Two Rivers Watershed
Stressor Identification Report

A study of the stressors limiting the aquatic biological communities in the Two Rivers Watershed.

North Branch Two Rivers

Minnesota Pollution Control Agency

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Cover photo

North Branch Two Rivers at County Road 58 (September 30, 2015)

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Acronyms

AUID – Assessment Unit Identification

BMP – Best Management Practices

CADDIS – Causal Analysis/Diagnosis Decision Information System

CD – County Ditch

CR – County Road

CSAH – County State Aid Highway

DO – Dissolved Oxygen

DNR – Minnesota Department of Natural Resources

EPA – U. S. Environmental Protection Agency

HSPF – Hydrological Simulation Program - FORTRAN

HUC – Hydrologic Unit Code

IBI – Index of Biological Integrity

IWM – Intensive Watershed Monitoring

MPCA – Minnesota Pollution Control Agency

MSHA – MPCA Stream Habitat Assessment

NAIP – National Agriculture Imagery Program

NLCD – National Land Cover Database

SI – Stressor Identification

SOE – Strength-of-Evidence

TALU – Tiered Aquatic Life Use

TIV – Tolerance Indicator Value

TMDL – Total Maximum Daily Load

TRW – Two Rivers Watershed

TRWD – Two Rivers Watershed District

TSS – Total Suspended Solids

USGS – United States Geological Survey

WHAF – Watershed Health Assessment Framework

Executive summary

The Minnesota Pollution Control Agency (MPCA) follows a watershed approach to systematically monitor and assess surface water quality in each of the state's 80 major watersheds. A key component of this approach is Intensive Watershed Monitoring (IWM), which includes biological (i.e., fish and macroinvertebrate) monitoring to evaluate overall stream health. In 2013 and 2014, the MPCA conducted biological monitoring at several stations throughout the Two Rivers Watershed (TRW). An Index of Biological Integrity (IBI) score was then calculated for the fish (F-IBI) and macroinvertebrate (M-IBI) communities of each station using the IWM and previously collected data. The biological monitoring results for the watershed were assessed to identify individual stream reaches that were not supporting a healthy fish and/or macroinvertebrate assemblage. A reach with a low IBI score(s) (i.e., below an established threshold) is considered "impaired" (i.e., unable to support its designated beneficial use) for aquatic life. A total of 13 reaches were determined to have an F-IBI and/or M-IBI impairment in the TRW, including segments of the North Branch Two Rivers, Middle Branch Two Rivers, South Branch Two Rivers, State Ditch 84, Lateral Ditch 1 of State Ditch 95, County Ditch 4, County Ditch 72, State Ditch 49, and Judicial Ditch 31.

This report identifies the main causes, or "stressors", that are likely contributing to the biological impairments in the watershed. Five candidate causes were examined as potential stressors in the report: loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, high suspended sediment, and low dissolved oxygen (DO). Causal analysis was performed to determine and evaluate connections between each candidate cause and the biological impairments. Table 1 provides a summary of the stressors identified for the biologically impaired reaches in the TRW.

Table 1. Summary of the stressors associated with the biologically impaired reaches in the TRW.

Name (AUID suffix)	Biological impairment(s)	Candidate causes				
		Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
North Branch Two Rivers (504 and 508)	F-IBI	•	•	•	•	•
Middle Branch Two Rivers (503)	F-IBI/M-IBI	•	•	•	•	•
South Branch Two Rivers (502, 505, and 506)	F-IBI/M-IBI	•	•	•	•	•
State Ditch 84 (514)	F-IBI	•	•	•		•
Lateral Ditch 1 of State Ditch 95 (521 and 539)	F-IBI/M-IBI	•	•	•	•	•
County Ditch 4 (522)	F-IBI	•	•	•		•
State Ditch 72 (531)	F-IBI/M-IBI	•	•	•		•
State Ditch 49 (544)	F-IBI	•	•	•		•
Judicial Ditch 31 (549)	F-IBI	•	•	•		•

The loss of longitudinal connectivity caused by the Hallock Dam, Lake Bronson Dam, and Northcote Dam severely limits the potential of the fish community of the affected reaches upstream by impeding the migration of many large bodied, longer-lived species that are found in the Red River of the North (e.g., channel catfish, sauger, and walleye). Removal or modification of these structures would not only directly improve the health of the fish community of these reaches, but also benefit the fishery of the Red River of the North by providing many species access to the physical habitat necessary to complete their life history (e.g., clean, coarse substrate for spawning). Each of the biologically impaired reaches is prone to high and quick peak flows and/or prolonged periods of low or no discharge. Historical changes in land cover (e.g., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) are the primary anthropogenic factors contributing to this flow regime instability. Additional runoff detention/retention is needed throughout the watershed to attenuate peak flows and augment base flows. The central and eastern portions of the watershed generally offer good instream habitat, including riffles and coarse substrate. However, the habitat of several reaches in these areas has been degraded as a result of hydrologic alterations. The habitat of the western portion of the watershed is inherently limited by the predominance of fine lacustrine sediment. Excess suspended sediment appears to be having a marginal effect on the biological communities of several impaired reaches. Soil erosion and channel degradation are believed to be the primary sources of this sediment. The implementation of additional soil conservation practices and the attenuation of peak flows would reduce sediment loads. Lastly, low DO is a stressor for nearly all of the impaired reaches. While the severity of low DO conditions varies amongst the reaches, the lowest concentrations generally coincide with low flow and lentic conditions that occur during the late summer. Base flow augmentation appears to be the primary means of alleviating this stressor.

Introduction

Stressor identification (SID) is a formal and rigorous methodology for determining the causes, or "stressors", that are likely contributing to the biological impairment of aquatic ecosystems (EPA, 2000). The initial step in the SID process (Figure 1) is to define the subject of the analysis (i.e., the case) by determining the geographic scope of the investigation and the effects that will be analyzed. Thereafter, a list of candidate causes (i.e., potential stressors) that may be responsible for the observed biological effects is developed. The candidate causes then undergo causal analysis, which involves the evaluation of available data. Typically, the majority of the data used in the analysis is from the study watershed, although evidence from other case studies or scientific literature can also be drawn upon. Analyses conducted during this step combine measures of the biological response, with direct measures of proximate stressors. Upon completion of causal analysis, strength-of-evidence (SOE) analysis is used to determine the probable stressors for the biological impairment. Confidence in the final SID results often depends on the quality of data available to the process. In some cases, additional data collection may be necessary to accurately identify the stressors.

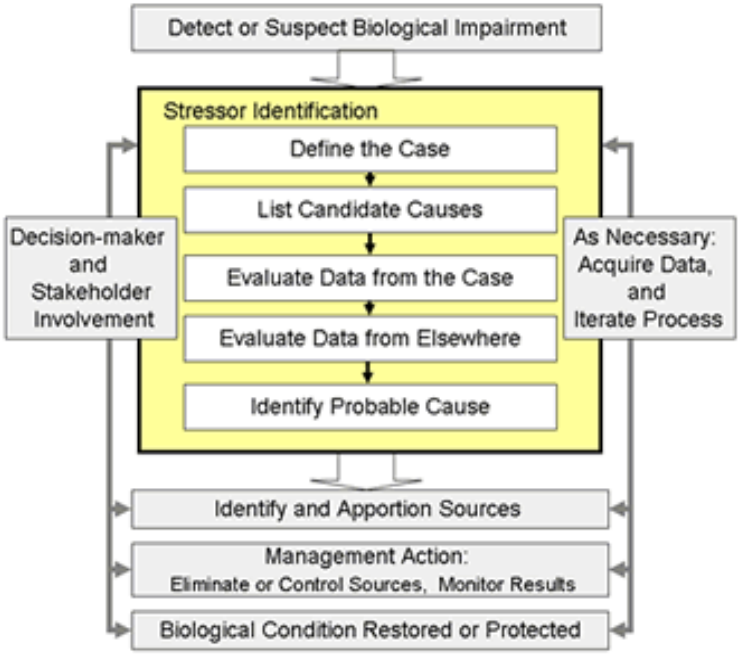


Figure 1. Conceptual model of the SI process (EPA 2012b).

Section 1: Watershed overview

1.1 Physical setting

The TRW, United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 09020312, is situated in northwestern Minnesota and is part of the larger Red River of the North Basin. The TRW has a drainage area of 1,101 square miles and encompasses portions of the following counties, listed in order of the percentage of watershed area: Kittson (54%), Roseau (45%), and Marshall (1%). Cities within the watershed include Badger, Greenbush, Hallock, Halma, Lake Bronson, Lancaster, and Strathcona.

1.2 Surface water resources

The Two Rivers and its three associated branches (i.e., north, middle, and south) are the prominent water features in the TRW. The Two Rivers outlets to the Red River of the North approximately 9 miles west of the city of Hallock. The TRW contains 510 miles of intermittent drainage ditch, 315 miles of intermittent stream, 182 miles of perennial stream and river, and 152 miles of perennial drainage ditch (DNR, 2003). According to the MPCA (2013), 71% of the watercourses in the TRW have been hydrologically altered (i.e., channelized, ditched, or impounded). There are no notable natural lakes in the watershed; however, there are several man-made impoundments. The largest of these impoundments is Lake Bronson, which is an approximately 300-acre reservoir along the South Branch Two Rivers.

1.3 Geology and soils

Two distinct physiographic regions are represented in the TRW. The drift plain/beach ridges region, which includes glacial drift deposits that were modified by glacial Lake Agassiz, as well as the ancient shorelines of glacial Lake Agassiz, encompasses approximately the eastern three-fourths of the watershed. This region is characterized by an undulating topography (1-8% slope) and soils of varying textures (sand to clay loam). There are also large inclusions of organic soils scattered throughout the region. The lake plain region is located in the western portion of the watershed. This region is characterized by an extremely flat topography (0-1% slope) and very fine textured soils (clay) derived from lacustrine sediments deposited in glacial Lake Agassiz.

1.4 Land use and ecoregions

The predominant land use in the TRW is agricultural crop production. According to the National Land Cover Database (NLCD) 2011 (USGS, 2011), cultivated crops comprised 64% of the watershed. Other notable land cover groups in the watershed included wetlands (16%), forest (10%), hay/pasture (5%), and developed (5%). There are two ecoregions represented in the TRW: Red River Valley and Northern Minnesota Wetlands (EPA, 2012a). A majority (80%) of the watershed is located within the Red River Valley ecoregion. The Minnesota wetlands ecoregion (20%) is isolated to the north-central portion of the watershed.

1.5 Ecological health

The Minnesota Department of Natural Resources (DNR) developed the Watershed Health Assessment Framework (WHAF) to assess the overall ecological health of a watershed. The WHAF evaluates and provides a score to each of the five core components of watershed health: hydrology, geomorphology, biology, connectivity, and water quality. Scores are ranked on a scale from 0 ("low") to 100 ("high"). Statewide mean health scores ranged from 40 (Marsh River Watershed) to 84 (Rapid River Watershed).

Figure 2 presents the watershed health scorecard for the TRW. The mean health score for the watershed was 54. The overall score was limited by the individual mean component scores for connectivity (31) and biology (43). Specifically, the watershed scored poorly for the following component indices: altered streams (0), terrestrial habitat quality (12), terrestrial habitat connectivity (16), hydrologic storage (30), climate vulnerability (30), perennial cover (32), at-risk species (36), and water quality assessments (50).

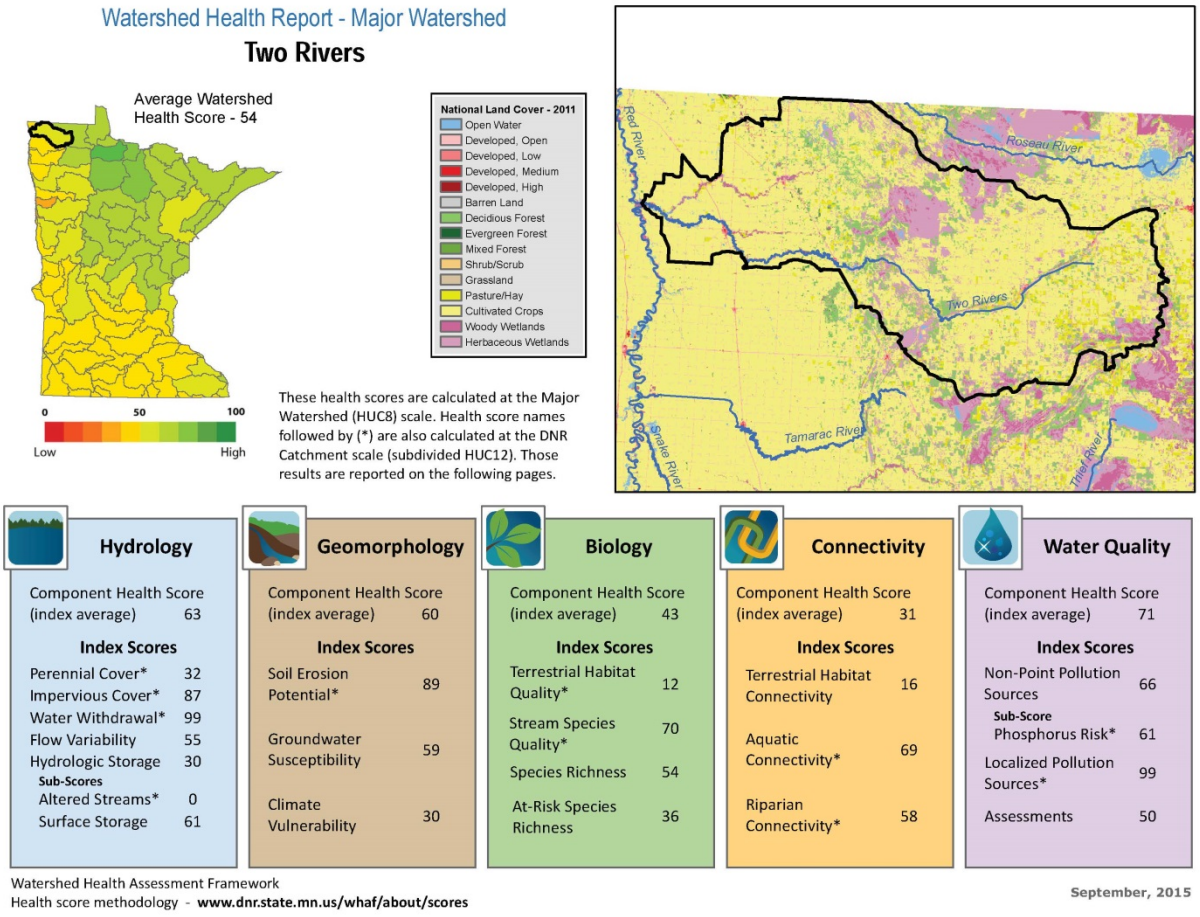


Figure 2. Watershed health assessment scores for the TRW.

1.6 Hydrological Simulation Program – FORTRAN Model

A Hydrological Simulation Program – FORTRAN (HSPF) model was developed for the TRW to simulate the hydrology and water quality conditions throughout the watershed on an hourly basis from 1996 to 2009. The HSPF model incorporates watershed-scale Agricultural Runoff Model and Non-Point Source models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. The model enables the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient concentrations, along with a time history of water quantity and quality at the outlet of each subwatershed. The HSPF model outputs were used in the evaluation of several of the candidate causes outlined in this report.

Section 2: Biological monitoring and impairments

2.1 Watershed approach

The MPCA utilizes a watershed approach (Figure 3) to systematically monitor and assess surface water quality in each of the state's 80 major watersheds. A key component of this approach is IWM, which includes biological (i.e., fish and macroinvertebrate) monitoring to evaluate overall stream health. In 2013 and 2014, the MPCA conducted biological monitoring at several stations throughout the TRW. An IBI score was then calculated for the F-IBI and M-IBI communities of each station using the IWM and previously collected data. The biological monitoring results for the watershed were assessed to identify individual stream reaches that were not supporting a healthy fish and/or macroinvertebrate assemblage. A reach with a low IBI score(s) (i.e., below an established threshold) is considered "impaired" (i.e., unable to support its designated beneficial use) for aquatic life. The biological impairments of the TRW are the focus of this SID report. The results of the SID process will guide the development of implementation strategies to correct the impaired conditions, which may include the preparation of a Total Maximum Daily Load (TMDL) study.

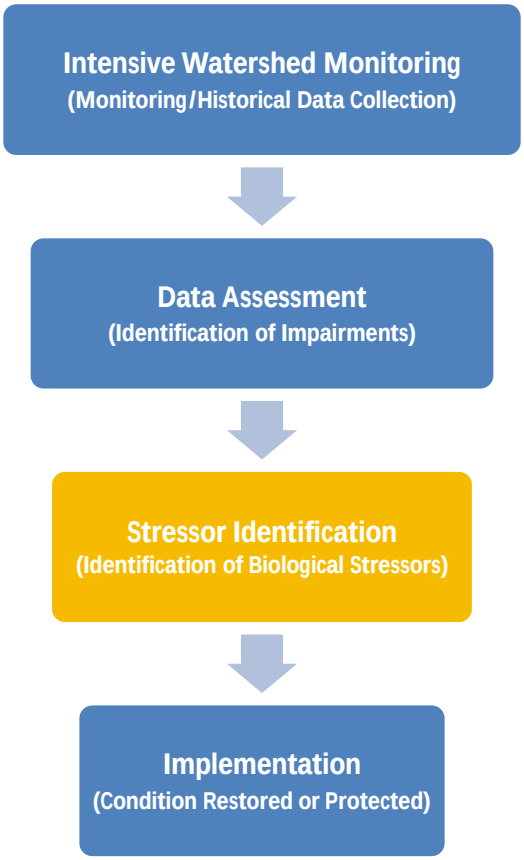


Figure 3. Conceptual model of the watershed approach processes.

2.2 Monitoring stations

Table 2 lists the 32 biological monitoring stations that were sampled for fish and/or macroinvertebrates in the TRW. The stations are situated along 21 separate reaches. For the purpose of this report, individual reaches will be referred to by their respective three-digit Assessment Unit Identification (AUID) number suffix.

Table 2. List of biological monitoring stations in the TRW.

AUID suffix	AUID	Name	Monitoring station(s)
501	09020312-501	Two Rivers	13RD056, 13RD084
502	09020312-502	South Branch Two Rivers	93RD401, 10EM192, 13RD082, 13RD085
503	09020312-503	Middle Branch Two Rivers	93RD405, 05RD093
504	09020312-504	North Branch Two Rivers	93RD403, 05RD094, 13RD070, 13RD089
505	09020312-505	South Branch Two Rivers	13RD042
506	09020312-506	South Branch Two Rivers	05RD181, 13RD045
507	09020312-507	South Branch Two Rivers	13RD096
508	09020312-508	North Branch Two Rivers	05RD053, 13RD041, 13RD053
509	09020312-509	Two Rivers	05RD004
514	09020312-514	State Ditch 84	13RD067
515	09020312-515	Lateral Ditch 4 of State Ditch 91	13RD058
521	09020312-521	Lateral Ditch 1 of State Ditch 95	13RD043
522	09020312-522	County Ditch 4	05RD002
531	09020312-531	State Ditch 72	13RD055
539	09020312-539	Lateral Ditch 1 of State Ditch 95	13RD048
544	09020312-544	State Ditch 49	13RD044
546	09020312-546	State Ditch 90	13RD064
547	09020312-547	State Ditch 85	13RD091
549	09020312-549	Judicial Ditch 31	13RD057
550	09020312-550	Unnamed Ditch	13RD054
551	09020312-551	Unnamed Ditch	13RD052

2.3 Monitoring results

Table 3 provides the F-IBI and M-IBI scores for each of the biological monitoring stations in the TRW. A total of 14 stations (44%) scored below their F-IBI impairment threshold, while 13 stations (50%) scored below their M-IBI impairment threshold; these stations are highlighted red.

Table 3. Summary of F-IBI and M-IBI scores for biological monitoring stations in the TRW.

Fish					Macroinvertebrate				
AUID suffix	Station	F-IBI Class[1] (Use[3])	F-IBI impairment threshold	F-IBI score (mean)	AUID suffix	Station	M-IBI Class[2] (Use[3])	M-IBI impairment threshold	M-IBI score (mean)
501	13RD056	SR(G)	49	68	501	13RD056	PFR(G)	31	37
501	13RD084	SR(G)	49	67	**501**	**13RD084**	**PFR(G)**	**31**	**23**
502	**93RD401**	**SR(G)**	**49**	**37**	502	93RD401	PFR(G)	31	31
502	10EM192	NR(G)	38	51	502	10EM192	PFR(G)	31	70
502	13RD082	NR(G)	38	60	502	13RD082	PFR(G)	31	59
502	13RD085	SR(G)	49	50	502	13RD085		Not Sampled	
503	93RD405	NH(G)	42	42	503	93RD405	PGP(G)	41	54
503	**05RD093**	**SS(G)**	**50**	**31**	503	05RD093	PGP(G)	41	42
504	93RD403	NS(G)	47	48	504	93RD403	PGP(G)	41	75
504	**05RD094**	**NS(G)**	**47**	**38**	504	05RD094	PGP(G)	41	69
504	13RD070	SS(G)	50	58	**504**	**13RD070**	**PGP(G)**	**41**	**37**
504	13RD089	NS(G)	47	54	504	13RD089	SRR(G)	37	63
505	**13RD042**	**NS(G)**	**47**	**36**	**505**	**13RD042**	**SRR(G)**	**37**	**29**
506	**05RD181**	**NS(G)**	**47**	**38**	**506**	**05RD181**	**PGP(G)**	**41**	**36**
506	13RD045	NS(G)	47	49	**506**	**13RD045**	**SRR(G)**	**37**	**32**
507	13RD096	NH(G)	42	56	507	13RD096		Not Sampled	
508	05RD053	SR(G)	49	67	**508**	**05RD053**	**PGP(G)**	**41**	**33**
508	**13RD041**	**SR(G)**	**49**	**40**	**508**	**13RD041**	**PGP(G)**	**41**	**35**
508	**13RD053**	**SR(G)**	**49**	**39**	**508**	**13RD053**	**PGP(G)**	**41**	**17**
509	05RD004	SR(G)	49	59	**509**	**05RD004**	**PFR(G)**	**31**	**10**
514	**13RD067**	**NH(G)**	**42**	**18**	514	13RD067		Not Sampled	
515	13RD058	NH(M)	23	55	515	13RD058	PGP(M)	22	38
521	**13RD043**	**NS(G)**	**47**	**28**	521	13RD043	PGP(G)	41	44
522	**05RD002**	**NH(G)**	**42**	**15**	**522**	**05RD002**	**SRR(G)**	**37**	**33**
531	**13RD055**	**NS(G)**	**47**	**33**	**531**	**13RD055**	**PGP(G)**	**41**	**34**
539	**13RD048**	**NS(M)**	**35**	**9**	**539**	**13RD048**	**PGP(M)**	**22**	**10**
544	**13RD044**	**NH(G)**	**42**	**0**	544	13RD044		Not Sampled	
546	13RD064	LG(G)	42	52	546	13RD064		Not Sampled	
547	13RD091	NH(G)	42	45	547	13RD091	SRR(G)	37	43
549	**13RD057**	**NH(G)**	**42**	**0**	549	13RD057		Not Sampled	
550	13RD054	NH(M)	23	41	550	13RD054	SRR(M)	24	30
551	13RD052	NH(M)	23	30	**551**	**13RD052**	**SRR(M)**	**24**	**13**

[1] F-IBI Classes: Low Gradient Streams (LGS), Northern Headwaters (NH), Northern Rivers (NR), Northern Streams (NS), Southern Rivers (SR), Southern Streams (SS)
[2] M-IBI Class: Prairie Forest Rivers (PFR), Prairie Streams-Glide/Pool Habitats (PGP), Southern Streams-Riffle/Run Habitats (SRR)
[3] Tiered Aquatic Life Use (TALU) Framework Designation: General Use (G), Modified Use (M)

2.4 Assessments and impairments

The biological monitoring results for the TRW were formally assessed as part of the development of the *Two Rivers Watershed Monitoring and Assessment Report* (MPCA, 2016) to determine if individual stream reaches met applicable aquatic life standards. As shown in Table 4, 13 reaches were determined to be biologically impaired; these reaches are highlighted red. The relative location of these reaches is displayed in Figure 4.

Table 4. Assessment results for stream reaches with biological monitoring data in the TRW.

AUID suffix	Name	Description	Length (mi)	Biological impairment(s)
501	Two Rivers	M. Branch Two Rivers to N. Branch Two Rivers	21	None
502	South Branch Two Rivers	Lake Bronson to M. Branch Two Rivers	33	F-IBI, M-IBI
503	Middle Branch Two Rivers	County Ditch 23 to S. Branch Two Rivers	30	F-IBI, M-IBI
504	North Branch Two Rivers	Headwaters to County Ditch 22	38	F-IBI
505	South Branch Two Rivers	Lateral Ditch 2 to Lake Bronson	8	F-IBI, M-IBI
506	South Branch Two Rivers	Unnamed Ditch to Lateral Ditch 2 of State Ditch 95	2	F-IBI, M-IBI
507	South Branch Two Rivers	Headwaters to Lateral Ditch 2 of State Ditch 91	11	None
508	North Branch Two Rivers	County Ditch 22 to Two Rivers	22	F-IBI
509	Two Rivers	N. Branch Two Rivers to Red River of the North	7	None
514	State Ditch 84	Headwaters to N. Branch Two Rivers	17	F-IBI
515	Lateral Ditch 4 of State Ditch 91	Headwaters to Lateral Ditch 12 of State Ditch 91	14	None
521	Lateral Ditch 1 of State Ditch 95	Unnamed Ditch to State Ditch 95	1	F-IBI, M-IBI
522	County Ditch 4	Unnamed Ditch to Unnamed Ditch	2	F-IBI
531	State Ditch 72	Judicial Ditch 31 to State Ditch 85	1	F-IBI, M-IBI
539	Lateral Ditch 1 of State Ditch 95	Unnamed Ditch to State Ditch 50	12	F-IBI, M-IBI
544	State Ditch 49	Headwaters to S. Branch Two Rivers	5	F-IBI
546	State Ditch 90	Upper Twin Lake to S. Branch Two Rivers	2	None
547	State Ditch 85	Headwaters to N. Branch Two Rivers	7	None
549	Judicial Ditch 31	Unnamed Creek to N. Branch Two Rivers	2	F-IBI
550	Unnamed Ditch	110th Street to Lateral Ditch 12 of State Ditch 91	7	None
551	Unnamed Ditch	110th Street to Lateral Ditch 4 of State Ditch 91	7	None

In addition to the abovementioned biological impairments, four reaches in the TRW were included on the 2012 Impaired Waters List for a water quality impairment that affects aquatic life (Table 5).

Table 5. Water quality impairments (2012 Impaired Waters List) associated with reaches in the TRW.

AUID suffix	Name	Description	Water Quality impairment(s)
501	Two Rivers	M. Branch Two Rivers to N. Branch Two Rivers	Turbidity[1]
504	North Branch Two Rivers	Headwaters to County Ditch 22	Dissolved Oxygen
508	North Branch Two Rivers	County Ditch 22 to Two Rivers	Dissolved Oxygen, Turbidity[1]
509	Two Rivers	N. Branch Two Rivers to Red River of the North	Turbidity[1]

[1] The MPCA has since replaced the turbidity standard with a total suspended solids standard

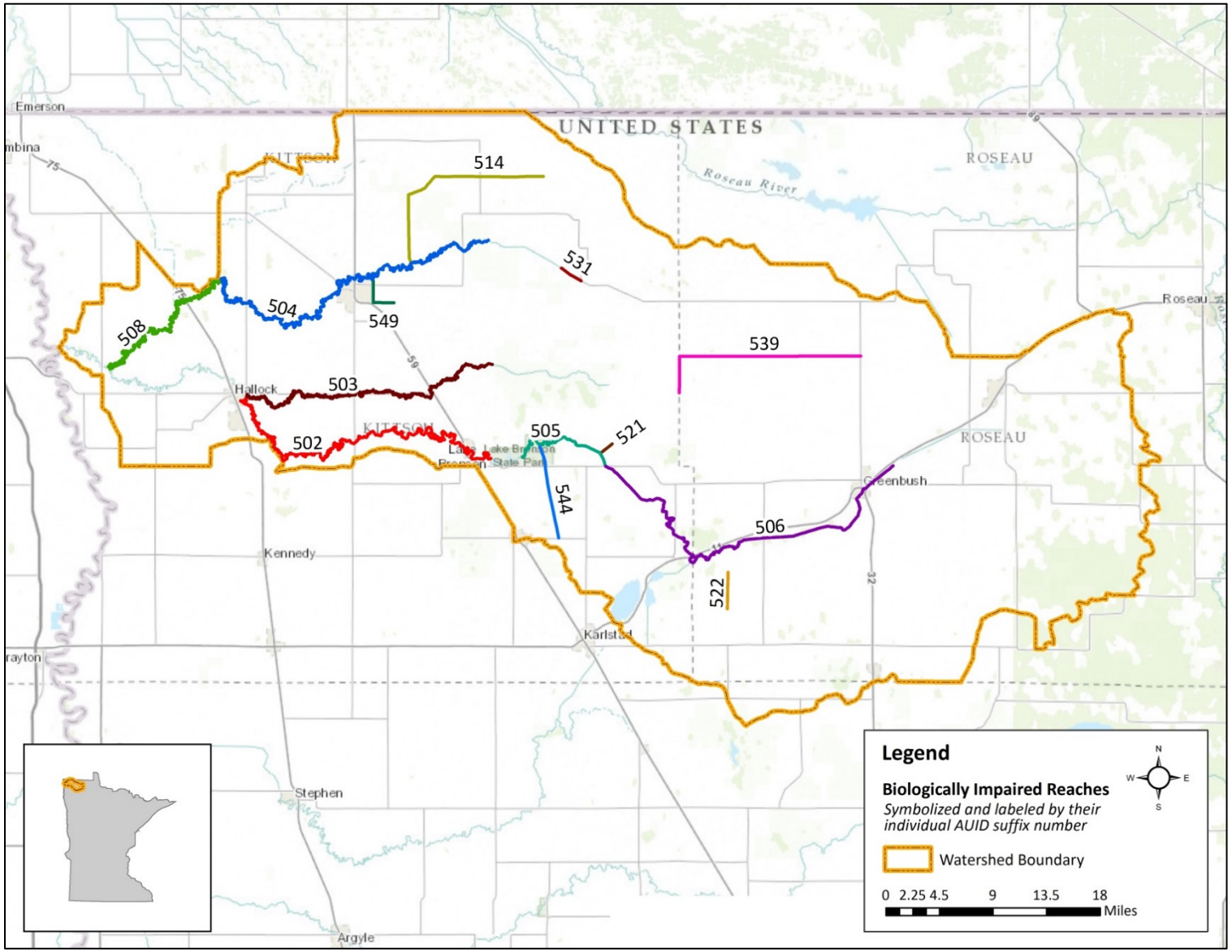


Figure 4. Map of the TRW and associated biologically impaired reaches.

Section 3: Stressor identification

3.1 Identification of candidate causes

A candidate cause is defined as a "hypothesized cause of an environmental impairment that is sufficiently credible to be analyzed" (EPA, 2012b). Identification of a set of candidate causes is an important early step in the SID process and provides the framework for gathering key data for causal analysis. Table 6 lists the nine common biotic stressors that were considered as potential candidate causes in the TRW. The list was developed based upon the results of other completed SID reports in the state. The credibility of each potential candidate cause as a stressor was then evaluated through a comprehensive review of available information for the watershed, including water quality and quantity data, as well as existing plans and reports, including the *Two Rivers Watershed Monitoring and Assessment Report* (MPCA, 2016), the *Overall Plan of the Two Rivers Watershed District* (TRWD, 2004), and the *Red River Basin Stream Survey Report: Two Rivers Watershed 2001* (Groshens et al., 2003). Based upon the results of this evaluation, five candidate causes were identified to undergo causal analysis (Section 3.3).

Table 6. Summary of common biotic stressors evaluated as potential candidate causes for the biologically impaired reaches of the TRW.

Stressor	Candidate cause identification	
	Summary of available information	Candidate cause (Yes/No)
Loss of longitudinal connectivity	Several of the biologically impaired reaches have connectivity barriers (e.g., dams and grade control structures) that are known obstructions to fish passage.	Yes
Flow regime instability	Many of the biologically impaired reaches are prone to high and quick peak flows, along with prolonged periods of very low discharge.	Yes
Insufficient physical habitat	Several of the biologically impaired reaches have insufficient instream habitat to support a healthy and diverse biotic community.	Yes
High suspended sediment	Several of the biologically impaired reaches have discrete total suspended solids values that exceed the applicable state standard (>30/65 mg/L).	Yes
Low dissolved oxygen	Several of the biologically impaired reaches have discrete dissolved oxygen values that are below the state standard (<5.0 mg/L). Two of the reaches have an existing dissolved oxygen impairment.	Yes
High nitrate-nitrite	Nitrate-nitrite concentrations associated with the biologically impaired reaches were generally well below the level expected to cause stress to aquatic biota (<10 mg/L).	No
Temperature regime alteration	Temperature values associated with the biologically impaired reaches were below the state standard (<30°C).	No
pH	Nearly all of the pH values associated with the biologically impaired reaches were within the state standard range (6.5-9.0).	No
Pesticide toxicity	There is no pesticide data for the biologically impaired reaches. As a result, there is insufficient information to declare pesticide toxicity as a candidate cause at this time.	No

3.2 Overview of candidate causes

3.2.1 Loss of longitudinal connectivity

Background

Connectivity in aquatic 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). Dams and other water control structures on river systems alter hydrologic (longitudinal) connectivity, often obstructing the movement of migratory fish and causing a change in the population and community structure (Brooker, 1981; Tiemann et al., 2004). These structures also alter stream flow, water temperature regime, and sediment transport processes; each of which can cause changes in fish and macroinvertebrate assemblages (Cummins, 1979; Waters, 1995). According to the DNR (2014), there are more than 1,200 dams in the state that serve a variety of purposes, including flood control, lake level control, wildlife habitat, and hydroelectric power generation. In addition to dams, culverts and beaver dams can also interfere with connectivity. A culvert that is raised (or perched) above the stream level can limit the ability of fish to migrate throughout the stream. A similar phenomenon can occur naturally with beaver dams acting as barriers to fish migration.

Applicable standards

There are no applicable standards for connectivity. However, the Two Rivers Watershed District (TRWD) and DNR have the permitting authority to require that road crossing structures be designed and installed to allow for fish passage.

3.2.2 Flow regime instability

Background

Flow is considered a "maestro" (Walker et al., 1995) or "master variable" (Power et al., 1995) that affects many fundamental characteristics of stream ecosystems, including biodiversity (Bunn and Arthington, 2002; Hart and Finelli, 1999; Poff et al., 1997). According to Poff and Zimmerman (2010), the flow regime of a stream is largely a function of climate (i.e., precipitation and temperature) and runoff-related controls (e.g., land cover and topography). The natural flow regime of most waterways in the Red River of the North Basin has been anthropogenically altered, primarily as a result of intensive agricultural drainage. Examples of drainage-related hydrologic alterations include ditching, channelization of natural streams, modification/cultivation of headwater streams, subsurface tiling, and wetland drainage. These practices are known to cause increased discharges following rain events and reduced base flows during dry periods (EOR, 2009; Franke and McClymonds, 1972; Miller, 1999; Mitsch and Gosselink, 2007; Moore and Larson, 1979; Verry, 1988).

Intense peak flows can directly result in the displacement of fish and macroinvertebrates downstream if they are unable to move into refuges, or if refuges are not available. The intensification of channel shear stresses associated with increased flows can cause the mobilization of sediment, woody debris, and plant materials, as well as increased channel scouring and bank destabilization. These effects often negatively impact instream habitat and turbidity. Diminished base flows result in decreased wetted width, cross sectional area, and water volume. Aquatic organisms require adequate living space, and when flows are reduced beyond normal baseflow, habitat can be scarce and the competition for resources increases. Additionally, low flow and lentic conditions can cause an increase in the concentration of pollutants, as well as result in a decrease in DO levels.

The United States Environmental Protection Agency's (EPA) Causal Analysis/Diagnosis Decision Information System (CADDIS) webpage contains a conceptual diagram of the sources and pathways for flow alteration as a candidate cause for impairment.

Applicable standards

There are limited standards for the protection of base flow. The DNR regulates the appropriation of water resources and may restrict the withdrawal of surface water when flows are below protected levels.

3.2.3 Insufficient physical habitat

Background

Physical habitat is primarily a function of channel geomorphology (Rosgen, 1996) and flow (Bovee, 1986). Geomorphology is determined naturally by geology and climate (Leopold et al., 1994), but may be altered directly by channelization and indirectly by land use changes affecting runoff and the removal of riparian vegetation (Aadland et al., 2005). A high frequency of bank-full flows often results in a subsequent increase in channel cross-sectional area (Verry, 2000) and a decrease in sinuosity (Verry and Dolloff, 2000). These geomorphic changes can result in reduced habitat quality and diversity, loss of interstitial space due to embeddedness, loss of pool depth due to sedimentation, and loss of cover (Aadland et al., 2005). Biotic population changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (EPA, 2012b).

The MPCA's Stream Habitat Assessment (MSHA) was used to evaluate the quality of habitat present at each of the biological monitoring stations in the TRW. The MSHA is comprised of five scoring subcategories, including land use, riparian zone, instream zone substrate, instream zone cover, and channel morphology, which are summed for a total possible score of 100 points.

The EPA's CADDIS webpage contains a conceptual diagram of the sources and pathways for physical habitat as a candidate cause for impairment.

Applicable standards

There are no applicable standards for physical habitat.

3.2.4 High suspended sediment

Background

Total suspended solids (TSS) is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water. Klimetz and Simon (2008) indicated that streams in the Red River of the North Basin had the highest median suspended sediment concentration of any region in Minnesota, with the exception of the Western Corn Belt Plains ecoregion (e.g., the Minnesota River Basin). Soil erosion from agricultural fields is believed to be the largest source of sediment to streams in the basin (Lauer et al., 2006). Modified headwater (i.e., first and second order) streams convey much of this sediment to receiving waters (EOR, 2009). The majority of the annual suspended sediment load associated with the streams in the basin is discharged between the months of March and May, when agricultural fields are particularly vulnerable to erosion (EOR, 2009).

According to Waters (1995), high suspended sediment can cause harm to fish and macroinvertebrates through two major pathways: 1) direct, physical effects (e.g., abrasion of gills and avoidance behavior) and 2) indirect effects (e.g., loss of visibility and increase in sediment oxygen demand). High suspended sediment can also reduce the penetration of sunlight and thus impede photosynthetic activity and limit primary production (Munavar et al., 1991; Murphy et al., 1981).

The EPA's CADDIS webpage contains a conceptual diagram of the sources and pathways for sediment as a candidate cause for impairment.

Applicable standards

The state TSS standard for waters in the Central River TSS Region is 30 milligrams per liter (mg/L). The state TSS standard for waters in the Southern River TSS Region is 65 mg/L. With the exception of AUIDs 505 and 506, which are located in the Central River TSS Region, all of the biologically impaired reaches in the TRW are in the Southern River TSS Region.

3.2.5 Low dissolved oxygen

Background

Dissolved oxygen (DO) refers to the concentration of oxygen gas within the water column. Oxygen diffuses into water from the atmosphere (turbulent flow enhances this diffusion) and from aquatic plants during photosynthesis. The concentration of DO changes 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. Low or highly fluctuating DO concentrations can cause adverse effects (e.g., avoidance behavior, reduced growth rate, and fatality) for many fish and macroinvertebrate species (Allan, 1995; Davis, 1975; Marcy, 2007; Nebeker et al., 1992; EPA, 2012b). Many species of fish avoid areas where DO concentrations are below 5.0 mg/L (Raleigh et al., 1986). According to Heiskary et al. (2010), DO flux of between 2.0 to 4.0 mg/L is typical in a 24-hour period.

Low DO can be an issue in streams with slow currents, excessive temperatures, high biological oxygen demand, and/or high groundwater seepage (Hansen, 1975). The critical conditions for DO usually occur during the late summer, when the water temperature is high and stream flow is low. Additionally, eutrophication (i.e., increased phosphorus) can cause excessive aquatic plant and algal growth, which can ultimately result in a decline in daily minimum DO concentrations and an increase in the magnitude of daily DO concentration fluctuations.

The EPA's CADDIS webpage contains a conceptual diagram of the sources and pathways for DO as a candidate cause for impairment.

Applicable standards

The state DO standard for Class 2B waters is 5.0 mg/L as a daily minimum; this includes all of the biologically impaired reaches in the TRW.

3.3 Causal analysis – profile of individual biologically impaired reaches

3.3.1 South Branch Two Rivers (AUID 502)

Physical setting

This reach represents the segment of the South Branch Two Rivers from Lake Bronson, to its confluence with the Middle Branch Two Rivers (Figure 5); a total length of 33 miles. The reach has a subwatershed area of 591 square miles (USGS, 2016). The subwatershed contains 365 miles of intermittent drainage ditch, 143 miles of intermittent stream, 71 miles of perennial drainage ditch, 49 miles of river (e.g., AUID 502), and three miles of perennial stream (DNR, 2003). According to the MPCA (2013), 81% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including two percent of AUID 502. The NLCD 2011 (USGS, 2011) lists cultivated crops (62%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (15%), forest (10%), hay/pasture (7%), and developed (5%).

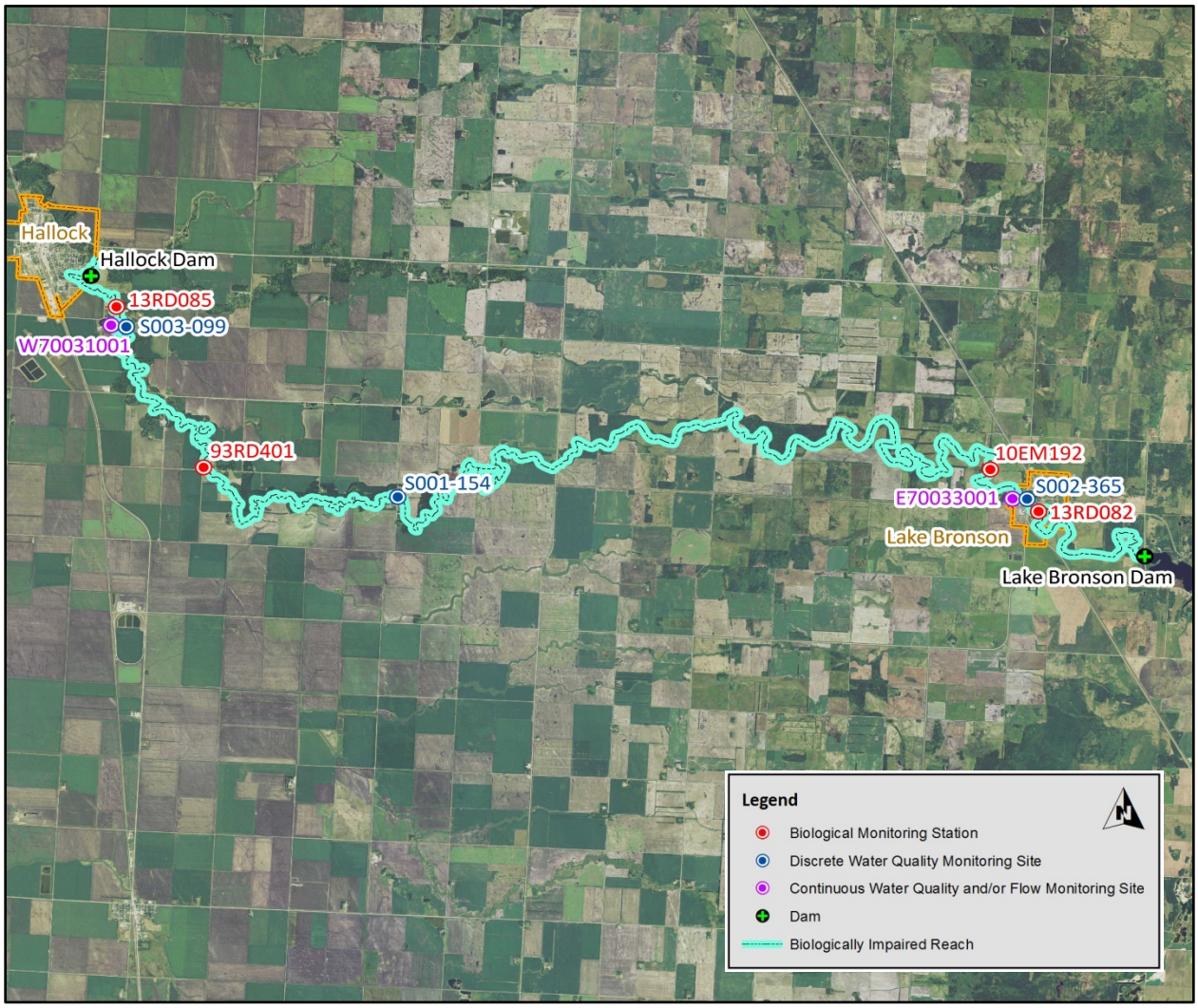


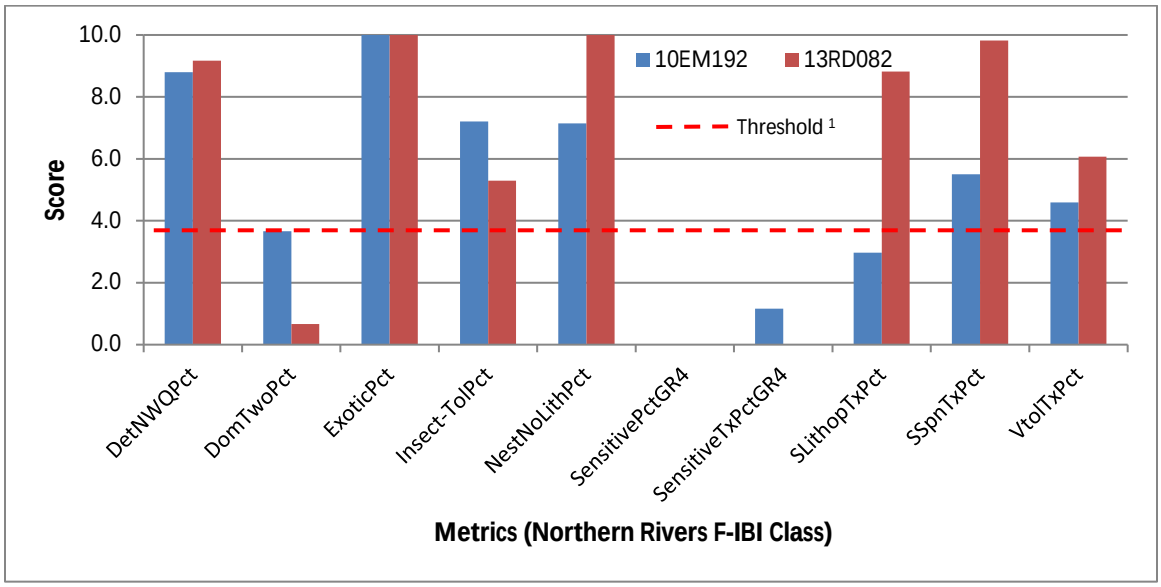
Figure 5. Map of AUID 502 and associated biological monitoring stations and flow/water quality monitoring sites (2013 National Agriculture Imagery Program (NAIP) aerial image).

Biological impairments

Fish (F-IBI)

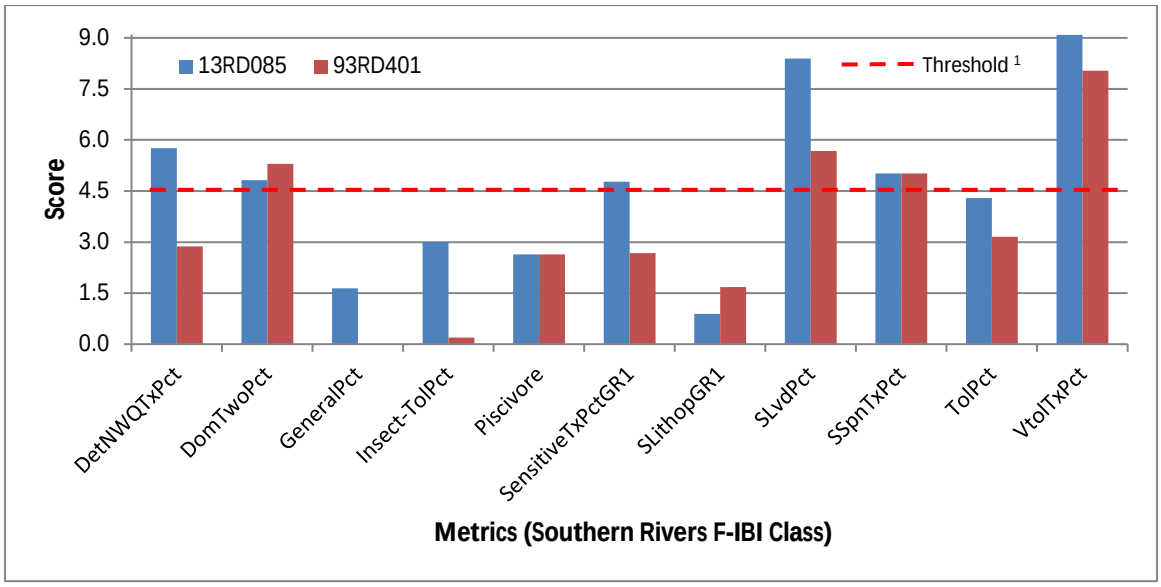
The fish community of AUID 502 was monitored at Station 10EM192 (1.1 mile downstream of the US Highway 59 crossing) on July 14, 2010; Station 13RD082 (0.2 mile upstream of the US Highway 59 crossing) on June 26, 2013; Station 13RD085 (0.3 mile downstream of the 250th Street crossing) on June 25, 2013; and Station 93RD401 (0.1 mile downstream of the 230th Street crossing) on July 10, 2013. The relative location of the stations is shown in Figure 5. Stations 10EM192 and 13RD082 were designated as General Use within the Northern Rivers F-IBI Class. The impairment threshold for these stations is an F-IBI score of 38. Stations 13RD085 and 93RD401 were designated as General Use within the Southern Rivers F-IBI Class. The impairment threshold for these stations is an F-IBI score of 49. Stations 10EM192 (F-IBI=51), 13RD082 (F-IBI=60), and 13RD085 (F-IBI=50) each scored above their respective impairment threshold, while Station 93RD401 (F-IBI=37) scored below its threshold. According to Figure 6, four individual metrics for Stations 10EM192 and/or 13RD082 scored below the mean value needed to meet the impairment threshold (i.e., DomTwoPct, SensitivePctGR4, SensitiveTxPctGR4, and SLithopTxPct). Additionally, seven individual metrics for Stations 13RD085 and/or 93RD401 (Figure 7) had such a substandard score (i.e., DetNWQTxPct, GeneralPct, Insect-TolPct, Piscivore, SensitiveTxPctGR1, SLithopGR1, and TolPct). A description of each metric is provided in the

Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams (MPCA, 2014a). Overall, the fish assemblage of the stations was dominated by tolerant taxa, specifically blacknose dace, blackside darter, common shiner, creek chub, and white sucker.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 6. Individual F-IBI metric scores for Stations 10EM192 and 13RD082 along AUID 502.



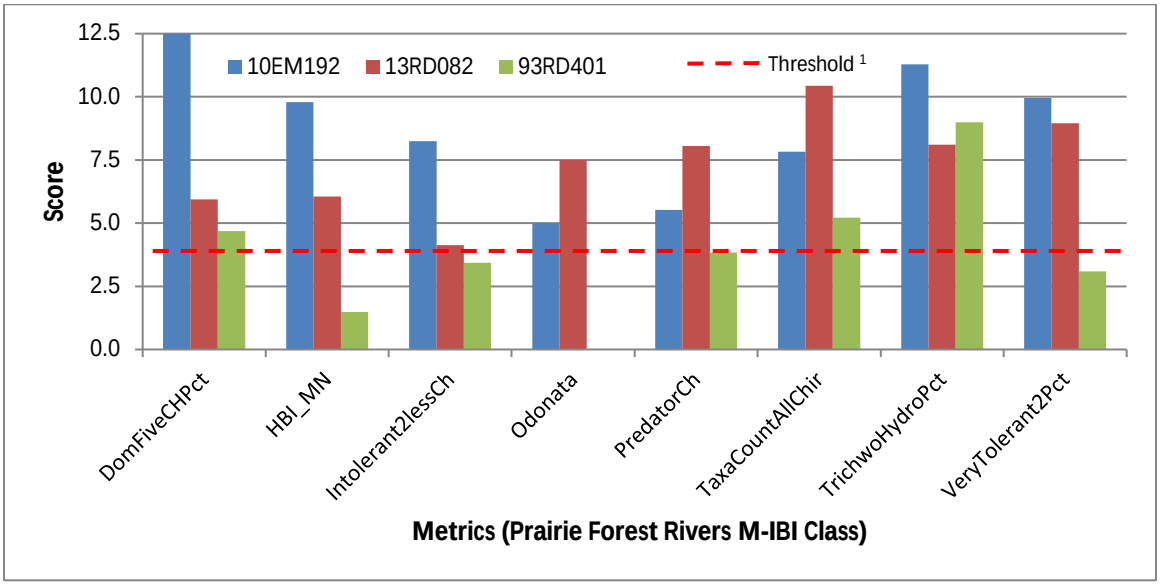
[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 7. Individual F-IBI metric scores for Stations 13RD085 and 93RD401 along AUID 502.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 502 was monitored at Station 10EM192 on September 1, 2010; Station 13RD082 on July 30, 2013; and Station 93RD401 on July 31, 2013. The stations were designated as General Use within the Prairie Forest Rivers M-IBI Class. Accordingly, the impairment threshold for the stations is an M-IBI score of 31. Stations 10EM192 (M-IBI=70), 13RD082 (M-IBI=59), and 93RD401 (M-IBI=31) each scored at or above the impairment threshold. However, the reach was determined to be impaired due to a high proportion of tolerant taxa, including *Hyalella* (amphipods),

Polypedilum (midges), and *Simulium* (black flies). According to Figure 8, five individual metrics for Stations 10EM192, 13RD082, and/or 93RD401 scored below the mean value needed to meet the impairment threshold (i.e., HBI_MN, Intolerant2lessCh, Odonata, PredatorCh, and VeryTolerant2Pct). A description of each metric is provided in the *Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014b).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 8. Individual M-IBI metric scores for Stations 10EM192, 13RD082, and 93RD401 along AUID 502.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 10EM192, 13RD082, 13RD085, and 93RD401 along AUID 502. According to the DNR (2014), there are two dams along the reach: the Lake Bronson Dam and the Hallock Dam. The Lake Bronson Dam (Figure 9) is a 36-foot-high concrete structure located at the upstream end of the reach, within Lake Bronson State Park. The dam is owned by the DNR and was completed in 1937 to create a reservoir for water supply and recreation purposes. However, the reservoir is no longer used as a water supply. The dam is a complete barrier to connectivity at all flow conditions. The Hallock Dam (Figure 9) is an 11-foot-high concrete structure situated near the downstream end of the reach. The dam is owned by the city of Hallock and was completed in 1938 to provide a water source for the community. However, the City has since been connected to the North Kittson Rural Water System and no longer draws water from the river. The dam has an associated pool and is a near complete barrier to connectivity (Aadland, 2015); fish passage may be possible during extremely high flow conditions. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo.

Figure 9. Photos of connectivity barriers along AUID 502, including the Lake Bronson Dam on September 23, 2015 (left) and the Hallock Dam on August 12, 2015 (right).

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 502 is provided by the following metric response (Appendix A):

- Below basin class average (<45/30%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 10EM192 (1%), 13RD082 (4%), 13RD085 (11%), and 93RD401 (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. According to Table 6, the collective fish assemblage of the stations sampled downstream of the Hallock Dam, which has unimpeded connectivity to the Red River of the North, included 17 species that were not sampled upstream of the dam. Many of these species were large bodied, longer-lived species that are vulnerable to extirpation by dams (e.g., channel catfish and sauger).

Table 7. Summary of fish species sampled downstream of the Hallock Dam along the Two Rivers (AUID 509) and the Middle Branch Two Rivers (AUID 501), as well as those species also sampled upstream of the Hallock Dam along the South Branch Two Rivers (AUID 502).

Fish species[1]	Present downstream of the Hallock Dam[2]	Present upstream of the Hallock Dam[3]
bigmouth buffalo	**X**	
bigmouth shiner	X	
black bullhead	X	
blackside darter	X	X
burbot	X	X
channel catfish	**X**	
common carp	X	
creek chub	X	X
emerald shiner	**X**	
fathead minnow	X	X
freshwater drum	**X**	
golden redhorse	X	X
goldeye	**X**	
johnny darter	X	X
mooneye	**X**	
northern pike	X	X
northern redbelly dace	X	
quillback	**X**	
river shiner	**X**	
rock bass	X	X
sand shiner	X	X
sauger	**X**	
shorthead redhorse	X	X
silver chub	**X**	
silver redhorse	**X**	
spotfin shiner	X	X
stonecat	X	X
tadpole madtom	X	X
trout-perch	X	
walleye	X	X
white bass	**X**	
white sucker	X	X
yellow perch	X	X

[1] Species highlighted red are those designated by Aadland (2015) as "vulnerable" and "most vulnerable" to extirpation by barrier dams.

[2] Stations 13RD056 and 13RD084 along AUID 501, as well as Station 05RD004 along AUID 509

[3] Stations 93RD401, 10EM192, 13RD082, and 13RD085 along AUID 502

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 502. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to the TRWD (2004), the reach has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge. The MPCA biological monitoring staff encountered minimal flow during an August 29, 2012, reconnaissance visit and a July 10, 2013, fish monitoring visit at Station 93RD401 (Figure 10). The USGS and DNR have conducted extensive continuous flow monitoring at Site E70033001 (US Highway 59 crossing) in Lake Bronson since 1928; the relative location of the site is shown in Figure 5. The highest mean daily peak flow recorded at the site was 5,290.0 cubic feet per second (cfs), while the lowest flow was 0.0 cfs. Approximately 10% of the total mean daily flow values were less than 1.0 cfs. Table 8 presents the percentile flow values for the site from 1928 to 1981 and from 1985 to 2015; the break in the data set is due to an extended gap in the flow record. The data shows the extreme variability in flow values for the site. Additionally, the data for the most recent period of record (1985-2015) indicate that flow values for the site have become more extreme, as there is a noticeable decrease in low flow (5^{th} and 10^{th} percentiles) values, as well as a substantial increase in higher flow (60^{th} and 80^{th} percentiles) values. Additionally, the TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 3 and 4% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, August 26, 2015, and September 23, 2015) and documented flow conditions. Staff observed no flow out of the Lake Bronson Dam on September 23, 2015. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

Table 8. Percentile flow values for Site E70033001 along AUID 502 from 1928 to 1981 and from 1985 to 2015.

Date range	*n*	Percentile values – Mean daily discharge (cfs)						
		5^{th}	10^{th}	20^{th}	40^{th}	60^{th}	80^{th}	100^{th}
1928-1981	15500	0.7	1.1	1.8	3.2	6.5	40.0	5290.0
1985-2015	11006	0.4	0.7	2.6	8.0	22.0	131.0	4210.0

Figure 10. Photos of low flow conditions at Station 93RD401 along AUID 502 on August 29, 2012 (left) and July 10, 2013 (right).

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 502 is provided by the following metric responses (Appendix A):

- Above basin class average (>54%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 10EM192 (60%) and 13RD082 (72%)
- Above basin class average (>26/24%) relative abundance of taxa that are generalists (GeneralTxPct) at Stations 10EM192 (31%), 13RD082 (36%), 13RD085 (33%), and 93RD401 (42%)
- Above basin class average (>47/58%) relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct) at Stations 10EM192 (95%), 13RD082 (91%), 13RD085 (62%), and 93RD401 (84%)
- Below basin class average (<0.37/0.65) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 10EM192 (0.34), 13RD082 (0.46), and 13RD085 (0.08)
- Above basin class average (>7/11%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 10EM192 (19%), 13RD085 (8%), and 93RD401 (25%)
- Below basin class average (<22%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Stations 10EM192 (19%) and 13RD082 (9%)
- Above basin class average (>10/13%) relative abundance of individuals that are short-lived (SLvdPct) at Stations 10EM192 (18%) and 93RD401 (23%)
- Above basin class average (>25/23%) relative abundance of individuals that are tolerant (TolPct) at Stations 10EM192 (33%), 13RD085 (46%), and 93RD401 (56%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

Evidence of a causal relationship between flow regime instability and the M-IBI impairment associated with AUID 502 is provided by the following metric responses (Appendix B):

- Above basin class average (>59%) relative abundance of the dominant five taxa in a subsample, chironomid genera treated individually (DomFiveCHPct) at Stations 13RD082 (63%) and 93RD401 (67%)
- Below basin class average (<6%) relative abundance of long-lived individuals (LongLivedPct) at Station 10EM192 (2%)

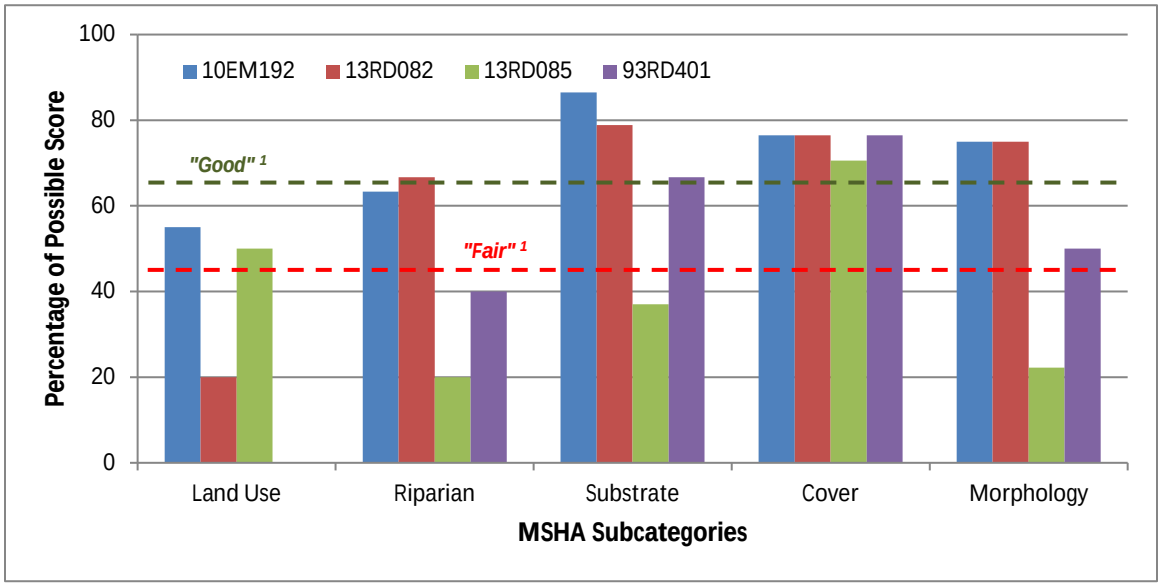
Flow regime alteration tends to limit macroinvertebrate diversity and favor taxa that are shorter-lived and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012b).

Insufficient physical habitat

Available data

The physical habitat of AUID 502 was evaluated at Stations 10EM192, 13RD082, 13RD085, and 93RD401 using the MSHA. All of the stations are located along natural segments of the reach (MPCA, 2013). Stations 10EM192 (76/"good") and 13RD082 (72/"good"), which are located along the upstream extent of the reach, scored substantially higher than Stations 93RD401 (55/"fair") and 13RD085 (36/"poor"), which are situated near the downstream end of the reach. Figure 11 displays the MSHA subcategory results for the stations. Stations 13RD082 and 93RD401 scored substantially lower in the land use subcategory than the other stations due to the predominance of agricultural row crops in the vicinity of

the stations. While the stations had a "moderate" to "wide" riparian zone width, substantial bank erosion was noted at Stations 13RD085 and 93RD401. Station 13RD085 had the lowest score in the substrate subcategory due to the absence of coarse substrate (e.g., cobble and gravel) and riffle habitat. The other stations offered both coarse substrate, with only "light" embeddedness, and riffle habitat. The stations scored uniformly well in the cover subcategory due to the diversity and "moderate" amount of cover present. Common cover types noted along the reach included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, rootwads, undercut banks, and woody debris. Lastly, Stations 13RD085 and 93RD401 scored lower in the morphology subcategory than the other stations due to "low" channel stability and "fair" channel development. Overall, the MSHA data suggest that the physical habitat of downstream extent of the reach is limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 11. MSHA subcategory results for Stations 10EM192, 13RD082, 13RD085, and 93RD401 along AUID 502.

On October 27, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 13RD085 along AUID 502 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 13RD085] on 10/27/15 was 88, which is good (stable) for a C5 stream type. A good, or stable, rating for C5 stream types ranges from 70-90. Almost all Pfankuch categories ranked as good or fair, with only bank rock content, rock angularity, and aquatic vegetation ranking as poor. The upper banks at this site were well vegetated, primarily with grasses and forbs, but there were also scattered mature trees. There was some evidence of mass erosion in the upper banks, and although most was healed over, some raw banks were still present. The lower banks were also well vegetated, primarily with grasses, sedges, and scattered willow saplings and brush. The lower banks showed some signs of cutting and deposition, but generally ranked as good or fair. The channel capacity overall ranked as good, but in some locations through the reach it appeared the channel was slightly incised. The substrate at this site was mostly sand with some silt mixed in, but it was well packed and appeared stable without excess scour or deposition."*

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 502 is provided by the following metric responses (Appendix A):

- Below basin class average (<24/29%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Stations 10EM192 (19%), 13RD082 (18%), 13RD085 (17%), and 93RD401 (17%)
- Below basin class average (<18/23%) relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPcT) at Stations 10EM192 (13%), 13RD082 (9%), 13RD085 (17%), and 93RD401 (17%)
- Above basin class average (>37%) relative abundance of individuals that are detritivorous (DetNWQPct) at Stations 13RD085 (57%) and 93RD401 (38%)
- Above basin class average (>26/18%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 10EM192 (19%) and 93RD401 (33%)
- Below basin class average (<11%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 10EM192 (4%) and 13RD082 (0%)
- Below basin class average (<47/45%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Stations 10EM192 (25%), 13RD082 (27%), 13RD085 (25%), and 93RD401 (25%)
- Below basin class average (<12/18%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Stations 10EM192 (13%), 13RD082 (9%), and 93RD401 (8%)
- Below basin class average (<5/6) taxa richness of simple lithophilic spawning species (SLithop) at Stations 10EM192 (5), 13RD082 (5), and 13RD085 (4)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

Biotic response – macroinvertebrate

Evidence of a causal relationship between insufficient physical habitat and the M-IBI impairment associated with AUID 502 is provided by the following metric responses (Appendix B):

- Below basin class average (<6) taxa richness of climbers (ClimberCh) at Station 93RD401 (2)
- Above basin class average (>19%) relative abundance of sprawler taxa (SprawlerChTxPct) at Stations 10EM192 (23%), 13RD082 (20%), and 93RD401 (25%)

Climber taxa require plants or debris habitat to climb, while sprawler macroinvertebrates are tolerant of degraded benthic habitat.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Stations 10EM192, 13RD082, 13RD085, and 93RD401 along AUID 502 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The stations had TSS concentrations ranging from 4 to 12 mg/L. Table 9 summarizes all available discrete TSS data for Sites S001-154 (280th Avenue crossing) and S002-365 (US Highway 59 crossing); the relative location of these sites is shown in Figure 5. The site had no exceedances of the 65 mg/L Southern River TSS Region standard. Additionally, the

TRW HSPF model estimates that the reach had a TSS concentration in excess of the standard 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Table 9. Discrete TSS data for Sites S001-154 and S002-365 along AUID 502.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S001-154	1987-1989	12	1	64	8	0
S002-365	1991-2014	75	1	46	6	0

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 502. None of the metrics or related data for Stations 10EM192, 13RD082, 13RD085, and 93RD401 (Appendix A) exhibited a correlation to this candidate cause.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 502 is provided by the following metric and data responses (Appendix B):

- Below basin class average (<15%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Station 93RD401 (4%)
- Above basin class average (>50%) relative abundance of high TSS tolerant individuals at Station 93RD401 (56%)
- Below basin class average (<4) taxa richness of high TSS intolerant macroinvertebrates at Station 93RD401 (3)

Collector-filterers utilize specialized mechanisms (e.g., silk nets) to strain organic material from the water column. High suspended sediment can interfere with these mechanisms (Arruda et al., 1983; Barbour et al., 1999; Lemley, 1982; Strand and Merritt, 1997).

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a combined six discrete DO measurements at Stations 10EM192, 13RD082, 13RD085, and 93RD401 along AUID 502 at the time of fish and/or macroinvertebrate monitoring. Measurement values ranged from 7.5 to 11.8 mg/L. Figure 12 displays all available discrete DO data for Sites S001-154 (1987-1989; *n*=12), S002-365 (1991-2014; *n*=131), and S003-099 (250th Street crossing; 2003-2014; *n*=18); the relative location of these sites is shown in Figure 5. Collectively, less than 1% of the DO values for the sites were below the 5.0 mg/L standard; however, only 10 of the DO measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of June, July, August, and September. The MPCA conducted continuous DO monitoring at Site W70031001 (250th Street crossing) from August 12, 2015, to August 24, 2015; the relative location of the site is shown in Figure 5. The monitoring results are provided in Table 10, as well as displayed in Figure 13. None of the DO measurements within the monitoring period were below the standard. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard between 1 and 4% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of low DO.

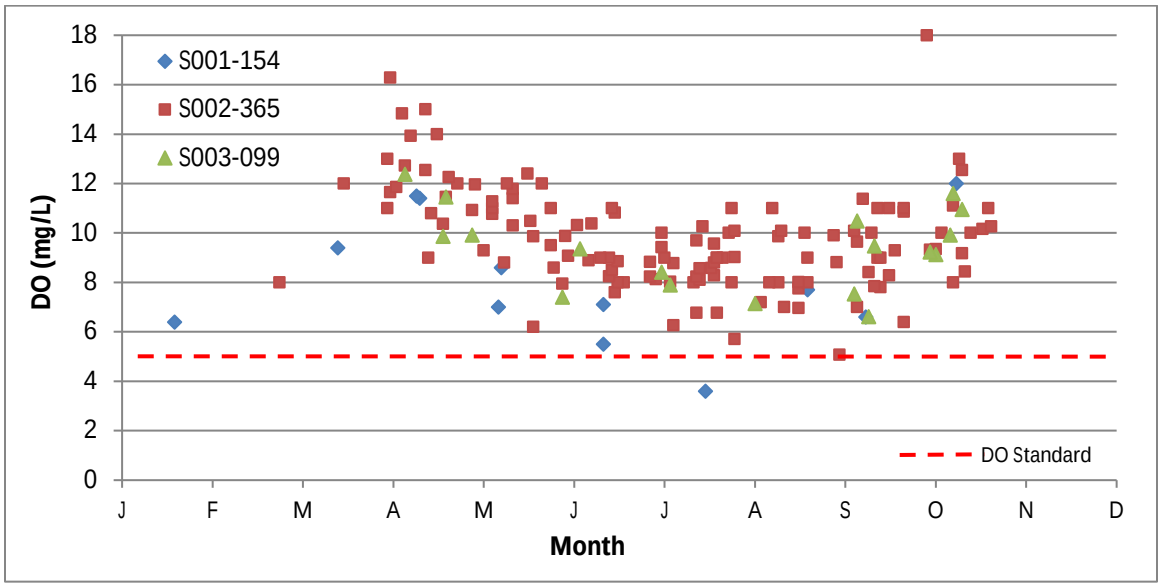


Figure 12. Discrete DO data for Sites S001-154, S002-365, and S003-099 along AUID 502.

Table 10. Continuous DO data for Site W70031001 along AUID 502.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 12, 2015 – August 24, 2015	1107	6.2	9.5	0	0	1.9

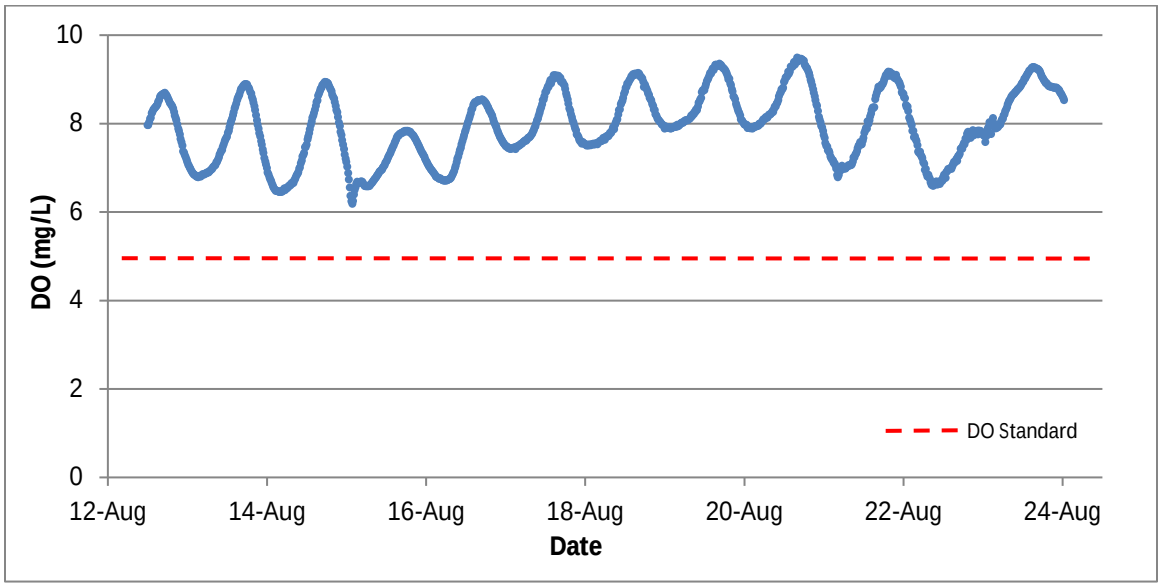


Figure 13. Continuous DO data for Site W70031001 along AUID 502.

Eutrophication-related data for AUID 502 is limited to the following parameters: total phosphorus (TP) and DO flux. Discrete TP data are available for Sites S001-154 (1987-1989; n=12) and S002-365 (1991-2014; n=76). Collectively, the mean TP concentration for the sites was 120 micrograms per liter (µg/L), while the highest concentration was 580 µg/L and the lowest concentration was 5 µg/L. Approximately 28% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. The mean daily DO

flux documented during continuous DO monitoring at Site W70031001 (Table 10) was 1.9 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., August 12, 2015, August 26, 2015, and September 23, 2015). Overall, the limited available data does not suggest that eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 502 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<0.37/0.65) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 10EM192 (0.34), 13RD082 (0.46), and 13RD085 (0.08)
- Below basin class average (<22%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Stations 10EM192 (19%) and 13RD082 (9%)
- Above basin class average (>23/22%) relative abundance of taxa that are tolerant (TolTxPct) at Stations 10EM192 (44%), 13RD082 (36%), 13RD085 (25%), and 93RD401 (42%)
- Below basin class average (<7.4/7.3 mg/L) mean DO Tolerance Indicator Value (TIV) at Stations 10EM192 (7.1 mg/L), 13RD082 (7.1 mg/L), 13RD085 (7.3 mg/L), and 93RD401 (7.3 mg/L)
- Below basin class average (<72%) probability of meeting the DO standard at Stations 10EM192 (51%), 13RD082 (51%), 13RD085 (60%), and 93RD401 (60%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 502 is provided by the following metric and data responses (Appendix B):

- Above basin class average (>7) Hilsenhoff's Biotic Index value (HBI_MN) at Station 93RD401 (8)
- Below basin class average (<12) taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET) at Station 93RD401 (10)
- Below basin class average (<7.0 mg/L) mean DO TIV at Station 13RD082 (6.9 mg/L)
- Above basin class average (>12%) relative abundance of low DO tolerant individuals at Station 13RD082 (30%)

Low DO often limits the taxa richness of macroinvertebrates, particularly members of the orders Plecoptera, Odonata, Ephemeroptera, and Trichoptera, and favors taxa that are tolerant (Weber, 1973; EPA, 2012b).

Strength-of-evidence analysis

Table 11 presents a summary of the SOE scores for the candidate causes associated with AUID 502. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, and insufficient physical habitat. Additionally, the evidence indicates that the M-IBI impairment is likely the result of flow regime instability and insufficient physical habitat marginally affecting the community. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 11. SOE scores for candidate causes associated with AUID 502.

Types of evidence	SOE scores per candidate cause[1]									
	Loss of longitudinal connectivity		Flow regime instability		Insufficient physical habitat		High suspended sediment		Low dissolved oxygen	
	Biological impairments									
	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI
Types of evidence that use data from the case										
Spatial/temporal co-occurrence	+++	--	++	+	++	+	0	0	0	0
Temporal sequence	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response relationship	+++	--	++	+	++	+	0	0	0	0
Causal pathway	+++	--	++	+	++	+	0	0	0	0
Evidence of exposure/bio-mechanism	+++	--	++	+	++	+	0	0	0	0
Manipulation of exposure	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Symptoms	+++	--	++	+	++	+	0	0	0	0
Types of evidence that use data from elsewhere										
Mechanistically plausible cause	+	-	+	+	+	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response in field studies	++	NE	++	++	++	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Multiple lines of evidence										
Consistency of evidence	**+++**	**--**	**++**	**+**	**++**	**+**	**0**	**0**	**0**	**0**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.2 Middle Branch Two Rivers (AUID 503)

Physical setting

This reach represents the Middle Branch Two Rivers (Figure 14), which extends from County Ditch (CD) 23, to its confluence with the South Branch Two Rivers; a total length of 30 miles. The reach has a subwatershed area of 78 square miles (USGS, 2016). The subwatershed contains 32 miles of river, 27 miles of intermittent stream, 17 miles of intermittent drainage ditch, 12 miles of perennial drainage ditch, and one mile of perennial stream (DNR, 2003). According to the MPCA (2013), 51% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 13% of AUID 503. The NLCD 2011 (USGS, 2011) lists cultivated crops (56%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (22%), forest (14%), developed (4%), and hay/pasture (3%).

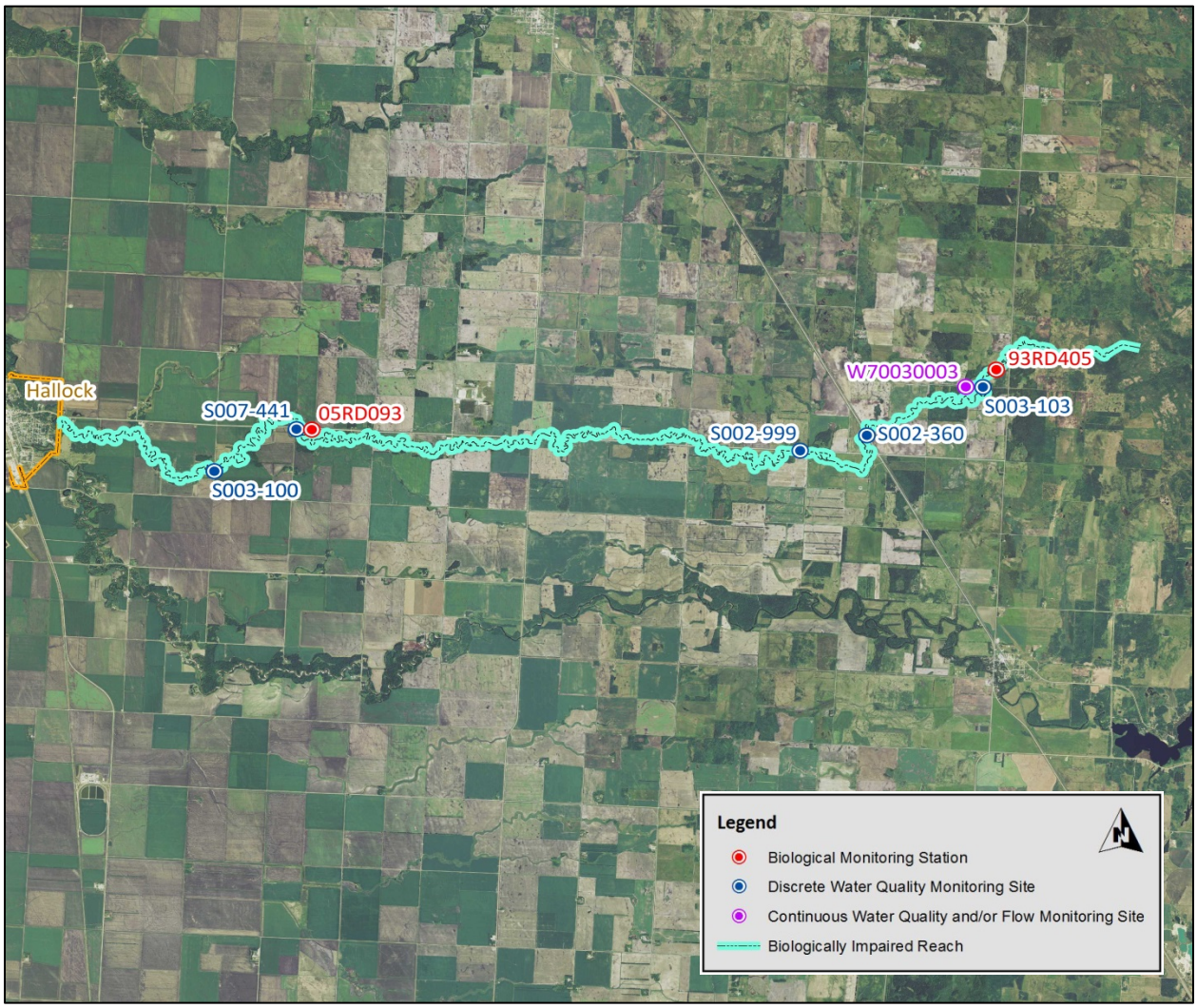
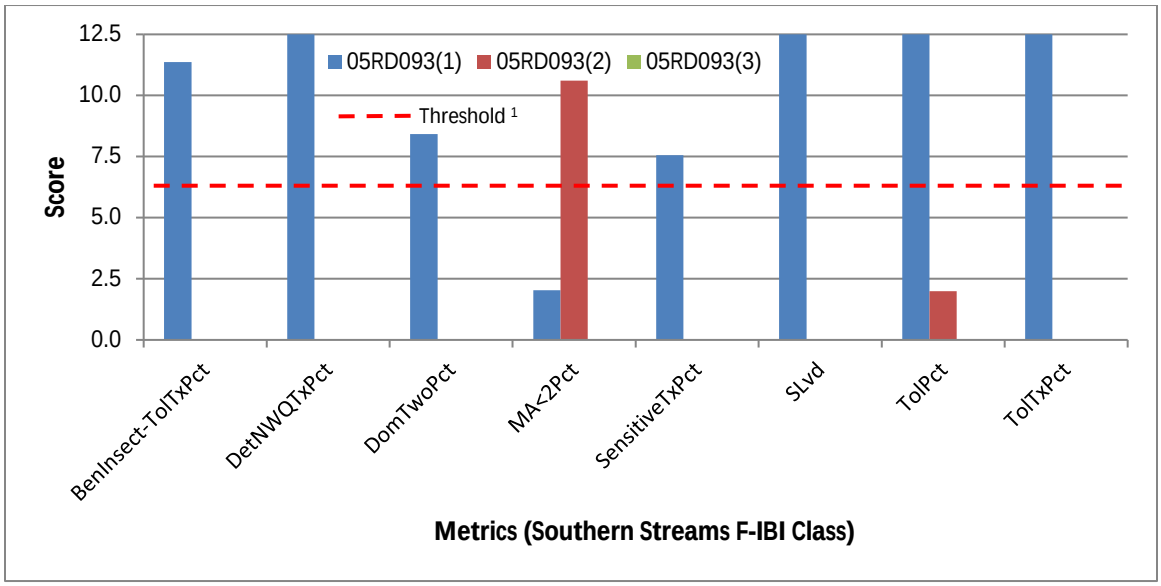


Figure 14. Map of AUID 503 and associated biological monitoring stations and water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

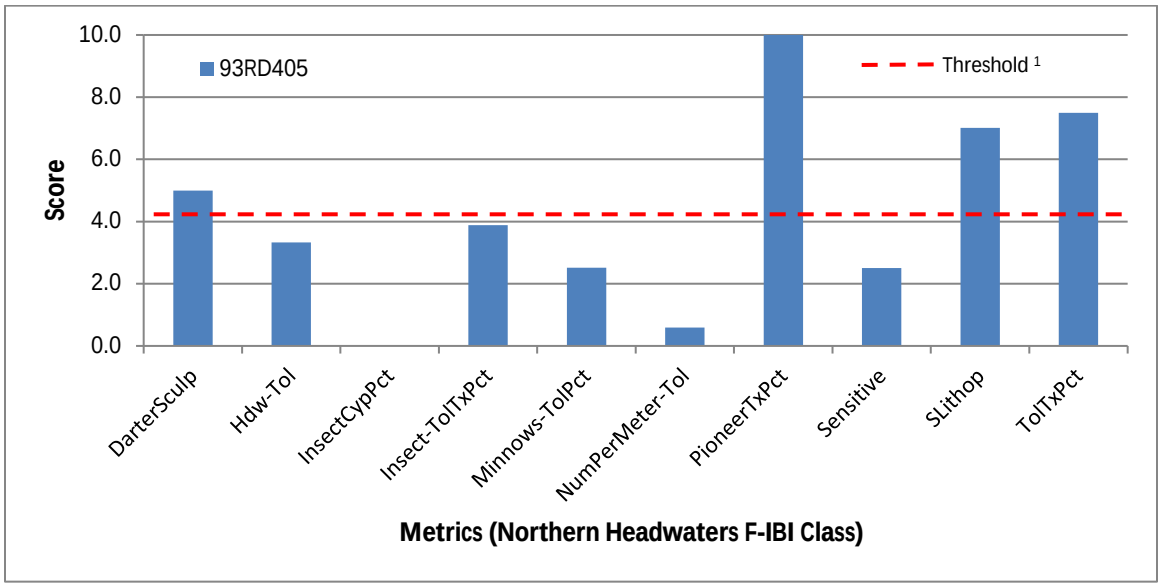
Fish (F-IBI)

The fish community of AUID 503 was monitored at Station 05RD093 (0.1 mile upstream of the State Highway 175 crossing) on July 24, 2006(1), July 16, 2013(2), and June 11, 2014(3); and Station 93RD405 (0.5 mile downstream of the County State Aid Highway (CSAH) 15 crossing) on July 2, 2013. The relative location of the stations is shown in Figure 14. Station 05RD093 was designated as General Use within the Southern Streams F-IBI Class. The impairment threshold for the station is an F-IBI score of 50. Station 93RD405 was designated as General Use within the Northern Headwaters F-IBI Class. The impairment threshold for the station is an F-IBI score of 42. Station 05RD093 (F-IBI=79, 13, and 0) had two scores that were below its respective impairment threshold, while Station 93RD405 (F-IBI=42) scored at its threshold. According to Figure 15, Station 05RD093 had multiple scores for each individual metric that were below the mean value needed to meet the impairment threshold. Additionally, six individual metrics for Station 93RD405 (Figure 16) had such a substandard score (i.e., Hdw-Tol, InsectCypPct, Insect-TolTxPct, Minnows-TolPct, NumPerMeter-Tol, and Sensitive). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the stations was dominated by tolerant taxa, specifically blackside darter, common shiner, creek chub, and white sucker.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 15. Individual F-IBI metric scores for Station 05RD093 along AUID 503.

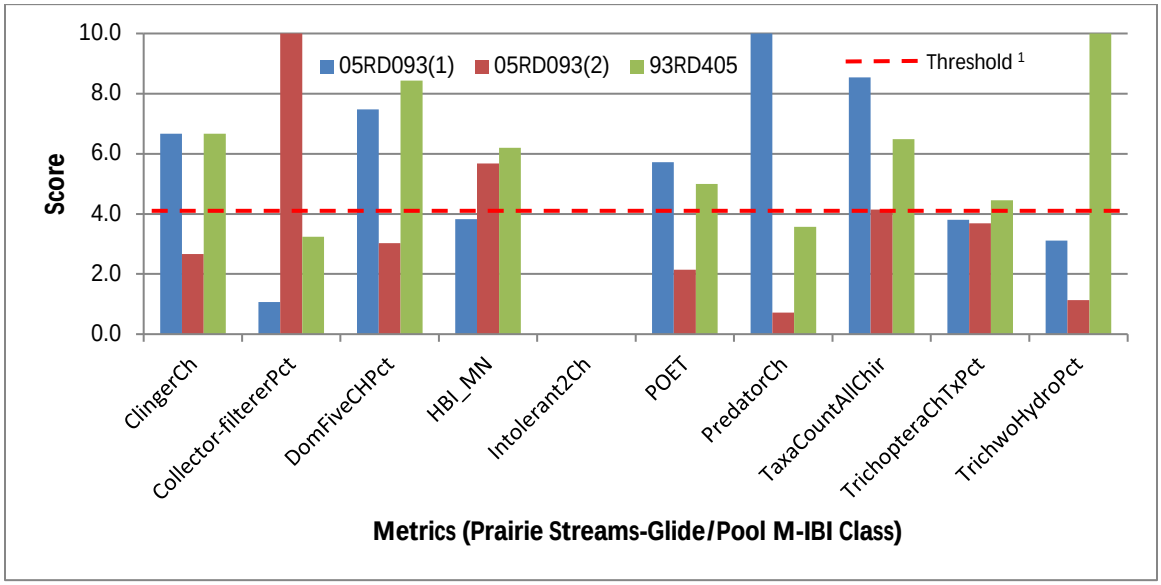


[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 16. Individual F-IBI metric scores for Station 93RD405 along AUID 503.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 503 was monitored at Station 05RD093 on August 30, 2005(1) and July 31, 2013(2); and Station 93RD405 on July 30, 2013. Both stations were designated as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the impairment threshold for the stations is an M-IBI score of 41. Station 05RD093 (M-IBI=50 and 33) had one score that was below its respective impairment threshold, while Station 93RD405 (M-IBI=54) scored above its threshold. According to Figure 17, nine individual metrics for Stations 05RD093 and/or 93RD405 scored below the mean value needed to meet the impairment threshold (i.e., ClingerCh, Collector-filtererPct, DomFiveCHPct, HBI_MN, Intolerant2Ch, POET, PredatorCh, TrichopteraChTxPct, and TrichwoHydroPct). A description of each metric is provided in the *Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014b). The macroinvertebrate assemblage of the stations was dominated by tolerant taxa, specifically, *Hydroptila* (caddisflies), *Simulium* (black flies), *Physa* (snails), and *Polypedilum* (midges).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 17. Individual M-IBI metric scores for Stations 05RD093 and 93RD405 along AUID 503.

Candidate causes

Loss of longitudinal connectivity

Available data

According to local water resource professionals in the TRW, beaver dams are common along the reach (MPCA, 2015). The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 05RD093 and 93RD405 along AUID 503. According to the DNR (2014), there are no man-made dams on the reach or between the reach and the Red River of the North. In October 2014, MPCA monitoring staff noted a beaver dam along the reach immediately upstream of the 260th Avenue crossing. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. A beaver dam (Figure 18) was again documented immediately upstream of the 260th Avenue crossing. The dam had been breached and did not appear to be interfering with connectivity at the time of discovery. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. Staff identified a beaver dam (Figure 18) immediately upstream of the last State Highway 175 crossing. The dam had an associated pool and appeared to be a complete barrier to connectivity at the time of the photo. Also, staff noted two private road crossings (Figure 18) immediately upstream of the city of Hallock. Both crossing appear to have a severely undersized culvert that is likely altering stream flow and potentially limiting connectivity.

Figure 18. Photos of connectivity barriers along AUID 503, including a beaver dam immediately upstream of the 260th Avenue crossing on September 23, 2015 (upper left); a beaver dam immediately upstream of the last State Highway 175 crossing on September 1, 2013, courtesy of Google Earth (upper right); and private road crossings immediately upstream of the city of Hallock on September 1, 2013, courtesy of Google Earth (lower left and lower right).

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 503 is provided by the following metric response (Appendix A):

- Below basin class average (<5/1%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 05RD093(2) (0%) and 93RD405 (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history.

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 503. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to the TRWD (2004), the reach has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge. Overflow from the Roseau River Watershed often exacerbates this condition (TRWD, 2004). The MPCA biological monitoring staff encountered minimal flow or lentic conditions at Station 05RD093 during the July 24, 2006, fish monitoring visit, the July 31, 2013, macroinvertebrate monitoring visit, and an August 12, 2015, reconnaissance visit (Figure 19). Lentic conditions were also noted at Station 93RD405 during the July 30, 2013, macroinvertebrate monitoring visit (Figure 19). The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 32 and 51% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, August 26, 2015, and September 23, 2015) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

Figure 19. Photos of lentic conditions along AUID 503, including Station 05RD093 on August 12, 2015 (left) and Station 93RD405 on July 30, 2013 (right).

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 503 is provided by the following metric responses (Appendix A):

- Above basin class average (>71/67%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 05RD093(2) (78%), 05RD093(3) (73%), and 93RD405 (87%)
- Above basin class average (>44%) relative abundance of taxa that are generalists (GeneralTxPct) at Station 05RD093(2) (60%)
- Above basin class average (>73%) relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct) at Stations 05RD093(1) (87%) and 05RD093(3) (91%)
- Below basin class average (<0.37/0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 05RD093(2) (0.08), 05RD093(3) (0.02), and 93RD405 (0.11)
- Below basin class average (<9/23%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Stations 05RD093(2) (0%), 05RD093(3) (0%), and 93RD405 (17%)
- Above basin class average (>62/66%) relative abundance of individuals that are tolerant (TolPct) at Stations 05RD093(2) (68%), 05RD093(3) (64%), and 93RD405 (87%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

Evidence of a causal relationship between flow regime instability and the M-IBI impairment associated with AUID 503 is provided by the following metric responses (Appendix B):

- Above basin class average (>70%) relative abundance of the dominant five taxa in a subsample, chironomid genera treated individually (DomFiveCHPct) at Stations 05RD093(2) (76%)
- Below basin class average (<4%) relative abundance of long-lived individuals (LongLivedPct) at Stations 05RD093(2) (0%) and 93RD405 (0%)
- Above basin class average (>13%) relative abundance of swimmer taxa (SwimmerChTxPct) at Stations 05RD093(1) (19%) and 05RD093(2) (24%)
- Above basin class average (>11%) relative abundance of swimmer individuals (SwimmerPct) at Stations 05RD093(1) (12%) and 93RD405 (20%)

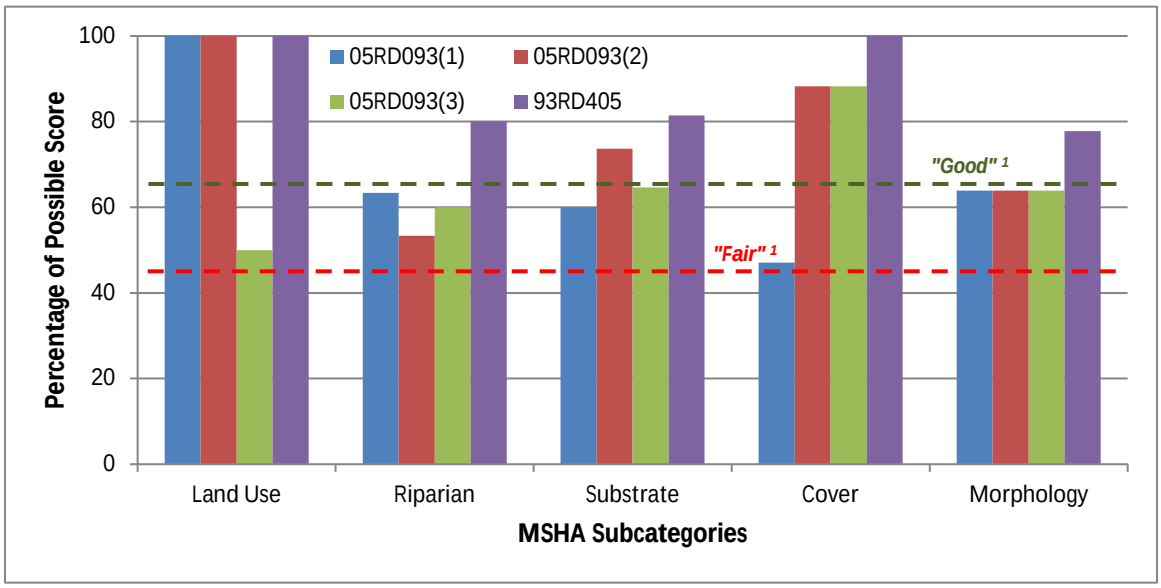
Flow regime instability tends to limit macroinvertebrate diversity and favor taxa that are shorter-lived, swimmers, and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012b).

Insufficient physical habitat

Available data

The physical habitat of AUID 503 was evaluated at Stations 05RD093 and 93RD405 using the MSHA. Both stations are located along natural segments of the reach (MPCA, 2013). Station 93RD405 (84/"good"), which is located along the upstream extent of the reach, scored markedly higher than Station 05RD093 (62/"fair", 71/"good", and 67/"good"), which is situated near the downstream end of the reach. Figure 20 displays the MSHA subcategory results for the stations. Station 05RD093(3) scored low in the land use subcategory due to the predominance of agricultural row crops in the vicinity of the station. The stations had a "moderate" to "extensive" riparian zone width; however, "moderate" bank erosion was noted at Station 93RD405. Both stations offered riffle habitat and coarse substrate (e.g.,

cobble and gravel) with “light” to “moderate” embeddedness. With the exception of Station 05RD093(1), the stations scored well in the cover subcategory due to the diversity and “moderate” to “extensive” amount of cover present. Common cover types noted along the reach included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, undercut banks, and woody debris. Lastly, the stations shared many of the channel morphology characteristics, including “moderate/high” channel stability and “fair” to “excellent” channel development. Overall, the MSHA data suggest that the physical habitat of downstream extent of the reach is slightly limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a “fair” and “good” MSHA rating.

Figure 20. MSHA subcategory results for Stations 05RD093 and 93RD405 along AUID 503.

On October 27, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 05RD093 along AUID 503 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *“The Pfankuch rating for [Station 05RD093] on 10/27/15 was 62, which is good (stable) for a C4 stream type. A good, or stable, rating for C4 stream types ranges from 70-90. The majority of Pfankuch categories ranked as good, with only bank rock content ranking as poor. The upper banks were well vegetated with mature trees, grasses, and forbs. There was also no evidence of mass erosion in the upper banks. The lower banks were well vegetated with only minor cutting and little evidence deposition. The channel capacity rated as fair because of some evidence of incision. The substrate at this location was gravel that appeared to be stable and well packed. Rooted aquatic vegetation was spotty, but there was abundant algae growth on rocks.”*

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 503 is provided by the following metric responses (Appendix A):

- Above basin class average (>48/18%) relative abundance of individuals that are detritivorous (DetNWQPct) at Stations 05RD093(2) (60%) and 93RD405 (74%)
- Below basin class average (<16/9%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 05RD093(1) (0%), 05RD093(2) (0%), 05RD093(3) (0%), and 93RD405 (0%)

- Below basin class average (<20/13%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 05RD093(2) (3%), 05RD093(3) (18%), and 93RD405 (1%)
- Below basin class average (<14%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Stations 05RD093(1) (9%), 05RD093(3) (0%)

Insectivores require quality physical habitat (e.g., riffles) to support a diverse and healthy food base, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of physical habitat (Aadland et al., 2006).

Biotic response – macroinvertebrate

Evidence of a causal relationship between insufficient physical habitat and the M-IBI impairment associated with AUID 503 is provided by the following metric responses (Appendix B):

- Below basin class average (<22%) relative percentage of clinger taxa (ClingerChTxPct) at Station 05RD093(2) (18%)
- Above basin class average (>20%) relative abundance of sprawler taxa (SprawlerChTxPct) at Station 93RD405 (25%)

Clinger taxa require clean, coarse substrate or other objects to attach themselves to, while sprawler macroinvertebrates are tolerant of degraded benthic habitat.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD093 and 93RD405 along AUID 503 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The stations had TSS concentrations ranging from 4 to 34 mg/L. Table 12 summarizes all available discrete TSS data for Sites S002-360 (US Highway 59), S002-999 (State Highway 175 crossing), S003-100 (260th Avenue crossing), and S007-441 (State Highway 175 crossing); the relative location of these sites is shown in Figure 14. The only exceedance of the 65 mg/L Southern River TSS Region standard occurred at Site S002-360. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 1 and 2% of the time during the period of 1996 to 2009. The aforementioned MSHA results indicate that the deposition of excess fine sediment caused the "moderate" level of embeddedness of coarse substrate documented at Station 05RD093. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Table 12. Discrete TSS data for Sites S002-360, S002-999, S003-100, and S007-441 along AUID 503.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S002-360	1991-2000	29	1	147	9	1
S002-999	2002	6	1	11	5	0
S003-100	2008-2010	20	1	35	8	0
S007-441	2013	11	1	12	5	0

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 503. None of the metrics or related data for Stations 05RD093 and 93RD405 (Appendix A) exhibited a correlation to this candidate cause.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 503 is provided by the following metric and data responses (Appendix B):

- Below basin class average (<9%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Station 05RD093(1) (4%)
- Below basin class average (<2) taxa richness of high TSS intolerant macroinvertebrates at Station 05RD093(2) (1)

Collector-filterers utilize specialized mechanisms (e.g., silk nets) to strain organic material from the water column. High suspended sediment can interfere with these mechanisms (Arruda et al., 1983; Barbour et al., 1999; Lemley, 1982; Strand and Merritt, 1997).

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a combined six discrete DO measurements at Stations 05RD093 and 93RD405 along AUID 503 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 6.4 to 13.1 mg/L. Figure 21 displays all available discrete DO data for Sites S002-360 (1991-2003; *n*=51), S002-999 (2001-2002; *n*=9), S003-100 (2003-2014; *n*=49), and S003-103 (270th Street crossing; 2003-2006; *n*=8); the relative location of these sites is shown in Figure 14. Collectively, 3% of the DO values for the sites were below the 5.0 mg/L standard; however, only three of the measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. The MPCA conducted continuous DO monitoring at Site W70030003 (270th Street crossing) from August 12, 2015, to August 26, 2015; the relative location of the site is shown in Figure 14. The monitoring results are provided in Table 13, as well as displayed in Figure 22. While 27% of the total values were below the standard, 77% of the daily minimum values were below the standard. A large storm event (≈4") interrupted the diurnal pattern on and after August 22, 2015. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard between 24 and 37% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences at least occasional periods of low DO.

Table 13. Continuous DO data for Site W70030003 along AUID 503.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 12, 2015 – August 26, 2015	1343	4.0	8.4	27	77	2.5

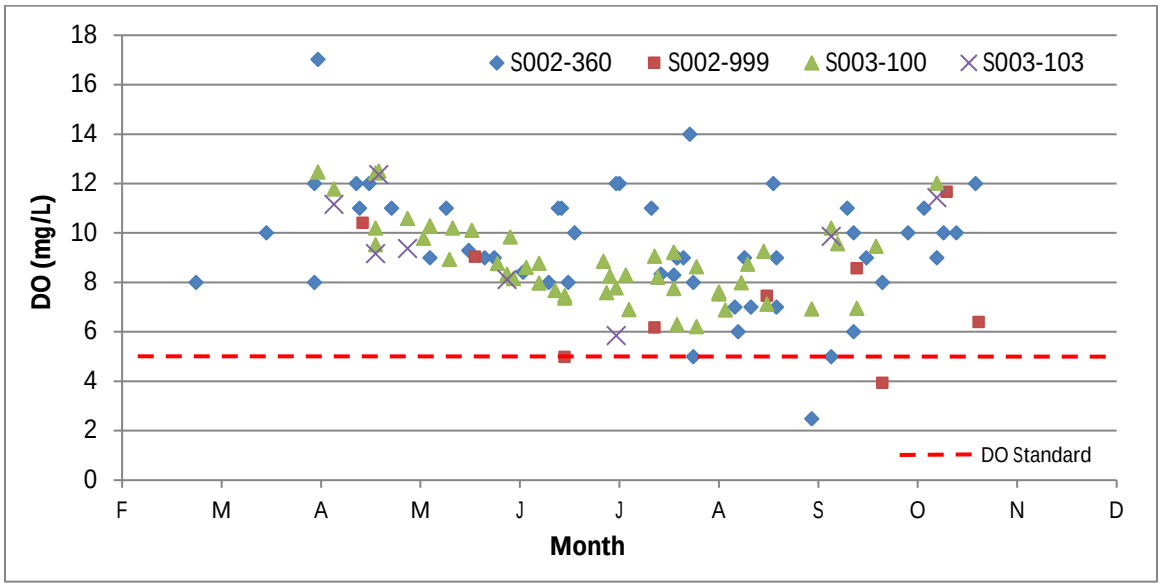


Figure 21. Discrete DO data for Sites S002-360, S002-999, S003-100, and S003-103 along AUID 503.

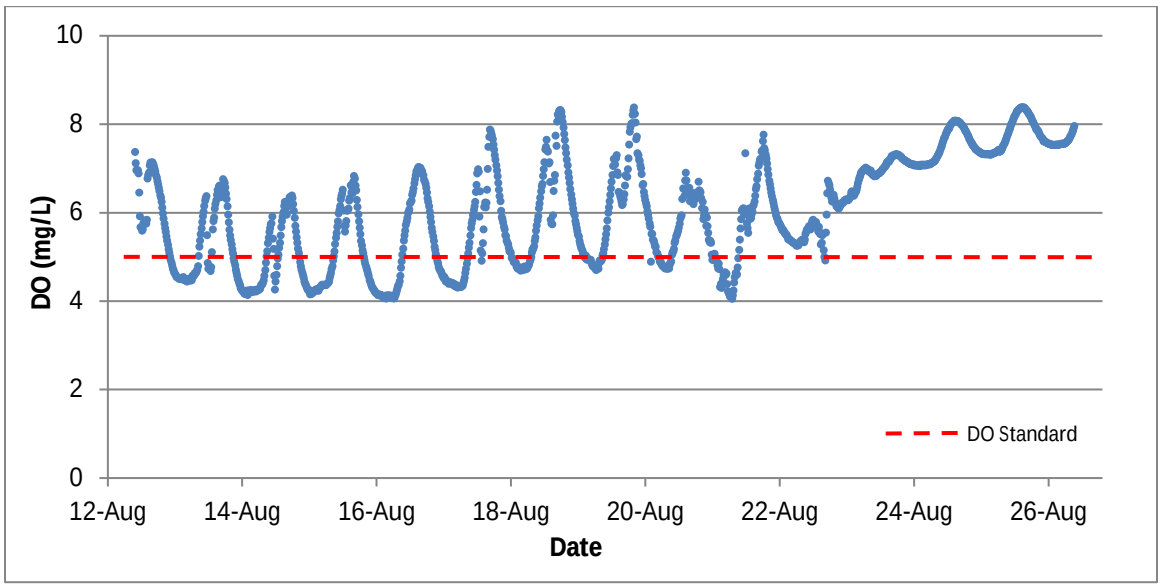


Figure 22. Continuous DO data for Site W70030003 along AUID 503.

Eutrophication-related data for AUID 503 is limited to the following parameters: TP, chlorophyll-a (Chl-a), and DO flux. Discrete TP data are available for Sites S002-360 (1991-2000; n=29), S002-999 (2001-2002; n=9), S003-100 (2008-2010; n=15), and S007-441 (2013; n=11). Collectively, the mean TP concentration for the sites was 66 µg/L, while the highest concentration was 560 µg/L and the lowest concentration was 5 µg/L. Approximately 6% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S003-100 (2009-2010; n=8). The mean Chl-a concentration for the site was 4 µg/L, while the highest concentration was 10 µg/L and the lowest concentration was 1 µg/L. There were no exceedances of the 35 µg/L South River Nutrient Region Chl-a standard. The mean daily DO flux documented during continuous DO monitoring at Site W70030003 (Table 13) was 2.5 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., August 12, 2015, August 26, 2015, and September 23, 2015). Overall, the limited available data does not suggest that eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 503 is provided by the following metric responses (Appendix A):

- Below basin class average (<0.37/0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 05RD093(2) (0.08), 05RD093(3) (0.02), and 93RD405 (0.11)
- Below basin class average (<9/23%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Stations 05RD093(2) (0%), 05RD093(3) (0%), and 93RD405 (17%)
- Above basin class average (>62/66%) relative abundance of individuals that are tolerant (TolPct) at Stations 05RD093(2) (68%), 05RD093(3) (64%), and 93RD405 (87%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 503 is provided by the following data response (Appendix B):

- Below basin class average (<2) taxa richness of low DO intolerant macroinvertebrates at Station 05RD093(1) (0)

Low DO often limits the taxa richness of macroinvertebrates and favors taxa that are tolerant (Weber, 1973; EPA, 2012b).

Strength-of-evidence analysis

Table 14 presents a summary of the SOE scores for the candidate causes associated with AUID 503. The evidence suggests that the F-IBI impairment is attributed to several stressors marginally affecting the community, including a loss of longitudinal connectivity, flow regime instability, and insufficient physical habitat. Similarly, the evidence also indicates that the M-IBI impairment is a result of multiple stressors marginally affecting the community, including flow regime instability, insufficient physical habitat, high suspended sediment, and low DO. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

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Table 14. SOE scores for candidate causes associated with AUID 503.

Types of evidence	SOE scores per candidate cause[1]									
	Loss of longitudinal connectivity		Flow regime instability		Insufficient physical habitat		High suspended sediment		Low dissolved oxygen	
	Biological impairments									
	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI
Types of evidence that use data from the case										
Spatial/temporal co-occurrence	+	--	+	+	+	+	0	+	0	+
Temporal sequence	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response relationship	+	--	+	+	+	+	0	+	0	+
Causal pathway	+	--	+	+	+	+	0	+	0	+
Evidence of exposure/bio-mechanism	+	--	+	+	+	+	0	+	0	+
Manipulation of exposure	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Symptoms	+	--	+	+	+	+	0	+	0	+
Types of evidence that use data from elsewhere										
Mechanistically plausible cause	+	-	+	+	+	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response in field studies	++	NE	++	++	++	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Multiple lines of evidence										
Consistency of evidence	**+**	**--**	**+**	**+**	**+**	**+**	**0**	**+**	**0**	**+**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.3 North Branch Two Rivers (AUID 504)

Physical setting

This reach represents the segment of the North Branch Two Rivers from its headwaters, to its confluence with CD 22 (Figure 23); a total length of 38 miles. The reach has a subwatershed area of 281 square miles (USGS, 2016). The subwatershed contains 78 miles of intermittent drainage ditch, 69 miles of perennial drainage ditch, 56 miles of intermittent stream, 38 miles of river (i.e., AUID 504), and three miles of perennial stream (DNR, 2003). According to the MPCA (2013), 70% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 1% of AUID 504. The NLCD 2011 (USGS, 2011) lists cultivated crops (59%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (23%), forest (11%), developed (3%), and hay/pasture (2%).

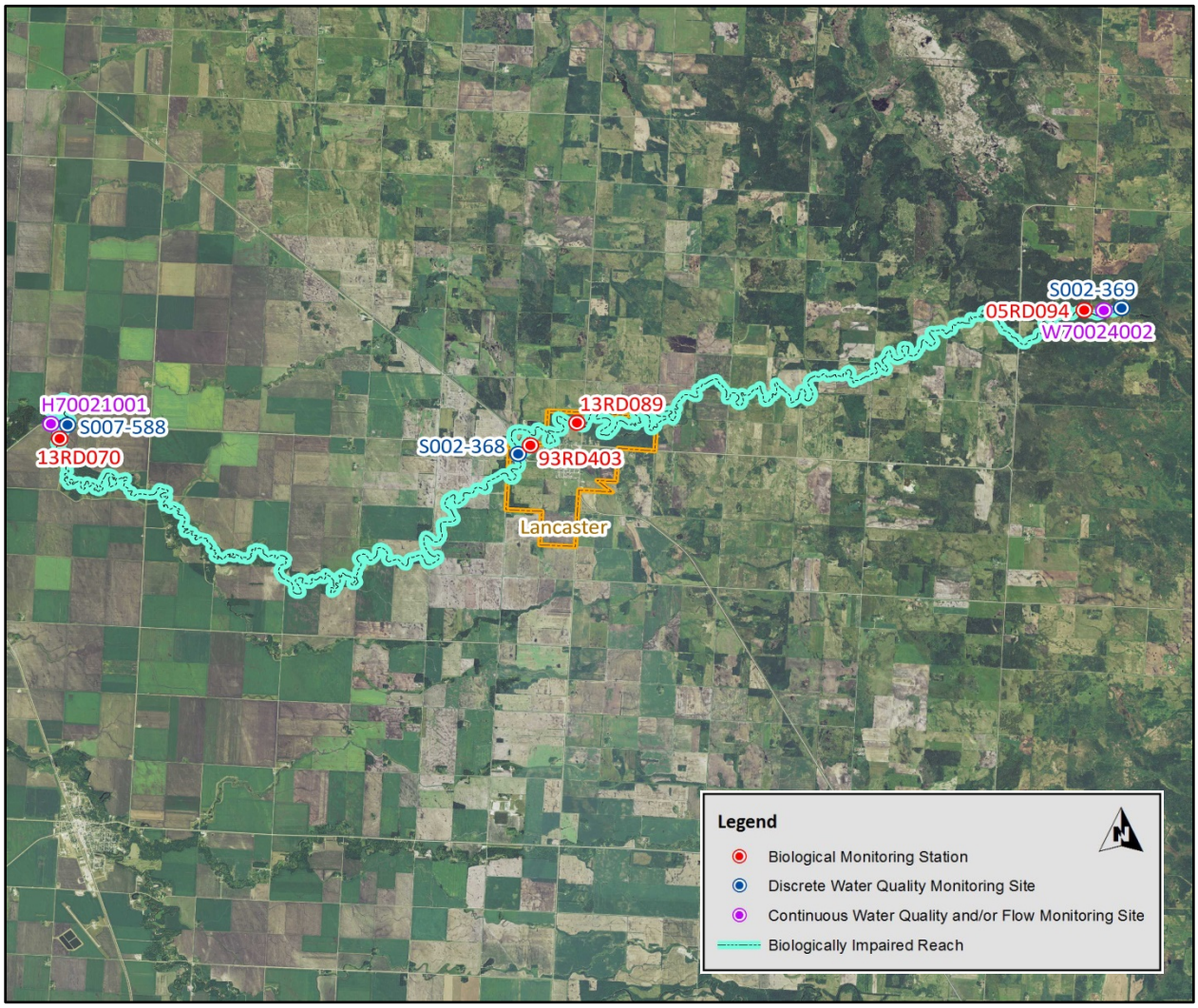
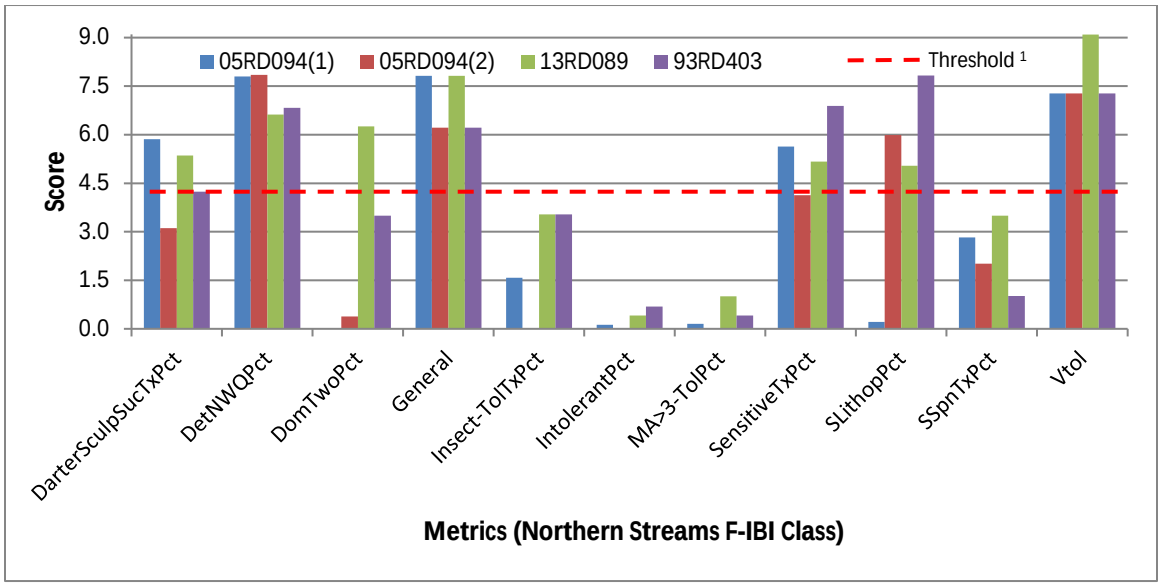


Figure 23. Map of AUID 504 and associated biological monitoring stations and flow/water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

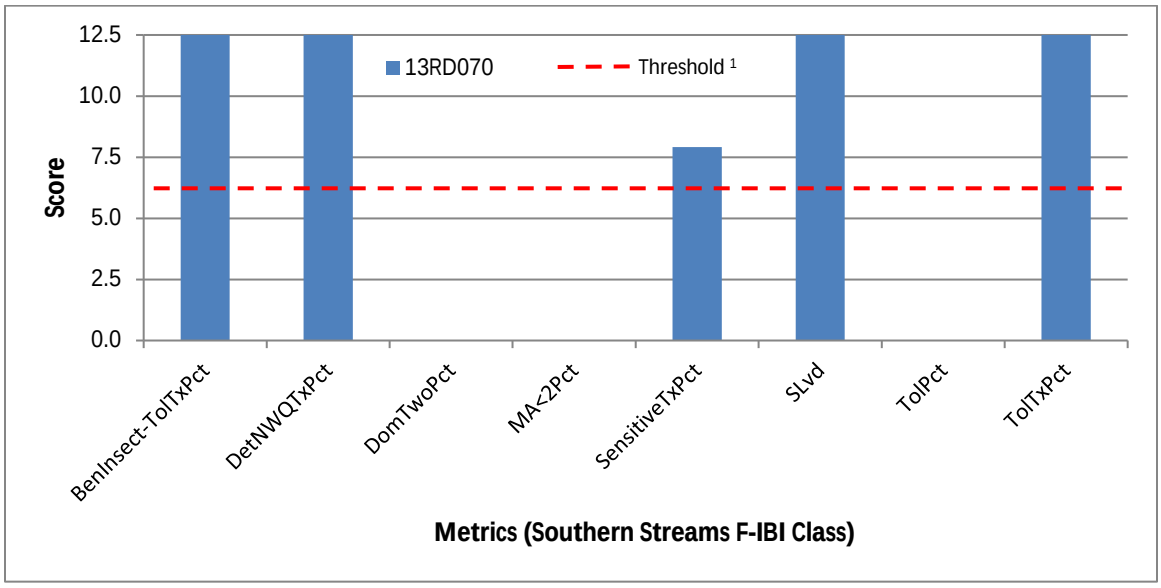
Fish (F-IBI)

The fish community of AUID 504 was monitored at Station 05RD094 (1.7 mile upstream of the CSAH 4 crossing) on August 31, 2005(1) and June 12, 2014(2); Station 13RD070 (0.1 mile upstream of the CSAH 4 crossing) on July 9, 2013; Station 13RD089 (0.1 mile downstream of the US Highway 59 crossing) on July 2, 2013; and Station 93RD403 (0.2 mile upstream of the CSAH 6 crossing) on July 2, 2013. The relative location of the stations is shown in Figure 23. Stations 05RD094, 13RD089, and 93RD403 were designated as General Use within the Northern Streams F-IBI Class. The impairment threshold for these stations is an F-IBI score of 47. Station 13RD070 was designated as General Use within the Southern Streams F-IBI Class. The impairment threshold for this station is an F-IBI score of 50. Station 05RD094 (F-IBI=39 and 37) scored below its impairment threshold, while Stations 13RD070 (F-IBI=58), 13RD089 (F-IBI=54), and 93RD403 (F-IBI=48) each scored above their respective threshold. According to Figure 24, eight individual metrics for Stations 05RD094, 13RD089, and/or 93RD403 scored below the mean value needed to meet the impairment threshold (i.e., DarterSculpSucTxPct, DomTwoPct, Insect-TolTxPct, IntolerantPct, MA>3-TolPct, SensitiveTxPct, SLithopPct, and SSpnTxPct). Additionally, three individual metrics for Station 13RD070 (Figure 25) had such a substandard score (i.e., DomTwoPct, MA<2Pct, and TolPct). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the stations was dominated by tolerant taxa, specifically brook stickleback, central mudminnow, common shiner, and creek chub.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 24. Individual F-IBI metric scores for Stations 05RD094, 13RD089, and 93RD403 along AUID 504.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 25. Individual F-IBI metric scores for Station 13RD070 along AUID 504.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 05RD094, 13RD070, 13RD089, and 93RD403 along AUID 504. However, staff spoke with local landowners who indicated that beaver dams are common along the upstream extent of the reach (personal communication, 2014). According to the DNR (2014), there are no man-made dams on the reach. However, the Northcote Dam is located directly downstream of the reach along the North Branch of the Two Rivers (AUID 508) and is at least a partial barrier to connectivity. On September 30, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. A beaver dam (Figure 26) was documented along 345th Street. The dam had been breached and did not appear to be interfering with connectivity at the time of discovery. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. Staff identified another beaver dam (Figure 26) along 345th Street. The dam had an associated pool and appeared to be at least a partial barrier to connectivity at the time of the photo.

Figure 26. Photos of connectivity barriers along AUID 504, including a beaver dam along 345th Street on September 30, 2015 (left) and a beaver dam along 345th Street on September 1, 2013, courtesy of Google Earth (right).

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 504 is provided by the following metric response (Appendix A):

- Below basin class average (<5%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 05RD094(1) (1%), 05RD094(2) (0%), 13RD089 (4%), and 93RD403 (2%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Northcote Dam on the fish community of the North Branch Two Rivers is discussed in Subsection 3.3.6 (AUID 508).

Flow regime instability

Available data

According to the TRWD (2004), the reach has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge. Overflow from the Roseau River Watershed often exacerbates this condition (TRWD, 2004). The MPCA biological monitoring staff did not encounter any flow-related issues during fish sampling at Stations 05RD094, 13RD070, 13RD089, and 93RD403. The DNR conducted continuous flow monitoring at Site H70021001 (CSAH 4 crossing) from 2003 to 2014; the relative location of the site is shown in Figure 23. The highest mean daily peak flow recorded at the site was 2735.4 cfs, while the lowest flow was 0.0 cfs. Approximately 10% of the total mean daily flow values were less than 1.0 cfs. Table 15 presents the percentile flow values for the site. The data shows the extreme variability in flow values for the site. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 14 and 44% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., July 22, 2015, August 4, 2015, and September 30, 2015) and documented flow conditions. Lentic conditions were noted at Site W70024002 (345th Street crossing) on August 4, 2015 (Figure 27); the relative location of the site is shown in Figure 23. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

Table 15. Percentile flow values for Site H70021001 along AUID 504 from 2003 to 2014.

Date range	*n*	Percentile values – Mean daily discharge (cfs)						
		5th	10th	20th	40th	60th	80th	100th
2003-2014	3124	0.5	1.0	2.5	8.0	26.0	297.2	2735.4

Figure 27. Photos of lentic conditions at Site W70024002 along AUID 504 on August 4, 2015.

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 504 is provided by the following metric responses (Appendix A):

- Above basin class average (>71/60%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 05RD094(1) (78%), 05RD094(2) (73%), and 93RD403 (61%)
- Above basin class average (>33%) relative abundance of taxa that are generalists (GeneralTxPct) at Station 05RD094(2) (40%)
- Above basin class average (>73/83%) relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct) at Stations 05RD094(1) (98%), 05RD094(2) (93%), 13RD089 (84%), and 93RD403 (90%)
- Below basin class average (<0.37/1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 05RD094(1) (0.38), 05RD094(2) (1.20), 13RD070 (0.03), and 13RD089 (0.39)
- Above basin class average (>17%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 05RD094(1) (27%) and 05RD094(2) (30%)
- Above basin class average (>43%) relative abundance of taxa that are tolerant (TolTxPct) at Stations 05RD094(1) (45%) and 05RD094(2) (50%)

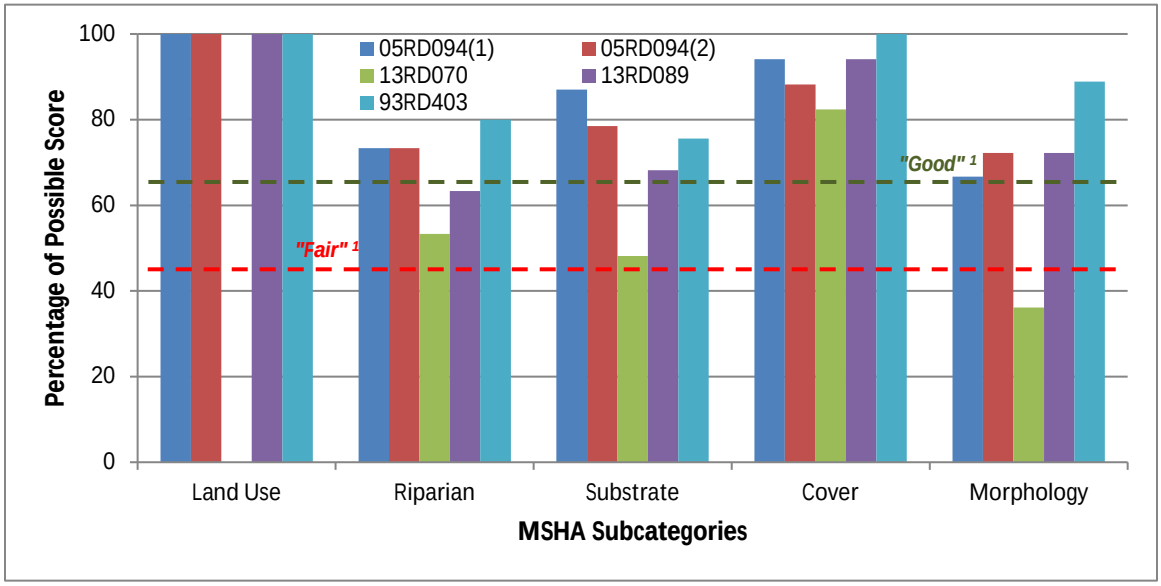
Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 504 was evaluated at Stations 05RD094, 13RD070, 13RD089, and 93RD403 using the MSHA. All of the stations are located along natural segments of the reach (MPCA, 2013). Stations 93RD403 (86/"good"), 05RD094 (80/"good" and 78/"good"), and 13RD089 (75/"good") scored

substantially higher than Station 13RD070 (48/"poor"), which is located at the downstream end of the reach. Figure 28 displays the MSHA subcategory results for the stations. With the exception of Station 13RD070, the stations scored well in the land use subcategory due to the predominance of natural vegetation surrounding the stations. The stations had a "wide" to "extensive" riparian zone width; however, "moderate" bank erosion was noted at Station 13RD070. Station 13RD070 scored lower in the substrate subcategory than the other stations due to a lack of riffle habitat and coarse substrate (e.g., cobble and gravel). The other stations offered riffle habitat and coarse substrate with only "light" embeddedness. The stations scored uniformly well in the cover subcategory due to the diversity and "moderate" to "extensive" amount of cover present. Common cover types noted along the reach included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, rootwads, undercut banks, and woody debris. Lastly, the stations shared many of the channel morphology characteristics, including "moderate/high" channel stability. However, the subcategory score for Station 13RD070 was adversely affected by "poor" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is limited in the vicinity of Station 13RD070.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 28. MSHA subcategory results for Stations 05RD094, 13RD070, 13RD089, and 93RD403 along AUID 504.

On October 27, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 13RD070 along AUID 504 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 13RD070] on 10/27/2015 was 66, which is fair (moderately unstable) for an E6 stream type. A good, or stable, rating for E6 stream types ranges from 40-63. Almost all Pfankuch categories ranked as good or excellent, with only three categories ranking as poor. The upper banks were well vegetated with reed canary grass and scattered mature trees. There was also infrequent mass wasting in the upper banks. The lower banks were generally in good condition, with some cutting on outside bends. Although the channel capacity ranked at good, the lower banks appeared to be slightly incised. The bottom through this reach was silt/clay and appeared to be stable, with no excess scouring or deposition occurring."*

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 504 is provided by the following metric responses (Appendix A):

- Below basin class average (<19%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Stations 05RD094(1) (18%) and 05RD094(2) (10%)
- Below basin class average (<15%) relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPcT) at Stations 05RD094(2) (10%) and 93RD403 (13%)
- Above basin class average (>19%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 05RD094(2) (20%), 13RD089 (25%), and 93RD403 (27%)
- Below basin class average (<16/8%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 05RD094(1) (1%), 05RD094(2) (0%), 13RD070 (0%), and 13RD089 (4%)
- Below basin class average (<20/23%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 05RD094(1) (2%), 05RD094(2) (1%), and 13RD070 (15%)
- Below basin class average (<14%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Stations 05RD094(1) (9%), 05RD094(2) (10%), and 13RD070 (0%)
- Below basin class average (<30%) relative abundance of taxa that are simple lithophilic spawning species (SLithopTxPct) at Stations 05RD094(1) (27%), 05RD094(2) (20%), and 13RD089 (25%)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD094, 13RD070, 13RD089, and 93RD403 along AUID 504 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The stations had TSS concentrations ranging from 4 to 26 mg/L. Table 16 summarizes all available discrete TSS data for Sites S002-368 (CSAH 6 crossing), S002-369 (345th Street crossing), and S007-588 (CSAH 4 crossing); the relative location of these sites is shown in Figure 23. Only Site S007-588 had exceedances of the 65 mg/L Southern River TSS Region standard. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the standard 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Table 16. Discrete TSS data for Sites S002-368, S002-369, and S007-588 along AUID 504.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S002-368	1991-2011	52	1	48	8	0
S002-369	1991-2002	36	1	37	6	0
S007-588	2014	25	7	536	40	2

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 504. None of the metrics or related data for Stations 05RD094, 13RD070, 13RD089, and 93RD403 (Appendix A) exhibited a correlation to this candidate cause.

Low dissolved oxygen

Available data

The reach has an existing DO impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a combined five discrete DO measurements at Stations 05RD094, 13RD070, 13RD089, and 93RD403 along AUID 504 at the time of fish monitoring. Measurement values ranged from 4.3 to 9.5 mg/L. One measurement was below the 5.0 mg/L standard; Station 05RD094 had a DO concentration of 4.3 mg/L at the time of fish sampling on June 12, 2014. Figure 29 displays all available discrete DO data for Sites S002-368 (1991-2011; *n*=111), S002-369 (1991-2005; *n*=86), and S007-588 (2014; *n*=23); the relative location of these sites is shown in Figure 23. Collectively, 8% of the DO values for the sites were below the standard; however, none of the measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. The MPCA conducted continuous DO monitoring at Site W70024002 from July 30, 2015, to August 4, 2015; the relative location of the site is shown in Figure 23. The monitoring results are provided in Table 17, as well as displayed in Figure 30. Approximately 98% of the total values were below the standard, including all of the daily minimum values. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard between 8 and 44% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

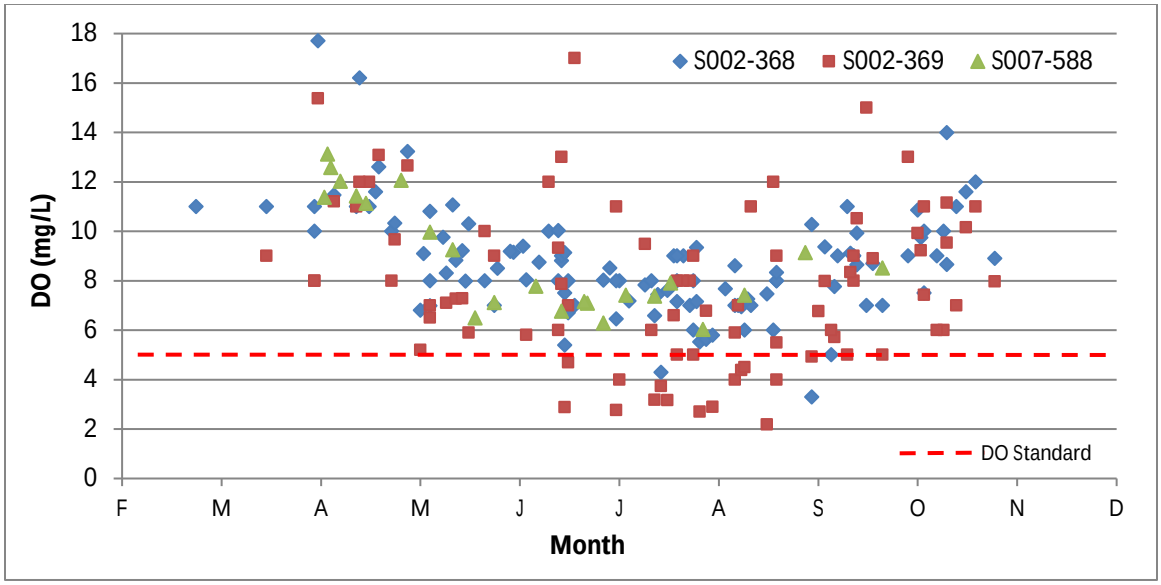


Figure 29. Discrete DO data for Sites S002-368, S002-369, and S007-588 along AUID 504.

Table 17. Continuous DO data for Site W70024002 along AUID 504.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 30, 2015 – August 4, 2015	500	1.1	5.3	98	100	1.8

Eutrophication-related data for the reach is limited to the following parameters: TP and DO flux. Discrete TP data are available for Sites S002-368 (1991-2010; n=54), S002-369 (1991-2002; n=47), and S007-588 (2014; n=25). Collectively, the mean TP concentration for the sites was 93 µg/L, while the highest concentration was 920 µg/L and the lowest concentration was 5 µg/L. Approximately 17% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. The mean daily DO flux documented during continuous DO monitoring at Site W70024002 (Table 17) was 1.8 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., July 22, 2015, August 4, 2015, and September 30, 2015). Overall, the limited available data does not suggest that eutrophication is adversely affecting the DO regime of the reach.

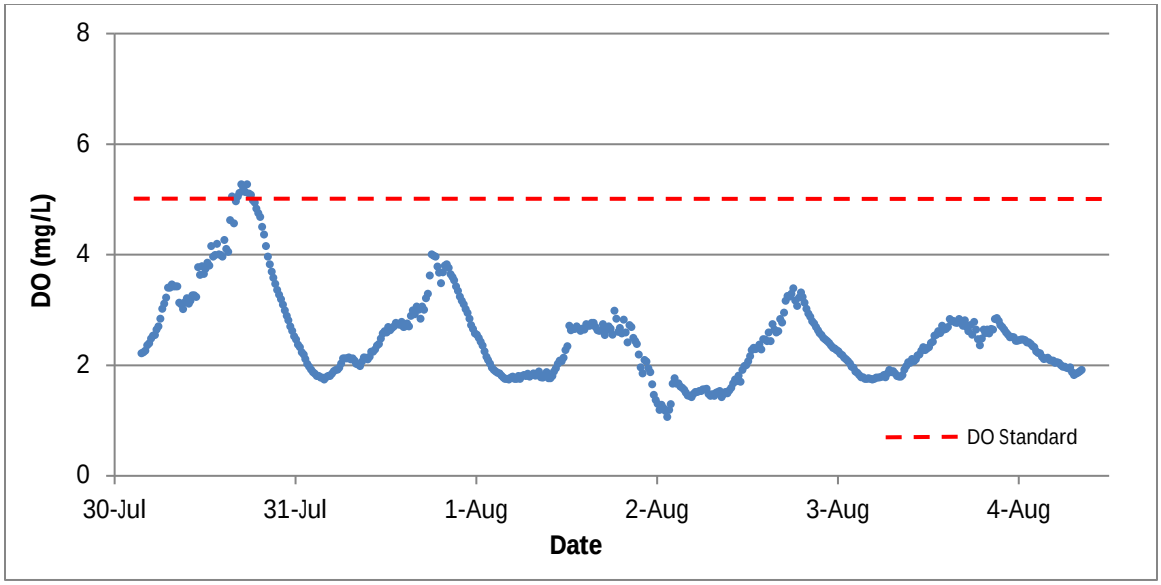


Figure 30. Continuous DO data for Site W70024002 along AUID 504.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 504 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<0.37/1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 05RD094(1) (0.38), 05RD094(2) (1.20), 13RD070 (0.03), and 13RD089 (0.39)
- Above basin class average (>43%) relative abundance of taxa that are tolerant (TolTxPct) at Stations 05RD094(1) (45%) and 05RD094(2) (50%)
- Below basin class average (<6.7/6.8 mg/L) mean DO TIV at Stations 05RD094(1) (5.7 mg/L), 05RD094(2) (6.6 mg/L), and 13RD070 (6.4 mg/L)
- Below basin class average (<37/40%) probability of meeting the DO standard at Stations 05RD094(1) (7%), 05RD094(2) (29%), and 13RD070 (25%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Strength-of-evidence analysis

Table 18 presents a summary of the SOE scores for the candidate causes associated with AUID 504. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, low DO, and to a lesser extent, insufficient physical habitat. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 18. SOE scores for candidate causes associated with AUID 504.

Types of evidence	SOE scores per candidate cause[1]				
	Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
	Biological impairment				
	F-IBI	F-IBI	F-IBI	F-IBI	F-IBI
Types of evidence that use data from the case					
Spatial/temporal co-occurrence	++	++	+	0	++
Temporal sequence	NE	NE	NE	NE	NE
Stressor-response relationship	++	++	+	0	++
Causal pathway	++	++	+	0	++
Evidence of exposure/bio-mechanism	++	++	+	0	++
Manipulation of exposure	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE
Symptoms	++	++	+	0	++
Types of evidence that use data from elsewhere					
Mechanistically plausible cause	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE
Stressor-response in field studies	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE
Multiple lines of evidence					
Consistency of evidence	**++**	**++**	**+**	**0**	**++**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.4 South Branch Two Rivers (AUID 505)

Physical setting

This reach represents the segment of the South Branch Two Rivers from its confluence with Lateral Ditch 2 of State Ditch 95, to Lake Bronson (Figure 31); a total length of eight miles. The reach has a subwatershed area of 534 square miles (USGS, 2016). The subwatershed contains 361 miles of intermittent drainage ditch, 109 miles of intermittent stream, 69 miles of perennial drainage ditch, 16 miles of river, and three miles of perennial stream (DNR, 2003). According to the MPCA (2013), 86% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 58% of AUID 505. The NLCD 2011 (USGS, 2011) lists cultivated crops (61%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (15%), forest (10%), hay/pasture (7%), and developed (4%).

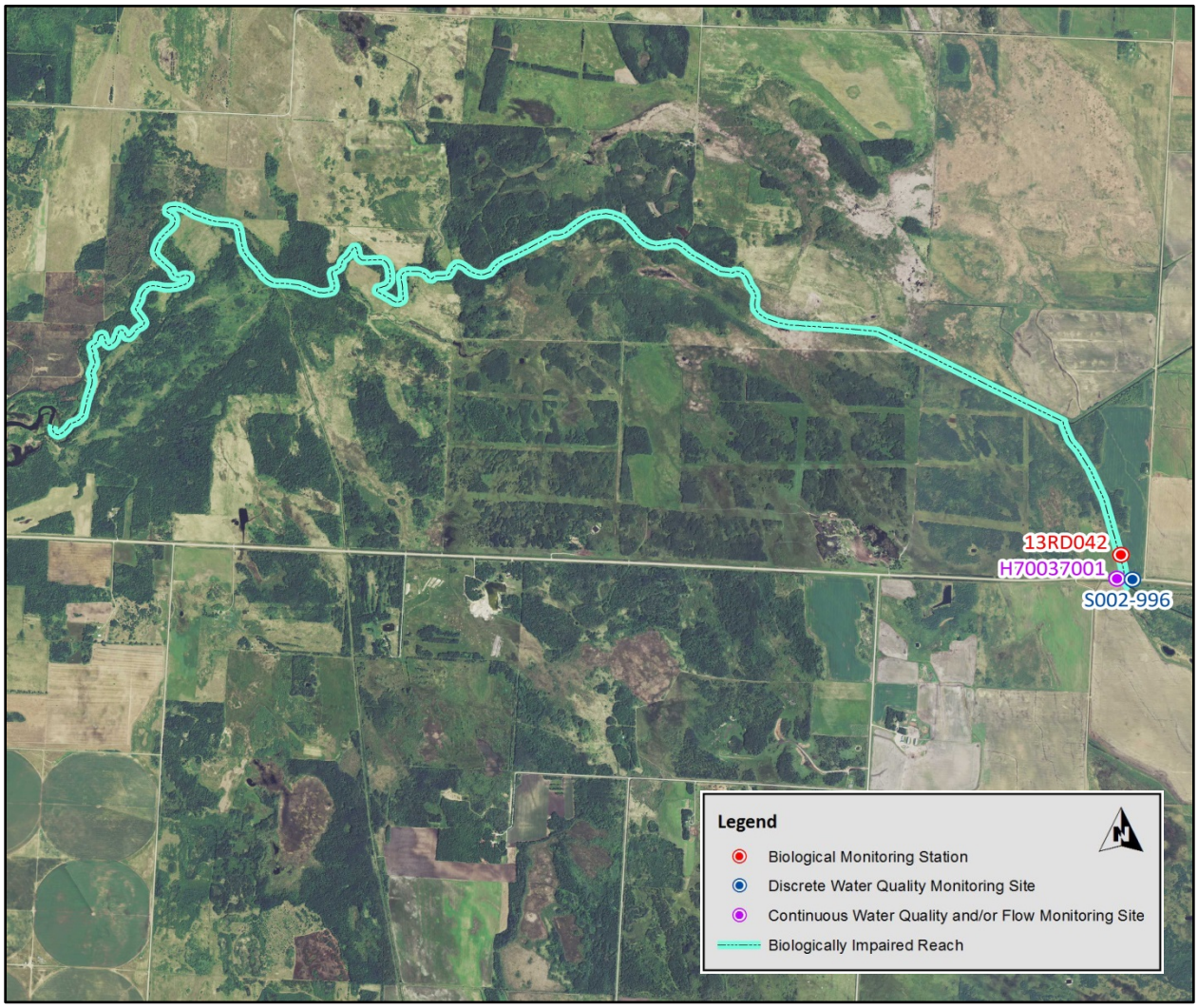
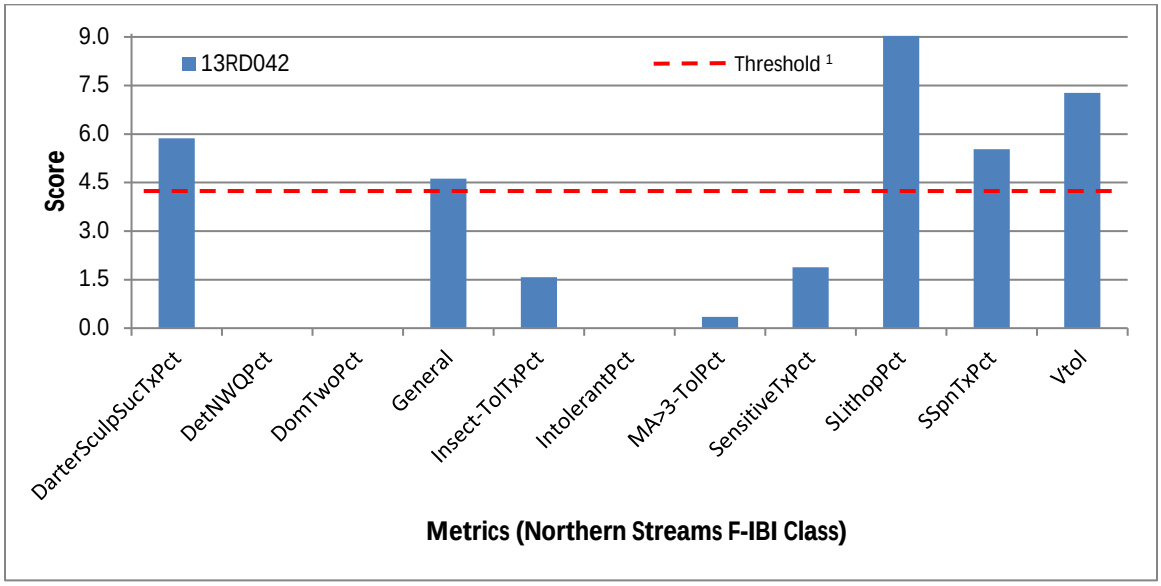


Figure 31. Map of AUID 505 and associated biological monitoring station and water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 505 was monitored at Station 13RD042 (0.1 mile downstream of the CSAH 10 crossing) on June 26, 2013. The relative location of the station is shown in Figure 31. The station was designated as General Use within the Northern Streams F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 47. Monitoring of the station yielded an F-IBI score (36) below the impairment threshold. According to Figure 32, six individual metrics for Station 13RD042 scored below the mean value needed to meet the impairment threshold (i.e., DetNWQPct, DomTwoPct, Insect-TolTxPct, IntolerantPct, MA>3-TolPct, and SensitiveTxPct). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the station was dominated by tolerant taxa, specifically northern pike and white sucker.

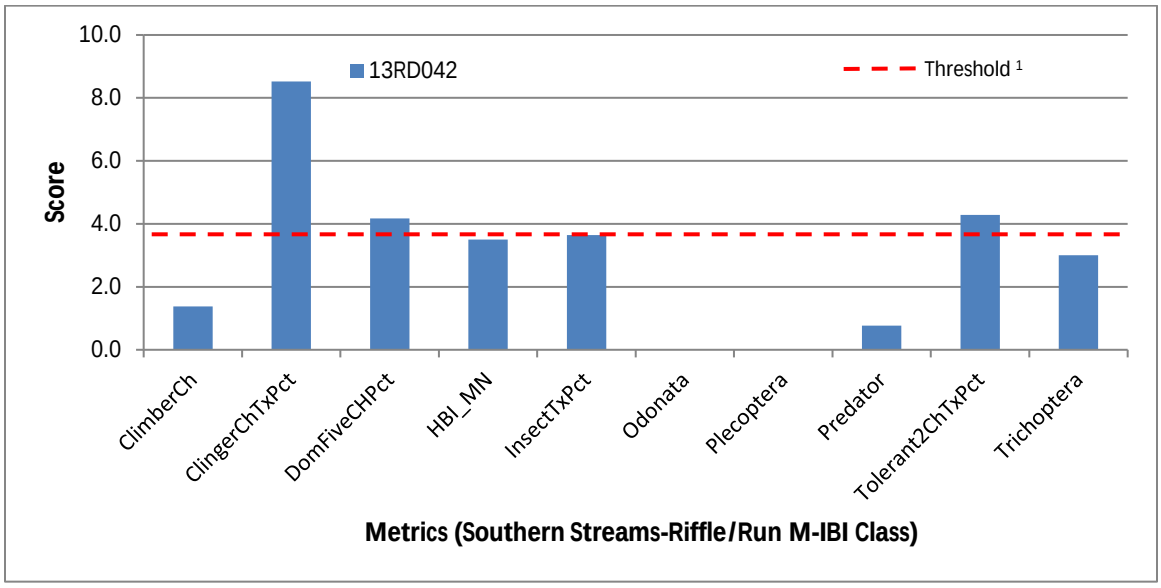


[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 32. Individual F-IBI metric scores for Station 13RD042 along AUID 505.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 505 was monitored at Station 13RD042 on July 30, 2013. The station was designated as General Use within the Southern Streams Riffle/Run Habitats M-IBI Class. Accordingly, the impairment threshold for the station is an M-IBI score of 37. Monitoring of the station yielded an M-IBI score (29) below the impairment threshold. According to Figure 33, seven individual metrics for Station 13RD042 scored below the mean value needed to meet the impairment threshold (i.e., ClimberCh, HBI_MN, InsectTxPct, Odonata, Plecoptera, Predator, and Trichoptera). A description of each metric is provided in the *Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014b). The macroinvertebrate assemblage of the station was dominated by tolerant taxa, including *Cheumatopsyche* (caddisflies), *Hydroptila* (caddisflies), and *Simulium* (black flies).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 33. Individual M-IBI metric scores for Station 13RD042 along AUID 505.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD042 along AUID 505. According to the DNR (2014), there are no man-made dams on the reach. However, the Lake Bronson Dam and Hallock Dam are located downstream of the reach along the South Branch Two Rivers (AUID 502) and are barriers to connectivity. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo.

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 505 is provided by the following metric response (Appendix A):

- Below basin class average (<5%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Station 13RD042 (1%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Lake Bronson Dam and Hallock Dam on the fish community of the South Branch Two Rivers is discussed in Subsection 3.3.1 (AUID 502).

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 505. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to the TRWD (2004), the reach has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge. The MPCA biological monitoring staff did not encounter any flow-related issues during fish and macroinvertebrate monitoring at Station 13RD042. There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 4% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, August 26, 2015, and September 23, 2015) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach is at least somewhat prone to extreme peak flows, as well as extended periods of minimal to no flow.

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 505 is provided by the following metric responses (Appendix A):

- Above basin class average (>60%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Station 13RD042 (86%)
- Above basin class average (>33%) relative abundance of taxa that are generalists (GeneralTxPct) at Station 13RD042 (45%)
- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD042 (0.37)
- Above basin class average (>17%) relative abundance of taxa that are pioneers (PioneerTxPct) at Station 13RD042 (27%)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 13RD042 (9%)
- Above basin class average (>50%) relative abundance of individuals that are tolerant (TolPct) at Station 13RD042 (66%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, pioneering, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

Evidence of a causal relationship between flow regime instability and the M-IBI impairment associated with AUID 505 is provided by the following metric responses (Appendix B):

- Above basin class average (>9%) relative abundance of swimmer taxa (SwimmerChTxPct) at Station 13RD042 (14%)
- Below basin class average (<40) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD042 (36)

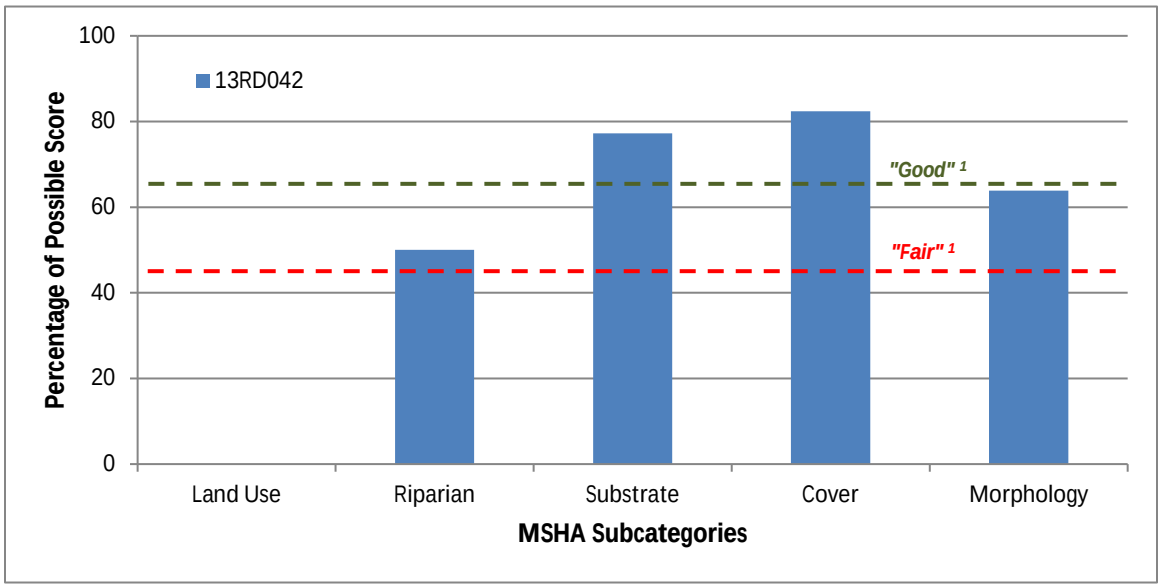
Flow regime instability tends to limit macroinvertebrate diversity and favor taxa that are swimmers and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012b).

Insufficient physical habitat

Available data

The physical habitat of AUID 505 was evaluated at Station 13RD042 using the MSHA. The station is located along a channelized segment of the reach (MPCA, 2013). The station yielded a score of 65 ("fair"). Figure 34 displays the MSHA subcategory results for the station. The station had a score of zero

for the land use subcategory due to the predominance of agricultural row crops immediately surrounding the station. The riparian zone width of the station was characterized as "narrow" to "moderate". A "moderate" level of bank erosion was also noted. The station scored well in the substrate subcategory, as it offered riffle habitat and coarse substrate (i.e., cobble and gravel) with only "light" embeddedness. The station also scored well in the cover subcategory, primarily due to the diversity and "moderate" amount of cover present. Cover types noted included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, rootwads, undercut banks, and woody debris. Lastly, the station had "moderate/high" channel stability and "good" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is slightly limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 34. MSHA subcategory results for Station 13RD042 along AUID 505.

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 505 is provided by the following metric responses (Appendix A):

- Above basin class average (>20%) relative abundance of individuals that are detritivorous (DetNWQPct) at Station 13RD042 (62%)
- Below basin class average (<8%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 13RD042 (0%)
- Below basin class average (<23%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Station 13RD042 (5%)
- Below basin class average (<14%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Station 13RD042 (9%)

Insectivores require quality physical habitat (e.g., riffles) to support a diverse and healthy food base, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of physical habitat (Aadland et al., 2006).

Biotic response – macroinvertebrate

Evidence of a causal relationship between insufficient physical habitat and the M-IBI impairment associated with AUID 505 is provided by the following metric response (Appendix B):

- Below basin class average (<7) taxa richness of climbers (ClimberCh) at Station 13RD042 (4)

Climber taxa require plants or debris habitat to climb.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD042 along AUID 505 at the time of the fish monitoring visit. The sample was analyzed for several parameters, including TSS. The station had a TSS concentration of 5 mg/L. Table 19 summarizes all available discrete TSS data for Site S002-996 (CSAH 10 crossing); the relative location of the site is shown in Figure 31. The site had only one exceedance of the 30 mg/L Central River TSS Region standard. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the standard 2% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Table 19. Discrete TSS data for Site S002-996 along AUID 505.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S002-996	2002-2013	36	1	45	6	1

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 505. None of the metrics or related data for Station 13RD042 (Appendix A) exhibited a correlation to this candidate cause.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 505 is provided by the following data response (Appendix B):

- Above basin class average (>21%) relative abundance of high TSS tolerant individuals at Station 13RD042 (29%)

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD042 along AUID 505 at the time of fish (6.5 mg/L) and macroinvertebrate (11.9 mg/L) monitoring. Figure 35 displays all available discrete DO data for Site S002-996 (2002-2014; *n*=32); the relative location of the site is shown in Figure 31. Approximately 3% of the DO values for the site were below the 5.0 mg/L standard; however, only one of the measurements was collected prior to 9:00 a.m. The lowest DO levels were in the months of June and July. The MPCA conducted continuous DO monitoring at Site H70037001 (CSAH 10 crossing) from August 12, 2015, to August 26, 2015; the relative location of the site is shown in Figure 31. The monitoring results are provided in Table 20, as well as displayed in Figure 36. While 8% of the total values were below the standard, 23% of the daily minimum values were below the standard. A large storm event (≈4") interrupted the diurnal pattern on and after August 22, 2015. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard approximately 3% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences occasional periods of low DO.

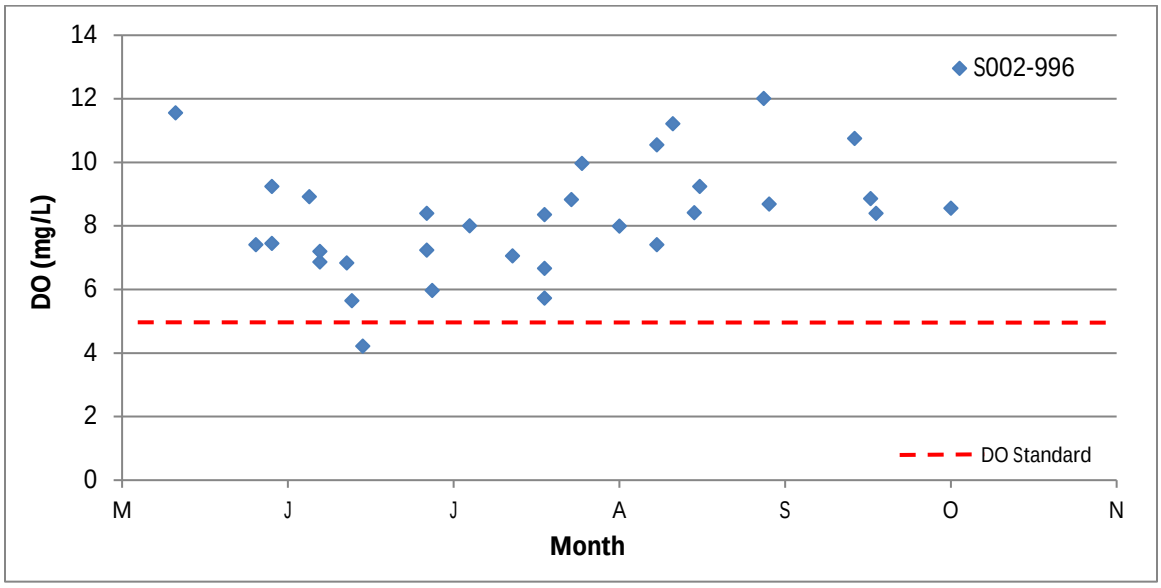


Figure 35. Discrete DO data for Site S002-996 along AUID 505.

Table 20. Continuous DO data for Site H70037001 along AUID 505.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 12, 2015 – August 26, 2015	1348	4.3	12.1	8	23	2.6

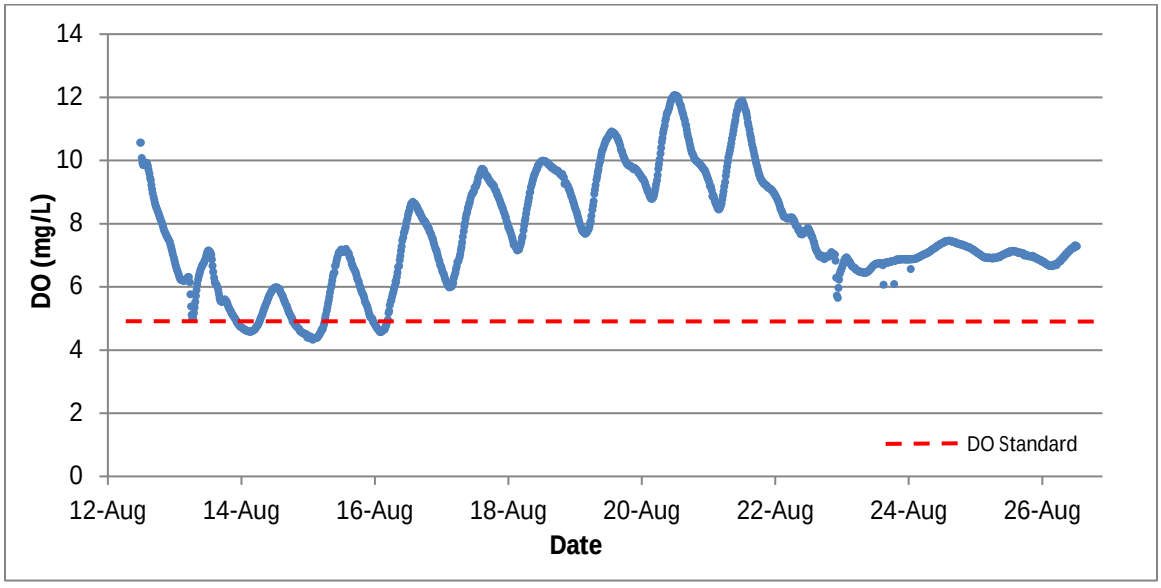


Figure 36. Continuous DO data for Site H70037001 along AUID 505.

Eutrophication-related data for the reach is limited to the following parameters: TP, Chl-a, and DO flux. Discrete TP data are available for Site S002-996 (2002-2013; n=25). The mean TP concentration for the site was 71 µg/L, while the highest concentration was 202 µg/L and the lowest concentration was 26 µg/L. Approximately 8% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S002-996 (2009-2010; n=8). The mean Chl-a concentration

for the site was 3 µg/L, while the highest concentration was 13 µg/L and the lowest concentration was 1 µg/L. There were no exceedances of the 35 µg/L South River Nutrient Region Chl-a standard. The mean daily DO flux documented during continuous DO monitoring at Site H70037001 (Table 20) was 2.6 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., August 12, 2015, August 26, 2015, and September 23, 2015). Overall, the limited available data does not suggest that eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 505 is provided by the following metric responses (Appendix A):

- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD042 (0.37)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 13RD042 (9%)
- Above basin class average (>50%) relative abundance of individuals that are tolerant (TolPct) at Station 13RD042 (66%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (USEPA, 2012b).

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 505 is provided by the following metric response (Appendix B):

- Below basin class average (<40) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD042 (36)

Low DO often limits the taxa richness of macroinvertebrates (Weber, 1973; EPA, 2012b).

Strength-of-evidence analysis

Table 21 presents a summary of the SOE scores for the candidate causes associated with AUID 505. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, and to a lesser extent, insufficient physical habitat. Additionally, the evidence indicates that the M-IBI impairment is likely the result of several stressors marginally affecting the community, including flow regime instability, insufficient physical habitat, and high suspended sediment. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 21. SOE scores for candidate causes associated with AUID 505.

Types of evidence	SOE scores per candidate cause[1]									
	Loss of longitudinal connectivity		Flow regime instability		Insufficient physical habitat		High suspended sediment		Low dissolved oxygen	
	Biological impairments									
	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI
Types of evidence that use data from the case										
Spatial/temporal co-occurrence	++	--	++	+	+	+	0	+	0	0
Temporal sequence	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response relationship	++	--	++	+	+	+	0	+	0	0
Causal pathway	++	--	++	+	+	+	0	+	0	0
Evidence of exposure/bio-mechanism	++	--	++	+	+	+	0	+	0	0
Manipulation of exposure	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Symptoms	++	--	++	+	+	+	0	+	0	0
Types of evidence that use data from elsewhere										
Mechanistically plausible cause	+	-	+	+	+	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response in field studies	++	NE	++	++	++	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Multiple lines of evidence										
Consistency of evidence	**++**	**--**	**++**	**+**	**+**	**+**	**0**	**+**	**0**	**0**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.5 South Branch Two Rivers (AUID 506)

Physical setting

This reach represents the segment of the South Branch Two Rivers from its confluence with an unnamed ditch, to its confluence with Lateral Ditch 2 of State Ditch 95; a total length of 25 miles. The first (upstream) 11 miles of the reach has been channelized and is also known as State Ditch 91. Additionally, the last (downstream) 4 miles of the reach has been channelized and is also known as State Ditch 95. The reach has a total subwatershed area of 326 square miles (USGS, 2016). The subwatershed contains 194 miles of intermittent drainage ditch, 50 miles of intermittent stream, 31 miles of perennial drainage ditch, 11 miles of river, and 2 miles of perennial stream (DNR, 2003). According to the MPCA (2013), 87% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 70% of AUID 506. The NLCD 2011 (USGS, 2011) lists cultivated crops (57%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (17%), forest (11%), hay/pasture (9%), and developed (4%).

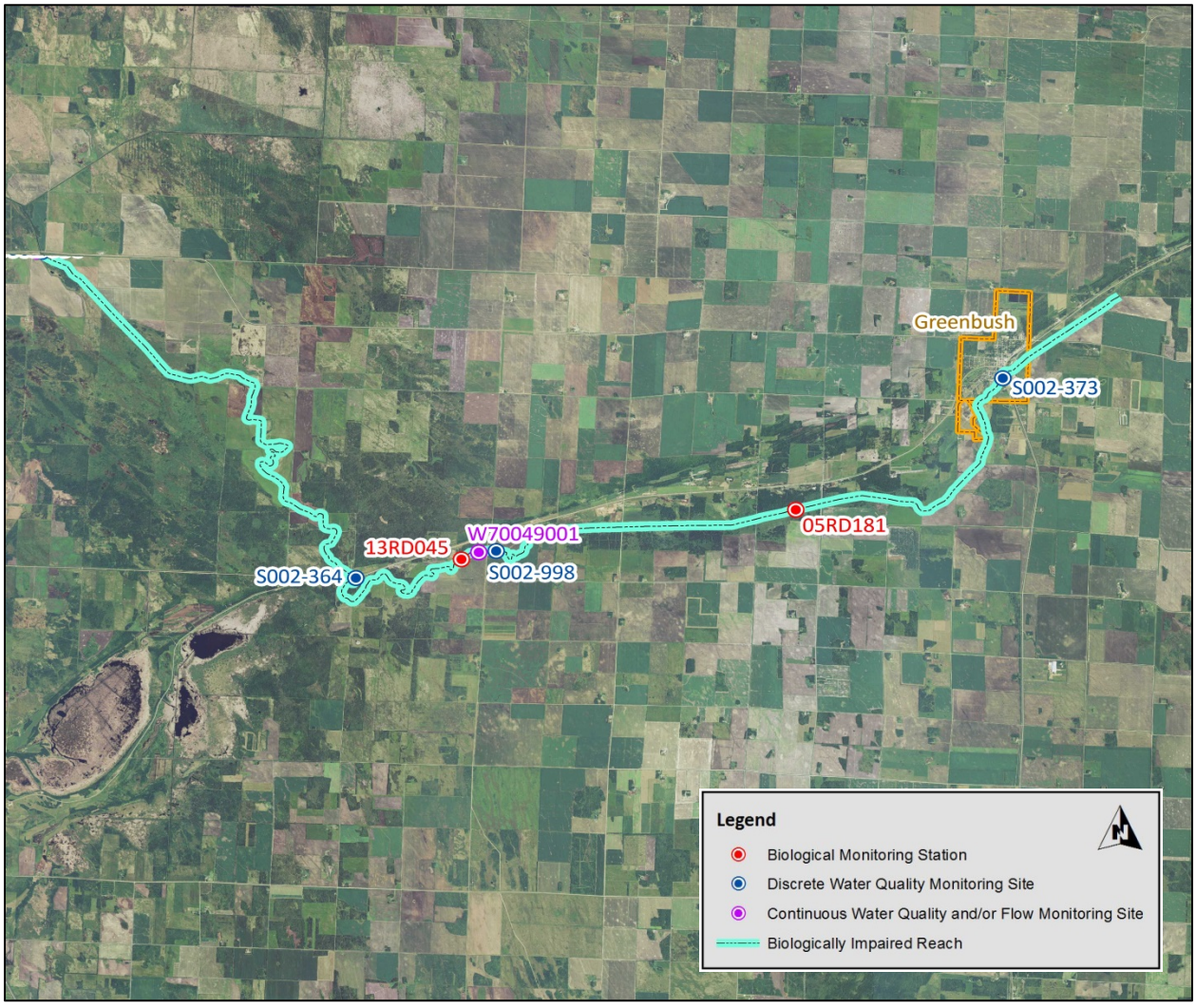
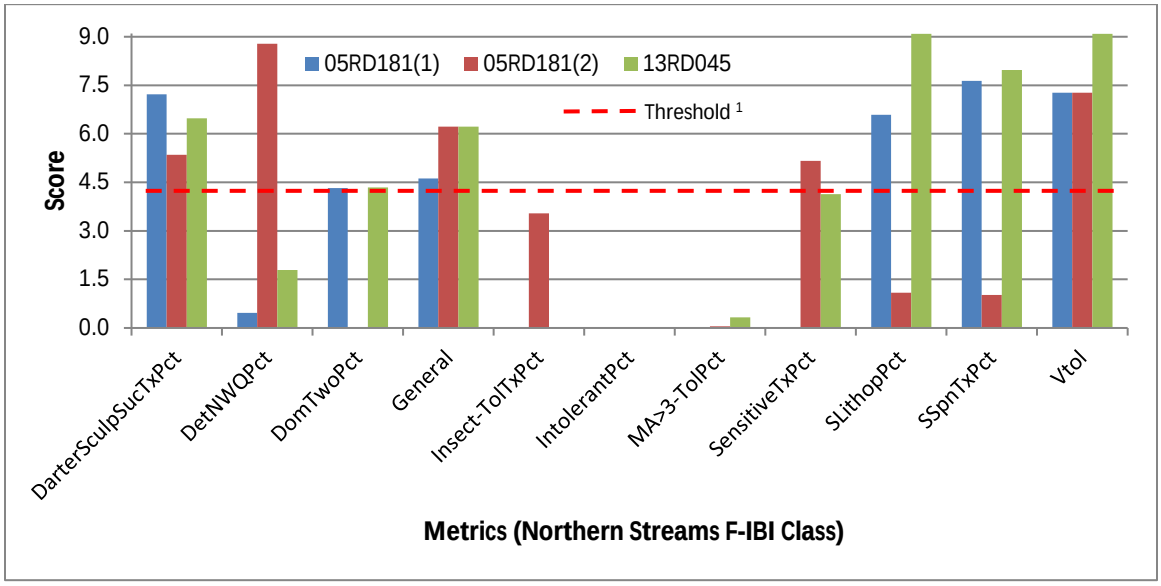


Figure 37. Map of AUID 506 and associated biological monitoring stations and water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 506 was monitored at Station 05RD181 (0.4 mile downstream of the CSAH 29 crossing) on June 19, 2006(1) and June 11, 2014(2); and Station 13RD045 (0.4 mile downstream of the County Road (CR) 105 crossing) on July 15, 2013. The relative location of the stations is shown in Figure 37. Both stations were designated as General Use within the Northern Streams F-IBI Class. The impairment threshold for the stations is an F-IBI score of 47. Station 05RD181 (F-IBI=38 and 38) scored below the impairment threshold, while Station 13RD045 (F-IBI=49) scored slightly above the threshold. According to Figure 38, eight individual metrics for Stations 05RD181 and/or 13RD045 scored below the mean value needed to meet the impairment threshold (i.e., DetNWQPct, DomTwoPct, Insect-TolTxPct, IntolerantPct, MA>3-TolPct, SensitiveTxPct, SLithopPct, and SSpnTxPct). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the stations was largely dominated by tolerant taxa, specifically common shiner, johnny darter, and white sucker.



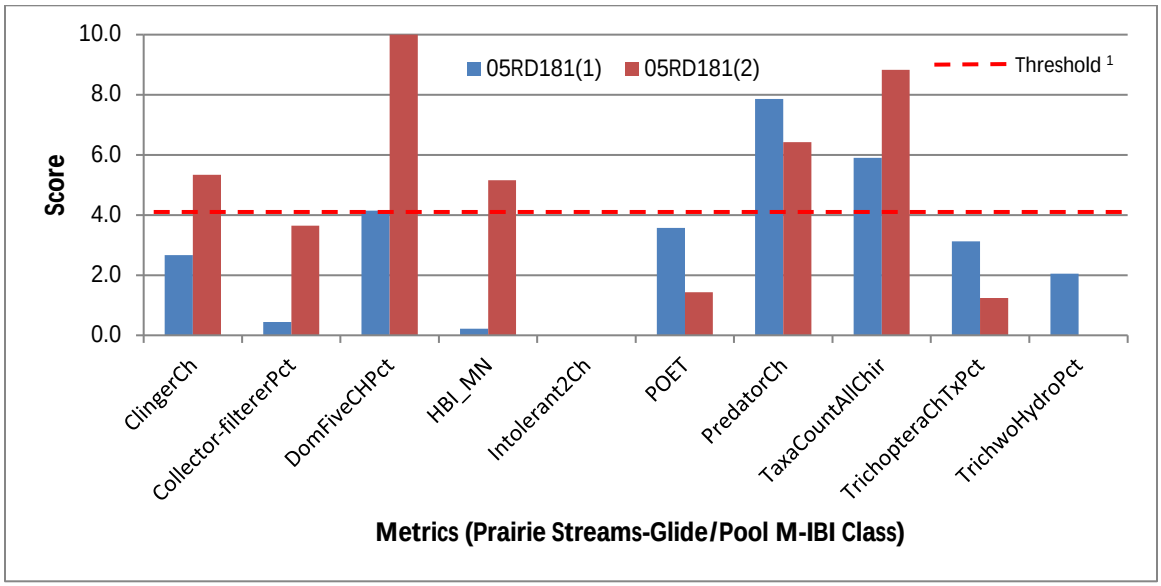
[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 38. Individual F-IBI metric scores for Stations 05RD181 and 13RD045 along AUID 506.

Macroinvertebrate (M-IBI)

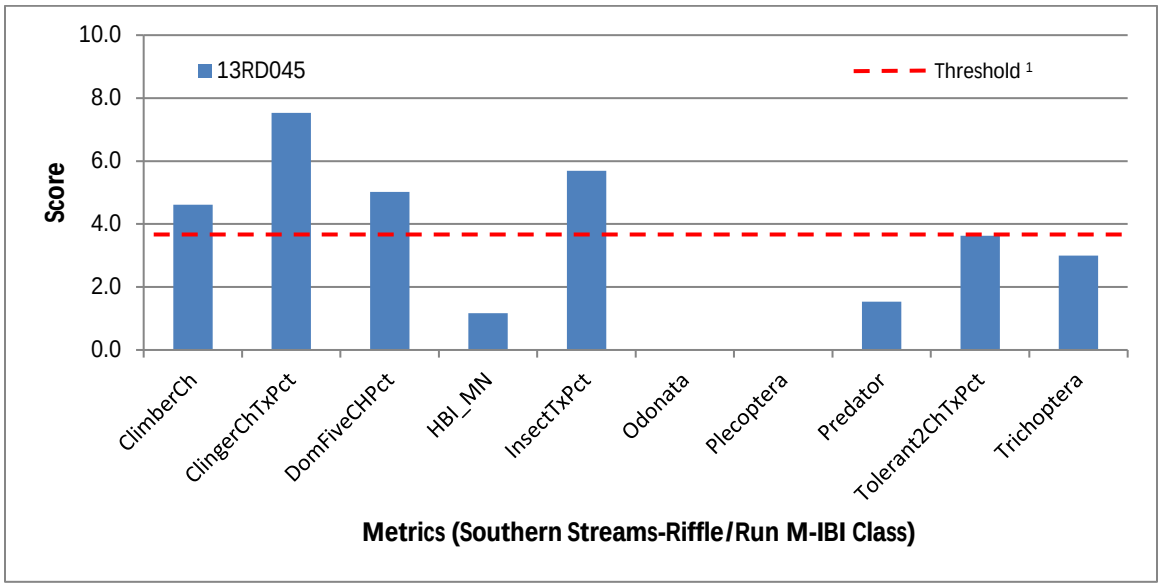
The macroinvertebrate community of AUID 506 was monitored at Station 05RD181 on August 16, 2006(1) and September 3, 2014(2); and Station 13RD045 on July 29, 2013. Station 05RD181 was designated as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. The impairment threshold for the station is an M-IBI score of 41. Station 13RD045 was designated as General Use within the Southern Streams-Riffle/Run Habitats M-IBI Class. Accordingly, the impairment threshold for this station is an M-IBI score of 37. Station 05RD181 (M-IBI=30 and 42) had one score below its respective impairment threshold, while Station 13RD045 (M-IBI=32) scored below its threshold. According to Figure 39, seven individual metrics for Station 05RD181 scored below the mean value needed to meet the impairment threshold (i.e., ClingerCh, Collector-filtererPct, HBI_MN, Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct). Additionally, six individual metrics for Station 13RD045 (Figure 40) had such a substandard score (i.e., HBI_MN, Odonata, Plecoptera, Predator, Tolerant2ChTxPct, and Trichoptera). A description of each metric is provided in the *Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA,

2014b). The macroinvertebrate assemblage of the stations was dominated by tolerant taxa, specifically, *Dicrotendipes* (midges), *Physa* (snails), *Physella* (snails), and *Polypedilum* (midges).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 39. Individual M-IBI metric scores for Station 05RD181 along AUID 506.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 40. Individual M-IBI metric scores for Station 13RD045 along AUID 506.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff noted a beaver dam upstream of Station 05RD181 at the time of the June 11, 2014, fish monitoring visit. According to the DNR (2014), there are no man-made dams on the reach. However, the Lake Bronson Dam and Hallock Dam are located downstream of the reach along the South Branch Two Rivers (AUID 502) and are barriers to connectivity. On October 7, 2014, MPCA monitoring staff noted a beaver dam along the reach immediately upstream of the CSAH 10 crossing. On

September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of May 8, 2013, and September 1, 2013, aerial photos (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photos.

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 506 is provided by the following metric response (Appendix A):

- Below basin class average (<5%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 05RD181(1) (0%), 05RD181(2) (0%), and 13RD045 (1%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Lake Bronson Dam and Hallock Dam on the fish community of the South Branch Two Rivers is discussed in Subsection 3.3.1 (AUID 502).

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 506. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to the TRWD (2004), the reach has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge. The MPCA biological monitoring staff encountered lentic conditions at Station 13RD045 during an August 28, 2012, reconnaissance visit (Figure 41). There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 7 and 17% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., July 22, 2015, August 4, 2015, and September 23, 2015) and documented flow conditions. Lentic condition were noted at the State Highway 32 crossing (Figure 41) in Greenbush on September 23, 2015. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

Figure 41. Photos of lentic conditions along AUID 506, including Station 13RD045 on August 28, 2012 (left) and the State Highway 32 crossing on September 23, 2015 (right).

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 506 is provided by the following metric responses (Appendix A):

- Above basin class average (>60%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Station 05RD181(2) (83%)
- Above basin class average (>33%) relative abundance of taxa that are generalists (GeneralTxPct) at Stations 05RD181(1) (56%) and 13RD045 (40%)
- Above basin class average (>83%) relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct) at Station 05RD181(2) (98%)
- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD045 (0.34)
- Above basin class average (>17%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 05RD181(1) (33%) and 13RD045 (20%)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Stations 05RD181(1) (0%) and 13RD045 (20%)
- Above basin class average (>28%) relative abundance of individuals that are short-lived (SLvdPct) at Stations 05RD181(1) (31%) and 05RD181(2) (76%)
- Above basin class average (>50%) relative abundance of individuals that are tolerant (TolPct) at Stations 05RD181(1) (68%) and 13RD045 (63%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

Evidence of a causal relationship between flow regime instability and the M-IBI impairment associated with AUID 506 is provided by the following metric responses (Appendix B):

- Below basin class average (<5/4%) relative abundance of long-lived individuals (LongLivedPct) at Stations 05RD181(2) (1%) and 13RD045 (1%)
- Above basin class average (>13%) relative abundance of swimmer taxa (SwimmerChTxPct) at Station 05RD181(2) (18%)

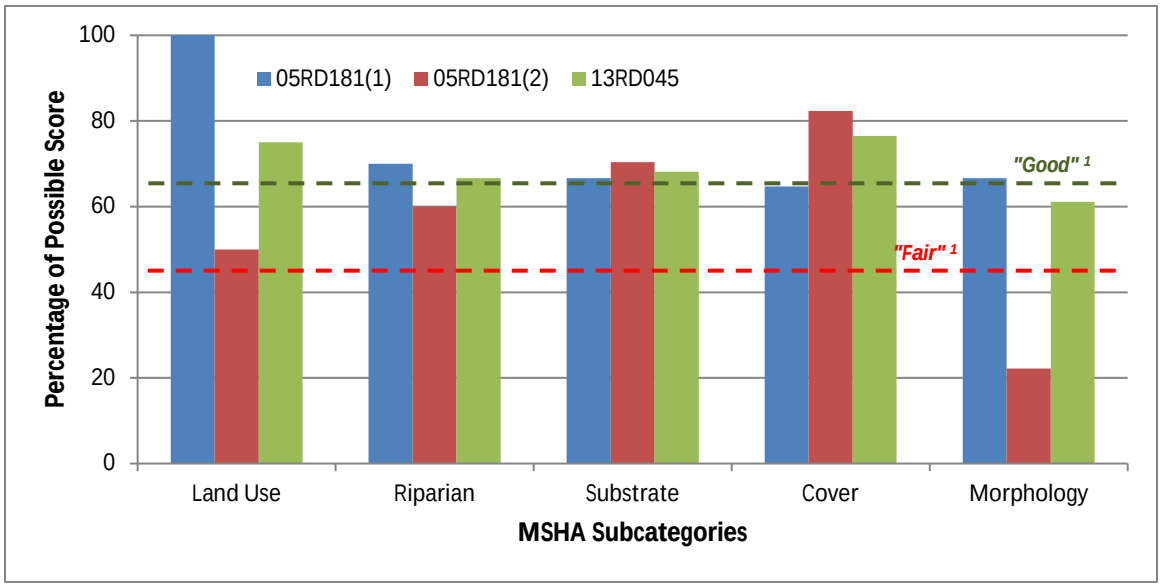
Flow regime instability tends to limit macroinvertebrate diversity and favor taxa that are shorter-lived, swimmers, and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012b). Overall, the macroinvertebrate assemblage of the stations was dominated by taxa that are adapted to lentic conditions (e.g., *Dicrotendipes and Physa*).

Insufficient physical habitat

Available data

The physical habitat of AUID 506 was evaluated at Stations 05RD181 and 13RD045 using the MSHA. Station 05RD181 is located along a channelized segment of the reach, while Station 13RD045 is situated along a natural segment of the reach (MPCA, 2013). Station 05RD181 yielded scores of 69 (“good”) and 53 (“fair”), while Station 13RD045 had a score of 67 (“good”). Figure 42 displays the MSHA subcategory results for the stations. Station 05RD181(2) had a low score in the land use subcategory due to the predominance of agricultural row crops in the vicinity of the station. Both stations had a “wide” to “extensive” riparian zone width; however, a “moderate” level of bank erosion was noted at Station 05RD181(2). The stations scored uniformly well in the substrate subcategory, offering both riffle habitat and coarse substrate (e.g., cobble and gravel). A “moderate” level of embeddedness was noted at

Station 05RD181(1). The stations also scored well in the cover subcategory due to the diversity and "moderate" amount of cover present. Common cover types noted along the reach included boulders, macrophytes (submergent), overhanging vegetation, undercut banks, and woody debris. Lastly, the stations shared many of the channel morphology characteristics, including "moderate/high" to "high" channel stability. However, the subcategory score for Station 05RD181(2) was adversely affected by "poor" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is somewhat limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 42. MSHA subcategory results for Stations 05RD181 and 13RD045 along AUID 506.

On October 21, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 05RD181 along AUID 506 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 05RD181] was 82. The entrenchment ratio (flood-prone width compared to the bankfull width) was 1.99, which classifies this channel as a B stream type. Naturally-formed B stream channels occur in soils derived from grussic granite, wind-deposited sands, and loose, unconsolidated sediments. The channel is currently maintained as a B stream type through ditch maintenance practices. Even though the entrenchment ratio places this site in a B stream type, it functions more like a F5 than a B5. With a Pfankuch rating of 82, this site, as a stable F5. A good, or stable, rating for F5 stream types is 90-115. If channel evolution was allowed to occur, this watercourse would probably move towards an E5 stream type. E5 stream types are considered moderately unstable with a score of 82. The individual Pfankuch ratings ranged from excellent to poor. The factors ranking higher (more unstable) included very steep upper banks, the channel was incised and significant cutting along the lower banks. The factors ranking lower (more stable) were no debris jam potential on the upper banks and abundant aquatic vegetation on the channel bottom."*

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 506 is provided by the following metric responses (Appendix A):

- Above basin class average (>20%) relative abundance of individuals that are detritivorous (DetNWQPct) at Stations 05RD181(1) (48%) and 13RD045 (41%)
- Below basin class average (<8%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 05RD181(1) (0%), 05RD181(2) (1%), and 13RD045 (0%)
- Below basin class average (<33%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Stations 05RD181(1) (22%) and 13RD045 (20%)
- Below basin class average (<14%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Stations 05RD181(1) (11%), 05RD181(2) (8%), and 13RD045 (10%)
- Below basin class average (<37%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 05RD181(2) (9%)

Insectivores and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

Biotic response – macroinvertebrate

Evidence of a causal relationship between insufficient physical habitat and the M-IBI impairment associated with AUID 506 is provided by the following metric responses (Appendix B):

- Above basin class average (>14%) relative abundance of burrowers (BurrowerPct) at Stations 05RD181(1) (16%) and 05RD181(2) (16%)
- Below basin class average (<22%) relative percentage of clinger taxa (ClingerChTxPct) at Stations 05RD181(1) (16%) and 05RD181(2) (20%)
- Above basin class average (>52/53%) relative abundance of legless individuals (LeglessPct) at Stations 05RD181(1) (55%), 05RD181(2) (59%), and 13RD045 (58%)
- Above basin class average (>20%) relative abundance of sprawler taxa (SprawlerChTxPct) at Station 05RD181(1) (25%)

Clinger taxa require clean, coarse substrate or other objects to attach themselves to, while burrower, legless, and sprawler macroinvertebrates are tolerant of degraded benthic habitat.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD181 and 13RD045 along AUID 506 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. Station 05RD181 had TSS concentrations of 4 and 46 mg/L, while Station 13RD045 had a concentration of 7 mg/L. Table 22 summarizes all available discrete TSS data for Sites S002-364 (State Highway 11 crossing), S002-373 (Old Highway 32 crossing), and S002-998 (CR 105 crossing); the relative location of these sites is shown in Figure 37. Site S002-364 had three TSS values that exceeded the 30 mg/L Central River TSS Region standard, while Site S002-373 had one such value. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the standard 2% of the time during the period of 1996 to 2009. The aforementioned MSHA results indicate that the deposition of excess fine sediment caused the "moderate" level of embeddedness of coarse substrate documented at Station 05RD181. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Table 22. Discrete TSS data for Sites S002-364, S002-373, and S002-998 along AUID 506.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S002-364	1991-2002	30	1	247	14	3
S002-373	2009-2011	24	1	60	5	1
S002-998	2002	5	1	16	6	0

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 506. None of the metrics or related data for Stations 05RD181 and 13RD045 (Appendix A) exhibited a correlation to this candidate cause.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 506 is provided by the following metric and data responses (Appendix B):

- Below basin class average (<16/9%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Station 05RD181(1) (2%) and 13RD045 (10%)
- Above basin class average (>22 mg/L) mean TSS TIV at Station 05RD181(1) (25 mg/L) and 05RD181(2) (25 mg/L)
- Above basin class average (>21%) relative abundance of high TSS tolerant individuals at Station 13RD045 (40%)
- Below basin class average (<2) taxa richness of high TSS intolerant macroinvertebrates at Station 05RD181(1) (1)

Collector-filterers utilize specialized mechanisms (e.g., silk nets) to strain organic material from the water column. High suspended sediment can interfere with these mechanisms (Arruda et al., 1983; Barbour et al., 1999; Lemley, 1982; Strand and Merritt, 1997).

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a combined five discrete DO measurements at Stations 05RD181 and 13RD045 along AUID 506 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 7.0 to 13.0 mg/L. Figure 43 displays all available discrete DO data for Sites S002-364 (1991-2003; *n*=51), S002-373 (2000-2011; *n*=43), and S002-998 (2000-2011; *n*=12); the relative location of these sites is shown in Figure 37. Collectively, 8% of the DO values for the sites were below the 5.0 mg/L standard; however, one of the measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. The MPCA conducted continuous DO monitoring at Site W70049001 (CR 105 crossing) from July 22, 2015, to August 4, 2015; the relative location of the site is shown in Figure 37. The monitoring results are provided in Table 23, as well as displayed in Figure 44. None of the DO measurements within the monitoring period were below the standard. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard between 3 and 17% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences occasional periods of low DO.

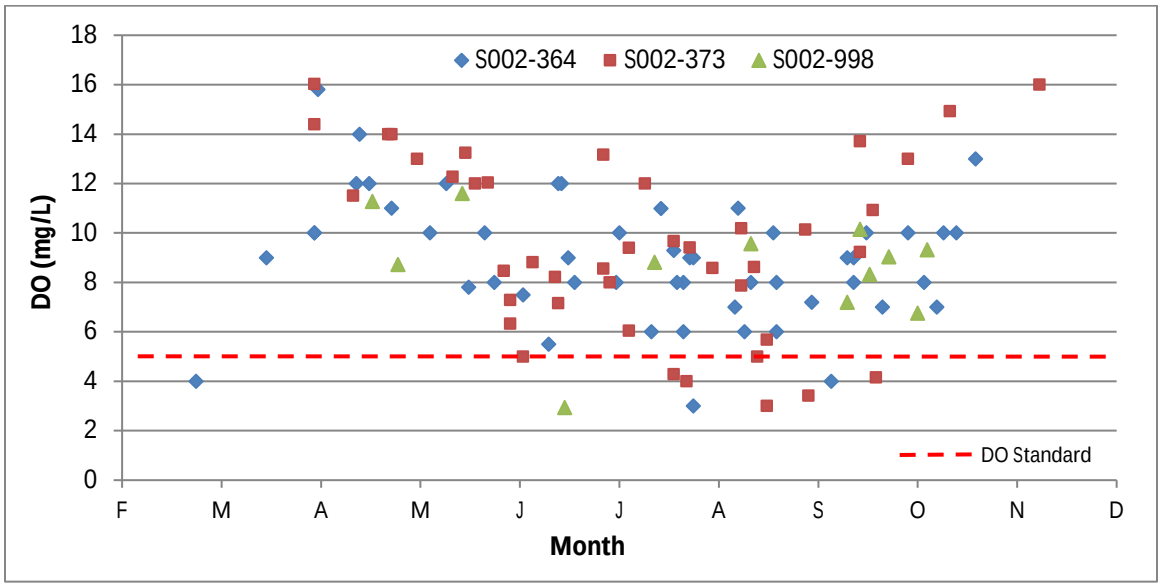


Figure 43. Discrete DO data for Sites S002-364, S002-373, and S002-998 along AUID 506.

Table 23. Continuous DO data for Site W70049001 along AUID 506.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 22, 2015 – August 4, 2015	1211	5.3	10.0	0	0	2.7

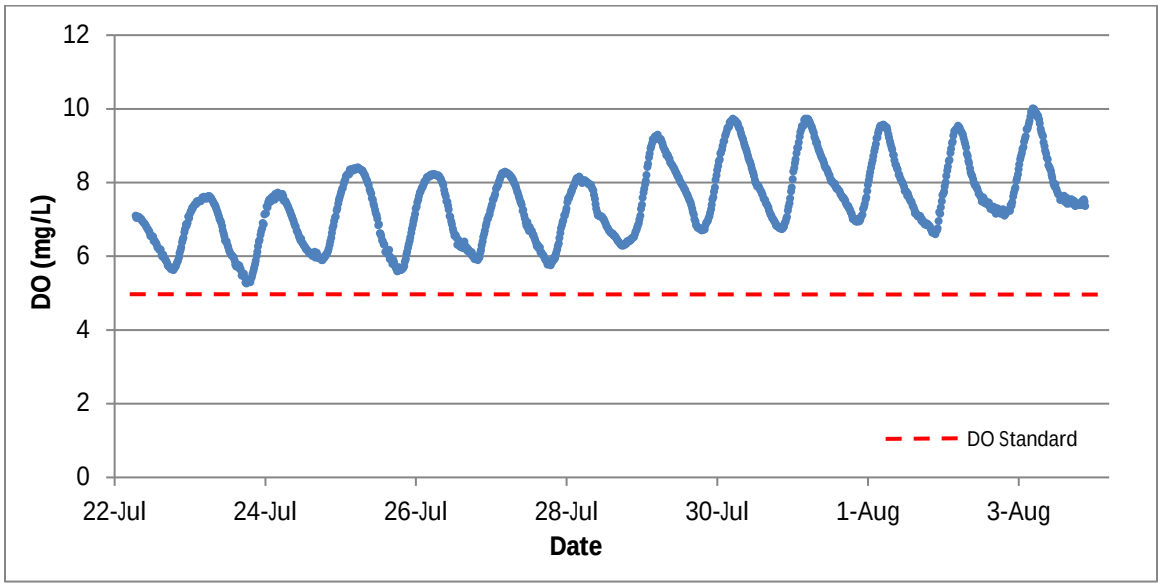


Figure 44. Continuous DO data for Site W70049001 along AUID 506.

Eutrophication-related data for the reach is limited to the following parameters: TP and DO flux. Discrete TP data are available for Sites S002-364 (1991-2002; n=30), S002-373 (2009-2010; n=10), and S002-998 (2000-2002; n=10). Collectively, the mean TP concentration for the sites was 84 µg/L, while the highest concentration was 330 µg/L and the lowest concentration was 5 µg/L. Approximately 24% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. The mean daily DO flux

documented during continuous DO monitoring at Site W70049001 (Table 23) was 2.7 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff observed signs of eutrophication (i.e., excessive algal growth) at the State Highway 32 crossing along the reach on September 23, 2015 (Figure 41). Overall, the limited available data suggest that eutrophication may be adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 506 is provided by the following metric responses (Appendix A):

- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD045 (0.34)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Stations 05RD181(1) (0%) and 13RD045 (20%)
- Above basin class average (>50%) relative abundance of individuals that are tolerant (TolPct) at Stations 05RD181(1) (68%) and 13RD045 (63%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 506 is provided by the following metric and data responses (Appendix B):

- Above basin class average (>7/8) Hilsenhoff's Biotic Index value (HBI_MN) at Stations 05RD181(1) (9) and 13RD045 (8)
- Below basin class average (<6) taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET) at Station 05RD181(2) (4)
- Below basin class average (<6.4 mg/L) mean DO TIV at Station 05RD181(2) (5.3 mg/L)
- Above basin class average (>34%) relative abundance of low DO tolerant individuals at Station 05RD181(1) (37%)
- Below basin class average (<2) taxa richness of low DO intolerant macroinvertebrates at Stations 05RD181(1) (1) and 05RD181(2) (1)

Low DO often limits the taxa richness of macroinvertebrates, particularly members of the orders Plecoptera, Odonata, Ephemeroptera, and Trichoptera, and favors taxa that are tolerant (Weber, 1973; EPA, 2012b).

Strength-of-evidence analysis

Table 24 presents a summary of the SOE scores for the candidate causes associated with AUID 506. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, and to a lesser extent, insufficient physical habitat. Additionally, the evidence indicates that the M-IBI impairment is likely the result of several stressors marginally affecting the community, including flow regime instability, insufficient physical habitat, and high suspended sediment. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 24. SOE scores for candidate causes associated with AUID 506.

Types of evidence	SOE scores per candidate cause[1]									
	Loss of longitudinal connectivity		Flow regime instability		Insufficient physical habitat		High suspended sediment		Low dissolved oxygen	
	Biological impairments									
	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI
Types of evidence that use data from the case										
Spatial/temporal co-occurrence	++	--	++	+	+	+	0	+	0	0
Temporal sequence	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response relationship	++	--	++	+	+	+	0	+	0	0
Causal pathway	++	--	++	+	+	+	0	+	0	0
Evidence of exposure/bio-mechanism	++	--	++	+	+	+	0	+	0	0
Manipulation of exposure	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Symptoms	++	--	++	+	+	+	0	+	0	0
Types of evidence that use data from elsewhere										
Mechanistically plausible cause	+	-	+	+	+	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response in field studies	++	NE	++	++	++	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Multiple lines of evidence										
Consistency of evidence	**++**	**--**	**++**	**+**	**+**	**+**	**0**	**+**	**0**	**0**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.6 North Branch Two Rivers (AUID 508)

Physical setting

This reach represents the segment of the North Branch Two Rivers from its confluence with CD 22, to its confluence with the Two Rivers (Figure 45); a total length of 22 miles. The reach has a subwatershed area of 380 square miles (USGS, 2016). The subwatershed contains 126 miles of intermittent stream, 103 miles of intermittent drainage ditch, 69 miles of perennial drainage ditch, 61 miles of river (e.g., AUID 508), and 4 miles of perennial stream (DNR, 2003). According to the MPCA (2013), 64% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded); AUID 508 is considered natural. The NLCD 2011 (USGS, 2011) lists cultivated crops (65%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (18%), forest (9%), developed (4%), and hay/pasture (2%).

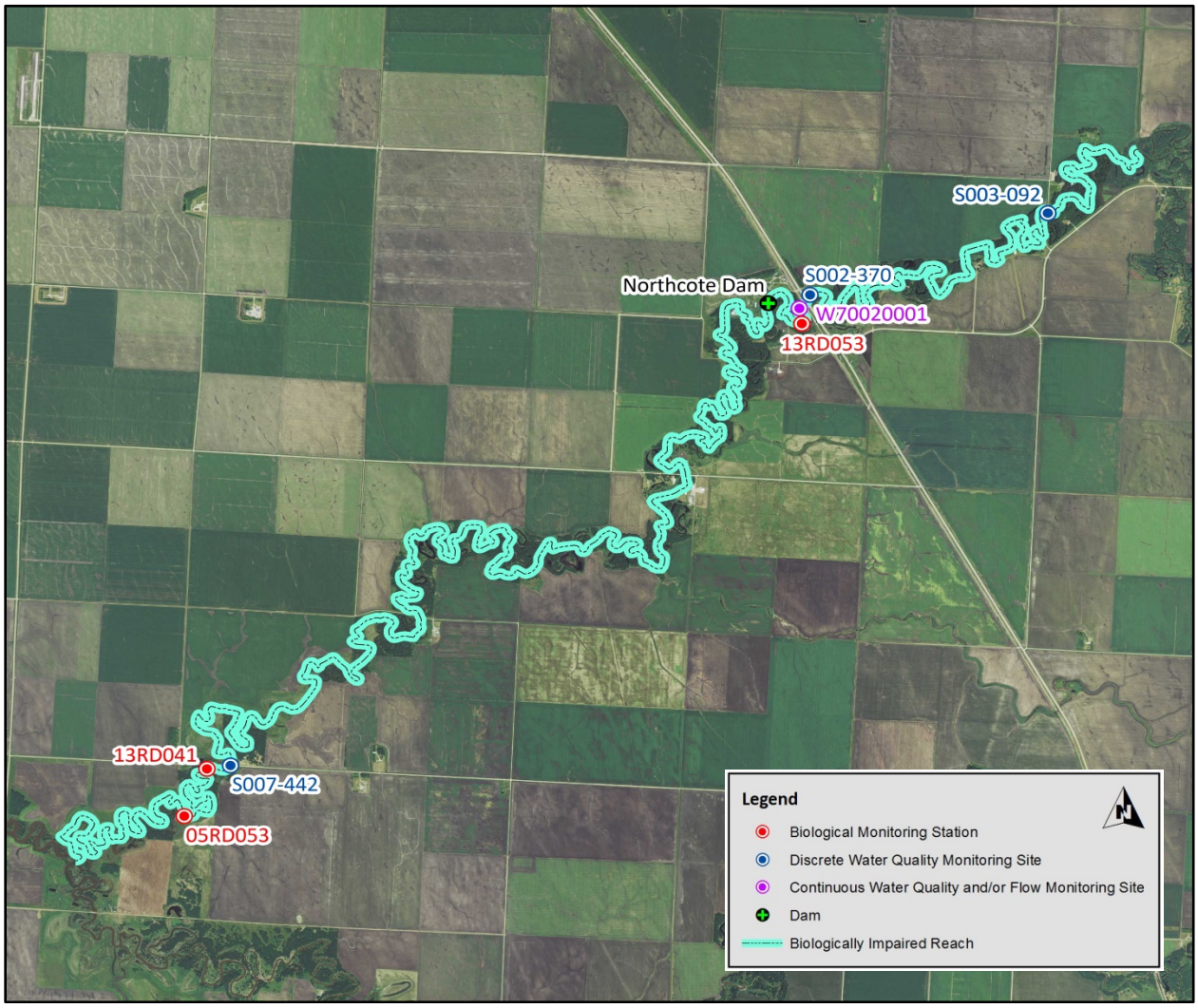
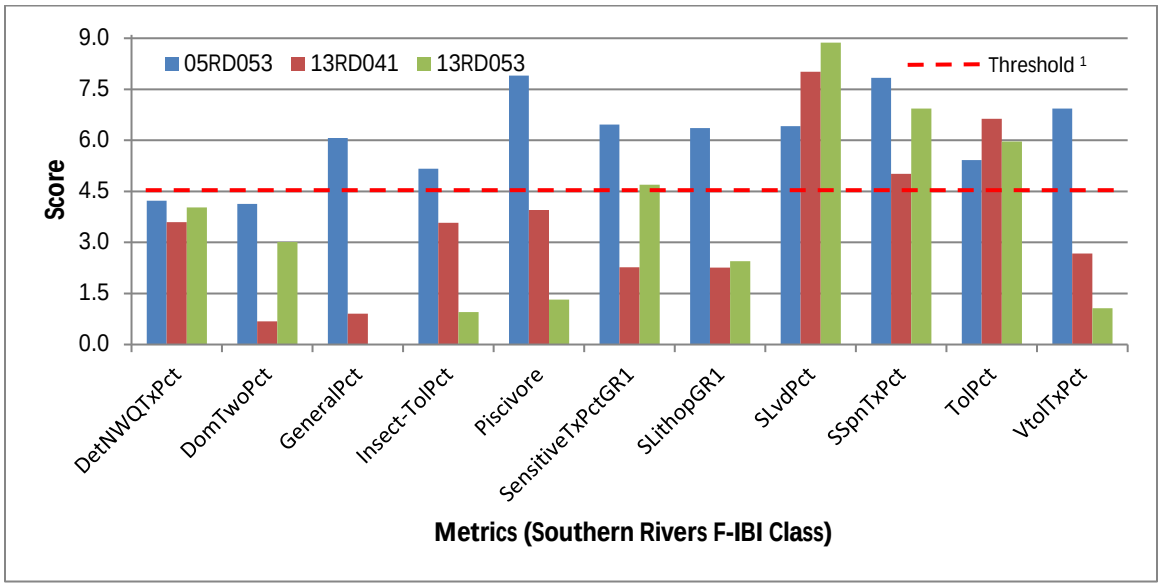


Figure 45. Map of AUID 508 and associated biological monitoring stations and water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 508 was monitored at Station 05RD053 (1.2 mile downstream of the CR 58 crossing) on June 27, 2006; Station 13RD041 (0.2 mile downstream of the CR 58 crossing) on July 16, 2013; and Station 13RD053 (0.2 mile downstream of the US Highway 75 crossing) on July 9, 2013. The relative location of the stations is shown in Figure 45. The stations were designated as General Use within the Southern Rivers F-IBI Class. Accordingly, the impairment threshold for the stations is an F-IBI score of 49. Stations 13RD041 (F-IBI=40) and 13RD053 (F-IBI=39) scored below the impairment threshold, while Station 05RD053 (F-IBI=67) scored above the threshold. According to Figure 46, eight individual metrics for Stations 05RD053, 13RD041, and/or 13RD053 scored below the mean value needed to meet the impairment threshold (i.e., DetNWQTxPct, DomTwoPct, GeneralPct, Insect-TolPct, Piscivore, SensitiveTxPctGR1, SLithopGR1, and VtolTxPct). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the stations was dominated by tolerant taxa, specifically common shiner and spotfin shiner.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 46. Individual F-IBI metric scores for Stations 05RD053, 13RD041, and 13RD053 along AUID 508.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff noted a beaver dam upstream of Station 13RD041 at the time of the July 16, 2013, fish monitoring visit. The Northcote Dam is located along the upstream extent of the Reach. The dam is an approximately seven-foot-high concrete structure that was constructed in the early 1900s as part of the James J. Hill bonanza farm. The structure has an associated pool and is at least a partial barrier to connectivity. Based upon aerial photo reconnaissance, a small side channel has developed around the dam that likely restores connectivity during high flow conditions. On September 30, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a

detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo.

Figure 47. Photos of the Northcote Dam along AUID 508 on April 18, 2007 (left) and September 1, 2013 (right), courtesy of Google Earth.

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 508 is provided by the following metric response (Appendix A):

- Below basin class average (<45%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 05RD053 (18%), 13RD041 (1%), and 13RD053 (15%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. According to Table 6, the collective fish assemblage of the stations sampled downstream of the Northcote Dam, which has unimpeded connectivity to the Red River of the North, included 13 species that were not sampled upstream of the dam. Many of these species were large bodied, longer-lived species that are vulnerable to extirpation by dam (e.g., channel catfish and sauger). In 2001, the DNR conducted fish sampling at several stations along the North Branch Two Rivers (Groshens et al., 2003). Of the 31 species sampled, nine species were found exclusively downstream of the Northcote dam (i.e., black crappie, brown bullhead, channel catfish, chestnut lamprey, common carp, freshwater drum, largemouth bass, sauger, and yellow perch). The sampling data indicates that the side channel around the dam has not adequately restored connectivity and the dam remains a barrier to fish passage along the North Branch Two Rivers.

Table 25. Summary of fish species sampled downstream of the Northcote Dam along the Two Rivers (AUID 509) and the North Branch Two Rivers (AUID 508), as well as those species also sampled upstream of the Northcote Dam along the North Branch Two Rivers (AUIDs 504 and 508).

Fish Species[1]	Present Downstream of the Northcote Dam[2]	Present Upstream of the Northcote Dam[3]
bigmouth buffalo	**X**	
bigmouth shiner	X	
black bullhead	X	X
blackside darter	X	X
burbot	X	X
channel catfish	**X**	
chestnut lamprey	X	X
common carp	X	X
common shiner	X	X
creek chub	X	X
emerald shiner	**X**	
fathead minnow	X	X
freshwater drum	**X**	
golden redhorse	X	X
goldeye	**X**	
johnny darter	X	X
northern pike	X	X
northern redbelly dace	X	X
river shiner	**X**	
rock bass	X	X
sand shiner	X	X
sauger	**X**	
shorthead redhorse	X	
silver chub	**X**	
silver redhorse	**X**	**X**
spotfin shiner	X	X
stonecat	X	X
tadpole madtom	X	X
trout-perch	X	
walleye	X	
white bass	**X**	
white sucker	X	X
yellow perch	X	X

[1] Species highlighted red are those designated by Aadland (2015) as "vulnerable" and "most vulnerable" to extirpation by barrier dams.

[2] Stations 05RD053 and 13RD041 along AUID 508, as well as Station 05RD004 along AUID 509

[3] Stations 93RD403, 05RD094, 13RD070, and 13RD089 along AUID 504, as well as Station 13RD053 along AUID 508

Flow regime instability

Available data

According to the TRWD (2004), the reach has a "flashy" flow regime, with high and quick peak flows, along with prolonged periods of low or no discharge. Overflow from the Roseau River Watershed often exacerbates this condition (TRWD, 2004). The MPCA biological monitoring staff did not encounter any flow-related issues during the sampling of Stations 05RD053, 13RD041, and 13RD053. There is no flow monitoring data for the reach. However, continuous flow monitoring data for Site H70021001, which is located directly upstream of the reach (AUID 504), suggests that the North Branch Two Rivers has an unstable flow regime. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 11 and 12% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, August 26, 2015, and September 30, 2015) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach is prone to extreme peak flows, as well as extended periods of minimal to no flow.

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 508 is provided by the following metric responses (Appendix A):

- Above basin class average (>54%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 05RD053 (55%), 13RD041 (72%), and 13RD053 (60%)
- Above basin class average (>26%) relative abundance of taxa that are generalists (GeneralTxPct) at Stations 13RD041 (44%) and 13RD053 (40%)
- Above basin class average (>47%) relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct) at Stations 05RD053 (68%), 13RD041 (91%), and 13RD053 (59%)
- Below basin class average (<0.37) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD053 (0.12)
- Above basin class average (>7%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 05RD053 (18%), 13RD041 (13%), and 13RD053 (10%)
- Above basin class average (>10%) relative abundance of individuals that are short-lived (SLvdPct) at Station 05RD053 (18%)
- Above basin class average (>25%) relative abundance of individuals that are tolerant (TolPct) at Stations 05RD053 (36%), 13RD041 (26%), and 13RD053 (32%)

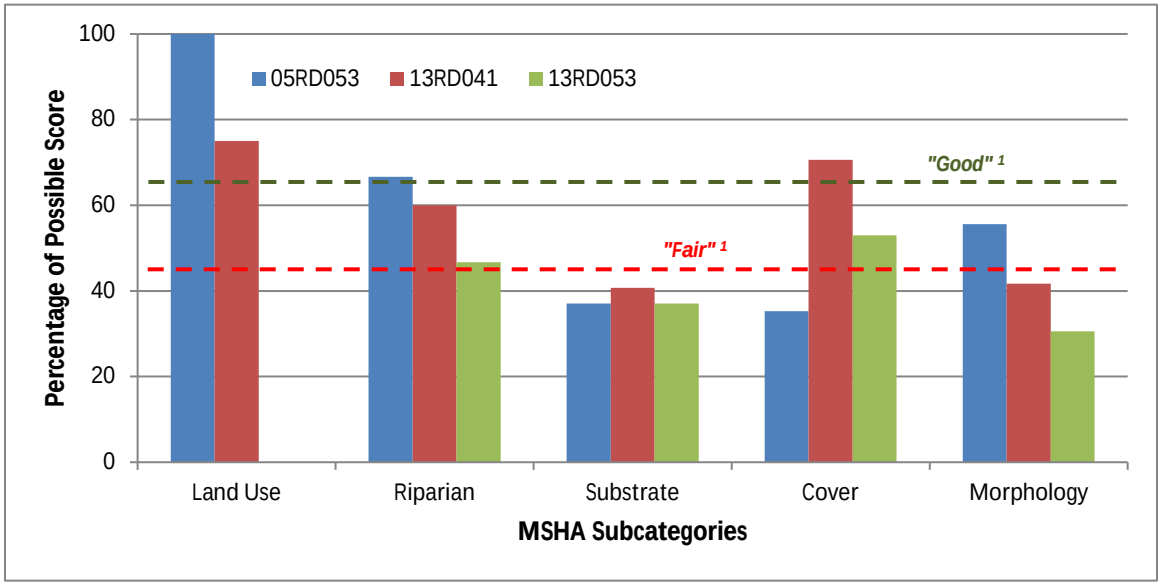
Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 508 was evaluated at Stations 05RD053, 13RD041, and 13RD053 using the MSHA. The stations are located along natural segments of the reach (MPCA, 2013). Station 13RD053 (37/"poor"), which is located along the upstream extent of the reach, scored slightly lower than Stations 05RD053 (51/"fair") and 13RD041 (51/"fair"), which are situated along the downstream end of the reach. Figure 48 displays the MSHA subcategory results for the stations. Station 13RD053 had a score of zero for the land use subcategory due to the predominance of agricultural row crops in the vicinity of the station. The stations had an "extensive" riparian zone width. However, the stations also had a

"moderate" to "heavy" level of bank erosion. The stations scored uniformly poor in the substrate subcategory due to a lack of riffle habitat and coarse substrate (e.g., cobble and gravel). Stations 05RD053 and 13RD053 only had a "sparse" amount of cover present. Common cover types noted along the reach included boulders, deep pools, macrophytes (emergent), overhanging vegetation, undercut banks, and woody debris. Lastly, Stations 13RD041 and 13RD053 had relatively low scores in the morphology subcategory due to "low" to "moderate" channel stability and "poor" to "fair" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 48. MSHA subcategory results for Stations 05RD053, 13RD041, and 13RD053 along AUID 508.

On October 2015, DNR staff conducted a fluvial geomorphology assessment of Stations 05RD053, 13RD041, and 13RD053 along AUID 508 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 05RD053] on 10/05/2015 was 86, which is fair (moderately unstable) for a C6 stream type. A fair, or moderately unstable, rating for C6 stream types ranges from 86-105. Most of the Pfankuch categories ranked as good or fair, with only bank rock content and rock angularity ranking as poor. The upper banks are where the ratings pushed this site more towards instability. The upper banks slope was 40-60%. There were moderate to heavy amounts of downed, woody material, and the vegetative bank protection had a lower density and limited diversity. The lower banks were in good condition with some obstructions to flow and some cutting and deposition."*
>
> *"The Pfankuch rating for [Station 13RD041] on 10/05/2015 was 89, which is fair (moderately unstable) for a C6 stream type. A fair, or moderately unstable, rating for C6 stream types ranges from 86-105. The majority of the Pfankuch categories ranked as good. The upper banks (above bankfull) had a moderate slope and it appeared that some mass erosion had occurred in the past, but was mostly healed over. Downed, woody debris had accumulated on the upper banks and the vegetative bank protection had a 70-90% density. The channel appeared to be slightly incised at this location. There was some cutting and deposition on the lower banks. The substrate on the bottom of the channel was mostly loose with no apparent overlap. The channel bottom also appeared to be affected by scour and deposition."*

"The Pfankuch rating for [Station 13RD053] on 10/6/2015 was 59, which is good (stable) for an E6 stream type. A good, or stable, rating for E6 stream types ranges from 40-63. Almost all Pfankuch categories ranked as excellent or good. The upper banks were well vegetated with reed canarygrass and sporadic red osier dogwood. There was also no evidence of mass wasting in the upper banks. The water level at this site was elevated, probably due to the low dam about 2300 feet downstream. For the portion of the lower banks that was visible, they appeared to have little to no obstructions to flow, cutting, or deposition. Th7e channel was too deep to wade across, but the substrate within a couple feet of the water's edge was dominated by silt and clay particles. It was moderately packed with some overlap."

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 508 is provided by the following metric responses (Appendix A):

- Below basin class average (<24%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Stations 05RD053 (18%), 13RD041 (13%), and 13RD053 (10%)
- Below basin class average (<18%) relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPcT) at Stations 13RD041 (6%) and 13RD053 (10%)
- Above basin class average (>26%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 05RD053 (29%), 13RD041 (31%), and 13RD053 (30%)
- Below basin class average (<21%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 13RD053 (2%)
- Below basin class average (<47%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Stations 05RD053 (29%), 13RD041 (25%), and 13RD053 (40%)
- Below basin class average (<12%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Station 13RD053 (0%)
- Below basin class average (<34%) relative abundance of taxa that are simple lithophilic spawning species (SLithopTxPct) at Stations 13RD041 (31%) and 13RD053 (20%)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Stations 05RD053, 13RD041, and 13RD053 along AUID 508 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The stations had TSS concentrations ranging from 16 to 36 mg/L. Table 26 summarizes all available discrete TSS data for Sites S002-370 (US Highway 75) and S007-442 (CR 58 crossing); the relative location of these sites is shown in Figure 45. Both sites had two TSS values that exceeded the 65 mg/L Southern River TSS Region standard. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between 2 and 29% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences occasional periods of high suspended sediment.

Table 26. Discrete TSS data for Sites S002-370 and S007-442 along AUID 508.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S002-370	1991-2011	71	1	74	18	2
S007-442	2013-2014	10	10	178	48	2

Biotic response – fish

Evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 508 is provided by the following data response (Appendix A):

- Below basin class average (<13%) probability of meeting the TSS standard at Stations 05RD053 (9%) and 13RD041 (12%)

Low dissolved oxygen

Available data

The reach has an existing DO impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a discrete DO measurement at Stations 05RD053, 13RD041, and 13RD053 along AUID 508 at the time of fish monitoring. Measurement values ranged from 6.4 to 8.4 mg/L. Figure 49 displays all available discrete DO data for Sites S002-370 (1991-2011; *n*=113), S003-092 (220th Avenue crossing; 2002-2014; *n*=22), and S007-442 (2014; *n*=10); the relative location of these sites is shown in Figure 45. Collectively, 8% of the DO values for the sites were below the 5.0 mg/L standard; however, only one of the measurements were collected prior to 9:00 a.m. Generally, the lowest DO levels were in June, July, and August. The MPCA conducted continuous DO monitoring at Site H70020001 (US Highway 75 crossing) from August 12, 2015, to August 26, 2015; the relative location of the site is shown in Figure 45. The monitoring results are provided in Table 27, as well as displayed in Figure 50. While 2% of the total values were below the standard, 15% of the daily minimum values were below the standard. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard between 4 and 6% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences at least occasional periods of low DO.

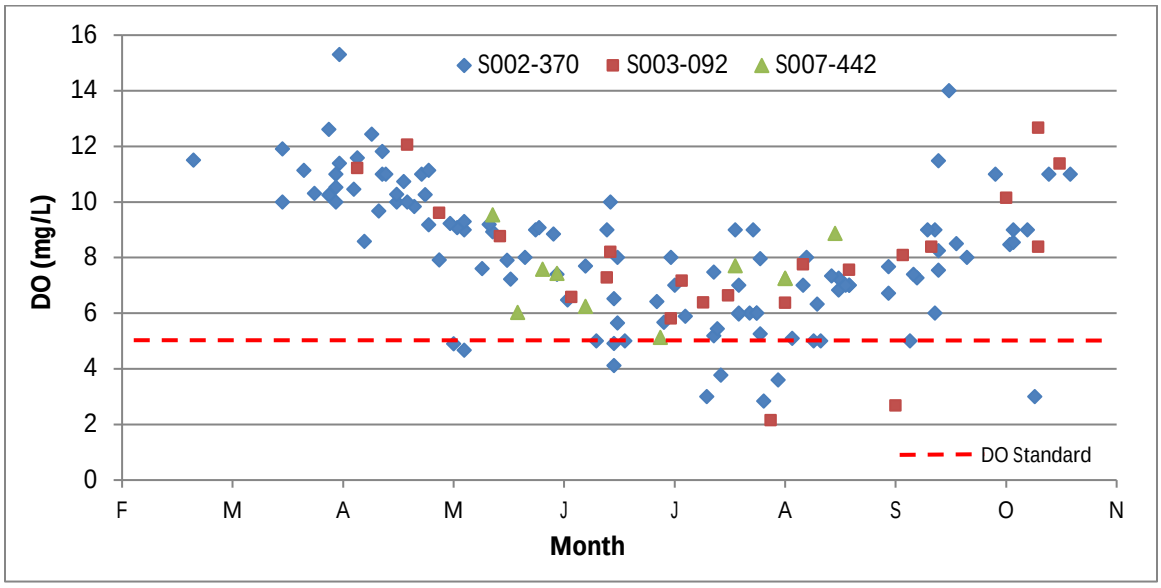


Figure 49. Discrete DO data for Sites S002-370, S003-092, and S007-442 along AUID 508.

Table 27. Continuous DO data for Site H70020001 along AUID 508.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 12, 2015 – August 26, 2015	1344	4.6	8.7	2	15	1.2

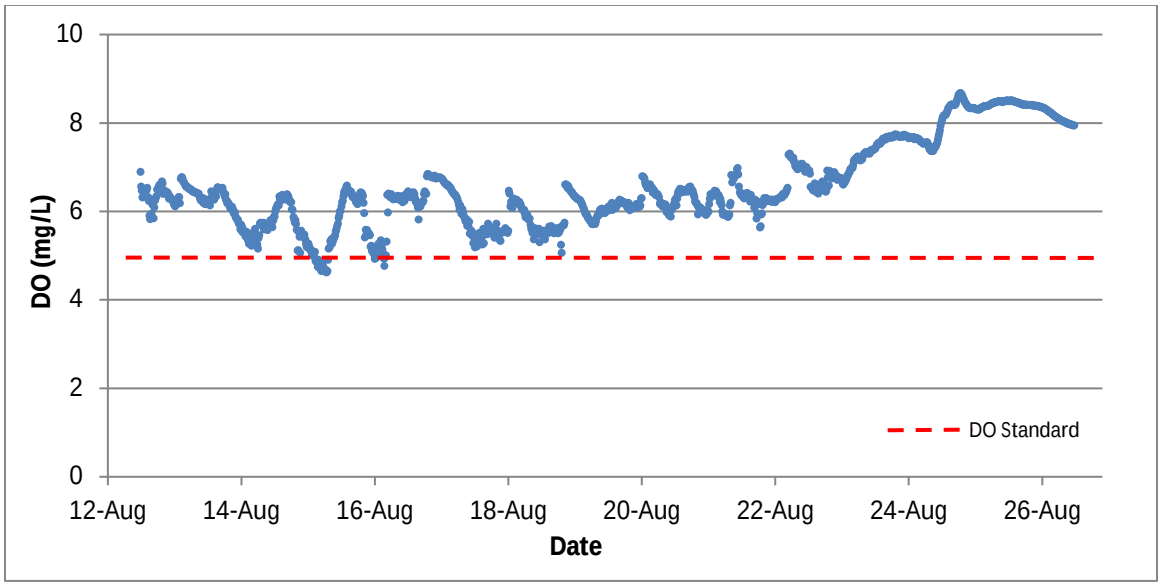


Figure 50. Continuous DO data for Site H70020001 along AUID 508.

Eutrophication-related data for the reach is limited to the following parameters: TP, Chl-a, and DO flux. Discrete TP data are available for Sites S002-370 (1991-2011; n=83) and S007-442 (2013-2014; n=10). Collectively, the mean TP concentration for the sites was 100 µg/L, while the highest concentration was 700 µg/L and the lowest concentration was 5 µg/L. Approximately 21% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. Discrete Chl-a data are also available for Site S002-370 (2009; n=8). The mean Chl-a concentration for the site was 3 µg/L, while the highest concentration was 5 µg/L and the lowest concentration was 1 µg/L. There were no exceedances of the 35 µg/L South River Nutrient Region Chl-a standard. The mean daily DO flux documented during continuous DO monitoring at Site H70020001 (Table 27) was 1.2 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., August 12, 2015, August 26, 2015, and September 30, 2015). Overall, the limited available data does not suggest that eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 508 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<0.37) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD053 (0.12)
- Above basin class average (>25%) relative abundance of individuals that are tolerant (TolPct) at Stations 05RD053 (36%), 13RD041 (26%), and 13RD053 (32%)
- Below basin class average (<7.4 mg/L) mean DO TIV at Stations 05RD053 (7.2 mg/L), 13RD041 (7.0 mg/L), and 13RD053 (6.5 mg/L)

- Below basin class average (<62%) probability of meeting the DO standard at Stations 05RD053 (59%), 13RD041 (48%), and 13RD053 (27%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Strength-of-evidence analysis

Table 28 presents a summary of the SOE scores for the candidate causes associated with AUID 508. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, low DO, and to a lesser extent, high suspended sediment. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 28. SOE scores for candidate causes associated with AUID 508.

Types of evidence	SOE scores per candidate cause[1]				
	Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
	Biological impairment				
	F-IBI	F-IBI	F-IBI	F-IBI	F-IBI
Types of evidence that use data from the case					
Spatial/temporal co-occurrence	+++	++	++	+	++
Temporal sequence	NE	NE	NE	NE	NE
Stressor-response relationship	+++	++	++	+	++
Causal pathway	+++	++	++	+	++
Evidence of exposure/bio-mechanism	+++	++	++	+	++
Manipulation of exposure	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE
Symptoms	+++	++	++	+	++
Types of evidence that use data from elsewhere					
Mechanistically plausible cause	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE
Stressor-response in field studies	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE
Multiple lines of evidence					
Consistency of evidence	**+++**	**++**	**++**	**+**	**++**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.7 State Ditch 84 (AUID 514)

Physical setting

This reach represents State Ditch 84 (Figure 51), which extends from its headwaters, to its confluence with the North Branch Two Rivers; a total length of 12 miles. The reach has a subwatershed area of 58 square miles (USGS, 2016). The subwatershed contains 19 miles of intermittent drainage ditch, six miles of perennial drainage ditch, 2 miles of intermittent stream, and 1 mile of perennial stream (DNR, 2003). According to the MPCA (2013), 96% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 514. The NLCD 2011 (USGS, 2011) lists cultivated crops (62%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (18%), forest (13%), shrub/scrub (2%), open water (2%), and developed (2%).

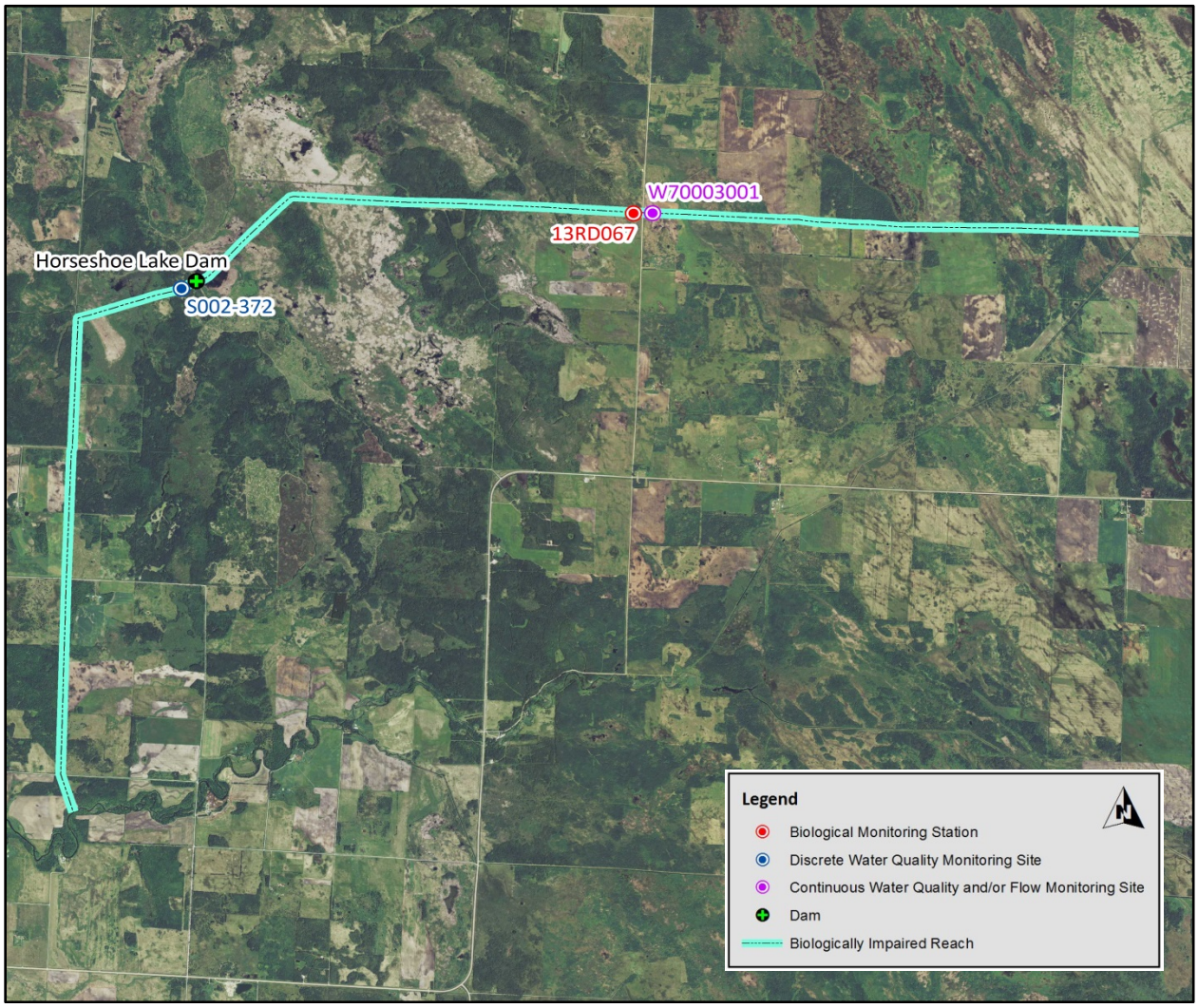
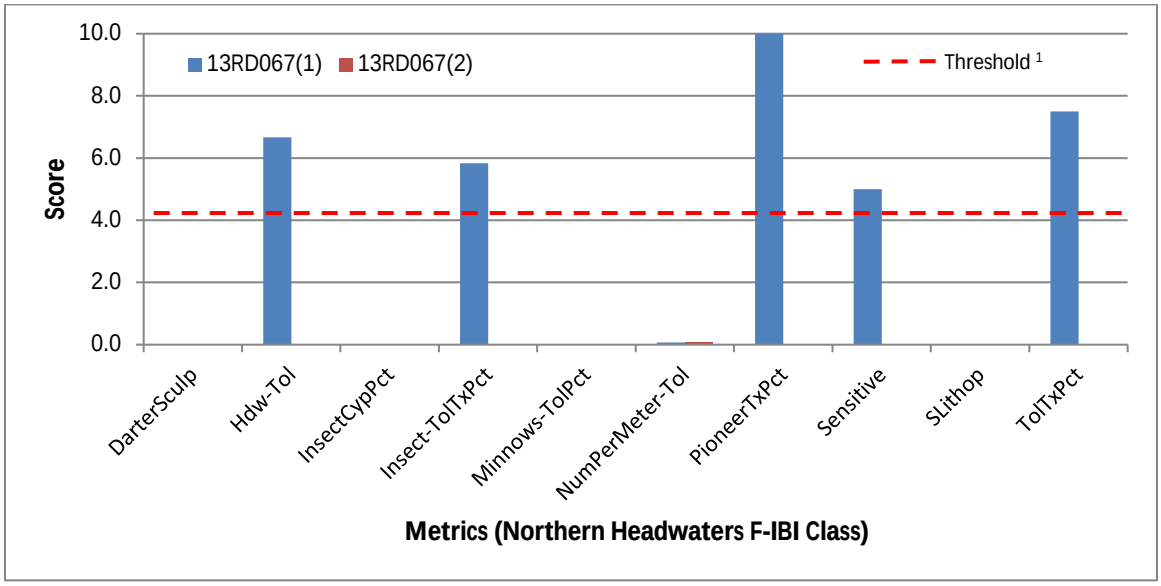


Figure 51. Map of AUID 514 and associated biological monitoring station and water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 514 was monitored at Station 13RD067 (0.1 mile downstream of the CR 51 crossing) on June 18, 2013(1) and June 10, 2014(2). The relative location of the station is shown in Figure 51. The station was designated as General Use within the Northern Headwaters F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 42. Monitoring of the station yielded F-IBI scores (35 and 0) below the impairment threshold. According to Figure 52, Station 13RD067 had at least one score for each individual metric that was below the mean value needed to meet the impairment threshold. A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the station was largely dominated by tolerant taxa, specifically brook stickleback, central mudminnow, and pearl dace.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 52. Individual F-IBI metric scores for Station 13RD067 along AUID 514.

Candidate causes

Loss of longitudinal connectivity

Available data

According to local water resource professionals in the TRW, there is a grade control structure (Figure 53) along the reach, near its confluence with the North Branch Two Rivers (MPCA, 2015). The structure is approximately 11 feet high and is a complete barrier to connectivity at all flow conditions. The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD067 along AUID 514. According to the DNR (2014), the Horseshoe Lake Dam (Figure 53) is a 15-foot-high structure situated along the reach, within the Skull Lake Wildlife Management Area. The dam is owned by the DNR and was completed in 1968 to create a reservoir for flood control, recreation, and wildlife habitat purposes. The dam is a complete barrier to connectivity at all flow conditions. Additionally, the Northcote Dam is located downstream of the reach along the North Branch Two Rivers (AUID 508) and is a barrier to connectivity. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013,

aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo.

Figure 53. Photos of connectivity barriers along AUID 514, including a grade control structure on September 1, 2013, courtesy of Google Earth (left), and the Horseshoe Lake Dam on September 23, 2015 (right).

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 514 is provided by the following metric response (Appendix A):

- Below basin class average (<1%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 13RD067(1) (0%) and 13RD067(2) (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Northcote Dam on the fish community of the North Branch Two Rivers is discussed in Subsection 3.3.6 (AUID 508).

Flow regime instability

Available data

According to D. Money, TRWD Administrator (personal communication, 2015), the reach has an intermittent flow regime and often goes dry. The MPCA biological monitoring staff did not encounter any flow-related issues during fish monitoring at Station 13RD067. There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 35 and 40% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, September 2, 2015, and September 23, 2015) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 514 is provided by the following metric responses (Appendix A):

- Above basin class average (>80%) combined relative abundance of the three most abundant taxa (DomThreePct) at Stations 13RD067(1) (89%) and 13RD067(2) (100%)
- Below basin class average (<0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD067(1) (0.01) and 13RD067(2) (0.01)
- Above basin class average (>44%) relative abundance of individuals that are short-lived (SLvdPct) at Station 13RD067(2) (67%)

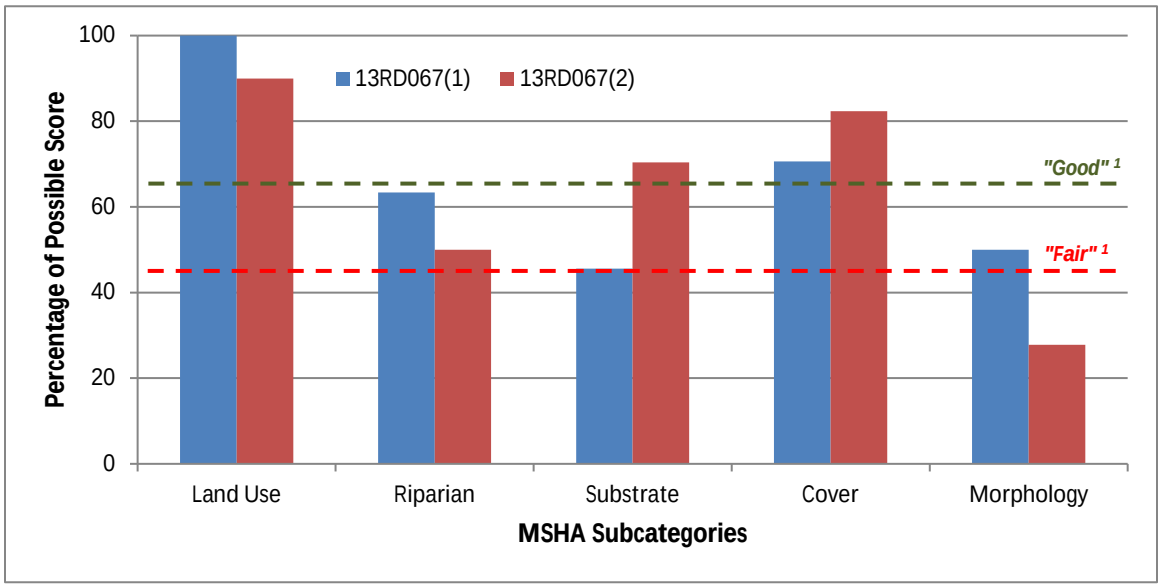
- Above basin class average (>66%) relative abundance of individuals that are tolerant (TolPct) at Stations 13RD067(1) (78%) and 13RD067(2) (67%)

Flow regime instability tends to limit species diversity and favor taxa that are short-lived and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 514 was evaluated at Station 13RD067 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded scores of 57 ("fair") and 55 ("fair"). Figure 54 displays the MSHA subcategory results for the station. The land use surrounding the station was largely natural (e.g., forest and wetlands). The riparian subcategory score for Station 13RD067(2) was adversely affected by a "narrow" riparian zone width and a "moderate" level of bank erosion. While the station offered coarse substrate (i.e., cobble and gravel) with only "light" embeddedness, there was little (5%) to no riffle habitat. The station also scored well in the cover subcategory, primarily due to the diversity and "moderate" to "extensive" amount of cover present. Cover types noted included deep pools, macrophytes (emergent and submergent), overhanging vegetation, undercut banks, and woody debris. Lastly, the station had "moderate/high" channel stability and "good" to "poor" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is somewhat limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 54. MSHA subcategory results for Station 13RD067 along AUID 514.

On October 27, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 13RD067 along AUID 514 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 13RD067] on 10/27/2015 was 60, which is good (stable) for an E5 stream type. A good, or stable, rating for E5 stream types ranges from 50-75. The factors with a higher rating (more unstable) were the increased slope of the banks above bankfull, <20% rock fragments within the lower banks, and well-rounded particles on the channel bottom. The upper banks were well vegetated with grasses and forbs, and on the right bank (looking downstream) there was an aspen windbreak set back about 40 feet from the channel. There was also no evidence of mass wasting on the upper banks. The lower banks were well vegetated with no cutting or*

deposition. Many of the channel bottom factors rated as "fair", indicating that the channel may be experiencing minor issues with either sediment supply or enough stream power to move the supplied sediment."

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 514 is provided by the following metric responses (Appendix A):

- Below basin class average (<9%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Stations 13RD067(1) (0%) and 13RD067(2) (0%)
- Below basin class average (<8%) relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPcT) at Stations 13RD067(1) (0%) and 13RD067(2) (0%)
- Below basin class average (<9%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 13RD067(2) (0%)
- Below basin class average (<13%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 13RD067(1) (11%) and 13RD067(2) (0%)
- Below basin class average (<9%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Stations 13RD067(1) (0%) and 13RD067(2) (0%)
- Below basin class average (<23%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Stations 13RD067(1) (0%) and 13RD067(2) (0%)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes (Aadland et al., 2006).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD067 along AUID 514 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The station had TSS concentrations of 4 and 5 mg/L. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L Southern River TSS Region standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 514. None of the metrics or related data for Station 13RD067 (Appendix A) exhibited a correlation to this candidate cause.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD067 along AUID 514 at the time of each fish monitoring visit (6.0 and 8.4 mg/L). Figure 55 displays all available discrete DO data for Site S002-372 (outlet of Horseshoe Lake Dam; 2000-2013; *n*=10); the relative location of the site is shown in Figure 51. None of the DO values for the site were below the 5.0 mg/L standard; however, none of the measurements were collected prior to 9:00 a.m. The MPCA conducted continuous DO monitoring at Site W70003001 (CR 51 crossing) from August 12, 2015, to September 2, 2015; the relative location of the site is shown in Figure 51. The monitoring results are provided in Table 29, as well as displayed in Figure 56. While 27% of the total values were below the standard, 75% of the

daily minimum values were below the standard. A large storm event (≈4") interrupted the diurnal pattern on and after August 22, 2015. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard between 25 and 38% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

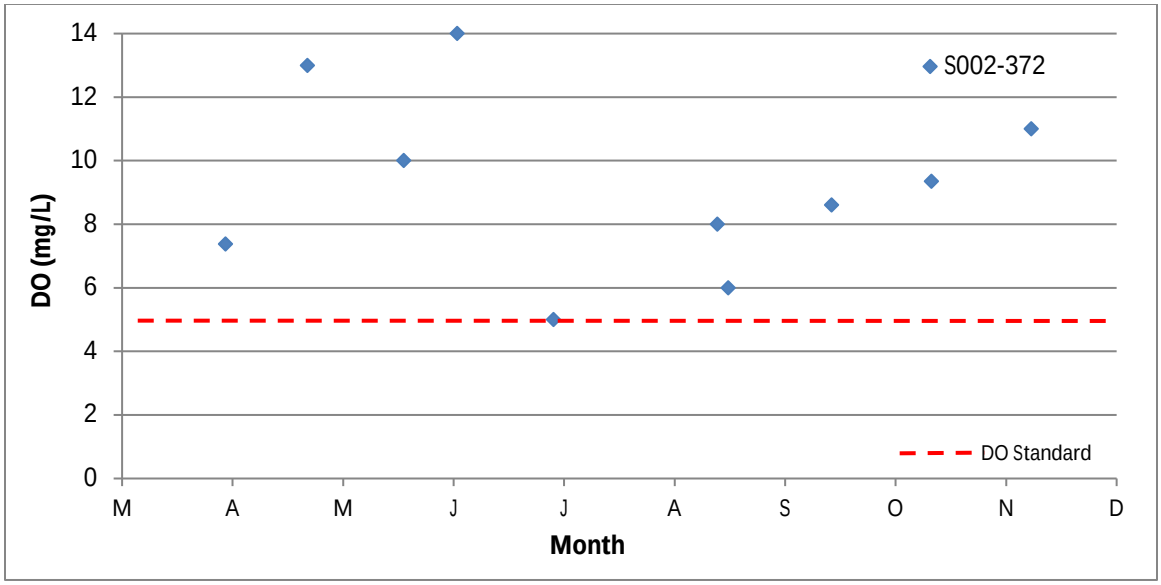


Figure 55. Discrete DO data for Site S002-372 along AUID 514.

Table 29. Continuous DO data for Site W70003001 along AUID 514.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 12, 2015 – September 2, 2015	2004	3.0	9.7	27	75	2.8

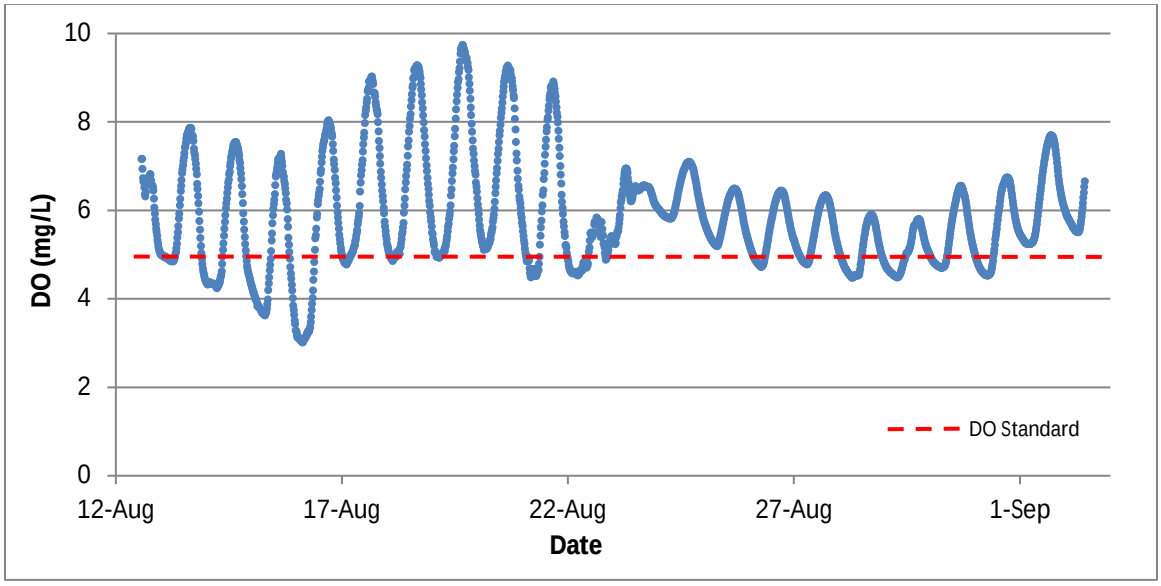


Figure 56. Continuous DO data for Site W70003001 along AUID 514.

Eutrophication-related data for the reach is limited to DO flux. The mean daily DO flux documented during continuous DO monitoring at Site W70003001 (Table 29) was 2.8 mg/L, which is well below the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., August 12, 2015, September 2, 2015, and September 23, 2015). Overall, the limited available data does not suggest that eutrophication is adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 514 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD067(1) (0.01) and 13RD067(2) (0.01)
- Above basin class average (>66%) relative abundance of individuals that are tolerant (TolPct) at Stations 13RD067(1) (78%) and 13RD067(2) (67%)
- Below basin class average (<6.3 mg/L) mean DO TIV at Stations 13RD067(1) (5.5 mg/L) and 13RD067(2) (5.5 mg/L)
- Below basin class average (<26%) probability of meeting the DO standard at Stations 13RD067(1) (6%) and 13RD067(2) (6%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Strength-of-evidence analysis

Table 30 presents a summary of the SOE scores for the candidate causes associated with AUID 514. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, and low DO. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 30. SOE scores for candidate causes associated with AUID 514.

Types of evidence	SOE scores per candidate cause[1]				
	Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
	Biological impairment				
	F-IBI	F-IBI	F-IBI	F-IBI	F-IBI
Types of evidence that use data from the case					
Spatial/temporal co-occurrence	++	++	++	0	++
Temporal sequence	NE	NE	NE	NE	NE
Stressor-response relationship	++	++	++	0	++
Causal pathway	++	++	++	0	++
Evidence of exposure/bio-mechanism	++	++	++	0	++
Manipulation of exposure	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE
Symptoms	++	++	++	0	++
Types of evidence that use data from elsewhere					
Mechanistically plausible cause	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE
Stressor-response in field studies	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE
Multiple lines of evidence					
Consistency of evidence	**++**	**++**	**++**	**0**	**++**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.8 Lateral Ditch 1 of State Ditch 95 (AUID 521)

Physical setting

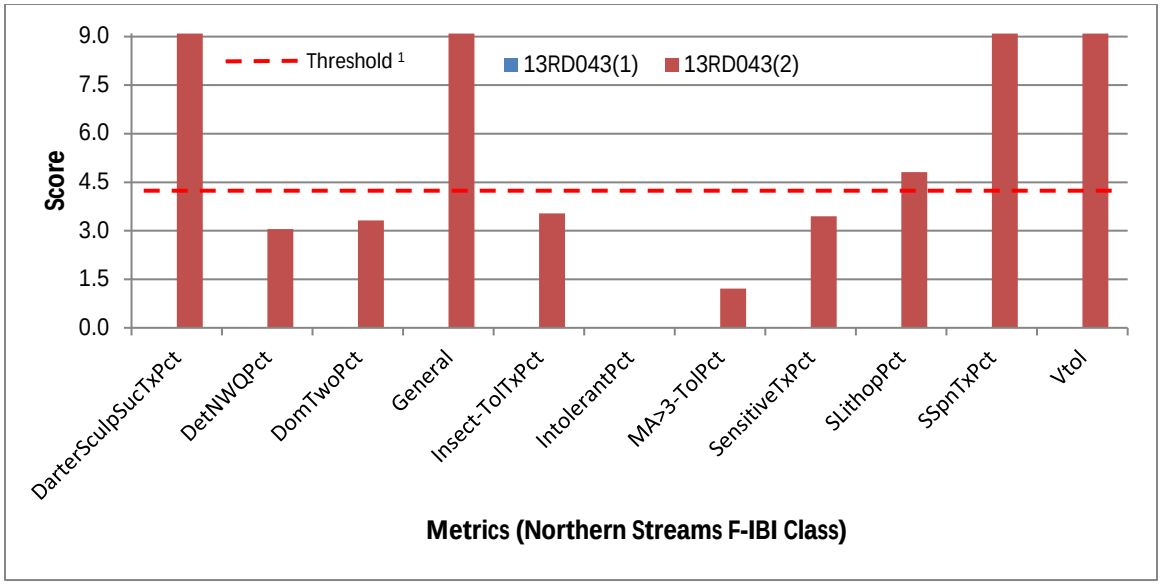
This reach represents the segment of Lateral Ditch 1 of State Ditch 95 from its confluence with an unnamed ditch, to the South Branch Two Rivers (Figure 57); a total length of 1 mile. The reach has a subwatershed area of 167 square miles (USGS, 2016). The subwatershed contains 152 miles of intermittent drainage ditch, 55 miles of intermittent stream, 36 miles of perennial drainage ditch (e.g., AUID 521), and less than 1 mile of perennial stream (DNR, 2003). According to the MPCA (2013), 85% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 521. The NLCD 2011 (USGS, 2011) lists cultivated crops (73%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (10%), forest (6%), hay/pasture (5%), and developed (5%).

Figure 57. Map of AUID 521 and associated biological monitoring station and water quality monitoring sites (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 521 was monitored at Station 13RD043 (0.1 mile downstream of the 440th Avenue crossing) on July 3, 2013(1) and July 30, 2013(2). The relative location of the station is shown in Figure 57. The station was designated as General Use within the Northern Streams F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 47. Monitoring of the station yielded F-IBI scores of 0 and 56. According to Figure 58, Station 13RD043 had at least one score for each individual metric that was below the mean value needed to meet the impairment threshold. A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the station was dominated by tolerant taxa, specifically central mudminnow, northern pike, and white sucker.

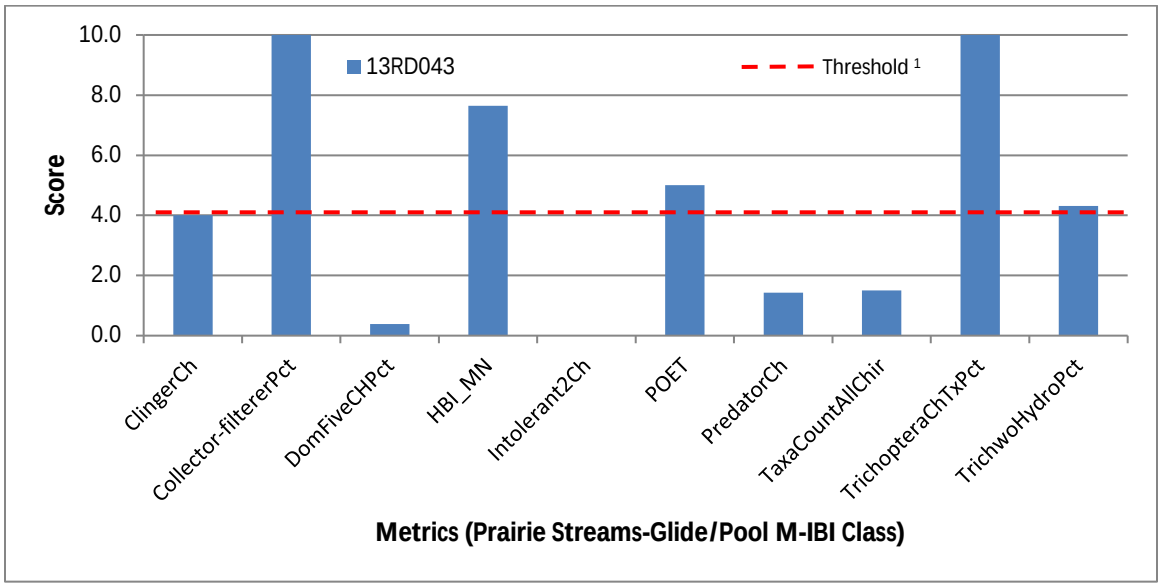


[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 58. Individual F-IBI metric scores for Station 13RD043 along AUID 521.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 521 was monitored at Station 13RD043 on July 30, 2013. The station was designated as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the impairment threshold for the station is an M-IBI score of 41. Monitoring of the station yielded an M-IBI score (44) slightly above the impairment threshold. However, the reach was determined to be impaired due to a high proportion of tolerant taxa, specifically *Simulium* (black flies). According to Figure 59, five individual metrics for Station 13RD043 scored below the mean value needed to meet the impairment threshold (i.e., ClingerCh, DomFiveCHPct, Intolerant2Ch, PredatorCh, and TaxaCountAllChir). A description of each metric is provided in the *Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014b).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 59. Individual M-IBI metric scores for Station 13RD043 along AUID 521.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD043 along AUID 521. According to the DNR (2014), there are no man-made dams on the reach. However, the Lake Bronson Dam and Hallock Dam are located downstream of the reach along the South Branch Two Rivers (AUID 502) and are barriers to connectivity. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed the lone road crossing on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo.

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 521 is provided by the following metric response (Appendix A):

- Below basin class average (<5%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Station 13RD043(1) (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Lake Bronson Dam and Hallock Dam on the fish community of the South Branch Two Rivers is discussed in Subsection 3.3.1 (AUID 502).

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 521. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to D. Money, TRWD Administrator (personal communication, 2015), the reach has an intermittent flow regime and often goes dry. The MPCA biological monitoring staff did not encounter any flow-related issues during fish and macroinvertebrate monitoring at Station 13RD043. There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 13% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, August 26, 2015, and September 23, 2015) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 521 is provided by the following metric responses (Appendix A):

- Above basin class average (>72%) combined relative abundance of the three most abundant taxa (DomThreePct) at Stations 13RD043(1) (83%) and 13RD043(2) (86%)
- Above basin class average (>33%) relative abundance of taxa that are generalists (GeneralTxPct) at Station 13RD043(1) (40%)
- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD043(1) (0.06) and 13RD043(2) (0.09)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Stations 13RD043(1) (20%) and 13RD043(2) (17%)
- Above basin class average (>50%) relative abundance of individuals that are tolerant (TolPct) at Station 13RD043(2) (59%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

Evidence of a causal relationship between flow regime instability and the M-IBI impairment associated with AUID 521 is provided by the following metric responses (Appendix B):

- Above basin class average (>70%) relative abundance of the dominant five taxa in a subsample, chironomid genera treated individually (DomFiveCHPct) at Station 13RD043 (89%)
- Below basin class average (<4%) relative abundance of long-lived individuals (LongLivedPct) at Station 13RD043 (1%)
- Above basin class average (>11%) relative abundance of swimmer individuals (SwimmerPct) at Station 13RD043 (16%)
- Below basin class average (<32) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD043 (23)

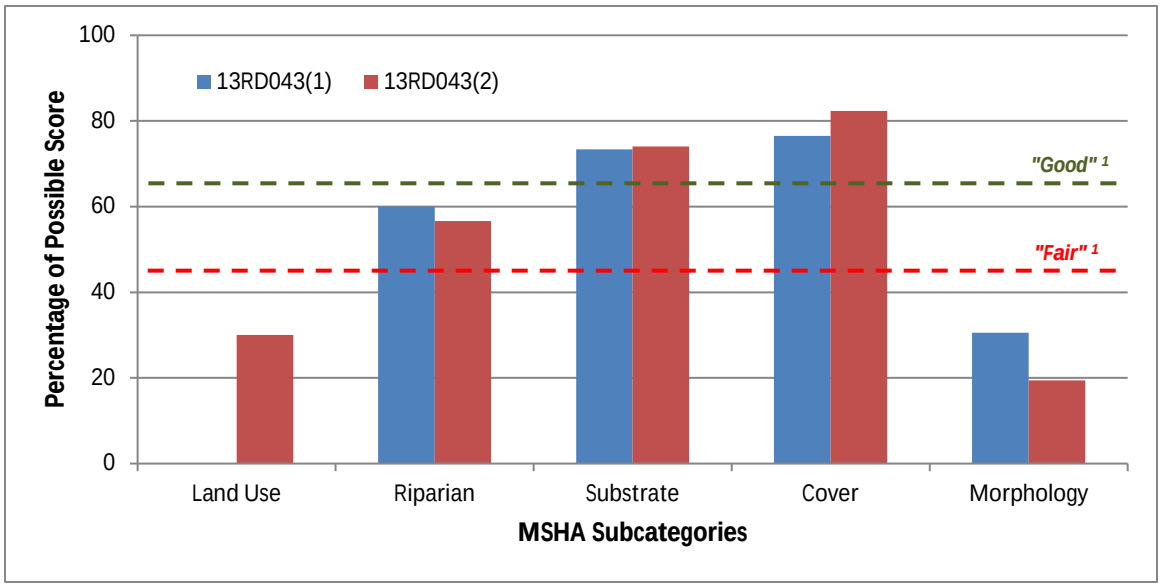
Flow regime instability tends to limit macroinvertebrate diversity and favor taxa that are shorter-lived, swimmers, and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012b).

Insufficient physical habitat

Available data

The physical habitat of AUID 521 was evaluated at Station 13RD043 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded scores of 53 (“fair”) and

51 ("fair"). Figure 60 displays the MSHA subcategory results for the station. The station scored poorly in the land use subcategory due to the predominance of agricultural row crops in the vicinity of the station. The riparian zone width of the station was characterized as "moderate" to "wide". No bank erosion was noted. The station scored well in the substrate subcategory, as it offered coarse substrate (i.e., gravel) with only "light" embeddedness. However, the station inherently lacked riffle habitat. The station also scored well in the cover subcategory, primarily due to the diversity and "extensive" amount of cover present. Cover types noted included boulders, macrophytes (emergent, floating leaf, and submergent), overhanging vegetation, and undercut banks. Lastly, the station had "moderate/high" channel stability and "poor" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is somewhat limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 60. MSHA subcategory results for Station 13RD043 along AUID 521.

On October 27, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 13RD043 along AUID 521 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 13RD043] was 77, which is good (stable) for an F4 stream type. A good, or stable, rating for F4 stream types is 85-110; however, F4 stream types in this valley type and parent soils, are not considered the highest (most stable) stream type and indicated that this channel was in the process of adjusting to a higher potential stream type. It is difficult to predict exactly which stream type this site was moving towards, but it was likely an E5 or C5. A Pfankuch rating of 77 is good, or stable, for a C4 stream type and fair, or moderately unstable, for an E4 stream type. Most Pfankuch categories ranked as good for this site. The upper banks were well vegetated and mass erosion has occurred, but appeared to be mostly healed over. The slope of the banks was greater than 60%. Cutting on the lower banks ranged from one to two feet and was fairly consistent along the channel. The bottom substrate was moderately packed with some overlapping. Approximately 5-30% of the channel was affected by deposition."*

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 521 is provided by the following metric responses (Appendix A):

- Below basin class average (<19%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Station 13RD043(1) (0%)
- Below basin class average (<15%) relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPcT) at Station 13RD043(1) (0%)
- Above basin class average (>20%) relative abundance of individuals that are detritivorous (DetNWQPct) at Stations 13RD043(1) (26%) and 13RD043(2) (34%)
- Below basin class average (<8%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 13RD043(1) (4%) and 13RD043(2) (0%)
- Below basin class average (<23%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Stations 13RD043(1) (4%) and 13RD043(2) (9%)
- Below basin class average (<4) taxa richness of simple lithophilic spawning species (SLithop) at Stations 13RD043(1) (2) and 13RD043(2) (2)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

Biotic response – macroinvertebrate

Evidence of a causal relationship between insufficient physical habitat and the M-IBI impairment associated with AUID 521 is provided by the following metric responses (Appendix B):

- Below basin class average (<8) taxa richness of climbers (ClimberCh) at Station 13RD043 (5)
- Above basin class average (>20%) relative abundance of sprawler taxa (SprawlerChTxPct) at Station 13RD043 (22%)

Climber taxa require plants or debris habitat to climb, while sprawler macroinvertebrates are tolerant of degraded benthic habitat.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD043 along AUID 521 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. Both samples had a TSS concentration of 4 mg/L. Table 31 summarizes all available discrete TSS data for Site S002-997 (440th Avenue crossing); the relative location of the site is shown in Figure 57. The site had no exceedances of the 65 mg/L Southern River TSS Region standard. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Table 31. Discrete TSS data for Site S002-997 along AUID 521.

Site	Date range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard exceedances (#)
S002-997	2002-2013	39	1	24	5	0

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 521. None of the metrics or related data for Station 13RD043 (Appendix A) exhibited a correlation to this candidate cause.

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 521. None of the metrics or related data for Station 13RD043 (Appendix B) exhibited a correlation to this candidate cause.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a combined three discrete DO measurements at Station 13RD043 along AUID 521 at the time of fish and macroinvertebrate monitoring. Measurement values ranged from 6.4 to 9.6 mg/L. Figure 61 displays all available discrete DO data for Site S002-997 (2002-2014; *n*=34); the relative location of the site is shown in Figure 57. Approximately 24% of the DO values for the site were below the 5.0 mg/L standard; however, only one of the measurements was collected prior to 9:00 a.m. Generally, the lowest DO levels were in the months of June and July. The MPCA conducted continuous DO monitoring at Site H70046001 (440th Avenue crossing) from August 12, 2015, to August 26, 2015; the relative location of the site is shown in Figure 57. The monitoring results are provided in Table 32, as well as displayed in Figure 62. While 11% of the total values were below the standard, 15% of the daily minimum values were below the standard. A large storm event (≈4") interrupted the diurnal pattern on and after August 22, 2015. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard approximately 4% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences at least occasional periods of low DO.

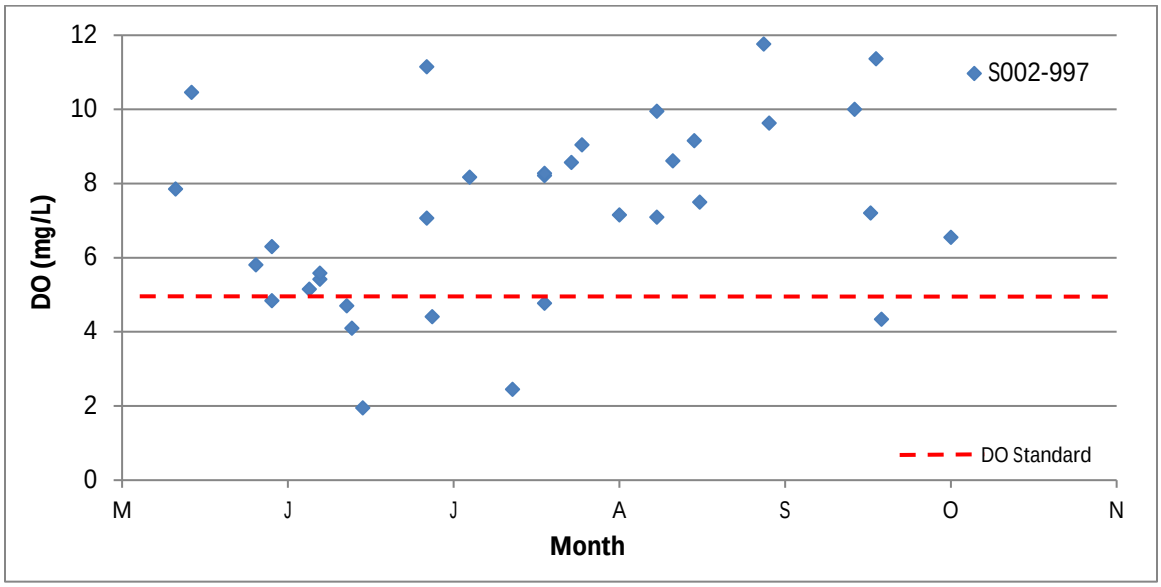


Figure 61. Discrete DO data for Site S002-997 along AUID 521.

Table 32. Continuous DO data for Site H70046001 along AUID 521.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 12, 2015 – August 26, 2015	1343	3.4	13.3	11	15	4.6

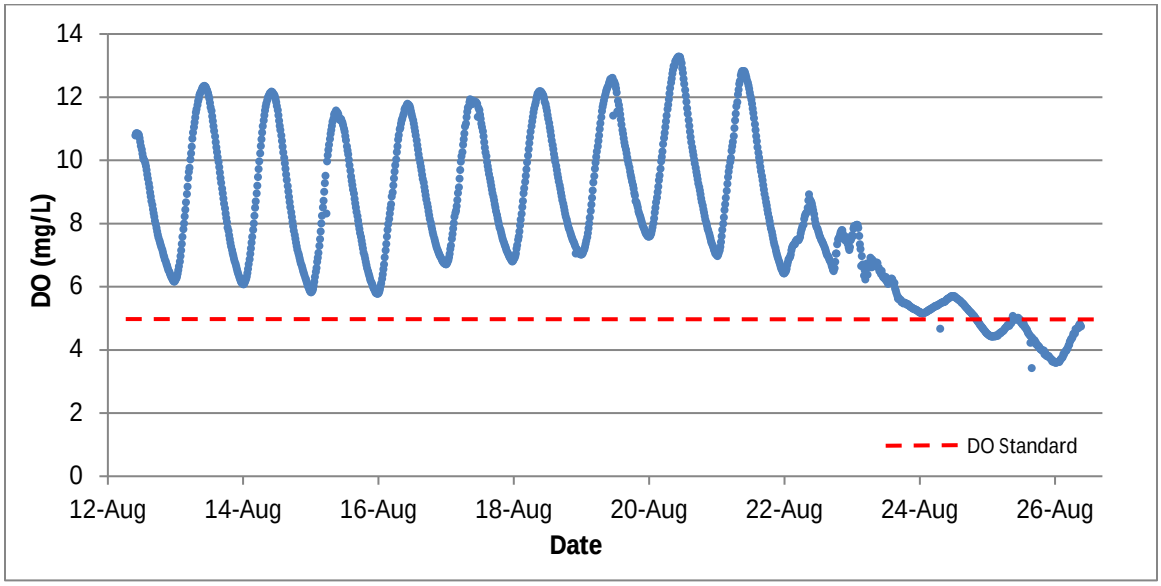


Figure 62. Continuous DO data for Site H70046001 along AUID 521.

Eutrophication-related data for the reach is limited to the following parameters: TP and DO flux. Discrete TP data are available for Site S002-997 (2002-2013; n=28). The mean TP concentration for the site was 75 µg/L, while the highest concentration was 179 µg/L and the lowest concentration was 22 µg/L. Approximately 7% of the values exceeded the 150 µg/L South River Nutrient Region TP standard. The mean daily DO flux documented during continuous DO monitoring at Site H70046001 (Table 32) was 4.6 mg/L, which is slightly above the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., August 12, 2015, August 26, 2015, and September 23, 2015). However, the MPCA biological monitoring staff noted "extensive" filamentous algae at Station 13RD043 at the time of each fish monitoring visit. Overall, the limited available data suggest that eutrophication may be adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 521 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD043(1) (0.06) and 13RD043(2) (0.09)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Stations 13RD043(1) (20%) and 13RD043(2) (17%)
- Above basin class average (>50%) relative abundance of individuals that are tolerant (TolPct) at Station 13RD043(2) (59%)

- Below basin class average (<6.8 mg/L) mean DO TIV at Stations 13RD043(1) (6.4 mg/L) and 13RD043(2) (6.5 mg/L)
- Below basin class average (<40%) probability of meeting the DO standard at Stations 13RD043(1) (25%) and 13RD043(2) (27%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 521 is provided by the following metric and data responses (Appendix B):

- Below basin class average (<32) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD043 (23)
- Below basin class average (<2) taxa richness of low DO intolerant macroinvertebrates at Station 13RD043 (1)

Low DO often limits the taxa richness of macroinvertebrates and favors taxa that are tolerant (Weber, 1973; EPA, 2012b).

Strength-of-evidence analysis

Table 33 presents a summary of the SOE scores for the candidate causes associated with AUID 521. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of flow regime instability and, to a lesser extent, insufficient physical habitat and low DO. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 33. SOE scores for candidate causes associated with AUID 521.

Types of evidence	SOE scores per candidate cause[1]									
	Loss of longitudinal connectivity		Flow regime instability		Insufficient physical habitat		High suspended sediment		Low dissolved oxygen	
	Biological impairments									
	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI
Types of evidence that use data from the case										
Spatial/temporal co-occurrence	++	--	++	++	++	+	0	0	++	+
Temporal sequence	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response relationship	++	--	++	++	++	+	0	0	++	+
Causal pathway	++	--	++	++	++	+	0	0	++	+
Evidence of exposure/bio-mechanism	++	--	++	++	++	+	0	0	++	+
Manipulation of exposure	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Symptoms	++	--	++	++	++	+	0	0	++	+
Types of evidence that use data from elsewhere										
Mechanistically plausible cause	+	-	+	+	+	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response in field studies	++	NE	++	++	++	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Multiple lines of evidence										
Consistency of evidence	++	--	++	++	++	+	0	0	++	+

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.9 County Ditch 4 (AUID 522)

Physical setting

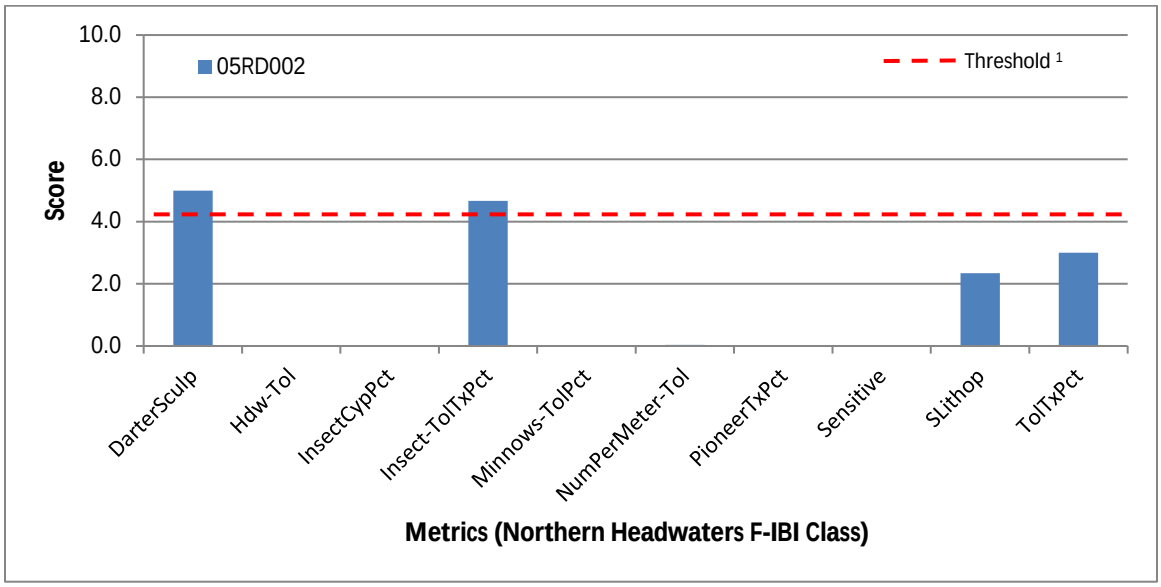
This reach represents the segment of CD 4 from its confluence with an unnamed ditch, to its confluence with an unnamed ditch (Figure 63); a total length of 2 miles. The reach has a subwatershed area of 10 square miles (USGS, 2016). The subwatershed contains 13 miles of intermittent drainage ditch (e.g., AUID 522) and 2 miles of intermittent DNR, 2003). According to the MPCA (2013), 93% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 522. The NLCD 2011 (USGS, 2011) lists cultivated crops (62%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (23%), forest (10%), developed (2%), and hay/pasture (2%).

Figure 63. Map of AUID 522 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 522 was monitored at Station 05RD002 (0.4 mile downstream of the 150th Street crossing) on June 23, 2005. The relative location of the station is shown in Figure 63. The station was designated as General Use within the Northern Headwaters F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 42. Monitoring of the station yielded an F-IBI score (15) below the impairment threshold. According to Figure 64, eight individual metrics for Station 05RD002 scored below the mean value needed to meet the impairment threshold (i.e., Hdw-Tol, InsectCypPct, Minnows-TolPct, NumPerMeter-Tol, PioneerTxPct, Sensitive, SLithop, and TolTxPct). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the station was entirely comprised of tolerant taxa (i.e., brook stickleback, central mudminnow, fathead minnow, johnny darter, and white sucker).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 64. Individual F-IBI metric scores for Station 05RD002 along AUID 522.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 05RD002 along AUID 522. According to the DNR (2014), there are no man-made dams on the reach. However, the Lake Bronson Dam and Hallock Dam are located downstream of the reach along the South Branch Two Rivers (AUID 502) and are barriers to connectivity. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. A perched culvert (Figure 65) was documented at the CR 105 crossing. The outlet of the culvert was elevated approximately two feet above the ditch bottom; rocks have been placed downstream of the outlet to prevent a scour pool from developing. The culvert obstructs connectivity during low flow conditions. Additionally, a rock check dam (Figure 65) was noted immediately downstream of the reach, near the confluence with the South Branch Two Rivers. The check dam is approximately three feet high and interferes with connectivity during low flow and, likely, moderate flow conditions. In addition to the assessment, MPCA SID staff performed a detailed review of

a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. No additional connectivity-related issues were identified in the photo.

Figure 65. Photos of connectivity barriers affecting AUID 522, including a perched culvert along CR 105 on September 23, 2015 (left) and a rock check dam along CR 105 on September 23, 2015 (right).

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 522 is provided by the following metric response (Appendix A):

- Below basin class average (<5%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Station 05RD002 (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Lake Bronson Dam and Hallock Dam on the fish community of the South Branch Two Rivers is discussed in Subsection 3.3.1 (AUID 502).

Flow regime instability

Available data

According to D. Money, TRWD Administrator (personal communication, 2015), the reach has an intermittent flow regime and often goes dry. The MPCA biological monitoring staff did not encounter any flow-related issues during fish monitoring at Station 05RD002. There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 38% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., July 22, 2015, August 4, 2015, and September 23, 2015) and documented flow conditions. Lentic condition were along the reach on August 4, 2015 and September 23, 2015 (Figure 66). Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Figure 66. Photos of lentic conditions along AUID 522 on September 23, 2015, including the 140th Street crossing (left) and the 150th Street crossing (right).

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 522 is provided by the following metric responses (Appendix A):

- Above basin class average (>67%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Station 05RD002 (90%)
- Above basin class average (>37%) relative abundance of taxa that are generalists (GeneralTxPct) at Station 05RD002 (40%)
- Above basin class average (>91%) relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct) at Station 05RD002 (98%)
- Below basin class average (<0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 05RD002 (0.01)
- Above basin class average (>20%) relative abundance of taxa that are pioneers (PioneerTxPct) at Station 05RD002 (40%)
- Below basin class average (<23%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 05RD002 (0%)
- Above basin class average (>44%) relative abundance of individuals that are short-lived (SLvdPct) at Station 05RD002 (82%)
- Above basin class average (>66%) relative abundance of individuals that are tolerant (TolPct) at Station 05RD002 (98%)

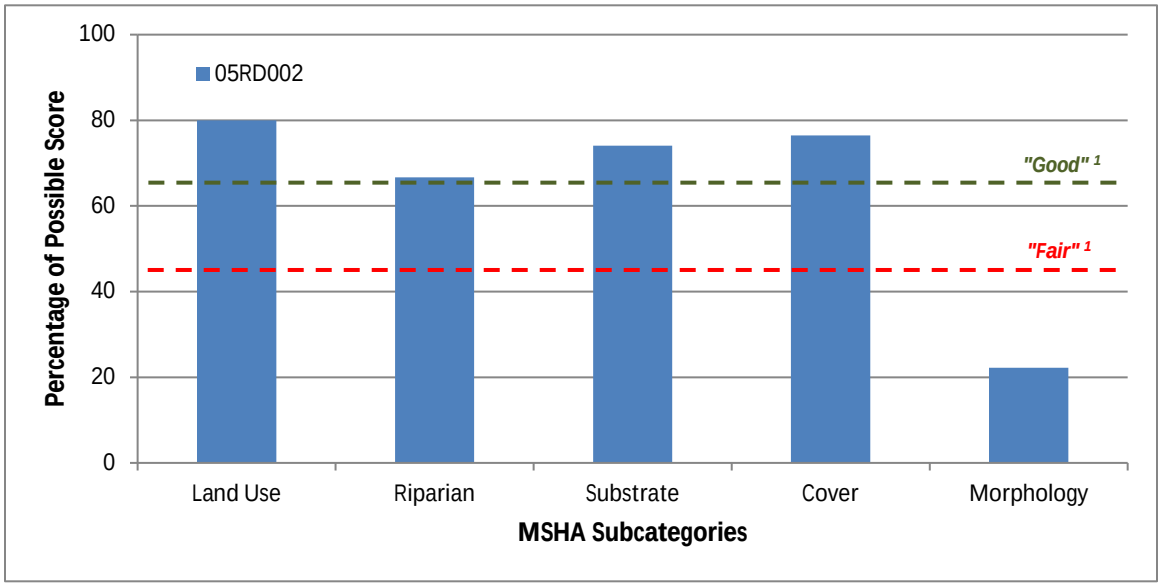
Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 522 was evaluated at Station 05RD002 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded a score of 55 (“fair”). Figure 67 displays the MSHA subcategory results for the station. The land use surrounding the station was dominated by agricultural fields. The riparian zone width of the station was characterized as “extensive”. A minimal amount of bank erosion was also noted. The station scored well in the substrate subcategory, as it offered coarse substrate (i.e., gravel) with only “light” embeddedness. However, the

station inherently lacked riffle habitat. The station also scored well in the cover subcategory, primarily due to the "extensive" amount of cover present. Cover types noted included macrophytes (emergent, floating leaf, and submergent), overhanging vegetation, and woody debris. Lastly, the morphology subcategory score for the station was adversely affected by "moderate" channel stability and "fair" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is somewhat limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 67. MSHA subcategory results for Station 05RD002 along AUID 522.

On October 21, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 05RD002 along AUID 522 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 05RD002] was 76, which is fair (moderately unstable) for a B stream type. Without completing a pebble count it would be difficult to estimate the 50th percentile particle size due to the high variation in substrate sizes observed. All sizes from silt and clay to a few cobbles were noted. With a score of Pfankuch score of 76, B4, B5, and B6 stream types are all considered moderately unstable. The upper banks had good vegetative cover and the debris jam potential was essentially absent from the channel. The banks above bankfull did have steeper slopes. The channel was incised and unable to access its adjacent floodplain during small flood events. The most notable unstable feature of the channel bottom was the wide variety of substrate observed. This channel had a decent amount of gravel it in, but it also had clay and silt mixed in. In its current form with the wider channel bottom, it does not appear to have the stream power to move this sediment downstream."*

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 522 is provided by the following metric responses (Appendix A):

- Above basin class average (>18%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Station 05RD002 (40%)
- Below basin class average (<9%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 05RD002 (0%)

- Below basin class average (<13%) relative abundance of individuals that are insectivorous, excluding tolerant species (Insect-TolPct) at Station 05RD002 (2%)
- Below basin class average (<23%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 05RD002 (2%)

Insectivores and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 05RD002 along AUID 522 at the time of fish monitoring. The sample was analyzed for several parameters, including TSS. The TSS concentration was 1 mg/L. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L Southern River TSS Region standard approximately 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 522. None of the metrics or related data for Station 05RD002 (Appendix A) exhibited a correlation to this candidate cause.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 05RD002 along AUID 522 at the time of the June 23, 2005 fish monitoring visit (2.3 mg/L). The MPCA conducted continuous DO monitoring at Site W70064001 (150th Street crossing) from July 22, 2015, to August 4, 2015; the relative location of the site is shown in Figure 63. The monitoring results are provided in Table 34, as well as displayed in Figure 68. None of the DO measurements within the monitoring period were below the 5.0 mg/L standard. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard approximately 40% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences at least occasional periods of low DO.

Table 34. Continuous DO data for Site W70064001 along AUID 522.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
July 22, 2015 – August 4, 2015	1213	5.5	12.3	0	0	5.0

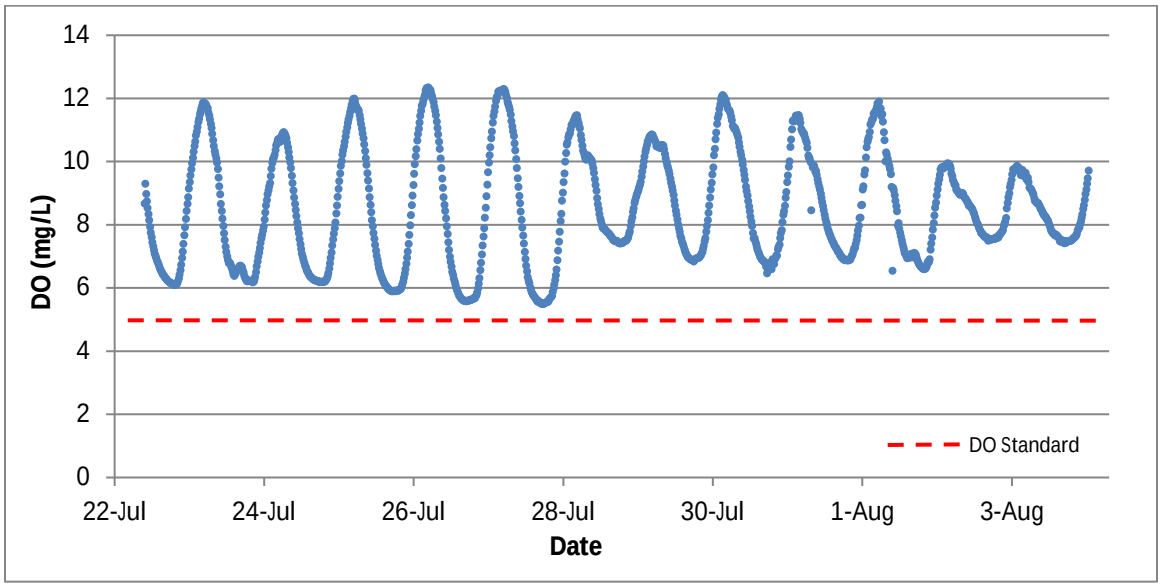


Figure 68. Continuous DO data for Site W70064001 along AUID 522.

Eutrophication-related data for the reach is limited to DO flux. The mean daily DO flux documented during continuous DO monitoring at Site W70064001 (Table 34) was 5.0 mg/L, which is above the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff observed signs of eutrophication (i.e., excessive algal growth) along the reach on September 23, 2015 (Figure 66). Overall, the limited available data suggest that eutrophication may be adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 522 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 05RD002 (0.01)
- Below basin class average (<23%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 05RD002 (0%)
- Above basin class average (>66%) relative abundance of individuals that are tolerant (TolPct) at Station 05RD002 (98%)
- Below basin class average (<6.3 mg/L) mean DO TIV at Station 05RD002 (5.7 mg/L)
- Below basin class average (<26%) probability of meeting the DO standard at Station 05RD002 (7%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Strength-of-evidence analysis

Table 35 presents a summary of the SOE scores for the candidate causes associated with AUID 522. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, and low DO. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 35. SOE scores for candidate causes associated with AUID 522.

Types of evidence	SOE scores per candidate cause[1]				
	Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
	Biological impairment				
	F-IBI	F-IBI	F-IBI	F-IBI	F-IBI
Types of evidence that use data from the case					
Spatial/temporal co-occurrence	++	++	++	0	++
Temporal sequence	NE	NE	NE	NE	NE
Stressor-response relationship	++	++	++	0	++
Causal pathway	++	++	++	0	++
Evidence of exposure/bio-mechanism	++	++	++	0	++
Manipulation of exposure	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE
Symptoms	++	++	++	0	++
Types of evidence that use data from elsewhere					
Mechanistically plausible cause	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE
Stressor-response in field studies	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE
Multiple lines of evidence					
Consistency of evidence	**++**	**++**	**++**	**0**	**++**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.10 State Ditch 72 (AUID 531)

Physical setting

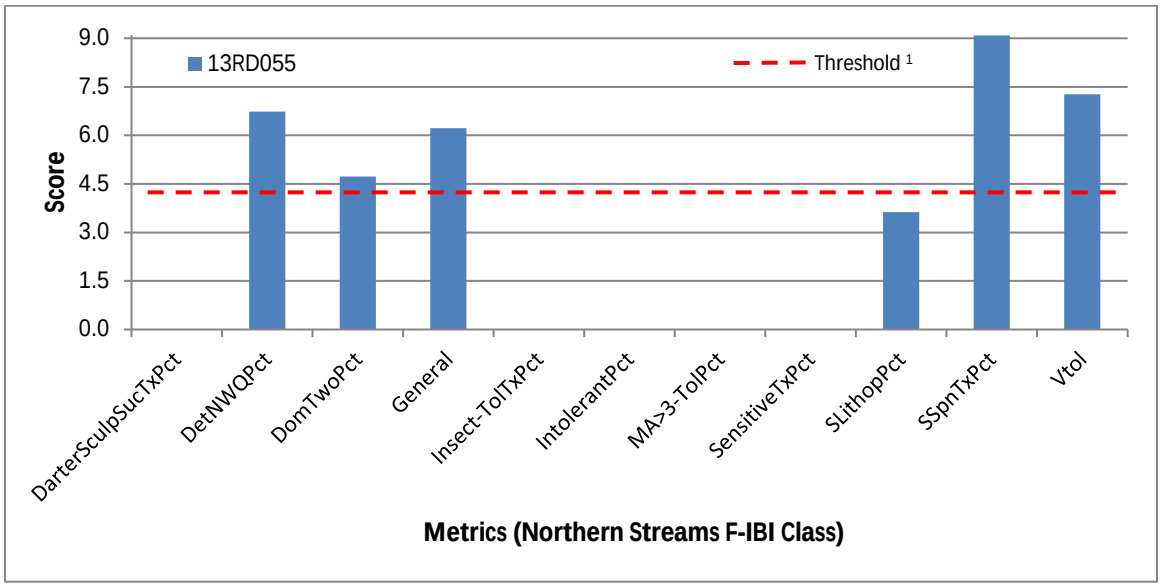
This reach represents the segment of State Ditch 72 from its confluence with JD 31, to its confluence with State Ditch 85 (Figure 69); a total length of one mile. The reach has a subwatershed area of 100 square miles (USGS, 2016). The subwatershed contains 56 miles of perennial drainage ditch (e.g., AUID 531), 17 miles of intermittent drainage ditch, 11 miles of intermittent stream, and 1 mile of perennial stream (DNR, 2003). According to the MPCA (2013), 93% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 531. The NLCD 2011 (USGS, 2011) lists cultivated crops (43%) and wetlands (43%) as the predominant land cover groups in the subwatershed. Other notable land cover groups in the subwatershed included forest (9%), developed (2%), and hay/pasture (1%).

Figure 69. Map of AUID 531 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 531 was monitored at Station 13RD055 (1.2 mile upstream of the 330th Street crossing) on July 10, 2013. The relative location of the station is shown in Figure 69. The station was designated as General Use within the Northern Streams F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 47. Monitoring of the station yielded an F-IBI score (33) below the impairment threshold. According to Figure 70, six individual metrics for Station 13RD055 scored below the mean value needed to meet the impairment threshold (i.e., DarterSculpSucTxPct, Insect-TolTxPct, IntolerantPct, MA>3-TolPct, SensitiveTxPct, and SLithopPct). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the station was entirely comprised of tolerant taxa (i.e., black bullhead, central mudminnow, common shiner, creek chub, northern pike, and white sucker).

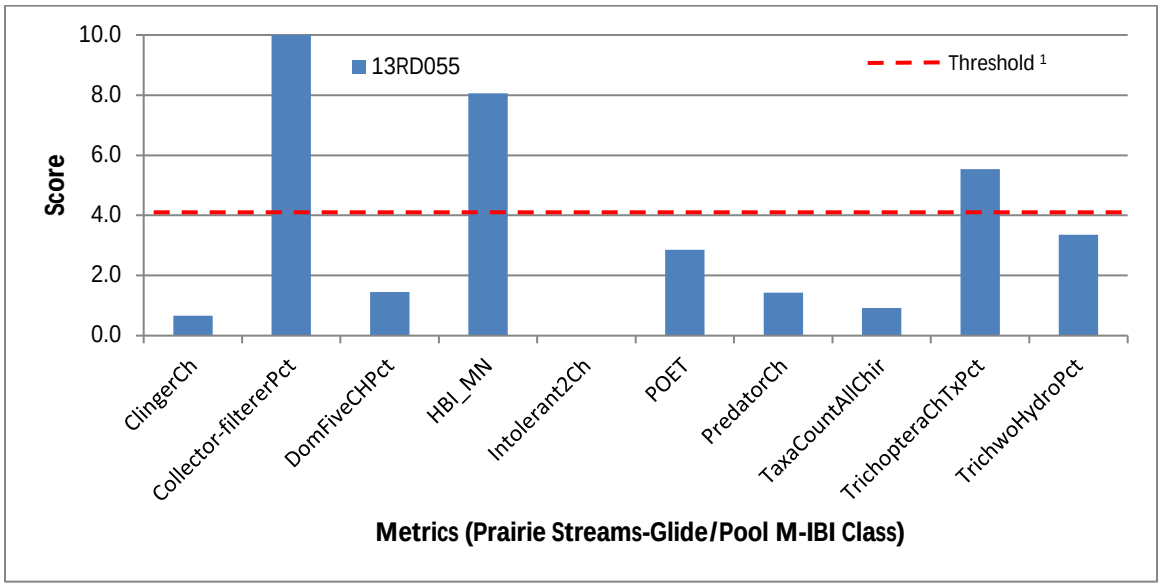


[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 70. Individual F-IBI metric scores for Station 13RD055 along AUID 531.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 531 was monitored at Station 13RD055 on July 30, 2013. The station was designated as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the impairment threshold for the station is an M-IBI score of 41. Monitoring of the station yielded an M-IBI score (34) below the impairment threshold. According to Figure 71, seven individual metrics for Station 13RD055 scored below the mean value needed to meet the impairment threshold (i.e., ClingerCh, DomFiveCHPct, Intolerant2Ch, POET, PredatorCh, TaxaCountAllChir, and TrichwoHydroPct). A description of each metric is provided in the *Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014b). The macroinvertebrate assemblage of the station was dominated by *Simulium* (black flies).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 71. Individual M-IBI metric scores for Station 13RD055 along AUID 531.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD055 along AUID 531. According to the DNR (2014), there are no man-made dams on the reach. However, the Northcote Dam is located downstream of the reach along the North Branch Two Rivers (AUID 508) and is a barrier to connectivity. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed the lone road crossing on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo.

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 531 is provided by the following metric response (Appendix A):

- Below basin class average (<5%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Station 13RD055 (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Northcote Dam on the fish community of the North Branch Two Rivers is discussed in Subsection 3.3.6 (AUID 508).

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 531. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to D. Money, TRWD Administrator (personal communication, 2015), the reach has an intermittent flow regime and often goes dry. The MPCA biological monitoring staff did not encounter any flow-related issues during fish and macroinvertebrate monitoring at Station 13RD055. There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 24% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, August 26, 2015, and September 23, 2015) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 531 is provided by the following metric responses (Appendix A):

- Above basin class average (>33%) relative abundance of taxa that are generalists (GeneralTxPct) at Station 13RD055 (67%)
- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD055 (0.07)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 13RD055 (0%)
- Above basin class average (>43%) relative abundance of taxa that are tolerant (TolTxPct) at Station 13RD055 (67%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

Evidence of a causal relationship between flow regime instability and the M-IBI impairment associated with AUID 531 is provided by the following metric responses (Appendix B):

- Above basin class average (>70%) relative abundance of the dominant five taxa in a subsample, chironomid genera treated individually (DomFiveCHPct) at Station 13RD055 (84%)
- Below basin class average (<4%) relative abundance of long-lived individuals (LongLivedPct) at Station 13RD055 (0%)
- Above basin class average (>13%) relative abundance of swimmer taxa (SwimmerChTxPct) at Station 13RD055 (19%)
- Below basin class average (<32) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD055 (21)

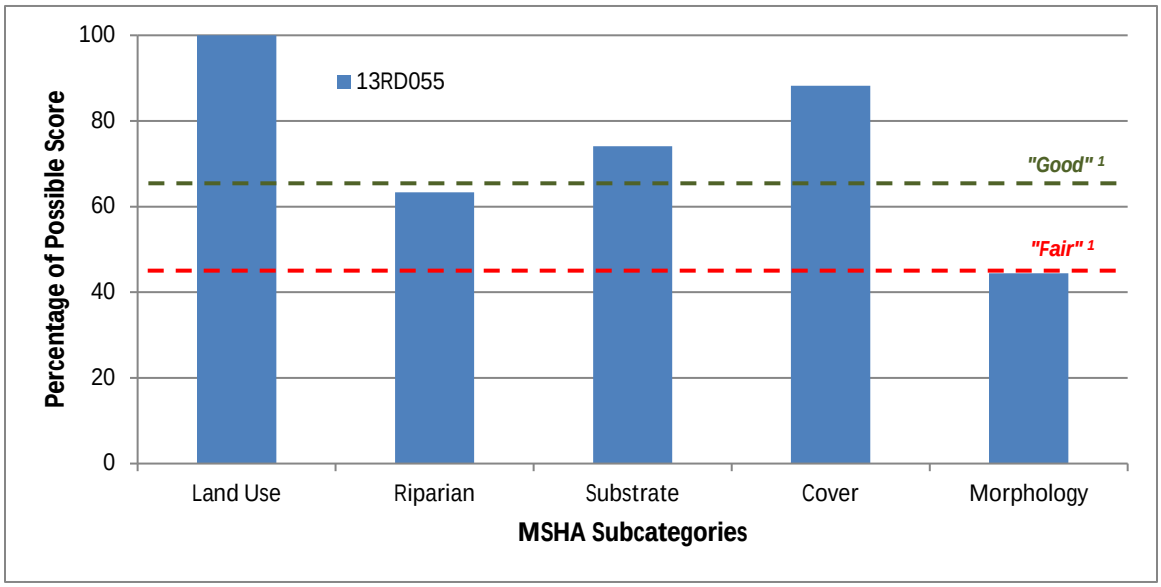
Flow regime instability tends to limit macroinvertebrate diversity and favor taxa that are shorter-lived, swimmers, and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; USEPA, 2012b).

Insufficient physical habitat

Available data

The physical habitat of AUID 531 was evaluated at Station 13RD055 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded a score of 66 (“good”). Figure 72 displays the MSHA subcategory results for the station. The land use surrounding the station was largely natural (e.g., forest and wetlands). The riparian zone width of the station was characterized

as “extensive”. A minimal amount of bank erosion was also noted. The station scored well in the substrate subcategory, as it offered coarse substrate (i.e., gravel) with only “light” embeddedness. However, the station inherently lacked riffle habitat. The station also scored well in the cover subcategory, primarily due to the diversity and “extensive” amount of cover present. Cover types noted included boulders, deep pools, macrophytes (submergent), overhanging vegetation, and undercut banks. Lastly, the morphology subcategory score for the station was adversely affected by “fair” channel development. Overall, the MSHA data suggest that the physical habitat of the reach is somewhat limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a “fair” and “good” MSHA rating.

Figure 72. MSHA subcategory results for Station 13RD055 along AUID 531.

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 531 is provided by the following metric responses (Appendix A):

- Below basin class average (<19%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Station 13RD055 (0%)
- Below basin class average (<15%) relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPcT) at Station 13RD055 (0%)
- Below basin class average (<8%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 13RD055 (0%)
- Below basin class average (<33%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Station 13RD055 (0%)
- Below basin class average (<37%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 13RD055 (28%)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate) for feeding and/or reproduction purposes (Aadland et al., 2006).

Biotic response – macroinvertebrate

Evidence of a causal relationship between insufficient physical habitat and the M-IBI impairment associated with AUID 531 is provided by the following metric responses (Appendix B):

- Below basin class average (<8) taxa richness of climbers (ClimberCh) at Station 13RD055 (7)
- Below basin class average (<7) taxa richness of clingers (ClingerCh) at Station 13RD055 (3)
- Below basin class average (<22%) relative percentage of clinger taxa (ClingerChTxPct) at Station 13RD055 (14%)
- Above basin class average (>20%) relative abundance of sprawler taxa (SprawlerChTxPct) at Station 13RD055 (24%)

Climber and clinger taxa require substrate or plants to attach themselves to, while sprawler macroinvertebrates are tolerant of degraded benthic habitat.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD055 along AUID 531 at the time of fish monitoring. The sample was analyzed for several parameters, including TSS. The TSS concentration was 4 mg/L. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L Southern River TSS Region standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 531. None of the metrics or related data for Station 13RD055 (Appendix A) exhibited a correlation to this candidate cause.

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 531. None of the metrics or related data for Station 13RD055 (Appendix B) exhibited a correlation to this candidate cause.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD055 along AUID 531 at the time of fish (12.5 mg/L) and macroinvertebrate (11.5 mg/L) monitoring. The MPCA conducted continuous DO monitoring at Site W70025002 (330th Street crossing) from August 12, 2015, to August 26, 2015; the relative location of the site is shown in Figure 69. The monitoring results are provided in Table 36, as well as displayed in Figure 73. While 8% of the total values were below the 5.0 mg/L standard, 38% of the daily minimum values were below the standard. A large storm event (≈4″) interrupted the diurnal pattern on and after August 22, 2015. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard approximately 24% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

Table 36. Continuous DO data for Site W70025002 along AUID 531.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 12, 2015 – August 26, 2015	1346	3.6	12.4	8	38	5.1

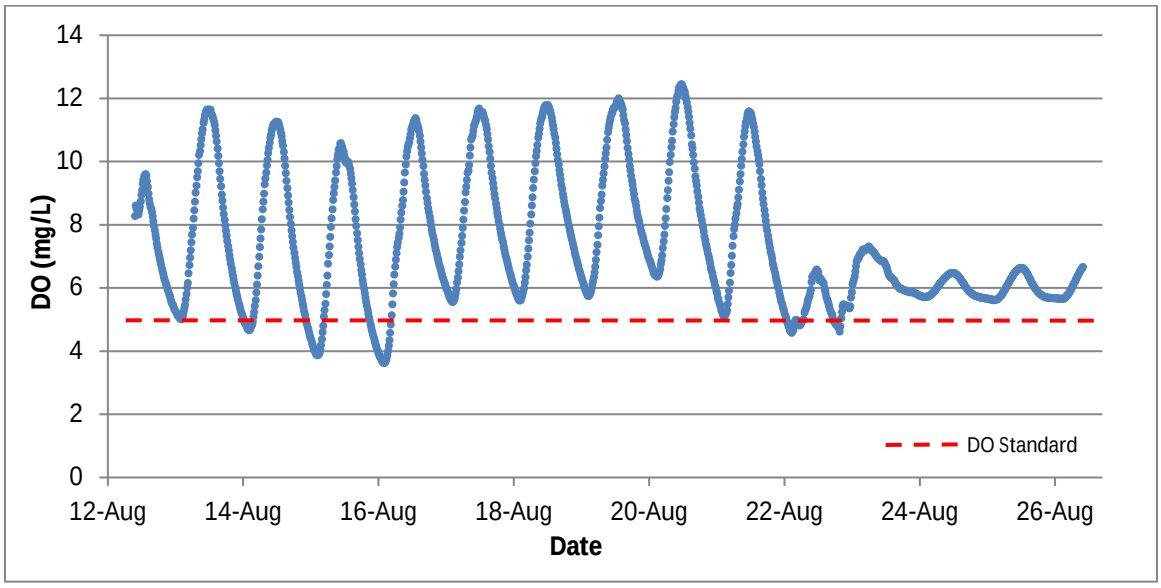


Figure 73. Continuous DO data for Site W70025002 along AUID 531.

Eutrophication-related data for the reach is limited to DO flux. The mean daily DO flux documented during continuous DO monitoring at Site W70025002 (Table 36) was 5.1 mg/L, which is above the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during three separate reconnaissance visits along the reach (i.e., August 12, 2015, August 26, 2015, and September 23, 2015). However, the MPCA biological monitoring staff noted a "large" amount of filamentous algae at Station 13RD055 at the time of the fish and macroinvertebrate monitoring visits. Overall, the limited available data suggest that eutrophication may be adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 531 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD055 (0.07)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 13RD055 (0%)
- Above basin class average (>43%) relative abundance of taxa that are tolerant (TolTxPct) at Station 13RD055 (67%)
- Below basin class average (<6.8 mg/L) mean DO TIV at Station 13RD055 (6.6 mg/L)
- Below basin class average (<40%) probability of meeting the DO standard at Station 13RD055 (30%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 531 is provided by the following metric and data responses (Appendix B):

- Below basin class average (<32) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD055 (21)
- Below basin class average (<2) taxa richness of low DO intolerant macroinvertebrates at Station 13RD055 (1)

Low DO often limits the taxa richness of macroinvertebrates and favors taxa that are tolerant (Weber, 1973; EPA, 2012b).

Strength-of-evidence analysis

Table 37 presents a summary of the SOE scores for the candidate causes associated with AUID 531. The evidence suggests that the F-IBI impairment is attributed to flow regime instability and, to a lesser extent, a loss of longitudinal connectivity, insufficient physical habitat, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of flow regime instability and, to a lesser extent, insufficient physical habitat and low DO. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 37. SOE scores for candidate causes associated with AUID 531.

Types of evidence	SOE scores per candidate cause[1]									
	Loss of longitudinal connectivity		Flow regime instability		Insufficient physical habitat		High suspended sediment		Low dissolved oxygen	
	Biological impairments									
	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI
Types of evidence that use data from the case										
Spatial/temporal co-occurrence	+	--	++	++	+	+	0	0	+	+
Temporal sequence	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response relationship	+	--	++	++	+	+	0	0	+	+
Causal pathway	+	--	++	++	+	+	0	0	+	+
Evidence of exposure/bio-mechanism	+	--	++	++	+	+	0	0	+	+
Manipulation of exposure	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Symptoms	+	--	++	++	+	+	0	0	+	+
Types of evidence that use data from elsewhere										
Mechanistically plausible cause	+	-	+	+	+	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response in field studies	++	NE	++	++	++	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Multiple lines of evidence										
Consistency of evidence	**+**	**--**	**++**	**++**	**+**	**+**	**0**	**0**	**+**	**+**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.11 Lateral Ditch 1 of State Ditch 95 (AUID 539)

Physical setting

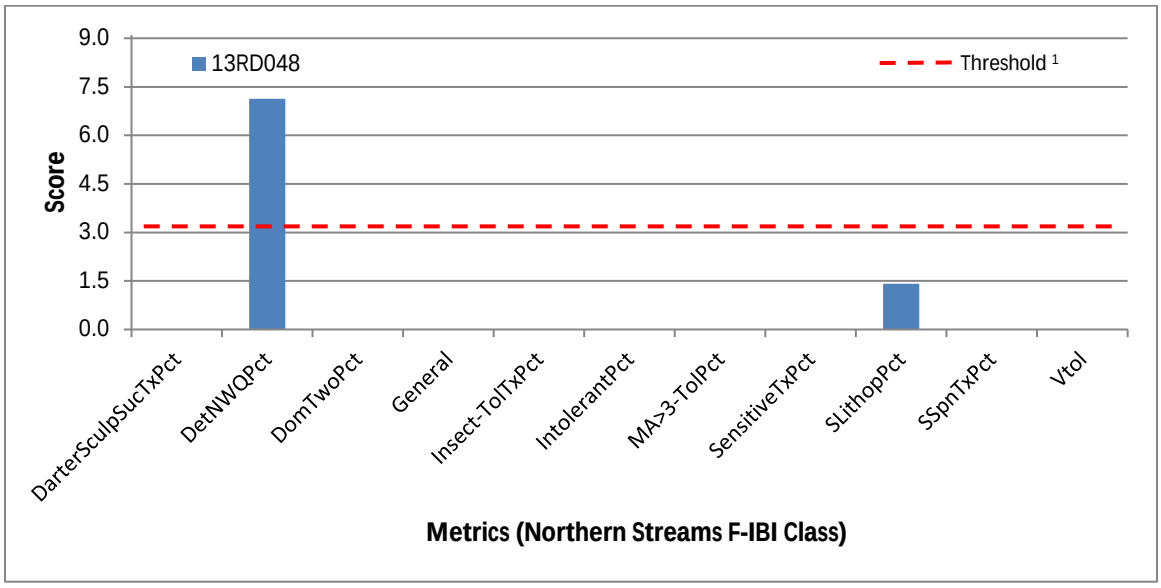
This reach represents the segment of Lateral Ditch 1 of State Ditch 95 from its confluence with an unnamed ditch, to its confluence with State Ditch 50 (Figure 74); a total length of 12 miles. The reach has a subwatershed area of 86 square miles (USGS, 2016). The subwatershed contains 76 miles of intermittent drainage ditch, 40 miles of intermittent stream, 28 miles of perennial drainage ditch (e.g., AUID 539), and less than 1 mile of perennial stream (DNR, 2003). According to the MPCA (2013), 80% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 539. The NLCD 2011 (USGS, 2011) lists cultivated crops (68%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (11%), hay/pasture (9%), forest (7%), and developed (5%).

Figure 74. Map of AUID 539 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 539 was monitored at Station 13RD048 (0.1 mile upstream of the 120th Avenue crossing) on July 10, 2013. The relative location of the station is shown in Figure 74. The station was designated as Modified Use within the Northern Streams F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 35. Monitoring of the station yielded an F-IBI score (9) below the impairment threshold. According to Figure 75, 10 individual metrics for Station 13RD048 scored below the mean value needed to meet the impairment threshold (i.e., DarterSculpSucTxPct, DomTwoPct, General, Insect-TolTxPct, IntolerantPct, MA>3-TolPct, SensitiveTxPct, SLithopPct, SSpnTxPct, and Vtol). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the station was entirely comprised of tolerant taxa (i.e., blackside darter, central mudminnow, fathead minnow, northern pike, and white sucker).

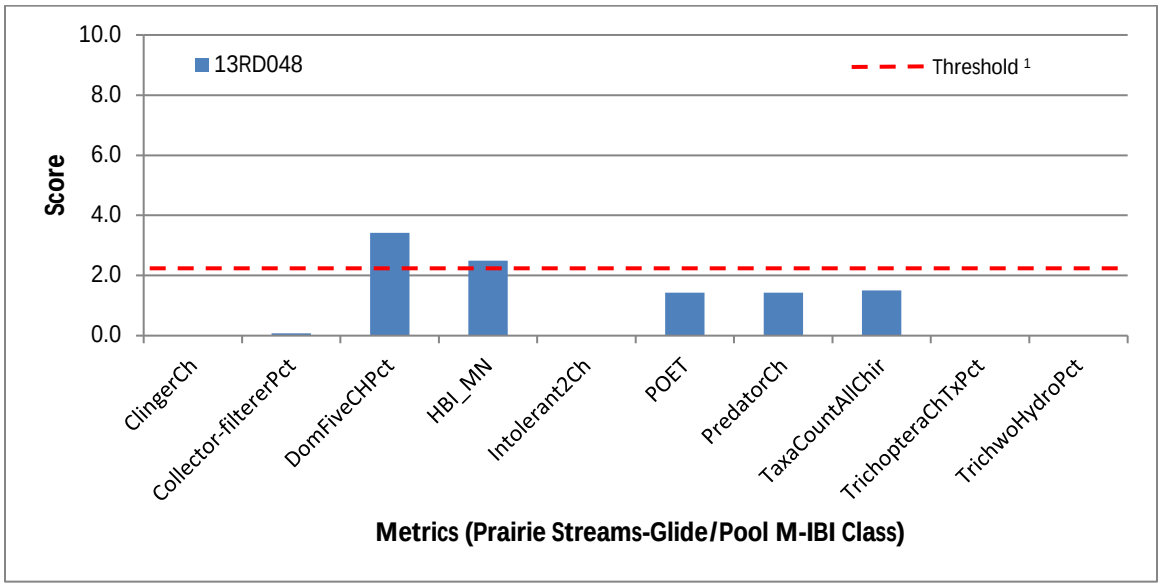


[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 75. Individual F-IBI metric scores for Station 13RD048 along AUID 539.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 539 was monitored at Station 13RD048 on July 30, 2013. The station was designated as Modified Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the impairment threshold for the station is an M-IBI score of 22. Monitoring of the station yielded an M-IBI score (10) below the impairment threshold. According to Figure 76, eight individual metrics for Station 13RD048 scored below the mean value needed to meet the impairment threshold (i.e.,ClingerCh, Collector-filtererPct, Intolerant2Ch, POET, PredatorCh, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct). A description of each metric is provided in the *Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014b). The macroinvertebrate assemblage of the stations was dominated by tolerant taxa, specifically, *Gyraulus* (snails), Planorbidae (snails), and *Valvata* (snails).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 76. Individual M-IBI metric scores for Station 13RD048 along AUID 539.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD048 along AUID 539. According to the DNR (2014), there are no man-made dams on the reach. However, the Lake Bronson Dam and Hallock Dam are located downstream of the reach along the South Branch Two Rivers (AUID 502) and are barriers to connectivity. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of May 8, 2013, and September 1, 2013, aerial photos (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photos.

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 539 is provided by the following metric response (Appendix A):

- Below basin class average (<5%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Station 13RD048 (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Lake Bronson Dam and Hallock Dam on the fish community of the South Branch Two Rivers is discussed in Subsection 3.3.1 (AUID 502).

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of longitudinal connectivity and the M-IBI impairment associated with AUID 539. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not readily affected by longitudinal connectivity barriers.

Flow regime instability

Available data

According to D. Money, TRWD Administrator (personal communication, 2015), the reach has an intermittent flow regime and often goes dry. The MPCA biological monitoring staff did not encounter any flow-related issues during fish and macroinvertebrate monitoring at Station 13RD048. However, staff observed intermittent flow conditions (i.e., interspersed pools of stagnant water) along the reach at the time of an August 28, 2012, reconnaissance visit (Figure 77). There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 16% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, August 26, 2015, and September 30, 2015) and documented flow conditions. Minimal flow or lentic conditions were noted along the entire reach on September 30, 2015 (Figure 77). Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Figure 77. Photos of lentic conditions along AUID 539, including Station 13RD048 on August 28, 2012 (left) and the 160th Avenue crossing on September 30, 2015 (right).

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 539 is provided by the following metric responses (Appendix A):

- Above basin class average (>60%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Station 13RD048 (91%)
- Above basin class average (>33%) relative abundance of taxa that are generalists (GeneralTxPct) at Station 13RD048 (40%)
- Above basin class average (>83%) relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct) at Station 13RD048 (91%)
- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD048 (0.10%)
- Above basin class average (>17%) relative abundance of taxa that are pioneers (PioneerTxPct) at Station 13RD048 (20%)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 13RD048 (0%)
- Above basin class average (>43%) relative abundance of taxa that are tolerant (TolTxPct) at Station 13RD048 (60%)

Flow regime instability tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Biotic response – macroinvertebrate

Evidence of a causal relationship between flow regime instability and the M-IBI impairment associated with AUID 539 is provided by the following metric responses (Appendix B):

- Above basin class average (>70%) relative abundance of the dominant five taxa in a subsample, chironomid genera treated individually (DomFiveCHPct) at Station 13RD048 (75%)
- Above basin class average (>13%) relative abundance of swimmer taxa (SwimmerChTxPct) at Station 13RD048 (17%)
- Below basin class average (<32) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD048 (23)

Flow regime instability tends to limit macroinvertebrate diversity and favor taxa that are shorter-lived, swimmers, and tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012b). Overall, the macroinvertebrate assemblage of the stations was dominated by taxa that are adapted to lentic conditions (i.e., *Gyraulus*, *Planorbidae*, and *Valvata*).

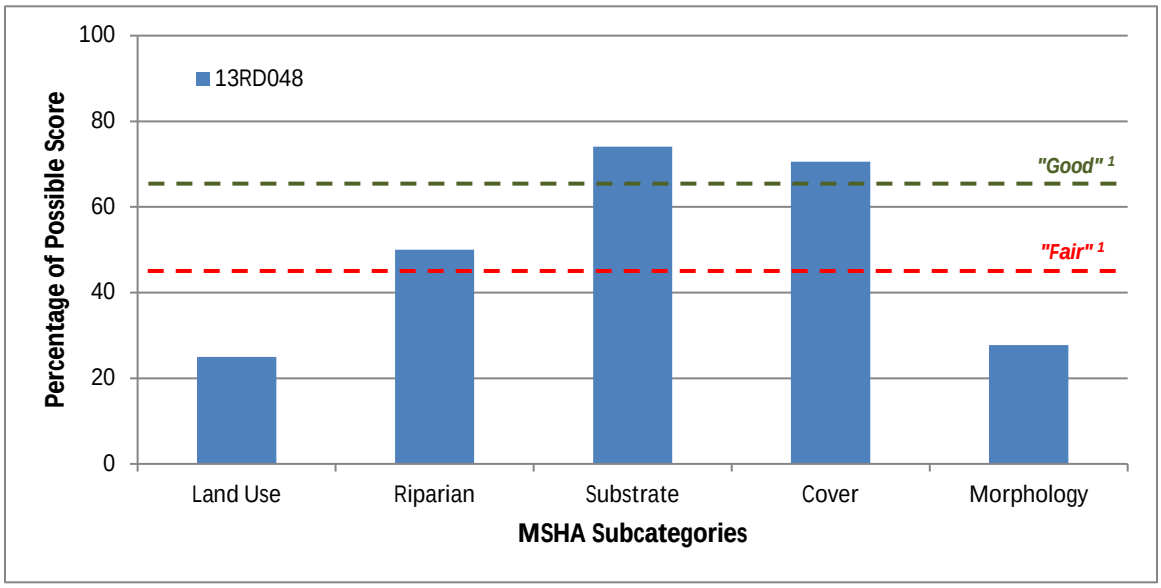
Insufficient physical habitat

Available data

The physical habitat of AUID 539 was evaluated at Station 13RD048 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded a score of 51 ("fair"). Figure 78 displays the MSHA subcategory results for the station. The land use subcategory score for the station was adversely affected by the predominance of agricultural row crops immediately surrounding the station. The riparian zone width of the station was characterized as "narrow" to "moderate". No bank erosion was noted. The station scored well in the substrate subcategory, as it offered coarse substrate (i.e., gravel) with only "light" embeddedness. However, the station inherently lacked riffle habitat. The station also scored well in the cover subcategory, primarily due to the "extensive" amount of cover present. Cover types noted included boulders and macrophytes (emergent, floating leaf, and submergent). Lastly, the morphology subcategory score for the station was adversely affected by "poor" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is somewhat limited.

On October 21, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 13RD048 along AUID 539 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 13RD048] was 82, which is good (stable) for an F5 stream type. A good, or stable, rating for F5 stream types is 90-115. Though the current stream type is an F5, this stream type is not its highest potential type, which would probably be an E5 or C5. A score of 82 is still stable for a C5 and moderately unstable for an E5. The individual Pfankuch ratings ranged from excellent to poor. The factors ranking higher (more unstable) included very steep upper banks, channel incision, and less than 20% rock fragments of gravel sizes within the lower banks. The factors ranking lower (more stable) were no debris jam potential on the upper banks, no obstructions to flow on the lower banks, and abundant aquatic vegetation on the channel bottom."*



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 78. MSHA subcategory results for Station 13RD048 along AUID 539.

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 539 is provided by the following metric responses (Appendix A):

- Above basin class average (>19%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Station 13RD048 (40%)
- Below basin class average (<8%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Station 13RD048 (0%)
- Below basin class average (<33%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Station 13RD048 (20%)
- Below basin class average (<37%) relative abundance of individuals that are simple lithophilic spawning species (SLithopPct) at Station 13RD048 (12%)

Insectivores and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

Biotic response – macroinvertebrate

Evidence of a causal relationship between insufficient physical habitat and the M-IBI impairment associated with AUID 539 is provided by the following metric responses (Appendix B):

- Below basin class average (<22%) relative percentage of clinger taxa (ClingerChTxPct) at Station 13RD048 (9%)
- Above basin class average (>57%) relative abundance of legless individuals (LeglessPct) at Station 13RD048 (76%)
- Above basin class average (>20%) relative abundance of sprawler taxa (SprawlerChTxPct) at Station 13RD048 (22%)

Clinger taxa require clean, coarse substrate or other objects to attach themselves to, while legless and sprawler macroinvertebrates are tolerant of degraded benthic habitat.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD048 along AUID 539 at the time of fish monitoring. The sample was analyzed for several parameters, including TSS. The TSS concentration was 4 mg/L. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L Southern River TSS Region standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 539. None of the metrics or related data for Station 13RD048 (Appendix A) exhibited a correlation to this candidate cause.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 539 is provided by the following metric response (Appendix B):

- Below basin class average (<9%) relative abundance of collector-filterer individuals (Collector-filtererPct) at Station 13RD048 (1%)

Collector-filterers utilize specialized mechanisms (e.g., silk nets) to strain organic material from the water column. High suspended sediment can interfere with these mechanisms (Arruda et al., 1983; Barbour et al., 1999; Lemley, 1982; Strand and Merritt, 1997).

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD048 along AUID 539 at the time of fish (15.7 mg/L) and macroinvertebrate (5.6 mg/L) monitoring. The MPCA conducted continuous DO monitoring at Site W70044001 (120th Avenue crossing) from August 12, 2015, to August 26, 2015; the relative location of the site is shown in Figure 74. The monitoring results are provided in Table 38, as well as displayed in Figure 79. While 26% of the total values were below the 5.0 mg/L standard, 85% of the daily minimum values were below the standard. A large storm event (≈4″) interrupted the diurnal pattern on and after August 22, 2015. Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard approximately 5% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences at least occasional periods of low DO.

Table 38. Continuous DO data for Site W70044001 along AUID 539.

Start date - End date	*n*	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
August 12, 2015 – August 26, 2015	1345	0.9	12.4	26	85	4.9

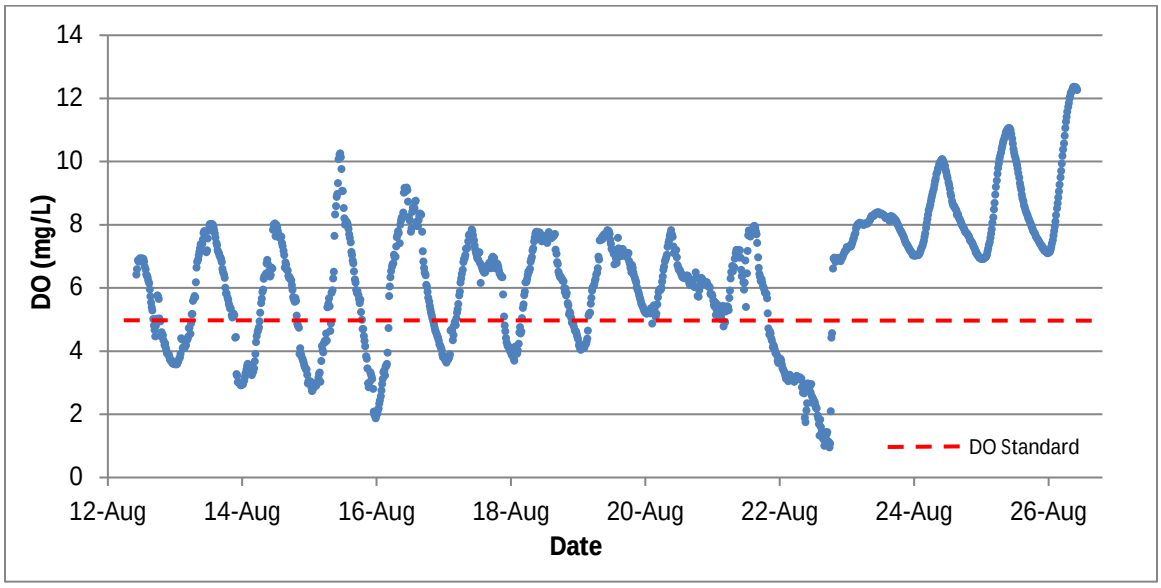


Figure 79. Continuous DO data for Site W70044001 along AUID 539.

Eutrophication-related data for the reach is limited to DO flux. The mean daily DO flux documented during continuous DO monitoring at Site W70044001 (Table 38) was 4.9 mg/L, which is above the 4.5 mg/L South River Nutrient Region DO flux standard. In addition, MPCA SID staff observed limited signs of eutrophication (i.e., excessive algal growth) along the reach on September 30, 2015. Overall, the limited available data suggest that eutrophication may be adversely affecting the DO regime of the reach.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 539 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<1.25) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Station 13RD048 (0.10%)
- Below basin class average (<21%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 13RD048 (0%)
- Above basin class average (>43%) relative abundance of taxa that are tolerant (TolTxPct) at Station 13RD048 (60%)
- Below basin class average (<6.8 mg/L) mean DO TIV at Station 13RD048 (6.4 mg/L)
- Below basin class average (<40%) probability of meeting the DO standard at Station 13RD048 (22%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 539 is provided by the following metric and data responses (Appendix B):

- Below basin class average (<6) taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET) at Station 13RD048 (4)
- Below basin class average (<32) total taxa richness of macroinvertebrates (TaxaCountAllChir) at Station 13RD048 (23)
- Below basin class average (<6.4 mg/L) mean DO TIV at Station 13RD048 (5.7 mg/L)

- Above basin class average (>34%) relative abundance of low DO tolerant individuals at Station 13RD048 (69%)
- Below basin class average (<2) taxa richness of low DO intolerant macroinvertebrates at Station 13RD048 (0)

Low DO often limits the taxa richness of macroinvertebrates, particularly members of the orders Plecoptera, Odonata, Ephemeroptera, and Trichoptera, and favors taxa that are tolerant (Weber, 1973; EPA, 2012b).

Strength-of-evidence analysis

Table 39 presents a summary of the SOE scores for the candidate causes associated with AUID 539. The evidence suggests that the F-IBI impairment is attributed to flow regime instability, insufficient physical habitat, low DO, and, to a lesser extent, a loss of longitudinal connectivity. Additionally, the evidence indicates that the M-IBI impairment is likely the result of low DO and, to a lesser extent, flow regime instability, insufficient physical habitat, and high suspended sediment. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 39. SOE scores for candidate causes associated with AUID 539.

Types of evidence	SOE scores per candidate cause[1]									
	Loss of longitudinal connectivity		Flow regime instability		Insufficient physical habitat		High suspended sediment		Low dissolved oxygen	
	Biological impairments									
	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI
Types of evidence that use data from the case										
Spatial/temporal co-occurrence	+	--	++	+	++	+	0	+	++	++
Temporal sequence	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response relationship	+	--	++	+	++	+	0	+	++	++
Causal pathway	+	--	++	+	++	+	0	+	++	++
Evidence of exposure/bio-mechanism	+	--	++	+	++	+	0	+	++	++
Manipulation of exposure	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Symptoms	+	--	++	+	++	+	0	+	++	++
Types of evidence that use data from elsewhere										
Mechanistically plausible cause	+	-	+	+	+	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-response in field studies	++	NE	++	++	++	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Multiple lines of evidence										
Consistency of evidence	+	--	++	+	++	+	0	+	++	++

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.12 State Ditch 49 (AUID 544)

Physical setting

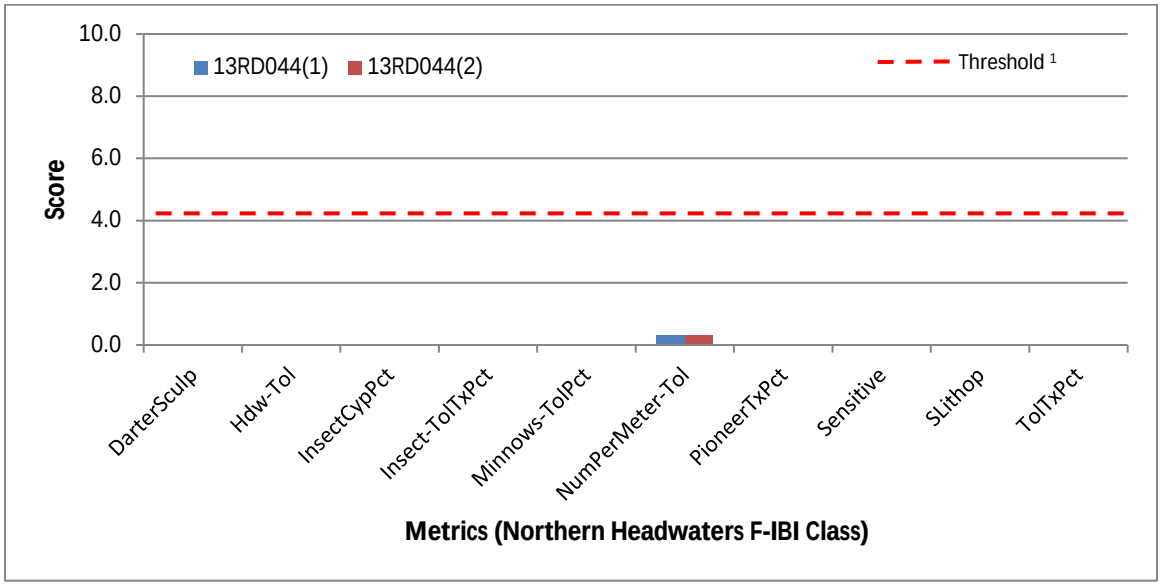
This reach represents State Ditch 49 (Figure 80), which extends from its headwaters, to its confluence with the South Branch Two Rivers; a total length of 5 miles. The reach has a subwatershed area of 31 square miles (USGS, 2016). The subwatershed contains 14 miles of intermittent drainage ditch (e.g., AUID 544) and 2 miles of intermittent stream (DNR, 2003). According to the MPCA (2013), all of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded). The NLCD 2011 (USGS, 2011) lists cultivated crops (51%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (21%), forest (20%), developed (3%), hay/pasture (2%), and shrub/scrub (2%).

Figure 80. Map of AUID 544 and associated biological monitoring station and water quality monitoring site (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 544 was monitored at Station 13RD044 (0.1 mile downstream of the CSAH 10 crossing) on June 18, 2013(1) and June 11, 2014(2). The relative location of the station is shown in Figure 80. The station was designated as General Use within the Northern Headwaters F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 42. Monitoring of the station yielded F-IBI scores of 0 and 0 (Figure 81). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the station was entirely comprised of brook stickleback, central mudminnow, northern pike, and northern redbelly dace.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 81. Individual F-IBI metric scores for Station 13RD044 along AUID 544.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD044 along AUID 544. According to the DNR (2014), there are no man-made dams on the reach. However, the Lake Bronson Dam and Hallock Dam are located downstream of the reach along the South Branch Two Rivers (AUID 502) and are barriers to connectivity. On September 23, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo.

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 544 is provided by the following metric response (Appendix A):

- Below basin class average (<1%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 13RD044(1) (0%) and 13RD044(2) (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Lake Bronson Dam and Hallock Dam on the fish community of the South Branch Two Rivers is discussed in Subsection 3.3.1 (AUID 502).

Flow regime instability

Available data

According to D. Money, TRWD Administrator (personal communication, 2015), the reach has an intermittent flow regime and often goes dry. The MPCA biological monitoring staff did not encounter any flow-related issues during fish monitoring at Station 13RD044. However, staff observed intermittent flow conditions (i.e., interspersed pools of stagnant water) along the reach at the time of an August 28, 2012, reconnaissance visit (Figure 82). There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 45% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on three separate dates (i.e., August 12, 2015, August 26, 2015, and September 23, 2015) and documented flow conditions. Lentic conditions were noted along the entire reach on September 23, 2015 (Figure 82). Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Figure 82. Photos of intermittent flow conditions along AUID 544, including Station 13RD044 on August 28, 2012 (left) and the 195th Street crossing on September 23, 2015 (right).

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 544 is provided by the following metric responses (Appendix A):

- Above basin class average (>67%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 13RD044(1) (94%) and 13RD044(2) (92%)
- Below basin class average (<0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD044(1) (0.05) and 13RD044(2) (0.05)

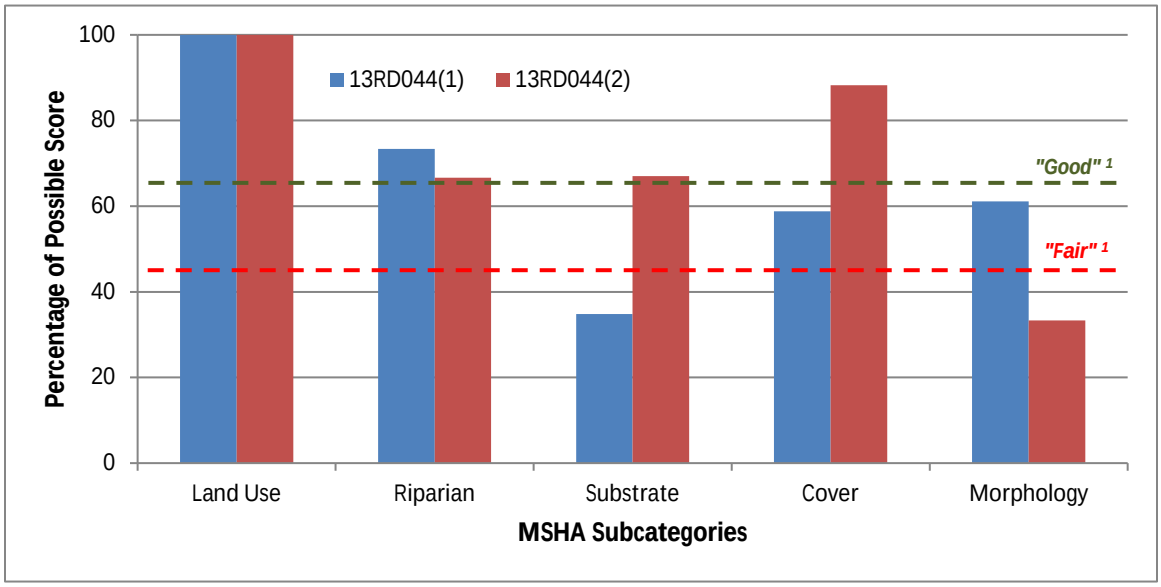
- Below basin class average (<23%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 13RD044(1) (0%)
- Above basin class average (>57%) relative abundance of taxa that are tolerant (TolTxPct) at Station 13RD044(1) (67%)

Flow regime instability tends to limit species diversity and favor taxa that are tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 544 was evaluated at Station 13RD044 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded scores of 57 ("fair") and 60 ("fair"). Figure 83 displays the MSHA subcategory results for the station. The land use surrounding the station was largely natural (e.g., forest and wetlands). The riparian zone width of the station was characterized as "extensive". A minimal amount of bank erosion was noted. The station offered coarse substrate (i.e., gravel) with only "light" embeddedness. However, the station inherently lacked riffle habitat (0-5%). The station scored well in the cover subcategory, primarily due to the diversity and "moderate" to "extensive" amount of cover present. Cover types noted included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, undercut banks, and woody debris. Lastly, the station had "moderate/high" channel stability and "good" to "poor" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is somewhat limited.



[1] The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 83. MSHA subcategory results for Station 13RD044 along AUID 544.

On October 27, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 13RD044 along AUID 544 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

> *"The Pfankuch rating for [Station 13RD044] was 83, which is fair, or moderately unstable, for a B5 stream type. The entrenchment ratio (flood-prone width compared to the bankfull width) was 1.7, which classifies this channel as a B stream type. Naturally-formed B stream channels occur in soils derived from grussic granite, wind-deposited sands, and loose, unconsolidated sediments. The upper banks were in decent condition at this location. There was no evidence of mass erosion and it was*

well vegetated. The lower banks had a low percentage of rock fragments (which is to be expected) and there was evidence of moderate levels of deposition. The bottom of the channel had some ratings that increased the Pfankuch rating at this site. There was an obvious shift on bottom sizes as gravel, sand, silt, and clay were all present. In addition, at least 30-50% of the bottom was affected by deposition."

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 544 is provided by the following metric responses (Appendix A):

- Below basin class average (<9%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Stations 13RD044(1) (0%) and 13RD044(2) (0%)
- Below basin class average (<8%) relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPcT) at Stations 13RD044(1) (0%) and 13RD044(2) (0%)
- Below basin class average (<9%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 13RD044(1) (0%) and 13RD044(2) (0%)
- Below basin class average (<22%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Stations 13RD044(1) (0%) and 13RD044(2) (0%)
- Below basin class average (<9%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Stations 13RD044(1) (0%) and 13RD044(2) (0%)
- Below basin class average (<2) taxa richness of simple lithophilic spawning species (SLithop) at Stations 13RD044(1) (0) and 13RD044(2) (0)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes (Aadland et al., 2006).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD044 along AUID 544 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. The station had TSS concentrations of 4 and 10 mg/L. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L Southern River TSS Region standard approximately 2% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 544. None of the metrics or related data for Station 13RD044 (Appendix A) exhibited a correlation to this candidate cause.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD044 along AUID 544 at the time of each fish monitoring visit (5.6 and 7.3 mg/L). Additionally, the TRW HSPF model estimates that the reach had a DO concentration below the standard approximately 45% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences frequent periods of low DO.

There is no eutrophication-related data for the reach. However, the MPCA SID staff observed signs of eutrophication (i.e., excessive algal growth) along the upstream portion of the reach on September 23, 2015 (Figure 82).

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 544 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD044(1) (0.05) and 13RD044(2) (0.05)
- Below basin class average (<23%) relative abundance of taxa that are sensitive (SensitiveTxPct) at Station 13RD044(1) (0%)
- Above basin class average (>57%) relative abundance of taxa that are tolerant (TolTxPct) at Station 13RD044(1) (67%)
- Below basin class average (<6.3 mg/L) mean DO TIV at Stations 13RD044(1) (5.8 mg/L) and 13RD044(2) (5.9 mg/L)
- Below basin class average (<26%) probability of meeting the DO standard at Stations 13RD044(1) (9%) and 13RD044(2) (10%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (USEPA, 2012b).

Strength-of-evidence analysis

Table 40 presents a summary of the SOE scores for the candidate causes associated with AUID 544. The evidence suggests that the F-IBI impairment is attributed to flow regime instability, insufficient physical habitat, low DO, and, to a lesser extent, a loss of longitudinal connectivity. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 40. SOE scores for candidate causes associated with AUID 544.

Types of evidence	SOE scores per candidate cause[1]				
	Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
	Biological impairment				
	F-IBI	F-IBI	F-IBI	F-IBI	F-IBI
Types of evidence that use data from the case					
Spatial/temporal co-occurrence	+	++	++	0	++
Temporal sequence	NE	NE	NE	NE	NE
Stressor-response relationship	+	++	++	0	++
Causal pathway	+	++	++	0	++
Evidence of exposure/bio-mechanism	+	++	++	0	++
Manipulation of exposure	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE
Symptoms	+	++	++	0	++
Types of evidence that use data from elsewhere					
Mechanistically plausible cause	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE
Stressor-response in field studies	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE
Multiple lines of evidence					
Consistency of evidence	**+**	**++**	**++**	**0**	**++**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

3.3.13 Judicial Ditch 31 (AUID 549)

Physical setting

This reach represents JD 31 (Figure 84), which extends from its confluence with an unnamed creek, to its confluence with the North Branch Two Rivers; a total length of 2 miles. The reach has a subwatershed area of 21 square miles (USGS, 2016). The subwatershed contains 15 miles of intermittent drainage ditch (e.g., AUID 549) and 7 miles of intermittent stream (DNR, 2003). According to the MPCA (2013), 73% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 549. The NLCD 2011 (USGS, 2011) lists cultivated crops (59%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetlands (19%), forest (14%), developed (3%), hay/pasture (3%), and shrub/scrub (1%).

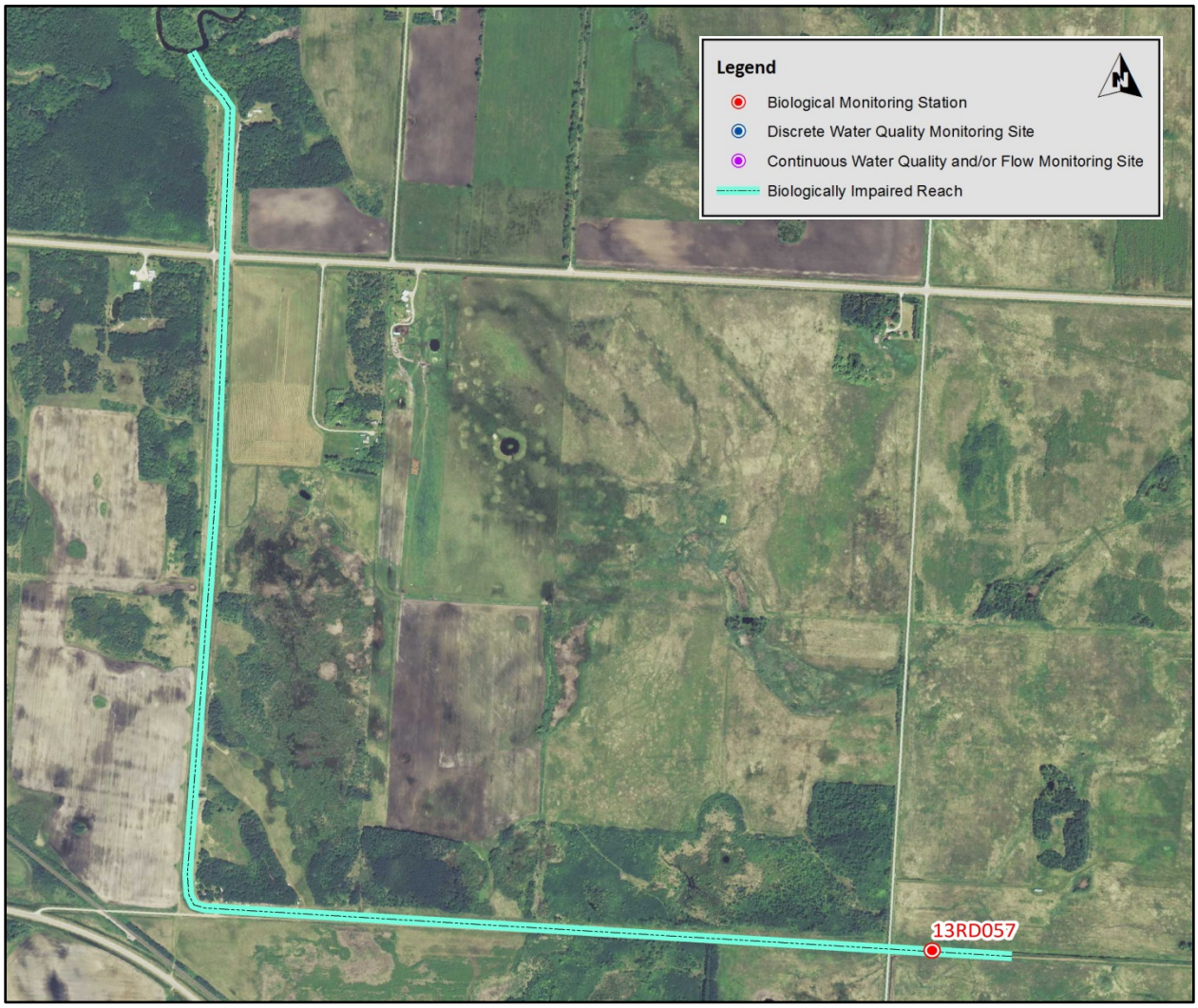
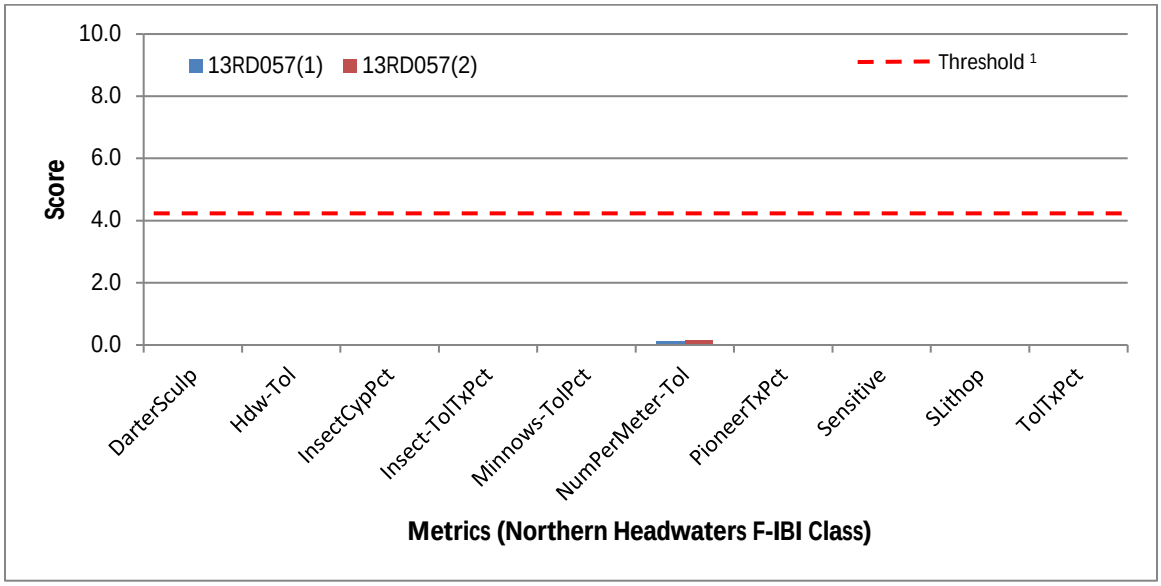


Figure 84. Map of AUID 549 and associated biological monitoring station (2013 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 549 was monitored at Station 13RD057 (0.1 mile upstream of the 320th Avenue crossing) on June 18, 2013(1) and June 10, 2014(2). The relative location of the station is shown in Figure 84. The station was designated as General Use within the Northern Headwaters F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 42. Monitoring of the station yielded F-IBI scores of 0 and 0 (Figure 85). A description of each metric is provided in the *Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams* (MPCA, 2014a). Overall, the fish assemblage of the station was entirely comprised of brook stickleback, fathead minnow, finescale dace, and northern redbelly dace.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold.

Figure 85. Individual F-IBI metric scores for Station 13RD057 along AUID 549.

Candidate causes

Loss of longitudinal connectivity

Available data

According to local water resource professionals in the TRW, there is a grade control structure (Figure 86) along the reach, near its confluence with the North Branch Two Rivers (MPCA, 2015). The structure is approximately 15 feet high and is a complete barrier to connectivity at all flow conditions. The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 13RD057 along AUID 549. According to the DNR (2014), there are no man-made dams on the reach. However, the Northcote Dam is located downstream of the reach along the North Branch Two Rivers (AUID 508) and is a barrier to connectivity. On September 30, 2015, MPCA SID staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity (e.g., perched culvert and beaver dam) were identified. In addition to the assessment, MPCA SID staff performed a detailed review of a September 1, 2013, aerial photo (courtesy of Google Earth) of the reach. No connectivity-related issues were identified in the photo.

Figure 86. Photo of a grade control structure along AUID 549, near its confluence with the North Branch Two Rivers, on September 30, 2015.

Biotic response – fish

Evidence of a causal relationship between a loss of longitudinal connectivity and the F-IBI impairment associated with AUID 549 is provided by the following metric response (Appendix A):

- Below basin class average (<1%) relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct) at Stations 13RD057(1) (0%) and 13RD057(2) (0%)

Late maturing and migratory fish species require well-connected environments in order to access the habitats and resources necessary to complete their life history. Additionally, the influence of the Northcote Dam on the fish community of the North Branch Two Rivers is discussed in Subsection 3.3.6 (AUID 508).

Flow regime instability

Available data

According to D. Money, TRWD Administrator (personal communication, 2015), the reach has an intermittent flow regime and often goes dry. The MPCA biological monitoring staff did not encounter any flow-related issues during fish monitoring at Station 13RD057. However, staff observed lentic conditions along the reach during an August 28, 2012, reconnaissance visit. There is no flow monitoring data for the reach. The TRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 52% of the time during the period of 1996 to 2009. The MPCA SID staff conducted reconnaissance along the reach on two separate dates (i.e., August 12, 2015 and September 30, 2015) and documented flow conditions. No flow-related issues were noted. Overall, the available data suggest that the reach experiences frequent periods of minimal to no flow.

Biotic response – fish

Evidence of a causal relationship between flow regime instability and the F-IBI impairment associated with AUID 549 is provided by the following metric responses (Appendix A):

- Above basin class average (>67%) combined relative abundance of the two most abundant taxa (DomTwoPct) at Stations 13RD057(1) (80%) and 13RD057(2) (71%)
- Below basin class average (<0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD057(1) (0.02) and 13RD057(2) (0.03)

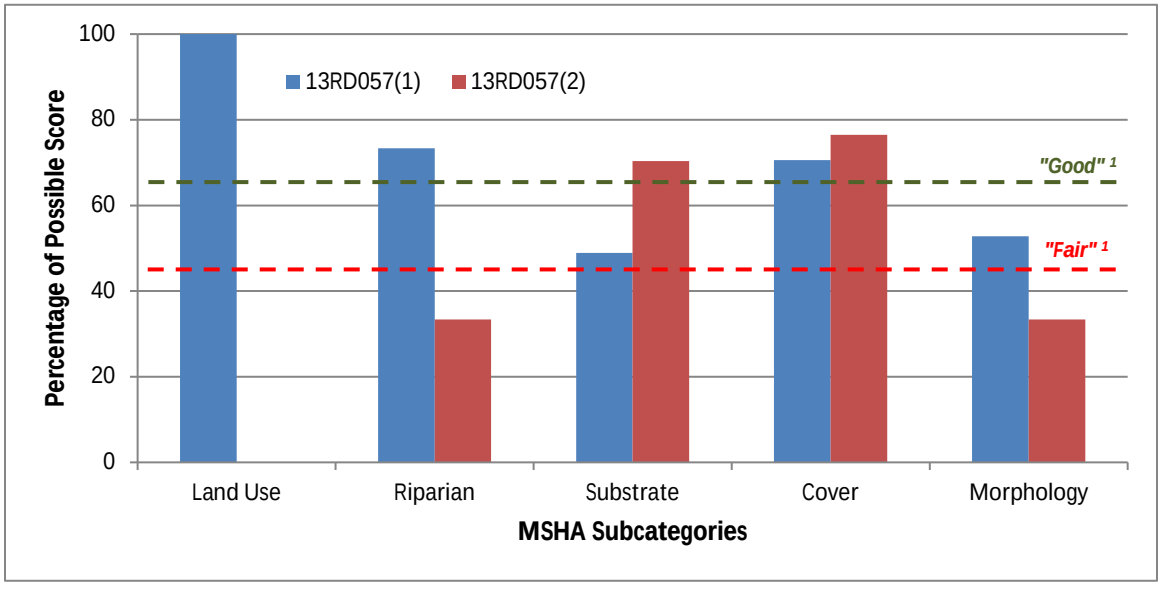
- Above basin class average (>20%) relative abundance of taxa that are pioneers (PioneerTxPct) at Stations 13RD057(1) (33%) and 13RD057(2) (33%)
- Below basin class average (<2) taxa richness of sensitive species (Sensitive) at Station 13RD057(1) (1)
- Above basin class average (>44%) relative abundance of individuals that are short-lived (SLvdPct) at Station 13RD057(2) (71%)
- Above basin class average (>57%) relative abundance of taxa that are tolerant (TolTxPct) at Station 13RD057(1) (67%)

Flow regime instability tends to limit species diversity and favor taxa that are pioneering, short-lived, and tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010).

Insufficient physical habitat

Available data

The physical habitat of AUID 549 was evaluated at Station 13RD057 using the MSHA. The station is located along a ditched segment of the reach (MPCA, 2013). The station yielded scores of 60 ("fair") and 49 ("fair"). Figure 87 displays the MSHA subcategory results for the station. The land use surrounding the station included agricultural crops and natural vegetation (e.g., forest). The riparian zone width of the station ranged from "narrow" to "extensive". A minimal amount of bank erosion was also noted. The station offered coarse substrate (i.e., gravel) with only "light" embeddedness. However, the station inherently lacked riffle habitat. The station scored well in the cover subcategory, primarily due to the diversity and "extensive" amount of cover present. Cover types noted included boulders, deep pools, macrophytes (emergent and submergent), overhanging vegetation, and undercut banks. Lastly, the station had "moderate/high" channel stability and "good" to "poor" channel development. Overall, the MSHA data suggest that the physical habitat of the reach is somewhat limited.



1 The minimum percentage of each subcategory score needed for the station to achieve a "fair" and "good" MSHA rating.

Figure 87. MSHA subcategory results for Station 13RD057 along AUID 549.

On October 27, 2015, DNR staff conducted a fluvial geomorphology assessment of Station 13RD057 along AUID 549 using the Pfankuch Stability Index (Appendix C). A summary of the assessment results is provided below:

"The Pfankuch rating for [Station 13RD057] on 10/27/2015 was 64, which is good (stable) for an E5 stream type. A good, or stable, rating for E5 stream types ranges from 50-75. All categories, except for bank rock content and rock angularity, rated as good or excellent. The upper banks were gently sloped, showed no evidence of mass erosion, and were well vegetated with grasses and forbs. The lower banks were also well vegetated with grasses and forbs and showed no evidence of cutting or deposition. The substrate near the biological monitoring station waypoint was sand with some silt mixed in. However, approximately 265 feet downstream was a small head-cut working its way upstream, and the substrate below this was small gravel. Aquatic vegetation was present through the reach, but was more abundant above the head-cut than below."

Biotic response – fish

Evidence of a causal relationship between insufficient physical habitat and the F-IBI impairment associated with AUID 549 is provided by the following metric responses (Appendix A):

- Below basin class average (<9%) relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct) at Stations 13RD057(1) (0%) and 13RD057(2) (0%)
- Below basin class average (<8%) relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPcT) at Stations 13RD057(1) (0%) and 13RD057(2) (0%)
- Above basin class average (>18%) relative abundance of taxa that are detritivorous (DetNWQTxPct) at Stations 13RD057(1) (33%) and 13RD057(2) (33%)
- Below basin class average (<9%) relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct) at Stations 13RD057(1) (0%)
- Below basin class average (<22%) relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct) at Station 13RD057(1) (0%)
- Below basin class average (<9%) relative abundance of species that predominately utilize riffle habitats (RiffleTxPct) at Stations 13RD057(1) (0%) and 13RD057(2) (0%)
- Below basin class average (<2) taxa richness of simple lithophilic spawning species (SLithop) at Stations 13RD057(1) (0) and 13RD057(2) (0)

Insectivores (e.g., darters and sculpins) and simple lithophilic spawners require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland et al., 2006).

High suspended sediment

Available data

The MPCA biological monitoring staff collected a discrete water quality sample at Station 13RD057 along AUID 549 at the time of each fish monitoring visit. The samples were analyzed for several parameters, including TSS. Both samples had a TSS concentration of 4 mg/L. Additionally, the TRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L Southern River TSS Region standard approximately 3% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach experiences infrequent periods of high suspended sediment.

Biotic response – fish

Evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 549 is provided by the following data responses (Appendix A):

- Above basin class average (>15 mg/L) mean TSS TIV at Station 13RD057(2) (16 mg/L)
- Below basin class average (<72%) probability of meeting the TSS standard at Station 13RD057(2) (66%)

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 13RD057 along AUID 549 at the time of each fish monitoring visit (8.4 and 10.3 mg/L). The TRW HSPF model estimates that the reach had a DO concentration below the 5.0 mg/L standard approximately 62% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to frequent periods of low DO.

There is no eutrophication-related data for the reach. The MPCA SID staff did not observe any signs of eutrophication (e.g., excessive algal growth) during two separate reconnaissance visits along the reach (i.e., August 12, 2015 and September 30, 2015

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 549 is provided by the following metric and data responses (Appendix A):

- Below basin class average (<0.69) number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol) at Stations 13RD057(1) (0.02) and 13RD057(2) (0.03)
- Below basin class average (<2) taxa richness of sensitive species (Sensitive) at Station 13RD057(1) (1)
- Above basin class average (>57%) relative abundance of taxa that are tolerant (TolTxPct) at Station 13RD057(1) (67%)
- Below basin class average (<6.3 mg/L) mean DO TIV at Stations 13RD057(1) (5.7 mg/L) and 13RD057(2) (5.7 mg/L)
- Below basin class average (<26%) probability of meeting the DO standard at Stations 13RD057(1) (9%) and 13RD057(2) (8%)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012b).

Strength-of-evidence analysis

Table 41 presents a summary of the SOE scores for the candidate causes associated with AUID 549. The evidence suggests that the F-IBI impairment is attributed to a loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, and low DO. For additional information regarding the SOE scoring system, refer to the USEPA's CADDIS Summary Table of Scores.

Table 41. SOE scores for candidate causes associated with AUID 549.

Types of evidence	SOE scores per candidate cause[1]				
	Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
	Biological impairment				
	F-IBI	F-IBI	F-IBI	F-IBI	F-IBI
Types of evidence that use data from the case					
Spatial/temporal co-occurrence	++	++	++	0	++
Temporal sequence	NE	NE	NE	NE	NE
Stressor-response relationship	++	++	++	0	++
Causal pathway	++	++	++	0	++
Evidence of exposure/bio-mechanism	++	++	++	0	++
Manipulation of exposure	NE	NE	NE	NE	NE
Laboratory tests of site media	NE	NE	NE	NE	NE
Verified predictions	NE	NE	NE	NE	NE
Symptoms	++	++	++	0	++
Types of evidence that use data from elsewhere					
Mechanistically plausible cause	+	+	+	+	+
Stressor-response in lab studies	NE	NE	NE	NE	NE
Stressor-response in field studies	++	++	++	++	++
Stressor-response in ecological models	NE	NE	NE	NE	NE
Manipulation experiments at sites	NE	NE	NE	NE	NE
Analogous stressors	NE	NE	NE	NE	NE
Multiple lines of evidence					
Consistency of evidence	**++**	**++**	**++**	**0**	**++**

[1] **Score key: +++** *convincingly supports* the case for the candidate cause as a stressor, **++** *strongly supports* the case for the candidate cause as a stressor, **+** *somewhat supports* the case for the candidate cause as a stressor**, 0** *neither supports nor weakens* the case for the candidate cause as a stressor**, -** *somewhat weakens* the case for the candidate cause as a stressor**, --** *strongly weakens* the case for the candidate cause as a stressor**, ---** *convincingly weakens* the candidate cause, **R** *refutes* the case for the candidate cause as a stressor, and **NE** *no evidence* available.

Section 4: Conclusions and recommendations

4.1 Conclusions

Table 42 presents a summary of the stressors associated with the biologically impaired reaches in the TRW. The Hallock Dam, Lake Bronson Dam, and Northcote Dam are severely limiting the potential of the fish community of the affected reaches upstream by impeding the migration of many large bodied, longer-lived species that are found in the Red River of the North (e.g., channel catfish, sauger, and walleye). Removal or modification of these structures would not only directly improve the health of the fish community of many of these reaches, but also benefit the fishery of the Red River of the North by providing many species access to the physical habitat necessary to complete their life history (e.g., clean, coarse substrate for spawning). Each of the biologically impaired reaches is prone to high and quick peak flows and/or prolonged periods of low or no discharge. Historical changes in land cover (e.g., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) are the primary anthropogenic factors contributing to this flow regime instability. Additional runoff detention/retention is needed throughout the watershed to attenuate peak flows and augment base flows. The central and eastern portions of the watershed generally offer good instream habitat, including riffles and coarse substrate. However, the habitat of several reaches in these areas has been degraded as a result of hydrologic alterations. The habitat of the western portion of the watershed is inherently limited by the predominance of fine lacustrine sediment. Excess suspended sediment appears to be having a marginal effect on the biological communities of several impaired reaches. Soil erosion and channel degradation are believed to be the primary sources of this sediment. The implementation of additional soil conservation practices and the attenuation of peak flows would reduce sediment loads. Lastly, low DO is a stressor for nearly all of the impaired reaches. While the severity of low DO conditions varies amongst the reaches, the lowest concentrations generally coincide with low flow and lentic conditions that occur during the late summer. Base flow augmentation appears to be the primary means of alleviating this stressor.

4.2 Recommendations

The recommended actions listed below, as well as included in *The Aquatic Biota Stressor and Best Management Practice Selection Guide*, will help to reduce the influence of the stressors that are limiting the fish and macroinvertebrate communities of the watershed.

- Remove or modify the Hallock Dam and Northcote Dam to enable fish passage at all flow conditions. Also, evaluate options to modify the Lake Bronson Dam to allow fish passage.
- Increase runoff detention/retention efforts throughout the watershed to attenuate peak flows and augment base flows.
- Prevent or mitigate activities that will further alter the hydrology of the watershed.
- Reduce soil erosion through the strategic implementation of BMPs.
- Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities.
- Evaluate and remove or modify private stream crossings that are impeding connectivity.

Table 42. Summary of the stressors associated with the biologically impaired reaches in the TRW.

AUID suffix	Reach name	Biological impairment(s)	Candidate causes[1]				
			Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
502	South Branch Two Rivers	F-IBI	+++	++	++		
		M-IBI		+	+		
503	Middle Branch Two Rivers	F-IBI	+	+	+		+
		M-IBI		+	+	+	+
504	North Branch Two Rivers	F-IBI	++	++	+		++
505	South Branch Two Rivers	F-IBI	++	++	+		+
		M-IBI		+	+	+	
506	South Branch Two Rivers	F-IBI	++	++	+		+
		M-IBI		+	+	+	+
508	North Branch Two Rivers	F-IBI	+++	++	++	+	++
514	State Ditch 84	F-IBI	++	++	++		++
521	Lateral Ditch 1 of State Ditch 95	F-IBI	++	++	++		++
		M-IBI		++	+		+
522	County Ditch 4	F-IBI	++	++	++		++
531	State Ditch 72	F-IBI	+	++	+		+
		M-IBI		++	+		+
539	Lateral Ditch 1 of State Ditch 95	F-IBI	+	++	++		++
		M-IBI		+	+	+	++
544	State Ditch 49	F-IBI	+	++	++		++
549	Judicial Ditch 31	F-IBI	++	++	++		++

[1] **Key:** +++ the available evidence *convincingly supports* the case for the candidate cause as a stressor, ++ the available evidence *strongly supports* the case for the candidate cause as a stressor, and + the available evidence *somewhat supports* the case for the candidate cause as a stressor. A blank space indicates that the available evidence *does not* support the case for the candidate cause as a stressor.

References

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Appendix A: Individual F-IBI metric and TIV data

Relative abundance (%) of individuals per selected F-IBI metric

AUID Suffix	Station	Visit Date	Class	Metrics												
				BenInsectPct	DetNWQPct	DomThreePct	DomTwoPct	ExoticPct	GeneralPct	HerbvPct	InsectCypPct	Insect-TolPct	IntolerantPct	MA<1Pct	MA<2Pct	MA>3-TolPct
502	10EM192	14-Jul-10	4	61	7	74	60	0	22	0	4	61	0	34	95	1
	13RD082	26-Jun-13	4	51	5	80	72	0	36	0	0	52	0	7	91	4
	13RD085	25-Jun-13	1	8	57	68	51	0	54	0	32	35	3	5	62	11
	93RD401	10-Jul-13	1	10	38	66	49	0	65	0	23	14	0	23	84	0
503	05RD093(1)	24-Jul-06	2	44	0	63	47	0	43	0	0	44	1	16	87	13
	05RD093(2)	16-Jul-13	2	3	60	90	78	0	80	0	0	3	0	0	40	0
	05RD093(3)	11-Jun-14	2	9	0	82	73	0	73	0	0	18	0	9	91	9
	93RD405	02-Jul-13	6	1	74	98	87	0	75	12	0	1	0	12	26	0
504	05RD094(1)	31-Aug-05	5	1	8	85	78	0	13	6	1	2	1	85	98	1
	05RD094(2)	12-Jun-14	5	0	8	87	73	0	59	36	0	1	0	4	93	0
	13RD070	09-Jul-13	2	15	0	80	60	0	60	0	0	15	5	0	30	30
	13RD089	02-Jul-13	5	27	15	71	49	0	60	0	4	29	2	27	84	4
	93RD403	02-Jul-13	5	21	13	75	61	0	66	4	8	24	3	19	90	2
505	13RD042	26-Jun-13	5	5	62	90	86	0	68	0	0	5	0	2	39	1
506	05RD181(1)	19-Jun-06	5	31	48	71	57	0	57	0	0	31	0	49	66	0
	05RD181(2)	11-Jun-14	5	7	3	86	83	0	7	74	1	7	0	13	98	0
	13RD045	15-Jul-13	5	15	41	69	57	0	77	0	0	15	0	7	58	1
508	05RD053	27-Jun-06	1	9	74	66	55	1	25	0	51	52	4	19	68	18
	13RD041	16-Jul-13	1	0	58	81	72	9	59	0	39	40	0	8	91	1
	13RD053	09-Jul-13	1	9	8	73	60	3	66	0	2	19	2	2	59	15
514	13RD067(1)	18-Jun-13	6	0	0	89	78	0	0	11	11	11	0	78	10	0
	13RD067(2)	10-Jun-14	6	0	0	100	67	0	0	33	0	0	0	67	10	0
521	13RD043(1)	03-Jul-13	5	0	26	83	61	0	39	0	4	4	0	22	74	0
	13RD043(2)	30-Jul-13	5	9	34	86	61	0	34	0	0	9	0	32	61	5
522	05RD002	23-Jun-05	6	2	8	96	90	0	8	0	0	2	0	98	98	0
531	13RD055	10-Jul-13	5	0	14	69	56	0	53	0	0	0	0	14	83	0
539	13RD048	10-Jul-13	5	3	12	94	91	0	12	0	0	3	0	6	91	0
544	13RD044(1)	18-Jun-13	6	0	0	100	94	0	0	0	0	0	0	56	10	0
	13RD044(2)	11-Jun-14	6	0	0	100	92	0	0	8	0	0	0	38	10	0
549	13RD057(1)	18-Jun-13	6	0	20	100	80	0	20	60	0	0	0	40	10	0
	13RD057(2)	10-Jun-14	6	0	43	100	71	0	43	29	29	29	0	43	10	0
Class 1 Basin Average				**22**	**37**	**66**	**54**	**10**	**28**	**0**	**21**	**51**	**2**	**10**	**47**	**45**
Class 2 Basin Average				**8**	**48**	**81**	**71**	**2**	**58**	**1**	**16**	**20**	**0**	**30**	**73**	**5**
Class 4 Basin Average				**36**	**19**	**67**	**54**	**1**	**32**	**1**	**11**	**48**	**7**	**14**	**58**	**30**
Class 5 Basin Average				**14**	**20**	**72**	**60**	**1**	**50**	**4**	**8**	**23**	**3**	**33**	**83**	**5**
Class 6 Basin Average				**5**	**18**	**80**	**67**	**0**	**45**	**10**	**9**	**13**	**1**	**44**	**91**	**1**

Relative abundance (%) of individuals per selected F-IBI metric (continued)

AUID Suffix	Station	Visit Date	Class	Metrics												
				Minnows-TolPct	NestNoLithPct	SLithopPct	SLvdPct	SSpnPct	TolPct							
502	10EM192	14-Jul-10	4	4	21	62	18	5	33							
	13RD082	26-Jun-13	4	22	3	86	8	1	21							
	13RD085	25-Jun-13	1	39	3	45	5	34	46							
	93RD401	10-Jul-13	1	33	4	55	23	23	56							
503	05RD093(1)	24-Jul-06	2	21	19	59	7	1	27							
	05RD093(2)	16-Jul-13	2	13	0	75	0	0	68							
	05RD093(3)	11-Jun-14	2	18	0	27	0	0	64							
	93RD405	02-Jul-13	6	13	1	75	13	12	87							
504	05RD094(1)	31-Aug-05	5	7	46	3	52	13	91							
	05RD094(2)	12-Jun-14	5	74	2	45	37	37	25							
	13RD070	09-Jul-13	2	20	25	35	0	5	40							
	13RD089	02-Jul-13	5	24	25	38	2	5	43							
	93RD403	02-Jul-13	5	54	16	58	8	11	25							
505	13RD042	26-Jun-13	5	2	4	67	3	2	66							
506	05RD181(1)	19-Jun-06	5	1	48	49	31	14	68							
	05RD181(2)	11-Jun-14	5	78	5	9	76	76	12							
	13RD045	15-Jul-13	5	16	5	80	12	0	63							
508	05RD053	27-Jun-06	1	40	11	30	18	58	36							
	13RD041	16-Jul-13	1	72	8	35	8	47	26							
	13RD053	09-Jul-13	1	36	7	43	2	5	32							
514	13RD067(1)	18-Jun-13	6	22	11	0	22	11	78							
	13RD067(2)	10-Jun-14	6	33	33	0	67	33	67							
521	13RD043(1)	03-Jul-13	5	17	0	39	0	0	48							
	13RD043(2)	30-Jul-13	5	0	11	36	0	0	59							
522	05RD002	23-Jun-05	6	0	84	2	82	6	98							
531	13RD055	10-Jul-13	5	14	0	28	0	0	53							
539	13RD048	10-Jul-13	5	0	3	12	3	3	15							
544	13RD044(1)	18-Jun-13	6	0	6	0	6	0	56							
	13RD044(2)	11-Jun-14	6	8	0	0	8	8	38							
549	13RD057(1)	18-Jun-13	6	60	40	0	10	80	40							
	13RD057(2)	10-Jun-14	6	57	43	0	71	100	43							
Class 1 Basin Average				**21**	**17**	**28**	**10**	**23**	**25**							
Class 2 Basin Average				**19**	**29**	**25**	**29**	**37**	**62**							
Class 4 Basin Average				**22**	**18**	**55**	**13**	**15**	**23**							
Class 5 Basin Average				**27**	**26**	**37**	**28**	**21**	**50**							
Class 6 Basin Average				**24**	**29**	**23**	**44**	**24**	**66**							

Taxa richness (#) per selected F-IBI metric

AUID Suffix	Station	Visit Date	Class	Metrics												
				DarterSculp	General	Hdw-Tol	Piscivore	Sensitive	SLithop	SLithopGR1	SLvd	Vtol	Wetland-Tol			
502	10EM192	14-Jul-10	4	2	5	0	4	3	5	0	4	2	1			
	13RD082	26-Jun-13	4	1	4	0	3	1	5	0	1	1	3			
	13RD085	25-Jun-13	1	0	4	0	3	3	4	-6	1	0	2			
	93RD401	10-Jul-13	1	2	5	0	3	2	5	-5	3	1	1			
503	05RD093(1)	24-Jul-06	2	2	3	0	3	3	5	0	1	1	1			
	05RD093(2)	16-Jul-13	2	1	3	0	1	0	3	0	0	0	1			
	05RD093(3)	11-Jun-14	2	1	2	0	0	0	2	0	0	1	0			
	93RD405	02-Jul-13	6	1	2	1	0	1	3	0	2	1	1			
504	05RD094(1)	31-Aug-05	5	2	3	2	2	3	3	0	3	2	3			
	05RD094(2)	12-Jun-14	5	1	4	2	1	2	2	0	3	2	3			
	13RD070	09-Jul-13	2	1	2	0	2	2	4	0	0	1	1			
	13RD089	02-Jul-13	5	2	3	0	2	3	3	0	1	1	1			
	93RD403	02-Jul-13	5	2	4	1	2	5	5	0	3	2	2			
505	13RD042	26-Jun-13	5	2	5	0	2	1	4	0	2	2	2			
506	05RD181(1)	19-Jun-06	5	2	5	0	0	0	4	0	3	2	0			
	05RD181(2)	11-Jun-14	5	2	4	2	2	3	4	0	3	2	4			
	13RD045	15-Jul-13	5	2	4	1	2	2	4	0	2	1	2			
508	05RD053	27-Jun-06	1	2	4	0	7	3	6	0	2	2	2			
	13RD041	16-Jul-13	1	0	7	0	4	2	5	-4	2	4	2			
	13RD053	09-Jul-13	1	0	4	0	2	1	2	-4	1	3	2			
514	13RD067(1)	18-Jun-13	6	0	0	2	0	2	0	0	2	1	2			
	13RD067(2)	10-Jun-14	6	0	0	1	0	1	0	0	2	1	1			
521	13RD043(1)	03-Jul-13	5	0	2	1	1	1	2	0	0	1	2			
	13RD043(2)	30-Jul-13	5	2	1	0	2	1	2	0	0	1	1			
522	05RD002	23-Jun-05	6	1	2	0	0	0	1	0	2	2	0			
531	13RD055	10-Jul-13	5	0	4	0	1	0	2	0	0	2	1			
539	13RD048	10-Jul-13	5	1	2	0	1	0	2	0	1	2	1			
544	13RD044(1)	18-Jun-13	6	0	0	0	1	0	0	0	1	1	1			
	13RD044(2)	11-Jun-14	6	0	0	1	1	1	0	0	1	1	2			
549	13RD057(1)	18-Jun-13	6	0	1	1	0	1	0	0	3	1	1			
	13RD057(2)	10-Jun-14	6	0	1	2	0	2	0	0	2	1	2			
Class 1 Basin Average				**1**	**4**	**0**	**3**	**2**	**5**	**-3**	**2**	**2**	**1**			
Class 2 Basin Average				**1**	**3**	**0**	**1**	**1**	**3**	**0**	**2**	**2**	**1**			
Class 4 Basin Average				**2**	**4**	**0**	**3**	**4**	**6**	**0**	**3**	**2**	**2**			
Class 5 Basin Average				**2**	**4**	**1**	**2**	**3**	**4**	**0**	**4**	**2**	**2**			
Class 6 Basin Average				**1**	**3**	**1**	**0**	**2**	**2**	**0**	**3**	**2**	**2**			

Relative abundance (%) of taxa per selected F-IBI metric

AUID Suffix	Station	Visit Date	Class	Metrics												
				BenInsect-TolTxPct	DarterSculpSucTxPct	DetNWQTxPct	GeneralTxPct	HerbvTxPct	Insect-TolTxPct	PioneerTxPct	RiffleTxPct	SensitiveTxPct	SensitiveTxPctGR1	SensitiveTxPctGR4	SLithopTxPct	SSpnTxPct
502	10EM192	14-Jul-10	4	19	13	19	31	0	25	19	13	19	0	-21	31	19
	13RD082	26-Jun-13	4	18	9	9	36	0	27	9	9	9	0	-36	45	9
	13RD085	25-Jun-13	1	17	17	25	33	0	25	8	17	25	-3	0	33	25
	93RD401	10-Jul-13	1	17	17	33	42	0	25	25	8	17	-12	0	42	25
503	05RD093(1)	24-Jul-06	2	36	27	0	27	0	36	18	9	27	0	0	45	9
	05RD093(2)	16-Jul-13	2	20	20	20	60	0	20	20	20	0	0	0	60	0
	05RD093(3)	11-Jun-14	2	20	20	0	40	0	40	20	0	0	0	0	40	0
	93RD405	02-Jul-13	6	17	17	17	33	17	17	0	17	17	0	0	50	17
504	05RD094(1)	31-Aug-05	5	18	18	18	27	9	27	27	9	27	0	0	27	27
	05RD094(2)	12-Jun-14	5	10	10	20	40	10	20	30	10	20	0	0	20	30
	13RD070	09-Jul-13	2	43	29	0	29	0	43	0	0	29	0	0	57	14
	13RD089	02-Jul-13	5	25	17	25	25	0	33	17	17	25	0	0	25	25
	93RD403	02-Jul-13	5	27	13	27	27	7	33	20	20	33	0	0	33	33
505	13RD042	26-Jun-13	5	27	18	18	45	0	27	27	9	9	0	0	36	18
506	05RD181(1)	19-Jun-06	5	22	22	22	56	0	22	33	11	0	0	0	44	11
	05RD181(2)	11-Jun-14	5	25	17	17	33	8	33	17	8	25	0	0	33	33
	13RD045	15-Jul-13	5	20	20	10	40	10	20	20	10	20	0	0	40	10
508	05RD053	27-Jun-06	1	18	18	29	24	0	29	18	12	18	4	0	35	18
	13RD041	16-Jul-13	1	13	6	31	44	0	25	13	13	13	-14	0	31	25
	13RD053	09-Jul-13	1	10	10	30	40	0	40	10	0	10	-3	0	20	20
514	13RD067(1)	18-Jun-13	6	0	0	0	0	25	25	0	0	50	0	0	0	25
	13RD067(2)	10-Jun-14	6	0	0	0	0	33	0	0	0	33	0	0	0	33
521	13RD043(1)	03-Jul-13	5	0	0	20	40	0	20	0	20	20	0	0	40	0
	13RD043(2)	30-Jul-13	5	33	33	17	17	0	33	17	17	17	0	0	33	0
522	05RD002	23-Jun-05	6	20	20	40	40	0	20	40	20	0	0	0	20	20
531	13RD055	10-Jul-13	5	0	0	17	67	0	0	17	17	0	0	0	33	0
539	13RD048	10-Jul-13	5	20	20	40	40	0	20	20	20	0	0	0	40	20
544	13RD044(1)	18-Jun-13	6	0	0	0	0	0	0	0	0	0	0	0	0	0
	13RD044(2)	11-Jun-14	6	0	0	0	0	33	0	0	0	33	0	0	0	33
549	13RD057(1)	18-Jun-13	6	0	0	33	33	33	0	33	0	33	0	0	0	67
	13RD057(2)	10-Jun-14	6	0	0	33	33	33	33	33	0	67	0	0	0	100
Class 1 Basin Average				**24**	**18**	**26**	**26**	**0**	**47**	**7**	**12**	**12**	**-7**	**0**	**34**	**15**
Class 2 Basin Average				**15**	**13**	**31**	**44**	**2**	**25**	**21**	**14**	**9**	**0**	**0**	**28**	**23**
Class 4 Basin Average				**29**	**23**	**18**	**24**	**2**	**45**	**11**	**18**	**22**	**0**	**-16**	**41**	**18**
Class 5 Basin Average				**19**	**15**	**19**	**33**	**6**	**33**	**17**	**14**	**21**	**0**	**0**	**30**	**22**
Class 6 Basin Average				**9**	**8**	**18**	**37**	**10**	**22**	**20**	**9**	**23**	**0**	**0**	**21**	**25**

Relative abundance (%) of taxa per selected F-IBI metric

AUID Suffix	Station	Visit Date	Class	Metrics												
				TolTxPct	VtolTxPct	WetlandTxPct										
502	10EM192	14-Jul-10	4	44	13	25										
	13RD082	26-Jun-13	4	36	9	36										
	13RD085	25-Jun-13	1	25	0	17										
	93RD401	10-Jul-13	1	42	8	17										
503	05RD093(1)	24-Jul-06	2	27	9	18										
	05RD093(2)	16-Jul-13	2	40	0	20										
	05RD093(3)	11-Jun-14	2	40	20	20										
	93RD405	02-Jul-13	6	50	17	50										
504	05RD094(1)	31-Aug-05	5	45	18	55										
	05RD094(2)	12-Jun-14	5	50	20	60										
	13RD070	09-Jul-13	2	14	14	29										
	13RD089	02-Jul-13	5	33	8	17										
	93RD403	02-Jul-13	5	33	13	27										
505	13RD042	26-Jun-13	5	45	18	36										
506	05RD181(1)	19-Jun-06	5	67	22	33										
	05RD181(2)	11-Jun-14	5	33	17	50										
	13RD045	15-Jul-13	5	40	10	30										
508	05RD053	27-Jun-06	1	29	12	18										
	13RD041	16-Jul-13	1	44	25	25										
	13RD053	09-Jul-13	1	30	30	40										
514	13RD067(1)	18-Jun-13	6	50	25	100										
	13RD067(2)	10-Jun-14	6	67	33	100										
521	13RD043(1)	03-Jul-13	5	40	20	60										
	13RD043(2)	30-Jul-13	5	33	17	33										
522	05RD002	23-Jun-05	6	80	40	60										
531	13RD055	10-Jul-13	5	67	33	50										
539	13RD048	10-Jul-13	5	60	40	60										
544	13RD044(1)	18-Jun-13	6	67	33	100										
	13RD044(2)	11-Jun-14	6	33	33	100										
549	13RD057(1)	18-Jun-13	6	67	33	100										
	13RD057(2)	10-Jun-14	6	33	33	100										
Class 1 Basin Average				**23**	**15**	**9**										
Class 2 Basin Average				**53**	**26**	**40**										
Class 4 Basin Average				**22**	**10**	**18**										
Class 5 Basin Average				**43**	**18**	**39**										
Class 6 Basin Average				**57**	**25**	**58**										

Fish TIVs and standard probability data

AUID Suffix	Station	Visit Date	Class	Data												
				Mean TSS TIV (mg/L)	Probability of Meeting TSS Standard (%)	Mean DO TIV (mg/L)	Probability of Meeting DO Standard (%)									
502	10EM192	14-Jul-10	4	13	80	7.1	51									
	13RD082	26-Jun-13	4	13	82	7.1	51									
	13RD085	25-Jun-13	1	22	32	7.3	60									
	93RD401	10-Jul-13	1	18	53	7.3	60									
503	05RD093(1)	24-Jul-06	2	13	82	7.2	55									
	05RD093(2)	16-Jul-13	2	15	75	7.1	51									
	05RD093(3)	11-Jun-14	2	19	48	7.2	56									
	93RD405	02-Jul-13	6	14	78	6.8	40									
504	05RD094(1)	31-Aug-05	5	14	79	5.7	7									
	05RD094(2)	12-Jun-14	5	12	86	6.6	29									
	13RD070	09-Jul-13	2	17	59	6.4	25									
	13RD089	02-Jul-13	5	15	75	7.1	53									
	93RD403	02-Jul-13	5	14	77	7.1	54									
505	13RD042	26-Jun-13	5	15	74	7.0	47									
506	13RD045	15-Jul-13	5	14	79	7.2	57									
508	05RD053	27-Jun-06	1	27	9	7.2	59									
	13RD041	16-Jul-13	1	26	12	7.0	48									
	13RD053	09-Jul-13	1	18	52	6.5	27									
514	13RD067(1)	18-Jun-13	6	12	87	5.5	6									
	13RD067(2)	10-Jun-14	6	12	86	5.5	6									
521	13RD043(1)	03-Jul-13	5	13	81	6.4	25									
	13RD043(2)	30-Jul-13	5	13	81	6.5	27									
522	05RD002	23-Jun-05	6	15	75	5.7	7									
531	13RD055	10-Jul-13	5	15	76	6.6	30									
539	13RD048	10-Jul-13	5	14	77	6.4	22									
544	13RD044(1)	18-Jun-13	6	13	83	5.8	9									
	13RD044(2)	11-Jun-14	6	13	83	5.9	10									
549	13RD057(1)	18-Jun-13	6	14	80	5.7	9									
	13RD057(2)	10-Jun-14	6	16	66	5.7	8									
Class 1 Basin Average				**30**	**13**	**7.4**	**62**									
Class 2 Basin Average				**22**	**38**	**6.7**	**37**									
Class 4 Basin Average				**17**	**61**	**7.3**	**58**									
Class 5 Basin Average				**15**	**73**	**6.8**	**40**									
Class 6 Basin Average				**15**	**72**	**6.3**	**26**									

Catch-Per-Unit-Effort (CPUE) F-IBI metric

AUID Suffix	Station	Visit Date	Class	Metric
				NumPerMeter-Tolerant
502	10EM192	14-Jul-10	4	0.34
	13RD082	26-Jun-13	4	0.46
	13RD085	25-Jun-13	1	0.08
	93RD401	10-Jul-13	1	2.09
503	05RD093(1)	24-Jul-06	2	0.94
	05RD093(2)	16-Jul-13	2	0.08
	05RD093(3)	11-Jun-14	2	0.02
	93RD405	02-Jul-13	6	0.11
504	05RD094(1)	31-Aug-05	5	0.38
	05RD094(2)	12-Jun-14	5	1.20
	13RD070	09-Jul-13	2	0.03
	13RD089	02-Jul-13	5	0.39
	93RD403	02-Jul-13	5	1.53
505	13RD042	26-Jun-13	5	0.37
506	05RD181(1)	19-Jun-06	5	1.86
	05RD181(2)	11-Jun-14	5	1.72
	13RD045	15-Jul-13	5	0.34
508	05RD053	27-Jun-06	1	0.38
	13RD041	16-Jul-13	1	1.11
	13RD053	09-Jul-13	1	0.12
514	13RD067(1)	18-Jun-13	6	0.01
	13RD067(2)	10-Jun-14	6	0.01
521	13RD043(1)	03-Jul-13	5	0.06
	13RD043(2)	30-Jul-13	5	0.09
522	05RD002	23-Jun-05	6	0.01
531	13RD055	10-Jul-13	5	0.07
539	13RD048	10-Jul-13	5	0.10
544	13RD044(1)	18-Jun-13	6	0.05
	13RD044(2)	11-Jun-14	6	0.05
549	13RD057(1)	18-Jun-13	6	0.02
	13RD057(2)	10-Jun-14	6	0.03
Class 1 Basin Average				**0.37**
Class 2 Basin Average				**0.37**
Class 4 Basin Average				**0.65**
Class 5 Basin Average				**1.25**
Class 6 Basin Average				**0.69**

Appendix B: Individual M-IBI metric and TIV data

Relative abundance (%) of individuals per selected M-IBI metric

AUID Suffix	Station	Visit Date	Class	Metrics												
				BurrowerPct	ChironomidaeChPct	ChironominiPct	Collector-filtererPct	DomFiveCHPct	HBI_MN	LeglessPct	LongLivedPct	SprawlerPct	SwimmerPct	TrichwoHydroPct	VeryTolerant2Pct	
502	10EM192	01-Sep-10	2	2	19	18	33	34	6	32	2	11	10	17	26	
	13RD082	30-Jul-13	2	3	17	60	35	63	7	22	6	32	5	7	31	
	93RD401	31-Jul-13	2	5	39	90	4	67	8	42	14	25	5	9	62	
503	05RD093(1)	30-Aug-05	7	9	23	25	4	55	8	53	5	18	12	1	44	
	05RD093(2)	31-Jul-13	7	14	22	65	43	76	7	46	0	4	10	0	33	
	93RD405	30-Jul-13	7	3	33	28	13	51	7	36	0	12	20	27	22	
505	13RD042	30-Jul-13	5	3	14	76	30	61	7	19	5	5	11	14	34	
506	05RD181(1)	16-Aug-06	7	25	31	76	2	71	9	78	6	13	2	1	83	
	05RD181(2)	03-Sep-14	7	16	38	44	14	42	7	70	1	12	13	0	58	
	13RD045	29-Jul-13	5	13	60	58	10	58	8	66	1	21	2	3	73	
521	13RD043	30-Jul-13	7	0	2	0	66	89	7	3	1	11	16	2	6	
531	13RD055	30-Jul-13	7	0	2	0	57	84	6	4	0	13	16	1	6	
539	13RD048	30-Jul-13	7	1	7	10	1	75	8	76	13	12	6	0	73	
Class 2 Basin Average				**7**	**23**	**55**	**15**	**59**	**7**	**30**	**6**	**16**	**20**	**8**	**42**	
Class 5 Basin Average				**11**	**31**	**38**	**16**	**59**	**7**	**50**	**5**	**19**	**10**	**5**	**46**	
Class 7 Basin Average				**13**	**27**	**44**	**9**	**70**	**8**	**57**	**4**	**17**	**11**	**2**	**54**	

Taxa richness (#) per selected M-IBI metric

AUID Suffix	Station	Visit Date	Class	Metrics												
				ClimberCh	ClingerCh	Intolerant2lessCh	IntolerantCh	Odonata	Plecoptera	POET	Predator	PredatorCh	TaxaCountAllChir	Trichoptera		
502	10EM192	01-Sep-10	2	7	23	14	6	2	0	19	7	11	52	14		
	13RD082	30-Jul-13	2	10	18	6	3	3	0	13	12	13	51	6		
	93RD401	31-Jul-13	2	2	14	5	4	0	2	10	6	8	36	3		
503	05RD093(1)	30-Aug-05	7	9	12	5	1	2	0	10	12	19	52	3		
	05RD093(2)	31-Jul-13	7	9	6	2	2	1	0	5	2	5	33	2		
	93RD405	30-Jul-13	7	7	12	4	2	2	1	9	6	9	40	3		
505	13RD042	30-Jul-13	5	4	15	3	3	0	0	10	4	7	36	5		
506	05RD181(1)	16-Aug-06	7	15	7	2	2	4	0	8	13	17	44	2		
	05RD181(2)	03-Sep-14	7	11	10	4	0	1	0	4	7	13	49	1		
	13RD045	29-Jul-13	5	7	17	4	1	0	0	10	5	8	43	5		
521	13RD043	30-Jul-13	7	5	8	4	1	1	0	9	3	6	23	4		
531	13RD055	30-Jul-13	7	7	3	2	0	2	0	6	3	6	21	2		
539	13RD048	30-Jul-13	7	8	2	3	0	2	0	4	4	6	23	0		
Class 2 Basin Average				**6**	**13**	**5**	**4**	**1**	**1**	**12**	**7**	**9**	**36**	**5**		
Class 5 Basin Average				**7**	**13**	**4**	**3**	**1**	**0**	**10**	**7**	**10**	**40**	**4**		
Class 7 Basin Average				**8**	**7**	**2**	**1**	**2**	**0**	**6**	**7**	**10**	**32**	**2**		

Relative abundance (%) of taxa per selected M-IBI metric

AUID Suffix	Station	Visit Date	Class	Metrics												
				BurrowerChTxPct	ChironomidaeChTxPct	ChironominiChTxPct	ClingerChTxPct	InsectTxPct	LeglessChTxPct	LongLivedChTxPct	SprawlerChTxPct	SwimmerChTxPct	Tolerant2ChTxPct	TrichopteraChTxPct		
502	10EM192	01-Sep-10	2	6	29	6	44	87	40	8	23	12	56	27		
	13RD082	30-Jul-13	2	10	22	8	35	82	37	14	20	14	69	12		
	93RD401	31-Jul-13	2	11	22	8	39	86	36	19	25	17	72	8		
503	05RD093(1)	30-Aug-05	7	15	42	13	23	87	52	6	19	19	73	6		
	05RD093(2)	31-Jul-13	7	6	33	9	18	79	52	3	18	24	79	6		
	93RD405	30-Jul-13	7	5	43	10	30	80	55	5	25	13	75	8		
505	13RD042	30-Jul-13	5	11	25	14	42	81	39	11	17	14	72	14		
506	05RD181(1)	16-Aug-06	7	16	27	9	16	75	55	11	25	7	84	5		
	05RD181(2)	03-Sep-14	7	16	41	16	20	86	59	4	20	18	71	2		
	13RD045	29-Jul-13	5	12	44	12	40	86	58	2	21	9	77	12		
521	13RD043	30-Jul-13	7	4	13	0	35	83	30	9	22	13	78	17		
531	13RD055	30-Jul-13	7	0	24	0	14	81	33	0	24	19	76	10		
539	13RD048	30-Jul-13	7	13	30	9	9	78	52	9	22	17	83	0		
Class 2 Basin Average				**13**	**28**	**11**	**34**	**88**	**40**	**11**	**19**	**15**	**73**	**14**		
Class 5 Basin Average				**14**	**35**	**12**	**31**	**82**	**52**	**9**	**22**	**9**	**77**	**9**		
Class 7 Basin Average				**14**	**32**	**11**	**22**	**78**	**53**	**8**	**20**	**13**	**84**	**4**		

Macroinvertebrate TIVs and tolerance-related data

AUID Suffix	Station	Visit Date	Class	Data												
				Mean TSS TIV (mg/L)	TSS Tolerant Individuals (%)	TSS Intolerant Taxa Richness (#)	Mean DO TIV (mg/L)	DO Tolerant Individuals (%)	DO Intolerant Taxa Richness (#)							
502	10EM192	01-Sep-10	2	4	24	8	7.4	2	10							
	13RD082	30-Jul-13	2	4	26	4	6.9	30	8							
	93RD401	31-Jul-13	2	12	56	3	7.1	13	6							
503	05RD093(1)	30-Aug-05	7	17	18	2	6.4	25	0							
	05RD093(2)	31-Jul-13	7	17	21	1	7.2	7	4							
	93RD405	30-Jul-13	7	4	19	4	7.1	7	4							
505	13RD042	30-Jul-13	5	5	29	3	7.4	4	7							
506	05RD181(1)	16-Aug-06	7	25	11	1	6.4	37	1							
	05RD181(2)	03-Sep-14	7	25	18	6	5.3	30	1							
	13RD045	29-Jul-13	5	7	40	2	6.9	16	7							
521	13RD043	30-Jul-13	7	4	17	3	7.3	10	1							
531	13RD055	30-Jul-13	7	4	11	2	7.2	11	1							
539	13RD048	30-Jul-13	7	4	7	3	5.7	69	0							
Class 2 Basin Average				**29**	**50**	**4**	**7.0**	**12**	**6**							
Class 5 Basin Average				**11**	**21**	**3**	**6.9**	**17**	**6**							
Class 7 Basin Average				**22**	**28**	**2**	**6.4**	**34**	**2**							