Stressor identification

August 2020

Mississippi River - Sartell Watershed Stressor Identification Report

A study of stressors limiting aquatic life in the Mississippi River - Sartell Watershed

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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List of Acronyms and Abbreviations

BOD	Biological Oxygen Demand
CADDIS	Causal Analysis/Diagnosis Decision Information System
CD	County Ditch
COD	Chemical Oxygen Demand
CR	County Road
CSAH	County State Aid Highway
DELT	Deformities, eroded fins, lesions, tumors
DNR	Minnesota Department of Natural Resources
DO	Dissolved oxygen
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
FIBI	Fish Index of Biological Integrity
HSPF	Hydrologic Simulation Program - FORTRAN
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
IWM	Intensive Watershed Monitoring
M&A	Monitoring and Assessment
MIBI	Macroinvertebrate Index of Biological Integrity
MNtol	Tolerance value calculated specifically for Minnesota
MPCA	Minnesota Pollution Control Agency
MRS	Mississippi River Sartell
MS	Minor Stressor
MSHA	Minnesota Stream Habitat Assessment
NH3	Ammonia
NH4	Ammonium
NOX	Inorganic Nitrogen (AKA nitrate+nitrite, NO2+NO3)
SID	Stressor Identification
SOD	Soil Oxygen Demand
SWCD	Soil and Water Conservation District
TALU	Tiered Aquatic Life Use
Temp	Temperature
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorous
TSS	Total Suspended Solids
TSVS	Total Suspended Volatile Solids
USGS	United States Geological Survey
VSS	Volatile Suspended Solids
WID	Waterbody Identification Number
WPLMN	Watershed Pollutant Load Monitoring Network
WRAPS	Watershed Restoration and Protection Strategies

Executive Summary

Since 2007, the Minnesota Pollution Control Agency (MPCA) has substantially increased the use of biological monitoring and assessment as a means to determine the condition of the state's rivers and streams. This basic approach is to systematically examine fish and aquatic macroinvertebrate communities throughout the state's 80 major watershed. From these data, an Index of Biological Integrity (IBI) score is calculated, which provides a measure of overall community health (MPCA 2017(a) & MPCA 2017(b)). For assessment purposes, rivers and streams are divided into specific reaches and are assigned a three-digit Waterbody Identification (WID) number. A WID (stream reach) can be of various lengths and have one or more biological and chemical sampling stations on it.

Of the 34 WIDs assessed for aquatic life in the Mississippi River – Sartell (MRS) Watershed by the MPCA in 2018, fourteen were designated impaired for aquatic life (Table 1). Seven were impaired for aquatic life due to nonsupport of the fish community (FIBI), three for nonsupport of the macroinvertebrates (MIBI), and four for nonsupport of both communities. Comprehensive results of the Intensive Watershed Monitoring (IWM) effort and assessment of the MRS Watershed were published in the Mississippi River- Sartell Monitoring and Assessment Report (MPCA 2019), hereafter referred to as the M&A Report.

Stressor identification (SID) is a formal and rigorous process that identifies stressors causing the impairment of aquatic ecosystems (Cormier *et al.* 2000). Stressor identification was performed on water bodies that were assessed as impaired for aquatic life due to not meeting fish (FIBI) or macroinvertebrate (MIBI) standards of biological integrity. The purpose of this report is to document the SID study of aquatic life impairments in the MRS Watershed.

The SID study revealed some systemic issues in the MRS Watershed. Streamflow alteration is one of the systemic stressors; it was concluded to be the cause of at least six aquatic life impairments and was an inconclusive stressor in six other instances. Streamflow alteration is caused by changes to a watershed's precipitation patterns, land use, vegetative cover, stream channel dimensions, and other factors. According to the M&A Report, 54% of rivers and streams in the MRS Watershed have been channelized in some way. In addition, this area of Minnesota shows a significantly increasing trend in annual precipitation. Because of the connected nature of streamflow, even non-channelized portions of rivers and streams are affected by the substantial amount of watershed channelization and changes in precipitation patterns. Other likely contributors to the streamflow alteration stressor in the watershed are: land conversion (from forested/wetlands to agriculture), subsurface tile drainage, groundwater withdrawals, and urbanization.

Another systemic stressor identified in this study is livestock access to rivers and streams. While this is often considered more of a localized, or reach-scale, issue, it is being considered a systemic stressor in the MRS Watershed for two reasons: (1) The frequency of occurrence has moved it beyond the local scale for multiple subwatersheds, including some not documented in this report (2) It is suspected that a combination of landscape characteristics and state/county rules are conducive to this type of land use. Much of the MRS Watershed is comprised of wet, low-lying land that makes row crop production difficult but is suitable for pasturing livestock. The co-occurrence of livestock access and riparian wetlands was very prevalent throughout the watershed and resulted in six inconclusive findings of a low dissolved oxygen (DO) stressor, and four conclusive. The stressor ID process was complicated by the frequency of ditched wetlands, which are likely to exacerbate water quality "issues" that wetlands can naturally cause to receiving waters, such as low DO and excess nutrients. It was not possible to tease apart the natural wetland vs. anthropogenically induced water quality issues in many cases. The prevalence of livestock access to waters of the MRS Watershed is also evidenced by a high number of aquatic recreation impairments: 70% of assessed stream reaches received this impairment status as a result of excessive *E. coli* levels.

Localized stressors differ from systemic stressors because their negative effects are generally limited to the aquatic communities of the single WID and were not commonly observed throughout the watershed. Localized stressors identified include: longitudinal connectivity barriers, nitrate toxicity, and high stream temperature. In addition, in four instances of streams that were strongly connected with groundwater, iron and potentially other metals were identified as inconclusive stressors.

The aquatic life in many WIDs are stressed by multiple things, but often one of the stressors is driving the others. For example, streamflow alteration is driving the degradation of habitat in the lower part of the Watab River (WID -528). When using information from this SID report to develop restoration and protection strategies for the watershed, planners should address the underlying cause of stressors to avoid wasting resources on temporary fixes that are likely to fail. In addition, the findings of this report may help predict how the aquatic life in currently unimpaired water bodies of the MRS Watershed will become impaired, and thus what preventative actions should be considered.

Table 1. Summary of aquatic life impairments and stressors in the Mississippi River – Sartell Watershed. All WID numbers have a unique, three-digit identifier after the MRS Watershed HUC8 number (07010201).

CS = Conclusive Stressor, I = Inconclusive, MS = Minor Stressor (stressor is present, but is not primary cause of impairment)

FIBI = Fishes Index of Biotic Integrity, MIBI = Macroinvertebrate Index of Biotic Integrity

Denotes Morrison County

Denotes Stearns County

Denotes Benton County

WID (07010201-###)	Impairment indicator	Temperature	Longitudinal connectivity	Streamflow alteration	Lack of habitat	Suspended sediment	Nitrate toxicity	Eutrophication	Low dissolved oxygen	Metals-iron
Trib to Platte (-634)	FIBI		CS						CS	I
Big Mink Cr (-647)	MIBI			I	CS	I	I	I	CS	I
Little Mink Cr (-645)	MIBI			I	CS	I	I	I	CS	I
Platte R (-507)	FIBI		CS		MS/I					
Rice Cr (-618)	MIBI			I		I		I	CS	
Unnamed Cr (-651)	FIBI & MIBI		CS	CS	CS				I	
Hazel Cr (-569)	FIBI		CS	I			I			
South Two R (-643)	FIBI			I	CS	I		I	I	
Watab R, South Fork (-554)	FIBI		CS	I	CS				I	I
Watab R (-528)	FIBI			CS	CS	I				
Little Rock Cr (-652)	FIBI		MS	CS	CS	I	I	I	I	
Little Rock Cr (-653)	FIBI & MIBI	CS	MS	CS	CS	I	CS	I	CS	
Bunker Hill Cr (-511)	FIBI & MIBI	CS	MS	CS	CS	I	CS	I	I	
Zuleger Cr (-539)	FIBI & MIBI	I	MS	CS	CS	I	I	I	I	

1. Introduction

Monitoring and Assessment

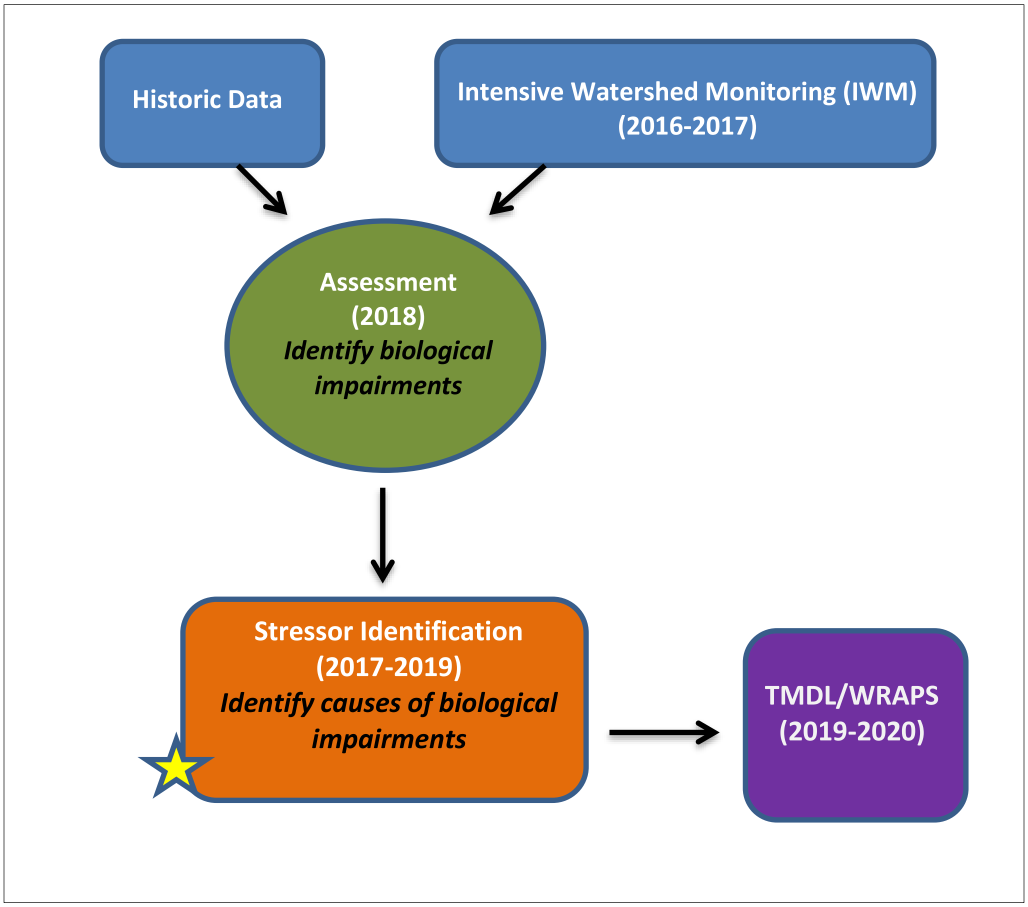
According to the MPCA's IWM schedule, the MRS Watershed was monitored for fish, macroinvertebrates, and chemical parameters in 2016-2017. Then, in 2018, each water body was assessed as meeting or not meeting Minnesota state standards. Those not meeting standards were included in the MPCA's 303(d) proposed impaired waters list of 2018. The results of the IWM and assessment were documented in the Mississippi River – Sartell Monitoring and Assessment Report (MPCA 2019), hereafter referred to as the M&A Report.

Stressor Identification

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

Once an aquatic life impairment is identified, SID is done to identify the source(s) of stress on the biological communities (fish and macroinvertebrates), and in some instances, a Total Maximum Daily Load (TMDL) is developed for the stressors. Strategies are then developed and written into a Watershed Restoration and Protection Strategies (WRAPS) report (Figure 1).

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



Hydrological Simulation Program - FORTRAN (HSPF) Model

The Hydrological Simulation Program - FORTRAN (HSPF) computer model is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic pollutants. The result of this simulation is a time history of the runoff rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at the outlet of subwatersheds.

HSPF incorporates a watershed-scale Agricultural Runoff Model and a Non-Point Source model into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. The model contains components to address runoff and constituent loading from pervious and impervious land surfaces, and the transport and transformation of chemical constituents in stream reaches. Primary external forcing is provided by the specification of meteorological time series. The model operates on a lumped basis within subwatersheds. Upland responses are separated into multiple land use categories within a subwatershed, simulated on a per-acre basis, and are converted to net loads upon linkage to stream reaches.

An HSPF watershed model was run for the MRS Watershed to predict water quality conditions throughout the watershed on an hourly basis from 1996 to 2015. Model results were used to evaluate streamflow and water quality in some instances for the stressor identification study.

2. Overview of Mississippi River-Sartell Watershed

Background

The Mississippi River – Sartell (MRS) Watershed is located in the greater Upper Mississippi River Basin, with the watershed outlet being the Mississippi River at Sartell, Minnesota. The MRS Watershed is approximately 1,020 square miles. The larger river systems in the watershed are the Platte, Skunk, Spunk, Watab, and Two Rivers. River and stream types found in the watershed vary from low gradient, wetland dominated systems to high gradient, boulder rivers. For a thorough discussion of watershed characteristics, see the M&A Report (MPCA 2019).

Possible Stressors to Biological Communities

A comprehensive list of potential stressors to aquatic biological communities compiled by the EPA can be found on the EPA's CADDIS webpage (CADDIS; EPA 2010). In some cases, the data may be inconclusive and limit the ability to confidently determine if a stressor is causing impairment to aquatic life. It is imperative to document if a candidate cause was suspected, but there was not enough information to make a scientific determination of whether or not it is causing harm to aquatic life. In this case, management decisions can include modification of sampling plans and future evaluation of the inconclusive case. Alternatively, there may be enough information to conclude that a candidate cause is not causing biological impairment and therefore can be eliminated. The inconclusive or eliminated causes will be discussed in more detail in the following sections.

Eliminated Stressors

Based on land use in the MRS Watershed, some candidate stressors from the EPA's comprehensive stressor list were eliminated. Those are: ionic strength and pH. These are usually associated with mining activity, industrial effluent, municipal effluent, and/or urbanization.

Uninvestigated Stressors

Based on limitations of available data, time, and resources, the following stressors were minimally investigated in this study, but could not be undoubtedly eliminated as potential stressors: ammonia, herbicides, insecticides, metals, unspecified toxins. Information on these stressors are discussed where available in the following sections.

Candidate Stressors Analyzed

The remaining candidate stressors analyzed in this SID study of the MRS Watershed are: temperature, longitudinal connectivity, streamflow alteration, lack of habitat, suspended sediment, nitrate toxicity, eutrophication, and low dissolved oxygen (DO). Those stressors are discussed by WID in the following sections.

3. Stressor Identification by Watershed

Stressors to aquatic life in the MRS Watershed are discussed by individual WID. Where possible, the WIDs are grouped into subwatershed sections, such as the Platte River Watershed in sections 3.1.1. – 3.1.5. A total of fourteenimpaired WIDs are discussed.

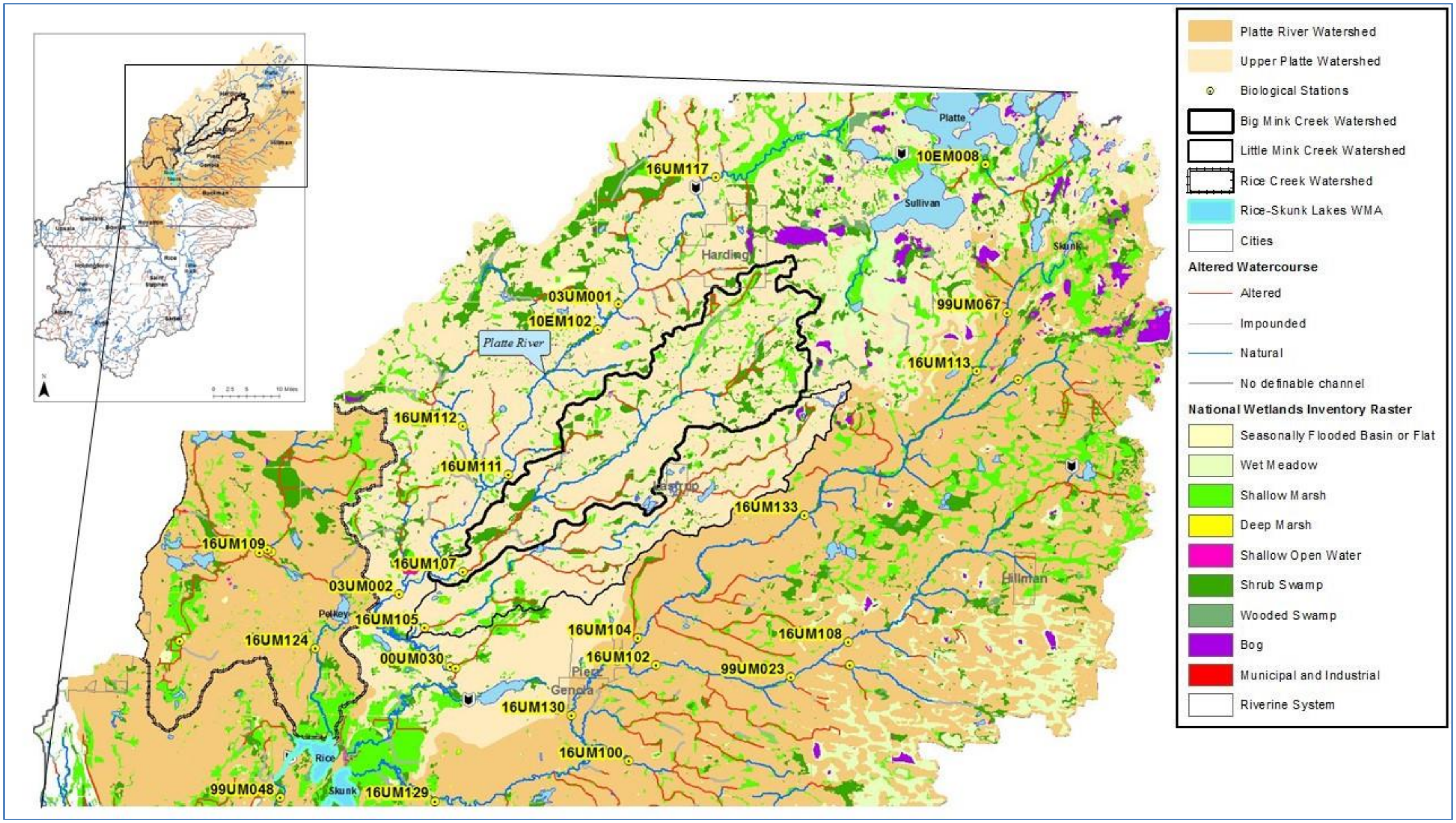
3.1. Platte River Watershed

The Platte River watershed is a "subwatershed" of the greater MRS Watershed, located in the northeastern part (Figure 2). The Platte River begins at the Sullivan Lake dam in Pulaski Township, and enters the Mississippi River three miles south of Royalton, Minnesota. The Crane Meadows National Wildlife Refuge divides the Platte River system into what are referred to as "upper" and "lower" sections of the watershed. This section of the report (3.1.1. – 3.1.5.) documents the SID of biologically impaired waterbodies in the upper part of the Platte River watershed, everything upstream of the Crane Meadows refuge. The Platte's main tributaries in the upper watershed are Big Mink Creek, Little Mink Creek, Wolf Creek, and two other unnamed tributaries. Also included in this upper portion is the Rice Creek subwatershed, which flows directly into Rice Lake of the wildlife refuge. For a map of impairments in the upper part of the Platte River watershed, see the M&A Report, Figure 19 (MPCA 2019).

In the lower part of the Platte River watershed, after the river flows through the refuge, the main tributaries are small agricultural and urban drainage ditches, including part of the US-10 and Royalton city drainage networks.

Generally, the lakes in the Platte watershed are shallow. Wetlands and other low-lying, wet areas make up a large portion of the landscape. Of note, multiple biological samples from the Platte River yielded exceptional IBI scores. Wild rice was also observed in areas of the upper watershed. The Platte River is one of the jewels of the MRS Watershed and warrants protection as well as restoration.

Figure 2. Map of the Platte River watershed and subwatersheds, with other relevant land features.



3.1.1. Tributary to Platte River – WID 07010201-634

Tributary to Platte River is a first order stream that originates in headwater wetlands and flows approximately three miles southeast to the Platte River. The watershed area is 9.7 square miles. The mainstem of the stream is WID -634 with biological station 16UM112 near the headwaters.

Biological Data

This WID is impaired for aquatic life for nonsupport of the fish community (Table 2). While the MIBI score is slightly lower than the impairment threshold, the macroinvertebrate community is not considered impaired, but is in a "vulnerable" condition and may soon become impaired. The main characteristic of the fish community that weighs down the FIBI score is low numbers of intolerant fish, especially insectivorous cyprinids and simple lithophilic spawners (Table 3, see highlighted rows).

Table 2. IBI scores at site 16UM112 on Tributary to Platte River (WID 07010201-634).

		Fish IBI			Macroinvertebrate IBI		
Station	Date	Class†	Impairment threshold	Score	Class†	Impairment threshold	Score
16UM112	6/27/2016	6	42	24.7	-	-	-
	9/7/2016	-	-	-	3	53	47.6

†FIBI Class: (6) Northern Headwaters
MIBI Class: (3) Northern Forest Streams – Riffle/Run

Table 3. Fish IBI metric scores from the fish sample at 16UM112 on 6/27/2016. Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown.

FIBI Class 6 Metric	**Raw Metric Result**	**Re-scaled IBI score**
DarterSculp *Number of darter and sculpin species*	1	5
FishDELTPct *Percent of individuals with DELT anomalies*	0%	0
Hdw-Tol *Number of headwater specialist taxa, excl. tolerant species*	1	3.33
InsectCypPct *Percent of insectivorous cyprinid individuals*	0%	0
Insect-TolTxPct *Percent of insectivorous taxa, excl. tolerant species*	11.11%	2.59
Minnows-TolPct *Percent of cyprinid individuals, excl. tolerant species*	2.22%	0.43
NumPerMeter-Tolerant *Number of fish per meter, excl. tolerant species*	0.25 fish/m	1.36
PioneerTxPct *Percent of pioneer species*	33.33%	2.12
Sensitive *Number of sensitive species*	1	2.5
SLithop *Number of simple lithophilic spawning species*	1	2.34
TolTxPct *Percent of tolerant species*	66.67%	5
Total (FIBI score)	--	24.67

Characteristics of the macroinvertebrate community that appear to be weighing down the MIBI score are a lack of Plecoptera and predator taxa, as well as a low percentage of insect taxa (Table 4, see highlighted rows). Some rather sensitive taxa were found, such as the following caddisflies: *Helicopsyche borealis*, *Uenoidae*, and *Oecetis*, as well as the mayfly *Leptophlebiidae*, the riffle beetle *Optioservus*, and two midges: *Stempellinella* and *Xylotopus*. Of those taxa, only two were represented by more than two individuals: *Leptophlebiidae* and *Optioservus*, with twenty and 24 individuals respectively, out of 327 total individuals in the subsample.

Table 4. Macroinvertebrate IBI metric scores from the sample at 16UM112 on 9/7/2016. Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown.

MIBI Class 3 Metric	Raw Metric Result	Re-scaled IBI score
ClimberCh *Number of climber taxa*	7	4.61
ClingerChTxPct *Percent of clinger taxa*	39.02%	7.33
DomFiveCHPct *Relative abundance of dominant five taxa*	58.72%	4.87
HBI_MN *Measure of pollution based on MNtol values*	6.35	5.86
InsectTxPct *Percent of insect taxa (versus non-insects, such as snails)*	82.93%	4.24
Odonata *Number of Odonata taxa*	2	6.13
Plecoptera *Number of Plecoptera taxa*	0	0
Predator *Number of predator taxa*	7	3.08
Tolerant2ChTxPct *Percent of taxa with a MNtol values $\geq$ 6*	63.41%	6.49
Trichoptera *Number of Trichoptera taxa*	7	5
Total (MIBI score)	--	47.60

Stressor Data

-Longitudinal Connectivity

Beavers have dammed this stream in various locations at various times, according to aerial imagery between 1991 and 2015. Also, there is physical evidence of beaver activity and two historic, breached dams at the upstream end of the biological station.

There are only two public road crossings on this stream between the biological station and the Platte River. Both were assessed by the Minnesota Department of Natural Resources (MN DNR) to determine if they are barriers to fish passage. It was determined that the crossing at 193rd St. is an impediment to some fish, especially at higher velocities, as a result of improper culvert design. A few other partial barriers to fish passage were also identified.

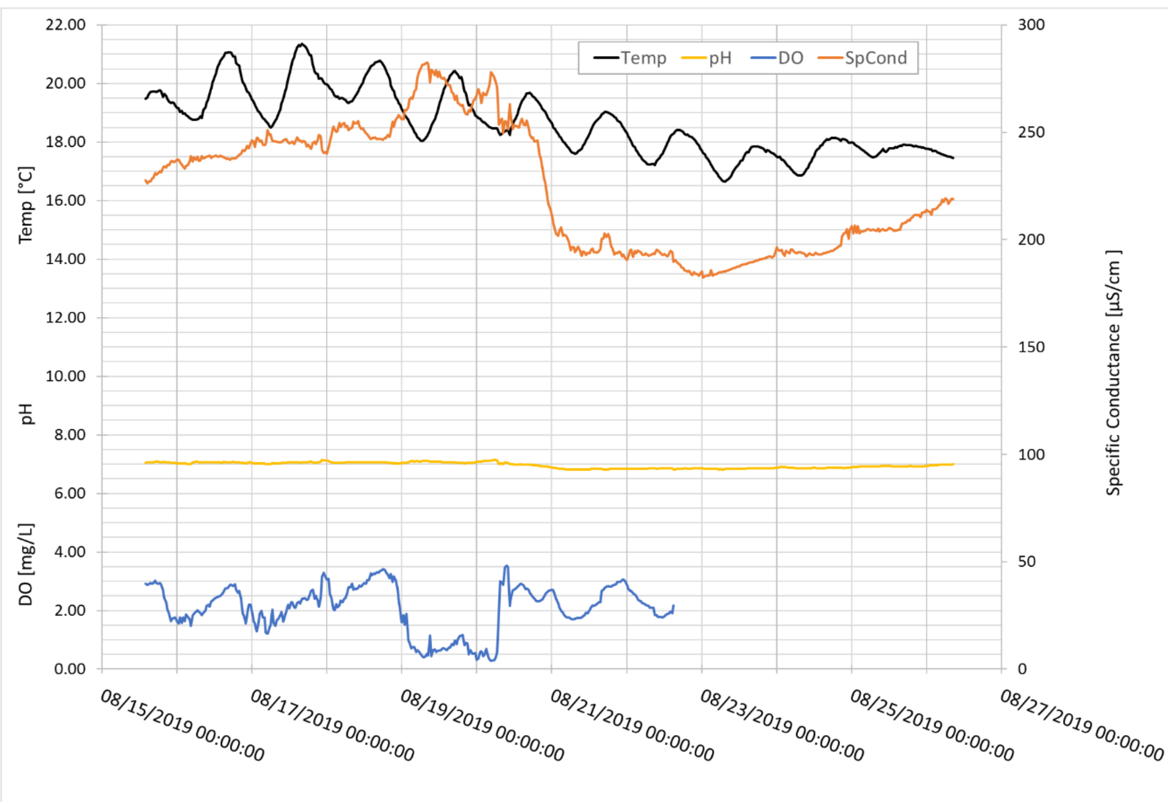
The only issue with the 193rd St. crossing noted by the MN DNR was a lack of substrate in the culverts, which are approximately 43 feet long. Without substrate to provide velocity breaks throughout the culvert, some fish will not be able to pass through because there are limits to how far they can swim at certain velocities. The lack of velocity breaks, or resting places, would most particularly limit smaller fishes, like some cyprinid species. The impact of this stressor aligns with the FIBI metrics showing a lack of cyprinid species and a low percent of migratory taxa (11.11%) and migratory individuals (4.89%). The 193rd St. stream crossing uses seven culverts across a span of 27.5 feet to accommodate the width of the braided channel at this location. Some of the offset culverts do have substrate, but will only have water flowing through them when the water levels are high enough. In the summer of 2019, a beaver dam was built into the culverts, and they are now more of a passage barrier than they were in 2016.

There are two private stream crossings between the biological station and the Platte River that were not investigated on the ground; they may or may not be barriers. Aerial imagery suggests that these two locations are likely not barriers at most flows. Downstream of the biological station is a stream section may be impassable at low flows due to shallowness created by livestock activity that has over-widened the channel.

Another potential barrier, especially to sensitive fish species, is the low DO environment that exists between the biological station and the Platte River. From the biological station, WID -634 flows through 1.5 stream miles of continuous shrub swamp before it reaches the Platte. A sonde was deployed in August of 2019 on WID -634 at 193rd St., and no DO measurements reached the 5.0mg/L standard (Figure 3). Oxygen-consuming processes are likely occurring in the stream due to microbial and nutrient inputs from the wetlands and possibly upstream pastures. While not a physical impediment, such as a dam, this area of low DO is disconnecting sections of the stream and prohibiting some fish from accessing 16UM112.

Although there is desirable habitat for lithophilic spawners in the sampled reach, which is discussed in detail below, it is possible that the combination of passage barriers and hurdles that fish must traverse to get from the Platte River to the biological station is limiting the fish community at 16UM112. In summary, the partial barriers referred to are: potential beaver dams, low DO, 193rd St. culverts, possibly private crossings, and a pasture.

Figure 3. Continuous sonde measurements on WID -634 at 193rd St.



-Streamflow

There are significant groundwater inputs into the stream in WID -634. Evidence of the groundwater connection is found in the iron concentration and temperature data, the prevalence of riparian wetlands, and physical evidence of iron in the stream (Table 5 and Figure 4). In July 2018, Secchi tube and TSS measurements were performed. The low transparency coupled with low TSS suggests that iron precipitates, not suspended solids, are causing the turbidity and discoloration of the stream.

Table 5. Data from Tributary to Platte River, collected upstream of CR265. MPCA EQUiS ID for this location is S013-527; data can be found on the MPCA's Environmental Data Access webpage.

	Date Time	**Temperature** [°C]	**Specific conductance** [µS/cm]	**Iron** [µg/L]	**Secchi tube** [cm]	**TSS** [mg/L]
June	6/27/2016 14:58	18.28	258		>100	3.6
	6/8/2017 13:00	17.31	254		>100	
	6/13/2018 13:46	18.99	202			
July	7/3/2018 9:21	19.63	239			
	7/9/2018 8:50	21.64	300			
	7/12/2018 10:10	22.08	300		25	
	7/18/2018 15:00	19.81	338		54	3.2
	7/19/2018 15:30	18.33	325		46	4.8
	7/26/2018 14:15	16.58	304		91	
August	8/15/2019 14:08	18.38	247	4590	62	
September	9/7/2016 12:45	17.55	279		96	
	9/10/2018 11:08	14.65	182		87	
November	11/8/2018 14:30	0.534	161	921		

Figure 4. Pictures showing orange coloration due to ferric iron hydroxide in stream (A) and adjacent spring (B), as well as cloudy white flocculence due to colloidal iron compounds (C).

Another important aspect of the flow regime to consider is the perennial versus ephemeral nature of the stream. The drainage area at the biological station is only 7.4mi^2. At this small size, it is possible the water level naturally gets quite low during dry spells, which reduces the amount and variety of available, wetted habitat. Pictures from the fish sampling event suggest that flow was low enough to limit the availability of some habitat (Figure 5).

Figure 5. June 27, 2016. Looking downstream from the middle of the biological sampling reach. A beaver dam was observed immediately upstream of this location, which is diverting flow from the main channel in this picture to a side channel off to the right (not pictured).

Streamflow magnitude was analyzed using daily mean discharge values from 10/1/1996 to 9/30/2015 (water years 1997-2015), obtained from the HSPF model. Discharge values from the model represent discharge at the outlet of the Trib. to Platte's 9.7mi^2 drainage area, which presumably represents the maximum possible discharge at the biological station upstream. Although, it is not known whether this stream contains any "losing" or "gaining reaches," which are types of surface-groundwater exchanges that could confound assumptions of longitudinal flow pattern.

To evaluate if low flow magnitude in WID -634 is a stressor to the biology, a low flow metric was calculated using the HSPF model data (see "ml1.12" in Henriksen *et al.* 2006). Minimum daily discharge for each month over the entire nine year record was calculated, then the mean and median of those values was calculated (Table 6). Based on the model estimates of monthly low flows for the last two decades, it is not uncommon for the stream to run at less than 2cfs for a period of time in late summer/early fall. This magnitude of low flow can be a limiting factor for aquatic life, especially some long-lived macroinvertebrates.

However, the low flow metric results suggest that it would be very rare for the primary stream habitat type (coarse substrate) and refugia (pools) to go dry. Also, given the stream's gradient and strong groundwater connection, even at low flows the water would likely remain cool and aerated enough to maintain sufficient DO levels for aquatic life. During the macroinvertebrate sample, *Hydropsyche betteni*, *Simulium*, *Optioservus*, *Heptageniidae*, and *Baetidae* (including some colder water species) were present. All five of these taxa are very common where water is moving with at least moderate velocity.

It does not appear that low flow magnitudes are driving the aquatic life impairment in WID -634. However, for a 43ft stretch of the biological station (7% of total station length), some habitat may not have been available during the fish sample, as seen in Figure 5, due to low water levels caused by a historic beaver dam that is diverting some flow to another part of the channel that was not sampled.

Table 6. Mean and median minimum discharge for spring-fall months throughout water years 1997-2015. Units are cubic feet per second (cfs).

	Mean [cfs]	**Median** [cfs]
April	3.55	2.86
May	2.80	2.24
June	3.26	2.55
July	1.66	1.44
August	0.90	0.77
September	0.74	0.44
October	0.98	0.77

--Metals: Iron and manganese

Studies have reported that iron can be a stressor to aquatic life, especially in the ferric hydroxide precipitate form (e.g. Vuori 1995; Gerhardt 1992; Wellnitz et al. 1994). Even at neutral pH, ferric hydroxide can precipitate on eggs and gill surfaces (Vuori 1995). Also, iron hydroxide suspended in the water column can trigger behavioral avoidance in some fishes (Updegraft & Sykora 1976). The mechanism of stress can be the disruption of the microbial and algal community, which is a primary food source for many macroinvertebrates and some fishes. In WID -634, the macroinvertebrates are considered “vulnerable,” and the fish community lacks sufficient abundance of insectivorous cyprinid individuals. Secchi tube measurements from the stream suggest that iron is indeed limiting the sunlight available for primary productivity; and, pictures of the blackened substrate indicate the presence of Fe/Mn-bacteria precipitates (Figure 6).

Figure 6. Substrate from 16UM112 on 7/12/2018. The dark coloration is due to deposition of minerals from the water, particularly manganese.

One water sample from WID -634 was analyzed for total iron on 11/8/2018, and measured 921µg/L, which is presumably lower than what concentrations would have been in the summer months, as the seasonal pattern for Fe and Mn concentrations decreases in late fall and winter. For context, the EPA's National Recommended Water Quality Criteria standard for chronic exposure of total iron is 1,000µg/L. In 2019, three more iron samples were collected, but only one result was available at the time of this writing. The total iron concentration at 16UM112 was 4,590µg/L on 8/15/2019, which is definitely a stressfully high concentration. On the same day, iron was sampled at the next downstream road crossing (193rd St.), and it was 4,430µg/L (MPCA EQUiS station S016-000).

More water chemistry samples of metals are needed to conclusively determine if iron, manganese, and/or other metals in the stream are stressing aquatic life in WID -634, but it is highly suspected. Samples should be collected especially in late July or early August.

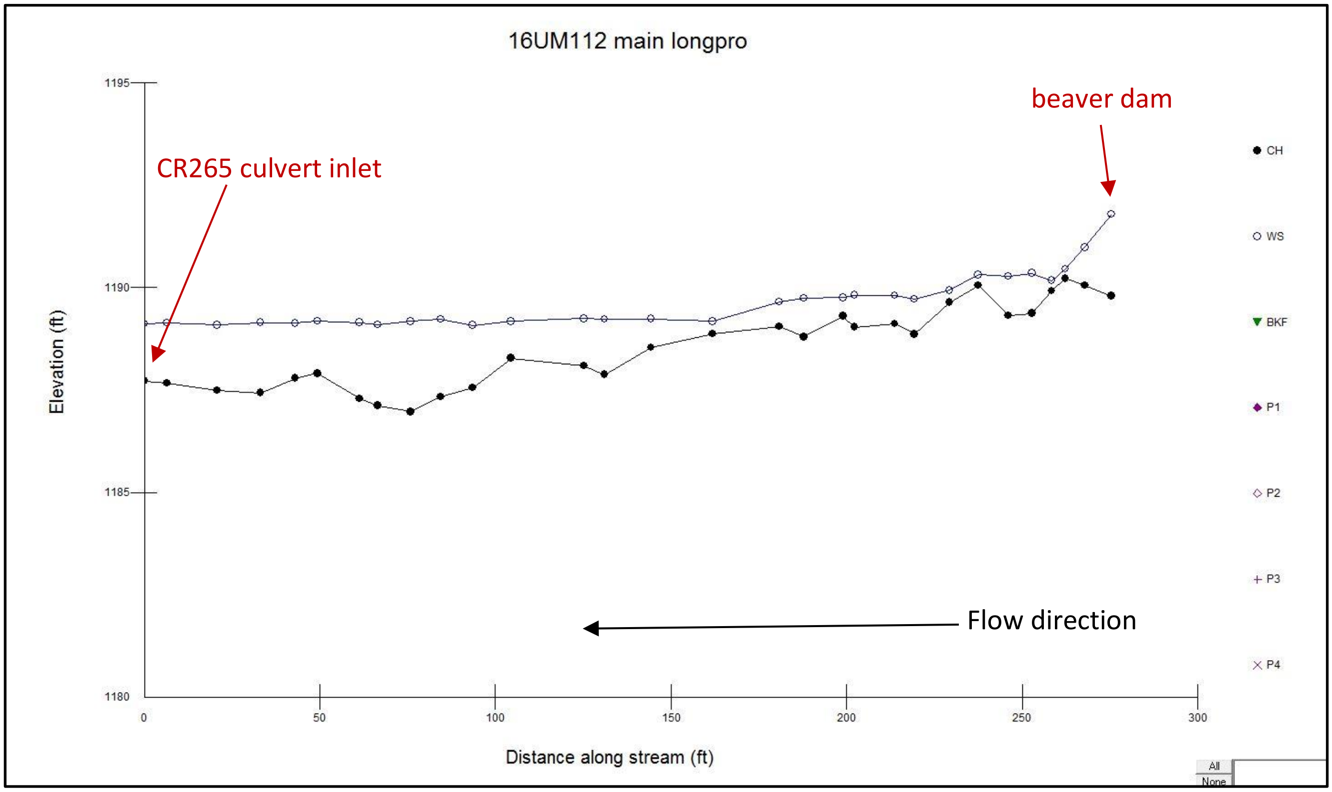
-Habitat

A depth-of-fines habitat analysis was conducted on 7/12/2018 at 16UM112. Depth-of-fines was measured by pressing the blunt end of a wooden dowel into the stream substrate and measuring how deep it will go, without applying excessive force. This measurement is a way to characterize the habitat and sediment transport capacity of a stream. Three-hundred feet of stream were surveyed in this manner, taking the measurements in the thalweg. Along the way, significant habitat features were noted and some Secchi tube measurements performed.

It was determined that the stretch of stream surveyed is indeed passing fine sediments through and not excessively depositing them on top of the coarse substrate. This indicates that the limiting factor for lithophilic spawning fish and riffle-dwelling macroinvertebrates is likely not due to embeddedness or siltation of coarse substrate. The range of depth-of-fines measured was 0-8cm, with a median of 0cm. The range of Secchi tube measurements was 35-46cm, due to cloudiness from metals in the water column.

A longitudinal profile of the streambed was performed on 11/8/2018 to evaluate the habitat based on depth variability and assess road crossing impacts (Figure 7). The section of stream nearest the road crossing, between 0-50ft, is a uniform run. This could be due to physical alteration of the channel during construction of the crossing, and/or it could be the result of an imperfect culvert design (elevation and slope).

Figure 7. Longitudinal profile of Tributary to Platte River from the culvert at CR265 (0ft on x-axis) upstream to the top of the beaver dam (275ft on x-axis). Survey performed on 11/8/2018.



Two Minnesota Stream Habitat Assessments (MSHAs) were completed in 2016. The total scores were 71.20 and 68.95 out of 100 possible points. These are considered "good" scores. Both MSHAs reported maximum depth to be greater than or equal to four times the minimum depth, which is corroborated by the longitudinal profile. This is good depth variability. The MSHAs reported embeddedness as 0% in June 2016 and 25-50% in September 2016. The light embeddedness noted in 2016 was also corroborated by the 2018 depth-of-fines analysis. In conclusion, lack of habitat does not appear to be stressing aquatic life in WID -634.

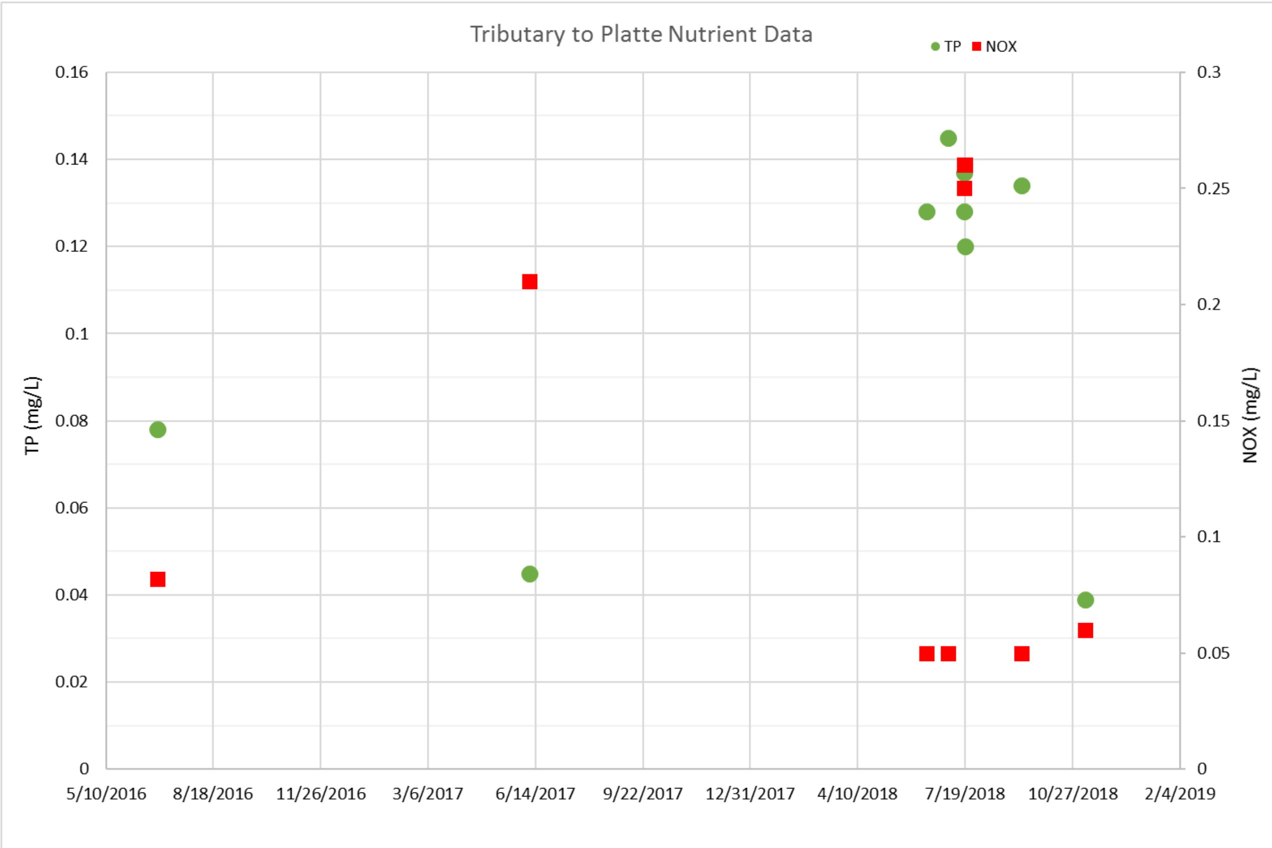
-Suspended Sediment

Only three total suspended solids (TSS) measurements are available for this WID (see Table 5), none of which are high concentrations. MPCA biologists calculated the likelihood that this WID would meet the state TSS standard based on the fish community, and it is an 82% chance. This information, coupled with the fact that habitat quality is not compromised due to embeddedness or excess siltation, suspended sediment is not a suspected stressor in WID -634.

-Nutrients

The available nitrogen data suggests it is not a stressor (Figure 8), as all values were below 0.3mg/L. Total phosphorus concentrations did exceed the standard of 0.100mg/L in July 2018 (Figure 8), but due to a lack of plant or algae growth, phosphorus also does not appear to be a stressor.

Figure 8. Total phosphorus (TP) and inorganic nitrogen (NOX) in Tributary to Platte River. Sampled just upstream of Morrison CR265. MPCA EQUiS ID for this location is S013-527; data can be found on the MPCA's Environmental Data Access webpage.



-Dissolved Oxygen

All of the instantaneous DO measurements collected at the biological station were above the state standard for aquatic life, 5mg/L (Table 7). However, only two of the instantaneous measurements were taken pre-9:00AM, when DO is lowest. The earliest measurement was at 8:30AM on 7/12/2018, and DO was 5.91mg/L. One that same day, a measurement of 2.26mg/L was made about 10ft upstream of the CR265 culvert, but this is presumably a localized spot of extremely low DO, perhaps due to a groundwater upwelling, because DO was greater than 5mg/L at the culvert and at an upstream riffle when measured within the same hour.

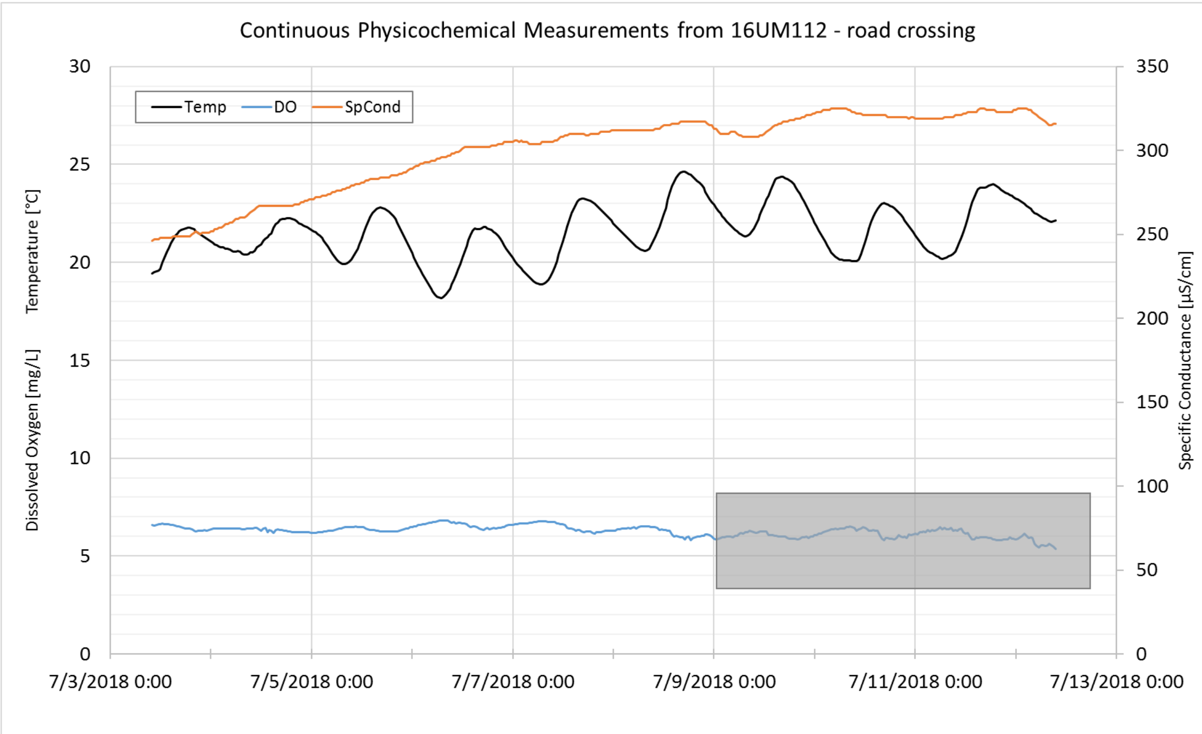
Continuous DO measurements were made on July 3-12, 2018, with a sonde deployed on the streambed approximately ten feet upstream of the CR265 culvert (Figure 9). On July 9, the deployed sonde was tracking well, but by the 12^{th}, the DO measurements were reading 0.53mg/L too low, as compared to a field check sonde. The range of valid DO measurements was 5.81 - 6.81mg/L (Figure 9, upper). Continuous measurements were again made July 12-18, 2018, with a sonde deployed in a riffle approximately 180 feet upstream of CR265. The range of DO during this time was 5.58 - 7.75mg/L (Figure 9, lower). Based on these twelve days of continuous DO measurements at two different areas in 16UM112, DO did not drop below the standard of 5mg/L. It appears that the extremely low DO, measured at 2.26mg/L, is localized to that one small section of the stream. However, if there are multiple instances of these extremely low pockets DO along the WID, it could be dragging down the overall DO levels.

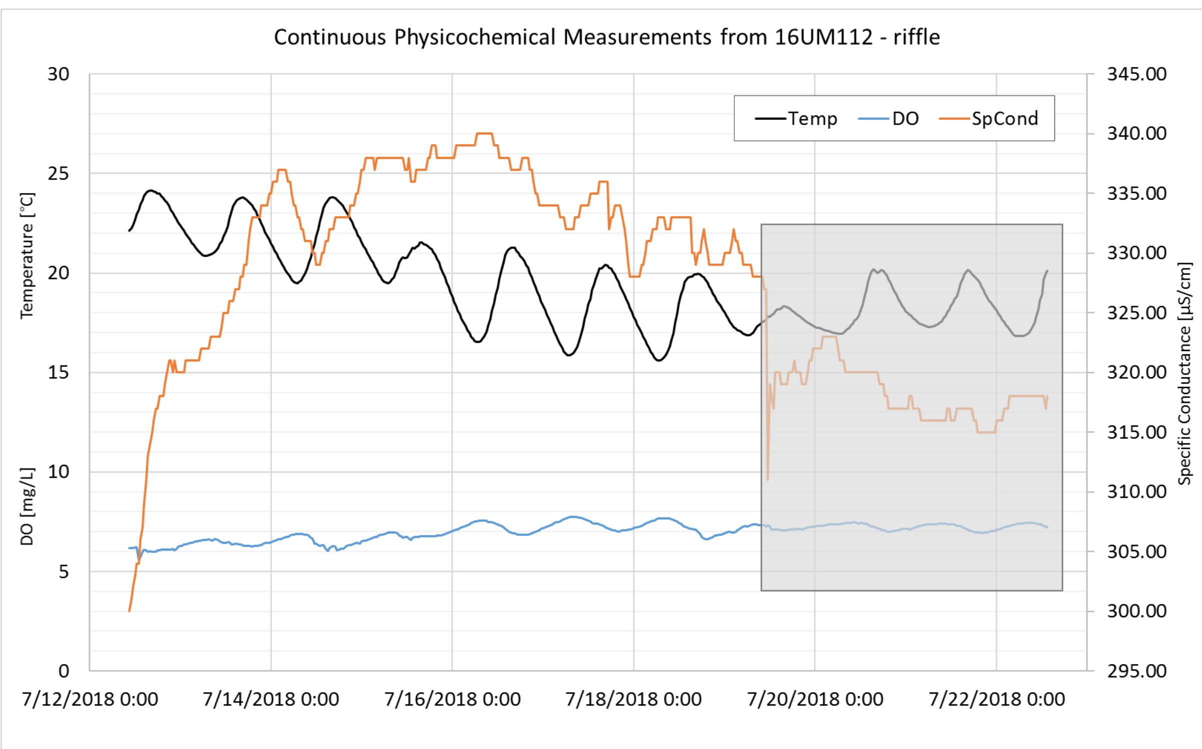
While DO measurements from 16UM112 did not drop below the standard, the fish community data suggest that it is a stressor. Using methods similar to Meador and Carlisle (2007), MPCA biologists calculated the likelihood the WID would meet the state DO standard based on the fish community sampled; the result was a 17% chance. This is likely the result of the low DO measured at 193rd St., the next road crossing downstream of CR265 (see Figure 3), which stands between the Platte River and 16UM112. Low DO is a stressor to aquatic life in WID -634, though it appears to be somewhat sporadic and likely a natural phenomenon from groundwater inputs and riparian wetlands.

Table 7. Instantaneous dissolved oxygen (DO) measurements collected between 2016 and 2019. All measurements taken at the Morrison CR265 crossing except where otherwise noted. MPCA EQUiS ID for this location is S013-527; data can be found on the MPCA's Environmental Data Access webpage.

Date	**Time**	**DO** [mg/L]	**Comment**
6/27/2016	14:58	7.82	
9/7/2016	12:45	7.16	
6/8/2017	13:00	8.01	
6/13/2018	13:46	7.40	
7/3/2018	9:21	6.62	
7/9/2018	8:50	6.46	
7/12/2018	8:30	5.91	
7/12/2018	9:40	2.26	At spring/upwelling
7/12/2018	10:10	6.05	At upstream riffle
7/18/2018	15:00	7.01	
7/18/2018	15:20	7.12	At upstream riffle
7/19/2018	15:30	5.47	
7/26/2018	14:03	8.01	
7/26/2018	14:15	5.95	At upstream riffle
8/15/2019	14:12	7.08	
8/22/2019	15:00	7.39	
8/26/2019	9:02	7.35	

Figure 9. Physicochemical parameters measured with continuous sonde deployment at the road crossing area (upper) and an upstream riffle (lower) in biological station 16UM112.
Grey boxes indicate where probes began to malfunction, otherwise the deployed sonde data was within acceptable ranges of the field sonde checks.





WID Summary

Longitudinal connectivity appears to be a primary stressor of the fish community in various ways. A combination of barrier types is preventing fish from reaching 16UM112 from the Platte River at various flow levels, namely: beaver dams, areas of extremely low DO possibly private culverts and a pasture, and the 193rd St. culverts. Therefore, low DO is also a stressor. The "vulnerable," or underperforming, macroinvertebrate community may be limiting the fish community, suggested by the lack of insectivorous cyprinid fishes.

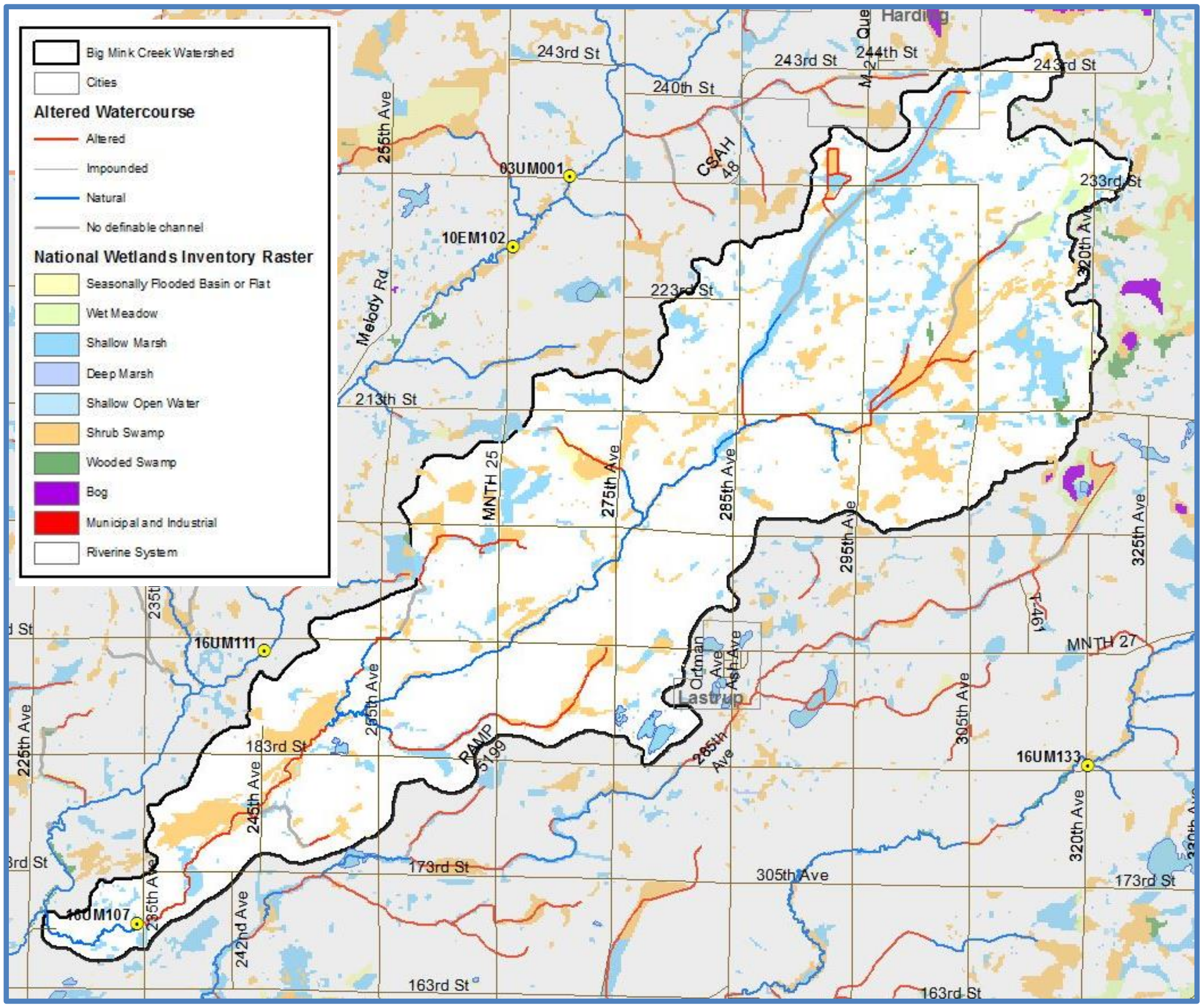
Metals, specifically iron and possibly manganese, are suspected stressors to aquatic life at the biological station, but that remains inconclusive until more data become available. The one sample analyzed for iron was taken during a time of year when iron concentrations are typically low, and still it was close to the EPA's suggested aquatic life standard. The presence of metals in WID -634 is presumably a result of the stream's natural groundwater connection. More iron samples were collected in August of 2019, but the results were not available at the time of this writing. In the future, those results can be found on the MPCA's Environmental Data Access webpage under stations S013-527 and S016-000.

Streamflow alteration does not appear to be a direct stressor, although a historical beaver dam may have affected the quality and availability of some habitat in 16UM112. Habitat in 16UM112, and even upstream of the station, is sufficient and is not limiting the aquatic life in WID -634. Although, parts of the WID exhibit localized habitat degradation, such as immediately up- and downstream of CR265 and in the pasture downstream of 16UM112.

3.1.2. Big Mink Creek – WID 07010201-647

Big Mink Creek is a tributary to the Platte River. The stream begins south of Harding, Minnesota, and flows southeast, reaching the Platte River just before the Platte crosses CR255 (Figure 10). About 1.5 miles upstream of the confluence with the Platte River is CR279, the section of Big Mink Creek between the Platte and CR279 is WID -647. There is one biological sampling station on WID -647, 16UM107, which begins just downstream of CR279 and extends downstream for approximately 550ft. Within the bounds of Big Mink's $22\mathrm{mi}^2$ drainage area are livestock pastures, wetlands, and row crop fields. For further watershed characterization, see the MPCA's M&A Report, Figure 18.

Figure 10. Big Mink Creek drainage area, showing wetlands and stream alteration. Note station 16UM107 near the outlet of the watershed.



Biological Data

WID -647 is impaired for aquatic life due to nonsupport of the macroinvertebrate community. The macroinvertebrates were sampled in September of 2016 and 2017; both MIBI scores failed to meet the general use threshold for the assigned MIBI Class 5 – Southern Streams Riffle Run (Table 8). The assigned FIBI Class is 6 – Northern Headwaters.

Table 8. IBI scores at site 16UM107 on Big Mink Creek (WID 07010201-647).

		Fish IBI			Macroinvertebrate IBI		
Station	Date	Class†	Impairment threshold	Score	Class†	Impairment threshold	Score
16UM107	6/27/2016	6	42	61.8	-	-	-
	9/1/2016	-	-	-	5	37	35.5
	9/13/2017	-	-	-	5	37	33.4

†FIBI Class: (6) Northern Headwaters
MIBI Class: (5) Southern Streams – Riffle/Run

Components of the macroinvertebrate community that are most notably weighing down the MIBI score are a lack of Trichoptera (caddisflies), Plecoptera (stoneflies), and predator taxa, as well as a high percentage of non-insect taxa (Table 9, note highlighted rows). In both 2016 and 2017, the two Trichoptera genera found were *Cheumatopsyche* and *Hydropsyche*, totaling nine individual organisms across both years. No Plecoptera (stoneflies) were observed during either survey. The samples contained approximately 20% non-insect taxa, such as *Hyalella* (scuds), *Hydrobiidae* (mud snails), and *Trepaxonemata* (flatworms). A composition of 20% non-insects may seem relatively low, but in the context of all 974 other MIBI Class 5 sites across the state, only 272 (28%) of them have a non-insect proportion that high, and only nineteen of those 272 achieved a passing MIBI score. This is a characteristic of an impaired community.

Table 9. Macroinvertebrate IBI metric scores from the samples at 16UM107.
Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown.

MIBI Class 5 Metric	Raw Metric Result		Re-scaled IBI Score	
	9/1/2016	9/13/2017	9/1/2016	9/13/2017
ClimberCh *Number of climber taxa*	7	9	4.61	6.77
ClingerChTxPct *Percent of clinger taxa*	35.0%	30.3%	5.78	3.97
DomFiveCHPct *Relative abundance of dominant five taxa*	54.0%	64.5%	6.03	3.42
HBI_MN *Measure of pollution based on MNtol values*	6.69	6.82	4.88	4.50
InsectTxPct *Percent of insect taxa (versus non-insects, e.g. snails)*	80.0%	78.8%	2.97	2.47
Odonata *Number of Odonata taxa*	1	2	3.87	6.13
Plecoptera *Number of Plecoptera taxa*	0	0	0	0
Predator *Number of predator taxa*	6	6	2.31	2.31
Tolerant2ChTxPct *Percent of taxa with a MNtol values $\geq$ 6*	70.0%	75.8%	5.08	3.84
Trichoptera *Number of Trichoptera taxa*	2	2	0	0
Total (MIBI score)	--	--	35.5	33.4

Tolerance of the macroinvertebrate community was analyzed in the context of all other MIBI Class 5 samples by looking at the taxa richness (number of taxa) of tolerant vs. intolerant taxa to specific stressors, and how that richness ranks in a percentile analysis (Table 10). For "Intolerant" categories, a high percentile is "good," but for "Tolerant" categories, a high percentile is "bad." Ecologically speaking, a high number of intolerant taxa indicates a healthy community, while a high number of tolerant taxa suggests the community is stressed.

The Intolerant and Very Intolerant percentiles are "inflated" because impaired communities were included in the analysis; they would be smaller if the sample was ranked only against unimpaired reference communities. Similarly, the Tolerant and Very Tolerant percentiles are "deflated." Therefore, a high percentile rank of the Very Intolerant and Intolerant categories should not be used to refute something as a stressor, but can be considered with other data as supporting information. These tolerance richness data are used as supporting evidence in the following discussions of stressor data.

In summary, the tolerance richness data show that the macroinvertebrate community composition is weighted toward taxa that are tolerant of low DO, fine substrate, and embedded substrate. The distribution of taxa tolerance to TSS and TP is not clearly weighted one way or the other. While a greater number of taxa were found that are NOX-tolerant than -intolerant, the percentiles show that the community features more NOX-intolerant taxa than at least 87.7% of all other MIBI Class 5 communities sampled.

Table 10. Number of taxa ("taxa richness") in the macroinvertebrate samples at 16UM107 that are tolerant and intolerant to specific stressors.
Percentile analysis was performed using all other MIBI Class 5 samples collected by MPCA (n=1,046). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Stressor	Very Intolerant Taxa richness - Percentile		Intolerant Taxa richness - Percentile		Tolerant Taxa richness - Percentile		Very Tolerant Taxa richness - Percentile	
	2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Low DO	1 – 6.7%	0 – 0%	1 – 3.9%	0 – 0%	9 – 87.5%	7 – 73.6%	3 – 79.4%	3 – 79.4%
Depth of Fines	0 – 0%	0 – 0%	0 – 0%	0 – 0%	9 – 90.2%	7 – 79.9%	4 – 83.5%	3 – 73.6%
Embedded Substrate	0 – 0%	0 – 0%	0 – 0%	0 – 0%	9 – 53.9%	11 – 73.4%	6 – 48.4%	8 – 75.6%
Total Suspended Solids (TSS)	0 – 0%	0 – 0%	2 – 67.5%	1 – 44.2%	9 – 30.1%	9 – 30.1%	4 – 36.3%	3 – 19.4%
Inorganic nitrogen (NOX)	1 – 73.9%	2 – 89.7%	5 – 92.7%	4 – 87.7%	13 – 17.2%	15 – 27.7%	8 – 16.1%	10 – 31.7%
Total phosphorus (TP)	0 – 0%	1 – 69.4%	2 – 46.2%	2 – 46.2%	10 – 62.6%	8 – 44.7%	6 – 79.5%	5 – 68.2%

Stressor Data

-Streamflow

Big Mink Creek's streamflow response to overland runoff and/or interflow has likely changed since the stream and wetlands in the watershed were ditched. According to the MPCA's Altered Watercourse spatial data layer, approximately three miles of the mainstem of the stream were ditched, and all five tributaries to the mainstem have some alteration (see Figure 10, red stream lines). Additionally, much of the plant life in the watershed is now grazed pasture and row crop, land use types that tend to have higher runoff coefficients than forested or wetland.

Big Mink Creek is strongly connected with groundwater, evidenced by the predominance of riparian wetland area and iron in the stream (Figure 11). Groundwater is often low in DO and can have high concentrations of metals, such as iron, which can be a stressor to aquatic life; see section 3.1.2. *–Metals: Iron and Manganese* for more information on iron as a stressor. No water chemistry samples were analyzed for iron concentration in Big Mink Creek, but the physical appearance suggests it is strong. Further, iron is a suspected stressor in two nearby streams that are also impaired for aquatic life: Tributary to Platte River (WID -634) and Little Mink Creek (WID -645). Iron is an inconclusive stressor to aquatic life in WID -647.

Analysis of the HSPF modeled flow data was not conducted for the Big Mink Creek watershed, but may be considered for future work. Other ways of measuring potential effects of streamflow alteration on aquatic communities, such as habitat quality, are discussed in the following sections. Some of those observations suggest that streamflow alteration may be a driver of other stressors identified, such as lack of habitat diversity and low DO. However, more data are needed to determine if streamflow alteration is the underlying cause. Streamflow alteration is currently an inconclusive stressor for WID -647.

Figure 11. Evidence of iron in Big Mink Creek at 16UM107 on 8/16/2018.
Ferric iron precipitate is causing the orange coloration of the water and an oily sheen on the surface. Dissolved oxygen was 0.36mg/L and specific conductance was 551µS/cm.

-Habitat

The channelization of Big Mink Creek and its tributaries can have a negative effect on the habitat of the stream. The sampled reach has not been modified. The habitat in this section of stream, however, could be indirectly affected by the upstream channelization through a change of natural stream processes, such as sediment transport capacity and streamflow pattern alterations. Assessments of habitat in the sample reach were made using the MSHA, macroinvertebrate taxa metrics, and records of site visit observations.

Immediately after macroinvertebrates were sampled in 2016 and 2017, habitat was assessed using the MSHA. Macroinvertebrate habitat types noted were: undercut banks, overhanging vegetation, logs or woody debris, shallows and backwaters, and macrophytes. The cover amount of these habitat types was recorded as >50%. Pictures indicate that at least half of that cover amount was macrophyte habitat. It was estimated that the sampling reach was primarily a run, with $\leq$15% pool habitat. The primary substrate in the channel was sand and gravel. Embeddedness of coarse substrate was noted as 25-50% in 2016 and 50-75% in 2017. Similarly, siltation was noted as “Normal” in 2016 and “Moderate” in 2017.

After the fish sample on June 27, 2016, an MSHA was performed, and the crew noted the presence of a sand/gravel riffle. No riffles were observed during either of the August macroinvertebrate samples, however. Seasonal differences in water level and in-channel vegetation between June and August may explain the different accounts of riffle presence between the MSHAs. Of note, the fish sample yielded fourteen logperch, a fish species that requires coarse substrate and at least moderate water velocity to thrive. In total, three MSHAs were performed in 2016-2017 with an average score of 58, which is considered the “Fair” (45-65) category.

While wading through the stream from CR279 during the summer months of 2017 and 2018, the following observations about habitat were made:

1. Embedded (~50%) coarse gravel in the run; this area also fostered extensive in-channel macrophyte growth
2. Several species of aquatic vegetation present
3. Up to six inches of soft, fine substrate in parts of the run
4. Excess fine sediment and filamentous algae accumulated on the vegetation, very noticeable at the surface (Figure 12)

Figure 12. Left: Looking at upstream end of 16UM107 from CR279 on 7/23/2018. Right: Close-up of fine sediment and algae accumulated on in-channel vegetation on 7/30/2018.

The tolerance richness metrics show an absence of taxa that are sensitive to embedded coarse substrate and fine bed material (Table 10). The macroinvertebrate community in 16UM107 has more taxa that are tolerant and very tolerant to embeddedness than ≥ 50% of the other MIBI Class 5 samples in Minnesota, and ≥ 73% for soft, fine bed material ("depth of fines" in Table 10). Additionally, the lack of Plecoptera and Trichoptera taxa, which generally live on coarse substrate, indicates that this habitat feature is either absent, degraded, and/or non-productive. Some macroinvertebrates were sampled that are known to cling to coarse substrate, like the midge *Rheotanytarsus* and the beetle *Stenelmis*. However, a greater taxa richness of these "clinger" type of organisms is expected from an MIBI Class 5 stream (Southern Streams Riffle/Run).

A lack of healthy riffle habitat appears to be stressing the macroinvertebrate community in 16UM107. The sediment tolerance richness metrics, MSHA, and field observations point to embedded coarse substrate/accumulation of fine bed material and homogeneity of stream facets. There may be additional factors affecting the invertebrates' ability to thrive on what coarse substrate is available, such as low DO, which is overall causing a lack of productive habitats. This can also explain the lack of dragonfly and damselfly taxa, and other predators, such as stoneflies.

-Suspended Sediment

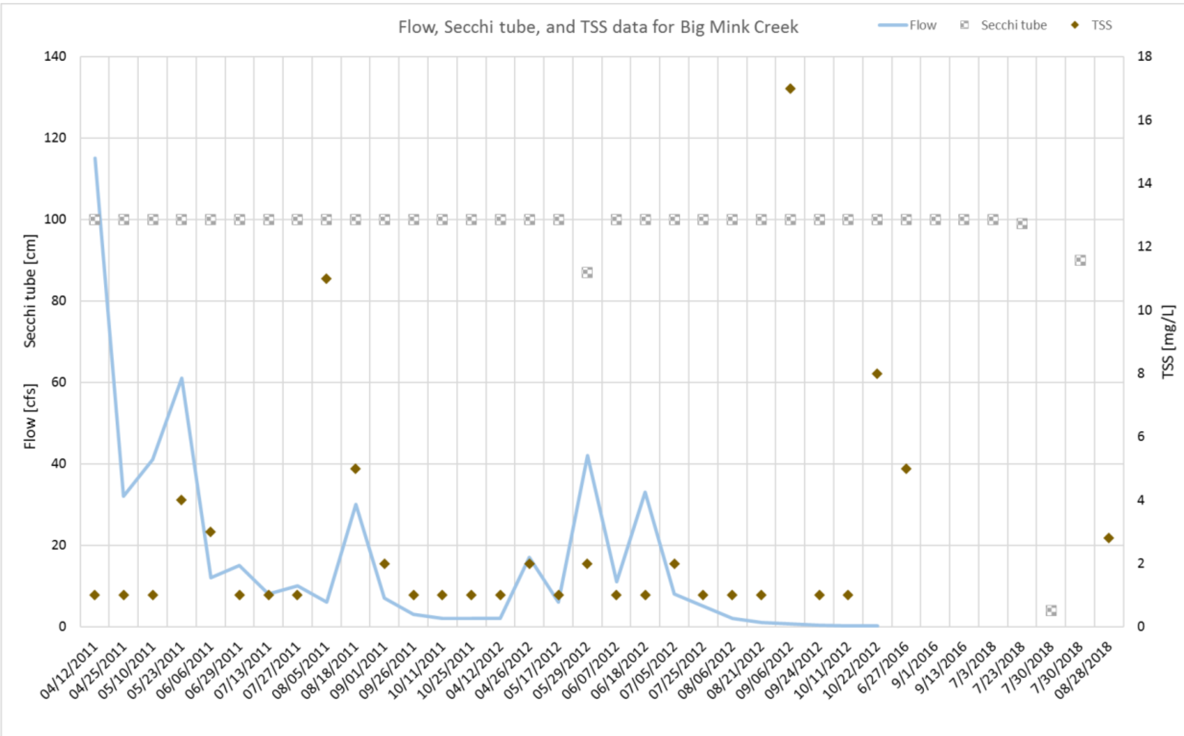
Based on the siltation and embedded substrate information provided above, there is evidence to suggest that the stream may be experiencing sediment transport and/or excess loading issues. More data are discussed in this section to determine if sediment in the suspended state is stressing the macroinvertebrate community in WID -647.

Big Mink Creek flows through numerous pastures where cattle have direct access to the channel and have trampled and eroded the banks; these pastures are sediment and nutrient sources. Downstream of the majority of these pastures is a shrub swamp, where many of the fines might settle out until a high flow event occurs. Downstream of the shrub swamp, the creek flows through row crop fields and functions as a drainage ditch. Then, at Morrison CR279, the stream regains its natural form, which contains the sampling reach 16UM107. Finally, between 16UM107 and the outlet of Big Mink to the Platte River, are two more livestock operations that are impacting the stream. In short, there is no lack of potential sediment sources in the watershed.

Recent suspended solids data for Big Mink are sparse, consisting of a few TSS samples and Secchi tube measurements. Bimonthly samples were collected in 2011-2012 (Figure 13). Ideally, an analysis of TSVS would be performed along with TSS to measure how much of the suspended solids in TSS are plant material and other volatile material, therefore explaining what proportion of TSS might actually be attributed to sediment particles vs organic matter. Only one paired TSS/TSVS measurement exists, which was 2.8/2.4 mg/L on 8/28/2018. On this date, a bit more than half of the suspended particles were plant material and not mineral (soil). Without TSVS to accompany the earlier TSS samples in Figure 14, it cannot be assumed that those values represent sediment. The 2011-2012 TSS and Secchi tube data do not suggest that suspended solids were at stressful levels when sampled.

It is prudent to contextualize TSS and even Secchi tube data with discharge data because of the interrelated nature of these parameters. The HSPF model was used to calculate daily mean discharges on the days TSS was sampled. The model's record only goes from 1/1/1996 to 12/31/2015, however, so the 2016-2018 chemistry does not have an associated discharge estimate. While the daily discharge certainly helps interpret the TSS and Secchi results, it carries the limitation of not representing the actual discharge at the moment the sample was taken. Some correlation can be seen between average daily discharge and TSS, but does not explain some of the TSS spikes, such as on 9/6/2012.

Figure 13. Flow values are average daily discharges, as calculated by the HSPF model. Secchi tube values of 100cm represent the maximum reporting limit. Some of the TSS values shown as 1mg/L were actually reported as <1mg/L, which is the detection limit. All samples were collected at the Morrison CR279 road crossing. MPCA EQUiS ID for this location is S006-575; data can be found on the MPCA's Environmental Data Access webpage.



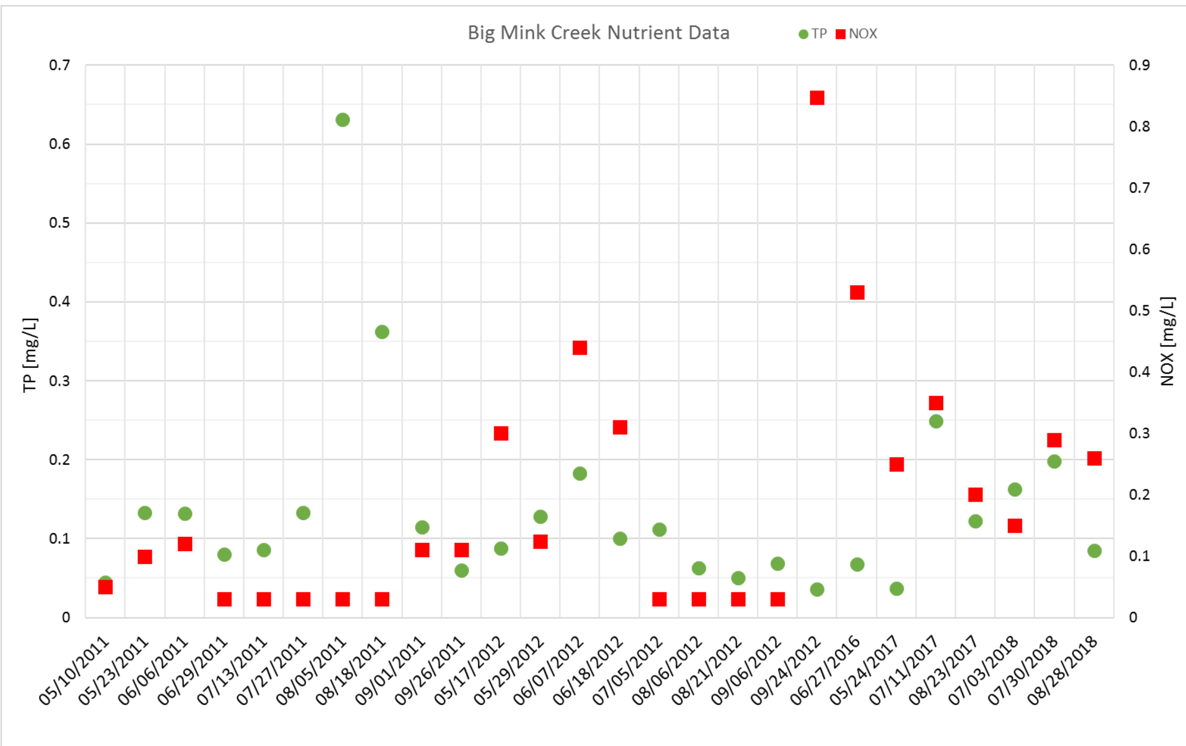
The two Secchi tube measurements on 7/30/2018 reflect the vast difference in water transparency when the vegetation is disturbed and all the fines that have accumulated on it dirty up the water column. The reading of 90cm was sampled from an area where the tube could be filled without disturbing the vegetation; the reading of 4cm was from placing the tube in the thalweg without taking special care to not disturb any of the thick vegetation. The 86cm difference in Secchi tube measurements taken on the exact same day shows how important sampling methods are to interpreting the results. At this time, little is known about how the 2011-2012 chemistry samples were collected; for example, were the samples gathered from directly below the culvert where there is no vegetation, or were they gathered from the vegetated area.

The tolerance richness metrics indicate that a greater proportion of the macroinvertebrate community is tolerant to TSS than is intolerant. However, when compared to MIBI Class 5 streams statewide (the percentages in Table 10), it is unclear whether that actually suggests a TSS stressor or not. A lack of clear signal from the tolerance metrics and current chemistry data makes suspended sediment an inconclusive stressor for the macroinvertebrate community in WID -647.

-Nutrients

A collection of bimonthly nutrient samples was compiled in 2011 and 2012, and then a few more samples were gathered between 2016 and 2018 (Figure 14). However, it is important to note that this dataset consists of somewhat randomly gathered samples and was not specifically designed to detect nitrate toxicity, whether acute or chronic. Additionally, the bulk of the data is seven years old and may not be representative of current stream conditions, as land management practices in the watershed may have changed.

Figure 14. Total phosphorus (TP) and inorganic nitrogen (NOX) data from Big Mink Creek, 2011-2012 and 2016-2018.
All samples were collected at the CR279 road crossing.



Nitrogen

The available chemistry data do not suggest that nitrate toxicity is a stressor. However, a more recent and comprehensive dataset is needed to be conclusive, especially because the tolerance richness metrics and lack of Trichoptera taxa suggest that NOX may be affecting the macroinvertebrate community. Nitrate toxicity is an inconclusive stressor.

Phosphorus

The chemistry data shows that TP concentrations are frequently at levels that may result in eutrophication for the region (above 0.100mg/L). The mean TP concentration across all samples is

0.124mg/L, with the monthly means as follows: May=0.086, June=0.107, July=0.148, August=0.195, September=0.062mg/L. Those TP concentrations are above the water quality standard set to protect against eutrophic conditions, spurring the excessive primary production in the channel that was witnessed by field staff 2016-2018.

Of nineteen Chl-a samples taken during the growing season (June-September) in 2011 and 2012, all were $\leq$ 3µg/L, except for a September sample in both years that resulted in 6µg/L (data not shown). However, Chl-a is not the ideal way to characterize primary productivity in small streams because shading and water movement typically do not allow much water column algae to develop. Filamentous algae was observed in Big Mink Creek, which is not measured with a Chl-a analysis. Not enough Chl-a, continuous DO, or biological oxygen demand (BOD) data are available to determine if the high TP concentrations observed are stressing the macroinvertebrates via eutrophication.

Pictures and field observations indicate that the in-channel vegetation is slowing the water velocity. It is suspected that the excessive plant and algal growth is not only impairing the channel's ability to carry fine material away, it is contributing to the mass of detritus and fine material that eventually accumulates on the streambed.

In conclusion, both nitrate toxicity and excess phosphorus are inconclusive stressors. More data are needed to determine if eutrophication is occurring and if it is affecting the macroinvertebrates via fluctuation of DO. If the thick in-channel vegetation is being driven by excessive phosphorus concentrations, then it could be a driver of habitat degradation by affecting streamflow and sediment transport. Phosphorus is an inconclusive, though suspected, stressor to the macroinvertebrate community in WID -647.

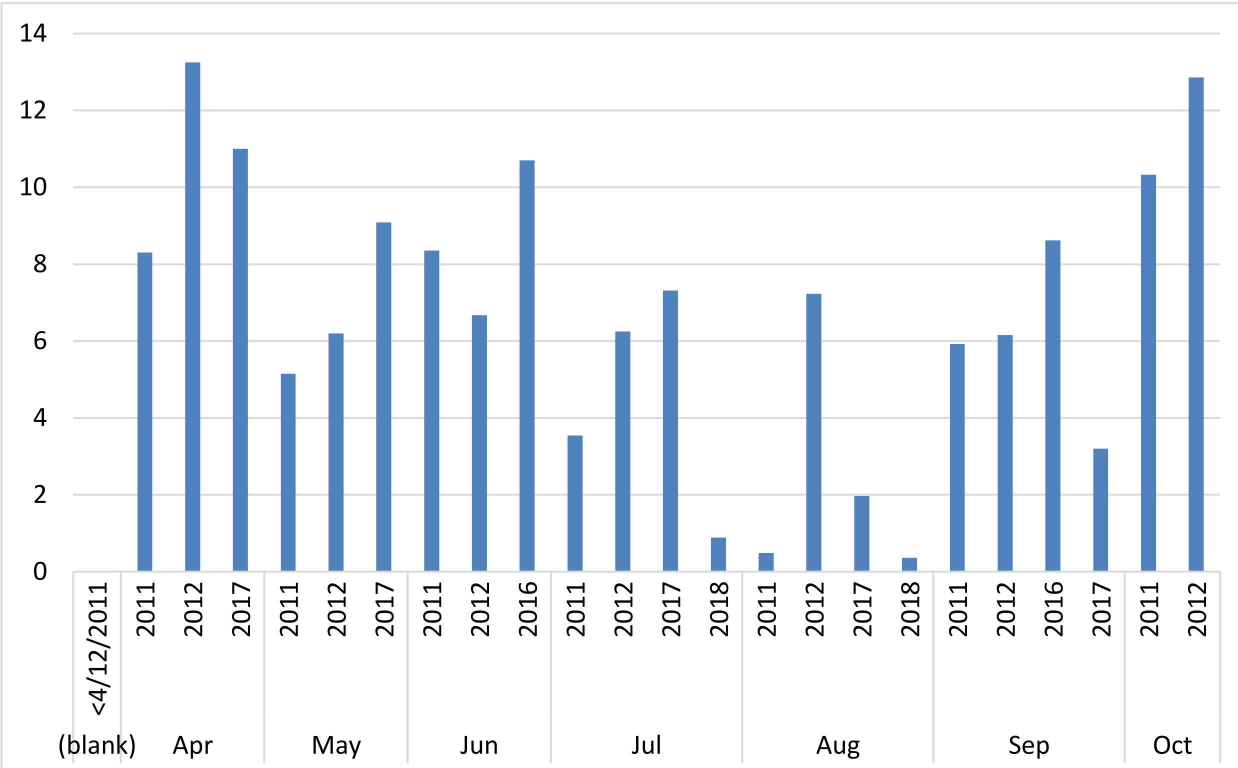
-Dissolved Oxygen

Some taxa were sampled that are commonly associated with low DO environments, such as the mayfly *Caenis* and the mud snail, *Hydrobiidae. Caenis* can live in stagnant water and resides on fine particulate bed material; it can be found in wetlands. *Hydrobiidae* is commonly associated with aquatic macrophytes and slow flows. In the 2017 sample, however, only one *Caenis* individual was sampled (versus eleven in 2016), while a similar amount of *Hydrobiidae* were sampled in both years.

As shown in Table 10, the samples yielded more low DO tolerant taxa in addition to *Caenis* and *Hydrobiidae*, and only one taxon that is intolerant to low DO. Additionally, the community contains more taxa that are tolerant and very tolerant to low DO than $\geq$ 73% of all other MIBI Class 5 samples. The upstream reach of Big Mink Creek (WID –646) is also impaired for aquatic recreation due to high bacteria counts, which is often associated with a high BOD.

The available DO data for Big Mink Creek consists of instantaneous measurements in 2011-2012 and 2016-2018 (Figure 15), one set of continuous data in 2018 (Figure 16), and three longitudinal surveys in 2018 (Figure 17). Collections of continuous data were attempted three times during the summers of 2017 and 2018, with only one success. Failures were due to probe fouling by particulates that settled onto the sonde that was deployed on the streambed. To keep the probes in flowing water and prevent accumulation of particulates, a new method of deploying the equipment was developed that kept the sonde suspended at about mid-depth in a run (Figure 18). The results of these data and implications for aquatic life are discussed below.

Figure 15. Summary of DO results (mg/L) by month, for the years 2011-2012 and 2016-2018. Values reported are the minimum DO measurement available, which may not represent the minimum DO level that actually occurred in the stream.

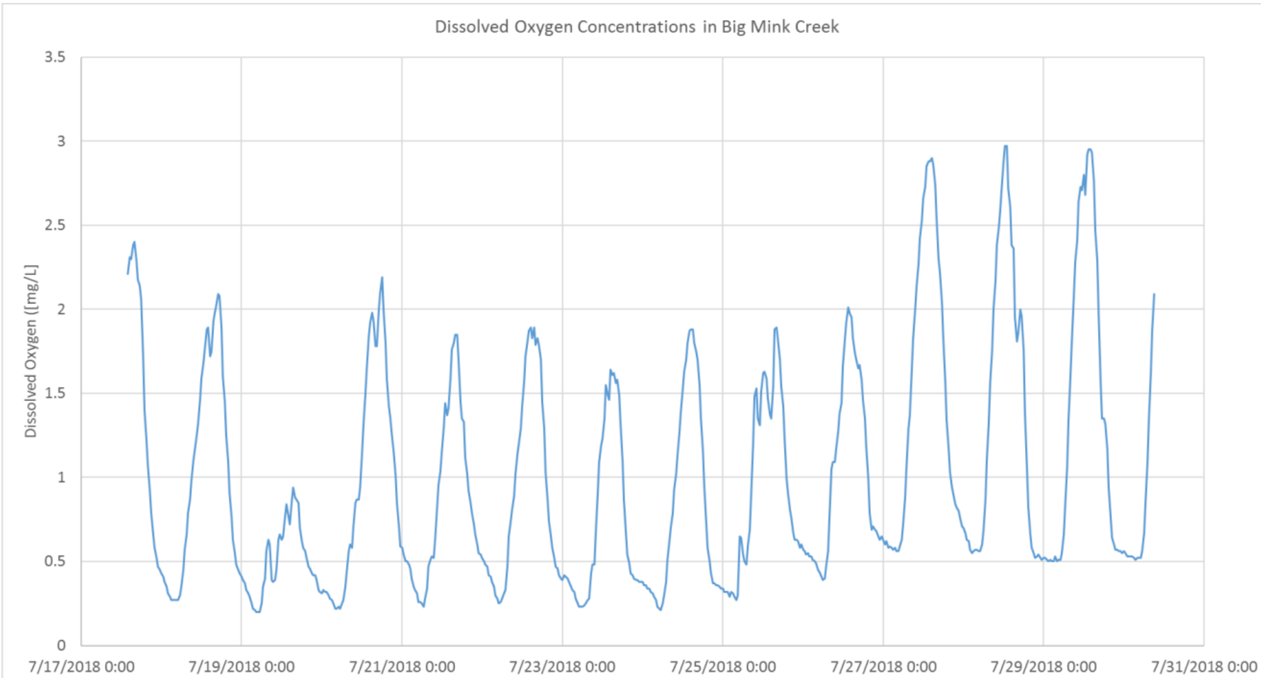


The 2011-2012 and 2016-2017 grab samples make up the bulk of the dataset, and show higher DO levels than in 2018. This is, in part, due to time of day those earlier measurements were taken; all were after 12:00pm, except two: (1) 9/6/2012 at 9:30am (DO=6.16mg/L) and (2) 9/13/2017 at 9:50am (DO=3.2mg/L). Whereas almost all 2018 measurements were taken before 11:00am. As a result, the dataset is biased toward the daily maximum DO levels because of the greater proportion of afternoon measurements. Additionally, however, 2018 was a summer plagued with many extreme precipitation events. It is likely that the water from the wetland areas, which would have been deficient in DO due to the oxygen demanding processes of the wetland environment, was repeatedly flushed into 16UM107 by the large rain events. Further, if water had been stagnating in the wetland areas long enough between the rain events, then it would've been even more DO deficient than, say, in the spring, when flows are continuously high and cold stream temperatures facilitate greater DO concentrations.

To better understand the full range of DO conditions experienced by the macroinvertebrate community at 16UM107, continuous measurements were made using a multi-parameter sonde in July of 2018 (Figure 16). The equipment was placed in the thalweg of a run, suspended at about mid-depth. During the sonde deployment, DO levels were stressfully low, barely reaching 3.0mg/L at most. The low DO levels do not appear to be driven by eutrophication in this instance because the diurnal DO fluctuation was about 2.0mg/L, lower than would be expected under eutrophic conditions. Additionally, eutrophic streams would typically have daily maximum DO levels much higher than what occurred during this deployment.

It is possible, however, that precipitation events and wetland flushing in 2018 had a greater control over the DO levels than did the plant community. More continuous DO measurements and/or BOD samples across multiple years and flow conditions would help clarify the role eutrophication may or may not be playing on the DO conditions in Big Mink Creek.

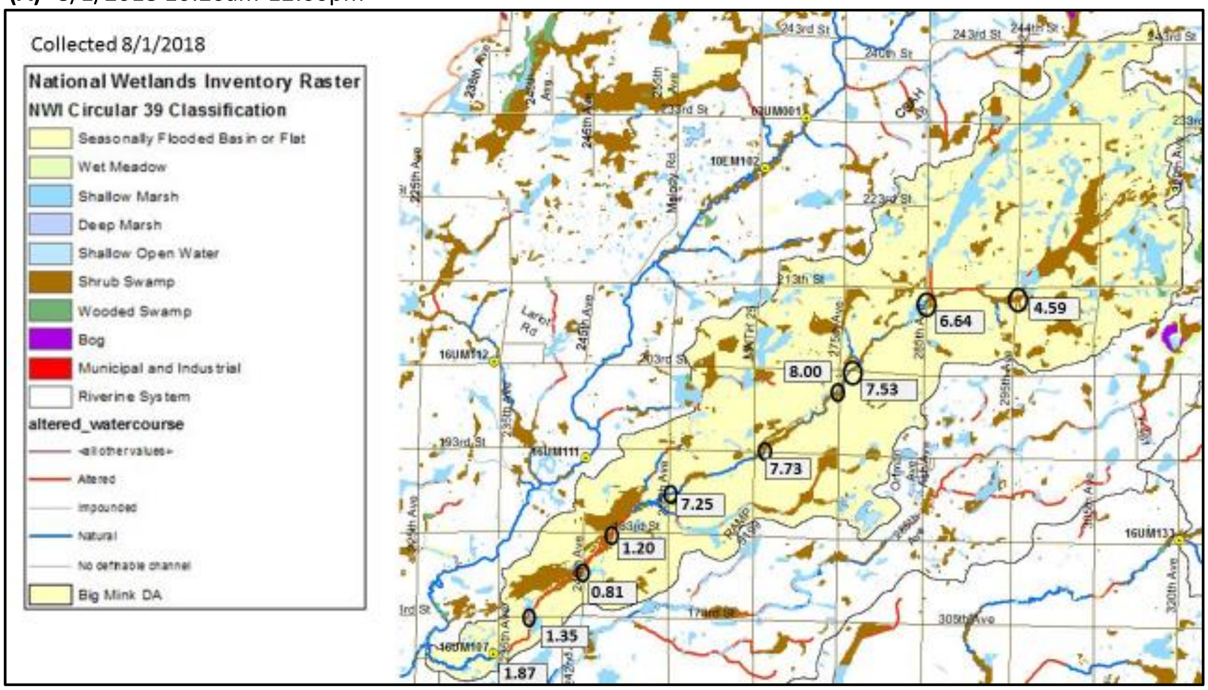
Figure 16. Continuous DO measurements (mg/L) in Big Mink Creek from July 17 to July 30, 2018.



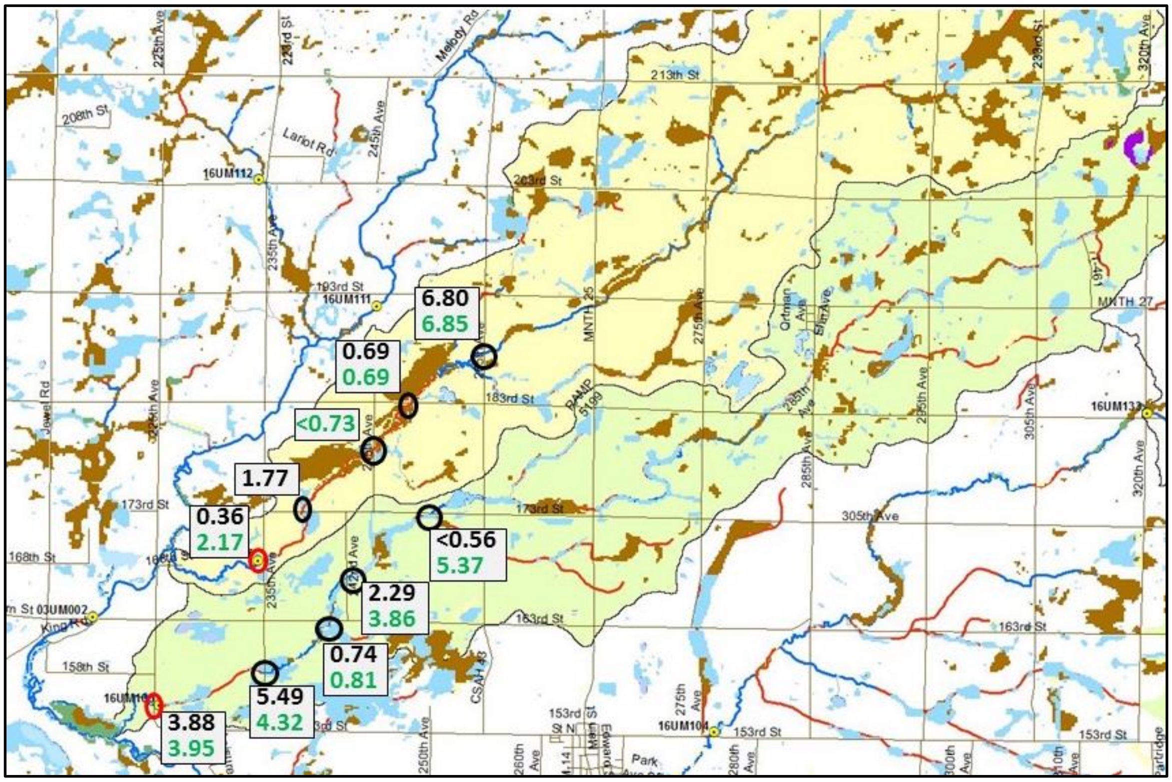
In August 2018, longitudinal DO surveys were performed on three separate days (Figure 17). On two of those days, similar surveys were performed on nearby streams that share the prevalent wetland characteristics of the Big Mink Creek watershed. One of those streams is Little Mink Creek, to the south, which also has extensive channel alteration. The other is Skunk River, to the southeast, which is mostly unaltered. Although Skunk River is a larger system, measurements were taken at upstream locations where the drainage area would be comparable to that of Big and Little Mink Creeks.

Figure 17. Longitudinal dissolved oxygen (DO) survey results. DO shown in units of mg/L.
(A) DO in Big Mink Creek watershed on August 1, 2018.
(B) DO in Big and Little Mink Creek watersheds on August 16, 2018 (top, black text) and on August 28, 2018 (bottom, green text). Red circles indicate biological sample sites 16UM107 on Big Mink and 16UM105 on Little Mink Creek.
(C) DO in the Skunk River watershed on August 28, 2018. Aqua-colored drainage area only shows that of the Skunk River up to the location of the most downstream DO measurement (of 8.04mg/L) on 320th Ave. The entire Skunk River Watershed is much larger, as the river flows southwest to Skunk Lake.

(A) 8/1/2018 10:20am-12:00pm



(B) 8/16/2018 12:20pm-1:37pm (top/black text), and 8/28/2018 10:20am-11:45am (bottom/green text)



(C) 8/28/2018 12:17-1:02pm

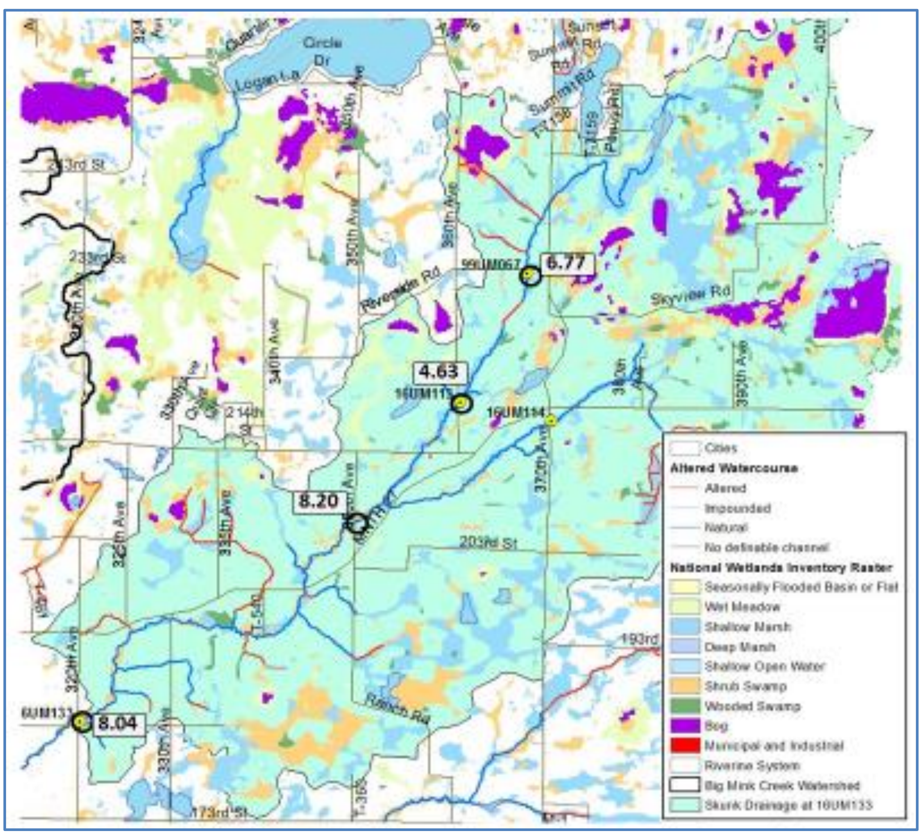


Figure 18. Successful sonde deployment method in a run at 16UM107.
Holes around PVC tube keep water flowing over sonde, which is suspended inside the tube at about mid-depth of the stream. Tube is laid in the stream at an angle, with the upper part secured to a fence post on the bank and the bottom resting on the streambed. This method was developed to keep the probes clean when deployed in a stream with high concentrations of particulate matter.

The longitudinal surveys of Big Mink Creek revealed a dramatic drop in DO levels between the 255th Ave. (upstream) and 183rd St. (downstream) road crossings. As shown in Figure 17(A), the DO dropped from 7.25mg/L at 255th Ave. down to 1.20mg/L at 183rd St. Between these locations, the stream flows through a sizeable shrub swamp (see Figure 10), and was straightened all the way from this point down to CR279, a distance of 2.7 stream-miles. A small riffle can be seen from the 255th Ave. crossing (Figure 19), indicating that this part of the stream has a steep enough gradient to incorporate oxygen from the atmosphere into the water, assuming substrate and flow are also sufficient, which partly explains the higher DO readings. The stream gradient flattens as it runs through the shrub swamp, after which Big Mink Creek does not reaerate, and loses oxygen to the biological, chemical, and/or soil oxygen demands of the wetland.

The DO levels in Big and Little Mink Creeks on August 16 and 28 were generally comparable; see Figure 17(B), except the 6.80mg/L measurement on Big Mink at 255th Ave. was higher than any of the Little Mink measurements. Of note, the Little Mink measurement of 5.49mg/L on 235th Ave. was taken on an algae mat that covered the entire stream area near the road crossing, which means that DO concentration is temporary and will drop dramatically after dark, when the algae switches from photosynthesis to respiration. As shown in the wetland symbology of the maps, Big Mink Creek has a greater area of adjacent wetland shrub swamps, while Little Mink tends to flow through less acreage of wetlands and are of the shallow marsh type, which may partly explain why DO levels in Big Mink appear to be slightly lower. As compared to sites in the headwaters of the Skunk River (see Figure 17(C)) on August 28, 2018, Big and Little Mink Creeks exhibit much lower DO. The adjacent wetlands of Skunk appear more similar in size and type to that of Little Mink Creek.

Stream gradient is a naturally controlling factor of in-stream DO levels. Digital elevation models were used to estimate stream gradient near the biological stations on Big and Little Mink, which are 0.200% and 0.249%, respectively. Those sites have a steeper gradient than at the three Skunk River stations where gradient was estimated, a range of 0.095-0.157%. Thus, despite the steeper gradients at the Big and Little Mink Creek biological stations, they exhibit lower DO than the Skunk River.

The purpose of the longitudinal DO surveys of Big Mink Creek and nearby, comparable streams was to determine if wetland area and type are a primary driver of the low DO levels seen in Big Mink, especially during 2018. Additionally, since macroinvertebrates were sampled in the two other streams, a comparison could be made on whether low DO was also experienced by the other macroinvertebrate communities and how well their MIBIs scored. In sum, it does appear that adjacent wetland size and type varies between the watersheds in a similar fashion as the DO variability. Further, Big Mink DO levels were similar to Little Mink, where the MIBI score is poor, and DO was much greater in the Skunk River, where MIBI scores were acceptable and the macroinvertebrate community is not impaired.

Figure 19. Big Mink Creek small riffle, looking downstream from 255th Ave. on 8/1/2018. DO at this time was 7.25mg/L.

Low DO is a stressor to the macroinvertebrates at 16UM107. However, details about the cause, frequency, and duration of low DO events remain unknown. Therefore, a DO TMDL is not recommended at this time. The following types of additional data may help determine whether a DO TMDL study would actually help the macroinvertebrate community recover: continuous multi-parameter sonde deployments, paired samples of TP and BOD, and continuous streamflow.

WID Summary

Although it is a small, first-order stream, Big Mink Creek is a direct tributary to a prized, yet threatened, resource: the Platte River. Management of the Platte River watershed should include consideration of protection priorities in balance with restoration of the impaired waters, such as Big Mink Creek.

Of the potential stressors investigated, lack of habitat (primarily productive riffle habitat) and low DO were conclusively determined to be stressors to the macroinvertebrate community in WID -647. Eutrophication and suspended sediments are inconclusive stressors, both of which may be interrelated and driven by streamflow alteration. Iron and nitrate toxicity are also inconclusive stressors.

-Future Work

As discussed at the end of the *Dissolved Oxygen* section, further data collection of continuous multi-parameter sonde deployments, paired samples of total iron, TP, and BOD, and continuous streamflow may help clarify the role eutrophication, low DO, and streamflow alteration are playing in this aquatic life impairment. It would be ideal to pair as much information as possible with a comparable stream that sustains a thriving macroinvertebrate community, such as the Skunk River.

3.1.3. Little Mink Creek – WID 07010201-645

Little Mink Creek is a tributary to the Platte River. It is just south of Big Mink Creek and flows almost parallel with it, entering the Platte River about 4-5 stream miles south of where Big Mink enters the Platte. The section of Little Mink Creek between the Platte River and Morrison CR255 is WID -645. There is one biological sampling station on WID -645, 16UM105, which begins at CR255 and extends upstream for approximately 522ft. Within the bounds of Little Mink's 16.4 square mile drainage area are pastures, wetlands, and row crop fields.

Biological Data

WID -645 is impaired for aquatic life due to nonsupport of the macroinvertebrate community. The macroinvertebrates were sampled in September of 2016 and August of 2017; both MIBI scores failed to meet the general use threshold of their designated MIBI Class: 6 – Southern Forest Streams Glide/Pool (Table 11). The FIBI score, in Class 6 – Northern Headwaters, exceeded the threshold value by a couple points; the WID was assessed as fully supporting the fish community, but is nearly impaired.

Table 11. IBI scores at site 16UM105 on Little Mink Creek (WID 07010201-645).

		Fish IBI			Macroinvertebrate IBI		
Station	**Date**	**Class†**	**Impairment threshold**	**Score**	**Class†**	**Impairment threshold**	**Score**
16UM105	6/23/2016	6	42	44.2	-	-	-
	9/1/2016	-	-	-	6	43	22.2
	8/8/2017	-	-	-	6	43	42.0

†FIBI Class: (6) Northern Headwaters
MIBI Class: (6) Southern Forest Streams – Glide/Pool

The total MIBI scores are most notably weighed down by a lack of intolerant taxa, especially from the following families: Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET), based on the MIBI metrics (Table 12, see-highlighted rows). The 2017 sample contained nine more taxa than the 2016 sample, including the following quasi-sensitive organisms: two dragonflies (Odonata) *Aeshna umbrosa* and *Sympetrum costiferum*. Only a single individual from each of those species was sampled. Also, fourteen individuals of the quasi-sensitive mayfly (Ephemeroptera) *Leptophlebiidae* were sampled in 2017, but none in 2016. Although taxa richness was greater in 2017, the evenness was only slightly improved. In 2016, Pielou's Evenness Index (Pielou 1966) was 0.685 (on a scale of 0-1, where 1 is maximum evenness), and in 2017 it was 0.737, which is an increase of 7.6%. For context, Pielou's Evenness for an excellent-scoring MIBI sample from the Platte River watershed (station 16UM123) was 0.840. Overall, the macroinvertebrate community at 16UM105 is dominated by tolerant organisms.

Even among the more sensitive taxonomic orders present, such as Ephemeroptera and Odonata, the genera sampled suggest that the habitat at 16UM105 is possibly degraded. Specifically, that the stream is more lentic than lotic in nature, featuring stagnant water, fine substrate, and low DO. These characteristics are appropriate for some stream types, but in an MIBI Class 6 stream, it may be a sign of habitat degradation. In 2016 and 2017, 37% and 10%, respectively, of individuals identified were the mayfly *Caenis diminuta*. Members of the *Caenis* genus are known to inhabit lotic-depositional areas and the fine sediments of lentic-littoral areas; they can also be found in wetlands. The dragonfly genus *Aeshna,* observed in 2017, is known to primarily inhabit lentic environments, commonly found in lakes, ponds, marshes, and bogs. Further, the other dragonfly genus found in 2017, *Sympetrum*, prefers lentic-littoral habitats, and some species will sprawl on silt and detritus.

Table 12. Macroinvertebrate IBI metric scores from the samples at 16UM105.
Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown.

MIBI Class 6 Metric	Raw Metric Result		Re-scaled IBI score	
	9/1/2016	8/8/2017	9/1/2016	8/8/2017
ClingerCh *Number of clinger taxa*	7	9	3.33	4.67
Collector-filtererPct *Percent of collector-filterer taxa*	5.67%	13.75%	1.42	3.57
DomFiveCHPct *Relative abundance of dominant five taxa*	68.33%	59.69%	4.72	6.54
HBI_MN *Measure of pollution based on MNtol values*	8.20	7.27	2.20	5.26
Intolerant2Ch *Number of taxa with a MNtol value ≤ 2*	0	0	0	0
POET *Number of taxa in orders: Plecoptera, Odonata, Ephemeroptera†, or Trichoptera*	3	6	0.71	2.86
PredatorCh *Number of predator taxa*	8	15	2.86	7.86
TaxaCountAllChir *Total number of taxa*	32	41	3.85	6.49
TrichopteraTxPct *Percent of Trichoptera taxa*	3.13%	2.44%	1.90	1.48
TrichwoHydroPct *Percent of non-Hydropsychidae Trichoptera individuals*	0.33%	1.25%	1.16	3.28
Total (MIBI score)	--	--	22.15	42.01

† All *Beatidae* taxa within Ephemeroptera treated as one taxon

Tolerance of the macroinvertebrate community was analyzed in the context of all other MIBI Class 6 samples by looking at the taxa richness (number of taxa) of tolerant vs. intolerant taxa to specific stressors, and how that richness ranks in a percentile analysis (Table 13). The proportion of tolerant and non-tolerant taxa are used as supporting evidence in the following discussion of stressor data. In summary, the data show that the macroinvertebrate community at station 16UM105 is tolerant of low DO, fine substrate, embedded substrate, and high TP. The taxa distribution for TSS and NOX appear skewed toward tolerance, but varies between years and more data are needed to determine if these are stressors.

Table 13. Number of taxa ("taxa richness") in the macroinvertebrate samples at 16UM105 that are tolerant and intolerant to specific stressors.
Percentile analysis was performed using all other MIBI Class 6 samples collected by MPCA (n=683). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Stressor	Very Intolerant Taxa richness - Percentile		Intolerant Taxa richness - Percentile		Tolerant Taxa richness - Percentile		Very Tolerant Taxa richness - Percentile	
	2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Low DO	0 – 0%	0 – 0%	1 – 19.7%	1 – 19.7%	11 – 80.4%	12 – 86.3%	5 – 79.7%	6 – 88.7%
Depth of Fines	1 – 24.1%	1 – 24.1%	0 – 0%	0 – 0%	10 – 65.9%	12 – 80.9%	7 – 78.5%	7 – 78.5%
Embedded Substrate	0 – 0%	0 – 0%	0 – 0%	0 – 0%	11 – 47.9%	16 – 88.8%	6 – 29.3%	9 – 69.6%
Total Suspended Solids (TSS)	0 – 0%	0 – 0%	0 – 0%	0 – 0%	4 – 2.0%	8 – 28.4%	1 – 2.0%	4 – 45.8%
Inorganic nitrogen (NOX)	0 – 0%	0 – 0%	2 – 64.8%	3 – 75.9%	10 – 11.5%	15 – 35.0%	7 – 14.5%	12 – 52.1%
Total phosphorus (TP)	0 – 0%	0 – 0%	0 – 0%	0 – 0%	12 – 59.8%	13 – 68.9%	8 – 75.8%	8 – 75.8%

Stressor Data

-Streamflow

A quantitative analysis of streamflow data was not performed for Little Mink Creek. However, a few lines of evidence suggest that the flow regime is more lentic than lotic in nature. First of all, the macroinvertebrate community composition, which is discussed above. Secondly, aerial images show that the stream is in a low-lying landscape position with extensive riparian wetlands. Areas of duckweed (or algae) cover indicate stagnant conditions. Further, the sample reach has been straightened through a shallow marsh wetland, at least since 1940 (Figure 20); and sometime between 1955 and 1963 the rest of the wetland area upstream of 16UM105 was also straightened (Figure 21).

Figure 20. Historical aerial photo of Little Mink Creek, 6/24/1940 from MN DNR's historical landview dataset compilation; some photos from USDA.
Flow direction is west (from right to left). Yellow circle is the general location of 16UM105. Red arrow indicates where stream goes from natural and sinuous to straighten.

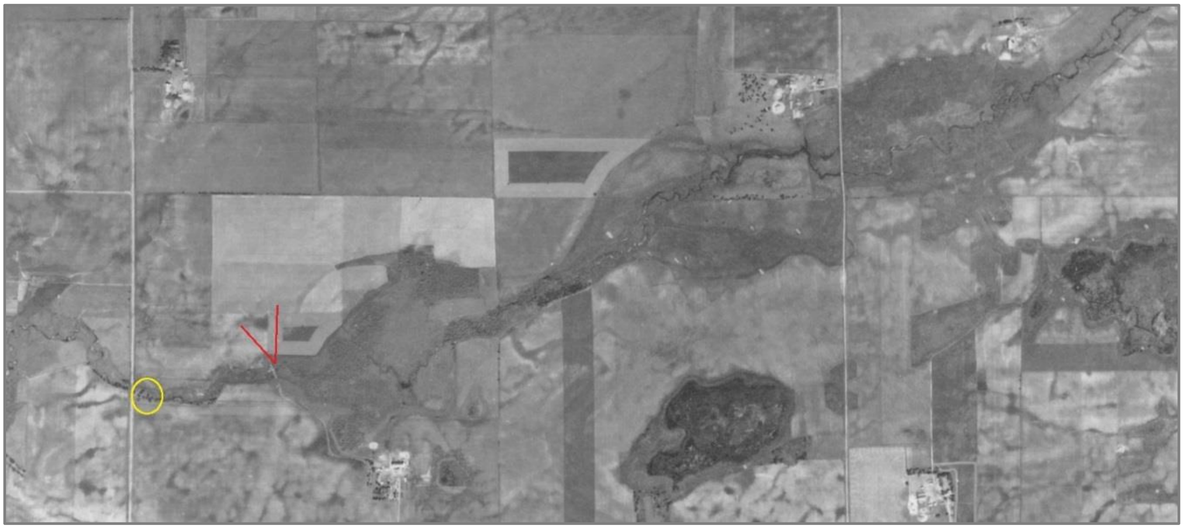


Figure 21. Historical aerial photo of Little Mink Creek, 6/26/1963 from MN DNR's historical landview dataset compilation, some photos from USDA.
Flow direction is west (from right to left). Yellow circle is the general location of 16UM105. Red arrow indicates same location as Figure 20 in 1940; the upstream section is now straight.

--Metals: Iron and manganese

No iron or other metals data are available for Little Mink Creek. However, observations of iron in the stream were made by the biologists and stressor identification staff multiple times between 2016 and 2018. In addition, in aerial imagery from May 2011 and May 2015, there is a stretch of stream 800ft upstream of 16UM105 that appears orange, a sign of ferric iron precipitate (Figure 22). Little Mink Creek is strongly connected with groundwater, where the metals would be coming from. For further discussion of the effects of metals from groundwater on aquatic life, see the *Metals: Iron and manganese* section in *3.1.1. Tributary to Platte River – WID 07010201-634*.

Figure 22. Aerial imagery from Google Earth, dated 5/29/2015.
Red line is a hydrography spatial data layer representing the stream location and that it is anthropogenically altered (red). This reach is 800ft upstream of the biological station 16UM105.

Figure 23. This sonde was suspended at mid-depth in Little Mink Creek for thirteen days. It appears to have been colonized by a bloom of iron-oxidizing bacteria.

Iron and possibly other metals originating in the underlying geology are suspected, though inconclusive, stressors to the aquatic life in WID -645. This is a similar situation as two other streams in the Platte River watershed, the Tributary to Platte River (WID -634) and Big Mink Creek (WID -647), where the macroinvertebrate communities are also stressed.

-Habitat

Three MSHAs were performed, one following each biological sample. The range of final scores is 47-52, out of 100 possible points. The range of a "Fair" score is 45-65 points, so this biological station is on the low end of Fair habitat quality, according to the MSHA. The variety of stream habitat types in the reach is poor, with only a run and small proportion of pool habitat. The run/pool ratio varied by assessment date, but at best was 80/20, with both having sand and "sludge" as the primary substrate on that day. Further, a biologist made the following comment about the coarse substrate on 6/23/2016: "…most was underneath half a foot of sludge."

The tolerance richness metrics (see Table 13) seem to corroborate the findings of the MSHAs, having high percentile ranking of taxa that are tolerant and very tolerant to Depth of Fines and Embedded Substrate, coupled with very low percentile standings of taxa that are intolerant to those stressors.

Habitat degradation due to excessive fine bedded sediment is a stressor to the aquatic life in WID -645. Alteration of the stream channel negatively impacts the stream's natural sediment transport capacity, and has possibly resulted in increased sediment input to this section of the creek.

-Suspended Sediment

The sediment dataset on Little Mink Creek consists of two paired TSS/TSVS measurements and six transparency measurements between 2016 and 2018 (Table 14). This is not enough data to determine if suspended sediment is stressing aquatic life, and there are reasons to suspect that it is. The MSHA and comments from biologists indicate that the sample reach has excessive, fine bedded sediment, and an upstream pasture is a potential source of sediment to 16UM105. According to NRCS's SSURGO soils spatial data layer (NRCS 2018), the soil type for a large portion of the pastured area is muck, which is very fine material and takes a long time to settle out of the water column once suspended. In addition, the tolerance richness metrics show that the macroinvertebrate community is somewhat skewed toward taxa that are tolerant to TSS, though there is considerable variability between the 2016 and 2017 results. Using similar methods as Meador & Carlisle (2007), MPCA fish biologists calculated a conditional probability to determine the likelihood that the stream would pass the TSS standard given the fish community sampled. The result was an 82% chance. Given the lack of chemistry data and unclear biological metrics, suspended sediment is an inconclusive stressor.

Table 14. Total suspended solids (TSS), total volatile solids (TSVS), and transparency (Secchi tube) data from Little Mink Creek for 2016-2018.
Samples were collected near the CR255 road crossing. The MPCA EQUiS ID for this location is S013-521.

Date	**TSS** [mg/L]	**TSVS** [mg/L]	**Secchi Tube** [cm]
6/23/2016	4.0	< 1.0	> 100
9/1/2016	-	-	89
8/8/2017	-	-	>100
7/3/2018	-	-	99
7/23/2018	-	-	>100
7/30/2018	-	-	84
8/28/2018	2.8	2.0	-

-Nutrients

Nitrogen

The inorganic nitrogen (NOX) measurements available for Little Mink Creek are not high enough to suggest that it is a stressor to aquatic life. However, some of the measurements are higher than the MRS Watershed-wide mean and median concentrations, which are 0.680 and 0.260mg/L, respectively[1]. Agricultural activity in the watershed is possibly elevating the NOX in Little Mink Creek through row crop fertilization and/or animal waste from the pasture. Little Mink Creek is especially sensitive to NOX pollution because of its strong connection to groundwater. The NOX tolerance richness metrics, in Table 13, show that station 16UM105 harbors a greater quantity of NOX-tolerant than -intolerant taxa; however, the percentiles show that there are more NOX-intolerant taxa than 65-76% of all other MIBI Class 6 samples. It is an inconclusive stressor at this time.

Phosphorus

Total phosphorus measurements at 16UM105 were high enough to suggest that it could be a stressor, with most exceeding the standard of 0.100mg/L (Table 15). The macroinvertebrate tolerance richness metrics also suggest that a TP-related stressor is affecting the community. However, TP acts a stressor through eutrophication, which does not appear to be occurring at 16UM105 based on the DO data (discussed in the following section) and the lack of excessive macrophyte or algae growth observed during several summer field visits. On two occasions in August 2018, there was an accumulation of duckweed at 16UM105, but this was not the norm throughout the summer.

Outside of 16UM105, however, dense duckweed and/or algae growth was frequently observed during two surveys (on 8/16 and 8/28/2018) of all the road crossings between 16UM105 and 173rd St. (e.g. Figure 25and Figure 26). Sources of phosphorus were also frequently observed, such as riparian wetlands and livestock in the stream. While Little Mink Creek appears to be eutrophic in areas upstream of 16UM105, it is unclear if that is stressing the macroinvertebrates. Thus, it is an inconclusive stressor.

[1] Mean and median concentrations for the MRS Watershed were calculated using all of the available inorganic nitrogen data in MPCA'S EQUiS database that was collected between 2008 and 2018 on a river or stream within the watershed (n=1511).

Table 15. Total phosphorus (TP), inorganic nitrogen (NOX), and ammonia (NH4) data from Little Mink Creek for 2016-2018.
Samples were collected near the CR255 road crossing. The MPCA EQUiS ID for this location is S013-521; data can be found on the MPCA's Environmental Data Access webpage.

Date	**TP** [mg/L]	**NOX** [mg/L]	**NH4** [mg/L]
6/23/2016	0.125	0.558	<0.10
5/24/2017	0.048	0.100	-
7/11/2017	0.137	0.670	-
8/23/2017	0.089	0.090	-
7/3/2018	0.163	0.140	-
7/30/2018	0.156	0.910	-
8/28/208	0.105	1.10	-

Figure 24. Little Mink Creek at Hawthorne Ave. (AKA Morrison CR43) on 8/28/2018.

-Dissolved Oxygen

Low DO (<5mg/L) was frequently observed in Little Mink Creek (Table 16). A sonde was deployed to make continuous measurements in July of 2018 (Figure 25). During the deployment, DO never reached the state standard at any point in the approximately 14-day period. In fact, it never reached 80% of the standard (which would be 4.0mg/L).

A longitudinal DO profile of the stream was compiled twice in August of 2018 (see Figure 17(B)). In summary, the DO profile on August 16, 2018, only yielded one measurement greater than 5.0mg/L, which was 5.49mg/L at 235th Ave. This reading was taken in an algae bloom that covered the stream area near the road crossing (Figure 26), which means the "high" DO concentration is temporary and will drop dramatically after dark, when the algae switches from photosynthesis to respiration. The DO profile on August 28, 2018, also only yielded one measurement greater than 5.0mg/L, which was 5.37mg/L at 173rd St. Both DO profiles were completed between 10:20am and 1:40pm.

Table 16. Instantaneous dissolved oxygen (DO) measurements at 16UM105.

Date	Time	**DO** [mg/L]	**DO Saturation** [%]
6/23/2016	13:56	4.53	49.3
9/1/2016	12:05	4.26	44.8
4/3/2017	13:00	9.78	--
5/24/2017	15:02	7.55	71.0
7/11/2017	12:15	2.65	27.5
8/8/2017	12:00	3.00	31.5
8/23/2017	15:30	3.38	35.4
7/3/2018	10:45	3.35	37.1
7/9/2018	9:55	2.78	32.4
7/17/2018	14:23	3.25	36.6
7/23/2018	9:20	2.34	25.4
7/30/2018	10:00	2.87	29.9
8/16/2018	12:20	3.88	40.0
8/28/2018	11:45	3.95	40.5

Figure 25. Temperature and dissolved oxygen (DO) at the pedestrian bridge at the upstream end of 16UM105. This is the sonde shown in Figure 23.

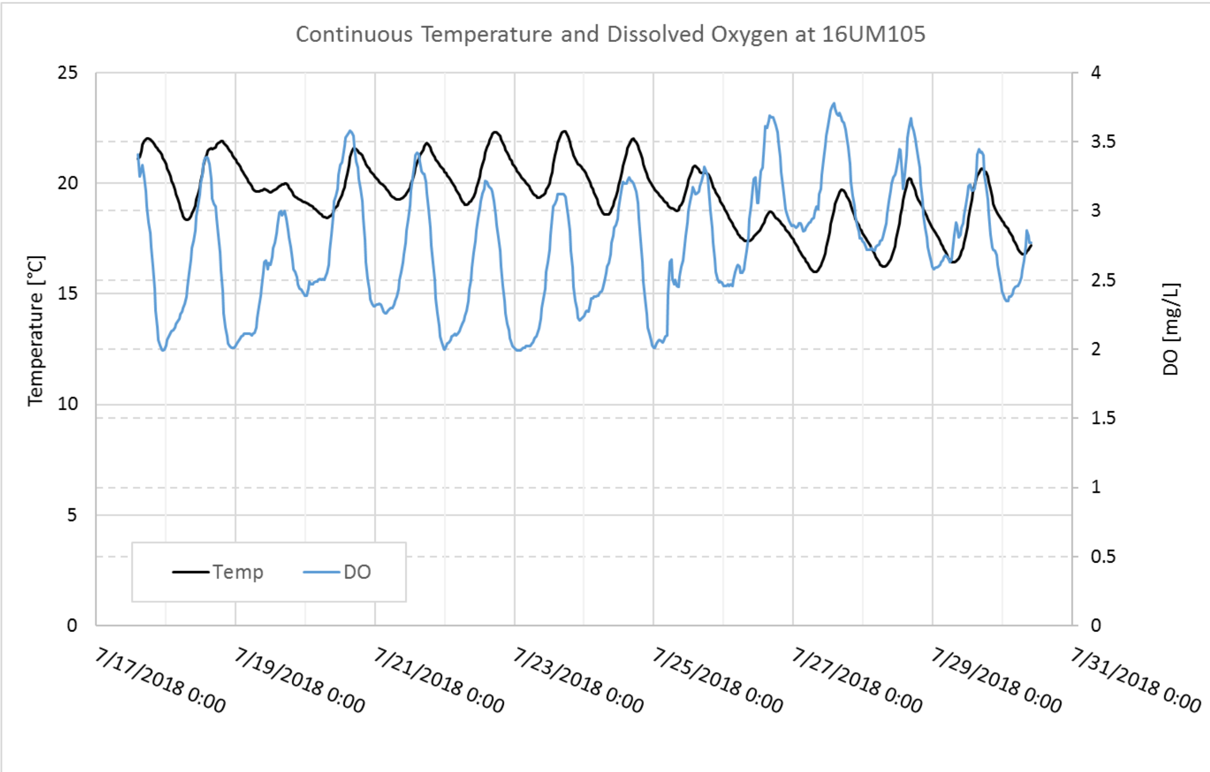
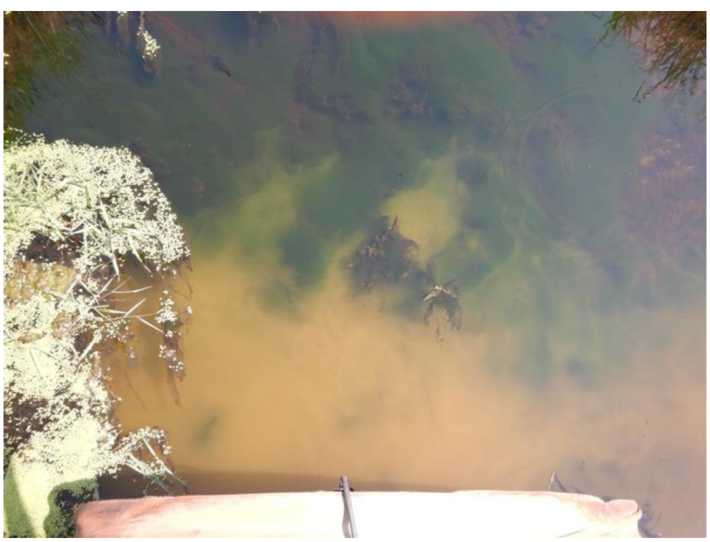


Figure 26. (Left) Close-up of algae mat near 235th Ave. road crossing; DO was 5.49mg/L here on 8/16/2018. (Right) Wide view of algae mat near road crossing, looking downstream.



The aquatic life observed in Little Mink Creek also suggests that low DO is a stressor. The macroinvertebrate tolerance richness metrics show a highly tolerant DO community. Using similar methods as Meador & Carlisle (2007), MPCA fish biologists calculated a conditional probability to determine the likelihood that the stream would pass the DO standard given the fish community. The result was only a 21% chance.

Low DO is a stressor to the aquatic life in Little Mink Creek. Although the TP concentrations are high, the continuous DO data show that eutrophication is not the cause of the DO problem at 16UM105. The most likely causes are the oxygen-demanding interactions that water in the stream has with the adjacent wetland soils and bacteria in the channel, which may be augmented above normal quantities by upstream human activities, including channel straightening through the wetland area. The high iron content of the water is also a natural user of oxygen. Soluble iron from groundwater interacts with oxygen in the stream water to create iron oxide, which precipitates as the rusty-colored material seen on stream substrate.

WID Summary

Much like Big Mink Creek, Little Mink is a small stream with low recreational suitability, but it is a direct tributary to the larger, high quality Platte River. Management and protection of the Platte River should include restoration of the smaller, impaired waters, such as Big and Little Mink Creeks. This will ultimately protect the Platte River from degrading and could even enhance its condition, and the condition of Mississippi River downstream.

Of the potential stressors investigated, low DO and degraded habitat due excess fine bedded sediment were conclusively determined to be stressors to the aquatic life in WID -645. Metals, particularly iron, in the stream is a suspected, though inconclusive, stressor. Streamflow alteration, a result of the stream channelization, may be driving or exacerbating the low DO and excess sediment, but that is also inconclusive at this time. Total phosphorus and NOX were determined to be inconclusive stressors.

3.1.4. Platte River (upper) – WID 07010201-507

The Platte River is approximately 55 miles long in total. It begins at the outlet of Sullivan Lake and flows southeast, entering the Mississippi River near Royalton, Minnesota. The upper half of the river, from the headwaters to the Rice-Skunk Lakes impoundment, is WID -507, which is impaired for aquatic life and aquatic recreation (excessive *E.coli*). The watershed area of WID -507 is 180mi^2, and contains primarily livestock pastures, hay fields, forest, and wetlands, as well as the small towns of Harding, Platte, and Lastrup (combined population of 584, according to U.S. Census Bureau). The Platte River mainstem generally has good water quality in terms of nutrients, DO, TSS, and temperature.

The main tributaries to WID -507 are three WIDs that are discussed in this report: Tributary to Platte River (WID -634), Big and Little Mink Creeks (WIDs -647 and 645). Wolf Creek (WID -557) is also a tributary to WID -507, but it is not discussed in this report because it was not sampled or assessed. Of the main tributaries listed, all three are impaired for aquatic life and one is impaired for aquatic recreation, while the other two were not sampled for *E.coli*.

The Platte River has many areas of very high quality habitat. Some MSHA scores were in the upper seventies to low eighties, exhibiting swiftly flowing water, cobble riffles, well developed pools, and boulder and woody debris habitat. Many locals recreate on the Platte River, especially for smallmouth bass fishing downstream of Royalton. The Platte River is one of the highest quality freshwater resources in the MRS Watershed, but it is threatened by the growing frequency of disturbance on the mainstem, such as dams, road crossings, and livestock access, as well as disturbance of the tributaries, such as livestock access and ditching (particularly of wetlands).

Biological Data

WID -507 is impaired for aquatic life due to nonsupport of the fish community. The macroinvertebrate communities, however, tend to yield very good MIBI scores. Six of the ten fish samples taken from WID -507 do not meet the FIBI Class 5 – Northern Streams impairment threshold for general use, although two sites (16UM111 and 03UM002) scored above the exceptional use threshold of 61 (Table 17).

Table 17. IBI data from all biological stations on the upper section of the Platte River, WID 07010201-507. Sites are listed in an up- to downstream order.

		Fish IBI			Macroinvertebrate IBI		
Station	Date	Class†	Impairment Threshold	Score	Class†	Impairment Threshold	Score
16UM117	7/5/2016	5	47	31	-	-	-
	6/15/2017	5	47	34	-	-	-
	8/7/2017	-	-	-	3	53	45.7
10EM102	6/21/2010	5	47	41	-	-	-
	7/6/2010	5	47	41	-	-	-
	9/8/2011	-	-	-	4	51	75.3
	7/6/2015	5	47	48	-	-	-
	8/25/2015	-	-	-	4	51	71.2
	6/15/2017	5	47	45	-	-	-
16UM111	7/5/2016	5	47	68	-	-	-
	8/7/2017	-	-	-	3	53	70
03UM002	8/27/2003	5	47	78	-	-	-
	7/6/2016	5	47	49	-	-	-
	8/7/2017	-	-	-	3	53	72.1
16UM123	7/6/2016	5	47	46	-	-	-
	8/7/2017	-	-	-	4	51	89.9

†FIBI Class: (5) Northern Streams
MIBI Class: (3) Northern Forest Streams – Riffle/Run (4) Northern Forest Streams – Glide/Pool

The conditional probabilities that the fish community sampled would come from a stream that meets the water quality standards for TSS and DO were calculated (Table 18). The likelihood that WID -507 would pass the state's TSS water quality standard is quite high at all biological stations. The macroinvertebrate community indicated the same (data not shown). Total suspended solids was minimally investigated as a stressor on AUD -507, as it is unlikely to be the primary cause of the aquatic life impairment.

Based on fish samples, the likelihood of meeting the DO standard is fair at the upstream-most station (16UM117), and generally good at all others, with the exception of 10EM102. Based on the macroinvertebrate samples, some stations tell a slightly different story, however. Not all macroinvertebrate sample conditional probabilities are shown, only those with >10% disagreement with the fish-based probabilities. Even using the macroinvertebrate-based probabilities as supplemental information, it is unclear whether or not low DO is influencing the quality of aquatic life in WID -507.

Table 18. Conditional probabilities (percent chance) that the stream would meet the state water quality standards for total suspended solids (TSS) and dissolved oxygen (DO) given the fish community sampled, and DO given the macroinvertebrate community where it is >10% different than the fish.

Station	Sample Date - fish	TSS - fish [%]	DO - fish [%]	DO – macroinvertebrates [%] (sample date)
16UM117	7/5/2016	88	68	
	6/15/2017	88	63	
10EM102	6/21/2010	89	70	
	7/6/2010	88	71	
	7/6/15	88	36	72 (8/25/15)
	6/15/17	88	48	
16UM111	7/5/16	92	84	70 (7/7/17)
03UM002	8/27/2003	93	88	
	7/6/16	89	79	66 (8/7/17)
16UM123	7/6/16	86	72	

To further understand the poor FIBI scores at 10EM102, the individual metric scores were analyzed (Table 19). Many of the scores are poor, but the two metrics IntolerantPct and MatureAge>3-TolPct seem to consistently score the worst. Interestingly, the DomTwoPct metric scores gradually improve from 2010 to 2017. This improving pattern was not analyzed for significance and could be random (not meaningful).

Table 19. Fish IBI metric scores from the fish samples at 10EM102.
Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown. Blue rows highlight where the FIBI consistently scores quite poorly. The green-shaded row highlights the increasing (improving) FIBI score for the DomTwoPct metric from 2010 to 2017.

Sample Date:	6/21/2010		7/6/2010		7/6/2015		6/15/2017	
FIBI Class 5 Metric	Re-scaled IBI score	Raw metric result	Re-scaled IBI score	Raw metric result	Re-scaled IBI score	Raw metric result	Re-scaled IBI score	Raw metric result
DarterSculpSucTxPct *Percent of darter, sculpin, and sucker taxa*	3.11	10.00%	1.85	6.25%	1.73	5.88%	6.15	19.05%
DetPct *Percent of detritivore individuals*	6.47	15.38%	6.82	13.44%	5.14	22.66%	7.78	8.17%
DomTwoPct *Combined relative abundance of the two most abundant taxa*	3.39	61.09%	4.26	57.49%	5.85	50.93%	8.30	40.87%
FishDELTPct *Percent of individuals with DELT anomalies*	0.00	0.90%	0.00	0.54%	0.00	0.00%	0.00	0.00%
General *Number of generalist taxa*	4.62	5.00	3.03	6.00	6.22	4.00	0.00	8.00
Insect-TolTxPct *Percent of insectivorous taxa, excl tolerant species*	2.46	30.00%	2.86	31.25%	2.27	29.41%	5.08	38.10%
IntolerantPct *Percent of intolerant individuals*	0.00	0.00%	0.00	0.00%	0.30	1.40%	0.21	0.96%
MA>3-TolPct *Percent of late-maturing individuals, excl tolerant species*	0.60	2.26%	0.27	1.00%	1.87	7.01%	0.90	3.37%
SensitiveTxPct *Percent of sensitive taxa*	4.13	20.00%	3.87	18.75%	6.08	29.41%	6.89	33.33%
SLithopPct *Percent of individuals that are simple lithophilic spawners*	5.79	43.44%	6.76	50.50%	3.37	25.93%	3.51	26.92%
SSpnTxPct *Percent of taxa that are serial spawners*	4.99	20.00%	5.36	18.75%	5.69	17.65%	2.44	28.57%
Vtol *Number of very tolerant taxa*	5.45	3.00	5.45	3.00	9.09	1.00	3.64	4.00
Total (FIBI score)	41	-	41	-	48	-	45	-

Stressor Data

-Temperature

Temperature data has been gathered from six different locations on WID -507. Other than at 16UM117 and 10EM102, temperatures did not exceed 25°C.

At 16UM117, normal summer temperatures (25-30°C) were measured using a deployed sonde that was placed in full sun at mid-depth in July 2018. Light shade (5-25%) was noted on three out of three MSHAs at the biological station, so temperatures measured by the sonde would be representative of the maximum that may occur in the station. Three days after the sonde deployment, a rain event occurred and brought the temperatures down to the 20-25°C range for a few days, then the daily peak began exceeding 25°C after about the third day post-rainfall.

At 10EM102, the warmest temperature measurement (28.6°C) was made in July of 2010, when fish were sampled. Pictures from that day show low water levels. Downstream of 10EM102, at 213th St., temperatures were measured in excess of 25°C a few times in 2011 and 2012. Stressfully warm temperatures (i.e. ≥30°C) were not observed, but it is important to be aware that excessive stream temperatures are most likely to occur in areas like these, where the river is wide, unshaded, and shallow.

In the event of a drought or exceptionally warm summer, these areas of the Platte River might get warm enough to cause thermal stress to aquatic life. The fish and macroinvertebrates would be relying on pools, shade, and undercut banks for refuge areas from the heat, especially if DO and temperature conditions in Rice Lake prevented fish from migrating to the Mississippi River. Rice Lake is a highly productive, shallow lake, with an impoundment holding pool elevation. In late summer every year, there is a die-off of the thick vegetation there, including curly-leaf pondweed. More detail about the Rice Lake area is provided in the following section, *Longitudinal Connectivity*.

-Longitudinal Connectivity

An inspection of stream-road crossings and dams on WID -507 was made using aerial imagery and on-the-ground investigations. The primary physical barrier to fish passage on WID -507 is the Platte River Dam, located approximately one stream mile downstream from 16UM117 (Figure 27). It is a concrete, fixed-level dam that does not feature a fish passage structure.

Figure 27. The Platte River Dam was constructed in 1933 and is owned by the MN DNR. It prohibits fish from moving upstream.

The Rice and Skunk Lakes area, in Crane Meadows National Wildlife Refuge, may be an unconventional type of barrier to some fish. The Platte River flows through this impoundment, a linear distance of 1.3mi from the lake inlet to outlet, plus there is 2.3mi of riverine wetland area above the lake inlet. It is suspected that the wetland-like conditions are deterring some fish from moving upstream into WID -507. For example, there is a notable lack of redhorse species at 16UM111 and 03UM002, despite the presence of suitable habitat. A map of where redhorse species have been sampled on the Platte River was created (Figure 28), illustrating that they are more abundant downstream of the Rice Lake impoundment, with 36 individuals sampled at 99UM048 alone. All four individuals sampled upstream of the impoundment, at 16UM123 and 10EM102, were young of the year (77-108mm long).

The Rice-Skunk Lakes impoundment has a fish passage structure, and low DO is not a problem in the spring when redhorse species migrate for spawning. So there is no physical barrier to the fish at this location, but it appears there is something holding them back from accessing the high-quality habitat upstream. The FIBI scores on WID -507 would be improved by the addition of redhorse to the samples. However, the FIBI scores at 16UM111 in 2016 and at 03UM002 in 2003 were still quite good, despite the lack of redhorse and other migratory species. Only two out of ten fish samples from WID -507 contained at least half as many migratory species as all other comparable samples (Table 20).

Figure 28. Number of redhorse individuals sampled from Platte River biological stations.

Stations have anywhere from one to four sampling events, all occurred during June-August of 2003-2018. Note the decline of redhorse observed above the Rice-Skunk Lakes area, immediately upstream of 99UM048.

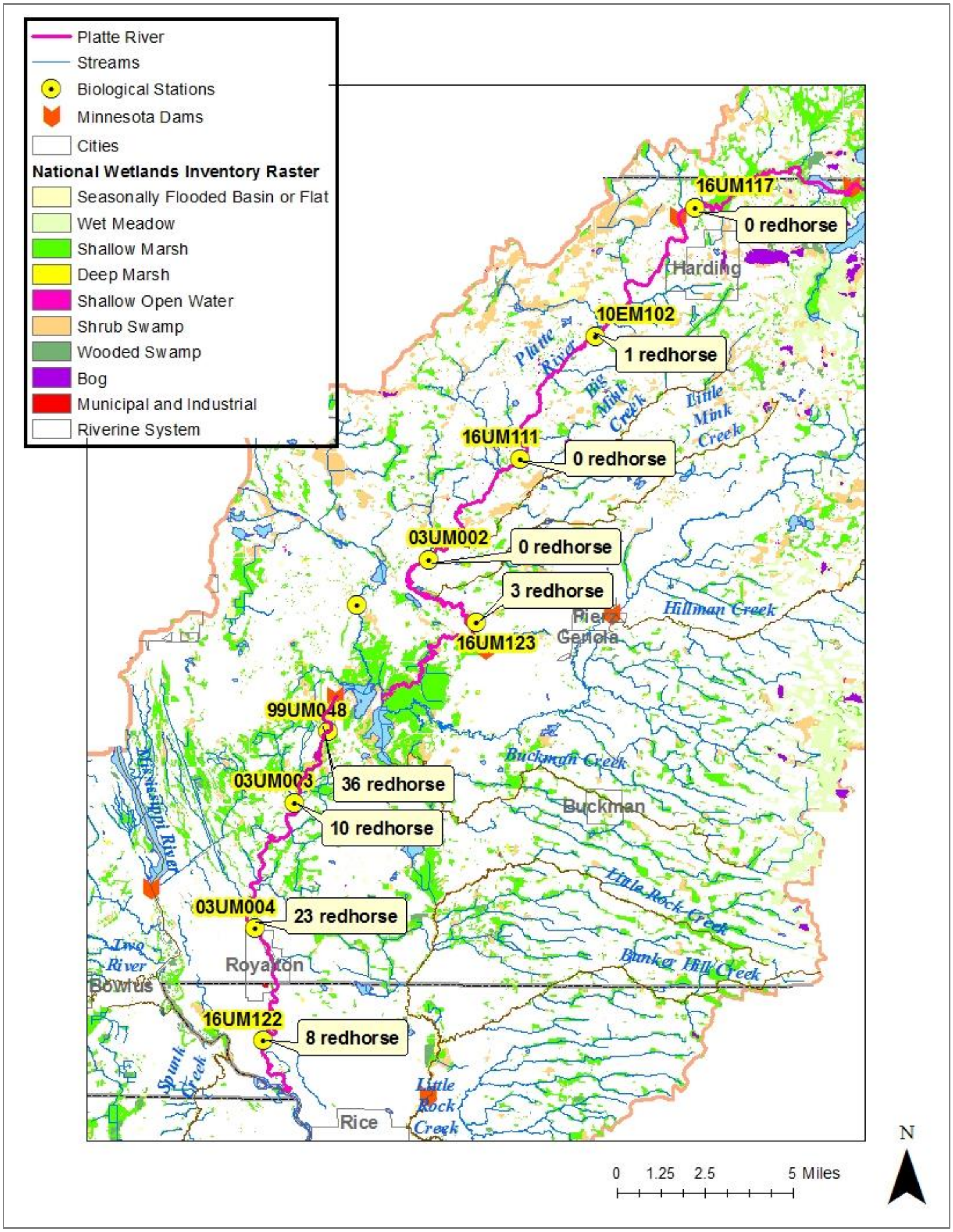


Table 20. Percent migratory fish metrics for all biological stations on the upper section of the Platte River, WID 07010201-507. All sites are FIBI Class 5, with an FIBI impairment threshold of 47.

Station	Date	FIBI Score	Migratory Taxa [%]	Migratory Taxa Percentile†
16UM117	7/5/2016	31	4.8	12.9
	6/15/2017	34	5.3	13.1
10EM102	6/21/2010	41	10.0	20.2
	7/6/2010	41	18.8	52.1
	7/6/2015	48	5.9	13.4
	6/15/2017	45	19.1	53.2
16UM111	7/5/2016	68	15.0	38.6
03UM002	8/27/2003	78	6.7	14.7
	7/6/2016	49	10.0	20.2
16UM123	7/6/2016	46	14.8	38.5

†Percentile is the standing of that Migratory Taxa value as compared to all other reportable, MPCA-collected fish samples to date (n=6,741). For instance, station 16UM117 had 4.8% migratory taxa in the sample on 7/5/2016, which is greater than what 12.9% of all the fish samples had. Put another way, 87.1% of the fish samples had a greater percent of migratory taxa than 16UM117 did.

-Streamflow

Evidence of a streamflow alteration stressor was investigated by searching for signs of channel instability in pictures of the biological stations, visiting the stream, and evaluating habitat data. Overall, the channel looks stable, with little to no bank erosion and has access to the floodplain in most places. The habitat in WID -507 is generally very good and does not seem to be compromised by channel instability (see following *Habitat* section). Also, the relatively high amount of watershed storage, such as wetlands, in the Platte River watershed makes it more resilient to the destabilizing effects of increased precipitation and/or overland runoff. Evidence of streamflow alteration causing biotic stress in WID -507 was not found. However, streamflow alteration was identified as a potential stressor for Big and Little Mink Creeks, which are tributaries to WID -507 and could, over time, degrade the water quality of the Platte River.

-Habitat

Habitat throughout most of the Platte River is very good; MSHA scores at three of the five sites range from 73.5 to 83.6. However, MSHA scores are in the Poor (<45) and Fair (45-65) ranges at 10EM102 and 16UM123, respectively (Table 21).

Table 21. Minnesota Stream Habitat Assessment (MSHA) scores at biological stations on WID 07010201-507. The maximum possible MSHA score is 100. Sites listed in an up- to downstream order.

Station	Date	MSHA
16UM117	7/5/2016	74
	6/15/2017	79.8
	8/7/2017	75.7
10EM102	6/21/2010	51
	7/6/2010	50.5
	7/6/15	58.3
	8/25/15	54.5
	6/15/17	40.5
16UM111	7/5/16	83.6
	8/7/17	74
03UM002	7/6/16	77.6
	8/7/17	73.5
16UM123	7/6/16	56.7
	8/7/17	55

At 10EM102, three quantitative habitat analyses were performed on 6/21/2010, 7/6/2010, and 7/6/2015. This is a more rigorous analysis than the MSHA. For the quantitative analyses, the length of the biological sampling reach was divided into thirteen transects. At each transect, information was recorded on the stream feature (riffle, run, pool), substrate type, depth of fines, embeddedness, habitat cover, algae, macrophytes, shade, bank erosion, and riparian buffers.

In the June 2010 analysis, twelve transects landed on a run stream feature and one on a pool. The runs were predominantly sand, with silt being the second-most frequently observed substrate, and gravel third. Depth of fines in the run was 0-120cm, with an approximate average of 16cm. The pool was sand and silt, with depth of fines ranging from 4-20cm. The MSHA on 6/21/2010 reported 95% run and 5% pool habitat features. Substrate in both was sand and silt.

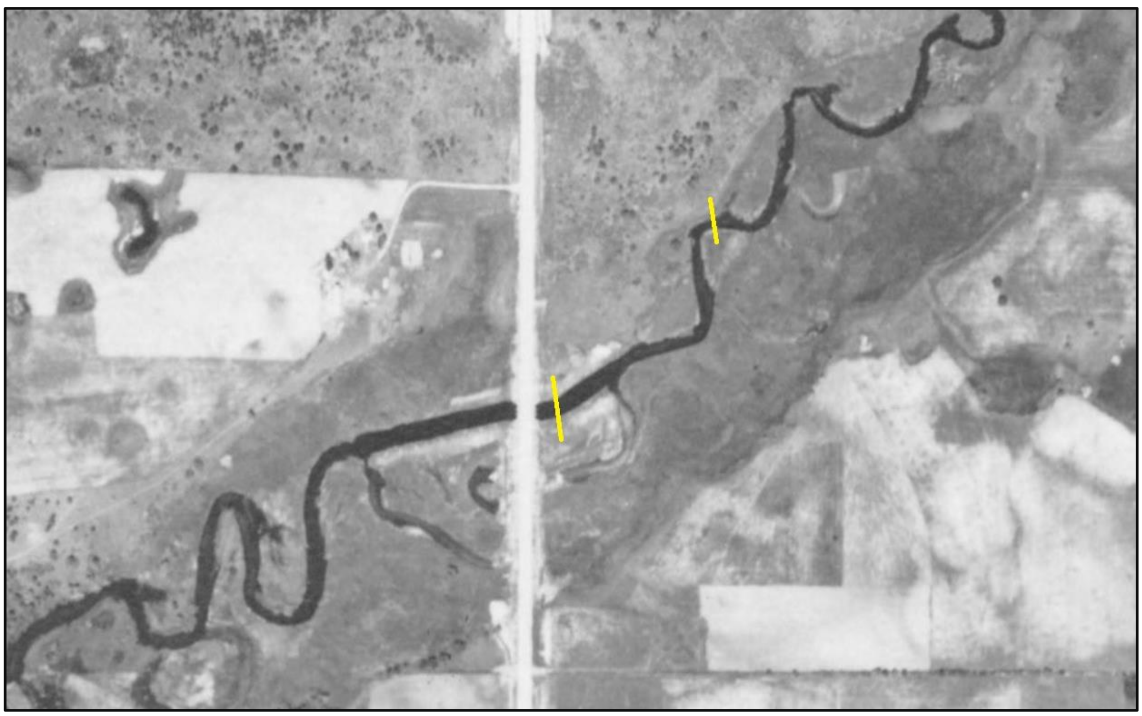
In the July 2010 analysis, ten transects landed on runs and two on pools. Substrate composition of the runs was similar to that in the June 2010 analysis, except gravel was not observed. Embeddedness was not reported since there was no gravel or other coarse substrate. Depth of fines was an approximate average of 7.5cm, and range of 0-25cm. In the pools, the substrate was sand with a depth of fines range of 0-7cm. The MSHA on 7/6/2010 reported 90% run and 10% pool habitat features. Substrate in both was sand and silt.

In both the June and July 2010 habitat analyses, the substrate in transect two was marked as "other," with "concrete" written in as the descriptor.

In the July 2015 analysis, all thirteen transects were runs. The predominant substrate was sand, with gravel being the next most observed substrate type, and then silt. The gravel was 25-50% embedded. The depth of fines average was 7cm with a range of 0-26cm. The MSHA on 7/6/2015 corroborates this, reporting that 100% of the biological station was a run, with both sand and gravel present, and the gravel being 25-50% embedded.

Based on the transect habitat analyses and MSHA information, the habitat complexity at 10EM102 is low, with only one stream facet-type observed at times. Some damage was done to the channel circa 1930's to install the stream-road crossing of MN-25 at the downstream end of 10EM102 (Figure 29). The channel was straightened and width was increased, which generally increases channel slope and width/depth ratio. The sediment transport capacity of a stream is mostly controlled by channel slope and dimensions, which were both altered at 10EM102. The lack of habitat complexity at 10EM102 may be a result of the damage done to the channel when the MN-25 road crossing was installed. Ultimately, however, the reason for the lack of coarse substrate and more homogenous habitat and in this section of the WID is unknown, and may be natural to some degree.

Figure 29. Crossing of Platte River and MN-25 on 6/11/1940.
Note the expansion of stream width where the channel was straightened to create a perpendicular road crossing. Yellow lines indicate endpoints of the 10EM102 biological station. Flow direction is to the southwest (right to left). Image from MN DNR's historical landview dataset compilation; some photos from USDA.



At the WID's furthest downstream station, 16UM123, both MSHA categories that scored the worst (in terms of achieving maximum possible points) were: Channel Morphology and Land Use. However, the Land Use category only has a maximum of five possible points, which does not strongly influence the total MSHA score. In both MSHAs, the Substrate category scored 53-54% of its maximum, which is 28 possible points. By contrast, Substrate scores at the other biological stations on WID -507 that had Good (>65) total MSHA scores had 70-84% of the maximum possible Substrate points. The habitat quality at 16UM123 suffers from a lack of coarse substrate overall, and when present it is >50% embedded.

Stream facet composition at 16UM123 was estimated as 80-85% sand-gravel run and 10-20% sand pool, with one of the MSHAs reporting a 5% presence of cobble-gravel riffle. The coarse substrate was moderately (50-75%) to severely (75-100%) embedded. A “normal” amount of siltation was observed. Channel Development was rated “Fair,” on a scale of Poor-Fair-Good-Excellent. Channel stability was rated Moderate and Moderate/High. Only two velocity types were observed: Moderate and Slow. While the MSHA scores suggest that the habitat at 16UM123 is fairly homogenous and that the streambed is potentially unstable here, more information is still needed to confirm lack of habitat as a stressor at this location, especially with such high MIBI scores.

Based on the MSHA scores, aerial imagery, and visits by the author, lack of habitat does not appear to be a stressor at three of the five biological stations, but it is a stressor at 10EM102, and possibly at 16UM123 as well. Habitat degradation may have occurred at both stations when the channel was altered to install state highway road crossings. Habitat at the other biological stations on WID -507 do not appear to have been degraded by adjacent road crossing, based on historical aerial imagery and LiDAR data. Those two stations yield the lowest FIBI scores on the WID, with the exception of 16UM117, where FIBI scores are greatly affected by the Platte River Dam.

-Suspended Sediment

Due to the low percent chance that the stream would be impaired for TSS based on the fish community, and the fact that the MIBI scores are good, TSS was minimally investigated as a stressor. The available data do not show problematic TSS levels or low stream transparency. Of twenty TSS samples taken from WID -507 since 2016, all were ≤6.4mg/L, with the exception of one sample of 15mg/L on the day of an extreme storm, July 12, 2016. Bedded sediment may or may not be a stressor in some locations, and is discussed as embeddedness in the *Habitat* section.

-Nutrients

Nitrogen

Nitrate toxicity is not a stressor to aquatic life in WID -507. Of the 32 data points available, the maximum concentrations was 0.59mg/L on 7/12/2016 at 16UM123.

Phosphorus

On WID -507, total phosphorus data exists for all five of the biological stations, as well as an additional two locations immediately upstream and downstream of 10EM102. The nutrient data ranges from 2010 to 2018, months May - September. The only station that yielded an exceedance of the nutrient river standard (0.100mg/L of TP) was 16UM123 on July 20 and August 3 of 2016, which were influenced by an extreme rainfall event that occurred on July 12. Excess TP does not appear to be a primary stressor in WID -507, although it is vulnerable to such conditions given the high amount of livestock activity and ditched wetlands in the watershed. Further, the Platte River is vulnerable to eutrophication because parts of it are wide and unshaded, shallow, slow-flowing, and have a sandy bottom, which is conducive to macrophyte and algae growth (e.g. Figure 30).

Figure 30. Pictures of the Platte River at various locations that depict its current level of in-stream, primary production, which could reach eutrophic levels if nutrient inputs are not managed.

-

-Dissolved Oxygen

At 16UM117, the upstream-most biological station, a sonde deployment revealed that DO dropped below 5mg/L every night between July 12th and 26th of 2018. The DO flux ranged from 2.47 to 5.39mg/L. This dramatic of a flux suggests that eutrophication may be occurring, and pictures show heavy plant-growth in some parts of the reach (e.g. Figure 31). On 7/5/2016, TP was 0.041mg/L, and on 7/3/2018 it was 0.048mg/L. The nutrient river standard for this location is 0.100mg/L. Because the sonde was placed in full sun, the dramatic DO flux may be a result of the combined effects of plant growth and extreme temperature fluctuations. Also, this location is immediately downstream of a sizeable shallow marsh wetland, and may naturally have low DO. The macroinvertebrate tolerance richness metrics for low DO suggest that it is stressing the community (Table 22), which had a low MIBI score. More taxa are low DO-tolerant than are –intolerant, and, the percentiles show that this community has more low DO-tolerant taxa than 75.4% of all other MIBI Class 3 samples.

Figure 31. Thick macrophyte growth in 16UM117.

Table 22. Number of taxa ("taxa richness") in the macroinvertebrate sample at 16UM117 that are tolerant and intolerant to low DO.
Percentile analysis was performed using all other MIBI Class 6 samples collected by MPCA (n=683). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Stressor	Very Intolerant Taxa richness - Percentile	Intolerant Taxa richness - Percentile	Tolerant Taxa richness - Percentile	Very Tolerant Taxa richness - Percentile
Low DO	3 – 20.3%	4 – 10.0%	7 – 75.4%	2 – 65.1%

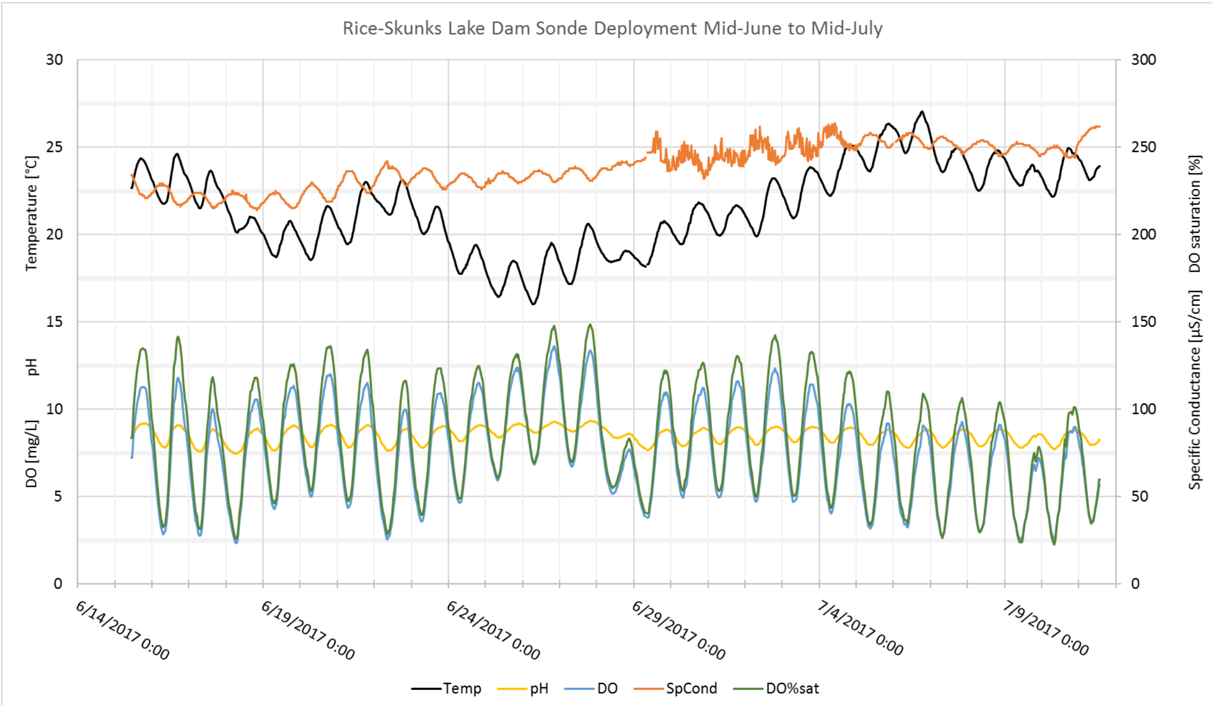
Downstream of 16UM117, DO data from stations 10EM102, 16UM111, and 03UM002 did not yield any samples below 7.27mg/L. However, very little of this data was collected in the early morning, when DO is the lowest. At Morrison CR47, downstream of 10EM102, some DO data from July 2011 and July 2012 shows that DO hovered around 5mg/L in the late afternoon, when it would normally be around the daily maximum. Only one measurement was made at this location in recent years: on 7/3/2018 at 8:58am, DO was a healthy 7.03mg/L. Stressfully low DO may be occurring at this location, but the data are inconclusive.

At the downstream most station, 16UM123, DO measured as early as 11:00AM was in the range of 5.81 - 6.40mg/L in July of 2016 and 2017. On 7/6/2016 at 13:00, DO was 10.37mg/L and DO percent saturation was 121.7%, which suggests that primary production is controlling DO in 16UM123, to some degree. This may be, in part, a result of the ditched wetland area that enters the river right in the middle of the 16UM123 sampling reach. After the fish sample on 7/6/2016, biologists commented that they "Could detect cold groundwater seeps in pool near X [midpoint of reach] (where road approaches stream)." Further, the highest TP and NOX concentrations in WID -507 were measured at this location. A sonde deployment to continuously measure DO would help determine if eutrophication is a stressor at the downstream end of the WID. It is currently unclear, though not suspected, considering the high MIBI score at 16UM123.

It appears that low DO (<5mg/L) does occur in some locations on WID -507, but tends to be flow-related, as a result of receiving water from wetland areas. Low DO is not the cause of the aquatic life impairment on WID -507, though it is a potential stressor at 16UM117. The high MIBI scores and conditional probabilities shown in the *Biological Data* section also support this conclusion (see Table 17and
Table 18).

Downstream of WID -507, sondes were deployed to understand the DO regime of the Rice-Skunk Lakes area, and if low DO from that area would persist downstream into the lower Platte River (WID –545). Nightly low DO occurs near the outlet of Rice Lake (Figure 32), with a median daily DO flux of 6.68mg/L between mid-June and mid-July. Downstream of the Rice Lake outlet, at biological station 99UM048 (upstream of Iris Rd.), DO still dips below 5mg/L (Figure 33), with a median daily DO flux of 7.88mg/L between late-June and mid-July. Low DO conditions appear to be occurring in Rice Lake, and the water leaving the lake re-aerates somewhat by time it reaches 99UM048. The magnitude of daily DO flux indicates that the in-channel primary productivity (see Figure 30, 99UM048 picture) is controlling the DO, and that eutrophication may be occurring. This information adds some evidence to the possibility that wetland-like conditions of the Rice-Skunks Lakes area are deterring some fish species, such as redhorse species, from accessing the high quality habitat in WID -507 (see discussion in *Longitudinal Connectivity* section).

Figure 32. Continuous water quality parameters measured at the outlet of Rice Lake in the summer of 2017.



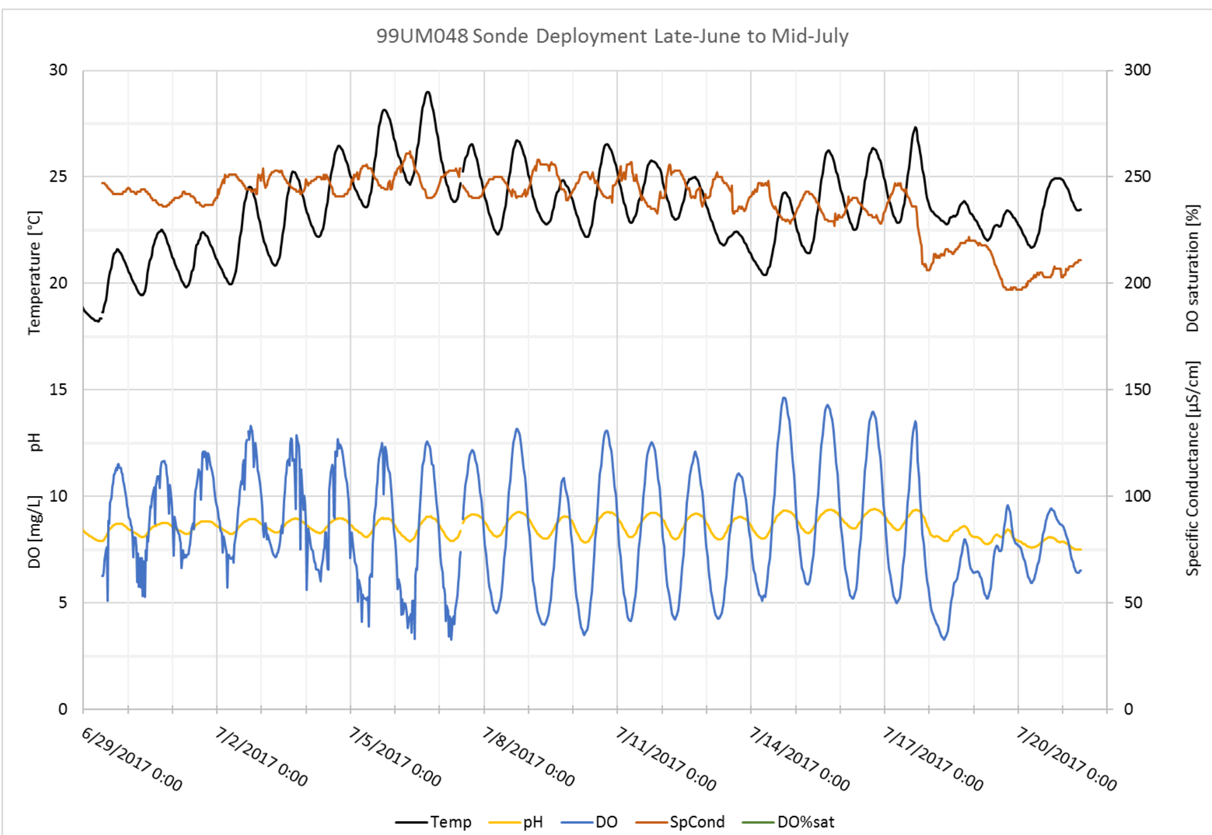
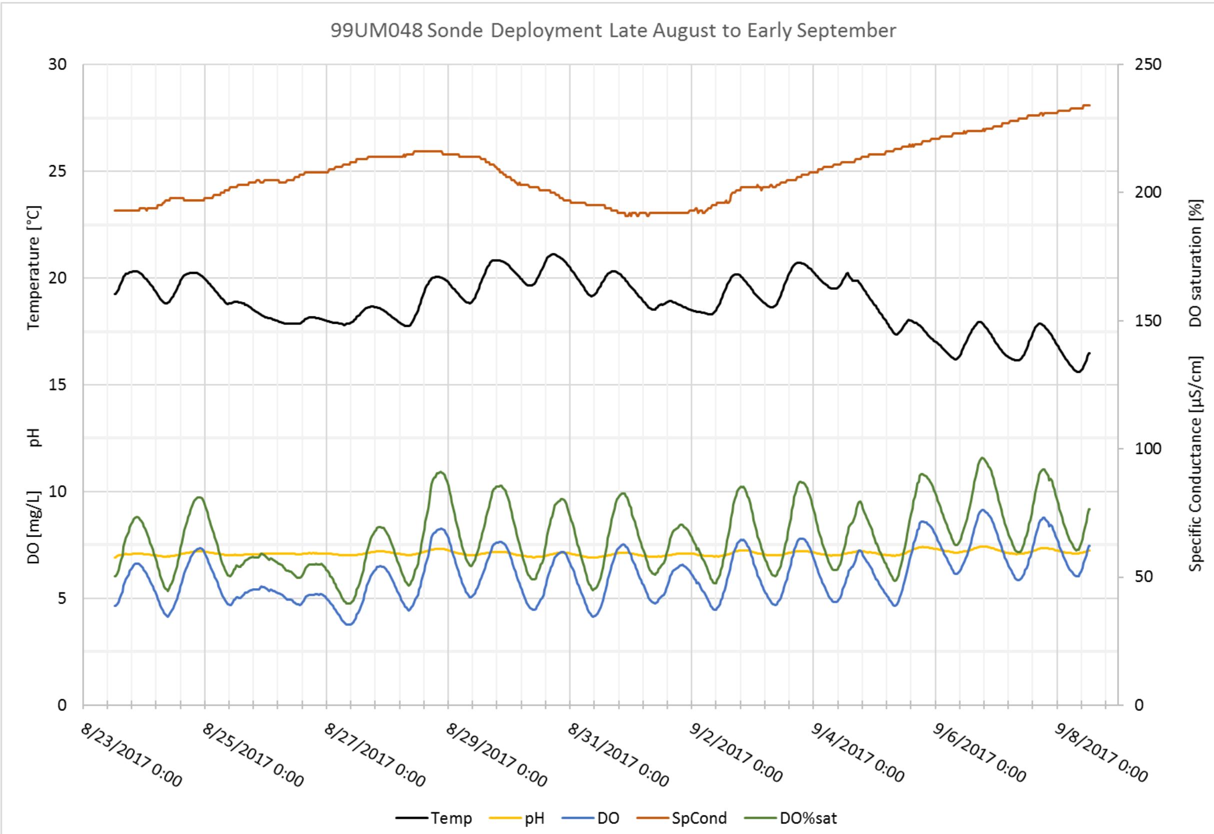


Figure 33. Continuous water quality parameters measured at biological station 99UM048, on Iris Rd., downstream of Rice Lake outlet.



WID Summary

In summary, the cause of the poor FIBI scores on WID -507 were not conclusively determined, with the exception of the Platte River Dam impeding fish passage into 16UM117 and lack of habitat at 10EM102. The stressors at the other locations with failing FIBI scores were inconclusive. For instance, lack of habitat is a potential stressor at 16UM123, but more data are needed to be conclusive. And, low DO is a suspected stressor at 16UM117. Another potential stressor to the fish community in WID -507 is the wetland-like and eutrophic condition of the Rice-Skunk Lakes area that may be deterring some sensitive fish species from moving into WID -507.

The Platte River has many areas of high quality habitat, and is a resource of local importance. The main threats to aquatic life thriving in WID -507 appear to be the growing frequency of localized disturbances on the mainstem, such as dams, road crossings, and livestock access, as well as disturbance of the tributaries (particularly Big and Little Mink Creeks), such as livestock access and wetland ditching. While TP concentrations in excess of the standard were not observed during this study, the Platte River is susceptible to river eutrophication based on watershed land use practices and the generally wide and shallow characteristics of the river that easily facilitate plant and algae growth.

3.1.5. Rice Creek Subwatershed – WIDs 07010201-618 & -651

Rice Creek is a tributary to Rice Lake, which drains to the lower portion of the Platte River. The mainstem of Rice Creek is WID -618, and the headwaters are WIDs -621, -622, and -651. WIDs -621 and -622 were assessed as "modified use," and held to a lower standard than general use streams; they were not determined to be impaired for aquatic life. However, WIDs -618 and -651 were assessed as general use streams and failed to meet IBI standards (Table 23). Most of the headwaters area of Rice Creek is comprised of cultivated crops and hay/pasture, and at least one third of the area is a type of wetland or open water. Nearly 100% of the total headwater stream length has been channelized.

The mainstem of Rice Creek, WID -618, begins at the outlet of Pelkey Lake and ends at the inlet of Rice Lake, which is approximately 4.51 miles of stream. Pelkey Lake has a fourteen-day residence time, which is one day shorter than the residence time required for the state's lake eutrophication standard to apply. It is a small lake that receives water from tributaries that have been completely altered for agricultural drainage and flow through wetland areas. Most of the Rice Creek watershed at this point is comprised of wetlands, primarily shallow marsh and some shrub swamp types. The rest of the area is mostly rangeland (pastures and hay fields).

The assessment results for WID -651 became available after the SID study was well underway. Due to time limitations, the analysis of WID -651 is relatively brief as compared to other WIDs in this report. However, the primary stressors affecting aquatic life in this area are not ambiguous.

Biological Data

WID -651 is impaired for aquatic life due to nonsupport of both the fish and macroinvertebrate communities, while the downstream WID -618 is impaired due to nonsupport of the macroinvertebrates only.

Table 23. IBI data from biological stations in the Rice Creek subwatershed (WIDs 07010201-651 and -618).

			Fish IBI			Macroinvertebrate IBI		
WID	**Station**	**Date**	**Class†**	**Impairment Threshold**	**Score**	**Class†**	**Impairment Threshold**	**Score**
-651	**16UM109**	6/23/2016	6	42	29.7	-	-	-
		9/1/2016	-	-	-	5	37	30.6
		7/26/2018	6	42	16.9	-	-	-
		8/7/2018	-	-	-	5	37	41.1
	18UM109	7/24/2018	6	42	29.3	-	-	-
		8/7/2018	-	-	-	5	37	36.1
-618	**16UM124**	8/4/2016	7	42	48.3	-	-	-
		9/14/2016	-	-	-	6	43	21

†FIBI Class: (6) Northern Headwaters (7) Low Gradient
MIBI Class: (5) Southern Streams – Riffle/Run (6) Southern Forest Streams – Glide/Pool

WID -618

Tolerance of the macroinvertebrate community to various stressors was analyzed in the context of all other MIBI Class 6 – Southern Forest Streams Glide/Pool samples in the state (Table 24). The proportion of tolerant and non-tolerant taxa are used as supporting evidence in the following discussion of stressor data. In summary, the macroinvertebrate community composition is skewed toward taxa that are tolerant of several stressors, namely: low DO, fine substrate, embedded substrate, TSS, and high TP.

Table 24. Number of taxa ("taxa richness") in the macroinvertebrate samples at 16UM124 that are tolerant and intolerant to specific stressors.
Percentile analysis was performed using all other MIBI Class 6 samples collected by MPCA (n=683). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Stressor	Very Intolerant Taxa richness - Percentile	Intolerant Taxa richness - Percentile	Tolerant Taxa richness - Percentile	Very Tolerant Taxa richness - Percentile
Low DO	0 – 0%	0 – 0%	15 – 95%	6 – 89%
Depth of Fines	0 – 0%	1 – 24%	14 – 91%	8 – 88%
Embedded Substrate	0 – 0%	1 – 37%	12 – 57%	9 – 70%
Total Suspended Solids (TSS)	0 – 0%	0 – 0%	7 – 17%	6 – 76%
Inorganic Nitrogen (NOX)	0 – 0%	3 – 76%	6 – 1.9%	4 – 2.1%
Total Phosphorus (TP)	0 – 0%	0 – 0%	13 – 69%	8 – 76%

Stressor Data

Considering the abundant wetland acreage and agricultural land use in the Rice Creek watershed, low DO was the most heavily investigated stressor, with other potential stressors being minimally considered. A large portion of the water chemistry data was collected at MN-27, which is downstream of the biological station by approximately 3,400 feet, but is still on the WID.

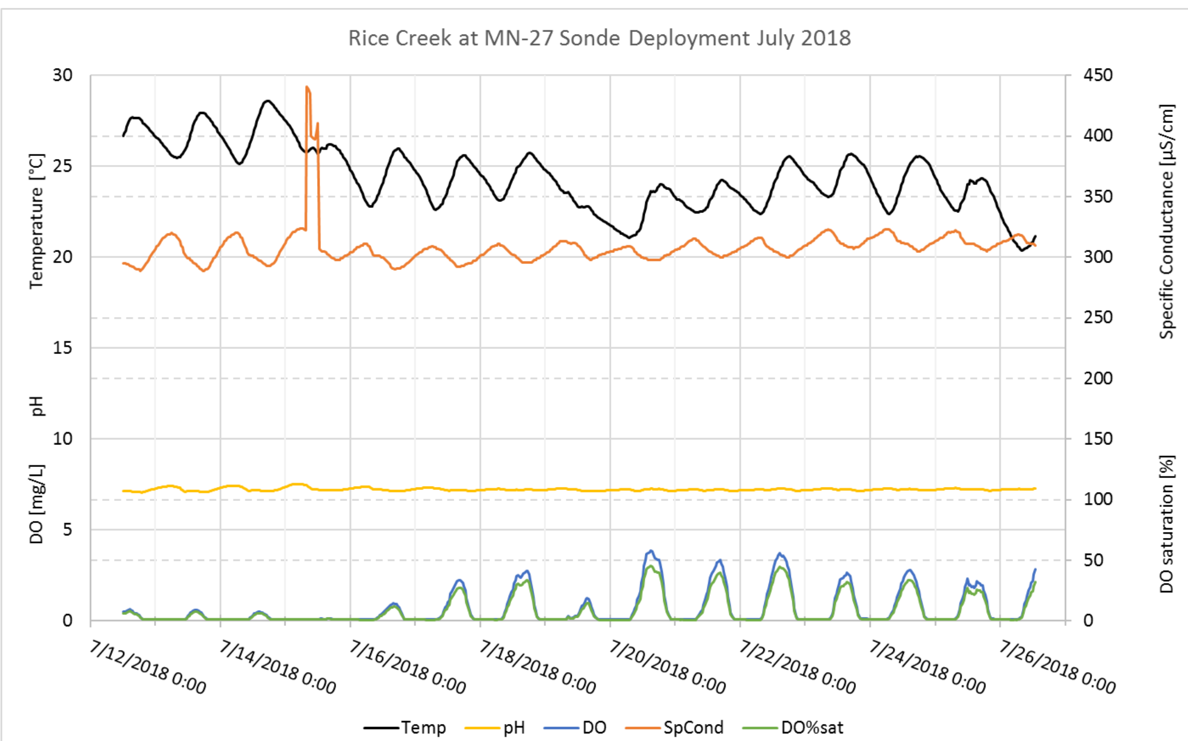
-Temperature

Instantaneous sonde measurements were made in 2016-2018 (Table 25). The highest temperature observed was 25.49°C, which is not stressfully warm for warmwater aquatic life. In July 2018, a sonde was deployed on WID -618 at MN-27. It was placed in full sun at mid-depth (Figure 34). Temperatures measured by the sonde were not of a concerning level (>30°C) for warmwater aquatic life. Warm stream temperature is not a stressor to aquatic life in WIDs -651 or -618. In fact, some of the temperature measurements at 16UM109 are relatively cool for the MRS Watershed and suggest a strong connection to groundwater.

Table 25. Instantaneous temperature measurements on WIDs -651 and -618.

Station (WID)	Date	Time	Temperature [°C]	DO [mg/L]
16UM109 (-651)	5/30/2017	10:40AM	11.50	9.58
	6/23/2016	8:43AM	17.07	7.59
	8/8/2017	8:28AM	15.66	8.67
	9/1/2016	8:36AM	15.35	8.88
	7/26/2018	9:30AM	16.50	8.36
	8/7/2018	3:25PM	20.50	8.60
18UM109 (-651)	7/24/2018	2:05PM	20.80	8.57
	8/7/2018	3:25PM	20.50	8.60
16UM124 (-618)	8/4/2016	12:50PM	25.49	5.98
	9/14/2016	11:39AM	13.89	1.74

Figure 34. Continuous water quality measurements on WID -618 at MN-27 road crossing. Sonde was deployed in full sun at mid-depth.



-Longitudinal Connectivity

The culverts at 173rd St. on WID -651 are impeding fish passage; they are set too high and appear oversized (Figure 35). Lack of longitudinal connectivity as a result of this road crossing is a stressor to the fish community in WID -651. Connectivity was not evaluated in WID -618 because the FIBI at 16UM124 scored above the general use threshold.

Figure 35. Culverts on downstream side of 173rd St. on 7/26/2018.
They are set at too high of an elevation and preventing fish from moving upstream into 18UM109 on WID -651.

-Streamflow

As previously stated, the headwaters of Rice Creek were channelized at some point in time. Some areas are maintained drainage ditches and some areas have not been maintained in so long that riparian forests have developed, such as the riparian area of WID -651. Despite the present riparian vegetation, pictures from the biological stations show that the stream channel has experienced severe destabilization, exhibiting raw, eroding banks, a mobile streambed, and fallen trees (Figure 36). Streamflow alteration, as a result of the watershed channelization, is a stressor to aquatic life in WID -651.

Figure 36. Pictures from WID -651, illustrating the geomorphic instability and lack of habitat.

Rice Creek, at WID -618, is a low gradient stream, which is reflected in the FIBI and MIBI class assignments. Biologists from the macroinvertebrate sampling crew noted that the streamflow velocity was generally slow throughout the reach and even imperceptible at times. Rice Creek is strongly connected with groundwater, evidenced by the predominance of riparian wetlands, springs, and iron in the stream. Streamflow alteration through ditching has occurred in the headwaters of the Rice Creek watershed, upstream of Pelkey Lake, which may influence the water chemistry in Rice Creek. If streamflow alteration is contributing to the aquatic life impairment in Rice Creek, it would be through the mechanism of influencing water chemistry, and unlikely through hydrologic mechanisms, such as flashiness or channel dimension alteration. This study did not investigate the degree to which the headwater ditching may or may not be contributing to the aquatic life impairment in WID -618.

-Habitat

As discussed above in the *Streamflow* section, streamflow alteration has degraded habitat in WID -651. According to the MSHA, siltation in the stream varies between normal and greater than normal, and embeddedness is moderate (50-75%) overall, but was noted as severe (75-100%) in one instance. The predominant substrate is sand, though gravel and silt were also observed, including small sand-gravel riffles observed at both sites. Biologists encountered difficulty in finding enough habitat to obtain a full-sized macroinvertebrate sample, and often had to create artificial flow when taking a sample because the water was stagnant. Information from the MSHA, MPCA staff observations, and pictures from the biological stations confirm that lack of habitat is a stressor in WID -651, driven by streamflow alteration.

Two MSHAs were completed on WID -618 at station 16UM124, with total scores of 41 and 41.5, a “Poor” (<45) score overall. In sum, the Land Use and Riparian categories had mediocre scores, Cover scored well primarily due to the extensive macrophyte growth, and Substrate and Channel Morphology scored very poorly. The habitat is almost completely homogenous, being all sand-silt run, though one MSHA noted 10% sand-silt pool. Siltation was evaluated as “Normal.”

The lack of habitat complexity makes it unlikely that Rice Creek could support a diverse community of aquatic life, though the FIBI and MIBI classes for this stream have built within them the expectation of a naturally lower diversity than occurs in somewhat larger streams. While the poor habitat measured at 16UM124 may be stressful to aquatic life, the situation is compounded by the stress of low DO (see *Dissolved Oxygen* section below). The FIBI score did pass the general use threshold when DO was above 5mg/L, while the MIBI score failed to meet the threshold when DO was 1.74mg/L, which lends support to the theory that low DO is the controlling stressor in WID –618.

-Suspended Sediment

Very little chemistry data exists regarding sediment for WID -618. What is available is shown in Table 26. The conditional probability that the streams would meet the water quality standard for TSS was good (Table 27); data for samples taken after 2016 were not available at the time of this writing. However, the macroinvertebrate tolerance richness metrics suggest that TSS is affecting that community.

The low stream transparency at 16UM109 on 6/23/2016 is not a result of suspended solids, as the TSS measurement was very low; it may be due to iron precipitate or metal colloids in the stream from a groundwater connection. This may also be the case at 16UM124 on 7/12/2018; pictures of the stream from that day look similar to pictures from Tributary to Platte River (WID -634), which has very high iron. There is not enough information available to determine if suspended sediment is a stressor to aquatic life in Rice Creek.

Table 26. Secchi tube (transparency), total suspended solids (TSS), and total suspended volatile solids (TSVS) from stations in the Rice Creek subwatershed (WIDs -651 and -618).

WID	**Station**	**Date**	**Secchi** [cm]	**TSS** [mg/L]	**TSVS** [mg/L]
-651	16UM109	6/23/2016	60	6.8	1.6
		9/1/2016	92	-	-
		7/26/2018	>100	1.2	1.0
		8/7/2018	98	-	-
		9/20/2018	-	1.2	1.0
	18UM109	7/24/2018	>100	1.8	-
		8/7/2018	98	-	-
-618	16UM124	8/4/2016	>100	2	1.2
		9/14/2016	94	-	-
		7/3/2018	>100	-	-
		7/12/2018	58	-	-
		7/26/2018	>100	-	-

Table 27. Conditional probabilities (percent chance) that WIDs -651 and -618 would meet the TSS and DO state standards based on the fish communities sampled in 2016.

WID	**Station**	**Sample Date**	**TSS** [%]	**DO** [%]
-651	16UM109	6/23/2016	82.7	5.4
-618	16UM124	8/4/2016	78.0	40.8

-Nutrients

Nitrogen

Ten chemistry samples were randomly collected from WIDs -651 and -618 throughout 2016-2018 (Table 28). The NOX and NH4 concentrations are not of concern, as they are all less than 0.50 and 0.20mg/L, respectively.

Phosphorus

The TP levels in WIDs -651 and -618 are some of the highest seen in the MRS Watershed in 2016-2018; four samples exceed the river nutrient standard of 0.100mg/L of TP. High TP acts as a stressor to aquatic life by inducing eutrophication. The riparian vegetation on WID -651 keeps the stream shaded, and excessive primary productivity was not observed in 2016-2018. Although TP is high there, it is not a suspected stressor. In downstream WID -618, however, eutrophication may be a stressor. See the following *Dissolved Oxygen* section for more discussion.

Table 28. Nutrient data from stations in the Rice Creek subwatershed. All data in units of mg/L.

WID	Station	Date	TP	NOX	NH4
-651	16UM109	6/23/2016	0.100	0.042	0.10
		5/30/2017	0.063	<0.05	-
		8/8/2017	0.102	<0.05	-
		8/24/2017	0.102	-	-
		7/26/2018	0.080	0.26	0.05
	18UM109	7/24/2018	0.233	0.212	0.10
-618	16UM124	8/4/2016	0.099	0.022	0.14
		7/11/2017	0.076	0.46	-
		8/31/2017	0.09	<0.05	-
		7/3/2018	0.111	<0.05	-

-Dissolved Oxygen

The likelihood that either stream reach would meet the DO standard based on the fish sample is quite low (see Table 27). Measurements of DO in WID -651, however, show DO at healthy levels both in the early morning and afternoon (see Table 25, in *Temperature* section). It is possible that other stressors acting on the fish community are confounding the conditional probability calculation. Alternatively, low DO that is occurring in other parts of the watershed, such as WID -618, may be restricting fish from migrating into WID -651. Low DO is an inconclusive stressor to aquatic life in WID -651.

Measurements from a sonde deployment suggest that low DO is a stressor to aquatic life in WID -618 (see Figure 34). Between July 12th and 26th of 2018, DO never reached 5mg/L at the MN-27 road crossing, which is approximately 3,400ft downstream of biological station 16UM124. The range of DO flux during the deployment was 0.06 – 3.8mg/L, with a median of 2.22mg/L. A DO flux of 3.5mg/L or greater is usually indicative of eutrophication, which is 1.28mg/L greater than the median. Given the high amount of wetland cover in the watershed, it is possible the low DO in Rice Creek is a result of receiving DO-stripped wetland water.

DO at the time of the macroinvertebrate sample was 1.74mg/L, while it was 5.98mg/L at the time of the fish sample, which may explain why the FIBI met the impairment threshold and the MIBI did not. A handful of instantaneous DO measurements were made at MN-27 in 2017-2018 (Table 29) that also yielded low DO. Further, the macroinvertebrate community composition is skewed toward taxa that are tolerant of low DO conditions. Low DO is a stressor to aquatic life in WID -618, though the cause(s) of the low DO are unclear.

Table 29. Instantaneous dissolved oxygen (DO) measurements from WID -618.

Location	Date	Time	DO [mg/L]
16UM124	8/4/2016	12:50	5.98
16UM124	9/14/2016	11:39	1.74
MN-27	7/11/2017	15:08	11.64
MN-27	7/12/2017	14:50	11.54
MN-27	7/18/2017	10:07	3.25
MN-27	7/26/2017	12:19	8.21
MN-27	8/31/2017	10:03	2.66
MN-27	7/3/2018	13:00	2.85
MN-27	7/12/2018	11:00	0.46
MN-27	7/17/2018	12:35	1.78
MN-27	7/23/2018	10:31	1.18
MN-27	7/26/2018	13:15	3.13

WID Summary

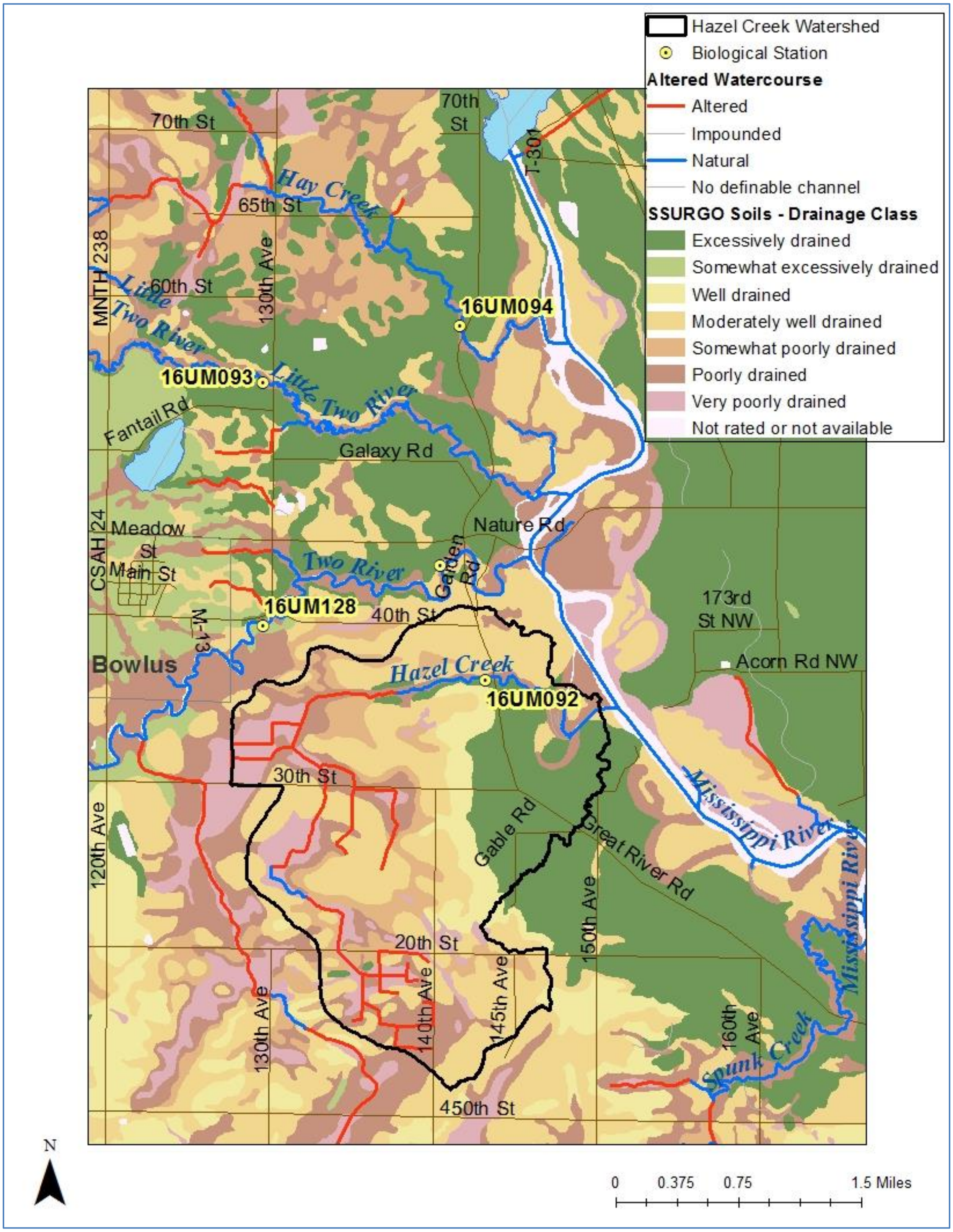
Streamflow alteration, which is degrading habitat, is the primary stressor to aquatic life in WID -651. In addition, the culvert at 173rd St. is impeding fish passage. It is unknown to what degree the low DO occurring downstream, in WID -618 and potentially other place, is responsible for the low FIBI scores.

Low DO is the primary stressor to aquatic life in WID -618. It is unclear if the low DO is naturally occurring due to the wetland conditions of the watershed, and/or if anthropogenic activity, such as ditching and nutrient input, has affected the water chemistry of Rice Creek. Therefore, streamflow alteration (due to channelization) and eutrophication are inconclusive stressors.

3.2. Hazel Creek – WID 07010201-569

Hazel Creek is a small tributary to the Mississippi River. The biological station is located near the watershed outlet and has a drainage area of 3.26 square miles at this location. Most of the stream network has been altered for agricultural drainage (Figure 37). Hazel Creek is just across the Mississippi River from the Little Rock Creek watershed and has similar geological characteristics, such as well-drained soils and shallow depth to groundwater.

Figure 37. Map showing Hazel Creek drainage area and other relevant land features.



Biological Data

Hazel Creek is impaired for aquatic life due to nonsupport of the fish community. Station 16UM092 was sampled in July 2016 and June 2017. Neither FIBI score meets the general use threshold for FIBI Class 6 – Northern Headwaters (Table 30).

Table 30. IBI data from site 16UM092 on Hazel Creek (WID 07010201-569).

		Fish IBI			Macroinvertebrate IBI		
Station	Date	Class†	Impairment Threshold	Score	Class†	Impairment Threshold	Score
16UM092	7/7/2016	6	42	25	-	-	-
	8/10/2016	-	-	-	5	37	40
	6/14/2017	6	42	35			

†FIBI Class: (6) Northern Headwaters
MIBI Class: (5) Southern Streams – Riffle/Run

In 2016, only five fish species were sampled: brook stickleback, blacknose dace, white sucker, johnny darter, and central mudminnow. In 2017, eight species were sampled, with the same five species as in 2016 and the additional three species only totaling five individuals: creek chub, longnose dace, smallmouth bass. Both fish samples yielded a low number of fish species and individuals, and especially low numbers of sensitive species. The breakout of FIBI metric scores shows how each affects the final FIBI score, with the worst scoring metrics highlighted in blue (Table 31).

Table 31. Fish IBI metric scores from the fish samples at 16UM092.
Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown.

FIBI Class 6 Metric	Raw Metric Result		Re-scaled IBI Score	
	7/7/2016	**6/14/2017**	**7/7/2016**	**6/14/2017**
DarterSculp *Number of darter and sculpin species*	1	1	5	5
FishDELTPct *Percent of individuals with DELT anomalies*	0%	0%	0	0
Hdw-Tol *Number of headwater specialist taxa, excl. tolerant species*	0	0	0	0
InsectCypPct *Percent of insectivorous cyprinid individuals*	0%	2.13%	0	1.02
Insect-TolTxPct *Percent of insectivorous taxa, excl. tolerant species*	20%	25%	4.67	5.83
Minnows-TolPct *Percent of cyprinid individuals, excl. tolerant species*	0%	2.13%	0	0.41
NumPerMeter-Tolerant *Number of fish per meter, excl. tolerant species*	0.18 fish/m	0.09 fish/m	0.99	0.48
PioneerTxPct *Percent of pioneer taxa*	20%	25%	6.62	4.94
Sensitive *Number of sensitive species*	0	2	0	5
SLithop *Number of simple lithophilic spawning taxa*	2	3	4.80	7.02
TolTxPct *Percent of tolerant taxa*	80%	62.5%	3	5.63
Total (FIBI score)	--	--	25.08	35.33

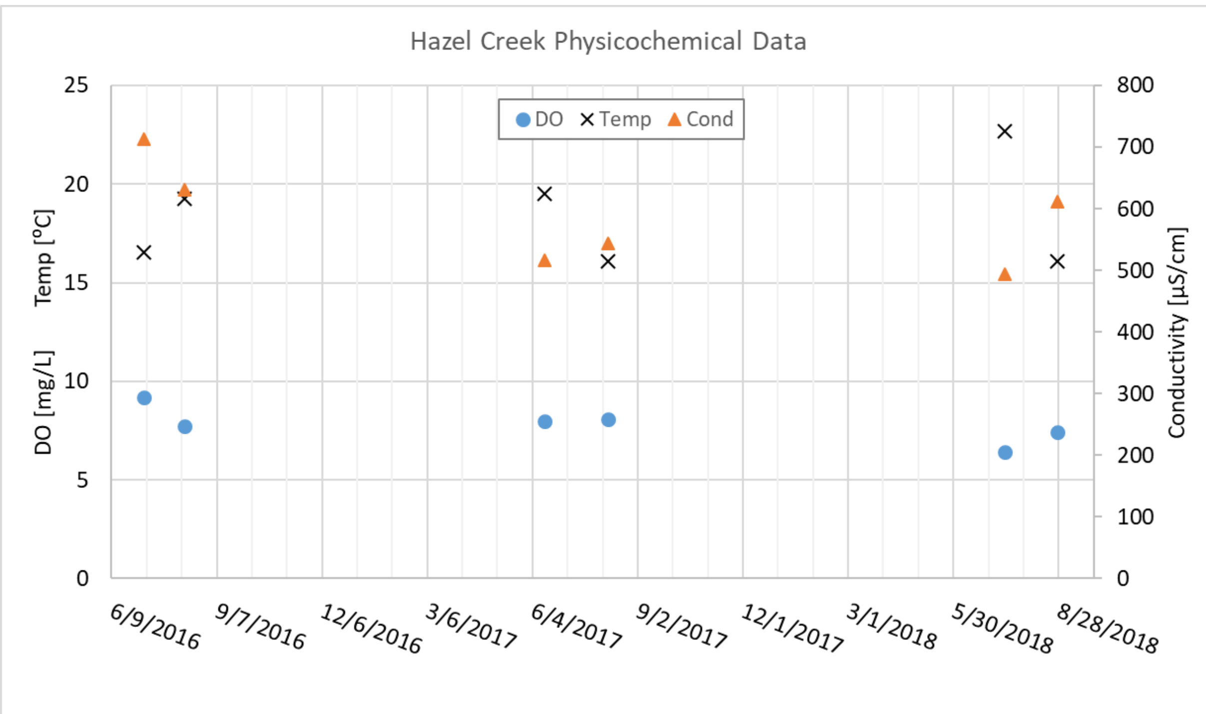
Stressor Data

-Temperature

Cool temperature and high specific conductance measurements suggest that Hazel Creek is strongly connected to groundwater (Figure 38). Also, black rocks on the streambed suggest the presence of manganese, which is naturally occurring in groundwater. Temperature measurements were never observed in excess of 23°C. Additionally, some of the macroinvertebrate taxa in the sample are known to prefer cool/coldwater, such as *Baetis brunneicolor* and *Baetis flavistriga*. Similar streams in the area, such as Stony Creek, Hay Creek, and Little Two River, had cool water fish that were not present in Hazel Creek, such as mottled sculpin, longnose dace, and burbot.

Thermal stress does not appear to be causing the fish impairment in Hazel Creek, but the cool temperatures and macroinvertebrate species suggest Hazel Creek is cooler than a typical warmwater stream, which means the resident aquatic life may have a lower threshold for thermal stress.

Figure 38. Dissolved oxygen (DO), temperature, and specific conductance data from Hazel Creek, 2016-2018. All samples were collected at the Great River Road crossing, MPCA EQuiS station S013-513.



-Longitudinal Connectivity

The culvert at Great River Rd. is a barrier to fish passage. It is a 100ft long corrugated metal culvert that lacks sufficient water depth and substrate to facilitate fish passage (Figure 39). The downstream side is perched (Figure 40), and has caused a large scour pool to form. Also, a small but forceful waterfall has been created on the upstream side from placement of a wooden board across the bottom of the inlet (Figure 41). According to MN DNR staff, the opening is undersized compared to the bankfull channel dimensions, and the crossing is causing bank erosion. The percent of migratory fish species sampled was mediocre-low, as compared to other sites (Table 32).

Figure 39. Inside the culvert under Great River Rd. Photo courtesy of MN DNR staff.

Figure 40. Outfall of Great River Rd. culvert. Photo taken 7/13/2018.

Figure 41. Inlet of Great River Rd. culvert. Photo taken 7/13/2018.
Wooden board laying across opening is creating a perched inlet and excessive velocity barrier to fish passage.

Table 32. Percent migratory fish metrics for biological station 16UM092 on Hazel Creek WID 07010201-569. All sites are FIBI Class 6, with an FIBI impairment threshold of 42.

Site	Date	FIBI Score	Migratory Taxa [%]	Migratory Taxa Percentile†
16UM092	7/7/2016	25	20.0	54.1
	6/14/2017	35	12.5	27.6

†Percentile is the standing of that Migratory Taxa value as compared to all other reportable, MPCA-collected fish samples to date (n=6,741).

-Streamflow

Streamflow in Hazel Creek has been documented to approach 0cfs (Figure 42). This is not surprising given the small drainage area, and may be an entirely natural phenomenon. However, the watershed has been extensively modified through ditching, possibly tiling, and center pivot irrigation, activities that could be exacerbating a naturally occurring low flow stressor. Pictures suggest the channel may have been over-widened due to streamflow alteration (Figure 43), but more precise measurements would be needed to determine.

Figure 42. Low water observed in 16UM092 on 7/7/2016.

Figure 43. Looking downstream from the upstream end of 16UM092. Picture taken 6/14/2017.

-Habitat

Three MSHAs were completed for Hazel Creek. The final score range is 61.5 – 68.7 out of 100 possible points. Those scores straddle the line of a Fair-Good habitat rating. There is abundant coarse substrate that is lightly embedded (25-50%). Three main stream facets were observed, primarily riffle, then run, and then pool making up the smallest proportion. Substrate in the riffles is cobble and gravel. Gravel and sand make up the runs and pools. Two of the three assessments marked sparse (25-50%) habitat cover, while the other one marked moderate (50-75%). It appears there is high quality habitat in Hazel Creek, but streamflow is a limiting factor as to whether or not the habitat is actually available for aquatic life to inhabit.

-Suspended Sediment

Very little sediment data exists for Hazel Creek (Table 33). It is unknown whether or not TSS is a stressor due to lack of data, but it is not suspected for several reasons:

(1) Coarse substrate was abundant and lightly embedded

(2) Siltation was marked “Normal” in all three MSHAs

(3) Using similar methods as Meador & Carlisle (2007), MPCA fish biologists calculated that the conditional probabilities that the stream would be impaired for TSS given the fish sampled were 24 and 15% chances, in 2016 and 2017, respectively.

Table 33. Total suspended solids (TSS), volatile solids (TSVS), and transparency (Secchi) tube measurements. Data collected near Great River Rd., MPCA EQUiS station S013-513.

Date	**Secchi tube** [cm]	**TSS** [mg/L]	**TSVS** [mg/L]
7/7/2016	>100	4	1.8
8/10/2016	>100		
6/14/2017	>100	2	
7/13/2018	>100		

-Nutrients

Nitrogen

Only five nutrient samples have been taken from Hazel Creek (Figure 44), two of which were greater than 8mg/L, suggesting that inorganic nitrogen may be a stressor. The NOX in Hazel Creek is considerably higher than what is found in low-agriculture landscapes, and higher than what has been measured in the MRS Watershed, second only to the Little Rock Lake subwatershed. Nearby streams, Little Two River and Stony Creek, also showed slightly elevated NOX, observed at 2.23 and 2.95mg/L, respectively, in 2016. It is possible that the soil type and/or geologic setting of the local area makes these streams especially sensitive to nitrate contamination.

Inorganic nitrogen moves into surface waters via groundwater and interflow. Depth to groundwater in the Hazel Creek watershed is 0-10 meters, and the soil type is predominantly sandy loam with areas of loam near the channel, according to MN DNR and NRCS’s SSURGO soils spatial data layer, respectively. The NOX in Hazel Creek is probably coming from what has leeched into the groundwater below the row crop fields in the surrounding area that overlies the same aquifer.

The macroinvertebrate community in Hazel Creek has a distribution of taxa richness that is highly skewed toward nitrate tolerance, having eighteen nitrate-tolerant taxa and only two that are intolerant (Table 34). However, the percentile ranks of where the community stands in terms of all other MIBI Class 5 samples suggests that the stream has more NOX-intolerant taxa than the median. Also, some sensitive taxa were observed, such as the caddisfly *Helicopsyche borealis*. More chemistry data are needed to be conclusive, but inorganic nitrogen is a suspected stressor.

Phosphorus

The TP data shows two readings in excess of the TP standard of 0.100mg/L, but no in-channel vegetation or excessive algae were observed in the stream. Excessive TP does not appear to be a stressor to the aquatic life.

Figure 44. Total phosphorus (TP), inorganic nitrogen (NOX), and ammonia-nitrogen (NH4) data from Hazel Creek. All samples were collected at the Great River Rd. road crossing, MPCA EQUiS station S013-513.

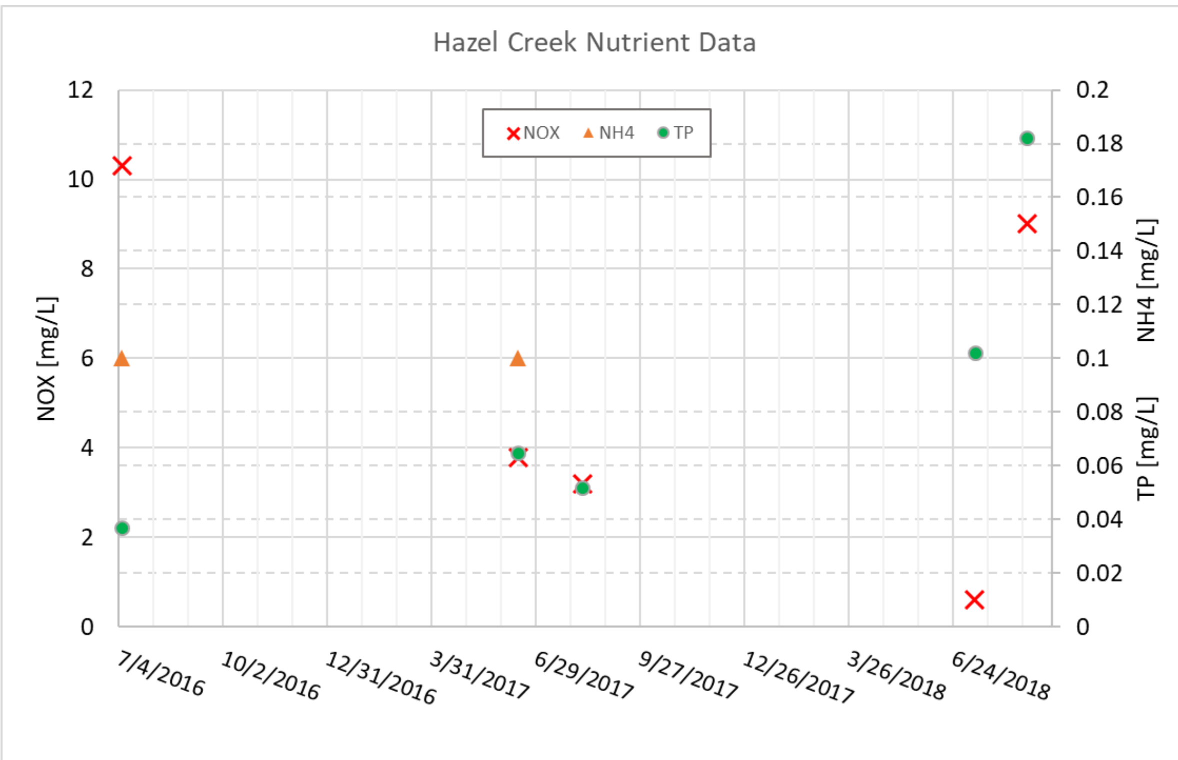


Table 34. Number of taxa ("taxa richness") in the macroinvertebrate samples at 16UM092 that are tolerant and intolerant to inorganic nitrogen.
Percentile analysis was performed using all other MIBI Class 5 samples collected by MPCA (n=1,046). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Stressor	Very Intolerant Taxa richness - Percentile	Intolerant Taxa richness - Percentile	Tolerant Taxa richness - Percentile	Very Tolerant Taxa richness - Percentile
Inorganic nitrogen (NOX)	1 – 74%	2 – 69%	18 – 49%	10 – 32%

-Dissolved Oxygen

To date, only six DO measurements have been taken at Hazel Creek (see Figure 38 in *Temperature* section); all were well above 5mg/L. Also, the cool temperatures observed in the stream are conducive to maintaining sufficient DO levels for aquatic life. Further, some sensitive macroinvertebrate species were sampled that are not low-DO tolerant, such as fifteen *Dicranota*, twelve *H. borealis*, ten *Protoptila,* one *Antocha* specimen.

The conditional probability that the stream would be impaired for DO given the fish community was 52% and 9% in 2016 and 2017, respectively. The sizeable discrepancy between the two probabilities is, in part, due to the addition of two sensitive species in the 2017 sample (longnose dace and smallmouth bass); one individual of each species was sampled. The 2016 sample was taken during extremely low flow conditions, but DO was 9.19mg/L, which is good. However, the ability of the conditional probability calculations to give a reliable signal is confounded by the effect of a longitudinal connectivity barrier on the fish community. Low dissolved oxygen is not a suspected stressor in WID -569.

WID Summary

Hazel Creek is impaired for aquatic life based on the failing FIBI scores. Longitudinal connectivity is the greatest stressor to the fish community in Hazel Creek, a result of the improperly installed culvert under Great River Rd. Lack of streamflow is also a stressor, but it is unclear whether or not the intermittent nature of the stream is due to anthropogenic activity. Nitrate toxicity is an inconclusive, though suspected, stressor. The MIBI scores are barely passing and the community is skewed toward nitrate-tolerant taxa.

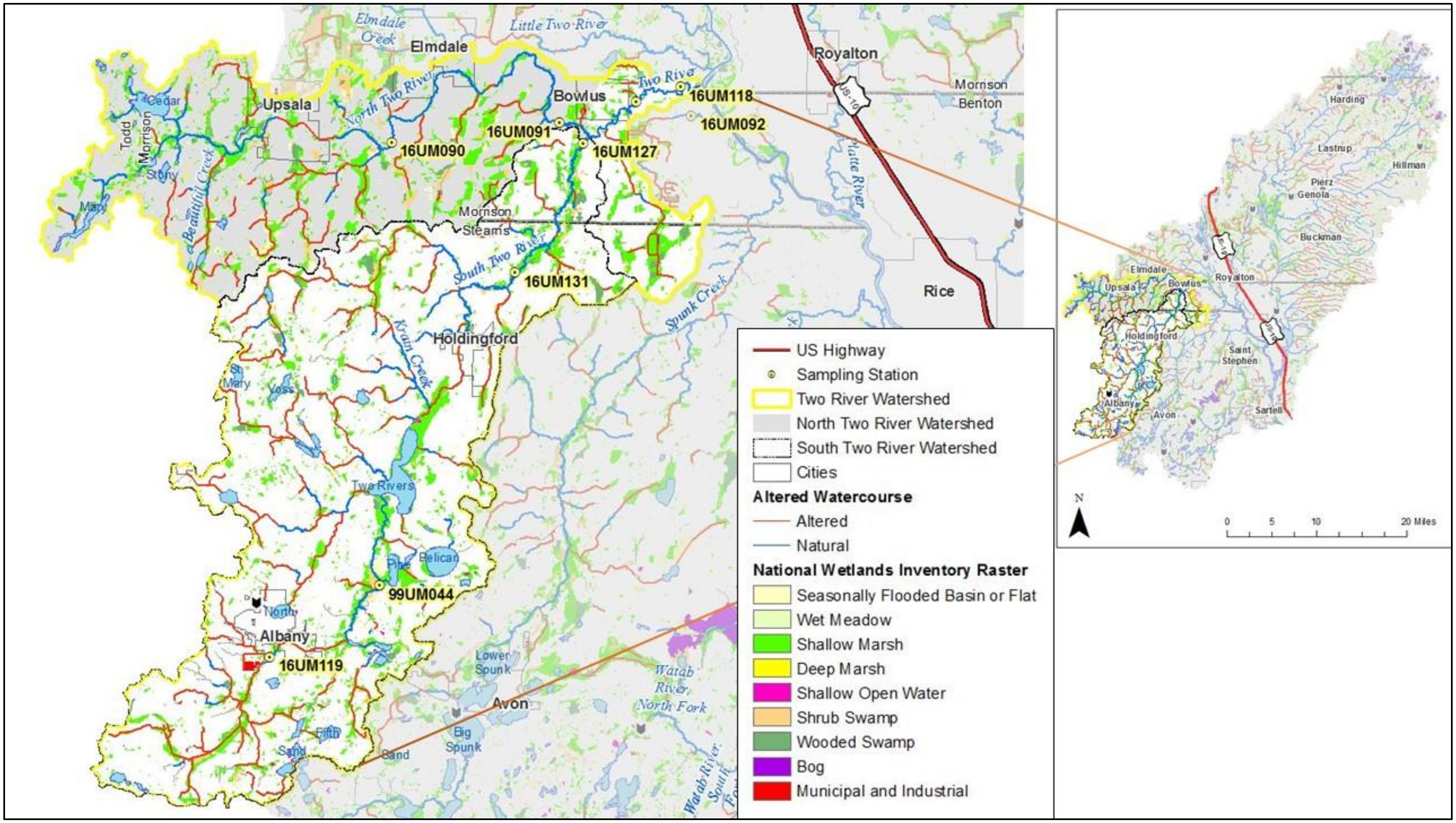
3.3. South Two River – WID 07010201-643

South Two River (WID -643) and North Two River (WID -524) come together near Bowlus, Minnesota to form Two River (WID -523) (Figure 45). Two River is approximately 5.58 stream-miles long, and outlets into the Mississippi River east of Bowlus. Biological samples from North Two River and Two River yielded higher IBI scores for both fish and macroinvertebrates than did South Two River. One station on the North Two, 16UM091, had an FIBI score of 67, very near the exceptional use threshold (68) for FIBI Class 6 – Northern Headwaters. That same site had an MIBI score of 69.9, which exceeds the exceptional use threshold (62) for MIBI Class 5 – Southern Streams Riffle/Run. Generally speaking, the North Two and Two Rivers are good quality water resources for aquatic life, while the South Two River is impaired for aquatic life. See the M&A Report, Figure 27, for a map of impairments in the South Two River watershed (MPCA 2019).

The upper section of South Two River, from the Albany, Minnesota area to Schwinghammer Lake, is WID -542. The headwaters of this WID are completely altered for agricultural and urban drainage. Fish and macroinvertebrates were sampled from 16UM119 on this headwater WID, but could not be assessed for aquatic life use because WID -542 is a Class 7 Limited Resource Value Water, so a formal assessment was not completed. However, all of the IBI scores were quite low. Stressor identification was minimally performed on this WID, and found that the WID suffers from many stressors, especially habitat degradation due to livestock access to the stream, and that it is similar to many other parts of the South Two River watershed.

The lower section of South Two River, from Holdingford to the confluence with Two River, is WID -643. The WID begins just downstream of Holdingford, where the river goes from a ditched state back to a natural channel. The WID is 12.73 miles long and primarily flows through agricultural land, both row crop fields and rangeland, though it maintains a healthy riparian buffer of mostly wetlands that is ≥200ft wide on both banks. The drainage area at the lowest biological sampling station, 16UM127, is 96.3 square miles. This WID was assessed as impaired for aquatic life. The remainder of this section discusses aquatic life stressors for this WID, which begins in Stearns County and crosses into Morrison between the two biological stations.

Figure 45. Map of the Two River Watershed and subwatersheds, with other relevant land features.
Note that WID -643 is the reach of South Two River that goes from Holdingford, Minnesota to the confluence with Two River, near Bowlus, Minnesota.



Biological Data

WID -643 is impaired for aquatic life due to nonsupport of the fish community. Both fish and macroinvertebrates were sampled in 2016. The FIBI score failed to meet the general use threshold for FIBI Class 5 – Northern Streams at both biological stations (Table 35). The macroinvertebrate communities are fully supporting their designated aquatic life use.

Conditional probabilities suggest that low DO is influencing the fish community at 16UM131 (Table 36). Also at 16UM131, low FIBI scores in the four metrics that relate to intolerant and sensitive taxa proportions were the lowest-scoring metrics of all (Table 37, see highlighted metrics). This suggests that the FIBI failed to meet the threshold primarily due to a lack of sensitive species overall, though other metrics also scored poorly.

At 16UM127, the fish sample did not indicate that the stream was likely to fail TSS or DO standards (Table 36). The lowest FIBI scores were in the following three metrics: DarterSculpSucTxPct, Insect-TolTxPct, and IntolerantPct. Again, this suggests a lack of intolerant taxa and individuals, as well as taxa that require coarse substrate (darters, sculpins, suckers). It seems odd that site 16UM131, which features less coarse substrate, had a better score than 16UM127 in the DarterSculpSucTxPct metric, but this appears to be a result of the low species richness at 16UM131, because the two tolerant darter and sucker species present made up a larger percent of the taxa list overall.

Table 35. IBI data from 16UM131 and 16UM127 on South Two River (WID 07010201-643).

		Fish IBI			Macroinvertebrate IBI		
Station	**Date**	**Class†**	**Impairment Threshold**	**Score**	**Class†**	**Impairment Threshold**	**Score**
16UM131	6/28/2016	5	47	38	-	-	-
	8/18/2016	-	-	-	6	43	57.4
16UM127	6/28/2016	5	47	43	-	-	-
	8/16/2016	-	-	-	5	37	48.3

†FIBI Class: (5) Northern Streams
MIBI Class: (5) Southern Streams – Riffle/Run (6) Southern Forest Streams – Glide/Pool

Table 36. Conditional probabilities (percent chance) that the stream would meet water quality standards for total suspended solids (TSS) and dissolved oxygen (DO) given the fish communities sampled.

Station	Date	**TSS** [%]	**DO** [%]
16UM131	6/28/16	67	26
16UM127	6/28/16	77	67

Table 37. Fish IBI metric scores for biological stations on WID -643.
Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown. Highlighted are the poor FIBI scores related to intolerant and sensitive taxa proportions.

	16UM131		16UM127	
FIBI Class 5 Metric	**Raw metric result**	**Re-scaled IBI score**	**Raw metric result**	**Re-scaled IBI score**
DarterSculpSucTxPct *Percent of darter, sculpin, and sucker taxa*	9.09%	2.81	4.76%	1.35
FishDELTPct *Percent of individuals with DELT anomalies*	0%	0	0%	0
DetPct *Percent of detritivore individuals*	11.43%	7.19	15.20%	6.50
DomTwoPct *Combined relative abundance of the two most abundant taxa*	48.57%	6.43	33.70%	9.09
Insect-TolTxPct *Percent of insectivorous taxa, excl tolerant species*	18.18%	0	28.57%	2
General *Number of generalist taxa*	5	4.62	6	3.03
IntolerantPct *Percent of intolerant individuals*	0%	0	10.79%	2.34
MA>3-TolPct *Percent of late-maturing individuals, excl tolerant species*	1.43%	0.38	12.56%	3.35
SensitiveTxPct *Percent of sensitive taxa*	0%	0	23.81%	4.92
SLithoPct *Percent of individuals that are simple lithophilic spawners*	20%	2.55	30.40%	3.99
SSpnTxPct *Percent of taxa that are serial spawners*	9.09%	8.24	28.57%	2.44
Vtol *Number of very tolerant taxa*	3	5.45	4	3.64
Total (FIBI Score)	--	37.67	--	42.65

Stressor Data

-Temperature

Between May of 2016 and August of 2018, 23 temperature measurements were made at 16UM127, eight of which were at the warmest time of day in the summer. The highest temperature recorded was 24.18°C, which is not stressfully warm for aquatic life. Neither of the biological stations are located downstream of urban development or other land uses that might contribute thermal pollution.

Further, almost the entire length of the WID has extensive riparian wetlands, and seems well connected with groundwater. Warm stream temperature is not a stressor in WID -643.

-Longitudinal Connectivity

Connectivity barriers that might prevent fish in North Two or Two Rivers (where FIBI scores were acceptable) from accessing 16UM127 and 16UM131 in WID -643 were investigated via aerial imagery and on the ground. None were found. Longitudinal connectivity is not the cause of the fish impairment on WID -643.

Of note, however, the culverts at the crossing of Great River Rd. and Two River appear to be a barrier at high flows. On 7/13/18, the author observed that the middle (thalweg) culvert was a velocity barrier, and the two offset culverts were perched (Figure 46). At that time, three of the three culverts were not passable. However, the upstream biological station, 16UM118, did yield a passing FIBI score on 6/29/2016. The middle culvert appears to only be a velocity barrier at high flows. It would be prudent to check this culvert as time goes on, in case the force of water at the outfall causes scouring below the culvert elevation; it could eventually become perched and pose a barrier to fish.

Figure 46. The set of three culverts under Great River Rd. at the Two River crossing, on downstream side (7/13/18).
(A) Left culvert (B) Middle (thalweg) culvert (C) Right culvert

-Streamflow

With WID -643 being surrounded by wetlands, a steady baseflow is likely maintained throughout the year. High specific conductance readings (>500µS/cm) at both biological stations suggest a strong groundwater connection. This particular reach of South Two River does not appear to be heavily affected by ditching, although that is occurring further upstream in the watershed.

Streamflow alteration is an inconclusive stressor on WID -643. There is no evidence to suggest that excessively high, low, or flashy flows are stressing aquatic life. However, a geomorphic analysis, discussed in the following *Habitat* section, shows that the stream channel is over-widened (often a symptom of flow alteration) and is contributing to a habitat stressor.

-Habitat

Minnesota DNR Region 3 Clean Water staff conducted geomorphic analyses on South Two River near the biological stations. Below is a synopsis of their findings related to WID -643:

16UM127

"The outlet of South Two River is stable with some erosion, but maintains access to the floodplain. The reach has poor riffle habitat due to fine sediments filling the interstitial spaces. Some deep pools and undercut bank habitats are present. Overall, some fine sediments are depositing on the streambed, but the stream is maintaining pools. Stream bank erosion occurs below the road crossing, where cattle have [had] access to the stream and reduced bank stability. This stream reach is relatively stable overall, except where cattle access the stream.

The D50 is a measure of average particle size and is used help determine the stability of the streambed. The stream riffle D50 is 17.91mm, D84 is 50.42mm, and D100 is 511.99mm, categorized as "coarse gravel," which is typical for C stream types. This reach has a bimodal particle distribution, with some large (boulder) particles, but also very small (silt) particles. The reach is over-widened, causing fine particles to settle out on the streambed. However, the stream has access to the floodplain and is therefore likely stable."

16UM131

"This reach is classified as an E type channel, where characteristic undercut banks and in-channel vegetation provide habitat for aquatic organisms (e.g. Figure 47). The channel is narrow and deep, with minimal observed erosion."

Figure 47. Photo taken from 16UM131 on 6/27/2017, depicting in-channel vegetation and undercut banks (not visible below waterline), also showing stable banks.

Total MSHA scores at both biological stations were in the "Fair" (45-65) category, with 16UM127 having better scores than 16UM131 (Table 38). Details of the MSHA are discussed by site in the following paragraphs.

16UM127

At 16UM127, embeddedness was scored as "Moderate" (25-50%) in June, with "Moderate" (more than normal) siltation. Then, in August, embeddedness was scored as "Light" (25-50%) with "Normal" siltation. Overall, the Substrate section scores were better in August, with gravel and sand observed in the run, but silt and sand observed in June. Though the stream facet composition (percent riffle, etc.) differed some between the MSHAs in June and August, both noted sand and silt in the pools and a cobble-gravel riffle (5-10%), with the rest being a run (50-80%). The Substrate scores of the MSHAs seem to corroborate the findings of the MN DNR geomorphic analysis, that fine sediments are settling onto and embedding the coarse substrate at 16UM127.

High flow events, such as the extreme rain event that occurred in July 2016, will scour away deposited fine sediment for a time, a possible explanation for the cleaner substrate observed in August. Further study, such as a Bank Assessment for Non-point Source Consequences of Sediment (BANCS) analysis, is needed to determine if the sediment transport equilibrium of this area of South Two River has been anthropogenically altered and is degrading habitat, and if so, where the sediment is coming from (in-channel or upland sources).

Besides coarse substrate, other habitat types observed at 16UM127 were undercut banks, overhanging vegetation, deep pools, woody debris, boulders, rootwads, shallows, and macrophytes, with a total cover amount of "Moderate" (25-50%) on both MSHAs. While the diversity of habitat types observed is quite healthy, the cover amount is possibly a stressor. A more precise estimate of the cover amount, rather than a range of 25-50%, would be helpful in determining if lack of habitat cover is a stressor at 16UM127.

Table 38. Minnesota Stream Habitat Assessment (MSHA) scores at biological stations on WID 07010201-643. The maximum possible MSHA score is 100, indicating excellent habitat.

Station	Date	MSHA Score
16UM131	6/28/16	45.5
	8/18/16	53
16UM127	6/28/16	59.45
	8/9/16	65.2

Three of the FIBI metrics that relate to habitat were analyzed further (Table 39). If lack of coarse substrate habitat were a stressor to the fish community, low metric values would be expected in DarterSculpSucTxPct and SLithoPct. A high raw metric value (and low IBI score) could be expected in SSpnTxPct, as serial-spawning taxa might make up a greater proportion of the community in the absence of lithophilic spawners. The fish community sampled at 16UM127 had a very low percent (4.76%) of darter, sculpin, and sucker taxa, with only 7% of all other FIBI Class 5 samples scoring lower than that. The score for percent of lithophilic spawning individuals was poor/mediocre. The percent of serial spawners was relatively high, with only 23% of samples from similar streams yielding a greater percent. The FIBI data support the suspicion that degraded quality of, or quantity of, coarse substrate habitat is a stressor at 16UM127.

Table 39. Adapted version of FIBI metrics table (Table 35), with selected habitat metrics.
Percentile analysis was performed using all other FIBI Class 5 samples since the year 2000 (n=866). A high percentile in the first two metrics (green) is good, whereas a high percentile in the last metric (red) is not good for the FIBI score. Where the percentile is above the median (>50%) the cell is highlighted green or red.

FIBI Class 5 Metric	16UM131			16UM127		
	Raw metric result	**Re-scaled IBI score**	**Percentile**	**Raw metric result**	**Re-scaled IBI score**	**Percentile**
DarterSculpSucTxPct *Percent of darter, sculpin, and sucker taxa*	9.09%	2.81	17	4.76%	1.35	7
SLithoPct *Percent of individuals that are simple lithophilic spawners*	20%	2.55	25	30.40%	3.99	38
SSpnTxPct *Percent of taxa that are serial spawners*	9.09%	8.24	13	28.57%	2.44	77

Although WID -643 was assessed as fully supporting of macroinvertebrates, the tolerance richness was analyzed for additional information about habitat quality (Table 40). The 16UM131 taxa richness seems skewed toward the tolerant side for embedded substrate and TSS. This signifies that sediment may be a problem. The 16UM127 taxa richness data do not show a strong signal of disturbance to any of the stressors listed, which is to be expected from a healthy community. However, the TSS-tolerance richness is skewed toward the tolerant side, while the percentile rankings also show that this site has more TSS-intolerant taxa than most others in its class, making it difficult to discern if TSS is actually stressing the macroinvertebrates or not without more data. Taken together, the macroinvertebrate tolerance richness is giving a mild signal of habitat degradation and/or a TSS stressor in WID -643, but additional evidence is needed to conclusively determine.

Table 40. Number of taxa ("taxa richness") in the macroinvertebrate samples on WID -643 that are tolerant and intolerant to specific stressors.
Percentile analysis was performed using all other MIBI Class 6 (n=683) and Class 5 (n=1,046) samples collected by MPCA for 16UM131 and 16UM127, respectively. A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

16UM131				
Stressor	**Very Intolerant** Taxa richness - Percentile	**Intolerant** Taxa richness - Percentile	**Tolerant** Taxa richness - Percentile	**Very Tolerant** Taxa richness - Percentile
Low DO	2 – 55%	4 – 61%	7 – 46%	3 – 53%
Depth of Fines	0 – 0%	3 – 67%	8 – 46%	3 – 28%
Embedded Substrate	0 – 0%	0 – 0%	11 – 48%	7 – 42%
Total Suspended Solids (TSS)	0 – 0%	2 – 73%	10 – 48%	5 – 63%
Inorganic nitrogen (NOX)	1 – 72%	4 – 84%	17 – 46%	9 – 28%
Total phosphorus (TP)	0 – 0%	2 – 60%	9 – 33%	4 – 26%
16UM127				
Low DO	4 – 55%	8 – 66%	2 – 13%	1 – 32%
Depth of Fines	5 – 86%	11 – 91%	4 – 46%	3 – 74%
Embedded Substrate	0 – 0%	5 – 73%	5 – 19%	3 – 12%
Total Suspended Solids (TSS)	2 – 91%	6 – 93%	15 – 87%	9 – 93%
Inorganic nitrogen (NOX)	3 – 97%	6 – 96%	14 – 22%	8 – 16%
Total phosphorus (TP)	0 – 0%	4 – 76%	7 – 33%	3 – 35%

16UM131

At 16UM131, very little coarse substrate was observed during both habitat assessments. Sand and silt were the dominant substrate types. In June, cobble and gravel were observed in <5% of the reach, and it was "Lightly" (25-50%) embedded. In August, only gravel was observed in <5% of the reach, and it was "Moderately" (50-75%) embedded. This seasonal pattern of embeddedness is backwards of what was observed downstream at 16UM127. One consistency, however, is that siltation was "Moderate" in June and "Normal" in August. The stream facet composition was 60-85% run, with pool making up the remainder. Depth variability was mediocre, with the greatest depth being 2-4 times the shallowest depth. Observed habitat cover types were: undercut banks, overhanging vegetation, deep pools, woody debris, rootwads, backwaters, shallows, and macrophytes. The amount of cover was "Extensive" (>75%). Overall, the surrounding land use, fine substrate, and moderate depth variability observed at 16UM131 are the main reasons for its "Fair" MSHA scores.

The three FIBI Class 6 metrics related to habitat (Table 39) show that: 1) 83% of other samples had a greater proportion of darter, sculpin, and sucker taxa 2) 75% of other samples had a greater proportion of lithophilic spawning individuals, but 3) 87% of other samples had a greater proportion of serial spawning taxa (a disturbance-tolerant method of reproduction). In this context, the first two of the three aforementioned FIBI metrics suggest that lack of coarse substrate is contributing to the fish impairment.

The MN DNR's geomorphic analysis does not suggest that the channel is unstable here. However, the channel at the sampling reach was altered sometime in the last 54 years to install the crossing with 165th Ave. and may still be reforming its sinuosity and deep pools (Figure 48).

Figure 48. Historic aerial photos of the crossing of South Two River and 165th Ave. in Stearns County, Minnesota. Flow direction is northeast (bottom-left to top-right in pictures).
Upper: Photo taken in 1965. Photo from MN DNR's historical landview dataset compilation.
Lower: Imagery taken in 1991, accessed via Google Earth.

In conclusion, lack of habitat is a stressor to the fish community in WID -643. The downstream site, 16UM127, has a steeper gradient and correspondingly coarser substrate. However, the FIBI metrics, geomorphic analysis, and MSHA data suggest that the quality of riffle habitat is being degraded by embeddedness, likely a consequence of channel over-widening. Lack of cover amount may also be a stressor. At the upstream site, 16UM131, where the channel has a lower gradient, coarse substrate is virtually absent and depth variability is poor. The macroinvertebrate community may also be experiencing habitat-related stress at 16UM131, evidenced by the tolerance richness metrics being slightly skewed toward sediment-tolerant taxa. The cause of the poor habitat on WID -643 is not known. One possibility is that streamflow alteration caused the over-widening of the channel at 16UM127, which is ultimately causing fine sediment to settle onto the streambed. Also, the historic channel alteration at 16UM131 may be having some legacy impacts on habitat in the area, although the channel appears stable.

-Suspended Sediment

On WID -643, TSS data exists primarily for 16UM127 (Table 41). There is some older data at S000-424 (located between the two biological stations on the county line, 450th St.) and one measurement from 16UM131. None of those measurements exceed the standard. On July 12, 2016, an intense precipitation event occurred (3-5in rainfall), and TSS was measured at 30mg/L at 16UM127. If excessive TSS was causing the aquatic life impairment, the measurement on a day of such extreme rainfall would very likely have far exceeded the TSS standard of 30mg/L. The TSS sample of 30mg/L was collected at 14:15 that day, which is after the event's water level peak (Figure 49. The in-stream TSS response to storm events usually shows the greatest concentration before water levels peak, so the sample is presumed to have been taken after the TSS-peak, suggesting the in-stream concentration may have exceeded the standard for a relatively short period of time. The July 12, 2016 storm was an uncommon event and the associated TSS concentration in exceedance of the standard is presumed to also be an uncommon event.

At 16UM131, there is a considerable amount of transparency data (Figure 50). The median transparency in 2003-2011 is considerably lower than the 2012-2016 median. The reason for this is currently unknown; it may or may not be a result of the difference in Secchi tube length. Only one TSS sample was available for this site, which was 2mg/L. At 16UM127, when transparency was 47cm, TSS was at the 30mg/L standard on 7/12/2016. Using that relationship to infer TSS concentrations from the transparency data at 16UM131, it is possible that for 104 of the 462 instances transparency was measured since 2003, TSS exceeded the 30mg/L standard. This inference is in no way a substitute for TSS/VSS measurements, and could be way off, but it does suggest that without more data, suspended sediment cannot be discounted as a stressor to aquatic life at 16UM131. And as previously mentioned, the macroinvertebrate tolerance richness is slightly skewed toward TSS-tolerance at 16UM131. Based on the fish samples, the probability that the stream would meet the regional TSS standard is 67% at 16UM131, which is mediocre/good. The probability is better at 16UM127, with a 77% likelihood (see Table 36).

In summary, there is enough evidence to suggest that suspended sediment may be a stressor to aquatic life in the upper part of WID -643, where 16UM131 is located, but not enough to confirm or deny, therefore it is inconclusive. At this time, suspended sediment is less suspected as a stressor in the lower part of the WID, near 16UM127, although bedded sediment is a stressor and is discussed as embeddedness in the *Habitat* section.

Table 41. Total suspended solids (TSS), volatile suspended solids (VSS), and transparency (Secchi tube) data from three locations on WID -643, listed in an up- to downstream order.
Except where otherwise noted, the Secchi tube used was 100cm long.

Location (Years)	TSS & VSS [mg/L]				Secchi tube [cm]	
	Range		Median		Range	Median
	TSS	VSS	TSS	VSS		
16UM131 (2003-2011)	--	--	--	--	>60* – 5 *n=273*	52
16UM131 (2012-2016)	2 *n=1*	--	--	--	>100 – 15 *n=189*	>100
S000-424 (2009-2010)	1-21 *n=20*	--	2 *n=1*	--	>120† – 72 *n=20*	109
16UM127 (2016-2018)	2-30 *n=13*	1.6-7.6 *n=13*	5.6	2.8	>100 – 47 *n=22*	>100

* Using 60cm tube
†Using 120cm tube

Figure 49. Water level and precipitation measured at a gage on the Two River near Bowlus, Minnesota. Data are from the MN DNR's Cooperative Stream Gaging (CSG) website (site ID 15067002). The red dot indicates the date-time of 7/12/2016 at 14:15, when the TSS sample was taken at 16UM127, resulting in 30mg/L.

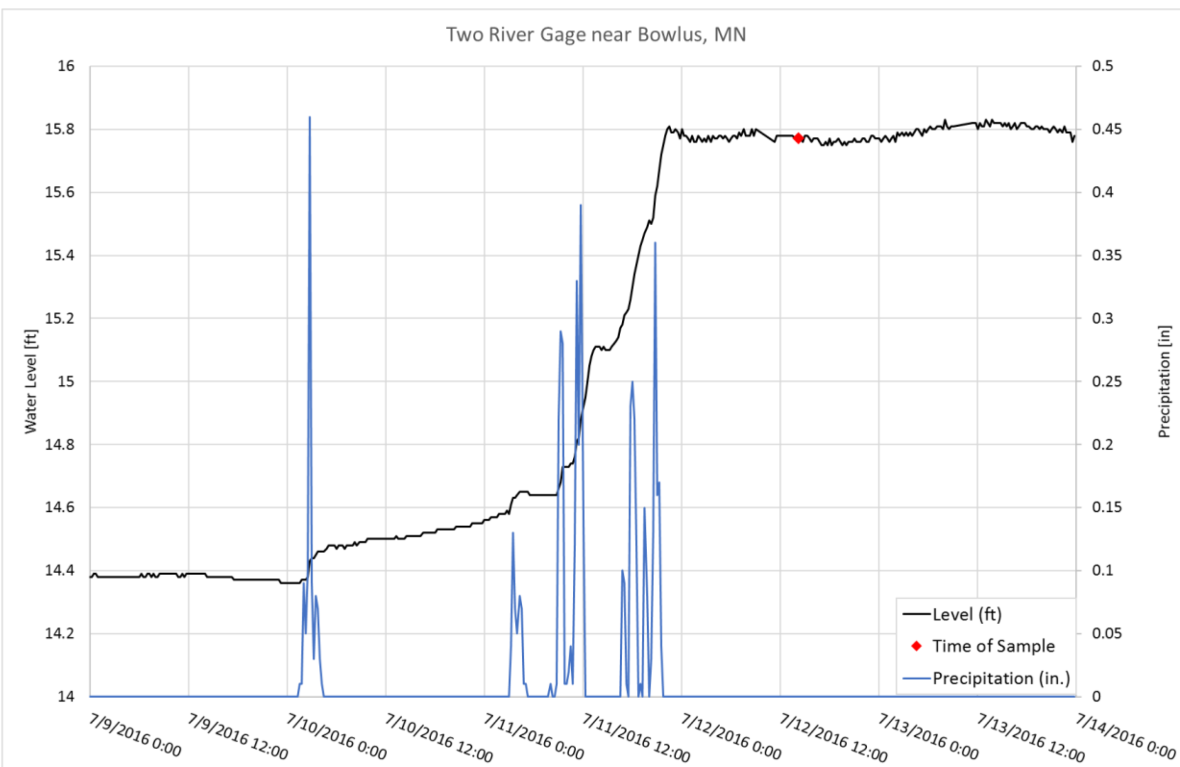
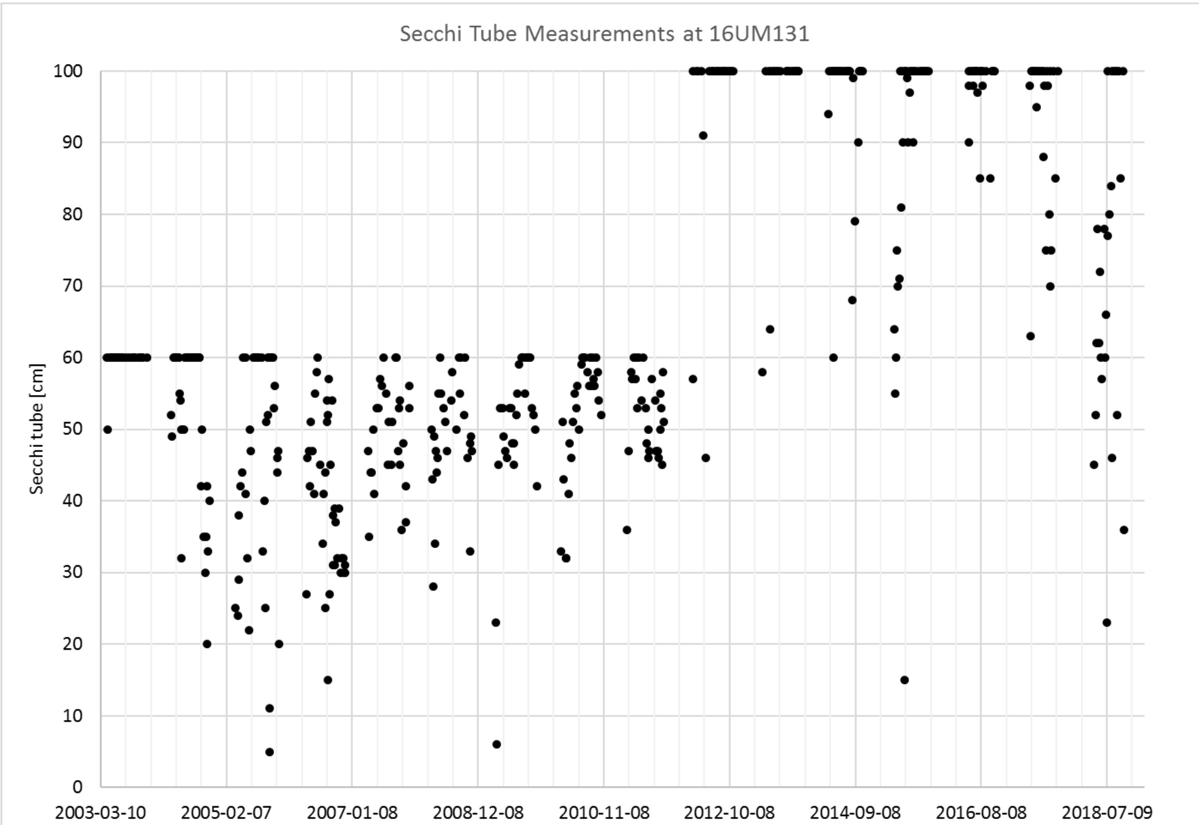


Figure 50. Transparency as measured with a Secchi tube at 16UM131.
In 2003-2011, a 60cm tube was used, therefore 60cm is the maximum possible transparency measurement; and in 2012-2018, a 100cm tube was used.



-Nutrients

Nitrogen

Inorganic nitrogen concentrations were mostly <1.0mg/L, and the macroinvertebrate tolerance richness metrics do show that the community is tolerant of NOX at either location. Thus, it is not a suspected stressor.

Phosphorus

WID -643 has eight locations with chemistry data in MPCA's EQUiS database. Some of the data is from as early as 1977 and 1987, and should be interpreted with caution. However, the sampling activity of this reach suggests the possibility that something in the watershed, perhaps a point source, was a concern. The constituents measured in 1977 and 1987 were: temperature, BOD, Chl-a, DO, TKN, NOX, TP, TSS, turbidity, and fecal coliform. The samples were reportedly collected for an "MPCA Intensive Survey 7727713" in 1977, and "MPCA Intensive Survey 872701" in 1987. In 2009-2010, data was collected by the Stearns County Lakes Monitoring Program. In 2016-2018, data was collected by various MPCA staff for the Mississippi River-Sartell IWM and WRAPS projects.

Total phosphorus data from all locations on WID -643 are elevated. Samples are from years 1977, 1987, 2009-2010, and 2016-2018, during May-September. Of 43 total samples, only thirteen were below the regional standard of 0.100mg/L. The Chl-a data shows that at S000-424, the highest concentration was 14µg/L on 6/11/2009; all other 2009 samples were $\leq$9µg/L. The Chl-a standard for the area is 18µg/L, with an associated exceedance of the TP standard. There are no contemporary Chl-a data for 16UM131 or 16UM127. Based on these data, it is unclear if the high TP is causing eutrophication, which could stress aquatic life. Benthic algae was estimated as "Sparse" or not observed in all four MSHAs and the stream is only lightly shaded in many areas, so sunlight for algal growth is available. Further information will be discussed in the following *Dissolved Oxygen* section.

-Dissolved Oxygen

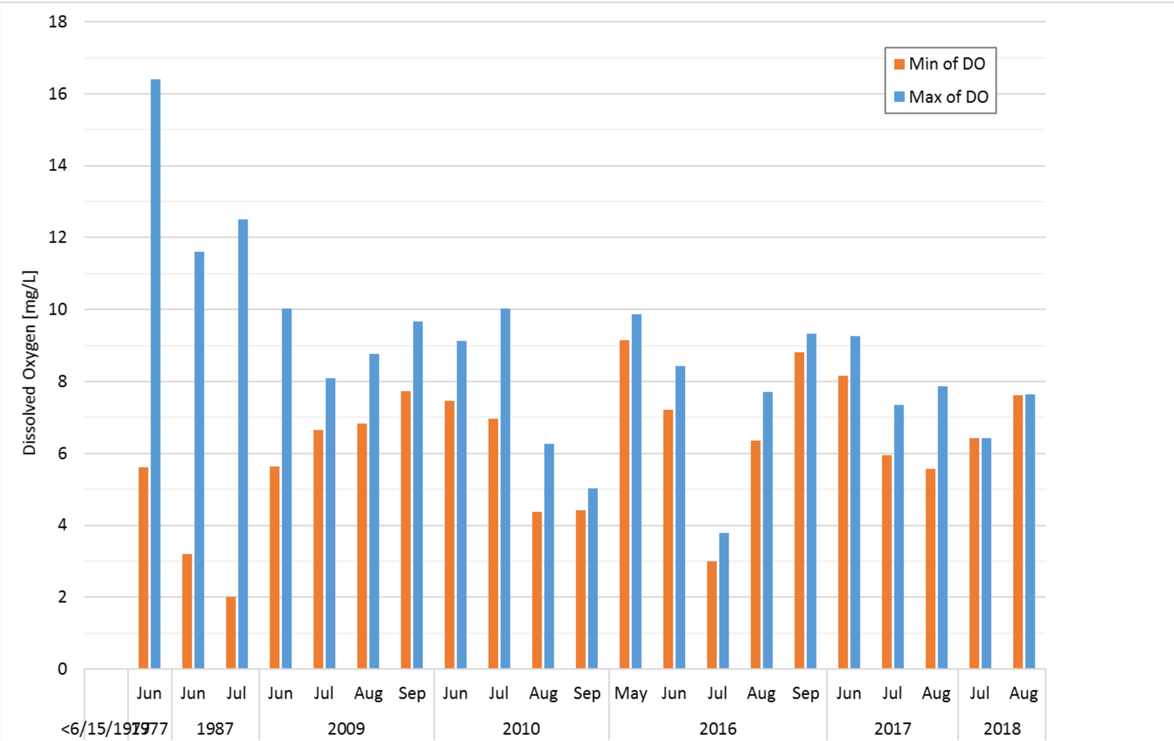
Sixty-two instantaneous DO data points were available on WID -643, 22 of those were taken at or before 10:00am (Table 42). Though pre-9:00am is when DO is expected to be the lowest, measurements taken between 9:00-10:00AM still provide useful information. No continuous DO data are available. The rest of the data are summarized in Figure 51. The available data do not clearly indicate if low DO is a stressor in the WID, though the earliest morning measurements suggest it is. These measurements, between 5:30 - 6:15 AM are from the time of day when DO is lowest (around sunrise). It would be helpful to have more measurements taken before 9:00am or continuously measured data.

Unfortunately, none of the DO measurements at 16UM131 were taken before 9:00am. The conditional probability that the stream in this location would meet the state DO standard is poor (26%), based on the fish community (see Table 36). However, the macroinvertebrates do not show that low DO is an influential stressor, if it is occurring (see Table 40). Dissolved oxygen at the time of the fish sample was 10.81mg/L, which was 132% saturation at 3:36PM. Total phosphorus that day was 0.119mg/L. This information taken together, suggests that primary productivity in the channel is controlling the DO levels and moderate eutrophication is occurring, but more data are needed to determine if it is a stressor to the fish in WID -643.

Table 42. Instantaneous dissolved oxygen (DO) measurements taken pre-10:00AM on WID -643. Data from 1977 and 1987 are shown as additional information, but should be interpreted with caution, as the accuracy of equipment used is unknown.

Date	**Time**	**DO** [mg/L]	**Location**
6/16/1977	9:05 AM	5.6	16UM127
6/29/2016	9:45 AM	7.97	16UM127
8/29/2016	9:45 AM	7.18	16UM127
9/14/2016	8:45 AM	9.33	16UM127
6/24/1987	6:05 AM	4.0	16UM131
7/30/1987	6:15 AM	2.0	16UM131
6/16/1977	9:50 AM	6.2	S000-424
6/24/1987	5:40 AM	3.2	S000-424
7/30/1987	5:50 AM	2.6	S000-424
6/24/2009	9:00 AM	5.63	S000-424
7/7/2009	9:55 AM	6.64	S000-424
7/31/2009	9:15 AM	7.52	S000-424
8/10/2009	9:45 AM	6.82	S000-424
8/13/2009	10:00 AM	6.89	S000-424
8/27/2009	9:25 AM	7.62	S000-424
8/31/2009	9:35 AM	8.77	S000-424
9/15/2009	9:30 AM	7.73	S000-424
9/29/2009	9:30 AM	9.67	S000-424
6/21/2010	10:00 AM	7.46	S000-424
7/20/2010	9:15 AM	6.96	S000-424
8/2/2010	9:15 AM	6.26	S000-424
9/29/2010	9:40 AM	5.02	S000-424

Figure 51. Minimum and maximum dissolved oxygen (DO) concentrations measured in WID -643, summarized by month and year. Data from 1977 and 1987 are shown as additional information, but should be interpreted with caution, as the accuracy of equipment used is unknown.



WID Summary

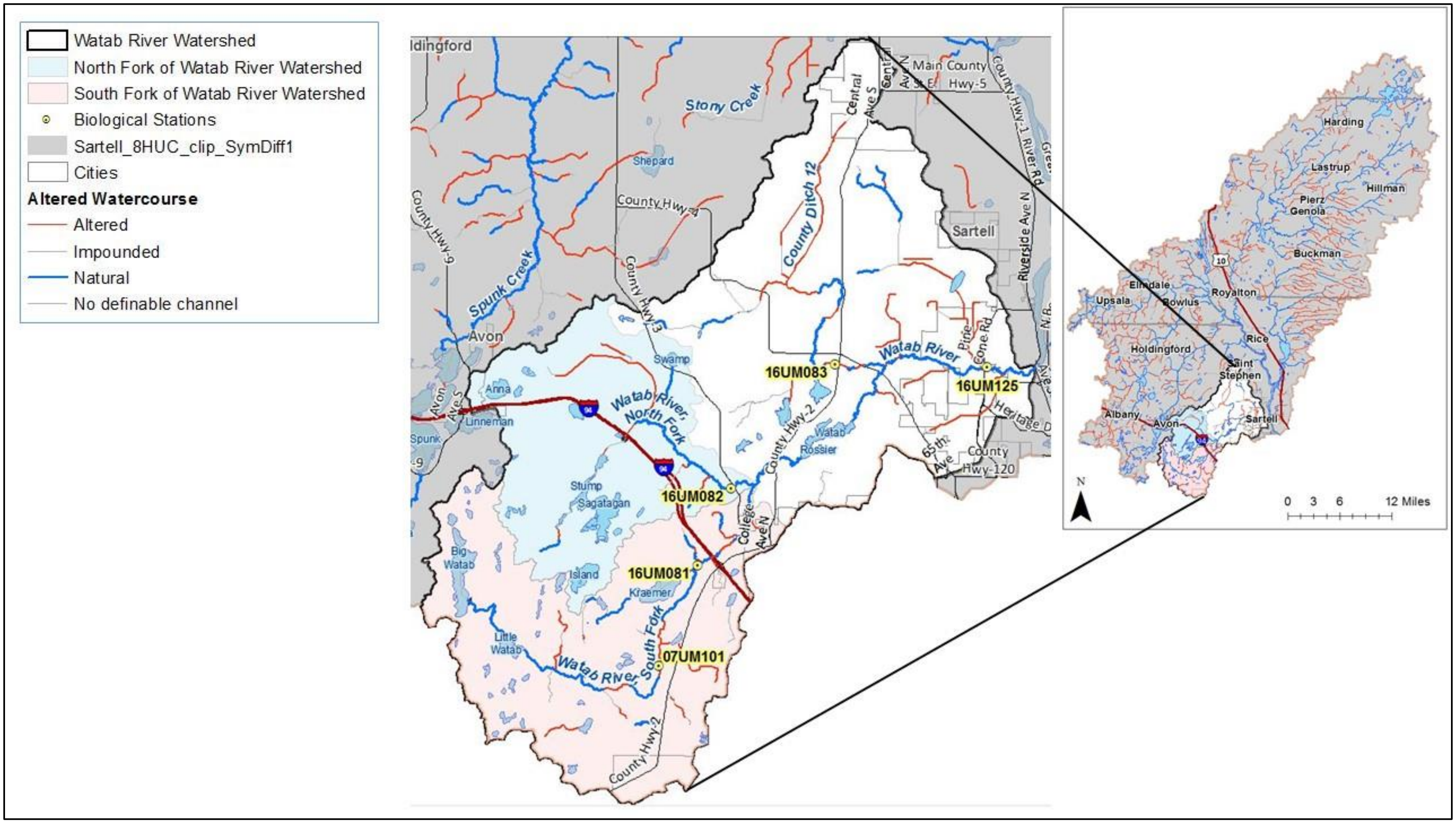
The most likely stressor of the fish community in WID -643 is a lack of habitat complexity and quality coarse substrate. At the upstream site, 16UM131, there is virtually no coarse substrate, moderate habitat complexity, and a historic channel modification. At the downstream site, 16UM127, the geomorphic analysis showed that the available coarse substrate habitat is being degraded by embeddedness due to channel over-widening. Also, there is only a moderate (25-50%) amount of habitat cover. It is unclear if the poor habitat at either site is a direct result of anthropogenic activity or not. Four stressors were inconclusive: eutrophication, low DO, suspended sediment, and streamflow alteration.

3.4. Watab River Watershed

The Watab River watershed is in the southern part of the MRS Watershed (Figure 52). The Watab River begins at the convergence of North Fork of the Watab River (WID -529) and South Fork of the Watab River (WID -554). The Watab River mainstem (WIDs -527 and -528) then flows east, through wetlands, agricultural land, lakes, and urban areas, until it reaches the Mississippi River in Sartell, Minnesota. Generally speaking, the lakes in the watershed are deep; most have acceptable water chemistry and healthy fish populations. Some have overwintering habitat.

Major tributaries to the Watab are the aforementioned North and South Forks of the river, as well as Stearns County Ditches 12, 13, and 16. The CD13 discussed in this report goes from Bakers Lake to the Watab River in Sartell, not be confused with CD13 located near Holdingford. All three of the county ditches are impaired for aquatic recreation due to excessive bacteria, and two are impaired for aquatic life for not meeting DO state standards. They are mentioned in section *3.4.2. Watab River – WID 07010201-528*. For a map of all current surface water impairments in the Watab River watershed, see the M&A Report, Figure 28 (MPCA 2019). The remainder of this section discusses stressors to aquatic life for WIDs -528 and -554.

Figure 52. Map of the Watab River watershed and subwatersheds.



3.4.1. Watab River, South Fork – WID 07010201-554

The South Fork of the Watab River begins at Big Watab Lake and winds its way through primarily forest and wetlands in the headwaters, then agricultural areas where part of the river was ditched for drainage. From there, it flows through a sizeable wetland and meets up with the North Fork of the Watab River, northwest of St. Joseph. WID -554 is 7.64 miles long; it begins at the outlet of Little Watab Lake and ends with the confluence of the North Fork of the Watab River.

Biological Data

This WID is impaired for aquatic life due to nonsupport of the fish community. Two biological stations were sampled in 2016 for both fish and macroinvertebrates (Table 43). The FIBI scores do not meet the general use impairment threshold for FIBI Class 6 – Northern Headwaters. Both sites generally lack specialist and intolerant species of fish, and have low numbers of simple lithophilic spawners (Table 44). There was a notable decline in fish species richness at site 07UM101 as compared to a 2007 sample. In 2007, MPCA biologists sampled fifteen fish species, but only eight in 2016 (Table 45).

Table 43. IBI data from two sites on South Fork of the Watab River (WID 07010201-554).

		Fish IBI			Macroinvertebrate IBI		
Station	**Date**	**F-IBI Class (Use)**	**F-IBI impairment threshold**	**F-IBI score**	**M-IBI Class (Use)**	**M-IBI impairment threshold**	**M-IBI score**
07UM101	6/18/2007	6	42	39.9	-	-	-
	8/8/2016	-	-	-	5	37	52
	8/16/2016	6	42	28	-	-	-
16UM081	6/30/2016	6	42	30	-	-	-
	8/18/2016	-	-	-	6	43	48

Table 44. Fish IBI metric scores from biological stations on WID -554.
Some raw metric values are mathematically transformed to calculate the IBI score. Both the raw and transformed metric values are shown in this table, where the top number is the transformed, 0-10 IBI value, and the bottom number is the raw metric value. Highlighted cells indicate the lowest scoring metrics.

	07UM101		16UM081	
FIBI Class 6 Metric	**Raw metric result**	**Re-scaled IBI score**	**Raw metric result**	**Re-scaled IBI score**
DarterSculp *Number of darter and sculpin species*	2	10	1	5
FishDELTPct *Percent of individuals with DELT anomalies*	0%	0	0%	0
Hdw-Tol *Number of headwater specialist taxa, excl. tolerant species*	0	0	0	0
InsectCypPct *Percent of insectivorous cyprinid individuals*	0%	0	0%	0
Insect-TolTxPct *Percent of insectivorous taxa, excl. tolerant species*	25%	5.83	40%	9.33
Minnows-TolPct *Percent of cyprinid individuals, excl. tolerant species*	0%	0	0%	0
NumPerMeter-Tolerant *Number of fish per meter, excl. tolerant species*	0.35 fish/m	1.94	0.13 fish/m	0.73
PioneerTxPct *Percent of pioneer species*	37.5%	0.72	30%	3.25
Sensitive *Number of sensitive species*	1	2.5	0	0
SLithop *Number of simple lithophilic spawning species*	0	0	1	2.34
TolTxPct *Percent of tolerant species*	50%	7.50	40%	9
Total (FIBI score)	--	28.49	--	29.65

Table 45. Fish species and number of individuals sampled at 07UM101.

Common Name	6/18/2007	8/16/2016
johnny darter	54	46
central mudminnow	87	26
creek chub	91	10
northern pike	4	5
green sunfish	4	2
black bullhead	1	1
Iowa darter		1
largemouth bass		1
blacknose dace	148	
pumpkinseed	31	
bluegill	9	
fathead minnow	8	
yellow bullhead	8	
blackchin shiner	7	
white sucker	7	
yellow perch	2	
common shiner	1	

Stressor Data

-Temperature

Temperature data for WID -554 do not suggest that thermal stress is causing the fish impairment. Between 2016 and 2018, twelve instantaneous measurements were made at 07UM101 and 16UM081 (Table 46), all of which were within acceptable ranges for warmwater fish species. In August 2017, continuous temperature measurements were made at those sites, and showed that the temperature range was approximately 15 – 25^{o}C (Figure 53 and Figure 54).

Table 46. Temperature data for two biological stations on WID 07010201-554.

Date	07UM101 Temp [^{o}C]	16UM081 Temp [^{o}C]
6/18/2007	23.7	-
6/30/2016	-	18.53
8/8/2016	22.91	-
5/8/2017	-	12.81
8/7/2017	21.36	22.46
8/22/2017	19.69	21.59
7/13/2018	25	24.82
8/27/2018	22.59	21.64

Figure 53. Physicochemical parameters measured with continuous sonde deployment at 07UM101 in August 2017. Sonde deployed upstream of Stearns County Rd 160.

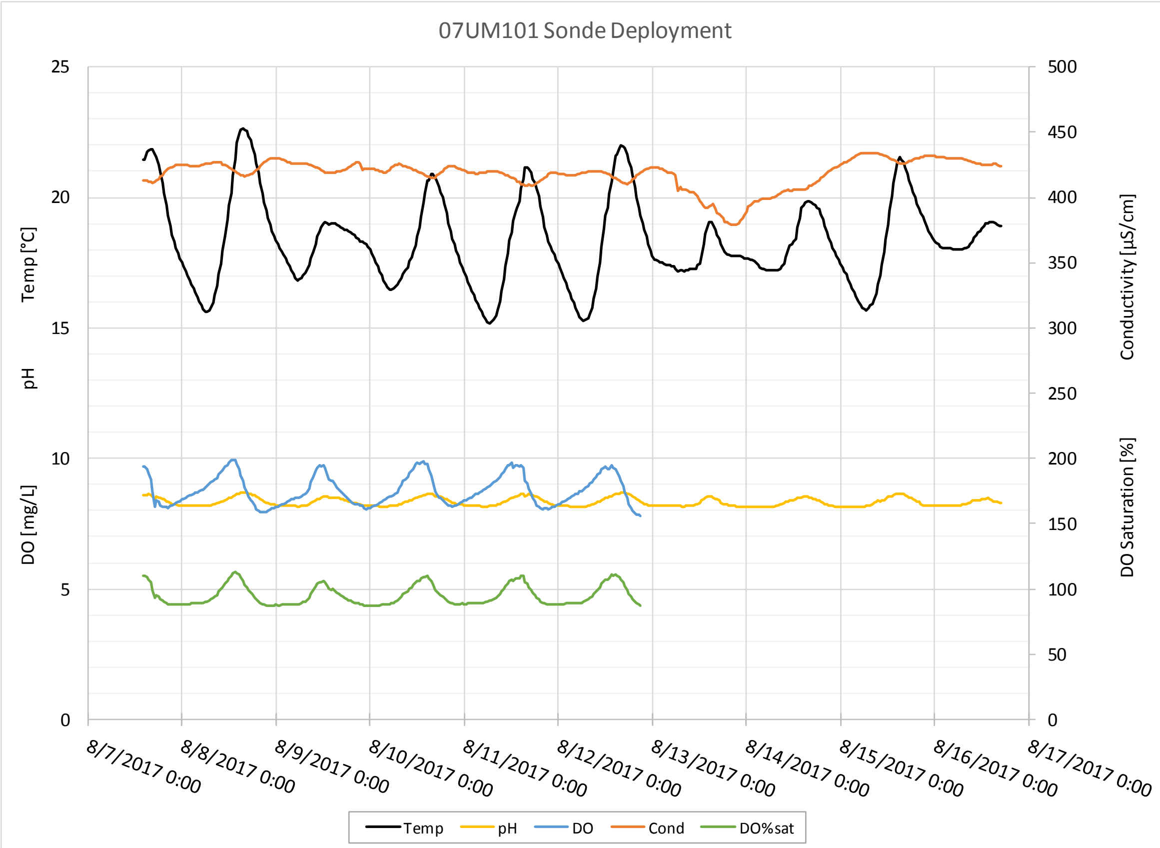
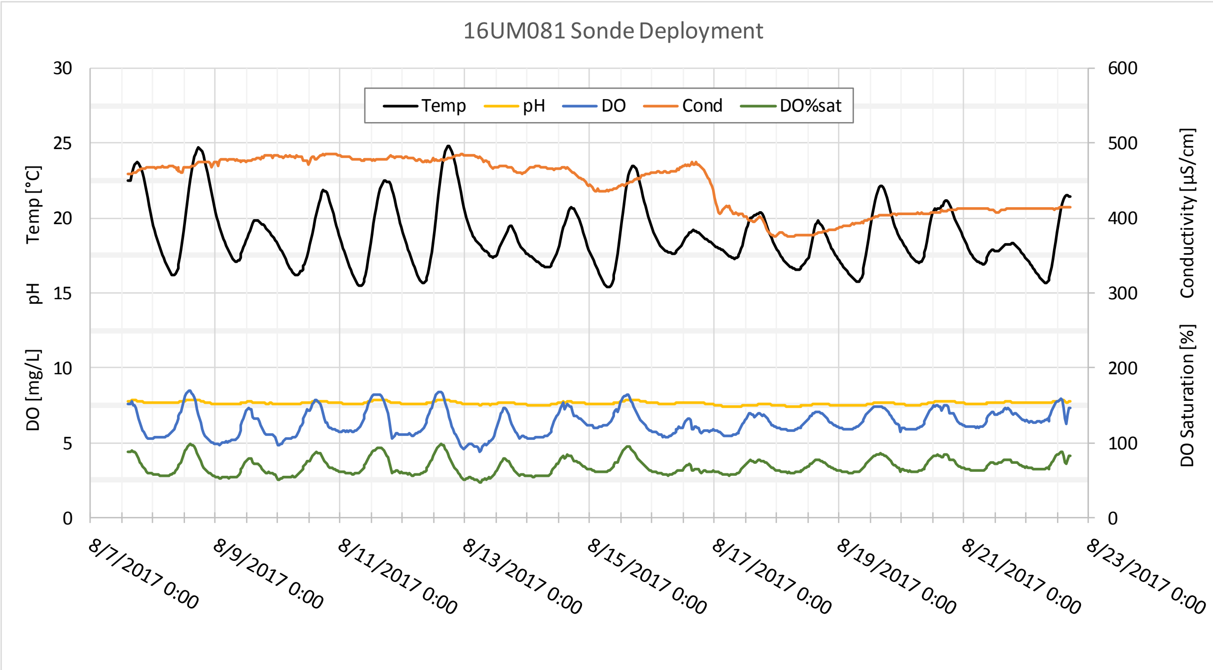


Figure 54. Physicochemical parameters measured with continuous sonde deployment at 16UM081 in August 2017. Sonde deployed upstream of Stearns County Rd 51.



-Longitudinal Connectivity

There are five road crossings on WID -554 between 16UM081 and the confluence with the rest of the Watab River system. Longitudinal connectivity downstream of this confluence is presumably sufficient because the fish communities in the North Fork of the Watab were not impaired.

Of the five road crossings, all but the I-94 crossing was investigated for fish passage. Three of the four checked were not issues. The CSAH75 crossing is a barrier to fish passage, however. It is a concrete box culvert, approximately 150 feet long, and did not have sufficient substrate or water depth (Figure 55). About twenty feet upstream of the culvert inlet there is a rock pile across the channel that appears to be there as a grade control for the crossing. The rocks also may be posing a minor physical barrier (Figure 56).

The river has signs of geomorphic instability in the vicinity of the crossing, which is not itself a connectivity problem, but is a sign that the crossing may be improperly installed. Upstream of the grade control rocks, the channel looks over-widened and has degraded habitat. There is predominantly fine substrate, bank erosion, downed trees, and shallow water depth (Figure 57). Bank erosion and a scour pool are present downstream of the crossing (Figure 58. The scour pool is likely a result of the culvert being too narrow, constricting incoming flow and having a “fire hose” effect on the downstream side. This would also make it a velocity barrier to fish passage.

Figure 55. Inlet of Stearns County CSAH75 culvert.

Figure 56. Artificial rock feature upstream of Stearns County CSAH75 crossing. Possibly for grade control.

Figure 57. Upstream view of WID -554 from Stearns County CSAH75 crossing.

Figure 58. Bank erosion at downstream scour pool at outlet of Stearns County CSAH75 road crossing.

Between 16UM081 and 07UM101, there are four public stream-road crossings and at least six private culverts. The public road crossings are passable for fish. A couple of the private culverts appear, from aerial imagery, to be causing localized instability, but are likely passable. One private culvert at the upstream end of the 07UM101 sample reach is a barrier to some fish (Figure 59). Although it is relatively short, the velocity and lack of substrate in the culvert are likely prohibiting some fish from getting further upstream. Based on aerial imagery, it appears the culvert has been in place since at least 2003. The next culvert upstream (eastern Stearns CR160) is also not properly installed; it is set at too high an elevation and appears to be causing deposition of fine sediments upstream (Figure 60). However, these culverts would not have prevented fish from migrating into 07UM101, because they are at the upstream end of the sample reach. They would be preventing fish from accessing potential spawning grounds and higher quality habitat upstream of 07UM101 (e.g. the Watab River, South Fork headwaters at CR160 further west Figure 61). Another private culvert upstream of the western CR160 crossing appears undersized, and possibly perched, and is scouring out the channel on the downstream side (Figure 62).

Only two of the stream-road crossings discussed could have been the cause of the lack of fish at the biological stations in 2016, namely, CSAH75 and possibly I-94. However, insufficient passability at stream-road crossings is a prevailing condition throughout the Watab River watershed, including on the next downstream reach, WID -528. Insufficient road crossings not only limit fish movement throughout the watershed, they cause geomorphic instability that degrades habitat. For a while, these negative affects will remain localized to the crossing area, but if neglected, can have significant impacts on overall stream stability and road safety.

Also, the fish data from both sites ranks poorly in the percent of migratory taxa as compared to other fish samples in the state, although the percent of migratory individuals at 16UM081 is mediocre (Table 47). Longitudinal connectivity is a stressor to the fish in WID -554.

Figure 59. Private culvert on upstream end of 07UM101.

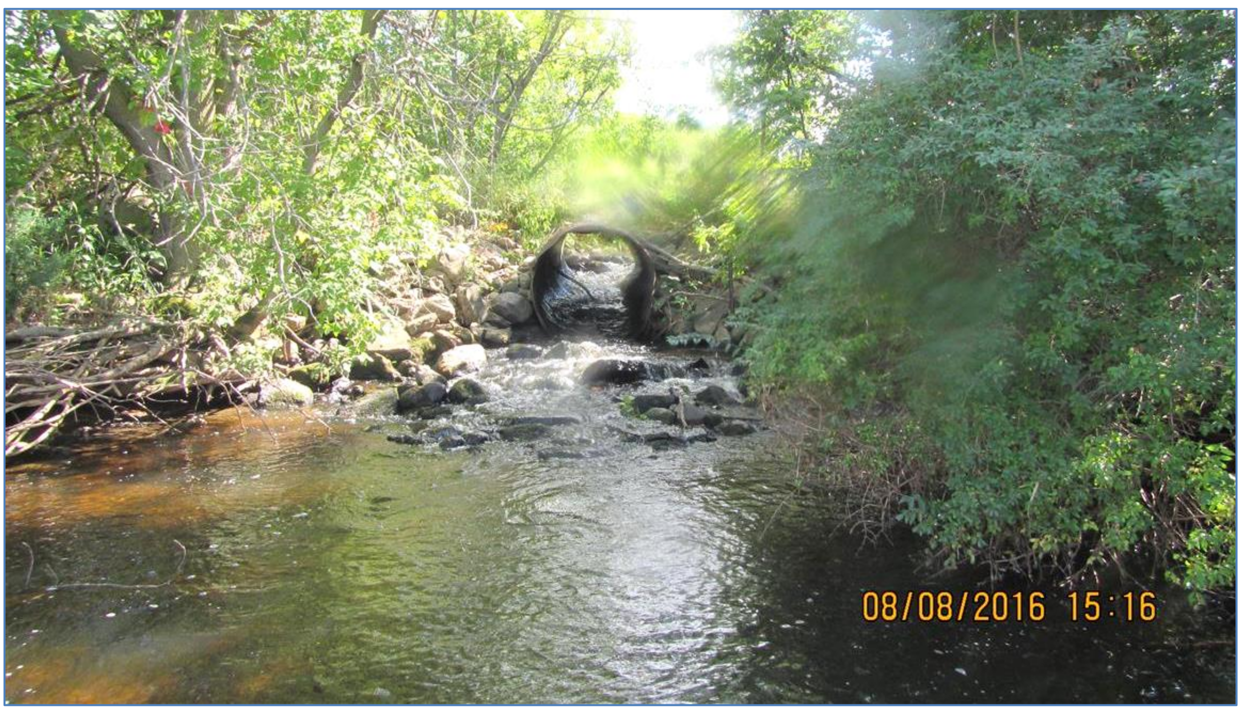


Figure 60. Inlet of culvert at Stearns CR160, just upstream of 07UM101. There are two CR160 crossings with the South Fork of the Watab River; this is the one furthest east.

Figure 61. Looking upstream at the South Fork of the Watab River headwaters from Stearns CR160. There are two CR160 crossings on the South Fork of the Watab River; this is the one farthest west.

Figure 62. Private stream-road crossing, upstream of CR160 towards Merden Lake.
Arrow points to evidence that the culvert is causing geomorphic instability. It is too small and causing a "fire hose" effect on the downstream side. Observed using Google Earth aerial imagery.

Table 47. Percent migratory metrics and ranking for fish data from biological stations on South Fork of the Watab River, WID 07010201-554.

Station	Date	Migratory Taxa [%]	Migratory Taxa Percentile†	Migratory Individuals [%]	Migratory Individuals Percentile†
07UM101	6/18/2007	6.7	14.1	1.5	18.5
	8/16/2016	12.5	27.6	1.1	16.7
16UM081	6/30/2016	10.0	20.2	20.7	68.7

†Percentile is the standing of that Migratory Taxa value as compared to all other reportable, MPCA-collected fish samples to date (n=6,741).

Beaver dams can also be barriers to fish passage. Although none were observed on the Watab River during an investigation of aerial imagery taken May of 2015, parts of the Watab are known to foster beaver activity. In fact, a dam was constructed at the downstream end of 16UM081 during the SID study, sometime between 7/13/2018 and 8/27/2018 (Figure 63). It is possible that a dam such as this existed in 2016 when the fish communities were sampled, but whether there was or not, and if it was a significant barrier, is unknown.

Figure 63. Beaver dam at downstream end of 16UM081 on 8/27/2018. View from Stearns CR51.

-Streamflow

The streamflow at 07UM101 can get quite low. During the macroinvertebrate sample, a biologist noted that although flow was sufficient for sampling, if the water level were to drop three inches, most of the overhanging vegetation would no longer be submerged. Overhanging vegetation is the predominant habitat type at 07UM101, comprising at least 50% of available habitat. Based on signs of geomorphic instability observed upstream of 07UM101 and the fact that 07UM101 is a straightened drainage ditch, it is suspected that the flow regime is flashy here and potentially affecting habitat availability through the frequency of low flow events. Streamflow alteration is potentially a stressor to the aquatic life in this location, but more information is needed to confirm. A study of geomorphic condition and hydrologic response, as compared to a reference stream, may help determine if streamflow alteration is degrading habitat and stressing aquatic life.

Streamflow at 16UM081 appears more stable. This area has riparian wetlands and groundwater springs. Throughout seven field visits between 2016 and 2018 the water level was never low enough to be considered limiting the habitat availability. Streamflow alteration is not a stressor at this location.

--Metals: Iron

Of note, there is evidence of iron in the stream, with orange coloration where a spring enters on the right bank of the sample reach, as well as cloudy-white water (Figure 64). An adjacent waterway that enters the Watab just downstream of 16UM081 has an orange coloration and is evident in aerial imagery[2]. Iron is a possible stressor to the aquatic life in this location. However, no water chemistry samples were collected for a metals analysis. For more information on the effects of iron on aquatic life, see the *Metals* section in 3.1.1. Tributary to Platte River – WID 07010201-634.

[2] See latitude/longitude 45°33'31.71"N / 94°20'31.38"W

Figure 64. Spring entering on right bank of 16UM081, with evidence of ferric iron precipitate.

-Habitat

Minnesota DNR Region 3 Clean Water staff conducted geomorphic surveys immediately upstream of 16UM081. They concluded that the stream reach is an E type channel that is in a stable condition, and that any habitat degradation due to geomorphic instability from modifications to the headwaters of the WID, such as at 07UM101, are "reset" by the large wetland area that begins around the 287th St. road crossing.

In 2016, two MSHAs were conducted at 16UM081, scoring a 49 and 56 out of 100 possible points, which is a "Fair" habitat rating. Overall, the stream facet composition in the sample reach is 80% sandy run and 20% sand-silt pool. The best habitat areas in E type channels are generally the banks and deep pools, with riffles generally not present. More than six habitat features (e.g. undercut banks, deep pools, woody debris) were noted in both MSHAs, with extensive ($\geq$50%) cover throughout the reach. Although habitat in this reach is not perfect, as it lacks coarse substrate in the runs and the pools are either infrequent or too shallow, degraded habitat is not suspected as the primary stressor in this location.

At 07UM101, three MSHAs were completed, with highly variable results. Due to inconsistent scoring methods, the 2007 MSHA total score (55) should not be compared directly with the 2016 MSHA total scores (69 and 49). The substrate at 07UM101 was described as "sparse cobble with marble-sized gravel and sand," which is poor quality coarse substrate for a site of this gradient (3.05m/km), an MIBI Class 5 - Southern Streams Riffle/Run. Also, the cobble presence was noted as less than 5% of the stream bed area, and it is artificial substrate placed around a private culvert in an attempt at stabilization of the crossing (see Figure 59). Stream facet composition was, again, quite variable between assessments, but overall the stream was scored as having 70-85% run and 10-30% riffle, both having sand and gravel as the primary substrate, and one assessment noted 5% presence of a sand-silt pool.

The discrepancy in MSHA scores between 8/8/2016 (49) and 8/16/2016 (69) is due to poorer: depth variability, channel stability, channel development, habitat cover, and shade; and greater:

embeddedness and bank erosion noted on 8/8 than on 8/16. Approximately three inches of rain fell on the watershed between 8/8 and 8/16, causing the water level in 07UM101 to rise. This explains the additional points scored in depth variability, channel development, and habitat cover on 8/16. This might also explain the decrease in observed embeddedness. It is common for MSHA scores on the same site and during the same year to vary by 5-10 points, but the twenty-point difference at 07UM101, over a span of eight days, is outside the norm and illustrates how important water levels are for making quality habitat available.

Despite the discrepancy in total MSHA scores at 07UM101, the details of the assessment regarding lack of coarse substrate and stream facet homogeneity point to poor quality habitat as a stressor at this location. Additionally, some of the quality habitat that is present becomes uninhabitable when water levels drop, which is also a suspected stressor (see *Streamflow* section).

-Suspended Sediment

A small dataset of TSS/TSVS and transparency was collected at the biological stations on WID -554 (Table 48). In 2009 and 2010, someone from the Stearns County Lakes Monitoring Program collected TSS and transparency data on the WID, upstream of CSAH75, at MPCA EQUiS station S005-715, which is a ways downstream of 16UM081 (Figure 65). The available chemistry data at the biological stations alone is not sufficient enough to conclusively determine if suspended sediment is a stressor.

The data collected downstream of the biological stations in 2009-2010 shows one event where TSS breached 20mg/L, which could be stressful to aquatic life if it were occurring for very long durations. None of the 2010 measurements show excessive TSS. The conditional probability that WID -554 would meet the state's TSS standard based on the fish sampled is mediocre-good (69-80%) (Table 49). With those lines of evidence considered together, suspended sediment is likely not a driving stressor of the aquatic life impairment on WID -554.

Table 48. Total suspended sediment (TSS), volatile solids (TSVS), and transparency data on WID -554. Transparency was measured with a 100cm Secchi tube.

Date	TSS [mg/L]		TSVS [mg/L]		Secchi Tube [cm]	
	07UM101	16UM081	07UM101	16UM081	07UM101	16UM081
6/18/2007	7.2				73.1	
6/30/2016		9.8		3.4		>100
8/8/2016					>100	
8/16/2016	4.6		3.2		>100	
8/18/2016						>100
5/18/2017						41
7/13/2018					>100	>100

Figure 65. Total suspended solids (TSS) and transparency data on WID -554 near CSAH75, at station S005-715. Transparency was measured with a 120cm Secchi tube in 2009 and a 100cm tube in 2010.

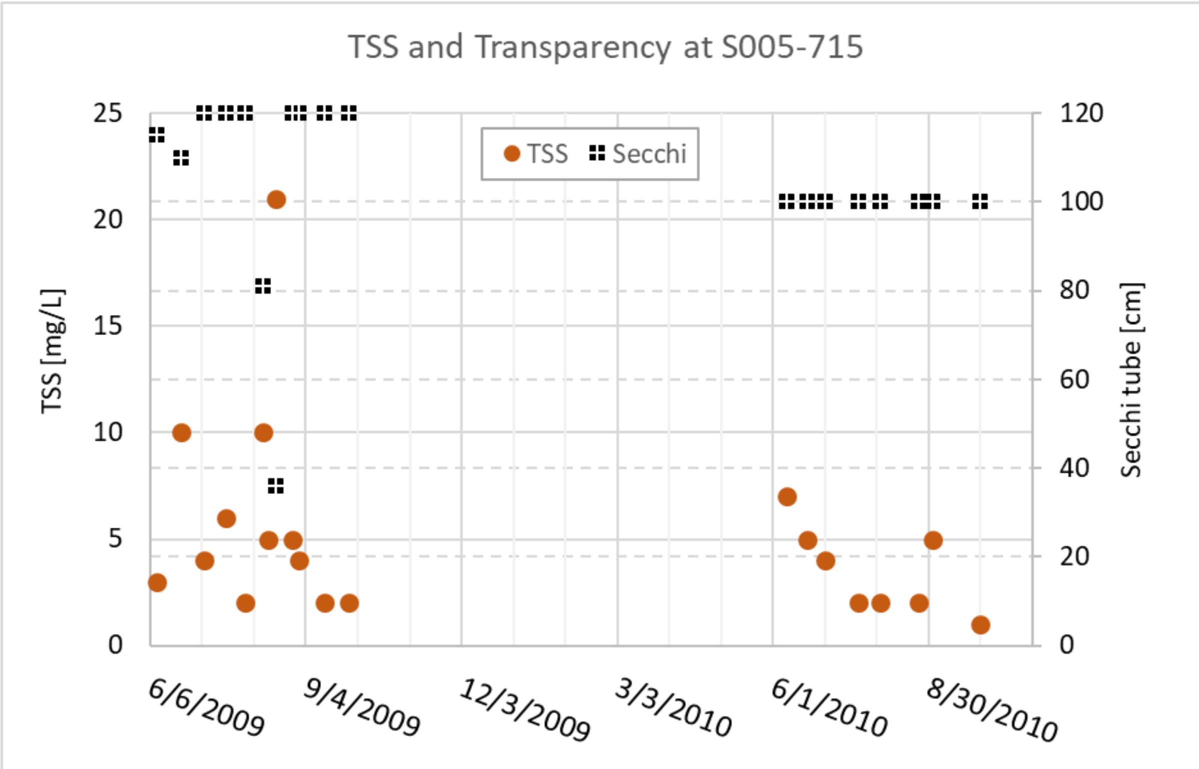


Table 49. Conditional probabilities (percent chance) that the stream would pass the state water quality standards for TSS given the fish community sampled.

Sample	Probability [%]
07UM101 (2007)	80
07UM101 (2016)	78
16UM081 (2016)	69

-Nutrients

A handful of nutrient samples were collected from the two biological stations on WID -554 by MPCA staff during 2016-2018 (Figure 66), and the Stearns County Lakes Monitoring Program collected a dataset in 2009-2010 near CSAH75, which is downstream of 16UM081.

Nitrogen

Based on the data gathered, NOX does not appear to be a stressor. It was never measured in excess of 0.45mg/L, which is far below levels that would cause an aquatic life impairment.

Phosphorus

Total phosphorus is mildly elevated at 16UM081, where it exceeded 0.100mg/L twice. This site also has more in-channel plant growth than 07UM101. The TP data alone does not strongly suggest that eutrophication is occurring and stressing the aquatic life in WID -554. The maximum daily DO fluctuation (DO "flux") measured using deployed sondes (see Figure 53 and Figure 54) was 2.01mg/L at 07UM101 and 3.83mg/L at 16UM081 (Table 50). At 16UM081, the DO flux exceeded the state standard of 3.5mg/L twice in sixteen days. In general, eutrophication does not appear to be a stressor on WID -554, although the area around 16UM081 is more productive than the rest of the WID, and might be considered mildly eutrophic. There is no evidence of excessive algal growth at either station. Many streams with groundwater springs emerging from within riparian wetlands naturally have elevated TP and low DO. It is unclear how "natural" the conditions are at 16UM081, but it is clear that eutrophication is not driving the aquatic life impairment in WID -554.

Figure 66. Nutrient chemistry data from 07UM101 and 16UM081.
The data series suffix, as shown in the legend (e.g. "101" in "TP_101"), indicates which station the sample was collected from.

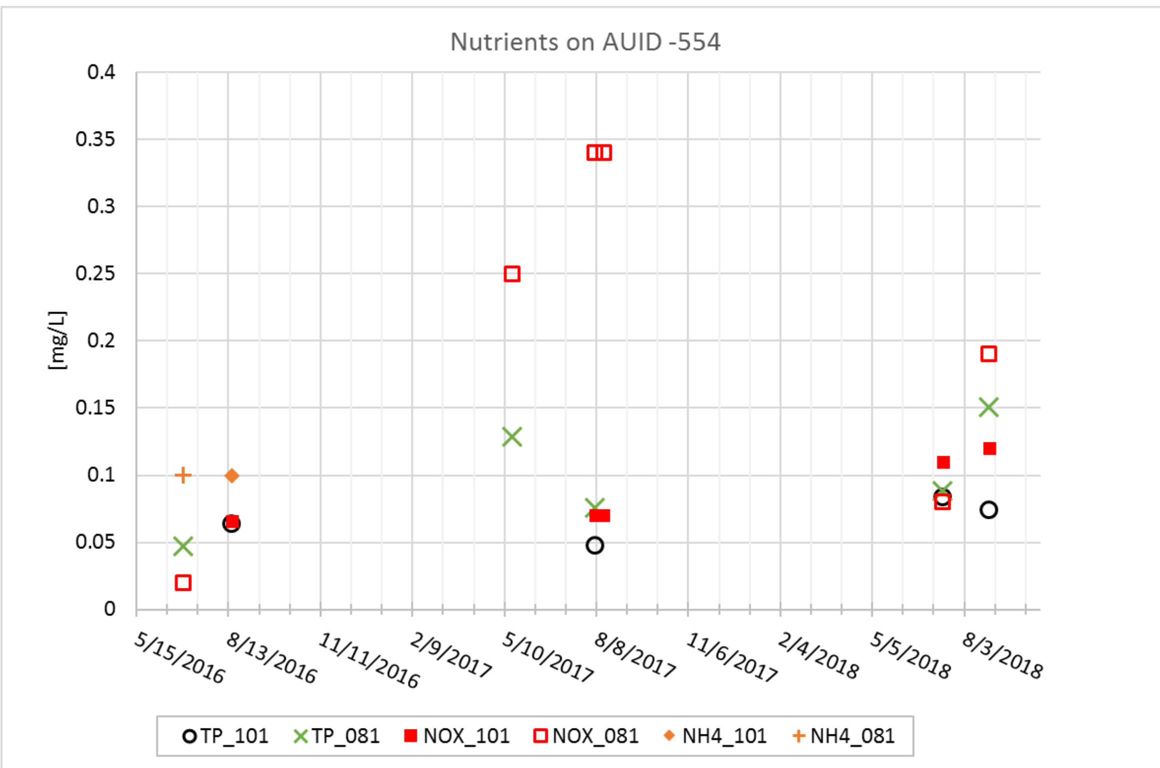


Figure 67. Total phosphorus (TP) and inorganic nitrogen (NOX) collected on WID -554 near CSAH75, at station S005-715.

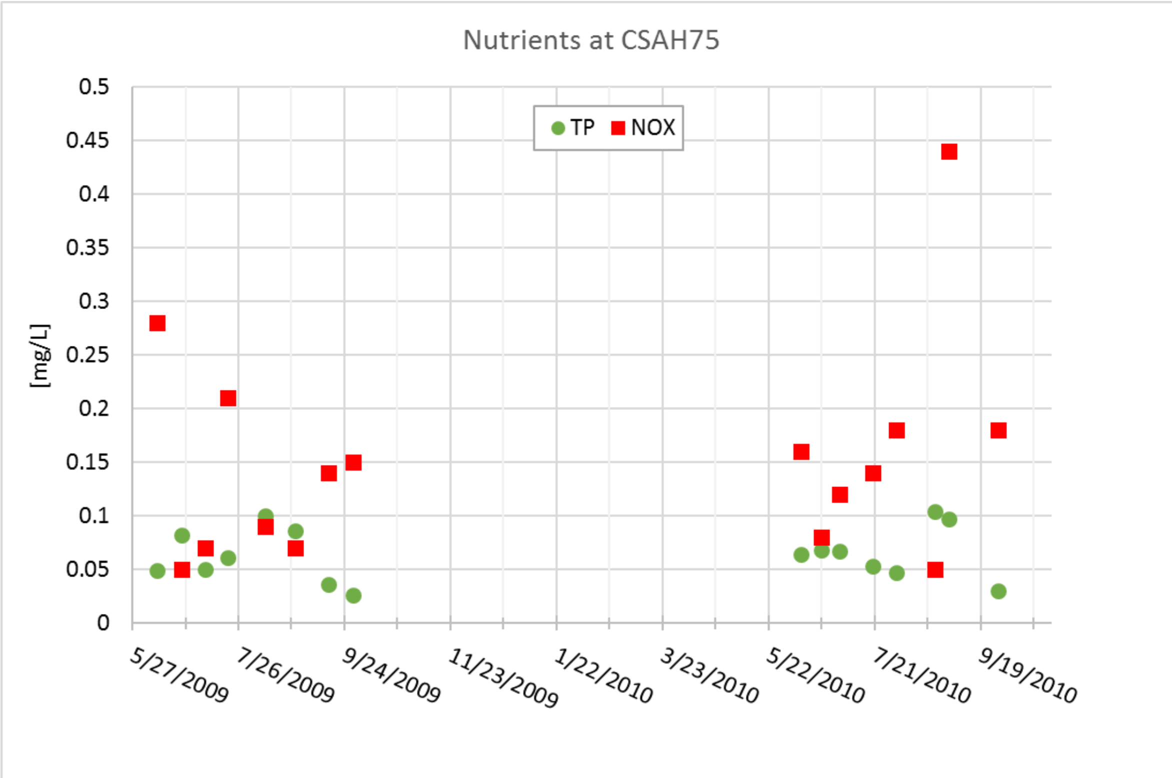


Table 50. Dissolved oxygen (DO) daily fluctuations (flux) during sonde deployment at 16UM081 in August 2017.

Date	DO Minimum [mg/L]	DO Maximum [mg/L]	Daily DO flux [mg/L/day]
August-7	**5.25**	7.74	2.49
August-8	**4.95**	8.49	3.54
August-9	**4.88**	7.36	2.48
August-10	**4.8**	7.9	3.1
August-11	**5.28**	8.23	2.95
August-12	**4.58**	8.41	3.83
August-13	**4.42**	7.37	2.95
August-14	**5.25**	7.67	2.42
August-15	**5.78**	8.21	2.43
August-16	**5.4**	6.63	1.23
August-17	**5.44**	6.99	1.55
August-18	**5.82**	7.09	1.27
August-19	**5.7**	7.45	1.75
August-20	**5.89**	7.53	1.64
August-21	**6.02**	7.3	1.28
August-22	6.29	7.91	1.62

-Dissolved Oxygen

Dissolved oxygen in WID -554 has been measured with instantaneous readings at various times and locations (Figure 68), and with sonde deployments at both biological stations in August of 2017 (see Figure 53and Figure 54). At 16UM081 and the next upstream road crossing (295th Ave), DO was measured as <u><</u>5.5mg/L. Interestingly, those low levels also occurred in May, when water temperatures were cold and DO is usually at least 7mg/L in rivers and streams. The springtime low DO is likely a result of low-DO water from wetland areas contributing to the stream, which can be exacerbated by high flow events. Low DO is potentially a stressor to aquatic life in this part of the Watab River, but the data are inconclusive. To help determine if low DO is a stressor, either pre-9:00AM instantaneous measurements or continuous measurements, need to be collected during spring and summer, and at various flow levels. It might be helpful in determining the cause and prevalence of DO issues to also collect data up- and downstream of 16UM081.

The conditional probability that the stream would pass the state's DO standard varies by biological station (Table 51). At 16UM081, the likelihood is lower than 07UM101, which aligns with the DO pattern observed at these stations. At 07UM101, there was a 24 percentage-point drop in likelihood from the 2007 sample to the 2016 sample. Because low DO has not been observed at 07UM101, it is suspected that the low conditional probability is due to influences on the fish community from other low DO areas of the Watab, and/or other stressors acting to limit the fish community in a similar way that low DO might. Low DO is not the most suspected stressor in this part of the Watab River, but there is just not enough data. Of note, the river flows through a large wetland between the biological stations, which is likely causing some longitudinal differences in the DO regime.

Figure 68. Minimum dissolved oxygen (DO) measured at various locations on WID 07010201-554.

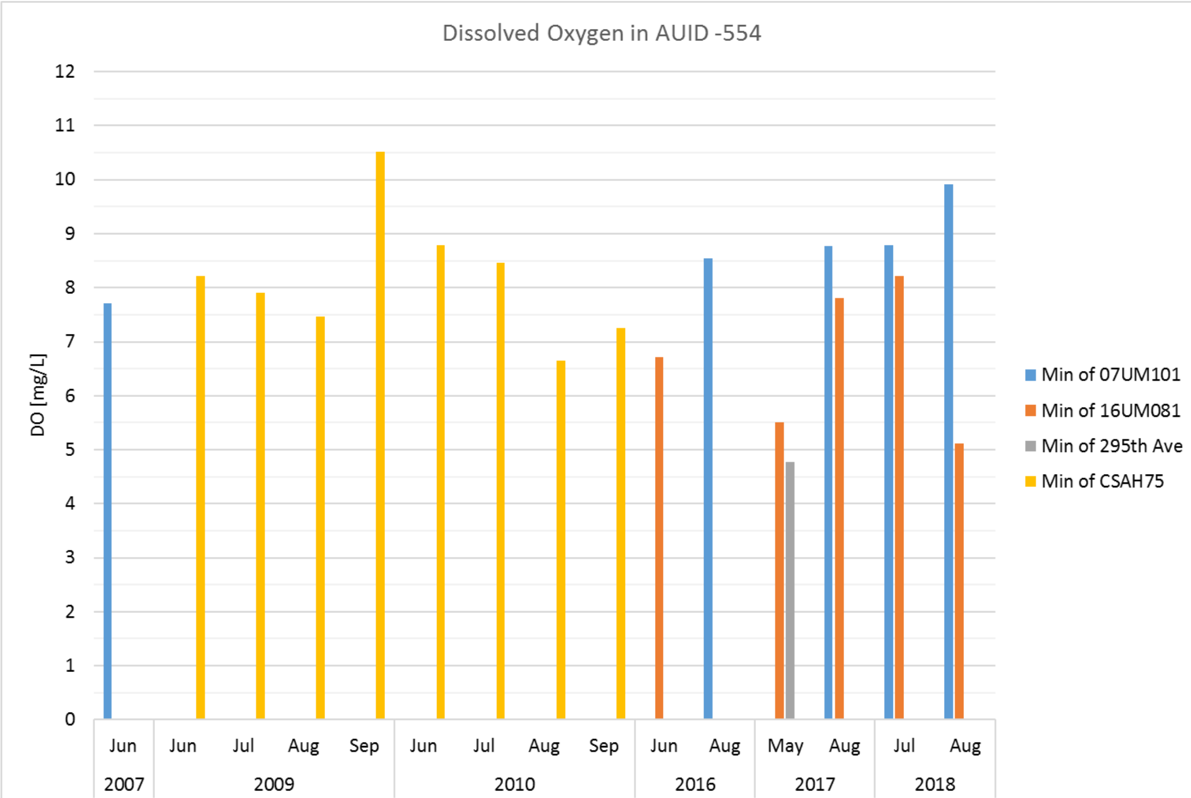


Table 51. Conditional probabilities (percent chance) that the stream would pass the water quality standard for dissolved oxygen (DO) given the fish community sampled.

Sample	Probability [%]
07UM101 (2007)	61
07UM101 (2016)	37
16UM081 (2016)	27

WID Summary

Of the potential stressors investigated, longitudinal connectivity was conclusively determined to be a stressor to the fish community in WID -554, particularly the CSAH75 culvert, though several crossings in the watershed are problematic. At 07UM101, lack of habitat is also a conclusive stressor, and low flow magnitude is an inconclusive stressor, both possibly driven by streamflow alteration. Streamflow alteration, as a result of the watershed land use and channelization of the stream near 07UM101, is currently an inconclusive stressor; it is suspected to be driving the lack of habitat and low flow at 07UM101. Other inconclusive stressors are iron and low DO at 16UM081.

3.4.2. Watab River – WID 07010201-528

The lower section of the Watab River, from Watab Lake to Sartell, is WID -528. The WID is 7.64 miles long, and the drainage area at the biological sampling station in Sartell, 16UM125, is 92 square miles.

Biological Data

WID -528 is impaired for aquatic life due to nonsupport of the fish community, which failed to meet the general use impairment threshold for FIBI Class 5 – Northern Streams in 2016 (Table 52).

Table 52. IBI scores at site 16UM125 on the Watab River (WID 07010201-528).

		Fish IBI			Macroinvertebrate IBI		
Station	**Date**	**Class†**	**Impairment Threshold**	**Score**	**Class†**	**Impairment Threshold**	**Score**
16UM125	8/6/2016	-	-	-	6	43	54.3
	8/3/2016	5	47	38.7	-	-	-

†FIBI Class: (5) Northern Streams
MIBI Class: (6) Southern Forest Streams – Glide/Pool

The lowest-scoring characteristics of the fish community from the FIBI are high numbers of generalist and very tolerant individuals, along with low numbers of intolerant and late-maturing individuals (Table 53, see highlighted rows).

Table 53. Fish IBI metric scores from the sample at 16UM125 on 8/3/2016.
Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown.

FIBI Class 5 Metric	Raw Metric Result	Re-scaled IBI Score
DarterSculpSucTxPct *Percent of darter, sculpin, and sucker taxa*	8%	2.44
FishDELTPct *Percent of individuals with DELT anomalies*	0.41%	0
DetPct *Percent of detritivore individuals*	18.18%	5.95
DomTwoPct *Combined relative abundance of the two most abundant taxa*	32.64%	9.09
Insect-TolTxPct *Percent of insectivorous taxa, excl tolerant species*	36%	4.40
General *Number of generalist taxa*	7	1.44
IntolerantPct *Percent of intolerant individuals*	5.37%	1.16
MA>3-TolPct *Percent of late-maturing individuals, excl tolerant species*	7.44%	1.98
SensitiveTxPct *Percent of sensitive taxa*	24%	4.96
SLithoPct *Percent of individuals that are simple lithophilic spawners*	21.90%	2.81
SSpnTxPct *Percent of taxa that are serial spawners*	28%	2.61
Vtol *Number of very tolerant taxa*	5	1.82
Total (FIBI Score)	--	38.7

Stressor Data

-Temperature

A collection of water chemistry and physicochemical measurements were taken near the biological sampling station in May-August of 2016 and 2017 by MPCA staff (Figure 69). Additionally, temperature data was collected further downstream, at Riverside Ave., between 2004 and 2011 by the Stearns County Lakes Monitoring Program (Figure 70).

Figure 69. Temperature, dissolved oxygen (DO), total phosphorus (TP), and inorganic nitrogen (NOX) data, collected near Pine Cone Rd. in Sartell, Minnesota (16UM125).
Data collected at MPCA EQUiS station S003-457, and can be found on the MPCA's Environmental Data Access webpage.

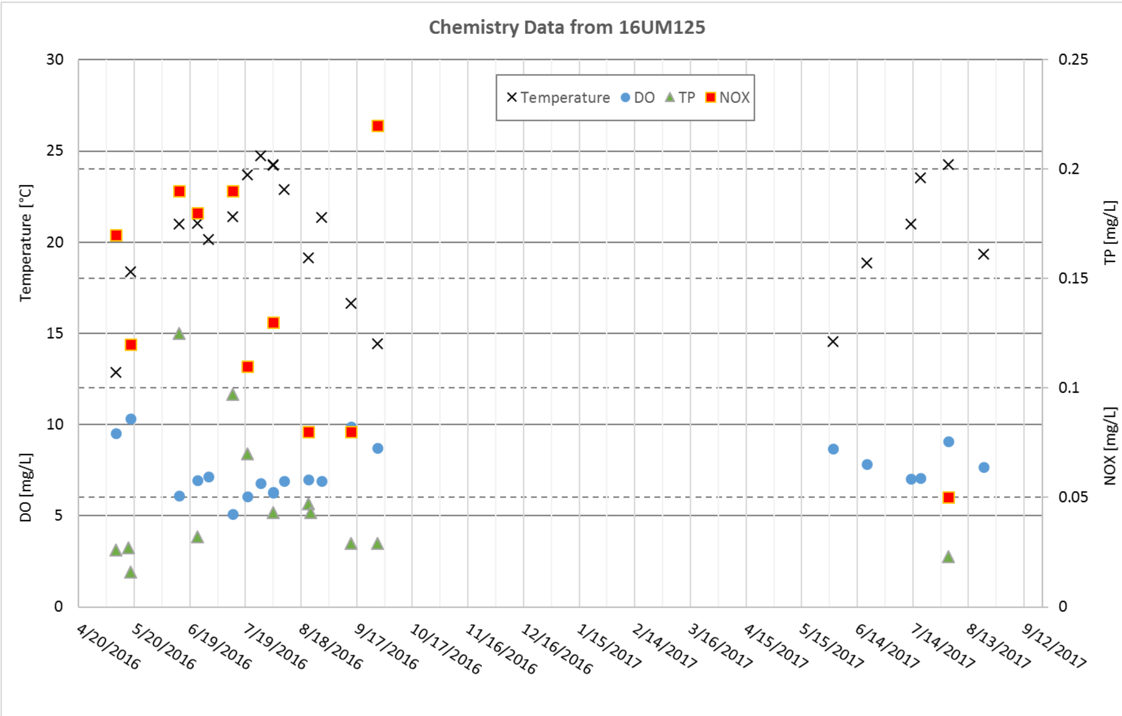
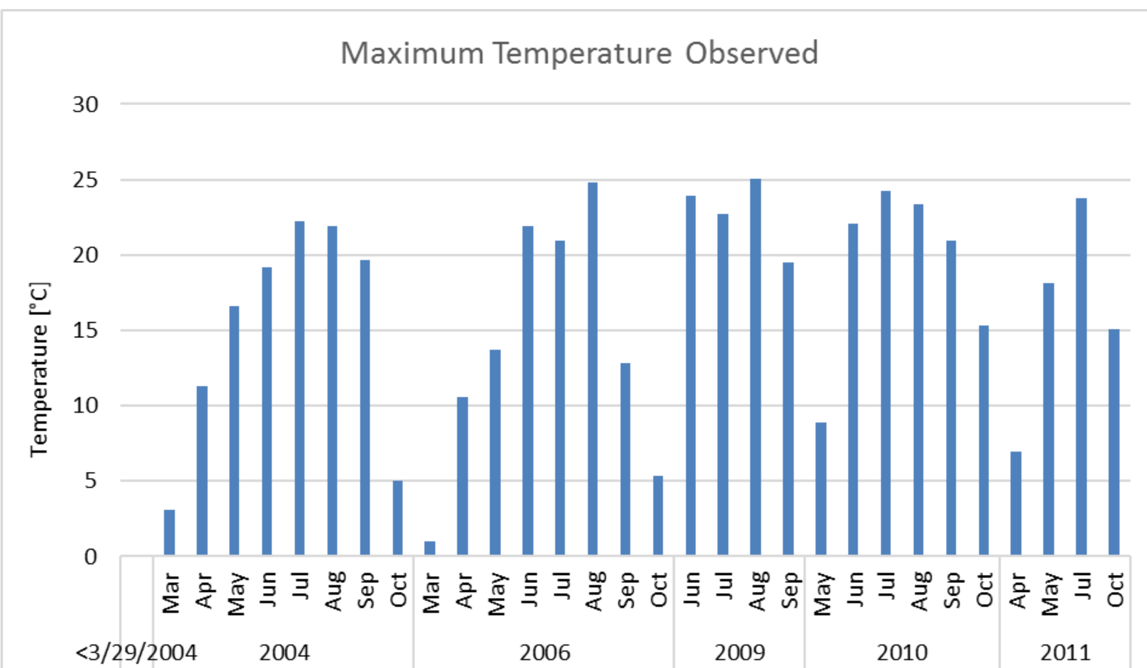


Figure 70. Historical temperature data in WID 07010201-528 near Riverside Ave. in Sartell, Minnesota. Data collected at MPCA EQUiS station S002-947.



Across all years of data, temperature in this lower portion of the Watab River annually exceeds 24.0°C in August, with a maximum recorded temperature of 25.04°C on 8/13/2009. These temperature ranges do not suggest that thermal stress is occurring.

-Longitudinal Connectivity

Approximately 1.5 stream miles downstream of 16UM125, the Watab River outlets to the Mississippi River just below the dam. Thus, the "source" of fish for 16UM125 would be any year-round residents of the Watab River system, including some high quality lakes, or fish migrating into the Watab from the Mississippi River. The smallmouth bass and suckers sampled at 16UM125 likely just migrated up from the Mississippi, as the sandy substrate at 16UM125 is not their preferred habitat.

Some beaver dams can be seen in the upper reaches of the watershed, but none were found that would affect the biological sample in 16UM125. Additionally, no road crossings or manmade dams were identified as fish passage barriers on WID -528. Longitudinal connectivity is not a stressor to the fish community in WID -528.

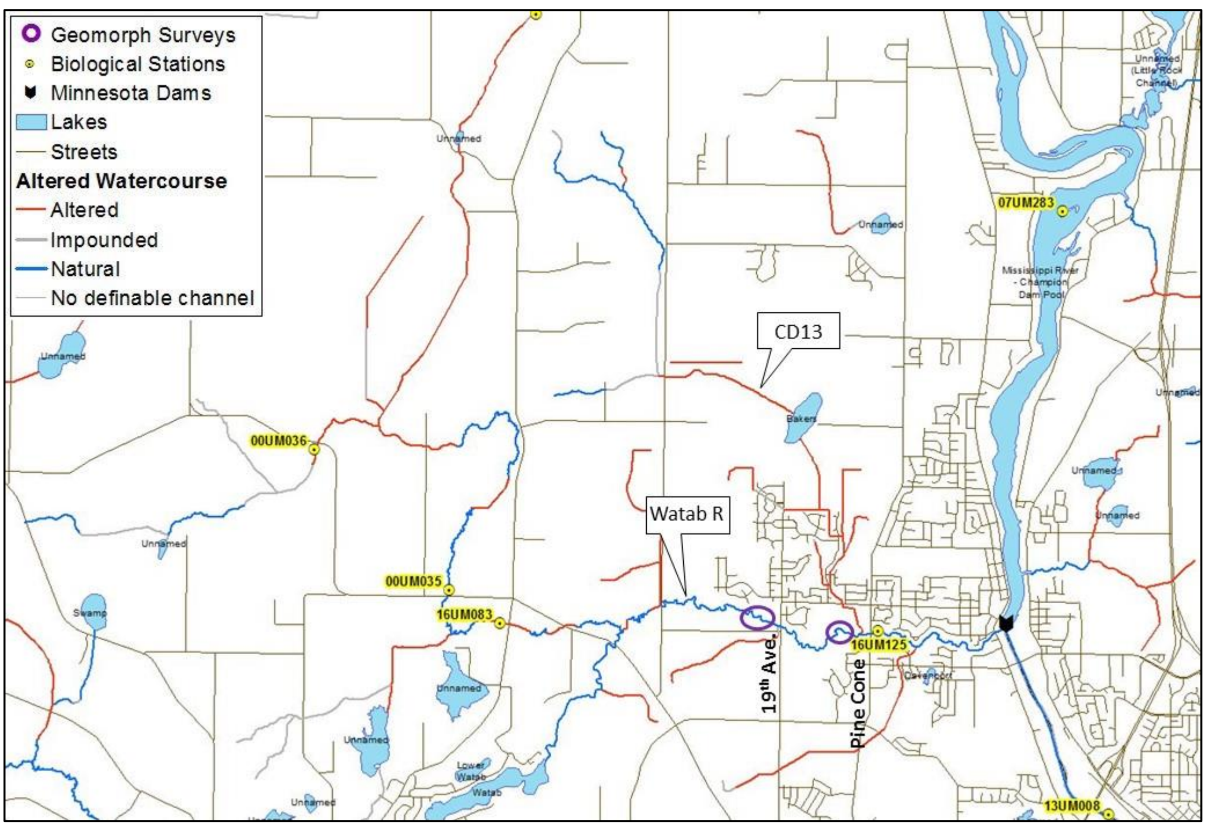
-Streamflow

Analyses of streamflow data were not conducted for WID -528. However, the geomorphological data indicate that alteration of natural flow conditions is degrading habitat, primarily as a result of the Pine Cone Rd. crossing. See the following *Habitat* section for further details. Additionally, the modified stream network in and around the city of Sartell is delivering more water faster to the Watab River, potentially resulting in increased flashiness of the flow regime. For example, Stearns CD13, which drains urban areas of Sartell to the Watab River, shows signs of channel instability (Figure 71). Again, the CD13 referred to in this report goes from Bakers Lake to the Watab River in Sartell, and is not the CD13 near Holdingford. Also, geomorphic analyses performed upstream of 19^{th} Ave. showed that the river is more stable there than downstream of 19^{th} Ave. (Figure 72). Most of the urban area of Sartell is east (downstream) of 19^{th} Ave.

Extreme climatological events, coupled with increased watershed delivery to the river may be exacerbating habitat damage caused by the Pine Cone Rd. crossing. Flow alteration is a stressor to the fish in 16UM125, primarily through its role in habitat degradation, which is discussed in the following *Habitat* section. Flow alteration stressors are often accompanied by water quality stressors, such as increased temperatures, nutrients, and various toxins. Although water quality parameters are not currently suspected stressors in WID -528 at this time, it would be wise to take actions that might prevent their occurrence.

Figure 71. Pictures of Stearns CD13 (near Sartell, Minnesota) taken on 8/3/2016, courtesy of MN DNR. The ditch shows signs of channel instability, such as bank erosion, widening, and channel incision.

Figure 72. Map of the Watab River at Sartell, Minnesota with approximate locations of geomorphological surveys.
Storm drain/sewer lines are not shown, but are presumably delivering stormflow to the river.



-Habitat

Minnesota DNR Region 3 Clean Water staff conducted geomorphic analyses in the Watab River watershed. A technical report of the results will be completed at a later date, and a link to that will be placed next to the link of this stressor ID report. Below is a synopsis of their findings in WID -528:

> "The Watab watershed is in good condition in the upper reaches but has stability issues in the downstream reaches. Stream stability is of most concern in the lower portion of the watershed where pressure from urbanization is highest. The majority of upstream reaches are in a stable condition. Some upper reaches with incision reset after flowing through lakes located in the middle portion of the watershed.
>
> Expanding urbanization has destabilized parts of the Watab's main branch at stream crossings by restricting floodplain access. Urban encroachment has resulted in the straightening and incision of reaches, which in turn has caused excessive bank erosion. The addition of sediment has consequences for aquatic life habitat, such as embedded riffles and filled pools, which are common in the downstream reaches.
>
> An example of this habitat degradation occurs where the main branch of the Watab crosses Pine Cone Road in the city of Sartell, Minnesota. The culverts at this location are drastically reducing the floodplain area and holding grade upstream of the crossing. The result is aggradation of fine sediments and sand upstream of the crossing, and incision and erosion downstream of the crossing.
>
> To begin protecting and restoring the Watab, stream practitioners should re-connect the floodplain, establish adequate riparian buffers (width and vegetation types), and design stream crossings with the proper dimension, pattern, profile, and flood prone width for this particular stream."

Pictures of the Pine Cone Rd. crossing in Sartell, Minnesota illustrate the problems that occur when a culvert is not set at a proper grade (too high). The channel on the upstream side is aggrading and filling with fine sediments, whereas the channel on the downstream side is eroding and incising, restricting floodplain access (Figure 73 and Figure 74).

Figure 73. Upstream (left) and downstream (right) view of the Watab River from Pine Cone Rd. in Sartell, Minnesota. Photos taken 4/14/2016.

Figure 74. Example of active bank erosion occurring in 16UM125, downstream of Pine Cone Rd. in Sartell, Minnesota.
Photo taken on 8/3/2016.

Two MSHAs were performed by the biological sampling crews in August of 2016. Out of 100 possible points, the total MSHA score was 57.2 on 8/3/2016 and 52.5 on 8/9/2016, which are about the middle of the “Fair” (45-65) category. Additionally, macroinvertebrate biologists noted “very limited good habitat” during the sampling event. The 70-90% of the reach in 16UM125 is a run, made of predominantly sand, with lesser amounts of gravel and silt also present. The only other stream facet noted was 10-30% sand-silt pool. Areas of detrital substrate were also present.

Embeddedness of coarse substrate was marked as None in one MSHA, and as 25-50% in the other. There is some discrepancy in the assessments, but that may mean the embeddedness is on the low end of the 25-50% range. However, the only coarse substrate found on which to assess embeddedness was some gravel in the run sections.

Pictures of in-channel habitat from the biological sampling events corroborate the “Fair” MSHA scores (e.g. Figure 75). While there is some habitat present where riparian trees are leaning, or have already fallen in, most of the bank habitat now sits too high above the stream due to incision of the channel. While the fallen and leaning trees do provide habitat, they are a sign of an unnaturally widening channel. Better habitat conditions would be available if the channel had remained narrower and deeper.

Figure 75. Picture of macroinvertebrate sample being collected at 16UM125. Photo exemplifies sparseness of habitat cover and variety.

Reduced habitat complexity is a stressor to the fish community in WID -528, specifically downstream of Pine Cone Rd. This is corroborated by the low score in the FIBI metric “General” (number of generalist taxa). This section of the Watab River is naturally a glide-pool type of stream, where the best habitat components are usually deep pools, under cut banks, and overhanging vegetation, since riffles are not naturally abundant in this type of stream. However, due to channel incision, the undercut banks and overhanging vegetation are no longer providing high quality cover for aquatic life at normal flow conditions. Few deep pools were observed in 16UM125, and the geomorphic analysis showed that pools upstream of Pine Cone Rd. are “filling” with fine substrate, making the channel depth more uniform.

-Suspended Sediment

The suspended sediment dataset for WID -528 consists of paired TSS/TSVS water chemistry samples taken in 2016, and Secchi tube measurements taken 2016-2017 (Figure 76). Discharge data from a nearby river are also shown for context. Also, a historical dataset of TSS samples was compiled by the Stearns County Lakes Monitoring Program in 2004-2010 (Figure 77). In the 2004-2010 dataset, the spring TSS peak exceeded 20mg/L for three out of the three years where early spring (~May) data are available. Also, some TSS spikes occurred during the summer, presumably from storm events.

In the 2016-2017 dataset, TSS was ≤6mg/L across all samples, except on 6/13/2016 and 7/20/2016. The percent of TSS that is accounted for by volatile solids (*not* sediment) ranged from 52-100% across all samples. The one TSS measurement on 6/13/2016 was 55mg/L, which could be stressful to aquatic life if it occurred for a long duration. The sample of 12mg/L on 7/20/2016 was taken during elevated flow conditions, presumably from the extreme rain event on 7/12/2016, and is not considered a high, or stressful, concentration of TSS for the Watab River.

The chemistry datasets show that somewhat high levels of TSS are co-occurring with high flow events, and that 50-100% off the TSS are volatile solids, not mineral (i.e. sediment). The primary sediment type in the channel is sand, which is more abrasive than finer sediments, such as clay particles. However, aquatic organisms usually seek refuge during high flow events to evade the consequences of gill and tissue damage from suspended sand particles. In 16UM125, however, refugia options have been lessened by the geomorphic instability. In sum, whether or not *suspended* sediment is a stressor in this WID is inconclusive. Suspended sediment levels can be driven by streamflow alteration, just like bedded sediment, which is definitely a stressor (discussed above in *Habitat* section). The lack of habitat variety, especially deep pools, macrophytes, and backwater refugia, exacerbates the issues suspended sediment might be causing for aquatic life. Therefore, the root stressor here is streamflow alteration.

Figure 76. Total suspended solids (TSS), total suspended volatile solids (TSVS), and Secchi tube transparency data collected near Pine Cone Rd. in Sartell, Minnesota.
Secchi tube values shown as 100cm are the maximum possible measurement. Discharge data is the average daily discharge of the Sauk River near Waite Park (USGS Station ID 05270500), which is approximately four miles south of WID -528. Chemistry and transparency data were collected at MPCA EQUiS station S003-457.

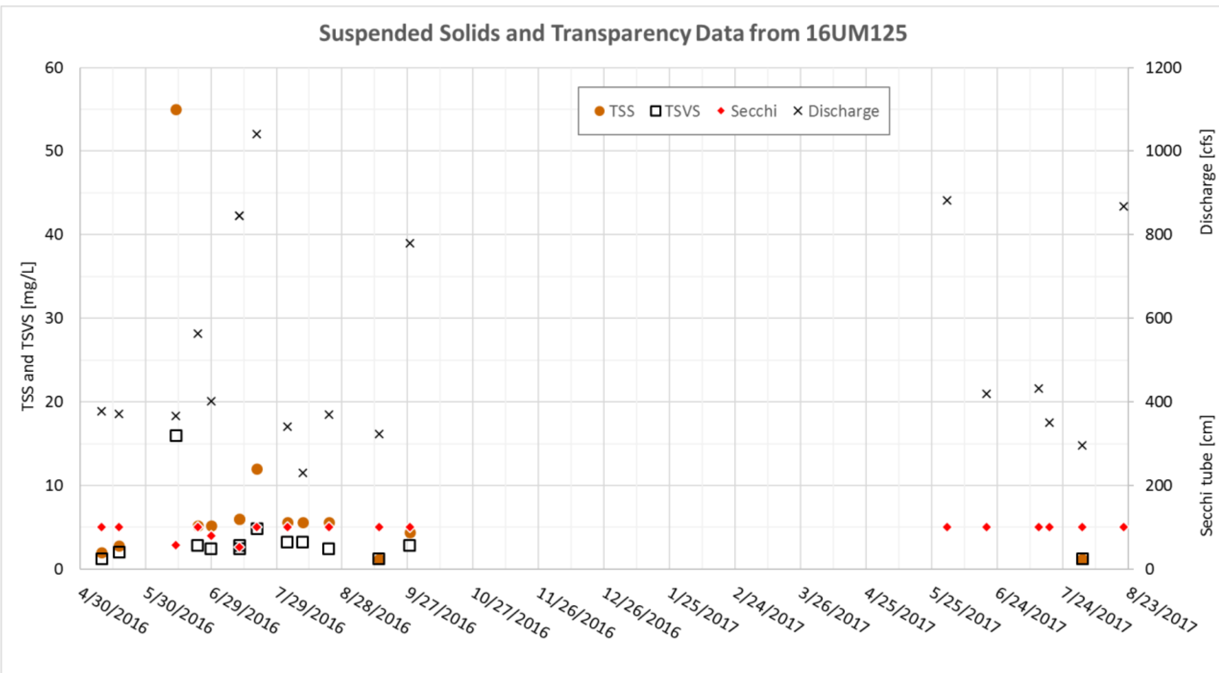
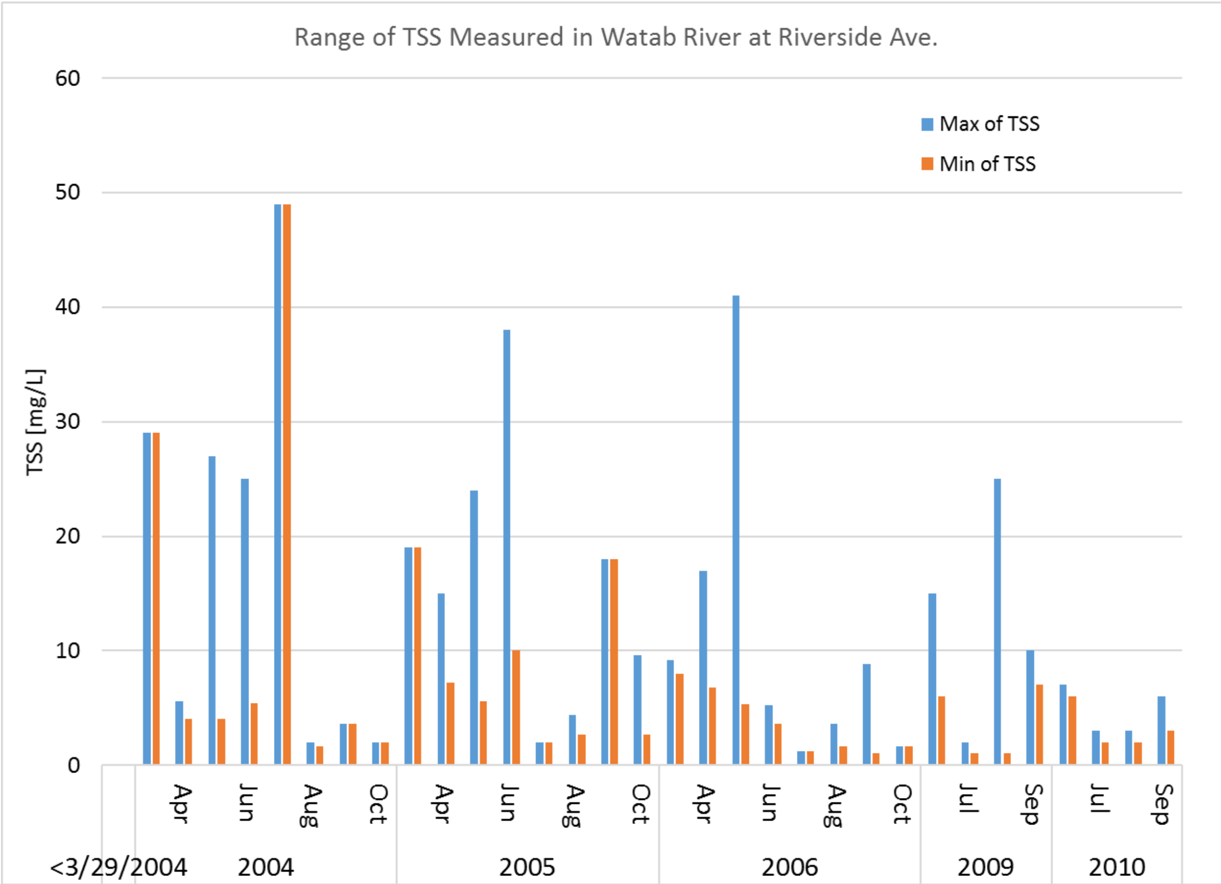


Figure 77. Maximum and minimum total suspended solids (TSS), by month, from the Watab River 2004-2010. Data were collected at station S002-947, near Riverside Ave.



-Nutrients

Data from 2016 and 2017, collected at 16UM125, do not indicate that TP or NOX are at stressful levels (Figure 78). Earlier data show that TP did exceed the state standard of 0.100mg/L at times between 2004 and 2006, but did not in 2009 and 2010 (Figure 79). Similarly, NOX was higher in 2004-2006 than in 2009-2010 (Figure 79). The discrepancy could be due to a difference in targeted flow levels for sampling, or due to changes on the landscape.

Figure 78. Total phosphorus (TP) and inorganic nitrogen (NOX) data from Watab River in 2016 and 2017. The X data points were collected 8/3/2017 and are shown on the x-axis with the 2016 data for simplicity, as these are the only 2017 data points. All samples were collected near the Pine Cone Rd. crossing, at MPCA EQUiS station S003-457.

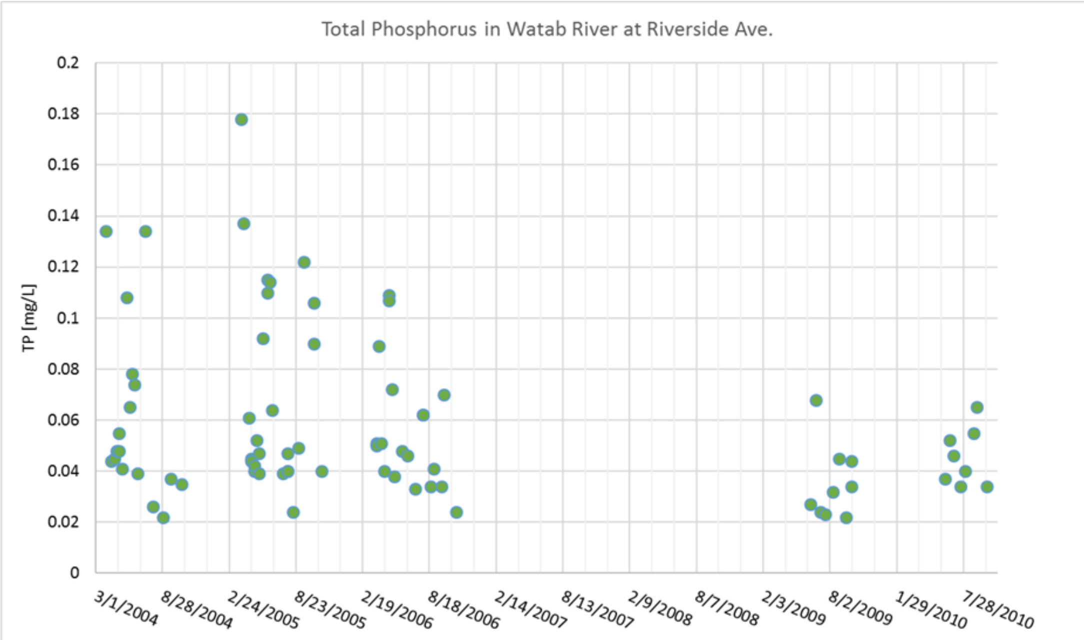
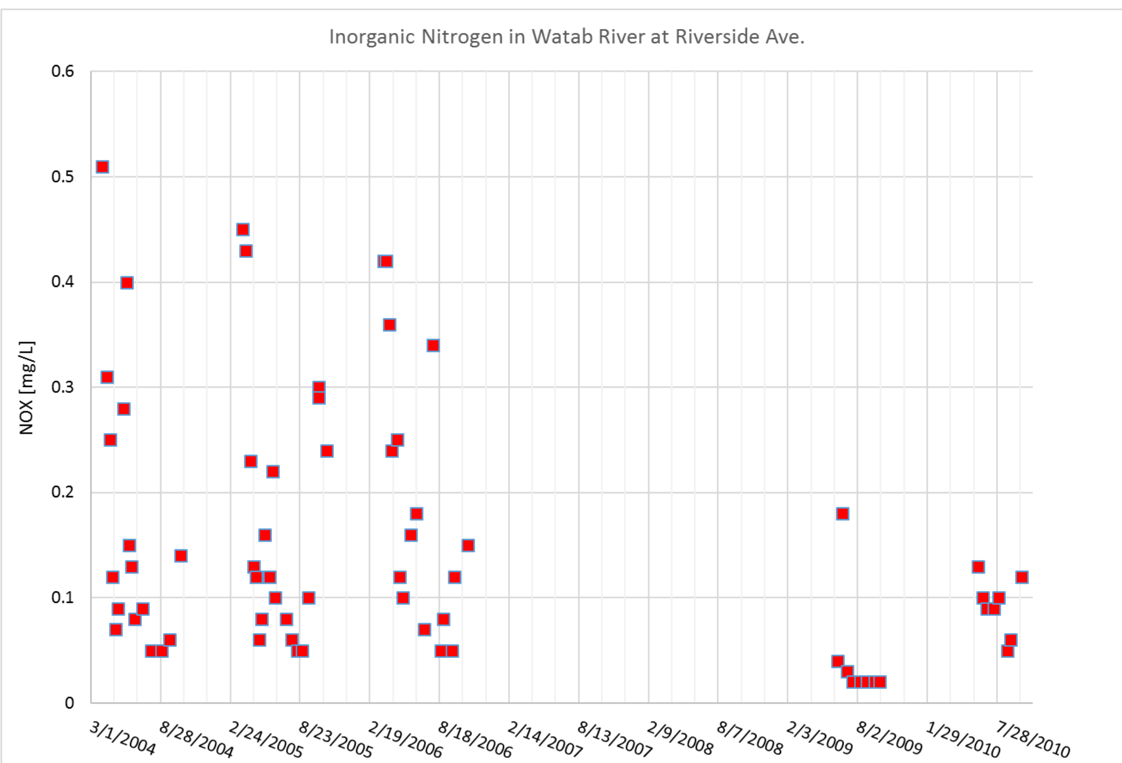


Figure 79. Total phosphorus (TP) (upper) and inorganic nitrogen (NOX) (lower) data from Watab River 2004-2010. Data were collected at station S002-947.



Of note, WID-528 is impaired for aquatic recreation due to high bacteria levels, as are its tributaries: North and South Forks of the Watab River, and Stearns County Ditches 12, 13, and 16. Because the sources of *E. coli* (e.g. animal waste) are also sources of phosphorus and nitrate, high bacteria levels often signal a likelihood of elevated nutrients. By addressing the aquatic recreation impairments with best management practices, aquatic life in the Watab River will also benefit from the improved water quality. Neither high TP or NOX toxicity appear to be stressing the fish community at 16UM125.

-Dissolved Oxygen

All measurements from both the recent data set (see Figure 69) and historical (Figure 80) are above 5mg/L. Eight of the 2016 measurements were taken June-August between 8:00-9:00AM, when DO is lowest, and the range of measurements is 6.04-7.14mg/L. All (except one) of the 2004-2010 DO measurements were taken after 10:24AM, and therefore do not represent the daily minimum DO conditions. The DO measurements do not suggest that low DO is occurring, due to eutrophication or otherwise. However, based on the fish sample, the likelihood that this WID would meet the DO standard is 42%, which is poor. With this somewhat conflicting data, the macroinvertebrate DO-tolerance richness metrics (Table 54) were calculated for additional information. The macroinvertebrate community does not appear weighted toward low DO-tolerance. As a result, low DO is not a suspected stressor in WID -528.

Figure 80. Minimum reported dissolved oxygen (DO) measurement by month.
Data were collected at station S002-947, near Riverside Ave., and can be found on the MPCA's Environmental Data Access webpage. With the exception of one measurement, all data were collected 10:24AM-5:35PM.

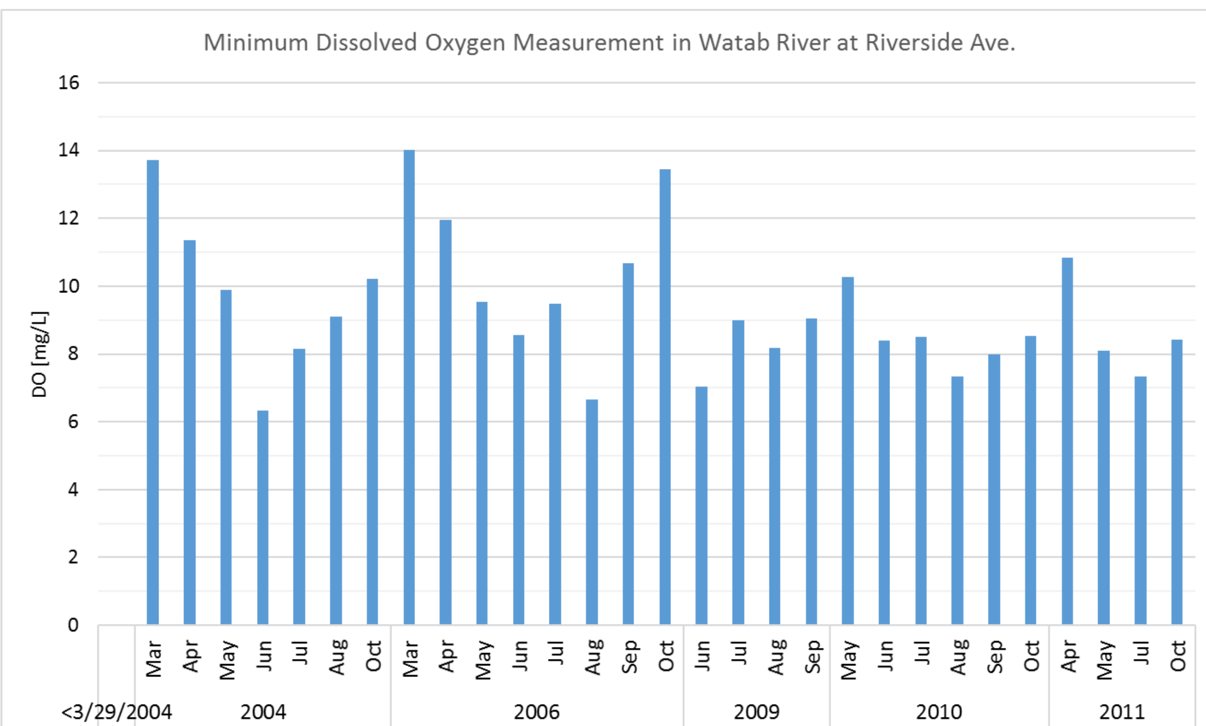


Table 54. Number of taxa ("taxa richness") in the macroinvertebrate sample at 16UM125 that are tolerant and intolerant to low DO.
Percentile analysis was performed using all other MIBI Class 6 samples collected by MPCA (n=683). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Stressor	Very Intolerant Taxa richness - Percentile	Intolerant Taxa richness - Percentile	Tolerant Taxa richness - Percentile	Very Tolerant Taxa richness - Percentile
Low DO	4 – 80.3%	7 – 83.4%	6 – 35.7%	1 – 13%

Of note, CD13, which enters the Watab just upstream of 16UM125, is impaired for its aquatic life use due to low DO (*not* IBI scores) and aquatic recreation due to high bacteria. Based on the available DO measurements, it seems that DO in the Watab is either not much affected by CD13 due to flow volume differences, or that it recovers by time it reaches Pine Cone Rd. However, how low DO in CD13 affects the Watab River is not fully understood and should be monitored to ensure aquatic life protection and prevent water quality degradation.

WID Summary

Of the potential stressors investigated, lack of habitat was conclusively determined to be a stressor to the fish community in WID -528. Habitat degradation is being driven by streamflow alteration and geomorphic instability of the Watab River. Stream stability in the Watab notably decreases as watershed urbanization increases, specifically downstream of 19th Ave. This is likely due to the increase of impervious surfaces (greater road and building density, parking lots, etc.), leading to greater runoff into the stream. Many of the tributaries to the Watab River are impaired for high levels of bacteria and one for low DO, which contributes to the river's water quality issues.

3.5. Little Rock Creek Watershed

The Little Rock Creek watershed is comprised of two major streams: Little Rock Creek and Bunker Hill Creek (Figure 81). Zuleger Creek runs parallel with Bunker Hill and flows into Little Rock Lake, which is formed by the Mississippi River dam in Sartell holding the pool elevation of the lake. For management purposes and consistency with past reports, Zuleger Creek is discussed as part of the Little Rock Creek watershed, though it drains directly to the lake. All three streams in the watershed are impaired for aquatic life.

Extensive work has been completed by the MPCA, MN DNR, Benton and Morrison County staff, and others to write a comprehensive characterization of the watershed. The reader can find that information in the introduction of both the Little Rock Creek TMDL Report (MPCA 2015) and the Little Rock Creek Stressor Identification Report (Benton SWCD 2009). Also see the M&A Report, Figure 23, for a map of current impairments in the Little Rock watershed. Due to time limitations of this stressor identification project, and since a thorough stressor identification study and TMDL were completed, the analyses and discussion in this section of the report are relatively brief as compared to the other WIDs.

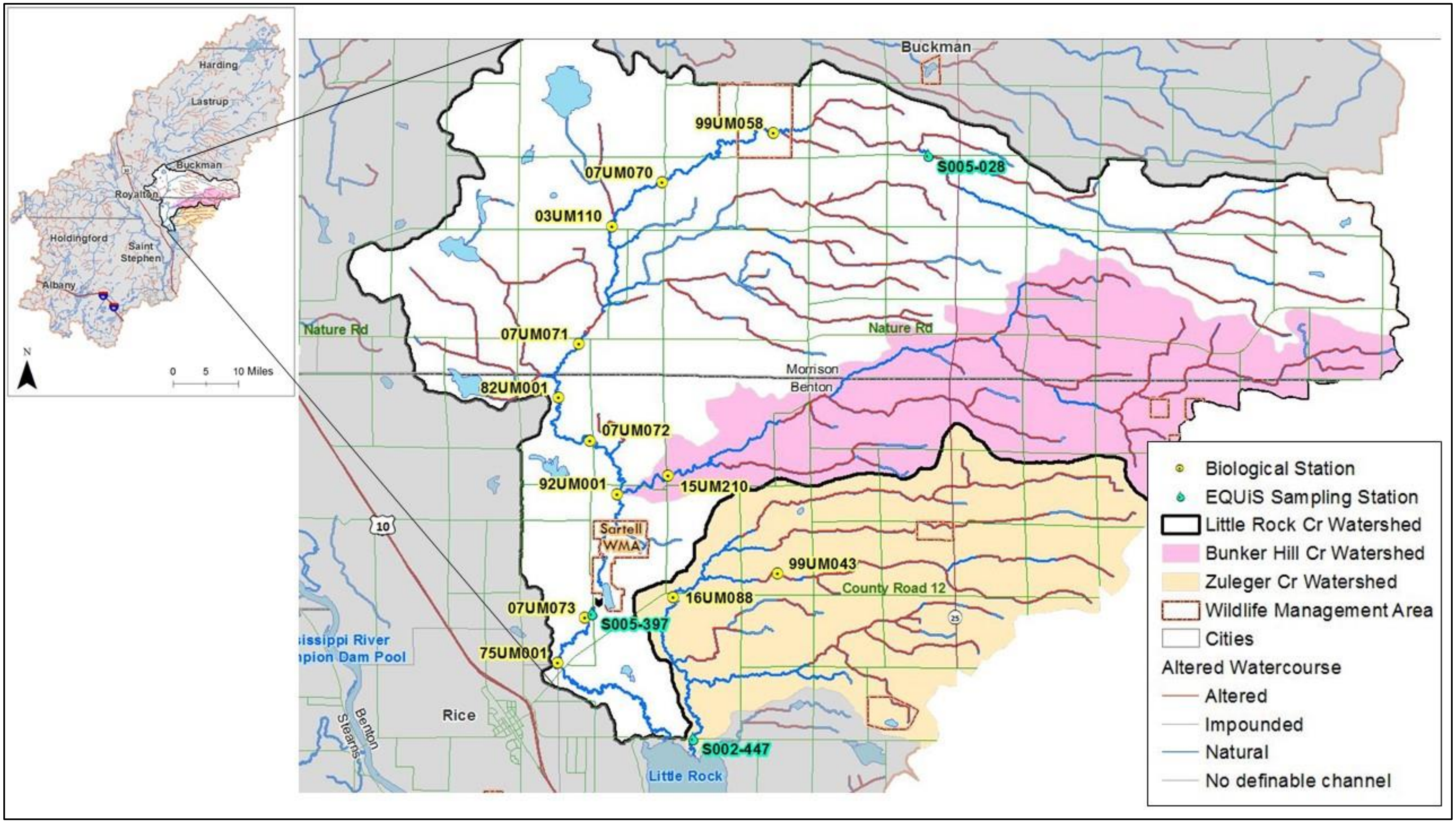
Uninvestigated Stressors

Based on limitations of available data, time, and resources, the following stressors were minimally or not investigated in this study, but could not be eliminated as potential stressors: ammonia, herbicides, insecticides, metals, and other unspecified toxins. In the 2009 SID report, it was noted that at least two of four samples collected by the MDA in 2005 exceeded the state standard concentration for the herbicide atrazine, though no additional exceedances were found during sampling in 2006-2007. Catching high in-stream concentrations of land-applied chemicals is notoriously difficult. Land-use in the Little Rock Creek watershed suggests the possibility that that type of contamination is occurring, which could stress aquatic life, but it is unknown at this time. Additional data would need to be collected in order to better understand this potential stressor.

Candidate Stressors Analyzed

The remaining candidate stressors analyzed for this SID project in the Little Rock Creek watershed are: temperature, lack of longitudinal connectivity, streamflow alteration, lack of habitat, nitrate toxicity, eutrophication, and low DO. Those stressors are discussed by WID in the following sections.

Figure 81. Map of Little Rock Creek watershed and subwatersheds



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3.5.1. Little Rock Creek (upper) – WID 07010201-652

Aquatic Life Impairment History

Little Rock Creek is partitioned into two assessment reaches; WID -652 is the section near the headwaters, and WID -653, discussed in section 3.5.2., is the lower section of the creek. The WID split occurs at 230th Ave. An important difference between these two WIDs is their designated use class. WID -652 is a warmwater (class 2B) use, while WID -653 is a coldwater (2A) use. The separation of the entire length of Little Rock Creek (previously WID -548) into two separate WIDs is because the groundwater contributions that keep the stream temperatures cold were found to be located downstream of 230th Ave. In 2018, the MPCA assessed WID -652 as impaired for aquatic life due to nonsupport of the warmwater fish community.

Biological Data

Many biological samples have been taken in this eight mile long WID. The FIBI failed to meet the impairment threshold in all five samples since 1999. The MIBI scores currently meet the threshold but show a decline over this seventeen-year period, particularly in 2016. In contrast, MIBI scores on the next downstream WID, -653, either declined by only a few points, stayed the same, or increased.

A large reason for the decline in MIBI scores is a shift in the community from lesser tolerant to predominantly tolerant organisms. And in 2016, there was a dramatic increase in the percent dominance of the community by just a few taxa (30-32% in 1999 and 2015 to 48% in 2016). In 1999, the most dominant macroinvertebrate species sampled was the intolerant mayfly, *Paraleptophlebia* (51 individuals). This species was not observed in any of the following samples. In 2015 and 2016, the macroinvertebrate samples were dominated by tolerant organisms: the mayfly *Caenis diminuta*, the beetle *Dubiraphia*, and the midge *Polypedilum*. In 2015, nineteen individuals of the relatively intolerant caddisfly *Triaenodes* were sampled, but only one individual in 2016.

Table 55. IBI scores at site 99UM058 in the headwaters of Little Rock Creek (WID 07010201-652).

		Fish IBI			Macroinvertebrate IBI		
Station	Date	Class†	Impairment Threshold	Score	Class†	Impairment Threshold	Score
99UM058	7/15/1999	6	42	15	-	-	-
	9/8/1999	-	-	-	5	37	51
	6/30/2015	6	42	16	-	-	-
	8/13/2015	-	-	-	5	37	49
	6/29/2016	6	42	19	-	-	-
	8/30/2016	-	-	-	5	37	39

†FIBI Class: (6) Northern Headwaters
MIBI Class: (5) Southern Streams – Riffle/Run

Stressor Data

To avoid redundancy, this stressor identification discussion is primarily based on information gathered after, but still in the context of, the 2009 Little Rock Creek Stressor Identification Report, hereafter referred to as the 2009 SID report.

-Temperature

Because of the 2018 warmwater assignment, the 2010 Little Rock Creek aquatic life impairment, which was due to a lack of coldwater fish assemblage, is no longer relevant to this WID. However, warmwater fish and macroinvertebrate species can still be stressed by warm temperatures. MPCA biologists placed a continuous temperature data logger at 99UM058 in 2015. Results of those measurements were used to calculate temperature metrics (Table 56). Instantaneous measurements were also made in 2016-2018 by the MPCA (Table 57). None of these measurements yield temperatures that would suggest thermal stress is occurring, which begins around 30°C for many warmwater species, dependent upon the duration of exposure.

Table 56. Summary of 99UM058 temperature data from 2015 monitoring season. Temperature in degrees Celsius.

Temperature Metric	June	July	August	Summer Total
Average	18.75	20.99	18.75	19.51
Average Minimum	17.41	19.62	17.66	18.24
Average Maximum	20.25	22.30	19.83	20.80

Table 57. Instantaneous temperature and DO measurements taken at 99UM058 prior to biological sampling.

Date	Time	Temperature [°C]	DO [mg/L]	DO [% saturation]
6/30/2015	9:55 AM	19.40	6.27	72
8/13/2015	9:09 AM	20.60	6.96	81
6/29/2016	10:25 AM	18.43	7.30	76
8/30/2016	11:34 AM	19.96	6.68	73

-Longitudinal Connectivity

There are relatively few road crossings of Little Rock Creek. Aerial imagery was used to locate crossings that might be barriers to fish attempting to reach WID -652. None were identified. The 2009 SID report cites the following longitudinal connectivity stressors, which are relevant to WID -652, on pages 114-115:

> "Three primary longitudinal connectivity stressors for the Little Rock Creek include: Little Rock Lake, Sartell Wildlife Management Area's [WMA] wetland impoundment, rock-dams, and numerous culvert crossings. Each one of these structures can change the hydrology of the system, as well as larger watershed changes, which can create unintended impacts for both the physical and biological entities of the creek. Finally, Little Rock Creek is also

> isolated from the Mississippi River and the rest of its downstream network by Little Rock Lake. The warm water, nutrient impaired lake poses a significant migratory barrier to sensitive, coldwater, and/or coolwater taxa (e.g. mottled sculpin, burbot, hornyhead chub, mimic shiner). These taxa are present in the Mississippi River and if they were to successfully colonize the creek, it would improve measures of Biological Integrity. Connectivity challenges may still exist even if Little Rock Lake's water quality were to improve; there will be a warm water thermal regime present which would continue to be a barrier to coldwater species, such as burbot & mottled sculpin."

The report goes on to detail that two potential barriers to fish passage under drought conditions are the rocks covering a pipeline near CR26 (Nature Rd.) and a "rock bridge" 1.5 miles downstream of CR26. According to the MN DNR Area Fisheries Manager, both the pipeline crossing and the low water ford (aforementioned "rock bridge") are still in place at the time of this writing, and would only be a barrier to upstream fish movement during extremely low flows. Also, the aforementioned wetland impoundment is a managed, not fixed, level structure; it is only a barrier to some fish at certain water levels (Figure 82).

Figure 82. Pictures of the Sartell State Wildlife Management Area (WMA) dam on Little Rock Creek, showing the varying degree to which this structure is a barrier to fish passage depending on dam height, water level, and other factors. Photos courtesy of MN DNR.

In summary, longitudinal connectivity is a minor stressor to the fish community in WID -652, primarily due to the WMA impoundment and eutrophic conditions of Little Rock Lake. However, longitudinal connectivity is not the reason for the aquatic life impairments in Little Rock Creek. For more detail, see the following sections.

-Streamflow

Streamflow alteration has occurred in the Little Rock Creek watershed and is stressing the aquatic life in WID -652 by degrading habitat (see *Habitat* section), diminishing water level and velocity, and potentially diminishing overall streamflow magnitude. Streamflow alteration is evidenced by two geomorphic analyses of Little Rock Creek, as well as pictures and comments from field visits.

In 2008, the MPCA conducted geomorphic analyses in several locations on Little Rock Creek for the 2009 SID report. "Site 2" from the report was located on WID -642; further details of the analysis can be found on pages 66-67 of that report. The study concludes that the channel is unstable and is undergoing a shift in geomorphic state in response to a change in the watershed's hydrology, riparian cover, land use, and/or connectivity.

In 2016, Minnesota DNR Region 3 Clean Water staff conducted geomorphic surveys at 99UM058. Below is a synopsis of their findings:

> "This area of Little Rock Creek is unstable. It is deeply incised, shows excessive erosion and buildup of fine material in the channel, which has degraded habitat by embedding riffles and filling in pools."

A deeply incised channel is separated from its habitat cover, especially the bank types (e.g. undercut banks, overhanging vegetation, rootwads). Further, the stream is cut off from its floodplain. When the energy of water velocity during high flow events cannot be dispersed over the appropriate floodplain width, excessive shear stress erodes the streambanks and/or streambed, further degrading in-stream habitat.

Diminished streamflow was a recurring issue for MPCA biologists when attempting to sample 99UM058. Pictures from 2015 and 2016 show low flow conditions and a separation of the stream channel from habitat cover (Figure 83 and Figure 84). Field notes from biologists on 6/30/2015 noted that "[The] stream will likely become intermittent in a few weeks. Very low water with little flow." On 8/13/2015, water levels were reportedly "0.3m below normal." The diminished streamflow is, in part, a result of the change in channel dimensions (the aforementioned "shift in geomorphic state"), such that the channel can no longer maintain a healthy water depth and velocity during baseflow conditions for aquatic life to thrive.

Streamflow alteration is the driving stressor of aquatic life in WID -652, as it has degraded habitat quality and quantity, as well as diminished the channel's ability to maintain healthy baseflow conditions.

Figure 83. Instream photos of 99UM058 in 2015 (WID 07010201-652).

Figure 84. Instream photos of 99UM058 in 2016 (WID 07010201-652).

-Habitat

Recent habitat assessments performed by MPCA biologists show that habitat quality at 99UM058 is in the “Fair” (45-65) range, with Substrate and Channel Morphology being the poorest scoring categories. The 2015-2016 set of MSHA data as well as the pebble count data in the 2009 SID report show that the predominant substrate type in WID -652 is sand and silt, with some gravel. Moderate to severe embeddedness has been observed in this location since 2007.

As illustrated in the preceding *Streamflow* section, the riffle and pool habitats of WID -652 have been degraded as a result of streamflow alterations, and the stream has been isolated from potential bank habitat, such as overhanging vegetation and rootwads, as a result of stream channel incision. Lack of habitat is a stressor to aquatic life in WID -652, and is driven by streamflow alteration.

Table 58. Minnesota Stream Habitat Assessment (MSHA) scores at 99UM058, shown by category, with the poorest scores highlighted in blue.

Date	Land Use Max=5	Riparian Max=14	Substrate Max=28	Cover Max=18	Channel Morphology Max=35	Total Score Max=100
6/30/2015	5	10	11	13	7	46
8/13/2015	2.5	13	16.1	11	11	53.6
6/29/2016	2.5	10	13.8	8	21	55.3
8/30/2016	2.5	12	13.2	10	17	54.7
Average (% of total possible points)	3.1 (62.5%)	11.3 (80.4%)	13.5 (48.3%)	10.5 (58.3%)	14 (40%)	52.4 (52.4%)

-Suspended Sediment

There is very little recent suspended sediment data from WID -652. Prior to the fish samples in 2015 and 2016, transparency was measured and a chemistry grab sample was taken (Table 59). During the 2009 SID study, suspended solids (which includes suspended sediment) was ruled out as a stressor. However, the report specifically did not rule out "Sediment load" as a stressor, meaning the authors felt that sediment dynamics in the stream could be a problem, but not sediment in the suspended state. As previously stated in the *Habitat* and *Streamflow* sections, bedded sediment is a stressor because it is burying coarse substrate and filling in deep pools. However, this sediment may be primarily "bedload" rolling along the stream bottom, and not suspended in the water column. Suspended sediment is not a suspected stressor in WID -652, but without more chemistry data, it is inconclusive.

Table 59. Total suspended solids (TSS) and total suspended volatile solids (TSVS) data from 99UM058. Transparency was measured with a 100cm Secchi tube.

Date	**TSS** [mg/L]	**TSVS** [mg/L]	**Secchi tube** [cm]
6/30/2015	7.2	4.0	>100
6/29/2016	5.2	1.2	>100

-Nutrients

Nitrogen

As with suspended sediment, there is very little recent data available on nutrients in WID -652. The two NOX samples taken prior to the 2015-2016 fish samples were both <1mg/L. The NOX concentrations from WID -652 ("Site 2") in the 2009 SID report were all <1mg/L; those were reportedly collected in 2008 on a bi-weekly basis from June through October. Also in 2008, five NOX samples were taken where the creek crosses 73rd St., east of 260th Ave. (Table 60). The tolerance richness metrics for the macroinvertebrate community at 99UM058 do not give a clear signal as to whether or not stressful NOX levels are occurring (data not shown).

This WID was changed from a cold to a warmwater IBI designation because the significant groundwater inputs to the creek are believed to be located downstream of WID -652. Since NOX moves via groundwater, as well as in overland runoff, it is possible that WID -652 is less impacted by nitrogen inputs than the rest of Little Rock Creek due to the lesser groundwater inputs. However, high NOX levels have been, and still are, found in other parts of Little Rock Creek, and without more chemistry data from recent years, high NOX cannot be ruled out as a stressor to the fish and macroinvertebrates in WID -652. Thus, it is inconclusive.

Table 60. Nutrient chemistry data from WID -652 at 73rd St., east of 260th Ave. (EQUiS station S005-028).

Date	Time	Comment	**TP** [mg/L]	**NOX** [mg/L]
April 23, 2008	11:40	Shallow groundwater sample taken adjacent to stream.	0.427	7.9
April 23, 2008	11:10		0.129	0.94
Aug. 20, 2008	13:55	Shallow groundwater sample taken adjacent to stream.	0.192	27
Aug. 20, 2008	12:45		0.055	19
Oct. 8, 2008	12:10		0.472	2.3

Phosphorus

In the 2009 SID report, “phosphorus (from fertilizer)” was ruled out as a candidate stressor and not analyzed. The only TP data points from recent years are the 2015 and 2016 grab samples taken prior to the fish samples. The results were 0.091mg/L and 0.123mg/L on 6/30/2015 and 6/29/2016, respectively. The 2016 result exceeds the regional TP standard of 0.100mg/L, which does not itself imply that TP is a stressor. Excessive phosphorus stresses aquatic life through the induction of eutrophication, and it is unclear if that is occurring in WID -652. Pictures of the stream taken in 1999, 2007, and 2015-2016 during six different biological samples do not show any in-stream primary production, with the exception of 2007, when the stream was intermittent and the only pools of water were covered in duckweed. The DO data are also sparse, and do not indicate if eutrophication is occurring or not. Overall, high TP, and thus eutrophication, is not a suspected stressor based on the lack of in-stream primary production.

-Dissolved Oxygen

Some data from WID -652 was used for the initial DO impairment listing of the (now retired) Little Rock Creek WID -548. Because of this, the impairment was retained when WID -548 was split into -652 and -653, which means WID -652 is currently on the MPCA’s 2018 proposed impaired waters list as not meeting state standards for DO. Current data with which to investigate low DO as an existing stressor is not sufficient. There are four instantaneous measurements (see Table 57), all of which were >6.0mg/L, though none were taken pre-9:00AM.

The fish-based conditional probability metrics were not available, at the time of this writing, for 99UM058 in the context of its new warmwater designation. In the context of coldwater streams, which have a higher DO standard of 7mg/L, the probability that this WID would pass the standard was <4% for all three fish samples. The macroinvertebrate tolerance richness metrics shed some light on the potential effects of low DO (Table 61). The number of taxa intolerant to low DO has declined since 1999, while the number of taxa that are tolerant to low DO has increased. Worsening DO conditions is a possible explanation for the decline in MIBI scores since 1999.

Low DO has been documented in this WID in years past; therefore, low DO is currently an inconclusive stressor to aquatic life. More data from recent years is needed to confirm or refute this as a current stressor.

Table 61. Number of taxa ("taxa richness") in the macroinvertebrate sample at 99UM058 that are tolerant and intolerant to low dissolved oxygen.
Percentile analysis was performed using all other MIBI Class 5 samples collected by MPCA (n=1,046). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Date (total taxa)	**Very Intolerant**		**Intolerant**		**Tolerant**		**Very Tolerant**	
	Taxa richness	Percentile	Taxa richness	Percentile	Taxa richness	Percentile	Taxa richness	Percentile
9/8/1999 (45)	2	19.9	5	37.7	5	53.1	1	31.5
8/13/2015 (41)	1	6.7	4	28.3	7	73.6	1	31.5
8/30/2016 (45)	1	6.7	2	9.2	6	63.7	0	0

WID Summary

In summary, the primary stressor to aquatic life in WID -652 is streamflow alteration and lack of habitat. The change in streamflow pattern has degraded and even eliminated habitat by causing bank erosion and channel incision. Longitudinal connectivity is also a stressor to some fish as a result of the frequently hypereutrophic conditions of Little Rock Lake and the Sartell WMA dam height, which varies. Stressors found to be inconclusive are suspended sediment, nitrate toxicity, eutrophication, and low DO.

3.5.2. Little Rock Creek (lower) – WID 07010201-653

Aquatic Life Impairment History

WID -653 was listed as impaired for aquatic life due to a lack of coldwater fish assemblage in 2010; the WID number was -548 at the time. In 2018 it was changed to -653 to separate it from the upstream, warmwater segment of Little Rock Creek (WID -652). At the time of this writing, WID -653 is a coldwater (class 2A) use, and has been assessed as impaired for aquatic life for not meeting the standards of a class 2A water for DO, fishes bioassessment, and macroinvertebrates bioassessment.

A stressor identification study was completed in 2009 to determine the cause of the original aquatic life impairment, which did not include a macroinvertebrate assessment. As a result of the findings, TMDLs were written for temperature, DO, and nitrate. Below is an excerpt from page 34 of the SID report, summarizing the results. Stressor identification was performed on this reach again in 2017-2019 to include consideration of the biological data collected in 2015-2016.

Summary: Identification of stressors

Six main stressors were identified for Little Rock Creek, all of which were confirmed by the sufficiency of evidence analysis. They are listed below in order of priority:

- Flow alteration
- Temperature
- Sediment – deposited and bedded
- Dissolved oxygen/BOD
- Connectivity
- Predation of trout by pike and other warmwater piscivores”

Biological Data

There are eight biological sampling stations on this 13.3 mile long WID. Of 24 fish samples that are reportable and assessable, only one meets the FIBI Class 11 – Northern Cold Water impairment threshold (Table 62). Of the seventeen macroinvertebrate samples that are reportable and assessable, eight meet the MIBI Class 9 – Southern Cold Water impairment threshold. While more MIBI scores meet their respective thresholds than do FIBI scores, they both have the lowest average score at 07UM070 and the highest average score at 07UM071, possibly indicating where stressors are acting the strongest.

Table 62. IBI data from all biological stations on the lower reach of Little Rock Creek (WID 07010201-653).

		Fish IBI			Macroinvertebrate IBI		
Station	Date	Class†	Impairment Threshold	Score	Class†	Impairment Threshold	Score
07UM070	7/25/2007	11	35	11	-	-	-
	7/2/2008	11	35	10	-	-	-
	6/30/2015	11	35	5	-	-	-
	8/13/2015	-	-	-	9	43	9
03UM110	7/30/2008	11	35	8	-	-	-
	7/2/2015	11	35	20	-	-	-
	8/13/2015	-	-	-	9	43	27
	6/29/2016	11	35	17	-	-	-
	8/30/2016	-	-	-	9	43	28
07UM071	8/12/2008	11	35	31	-	-	-
	7/30/2015	11	35	31	-	-	-
	8/13/2015	-	-	-	9	43	64
	7/27/2016	11	35	30	-	-	-
	8/30/2016	-	-	-	9	43	64
82UM001	8/12/2008	11	35	21	-	-	-
	6/25/2015	11	35	21	-	-	-
	8/13/2015	-	-	-	9	43	64
	7/27/2016	11	35	38	-	-	-
	8/30/2016	-	-	-	9	43	61
07UM072	8/7/2007	-	-	-	9	43	37
	8/13/2008	11	35	25	-	-	-
	7/30/2015	11	35	10	-	-	-
	8/25/2015	-	-	-	9	43	56
	7/27/2016	11	35	28	-	-	-
	8/31/2016	-	-	-	9	43	71
92UM001	8/13/2008	11	35	18	-	-	-
	6/24/2015	11	35	28	-	-	-
	8/25/2015	-	-	-	9	43	26
	7/26/2016	11	35	22	-	-	-
	9/14/2016	-	-	-	9	43	60
07UM073	8/7/2007	-	-	-	9	43	31
	8/18/2008	11	35	25	-	-	-
	6/24/2015	11	35	35	-	-	-
	8/25/2015	-	-	-	9	43	30
	7/26/2016	11	35	31	-	-	-
	8/10/2016	-	-	-	9	43	27
75UM001	8/19/2008	11	35	15	-	-	-
	6/24/2015	11	35	40	-	-	-
	8/25/2015	-	-	-	9	43	35
	7/6/2016	11	35	32	-	-	-
	8/10/2016	-	-	-	9	43	54

†FIBI Class: (11) Northern Coldwater
MIBI Class: (9) Southern Coldwater

Stressor Data

-Temperature

The 2009 SID report concluded that temperature was a stressor to the fish community; temperatures often exceeded the “threat” and “critical” temperature thresholds for brown trout, 18.3°C and 24°C, respectively, based on values from Wehrly *et al.* (2007). The 2008 July mean temperatures in the report from seven sites on Little Rock Creek were in the range of 16.02 – 18.73°C, except one site: 75UM001, which was 20.70°C. Continuous temperature loggers were deployed during the 2015 monitoring season at six locations on WID -653, and five of them were repeated in 2016 (Table 63). The range of July mean temperatures measured in 2015 and 2016 (19.6 - 23.3°C) was higher than in 2008.

Based on recent temperature data from 2015-2016, temperature is still a stressor to aquatic life in WID -653. Some sites have temperatures in the “stress” range for >50% of the deployment time. At two sites where the “% Stress” is lowest, 07UM071 and 82UM001, the IBI scores tend to be higher than at other sites. This pattern is not 100% consistent across all sites. For example, site 03UM110 featured the second-worst IBI score averages for both fish and macroinvertebrates, but had a “% Stress” range of 8.7-13.4%, which is only 1-2% more than 07UM071. While temperature is a stressor in this WID, other stressors are also affecting the fish and macroinvertebrate communities.

Table 63. Summary metrics of continuous temperature data from biological monitoring stations on WID -653. Temperature shown in degrees Celsius. The "% Stress/Growth/Lethal" represents the percent of time during the deployment that temperature was in the associated range. Sites are grouped by cell color.

Biological Station (year)	**July (Avg Max)**	**August (Avg Max)**	**Summer (Avg Max)**	**% Stress (20.1-25°C)**	**% Growth (7.9-20°C)**	**% Lethal (>25°C)**
07UM070 (2015)	21.6	19.4	19.1	23.3	76.7	0
03UM110 (2015)	20.6	17.9	18.9	8.7	91.3	0
03UM110 (2016)	20.6	19.4	19.7	13.4	86.6	0
07UM071 (2015)	19.7	17.1	18.2	6.8	93.2	0
07UM071 (2016)	20.0	19.0	15.9	12.0	88.0	0
82UM001 (2015)	19.6	17.3	18.2	6.6	93.4	0
82UM001 (2016)	20.1	19.1	19.0	12.9	87.1	0
07UM073 (2015)	23.3	20.1	21.5	54.4	45.6	0
07UM073 (2016)	23.0	21.2	22.1	56.7	42.0	1.3
75UM001 (2015)	22.5	19.6	20.9	51.5	48.5	0
75UM001 (2016)	22.0	20.6	21.2	48.9	51.1	0

-Longitudinal Connectivity

As discussed in section 3.5.1. on WID -652, lack of connectivity was found to be a stressor in the 2009 SID report, and persists to the present day as a minor stressor to the fish community in WID -653. The primary connectivity barriers are the eutrophic conditions of Little Rock Lake and the Sartell WMA dam. See the *Longitudinal Connectivity* section in 3.5.1. for further details and discussion.

-Streamflow

Findings from the 2009 SID report show that streamflow alteration is a stressor to aquatic life, particularly as a driver of excess bedded sediment. Streamflow alteration was investigated as a stressor to aquatic life for this study, but due to the existing SID publication and time limitations of this project, the analysis is relatively brief. Stream discharge data was not analyzed to assess changes in streamflow pattern for this SID project. Rather, the effects of streamflow alteration on the geomorphic state of the channel, and subsequent habitat changes, were investigated.

Minnesota DNR Region 3 Clean Water staff conducted geomorphic analyses on WID -653, approximately 300ft upstream of Nature Rd. It was concluded that the stream here is between an E and C stream type; it is unstable and exhibits active bank erosion (Figure 85). However, it was also noted that riffle and pool habitat was better here than upstream at 99UM058 on WID -652. As stated for WID -652, the unstable, transitional state of the stream is a response to a change in the watershed's hydrology, riparian cover, land use, and/or connectivity.

Figure 85. Bank erosion observed during geomorphic survey upstream of Nature Rd. on 10/21/2015.

-Habitat

In 2015 and 2016, habitat was assessed using the MSHA three or four times at each biological station. Older MSHA data also exists, but is not discussed for purposes of this SID analysis. Total 2015-2016 MSHA scores were averaged by site (Table 64). Sites 07UM071 and 82UM001 have the best total scores, falling in the "Good" range (>65). All other sites are in the "Fair" range (45-65). While the poorest scoring category varies by site, all sites scored poorly in the Substrate and Channel Morphology categories. The closest score to the maximum is 18.35 for Substrate and 25.5 for Channel Morphology, both at 07UM071, which also yields the highest average of FIBI and MIBI scores.

The MSHA data suggests that poor habitat is a systemic stressor in Little Rock Creek. Areas near sites 07UM071 and 82UM001 have been able to maintain better coarse substrate and depth variability, likely due to the steeper stream gradient in this part of the watershed, which more effectively transports fine sediment. The 2009 SID report also found that degraded habitat, primarily embedded coarse substrate, was a stressor.

Table 64. Average of Minnesota Stream Habitat Assessment (MSHA) scores for all MSHAs conducted in 2015 and 2016 on WID -653.
The maximum possible points (max) for each category is shown. Site gradient is shown in meters of elevation difference per kilometer of stream, estimated using LiDAR spatial data. Sites listed in up- to downstream order.

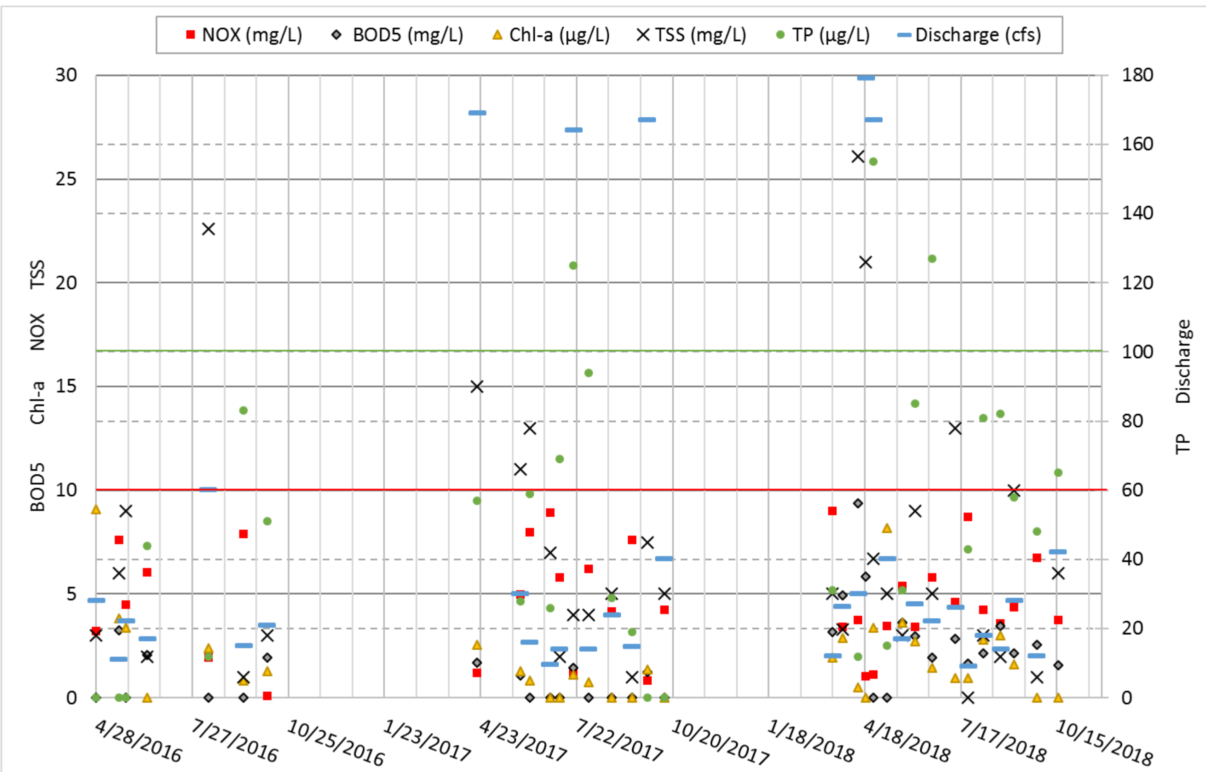
Biological Station	**Gradient** [m/km]	**Land Use** Max=5	**Riparian** Max=14	**Substrate** Max=28	**Cover** Max=18	**Channel Morphology** Max=35	**Total Score** Max=100
07UM070	1.22	0	10.5	12.85	15	14.5	52.85
03UM110	1.34	3.75	12.75	11.45	11.5	15.5	54.95
07UM071	1.53	1.25	11.63	18.35	16.75	25.5	73.48
82UM001	2.02	2.5	12.25	18.15	14.25	24.75	71.9
07UM072	1.17	1.88	12.5	12.3	11.75	14.5	52.93
92UM001	0.52	3.75	11.13	12.6	13.25	17	57.73
07UM073	0.00009	3	9.38	15.15	12.25	14.5	54.28
75UM001	0.64	3.75	11.25	13.85	8.5	14	51.35

-Suspended Sediment

The Benton County SWCD monitored various water chemistry parameters, including TSS, in Little Rock Creek at Benton County Road 40, just upstream of 92UM001 (EQUiS station S004-062), in April-October of 2016-2018 (Figure 86). Of the 34 data points collected, 25% of them exceed the statewide TSS standard of 10mg/L for class 2A waters. There are no associated volatile solids data to determine how much of the TSS can be attributed to sediment as opposed to volatile substances, such as algal cells and other organic material.

In lieu of volatile solids data, an analysis of Pearson correlation coefficients[3] was performed to determine if TSS patterns were correlated with either TP or Chl-a patterns from the set of 34 samples. The absolute value of both coefficients ("r") was <0.2, suggesting that neither TP nor Chl-a are linearly correlated with TSS in that dataset. This analysis means that suspended sediment cannot be ruled out as a major contributor to the total suspended solids at this time.

Figure 86. Water chemistry results from Benton County SWCD monitoring of Little Rock Creek at CR40/160th St. NW, just upstream of 92UM001 (EQUiS station S004-062).
Samples were collected April-October of 2016-2018. Daily average discharge is shown in cubic feet per second (cfs), as measured at a MN DNR flow gaging station on Benton County Road 40 (CSG Site ID 15029002); 2017-2018 discharge is estimated, provisional data. The red line at NOX = 10mg/L represents the drinking water standard. The green line at TP = 100µg/L is the regional nutrient standard.



To further understand the nature of suspended material in Little Rock Creek, relevant data from 2016-2018 were plotted on hydrographs (Figure 87). The discharge data was obtained from MN DNR's Cooperative Stream Gaging (CSG) website from a flow monitoring station on Benton County Road 40 (Site ID 15029002). Some of the 2016 high flow values were coded as "Estimated," and the 2017-2018 discharge data were quality-coded as "Provisional" and should be considered as close estimations.

Three paired TSS+VSS samples were taken during the extreme high flow event that occurred starting July 12, 2016 (see Figure 87, top plot). On July 11, the daily average discharge was 77cfs, and on

[3] For information on the Pearson correlation coefficient, see: Wang, J. 2013. Pearson correlation coefficient. In: W. Dubitzky, O. Wolkenhauer, KH. Cho, and H. Yokota. (eds) Encyclopedia of Systems Biology. Springer, New York, NY.

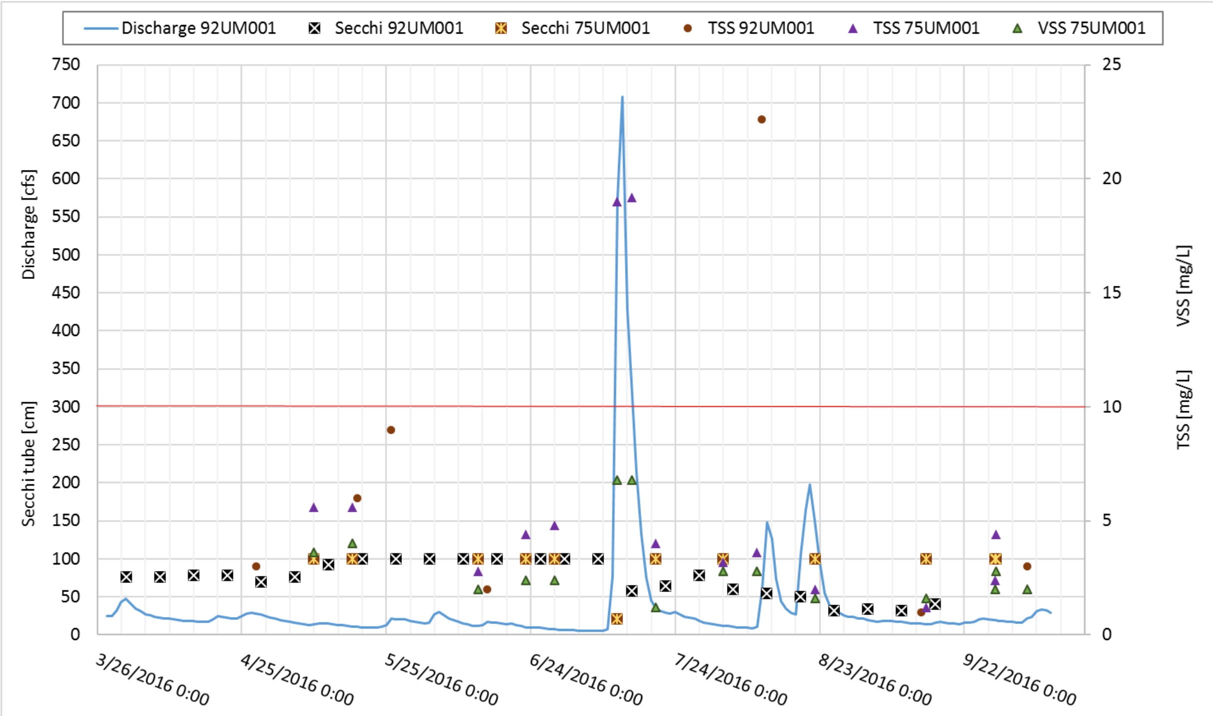
the 12th it jumped to 573cfs in response to an extreme rain event. Discharge peaked the following day, averaging 708cfs on July 13. The TSS sample taken on 7/12/2016 at 9:30AM at 75UM001 (most downstream station) was 19mg/L, and may not be the maximum concentration that occurred. On July 15, TSS at 75UM001 was still high, at 19.2mg/L, and by the 20th it had returned to baseflow levels of 4mg/L, with 1.2mg/L of VSS. Transparency measurements had also returned to baseflow levels, increasing from 21cm during the storm event to 100cm on 7/20/2016. However, at sites further upstream than 75UM001, which is below the Sartell WMA where fine sediments would settle out, TSS+VSS levels were still high on July 26-27 (Table 65).

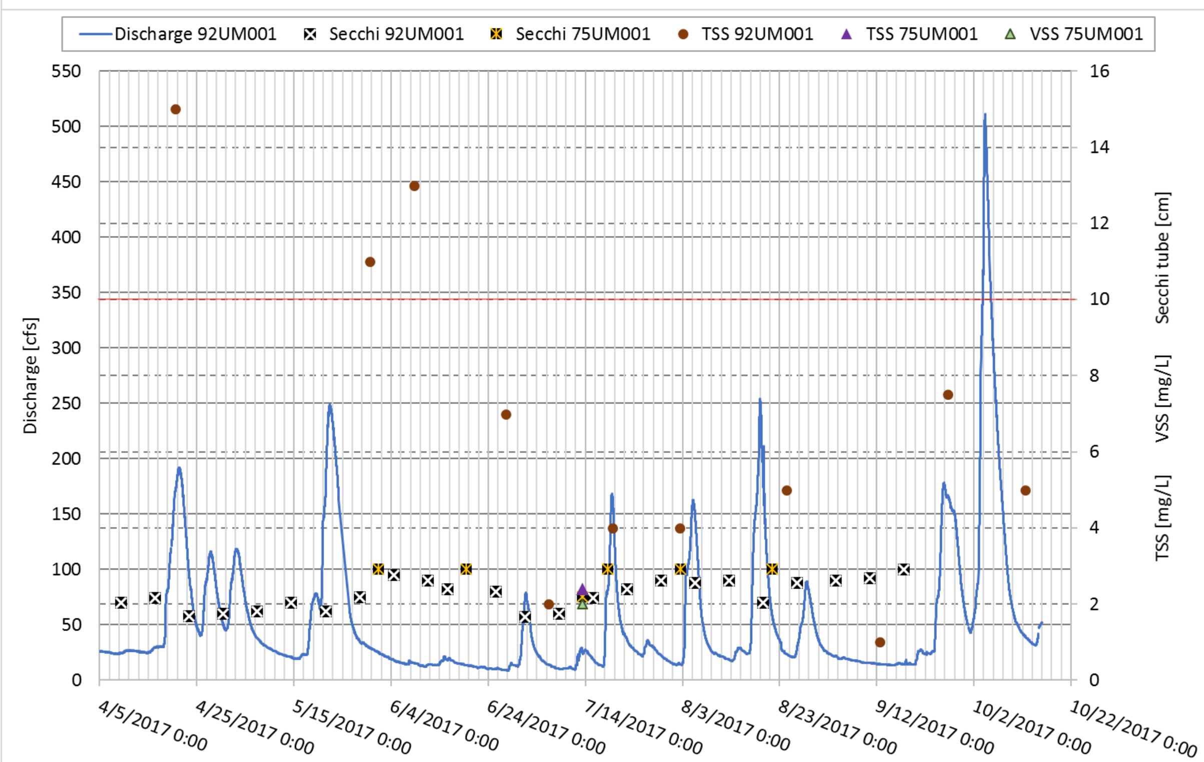
In 2017, the highest TSS measured at 92UM001 was 15mg/L when discharge was elevated in the spring (>130cfs) (see Figure 87, middle plot). Of note, TSS was not as high during similar flow events later in the year, which could be a result of the lack of vegetative cover in the watershed in April. Later in the year, multiple high flow events occurred July-October, when discharge was in the range of 160 to >250cfs. Six TSS samples were taken during this timeframe and all were <8mg/L. More specifically, TSS was 4mg/L on 7/19 when discharge peaked at 168cfs. Also, TSS was 5mg/L on 8/24, five days after an 8/19 event when discharge peaked in excess of 250cfs. However, two relatively high measurements were taken on 5/30/2017 (11mg/L) and 6/8/2017 (13mg/L) during baseflow conditions. It would be helpful to have volatile solids data to accompany these measurements, as algae may be comprising a large part of the TSS at baseflow and low-flow conditions.

The hydrograph/TSS plots from 2016 and 2017 indicate that problematic TSS levels (e.g., in excess of the statewide class 2A standard of 10mg/L) are more likely to occur in the spring, and can occur in the summer during extremely high flow events, such as in July 2016. A visual analysis of the 2018 plot (Figure 87, bottom) supports these findings as well.

Additional data collection would be helpful to characterize the duration of aquatic life exposure to high TSS. Additional data needed include paired TSS and TSVS (or VSS) measurements, and multiple samples within the timeframe of the rising and falling limbs of a hydrograph of typical spring and summer high-flow events, as well as baseflow conditions. This would help determine the duration of exposure of aquatic life to acute and chronic high TSS conditions, and how much of the TSS is sediment versus volatile solids.

Figure 87. Hydrographs and chemistry data from Little Rock Creek for select months in 2016 (top), 2017 (middle), and 2018 (bottom).
Discharge data was obtained from MN DNR's Cooperative Stream Gaging website from flow monitoring station on Benton County Road 40 (Site ID 15029002). The 2017-2018 discharge data were quality coded as "Provisional." The red line drawn at TSS = 10mg/L is the statewide standard for class 2A streams. The maximum Secchi tube reading is 100cm.





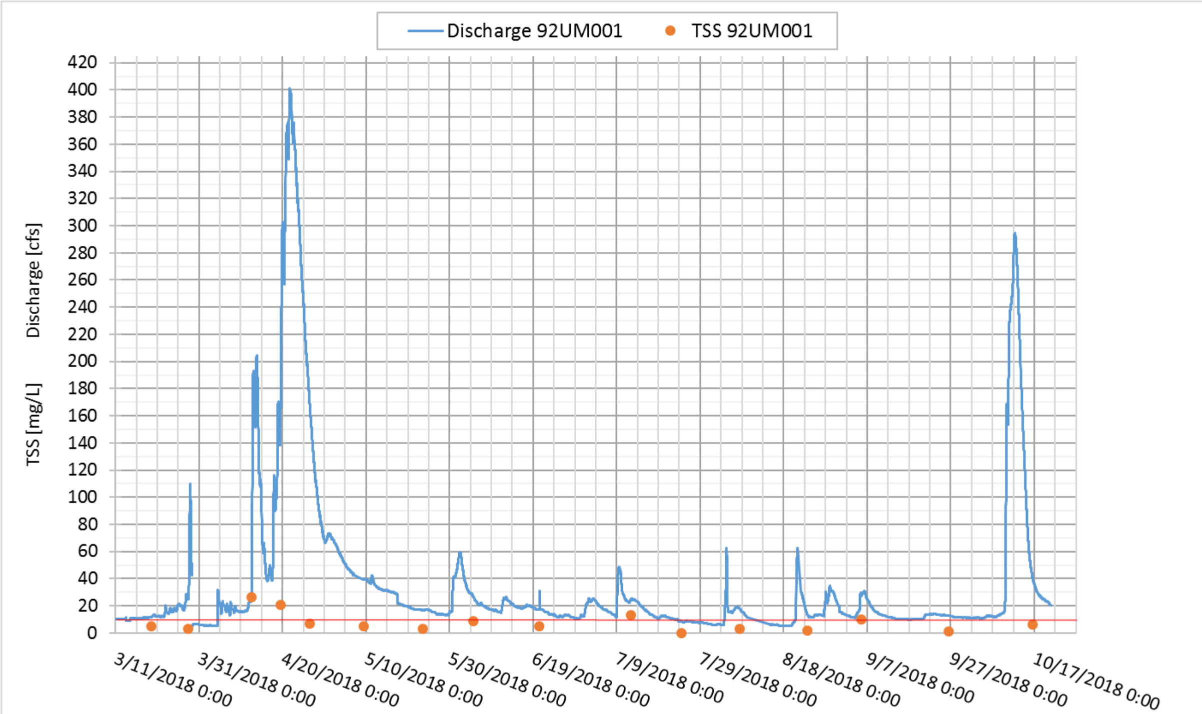


Table 65. Total suspended solids (TSS) and volatile suspended solids (VSS) chemistry results from samples taken prior to biological sampling in 2016.

Station	**Date**	**TSS** [mg/L]	**VSS** [mg/L]
07UM071	7/27/2016	14	6.4
82UM001	7/27/2016	9.6	4.8
07UM072	7/27/2016	34	10
92UM001	7/26/2016	13	4.8

The Secchi tube measurement associated with the state TSS standard of 10mg/L is 55cm. A dataset of Secchi tube readings was collected at CR239/15th Ave. NW, just upstream of 07UM073 (EQUiS station S005-397). The dataset contains measurements from April-September in 2008 and 2010-2016. Of the 136 total measurements, twelve are less than 55cm, and 56 are in the range of 56-99cm, the other 68 data points are the maximum possible measurement of >100cm. The Secchi tube data do not suggest that TSS is a stressor in the area in which the measurements were collected. However, this Secchi tube dataset does not capture important nuances in the mechanism of a TSS stressor, such as the duration of decreased transparency conditions. Also, stream transparency can be reduced by things besides TSS, such as iron and other metals naturally occurring in groundwater.

The conditional probability that Little Rock Creek would meet the TSS standard based on the fish communities sampled is mediocre, 57±2% at all sites (Table 66). The macroinvertebrate community tolerance richness metrics, such as in do not give a clear signal as to whether or not high TSS is affecting the community (data not shown).

Table 66. Conditional probabilities (percent chance) that WID -653 would meet the TSS and DO standards based on the fish communities sampled in 2015 and 2016.

Biological Station	TSS 2015 [%]	TSS 2016 [%]	DO 2015 [%]	DO 2016 [%]
07UM070	55	-	22	-
03UM110	56	57	2	11
07UM071	58	57	74	60
82UM001	58	56	48	63
07UM072	56	56	14	17
92UM001	57	56	32	46
07UM073	57	57	22	9
75UM001	59	56	41	65

Measurements of elevated TSS and low stream transparency suggest the possibility of a TSS stressor, but additional data are needed to clarify. Biological metrics do not clearly indicate overall community tolerance or intolerance to TSS. Whether suspended sediment is a stressor or not in WID - 653 is inconclusive.

-Nutrients

Much of the available chemistry data for nutrients was presented with other monitoring data in in the preceding sections.

Nitrogen

WID -653 is listed as impaired for its drinking water use due to high nitrate levels, and a TMDL has been completed. However, aquatic life can be stressed by nitrate concentrations less than what the drinking water standard is (10mg/L). Nitrate was investigated as a stressor, but due to the existing TMDL and time limitations of this project, the analysis is relatively brief. For information on nitrogen trends over time in the Little Rock Creek watershed, see the Mississippi River-Sartell Watershed Restoration and Protection Strategies (WRAPS) report.

In the 2009 SID report, it was concluded that nitrate toxicity was a likely stressor to aquatic life based on high NOX concentrations, especially in the upstream areas, and the decline of nitrate-sensitive fish species abundance. Nitrate concentrations measured at the time of fish sampling in 2015 and 2016 were not as high as those reported in the 2009 SID study (Table 67), nor were any of the 2016-2018 samples taken by the Benton SWCD (see Figure 86). Similar to the 2009 SID study, the highest NOX concentrations observed in 2015-2016 were at the upstream locations. The consistency of NOX in excess of 4.0mg/L implies that chronic NOX exposure is likely a systemic stressor to the most sensitive species of both fish and macroinvertebrates that are/were in WID -653 (Camargo *et al.* 2005).

The macroinvertebrate tolerance richness metrics show that all sites have much more taxa that are very tolerant to NOX than are intolerant, especially at the two uppermost sites (07UM070 and 03UM110) (Table 68). However, in using percentiles to put the tolerance richness in context with all other MIBI Class 9 samples in the state, some sites (e.g. 07UM073, 92UM001) have more intolerant taxa than most of all other samples, while simultaneously having more tolerant taxa than >80% of all other sites. High NOX does appear to have some influence on the macroinvertebrate community composition, but it is unclear if this is a truly limiting stressor. More telling details might be found in an analysis of community evenness across the tolerance spectrum (e.g. how many *individuals* in the community are intolerant of NOX).

Phosphorus

Only three of the 34 TP samples collected upstream of 92UM001 (S004-062) in April-October of 2016-2018 were above the regional standard of 0.100mg/L (see Figure 86. Results from chemistry samples taken prior to the biological sampling events show elevated TP on July 26 and 27th, 2016 (Table 67). Pictures of the stream from those days show that the stream was more turbid than it was during the 2015 samples. It is likely that the turbidity and elevated TP levels are a lingering result of the extreme rain event that occurred on July 12, 2016. The hydrograph of Little Rock Creek at CR40 (upstream of 92UM001) shows that the discharge was still somewhat elevated on July 26-27th (see Figure 87). Despite the high TP measured in July 2016, no TP data more recent than 2008 was found that indicates excessive phosphorus is triggering eutrophication and stressing aquatic life. However, low DO is occurring and is a stressor to aquatic life (see *Dissolved Oxygen* section), and could be caused by eutrophication. High TP, and thus eutrophication, is an inconclusive stressor at this time.

Table 67. Chemistry data taken prior to the biological samples on WID -653.

Station	Date	Time	**NOX** [mg/L]	**NH4** [mg/L]	**TP** [mg/L]	**DO** [mg/L]
07UM070	6/30/2015	10:16	11.6	0.100	0.084	7.76
	8/13/2015	10:05				8.54
03UM110	7/2/2015	14:12	6.38	0.114	0.066	9.42
	8/13/2015	11:00				9.27
	6/29/2016	16:56	6.96	0.100	0.074	8.67
	8/30/2016	09:45				7.11
07UM071	7/30/2015	08:50	4.35	0.100	0.086	--
	8/13/2015	12:05				10.03
	7/27/2016	13:06	3.70	0.080	0.249	6.9
	8/30/2016	14:16				7.94
82UM001	6/25/2015	09:30	4.8	0.050	0.059	8.35
	8/13/2015	13:20				10.36
	7/27/2016	08:26	4.4	0.060	0.263	7.37
	8/30/2016	16:11				8.27
07UM072	7/30/2015	11:55	4.72	0.100	0.083	--
	8/25/2015	15:01				10.15
	7/27/2016	14:06	4.4	0.060	0.282	7.65
	8/31/2016	15:21				8.57
92UM001 (S004-062)	6/24/2015	16:39	5.6	0.050	0.076	8.33
	8/25/2015	12:56				10.15
	7/26/2016	09:56	4.5	0.060	0.218	7.14
	9/14/2016	15:00				9.5
07UM073	6/24/2015	12:36	4.8	0.060	0.047	10.41
	8/25/2015	11:12				9.54
	7/26/2016	14:12	4.8	0.050	0.129	10.63
	8/10/2016	10:35				5.33
75UM001 (S004-061)	6/24/2015	08:21	5.0	0.060	0.061	9.14
	8/25/2015	09:56				9.64
	7/6/2016	17:40				8.07
	8/10/2016	09:12				7.55

Table 68. Number of taxa ("taxa richness") found in the 2015-2016 macroinvertebrate samples on WID -653 that are tolerant and intolerant to inorganic nitrogen (NOX). Sites are listed in an up- to downstream order. Percentile analysis was performed using all other MIBI Class 9 samples collected by MPCA (n=399). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Biological Station	Sample year (total taxa richness)	Very Intolerant Taxa richness - Percentile	Intolerant Taxa richness - Percentile	Tolerant Taxa richness - Percentile	Very Tolerant Taxa richness - Percentile
07UM070	2015 (54)	0 – 0%	2 – 71.3%	24 – 94.4%	16 – 88.4%
03UM110	2015 (38)	0 – 0%	3 – 85.4%	15 – 39.6%	10 – 39.9%
	2016 (37)	0 – 0%	1 – 39.4%	14 – 32.9%	9 – 33.6%
07UM071	2015 (47)	1 – 89.4%	2 – 71.3%	12 – 20.6%	7 – 15%
	2016 (60)	2 – 96.7%	8 – 99.7%	18 – 63.3%	13 – 69%
82UM001	2015 (43)	1 – 89.4%	5 – 97.2%	14 – 32.9%	11 – 50%
	2016 (59)	2 – 96.7%	6 – 98.2%	19 – 72.1%	14 – 78.1%
07UM072	2015 (34)	0 – 0%	2 – 71.3%	12 – 20.6%	8 – 23.1%
	2016 (34)	0 – 0%	2 – 71.3%	9 – 4.7%	6 – 9.2%
92UM001	2015 (59)	0 – 0%	3 – 85.4%	29 – 99.2%	20 – 98.9%
	2016 (52)	0 – 0%	4 – 93.9%	18 – 63.3%	11 – 50%
07UM073	2015 (41)	0 – 0%	1 – 39.4%	13 – 27.1%	9 – 33.6%
	2016 (66)	1 – 89.4%	7 – 99.4%	21 – 81.4%	16 – 88.4%
75UM001	2015 (59)	0 – 0%	2 – 71.3%	22 – 86.6%	11 – 50%
	2016 (46)	0 – 0%	2 – 71.3%	10 – 10.3%	6 – 9.2%

-Dissolved Oxygen

WID -653 is currently listed as impaired for aquatic life due to low DO and a TMDL has been completed. Low DO was investigated as a stressor to aquatic life, but due to the existing TMDL and time limitations of this project, the analysis is relatively brief. Much of the available DO data was presented with other monitoring data in the preceding sections (Table 66 and Table 67).

The likelihood that this WID would meet the DO standard of 7mg/L based on the fish communities sampled is low-mediocre at most of the sites (see Table 66). The macroinvertebrate community tolerance richness metrics show that low DO is likely a stressor at sites 07UM070 and -073, and that it may not be a stressor at 07UM072 and 82UM001 (Table 69). Dissolved oxygen levels are likely higher at sites 07UM072 and 82UM001 because the steeper stream gradients here (and at 07UM071) facilitate turbulence and incorporation of atmospheric oxygen. Tolerance richness data for the other sites are more ambiguous and do not clearly refute or confirm the presence of a low DO stressor.

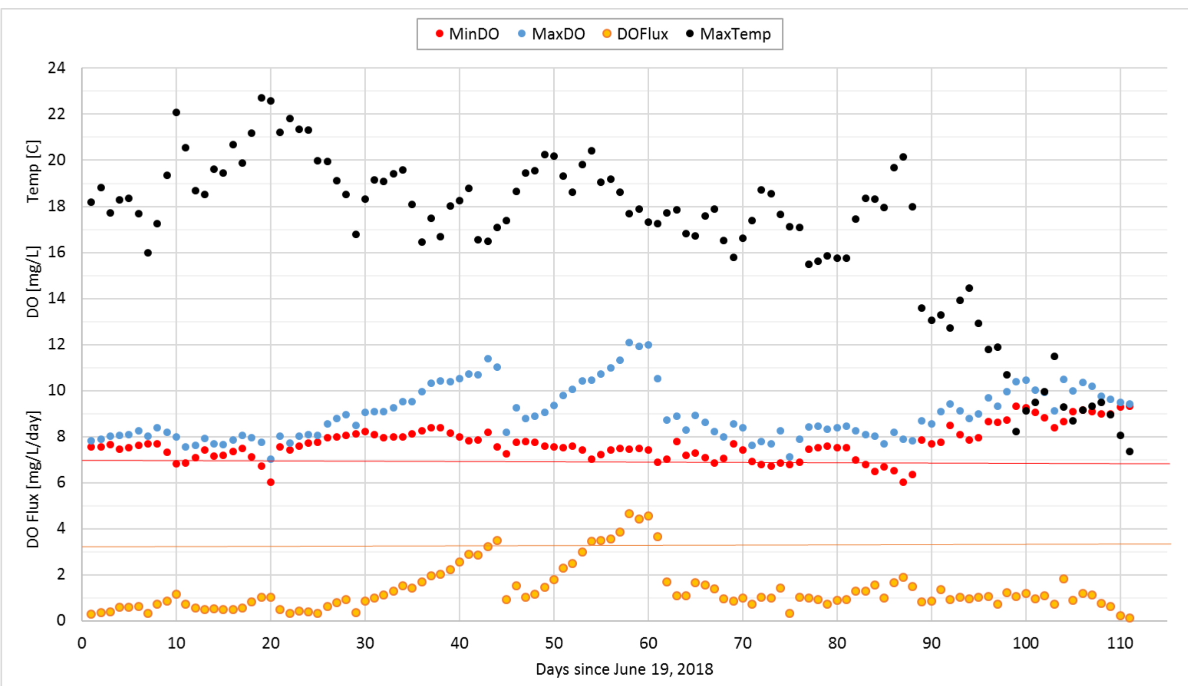
Table 69. Number of taxa in the 2015-2016 macroinvertebrate samples on WID -653 that are tolerant and intolerant to low DO. Sites are listed in an up- to downstream order.
Percentages are the percentile of that value among all other MIBI Class 9 samples collected by the MPCA (n=399). Where the percentile is above the median (>50%) the cell is highlighted green for intolerance (which is "good") or red for tolerance (which is "bad").

Biological Station	**Sample year** (total richness)	**Very Intolerant** Taxa richness - Percentile	**Intolerant** Taxa richness - Percentile	**Tolerant** Taxa richness - Percentile	**Very Tolerant** Taxa richness - Percentile
07UM070	2015 (54)	6 – 8.7%	3 – 3.2%	5 – 81.6%	1 – 48.4%
03UM110	2015 (38)	8 – 26.3%	4 – 8.2%	1 – 17%	0 – 0%
	2016 (37)	9 – 40.7%	5 – 21.3%	3 – 56.7%	2 – 76.3%
07UM071	2015 (47)	16 – 96.9%	8 – 71.3%	1 – 17%	1 – 48.4%
	2016 (60)	15 – 95.2%	7 – 54.5%	4 – 71.8%	0 – 0%
82UM001	2015 (43)	15 – 95.2%	7 – 54.5%	1 – 17%	0 – 0%
	2016 (59)	20 – 99.4%	11 – 96.4%	1 – 17%	1 – 48.4%
07UM072	2015 (34)	10 – 55%	7 – 54.5%	0 – 0%	0 – 0%
	2016 (34)	12 – 76.3%	8 – 71.3%	1 – 17%	0 – 0%
92UM001	2015 (59)	10 – 55%	7 – 54.5%	3 – 56.7%	0 – 0%
	2016 (52)	13 – 84.4%	8 – 71.3%	6 – 89.4%	1 – 48.4%
07UM073	2015 (41)	3 – 1.2%	1 – 0.5%	7 – 93.9%	5 – 98.4%
	2016 (66)	7 – 15%	3 – 3.2%	10 – 99.4%	7 – 100%
75UM001	2015 (59)	13 – 84.4%	9 – 84.4%	8 – 96.2%	2 – 76.3%
	2016 (46)	10 – 55%	5 – 21.3%	1 – 17%	0 – 0%

In 2018, Benton SWCD staff deployed a continuously measuring data logger from June 20 to October 11 at CR40, just upstream of 92UM001 (S004-062) (Figure 88). The results show that DO dipped below the state standard on two days in June, three in July, one in August, and eight in September. The daily DO flux does not seem to indicate eutrophic conditions, which would be ≥3.5mg/L/day, except August 13-20th.

Also at site 92UM001 (S004-062), results from Benton SWCD monitoring show twelve BOD5 concentrations in excess of 2mg/L (see Figure 86), which may suggest eutrophic conditions and/or excessive inputs of an organic pollutant. In an analysis of Pearson correlation coefficients of the Benton SWCD's dataset, BOD5 was linearly correlated with TKN (r=0.596) but not with TP (r=0.344), Chl-a (r=-0.083), or NOX (r=-0.135). Because TKN is a measure of the combined amount of organic nitrogen and ammonia, which has a positive linear relationship with BOD in this case, it is possible that the elevated oxygen demand is a result of the decay of excessive inputs of some form of organic pollutant, such as human/animal waste or milkhouse waste.

Figure 88. Daily minimum/maximums from continuous measurements of dissolved oxygen and temperature at Benton CR40 (upstream of 92UM001).
"DO Flux" is the difference between the daily maximum and minimum DO measurement. Red line at DO = 7mg/L is the class 2A standard. Orange line drawn at DO Flux = 3.5mg/L/day is the "response variable" standard when considering eutrophication impairment. Data collected by Benton SWCD.



In 2016 and 2017, MPCA staff made DO measurements at 75UM001 (S004-061), several of which were below 7mg/L (Table 70). Of the DO measurements taken right before the 2015-2016 biological samples, one was below the standard, at 07UM073 in 2015 (see Table 67).

The DO measurements presented here show that DO in WID -653 has dropped below the standard in 2016-2018. Also, the effects of low DO are apparent in the macroinvertebrate and fish community compositions. While additional continuous data would be ideal, the existing DO impairment and data presented here suggest that low DO is still a stressor to aquatic life in WID -653. The cause of low DO was not analyzed, and could be driven by warm temperatures, lack of streamflow, high BOD, and/or eutrophic conditions. Of those, warm temperatures, streamflow alteration, and high BOD were documented in this report. The occurrence of eutrophication remains inconclusive.

Table 70. Instantaneous DO measurements at 75UM001 (EQUiS site S004-061).

Date	**Time**	**DO** [mg/L]
5/10/2016	14:00	9.47
5/18/2016	10:15	10.81
6/13/2016	9:45	6.8
6/23/2016	9:45	7.49
6/29/2016	9:00	8.16
7/12/2016	9:30	4.23
7/20/2016	9:00	5.55
7/27/2016	15:39	7.26
8/3/2016	8:55	7.25
8/22/2016	9:45	3.92
8/29/2016	8:45	6.51
9/14/2016	13:45	8.98
9/28/2016	10:15	9.0
6/1/2017	10:30	9.97
6/19/2017	10:30	7.69
7/13/2017	9:45	6.01
7/18/2017	13:20	5.8
8/2/2017	13:00	7.29
8/21/2017	11:45	5.39

WID Summary

Of the stressors investigated, those confirmed include high temperature, lack of connectivity, streamflow alteration, lack of habitat, and low DO. Inconclusive stressors are nitrate toxicity, high TSS and TP (eutrophication). The primary stressor is streamflow alteration, which is driving the warm temperatures, lack of connectivity, lack of habitat, and likely the low DO. These findings agree with the

2009 SID report, summarized at the beginning of this WID section. Species interactions, such as the predation of trout by pike and other warmwater piscivores, were not analyzed in this study, though it was found to be a stressor in 2009.

3.5.3. Bunker Hill Creek – WID 07010201-511

Bunker Hill Creek is a tributary to Little Rock Creek. The stream begins east of Little Rock, Minnesota and flows southwest until its confluence with Little Rock Creek near CR40. The total drainage area of Bunker Hill Creek is 16.7mi^2. WID -511 begins at the county line between Morrison and Benton counties, and continues for 4.7 stream miles to the confluence with Little Rock.

Biological Data

There is one biological sampling station on WID -511, 15UM210, which is located on the upstream side of Benton CR56, near the Bunker Hill outlet to Little Rock Creek. Station 15UM210 was sampled twice for both fish and macroinvertebrates (Table 71). All four IBI scores failed to pass the general use threshold. WID -511 is a coldwater (class 2A) stream, and is impaired for aquatic life due to nonsupport of the fish and macroinvertebrate communities. Similar to WID -652, the MIBI score declined sharply between 2015 and 2016, while the FIBI remained virtually the same.

Table 71. IBI scores at site 15UM210 on Bunker Hill Creek (WID 07010201-511).

		Fish IBI			Macroinvertebrate IBI		
Station	**Date**	**Class†**	**Impairment Threshold**	**Score**	**Class†**	**Impairment Threshold**	**Score**
15UM210	7/2/2015	11	35	15	-	-	-
	8/25/2015	-	-	-	8	32	30
	6/29/2016	11	35	16	-	-	-
	8/30/2016	-	-	-	8	32	13

†FIBI Class: (11) Northern Coldwater
MIBI Class: (8) Northern Coldwater

Macroinvertebrates

The MIBI metrics show that the sharp decline in MIBI total score from 2015 to 2016 is largely due to an increase in the proportion of collector-gatherer and tolerant taxa, plus a decrease in POET taxa presence, especially Odonates and other predators (Table 72, see highlighted rows). Also, there were eleven fewer taxa overall in 2016 than in 2015. The habitat types sampled were almost identical between the two years; all sampling efforts were divided evenly among three habitat types: rocks in the riffle/run areas, banks (undercut/overhanging vegetation), and wood/root wads.

Both years, the macroinvertebrate community was dominated by the caddisfly genus *Hydropsyche*. In 2015, 35% of the *Hydropsyche* individuals could not be identified to species, and therefore are of an unknown tolerance. While many of the species in the Hydropsyche genus are considered tolerant, some are cold water obligates and could be a sign of a healthy coldwater stream. In 2016, all of the 66 *Hydropsyche* individuals were the tolerant species *H. betteni*, and 27 individuals were reported as the Hydropsychidae family, and could be in the *Hydropsyche*, *Cheumatopsyche*, or other genus. The co-dominance of the 2016 sample by *H. betteni* and *Cheumatopsyche* is a sign of disturbance, as both are tolerant of a variety of stressors.

Some of the sensitive taxa sampled include the coldwater dweller *Beatis flavistriga* (1 in 2015 and 8 in 2016), plus some *Beatis* individuals that could not be identified to species and may or may not be cool/coldwater dwellers. In 2015, the intolerant caddisfly *Helicopsyche borealis* was found in substantial numbers, but none were sampled in 2016. However, *H. Borealis* can withstand moderate embeddedness because the large pebble cases they make are not suitable for tight crevices, so they tend to live on top of rocks. And lastly, two genera of riffle beetles in the Elmidae family, *Optioservus* and *Stenelmis*, were observed in both samples and are indicators of good flow over coarse substrate.

Table 72. Macroinvertebrate IBI metric scores for 15UM210.
Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown.

MIBI Class 8 Metric	Raw Metric Result		Re-scaled IBI Score	
	8/25/2015	8/30/2016	8/25/2015	8/30/2016
Collector-gathererChTxPct *Percent of collector-gatherer taxa*	29.31%	42.50%	7.06	0
HBI_MN *Measure of pollution based on MNtol values*	6.71	7.08	1.27	0
Intolerant2 *Number of taxa with a MNtol values ≤ 2*	1	1	0.93	0.93
LongLivedChTxPct *Percent of long-lived taxa*	12.07%	12.50%	3.37	3.61
NonInsectTxPct *Percent of insect taxa (versus non-insects, such as snails)*	12.07%	15%	5.29	3.51
OdonataChTxPct *Percent of Odonata taxa in sample*	3.45%	2.50%	4.01	2.91
POET *Number of Plecoptera, Odonata, Ephemeroptera, and Trichoptera taxa in sample*	19	12	5.81	2.11
Predator *Number of predator taxa*	7	3	2.02	0
VeryTolerant2ChTxPct *Percent of taxa with a MNtol values ≥ 8*	31.03%	32.50%	0.68	0
Total (MIBI Score)	--	--	30.44	13.07

The tolerance richness metrics of the macroinvertebrate community show that excessive nutrient inputs are affecting the community composition, as the samples contained a considerably larger proportion of NOX- and TP-tolerant taxa, even in the context of all other MIBI Class 8 samples (Table 73). Two other stressors are also suggested by the tolerance richness metrics: embedded substrate and TSS, though the tolerance composition is more evenly distributed for these stressors than for the nutrients.

Table 73. Number of taxa ("taxa richness") in the macroinvertebrate samples at 15UM210 that are tolerant and intolerant to specific stressors.
Percentile analysis was performed using all other MIBI Class 8 samples collected by MPCA (n=537). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Stressor	Very Intolerant Taxa richness - Percentile		Intolerant Taxa richness - Percentile		Tolerant Taxa richness - Percentile		Very Tolerant Taxa richness - Percentile	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Low DO	4 – 12.5%	4 – 12.5%	9 – 17.3%	9 – 17.3%	2 – 41.9%	5 – 75.5%	0 – 0%	0 – 0%
Depth of Fines	6 – 28.3%	5 – 22.5%	12 – 33.9%	9 – 22.5%	4 – 58.3%	4 – 58.3%	2 – 70.1%	2 – 70.1%
Embedded Substrate	1 – 5.9%	2 – 13%	6 – 17.1%	6 – 17.1%	10 – 85.4%	6 – 64.1%	7 – 89.3%	6 – 83.3%
Total Suspended Solids (TSS)	2 – 16.6%	1 – 6.7%	4 – 10.6%	5 – 16.7%	10 – 87.6%	7 – 62.1%	5 – 94.4%	4 – 87.6%
Inorganic nitrogen (NOX)	1 – 8.7%	2 – 22.5%	4 – 9.5%	5 – 15.1%	28 – 100%	16 – 75.5%	19 – 99.6%	12 – 86.9%
Total phosphorus (TP)	1 – 4.6%	1 – 4.6%	2 – 1.8%	4 – 7.4%	10 – 91.4%	6 – 70.7%	5 – 90.4%	2 – 53.3%

Fishes

While the FIBI scores were poor for many of the metrics, the lowest-scoring metrics are those related to the presence of coldwater species (Table 74). The only coldwater fish sampled in Bunker Hill Creek were three brown trout in 2016; none were observed in 2015. Based on the fish samples of 2015 and 2016, the likelihood that WID -511 would meet the water quality standards for TSS is mediocre, and for DO it is good-fair (Table 75). These results have a similar pattern as observed in the macroinvertebrate tolerance richness metrics.

Table 74. Fish IBI metric scores from the samples at 15UM210. Poorest-scoring metrics highlighted in blue. Some metric results are re-scaled to calculate the final 0-100 IBI score. Both the raw metric results and re-scaled IBI scores are shown.

FIBI Class 11 Metric	Raw Metric Score		Re-scaled IBI Score	
	7/25/2015	6/29/2016	7/25/2015	6/29/2016
Cold *Number of coldwater species*	0	1	0	6.25
CWIntolerantPct *Percent intolerant individuals, specific to coldwater*	0.79%	0.36%	0.12	0.05
CWSensitiveTXPct_11Grad *Percent sensitive taxa, specific to coldwater, adjusted for gradient*	-27.76	-20.18	0	1.74
CWTolPct *Percent tolerant individuals in sample, specific to coldwater*	10.70%	16.43%	3.52	2.06
NestNoLithPct *Percent non-lithophilic, nest-building individuals*	11.76%	21.61%	4.26	2.41
OmnivoreTxPct *Percent of omnivorous taxa*	18.18%	16.67%	1.14	2.08
PercfmPct *Percent of Perciformes individuals*	10.83%	21.25%	3.70	1.45
PioneerTxPct *Percent of pioneer taxa*	27.27%	33.33%	2.27	0
FishDELTPct *Percent of individuals with deformities, eroded fins, lesions, or tumors*	0	0	0	0
Total (FIBI Score)	--	--	15	16

Table 75. Conditional probabilities (likelihood) that WID -511 would meet the TSS and DO standards based on the fish communities sampled in 2015 and 2016.

	TSS 2015 [%]	**TSS 2016** [%]	**DO 2015** [%]	**DO 2016** [%]
15UM210	58	56	85	75

Stressor Data

-Temperature

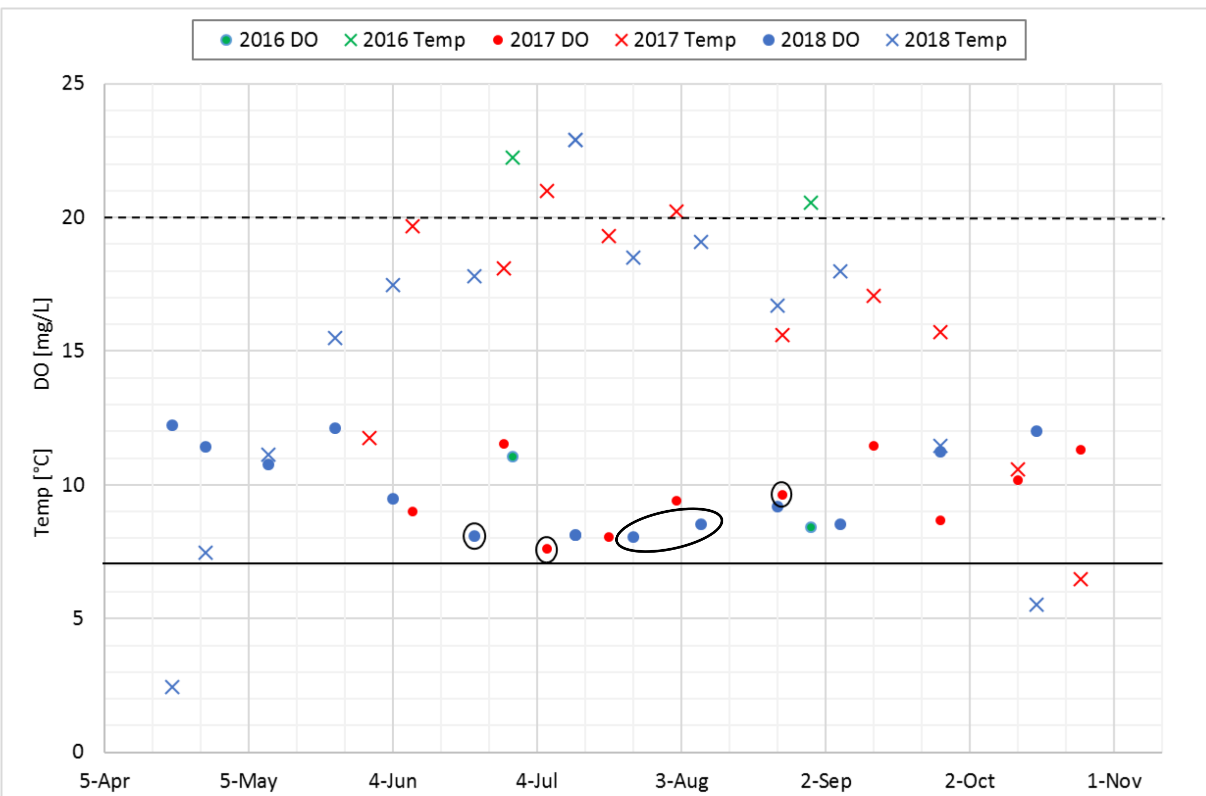
A continuous temperature logger was deployed at 15UM210 during the 2015 and 2016 monitoring seasons (Table 76). Also, instantaneous measurements have been taken at various times of day throughout 2015 – 2018 (Figure 89). The continuous data show that for ≥37% of the deployment time, stream temperature was stressful to aquatic life, and the instantaneous data show five measurements from June-August that were in excess of the stress threshold (20°C). While the MPCA biologists use a threshold of 20°C to identify thermal stress, some other researchers use lower thresholds, such as 18.3°C defined by Wehrly *et al.* (2007), referenced in the 2009 SID report.

The recent temperature data shown here for WID -511, the lack of coldwater fish species, and the fact that the next downstream WID (-653) has a confirmed temperature stressor suggests that high temperatures in WID -511 are stressing aquatic life and contributing at least to the impairment of the fish community, but likely the macroinvertebrates as well.

Table 76. Summary metrics of continuous temperature data from biological monitoring station 15UM210. Temperature shown in degrees Celsius. The "% Stress/Growth/Lethal" represents the percent of time during the deployment that temperature was in the associated range.

Monitoring Year	July (Avg Max)	August (Avg Max)	Summer (Avg Max)	% Stress (20.1-25°C)	% Growth (7.9-20°C)	% Lethal (>25°C)
2015	22.5	20.5	21.0	37.3	62.2	0.5
2016	22.6	21.7	21.9	46.8	52.2	1.1

Figure 89. Temperature (temp) and dissolved oxygen (DO) measurements taken at 15UM210 in 2015 – 2018. The dashed line at Temp = 20°C represents the threshold for stress used by MPCA. The solid line drawn at DO = 7mg/L represents the state standard. The five circled DO data points were measured before 9:00AM.



-Longitudinal Connectivity

In a visual scan of aerial imagery, no connectivity issues were identified between Little Rock Creek and the upstream end of WID -511, but the same connectivity barriers identified for WID -653 would be stressors for fish in this WID as well. For WID -653, two minor connectivity barriers were identified, Little Rock Lake and the Sartell WMA dam, making connectivity barriers a minor stressor to the Bunker Hill fish community as well. See *Longitudinal Connectivity* in section 3.5.2. for further details and discussion.

-Streamflow

Physical evidence of streamflow alteration is apparent from the bank erosion and channel over-widening that has occurred at 15UM210 (e.g. Figure 90) and throughout the rest of the Little Rock Creek watershed. This degree of bank erosion and channel instability is virtually absent throughout the rest of the MRS Watershed, except in Little Rock and Zuleger Creeks. Nearly 100% of the tributaries to Bunker Hill Creek have been physically altered, as well as parts of the mainstem (see Figure 81). Local watershed staff observe dramatic changes in the channel's dimension, substrate, and bank erosion from year to year.

Channel over-widening reduces the available wetted habitat for aquatic life, such as undercut banks. Also, by spreading out the volume of water in the channel over a greater width, the depth is reduced, which can make coarse substrate uninhabitable and/or impassable, and cause increased water temperatures. Streamflow alteration is a stressor to aquatic life, and is driving other stressors, such as reduced habitat diversity and possibly high temperatures.

Figure 90. August 2015 pictures from 15UM210, illustrating bank erosion and channel over-widening caused by streamflow alteration.

-Habitat

Four MSHAs were completed in 2015-2016 (Table 77). The average total score of 66.85 puts this site just over the “Fair” threshold and into the “Good” range (>65). In summary, the riparian buffer width was 50->100m and shade was moderate. The stream facet composition was 20% cobble/gravel riffle, 10-30% sand/gravel pool, and the rest being a sand/gravel run. Habitat cover was moderate (~50%) and depth variability was fair-good. The MSHA data and pictures of the site show that some coarse substrate is present with moderate (50-75%) embeddedness (Figure 91). Also, the macroinvertebrate tolerance richness metrics show that the community is skewed toward species that are tolerant of embedded substrate (see Table 73).

Table 77. Average of Minnesota Stream Habitat Assessment (MSHA) scores for all MSHAs conducted in 2015 and 2016 on WID -511 (n=4).
The maximum possible points (max) for each category is shown. Site gradient is shown in meters of elevation difference per kilometer of stream surrounding the site, estimated using LiDAR spatial data.

Biological Station	**Gradient** [m/km]	**Land Use** Max=5	**Riparian** Max=14	**Substrate** Max=28	**Cover** Max=18	**Channel Morphology** Max=35	**Total Score** Max=100
15UM210	3.33	3.12	9.63	18.85	14.00	21.25	66.85

Figure 91. Coarse substrate at 15UM210 that is covered with a layer of fine particulates and is moderately embedded. Pictures taken 6/29/2016.

The MSHA results suggest that a decent diversity of habitat types and cover amount are present. However, channel instability is compromising the quality and availability of that habitat. Lack of habitat is a stressor to aquatic life in WID -511, though it is largely driven by the geomorphic instability, which is brought on by some form(s) of streamflow alteration, such as changing precipitation and land use patterns. While the average total MSHA score is, just barely, in the “Good” category, degradation is occurring to an extent that would stress sensitive, coldwater taxa, though it is not the sole acting stressor.

-Suspended Sediment

There are three datasets related to suspended sediment for analysis. Of the 31 TSS samples collected between 2015 and 2018, four were >10mg/L, with the maximum being 58.5mg/L on 7/12/2016, the day of an extreme rainfall event (Figure 92/Table 78). The conditional probability that the stream would pass the TSS standards based on the fish samples is mediocre, at 56-58% (see Table 75), and the macroinvertebrate community seems weighted toward TSS-tolerant taxa (see Table 73). However, none of these data are strong enough to confirm or refute that TSS is a stressor to aquatic life in WID -511, therefore it is inconclusive.

Figure 92. Water chemistry results from monitoring of Bunker Hill Creek at 15UM210 by Benton County SWCD and others (EQUiS station S004-063).
Samples were collected April-October of 2016-2018. The green line at TP = 100µg/L is the regional nutrient standard. The upper extent of the left vertical axis (NOX = 10mg/L) represents the state drinking water standard.

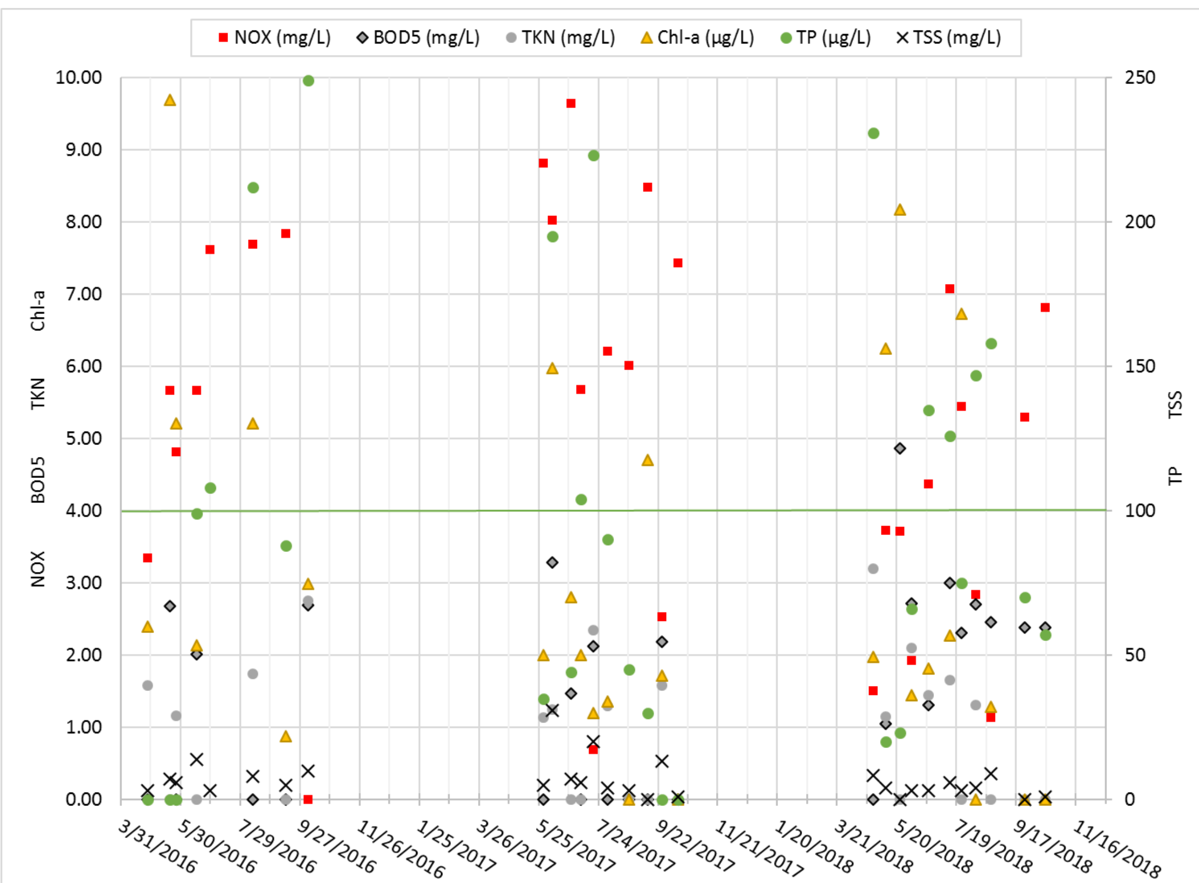


Table 78. Water chemistry results from 15UM210. For graphing purposes, these two datum are not shown in Figure 92. Results from 7/12/2016 represent conditions of the stream at the pre-peak stages of an extremely high flow event.

Date	**NOX** [mg/L]	**TKN** [mg/L]	**BOD5** [mg/L]	**TP** [mg/L]	**Chl-a** [µg/L]	**TSS** [mg/L]
7/2/2015	7.49	-	-	0.035	-	<4
7/12/2016	2.65	1.946	1.305	0.419	3.74	58.5

-Nutrients

Nutrient data collected from 15UM210 by various parties shows TP frequently in excess of the regional nutrient standard (TP=0.100mg/L), but no exceedances of the NOX drinking water standard of 10mg/L (Figure 92).

Nitrate

Nitrate toxicity to aquatic life, especially sensitive species, occurs at levels lower than the drinking water standard of 10mg/L (Camargo *et al.* 2005). The consistency of NOX>4mg/L and the macroinvertebrate tolerance metrics (see Table 73) suggest that nitrate toxicity is a stressor to the aquatic life in WID -511.

Phosphorus

Excess TP may be stressing aquatic life by causing eutrophication. The BOD values >2.0mg/L (42% of data points) add further evidence that eutrophication may be occurring (see Figure 92). On 8/25/2015, a floating algae mat was observed at 15UM210, and benthic algae was rated as "moderate" in three out of the four MSHAs. However, this is still not enough information to confirm whether or not eutrophication is occurring or stressing aquatic life. Additional TP samples and continuous DO measurements during the growing season would help make this determination.

-Dissolved Oxygen

Based on the 2015 and 2016 fish sample data, the likelihood that WID -511 would meet the standard for DO is 85 and 75%, respectively. The macroinvertebrate tolerance richness metrics do not clearly support or refute that low DO is a stressor. The instantaneous DO measurements made throughout 2015-2018 do not show any measurements below the 7mg/L class 2A threshold, although only five of those measurements were made at the time of day when DO is lowest (prior to 9:00AM).

If low DO were a stressor, it seems that it would more likely be driven by eutrophication or decay of organic matter than by warm temperatures, because the DO measurements presented in Figure 92 were taken during warm times of the day. No afternoon DO measurements were greater than 12mg/L during the typical growing season for in-stream macrophytes and algae (June-September), which is when eutrophication is evident in the daily DO profile. High TP and BOD measurements indicate that eutrophication may be occurring in WID -511, but it cannot be confirmed without continuous DO data to measure the daily DO flux. Both eutrophication and low DO are inconclusive stressors at this time.

WID Summary

Of the stressors investigated, those confirmed were high temperatures, connectivity barriers, streamflow alteration, lack of habitat, and nitrate toxicity. Inconclusive stressors were suspended sediment, eutrophication, and low DO.

3.5.4. Zuleger Creek – WID 07010201-539

Zuleger Creek is a tributary to Little Rock Lake. WID -539 is a section of Zuleger Creek that begins just upstream of Benton CR12 and ends at 135th St. NW. Biological station 16UM088 is the only one on the WID; it is just downstream of CR12 and has a 12mi^2 drainage area. A thorough description of watershed characteristics can be found in the Little Rock Creek TMDL and Stressor Identification reports, published on the MPCA's webpage for the Mississippi River – Sartell watershed.

Biological Data

WID -539 is impaired for aquatic life due to nonsupport of the fish and macroinvertebrate communities. The FIBI failed to meet the general use threshold (Table 79) for FIBI Class 6 – Northern Headwaters. The MIBI Class 5 – Southern Streams Riffle/Run score was within the upper confidence interval of the threshold, and when considered with other lines of evidence, the creek was also determined as nonsupporting for macroinvertebrates.

Table 79. IBI scores at site 16UM088 on Zuleger Creek (WID 07010201-539).

		Fish IBI			Macroinvertebrate IBI		
Station	**Date**	**Class†**	**Impairment Threshold**	**Score**	**Class†**	**Impairment Threshold**	**Score**
16UM088	6/29/2016	6	42	26	-	-	-
	8/30/2016	-	-	-	5	37	38

†FIBI Class: (6) Northern Headwaters
MIBI Class: (5) Southern Streams – Riffle/Run

Macroinvertebrates

The 2016 macroinvertebrate sample was dominated by two tolerant Chironomid genera: *Polypedilum* (36%) and *Rheotanytarsus* (6.8%), a combined dominance of 43%. Several cool-to-coldwater taxa were present, such as, the mayflies *Baetis brunneicolor* and *Baetis flavistriga*, the cranefly *Tipula*, the riffle beetle *Optioservu*s, and the midge *Brillia*. The intolerant vs. tolerant taxa richness was analyzed by stressor, and contextualized with all other MIBI Class 5 samples (Table 80). The tolerance richness is not clearly skewed one way or the other for the stressors of embedded substrate, TSS, or total phosphorus. Based on the metrics, low DO is an unlikely stressor to the macroinvertebrates, as the sample contains more taxa that are intolerant to this stressor, even in the context of all other MIBI Class 5 samples. Also, the macroinvertebrate metrics suggest that NOX may be a stressor.

Table 80. Number of taxa ("taxa richness") in the macroinvertebrate sample at 16UM088 that are tolerant and intolerant to specific stressors.
Percentile analysis was performed using all other MIBI Class 5 samples collected by MPCA (n=1,046). A high percentile in the intolerant metrics (green) is good, whereas a high percentile in the tolerant metrics (red) is not good, ecologically speaking. Where the percentile is above the median (>50%) the cell is highlighted green or red.

Stressor	Very Intolerant Taxa richness - Percentile	Intolerant Taxa richness - Percentile	Tolerant Taxa richness - Percentile	Very Tolerant Taxa richness - Percentile
Low DO	3 – 36.8%	8 – 66.3%	1 – 3.6%	0 – 0%
Embedded Substrate	1 – 33.9%	4 – 61.4%	3 – 6.6%	3 – 11.9%
Total Suspended Solids (TSS)	0 – 0%	3 – 78.5%	8 – 20%	3 – 19.4%
Inorganic nitrogen (NOX)	0 – 0%	2 – 69%	15 – 27.7%	10 – 31.7%
Total phosphorus (TP)	0 – 0%	3 – 63%	3 – 3.6%	0 – 0%

Fishes

Nine species of fish were sampled (Table 81), none of which are sensitive species. Given the fish community sampled, the likelihood that WID -539 would meet the standards for TSS and DO are good and mediocre, respectively (Table 82).

Table 81. Fish species and abundance from 6/29/2016 sample of 16UM088.

Common name	Number	Minimum length [mm]	Maximum length [mm]
johnny darter	41	25	68
blacknose dace	20	45	92
white sucker	14	87	135
bigmouth shiner	8	48	69
creek chub	6	25	60
brook stickleback	5	30	57
central mudminnow	3	46	82
yellow perch	2	80	88
fathead minnow	1	56	56

Table 82. Conditional probabilities (percent chance) that WID -539 would meet the TSS and DO state standards based on the fish community sampled in 2016.

	TSS	DO
16UM088	82%	57%

Stressor Data

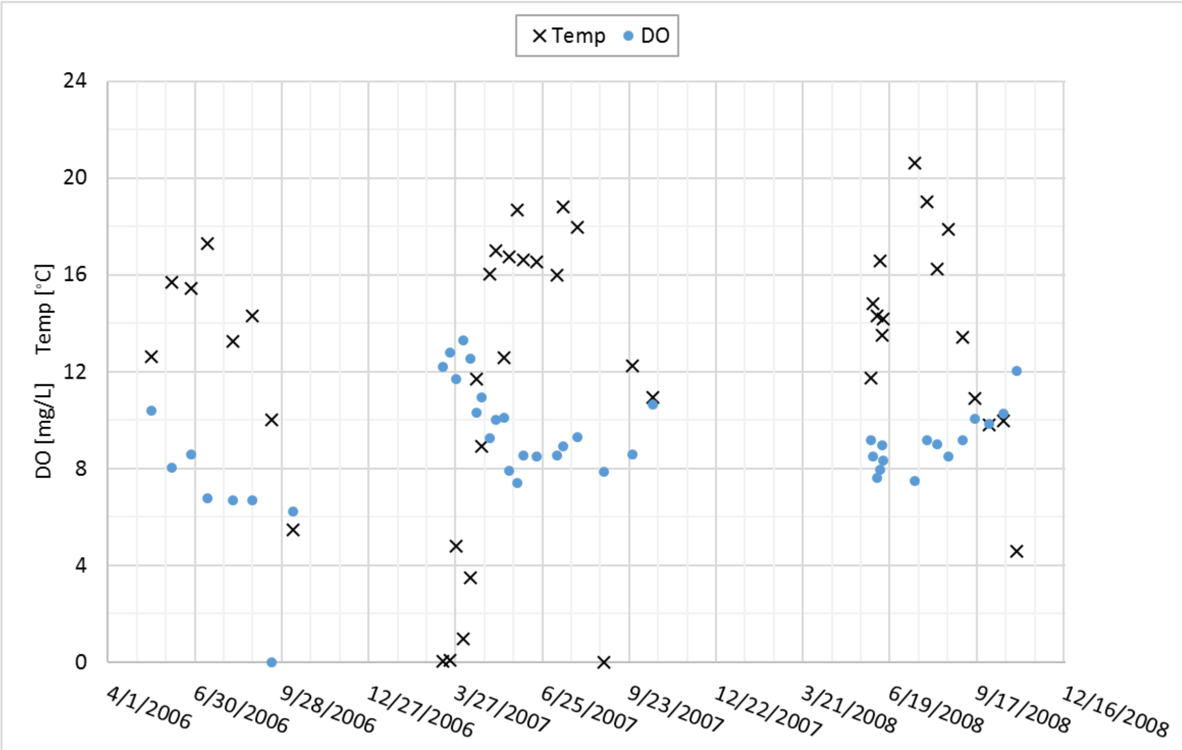
-Temperature

Unlike nearby WIDs -653 (lower reach of Little Rock Creek) and -511 (Bunker Hill Creek), Zuleger Creek is not expected to support coldwater aquatic life. Temperatures should at least approach 30°C before it might be considered a stressor to warmwater aquatic life. However, warmwater aquatic life can also be stressed by temperatures that are too cool to support growth.

Only two temperature measurements could be found for Zuleger Creek that were taken more recently than 2008. On 6/29/2016, the stream temperature at 16UM088 was 18.8°C, and on 8/30/2016 it was 20.1°C. In April-October of 2006-2008, 43 temperature measurements were made at CSAH2, just upstream of where Zuleger Creek enters Little Rock Lake (Figure 93). Of those data, only two exceeded 19°C. Including only temperatures measured June-August (n=19), the median was 16.24°C.

Some cool-to-coldwater species were observed in the macroinvertebrate sample, but none in the fish sample. This suggests that pockets of groundwater-connected areas in Zuleger Creek are keeping stream temperatures somewhat low, and cool-coldwater macroinvertebrates are surviving in these microhabitats, but that the stream may not be cool enough to fully support a community of coldwater fish. Installation of a continuous temperature data logger would help determine the temperature regime and variation of Zuleger Creek as a whole. At present, it is unclear if the temperature is too cool for warmwater species, but also too warm for coldwater species. Temperature is an inconclusive stressor at this time.

Figure 93. Data from Zuleger Creek WID -539 at CSAH2 (EQUiS station S002-447), collected April-October of 2006-2008.



-Longitudinal Connectivity

A visual scan of aerial imagery was performed to locate potential barriers to fish passage. One was found at Benton CR12 and was investigated on the ground by the MN DNR. Minnesota DNR Region 3 Clean Water staff assessed the crossing of Zuleger Creek with CR12, which is immediately upstream of 16UM088. They determined it was barrier to fish passage. Below is a synopsis of their findings and pictures of the crossing (Figure 94). Lack of longitudinal connectivity is a stressor to the fish community in WID -539, though it is likely not causing the fish impairment since it is located upstream of the sampling reach.

> "Zuleger Creek crossing [at Benton County Road 12] is a double box culvert with one side of the crossing partially filled with sediment. The crossing is undersized compared to the bank full width of the stream. One side of the crossing is acting as the active channel/thalweg and the other, partially filled, is acting as a small floodplain. Concerns at this crossing include: shallow water depth, lack of substrate, a large, deep scour pool, and a significant outlet drop."

Figure 94. Pictures of the Zuleger Creek crossing with Benton County Road 12, illustrating the barrier to fish passage.

-Streamflow

As with nearby Little Rock and Bunker Hill Creeks, physical evidence of streamflow alteration in Zuleger Creek is apparent from the bank erosion and channel over-widening that has occurred at 16UM088 and throughout the rest of the Little Rock Creek watershed. Streamflow alteration is a systemic stressor to aquatic life in this area, and is driving other stressors, such as lack of habitat. See the following *Habitat* section for further details and discussion.

-Habitat

Habitat was evaluated twice in 2016 using the MSHA right after the biological samples were collected. The final scores were 46 and 45 in June and August, respectively. Both assessments reported a sparse amount (0-25%) of habitat cover. There was only one sampleable habitat type for macroinvertebrates, which was large woody debris. Additionally, the macroinvertebrate crew had difficulty finding enough habitat to obtain a full-sized sample.

The substrate section of the MSHA in August reports that the sampling reach is 90% sand-silt run, with 10% sand-silt pool. While the June MSHA reports that the crew encountered a sand-gravel riffle, 75% of the channel substrate was again reported as sand-silt. This indicates that the stream has a highly mobile bed. Photos from the sampling events corroborate the MSHA substrate scores, as well as depict the channel instability and lack of habitat diversity in the stream (e.g. Figure 95).

Figure 95. Photos of 16UM088 on 6/29/2016 (top) and 8/30/2016 (bottom), illustrating the homogenous habitat and geomorphic instability of Zuleger Creek.

The channel in WID -539 appears over-widened, which could be inhibiting the stream's ability to maintain sufficient depth and velocity for aquatic life to thrive. Reduced baseflow volumes may be exacerbating this condition and can be caused by decreased landscape water storage as well as decreased groundwater contribution to the channel. Smaller baseflow volumes in the channel causes a loss of habitat in a variety of ways: 1) The water level is too low to reach some habitat features, such as overhanging vegetation 2) Fine particulates settle out of the water column onto substrate due to reduced flow velocity 3) The velocity is too slow create turbulence that incorporates atmospheric oxygen into the water 4) Shallow water depth can facilitate warmer temperatures and lower DO, as well as impose a size limit on aquatic inhabitants.

Some data were collected and analyzed in preparation for the Little Rock Creek TMDL study. The most recent of those data are from 2008, and may not represent current stream conditions. The report does indicate that Zuleger Creek lacks coarse substrate, with woody debris being the only "coarse substrate" with which to estimate embeddedness, which was 30%. Also, it was noted that biological samples could not be collected at CR12 due to low flows. It seems that habitat conditions have not improved since that report was written.

Based on the MSHA, field observations, and photos, lack of habitat diversity is stressing the fish and macroinvertebrate communities in WID -539. Habitat degradation is occurring through both deposition of fine sediment onto the streambed and reduced baseflow, driven by streamflow alteration. The reduced baseflow may also be driven by irrigation withdrawals from the stream directly or a connected aquifer.

-Suspended Sediment

Very little recent chemical data exists for Zuleger Creek (Table 83). The single TSS/TSVS sample indicates there was very little suspended sediment at that time. Also, the Secchi tube reading was greater than 100cm. The likelihood that the stream would meet the TSS standard based on the fish sample is good (82%). With such little data, however, it cannot be concluded whether or not suspended sediment is a stressor in WID -539, though it is not suspected.

Table 83. Data collected prior to biological sampling at 16UM088.

	Temp. [°C]	**DO** [mg/L]	**Specific Conductance** [µS/cm]	**pH**	**NOX** [mg/L]	**TP** [mg/L]	**TSS/TSVS** [mg/L]	**Ammonia-N** [mg/L]	**Secchi tube** [cm]
6/29/2016	18.8	8.69	428	8.09	9.16	0.215	5.6/4.0	0.1	>100
8/30/2016	20.1	8.21	425	7.93	-	-	-	-	>100

-Nutrients

Nitrogen

There is only one recent sample for both NOX and TP, collected with the fish sample on 6/29/2016 (Table 83). An in-stream NOX concentration of 9.16mg/L is approaching the drinking water standard of 10mg/L and is definitely stressful to aquatic life via nitrate toxicity. As previously shown, the macroinvertebrate tolerance richness metrics suggest that NOX is a stressor to the macroinvertebrate community. However, more chemistry data are needed to conclusively determine the frequency and duration of high NOX levels, and if it is the driving stressor of both the macroinvertebrate and fish communities. It is inconclusive at this time, though highly suspected.

Phosphorus

The TP concentration of 0.215mg/L on 6/29/2019 is more than double the regional standard of 0.100mg/L. The HSPF model suggests that TP concentration in Zuleger Creek exceeds the standard of 0.100mg/L across a wide range of flow conditions (Table 84). However, more observed TP and DO data from recent years would be needed to conclusively determine if TP levels are causing eutrophication, and thus stressing aquatic life.

Table 84. Average TP concentration in Zuleger Creek by flow event size, using HSPF modeled data from 1996-2015.

Flow (percentile)	Total phosphorus [mg/L]
Low (0-10)	0.106
Dry (10-40)	0.139
Mid (40-60)	0.121
Wet (60-90)	0.123
High (90->100)	0.178

-Dissolved Oxygen

As with the other stressors, very little DO data could be found for WID -539 that is more recent than 2008. The two measurements in Table 83 show sufficient DO levels, but are not representative of the daily minimum conditions. The macroinvertebrate tolerance richness metrics (see Table 80) do not show a signal of low DO stress, neither do the conditional probabilities based on the fish data (see Table 82). With such little data, it cannot be concluded whether or not low DO is a stressor in WID -539.

WID Summary

Zuleger Creek, WID -539, is impaired for aquatic life due to failing IBI scores of both fish and macroinvertebrates. Of the stressors investigated, those confirmed were longitudinal connectivity, streamflow alteration, and lack of habitat, although streamflow alteration is driving the habitat degradation.

4. Conclusions and Recommendations

The most frequently cited stressor to aquatic life in the MRS Watershed is streamflow alteration, a result of channelization and changes in land use, vegetation, and precipitation patterns. In many instances, streamflow alteration was the driving force of other stressors, especially lack of habitat. Difficulty in determining natural versus unnatural DO conditions were encountered as a result of the abundance of wetlands combined with wetland channelization and anthropogenic sources of pollution, such as the case for Big Mink Creek (WID -647).

To protect and enhance aquatic life in the MRS Watershed, the following actions are recommended:

- Protect the rivers and streams that currently foster high quality fish and macroinvertebrate communities, including the non-impaired water bodies that are not discussed in this report, such as the Skunk River, Hillman and Krain Creeks, and several of the lakes in Stearns County.
- Do not channelize streams, and especially do not drain wetlands. Rather, allow streams to maintain or regain their natural form and floodplain access; also consider watershed storage practices, such as wetland restoration.

- Fence livestock out of water bodies and implement riparian buffers of native, deep-rooted vegetation.
- Incorporate stormwater best management practices into existing urban and agricultural areas, as well as into the plans of new developments. Increasing watershed storage will help prevent the negative effects of streamflow alteration. When making these plans, consider the predicted patterns of climate change for the area. This may facilitate resilience of aquatic life to the drastic disturbances of the future.
- When implementing stream and crossing projects, design them with proper channel dimension, pattern, and profile specifications, and ensure stream-floodplain connections.
- Holistically consider all the components of watershed health, such as wetlands, lakes, and groundwater quality, which are not discussed in this report. For instance, the pollution sensitivity of near-surface materials is high in many parts of the MRS Watershed, and many residents rely on groundwater as their drinking water source. This connection is also important for aquatic life that live in streams with strong groundwater connections. See the M&A report for an in-depth discussion of this topic.

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