Lower Red River of the North Watershed Stressor Identification Report

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

Stephen Dam

Minnesota Pollution Control Agency

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Authors

Michael Sharp (MPCA)
Bruce Paakh (MPCA)

Contributors/acknowledgements

Elizabeth Anderson (MPCA)
Chandra Carter (MPCA)
Joseph Hadash (MPCA)
Cary Hernandez (MPCA)
Stephanie Klamm (MDNR)
Joe Magee (MPCA)
Tara Mercil (MPCA)
Nathan Mielke (MPCA)
Danny Omdahl (MSTRWD)
Michael Vavricka (MPCA)

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Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 |

651-296-6300 | 800-657-3864 | Or use your preferred relay service. | Info.pca@state.mn.us

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Acronyms

AUID – Assessment Unit Identification

BEHI – Bank Erosion Hazard Index

BMP – Best Management Practices

CADDIS – Causal Analysis/Diagnosis Decision Information System

CSAH – County State Aid Highway

DO – Dissolved Oxygen

EPA – U. S. Environmental Protection Agency

HSPF – Hydrological Simulation Program - FORTRAN

HUC – Hydrologic Unit Code

IBI – Index of Biological Integrity

IWM – Intensive Watershed Monitoring

LRRNW – Lower Red River of the North Watershed

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 Dataset

SI – Stressor identification

SOE – Strength-of-Evidence

TALU – Tiered Aquatic Life Use

TIVs – Tolerance Indicator Values

TMDL – Total Maximum Daily Load

TSS – Total Suspended Solids

USGS – United States Geological Survey

WHAF – Watershed Health Assessment Framework

Executive summary

The Minnesota Pollution Control Agency (MPCA) follows a watershed approach to systematically monitor and assess surface water quality in each of the state's 80 major watersheds. A key component of this approach is Intensive Watershed Monitoring (IWM), which includes biological (i.e., fish and macroinvertebrate) monitoring to evaluate overall stream health. In 2008, the MPCA conducted biological monitoring at several stations in the Lower Red River of the North Watershed (LRRNW). 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 LRRNW were formally assessed as part of the development of the *Lower Red River of the North Watershed Monitoring and Assessment Report* (MPCA, 2013a) to determine if individual stream reaches, denoted by their respective Assessment Unit Identification (AUID) number, met applicable aquatic life standards. One reach in the watershed was found to be supporting both a healthy fish and macroinvertebrate community (i.e., AUID 511/Tamarac River from its headwaters, to the Florian Dam), while one reach was determined to be "impaired" due to a poor fish and macroinvertebrate community (i.e., AUID 503/Tamarac River from the Florian Dam, to the Stephen Dam). The assessments for 13 other reaches in the LRRNW were deferred due to extensive channelization (>50%), pending the future implementation of the MPCA's Tiered Aquatic Life Use (TALU) standards.

This report identifies the causes, or "stressors", that are likely contributing to the biological impairments associated with AUID 503. Five candidate causes were examined as potential stressors in the report: loss of longitudinal connectivity, flow regime alteration, lack of physical habitat, high suspended sediment, and low dissolved oxygen (DO). Causal analysis was performed to determine and evaluate connections between each candidate cause and the biological impairments. Table 1 ranks the stressors identified for AUID 503 by the strength of supporting evidence.

Table 1. Summary of the stressors associated with AUID 503.

AUID Suffix	Reach Name	Biological Impairments	Candidate Causes[1]				
			Loss of Longitudinal Connectivity	Flow Regime Alteration	Lack of Physical Habitat	High Suspended Sediment	Low Dissolved Oxygen
503	Tamarac 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.

The reach is situated between two dams (i.e., Florian and Stephen dams) that obstruct fish passage, thereby severely limiting the potential of the fish community. Flow regime alteration attributed to the dams and intensive agricultural drainage appears to be inhibiting biotic diversity, particularly along the lower half of AUID 503. The available data also suggests that these hydrologic alterations are contributing to the degradation of physical habitat, high suspended sediment, and low DO conditions that are adversely affecting the fish and macroinvertebrate communities of the reach. These conditions are most pronounced along the downstream extent of the reach.

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.

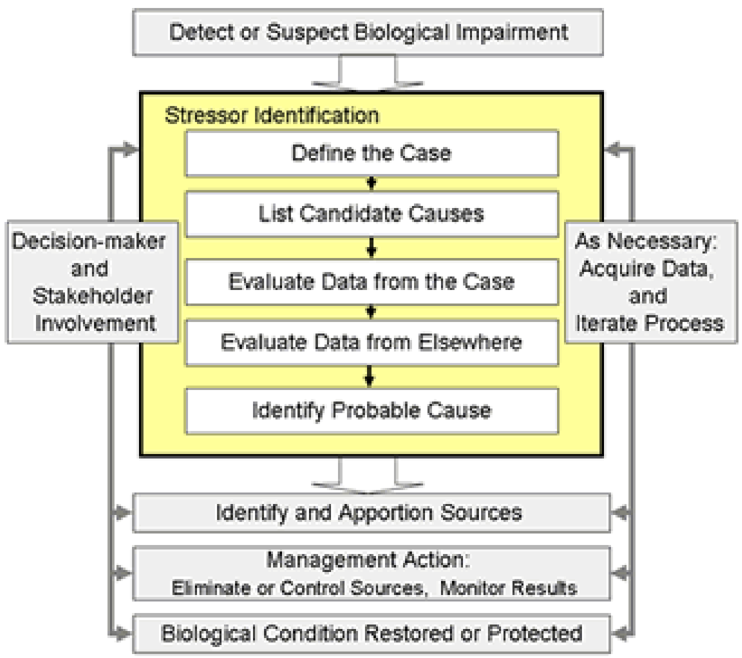


Figure 1. Conceptual model of the SI process (EPA 2012).

Section 1: Watershed overview

1.1 Physical setting

The LRRNW, United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 09020311, is situated in northwestern Minnesota and is part of the larger Red River of the North Basin. The LRRNW has a drainage area of 886 square miles and encompasses portions of the following counties, listed in order of the percentage of watershed area: Kittson (54%), Marshall (45%), and Roseau (1%). Cities in the watershed include Donaldson, Halma, Humboldt, Karlstad, Kennedy, Saint Vincent, Stephen, and Strandquist.

1.2 Surface water resources

The Tamarac River is the prominent surface water feature in the LRRNW and extends from its headwaters, situated northwest of Strandquist, to its confluence with the Red River of the North, located west of Stephen. The LRRNW contains 140 miles of perennial stream and river (e.g., Tamarac River), 355 miles of intermittent stream, 24 miles of perennial drainage ditch, and 471 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013b), 72% of the watercourses in the LRRNW have been hydrologically altered (i.e., channelized, ditched, or impounded). There are no lakes in the watershed.

1.3 Geology and soils

The LRRNW intersects the following distinct physiographic regions: till plain, beach ridges, and lake plain. The till plain region extends from the eastern (i.e., upstream) boundary of the watershed, to approximately Karlstad. This region is characterized by a slightly undulating topography and loam soils derived 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 six miles wide through the center of the LRRNW, from the eastern extent of the till plain region, to approximately the unincorporated community of Florian. This region represents the ancient shorelines of glacial Lake Agassiz. The Tamarac River drops roughly 110 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 located on the lake plain formed by glacial Lake Agassiz. This region 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 LRRNW is agricultural crop production. According to the National Land Cover Database (NLCD) 2006 (USGS, 2006), cultivated crops comprised 79% of the watershed. Notable minor land cover groups in the watershed included wetlands (7%) forest (6%), developed areas (5%), hay/pasture (2%), and open water (1%). These minor cover groups were primarily found in the till plain and beach ridges physiographic regions. The entire watershed is located within the Red River Valley ecoregion.

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 LRRNW. The mean health score for the watershed was 44. The overall score was limited by the individual mean component scores for biology (37) and connectivity (15). Specifically, the watershed scored poorly for the following component indices: water quality assessments (40), surface storage (34), at-risk species richness (30), dams (28), aquatic connectivity (20), storage (18), riparian connectivity (17), perennial cover (15), bridges/culverts (13), climate vulnerability (11), terrestrial habitat connectivity (7), terrestrial habitat quality (5), and stream/ditch ratio (2).

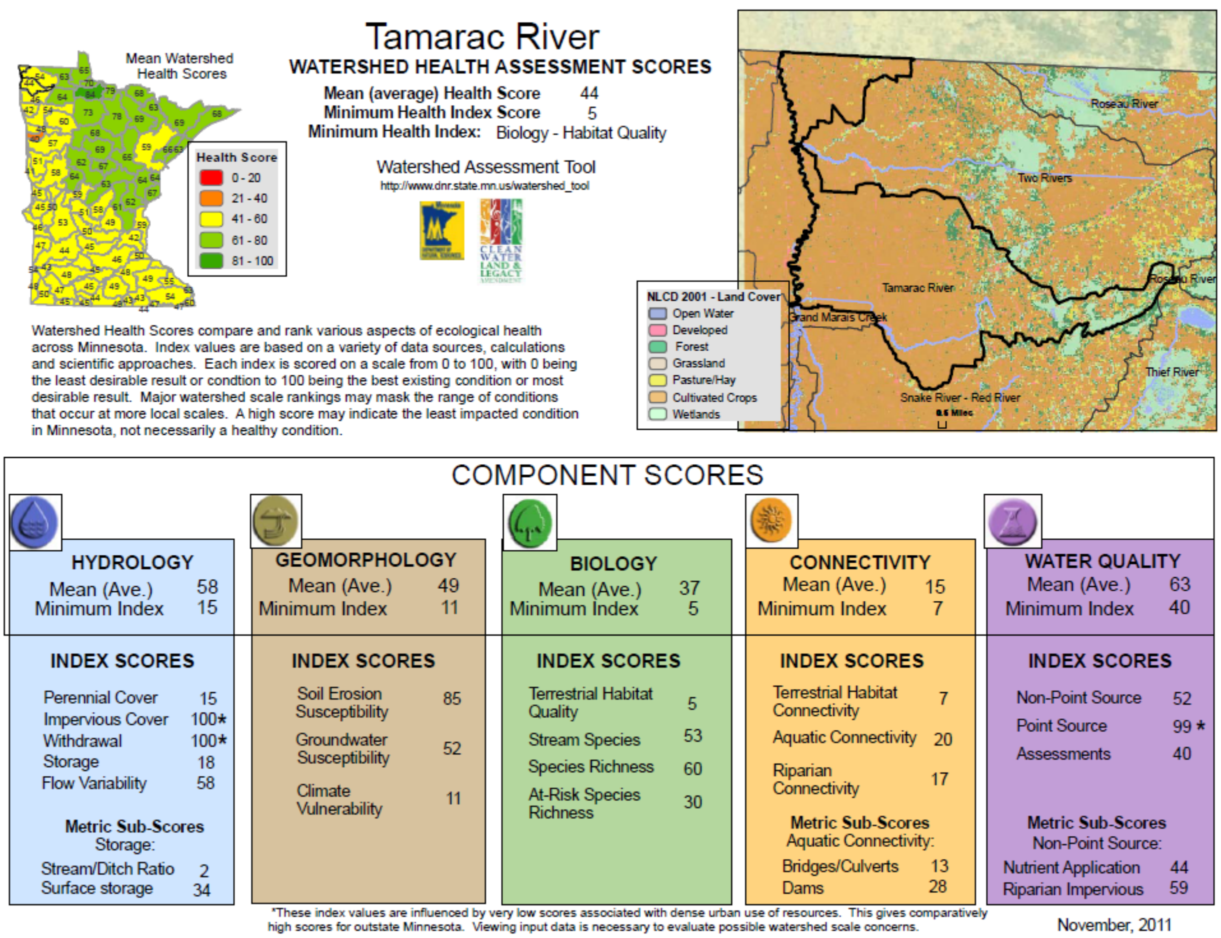


Figure 2. Watershed health assessment scores for the LRRNW.

1.6 Hydrological Simulation Program - FORTRAN model

A Hydrological Simulation Program - FORTRAN (HSPF) model was developed for the LRRNW 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 and non-point source models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient concentrations, along with a time history of water quantity and quality at the outlet of each subwatershed. The HSPF model outputs were used in the evaluation of several of the candidate causes outlined in this report.

Section 2: Biological monitoring and impairments

2.1 Watershed approach

The MPCA utilizes a watershed approach (Figure 3) to systematically monitor and assess surface water quality in each of the state's 80 major watersheds. A key component of this approach is IWM, which includes biological (i.e., fish and macroinvertebrate) monitoring to evaluate overall stream health. In 2008, the MPCA conducted biological monitoring at several stations throughout the LRRNW. An IBI core 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 LRRNW are the focus of this SI report. The results f 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.

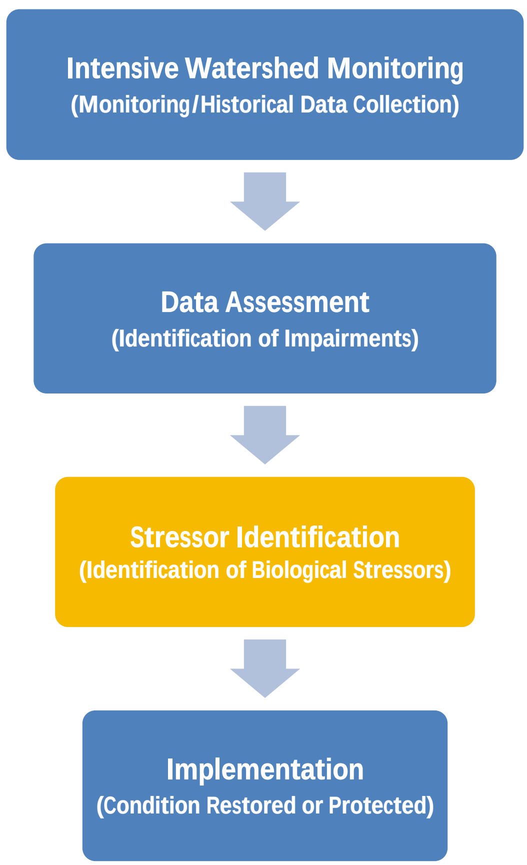


Figure 3. Conceptual model of the watershed approach processes.

2.2 Monitoring stations

Table 2 lists the 21 biological monitoring stations that were sampled for fish and/or macroinvertebrates in the LRRNW. The stations are situated along 15 separate reaches. For the purpose of this report, individual reaches will be referred to by their respective three digit AUID number suffix.

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

AUID Suffix	AUID	Reach Name	Monitoring Station(s)
503	09020311-503	Tamarac River	05RD042, 05RD179, 08RD007, 08RD015, 08RD031
505	09020311-505	Tamarac River	08RD001, 08RD024
509	09020311-509	County Ditch 27	08RD003, 08RD027
511	09020311-511	Tamarac River	08RD042
513	09020311-513	Joe River	93RD400
516	09020311-516	Judicial Ditch 19	08RD014
518	09020311-518	County Ditch 10	08RD036
521	09020311-521	Judicial Ditch 10	08RD035
524	09020311-524	Judicial Ditch 10	08RD002
526	09020311-526	State Ditch 90	08RD010
527	09020311-527	Lateral Ditch 5	08RD011
538	09020311-538	State Ditch 1	08RD023
540	09020311-540	Unnamed Creek	08RD037
541	09020311-541	Judicial Ditch 19	08RD016
545	09020311-545	Judicial Ditch 19	08RD004

2.3 Monitoring results

Table 3 provides the F-IBI and M-IBI scores for each of the biological monitoring stations in the LRRNW. A total of 12 stations (57%) scored below the F-IBI impairment threshold, while 15 stations (83%) scored below the M-IBI impairment threshold; these stations are highlighted red.

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

Fish					Macroinvertebrate				
AUID Suffix	Station	F-IBI Class[1]	F-IBI Impairment Threshold	F-IBI Score (Mean)	AUID Suffix	Station	M-IBI Class[2]	M-IBI Impairment Threshold	M-IBI Score (Mean)
503	05RD042	SS	45	51	503	05RD042	PSGP	38	71
503	05RD179	SS	45	45	**503**	**05RD179**	**PSGP**	**38**	**34**
503	**08RD007**	**SS**	**45**	**34**	**503**	**08RD007**	**PSGP**	**38**	**21**
503	**08RD015**	**SS**	**45**	**44**	**503**	**08RD015**	**PSGP**	**38**	**33**
503	**08RD031**	**SS**	**45**	**30**	**503**	**08RD031**	**PSGP**	**38**	**26**
505	08RD001	SR	46	52	**505**	**08RD001**	**PSGP**	**38**	**24**
505	**08RD024**	**SR**	**46**	**42**	**505**	**08RD024**	**PSGP**	**38**	**24**
509	**08RD003**	**SS**	**45**	**36**	509	Not Sampled (Insufficient Flow)			
509	**08RD027**	**SS**	**45**	**0**	**509**	**08RD027**	**PSGP**	**38**	**19**
511	08RD042	NS	50	51	511	08RD042	SSRR	36	52
513	**93RD400**	**SS**	**45**	**0**	**513**	**93RD400**	**PSGP**	**38**	**9**
516	**08RD014**	**NS**	**50**	**38**	516	08RD014	PSGP	38	70
518	08RD036	LG	40	44	**518**	**08RD036**	**PSGP**	**38**	**10**
521	**08RD035**	**SS**	**45**	**0**	**521**	**08RD035**	**PSGP**	**38**	**19**
524	**08RD002**	**SS**	**45**	**0**	**524**	**08RD002**	**PSGP**	**38**	**10**
526	08RD010	LG	40	56	**526**	**08RD010**	**PSGP**	**38**	**28**
527	08RD011	NH	40	63	**527**	**08RD011**	**PSGP**	**38**	**17**
538	**08RD023**	**SS**	**45**	**30**	538	Not Sampled (Insufficient Flow)			
540	08RD037	LG	40	41	**540**	**08RD037**	**PSGP**	**38**	**26**
541	**08RD016**	**NH**	**40**	**38**	541	Not Sampled (Insufficient Flow)			
545	08RD004	NH	40	40	**545**	**08RD004**	**SSRR**	**36**	**28**

[1] F-IBI Classes: Low Gradient (LG), Northern Headwaters (NH), Northern Streams (NS), Southern Rivers (SR), and Southern Streams (SS)
[2] M-IBI Classes: Prairie Streams-Glide/Pool Habitats (PSGP) and Southern Streams-Riffle/Run Habitats (SSRR)

2.4 Assessments and impairments

The biological monitoring results for the LRRNW were formally assessed as part of the development of the *Lower Red River of the North Watershed Monitoring and Assessment Report* (MPCA, 2013a) to determine if individual stream reaches met applicable aquatic life standards. Table 4 lists the 15 reaches in the watershed with associated biological monitoring data. One reach in the LRRNW was found to be supporting both a healthy fish and macroinvertebrate community (i.e., AUID 511/Tamarac River from its headwaters, to the Florian Dam), while one reach was determined to be "impaired" (highlighted red) due to a poor fish and macroinvertebrate community (i.e., AUID 503/Tamarac River from the Florian Dam, to the Stephen Dam). The relative location of AUID 503 is displayed in Figure 4. The assessments for 13 other reaches in the watershed were deferred due to extensive channelization (>50%), pending the future implementation of the MPCA's TALU standards.

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

AUID Suffix	AUID	Reach Name	Description	Length (mi)	Biological Impairment(s)
503	**09020311-503**	**Tamarac River**	**Florian Dam to Stephen Dam**	**36**	**F-IBI, M-IBI**
505	09020311-505	Tamarac River	Stephen Dam to Red River	16	Not Assessed
509	09020311-509	County Ditch 27	Headwaters to Red River	32	Not Assessed
511	09020311-511	Tamarac River	Headwaters to Florian Dam	26	None
513	09020311-513	Joe River	Salt Coulee to MN/Canada Border	3	Not Assessed
516	09020311-516	Judicial Ditch 19	Headwaters to Tamarac River	13	Not Assessed
518	09020311-518	County Ditch 10	Unnamed Creek to Unnamed Creek	4	Not Assessed
521	09020311-521	Judicial Ditch 10	Unnamed Creek to County Ditch 16	8	Not Assessed
524	09020311-524	Judicial Ditch 10	Unnamed Ditch to County Ditch 19	2	Not Assessed
526	09020311-526	State Ditch 90	Unnamed Ditch to Lateral Ditch 5	2	Not Assessed
527	09020311-527	Lateral Ditch 5	Headwaters to State Ditch 90	6	Not Assessed
538	09020311-538	State Ditch 1	Unnamed Creek to Unnamed Creek	7	Not Assessed
540	09020311-540	Unnamed Creek	Unnamed Creek to County Ditch 10	2	Not Assessed
541	09020311-541	Judicial Ditch 19	Unnamed Ditch to Unnamed Ditch	4	Not Assessed
545	09020311-545	Judicial Ditch 19	Unnamed Ditch to Unnamed Ditch	2	Not Assessed

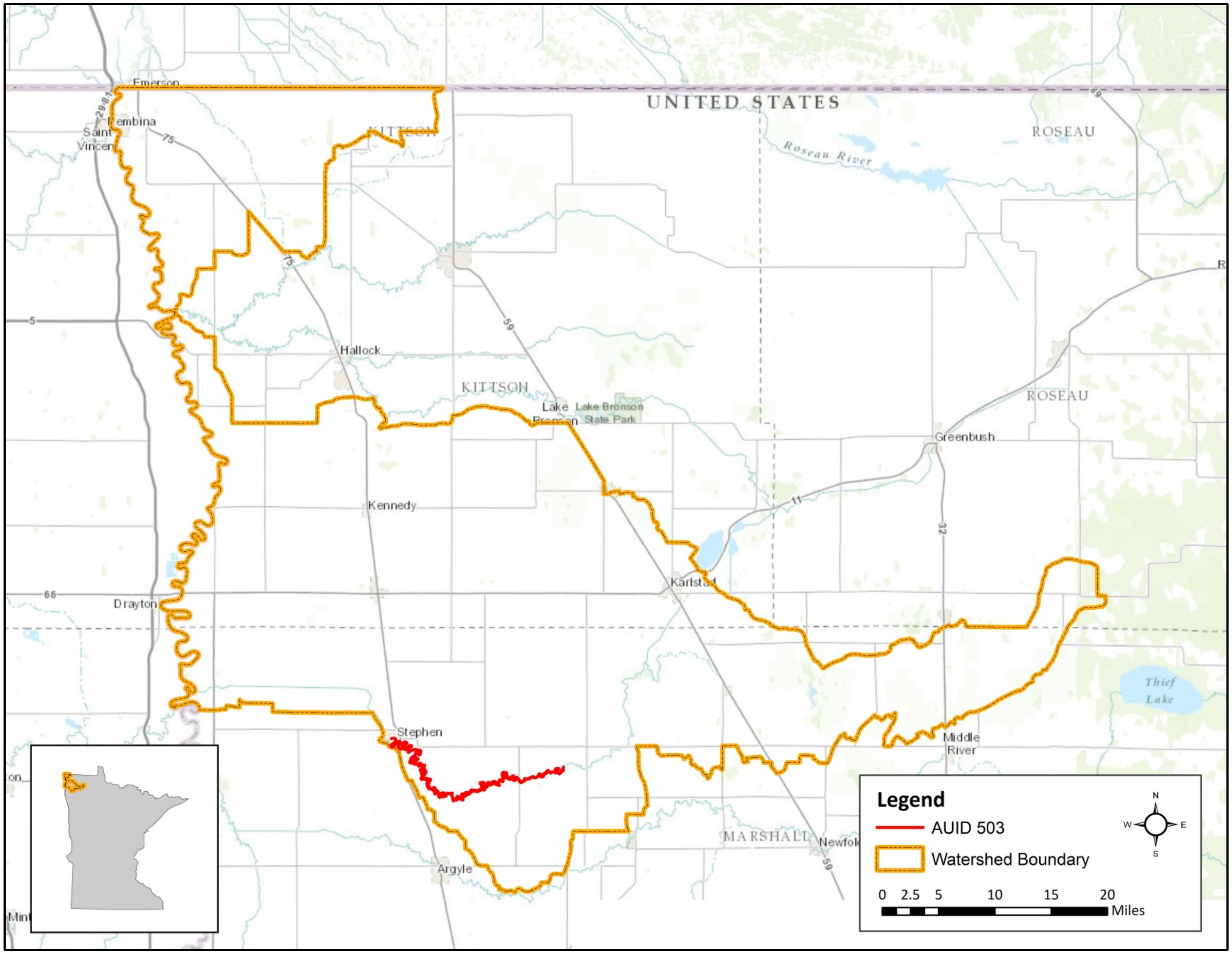


Figure 4. Map of the LRRNW and AUID 503.

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 5 lists the 10 common biotic stressors that were considered as potential candidate causes for AUID 503. 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 *Lower Red River of the North Monitoring and Assessment Report* (MPCA, 2013a), the *Middle-Snake-Tamarac Rivers Watershed District's Ten Year Watershed Management Plan* (MSTRWD, 2011), and the *Red River Basin Stream Survey Report: Snake River and Tamarac River Watersheds 2006* (Groshens, 2007). Based upon the results of this evaluation, five candidate causes were identified to undergo causal analysis (highlighted red) in Section 3.3.

Table 5. Summary of common biotic stressors evaluated as potential candidate causes for AUID 503.

Stressor	Summary of Available Information	Candidate Cause (Yes/No)
Loss of Longitudinal Connectivity	The reach is situated between two dams that completely obstruct fish passage.	**Yes**
Flow Regime Alteration	The flow regime of the reach has been altered by intensive agricultural drainage and the dams.	**Yes**
Lack of Physical Habitat	There are segments of the reach that have insufficient physical habitat (e.g., clean, coarse substrate) to support a healthy biotic community.	**Yes**
High Suspended Sediment	The discrete total suspended solids data (2002-2010; *n*=69) for the reach had a range of 3 to 69 mg/L. The data indicates that the reach is prone to high suspended sediment.	**Yes**
Low Dissolved Oxygen	The discrete dissolved oxygen data (1999-2014; *n*=154) for the reach had a range of 4.2 to 14.1 mg/L. The data indicates that the reach is prone to low dissolved oxygen.	**Yes**
Eutrophication	The discrete total phosphorus data (1999-2010; *n*=80) for the reach had a range of 0.03 to 0.291 mg/L. The discrete chlorophyll-a data (2009-2010; *n*=60) for the reach had a range of 1 to 12 µg/L. Additionally, continuous dissolved oxygen data (August 14, 2014-August 27, 2014; *n*=1243) had a range of 3.5 to 7.5 mg/L, with a mean daily flux of 1.0 mg/L. The data suggests that the reach is not prone to the effects of eutrophication.	No
High Nitrate-Nitrite	The discrete inorganic nitrogen data (1999-2010; *n*=83) for the reach had a range of 0.02 to 0.7 mg/L, which is below the level expected to cause stress to aquatic biota.	No
Temperature Regime Alteration	The discrete temperature data (1999-2014; *n*=155) for the reach had a range of 0.1-25°C, which is within a range that is not expected to cause stress to aquatic biota.	No
pH	The discrete pH data (1999-2014; *n*=151) for the reach had a range of 7.1-8.8, which is within a range that is not expected to cause stress to aquatic biota.	No
Pesticide Toxicity	There is no pesticide data for the reach. As a result, there is insufficient information to declare pesticide toxicity as a candidate cause at this time.	No

3.2 Overview of candidate causes

3.2.1 Loss of longitudinal connectivity

Background

Longitudinal 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 interfere with longitudinal connectivity, often obstructing the movement of migratory fish and altering stream flow, water temperature regime, and sediment transport processes. The loss of connectivity can adversely affect the population and structure of the fish community upstream and downstream of a dam (Aadland, 2015; Brooker, 1981; Tiemann et al., 2004). Culverts and beaver dams can also interfere with longitudinal connectivity. A culvert that is raised (perched) above the stream level can limit the migration of fish. A similar phenomenon can occur naturally with beaver dams.

Applicable standards

There are no applicable standards for longitudinal 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 Flow regime alteration

Background

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

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

Applicable standards

There are no specific standards for flow regime alteration. However, the LRRNW intersects three separate watershed districts (i.e., Joe River, Middle-Snake-Tamarac Rivers, and Two Rivers) that regulate many drainage-related activities.

3.2.3 Lack of physical 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 LRRNW. 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 physical habitat as a candidate cause for impairment.

Applicable standards

There are no applicable standards for physical habitat.

3.2.4 High suspended sediment

Background

Total suspended solids (TSS) is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water. Klimetz and Simon (2008) indicated that streams in the Red River of the North Basin had the highest median suspended sediment concentration of any region in Minnesota, with the exception of the Western Corn Belt Plains ecoregion (e.g., the Minnesota River Basin). Soil erosion from agricultural fields is a substantial source of sediment to streams in the basin (Brigham et al., 2001; Lauer et al., 2006; Paakh 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, thereby impeding photosynthetic activity and limiting 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 biologically impaired segment of the Tamarac River (i.e., AUID 503) is located within the Southern River TSS Region. The state TSS standard for this region is 65 mg/L.

3.2.5 Low dissolved oxygen

Background

Dissolved oxygen 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), a 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 DO 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 AUID 503.

3.3 Causal analysis

3.3.1 Tamarac River (AUID 503)

Physical setting

This reach represents the segment of the Tamarac River from the Florian Dam, to the Stephen Dam; a total length of 36 miles. The reach has a subwatershed area of 283 square miles (181,171 acres). Although the reach is located in the lake plain region of the LRRNW, a majority of its subwatershed lies in the till plain and beach ridges regions. The subwatershed contains 65 miles of perennial stream and river (e.g., Tamarac River), 103 miles of intermittent stream, 16 miles of perennial drainage ditch, and 133 miles of intermittent drainage ditch (MDNR, 2003). According to the MPCA (2013b), 68% of the watercourses in the subwatershed have been hydrologically altered (i.e., channelized, ditched, or impounded), including 4% of AUID 503. The NLCD 2006 (USGS, 2006) lists cultivated crops (62%) as the predominant land cover in the subwatershed. Notable secondary land cover groups in the subwatershed included wetlands (17%), forest (12%), developed areas (4%), and pasture/hay (4%).

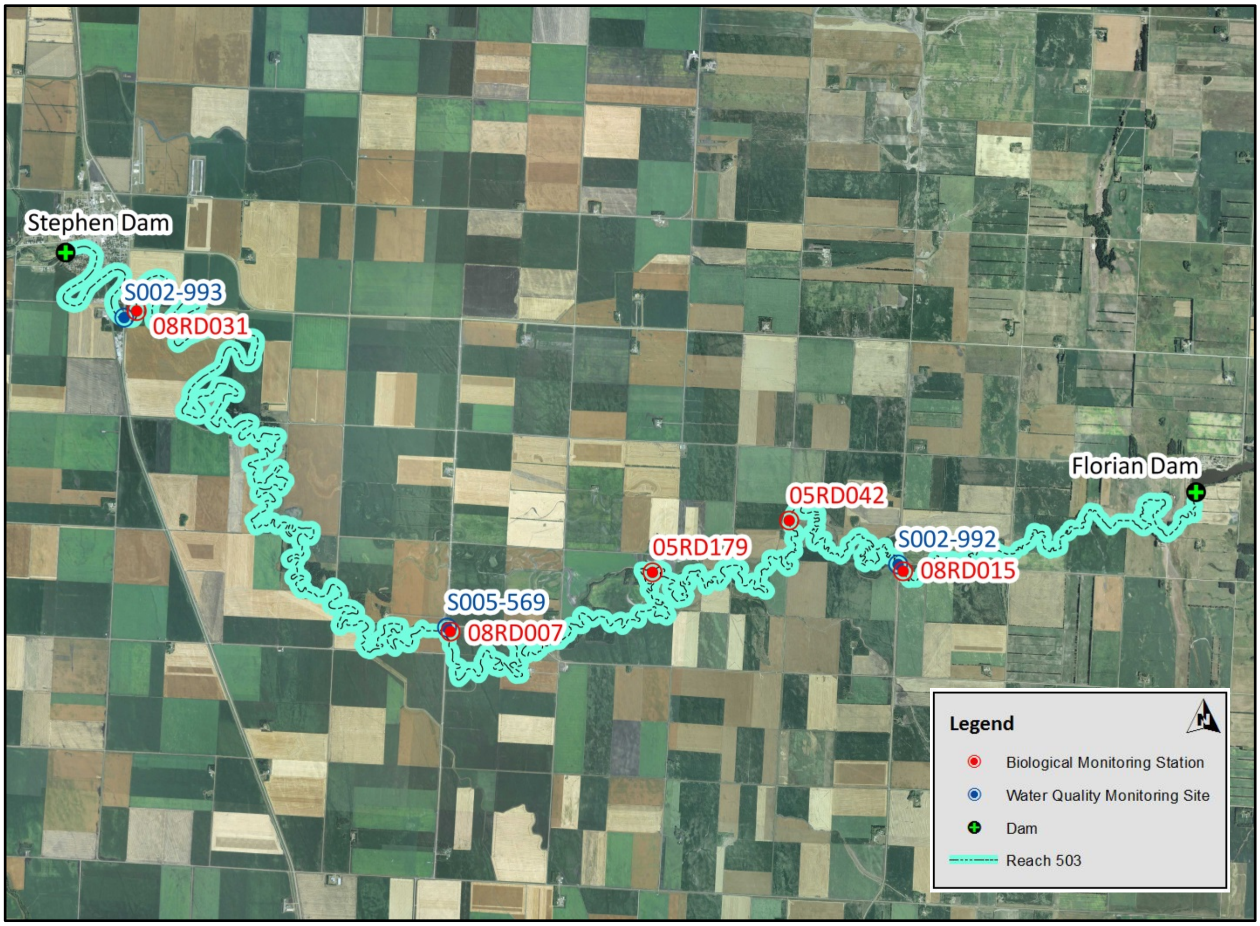


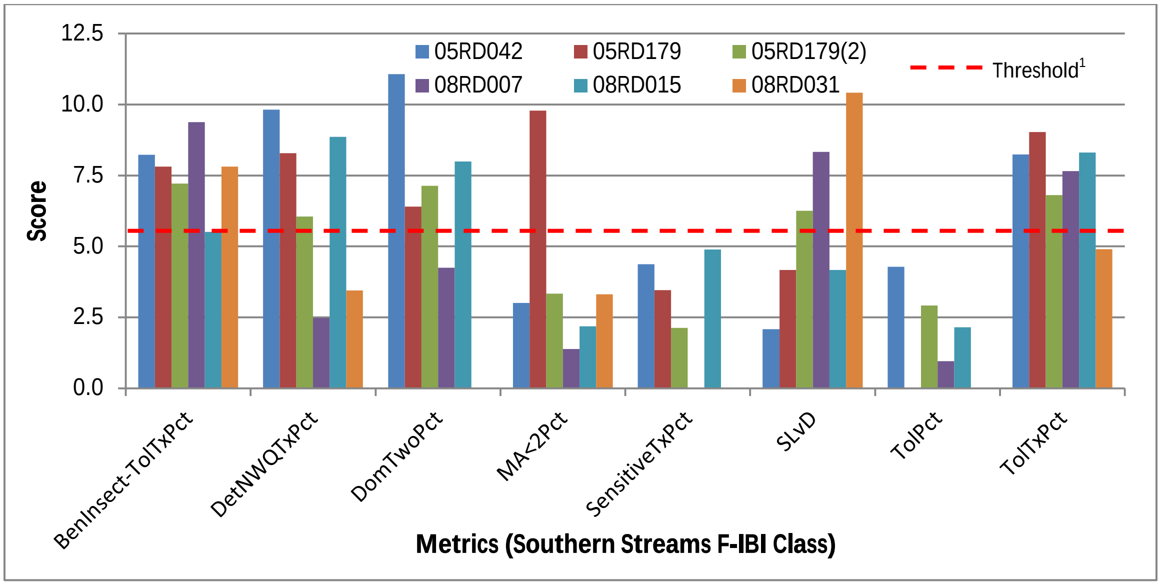
Figure 5. Map of AUID 503 and associated biological monitoring stations and water quality monitoring sites (2006 NAIP aerial image).

Biological impairments

Fish (F-IBI)

The fish community of AUID 503 was monitored at Station 05RD042 (2.0 mi upstream of the 325th Avenue NW crossing) on June 29, 2006, Station 05RD179 (2.0 mi downstream of the 325th Avenue NW crossing) on June 28, 2006 and August 8, 2006, Station 08RD007 (0.1 mi upstream of the 350th Avenue NW crossing) on September 3, 2008, Station 08RD015 (0.1 mi upstream of the 310th Avenue NW crossing) on July 16, 2008, and Station 08RD031 (0.2 mi upstream of the US Hwy. 75 crossing) on September 3, 2008. The relative location of the stations is shown in Figure 5. The stations are included in the Southern Streams F-IBI Class. Accordingly, the applicable impairment threshold for these stations is an F-IBI score of 45. Stations 08RD015 (F-IBI=44), 05RD042 (F-IBI=51), and 05RD179 (F-IBI=42 and 49), which are located along the upstream extent of the reach, each had a score(s) near the impairment threshold, while further downstream, Stations 08RD007 (F-IBI=34) and 08RD031 (F-IBI=30) each scored substantially below the threshold.

Figure 6 provides the individual F-IBI metric scores for the fish monitoring stations along AUID 503; a description of each metric is provided in Appendix A. At least one of the stations had a "low" score for each of the metrics. Collectively, the stations had the lowest scores for the following metrics: MA<2Pct, SensitiveTxPct, and TolPct. Overall the fish assemblage of the stations was dominated by tolerant species (i.e., black bullhead, creek chub, fathead minnow, and white sucker).



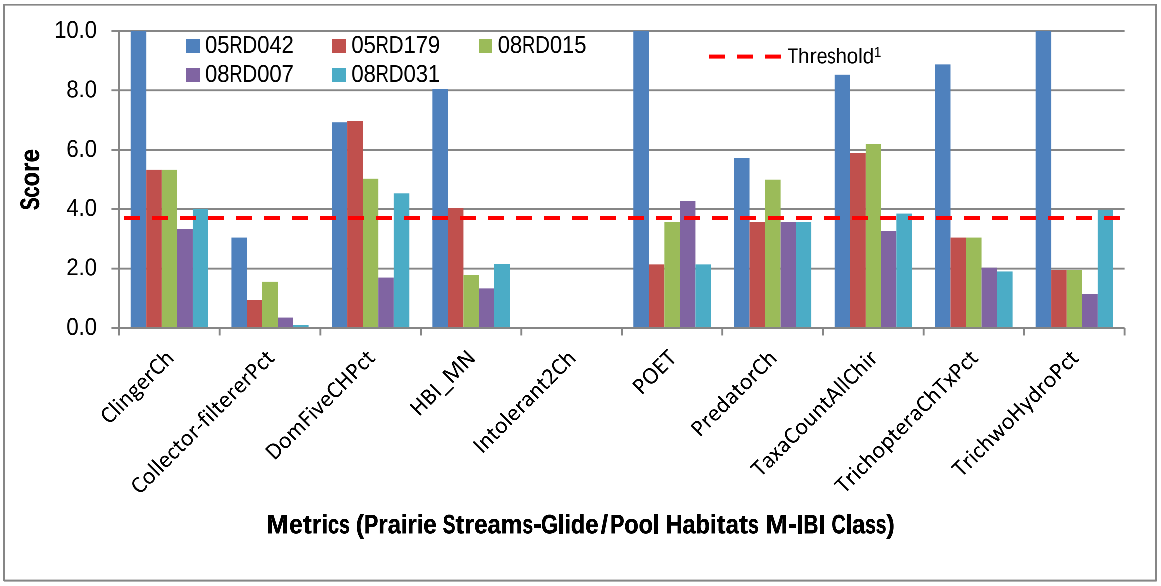
[1] The mean individual metric score needed for the station to meet its applicable impairment threshold. An individual metric score below this level is considered "low" and is contributing to the biological impairment.

Figure 6. Individual F-IBI metric scores for Stations 05RD042, 05RD179, 08RD007, 08RD015, and 08RD031 along AUID 503.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of AUID 503 was monitored at Station 05RD042 on September 29, 2005, Station 05RD179 on August 16, 2006, Station 08RD007 on September 10, 2008, Station 08RD015 on September 10, 2008, and Station 08RD031 on September 11, 2008. The stations are included in the Prairie Streams-Glide/Pool M-IBI Class. Accordingly, the impairment threshold for these stations is an M-IBI score of 38. Only Station 05RD042 (M-IBI=71) scored above the impairment threshold. Stations 05RD179 (M-IBI=34), 08RD007 (M-IBI=21), 08RD015 (M-IBI=33), and 08RD031 (M-IBI=26) each scored below the threshold.

Figure 7 provides the individual M-IBI metric scores for the macroinvertebrate monitoring stations along AUID 503; a description of each metric is provided in Appendix B. At least one of the stations had a "low" score for each of the metrics. Collectively, the stations had the lowest scores for the following metrics: Collector-filtererPct, Intolerant2Ch, and TrichopteraChTxPct. The macroinvertebrate assemblage of the stations was dominated by tolerant taxa, specifically Corixidae (water boatman), *Ferrissia* (limpets), *Glyptotendipes* (midges), *Physa* (snails), and *Stenacron* (mayflies).



[1] The mean individual metric score needed for the station to meet its applicable impairment 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 05RD042, 05RD179, 08RD007, 08RD015, and 08RD031 along AUID 503.

Candidate causes

Loss of longitudinal connectivity

Available data

The MPCA biological monitoring staff documented the remnants of a private stream crossing (Figure 8) during fish sampling at Station 08RD031 along AUID 503. The crossing included an undersized culvert and concrete debris that was used for fill. The crossing appeared to be potentially limiting connectivity at the time of discovery. According to the MDNR (2014), the reach is situated between the Florian Dam and the Stephen Dam. The Florian Dam (Figure 8) is owned by the Marshall County Soil and Water Conservation District and was completed in 1975 for the primary purpose of flood control. The structure has an associated reservoir and is a complete barrier to connectivity at all flow conditions. The Stephen Dam (Figure 8) is owned by the city of Stephen and was built in 1988 to provide a water source for the community and the local golf course. However, the City has since been connected to the North Kittson Rural Water System and no longer draws water from the Tamarac River. The structure is nearly a complete barrier to connectivity (Aadland, 2015); fish passage may be possible during extremely high flows. In addition, MPCA SI staff performed a detailed review of a September 1, 2013, aerial photo of the reach; the photo was collected during low flow conditions. Staff identified the remnants of nine additional private stream crossings, several of which appeared to be potentially limiting connectivity. Figure 8 displays one of these crossings.

Figure 8. Photos of connectivity barriers along AUID 503, including the remnants of a private stream crossing at Station 08RD031 on September 3, 2008 (upper left); the Florian Dam on September 2, 2015 (upper right); the Stephen Dam on July 30, 2014 (lower left); and the remnants of a private stream crossing downstream of the 330th Ave. NW crossing on September 1, 2013, courtesy of Google Earth (lower right).

Biotic response - fish

Evidence of a causal relationship between the loss of longitudinal connectivity and the F-IBI impairment associated with AUID 503 is provided by the difference in fish species sampled upstream and downstream of the Stephen Dam. According to Table 6, the fish assemblage below the dam (i.e., Stations 08RD001 and 08RD024) included nine species (highlighted red) that were not present along AUID 503. Many of these species were large bodied, longer-lived species that are characteristic of well-connected riverine habitats (e.g., channel catfish, sauger, and walleye). The Stephen Dam, along with the Florian Dam, not only limit the biotic potential of AUID 503, but also adversely affect the fish community of the Red River of the North, as many of these excluded fish species cannot access the necessary physical habitat to complete their life history (e.g., clean, coarse substrate for spawning).

Table 6. Summary of fish species sampled upstream and downstream of the Stephen Dam.

Fish Species	Sampled Upstream of the Stephen Dam[1]	Sampled Downstream of the Stephen Dam[2]
black bullhead	X	X
blacknose dace	X	
blackside darter	X	X
brassy minnow	X	
brook stickleback	X	X
carmine shiner		**X**
central mudminnow	X	X
channel catfish		**X**
common carp		**X**
common shiner	X	X
creek chub	X	X
fathead minnow	X	X
freshwater drum		**X**
golden redhorse	X	
goldeye		**X**
hybrid sunfish	X	
johnny darter	X	X
northern pike	X	X
northern redbelly dace	X	
pearl dace	X	
pumpkinseed	X	
rock bass	X	X
sand shiner	X	X
sauger		**X**
shorthead redhorse	X	X
silver redhorse		**X**
spotfin shiner	X	X
tadpole madtom	X	X
trout-perch		**X**
walleye		**X**
white sucker	X	X

[1] Stations 05RD042, 05RD179, 08RD007, 08RD015, and 08RD031 along AUID 503
[2] Stations 08RD001 and 08RD024 along AUID 505

Biotic response - macroinvertebrate

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

Flow regime alteration

Available data

There is no flow monitoring data for AUID 503; however, the MPCA and MDNR cooperatively operate a gaging site immediately upstream and downstream of the reach on the Tamarac River. The upstream gage site (69036001) is located at the CSAH 1 crossing south of Florian and has a flow record of March 29, 2012, to December 31, 2014. The mean flow for the time period was 44 cubic feet per second (cfs), while the highest peak flow was 1,636 cfs and the lowest flow was 0 cfs. The downstream site (69051001) is located at the CSAH 22 crossing northwest of Stephen and has data available from May 1, 2007, to December 31, 2014. The mean flow for the time period was 120 cfs, while the highest peak flow was 5,510 cfs and the lowest flow was 0 cfs. Figures 10 and 11 provide example annual hydrographs for both gaging sites. The flow regime of the Tamarac River is considered “flashy”, with high and quick peak flows (Figure 9), along with prolonged periods of very low discharge (Groshens, 2007; MSTRWD, 2011; VanOffelen, 2010). Groshens (2007) attributed the river’s “flashy” flow regime to historical changes in land cover (i.e., native vegetation to cropland) and drainage patterns (e.g., ditching and channelization) that have altered the natural hydrology of the watershed. Additionally, the Stephen Dam often creates lentic conditions along the downstream extent of the reach (Figure 9).

Figure 9. Photos of the effects of a “flashy” flow regime along AUID 503, including a flood prone area near the 380th St. NW crossing on September 2, 2015 (left) and lentic conditions at Site S002-993 on August 14, 2014 (right).

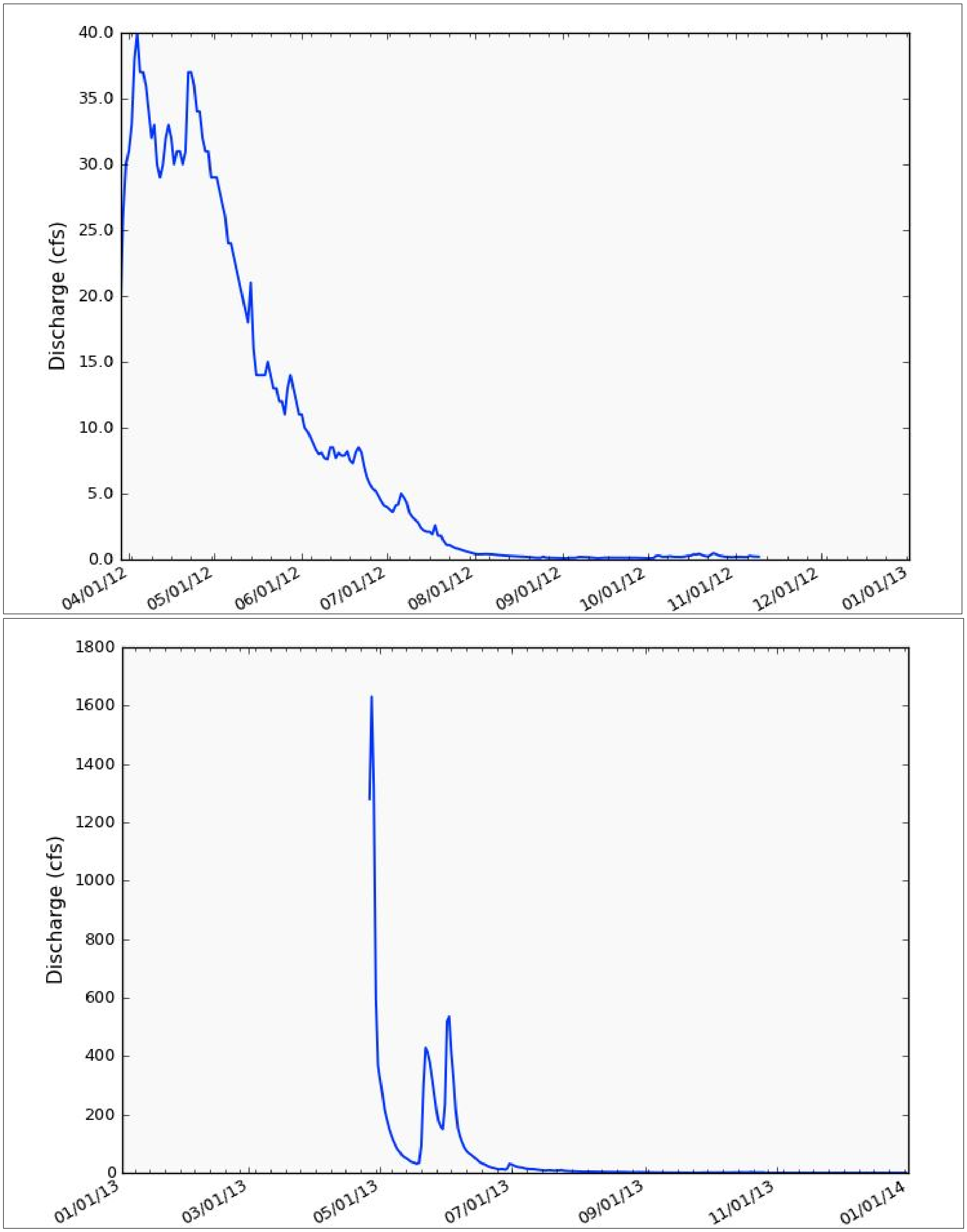


Figure 10. Annual (2012 and 2013) hydrographs for Site 69036001 upstream of AUID 503.

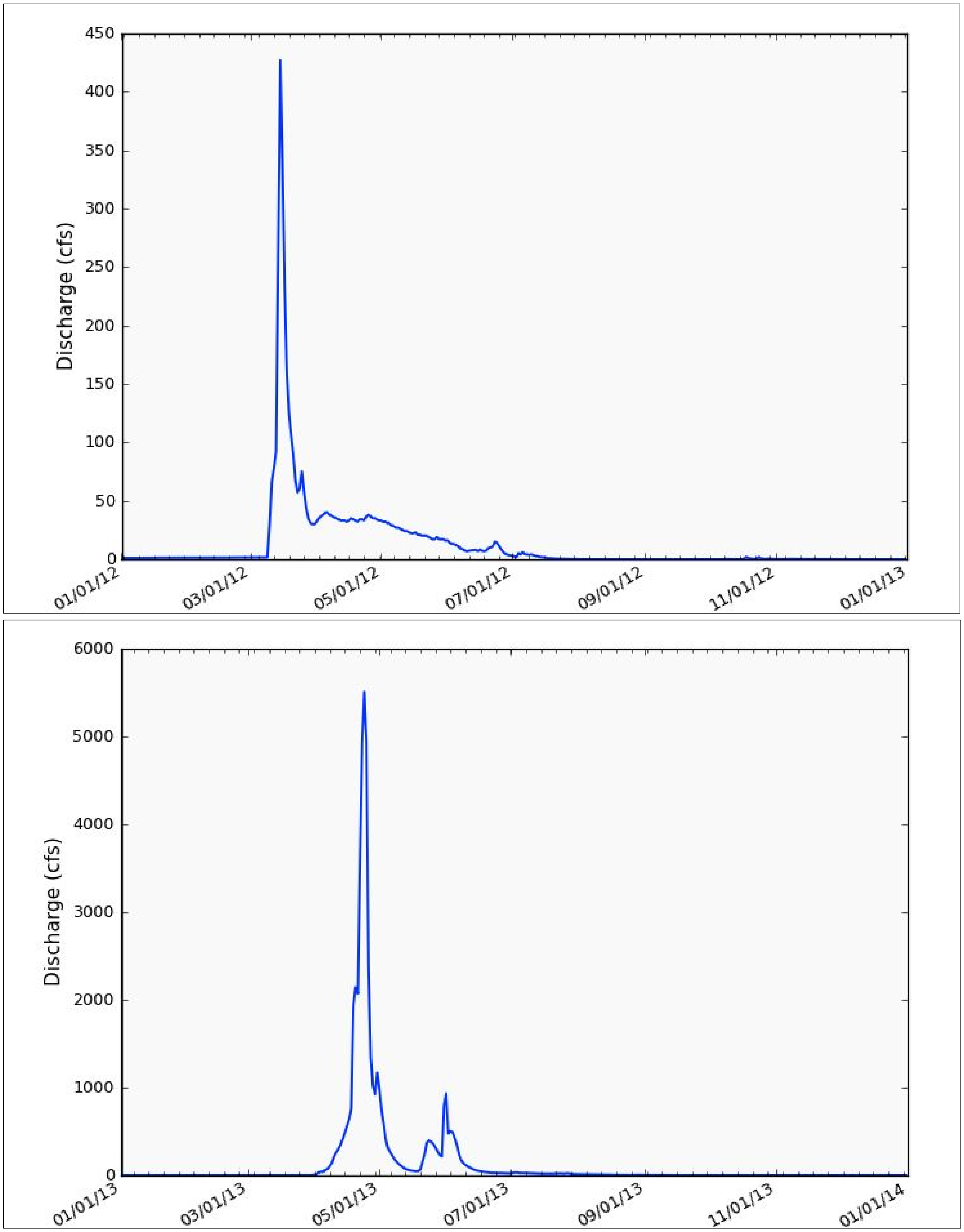


Figure 11. Annual (2012 and 2013) hydrographs for Site 69051001 downstream of AUID 503.

Biotic response - fish

Evidence of a causal relationship between flow regime alteration and the F-IBI impairment associated with AUID 503 is provided by the following individual F-IBI metric responses (Appendix C) for multiple monitoring stations along the reach:

- High combined relative abundance (>60%) of the two most abundant taxa (domtwopct)
- High relative abundance (>35%) of taxa that are generalists (generaltxpct)
- High relative abundance (>76%) of early-maturing individuals with a female mature age equal to or less than two years (MA<2Pct)
- High relative abundance (>18%) of taxa that are pioneers (pioneertxpct)
- Low relative abundance (<11%) of taxa that are sensitive (sensitivetxpct)
- High relative abundance (>45%) of individuals that are tolerant (tolpct)
- High relative abundance (>41%) of taxa that are tolerant (TolTxPct)

Flow regime alteration tends to limit species diversity and favor taxa that are trophic generalists, early maturing, pioneering, and/or tolerant of environmental disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). The two most abundant species sampled along the reach were black bullhead and fathead minnow, which are generalists, early maturing, pioneering, and/or tolerant species. According to Figure 6, five of the abovementioned individual metrics (i.e., DomTwoPct, MA<2Pct, SensitiveTxPct, TolPct, and TolTxPct) were used in the calculation of the F-IBI score(s) for monitoring stations along the reach. The "low" score(s) for these metrics negatively affected the overall F-IBI scores and directly contributed to the biological impairment of the reach. The F-IBI metric data suggest that the influence of flow regime alteration on the fish community of AUID 503 is most pronounced along the lower extent of the reach, as Stations 08RD007 and 08RD031 exhibited all of the these responses.

Biotic response - macroinvertebrate

Evidence of a causal relationship between flow regime alteration and the M-IBI impairment associated with AUID 503 is provided by the following individual M-IBI metric responses (Appendix D) for multiple monitoring stations along the reach:

- Low relative abundance (<14%) of collector-filterer individuals (Collector-filtererpct)
- Low relative abundance (<5%) of long-lived individuals (longlivedpct)
- Low taxa richness (<9) of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- High relative abundance (>12%) of swimmer individuals (swimmerpct)
- Low total taxa richness (<39) of macroinvertebrates (taxacountallchir)
- High relative percentage (>81%) of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low relative percentage (<7%) of taxa belonging to Trichoptera (TrichopteraChTxPct)
- Low relative percentage (<3%) of non-hydropsychid Trichoptera individuals (TrichwoHydroPct)

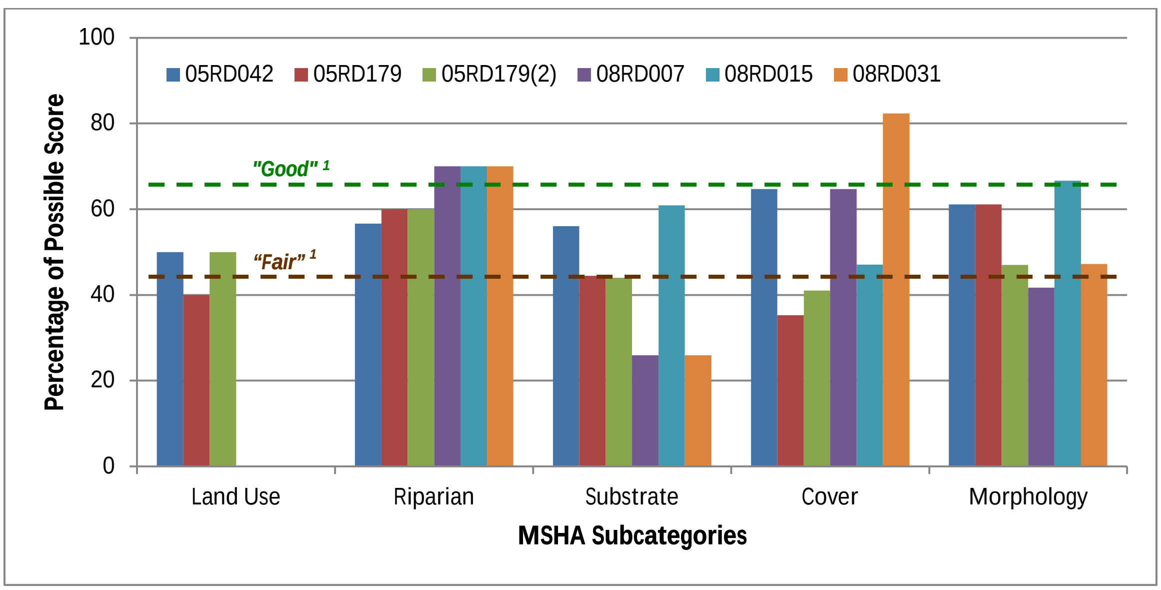
Flow regime alteration tends to limit macroinvertebrate diversity, specifically taxa belonging to the orders of Plecoptera, Ephemeroptera, and Trichoptera (many of which are collector-filterers), and favor taxa that are tolerant of environmental disturbances (Klemm et al., 2002; Poff and Zimmerman, 2010; EPA, 2012). The macroinvertebrate assemblage of the stations was dominated by taxa that are adapted to lentic conditions (e.g., Corixidae, Glyptotendipes, Physa, and Stenacron). According to Figure 7, five of the abovementioned individual metrics (i.e., Collector-filtererPct, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI scores for monitoring stations along the reach. The "low" scores for these metrics negatively affected the overall

M-IBI scores and directly contributed to the biological impairment of the reach. The M-IBI metric data suggest that the influence of flow regime alteration on the macroinvertebrate community of AUID 503 is also most pronounced along the lower extent of the reach, as Stations 08RD007 and 08RD031 exhibited nearly all of these responses.

Lack of physical habitat

Available data

The physical habitat of AUID 503 was evaluated at each of the biological monitoring stations using the MSHA. All of the stations are located along natural segments of the reach (MPCA, 2013b). Total MSHA scores for the stations declined from upstream to downstream. Stations 05RD042 and 08RD015 yielded the highest scores (59/"fair") along the reach, while further downstream, Stations 05RD179 (47 and 51/"fair"), 08RD007 (43/"poor"), and 08RD031 (48/"fair") had markedly lower scores. Figure 12 displays the MSHA subcategory results for each of the stations. The land use subcategory scores were substantially limited by the predominance of agricultural row crops surrounding the reach. The stations scored uniformly well in the riparian zone subcategory; however, bank erosion was noted throughout the reach. Station 08RD015 had the highest amount of erosion ("moderate" to "heavy"). The upstream portion of the reach (i.e., Stations 05RD042, 05RD179, and 08RD015) scored markedly higher than the downstream extent (i.e., Stations 08RD007 and 08RD031) in the substrate subcategory. Only the upstream stations offered coarse substrate (i.e., sand and gravel). However, the coarse substrate at Stations 05RD042 and 05RD179 had a "moderate" level of embeddedness. All of the stations were dominated by pools and/or runs, with a few (≤12%) riffles. The dominant cover types were largely similar along the reach (i.e., overhanging vegetation, deep pools, and woody debris); although, the downstream stations had a higher amount of cover than the upstream stations. Channel morphology subcategory scores declined from upstream to downstream. Stations 05RD179, 08RD007, and 08RD031 each had "fair" to "poor" channel development, no riffles, and a "slow" velocity. While Station 08RD015 had the highest score for this subcategory along the reach, the station had "low" channel stability. Groshens (2007) asserted that the cumulative effects of hydrologic alterations to the river and surrounding landscape have degraded the quality of physical habitat.



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

Figure 12. MSHA subcategory results for Stations 05RD042, 05RD179, 08RD007, 08RD015, and 08RD031 along AUID 503.

Biotic response - fish

Evidence of a causal relationship between the lack of physical habitat and the F-IBI impairment associated with AUID 503 is provided by the following individual F-IBI metric responses (Appendix C) for multiple monitoring stations along the reach:

- High relative abundance (>25%) of taxa that are detritivorous (detnwqtxpct)
- Low relative abundance (<30%) of individuals that are insectivorous Cyprinids (insectcyppct)
- Low relative abundance (<36%) of taxa that are insectivorous, excluding tolerant species (Insect-toltxpct)

Insectivores require quality physical habitat to support a diverse and healthy food base, while detritivores utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of physical habitat (Aadland et al., 2006). According to Figure 6, the DetNWQTxPct metric was used in the calculation of the F-IBI score(s) for monitoring stations along the reach. The "low" scores for this metric negatively affected the overall F-IBI scores and directly contributed to the biological impairment of the reach. The F-IBI metric data suggest that the influence of the lack of physical habitat on the fish community of AUID 503 is most pronounced along the lower extent of the reach, as Stations 05RD179, 08RD007, and 08RD031 exhibited nearly all of these responses.

Biotic response - macroinvertebrate

Evidence of a causal relationship between the lack of physical habitat and the M-IBI impairment associated with AUID 503 is provided by the following individual M-IBI metric responses (Appendix D) for multiple monitoring stations along the reach:

- High relative abundance (>12%) of burrowers (burrowerpct)
- Low taxa richness (<10) of clinger taxa (clingerch)
- Low relative abundance (<14%) of collector-filterer individuals in a subsample (Collector-filtererpct)
- High relative abundance (>50%) of legless individuals (LeglessPct)

Clinger taxa, including many collector-filterers, require clean, coarse substrate or other objects to attach themselves to, while burrowers and legless macroinvertebrates are tolerant of degraded benthic habitat. According to Figure 7, two of the abovementioned individual metrics (i.e., ClingerCh and Collector-filtererPct) were used in the calculation of the M-IBI scores for monitoring stations along the reach. The "low" scores for these metrics negatively affected the overall M-IBI scores and directly contributed to the biological impairment of the reach. The M-IBI metric data suggest that the influence of the lack of physical habitat on the macroinvertebrate community of AUID 503 is also most pronounced along the lower extent of the reach, as Stations 05RD179 and 08RD031 exhibited nearly all of these responses.

High suspended sediment

Available data

The MPCA biological monitoring staff collected a water quality sample at each of the biological monitoring stations at the time of fish sampling. The samples were analyzed for several parameters, including TSS. All of the stations had a low level of TSS, with concentrations ranging from 4 to 12 mg/L. Table 7 summarizes discrete TSS data for Sites S002-992 (CSAH 34 crossing), S002-993 (US Highwway 75 crossing), and S005-569 (CSAH 32 crossing); the relative location of these sites is shown in Figure 5. Collectively, the sites had a low proportion of exceedances of the 65 mg/L standard (3%). Additionally, the LRRNW HSPF model estimates that the reach had a TSS concentration in excess of the standard between one and 22% of the time during the period of 1996 to 2009. The percentage of modeled exceedances increased from upstream to downstream, with the highest values (>10%) occurring downstream of Station 05RD179. The aforementioned MSHA results indicate that the deposition of excess suspended sediment has caused the embeddedness of coarse substrate documented at Stations 05RD042 and 05RD179. Overall, the available data suggest that the reach is prone to occasional periods of high suspended sediment.

Table 7. Discrete TSS data for Sites S002-992, S002-993, and S005-569 along AUID 503.

Site	Date Range	*n*	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Standard Exceedances
S002-992	2002-2010	35	3	69	12	1
S002-993	2002	3	13	68	39	1
S005-569	2009-2010	31	7	60	18	0

The MDNR conducted stream morphology and stability evaluations at two sites along the lower extent of AUID 503 in 2006 (Groshens, 2007). Site TR301 was located approximately five miles upstream of Station 08RD031, near the 380th Street NW crossing, while Site TR302 was located approximately two miles upstream of Station 05RD179, near the 325th Avenue NW crossing. Stream morphology evaulations were conducted in accordance with the methodology outlined by Rosgen (1996). Site TR301, which was classified as a B6c stream type, had the following characteristics: 1) a moderate width/depth ratio (21.7), 2) a high entrenchment ratio (1.7), 3) a silt/clay D50 substrate type, and 4) a moderate sinuosity ratio (2.2). A very limited evaulation was performed on Site TR302. The site was noted as having a sand D50 substrate type and a high sinuosity ratio (1.9). Stream stability was evaulated at both stations following the methods described by Pfankuch (1975) and Rosgen (1996). Site TR301 had a "poor" Pfankuch score (129) and a "high" Bank Erosion Hazard Index (BEHI) score (36.3). Site TR302 had a "poor" Pfankuch score (148) and an "extreme" BEHI score (148). According to Groshens (2007), the instability documented along the reach is a direct result of hydrologic alterations to the surrounding landscape. The stream stability evaluation results suggest that instream erosion is a contributing source of excess suspended sediment to the reach.

Biotic response - fish

Evidence of a causal relationship between high suspended sediment and the F-IBI impairment associated with AUID 503 is provided by the following individual F-IBI metric response (Appendix C) for multiple monitoring stations along the reach:

- Low relative abundance (<1%) of herbivorous individuals (HerbvPct)

Herbivores are amongst the most sensitive feeding guilds to high suspended sediment (Kemp et al., 2011). The metric data suggest that the influence of high suspended sediment on the fish community of AUID 503 is most pronounced along the lower extent of the reach, as Stations 05RD179, 08RD007, and 08RD031 strongly exhibited this response. The mean TSS Tolerance Indicator Values (TIVs) for the reach (Appendix C) were substantially higher than the basin average (22 mg/L). This suggests that the fish community was largely comprised of species that are tolerant of high suspended sediment. The TIVs were also used to estimate the likelihood of each station meeting the TSS standard based upon its sampled fish assemblage (Appendix C). Only Station 08RD031 had a low probability (<36%) of meeting the standard.

Biotic response - macroinvertebrate

Evidence of a causal relationship between high suspended sediment and the M-IBI impairment associated with AUID 503 is provided by the following individual M-IBI metric responses (Appendix D) for multiple monitoring stations along the reach:

- Low relative abundance (<14%) of collector-filterer individuals in a subsample (Collector-filtererpct)
- Low relative percentage (<7%) of taxa belonging to Trichoptera (trichopterachtxpct)
- Low relative percentage (<3%) 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, all of the abovementioned individual metrics were used in the calculation of the M-IBI scores for monitoring stations along the reach. The "low" scores for these metrics negatively affected the overall M-IBI scores and directly contributed to the biological impairment of the reach. The M-IBI metric data suggest that the influence of high suspended sediment on the macroinvertebrate community of AUID 503 is most pronounced along the lower extent of the reach, as Stations 05RD179, 08RD007, and 08RD031 exhibited nearly all of these responses. The TSS TIVs for the reach (Appendix D) indicate that Stations 05RD042, 05RD179, 08RD007, and 08RD031 each had a high abundance (>32%) of taxa that are tolerant of high suspended sediment. Additionally, Stations 05RD179, 08RD007, 08RD015, and 08RD031 had a low number (<2) of taxa that are intolerant of high suspended sediment.

Low dissolved oxygen

Available data

The MPCA biological monitoring staff collected a discrete DO measurement at each of the biological monitoring stations during fish sampling. Only one of the measurements was below the 5.0 mg/L standard; Station 05RD179 had a DO concentration of 3.7 mg/L on August 8, 2006. Figure 13 displays discrete DO data for Sites S002-992 (2002-2014; n=103), S002-993 (1999-2014; n=20), and S005-569 (2009-2014; n=31). Only 1% of the DO values for the site were below the standard; however, only seven measurements were taken prior to 9:00 a.m. Generally, the lowest DO levels were in the months of June, July, and August. The MPCA conducted continuous DO monitoring at Site S002-993 from August 14, 2014, to August 27, 2014. According to Table 8, the site had a high proportion of total and daily minimum values below the standard (33 and 64%), but the level of mean daily DO flux was nominal (1.0 mg/L). Additionally, the LRRNW HSPF model estimates that the reach had a DO concentration below the standard between 1 and 5% of the time during the period of 1996 to 2009. The percentage of modeled values below the standard generally increased from upstream to downstream, with the highest proportion (>2%) occurring downstream of Station 08RD007. Overall, the available data suggest that the lower extent of the reach, which is predisposed to lentic conditions, is prone to at least occasional periods of low DO.

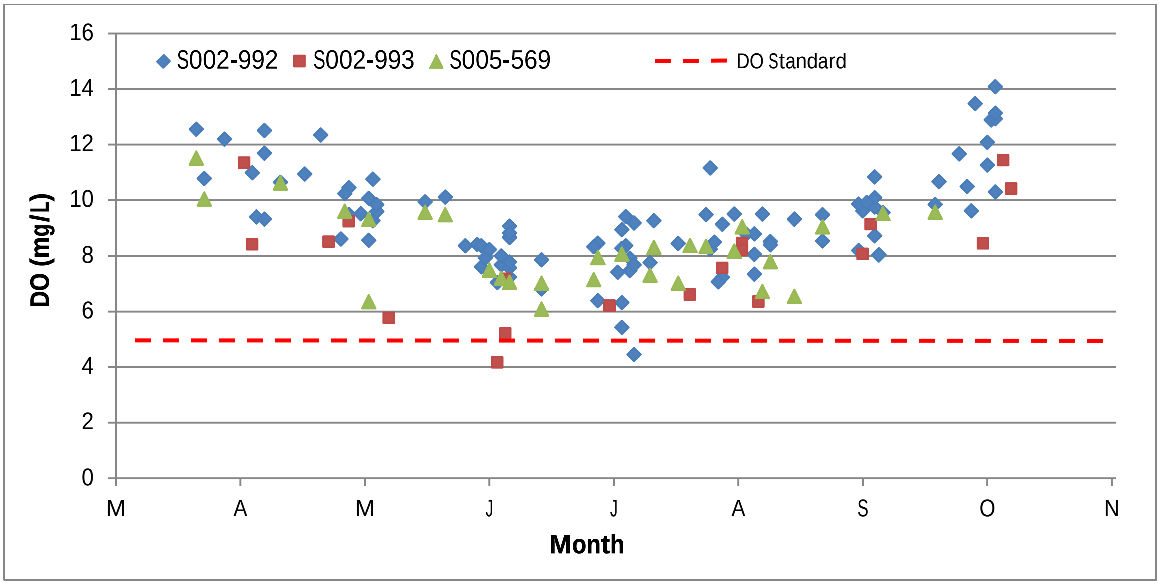


Figure 13. Discrete DO data for Sites S002-992, S002-993, and S005-569 along AUID 503.

Table 8. Continuous DO data for Site S002-993 along AUID 503.

Site	Start Date - End Date	*n*	Min. (mg/L)	Max. (mg/L)	% Total Values Below Standard	% Daily Min. Values Below Standard	Mean Daily Flux (mg/L)
S002-993	August 14, 2014 - August 27, 2014	1243	3.5	7.5	33	64	1.0

Biotic response - fish

Evidence of a causal relationship between low DO and the F-IBI impairment associated with AUID 503 is provided by the following individual F-IBI metric response (Appendix C) for multiple monitoring stations along the reach:

- Low relative abundance (<11%) of taxa that are sensitive (sensitivetxpct)
- High relative abundance (>45%) of individuals that are tolerant (tolpct)
- High relative abundance (>41%) 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 the abovementioned individual metrics (i.e., SensitiveTxPct, TolPct, and TolTxPct) were used in the calculation of the F-IBI score(s) for monitoring stations along the reach. The "low" score(s) for these metrics negatively affected the overall F-IBI scores and directly contributed to the biological impairment of the reach. The F-IBI metric data suggest that the influence of low DO on the fish community of AUID 503 is most pronounced along the lower extent of the reach, as Stations 08RD007 and 08RD031 exhibited all of these responses. With the exception of Station 08RD031, all of the stations had a mean DO TIV (Appendix C) at or above the basin average (6.9 mg/L). The TIVs were also used to estimate the likelihood of each station meeting the DO standard based upon its sampled fish assemblage (Appendix C). Stations 05RD179, 08RD007, 08RD015, and 08RD031 each had a low probability (<46%) of meeting the standard.

Biotic response - macroinvertebrate

Evidence of a causal relationship between low DO and the M-IBI impairment associated with AUID 503 is provided by the following individual M-IBI metric responses (Appendix D) for multiple monitoring stations along the reach:

- High (>8) Hilsenhoff's Biotic Index value (HBI_MN)
- Low taxa richness (<9) of Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET)
- Low total taxa richness (<39) of macroinvertebrates (taxacountallchir)
- High relative percentage (>81%) of taxa with tolerance values equal to or greater than six (Tolerant2ChTxPct)
- Low relative percentage (<7%) of taxa belonging to Trichoptera (trichopterachtxpct)
- Low relative percentage (<3%) of non-hydropsychid Trichoptera individuals (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 (Weber, 1973; EPA, 2012). According to Figure 7, five of the abovementioned individual metrics (i.e., HBI_MN, POET, TaxaCountAllChir, TrichopteraChTxPct, and TrichwoHydroPct) were used in the calculation of the M-IBI scores for monitoring stations along the reach. The "low" scores for these metrics negatively affected the overall M-IBI scores and directly contributed to the biological impairment of the reach. The M-IBI metric data suggest that the influence of low DO on the macroinvertebrate community of AUID 503 is most pronounced along the lower extent of the reach, as Stations 08RD007 and 08RD031 exhibited nearly all of these responses. The DO TIVs for the reach (Appendix D) indicate that all of the stations had a low abundance (<22%) of taxa that are tolerant of low DO conditions. However, Stations 05RD179, 08RD007, and 08RD031 had a low number (<3) of taxa that are intolerant of low DO conditions.

Strength-of-evidence analysis

Table 9 presents a summary of the SOE scores for the various candidate causes associated with AUID 503. The evidence suggests that the F-IBI impairment is likely attributed to the following stressors: loss of longitudinal connectivity, flow regime alteration, lack of physical habitat, high suspended sediment, and low DO. Additionally, the evidence indicates that the M-IBI impairment is likely the result of the following stressors: flow regime alteration, lack of physical 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 9. SOE scores for candidate causes associated with AUID 503.

Types of Evidence	SOE Scores for Candidate Causes[1]									
	Loss of Longitudinal Connectivity		Flow Regime Alteration		Lack of Physical Habitat		High Suspended Sediment		Low Dissolved Oxygen	
	Biological Impairments									
	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI	F-IBI	M-IBI
Types of Evidence that Use Data from the Case										
Spatial/Temporal Co-Occurrence	+++	--	++	++	++	++	+	+	++	+
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 10 presents a summary of the stressors associated with AUID 503. The loss of longitudinal connectivity caused by the Florian and Stephen dams severely limits the potential of the fish community of the reach by obstructing the migration of many large bodied, longer-lived species that are characteristic of well-connected riverine habitats (e.g., channel catfish, sauger, and walleye). Removal or modification of these structures would not only improve the health of the fish community of the reach, but also benefit the fishery of the Red River of the North by providing many species access to the physical habitat necessary to complete their life history (e.g., clean, coarse substrate for spawning). The available data suggests that the dams and intensive agricultural drainage have altered the natural flow regime of the reach, resulting in increased and quicker peak flows, along with prolonged periods of low discharge. The "flashy" flow regime is inhibiting biotic diversity, particularly along the lower extent of the reach (i.e., Station 08RD007, to the Stephen Dam). The aforementioned hydrologic alterations are also likely contributing to the degradation of physical habitat, high suspended sediment, and low DO conditions that are limiting the fish and macroinvertebrate communities of the reach. These conditions are most pronounced along the downstream portion of the reach (i.e., Station 08RD007, to the Stephen Dam). The restoration of a more natural hydrograph, including peak flow attenuation and base flow augmentation, would help to alleviate these stressors.

Table 10. Summary of the stressors associated with AUID 503.

AUID Suffix	Reach Name	Biological Impairments	Candidate Causes[1]				
			Loss of Longitudinal Connectivity	Flow Regime Alteration	Lack of Physical Habitat	High Suspended Sediment	Low Dissolved Oxygen
503	Tamarac 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 recommended management actions specified below and included in the MPCA's Aquatic Biota Stressor and Best Management Practices (BMP) Relationship Guide (Appendix E) will help to reduce the influence of the stressors that are limiting the fish and macroinvertebrate communities of AUID 503. Whenever possible, actions should be implemented progressing from upstream to downstream.

- Remove or modify longitudinal connectivity barriers (e.g., Stephen Dam and Florian Dam) to enable fish passage.
- Prevent or mitigate activities that will further alter the hydrology of the watershed.
- Evaluate options to attenuate peak flows and augment base flows.
- Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities.
- Increase the quantity and quality of physical habitat.
- Establish and/or protect riparian corridors along all waterways, including ditches, using native vegetation whenever possible.
- Implement BMPs to reduce soil erosion.

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