Red Lake River Watershed Stressor Identification Report

A study of the stressors limiting the aquatic biological communities in the Red Lake River Watershed.

Minnesota Pollution Control Agency

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Cover photo

Red Lake River at Red Lake Falls, MN; courtesy of Corey Hanson, RLWD

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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

HSPF – Hydrological Simulation Program - FORTRAN

HUC – Hydrologic Unit Code

IBI – Index of Biological Integrity

IWM – Intensive Watershed Monitoring

MDNR – Minnesota Department of Natural Resources

MPCA – Minnesota Pollution Control Agency

MSHA – MPCA Stream Habitat Assessment

NAIP – National Agriculture Imagery Program

NLCD – National Land Cover Database

RLRW – Red Lake River Watershed

RLWD – Red Lake Watershed District

SI – Stressor identification

SOE – Strength-of-Evidence

TALU – Tiered Aquatic Life Use

TIV – Tolerance Indicator Value

TMDL – Total Maximum Daily Load

TSS – Total Suspended Solids

EPA – United States Environmental Protection Agency

USGS – United States Geological Survey

WHAF – Watershed Health Assessment Framework

Executive summary

The MPCA follows a watershed approach to systematically monitor and assess surface water quality in each of the state's 81 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 2012, the MPCA conducted biological monitoring at several stations in the Red Lake River Watershed (RLRW). 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. A stream segment with a low IBI score(s) (i.e., below an established threshold) is considered "impaired" or unable to support its designated beneficial use for aquatic life. A total of 10 stream reaches in the RLRW were determined to have an F-IBI and/or M-IBI impairment.

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 physical connectivity, lack of base flow, lack of instream habitat, high suspended sediment, and low dissolved oxygen. Causal analysis was performed to determine and evaluate connections between each candidate cause and the biological impairments. Table 1 lists the stressors identified for each of the biologically impaired reaches in the RLRW.

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

AUID Suffix	Reach Name	Biological Impairment(s)	Stressors				
			Loss of Physical Connectivity	Lack of Base Flow	Lack of Instream Habitat	High Suspended Sediment	Low Dissolved Oxygen
515	Burnham Creek	F-IBI/M-IBI		●	●	●	●
525	Kripple Creek	F-IBI/M-IBI		●	●	●	●
526	Kripple Creek	F-IBI/M-IBI		●	●	●	●
528	Little Black River	F-IBI	●	●	●	●	●
545	County Ditch 96	F-IBI		●			●
547	County Ditch 43	F-IBI/M-IBI		●	●		●
551	Burnham Creek	F-IBI/M-IBI		●	●	●	●
554	Gentilly River	F-IBI/M-IBI		●	●	●	●
556	Cyr Creek	F-IBI		●			●
558	Black River	F-IBI/M-IBI	●	●	●	●	●

A lack of base flow is a prominent stressor for all of the biologically impaired reaches. Many of the reaches are prone to extended periods of intermittency, particularly in the latter summer months. The reaches are also subject to periods of low DO, which appear to coincide with low flow conditions. Several of the reaches have a lack of instream habitat (e.g., clean, coarse substrate). High suspended sediment is contributing to nearly all of the M-IBI impairments in the watershed. Lastly, a loss of physical connectivity is a stressor for the F-IBI impairment associated with AUID 528 (Little Black River) and 558 (Black River).

Introduction

Stressor identification (SI) 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 SI 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 SI 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.

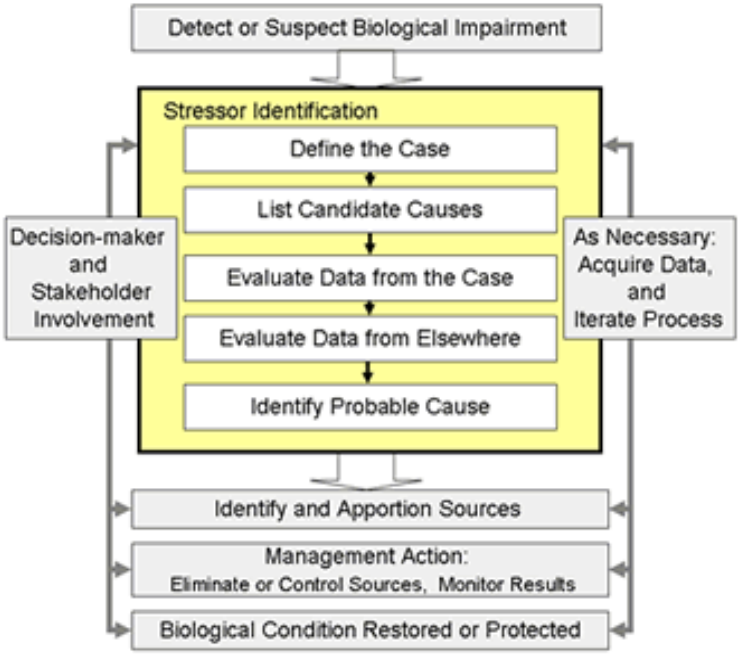


Figure 1. Conceptual model of the SI process (EPA 2012).

Section 1: Watershed overview

1.1 Physical setting

The Red Lake River Watershed (RLRW), United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 09020303, is located in northwestern Minnesota and is part of the larger Red River of the North Basin. The RLRW has a drainage area of 1,340 square miles and encompasses portions of the following counties, listed in order of the percentage of watershed area: Polk (35%), Pennington (33%), Beltrami (13%), Red Lake (11%), Clearwater (7%), and Marshall (<1%). The extreme eastern portion of the watershed is located on the Red Lake Indian Reservation. Cities in the watershed include Crookston, East Grand Forks, Fisher, Red Lake Falls, Saint Hilaire, and Thief River Falls.

1.2 Surface water resources

The Red Lake River is the prominent surface water feature in the RLRW and extends from the outlet of Lower Red Lake to its confluence with the Red River of the North at East Grand Forks. The RLRW contains 279 miles of perennial stream and river (e.g., Red Lake River), 371 miles of intermittent stream, 69 miles of perennial drainage ditch, and 746 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 66% of the watercourses in the RLRW have been hydrologically altered (i.e., channelized, ditched, or impounded). There are no major lakes in the watershed; Upper and Lower Red Lakes are located in the Upper/Lower Red Lake Watershed.

1.3 Geology and soils

The RLRW intersects the following four distinct physiographic regions: peatlands, till plain, beach ridges, and lake plain. The peatlands region is located in the far upstream (i.e., eastern) portion of the watershed and closely mirrors the extent of the Red Lake Indian Reservation. The soils in this area are organic (i.e., derived from the accumulation of dead plant material). The till plain region extends from the peatlands to approximately St. Hilaire. This region is characterized by a flat topography and fine textured soils that were formed from glacial till that was deposited during the last glaciation and later modified and reworked by glacial Lake Agassiz. The beach ridges region follows a north-south corridor roughly 12 miles wide through the center of the watershed, from approximately St. Hilaire to just east of Crookston. The region represents the ancient shorelines of glacial Lake Agassiz. The Red Lake River drops approximately 200 feet in elevation through this area. The soils of this region are generally coarse textured and derived from sand and gravel deposits. Lastly, the western portion of the watershed is also part of the lake plain of glacial Lake Agassiz. This portion of the lake plain is characterized by an extremely flat topography (0-1% slope) and very fine textured soils derived from lacustrine sediments.

1.4 Land use and ecoregions

The predominant land use in the RLRW is agricultural crop production. According to the National Land Cover Database (NLCD) 2011 (USGS, 2011), cultivated crops comprised 59% of the watershed. Other notable land cover groups in the watershed included wetlands (24%), hay/pasture (5%), developed areas (5%), forest (4%), and open water (1%). These minor cover groups were primarily found in the peatlands and beach ridges regions of the watershed. There are two ecoregions represented in the RLRW: the Lake

Agassiz Plain and the North Minnesota Wetlands. A majority (79%) of the watershed is located within the Lake Agassiz Plain ecoregion; the Northern Minnesota Wetlands ecoregion is found in the extreme eastern extent of the watershed.

1.5 Ecological health

The Minnesota Department of Natural Resources (MDNR) 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 ("extremely poor") to 100 ("extremely good"). Statewide mean health scores ranged from 40 (Marsh River Watershed) to 84 (Rapid River Watershed).

Figure 2 presents the watershed health scorecard for the RLRW. The mean health score for the RLRW was 54. The overall score was limited by the individual mean component scores for biology (46) and connectivity (32). Specifically, the watershed scored poorly for the following component indexes: at-risk species richness (38), terrestrial habitat connectivity (23), terrestrial habitat quality (18), and aquatic connectivity (16).

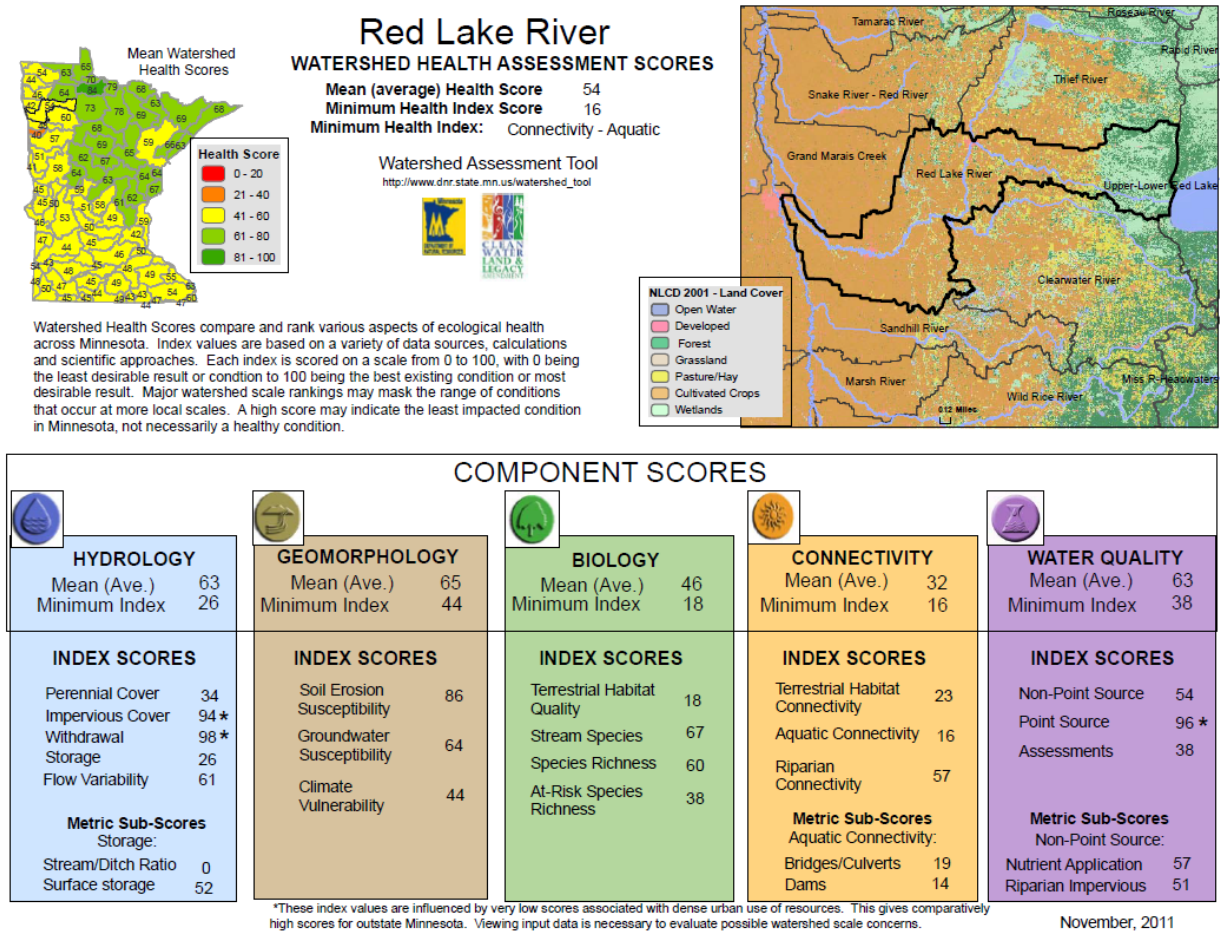


Figure 2. Watershed health assessment scores for the RLRW.

1.6 Hydrological Simulation Program - FORTRAN (HSPF) Model

A Hydrological Simulation Program - FORTRAN (HSPF) model was developed for the RLRW 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 (NPS) models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient 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 Minnesota Pollution Control Agency (MPCA) utilizes a watershed approach (Figure 3) to systematically monitor and assess surface water quality in each of the state's 81 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 2012, the MPCA conducted biological monitoring at several stations throughout the RLRW. 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 stream segment 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 RLRW are the focus of this SI report. The results of the SI 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.

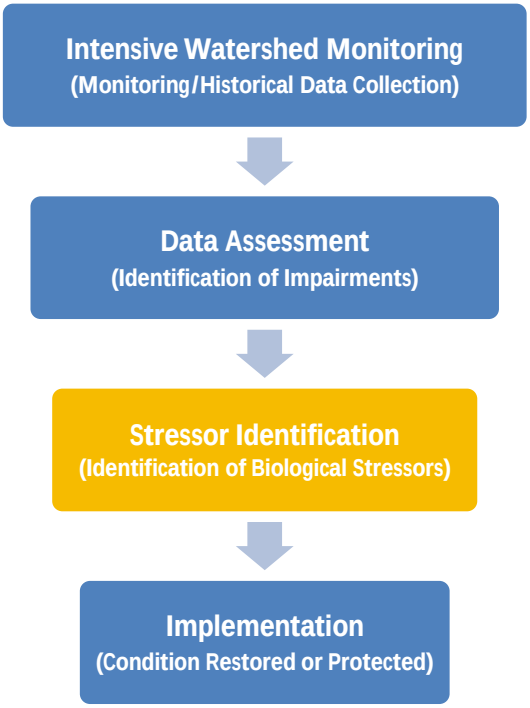


Figure 3. Conceptual model of the watershed approach processes.

2.2 Monitoring stations

Table 2 lists the 54 biological monitoring stations that were sampled for fish and/or macroinvertebrates in the RLRW. The stations are situated along 28 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 RLRW.

AUID Suffix	AUID	Reach Name	Monitoring Station(s)
501	09020303-501	Red Lake River	76RD023, 12RD110
502	09020303-502	Red Lake River	12RD015
503	09020303-503	Red Lake River	12RD010
504	09020303-504	Red Lake River	12RD003, 12RD105
505	09020303-505	County Ditch 76	07RD021
506	09020303-506	Red Lake River	94RD513, 05RD080, 12RD004, 12RD103, 12RD108, 12RD112
508	09020303-508	Red Lake River	05RD034, 05RD129, 10EM149, 12RD007, 12RD008, 12RD018, 12RD104
510	09020303-510	Red Lake River	10EM048, 12RD113
511	09020303-511	Red Lake River	05RD057
512	09020303-512	Red Lake River	12RD013
513	09020303-513	Red Lake River	76RD014, 05RD121, 05RD171
515	09020303-515	Burnham Creek	10EM112, 12RD001, 12RD032, 12RD115
525	09020303-525	Kripple Creek	05RD077, 12RD022
526	09020303-526	Kripple Creek	07RD006, 12RD044
528	09020303-528	Little Black River	12RD024
529	09020303-529	Black River	12RD002
543	09020303-543	Red Lake River Trib.	12RD006
544	09020303-544	Red Lake River Trib.	12RD009
545	09020303-545	County Ditch 96	12RD039
546	09020303-546	Judicial Ditch 60	12RD040
547	09020303-547	County Ditch 43	12RD045
548	09020303-548	Unnamed Ditch	12RD049
549	09020303-549	RLWD Ditch 12	10EM160
551	09020303-551	Burnham Creek	12RD030
554	09020303-554	Gentilly River	12RD021, 12RD043
556	09020303-556	Cyr Creek	12RD023
557	09020303-557	Black River	07RD022, 10EM176, 12RD014
558	09020303-558	Black River	05RD122, 12RD012, 12RD102

2.3 Monitoring results

2.3.1 Fish monitoring results

Table 3 provides the F-IBI scores for the fish monitoring stations in the RLRW. A total of 18 stations (33%) scored below the impairment threshold for their respective class and use designation.

Table 3. Summary of F-IBI scores for fish monitoring stations in the RLRW.

AUID Suffix	Station	F-IBI Class[1] (Use[2])	F-IBI Impairment Threshold	F-IBI Score (Mean)	AUID Suffix	Station	F-IBI Class[1] (Use[2])	F-IBI Impairment Threshold	F-IBI Score (Mean)
501	76RD023	SR (GU)	49	55	515	10EM112	SS (GU)	50	58
501	12RD110	SR (GU)	49	72	515	12RD001	SS (GU)	50	0
502	12RD015	NR (GU)	38	59	515	12RD032	SS (GU)	50	0
503	12RD010	SR (GU)	49	61	515	12RD115	SS (GU)	50	0
504	12RD003	NR (GU)	38	50	525	05RD077	NH (GU)	42	21
504	12RD105	NR (GU)	38	71	525	12RD022	SS (GU)	50	41
505	07RD021	LG (MU)	15	32	526	07RD006	NH (GU)	42	35
506	94RD513	SR (GU)	49	46	526	12RD044	NH (GU)	42	33
506	05RD080	SR (GU	49	73	528	12RD024	NH (GU)	42	24
506	12RD004	SR(GU)	49	65	529	12RD002	NS (GU)	47	50
506	12RD103	SR (GU)	49	75	543	12RD006	NS (GU)	47	48
506	12RD108	SR (GU)	49	81	544	12RD009	LG (GU)	42	82
506	12RD112	SR (GU)	49	90	545	12RD039	NH (MU)	23	0
508	05RD034	NR (GU)	38	63	546	12RD040	NH (MU)	23	0
508	05RD129	NR (GU)	38	58	547	12RD045	LG (MU)	15	18
508	10EM149	NR (GU)	38	59	548	12RD049	LG (GU)	42	0
508	12RD007	NR (GU)	38	61	549	10EM160	SH (MU)	33	0
508	12RD008	NR (GU)	38	71	551	12RD030	SS (MU)	35	13
508	12RD018	NR (GU)	38	48	554	12RD021	SS (GU)	50	50
508	12RD104	NR (GU)	38	44	554	12RD043	NH (GU)	42	34
510	10EM048	NR (GU)	38	65	556	12RD023	NH (GU)	42	7
510	12RD113	NR (GU)	38	74	557	07RD022	NH (MU)	23	51
511	05RD057	NR (GU)	38	61	557	10EM176	NH (MU)	23	38
512	12RD013	SR (GU)	49	83	557	12RD014	NH (MU)	23	27
513	76RD014	NR (GU)	38	66	558	05RD122	NS (GU)	47	25
513	05RD121	NR (GU)	38	62	558	12RD012	NS (GU)	47	37
513	05RD171	NR (GU)	38	58	558	12RD102	NS (GU)	47	35

[1] F-IBI Classes: Low Gradient (LG), Northern Headwaters (NH), Northern Rivers (NR), Northern Streams (NS), Southern Headwaters (SH), Southern Rivers (SR), and Southern Streams (SS)
[2] Tiered Aquatic Life Use (TALU) framework designations: General Use (GU) and Modified Use (MU)

2.3.2 Macroinvertebrate monitoring results

Table 4 provides the M-IBI scores for the macroinvertebrate monitoring stations in the RLRW. A total of 14 stations (33%) scored below the impairment threshold for their respective class and use designation.

Table 4. Summary of M-IBI scores for macroinvertebrate monitoring stations in the RLRW.

AUID Suffix	Station	M-IBI Class[1] (Use[2])	M-IBI Impairment Threshold	M-IBI Score (Mean)	AUID Suffix	Station	M-IBI Class[1] (Use[2])	M-IBI Impairment Threshold	M-IBI Score (Mean)
501	76RD023	PR (GU)	31	59	513	05RD121	PR (GU)	31	68
501	12RD110	PR (GU)	31	47	513	05RD171	PR (GU)	31	83
502	12RD015	PR (GU)	31	50	515	10EM112	PS (GU)	41	23
504	12RD003	PR (GU)	31	49	515	12RD001	PS (GU)	41	29
504	12RD105	PR (GU)	31	43	525	05RD077	PS (GU)	41	34
505	07RD021	PS (MU)	22	36	526	07RD006	PS (GU)	41	15
506	94RD513	PR (GU)	31	46	526	12RD044	PS (GU)	41	37
506	05RD080	PR (GU)	31	43	529	12RD002	SS (GU)	37	45
506	12RD004	PR (GU)	31	59	543	12RD006	NS (GU)	51	29
506	12RD103	PR (GU)	31	52	544	12RD009	NS (GU)	51	37
506	12RD108	PR (GU)	31	33	545	12RD039	PS (MU)	22	36
506	12RD112	PR (GU)	31	38	547	12RD045	PS (MU)	22	11
508	05RD034	PR (GU)	31	62	549	10EM160	PS (MU)	22	23
508	05RD129	PR (GU)	31	42	551	12RD030	PS (MU)	22	20
508	12RD008	PR (GU)	31	47	554	12RD021	PS (GU)	41	27
508	12RD018	PR (GU)	31	57	554	12RD043	PS (GU)	41	28
508	12RD104	PR (GU)	31	33	557	07RD022	SS (MU)	24	11
510	10EM048	PR (GU)	31	53	557	10EM176	PS (MU)	22	42
510	12RD113	PR (GU)	31	57	557	12RD014	PS (MU)	22	23
511	05RD057	PR (GU)	31	66	558	12RD012	PS (GU)	41	24
512	12RD013	PR (GU)	31	57	558	12RD102	SS (GU)	37	24
513	76RD014	PR (GU)	31	44					

[1] M-IBI Classes: Northern Forest Streams (NS), Prairie Forest Rivers (PR), Prairie Streams-Glide/Pool Habitats (PS), and Southern Streams-Riffle/Run Habitats (SS)
[2] TALU framework designations: General Use (GU) and Modified Use (MU)

2.4 Assessments and impairments

The biological monitoring results for the RLRW were formally assessed as part of the development of the *Red Lake River Watershed Monitoring and Assessment Report* (MPCA, 2015) to determine if individual stream reaches met applicable aquatic life standards. As shown in Table 5, 10 reaches were determined to be biologically impaired. The relative location of these reaches is displayed in Figure 4. All of the biologically impaired reaches are tributaries of the Red Lake River.

Table 5. Assessment results for stream reaches with biological monitoring data in the RLRW.

AUID Suffix	AUID	Reach Name	Reach Description	Length (mi)	Biological Impairment(s)
501	09020303-501	Red Lake River	Burnham Creek to Unnamed Creek	31	None
502	09020303-502	Red Lake River	Black River to Gentilly River	10	None
503	09020303-503	Red Lake River	Unnamed Creek to Red River	2	None
504	09020303-504	Red Lake River	County Ditch 76 to Clearwater River	21	None
505	09020303-505	Pennington CD 76	Headwaters to Red Lake River	11	None
506	09020303-506	Red Lake River	County Ditch 99 to Burnham Creek	25	None
508	09020303-508	Red Lake River	Headwaters to Thief River	66	None
510	09020303-510	Red Lake River	Clearwater River to Cyr Creek	8	None
511	09020303-511	Red Lake River	Cyr Creek to Black River	5	None
512	09020303-512	Red Lake River	Gentilly River to County Ditch 99	12	None
513	09020303-513	Red Lake River	Thief River Falls Dam to County Ditch 76	14	None
515	09020303-515	Burnham Creek	Polk County Ditch 15 to Red Lake River	20	F-IBI/M-IBI
525	09020303-525	Kripple Creek	Unnamed Creek to Gentilly River	9	F-IBI/M-IBI
526	09020303-526	Kripple Creek	Unnamed Ditch to Unnamed Creek	6	F-IBI/M-IBI
528	09020303-528	Little Black River	Unnamed Ditch to Black River	2	F-IBI
529	09020303-529	Black River	Little Black River to Red Lake River	8	None
531	09020303-531	Unnamed Ditch	Unnamed ditch to Gentilly River	2	Not Assessed
532	09020303-532	Unnamed Ditch	No Connection	2	Not Assessed
533	09020303-533	Unnamed Ditch	Headwaters to Unnamed Ditch	2	Not Assessed
543	09020303-543	Unnamed Ditch	Unnamed Ditch to Red Lake River	10	None
544	09020303-544	Unnamed Creek	Headwaters to Red Lake River	1	None
545	09020303-545	County Ditch 96	Branch 5 to Branch 3	1	F-IBI
546	09020303-546	Judicial Ditch 60	County Ditch 147 to Unnamed Ditch	2	Not Assessed
547	09020303-547	County Ditch 43	Unnamed Ditch to Red Lake River	7	F-IBI/M-IBI
548	09020303-548	County Ditch 76	County Ditch 76 to Unnamed Ditch	1	Not Assessed
549	09020303-549	RLWD Ditch 12	Headwaters to County Ditch 115	7	Not Assessed
551	09020303-551	Burnham Creek	County Ditch 106 to Polk County Ditch 15	7	F-IBI/M-IBI
554	09020303-554	Gentilly River	County Ditch 140 to Red Lake River	8	F-IBI/M-IBI
556	09020303-556	Cyr Creek	County Road 14 to Red Lake River	9	F-IBI
557	09020303-557	Black River	Headwaters to -96.4328 48.0146	16	None
558	09020303-558	Black River	-96.4328 48.0146 to Little Black River	14	F-IBI/M-IBI

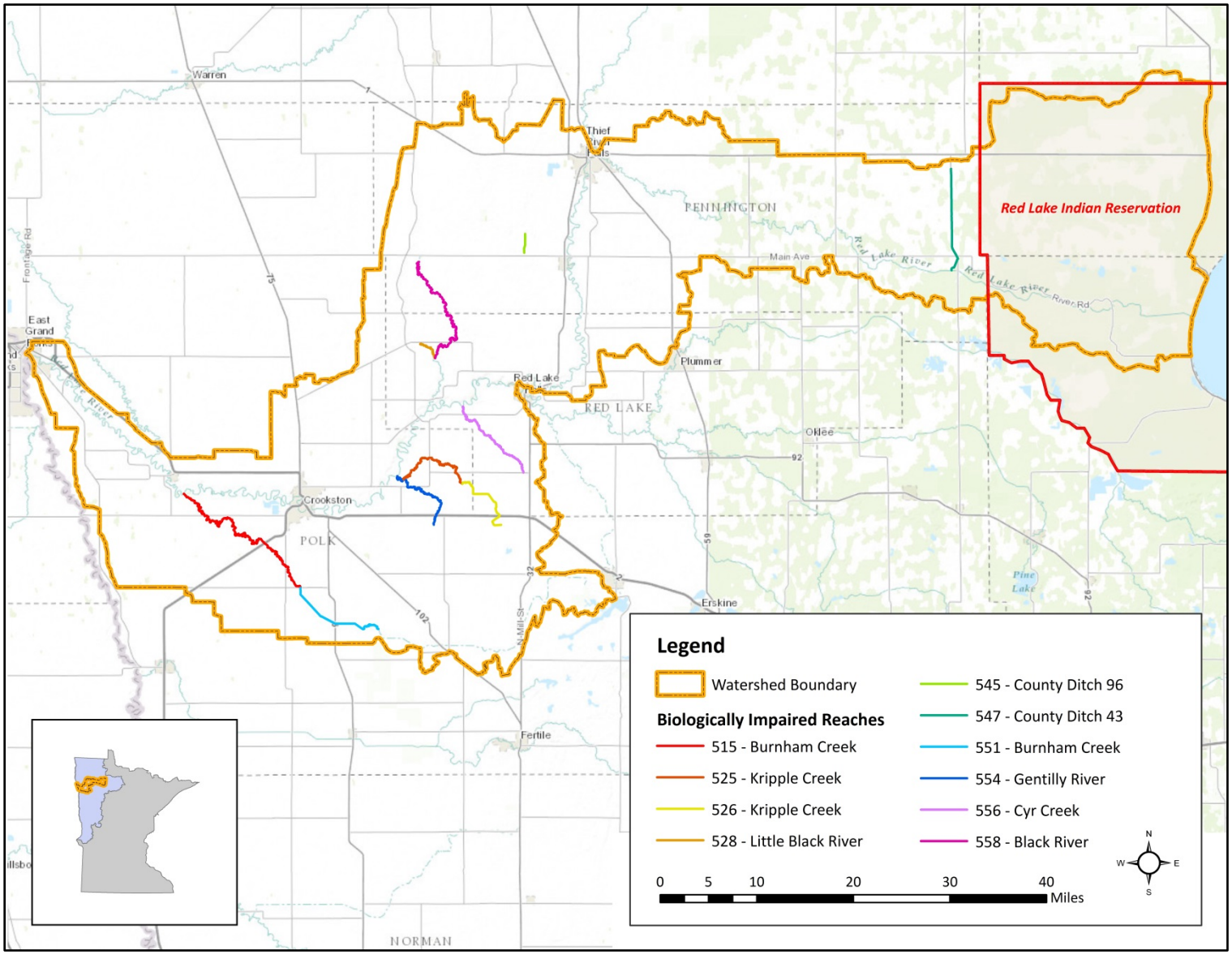


Figure 4. Map of the RLRW and associated biologically impaired reaches.

In addition to biological impairments, there are 11 reaches in the RLRW that were included on the 2012 Impaired Waters List for water quality impairments affecting aquatic life (Table 6). Two of these reaches are also biologically impaired. AUID 515 was listed for high turbidity, while AUID 530 was listed for high turbidity and low dissolved oxygen. The latter reach, which is not listed in Table 5, was split into AUID 557 and 558 for the purposes of biological monitoring.

Table 6. Water quality impairments associated with stream reaches in the RLRW (2012 Impaired Waters List).

AUID Suffix	AUID	Reach Name	Reach Description	Water Quality Impairment(s)
501	09020303-501	Red Lake River	Burnham Creek to Unnamed Creek	Turbidity[1]
502	09020303-502	Red Lake River	Black River to Gentilly River	Turbidity[1]
503	09020303-503	Red Lake River	Unnamed Creek to Red River	Turbidity[1]
504	09020303-504	Red Lake River	County Ditch 76 to Clearwater River	Turbidity[1]
506	09020303-506	Red Lake River	County Ditch 99 to Burnham Creek	Turbidity[1]
508	09020303-508	Red Lake River	Headwaters to Thief River	Dissolved Oxygen
512	09020303-512	Red Lake River	Gentilly River to County Ditch 99	Turbidity[1]
513	09020303-513	Red Lake River	Thief River Falls Dam to County Ditch 76	Turbidity[1]
515	**09020303-515**	**Burnham Creek**	**Polk County Ditch 15 to Red Lake River**	**Turbidity[1]**
529	09020303-529	Black River	Little Black River to Red Lake River	Turbidity[1]
530	**09020303-530**	**Black River**	**Headwaters to Little Black River**	**Dissolved Oxygen and Turbidity[1]**

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

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, 2012). Identification of a set of candidate causes is an important early step in the SI process and provides the framework for gathering key data for causal analysis. Table 7 lists the nine common biotic stressors that were considered as potential candidate causes in the RLRW. The list was developed based upon the results of the *Red River Valley Biotic Impairment Assessment* (EOR, 2009) and other completed SI reports in the state. The credibility of each stressor as a candidate cause 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 *Red Lake River Watershed Monitoring and Assessment Report* (MPCA, 2015), the *Red Lake Watershed District's 10-Year Comprehensive Plan* (RLWD, 2006), and the *Red River Basin Stream Survey Report: Red Lake River Watershed 2004* (Groshens, 2005). Based upon the results of this evaluation, five candidate causes were identified to undergo causal analysis (Section 3.3).

Table 7. Summary of common biotic stressors evaluated as potential candidate causes for the biologically impaired reaches of the RLRW.

Stressor	Candidate Cause Identification - RLRW Biologically Impaired Reaches	
	Summary of Available Information	Candidate Cause (Yes/No)
Loss of Physical Connectivity	Several of the biologically impaired reaches have connectivity barriers (e.g., dams and beaver dams) that are or could be limiting fish passage.	Yes
Lack of Base Flow	Many of the biologically impaired reaches are prone to periods of intermittency.	Yes
Lack of Instream Habitat	Several of the biologically impaired reaches have insufficient instream habitat for aquatic life.	Yes
High Suspended Sediment	Several of the biologically impaired reaches are prone to periods of high suspended sediment that are above the level expected to cause stress to aquatic life.	Yes
Low Dissolved Oxygen	Many of the biologically impaired reaches are prone to periods of low dissolved oxygen that are below the level expected to cause stress to aquatic life.	Yes
High Nitrate	Nitrate concentrations associated with the biologically impaired reaches were low and below the level expected to cause stress to aquatic life.	No
Temperature Regime Alteration	Temperature values associated with the biologically impaired reaches were within a range that is not expected to cause stress to aquatic life.	No
pH	Values for pH associated with the biologically impaired reaches were within a range that is not expected to cause stress to aquatic life.	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 physical 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 MDNR (2014a), 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 MDNR's Public Waters Work Permit requires that road crossing structures be designed and installed to allow for fish passage.

3.2.2 Lack of base flow

Background

Flow is considered a "maestro" (Walker et al., 1995) or "master variable" (Power et al., 1995) that affects many fundamental ecological characteristics of stream ecosystems, including biodiversity (Poff et al., 1997; Hart and Finelli, 1999; Bunn and Arthington, 2002). 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).

In the Red River of the North Basin, evapotranspiration generally exceeds precipitation by 2 to 10 inches on an annual basis (EOR, 2009). As a result, streams in the basin are inherently prone to intermittency (EOR, 2009). Additionally, the natural flow regime of many streams in the basin has been anthropogenically altered, primarily to expedite drainage for agricultural purposes (e.g., ditching, channelization of natural streams, modification/cultivation of headwater streams, subsurface tiling, and wetland drainage). These practices are known to cause increased and quicker peak discharges following rain events and reduced base flows during dry periods (Franke and McClymonds, 1972; Mitsch and Gosselink, 2007; EOR, 2009).

Fish and macroinvertebrates vary in their preferences for flow characteristics. A lack of base flow tends to favor taxa that are adapted to lentic conditions, while often reducing stream productivity and species diversity (EPA, 2012). Generally, fish take longer to recover from the effects of extreme low flow conditions than macroinvertebrates (Griswold et al., 1982).

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 MDNR regulates the appropriation of water resources and may restrict the withdrawal of surface water when flows are below protected levels.

3.2.3 Lack of instream habitat

Background

Habitat is a broad term encompassing all aspects of the physical, chemical, and biological conditions needed to support a biological community (EPA, 2012). Healthy biotic communities have diverse instream habitat, enabling fish and macroinvertebrate habitat specialists to prosper. Instream 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, 2012).

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 RLRW. 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 lack of instream habitat as a candidate cause for impairment.

Applicable standards

There are no applicable standards for instream 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 high suspended sediment as a candidate cause for impairment.

Applicable standards

The state water quality standard for TSS is 65 mg/L for the Southern River TSS Region and 30.0 mg/L for the Central River TSS Region. With the exception of AUIDs 545 and 547, which are in the Central River TSS Region, all of the biologically impaired reaches in the watershed 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. 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). 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. In most streams and rivers, the critical conditions for DO usually occur during the late summer, when the water temperature is high and stream flow is low. Low DO can also be an issue in streams with high biological oxygen demand and high groundwater seepage (Hansen, 1975).

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

Applicable standards

The state water quality standard for DO is 5.0 mg/L as a daily minimum for Class 2B and 2C waters; this includes all of the biologically impaired reaches of the RLRW. For additional information regarding this standard, refer to the MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List.

3.3 Causal analysis - profile of individual biologically impaired reaches

3.3.1 Burnham Creek (AUID 515)

Physical setting

This reach represents the segment of Burnham Creek from its confluence with County Ditch 15 to its outlet to the Red Lake River (Figure 5); a total length of 20 miles. The reach has a subwatershed area of 150 square miles (95,767 acres). Although the reach is entirely located in the lake plain region of the RLRW, the eastern one-third of its subwatershed lies within the beach ridges region. The subwatershed contains 25 miles of perennial stream (e.g., AUID 515), 68 miles of intermittent stream, four miles of perennial drainage ditch, and 95 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 69% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 11% of AUID 515. The NLCD 2011 (USGS, 2011) lists cultivated crops (84%) as the predominant land cover in the subwatershed; this percentage was substantially higher in the lake plain region. Notable minor land cover groups in the subwatershed included wetlands (5%), developed areas (5%), forest (2%), and hay/pasture (2%). The southwest corner of the city of Crookston is located within the subwatershed.

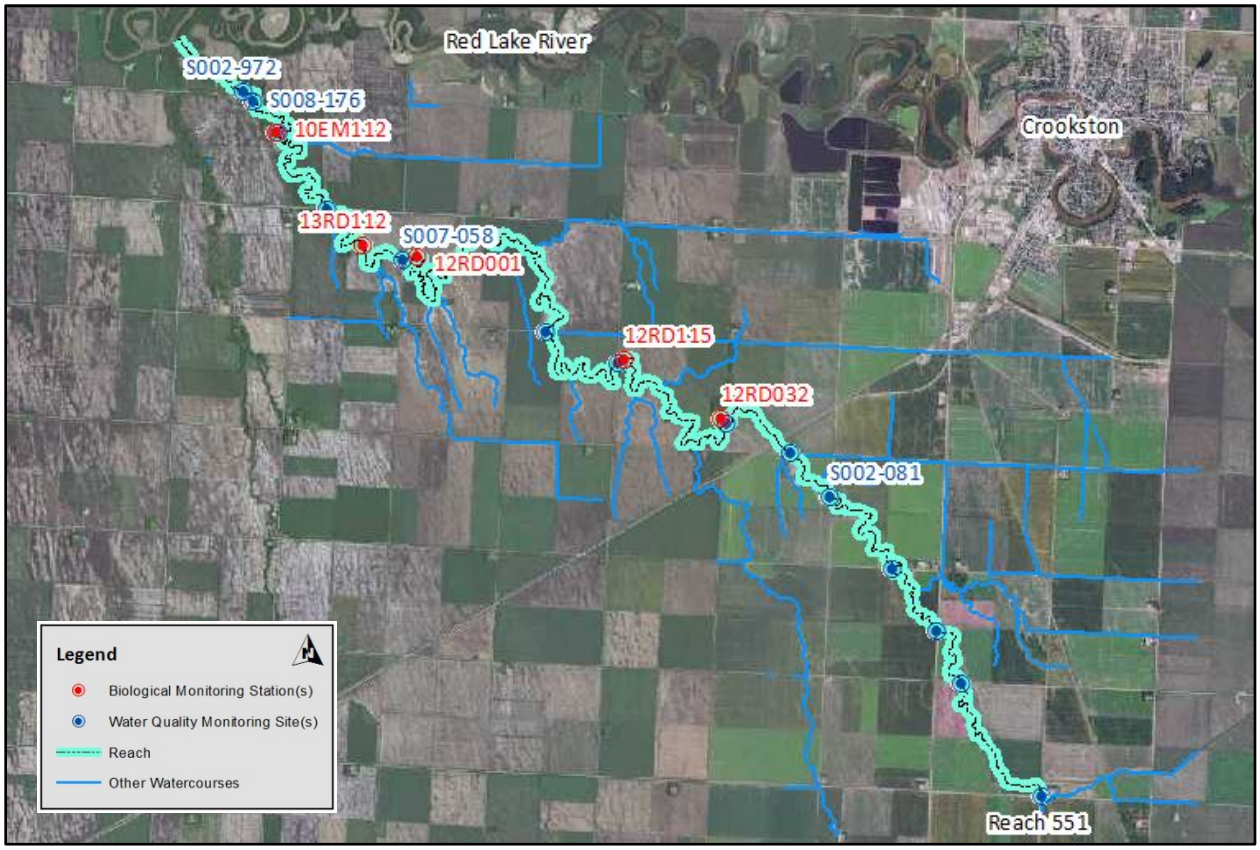


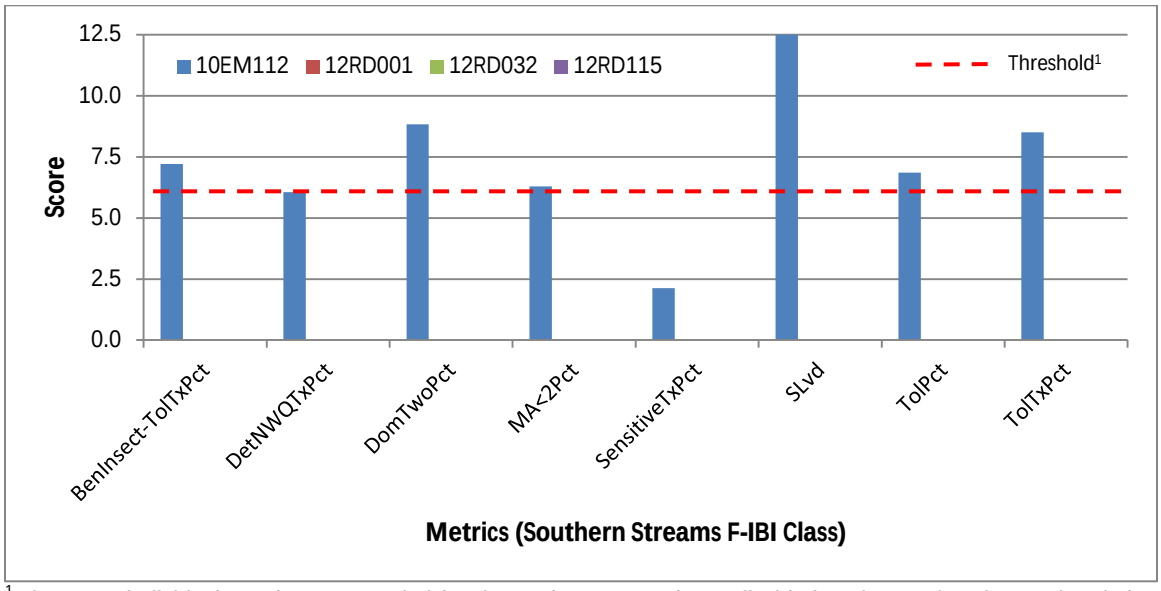
Figure 5. Map of AUID 515 and associated biological monitoring stations and water quality monitoring sites (2010 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 515 was monitored at Station 10EM112 (1.5 mi upstream of the CR 216 crossing) on July 13, 2010, Station 12RD001 (0.2 mi upstream of the 320th Avenue SW crossing) on June 11, 2012, Station 12RD032 (0.1 mi downstream of the CR 217 crossing) on June 12, 2012, and Station 12RD115 (0.1 mi upstream of the 300th Avenue SW crossing) on June 13, 2012. The relative location of the stations is shown in Figure 5. The stations were designated as General Use within the Southern Streams F-IBI Class. Accordingly, the applicable impairment threshold for these stations is an F-IBI score of 50. Station 10EM112, which represents the farthest downstream station along the reach, scored slightly above the impairment threshold, with an F-IBI score of 58. Monitoring at the upstream stations (i.e., 12RD001, 12RD032, and 12RD115) each yielded an F-IBI score of zero.

Figure 6 provides the individual F-IBI metric scores for the fish monitoring stations along AUID 515; a description of each metric is provided in Appendix A. Station 10EM112 had only one metric that scored below the threshold score (i.e., SensitiveTxPct). The fish assemblage of the station consisted of 13 taxa, but was primarily comprised of white sucker. The upstream stations (i.e., 12RD001, 12RD032, and 12RD115) each scored zero for all of the metrics. Stations 12RD001 and 12RD032 had a very limited sample population (<25 individuals) that was dominated by tolerant species (e.g., central mudminnow). No fish were sampled at Station 12RD115.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

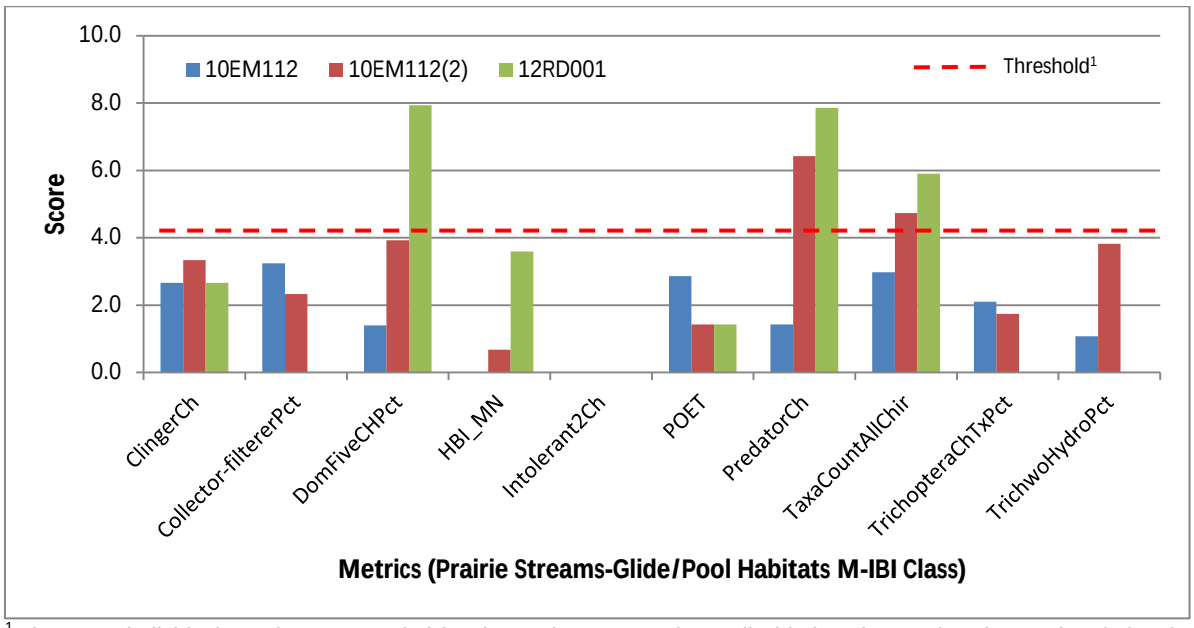
Figure 6. Individual F-IBI metric scores for Stations 10EM112, 12RD001, 12RD032, and 12RD115 along AUID 515.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 515 was monitored at Station 10EM112 on September 20, 2010 and Station 12RD001 on August 8, 2012. Station 10EM112 was sampled twice on the same date. Both stations were designated as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the applicable impairment threshold for the stations is an M-IBI score of 41. Monitoring of the stations yielded M-IBI scores below the impairment threshold; Station 10EM112 had a mean score of 23 and Station 12RD001 had a score of 29.

Figure 7 provides the individual M-IBI metric scores for the two macroinvertebrate monitoring stations along AUID 515; a description of each metric is provided in Appendix B. Collectively, one or both of the

stations scored below the threshold score for eight metrics (i.e., ClingerCh, Collector-filtererPct, DomFiveCHPct, HBI_MN, Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct). The macroinvertebrate assemblage of both stations was dominated by tolerant taxa, specifically Coenagrionidae (damselflies), Oligochaeta (worms), and *Physa* (snails).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 7. Individual M-IBI metric scores for Stations 10EM112 and 12RD001 along AUID 515.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff documented the remnants of a concrete structure (Figure 8) during fish sampling at Station 12RD032 along AUID 515. The concrete debris did not appear to be limiting connectivity at the time of discovery, but could potentially inhibit fish passage during low flow conditions. In addition, biological monitoring staff spoke with a local land owner who indicated that beaver dams are common along the reach (personal communication, 2014). According to the MDNR (2014b), there are no man-made dams on the reach. On September 17, 2014, MPCA SI staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No manmade obstructions to connectivity were noted (e.g., perched culverts); however, a large beaver dam was observed upstream of the 290th Street SW road crossing (Figure 8), which is situated between Stations 12RD001 and 12RD115. The beaver dam had an associated pool and posed a complete barrier to connectivity at the time of discovery. In addition to the assessment, MPCA SI staff performed a detailed review of an April 2, 2012, aerial photo of the reach; the photo was collected approximately two months prior to fish sampling at the upstream stations. The beaver dam documented during the connectivity assessment was not present in the photo. Staff identified a "Texas" crossing near the 305th Street SW crossing (Figure 8) and the remnants of two other similar crossings immediately upstream of the 300th Street SW crossing; one of which is shown in Figure 8. These structures did not appear to be limiting connectivity at the time of the photo, but could act as a fish barrier during low flow conditions.

Figure 8. Photos of potential connectivity barriers along AUID 515, including the remnants of a concrete structure at Station 12RD032 on June 12, 2012 (upper left); a beaver dam immediately upstream of the 290th Street SW crossing on September 17, 2014 (upper right); a "Texas" crossing near the 305th Street SW on April 2, 2012, courtesy of Google Earth (lower left); and the remnants of a "Texas" crossing immediately upstream of the 300th Street SW crossing on April 2, 2012, courtesy of Google Earth (lower right).

Biotic response – fish

There is inconclusive evidence of a causal relationship between a loss of physical connectivity and the F-IBI impairment associated with AUID 515. None of the potential connectivity barriers identified by MPCA staff were known to be limiting fish passage at the time of sampling, which occurred in late spring and early summer. Additionally, the fish assemblage of Station 12RD030, which is located along AUID 551 (immediately upstream) and was sampled during the same timeframe as Stations 12RD001, 12RD032, and 12RD115, was dominated by young of the year white sucker and, therefore, suggests that adult fish of this specie were able to migrate upstream of AUID 515 to spawn. White sucker commonly migrate up into the headwater region of streams to reproduce (Paulson and Hatch, 2004) However, as previously mentioned, the potential connectivity barriers identified by MPCA staff could be limiting fish passage during low flow periods. Also, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of physical connectivity and the M-IBI impairment associated with AUID 515. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not directly affected by physical connectivity barriers.

Lack of base flow

Available data

The MPCA biological monitoring staff was unable to perform macroinvertebrate sampling at Stations 12RD115 and 13RD112 along AUID 515 due to the absence of flow. Continuous stage data was collected at Site S007-058 (320th Avenue SW crossing) from March 19, 2012, to November 15, 2012 (RLWD) and from April 22, 2013, to November 12, 2013 (MPCA). The results are displayed in Figures 9 and 10. Based upon preliminary flow rating table values, the site had no flow 43% of the time in 2012 and 72% of the time in 2013. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow less than 1% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on four separate dates (i.e., July 23, 2014, July 30, 2014, August 7, 2014, and September 17, 2014) and documented flow conditions. The reach had minimal (estimated <1 cfs) to no flow on each of these dates. The reach was dominated by interspersed pools of stagnant water at the time of the last visit (Figure 11). The beaver dam located upstream of the 290th Street SW crossing did not appear to be limiting flow along the reach; intermittent flow conditions were also noted several miles upstream of the beaver dam. According to C. Hanson (personal communication, 2014), low flow conditions are common along the reach. Overall, the available data suggest that the reach is prone to frequent periods of minimal to no flow.

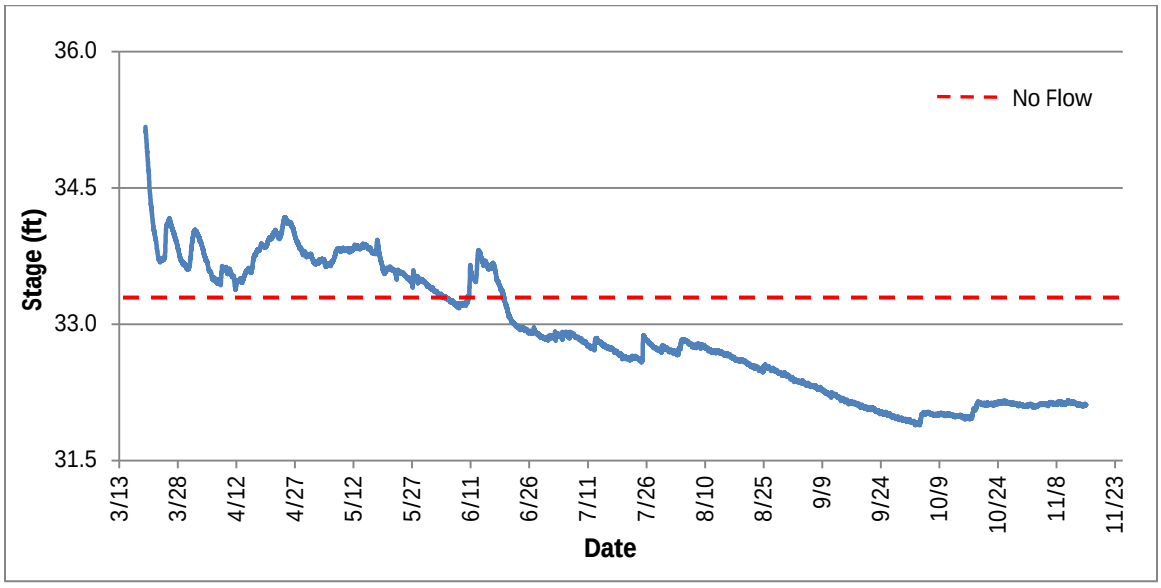


Figure 9. Continuous stage data (March 19, 2012, to November 15, 2012) for Site S007-058 along AUID 515.

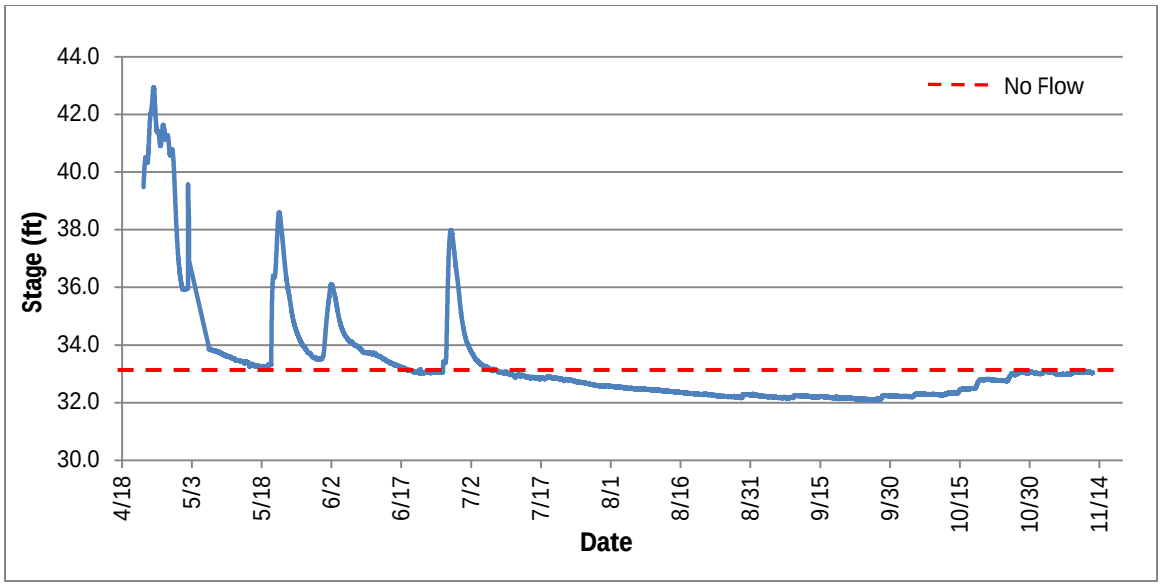


Figure 10. Continuous stage data (April 22, 2013, to November 12, 2013) for Site S007-058 along AUID 515.

Figure 11.Photos of intermittent flow conditions along AUID 515 on September 17, 2014, including Site S002-972 (upper left); Site S007-058 (upper right); the 300th Avenue SW crossing (lower left); and the US Hwy. 75 crossing (lower right).

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 515 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 10EM112, 12RD001, 12RD032, and/or 12RD115:

- High combined relative abundance of the two most abundant taxa (DomTwoPct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are early maturing and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 6, five of the aforementioned individual metrics (i.e., DomTwoPct, MA<2Pct, SensitiveTxPct, TolPct, and TolTxPct) were used in the calculation of the F-IBI score for each of the monitoring stations. Stations 10EM112, 12RD001, 12RD032, and/or 12RD115 had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of base flow and the M-IBI impairment associated with AUID 515 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 10EM112 and/or 12RD001:

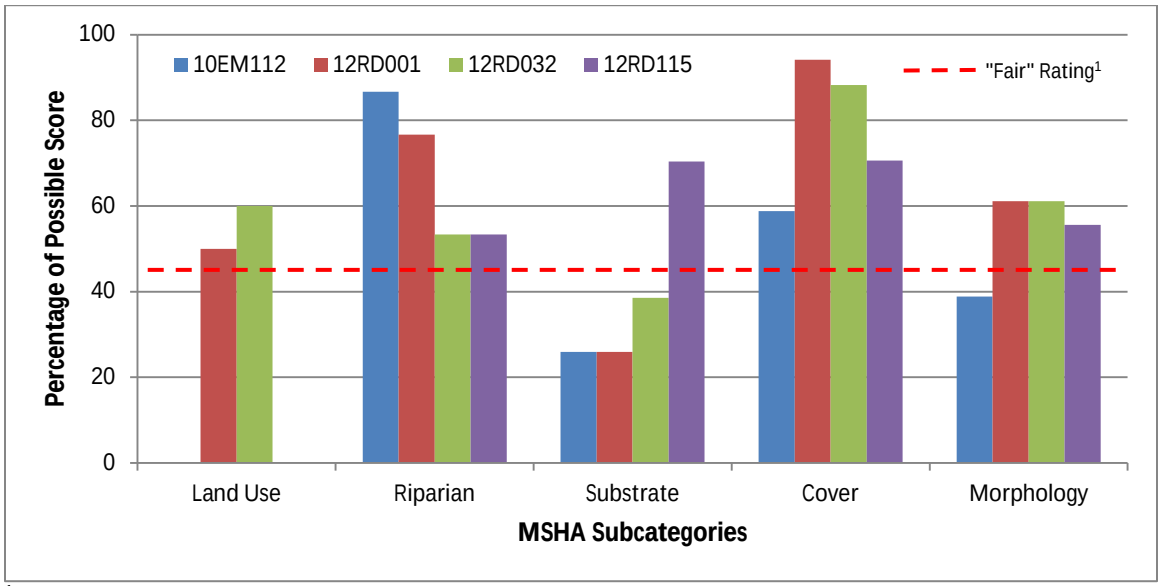
- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- High relative abundance of the dominant five taxa in a subsample (DomFiveCHPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity, specifically taxa belonging to the orders of Plecoptera, Ephemeroptera, and Trichoptera (many of which are collector-filterers), and favor taxa that are tolerant of environmental disturbances (EPA, 2012; Klemm et al., 2002, Poff and Zimmerman, 2010). According to Figure 7, seven of the aforementioned individual metrics (i.e., Collector-filtererPct, DomFiveCHPct, Intolerant2Ch, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score(s) for both monitoring stations. Station 10EM112 and/or 12RD001 had a "low" score(s) for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. Overall, the macroinvertebrate assemblage of the stations was dominated by taxa that are adapted to lentic conditions (i.e., Coenagrionidae, Oligochaeta, and *Physa*).

Lack of instream habitat

Available data

The instream habitat of AUID 515 was evaluated at Stations 10EM112, 12RD001, 12RD032, and 12RD115 using the MSHA. The stations are located along a natural segment of the reach (MPCA, 2013). Total MSHA scores for the stations tended to improve from downstream to upstream. Station 10EM112 yielded a score of 44 ("poor"), while farther upstream, Stations 12RD001 (59), 12RD032 (58), and 12RD115 (59) each received a "Fair" rating. According to Figure 12, total MSHA scores for the stations were generally limited by the land use and substrate subcategories. The reach is located in an intensively agricultural region of the RLRW that is dominated by row crops (e.g., corn and sugar beets). The stations were dominated by runs, with few riffles, and had very limited coarse substrate. Stations 12RD032 and 12RD115 each offered a minimal amount of coarse substrate; however, the substrate had a "moderate" level of embeddedness.



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

Figure 12. MSHA subcategory results for Stations 10EM112, 12RD001, 12RD032, and 12RD115 along AUID 515.

Biotic response – fish

Evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 515 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 10EM112, 12RD001, 12RD032, and/or 12RD115:

- Low relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct)
- High relative abundance of taxa that are detritivorous (DetNWQTxPct)
- Low relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct)
- Low relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct)
- Low taxa richness of simple lithophilic spawning species (SLithop)

Benthic 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). According to Figure 6, two of the aforementioned individual metrics (i.e.,

BenInsect-TolTxPct and DetNWQTxPct) were used in the calculation of the F-IBI score for each of the monitoring stations. Stations 12RD001, 12RD032, and 12RD115 had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of instream habitat and the M-IBI impairment associated with AUID 515 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 10EM112 and/or 12RD001:

- High relative abundance of burrower individuals (BurrowerPct)
- Low taxa richness of clinger taxa (ClingerCh)
- Low relative abundance of collector-filterer individuals in a subsample (Collector-filtererPct)
- High relative abundance of legless individuals (LeglessPct)

Clinger taxa, including many collector-filterers, require clean, coarse substrate or other objects to attach themselves to, while burrowing and legless macroinvertebrates are tolerant of degraded benthic habitat. According to Figure 7, two of the aforementioned individual metrics (i.e., ClingerCh and Collector-filtererPct) were used in the calculation of the M-IBI score(s) for Stations 10EM112 and 12RD001. Both stations had a "low" score(s) for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach.

High suspended sediment

Available data

The reach has an existing turbidity impairment that was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a water quality sample at Stations 10EM112, 12RD001, 12RD032, and 12RD115 along AUID 515 at the time of fish sampling. The samples were analyzed for several parameters, including TSS. Each of the stations had a low TSS concentration (4 to 16 mg/L). Table 8 summarizes discrete TSS data for Sites S002-081 (280th Avenue SW crossing), S002-972 (near 269th Street SW), and S007-058; the relative location of these sites is shown in Figure 5. Site S002-972 had a high proportion of exceedances of the 65 mg/L standard (14.3%). Sites S002-081 and S007-058 each had a standard exceedance rate of 7.7%. Additionally, the RLRW HSPF model estimates that the reach had a TSS concentration in excess of the standard between three and 5% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to periods of high suspended sediment.

Table 8. Discrete TSS data for Sites S002-081, S002-972, and S007-058 along AUID 515.

Site	Date Range	*n*	Min	Max	Mean	% Total Values Above Standard
S002-081	1994-2013	52	0	144	23	7.7
S002-972	2002-2013	14	2	264	38	14.3
S007-058	2012-2014	26	0	400	31	7.7

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 515. None of the individual F-IBI metrics for Stations 10EM112,

12RD001, 12RD032, and 12RD115 exhibited a correlation to this candidate cause. However, the deposition of suspended sediment has caused the aforementioned embeddedness of coarse substrate and the related biotic response associated with Stations 12RD032 and 12RD115.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 515 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 10EM112 and/or 12RD001:

- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (trichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Collector-filterers, including several members of the order Trichoptera, 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). According to Figure 7, four of the aforementioned individual metrics (i.e., Collector-filtererPct, Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score(s) for Stations 10EM112 and 12RD001. Both stations had a "low" score(s) for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. Additionally, the MPCA calculated TSS Tolerance Indicator Values (TIVs), which provide a means of comparing the relative tolerance of sampled taxa, for the stations (Appendix D). Station 10EM112 had a low number of TSS intolerant taxa, while Station 12RD001 had a high percentage of TSS tolerant taxa.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Stations 10EM112, 12RD001, 12RD032, and 12RD115 along AUID 515 during sampling. Only one of the measurements was below the 5.0 mg/L standard; Station 12RD001 had a DO concentration of 4.3 mg/L at the time of macroinvertebrate sampling. Figure 13 displays discrete DO data for Sites S002-081 (1989-2014; *n*=117), S002-972 (1999-2013; *n*=28), and S007-058 (2012-2014; *n*=46). Collectively, only 5% of the DO values for the sites were below the standard; however, only one measurement was taken prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. Continuous DO monitoring was conducted at Site S007-058 from May 2, 2012, to September 11, 2012 (RLWD) and from July 23, 2014, to August 7, 2014 (MPCA). The MPCA also conducted continuous DO monitoring at Site S008-176 (CR 216 crossing) from July 23, 2014, to August 7, 2014. Table 9 provides a summary of the results for the sites. Site S007-058 had a high proportion of daily minimum DO values that were below the standard (38.8 and 50.0%). Site S008-176 had a low percentage of such values (6.2%). The mean daily DO flux was nominal for both sites and ranged from 1.4 to 2.3 mg/L. Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard less than 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to occasional periods of low DO.

Table 9. Continuous DO data for Sites S007-058 and S008-176 and along AUID 515.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S007-058 (RLWD)	May 2, 2012 - Sept. 11, 2012	4124	2.8	12.7	38.8	15.2	1.7
S007-058 (MPCA)	July 23, 2014 - Aug. 7, 2014	1453	3.6	8.6	50.0	7.3	2.3
S008-176 (MPCA)	July 23, 2014 - Aug. 7, 2014	1448	4.9	7.8	6.2	<0.1	1.4

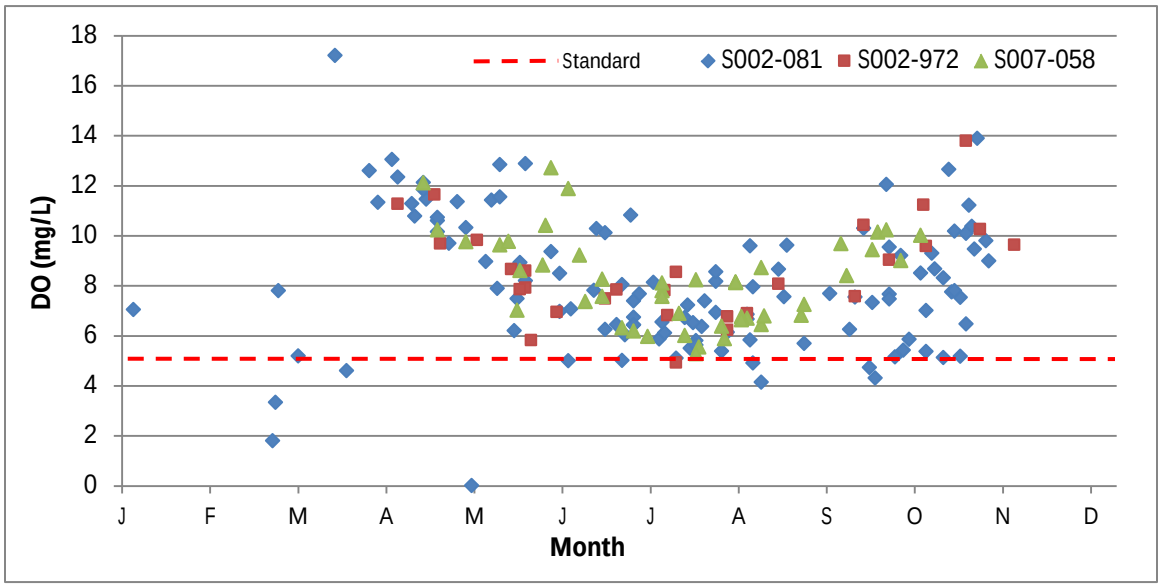


Figure 13. Discrete DO data for Sites S002-081, S002-972, and S007-058 along AUID 515.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 515 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 10EM112, 12RD001, 12RD032, and/or 12RD115:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa EPA, 2012). According to Figure 6, three of these individual metrics (SensitiveTxPct, TolPct, and TolTxPct) were used in the calculation of the F-IBI score for each of the monitoring stations. Stations 10EM112, 12RD001, 12RD032, and/or 12RD115 had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach. Sandberg (2014)

utilized TIVs to estimate the likelihood of each station meeting the DO standard based upon its sampled fish assemblage (Appendix C). Stations 12RD001 and 12RD032 had a low probability (both 18%) of meeting the standard. Conversely, Station 10EM112 had a relatively high probability (48%) of meeting the standard. Station 12RD115 was not evaluated due to the fact that no fish were sampled.

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 515 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 10EM112 and 12RD001:

- High Hilsenhoff's Biotic Index value (HBI_MN)
- Low taxa richness of macroinvertebrates with tolerance values less than or equal to two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (trichopteraChTxPct)
- Low relative abundance of non-hydropsychid Trichoptera individuals in a subsample (TrichwoHydroPct)

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 (EPA, 2012; Weber, 1973). According to Figure 7, five of these individual metrics (HBI_MN, Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score(s) for Stations 10EM112 and 12RD001. Both stations had a "low" score(s) for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. Additionally, the MPCA calculated DO TIVs for Stations 10EM112 and 12RD001 (Appendix D). Both stations had a high percentage of low DO tolerant taxa and a low number of low DO intolerant taxa.

Strength-of-evidence analysis

Table 10 presents a summary of the SOE scores for the various candidate causes associated with AUID 515. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: lack of base flow, lack of instream habitat, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of the following stressors: lack of base flow, lack of instream habitat, high suspended sediment, and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 10. SOE scores for candidate causes associated with AUID 515.

Types of Evidence	SOE Scores for Candidate Causes[1]									
	Loss of Physical Connectivity		Lack of Base Flow		Lack of Instream Habitat		High Suspended Sediment		Low Dissolved Oxygen	
	Biological Impairment(s)									
	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.

3.3.2 Kripple Creek (AUID 525)

Physical setting

This reach represents the segment of Kripple Creek from its confluence with an unnamed creek to its outlet to the Gentilly River (Figure 14); a total length of nine miles. The reach has a subwatershed area of 33 square miles (21,053 acres). The reach and its subwatershed are situated in the beach ridges region of the RLRW. The subwatershed contains 10 miles of perennial stream (e.g., AUID 525), 10 miles of intermittent stream, five miles of perennial drainage ditch, and seven miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 52% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 7% of AUID 525. The NLCD 2011 (USGS, 2011) lists cultivated crops (82%) as the predominant land cover in the subwatershed. Notable minor land cover groups in the subwatershed included wetlands (5%), hay/pasture (4%), and developed areas (4%).

Figure 14. Map of AUID 525 and associated biological monitoring stations and water quality monitoring site (2010 NAIP aerial image).

Biological impairments

Fish (F-IBI)

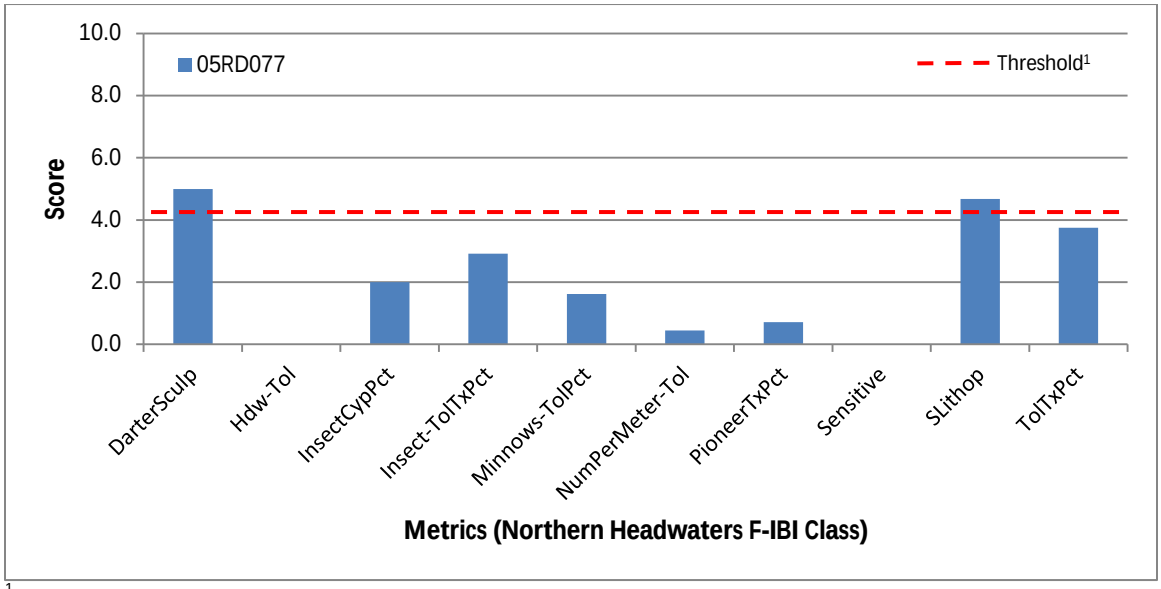
The fish community of AUID 525 was monitored at Station 05RD077 (0.1 mi upstream of the 250th Street SW crossing) on June 21, 2005 and Station 12RD022 (0.1 mi upstream of the 180th Avenue SW crossing) on June 14, 2012. The relative location of the stations is shown in Figure 14. Station 05RD077 was designated as General Use within the Northern Headwaters F-IBI Class, while Station 12RD022 was classified as General Use within the Southern Streams F-IBI Class. Accordingly, the impairment threshold

for the stations is an F-IBI score of 42 and 50, respectively. Monitoring of the stations yielded F-IBI scores below their applicable impairment threshold; Station 05RD077 had a score of 21 and Station 12RD022 had a score of 41.

Figures 15 and 16 provide the individual F-IBI metric scores for the two fish monitoring stations along AUID 525; a description of each metric is provided in Appendix A. Station 05RD077 had eight metrics that scored below the threshold score (i.e., Hdw-Tol, InsectCypPct, Insect-TolTxPct, Minnows-TolPct, NumPerMeter-Tol, PioneerTxPct, Sensitive, and TolTxPct). Station 12RD022 had four metrics that failed to meet the threshold score (i.e., MA<2Pct, SensitiveTxPct, TolPct, and TolTxPct). Overall, the fish assemblage of both stations was dominated by tolerant taxa (e.g., brook stickleback and white sucker).

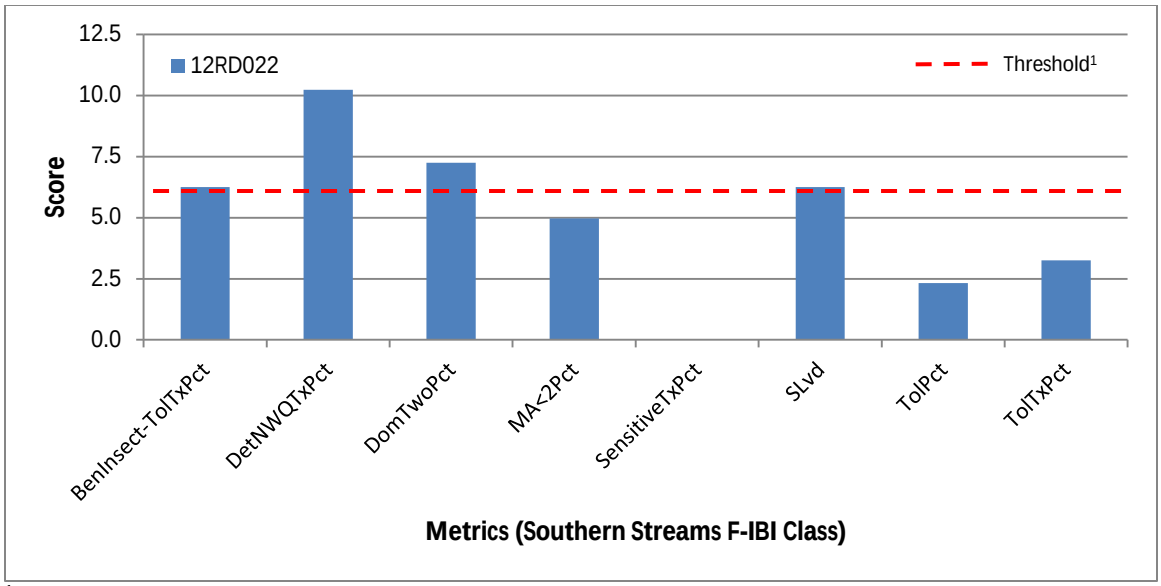
Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 525 was monitored at Station 05RD077 on August 24, 2005. The station was designated as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the applicable impairment threshold for the station is an M-IBI score of 41. Monitoring at the station yielded an M-IBI score (34) beneath this threshold. According to Figure 17, the station had six individual metrics that scored below the threshold score (i.e., ClingerCh, Collector-filtererPct, HBI_MN, Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct). A description of each metric is provided in Appendix B. Overall, the macroinvertebrate assemblage of the station was dominated by tolerant taxa, specifically *Hyalella* (amphipods) and *Physa* (snails).



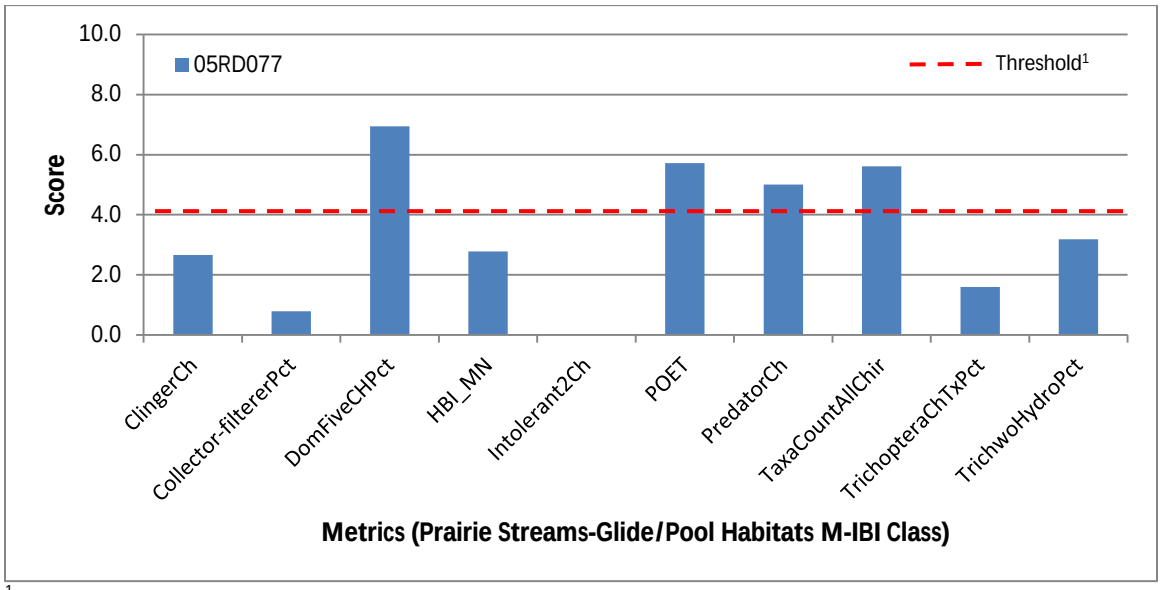
[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 15. Individual F-IBI metric scores for Station 05RD077 along AUID 525.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 16. Individual F-IBI metric scores for Station 12RD022 along AUID 525.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 17. Individual M-IBI metric scores for Station 05RD077 along AUID 525.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 05RD077 and 12RD022 along AUID 525. According to the MDNR (2014b), there are no man-made dams on the reach. On October 8, 2014, MPCA SI 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 were identified (e.g., perched culverts and beaver dams). In

addition to the assessment, MPCA SI staff performed a detailed review of an April 2, 2012, aerial photo of the reach; the photo was collected approximately two months prior to fish sampling at the downstream station. No connectivity-related issues were identified in the photo.

Biotic response – fish and macroinvertebrate

There is no evidence of a causal relationship between a loss of physical connectivity and the F-IBI and M-IBI impairments associated with AUID 525. There are no known obstructions to connectivity along the reach. However, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Lack of base flow

Available data

The MPCA biological monitoring staff was unable to perform macroinvertebrate sampling at Station 12RD022 along AUID 525 due to the absence of flow. Figure 18 displays continuous flow data for Site S004-835 (180th Avenue SW crossing) from March 12, 2012, to November 15, 2012; the relative location of the site is shown in Figure 14. The RLWD collected the stage data, while the MDNR collected the flow measurements. The mean flow for the period was 1 cfs, while the highest peak flow was 36 cfs and the lowest flow was 0 cfs. The site had minimal (<1 cfs) to no flow 69% of the time. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 15 and 23% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on three separate dates (i.e., July 23, 2014, August 14, 2014, and October 8, 2014) and documented flow conditions. Staff observed low flow conditions (estimated ≈1 cfs) along the reach at the time of the last visit (Figure 19). Overall, the available data suggest that the reach is prone to frequent periods of minimal to no flow.

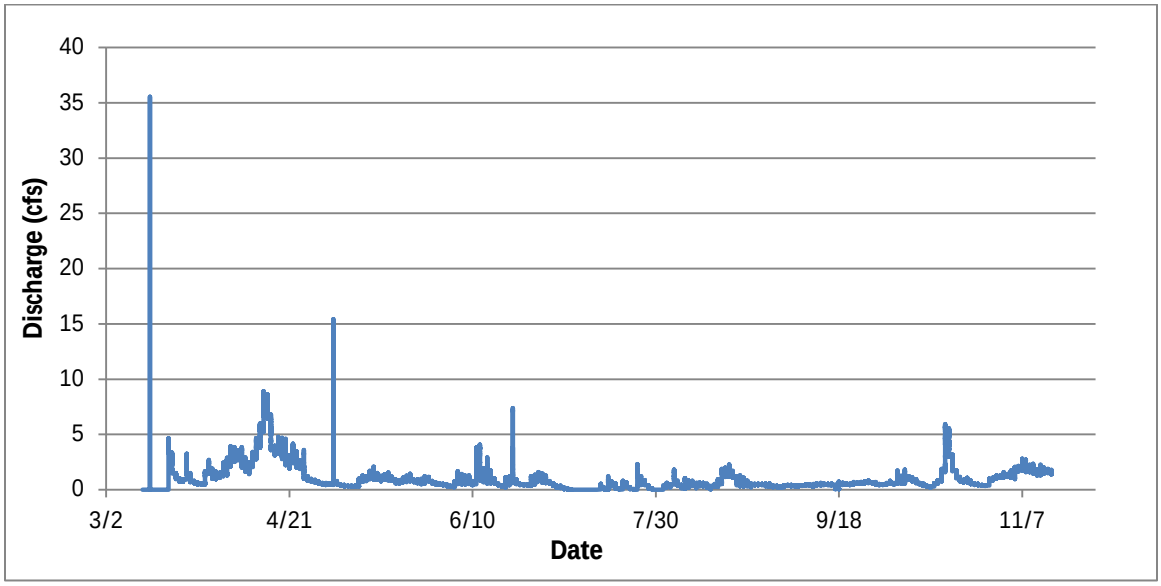


Figure 18. Continuous flow data (March 12, 2012, to November 15, 2012) for Site S004-835 along AUID 525.

Figure 19. Photos of low flow conditions along AUID 525 on October 8, 2014, including Site S004-835 (left) and the 160th Avenue SW crossing (right).

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 525 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 05RD077 and/or 12RD022:

- High relative abundance of taxa that are generalists (GeneralTxPct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- High relative abundance of taxa that are pioneers (PioneerTxPct)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High taxa richness of short-lived species (SLvd)
- High relative abundance of individuals that are tolerant (ToPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 15, four of the aforementioned individual metrics (i.e., NumPerMeter-Tol, Sensitive, PioneerTxPct, and TolTxPct) were used in the calculation of the F-IBI score for Station 05RD077. Additionally, five of the individual metrics (i.e., MA<2Pct, SensitiveTxPct, TolPct, TolTxPct, and SLvd) were used in the calculation of the F-IBI score for Station 12RD022 (Figure 16). The stations had a "low" score for each of these respective metrics, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of base flow and the M-IBI impairment associated with AUID 525 is provided by the following individual M-IBI metric responses (Appendix D) for Station 05RD077:

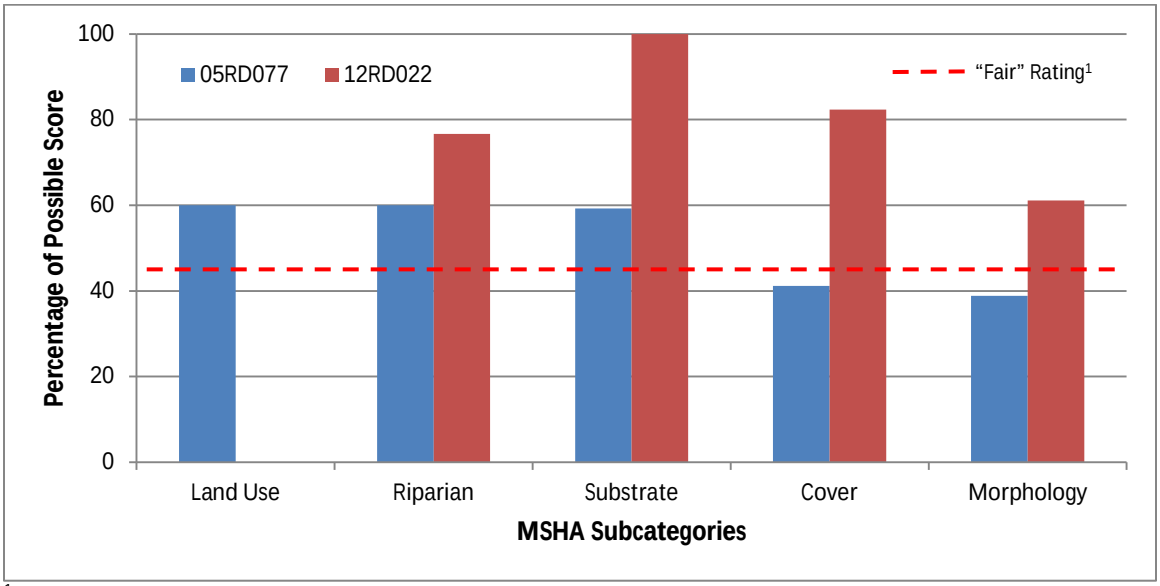
- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Frequent and/or prolonged periods of very low or no flow tend to limit Trichoptera taxa, many of which are collector-filterers, and favor taxa that are tolerant of environmental disturbances (EPA, 2012; Klemm et al., 2002, Poff and Zimmerman, 2010). According to Figure 17, four of the aforementioned individual metrics (i.e., Collector-filtererPct, Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 05RD077. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach. Overall, the macroinvertebrate assemblage of the station was dominated by taxa that are adapted to lentic conditions (i.e., *Hyalella* and *Physa*).

Lack of instream habitat

Available data

The instream habitat of AUID 525 was evaluated at Stations 05RD077 and 12RD022 using the MSHA. Station 05RD077, which is located along an altered segment of the reach (MPCA, 2013), had a total MSHA score of 49 ("fair"). According to Figure 20, the MSHA score for the station was limited by the cover and channel morphology subcategories. The station only had a "sparse" amount of cover, with no macrophytes present. Additionally, the station had no riffle habitat, "low" channel stability, and "poor" channel development. Station 12RD022, which is situated along a natural segment of the reach (MPCA, 2013), had a total MSHA score of 74 ("good"). The MSHA score for Station 12RD022 was limited by the land use subcategory (Figure 20). The land use adjacent to the station was dominated by row crop agriculture (e.g., corn and soybeans). In addition, the station had abundant riffle habitat. Both stations offered coarse substrate, with only "light" embeddedness.



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

Figure 20. MSHA subcategory results for Stations 05RD077 and 12RD022 along AUID 525.

Biotic response – fish

Evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 525 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 05RD077 and/or 12RD022:

- Low relative abundance of taxa that are benthic insectivores, excluding tolerant species (BenInsect-TolTxPct)
- High relative abundance of taxa that are detritivorous (DetNWQTxPct)
- Low relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct)
- Low relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct)
- Low taxa richness of simple lithophilic spawning species (SLithop)

Benthic 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). According to Figure 15, three of the aforementioned individual metrics (i.e., InsectCypPct, Insect-TolTxPct, and SLithop) were used in the calculation of the F-IBI score for Station 05RD077. Additionally, two of the individual metrics (i.e., BenInsect-TolTxPct and DetNWQTxPct) were used in the calculation of the F-IBI score for Station 12RD022 (Figure 16). Station 05RD077 had a "low" score for a majority of these respective metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of instream habitat and the M-IBI impairment associated with AUID 525 is provided by the following individual M-IBI metric responses (Appendix D) for Station 05RD077:

- Low taxa richness of clinger taxa (Clingerch)
- Low relative abundance of collector-filterer individuals in a subsample (Collector-FiltererPct)

Clinger taxa, including many collector-filterers, require clean, coarse substrate or other objects to attach themselves to. According to Figure 17, these metrics were used in the calculation of the M-IBI score for Station 05RD077. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at Stations 05RD077 and 12RD022 along AUID 525 at the time of fish sampling. The samples were analyzed for several parameters, including TSS. Both stations had a low TSS concentration (8 and 22 mg/L). Table 11 summarizes discrete TSS data for Site S004-835. Only 4.3% of the total values exceeded the 65 mg/L standard. Additionally, the RLRW HSPF model estimates that the reach had a TSS concentration in excess of the standard approximately 3% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to occasional periods of high suspended sediment.

Table 11. Discrete TSS data for Site S004-835 along AUID 525.

Site	Date Range	*n*	Min	Max	Mean	% Total Values Above Standard
S004-835	2008-2014	94	0	210	15	4.3

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 525. None of the individual F-IBI metrics for Stations 05RD077 and 12RD022 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 525 is provided by the following individual M-IBI metric responses (Appendix D) for Station 05RD077:

- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Collector-filterers, including several members of the order Trichoptera, 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). According to Figure 17, four of the aforementioned individual metrics (i.e., Collector-filtererPct, Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 05RD077. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach. The MPCA also calculated TSS TIVs for Station 05RD077 (Appendix D). The station had a low percentage of TSS intolerant taxa.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Stations 05RD077 and 12RD022 along AUID 525 at the time of fish sampling. Neither of the measurements was below the 5.0 mg/L standard. Figure 21 displays discrete DO data for Site S004-835 (2008-2014; *n*=124). None of the measurements were below the standard; however, only six measurements were taken prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. The RLWD conducted continuous DO monitoring at Site S004-835 from May 22, 2013, to October 7, 2013. Table 12 provides a summary of the monitoring results. The site had a low proportion of daily minimum DO values that were below the standard (3.0%), as well as a nominal level of mean daily DO flux (1.8 mg/L). Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard between 11 and 39% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to occasional periods of low DO.

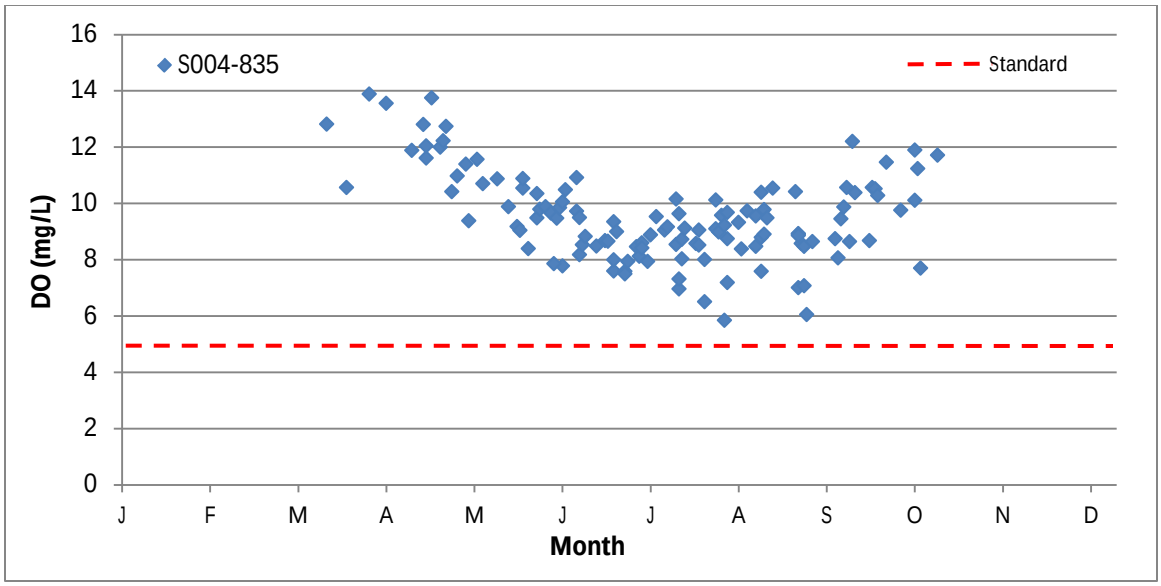


Figure 21. Discrete DO data for Site S004-835 along AUID 525.

Table 12. Continuous DO data for Site S004-835 along AUID 525.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S004-835 (RLWD)	May 22, 2013 - Oct. 7, 2013	6178	3.1	13.5	3.0	1.1	1.8

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 525 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 05RD077 and 12RD022:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 15, three of the aforementioned individual metrics (i.e., NumPerMeter-Tol, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 05RD077. Additionally, three of the individual metrics (i.e., SensitiveTxPct, TolPct, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD022 (Figure 16). The stations had a "low" score for each of these respective metrics, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of each

station meeting the DO standard based upon its sampled fish assemblage (Appendix C). Station 05RD077 had a low probability (14%) of meeting the standard, while Station 12RD022 had a relatively high probability (57%) of meeting the standard.

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 525 is provided by the following individual M-IBI metric responses (Appendix D) for Station 05RD077:

- High Hilsenhoff's Biotic Index value (HBI_MN)
- Low taxa richness of macroinvertebrates with tolerance values less than or equal to two (Intolerant2Ch)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative abundance of non-hydropsychid Trichoptera individuals in a subsample (TrichwoHydroPct)

Low DO often limits the taxa richness of macroinvertebrates and favors taxa that are tolerant (EPA, 2012; Weber, 1973). According to Figure 17, four of these individual metrics (HBI_MN, Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 05RD077. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach. Additionally, the MPCA calculated DO TIVs for Station 05RD077 (Appendix D). The station had a high percentage of low DO tolerant taxa and a low number of low DO intolerant taxa.

Strength-of-evidence analysis

Table 13 presents a summary of the SOE scores for the various candidate causes associated with AUID 525. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: lack of base flow and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of the following stressors: lack of base flow, high suspended sediment, and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 13. SOE scores for candidate causes associated with AUID 525.

Types of Evidence	SOE Scores for Candidate Causes[1]									
	Loss of Physical Connectivity		Lack of Base Flow		Lack of Instream Habitat		High Suspended Sediment		Low Dissolved Oxygen	
	Biological Impairment(s)									
	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.

3.3.3 Kripple Creek (AUID 526)

Physical setting

This reach represents the segment of Kripple Creek from its confluence with an unnamed ditch to its confluence with an unnamed creek (Figure 22); a total length of six miles. A majority of the reach is channelized and is part of Judicial Ditch 66. The reach has a subwatershed area of 19 square miles (11,879 acres). The reach and its subwatershed are situated in the beach ridges region of the RLRW. The subwatershed contains one mile of perennial stream, six miles of intermittent stream, five miles of perennial drainage ditch (e.g., AUID 526), and six miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 77% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 83% of AUID 526. The NLCD 2011 (USGS, 2011) lists cultivated crops (80%) as the predominant land cover in the subwatershed. Notable minor land cover groups in the subwatershed included wetlands (6%), hay/pasture (5%), and developed areas (4%).

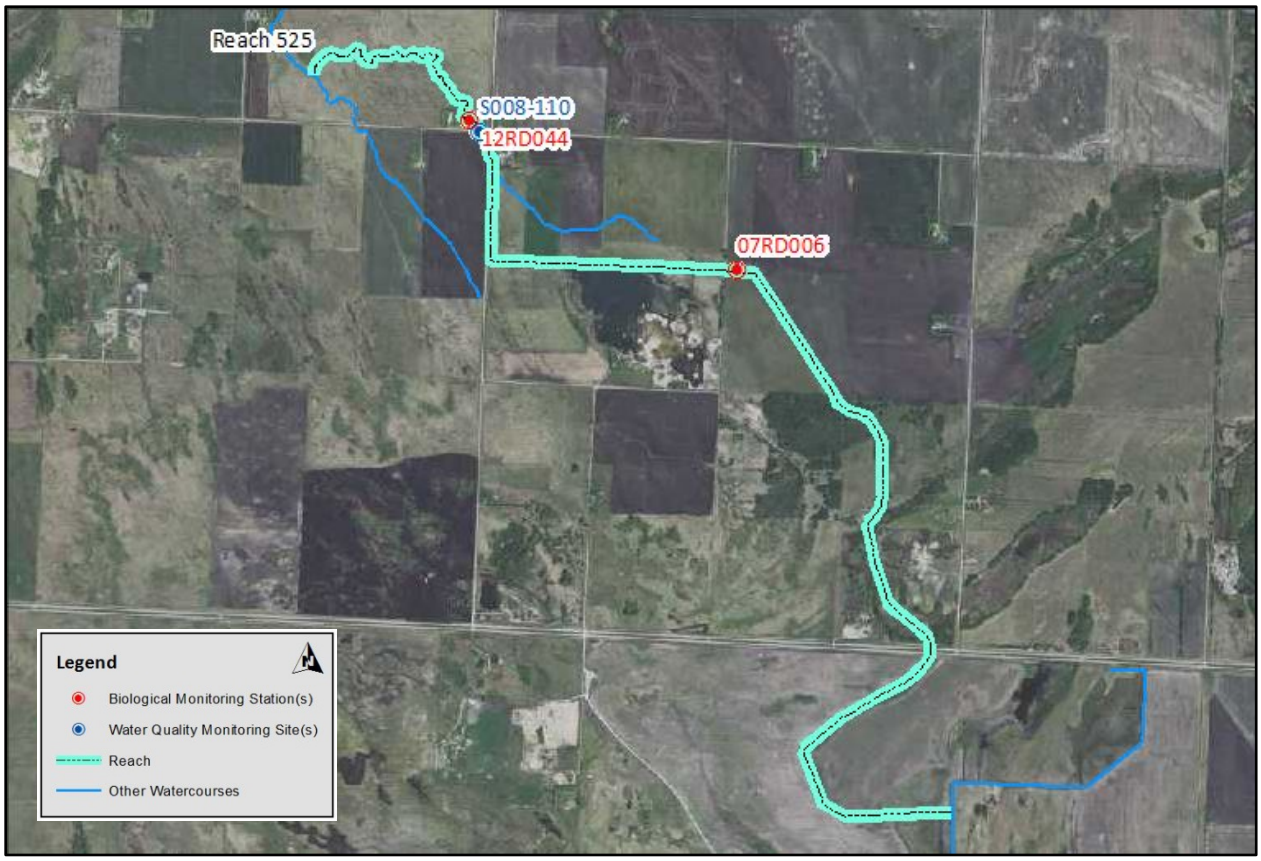


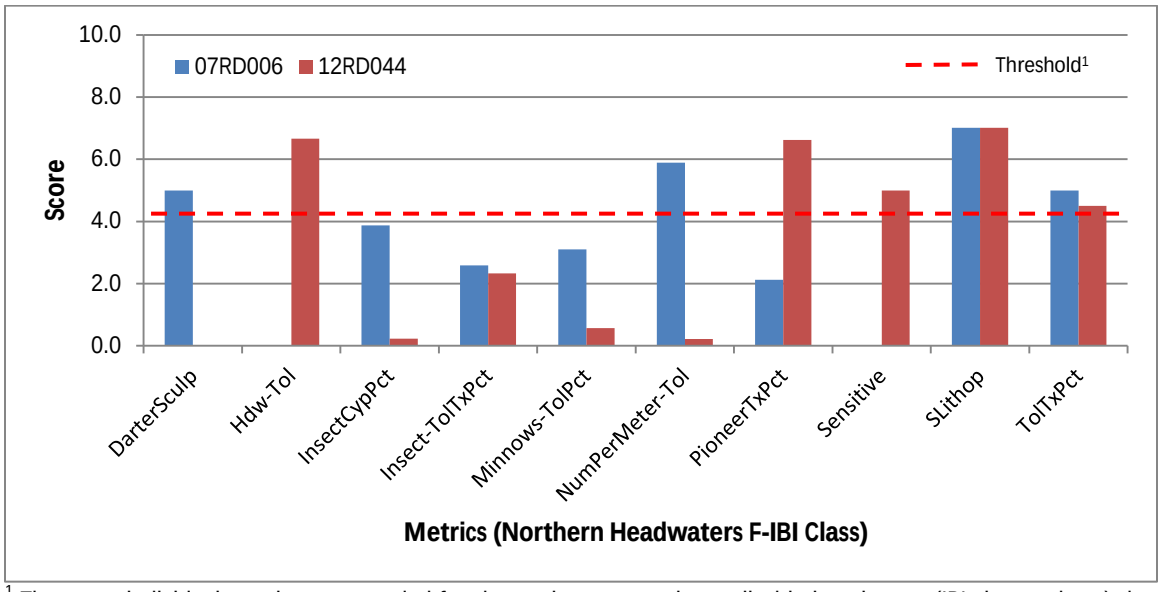
Figure 22. Map of AUID 526 and associated biological monitoring stations and water quality monitoring site (2010 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 526 was monitored at Station 07RD006 (1.9 mi downstream of the US Hwy. 2 crossing) on August 8, 2007 and Station 12RD044 (0.1 mi downstream of the CSAH 53 crossing) on June 12, 2012. The relative location of the stations is shown in Figure 22. Both of the stations were designated as General Use within the Northern Headwaters F-IBI Class. Accordingly, the applicable impairment threshold for the stations is an F-IBI score of 42. Both stations had an F-IBI score below this threshold; Station 07RD006 had a score of 35 and Station 12RD044 had a score of 33.

Figure 23 provides the individual F-IBI metrics for the two fish monitoring stations along AUID 526; a description of each metric is provided in Appendix A. Station 07RD006 had six metrics that scored below the threshold score (i.e., Hdw-Tol, InsectCypPct, Insect-TolTxPct, Minnows-TolPct, PioneerTxPct, and Sensitive). Station 12RD044 had five metrics that failed to meet the threshold score (i.e., DarterSculp, InsectCypPct, Insect-TolTxPct, Minnows-TolPct, and NumPerMeter-Tol). Overall, the fish assemblage of both stations was dominated by tolerant and/or pioneer species (e.g., creek chub and central mudminnow).



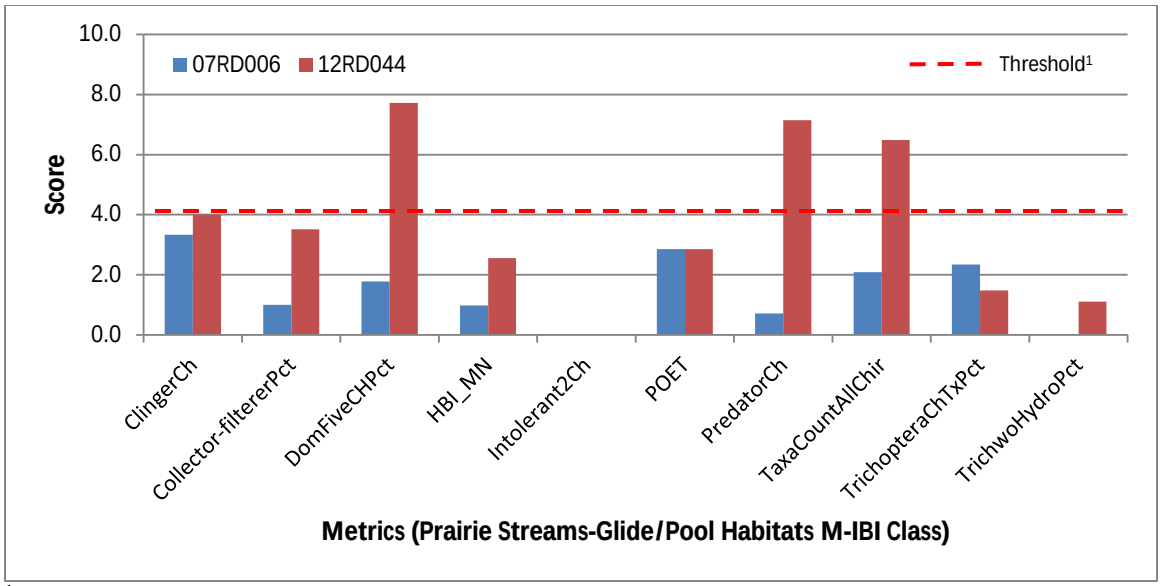
[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 23.Individual F-IBI metric scores for Stations 07RD006 and 12RD044 along AUID 526.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 526 was monitored at Station 07RD006 on August 15, 2007 and Station 12RD044 on July 31, 2012. The stations were designated as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the applicable impairment threshold for these stations is an M-IBI score of 41. Both stations had an M-IBI score below this threshold; Station 07RD006 had a score of 15 and 12RD044 had a score of 37.

Figure 24 provides the individual M-IBI metrics for the two macroinvertebrate monitoring stations along AUID 526; a description of each metric is provided in Appendix B. None of the metrics associated with Station 07RD0006 scored above the threshold score. Station 12RD044 had seven metrics that failed to meet the threshold score (i.e., ClingerCh, Collector-filtererPct, HBI_MN, Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct). Overall, the macroinvertebrate assemblage of both stations was dominated by tolerant taxa, specifically *Dicrotendipes* (midges), *Physa* (snails), and *Pseudocloeon* (mayflies).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 24. Individual M-IBI metric scores for Stations 07RD006 and 12RD044 along AUID 526.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff documented a beaver dam (Figure 25) during macroinvertebrate sampling at Station 12RD044 along AUID 526. The beaver dam had an associated pool and appeared to be a complete barrier to connectivity at the time of discovery. According to the MDNR (2014b), there are no man-made dams on the reach or the downstream segment of Kripple Creek, from the reach to its confluence with the Gentilly River (i.e. AUID 525). On October 8, 2014, MPCA SI 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 were identified (e.g., perched culverts and beaver dams). In addition to the assessment, MPCA SI staff performed a detailed review of an April 2, 2012, aerial photo of AUID 525 and 526; the photo was collected approximately two months prior to fish sampling at Station 12RD044. The aforementioned beaver dam was not present in the photo. However, two beaver dams were identified immediately upstream of Station 07RD006; a photo of one of these dams is shown in Figure 25. The beaver dams appeared to be limiting connectivity.

Biotic Response – fish

There is inconclusive evidence of a causal relationship between a loss of physical connectivity and the F-IBI impairment associated with AUID 526. Station 12RD044 had a species assemblage comparable to Station 12RD022, which is situated downstream of this reach (AUID 525) and was sampled during the same timeframe; the stations shared 70% of the same species. However, the aforementioned beaver dams were likely limiting fish passage at the time of sampling. Additionally, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of physical connectivity and the M-IBI impairment associated with AUID 526. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not directly affected by physical connectivity barriers.

Figure 25. Photos of potential connectivity barriers along AUID 526, including a beaver dam at Station 12RD044 on July 31, 2012 (left) and a beaver dam immediately upstream of Station 07RD006 on April 2, 2012, courtesy of Google Earth (right).

Lack of base flow

Available data

The MPCA biological monitoring staff did not encounter any flow-related issues during fish and macroinvertebrate sampling at Stations 07RD006 and 12RD044 along AUID 526. There is no flow monitoring data for the reach. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 23 and 38% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on four separate dates (i.e., July 23, 2014, August 14, 2014, August 27, 2014, and October 8, 2014) and documented flow conditions. Staff observed low flow conditions (estimated ≈1 cfs) along the reach at the time of the last visit (Figure 26). Overall, the available data suggest that the reach is prone to frequent periods of minimal to no flow.

Biotic response – fish

Evidence of a causal relationship between a lack of baseflow and the F-IBI impairment associated with AUID 526 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 07RD006 and/or 12RD044:

- High combined relative abundance of the two most abundant taxa (DomTwoPct)
- High relative abundance of taxa that are generalists (GeneralTxPct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- High relative abundance of taxa that are pioneers (PioneerTxPct)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of taxa that are serial spawners (SSpnTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, serial spawners, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 23, four of the aforementioned individual metrics (i.e., NumPerMeter-Tol, PioneerTxPct, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Stations 07RD006 and 12RD044. Station 07RD006 had a "low" score for the PioneerTxPct and Sensitive metrics, while Station 12RD044 had a "low" score for the NumPerMeter-Tol metric. The "low" score for these metrics directly contributing to the biological impairment of the reach.

Figure 26.Photos of low flow conditions along AUID 526 on October 8, 2014, including Site S008-110 (left) and the 130th Avenue SW crossing (right).

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of baseflow and the M-IBI impairment associated with AUID 526 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 07RD006 and/or 12RD044:

- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- High relative abundance of the dominant five taxa in a subsample (DomFiveCHPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- High relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

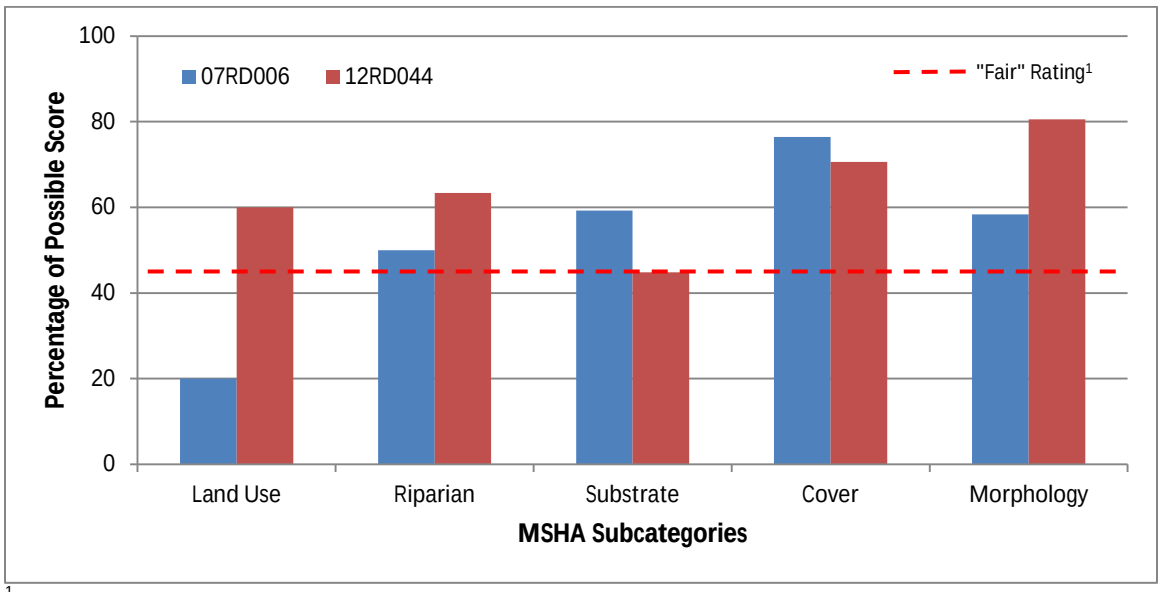
Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity, specifically taxa belonging to the orders of Plecoptera, Ephemeroptera, and Trichoptera (many of which are collector-filterers), and favor taxa that are tolerant of environmental disturbances (EPA, 2012; Klemm et al., 2002, Poff and Zimmerman, 2010). According to Figure 24, seven of the aforementioned individual metrics (i.e., Collector-filtererPct, DomFiveCHPct, Intolerant2Ch, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for both monitoring stations. Station 07RD006 and/or 12RD044 had a "low" score for each of these metrics, thereby negatively

affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. Overall, the macroinvertebrate assemblage of the stations was dominated by taxa that are adapted to lentic conditions (i.e., *Dicrotendipes* and *Physa*).

Lack of instream habitat

Available data

The instream habitat of AUID 526 was evaluated at Stations 07RD006 and 12RD044 using the MSHA. Station 07RD006, which is located along an altered segment of the reach (MPCA, 2013), had a total MSHA score of 58 ("fair"). According to Figure 27, the MSHA score for the station was limited by the land use subcategory. The land use adjacent to the station was dominated by agriculture (i.e., row crops and no till). Additionally, the station had very limited riffle habitat. Station 12RD044, which is also situated along an altered segment of the reach (MPCA, 2013), had a total MSHA score of 66 ("fair"). The MSHA score for the station was slightly limited by the substrate subcategory (Figure 27); although, the station had abundant riffle habitat. Both stations offered coarse substrate, but also had a "moderate" level of embeddedness.



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

Figure 27. MSHA subcategory results for Stations 07RD006 and 12RD044 along AUID 526.

Biotic response – fish

Evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 526 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 07RD006 and/or 12RD044:

- Low relative abundance of taxa that are benthic insectivores, excluding tolerant species (Beninsect-TolTxPct)
- Low taxa richness of darter and sculpin species (DarterSculp)
- Low relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct)
- Low relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct)

Benthic insectivores (e.g., darters and sculpins) require quality benthic habitat (e.g., clean, coarse substrate) for feeding and/or reproduction purposes (Aadland et al., 2006). According to Figure 23, three of the aforementioned individual metrics (i.e., DarterSculp, InsectCypPct, and Insect-TolTxPct)

were used in the calculation of the F-IBI score for Stations 07RD006 and 12RD044. The stations had a "low" score for a majority of these respective metrics, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of instream habitat and the M-IBI impairment associated with AUID 526 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 07RD006 and/or 12RD044:

- High relative abundance of burrower individuals (BurrowerPct)
- Low taxa richness of clinger taxa (Clingerch)
- Low relative abundance of collector-filterer individuals in a subsample (Collector-filtererPct)
- High relative abundance of legless individuals (LeglessPct)

Clinger taxa, including many collector-filterers, require clean, coarse substrate or other objects to attach themselves to, while burrowing and legless macroinvertebrates are tolerant of degraded benthic habitat. According to Figure 24, two of the aforementioned individual metrics (i.e., ClingerCh and Collector-filtererPct) were used in the calculation of the M-IBI score for Stations 07RD006 and 12RD044. Both stations had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at Stations 07RD006 and 12RD044 along AUID 526 at the time of fish sampling. The samples were analyzed for several parameters, including TSS. Both stations had a low TSS concentration (7 and 9 mg/L). In 2014, the RLWD collected three samples at Site S008-100 that were analyzed for TSS. The TSS concentration of the samples ranged from 2 to 19 mg/L. The RLRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L standard approximately 3% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to 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 526. None of the individual F-IBI metrics for Stations 07RD006 and 12RD044 exhibited a correlation to this candidate cause. However, the deposition of suspended sediment has caused the aforementioned embeddedness of coarse substrate and the related biotic response associated with both stations.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 526 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 07RD006 and/or 12RD044:

- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Collector-filterers, including several members of the order Trichoptera, 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). According to Figure 24, four of the aforementioned individual metrics (i.e., Collector-filtererPct, Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Stations 07RD006 and 12RD044. The stations had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. The MPCA also calculated TSS TIVs for the stations. Station 07RD006 had a high percentage of high TSS tolerant taxa and a low number of high TSS intolerant taxa, while Station 12RD044 had a low number of high TSS intolerant taxa. Additionally, the deposition of suspended sediment has resulted in the embeddedness of coarse substrate and the associated biotic response at both stations.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Stations 07RD006 and 12RD044 along AUID 526 at the time of sampling. None of the measurements were below the 5.0 mg/L standard. In 2014, the RLWD collected seven discrete DO measurements at Site S008-100. The DO concentrations ranged from 6.2 to 8.4 mg/L. The MPCA conducted continuous DO monitoring at Site S008-110 (CSAH 53 crossing) from August 14, 2014, to August 27, 2014; the relative location of the site is shown in Figure 22. Table 14 provides a summary of the monitoring results. The site had a no DO values below the standard, as well as a nominal level of mean daily DO flux (0.9 mg/L). Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard between 39 and 47% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is likely prone to periods of low DO.

Table 14. Continuous DO data for Site S008-110 along AUID 526.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S008-110 (MPCA)	Aug. 14, 2014 - Aug. 27, 2014	1246	5.6	9.0	0.0	0.0	0.9

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 526 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 07RD006 and/or 12RD044:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 23, three of these individual metrics (NumPerMeter-Tol, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for each of the monitoring stations. Station 07RD006 had a "low" score for the Sensitive metric, while Station 12RD044 had a "low" score for the NumPerMeter-Tol metric. The "low" score for these metrics directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of each station meeting the DO standard based upon its sampled fish assemblage (Appendix C). Station 12RD044 had a low probability (6%) of meeting the standard, while Station 07RD006 had a relatively high probability (54%) of meeting the standard.

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 526 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 07RD006 and/or 12RD044:

- High Hilsenhoff's Biotic Index value (HBI_MN)
- Low taxa richness of macroinvertebrates with tolerance values less than or equal to two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- High relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative abundance of non-hydropsychid Trichoptera individuals in a subsample (TrichwoHydroPct)

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 (EPA, 2012; Weber, 1973). According to Figure 24, five of these individual metrics (HBI_MN, Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for both monitoring stations. Station 07RD006 and/or 12RD044 had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. Additionally, the MPCA calculated DO TIVs for both stations (Appendix D). Station 12RD044 had a high percentage of low DO tolerant taxa and a low number of low DO intolerant taxa.

Strength-of-evidence analysis

Table 15 presents a summary of the SOE scores for the various candidate causes associated with AUID 526. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: lack of base flow, lack of instream habitat, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of the following stressors: lack of base flow, lack of instream habitat, high suspended sediment, and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 15. SOE scores for candidate causes associated with AUID 526.

Types of Evidence	SOE Scores for Candidate Causes[1]									
	Loss of Physical Connectivity		Lack of Base Flow		Lack of Instream Habitat		High Suspended Sediment		Low Dissolved Oxygen	
	Biological Impairment(s)									
	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**	**--**	**++**	**++**	**++**	**++**	**+**	**+**	**+**	**+**

[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 Little Black River (AUID 528)

Physical setting

This reach represents the segment of the Little Black River from its confluence with an unnamed ditch to its outlet to the Black River (Figure 28); a total length of two miles. The reach has a subwatershed area of 25 square miles (15,787 acres). The reach and its subwatershed are situated in the beach ridges region of the RLRW. The subwatershed contains five miles of intermittent stream (e.g., AUID 528) and four miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 56% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 32% of AUID 528. The NLCD 2011 (USGS, 2011) lists cultivated crops (62%) as the predominant land cover in the subwatershed. Notable minor land cover groups in the subwatershed included wetlands (17%), open water (9%), forest (5%), and developed areas (4%).

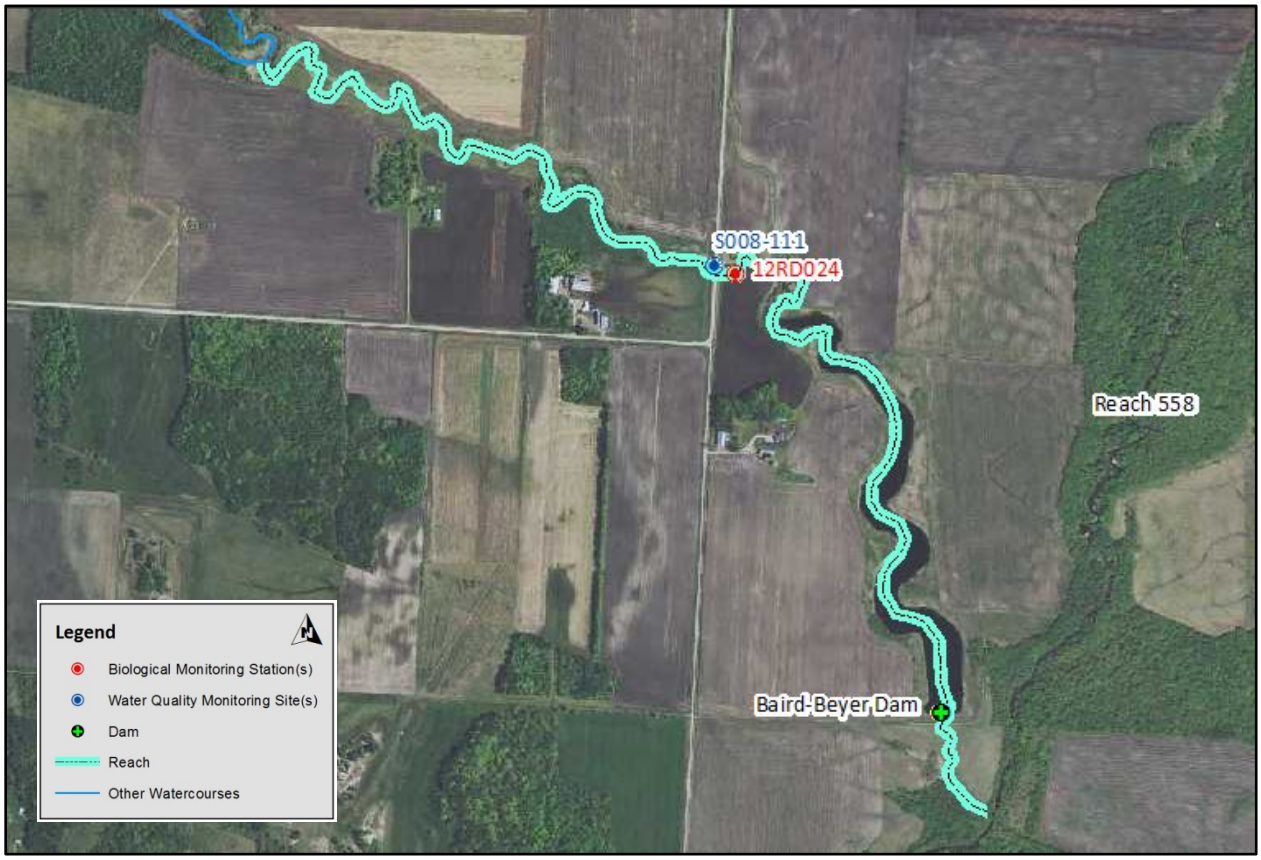


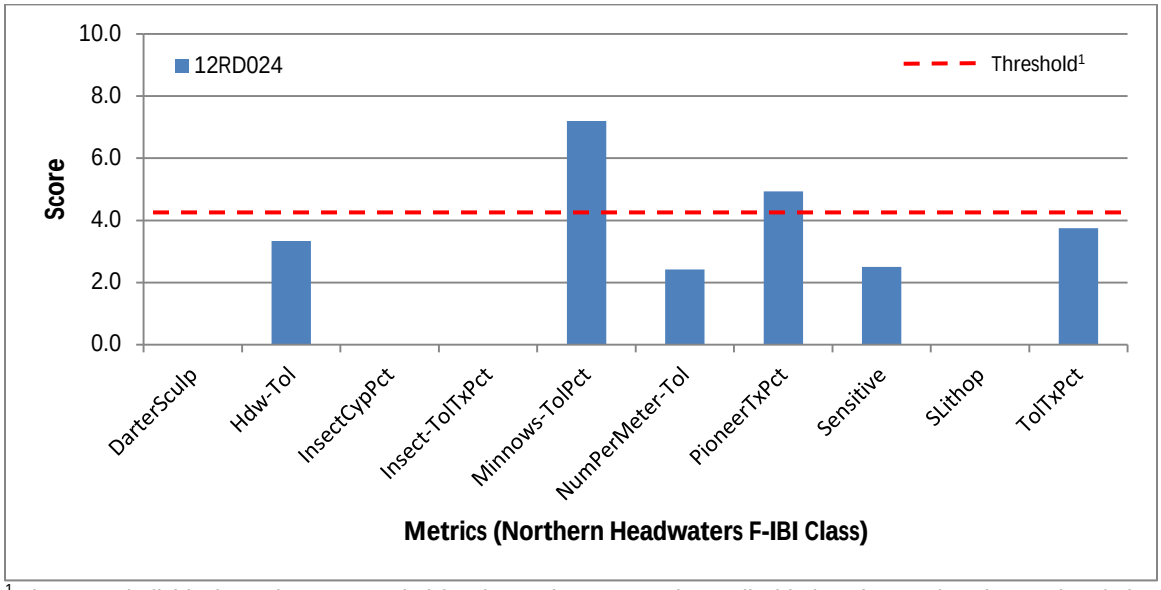
Figure 28. Map of AUID 528 and associated biological monitoring station and water quality monitoring site (2010 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 528 was monitored at Station 12RD024 (<0.1 mi downstream of the CR 102 crossing) on June 12, 2012. The relative location of the station is shown in Figure 28. 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. The station had an F-IBI score (24) well beneath this threshold. According to Figure 29, the station had eight individual metrics that scored below the threshold score (i.e., DarterSculp, Hdw-Tol, InsectCypPct, Insect-TolTxPct, NumPerMeter-Tol, Sensitive,

SLithop, and TolTxPct). A description of each metric is provided in Appendix A. Overall, the fish assemblage of the station was dominated by tolerant species (e.g., brook stickleback and fathead minnow).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 29. Individual F-IBI metric scores for Station 12RD024 along AUID 528.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 12RD024 along AUID 528. According to the MDNR (2014b), the Baird-Beyer Dam (Figure 30) is located on the downstream end of the reach, near its confluence with the Black River. The dam is privately owned and was constructed in 1979 for flood control, irrigation, and wildlife purposes. The structure has an associated impoundment and is a complete barrier to connectivity. On October 8, 2014, MPCA SI staff conducted a connectivity assessment along the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No additional obstructions to connectivity were identified (e.g., perched culverts and beaver dams). In addition to the assessment, MPCA SI staff performed a detailed review of an April 2, 2012, aerial photo of the reach; the photo was collected approximately two months prior to fish sampling at the station. No additional connectivity-related issues were identified in the photo.

Figure 30. Photos of the Baird-Beyer Dam along AUID 528 on October 8, 2014, including the impoundment (left) and outlet (right).

Biotic response – fish

Evidence of a causal relationship between a loss of physical connectivity and the F-IBI impairment associated with AUID 528 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD024:

- Low relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-TolPct)
- Low relative abundance of individuals that are migratory (MgrPct)

The fish assemblage sampled at Station 12RD024 was comprised of 178 individuals and only four species: brook stickleback, central mudminnow, fathead minnow, and northern redbelly dace. These species are early maturing and non-migratory. In 2003, the MDNR conducted fish sampling at a station located immediately downstream of this reach along the lower extent of the Black River (Groshens, 2005). The sampling yielded 382 individuals and 22 species, including 10 sensitive species. While the Little Black River is a substantially smaller riverine system than the Black River and would likely not support some of the species that the MDNR sampled (e.g., smallmouth bass), the connectivity barrier posed by the Baird-Beyer Dam is undoubtedly limiting the species diversity of the reach. Additionally, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Lack of base flow

Available data

The MPCA biological monitoring staff was unable to perform macroinvertebrate sampling at Station 12RD024 along AUID 528 due to the absence of flow. There is no flow monitoring data for the reach. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow nearly 29% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on three separate dates (i.e., July 3, 2014, July 23, 2014, and October 8, 2014) and documented flow conditions. Staff observed low flow conditions (estimated ≈1-2 cfs) along the reach at the time of the last visit (Figure 31); a majority of the flow appeared to be originating from a large wetland complex located immediately upstream of the reach. Overall, the available data suggest that the reach is prone to frequent periods of minimal to no flow.

Figure 31. Photos of low flow conditions along AUID 528 on October 8, 2014, including Site S008-111 (left) and the CR 13 crossing (right).

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 528 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD024:

- High combined relative abundance of the two most abundant taxa (DomTwoPct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- High relative abundance of taxa that are pioneers (PioneerTxPct)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of taxa that are serial spawners (SSpnTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

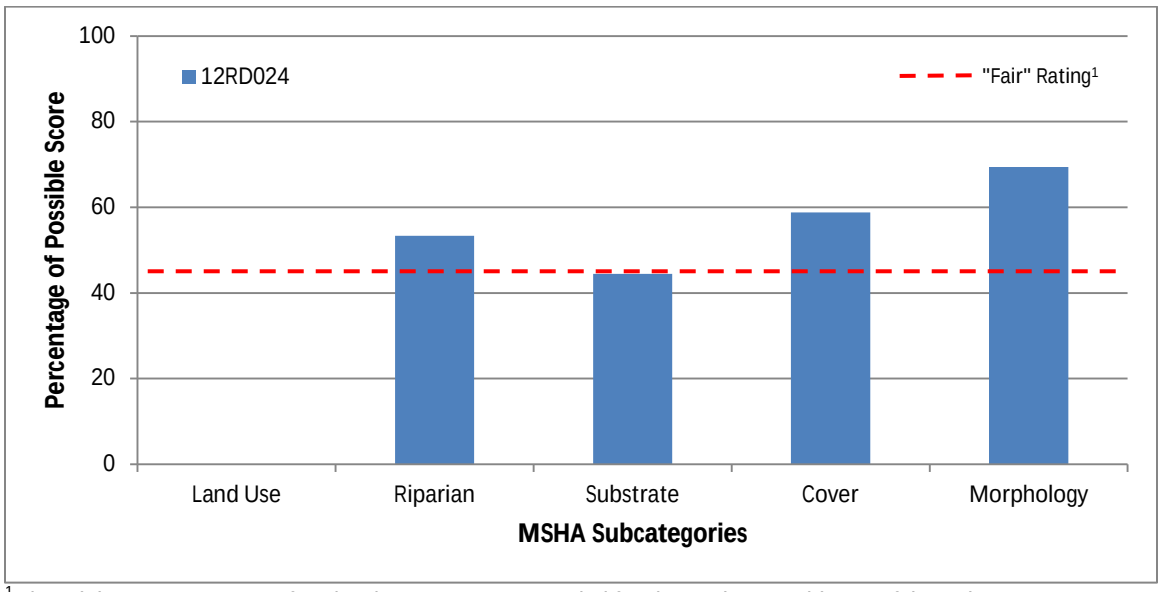
Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are early maturing, pioneering, serial spawners, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 29, four of the aforementioned individual metrics (i.e., NumPerMeter-Tol, PioneerTxPct, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD024. The station had a "low" score for a majority of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Lack of instream habitat

Available data

The instream habitat of AUID 528 was evaluated at Station 12RD024 using the MSHA. The station, which is located along a natural segment of the reach (MPCA, 2013), yielded a total MSHA score of 55 ("fair"). According to Figure 32, the MSHA score for the station was limited by the land use and substrate subcategories. The land use adjacent to the station was dominated by row crop agriculture (e.g., corn

and soybeans). Additionally, the station had abundant riffle habitat and offered coarse substrate; however, the substrate had a "moderate" level of embeddedness.



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

Figure 32. MSHA subcategory results for Station 12RD024 along AUID 528.

Biotic response – fish

Evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 528 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD024:

- Low relative abundance of taxa that are benthic insectivores, excluding tolerant species (BGeninsect-TolItxPct)
- Low taxa richness of darter and sculpin species (DarterSculp)
- High relative abundance of taxa that are detritivorous (DetNWQTxPct)
- Low relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct)
- Low relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct)
- Low taxa richness of simple lithophilic spawning species (SLithop)

Benthic 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). According to Figure 29, four of the aforementioned individual metrics (i.e., DarterSculp, InsectCypPct, Insect-TolTxPct, and SLithop) were used in the calculation of the F-IBI score for Station 12RD024. The station had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at Station 12RD024 along AUID 528 at the time of fish sampling. The sample was analyzed for several parameters, including TSS. The

sample had a TSS concentration of 7 mg/L. The RLRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L standard approximately 3% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to occasional 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 528. None of the individual F-IBI metrics for Station 12RD024 exhibited a correlation to this candidate cause. However, the deposition of suspended sediment has caused the aforementioned embeddedness of coarse substrate and the related biotic response associated with Station 12RD024.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 12RD024 along AUID 528 at the time of fish sampling. The measurement was above the 5.0 mg/L standard. In 2014, the RLWD collected 11 discrete DO measurements at Site S008-111. The DO concentrations ranged from 4.1 to 7.6 mg/L, with seven measurements below the standard. The MPCA conducted continuous DO monitoring at Site S008-111 (CR 102 crossing) from July 3, 2014, to July 17, 2014; the relative location of the site is shown in Figure 28. Table 16 provides a summary of the monitoring results. All of the daily minimum DO values for the site were below the standard. However, the site had a nominal level of mean daily DO flux (2.7 mg/L). Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard nearly 27% 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. According to C. Hanson (personal communication, 2015), the low DO conditions along the reach are a result of the influence of Goose Lake, which is located upstream of the reach.

Table 16. Continuous DO data for Site S008-111 along AUID 528.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S008-111 (MPCA)	July 3, 2014 - July 17, 2014	1369	2.0	7.1	100.0	75.5	2.7

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 528 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD024:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 29, three of the aforementioned individual metrics (i.e., NumPerMeter-Tol, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD024. The station

had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of Station 12RD024 meeting the DO standard based upon its sampled fish assemblage (Appendix C). The station had a low probability (10%) of meeting the standard.

Strength-of-evidence analysis

Table 17 presents a summary of the SOE scores for the various candidate causes associated with AUID 528. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: loss of physical connectivity, lack of base flow, lack of instream habitat, and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 17. SOE scores for candidate causes associated with AUID 528.

Types of Evidence	SOE Scores for Candidate Causes[1]				
	Loss of Physical Connectivity	Lack of Base Flow	Lack of Instream Habitat	High Suspended Sediment	Low Dissolved Oxygen
	Biological Impairment(s)				
	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.

3.3.5 County Ditch 96 (AUID 545)

Physical setting

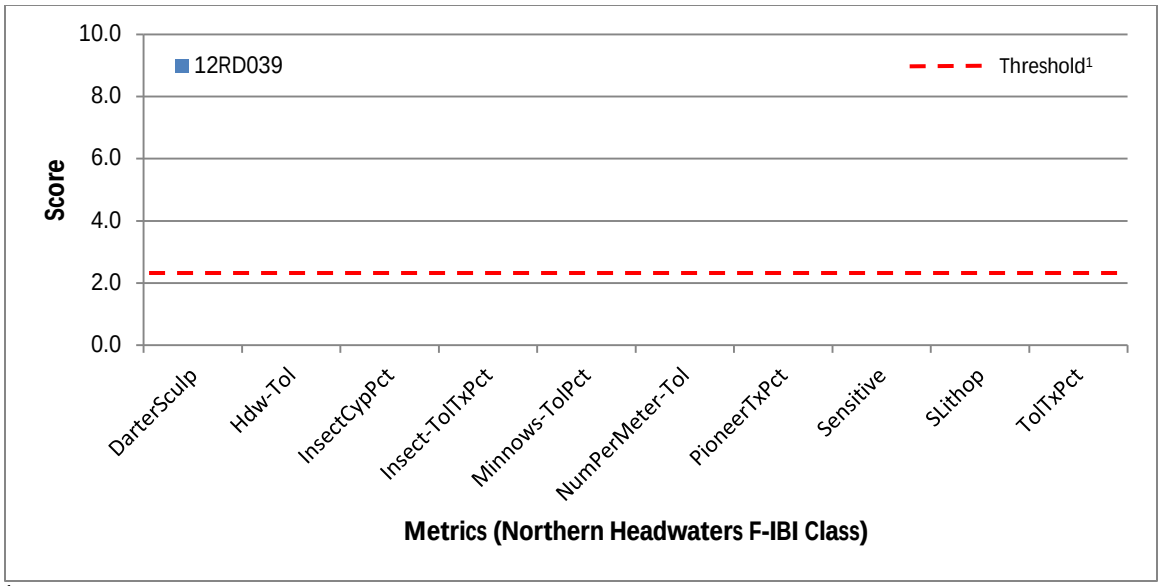
This reach represents the segment of County Ditch 96 from Branch 5 to Branch 3 (Figure 33); a total length of one mile. The reach has a subwatershed area of 24 square miles (15,460 acres). The reach and its subwatershed are situated in the beach ridges region of the RLRW. The subwatershed contains three miles of intermittent stream and 27 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 95% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 545. The NLCD 2011 (USGS, 2011) lists cultivated crops (68%) as the predominant land cover in the subwatershed. Notable minor land cover groups in the subwatershed included wetlands (9%), forest (9%), hay/pasture (9%), and developed areas (5%).

Figure 33.Map of AUID 545 and associated biological monitoring station and water quality monitoring site (2010 NAIP aerial image).

Biological impairment

Fish (F-IBI)

The fish community of AUID 545 was monitored at Station 12RD039 (0.1 mi downstream of the CR 57 crossing) on June 18, 2012. The relative location of the station is shown in Figure 33. The station was designated as Modified Use within the Northern Headwaters F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 23. The station had an F-IBI score of zero. Correspondingly, all of the individual metrics associated with the station had a score of zero (Figure 34). A description of each metric is provided in Appendix A. The only taxa sampled at the station were brook stickleback and central mudminnow.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 34. Individual F-IBI metric scores for Station 12RD039 along AUID 545.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff documented what appeared to be a small check dam constructed out of rocks during the sampling of Station 12RD039 along AUID 545. The rocks could potentially limit connectivity, but only during low flow conditions. According to the MDNR (2014b), there are no man-made dams on the reach or the downstream segment of CD 96, from the outlet of the reach to its confluence with the Red Lake River. On October 8, 2014, MPCA SI 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 were identified (e.g., perched culverts and beaver dams). In addition to the assessment, MPCA SI staff performed a detailed review of a September 8, 2011, aerial photo of the reach and the downstream segment of CD 96. Staff identified a perched culvert at the State Hwy. 32 crossing that was limiting connectivity at the time of the photo; the photo was acquired during low flow conditions.

Biotic response – fish

There is inconclusive evidence of a causal relationship between a loss of physical connectivity and the F-IBI impairment associated with AUID 545. None of the potential connectivity barriers identified by MPCA staff were known to be limiting fish passage at the time of sampling, which occurred in late spring.

However, as previously mentioned, the potential connectivity barriers could limit fish passage during low flow periods. Also, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Lack of base flow

Available data

The MPCA biological monitoring staff did not encounter any flow-related issues during fish and macroinvertebrate sampling at Station 12RD039 along AUID 545. There is no flow monitoring data for the reach. However, the RLWD collected continuous stage data at a site (S005-683) on CD 96

downstream of the reach in 2012, 2013, and 2014. Based upon preliminary flow rating table values, the site had no flow 72% of the time in 2012, 59% of the time in 2013, and 73% of the time in 2014. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 35% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on four separate dates (i.e., July 3, 2014, July 23, 2014, August 7, 2014, and October 8, 2014) and documented flow conditions (Figure 35). Site S008-174 (CR 57 crossing) had minimal (estimated <1 cfs) to no flow on each of these dates, with the exception of the July 23, 2014 visit, which occurred after an estimated four inch rain event. Overall, the available data suggest that the reach is prone to frequent periods of minimal to no flow.

Figure 35. Photos of flow conditions at Site S008-174 along AUID 545 on July 3, 2014 (upper left); July 23, 2014 (upper right); August 7, 2014 (lower left); and October 8, 2014 (lower right).

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 545 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD039:

- High combined relative abundance of the two most abundant taxa (DomTwopct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPermeter-Tol)

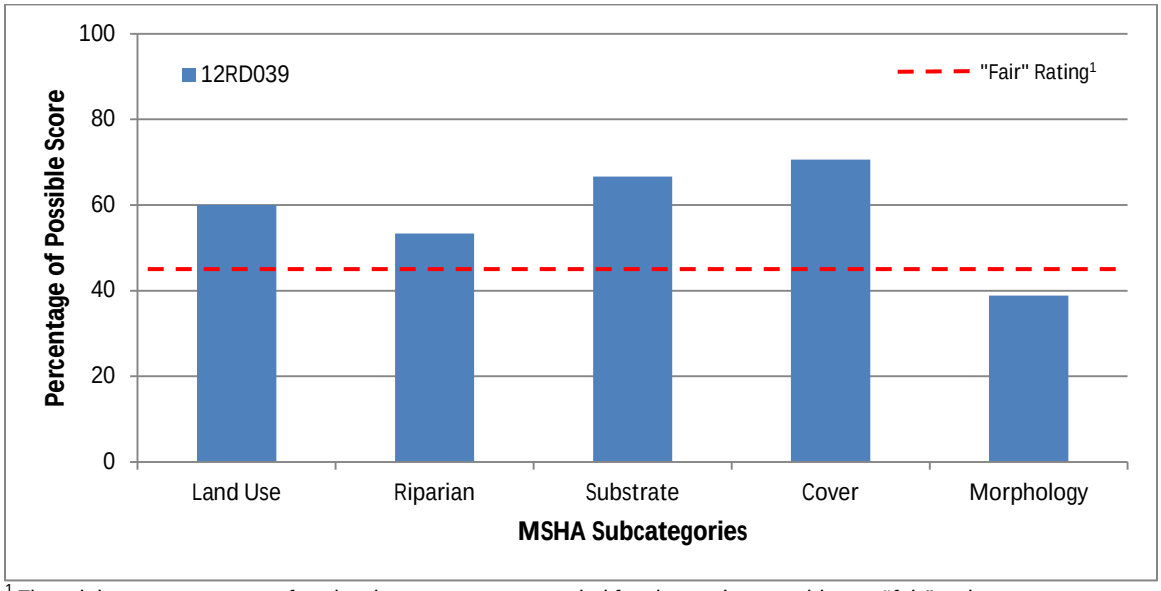
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are early maturing and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 34, three of the aforementioned individual metrics (i.e., NumPerMeter-Tol, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD039. The station had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Lack of instream habitat

Available data

The instream habitat of AUID 545 was evaluated at Station 12RD039 using the MSHA; the entire length of the reach has been altered (MPCA, 2013). The station yielded a total MSHA score of 55 ("fair"). According to Figure 36, the MSHA score for the station was limited by the channel morphology subcategory; the station lacked sinuosity. Additionally, the station had riffle habitat, offered coarse substrate, with only "light" embeddedness, and had an "extensive" amount of cover.



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

Figure 36. MSHA subcategory results for Station 12RD039 along AUID 545.

Biotic response – fish

There is no evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 545. Specifically, there is no indication that the instream habitat of the reach is limited.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at Station 12RD039 along AUID 545 at the time of fish sampling. The sample was analyzed for several parameters, including TSS. The station had a high TSS concentration (48 mg/L). The RLRW HSPF model estimates that the reach had a TSS concentration in excess of the 30 mg/L standard approximately 7% of the time during the period of

1996 to 2009. Overall, the available data suggest that the reach is prone to occasional 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 545. None of the individual F-IBI metrics for Station 12RD039 exhibited a correlation to this candidate cause.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 12RD039 along AUID 545 at the time of fish and macroinvertebrate sampling. Neither of the measurements was below the 5.0 mg/L standard. The MPCA conducted continuous DO monitoring at Site S008-174 (Figure 33) from July 23, 2014, to August 7, 2014. Table 18 provides a summary of the monitoring results. All of the daily minimum DO values for the site were below the standard. However, the site had a nominal level of mean daily DO flux (3.0 mg/L). Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard approximately 26% 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.

Table 18. Continuous DO data for Site S008-174 along AUID 545.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S008-174 (MPCA)	July 23, 2014 - Aug. 7, 2014	1419	0.0	6.2	100.0	89.4	3.0

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 545 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD039:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 34, three of the aforementioned individual metrics (i.e., NumPerMeter-Tol, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD039. The station had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of Station 12RD039 meeting the DO standard based upon its sampled fish assemblage (Appendix C). The station had a low probability (5%) of meeting the standard.

Strength-of-evidence analysis

Table 19 presents a summary of the SOE scores for the various candidate causes associated with AUID 545. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: lack

of base flow and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 19. SOE scores for candidate causes associated with AUID 545.

Types of Evidence	SOE Scores for Candidate Causes[1]				
	Loss of Physical Connectivity	Lack of Base Flow	Lack of Instream Habitat	High Suspended Sediment	Low Dissolved Oxygen
	Biological Impairment(s)				
	F-IBI	F-IBI	F-IBI	F-IBI	F-IBI
Types of Evidence that Use Data from the Case					
Spatial/Temporal Co-Occurrence	0	+++	0	0	+++
Temporal Sequence	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
Laboratory Tests of Site Media	NE	NE	NE	NE	NE
Verified Predictions	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
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**	**+++**	**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 County Ditch 43 (AUID 547)

Physical setting

This reach represents County Ditch 43, which extends from its confluence with an unnamed ditch to its outlet to the Red Lake River (Figure 37); a total length of seven miles. The reach has a subwatershed area of 24 square miles (15,591 acres). The reach and its subwatershed are situated at the interface of the peatlands and lake plain regions. The subwatershed contains three miles of intermittent stream, one mile of perennial drainage ditch, and 18 miles of intermittent drainage ditch (MDNR, 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 547. The NLCD 2011 (USGS, 2011) lists wetlands (44%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included cultivated crops (28%), hay/pasture (18%), forest (5%), and developed areas (3%).

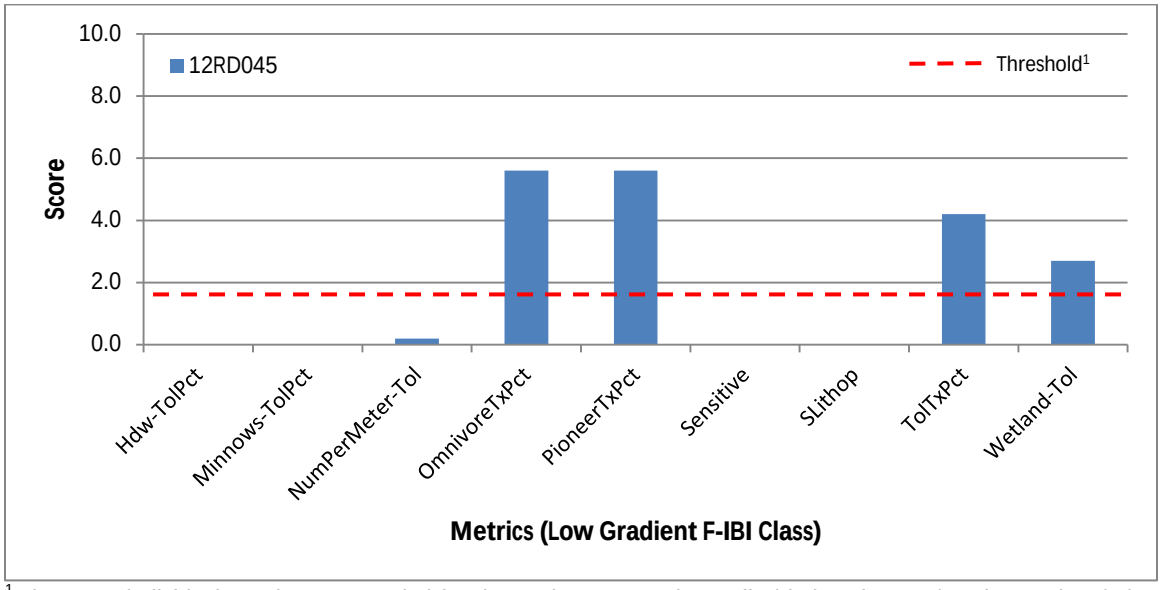
Figure 37.Map of AUID 547 and associated biological monitoring station and water quality monitoring site (2010 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 547 was monitored at Station 12RD045 (0.1 mi upstream of the CSAH 3 crossing) on June 18, 2012. The relative location of the station is shown in Figure 37. The station was designated as Modified Use within the Low Gradient F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 15. The station had an F-IBI score of 18. According to Figure 38, the station had five individual metrics that scored below the threshold score (i.e., Hdw-TolPct, Minnows-TolPct, NumPerMeter-Tol, Sensitive, and SLithop). A description of each metric is provided in Appendix

A. While the F-IBI score slightly exceeded the impairment threshold, the reach was determined to be impaired based upon the station's limited sample population (<25 individuals) that was dominated by tolerant species (i.e., brook stickleback, central mudminnow, and fathead minnow).

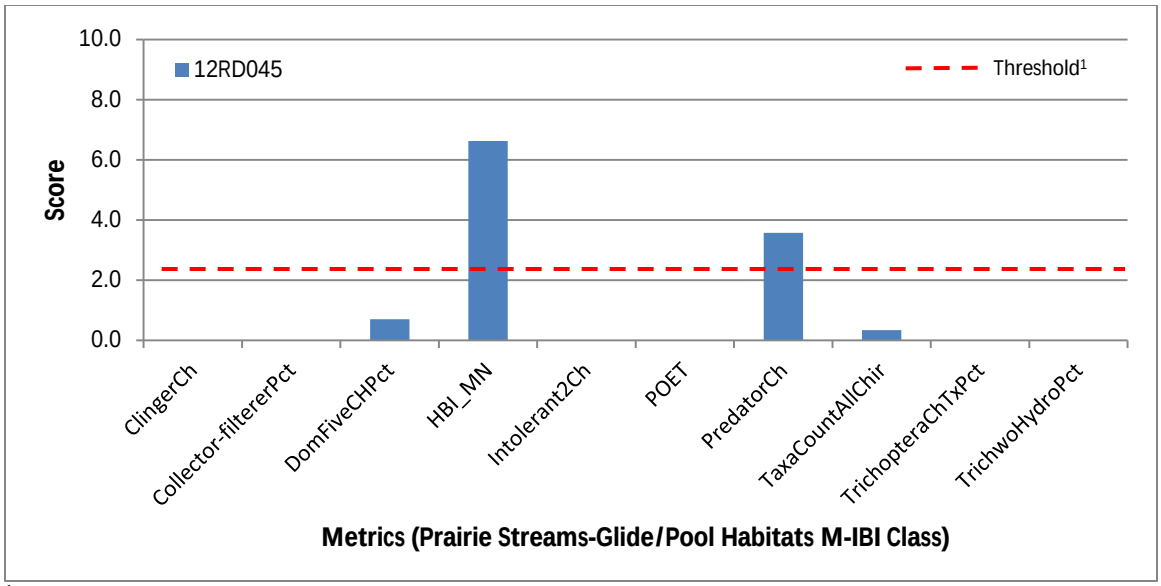


[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 38. Individual F-IBI metric scores for Station 12RD045 along AUID 547.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 547 was monitored at Station 12RD045 on August 7, 2012. The station was designated as Modified Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the applicable impairment threshold for the station is an M-IBI score of 22. The monitoring results for the station yielded an M-IBI score (11) below this threshold. According to Figure 39, the station had eight individual metrics that scored below the threshold score (i.e., ClingerCh, Collector-filtererPct, DomFiveCHPct, Intolerant2Ch, POET, TaxaCountAllChir, TrichopteraChTxPct, TrichwoHydroPct). A description of each metric is provided in Appendix B. Overall, the macroinvertebrate assemblage of the station was dominated by tolerant taxa, specifically *Valvata* (snails).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 39.Individual M-IBI metric scores for Station 12RD045 along AUID 547.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 12RD045 along AUID 547. According to the MDNR (2014b), there are no man-made dams on the reach. On October 8, 2014, MPCA SI 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 were identified (e.g., perched culverts and beaver dams). In addition to the assessment, MPCA SI staff performed a detailed review of a September 8, 2011, aerial photo of the reach. No connectivity-related issues were identified in the photo.

Biotic response – fish and macroinvertebrate

There is no evidence of a causal relationship between a loss of physical connectivity and the F-IBI and M-IBI impairments associated with AUID 547. There are no known obstructions to connectivity along the reach. However, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Lack of base flow

Available data

The MPCA biological monitoring staff did not encounter any flow-related issues during fish and macroinvertebrate sampling at Station 12RD045 along AUID 547. There is no flow monitoring data for the reach. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow approximately 26% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on three separate dates (i.e., August 14, 2014, August 27, 2014, and October 8, 2014) and documented flow conditions. The reach had minimal (estimated <1 cfs) to no flow on each of these dates. The reach was dominated by interspersed pools of stagnant water at the time of the last visit (Figure 40). Overall, the available data suggest that the reach is prone to frequent periods of minimal to no flow.

Figure 40. Photos of intermittent flow conditions along AUID 547, including Site S008-177 on August 14, 2014 (upper left); Site S008-177 on October 8, 2014 (upper right); the 120th Street NE crossing on October 8, 2014 (lower left); and the 150th Street NE crossing on October 8, 2014 (lower right).

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 547 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD045:

- High combined relative abundance of the two most abundant taxa (DomTwoPct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- High relative abundance of taxa that are pioneers (pioneerTxPct)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of taxa that are serial spawners (SSpnTxpct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are early maturing, pioneering, serial spawners, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 38, four of the aforementioned individual metrics (i.e., NumPerMeter-Tol, PioneerTxPct, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD045. The station had a "low" score for the NumPerMeter-Tol and Sensitive metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of base flow and the M-IBI impairment associated with AUID 547 is provided by the following individual M-IBI metric responses (Appendix D) for Station 12RD045:

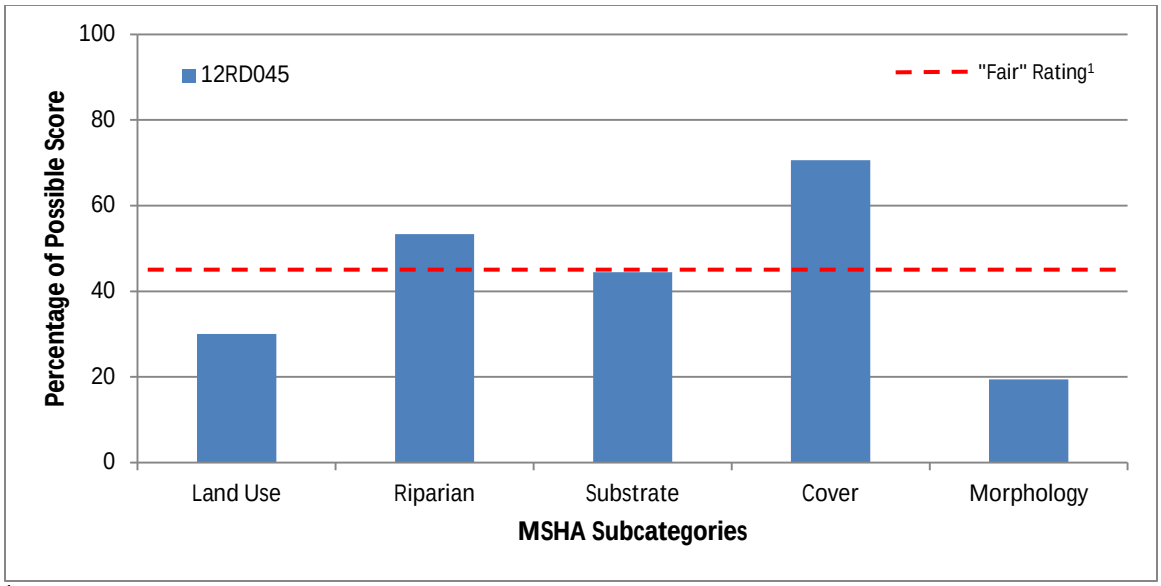
- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- High relative abundance of the dominant five taxa in a subsample (DomFiveChPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity, specifically taxa belonging to the orders of Plecoptera, Ephemeroptera, and Trichoptera (many of which are collector-filterers), and favor taxa that are tolerant of environmental disturbances (EPA, 2012; Klemm et al., 2002, Poff and Zimmerman, 2010). According to Figure 39, seven of the aforementioned individual metrics (i.e., Collector-filtererPct, DomFiveCHPct, Intolerant2Ch, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 12RD045. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach. Overall, the macroinvertebrate assemblage of the stations was dominated by taxa that are adapted to lentic conditions (i.e., *Gyraulus* and *Valvata*).

Lack of instream habitat

Available data

The instream habitat of AUID 547 was evaluated at Station 12RD045 using the MSHA; the entire length of the reach has been altered (MPCA, 2013). The station yielded a total MSHA score of 40 ("poor"). According to Figure 41, the MSHA score for the station was limited by the land use, substrate, and channel morphology subcategories. The land use adjacent to the station was dominated by agriculture (i.e., hay fields and row crops). In addition, the station lacked riffle habitat, had limited coarse substrate, lacked sinuosity, and had "poor" channel development.



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

Figure 41. MSHA subcategory results for Station 12RD045 along AUID 547.

Biotic response – fish

Evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 547 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD045:

- Low relative abundance of taxa that are benthic insectivores, excluding tolerant species (Beninsect-TolTxPct)
- Low taxa richness of darter and sculpin species (DarterSculp)
- High relative abundance of taxa that are detritivorous (DetNWQTxPct)
- Low relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct)
- Low relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct)
- Low taxa richness of simple lithophilic spawning species (SLithop)

Benthic 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). According to Figure 38, the SLithop metric was used in the calculation of the F-IBI score for Station 12RD045. The station had a "low" score for the metric, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of instream habitat and the M-IBI impairment associated with AUID 547 is provided by the following individual M-IBI metric responses (Appendix D) for Station 12RD045:

- Low taxa richness of clinger taxa (ClingerCh)
- Low relative abundance of collector-filterer individuals in a subsample (Collector-filtererPct)
- High relative abundance of legless individuals (LeglessPct)

Clinger taxa, including many collector-filterers, require clean, coarse substrate or other objects to attach themselves to, while legless macroinvertebrates are tolerant of degraded benthic habitat. According to Figure 39, two of the aforementioned individual metrics (i.e., ClingerCh and Collector-filtererPct) were used in the calculation of the M-IBI score for Station 12RD045. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at Station 12RD045 along AUID 547 at the time of fish sampling. The sample was analyzed for several parameters, including TSS. The sample had a TSS concentration of 6 mg/L. The RLRW HSPF model estimates that the reach had a TSS concentration in excess of the 30 mg/L standard approximately 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is not prone to high suspended sediment.

Biotic response – fish and macroinvertebrate

There is no evidence of a causal relationship between high suspended sediment and the F-IBI and M-IBI impairments associated with AUID 547. Specifically, the available data suggest that the reach is not prone to high suspended sediment.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 12RD045 along AUID 547 at the time of fish and macroinvertebrate sampling. Neither of the measurements was below the 5.0 mg/L standard. The MPCA conducted continuous DO monitoring at Site S008-177 (CSAH 3 crossing) from August 14, 2014, to August 27, 2014; the relative location of the site is shown in Figure 37. Table 20 provides a summary of the monitoring results. All of the daily minimum DO values for the site were below the standard. Also, the site had a high level of mean daily DO flux (5.8 mg/L). Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard approximately 8% 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.

Table 20. Continuous DO data for Site S008-177 along AUID 547.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S008-177 (MPCA)	Aug. 14, 2014 - Aug. 27, 2014	1247	0.0	16.3	100.0	73.6	5.8

Biotic response – fish

Evidence of a causal relationship between a low DO and the F-IBI impairment associated with AUID 547 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD045:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)

- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 38, three of the aforementioned individual metrics (i.e., NumPerMeter-Tol, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD045. The station had a "low" score for the NumPerMeter-Tol and Sensitive metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of Station 12RD045 meeting the DO standard based upon its sampled fish assemblage (Appendix C). The station had a low probability (12%) of meeting the standard.

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 547 is provided by the following individual M-IBI metric responses (Appendix D) for Station 12RD045:

- Low taxa richness of macroinvertebrates with tolerance values less than or equal to two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative abundance of non-hydropsychid Trichoptera individuals in a subsample (TrichwoHydroPct)

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 (EPA, 2012; Weber, 1973). According to Figure 39, five of these individual metrics (Intolerant2Ch, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 12RD045. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach. Additionally, the MPCA calculated DO TIVs for Station 12RD045 (Appendix D). The station had a high percentage of low DO tolerant taxa and a low number of low DO intolerant taxa.

Strength-of-evidence analysis

Table 21 presents a summary of the SOE scores for the various candidate causes associated with AUID 547. The evidence suggests that the F-IBI and M-IBI impairments are likely attributed to the following stressors: lack of base flow, lack of instream habitat, and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 21. SOE scores for candidate causes associated with AUID 547.

Types of Evidence	SOE Scores for Candidate Causes[1]									
	Loss of Physical Connectivity		Lack of Base Flow		Lack of Instream Habitat		High Suspended Sediment		Low Dissolved Oxygen	
	Biological Impairment(s)									
	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.

3.3.7 Burnham Creek (AUID 551)

Physical setting

This reach represents the segment of Burnham Creek from its confluence with County Ditch 106 to its confluence with County Ditch 15 (Figure 42); a total length of seven miles. The reach has a subwatershed area of 73 square miles (46,769 acres). Although the reach is entirely located in the lake plain region of the RLRW, the eastern one-half of its subwatershed lies within the beach ridges region. The subwatershed contains 26 miles of intermittent stream, four miles of perennial drainage ditch, and 43 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 79% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including the entire length of AUID 551. The NLCD 2011 (USGS, 2011) lists cultivated crops (77%) as the predominant land cover in the subwatershed; this percentage was substantially higher in the lake plain region. Notable minor land cover groups in the subwatershed included wetlands (9%), developed areas (4%), forest (4%), and hay/pasture (3%).

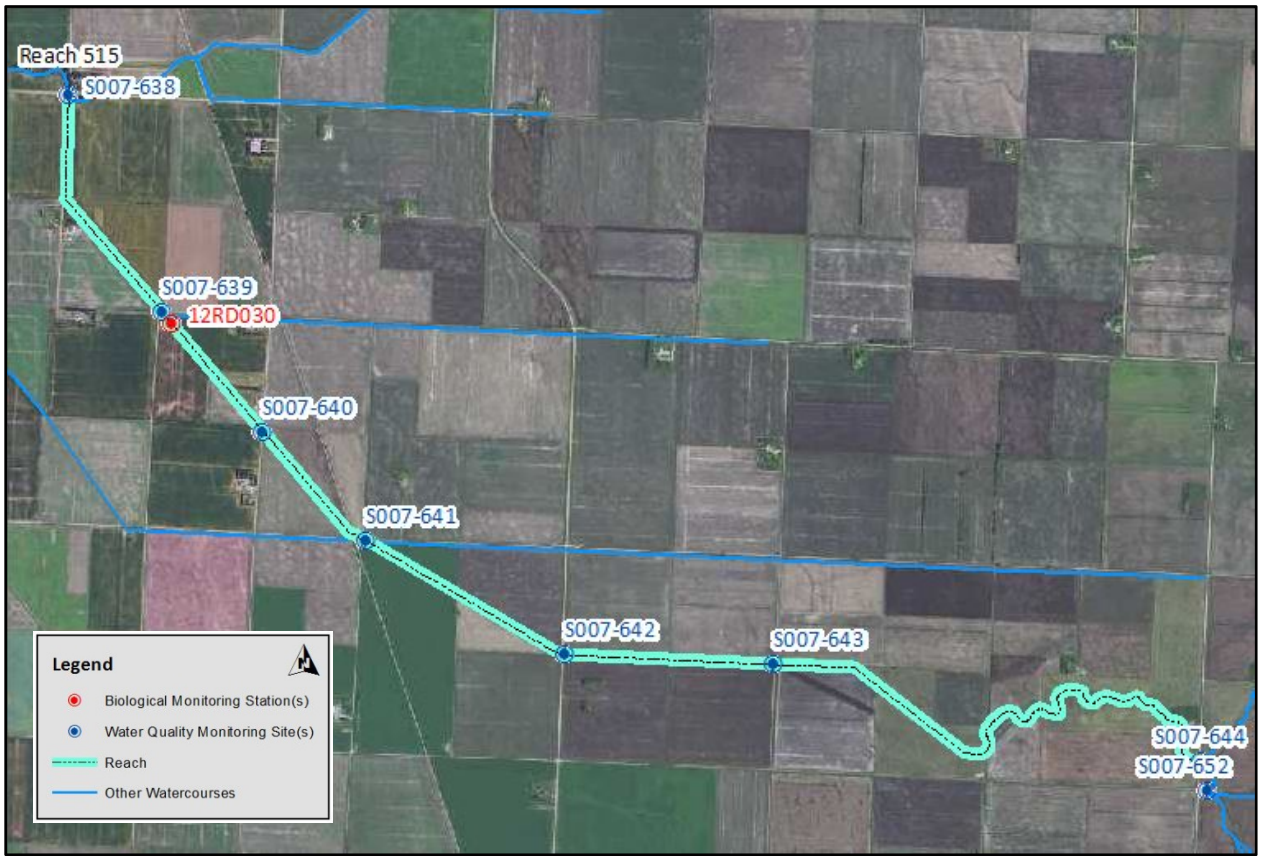


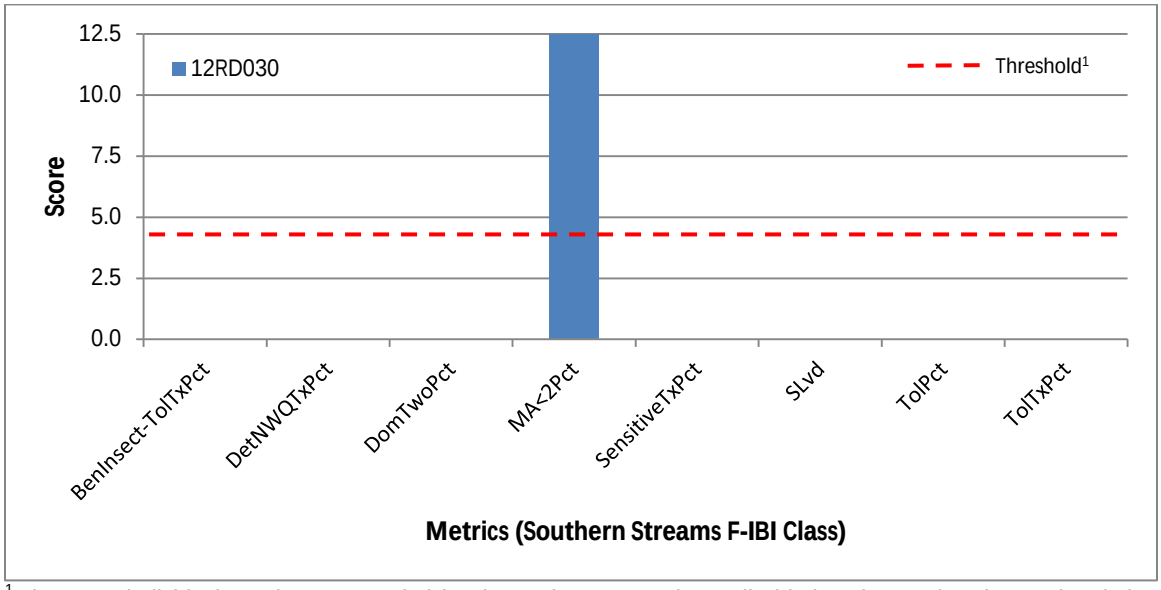
Figure 42. Map of AUID 551 and associated biological monitoring station and water quality monitoring sites (2010 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 551 was monitored at Station 12RD030 (0.1 mi upstream of the 340th Street SW crossing) on June 11, 2012. The relative location of the station is shown in Figure 42. The station was designated as Modified Use within the Southern Streams F-IBI Class. Accordingly, the impairment threshold for the station is an F-IBI score of 35. The station had an F-IBI score (13) well beneath this threshold. According to Figure 43, the station had seven individual metrics that scored below the

threshold score (i.e., BenInsect-TolTxPct, DetNWQTxPct, DomTwoPct, SensitiveTxPct, SLvd, TolPct, and TolTxPct). A description of each metric is provided in Appendix A. Overall, the fish assemblage of the station was dominated by young of the year white sucker.

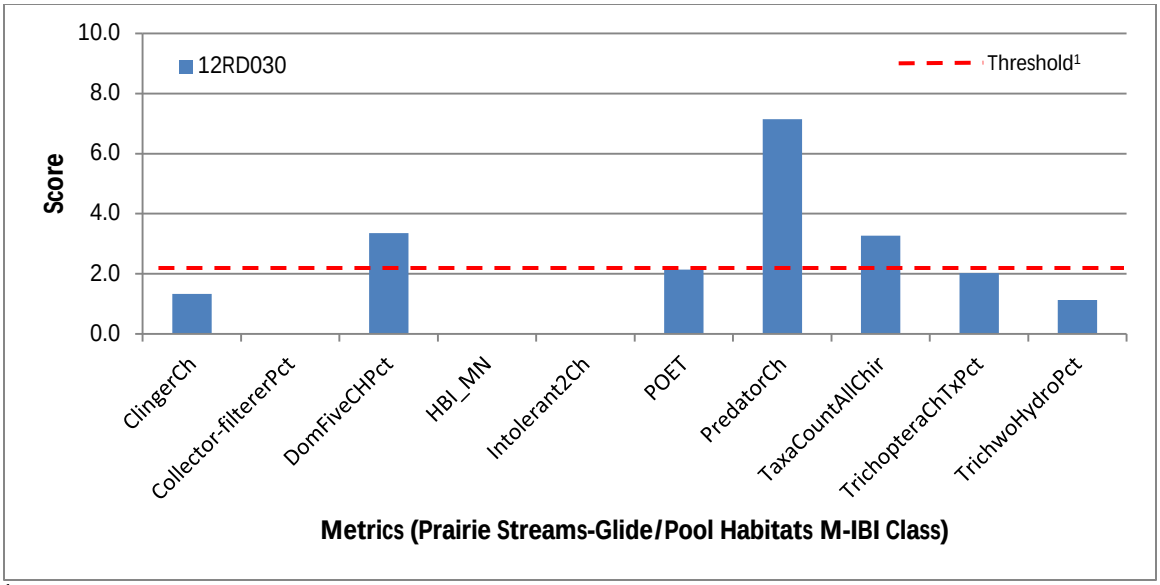


[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 43. Individual F-IBI metric scores for Station 12RD030 along AUID 551.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 551 was monitored at Station 12RD030 on August 8, 2012. The station was designated as Modified Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the applicable impairment threshold for the station is an M-IBI score of 22. The monitoring results for the station yielded an M-IBI score (20) slightly below this threshold. According to Figure 44, the station had seven individual metrics that scored below the threshold score (i.e., ClingerCh, Collector-filtererPct, HBI_MN, Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct). A description of each metric is provided in Appendix B. Overall, the macroinvertebrate assemblage of the station was dominated by tolerant taxa, specifically Coenagrionidae (damselflies).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 44. Individual M-IBI metric scores for Station 12RD030 along AUID 551.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 12RD030 along AUID 551. According to the MDNR (2014b), there are no man-made dams on the reach or the downstream segment of Burnham Creek, from the reach to its confluence with the Red Lake River (i.e., AUID 515). On September 17, 2014, MPCA SI staff conducted a connectivity assessment of the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No obstructions to connectivity were identified (e.g., perched culverts and beaver dams). In addition to the assessment, MPCA SI staff performed a detailed review of an April 2, 2012, aerial photo of AUID 515 and 551. Staff identified a "Texas" crossing and the remnants of two other similar structures along AUID 515 that could potentially limit connectivity during low flow conditions.

Biotic response – fish

There is inconclusive evidence of a causal relationship between a loss of physical connectivity and the F-IBI impairment associated with AUID 551. None of the potential connectivity barriers identified by MPCA staff along AUID 515 were known to be limiting fish passage at the time of sampling, which occurred in late spring. Additionally, the fish assemblage of Station 12RD030 was dominated by young of the year white sucker, which suggests that adult fish of this specie were able to migrate upstream of AUID 515 to spawn. White sucker commonly migrate up into the headwater region of streams to reproduce (Paulson and Hatch, 2004). However, as previously mentioned, the potential connectivity barriers identified by MPCA staff along AUID 515 could limit fish passage during low flow periods. Also, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of physical connectivity and the M-IBI impairment associated with AUID 551. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not directly affected by physical connectivity barriers.

Lack of base flow

Available data

The MPCA biological monitoring staff did not encounter any flow-related issues during fish and macroinvertebrate sampling at Station 12RD030 along AUID 551. There is no flow monitoring data for the reach. However, as previously mentioned, continuous stage data was collected at a site (S007-058) along AUID 515 from March 19, 2012, to November 15, 2012 (RLWD) and from April 22, 2013, to November 12, 2013 (MPCA). Based upon preliminary flow rating table values, the site had no flow 43% of the time in 2012 and 72% of the time in 2013. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow only 3% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on three separate dates (i.e., July 23, 2014, August 7, 2014, and September 17, 2014) and documented flow conditions. The reach had minimal (estimated <1 cfs) to no flow at the time of the last visit (Figure 45). Overall, the available data suggest that the reach is prone to occasional periods of minimal to no flow.

Figure 45. Photos of low flow conditions along AUID 551 on September 17, 2014, including Site S007-639 (left) and Site S007-642 (right).

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 551 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD030:

- High combined relative abundance of the two most abundant taxa (DomTwoPct)
- High relative abundance of taxa that are generalists (GeneralTxPct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- High relative abundance of taxa that are pioneers (PioneerTxPct)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High taxa richness of short-lived species (SLvd)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are trophic generalists, pioneering, short-lived, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 43, five of the aforementioned

individual metrics (i.e., DomTwoPct, SensitiveTxPct, SLvd, TolPct, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD030. The station had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of base flow and the M-IBI impairment associated with AUID 551 is provided by the following individual M-IBI metric responses (Appendix D) for Station 12RD030:

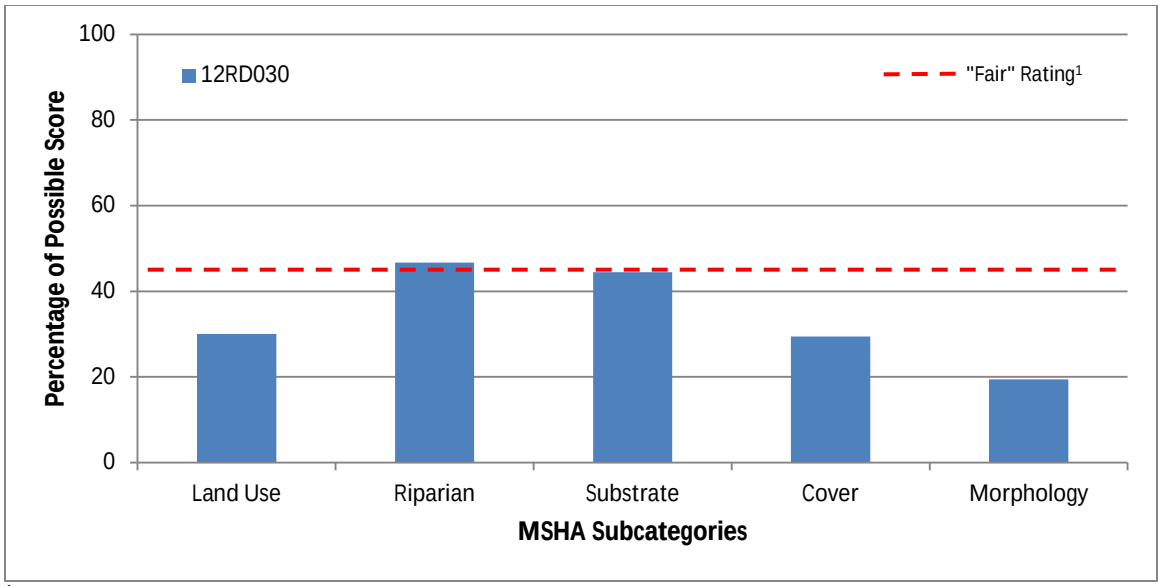
- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- High relative abundance of the dominant five taxa in a subsample (DomFiveChPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- High relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity, specifically taxa belonging to the orders of Plecoptera, Ephemeroptera, and Trichoptera (many of which are collector-filterers), and favor taxa that are tolerant of environmental disturbances (EPA, 2012; Klemm et al., 2002, Poff and Zimmerman, 2010). According to Figure 44, seven of the aforementioned individual metrics (i.e., Collector-filtererPct, DomFiveCHPct, Intolerant2Ch, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 12RD030. The station had a "low" score for five of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach. Overall, the macroinvertebrate assemblage of the station was dominated by taxa that are adapted to lentic conditions (i.e., Coenagrionidae).

Lack of instream habitat

Available data

The instream habitat of AUID 551 was evaluated at Station 12RD030 using the MSHA; the entire length of the reach has been altered (MPCA, 2013). The station yielded a total MSHA score of 34 ("poor"). According to Figure 46, the MSHA score for the station was limited by the land use, substrate, cover, and channel morphology subcategories. The land use adjacent to the station was dominated by row crop agriculture (i.e., corn and sugar beets). In addition, the station lacked riffle habitat, had no coarse substrate, lacked sinuosity, and had "poor" channel development.



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

Figure 46.MSHA subcategory results for Station 12RD030 along AUID 551.

Biotic response – fish

Evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 551 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD030:

- High relative abundance of taxa that are detritivorous (DetNWQTxPct)
- Low relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct)
- Low relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct)

Insectivores 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). According to Figure 43, the DetNWQTXPct metric was used in the calculation of the F-IBI score for Station 12RD030. The station had a "low" score for the metric, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of instream habitat and the M-IBI impairment associated with AUID 551 is provided by the following individual M-IBI metric responses (Appendix D) for Station 12RD030:

- Low taxa richness of clinger taxa (ClingerCh)
- Low relative abundance of collector-filterer individuals in a subsample (Collector-FiltererPct)

Clinger taxa, including many collector-filterers, require clean, coarse substrate or other objects to attach themselves to. According to Figure 44, these metrics were used in the calculation of the M-IBI score for Station 12RD030. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at Station 12RD024 along AUID 551 at the time of fish sampling. The sample was analyzed for several parameters, including TSS. The station had a high TSS concentration (70 mg/L). On May 22, 2013, the RLWD conducted a longitudinal survey along the reach and collected four samples (Sites S007-639, S007-641, S007-642, and S007-644) that were analyzed for TSS. The TSS concentration of the samples ranged from 25 to 37 mg/L. In 2014, the RLWD collected six samples at Site S007-644 that were analyzed for TSS. The TSS concentration of the samples ranged from 3 to 37 mg/L. Additionally, the RLRW HSPF model estimates that the reach had a TSS concentration in excess of the 65 mg/L standard approximately 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to occasional 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 551. None of the individual F-IBI metrics for Station 12RD030 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 551 is provided by the following individual M-IBI metric responses (Appendix D) for Station 12RD030:

- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Collector-filterers, including several members of the order Trichoptera, 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). According to Figure 44, four of the aforementioned individual metrics (i.e., Collector-filtererPct, Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 12RD030. The station had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach. The MPCA also calculated TSS TIVs for Station 12RD030. The station had a high percentage of high TSS tolerant taxa and a low number of high TSS intolerant taxa.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 12RD030 along AUID 551 at the time of fish and macroinvertebrate sampling. One of the measurements was below the 5.0 mg/L standard; the station had a DO concentration of 1.5 mg/L at the time of macroinvertebrate sampling. On May 22, 2013, RLWD staff conducted a longitudinal DO survey along AUID 551; a discrete DO measurement was collected at six points distributed over the length of the reach. None of the DO measurements were below the standard. In 2014, the RLWD collected six discrete DO measurements at Site S007-644. One measurement (4.1 mg/L) was below the standard. The MPCA conducted continuous DO monitoring at Site S007-639 (340th Street SW crossing) from July 23, 2014, to August 7, 2014; the

relative location of the site is shown in Figure 42. Table 22 provides a summary of the monitoring results. The site had no DO values below the standard, as well as a nominal level of mean daily DO flux (2.4 mg/L). Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard only 2% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to occasional periods of low DO.

Table 22. Continuous DO data for Site S007-639 along AUID 551.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S007-639 (MPCA)	July 23, 2014 - Aug. 7, 2014	1459	6.0	9.4	0.0	0.0	2.4

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 551 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD030:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of individuals that are tolerant (TolPpct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 43, three of the aforementioned individual metrics (i.e., SensitiveTxPct, TolPct, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD030. The station had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of Station 12RD030 meeting the DO standard based upon its sampled fish assemblage (Appendix C). The station had a relatively high probability (57%) of meeting the standard.

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 551 is provided by the following individual M-IBI metric responses (Appendix D) for Station 12RD030:

- High Hilsenhoff's Biotic Index value (HBI_MN)
- Low taxa richness of macroinvertebrates with tolerance values less than or equal to two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- High relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxpct)
- Low relative abundance of non-hydropsychid Trichoptera individuals in a subsample (TrichwoHydroPct)

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 (EPA, 2012; Weber, 1973). According to Figure 44, six of these individual metrics (HBI_MN, Intolerant2Ch, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 12RD030. The station had a "low" score for five of these metrics, thereby negatively affecting the overall M-IBI score and directly contributing to the biological impairment of the reach. Additionally, the MPCA calculated DO TIVs for Station 12RD030 (Appendix D). The station had a high percentage of low DO tolerant taxa and a low number of low DO intolerant taxa.

Strength-of-evidence analysis

Table 23 presents a summary of the SOE scores for the various candidate causes associated with AUID 551. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: lack of base flow, lack of instream habitat, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of the following stressors: lack of base flow, lack of instream habitat, high suspended sediment, and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 23. SOE scores for candidate causes associated with AUID 551.

Types of Evidence	SOE Scores for Candidate Causes[1]									
	Loss of Physical Connectivity		Lack of Base Flow		Lack of Instream Habitat		High Suspended Sediment		Low Dissolved Oxygen	
	Biological Impairment(s)									
	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.

3.3.8 Gentilly River (AUID 554)

Physical setting

This reach represents the segment of the Gentilly River from its confluence with County Ditch 140 to its outlet to the Red Lake River (Figure 47); a total length of eight miles. The reach has a subwatershed area of 68 square miles (43,331 acres). The reach and its subwatershed are situated in the beach ridges region of the RLRW. The subwatershed contains 18 miles of perennial stream (e.g., AUID 554), 17 miles of intermittent stream, five miles of perennial drainage ditch, and 39 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 67% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 12% of AUID 554. The NLCD 2011 (USGS, 2011) lists cultivated crops (80%) as the predominant land cover in the subwatershed. Notable minor land cover groups in the subwatershed included wetlands (6%), hay/pasture (5%), and developed areas (4%). The unincorporated community of Gentilly is located within the subwatershed.

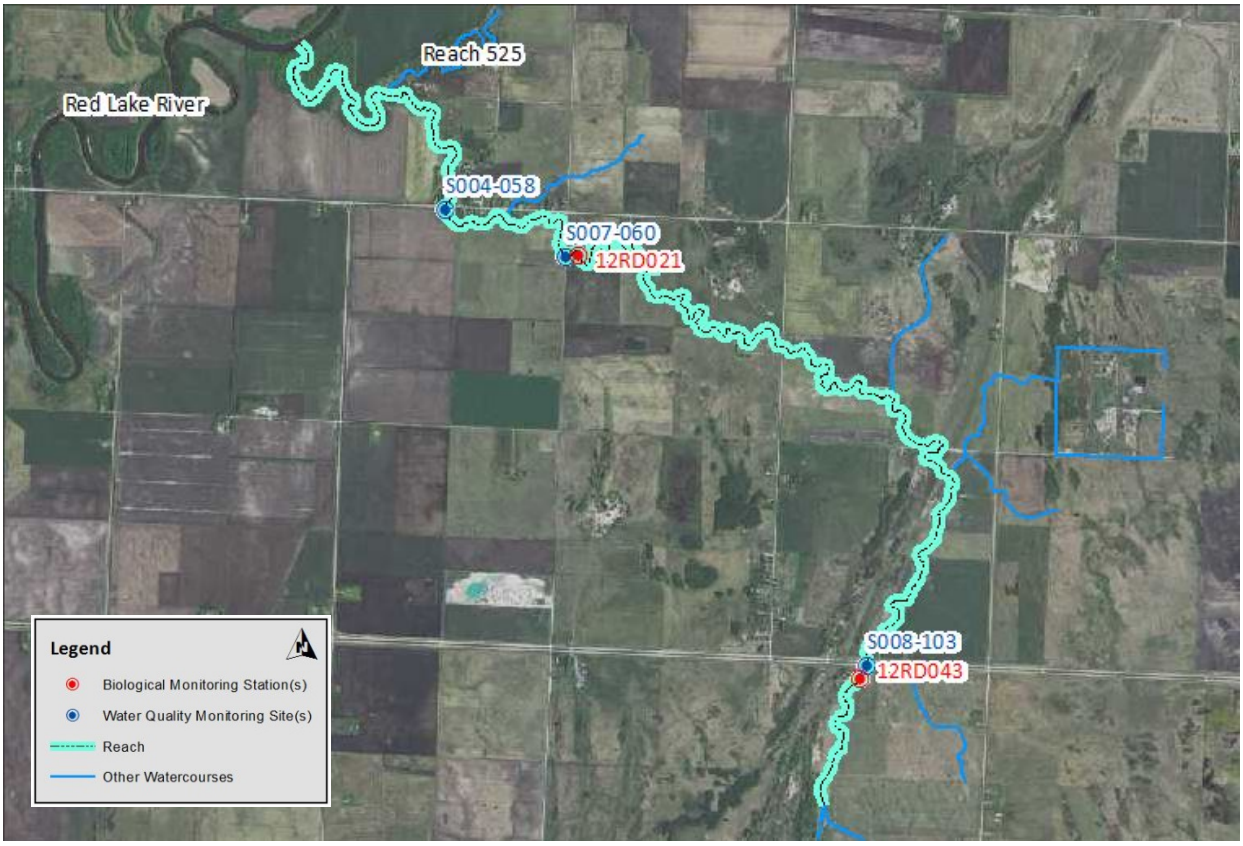


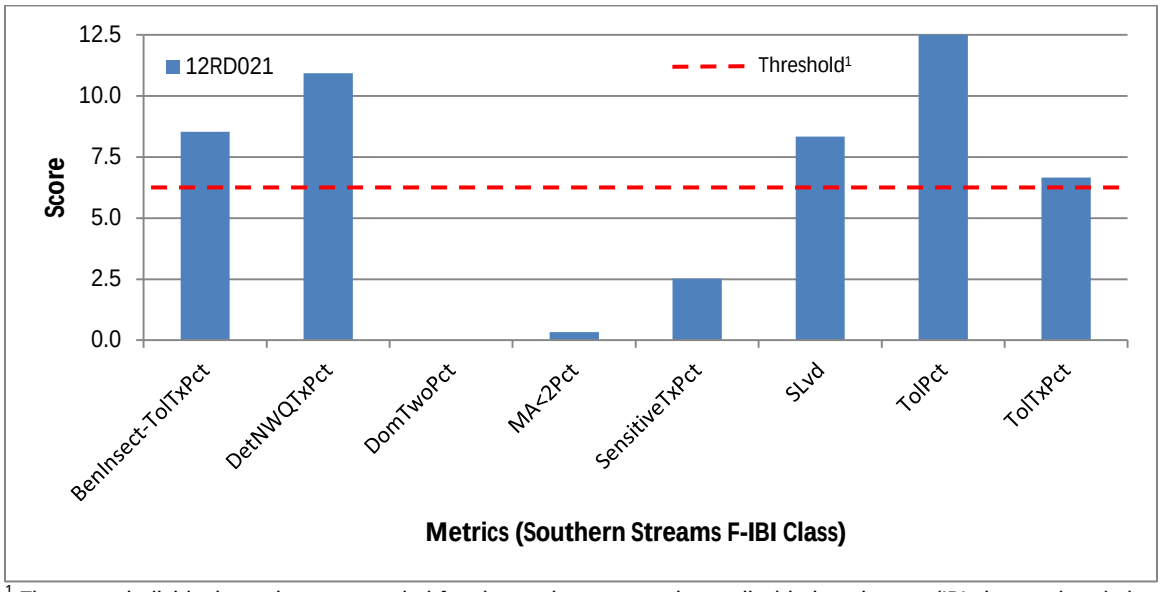
Figure 47. Map of AUID 554 and associated biological monitoring stations and water quality monitoring sites (2010 NAIP aerial image).

Biological impairments

Fish (F-IBI)

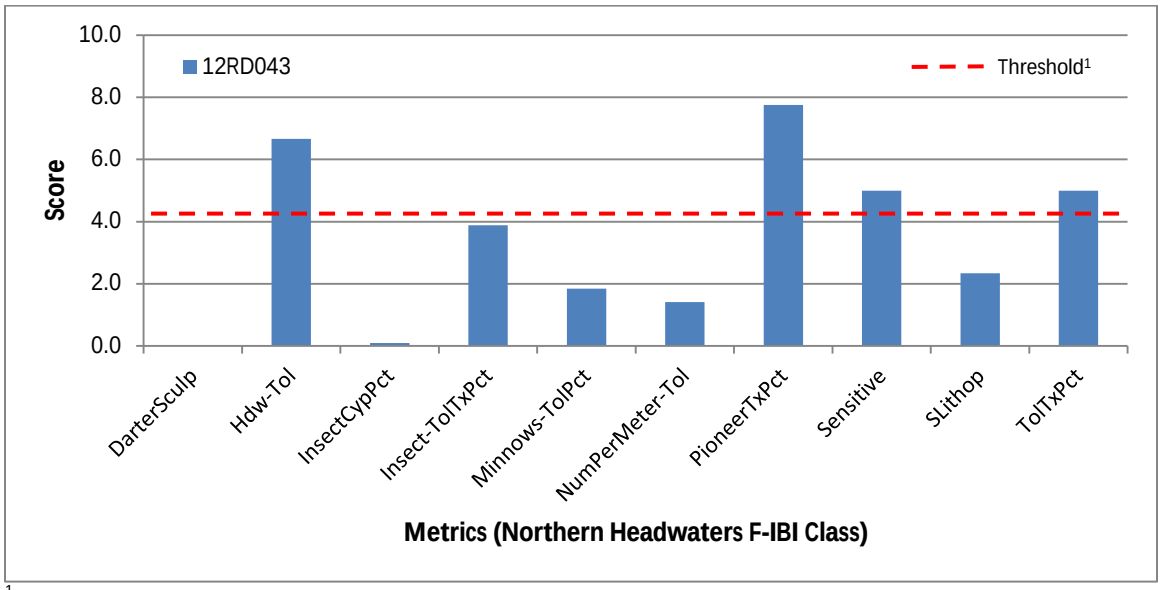
The fish community of AUID 554 was monitored at Station 12RD021 (0.1 mi upstream of the 180th Avenue SW crossing) on June 12, 2012 and Station 12RD043 (0.1 mi upstream of the US Hwy. 2 crossing) on June 12, 2012. The relative location of the stations is shown in Figure 47. Station 12RD021 was designated as General Use within the Southern Streams F-IBI Class, while Station 12RD043 was classified as General Use within the Northern Headwaters F-IBI Class. Accordingly, the F-IBI impairment threshold is a score of 50 for Station 12RD021 and 42 for Station 12RD043. Station 12RD021 had an F-IBI score of 50, while Station 12RD043 had a score of 34.

Figures 48 and 49 provide the individual F-IBI metric scores for the two fish monitoring stations along AUID 554; a description of each metric is provided in Appendix A. Station 12RD021 had three metrics that scored below the threshold score (I.e., DomTwoPct, MA<2Pct, and SensitiveTxPct). The fish assemblage of the station consisted of several taxa (11), but was dominated by common shiner. Station 12RD043 had six metrics that failed to meet the threshold score (i.e., DarterSculp, InsectCypPct, Insect-TolTxPct, Minnows-TolPct, NumPerMeter-Tol, and SLithop). The fish community of Station 12RD043 consisted of fewer taxa (6) and was primarily comprised of tolerant species (e.g., white sucker and brook stickleback).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 48. Individual F-IBI metric scores for Station 12RD021 along AUID 554.



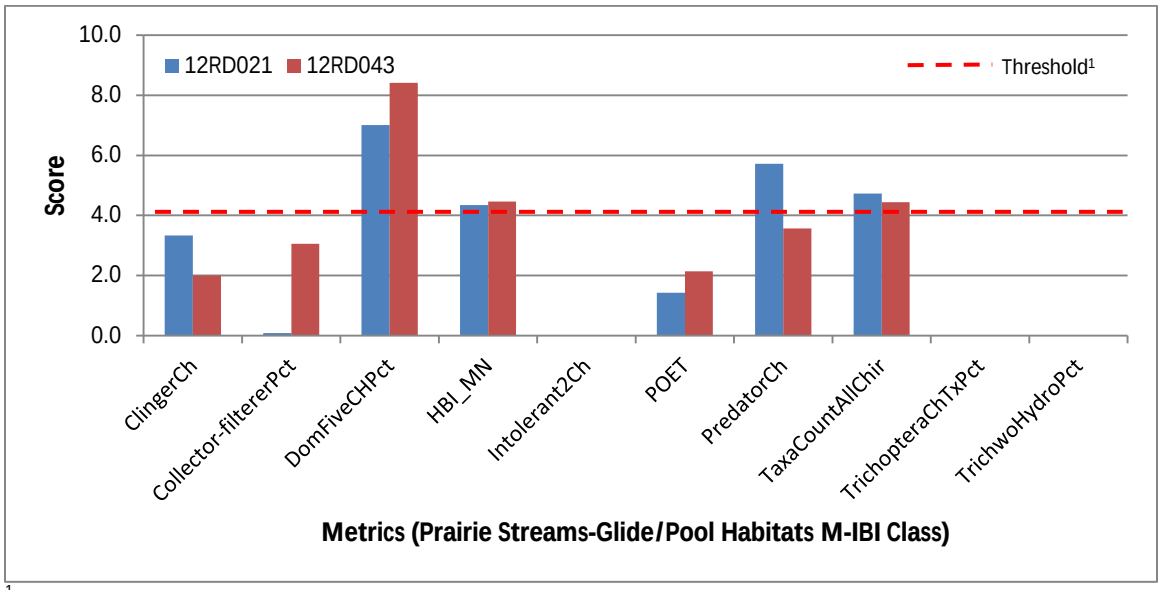
[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 49. Individual F-IBI metric scores for Station 12RD043 along AUID 554.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 554 was monitored at Station 12RD021 on July 31, 2012 and Station 12RD043 on July 31, 2012. The stations were designated as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the applicable impairment threshold for these stations is an M-IBI score of 41. Monitoring at Station 12RD021 yielded M-IBI score of 27, while Station 12RD043 had an M-IBI score of 28; both score are beneath the impairment threshold.

Figure 50 provides the individual M-IBI metric scores for the two macroinvertebrate monitoring stations along AUID 554; a description of each metric is provided in Appendix B. Station 12RD021 had six metrics that scored below the threshold score (i.e., ClingerCh, Collector-filtererPct, Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct). Station 12RD043 had seven metrics that failed to meet the threshold score (i.e., ClingerCh, Collector-filtererPct, Intolerant2Ch, POET, PredatorCh, TrichopteraChTxPct, and TrichwoHydroPct). Overall, the macroinvertebrate assemblage of both stations was dominated by tolerant taxa, specifically *Endochironomus* (midges), *Hyalella* (amphipods), and Oligochaeta (worms).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 50. Individual M-IBI metric scores for Stations 12RD021 and 12RD043 along AUID 554.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 12RD021 and 12RD043 along AUID 554. According to the MDNR (2014b), there are no man-made dams on the reach. On October 8, 2014, MPCA SI staff conducted a connectivity assessment of the reach. Staff viewed all of the road crossings on the reach as part of the assessment. A small concrete dam (Figure 51) was documented immediately downstream of the CR 11 crossing. The structure likely limits flow during low flow periods. Also, a beaver dam was noted downstream of the 180th Avenue SW road crossing. The beaver dam posed a complete barrier to connectivity at the time of discovery. In addition to the assessment, MPCA SI staff performed a detailed review of an April 2, 2012, aerial photo of the reach; the photo was collected approximately two months prior to fish sampling at

the stations. Staff identified two beaver dams and two "Texas" crossings that could have potentially limited connectivity at the time of biological monitoring. The beaver dam documented during the connectivity assessment was not present in the aerial photo.

Figure 51. Photos of potential connectivity barriers along AUID 554 on October 8, 2014, including a small concrete dam immediately downstream of the CR 11 crossing (left) and a beaver dam downstream of the 180th Avenue SW crossing (right).

Biotic response – fish

There is inconclusive evidence of a causal relationship between a loss of physical connectivity and the F-IBI impairment associated with AUID 554. The fish assemblage sampled at Station 12RD043 was largely comprised of white sucker (58%), which is an indicator of unimpeded connectivity. White sucker commonly migrate up into the headwater region of streams to reproduce (Paulson and Hatch, 2004). However, as previously mentioned, the potential connectivity barriers identified by MPCA staff could be limiting fish passage during low flow periods. Also, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of physical connectivity and the M-IBI impairment associated with AUID 554. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not directly affected by physical connectivity barriers.

Lack of base flow

Available data

The MPCA biological monitoring staff encountered intermittent flow conditions at Station 12RD043 along AUID 554 during macroinvertebrate sampling; a segment of the reach was dry (Figure 54). The RLRW conducted continuous flow monitoring at Site S004-058 (CSAH 11 crossing) from April 10, 2012, to November 15, 2012 (Figure 52) and from April 21, 2013, to November 12, 2013 (Figure 53); the relative location of the site is shown in Figure 47. In 2012, the mean flow was <1 cfs, while the highest peak flow was 8 cfs and the lowest flow was 0 cfs; the site had minimal (<1 cfs) to no flow 90% of the time. In 2013, the mean flow was 5 cfs, while the highest peak flow was 208 cfs and the lowest flow was 0 cfs; the site had minimal (<1 cfs) to no flow 76% of the time. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow nearly 17% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on four separate dates (i.e., July 23, 2014, August 14, 2014, August 27, 2014, and October 8, 2014) and documented flow conditions. Staff observed low flow conditions (estimated <1 cfs) along the reach at the time of the last visit (Figure 54). The beaver dam

discovered downstream of the 180th Avenue SW crossing on the same date did not appear to be limiting flow along the reach; intermittent flow conditions were also noted several miles upstream of the beaver dam. Overall, the available data suggest that the reach is prone to frequent periods of minimal to no flow.

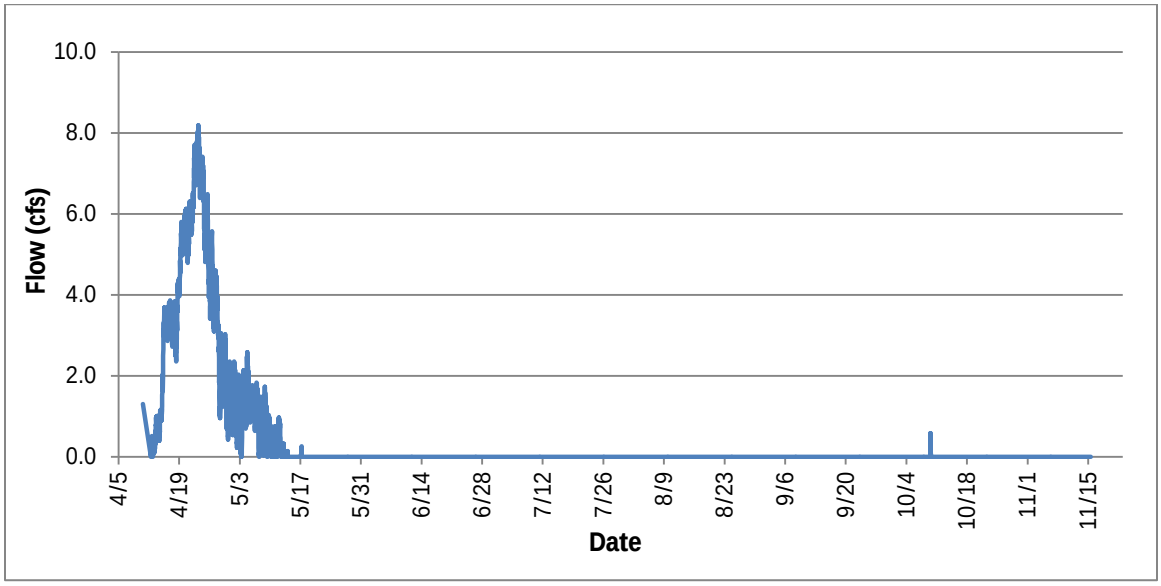


Figure 52. Continuous flow data (April 10, 2012, to November 15, 2012) for Site S004-058 along AUID 554.

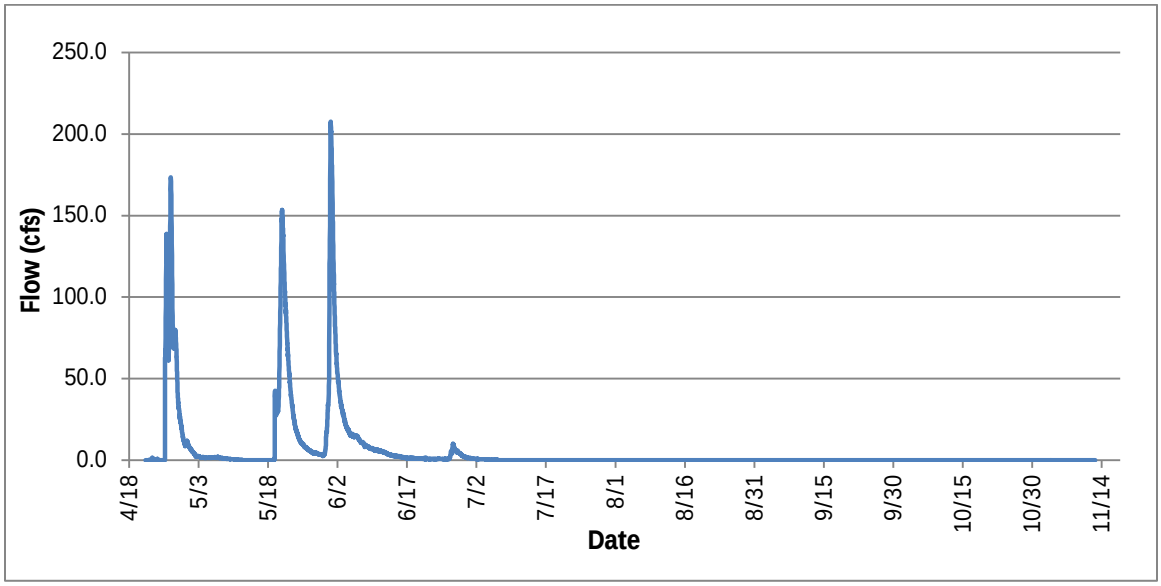


Figure 53. Continuous flow data (April 21, 2013, to November 12, 2013) for Site S004-058 along AUID 554.

Figure 54. Photos of low/intermittent flow conditions along AUID 554, including Station 12RD043 on July 31, 2012 (upper left); S008-103 on October 8, 2014 (upper right); the 180th Avenue SW crossing on October 8, 2014 (lower left); and the 170th Avenue SW crossing on October 8, 2014 (lower right).

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 554 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 12RD021 and/or 12RD043:

- High combined relative abundance of the two most abundant taxa (DomTwoPct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- High relative abundance of taxa that are pioneers (PioneerTxPct)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of taxa that are serial spawners (SSpnTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are early maturing, pioneering, serial spawners, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 48, five of the aforementioned

individual metrics (i.e., DomTwoPct, MA<2Pct, SensitiveTxPct, TolPct, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD021. Additionally, three of the individual metrics (i.e., NumPerMeter-Tol, PioneerTxPct, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD043 (Figure 49). Station 12RD021 had a "low" score for the DomTwoPct, MA<2Pct, and SensitiveTxPct metrics, while Station 12RD043 had a "low" score for the NumPerMeter-Tol metric. The "low" score for these metrics directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of base flow and the M-IBI impairment associated with AUID 554 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 12RD021 and/or 12RD043:

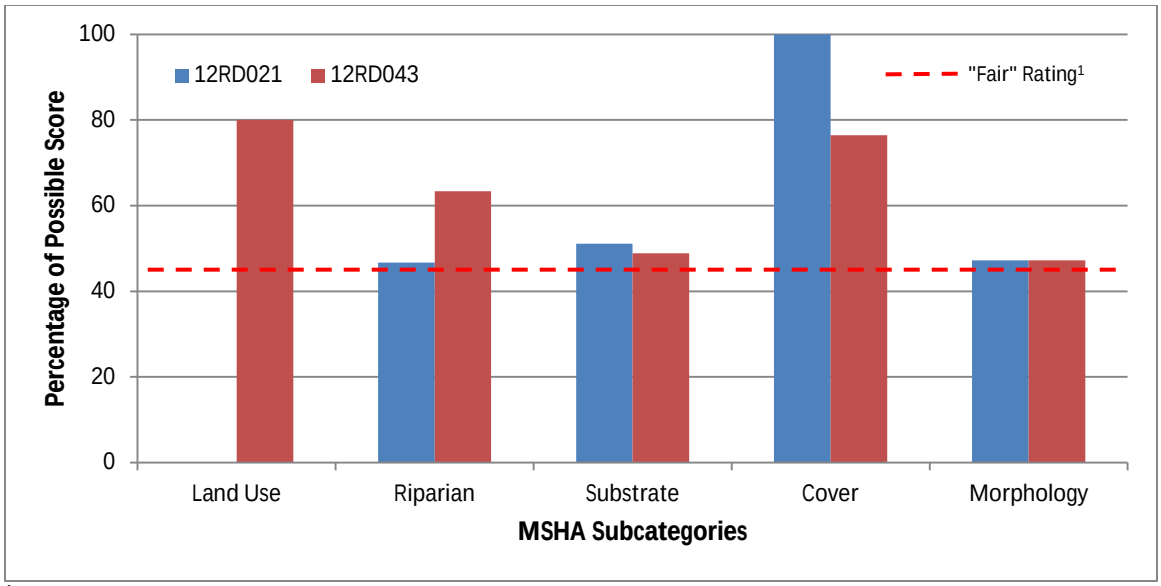
- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- High relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity, specifically taxa belonging to the orders of Plecoptera, Ephemeroptera, and Trichoptera (many of which are collector-filterers), and favor taxa that are tolerant of environmental disturbances (EPA, 2012; Klemm et al., 2002, Poff and Zimmerman, 2010). According to Figure 50, five of the aforementioned individual metrics (i.e., Collector-filtererPct , Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Stations 12RD021 and 12RD043. Both stations had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. Overall, the macroinvertebrate assemblage of the stations was dominated by taxa that are adapted to lentic conditions (e.g., *Endochironomus*, *Hyalella*, and Oligochaeta).

Lack of instream habitat

Available data

The instream habitat of AUID 554 was evaluated at Stations 12RD021 and 12RD043 using the MSHA. Station 12RD021, which is located along a natural segment of the reach (MPCA, 2013), had a MSHA score of 55 ("fair"). According to Figure 55, the MSHA score for the station was limited by the land use subcategory. The land use adjacent to the station was dominated by row crop agriculture (e.g., corn and soybeans). Station 12RD043, which is situated along an altered segment of the reach (MPCA, 2013), had a total MSHA score of 57 ("fair"). The station scored above the "fair" rating threshold for all subcategories (Figure 55). Additionally, both stations lacked riffle habitat, but offered coarse substrate; however, the substrate had a "moderate" level of embeddedness.



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

Figure 55. MSHA subcategory results for Stations 12RD021 and 12RD043 along AUID 554.

Biotic response – fish

Evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 554 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 12RD021 and/or 12RD043:

- Low relative abundance of taxa that are benthic insectivores, excluding tolerant species (Beninsect-TolTxPct)
- Low taxa richness of darter and sculpin species (DarterSculp)
- High relative abundance of taxa that are detritivorous (DetNWQTxPct)
- Low relative abundance of individuals that are insectivorous Cyprinids (InsectCypPct)
- Low relative abundance of taxa that are insectivorous, excluding tolerant species (Insect-TolTxPct)
- Low taxa richness of simple lithophilic spawning species (SLithop)

Benthic 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). According to Figure 48, two of the aforementioned individual metrics (i.e., BenInsect-TolTxPct and DetNWQTxPct) were used in the calculation of the F-IBI score for Station 12RD021. Additionally, four of the individual metrics (i.e., DarterSculp, InsectCypPct, Insect-TolTxPct, and SLithop) were used in the calculation of the F-IBI score for Station 12RD043 (Figure 49). Station 12RD043 had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of instream habitat and the M-IBI impairment associated with AUID 554 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 12RD021 and/or 12RD043:

- High relative abundance of burrower individuals (BurrowerPct)
- Low taxa richness of clinger taxa (ClingerCh)
- Low relative abundance of collector-filterer individuals in a subsample (Collector-filtererPct)
- High relative abundance of legless individuals (LeglessPct)

Clinger taxa, including many collector-filterers, require clean, coarse substrate or other objects to attach themselves to, while burrowing and legless macroinvertebrates are tolerant of degraded benthic habitat. According to Figure 50, two of the aforementioned individual metrics (i.e., ClingerCh and Collector-filtererPct) were used in the calculation of the M-IBI score for Stations 12RD021 and 12RD043. Both stations had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at Stations 12RD021 and 12RD043 along AUID 554 at the time of fish sampling. The samples were analyzed for several parameters, including TSS. Both stations had a low TSS concentration (both 4 mg/L). Table 24 summarizes discrete TSS data for Sites S004-058 and S007-060 (180th Avenue SW crossing); the relative location of these sites is shown in Figure 47. Both sites had a low proportion of total values that exceeded the 65 mg/L standard (2.4 and 0.0%). Additionally, the RLRW HSPF model estimates that the reach had a TSS concentration in excess of the standard approximately 2% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to infrequent periods of high suspended sediment.

Table 24. Discrete TSS data for Sites S004-058 and S007-060 along AUID 554.

Site	Date Range	*n*	Min	Max	Mean	% Total Values Above Standard[1]
S004-058	2005-2014	42	0	135	8	2.4
S007-060	2012-2014	14	0	7	4	0.0

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 554. None of the individual F-IBI metrics for Station 12RD021 and 12RD043 exhibited a correlation to this candidate cause. However, the deposition of suspended sediment has caused the aforementioned embeddedness of coarse substrate and the related biotic response associated with the stations.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 554 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 12RD021 and/or 12RD043:

- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Trichoptera (Trichoptera)

- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Collector-filterers, including several members of the order Trichoptera, 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). According to Figure 50, four of the aforementioned individual metrics (i.e., Collector-filtererPct, Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Stations 12RD021 and 12RD043. The stations had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. The MPCA also calculated TSS TIVs for the stations. Station 12RD021 had a low number of high TSS intolerant taxa, while Station 12RD043 had a high percentage of high TSS tolerant taxa and a low number of high TSS intolerant taxa. Additionally, the deposition of suspended sediment has resulted in the embeddedness of coarse substrate and the associated biotic response at both stations.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Stations 12RD021 and 12RD043 along AUID 554 at the time of fish and macroinvertebrate sampling. None of the measurements were below the 5.0 mg/L standard. Figure 56 displays discrete DO data for Sites S004-058 (2005-2014; *n*=58) and S007-060 (2012-2013; *n*=32). Collectively, only 5% of the DO values for the sites were below the standard; however, only one measurement was taken prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. Continuous DO monitoring was conducted at Site S007-060 from May 3, 2012, to September 22, 2012 (RLWD) and at Site S008-103 (US Hwy. 2 crossing) from August 14, 2014, to August 27, 2014). Table 25 provides a summary of the monitoring results. The sites had a high proportion of daily minimum DO values that were below the standard (58.5 and 71.4%), as well as an elevated level of mean daily DO flux (3.8 and 4.7 mg/L). Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard approximately 32% 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.

Table 25. Continuous DO data for Sites S007-060 and S008-103 along AUID 554.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S007-060 (RLWD)	May 3, 2012 - Sept. 22, 2012	3753	0.0	22.0	58.5	24.9	3.8
S008-103 (MPCA)	Aug. 14, 2014 - Aug. 27, 2014	1246	2.6	11.2	71.4	33.8	4.7

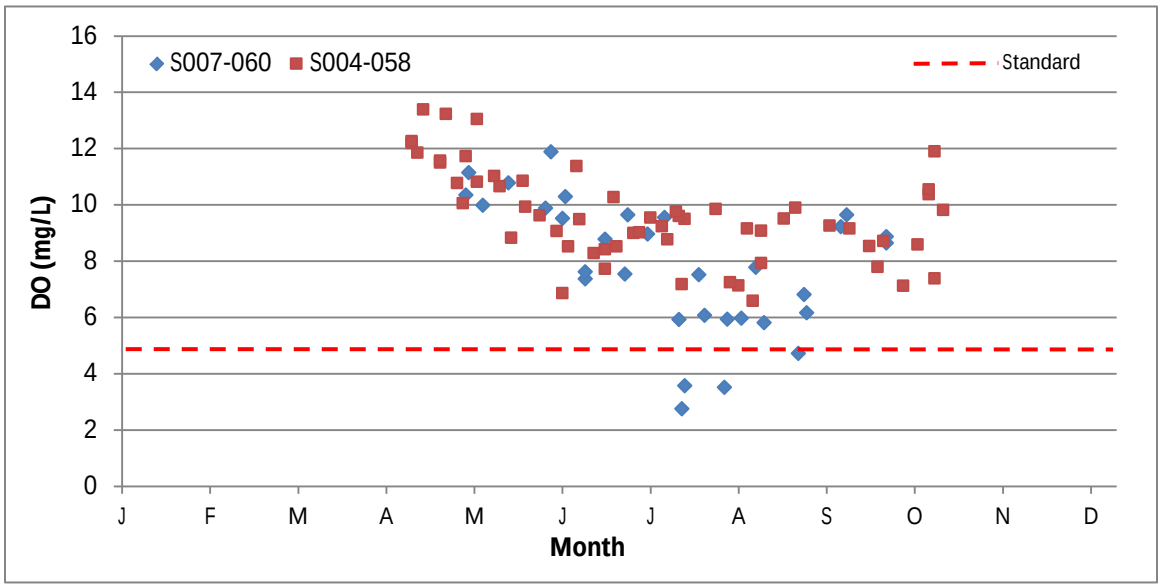


Figure 56. Discrete DO data for Sites S007-060 and S004-058 along AUID 554.

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 554 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 12RD021 and/or 12RD043:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 48, three of the aforementioned individual metrics (i.e., SensitiveTxPct, TolPct, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD021. Additionally, three of the individual metrics (i.e., NumPerMeter-Tol, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD043 (Figure 49). Station 12RD021 had a "low" score for the SensitiveTxPct metric, while Station 12RD043 had a "low" score for the NumPerMeter-Tol metric. The "low" score for these metrics directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of each stations meeting the DO standard based upon its sampled fish assemblage (Appendix C). Station 12RD021 had a relative high probability (44%) of meeting the standard, while Station 12RD043 had a relatively low probability (29%) of meeting the standard.

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 554 is provided by the following individual M-IBI metric responses (Appendix D) for Stations 12RD021 and/or 12RD043:

- Low taxa richness of macroinvertebrates with tolerance values less than or equal to two (Intolerant2Ch)

- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- High relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative abundance of non-hydropsychid Trichoptera individuals in a subsample (TrichwoHydroPct)

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 (EPA, 2012; Weber, 1973). According to Figure 50, four of these individual metrics (Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Stations 12RD021 and 12RD043. Both stations had a "low" score for each of these metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. Additionally, the MPCA calculated DO TIVs for Stations 12RD021 and 12RD043 (Appendix D). Both stations had a high percentage of low DO tolerant taxa and a low number of low DO intolerant taxa.

Strength-of-evidence analysis

Table 26 presents a summary of the SOE scores for the various candidate causes associated with AUID 554. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: lack of base flow, lack of instream habitat, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of the following stressors: lack of base flow, lack of instream habitat, high suspended sediment, and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 26. SOE scores for candidate causes associated with AUID 554.

Types of Evidence	SOE Scores for Candidate Causes[1]									
	Loss of Physical Connectivity		Lack of Base Flow		Lack of Instream Habitat		High Suspended Sediment		Low Dissolved Oxygen	
	Biological Impairment(s)									
	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.

3.3.9 Cyr Creek (AUID 556)

Physical setting

This reach represents the segment of Cyr Creek from the CR 14 crossing to its outlet to the Red Lake River (Figure 57); a total length of nine miles. The reach has a subwatershed area of 25 square miles (15,922 acres). The reach and its subwatershed are situated in the beach ridges region of the RLRW. The subwatershed contains 12 miles of perennial stream (e.g., AUID 556), 16 miles of intermittent stream, and 14 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 52% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded); no such alterations have been made to AUID 556. The NLCD 2011 (USGS, 2011) lists cultivated crops (74%) as the predominant land cover in the subwatershed. Notable minor land cover groups in the subwatershed included wetlands (9%), hay/pasture (8%), and developed areas (5%).

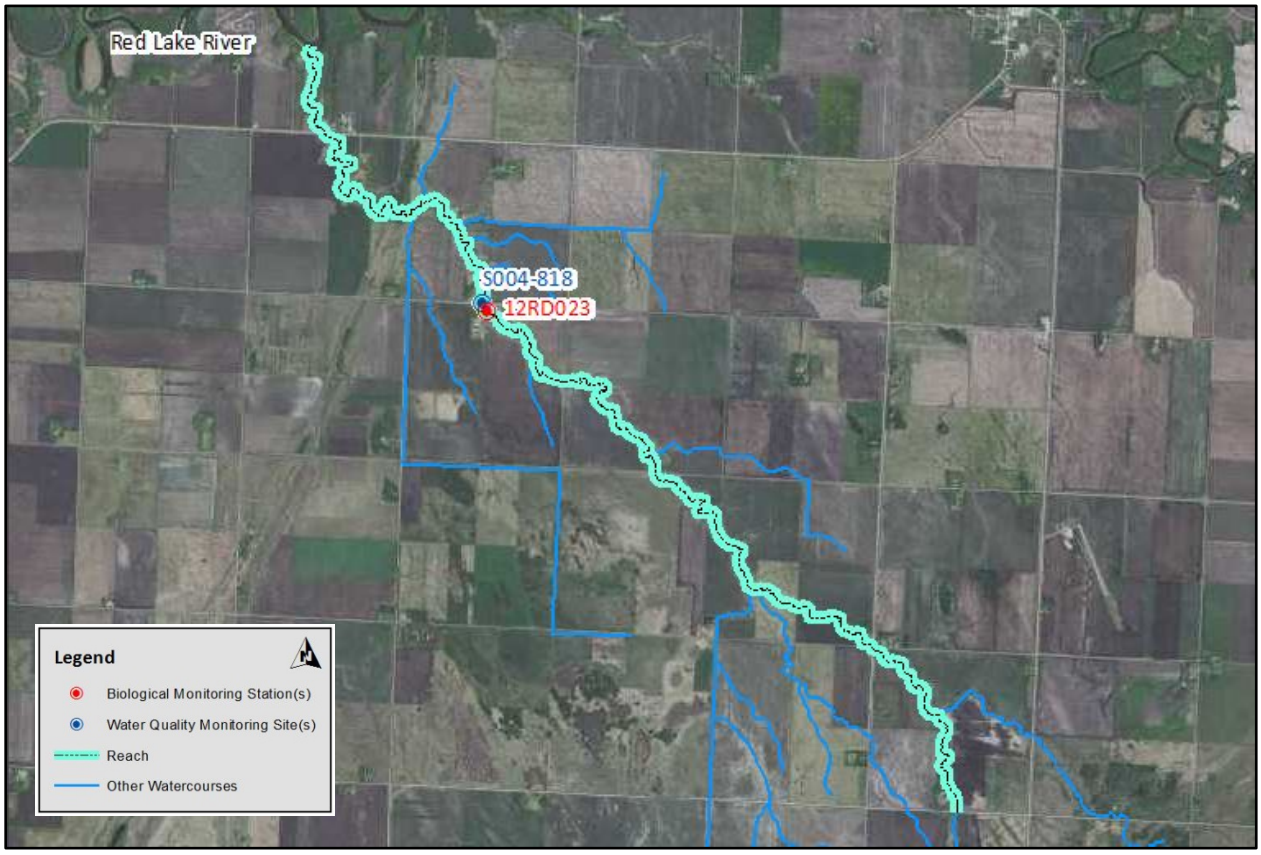


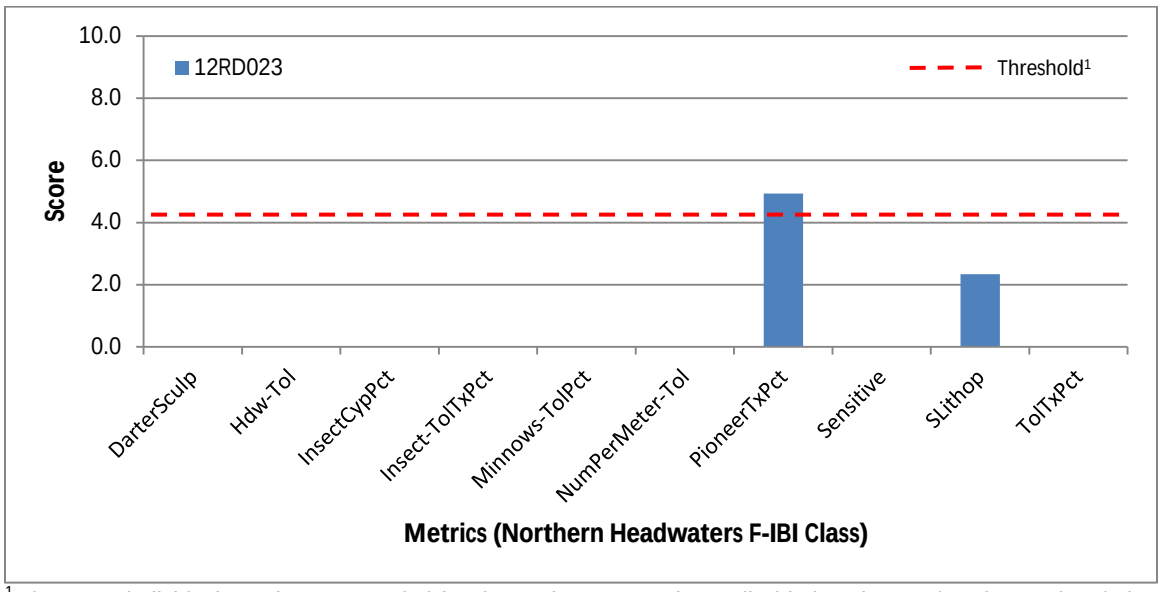
Figure 57.Map of AUID 556 and associated biological monitoring station and water quality monitoring site (2010 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 556 was monitored at Station 12RD023 (0.1 mi upstream of the CR 110 crossing) on June 12, 2012. The relative location of the station is shown in Figure 57. 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. The station had an F-IBI score (7) well beneath this threshold. According to Figure 58, the station had nine individual metrics that scored below the threshold score (i.e., DarterSculp, Hdw-Tol, InsectCypPct, Insect-TolTxPct, Minnows-TolPct, NumberPerMeter-Tol, Sensitive, SLithop, and TolTxPct). A description of each metric is provided in

Appendix A. Overall, the fish assemblage of the station consisted of few taxa (4) and was dominated by brook stickleback.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 58. Individual F-IBI metric scores for Station 12RD023 along AUID 556.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Station 12RD023 along AUID 556. According to the MDNR (2014b), there are no man-made dams on the reach. On October 8, 2014, MPCA SI staff conducted a connectivity assessment of the reach. Staff viewed all of the road crossings on the reach as part of the assessment. A beaver dam was documented immediately upstream of the CR 110 crossing. The beaver dam had an associated pool and posed a complete barrier to connectivity at the time of discovery. In addition to the assessment, MPCA SI staff performed a detailed review of an April 2, 2012, aerial photo of the reach; the photo was collected approximately two months prior to fish sampling at Station 12RD023. The beaver dam documented during the connectivity assessment was not present in the aerial photo. No connectivity-related issues were identified in the photo. According to C. Hanson (personal communication, 2015), beaver dams are common along the reach.

Biotic response – fish

There is no evidence of a causal relationship between a loss of physical connectivity and the F-IBI impairment associated with AUID 556. There were no known fish passage barriers along the reach at the time of sampling. However, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Lack of base flow

Available data

The MPCA biological monitoring staff was unable to perform macroinvertebrate sampling at Station 12RD023 along AUID 556 due to the absence of flow (Figure 61). The RLWD collected continuous stage data at Site S004-818 (CR 110 crossing) from March 12, 2012, to October 24, 2012 (Figure 59) and from

April 21, 2013, to November 12, 2013 (Figure 60); the relative location of the site is shown in Figure 57. Based upon preliminary flow rating table values, the site had no flow 48% of the time in 2012 and 52% of the time in 2013. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between 21 and 46% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on four separate dates (i.e., July 23, 2014, August 14, 2014, August 27, 2014, and October 8, 2014) and documented flow conditions. The reach had minimal (estimated <1 cfs) to no flow on each of these dates. The reach was dominated by interspersed pools of stagnant water at the time of the last visit (Figure 61). The beaver dam located upstream of Site S004-818 did not appear to be limiting flow along the reach; intermittent flow conditions were also noted several miles upstream of the beaver dam. According to C. Hanson (personal communication, 2015), the RLWD noted that the reach had "no flow" in August 2008, September 2011, August through September 2012, August through October 2013, and September 2014. Overall, the available data suggest that the reach is prone to frequent periods of minimal to no flow.

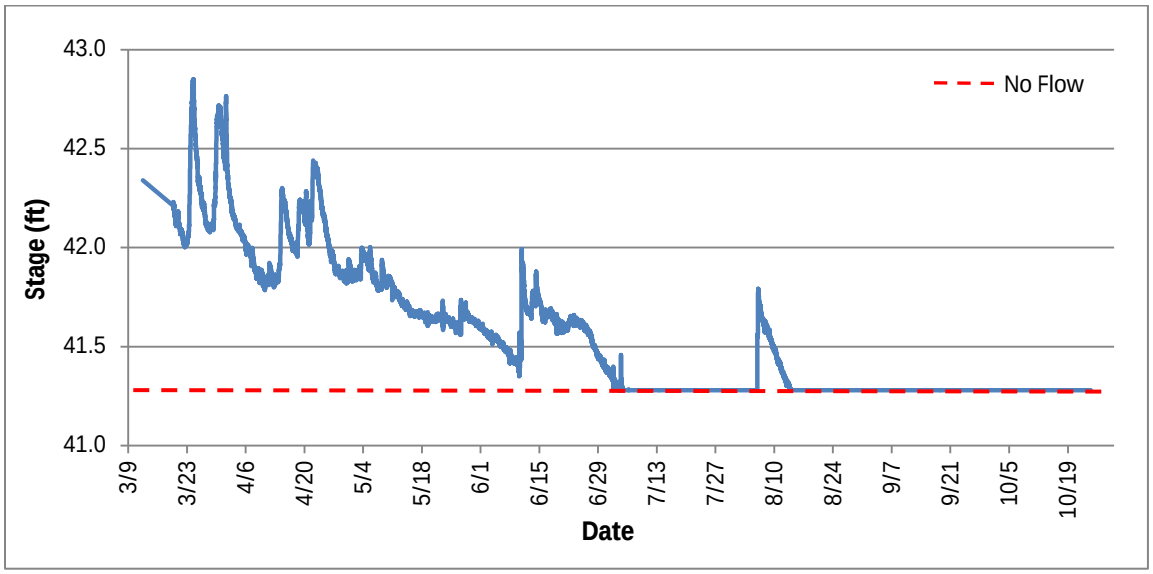


Figure 59.Continuous stage data (March 12, 2012, to October 24, 2012) for Site S004-818 along AUID 556.

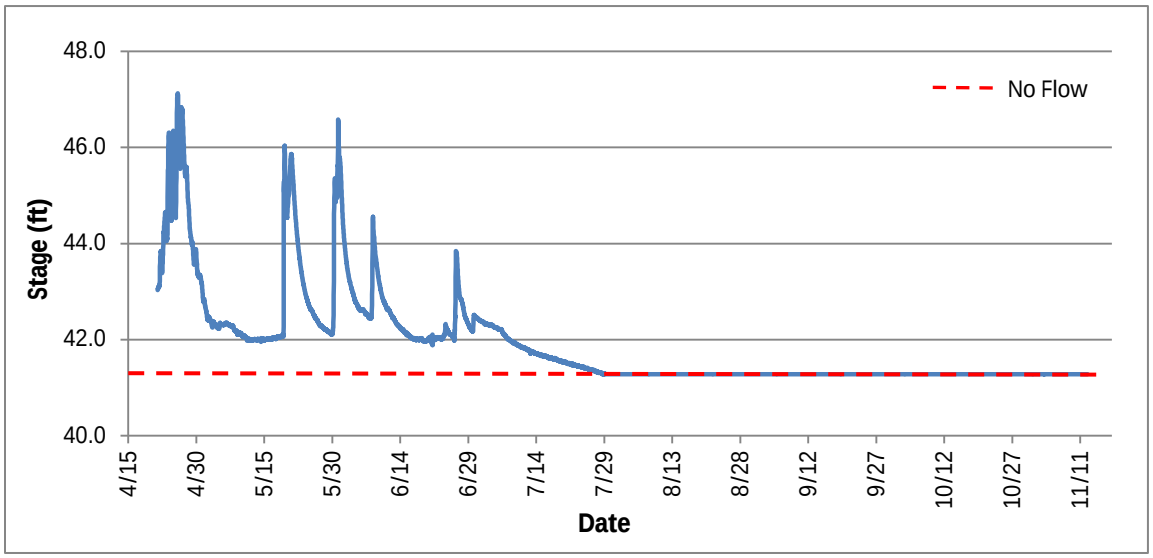


Figure 60. Continuous stage data (April 21, 2013, to November 12, 2013) for Site S004-818 along AUID 556.

Figure 61. Photos of the flow conditions along AUID 556, including Station 12RD023 on August 6, 2013 (upper left); Site S004-818 on October 8, 2014 (upper right); 230th Street SW crossing on October 8, 2014 (lower left); and CR 14 crossing on October 8, 2014 (lower right).

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 556 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD023:

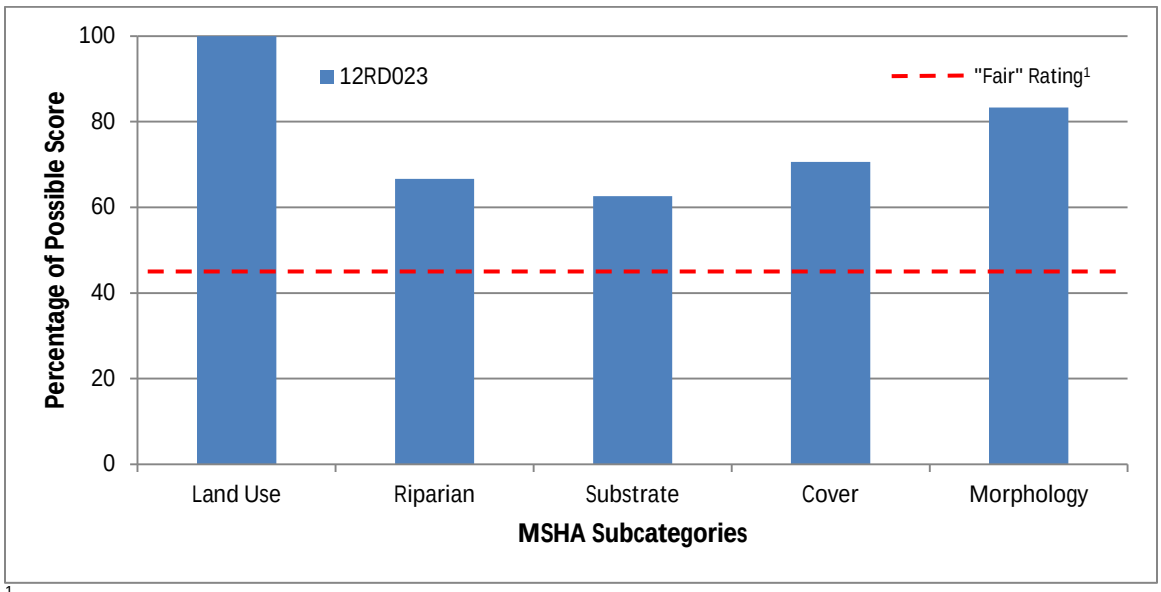
- High combined relative abundance of the two most abundant taxa (DomTwoPct)
- High relative abundance of taxa that are generalists (GeneralTxPct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant species (NumPerMeter-Tol)
- High relative abundance of taxa that are pioneers (PioneerTxPct)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High taxa richness of short-lived species (SLvd)
- High relative abundance of taxa that are serial spawners (SSpnTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, serial spawners, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 58, four of the aforementioned individual metrics (i.e., NumPerMeter-Tol, PioneerTxPct, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD023. The station had a "low" score for a majority of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach.

Lack of instream habitat

Available data

The instream habitat of AUID 556 was evaluated at Station 12RD023 using the MSHA; the entire length of the reach is natural (MPCA, 2013). The station yielded a total MSHA score of 74 ("good"). According to Figure 62, the station scored above the "fair" rating threshold for all MSHA subcategories. The station had abundant riffle habitat, offered coarse substrate, with only "light" embeddedness, and had a "moderate" amount of cover.



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

Figure 62. MSHA subcategory results for Station 12RD023 along AUID 556.

Biotic response – fish

There is no evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 556. Specifically, there is no indication that the instream habitat of the reach is limited.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at Station 12RD023 along AUID 556 at the time of fish sampling. The sample was analyzed for several parameters, including TSS. The sample had a TSS concentration of 10 mg/L. Table 27 summarizes discrete TSS data for Site S004-818. The site had no exceedances of the 65 mg/L standard. Additionally, the RLRW HSPF model estimates that the reach had a TSS concentration in excess of the standard approximately 3% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to infrequent periods of high suspended sediment.

Table 27. Discrete TSS data for Site S004-818 along AUID 556.

Site	Date Range	*n*	Min	Max	Mean	% Total Values Above Standard[1]
S004-818	2008-2014	45	1	38	11	0.0

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 556. None of the individual F-IBI metrics for Station 12RD023 exhibited a correlation to this candidate cause.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at Station 12RD023 along AUID 556 at the time of fish sampling. The measurement was above the 5.0 mg/L standard. Figure 63 displays discrete DO data for Site S004-818 (2008-2014; *n*=63). None of the measurements were below the standard; however, only 13 measurements were taken prior to 9:00 a.m. Generally, the lowest DO levels were in the months of July, August, and September. The MPCA and RLWD conducted continuous DO monitoring at Site S004-818 (May 29, 2013, to August 7, 2013; August 14, 2014, to August 27, 2014). Table 28 provides a summary of the monitoring results. The site had a high proportion of daily minimum DO values that were below the standard (45.1 and 100.0%); however, the level of mean daily DO flux was normal (3.9 and 2.5 mg/L). All of the values collected in August 2014 were below the standard. Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard between 38 and 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.

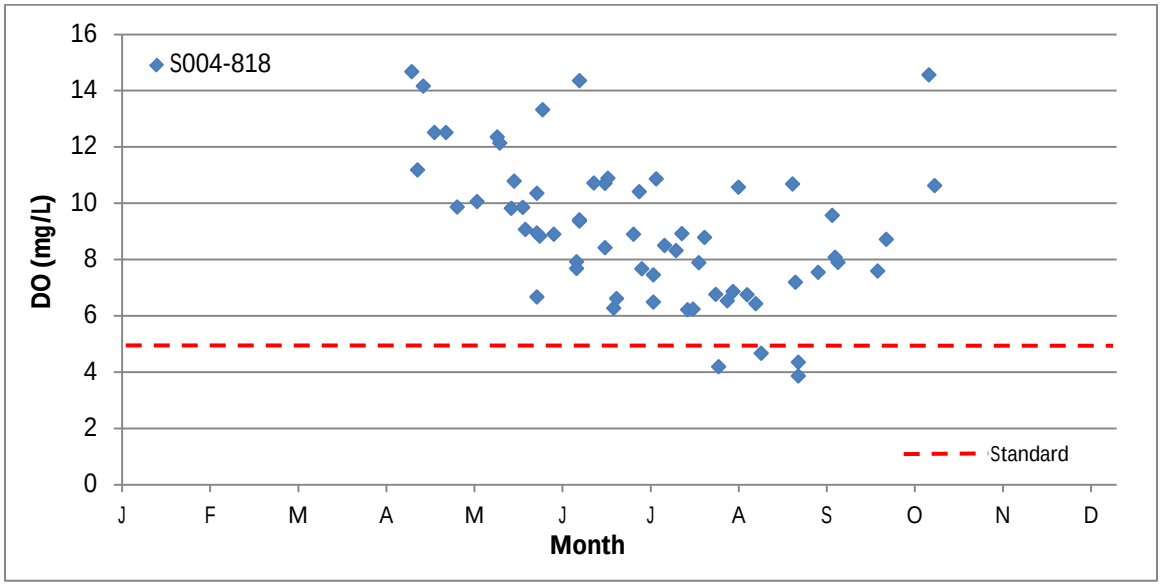


Figure 63. Discrete DO data for Site S004-818 along AUID 556.

Table 28. Continuous DO data for Site S004-818 along AUID 556.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S004-818 (RLWD)	May 29, 2013 - Aug. 7, 2013	3768	0.6	12.8	45.1	10.4	3.9
S004-818 (MPCA)	Aug. 14, 2014 - Aug. 27, 2014	1245	0.0	4.9	100.0	100.0	2.5

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 556 is provided by the following individual F-IBI metric responses (Appendix C) for Station 12RD023:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa (NumPerMeter-Tol)
- Low taxa richness of sensitive species (Sensitive)
- Low relative abundance of taxa that are sensitive (SensitiveTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 58, three of the aforementioned individual metrics (i.e., NumPerMeter-Tol, Sensitive, and TolTxPct) were used in the calculation of the F-IBI score for Station 12RD023. The station had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI score and directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of Station 12RD023 meeting the DO standard based upon its sampled fish assemblage (Appendix C). The station had a low probability (7%) of meeting the standard.

Strength-of-evidence analysis

Table 29 presents a summary of the SOE scores for the various candidate causes associated with AUID 556. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: lack of base flow and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 29. SOE scores for candidate causes associated with AUID 556.

Types of Evidence	SOE Scores for Candidate Causes[1]				
	Loss of Physical Connectivity	Lack of Base Flow	Lack of Instream Habitat	High Suspended Sediment	Low Dissolved Oxygen
	Biological Impairment(s)				
	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 Black River (AUID 558)

Physical setting

This reach represents the segment of the Black River from directly south of the CR 3 crossing to its confluence with the Little Black River (Figure 64); a total length of 14 miles. The reach has a subwatershed area of 111 square miles (71,073 acres). The reach and its subwatershed are situated in the beach ridges region of the RLRW. The subwatershed contains 16 miles of perennial stream (e.g., AUID 558), 56 miles of intermittent stream, and 71 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013), 60% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded); no such alterations have been made to AUID 558. The NLCD 2011 (USGS, 2011) lists cultivated crops (78%) as the predominant land cover in the subwatershed. Notable minor land cover groups in the subwatershed included wetlands (9%), forest (5%), developed areas (4%), and hay/pasture (3%).

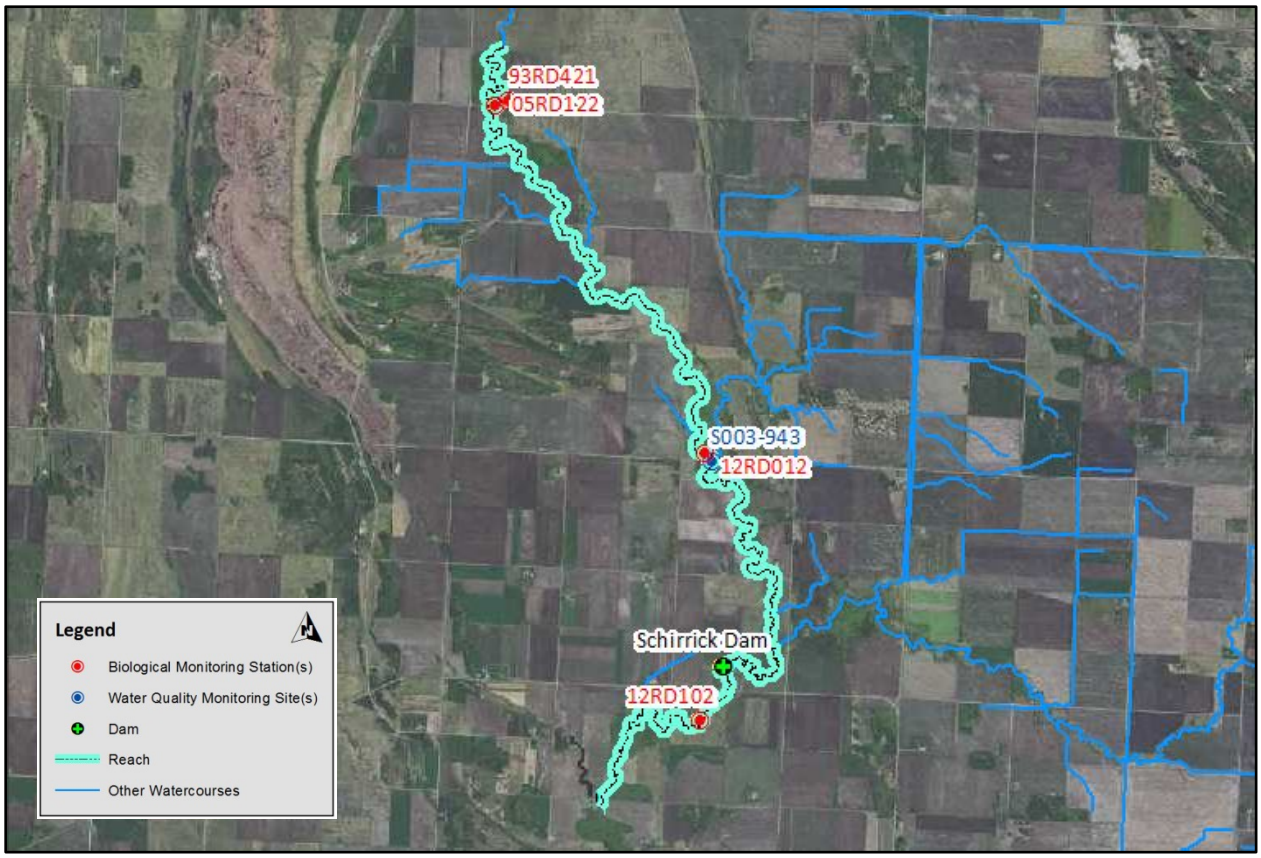


Figure 64. Map of AUID 558 and associated biological monitoring stations and water quality monitoring site (2010 NAIP aerial image).

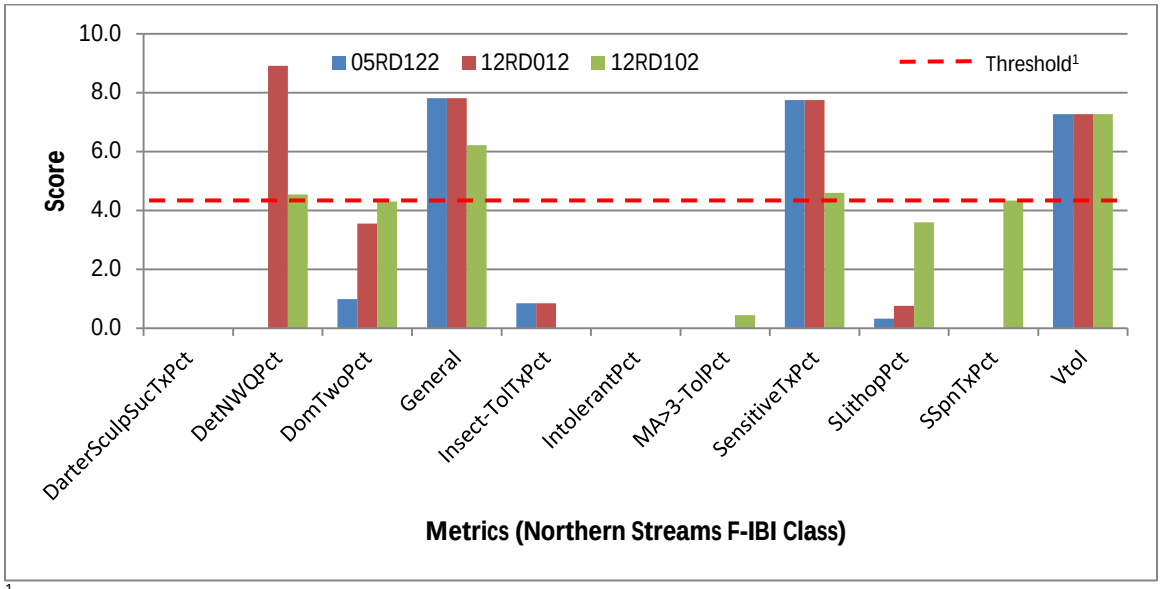
Biological impairments

Fish (F-IBI)

The fish community of AUID 558 was monitored at Station 05RD122 (0.1 mi upstream of the 110th Street SW crossing) on June 21, 2006, Station 12RD012 (0.1 mi upstream of the CR 52 crossing) on July 17, 2012, and Station 12RD102 (0.4 mi downstream of the CR 13 crossing) on June 12, 2012. The relative location of the stations is shown in Figure 64. All of the stations were designated as General Use within the Northern Streams F-IBI Class. Accordingly, the applicable impairment threshold for these stations is

an F-IBI score of 47. Monitoring at these stations yielded the following F-IBI scores, which are below the impairment threshold: 25 (05RD122), 35 (12RD102), and 37 (12RD012).

Figure 65 provides the individual F-IBI metric scores for the three fish monitoring stations along AUID 558; a description of each metric is provided in Appendix A. Overall, one or more of the stations scored below the need threshold score for seven out of 10 metrics (i.e., DarterSculpSucTxPct, DetNWQPct, DomTwoPct, Insect-TolTxPct, IntolerantPct, MA>3-TolPct, SLithopPct, and SSpnTxPct). The fish assemblage of all of the stations was dominated by tolerant species (e.g., brook stickleback and fathead minnow).



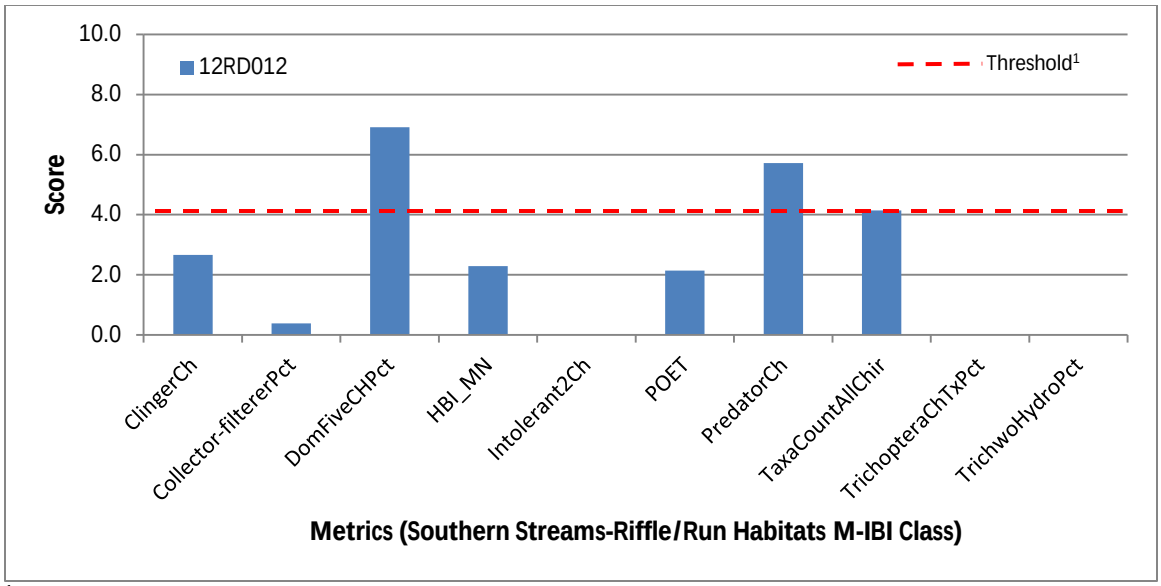
[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 65.Individual F-IBI metric scores for Stations 05RD122, 12RD012, and 12RD102 along AUID 558.

Macroinvertebrate (M-IBI)

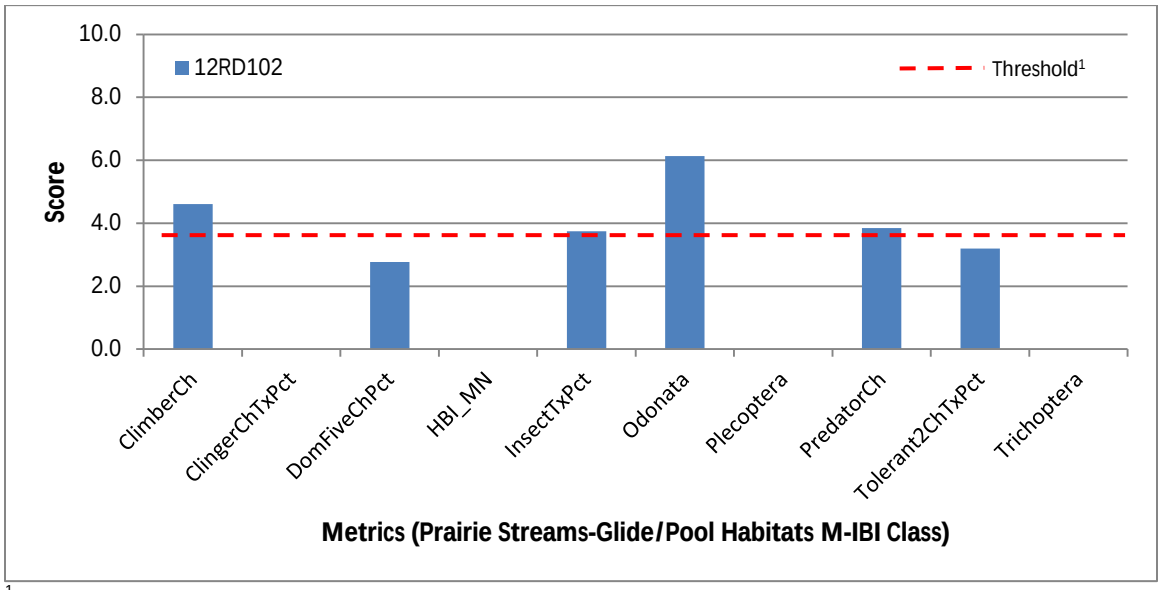
The macroinvertebrate community of AUID 558 was monitored at Station 12RD012 on July 31, 2012 and Station 12RD102 on July 31, 2012. Station 12RD102 was designated as General Use within the Southern Streams-Riffle/Run Habitats M-IBI Class, while Station 12RD012 was classified as General Use within the Prairie Streams-Glide/Pool Habitats M-IBI Class. Accordingly, the M-IBI impairment threshold is score of 37 for Station 12RD102 and a score of 41 for Station 12RD012. Monitoring at both stations yielded an M-IBI score of 24.

Figures 66 and 67 provide the individual M-IBI metric scores for the two macroinvertebrate monitoring stations along AUID 558; a description of each metric is provided in Appendix B. Station 12RD012 had seven metrics that scored below the threshold score (i.e., ClingerCh, Collector-filtererPct, HBI_MN, Intolerant2Ch, POET, TrichopteraChTxPct, and TrichwoHydroPct). Station 12RD102 had six metrics that failed to meet the threshold score (i.e., ClingerChTxPct, DomFiveCHPct, HBI_MN, Plecoptera, Tolerant2ChTxPct, and Trichoptera). Overall, the macroinvertebrate assemblage of both stations was dominated by tolerant taxa, specifically *Caenis* (mayflies), Coenagrionidae (damselflies), and *Dubiraphia* (riffle beetles).



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 66. Individual M-IBI metric scores for Station 12RD012 along AUID 558.



[1] The mean individual metric score needed for the station to meet its applicable impairment (IBI class and use) threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 67. Individual M-IBI metric scores for Station 12RD102 along AUID 558.

Candidate causes

Loss of physical connectivity

Available data

The MPCA biological monitoring staff did not encounter any connectivity-related issues during the sampling of Stations 05RD122, 12RD012, and 12RD102 along AUID 558. According to the MDNR (2014b), the Schirrick Dam (Figure 68) is located on the downstream extent of the reach. The dam is owned by the RLWD and was constructed in 1984 for the primary purpose of flood control. The structure has an associated impoundment and is a complete barrier to connectivity. On October 8, 2014, MPCA SI staff

conducted a connectivity assessment of the reach. Staff viewed all of the road crossings on the reach as part of the assessment. No additional obstructions to connectivity were identified (e.g., perched culverts and beaver dams). In addition, MPCA SI staff performed a detailed review of an April 2, 2012, aerial photo of the reach and the downstream segment of the Black River, from the reach to its confluence with the Red Lake River; the photo was taken approximately two months prior to fish sampling at Stations 12RD012 and 12RD102. In addition to the Schirrick Dam, staff identified a "Texas" crossing (Figure 68) along the lower extent of the reach that appeared to be a barrier to connectivity.

Figure 68. Photos of connectivity barriers along AUID 558, including the Schirrick Dam, courtesy of Corey Hanson, RLWD (left) and a "Texas" crossing on April 2, 2012, courtesy of Google Earth (right).

Biotic response – fish

Evidence of a causal relationship between a loss of physical connectivity and the F-IBI impairment associated with AUID 558 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 05RD122, 12RD012, and 12RD102:

- Low relative abundance of individuals with a female mature age of equal to or greater than three years, excluding tolerant taxa (MA>3-tolpct)
- Low relative abundance of individuals that are migratory (MgrPct)

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 Figure 65, the MA>3-TolPct metric was used in the calculation of the F-IBI score for each of the monitoring stations. Stations 05RD122 and 12RD012, which are located upstream of the Schirrick Dam, each had a score of zero for the metric; no late maturing fish species were sampled. The fish assemblage sampled at Station 12RD102, which is situated between the Schirrick Dam and a 'Texas" crossing farther downstream, included six rock bass and yielded a score of 0.4 for the metric. In 2003, the MDNR conducted fish sampling on the Black River at a station located immediately downstream of AUID 558 (Groshens, 2005); there are no known connectivity barriers between this station and the Red Lake River. The fish community of the station included four late maturing fish species belonging to the aforementioned metric (i.e., rock bass, shorthead redhorse, smallmouth bass, and stonecat). The data affirms the presence of these species in the Black River and that the Schirrick Dam, and likely the "Texas" crossing, is an obstruction to connectivity. Additionally, the influence of culverts along the reach on fish passage during high flow periods is unknown.

Biotic response – macroinvertebrate

There is no evidence of a causal relationship between a loss of physical connectivity and the M-IBI impairment associated with AUID 558. Macroinvertebrates are generally sessile or have limited migration patterns and, therefore, are not directly affected by physical connectivity barriers.

Lack of base flow

Available data

The MPCA biological monitoring staff encountered intermittent flow conditions during macroinvertebrate sampling at Station 12RD012 along AUID 558; this portion of the reach was dominated by interspersed pools of stagnant water (Figure 69). There is no flow monitoring data for the reach; however, the RLWD collected continuous stage data at a site (S002-132) on the Black River located downstream of the reach from March 12, 2012, to November 15, 2012 and from April 25, 2013, to November 12, 2013. Based upon preliminary flow rating table values, the site had no flow 38% of the time in 2012 and 85% of the time in 2013. The RLRW HSPF model estimates that the reach had minimal (<1 cfs) to no flow between one and 5% of the time during the period of 1996 to 2009. The MPCA SI staff conducted reconnaissance along the reach on four separate dates (i.e., July 23, 2014, August 14, 2014, August 27, 2014, and October 8, 2014) and documented flow conditions. Staff observed low flow conditions (estimated ≈1 cfs) along the reach at the time of the last visit (Figure 69). Overall, the available data suggest that the reach is prone to periods of minimal to no flow.

Biotic response – fish

Evidence of a causal relationship between a lack of base flow and the F-IBI impairment associated with AUID 558 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 05RD122, 12RD012, and/or 12RD102:

- High combined relative abundance of the two most abundant taxa (DomTwoPct)
- High relative abundance of taxa that are generalists (GeneralTxPct)
- High relative abundance of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa NumPerMeter-Tol)
- High relative abundance of taxa that are pioneers (PioneerTxPct)
- High taxa richness of short-lived species (SLvd)
- High relative abundance of taxa that are serial spawners (SSpnTxPct)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, short-lived, serial spawners, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). According to Figure 65, two of the aforementioned individual metrics (i.e., DomTwoPct and SSpnTxPct) were used in the calculation of the F-IBI score for each of the monitoring stations. Stations 05RD122, 12RD012, and 12RD102 had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach.

Figure 69. Photos of low/intermittent flow conditions along AUID 558, including Station 12RD012 on July 17, 2012 (upper left); Station 12RD012 on July 31, 2012 (upper right); CR 13 crossing on October 8, 2014 (lower left); and 120th Street SW crossing on October 8, 2014 (lower right).

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of base flow and the M-IBI impairment associated with AUID 558 is provided by the following individual M-IBI metric responses (Appendix D) for 12RD012 and/or 12RD102:

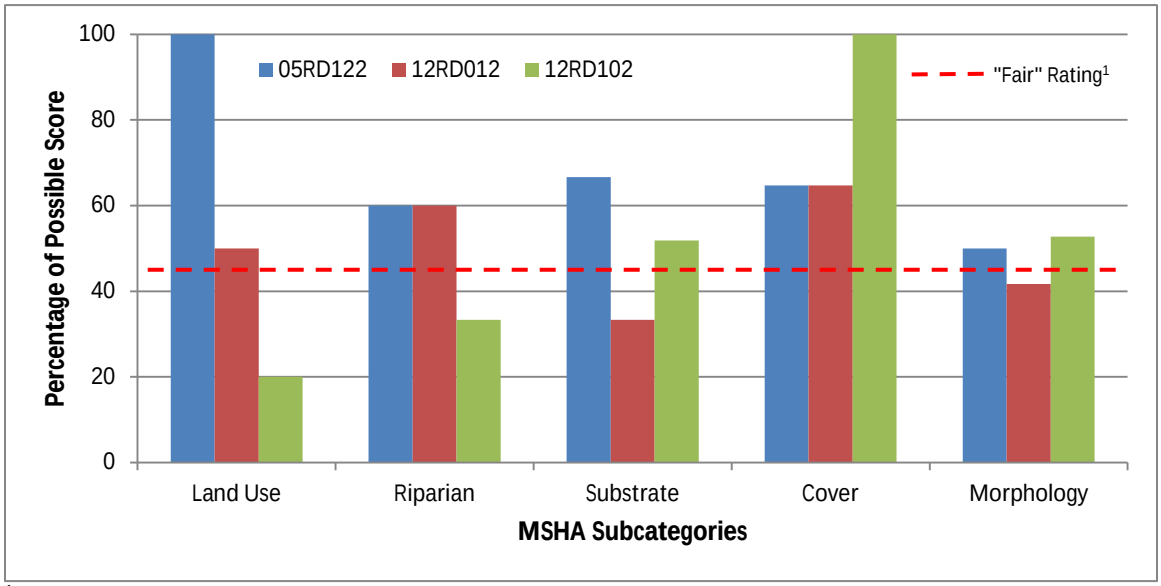
- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- High relative abundance of the dominant five taxa in a subsample (DomFivechpct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Plecoptera (Plecoptera)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- High relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Frequent and/or prolonged periods of minimal to no flow tend to limit species diversity, specifically taxa belonging to the orders of Plecoptera, Ephemeroptera, and Trichoptera (many of which are collector-filterers), and favor taxa that are tolerant of environmental disturbances (EPA, 2012; Klemm et al., 2002, Poff and Zimmerman, 2010). According to Figure 66, seven of the aforementioned individual metrics (i.e., Collector-filtererPct , DomFiveCHPct, Intolerant2Ch, POET, TaxaCountAllChir TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 12RD012. Additionally, four of the individual metrics (i.e., DomFiveCHPct, Plecoptera, Tolerant2ChTxPct, and Trichoptera) were used in the calculation of the M-IBI score for Station 12RD102 (Figure 67). The stations had a "low" score for a majority of these respective metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. Overall, the macroinvertebrate assemblage of both stations was dominated by taxa that are adapted to lentic conditions (e.g., *Caenis*, Coenagrionidae, and *Dubiraphia*).

Lack of instream habitat

Available data

The instream habitat of AUID 558 was evaluated at Stations 05RD122, 12RD012, and 12RD102 using the MSHA; the entire length of the reach is natural (MPCA, 2013). Each of the stations had a total MSHA score in the "fair" range; 05RD122 (61), 12RD012 (46), and 12RD102 (53). According to Figure 70, at least two of the stations scored above the "fair" rating threshold for each of the subcategories. Station 05RD122 exceeded this criterion for all subcategories. The MSHA score for Station 12RD012 was limited by the substrate and channel morphology subcategories, while Station 12RD102 scored poorly in the land use and riparian subcategories. The stations had very limited to no riffle habitat. Additionally, two stations (i.e., 05RD112 and 12RD102) offered coarse substrate; however, the substrate had a "moderate" level of embeddedness. Station 12RD012 entirely lacked coarse substrate.



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

Figure 70. MSHA subcategory results for Stations 05RD122, 12RD012, and 12RD102 along AUID 558.

Biotic response – fish

Evidence of a causal relationship between a lack of instream habitat and the F-IBI impairment associated with AUID 558 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 05RD122, 12RD012, and/or 12RD102:

- Low relative abundance of taxa that are benthic insectivores, excluding tolerant species (Beninsect-TolTxPct)
- Low relative abundance of taxa that are darters, sculpins, and round-bodied suckers (DarterSculpSucTxPct)
- Low relative abundance of individuals that are insectivorous Cyprinids (InsectCyppct)
- Low relative abundance of taxa that are insectivorous, excluding tolerant taxa (Insect-TolTxPct)
- Low relative abundance of individuals that are simple lithophilic spawners (SLithopPct)

Benthic 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). According to Figure 65, three of the aforementioned individual metrics (i.e., DarterSculpSucTXPct, Insect-TolTxPct, and SLithopPct) were used in the calculation of the F-IBI score for each of the monitoring stations. Stations 05RD122, 12RD012, and 12RD102 had a "low" score for each of these metrics, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach.

Biotic response – macroinvertebrate

Evidence of a causal relationship between a lack of instream habitat and the M-IBI impairment associated with AUID 558 is provided by the following individual M-IBI metric responses (Appendix D) for 12RD012 and/or 12RD102:

- High relative abundance of burrower individuals (Burrowerpct)
- Low taxa richness of clinger taxa (ClingerCh)
- Low relative percentage of taxa adapted to cling to substrate in swift flowing water (ClingerChTxPct)
- Low relative abundance of collector-filterer individuals in a subsample (Collector-filtererPct)
- High relative abundance of legless individuals (LeglessPct)

Clinger taxa, including many collector-filterers, require clean, coarse substrate or other objects to attach themselves to, while burrowing and legless macroinvertebrates are tolerant of degraded benthic habitat. According to Figure 66, two of the aforementioned individual metrics (i.e., ClingerCh and Collector-filtererPct) were used in the calculation of the M-IBI score for Station 12RD012. Additionally, one individual metric (i.e., ClingerChTxPct) was used in the calculation of the M-IBI score for Station 12RD102 (Figure 67). The stations had a "low" score for each of these respective metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach.

High suspended sediment

Available data

The reach has an existing turbidity impairment; the reach is part of AUID 530, which was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a water quality sample at Stations 05RD122, 12RD012, and 12RD102 along AUID 558 at the time of fish sampling. The samples were analyzed for several parameters, including TSS. The stations had a TSS concentration substantially below the 65 mg/L standard (8 to 38 mg/L). Table 30 summarizes discrete TSS data for Site S003-943 (CR 52 crossing); the relative location of the site is shown in Figure 64. The site had no exceedances of the TSS standard. Additionally, the RLRW HSPF model estimates that the reach had a TSS concentration in excess of the standard nearly 3% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to occasional periods of high suspended sediment.

Table 30. Discrete TSS data for Site S003-943 along AUID 558.

Site	Date Range	*n*	Min	Max	Mean	% Total Values Above Standard[1]
S003-943	1998-2014	107	0	59	8	0.0

Biotic response – fish

There is no evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 558. None of the individual F-IBI metrics for Stations 05RD122, 12RD012, and 12RD102 exhibited a correlation to this candidate cause. However, the deposition of suspended sediment has caused the aforementioned embeddedness of coarse substrate and the related biotic response associated with Stations 05RD112 and 12RD102.

Biotic response – macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 558 is provided by the following individual M-IBI metric responses (Appendix D) for 12RD012 and 12RD102:

- Low relative abundance of collector-filterer individuals (Collector-filtererPct)
- Low taxa richness of macroinvertebrates with tolerance values less than two (Intolerant2Ch)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

Collector-filterers, including several members of the order Trichoptera, 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). According to Figure 66, four of the aforementioned individual metrics (i.e., Collector-filtererPct , Intolerant2Ch, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 12RD012. One individual metric (i.e., Trichoptera) was used in the calculation of the M-IBI score for Station 12RD102 (Figure 67). The stations had a "low" score for each of these respective metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach. The MPCA also calculated TSS TIVs for the Stations 12RD012 and 12RD102. Both stations had a low number of high TSS intolerant taxa. Additionally, the deposition of suspended sediment has resulted in the embeddedness of coarse substrate and the associated biotic response at Station 12RD102.

Low dissolved oxygen

Available data

The reach has an existing low DO impairment; the reach is part of AUID 530, which was included on the 2012 Impaired Waters List. The MPCA biological monitoring staff collected a discrete DO measurement at Stations 05RD122, 12RD012, and 12RD102 along AUID 558 at the time of sampling. Two of the measurements were below the 5.0 mg/L standard. Stations 12RD012 and 12RD102 had a DO concentration of 2.6 and 2.2. mg/L, respectively, during macroinvertebrate sampling. Figure 71 displays discrete DO data for Site S003-943 (1998-2014; *n*=99). While 18% of the total values were below the standard, only 16 measurements were taken 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 S003-943 (August 14, 2014, to August 27, 2014). Table 31 provides a summary of the monitoring results.

The site had an elevated proportion of daily minimum DO values that were below the standard (28.6%); however, the level of mean daily DO flux was nominal (2.5 mg/L). Additionally, the RLRW HSPF model estimates that the reach had a DO concentration below the standard only 1% of the time during the period of 1996 to 2009. Overall, the available data suggest that the reach is prone to periods of low DO.

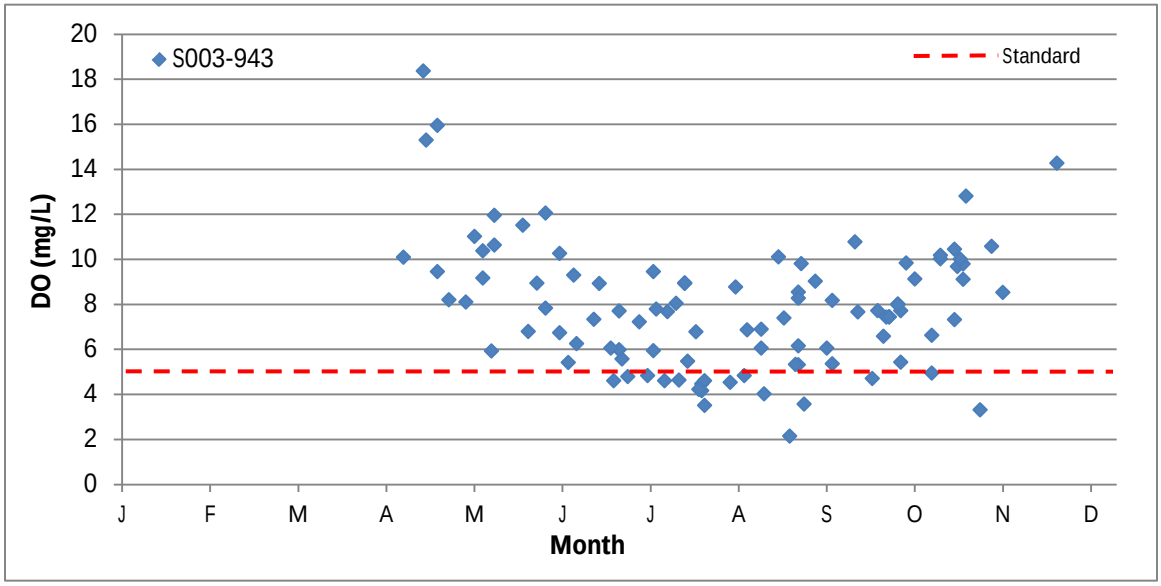


Figure 71. Discrete DO data for Site S003-943 along AUID 558.

Table 31. Continuous DO data for Site S003-943 along AUID 558.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Daily Min. Values Below Standard	% Total Values Below Standard	Mean Daily Flux (mg/L)
S003-943 (MPCA)	Aug. 14, 2014 - Aug 27, 2014	1246	3.9	10.0	28.6	10.0	2.5

Biotic response – fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 558 is provided by the following individual F-IBI metric responses (Appendix C) for Stations 05RD122, 12RD012, and/or 12RD102:

- Low relative abundance of individuals that are intolerant (IntolerantPct)
- Low number of individuals per meter of stream sampled, excluding tolerant taxa (NumperMeter-Tol)
- High relative abundance of individuals that are tolerant (TolPct)
- High relative abundance of taxa that are tolerant (TolTxPct)

Low DO often results in a limited fish community that is dominated by tolerant taxa (EPA, 2012). According to Figure 65, the IntolerantPct metric was used in the calculation of the F-IBI score for each of the monitoring stations. Stations 05RD122, 12RD012, and 12RD102 had a "low" score for this metric, thereby negatively affecting the overall F-IBI scores and directly contributing to the biological impairment of the reach. Sandberg (2014) utilized TIVs to estimate the likelihood of each station

meeting the DO standard based upon its sampled fish assemblage (Appendix C). All of the station had a relatively low probability (14-20%) of meeting the standard.

Biotic response – macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 558 is provided by the following individual M-IBI metric responses (Appendix D) for 12RD012 and/or 12RD102:

- High Hilsenhoff's Biotic Index value (HBI_MN)
- Low taxa richness of macroinvertebrates with tolerance values less than or equal to two (Intolerant2Ch)
- Low taxa richness of Plecoptera (Plecoptera)
- Low taxa richness of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness of macroinvertebrates (TaxaCountAllChir)
- High relative percentage of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low taxa richness of Trichoptera (Trichoptera)
- Low relative percentage of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative abundance of non-hydropsychid Trichoptera individuals in a subsample (TrichwoHydroPct)

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 (EPA, 2012; Weber, 1973). According to Figure 66, six of the aforementioned individual metrics (i.e., HBI_MN, Intolerant2Ch, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI score for Station 12RD012. Four of the metrics (i.e., HBI_MN, Plecoptera, Tolerant2ChTxPct, and Trichoptera) were used in the calculation of the M-IBI score for Station 12RD102 (Figure 67). The stations had a "low" score for a majority of these respective metrics, thereby negatively affecting the overall M-IBI scores and directly contributing to the biological impairment of the reach.

The MPCA also calculated DO TIVs for the Stations 12RD012 and 12RD102. Both stations had a high percentage of low DO tolerant taxa and a low number of low DO intolerant taxa.

Strength-of-evidence analysis

Table 32 presents a summary of the SOE scores for the various candidate causes associated with AUID 558. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: loss of physical connectivity, lack of base flow, lack of instream habitat, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of the following stressors: lack of base flow, lack of instream habitat, high suspended sediment, and low DO. For additional information regarding the SOE scoring system, refer to the EPA's CADDIS Summary Table of Scores.

Table 32. SOE scores for candidate causes associated with AUID 558.

Types of Evidence	SOE Scores for Candidate Causes[1]									
	Loss of Physical Connectivity		Lack of Base Flow		Lack of Instream Habitat		High Suspended Sediment		Low Dissolved Oxygen	
	Biological Impairment(s)									
	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	+++	--	++	++	++	++	+	+	++	++
Temporal Sequence	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Stressor-Response Relationship	+++	--	++	++	++	++	+	+	++	++
Causal Pathway	+++	--	++	++	++	++	+	+	++	++
Evidence of Exposure/Bio-Mechanism	+++	--	++	++	++	++	+	+	++	++
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	+++	--	++	++	++	++	+	+	++	++
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	**+++**	**--**	**++**	**++**	**++**	**++**	**+**	**+**	**++**	**++**

[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 33 presents a summary of the stressors associated with the biologically impaired reaches in the RLRW. A lack of base flow was identified as a stressor for all of the reaches and their related biological impairments. Many of the reaches are prone to periods of low DO, which appear to coincide with low flow conditions. Several of the reaches have a lack of instream habitat (e.g., clean, coarse substrate). High suspended sediment is contributing to nearly all of the M-IBI impairments in the watershed. Lastly, a loss of physical connectivity is a stressor for the F-IBI impairment associated with AUID 528 (Little Black River) and 558 (Black River).

Table 33. Summary of the stressors associated with the biologically impaired reaches in the RLRW.

AUID Suffix	Reach Name	Biological Impairment(s)	Stressors[1]				
			Loss of Physical Connectivity	Lack of Base Flow	Lack of Instream Habitat	High Suspended Sediment	Low Dissolved Oxygen
515	Burnham Creek	F-IBI		++	++	+	++
		M-IBI		++	++	+	++
525	Kripple Creek	F-IBI		++	+		+
		M-IBI		++	+	+	+
526	Kripple Creek	F-IBI		++	++	+	+
		M-IBI		++	++	+	+
528	Little Black River	F-IBI	+++	++	++	+	+++
545	County Ditch 96	F-IBI		+++			+++
547	County Ditch 43	F-IBI		+++	++		+++
		M-IBI		+++	++		+++
551	Burnham Creek	F-IBI		++	++		+
		M-IBI		++	++	+	+
554	Gentilly River	F-IBI		+++	++	+	++
		M-IBI		+++	++	+	++
556	Cyr Creek	F-IBI		+++			++
558	Black River	F-IBI	+++	++	++	+	++
		M-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.

4.2 Recommendations

The biologically impaired reaches of the RLRW have the potential to support healthier fish and macroinvertebrate communities. The recommended management actions specified below and included in the MPCA's Aquatic Biota Stressor and Best Management Practice (BMP) Relationship Guide (Appendix E) will help to reduce the influence of the stressors that are limiting these communities. Whenever possible, actions should be implemented progressing from upstream to downstream.

- Prevent or mitigate activities that will further alter the hydrology of the watershed.
- Consider opportunities and options to reduce peak flows and increase base flows throughout the watershed.
- Re-establish natural functioning stream channels wherever possible using natural channel design principles.
- Increase the quantity and quality of instream habitat throughout the watershed.
- Establish and/or protect riparian corridors along all waterways, including ditches, using native vegetation whenever possible.
- Implement agricultural BMPs to reduce soil erosion.
- Limit or exclude the access of livestock to waterways.
- Remove or retrofit private watercourse crossings (e.g., "Texas" crossings) that are obstructing connectivity.
- Conduct an inventory of culverts in the watershed that are limiting fish passage.

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