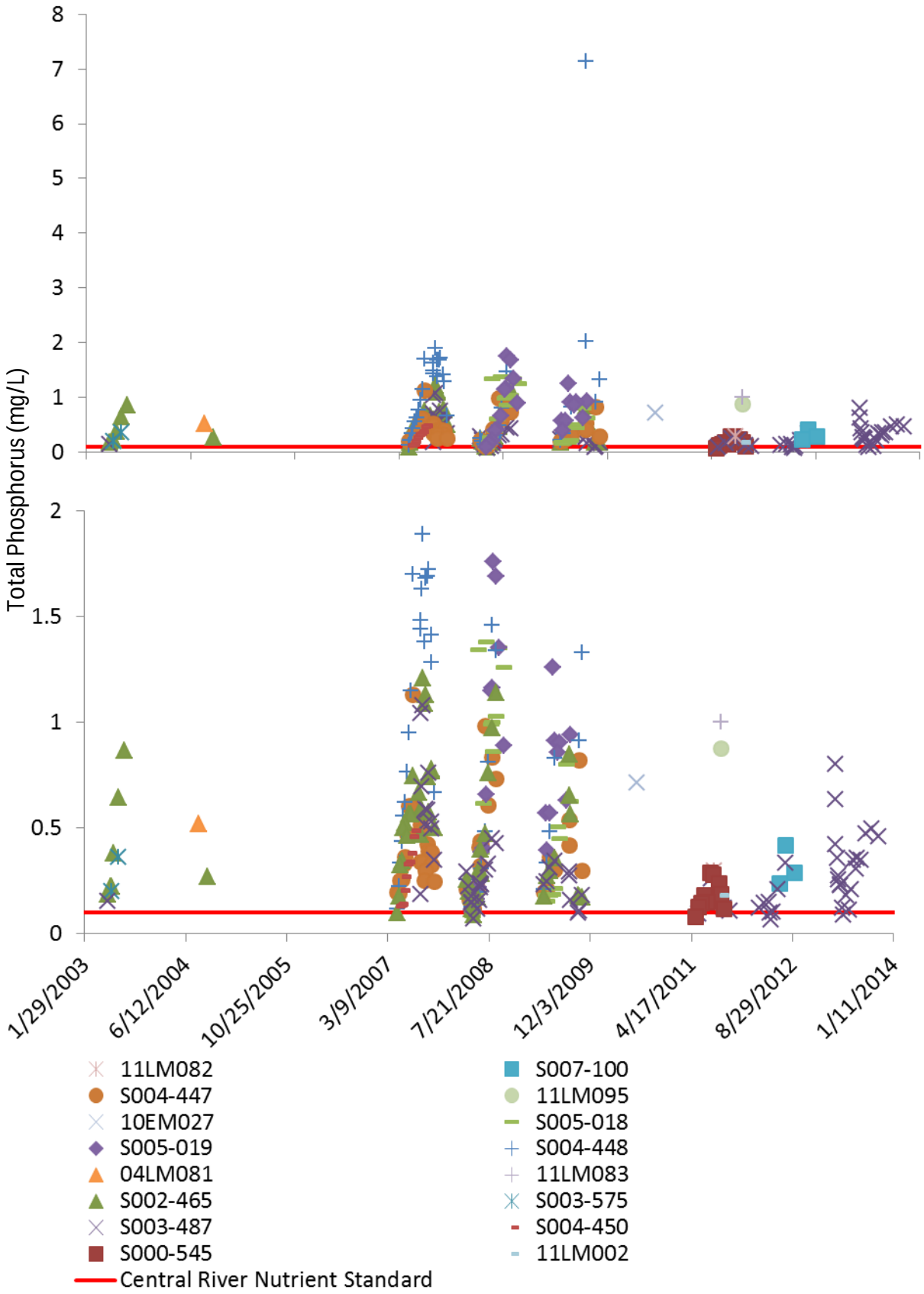


Figure 279. TP by station in the Upper Cannon River (2003-2013)

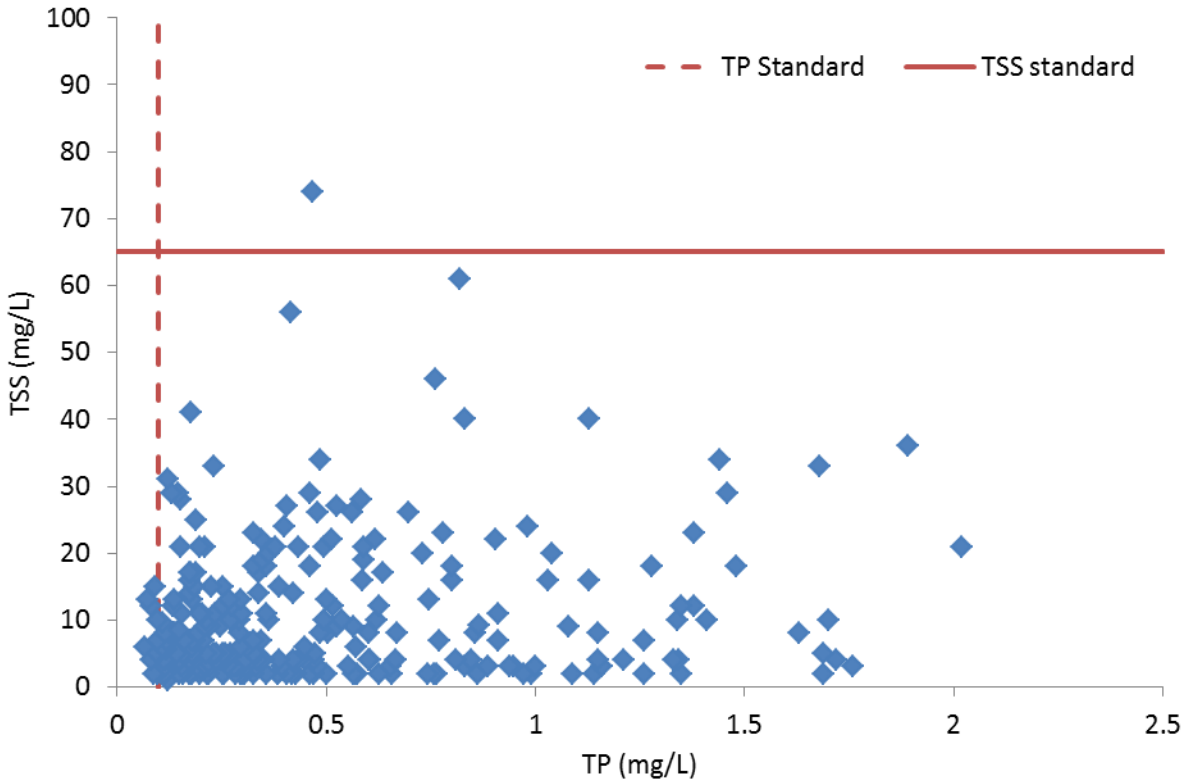


Figure 280. TSS and TP relationship in the Upper Cannon River (2003-2013)

Table 215. BOD in the Upper Cannon River

Station	Number of Samples	Minimum BOD	Maximum BOD	Percent of Samples >2 mg/L
S004-447	36	<2	23	64%
S004-448	36	<2	15	39%
S002-465	37	<2	6	32%
S003-487	26	<2	7	77%
S004-450	10	3	7	100%

The macroinvertebrate metrics that are related with elevated TP and the response variables had an expected response for five of the six visits in the Upper Cannon River (Table 216). The taxa count was low, only half of the statewide average for similar stations that are meeting the biocriteria. Similarly, collector-gatherers were low, along with low EPT taxa in the five stations. Collector-filterer taxa were reduced at all six stations in the Upper Cannon River. There were no intolerant taxa found at the five upstream stations and the tolerant taxa dominated. The downstream most station (11LM002) does not exhibit a similar macroinvertebrate response, and it is likely not impacted in the same fashion as those five upstream stations.

Table 216. Macroinvertebrate metrics that respond to TP and response variables in the Upper Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	Collector-filtererCh	Collector-gathererCh	EPT	Intolerant2Ch	Tolerant2ChTxPct
11LM082 (2011)	**19**	**2**	**5**	**0**	**0**	**89.5**
11LM095 (2011)	**20**	**0**	**7**	**0**	**0**	**95**
10EM027 (2010)	**19**	**1**	**8**	**0**	**0**	**89.5**
04LM081 (2004)	**19**	**1**	**7**	**0**	**0**	**89.5**
11LM083 (2011)	**19**	**2**	**8**	**1**	**0**	**89.5**
11LM002 (2012)	48	**1**	18	12	1	72.9
Southern Forest Streams Average	*41.2*	*5.9*	*15.0*	*8.8*	*0.5*	*74.9*
Expected response to stress	↓	↓	↓	↓	↓	↑

Although the fish community is not currently impaired in the Upper Cannon River, the community can help inform on stressors present. Six fish metrics are helpful in linking TP or response variable stress (Table 217). Similarly to the macroinvertebrate community, five of the six visits show similar results to each other. The fish community at station 11LM002 shows less of a response to elevated TP and related stressors. Station 10EM027 had no fish. This station was channelized and functioned more like a wetland, so it was not assessed. At the five stations with fish surveyed, four stations had low percentages of sensitive fish, darters, simple lithophilic spawners, and intolerant fish. The taxa count for station 11LM082 was just below the average for similar stations meeting the fish biocriteria. Stations 11LM095, 04LM081, and 11LM083 exhibited only 8-10 taxa where the average for similar stations meeting the fish biocriteria was 18.8 taxa. The percent of tolerant fish individuals was lower than expected with TP related stress, except at station 11LM082.

The macroinvertebrate communities and fish communities indicated TP related stress (except station 11LM002). In the Upper Cannon River, there were elevated levels of TP along with elevated response variables of chlorophyll-a, BOD, DO flux, and some elevated pH. Overwhelmingly, TP and the related response variables are stressors to the biological community within the Upper Cannon River, not including station 11LM002.

Table 217. Fish metrics that respond to TP and response variables in the Upper Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	SensitivePct	DarterPct	SLithopPct	TolPct	TaxaCount	IntolerantPct
11LM082 (2011)	**0**	**0**	**0**	**80.8**	**11**	**0**
Southern Headwaters Average	*6.8*	*10.9*	*31.3*	*74.3*	*11.3*	*1.4*
11LM095 (2011)	**2.6**	**0**	**0**	18.4	**10**	**0**
10EM027 (2010)	No fish sampled					
04LM081 (2004)	**0**	**0**	**0**	36.7	**8**	**0**
11LM083 (2011)	**6.1**	**6.1**	**6.1**	18.2	**9**	**6.1**
11LM002 (2011)	22.1	22.6	**26.6**	17.0	19	21.9
Southern Streams Average	*14.8*	*11.8*	*35.2*	*48.4*	*18.8*	*3.3*
Expected response to stress	↓	↓	↓	↑	↓	↓

pH

The pH standard for class 2B streams is 6.5 as a minimum and 9.0 as a maximum. The EPA's CADDIS states that the effects of either low or high pH are not specific enough to be symptomatic. An increase in pH can lead to higher susceptibility to other stressors (CADDIS, 2014). In the Upper Cannon River, pH ranged from 5.3 to 9.90 in 59 measurements (in 2004, 2009, 2010, 2011, 2012, and 2013). The pH of 5.3 was taken at the time of fish sampling on August 17, 2004, at station 04LM081. This was the only low pH measurement observed. Three stations had pH greater than 9.0; station S004-448 (downstream of Sabre Lake), station S002-465 (upstream of Tetonka Lake), and station S003-487 in Morristown. Elevated levels are likely driven by plant processes. The three dates with elevated pH all occurred in 2009 (April 20, May 18, and June 11). These dates also resulted in elevated TP (0.175-0.831 mg/L) with TSS below 23 mg/L. pH was within normal and expected range during DO deployments and held steady (deployed from August 22, 2014 to August 28, 2014).

Levels between 9.0 and 9.5 can reduce populations of warm-water fish, and levels between 9.0 and 10.0 can result in partial mortality for bluegill, trout, and perch (Robertson-Bryan, Inc., 2004). Minnows are often less sensitive to high pH levels than perch (CADDIS 2103). In the Cannon River, there were 2-8 Perciformes taxa present (4.66-76.32% of the individuals; Table 218). Stations 04LM081 and 11LM083 are situated between two of the chemistry stations (S004-448 and S002-465) that exhibited high pH in 2009. None of the biological stations were sampled in 2009, and 2004 only had two measurements of pH (5.3 and 7.6).

Table 218. Perciformes taxa and percent individuals in the Upper Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Perciformes Taxa	% Perciformes individuals
11LM082 (2011)	4	**4.7**
Southern Headwaters Average	*2.6*	*15.45*
11LM095 (2011)	**4**	76.3
10EM027 (2010)	No fish sampled	
04LM081 (2004)	**2**	**20.4**
11LM083 (2011)	**4**	45.5
11LM002 (2011)	8	71.9
Southern Streams Average	*5.53*	*23.08*
Expected response to stress	↓	↓

Levels of pH between 9.5 and 10 causes reduced emergence of some stoneflies. At all the stations within this upper Cannon River reach, there were no stoneflies (Plecoptera), but the lack of stoneflies could also be due to other factors. It is difficult to pinpoint pH as a stressor in the Cannon River, but pH should be monitored to ensure that there are not further excursions above or below the standard.

Dissolved Oxygen

This reach of the Cannon River is impaired for low DO levels. DO levels in this reach are low throughout different times of the day, even when it would be expected to be closer to the maximum of the daily DO concentrations. DO was recorded at the time of fish sampling, and four of the six stations had DO less than the 5 mg/L standard (Table 219). A longitudinal DO survey was completed on the afternoon of July 30, 2014 (Table 220). Six of the eight station visits exhibited low DO even when it should be closer to the maximum DO levels.

Two YSI sondes were deployed from August 22 to 28, 2014. Station S002-456 exhibited DO concentrations that ranged from 1.18 – 5.65 mg/L, and flux just greater than the standard (3.6 mg/L). At station S006-672, the maximum DO flux while deployed was 2.88 mg/L. The DO concentration was always below 5 mg/L while deployed, with a range of 0.2 – 3.76 mg/L.

Table 219. Dissolved oxygen at the time of fish sampling in the Cannon River

Station	Date	Time	DO (mg/L)
04LM081	17-Aug-04	11:00 AM	**1.1**
10EM027	21-Jul-10	5:15 PM	**0.15**
11LM082	10-Aug-11	8:30 AM	**2.38**
11LM095	12-Sep-11	4:01 PM	9.69
11LM083	12-Sep-11	1:30 PM	**3.15**
11LM002	13-Sep-11	10:50 AM	7.13

Table 220. Longitudinal DO survey in the Cannon River on July 30, 2014

Station	Time	DO (mg/L)
S008-047	15:40	**4.67**
S008-046	15:20	5.33
S008-045	14:55	**2.59**
S004-447	14:40	**3.86**
S006-672	14:20	**3.09**
S005-019	14:05	**3.75**
S002-465	13:45	**4.33**
S000-545	13:20	7.41

The stations upstream of Lake Tetonka had particularly low DO index scores for macroinvertebrates (Table 221). Only station 11LM002 had presence of DO intolerant taxa. Additionally, upstream there was over 73% low DO tolerant individuals in each survey. The five upstream stations had low overall taxa counts and only station 04LM081 had one EPT taxon. The metric HBI_MN was okay for many of the stations, but was low for stations 10EM027 and 11LM002. Only station 10EM027 had a low MIBI metric score related to the HBI_MN metric (Figure 273).

The chemical and biological evidence for low DO as a stressor is overwhelming. In particular, the five upstream stations exhibit the most stress from low DO. Many factors may be contributing to the low DO conditions, such as algal decay, wetland contribution, or groundwater contribution. It is likely a combination of factors and not one factor alone. More information will need to be collected and analyzed to understand the source of the low DO water. Low DO is a stressor in the Upper Cannon River.

In 2014, wetland monitoring in three locations (stations 14Rice003, 14LeSu001, and 14LeSu003) took place to assist with resolving stream channel classification issues and to characterize the extent to which wetlands may be contributing to natural background (DO) conditions, particularly in the low gradient reaches in the upper Cannon River.

Natural background influences from wetlands in the Cannon Watershed, particularly depressing DO levels are not likely fully accounting for all oxygen impairments. DO concentrations within the channel/wetland in the upper headwaters of the Cannon River at station 14Rice003 compared with downstream at station 14LeSu003 found more than half as much DO at the downstream location. The

estimated drainage area of these two wetland sites differed greatly (14Rice003 = ~2.7 square miles vs. 14LeSu003 = ~100 square miles). Extent of wetlands associated with the upper reaches of the Cannon River between 14Rice003 and 14LeSU001 is certainly greater compared with downstream at station 14LeSu003. It would not be unreasonable to expect the extent of wetlands within the upper drainage area could influence the DO concentration and suppress it compared with the extent of wetlands present below station 14Rice003, but above station 14LeSu003. By this point the increased flow volume would be expected to increase the typical channel DO compared with upstream regions. This is not what was observed, which suggests wetland background DO suppression does not entirely account for the observed low channel DO reading. This supports other sources such as pollutant loads to be contributing to the suppressed DO concentration at the downstream location. However, these few grab sample results should be augmented with other data to verify this observation and assertions.

Table 221. Macroinvertebrate metrics that respond to low DO stress in the Cannon River (542) compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	TaxaCountAllChir	EPTCh	HBI_MN	Low DO Index Score	Low DO Intolerant Taxa	Low DO Tolerant Taxa	Low DO Tolerant Pct
11LM082 (2011)	**19**	**0**	6.7	**5.8**	**0**	**8**	**73.8**
11LM095 (2011)	**20**	**0**	6.4	**5.8**	**0**	**11**	**73.6**
10EM027 (2010)	**19**	**0**	**7.6**	**5.8**	**0**	**10**	**90.5**
04LM081 (2004)	**19**	**1**	6.5	**5.8**	**0**	**11**	**82.3**
11LM083 (2011)	**19**	**0**	6.9	**4.7**	**0**	**9**	**80.6**
11LM002 (2012)	48	14	**7.2**	**6.6**	**5**	**10**	**27.5**
Southern Forest Streams Average	*41.3*	*10.2*	*7.1*	*7.04*	*6.51*	*5.57*	*13.99*
Expected response to stress	↓	↓	↑	↓	↓	↑	↑

TSS/Turbidity

In the Upper Cannon River, there were 279 samples of TSS collected over the years of 2003, 2004, and 2007 - 2013. Four of the samples were greater than the draft TSS standard of 65 mg/L for the south region (1.4%). The exceedances occurred at stations S000-545 (June 21, 2011), S004-448 (August 20, 2009), S002-465 (August 19, 2007), and 11LM095 (September 12, 2011). These stations are spread out over the large AUID, with no cluster of exceedances. There were 517 measurements of transparency collected over 2001 – 2013, at 11 stations. Converted to secchi tube measurements, only one measurement (<1%) was less than the 10 cm draft standard of the south TSS region. Overall, the chemical data does not strongly suggest elevated TSS as a stressor.

The macroinvertebrate metrics that respond to elevated TSS stress show mixed results (Table 222). There was a lack of stoneflies (Plecoptera) and low proportion of collector-filterers in all stations except station 11LM002. The TSS index scores were mixed, with the two upstream stations above the average

of similar stations meeting the biocriteria and the downstream stations below. Additionally there were no taxa that are intolerant to TSS in four of the six stations. The TSS tolerant taxa were not relatively high, and the TSS tolerant individuals comprised 6.2 to 44.8% of the community.

The large dataset of chemical information is not indicative of elevated TSS stress. The macroinvertebrate community indicates some stress according to the biological metrics, but can be explained by the presence of other stressors and an overwhelmingly poor community in many of the stations. At this time, elevated TSS is not a stressor to the macroinvertebrate community in the Upper Cannon River.

Table 222. Macroinvertebrate metrics that respond to TSS stress in the Upper Cannon River compared to the statewide average of visits meeting the biocriteria. Bold indicates metric value indicative of stress.

Station (Year sampled)	Collector-filtererPct	PlecopteraPct	TSS Index Score	TSS Intolerant Taxa	TSS Tolerant Taxa	TSS Tolerant Pct
11LM082 (2011)	**14.8**	**0**	**20.1**	**0**	7	**44.8**
11LM095 (2011)	**12.1**	**0**	**18.5**	**0**	8	**37.7**
10EM027 (2010)	**0.3**	**0**	15.6	**0**	6	6.2
04LM081 (2004)	**9.4**	**0**	15.5	**0**	6	11.1
11LM083 (2011)	**9.3**	**0**	13.2	**1**	4	7.4
11LM002 (2012)	66.5	**0**	14.3	5	**13**	**29.6**
Southern Forest Streams Average	*24.7*	*0.4*	*16.2*	*2.0*	*10.2*	*27.2*
Expected response to stress	↓	↓	↑	↓	↑	↑

Lack of Habitat

The MSHA scores in this reach of the Cannon River ranged from 38 to 57.5 (poor to fair). All of the stations had no riffle features present and poor substrate and channel morphology scores (Figure 281). There were many visits that noted green algal problems. The stations were dominant in run features with primarily sand, silt, clay, and detritus substrates. Only the lower two stations, 11LM083 and 11LM002, had presence of gravel as a dominant substrate type. All stations had macrophytes present, including most with emergent and floating leaf, and all with submergent. In some cases the macrophytes were overly abundant (e.g. station 11LM082).

Four of the six stations had very high percentages of macroinvertebrates that burrow. All of these stations had Oligochaetes (worms) dominating the communities (which are considered burrowers). Station 10EM027 had a high percentage of sprawlers indicating excess of fine sediments (Figure 282). Station 11LM002 was the closest to exhibiting similar habitat community characteristics as the average of similar stations. Many of the fish species that were present are commonly found in lake systems.

In 2014, wetland monitoring in three locations (stations 14Rice003, 14LeSu001, and 14LeSu003) took place to assist with resolving stream channel classification issues and characterize the extent to which wetlands may be contributing to natural background (DO) conditions, particularly in the low gradient reaches in the upper Cannon River.

At station 14Rice003, which is collocated with station 11LM082, there was 75-95% aquatic vegetation cover. The other two stations were <1% and <5-25%, at 14LeSu001 and 14LeSu003 respectively. Two of the three stations had muck as the predominant substrate, and there was no substrate information available on station 14LeSu001. Only the upper station with the highest percentage of aquatic vegetation fits the wetland channel indicator criteria indicating that it would be best classified and assessed as a wetland system.

Depression systems have slower water movement and allow particulates to accumulate, which can result in significant deposition, particularly of fine particles. The three stations (14Rice003, 14LeSu001 & 14LeSu003) in the upper Cannon River were classed as basins within the landscape and appear to have accumulated significant amounts of sediment and nutrients as demonstrated by the dominance of cattails and other invasive species which thrive on fine unconsolidated sediments and high nutrients. Deep, mucky, unconsolidated sediment within these sites was additional evidence of sediment accumulation within these sites.

Lack of adequate habitat is a stressor within this reach. The reach exhibits characteristics of wetlands in some areas, and river characteristics in other areas (Figures 283 - 287). It is unknown the extent of a natural lack of habitat, or an anthropogenic reasoning. There are attributes that could be evidence for both.

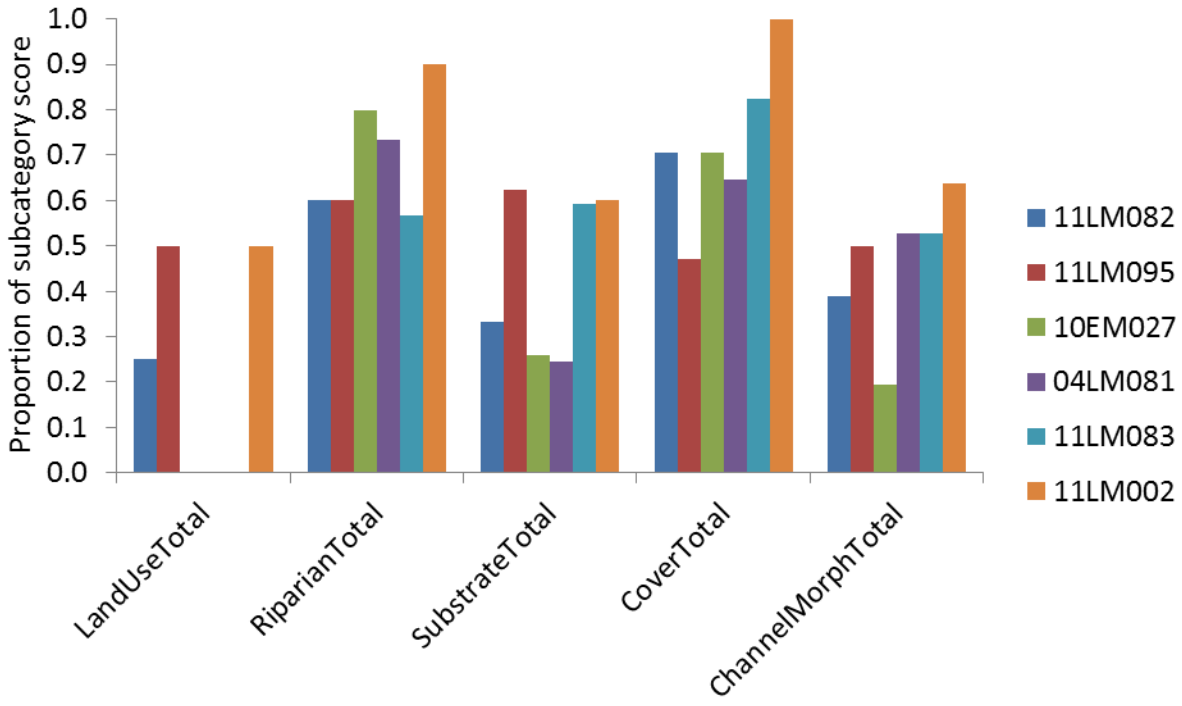


Figure 281. MSHA subcategory scores for the upper Cannon River

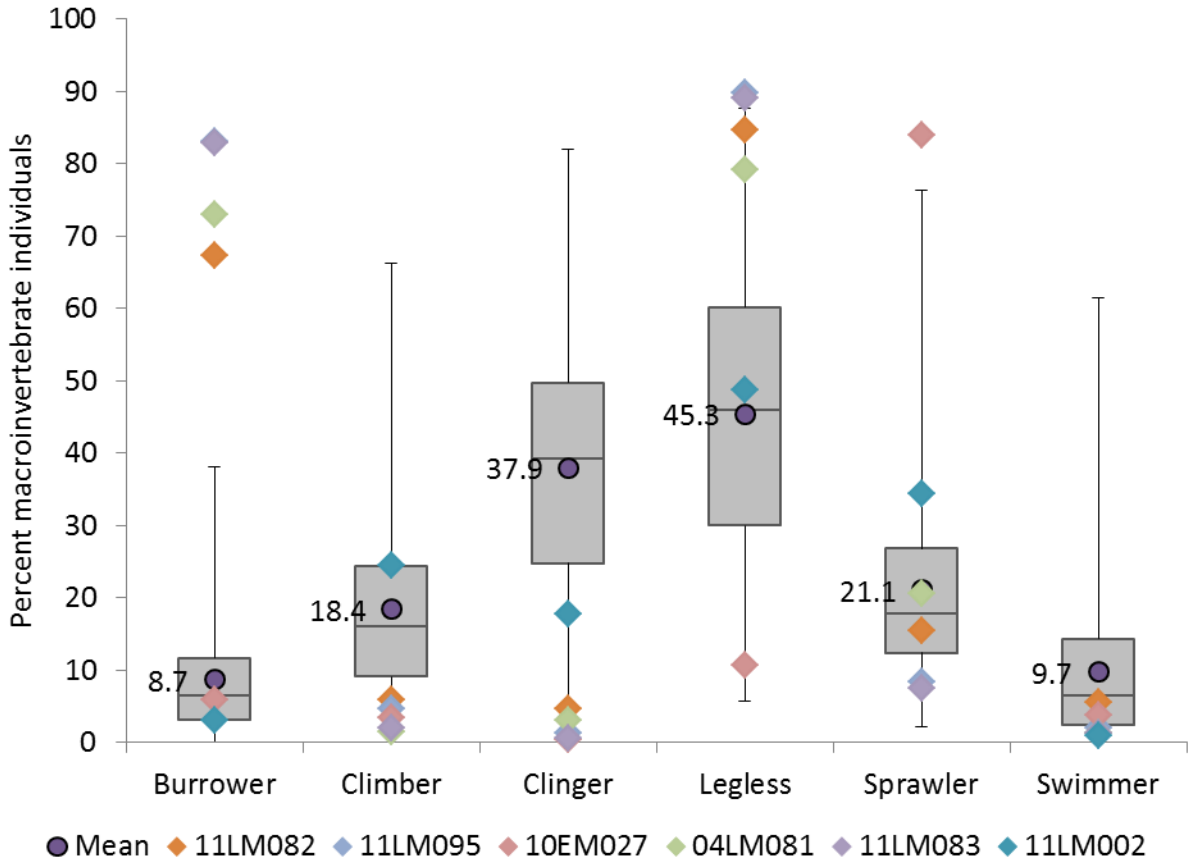


Figure 282. Macroinvertebrate habitat metrics with box plot showing range of values from natural channel Southern Forest Streams GP stations with MIBI greater than 46.8 (threshold), mean of those stations, and metric values from stations in headwaters of the Cannon River

Figure 283. Station 11LM082, downstream looking upstream, macrophytes growth (August 10, 2011)

Figure 284. Station 11LM095, downstream looking downstream (September 12, 2011)

Figure 285. Station 04LM081, upstream looking downstream (August 17, 2004)

Figure 286. Station 11LM083, upstream looking upstream (September 12, 2011)

Figure 287. Station 11LM002, downstream looking upstream (September 13, 2011)

Fish Passage

There are outlet structures on the flow through lakes in the Cannon River, as well as many lake fish species present in the community. Currently, connectivity for the macroinvertebrate community is not a concern.

Conclusion

This upper reach of the Cannon River is impaired for lack of macroinvertebrate assemblage and dissolved oxygen. The stressors to the macroinvertebrate community include elevated TP and response variables of BOD and chlorophyll-a, with elevated DO flux and low DO, with lack of habitat. Elevated temperature and elevated pH may be contributing, but there is a lack of information to confirm as individual direct stressors, although they are likely contributing to the other stressors. Nitrate may be playing a role in stressing the macroinvertebrate community; it is inconclusive as a stressor due to inconsistencies in the data.

Temperature has been recorded elevated in the upper Cannon River. The capacity of water to retain DO as temperature increases may be the direct stressor with increased temperature playing an indirect role when it comes to increased macroinvertebrate mortality. There is limited evidence to temperature as a stressor on its own, but it is likely contributing with other stressors. It is a potential factor, but not a confirmed direct stressor at this time.

The elevated nitrate is most prominent in the upstream stations, similarly, the upstream stations is where there was a lack of nitrate intolerant taxa. Although there are likely other stressors contributing to the degradation of the biological community, it is likely that elevated nitrate may be playing a role in stressing the macroinvertebrate community. It would be advantageous to understand the longitudinal differences of nitrate with samples collected on the same day.

The macroinvertebrate communities and fish communities indicated TP related stress (except station 11LM002). In the Upper Cannon River, there were elevated levels of TP, along with elevated response variables of chlorophyll-a, BOD, DO flux, and some elevated pH. Overwhelmingly, TP and the related response variables are stressors to the biological community within the Upper Cannon River, not including station 11LM002.

Levels of pH between 9.5 and 10 causes reduced emergence of some stoneflies. At all the stations within this upper Cannon River reach, there were no stoneflies (Plecoptera), but the lack of stoneflies could also be due to other factors. It is difficult to pinpoint pH as a stressor in the Cannon River, but pH should be monitored to ensure that there are not further excursions above or below the standard.

This reach of the Cannon River is impaired for low DO levels. DO levels in this reach are low throughout different times of the day, even when it would be expected to be closer to the maximum of the daily DO concentrations. The chemical and biological evidence for low DO as a stressor is overwhelming. In particular, the five upstream stations exhibit the most stress from low DO. Many factors may be contributing to the low DO conditions, such as algal decay, wetland contribution, macrophytes, algal growth, or groundwater contribution. It is likely a combination of factors and not one factor alone. More information will need to be collected and analyzed to understand the source of the low DO water. The wetland background DO suppression data does not entirely account for observed low channel DO readings. This supports other sources such as pollutant loads to be contributing to the suppressed DO concentration at the downstream location. Low DO is a stressor in the Upper Cannon River.

The large dataset of chemical information is not indicative of elevated TSS stress. The macroinvertebrate community indicates some stress according to the biological metrics, but can be explained by the presence of other stressors and an overwhelmingly poor community in many of the stations. At this time, elevated TSS is not a stressor to the macroinvertebrate community in the Upper Cannon River.

Lack of adequate habitat is a stressor within this reach. The river exhibits characteristics of wetlands in some areas and in some areas a river. It is unknown the extent of a natural lack of habitat or an anthropogenic reasoning. There are attributes that could be evidence for both.

The dams on the lakes control water levels in this AUID as well as the lake levels. The manipulation of water levels in this reach of the Cannon, particularly the backing up of water may be contributing to some of the stressors in the watershed.

Resources should be directed to reducing nutrient loading in the watershed to deal with the eutrophication as well as the source of low DO levels. Habitat along with nutrient delivery should be

evaluated in terms of impacts from altered hydrology. Increases in flow alteration may bring these systems out of equilibrium. Elevated temperature and elevated pH may be contributing and should be monitored to assess their individual stress.

The headwater AUID of Cannon River (07040002-542) is mostly a natural channel, but there is a considerable amount of altered watercourse to the AUID. Within the upper Cannon River Watershed, there are approximately 164.4 miles of altered watercourses, or 47% of the contributing watercourses in the watershed. There are 76.4 miles of natural channels in this watershed as well. There are many instream lakes in this AUID contributing to the impounded stream miles which comprise about 7.6% or 26.4 miles. The dams on the lakes control water levels in this AUID as well as the lake levels. The manipulation of water levels in this reach of the Cannon, particularly the backing up of water, may be contributing to some of the stressors in the watershed.

Upper Cannon River 10 digit HUC Summary

Within the Upper Cannon River 10 digit HUC common stressors are lack of habitat (Table 223). Low DO and nitrate are also found as stressors within this region. Elevated phosphorus is common through this region, but lack of connecting response variables led to inconclusive determinations of stressors.

Table 223. Upper Cannon river 10-digit HUC stressor summary (• = stressor, ○ = inconclusive stressor, blank = not a stressor)

Reach	AUID	Biological Impairment	Class	Stressors							
				Temperature	Nitrate	Phosphorus	DO	TSS	Habitat	Fish Passage	pH
Whitewater Creek	706	Macroinvertebrates	2B		●	○	○	○	●		○
Waterville Creek	560	Fish and Macroinvertebrates	2B		●	○		○	●		
Devils Creek	577	Macroinvertebrates	2B		○	○	●	○	○		
Tributary to Cannon River (Dixon)	705	Fish	2B		○	○	○	○	●	○	
Mackenzie Creek	576	Macroinvertebrates	2B		●			○	●		
Tributary to Cannon River	638	Macroinvertebrates	2B			●	●		●		
Cannon River	542	Macroinvertebrates	2B	C	○	●	●		●		○

5. Conclusions in the Cannon River Watershed

A summary of stressors to the biota in the Cannon River Watershed is found in Table 224. Strength of evidence analysis was completed for each AUID and parameter, and is available upon request.

Table 224. Summary of stressors in the Cannon River watershed (● = stressor, ○ = inconclusive stressor, blank = not a stressor, C = contributing to a stressor).

10 Digit HUC	AUID	Reach	Biological Impairment	Class	Stressors										
					Temperature	Nitrate	Phosphorus	DO	TSS	Habitat	Fish Passage	Flow Alteration*	Ammonia	Chloride	pH
Chub Creek	528	Chub Creek	Fish and Macroinvertebrates	2B		○	●	●	●	●					
Little Cannon	526	Little Cannon River	Macroinvertebrates	2B		●	○		●	●					
Little Cannon	589	Little Cannon River	Fish and Macroinvertebrates	2A	●	●	○	○	●	●	●				
Little Cannon	590	Butler Creek	Macroinvertebrates	2B		○	○		●	○					
Little Cannon	639	Trib to Little Cannon River	Macroinvertebrates	2B		●	○		○	●					
Little Cannon	670	Trib to Little Cannon River	Macroinvertebrates	2B	○	●	○	○	○	○					
Prairie Creek	504	Prairie Creek	Macroinvertebrates	2C		●	○		●	●					
Prairie Creek	512	Unnamed Creek	Macroinvertebrates	2B		●	○	○	●	●					

Prairie Creek	587	Unnamed Creek	Macroinvertebrates	2B		●	○		○	●						
Prairie Creek	723	Trib to Prairie Creek	Macroinvertebrates	2B	○	●	○	○	○	●						
Straight River	503	Straight River	Macroinvertebrates	2B		●	○		●	○			○			
Straight River	515	Straight River	Macroinvertebrates	2B		●	○		●	○						
Straight River	536	Straight River	Macroinvertebrates	2B		●	○	○	●	●						
Straight River	547	Medford Creek	Fish and Macroinvertebrates	2B		●	○	○	○	●	○					
Straight River	731	Unnamed Creek	Macroinvertebrates	2B		●	○	○	○	○						
Straight River	732	Unnamed Creek to Unnamed Creek	Macroinvertebrates	2B		●	○		○	○						
Lower Cannon	580	Trib to Trout Brook	Macroinvertebrates	2A		●	○	○	○	●						
Lower Cannon	573	Trout Brook	Macroinvertebrates	2A		●	○	○	○	●						
Middle Cannon	582	Cannon River	Macroinvertebrates	2B		○	○		○	○						
Middle Cannon	507	Cannon River	Macroinvertebrates	2B		○	○		○	○						
Middle Cannon	509	Cannon River	Fish and Macroinvertebrates	2B		●	●		●	○	●					
Middle Cannon	539	Cannon River	Macroinvertebrates	2B		○	○			○						

Middle Cannon	591	Spring Creek	Macroinvertebrates	2B	○	●	○		○	●						
Middle Cannon	557	Unnamed - Spring Brook (Rice Creek)	Macroinvertebrates	2A		●	○		○	●						
Middle Cannon	555	Unnamed Ditch - Heath Creek	Fish and Macroinvertebrates	2B		○	○	○	○	●	○			●		
Middle Cannon	531	Heath Creek	Fish and Macroinvertebrates	2B			●	●	○	●						
Upper Cannon	542	Cannon River	Macroinvertebrates	2B	C	○	●	●		●		C			○	
Upper Cannon	577	Devils Creek	Macroinvertebrates	2B		○	○	●	○	○						
Upper Cannon	576	Mackenzie Creek	Macroinvertebrates	2B		●			○	●						
Upper Cannon	705	Trib to Cannon River (Dixon)	Fish	2B		○	○	○	○	●	○	●				
Upper Cannon	638	Trib to Cannon River	Macroinvertebrates	2B			●	●		●		○				
Upper Cannon	560	Waterville Creek	Fish and Macroinvertebrates	2B		●	○		○	●						
Upper Cannon	706	Whitewater Creek	Macroinvertebrates	2B		●	○	○	○	●					○	

***For the most part, flow alteration was not looked at on an individual AUID basis, but was examined on the larger watershed scale (8 digit HUC). See Section 3 for more information on flow alteration in the Cannon River Watershed.**

6. References

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

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C., USA.

Becker, G. C. 1983. Fishes of Wisconsin. Univ. Wisconsin Press, Madison. 1052 pp.

Bell, J. 2006. "The Assessment of Thermal Impacts on Habitat Selection, Growth, Reproduction and Mortality in Brown Trout (*Salmo trutta L*): A Review of the Literature," Applied Ecological Services Inc., September 2006, 23 pp

Blake, R. W. 1983. Fish Locomotion. London: Cambridge University Press.

Brooker, M. (1981). The impact of impoundments on the downstream fisheries and general ecology of rivers. *Advances in Applied Biology , 6*, 91 - 152.

Bruton, M.N. (1985). The effects of suspensoids on fish. Hydrobiologica 125(1), 221-242.

Bryce, S.A., J.M. Omernik, and D.P. Larsen. 1999. Ecoregions - a geographic framework to guide risk characterization and ecosystem management: Environmental Practice 1(3):141-155.

CADDIS. 2011. http://www.epa.gov/caddis/

CADDIS Volume 2: Sources, Stresssors 7 Responses. (2013). http://www.epa.gov/caddis/ssr_ph_int.html

CADDIS. 2014. http://www.epa.gov/caddis/

Carlisle et al. 2007. Estimation and application of indicator values for common macroinvertebrate genera and families of the United States. National Water Quality Assessment Program, U.S. Geological Survey.

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

Chapman, D. (1988). Critical review of variables used to define effects of fines in reds of large salmonids. Transactions of the American Fisheries Society 117, 1-21.

Cormier et al. 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency, Washington D.C., EPA/822/B-00/025.
http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/biocriteria/upload/stressorid.pdf

Cummins, K. (1979). *The natural stream ecosystem.* New York: Plenum.

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

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

Environmental Protection Agency (EPA). 2007. Minnesota Level III and Level IV Ecoregions. Provisional, 11 May 2007. ftp://ftp.epa.gov/wed/ecoregions/mn/mn_eco_desc.pdf

EPA. (1986). Quality Criteria for Water 1986. Washington D.C. Office of Water Regulations and Standards, United States Environmental Protection Agency. (EPA 440/5-86-001).

Erman, D. C. & Ligon, F.K. (1988). Effects of discharge fluctuation and the addition of fine sediment on stream fish and macroinvertebrates below a water-filtration facility. Environmental Management 12, 85-97.

Feist, M. & Niemala, S. (2005). Examining relationships among stream temperature variables and fish community attributes in warmwater streams of the MN River Basin. Minnesota Pollution Control Agency. St. Paul, Minnesota. http://www.pca.state.mn.us/index.php/view-document.html?gid=6075

Folmar, L.C., J.O. Sanders, and A.M. Julin. 1979. Toxicity of the Herbicide Glyphosate and Several of its Formulations to Fish and Aquatic Invertebrates. Arch. Environ. Contain. Toxicol. Vol. 8. pp. 269-278

Gray, L.J. & Ward, J.V. (1982). Effects of sediment releases from a reservoir on stream macroinvertebrates. Hydrobiologia 96 (2), 177-184.

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

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

Heino, J. 2005. *Functional biodiversity of macroinvertebrate assemblages along major ecological gradients of boreal headwater streams*. Freshw. Biol. 50: 1578–1587.

Heino, Jani. 2008. *Patterns of functional biodiversity and function – environment relationships in lake littoral macroinvertebrates.* American Society of Limnology and Oceanography, Inc. 53(4): 1446-1455.

Heiskary, S., R.W. Bouchard Jr., and H. Markus. 2013. Water Quality Standards Guidance and References to Support Development of Statewide Water Quality Standards, Draft. Minnesota Pollution Control Agency, St. Paul, Minnesota. 197 p. http://www.pca.state.mn.us/index.php/view-document.html?gid=14947

Ickes, B. S., Vallazza, J., Kalas, J., and Knights, B. 2005. River Floodplain Connectivity and Lateral Fish Passage: A Literature Review.U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI June 2005.

Kauffman, J. &. (1984). Livestock Impacts on riparian ecosystems and streamside management implications: a review. *Journal of Range Management, 37*, 430-438.

Kolander, T. 2012. Straight River Geomorphology Sampling Summary. Minnesota Department of Natural Resources, St. Paul, MN.

Kolander, T. 2012. Straight River Presentation. Minnesota Department of Natural Resources, St. Paul, MN.

Kolbe, C. and Luedke, M. 2005. Chapter 6: Freshwater Macroinvertebrates, A guide to Freshwater Ecology. Texas Commission on Environmental Quality, Austin, TX.

Lore, J. G. 2011. Identifying stressors causing fish community impairments in the High Island Creek watershed. Minnesota State University, Mankato Master's Thesis.

McKeown, B. A. 1984. Fish migration. Croom Helm, London.

Merritt, R., Cummins, K., & Resch, V. (1996). *An introduction to the aquatic insects of North America.* Dubuque, Iowa: Kendall/Hunt Publishing.

Minnesota Department of Natural Resources. 2014. Upper Cannon River Watershed Geomorphology and Hydrology: A Report to MNDNR Fisheries. Minnesota Department of Natural Resources – Ecological and Water Resources.

Mitchell, S.C. and Cunjak, R.A. 2007. Stream flow, salmon and beaver dams: roles in the construction of stream fish communities within an anadromous salmon dominated stream. Journal of Animal Ecology 76: 1062-1074.

MPCA. 2008. Draft Biota TMDL Protocols and Submittal Requirements. Minnesota Pollution Control Agency, St. Paul, MN. http://www.pca.state.mn.us/index.php/view-document.html?gid=8524

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

MPCA. 2012. 2012 Clean Water Act Reporting Cycle Stream Assessment Transparency Documentation. Minnesota Pollution Control Agency, St. Paul, MN.

MPCA. 2013. Nitrogen in Minnesota Surface Waters.

MPCA. 2014. Cannon River Monitoring and Assessment Report.

MPCA. 2015. Environmental Data Access (http://www.pca.state.mn.us/data/index.html).

MPCA and Cannon River Watershed Partnership. 2013. Byllesby Reservoir Phosphorus TMDL Report. Minnesota Pollution Control Agency, St. Paul, MN. http://www.pca.state.mn.us/index.php/view-document.html?gid=19406

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

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

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

National Resource Conservation Service (NRCS). 2006. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. United States Department of Agriculture Handbook 296. 682 p.

National Resource Conservation Service (NRCS). 2007. Rapid Watershed Assessment: Cannon River (MN) HUC: 07040002. National Resource Conservation Service. United States Department of Agriculture. 18 p. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022044.pdf

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

Newcombe, C. P. & MacDonald, D. D. (1991). Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11, 72-82.

Omernik, J.M. and A.L. Gallant. 1988. Ecoregions of the Upper Midwest States. EPA/600/3-88/037. Corvallis, OR: United States Environmental Protection Agency. 56 p.

Omernik, J.M. 1995. Ecoregions—a framework for environmental management in Davis, W.S. and Simon, T.P., editors, Biological assessment and criteria-tools for water resource planning and decision making. Lewis Publishers, Boca Raton, Florida. p. 49-62.

Omernik, J.M., S.S. Chapman, R.A. Lillie and R.T. Dumke. 2000. Ecoregions of Wisconsin: Transactions of the Wisconsin Academy of Sciences, Arts, and Letters: 88:77-103.

Pekarsky, B.L. (1984) Predator-prey interactions among aquatic insects. In V.H. Resch and D.M. Rosenberg (Eds.), The Ecology of Aquatic Insects (pp. 196-254). NY: Praeger Scientific.

Pringle, C.M., 2003. What is Hydrologic Connectivity and Why is it Ecologically Important? *Hydrological Processes* 17:2685-2689.

Proulx, N. 2015. Little Cannon River Watershed Geomorphology Assessment Report. Minnesota Department of Natural Resources, St. Paul, MN.

Rabeni, C., Doisy, K., & Zweig, L. (2005) Stream invertebrate community functional responses to deposited sediment. *Aquatic Sciences - Research Across Boundaries* , 395-402.

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

Robertson-Bryan, Inc. (2004). Technical Memorandum: PH Requirements of Freshwater Aquatic Life. http://www.swrcb.ca.gov/rwqcb5/water_issues/basin_plans/ph_turbidity/ph_turbidity_04phreq.pdf

Rosgen, D. 1996. *Applied River Morphology. Wildlands Hydrology*. Pagosa Springs, Colorado.

Rosenberg, D. & Wiens, A. (1978). Effect of sediment addition on macrobenthic invertebrates in a northern Canadian river. Water Research 12, 753 - 763.

Roy, A. H., A. D. Rosemond, M. J. Paul, D. S. Leigh, and J. B. Wallace. 2003. Stream macroinvertebrate response to catchment urbanization (Georgia, U.S.A.). Freshwater Biology 48: 329–346.

Santucci Jr., V. J., S. R. Gephard, and S. M. Pescitelli. 2005. Effects of multiple low-head dams on fish, macroinvertebrates, habitat, and water quality in the Fox River, Illinois. North American Journal of Fisheries Management 25: 975-992.

Scheimer, F. 2000. Fish as indicators for the assessment of ecological integrity of large rivers. Hydrobiologia 422/423:271–278.

Schlosser, I. 1990. Environmental variation, life history attributes, and community structure in stream fishes: Implications for environmental management and assessment. Environmental Management 14(5):621-628.

Schottler et al. 2013. Twentieth century agricultural drainage creates more erosive rivers. Hydrological Processes doi: 10.1002/hyp.9738. http://onlinelibrary.wiley.com/doi/10.1002/hyp.9738/abstract

Slawski, T. M., F. M. Veraldi, S. M. Pescitelli, and M. J. Pauers. 2008. Effects of tributary spatial position, urbanization, and multiple low-head dams on warmwater fish community structure in a Midwestern stream. North American Journal of Fisheries Management 28: 1020-1035.

Stranko et al. 2013. Do Road Salts Cause Environmental Impacts? Maryland Department of Natural Resources.

Tiemann, J., Gillette, D., Wildhaber, M., & Edds, D. (2004). Effects of lowhead dams on riff-dwelling fishes and macroinvertebrates in a midwestern river. *Transactions of the American Fisheries Society , 133*, 705-717.

Tockner, K., D. Pennetzdorfer, N. Reiner, F. Scheimer, and J. V. Ward. 1999. Hydrological connectivity and the exchange of organic matter and nutrients in a dynamic river floodplain system (Danube, Austria). Freshwater Biology 41(3):521-535.

U.S. EPA. 1988. Ambient Water Quality Criteria for Chloride – 1988.

U. S. EPA. 2003. National Water Quality Report to Congress (305(b) report).

U.S. EPA. 2010. Causal Analysis/Diagnosis Decision Information System (CADDIS). Environmental Protection Agency. Office of Research and Development, Washington, DC. Available online at http://www.epa.gov/caddis.

U.S. EPA. 2012. CADDIS Volume 2 Sources, Stressors & Responses, 2012.

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

Welcomme, R. L. 1979. Fishery management in large rivers. Food and Agriculture Organization of the Unites Nations, Rome, Italy. Food and Agriculture Organization Fisheries Technical Paper 194.

Winston, M. R., C. M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. Transactions of the American Fisheries Society 120: 98-105.

7. Appendix

Appendix A

Table 225. Fish and macroinvertebrate metrics used in stressor analysis in the Cannon River Watershed. Some of the metrics below are more "general" stress indicators, while others are more "stressor specific" indicators.

Metric Name	Type	Metric Description	Use in Report
MA>3Pct	Fish	relative abundance of individuals with a female mature age >=3 (Frimpong)	DO
Sensitive	Fish	Taxa richness of sensitive species	DO, FIBI
SSpnPct	Fish	Relative abundance (%) of individuals that are serial spawning species	DO, FIBI
DetNWQTXPct	Fish	relative abundance (%) of taxa that are detritivorous (NAWQA database)	FIBI
GeneralPct	Fish	Relative abundance (%) of individuals that are generalist species	FIBI
Insect-TolPct	Fish	Relative abundance (%) of individuals that are insectivore species (excludes tolerant species)	FIBI
Piscivore	Fish	Taxa richness of piscivore species	FIBI
SLvdPct	Fish	Relative abundance (%) of individuals that are short-lived	FIBI
SSpnTXPct	Fish	Relative abundance (%) of taxa that are serial spawners	FIBI
VtolTXPct	Fish	Relative abundance (%) of taxa that are very tolerant species	FIBI
SensitiveTXPct	Fish	Relative abundance (%) of taxa that are sensitive	FIBI
SLithop	Fish	Taxa richness of simple lithophilic spawning species	FIBI
FishDELTPct	Fish	Relative abundance (%) of individuals with DELT anomalies (deformities, eroded fins, lesions, or tumors)	FIBI
BenInsect-TolTXPct	Fish	Relative abundance (%) of taxa that are non-tolerant benthic insectivores	FIBI
MA<2Pct	Fish	relative abundance (%) of individuals with a female mature age <=2 (Frimpong)	FIBI
SLvd	Fish	Taxa richness of short-lived species	FIBI
TolTXPct	Fish	Relative abundance (%) of taxa that are tolerant species	FIBI
GeneralTXPct	Fish	Relative abundance (%) of taxa that are	FIBI

		generalists	
CWSensitivePct_10DrgArea	Fish	Relative abundance (%) of individuals that are considered Sensitive in coldwater streams, adjusted for Drainage Area using the residuals	FIBI
CWTol_10DrgArea	Fish	Number of taxa that are considered Tolerant in coldwater streams, adjusted for Drainage Area	FIBI
NativeColdTXPct_10DrgArea	Fish	Relative abundance (%) of taxa that are native and prefer coldwater, adjusted for Drainage Area	FIBI
NativeColdPct	Fish	Relative abundance (%) of individuals that are native coldwater species	FIBI
HerbvPct	Fish	Relative abundance (%) of individuals that are herbivore species	FIBI
SdetTXPct_10DrgArea	Fish	Relative abundance (%) of taxa that are detritivorous, adjusted for Drainage Area using the residuals	FIBI
DomTwoPct	Fish	Relative abundance (%) of individuals of the dominant two species	FIBI, Habitat
TolPct	Fish	Relative abundance (%) of individuals that are tolerant species	FIBI, Phosphorus, DO, Habitat
BenInsectPct	Fish	Relative abundance (%) of individuals that are benthic insectivore species	Habitat
LithFrimPct	Fish	Relative abundance (%) of individuals that are lithophilic spawners	Habitat
DarterSculpSucPct	Fish	Relative abundance (%) of individuals that are darter, sculpin, and round bodied sucker species	Habitat
BenInsect-TolPct	Fish	Relative abundance (%) of individuals that are non-tolerant benthic insectivore species	Habitat
PiscivorePct	Fish	Relative abundance (%) of individuals that are piscivore species	Habitat
PioneerPct	Fish	Relative abundance (%) of individuals that are pioneer species	Habitat, FIBI
DarterPct	Fish	Relative abundance (%) of individuals that are darter species	Phosphorus
TaxaCount	Fish	total taxa richness of fish species (hybrids and exotics often excluded)	Phosphorus, DO
SLithopPct	Fish	Relative abundance (%) of individuals that are simple lithophilic spawners	Phosphorus, Habitat

SensitivePct	Fish	Relative abundance (%) of individuals that are sensitive species	Phosphorus, TSS
ColdPct	Fish	Relative abundance (%) of individuals that are coldwater species	Temperature
ColdCoolPct	Fish	Relative abundance (%) of individuals that are coldwater and coolwater species	Temperature
BenFdFrimPct	Fish	Relative abundance (%) of individuals that are exclusively benthic feeders (Frimpong)	TSS
Centr-TolPct	Fish	relative abundance (%) of individuals that are non-tolerant Centrarchidae	TSS
HrbNWQPct	Fish	Relative abundance (%) of individuals that are herbivore species (NAWQA database)	TSS
IntolerantPct	Fish	Relative abundance (%) of individuals that are tolerant species	TSS
LLvdPct	Fish	Relative abundance (%) of individuals that are long-lived (Frimpong)	TSS
Percfm-TolPct	Fish	Relative abundance (%) of individuals of the Order Perciformes (excluding tolerant)	TSS
SLithFrimPct	Fish	Relative abundance (%) of individuals that are simple lithophilic spawners, as per Frimpong database	TSS
TSS Index Score (RA)	Fish	TSS index score	TSS
RifflePct	Fish	Relative abundance (%) of individuals that are riffle-dwelling species	TSS, Habitat
Low DO Index Score	Macroinvertebrates	Low DO index score	DO
Low DO Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 25th percentile of stressor tolerance scores	DO
Low DO Very Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 15th percentile of stressor tolerance scores	DO
Low DO Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores	DO
Low DO Very Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 15th percentile of stressor tolerance scores	DO
Low DO Tolerant Pct	Macroinvertebrates	Relative Abundance of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores	DO
Low DO Very	Macroinvertebrates	Relative Abundance of taxa with tolerance	DO

Tolerant Pct		values in the upper 15th percentile of stressor tolerance scores	
HBI_MN	Macroinvertebrates	A measure of pollution based on tolerance values assigned to each individual taxon developed by Chirhart	DO, Nitrate, MIBI
Burrower	Macroinvertebrates	Taxa richness of burrowers (excluding chironomid burrower taxa)	Habitat
Climber	Macroinvertebrates	Taxa richness of climbers (excluding chironomid climber taxa)	Habitat
Clinger	Macroinvertebrates	Taxa richness of clingers (excluding chironomid clinger taxa)	Habitat
Legless	Macroinvertebrates	Taxa richness of legless macroinvertebrates (chironomid taxa treated as one taxon)	Habitat
Sprawler	Macroinvertebrates	Taxa richness of sprawlers (excluding chironomid and baetid sprawler taxa)	Habitat
Swimmer	Macroinvertebrates	Taxa richness of swimmers (excluding chironomid, baetid taxa treated as one taxon)	Habitat
ClimberCh	Macroinvertebrates	Taxa richness of climbers	MIBI
ClingerChTxPct	Macroinvertebrates	Relative percentage of taxa adapted to cling to substrate in swift flowing water	MIBI
DomFiveCHPct	Macroinvertebrates	Relative abundance (%) of dominant five taxa in subsample (chironomid genera treated individually)	MIBI
InsectTxPct	Macroinvertebrates	Relative percentage of insect taxa	MIBI
Odonata	Macroinvertebrates	Taxa richness of Odonata	MIBI
Plecoptera	Macroinvertebrates	Taxa richness of Plecoptera	MIBI
PredatorCh	Macroinvertebrates	Taxa richness of predators	MIBI
Trichoptera	Macroinvertebrates	Taxa richness of Trichoptera	MIBI
ClingerCh	Macroinvertebrates	Taxa richness of clingers	MIBI
POET	Macroinvertebrates	Taxa richness of Plecoptera, Odonata, Ephemeroptera, & Trichoptera (baetid taxa treated as one taxon)	MIBI
ChiroDip	Macroinvertebrates	Ratio of chironomid abundance to total dipteran abundance	MIBI
VeryTolerant2Pct	Macroinvertebrates	Relative abundance (%) of macroinvertebrate individuals in subsample with tolerance values equal to or greater than 8, Using MN TVs	MIBI
TrichopteraCh	Macroinvertebrates	Taxa richness of Trichoptera	Nitrate
Nitrate Index Score	Macroinvertebrates	Nitrate index score	Nitrate
Nitrate Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 25th percentile of stressor tolerance	Nitrate

		scores	
Nitrate Very Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 15th percentile of stressor tolerance scores	Nitrate
Nitrate Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores	Nitrate
Nitrate Very Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 15th percentile of stressor tolerance scores	Nitrate
Nitrate Tolerant Pct	Macroinvertebrates	Relative Abundance of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores	Nitrate
Nitrate Very Tolerant Pct	Macroinvertebrates	Relative Abundance of taxa with tolerance values in the upper 15th percentile of stressor tolerance scores	Nitrate
TrichwoHydroPct	Macroinvertebrates	Relative abundance (%) of non-hydropsychid Trichoptera individuals in subsample	Nitrate, MIBI
TrichopteraChTxPct	Macroinvertebrates	Relative percentage of taxa belonging to Trichoptera	Nitrate, MIBI
Intolerant2Ch	Macroinvertebrates	Taxa richness of macroinvertebrates with tolerance values less than or equal to 2, using MN TVs	Nitrate,Phosphorus, MIBI
Collector-filtererCh	Macroinvertebrates	Taxa richness of collector-filterers	Phosphorus
Collector-gathererCh	Macroinvertebrates	Taxa richness of collector-gatherers	Phosphorus
EPT	Macroinvertebrates	Taxa richness of Ephemeroptera, Plecoptera & Trichoptera (baetid taxa treated as one taxon)	Phosphorus, DO
TaxaCountAllChir	Macroinvertebrates	Total taxa richness of macroinvertebrates	Phosphorus, DO, MIBI
Tolerant2ChTxPct	Macroinvertebrates	Relative percentage of taxa with tolerance values equal to or greater than 6, using MN TVs	Phosphorus, DO, MIBI
CBI	Macroinvertebrates	Coldwater Biotic Index score based on coldwater tolerance values derived from Minnesota taxa/temperature data	Temperature
PlecopteraPct	Macroinvertebrates	Relative abundance (%) of Plecoptera individuals in subsample	TSS
TSS Index Score	Macroinvertebrates	TSS index score	TSS
TSS Intolerant	Macroinvertebrates	Number of taxa with tolerance values in the	TSS

Taxa		lower 25th percentile of stressor tolerance scores	
TSS Very Intolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the lower 15th percentile of stressor tolerance scores	TSS
TSS Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores	TSS
TSS Very Tolerant Taxa	Macroinvertebrates	Number of taxa with tolerance values in the upper 15th percentile of stressor tolerance scores	TSS
TSS Tolerant Pct	Macroinvertebrates	Relative Abundance of taxa with tolerance values in the upper 25th percentile of stressor tolerance scores	TSS
TSS Very Tolerant Pct	Macroinvertebrates	Relative Abundance of taxa with tolerance values in the upper 15th percentile of stressor tolerance scores	TSS
IntolerantPct	Macroinvertebrates	Relative abundance (%) of macroinvertebrate individuals in subsample with tolerance values less than or equal to 2	TSS
LongLivedPct	Macroinvertebrates	Relative abundance (%) of longlived individuals in subsample	TSS
Collector-filtererPct	Macroinvertebrates	Relative abundance (%) of collector-filterer individuals in subsample	TSS, MIBI