Watershed

February 2026

Little Fork River Watershed Stressor Identification Report

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

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Acronyms and term definitions

AUID	Assessment Unit (Identification Number) MPCA's pre-determined stream segments used as units for stream/river assessment – each has a unique number
BMPs	best management practices
CADDIS	Causal Analysis/Diagnosis Decision Information System, an EPA developed methodology
CSAH	County State Aid Highway
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DNR	Minnesota Department of Natural Resources
EPT	Three important taxonomic orders of stream macroinvertebrates whose members are typically sensitive to stream degradation - Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
FIBI	Fish-based lake Index of Biological Integrity; an index developed by the DNR that compares the types and numbers of fish observed in a lake to what is expected for a healthy lake (range from 0–100). More information can be found at the DNR Lake Index of Biological Integrity website
GIS	Geographic Information System
HUC	Hydrologic Unit Code (a multi-level coding system of the U.S. Geological Survey, with levels corresponding to scales of geographic region size)
IBI	Index of Biological Integrity – a multi-metric index used to score the condition of a biological community.
Intolerant species	A species whose presence or abundance decreases as human disturbance increases.
IWM	MPCA's Intensive Watershed Monitoring, which includes chemistry, habitat, and biological sampling. Two rounds of monitoring have occurred in LFRW (IWM-1, IWM-2)
LFRW	Little Fork River Watershed
m	meter
mg/L	milligrams per liter
Macrophyte	Macro (= large), phyte (= plant). These are the large aquatic plants, such as *Elodea* and Coontail.
MPCA	Minnesota Pollution Control Agency
MSHA	Minnesota Stream Habitat Assessment
NLCD	National Land Cover Database, a GIS layer
NWI	National Wetlands Inventory map.
Natural background	An amount of a water chemistry parameter coming from natural sources, or a situation caused by natural factors.

P	Phosphorus
SID	Stressor Identification – The process of determining the factors (stressors) responsible for causing a reduction in the health of aquatic biological communities.
Sonde	A deployable, continuous-recording water quality instrument that collects temperature, pH, DO, and conductivity data and stores the values which can be transferred to a computer for analysis
TALU	Tiered Aquatic Life Uses, a framework of setting biological standards for different categories of streams
Taxa	Plural form - refers to types of organisms; singular is taxon. May refer to any level of the classification hierarchy (species, genus, family, order, etc.). In order to understand the usage, one needs to know the level of biological classification being spoken of. For MPCA fish analyses, taxa/taxon usually refers to the species level, whereas for macroinvertebrates, it usually refers to genus level.
TIV	Tolerance Indicator Value
TMDL	Total Maximum Daily Load
Tolerant species	A species whose presence or absence does not decrease, or may even increase, as human disturbance increases
TP	total phosphorus (measurement of all forms of phosphorus combined)
TSS	Total Suspended Solids (i.e. all particulate material in the water column)
TSVS	Total Suspended Volatile Solids (i.e. organic particles)
UAA	Use attainability analysis
EPA	U.S. Environmental Protection Agency
WHAF	Watershed Health Assessment Framework
WRAPS	Watershed Restoration and Protection Strategy, with watershed at the 8-digit Hydrological Unit Code scale

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Executive summary

This report documents the efforts that were taken to identify the causes, and to some degree the source(s) of impairments to aquatic biological communities in streams in the Little Fork River Watershed (LFRW). Though the LFRW has undergone the second round of Intensive Watershed Monitoring (IWM; 2008 and 2018), this is the first Stressor Identification (SID) Report for the LFRW. The first IWM (in 2008) results are described in the IWM and Assessment Report (MPCA, 2011). An IWM Report Update was created for the second IWM in 2018 (MPCA, 2021). The SID effort for IWM-2 began in summer 2019 and investigated stream segments that were either new biological impairments or stream health/protection issues. The Minnesota Department of Natural Resources (DNR) conducted geomorphic surveys/assessments at two stream segments on Flint Creek in 2011 and 2021 that showed signs of channel instability likely leading to high total suspended solids (TSS) concentrations. Another geomorphic assessment was done by DNR on an unnamed tributary to the Little Fork River near International Falls, with similar results to those at Flint Creek.

Information on the SID process can be found on the U.S. Environmental Protection Agency's (EPA) website http://www.epa.gov/caddis/. Specific information on Minnesota's processes for SID in streams can be found on MPCA's webpage "Is Your Stream Stressed".

Biological sampling during the IWM-2 resulted in three stream reaches being assessed as having impaired fish and/or macroinvertebrate communities. These reaches were brought into the SID process (listed below and shown on Figure 1) because they were determined to have sub-standard biological communities during the 2020 Assessment.

Stream impairment investigations

- Gilmore Creek (AUID 09030005-594) - Macroinvertebrates
- Johnson Creek (AUID 09030005-679) - Fish and Macroinvertebrates
- Timber Creek (AUID 09030005-630) - Macroinvertebrates
- Flint Creek (AUID 09030005-574, 588, 612, 613) - TSS

Geomorphology investigations

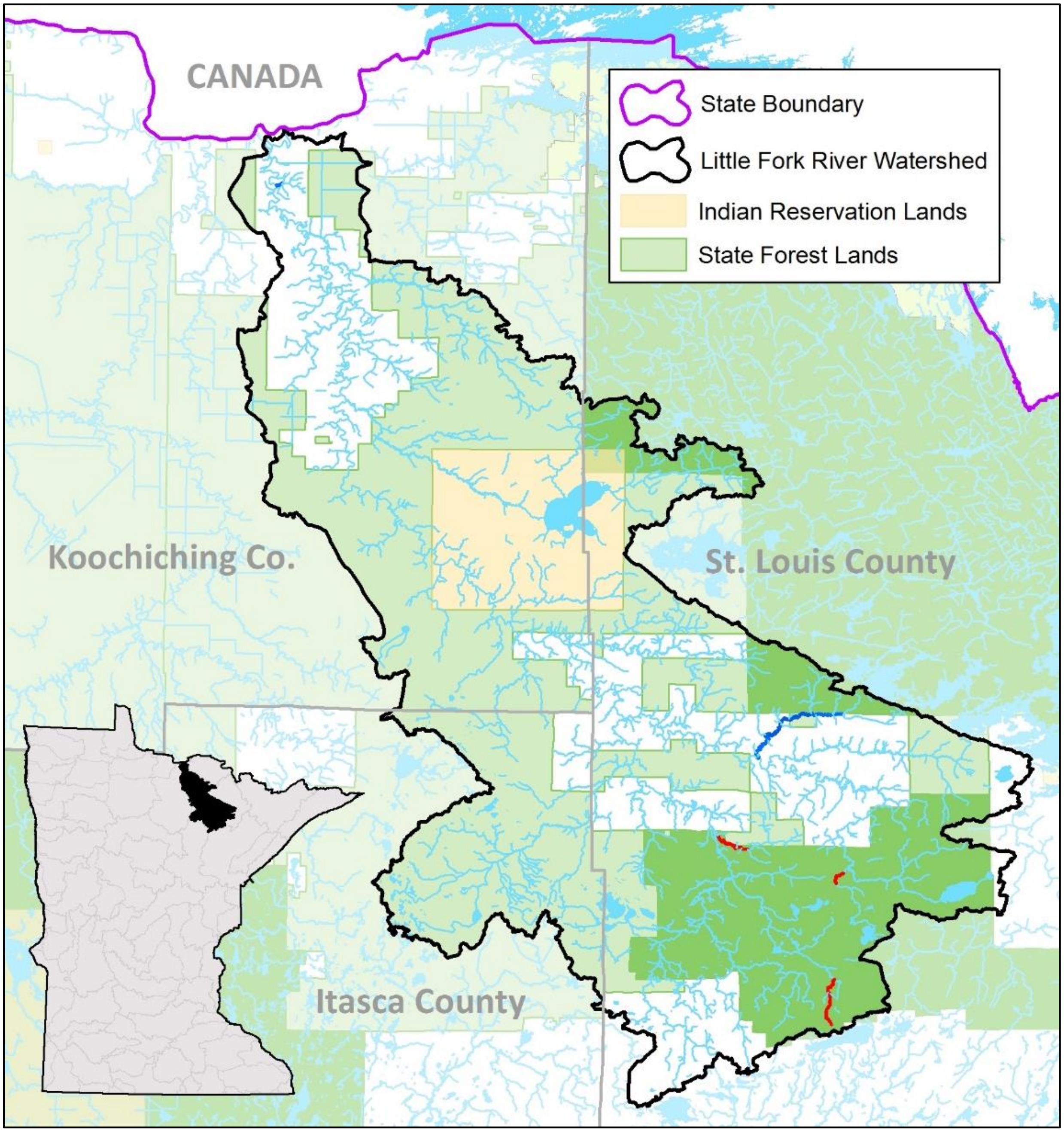
- Unnamed Creek (AUID 09030005-676)
- Flint Creek (AUID 09030005-612)

The stressors of aquatic biological communities in the LFRW are either natural, related to altered hydrology (including channel straightening), or mining-related (high specific conductivity). The natural stressors are low dissolved oxygen (DO), due to the extensive wetlands that can also supply water to streams, and beaver dams, which can cause reduced DO concentration levels and can also block fish passage, preventing repopulation of smaller streams in spring from downstream overwintering habitat. The altered hydrology (increased flashiness) appears to have caused channel instability in Flint Creek and at other locations. Land cover (i.e., vegetation) changes alter the water-retentive abilities of landscapes, resulting in greater runoff of melting snow and rain. Some of this alteration goes back in time to the era of the original logging at European settlement, when vast areas of old-growth forests were clear cut across northern Minnesota. In modern times, forest alteration has continued as very significant amounts of logging for the paper and wood products industries has occurred in the second and third growth forests. In parts of the LRFW, particularly in the southern half, significant forest cover has been converted from the original pine to poplar, as it is the dominant species that arises from forest disturbance, as well as the predominant species utilized in the region for paper production.

The findings of the various investigations listed above are:

- **Gilmore Creek** - The biological impairment is caused by low DO concentrations due to natural factors (wetland influence and beaver impoundment) with potential influence of channel straightening.
- **Johnson Creek** - The biological impairment is caused by low DO concentrations due to a combination of three natural factors (wetland influence, strong groundwater contributions, and beaver impoundment). This has been now classified in the natural background category of impairments.
- **Timber Creek** - The biological impairment has two apparent causes 1) high ionic concentration (high specific conductivity) from groundwater input originating from the large tailings basin immediately adjacent to the stream, 2) there are likely some contributions of natural factors, those being wetland influence and headwaters beaver impoundments depressing DO concentrations.
- **Flint Creek** - Elevated TSS appears to be due to channel instability from altered hydrology.
- **Unnamed Creek** - Stream channel incision with reduced floodplain connectivity and unstable banks.
- **Flint Creek** - Stream channel incision with reduced floodplain connectivity and unstable banks.

Figure 1. Biological impairments (red) and other investigations (dark blue) locations in the LFRW discussed in this report. 1. Gilmore Creek (594), 2. Timber Creek (630), 3. Johnson Creek (679), 4. Unnamed Creek (676), 5. Flint Creek (multiple AUIDs).



Introduction

The Minnesota Pollution Control Agency (MPCA), in response to the Clean Water Legacy Act, has developed a strategy for improving water quality of the state's streams, rivers, wetlands, and lakes in Minnesota's 80 Major Watersheds, known as Watershed Restoration and Protection Strategy (WRAPS). The MPCA receives assistance from DNR and local governmental units to complete a WRAPS project. A WRAPS is in part comprised of several types of monitoring. The IWM is the first step in the WRAPS process. The MPCA conducted the first IWM effort in the LFRW during the summer of 2008. The IWM assessed the aquatic biology and water chemistry of the LFRW streams and rivers. A second monitoring effort, known as SID, seeks to find the cause(s) of impairments of stream biological communities discovered in the IWM effort, as well as identifying streams that would benefit from protective measures to ensure that their biological communities do not become impaired. The first WRAPS effort done for the LFRW did not produce a report of SID work.

The MPCA and local governmental partners conducted a second IWM effort 10 years after the original IWM (in 2018). Following the IWM, MPCA, along with DNR, conducted SID work during 2018-2022. The MPCA performs SID for river and stream biological impairments, while DNR does SID for fish impairments in lakes (new since the first WRAPS) and assessments of stream geomorphology. This document reports on the SID work for both IWM efforts in streams and also includes SID for lakes, done following the second IWM effort.

It is important to recognize that this report is part of a series, and thus not a stand-alone document. Information pertinent to understanding this report can be found in the two LFRW Monitoring and Assessment Reports. Those documents (MPCA, 2011; MPCA, 2021) should be read together with this SID Report and can be found from links on the MPCA's Little Fork River Watershed webpage.

Landscape of the LFRW

A detailed description of various geographical and geological features of the landscape of the LFRW is documented in the LFRW Monitoring and Assessment Report (MPCA, 2011). Additionally, the web-based DNR Watershed Health Assessment Framework (WHAF) has a wealth of landscape data for each of the major watersheds of Minnesota, including a Watershed Context Report feature (DNR, 2017). All of this information is useful and necessary for understanding the settings of pertinent LFR Subwatersheds, and how various landscape factors influence the hydrology within the LFRW. The reader is encouraged to utilize these other resources. The following information is intended to provide a basic description of the LFRW landscape.

The original, pre-settlement landscape was almost exclusively forest and forested wetland (Figure 2). Though the original forest harvest at the turn of the century changed much of the forest from older growth to the younger forests that exist now, a large percentage of the originally-forested landscape is still in a forested state. Wetlands, especially forested, are abundant in the LFRW, covering over half of the LFRW area. They are fairly evenly scattered throughout the watershed. Very little of the land area is either developed, or in agriculture, even as hay land or pasture. Percentages of various categories of land cover are presented in Table 1. Figure 3 shows the extent and locations of these cover types.

Figure 2. Original vegetation of the LFRW (Marschner, 1930).

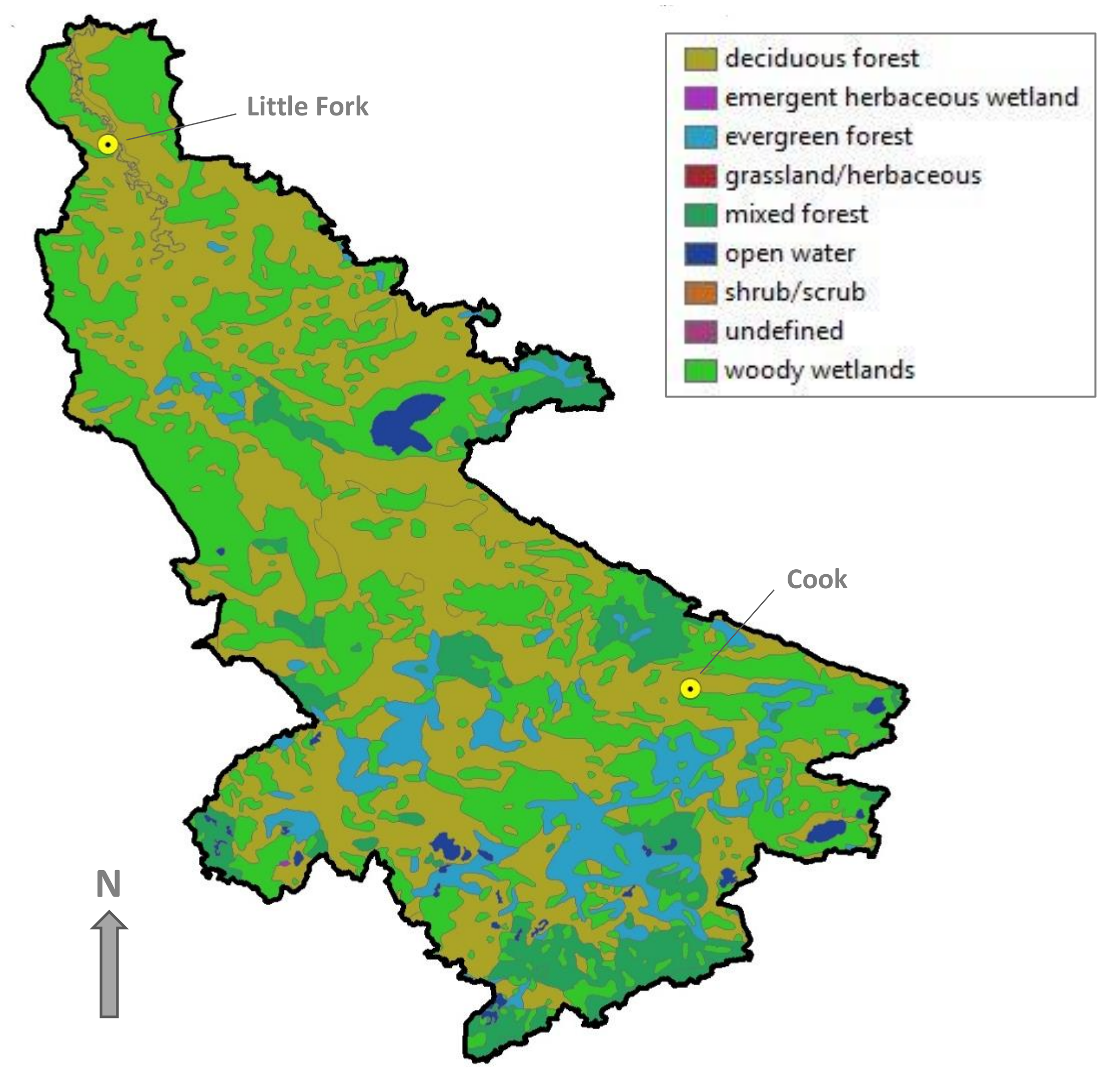


Table 1. Percentages of the various land cover types from 2016 National Land Cover Dataset GIS layer, ranked by percentage (DNR, 2021).

Land cover type	Percent of land area
Wetland	54.8
Forest	29.5
Shrub and Herbaceous	9.3
Water	2.5
Developed (all intensities grouped)	1.9
Pasture and Hay	1.2
Barren (i.e., rock outcrop, etc.)	0.7
Cultivated Crops	0.1

The LFRW is a varied watershed topographically, though most of the steeper-sloped lands are along the southern edge of the LFRW. This sloped area is part of the Lake Superior Uplands Section of the Ecological Classification System of Minnesota. Almost all of the remaining LFRW areas are part of the Northern Minnesota and Ontario Peatlands. That area is quite synonymous with the historical extent of Glacial Lake Agassiz within the LFRW (Figure 4). Because of the coverage of the ancient lake, this large part of the LRFW has soils containing much clay. This in turn creates significantly turbid streams, especially the Little Fork River itself. Streams within the Lake Superior Uplands along the southern part of the LFRW have clearer flow due to the coarser texture soils in that area.

A large part of the northern half of the LFRW is flat, and contains much wetland/peatland, resulting in streams that are low gradient, soft bottomed, and darkly tannin-stained. Slow flow velocity can influence the DO levels in the streams both due to lower mixing of water that reduces water column contact with the atmosphere. Additionally, low gradient streams can take on wetland characteristics, having accumulations of organic particulate sediment that reduce the amount of DO in the water column as bacteria consume oxygen during decomposition of this organic material. Streams in the southern one third of the LFRW have more gradient, swifter flows, and their beds are often lined with gravel, cobble, and boulders. Streams with these characteristics generally have better concentrations of DO.

Figure 3. LFRW land use/cover as determined by the 2016 National Land Cover Dataset, with some categories lumped (e.g., wetland types).

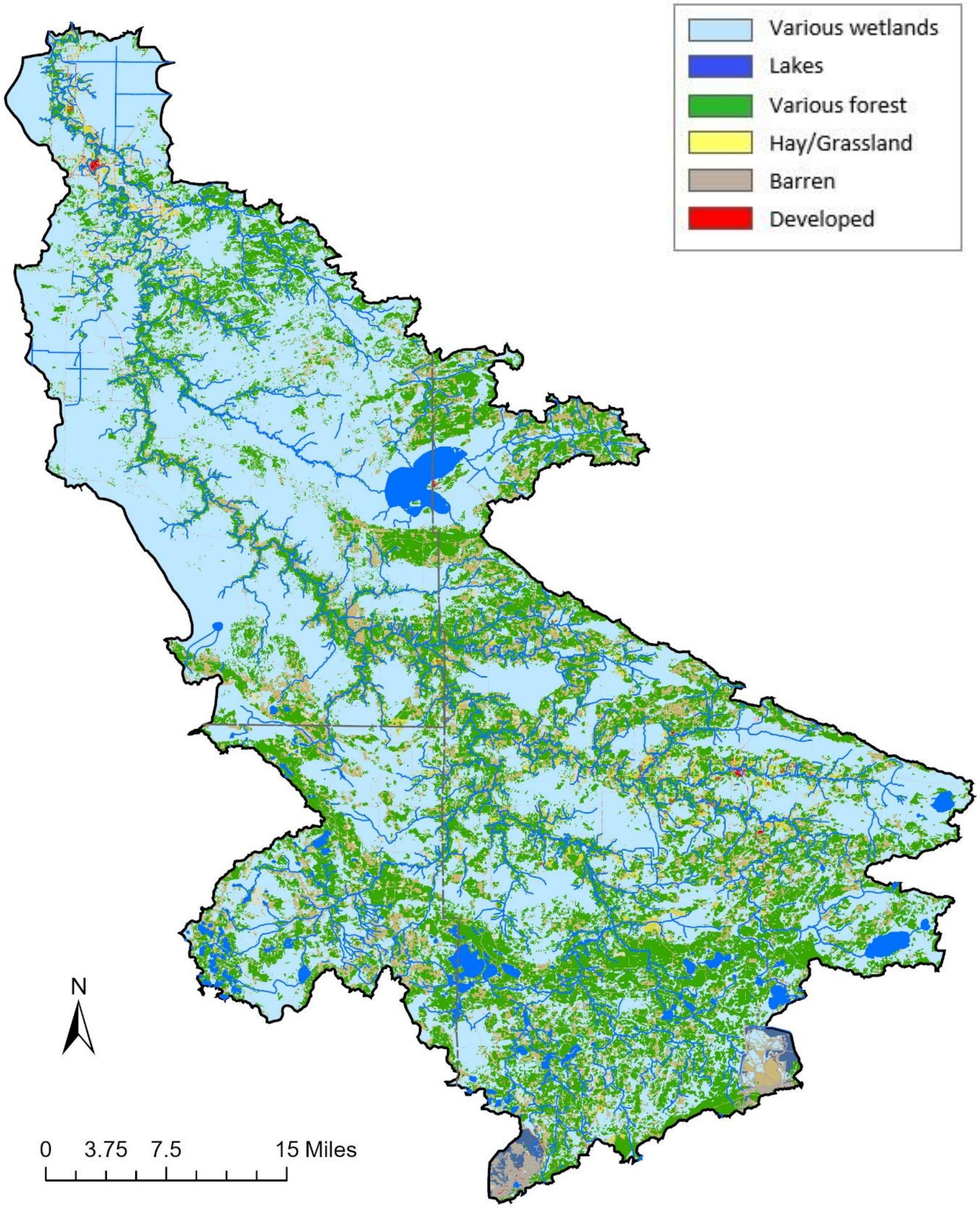
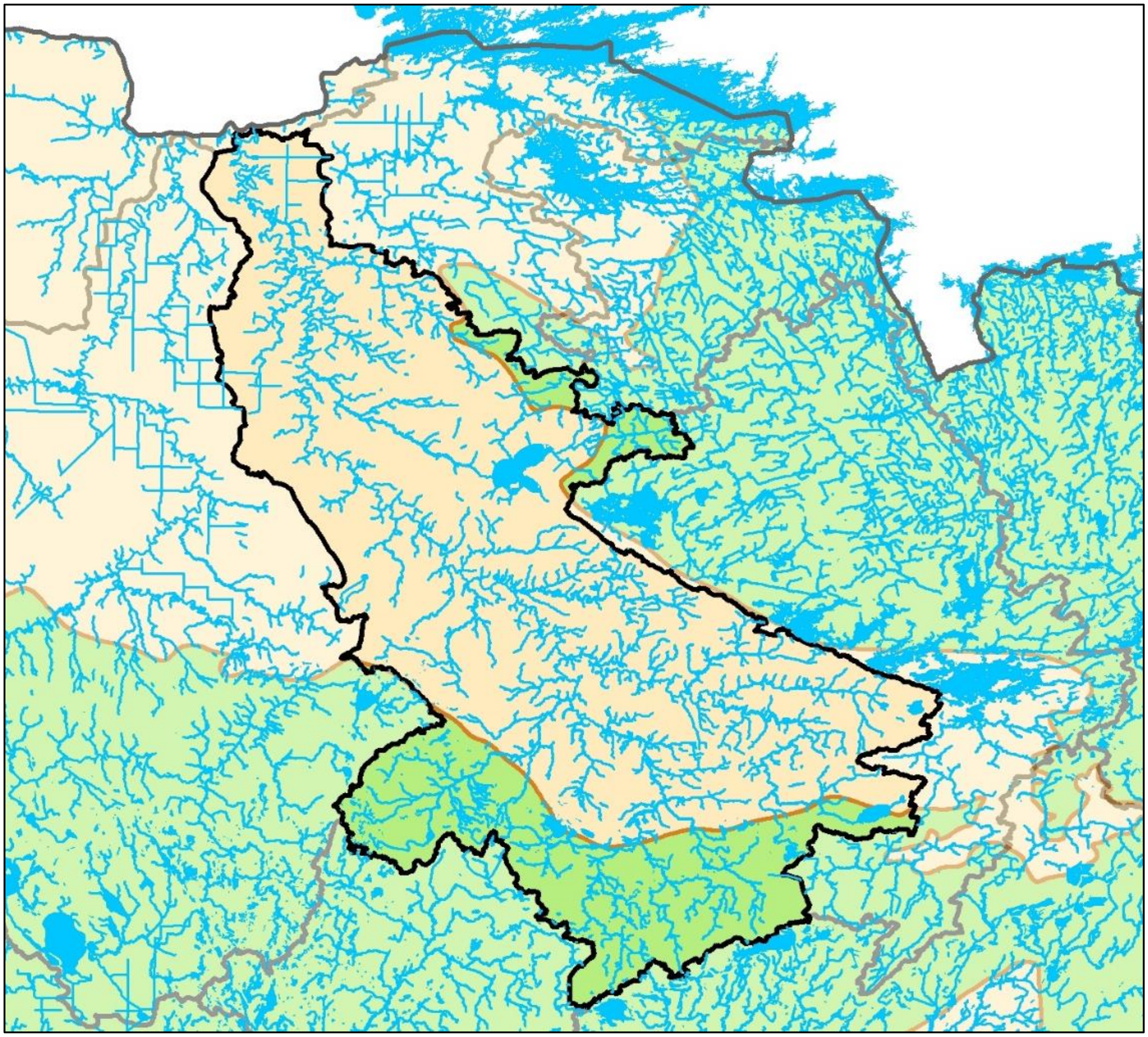


Figure 4. Extent of Glacial Lake Agassiz (tan-colored area) over the LFRW and parts of surrounding watersheds.



Background information on data and analyses

Mechanisms of candidate stressors and applicable standards

A separate document has been developed by MPCA describing the various candidate stressors of aquatic biological communities, including where they are likely to occur, their mechanism of harmful effect, and Minnesota's Standards for those stressors (MPCA, 2017). Many literature references are cited, which are additional sources of information. The document is titled "Stressors to Biological Communities in Minnesota's Rivers and Streams" and can be found on the web at: https://www.pca.state.mn.us/sites/default/files/wq-ws1-27.pdf. EPA (2019) has yet more information, conceptual diagrams of sources and causal pathways, and publication references for numerous stressors on their Causal Analysis/Diagnosis Decision Information System (CADDIS) website at https://www.epa.gov/caddis.

Notes on analysis of biological data

Biological data (the list of taxa present in the sample and the number of each) form the basis of the assessment of a stream's aquatic life use status. Information on the MPCA's biological monitoring program and protocols can be found on the MPCA website (MPCA, 2026a). Various metrics can be calculated from the fish or macroinvertebrate sample data. An Index of Biological Integrity (IBI), a collection of metrics that have been shown to respond to human disturbance, is used in the assessment process (https://www.pca.state.mn.us/water/index-biological-integrity). Similarly, metrics calculated from biological data can be useful in determining more specifically the cause(s) of a biological impairment. Numerous studies have been done to search for particular metrics that link a biological community's characteristics to specific stressors (Hilsenhoff, 1987, Griffith et al., 2009, Álvarez-Cabria et al., 2010). This information can be used to inform people of situations encountered in impaired streams in Minnesota's WRAPS process. This is a relatively new science, and much is still being learned regarding the best metric/stressor linkages. Use of metrics gets more complicated if multiple stressors are acting in a stream (Statzner and Beche, 2010; Ormerod et. al., 2010, Piggott et. al., 2012).

Staff in MPCA's Standards, Biological Monitoring, and SID programs have worked to find metrics that link biological communities to stressors, and work continues toward this goal. Much work in this area was recently done to show the impact of nutrients (particularly phosphorus) on biological stream communities when Minnesota's River Nutrient Standards were developed (MPCA, 2013b; MPCA, 2019b). The Biological Monitoring Units of MPCA have worked to develop Tolerance Indicator Values (TIV) for many water quality parameters and habitat features for species of fish and genera of macroinvertebrates. This is a take-off on the well-known work of Hilsenhoff (1987; EPA, 2006). For each parameter, a relative score is given to each taxon regarding its sensitivity to that particular parameter by calculating the weighted average of a particular parameter's values collected during the biological sampling for all sampling visits in the MPCA biological monitoring database. Using those scores, a weighted average community score (a community index) can be calculated for each sample. Using logistical regression, biologists have also determined the probability of the sampled community being found at a site meeting the TSS and/or DO standards, based on a site's community score compared to all MPCA biological sites to date. Such probabilities are only available for parameters that have developed standards, though community-based indices can be created for any parameter for which data exists from sites overlapping the biological sampling sites.

Some of these stressor-linked metrics and/or community indices will be used in this report as contributing evidence of a particular stressor's responsibility in degrading biological communities in an impaired reach. It is best, when feasible, to also include field observations, water chemistry samples, and physical data from the impaired reach in determining the stressor(s).

Notes on analysis of physical and hydrological data

Staff of the DNR assist the SID process by collecting physical data (e.g., Pfankuch assessments and Rosgen geomorphology (Rosgen, 1996 and 2009) studies) about the stream channel and analyzing hydrological data. This information is not widely collected in SID work but is generally limited to streams where MPCA impairments have been found, and perhaps a couple reference streams in each Hydrologic Unit Code (HUC)-8 watershed. Summary information about these topics are included in this report for the studied streams. Detailed stream survey data (e.g., channel bed elevations, water slope, etc.) from these efforts is available from DNR Watershed Specialists in the Grand Rapids DNR office.

Use attainability analysis

A beneficial use attainability analysis (UAA) is done prior to making assessment decisions using biological monitoring data. This assessment assigns a stream reach a use class as either “modified use” or “general use”. These uses have different scoring thresholds for biological monitoring data. A document is available that explains the UAA protocol (MPCA, 2018).

Common water parameter occurrences in LFRW

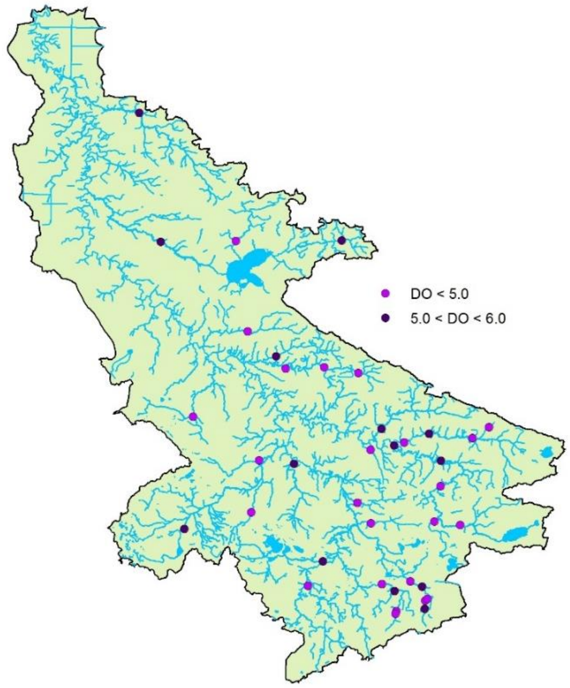
Introduction

Over the course of the first 10 year IWM monitoring cycle (covering all of Minnesota), particularly in the major watersheds of the northern half of the state where lesser levels of historical water quality sampling had been conducted, it was found that many streams and rivers in quite natural landscapes have sub-standard DO levels in July and August. This is true in many streams and rivers of the LFRW. Low levels of DO can be a human-caused condition when activities result in excess plant nutrients entering streams. Human activities (farming, urban development, etc.) and population density in the LFRW are much lower than in areas typically experiencing nutrient issues in streams. Thus, it is counterintuitive that low-DO would be a common condition of streams in the relatively undeveloped areas of northern Minnesota.

Low DO in the LFRW

In the LFRW, there are 21 sites where the DO measured during a biological monitoring event was below the 5.0 Milligrams per liter (mg/L) standard (Figure 5). Most biological monitoring visits occur during the time of day that DO is not at its daily low (which occurs at dawn), so there are likely more sites than these 21, which have substandard DO levels in early morning. An additional 11 sites had DO levels between 5 and 6 mg/L at a biological visit that occurred after 9:00 a.m. At these locations there is a strong likelihood that DO levels were below the standard earlier in the morning of those days.

Figure 5. Locations in the LFRW where biological monitoring visits found DO levels that did not meet (< 5.0 mg/L) or were very near to not meeting the DO standard (5.0 - 5.99 mg/L measurements taken after 9:00 a.m.).



Characteristics of streams with low DO

There are several natural landscape factors that influence the low DO found in many northern streams where human alterations to water quality are generally minimal.

Gradient

A large area of northern Minnesota has a topography with little relief (i.e., the landscape is very flat), related to how the glaciers moved across the land and formed it, including the long-lived Glacial Lake Agassiz. As a result, the streams of this region of the state have low gradient and slow flow velocities. Many of these streams have substrate that is composed of deposition of fine organic particles from the natural breakdown of both land and aquatic plants due to the non-powerful flows. The continued breakdown of this material deposited by bacteria utilizes oxygen from the water. The slow flow velocity of these streams and rivers also reduces mixing of the water column, meaning there is less frequent opportunity for the water to experience atmospheric contact, where oxygen can diffuse into the water.

Wetland connectivity

It is extremely common for northern Minnesota streams to have riparian areas that are wetland. Wetlands have deep, organic material soils, where breakdown of this material is slow, and the organic material accumulates. In the warmest parts of the year (July/August), these wetlands become anoxic from bacterial decomposition activity. Water from upland areas, both shallow groundwater and surface water runoff, pass through these wetlands (slowly) as it makes its way to streams and rivers. These areas then contribute water having low DO to the streams. Much of the water in northern Minnesota streams has spent time in wetlands. The tannin-stained color of many northern Minnesota streams is evidence of this.

Beaver impoundments

Because of the abundance of low gradient streams and surrounding forest cover, northern Minnesota has an abundance of beaver. The dams they construct can exacerbate low DO levels in stream water, by further reducing gradient, creating additional wetland area, and by their impoundments creating stagnant water that increases in temperature by solar radiation. Because warmer water holds less oxygen than colder water, as beaver impoundments warm the stream, oxygen levels will decrease.

“Elevated” levels of total phosphorus

The second chemistry parameter that is curious in the LFRW is total phosphorus (TP). More specifically, TP in smaller streams often appears elevated relative to the River Nutrient Standard for Northern Minnesota, which is 0.050 mg/L (note that TP is just a part of this multi-parameter standard). This phenomenon has been seen in numerous north central and northeastern forested watersheds in Minnesota. The word “elevated” in this section’s title was put in quotations because the large number of instances of this finding across many of Minnesota’s least disturbed watersheds suggests that this may be a natural phenomenon. This finding includes the streams of the LFRW, excluding the two larger rivers (Little Fork River and Sturgeon River), where the majority of stream measurements were above the TP concentration within the Minnesota North Region Eutrophication Standard of 0.050 mg/L (Figure 6). This has been written about in other Watershed SID reports, including those for the Crow Wing River, Mississippi River - Headwaters, Mississippi River - Grand Rapids, Kettle River, and Leech Lake River. These reports are archived on the MPCA website, on a page dedicated to each of these watersheds.

A short summary of the situation in multiple smaller streams in several other northern Minnesota watersheds is that TP concentrations have a bell-shaped curve across the nonfrozen annual period, with peak phosphorus levels occurring in late July/early August. Coincident with this pattern is that DO levels tend to be at their yearly minimums at this same time of year. A particularly good example is the seasonal DO and TP patterns found at Pokety Creek in the Leech Lake River Watershed (Figure 7). Phosphorus can leak out of hydrologically connected peatlands/wetlands during the warmer parts of the season, when wetland soils become very anoxic. Sequestered phosphorus becomes soluble in low oxygen environments.

Figure 6. TP measurements in mg/L at biological sampling visits for all streams except the Little Fork River and Sturgeon River, from 2005-2018. Wisker ends are at the lowest concentration and the 90th percentile, the box represents the 25th - 75th percentiles. The solid line in the box is the median concentration and the X is the average concentration. The red dashed line is the TP threshold concentration within the MN North Region Eutrophication Standard of 0.050 mg/L.

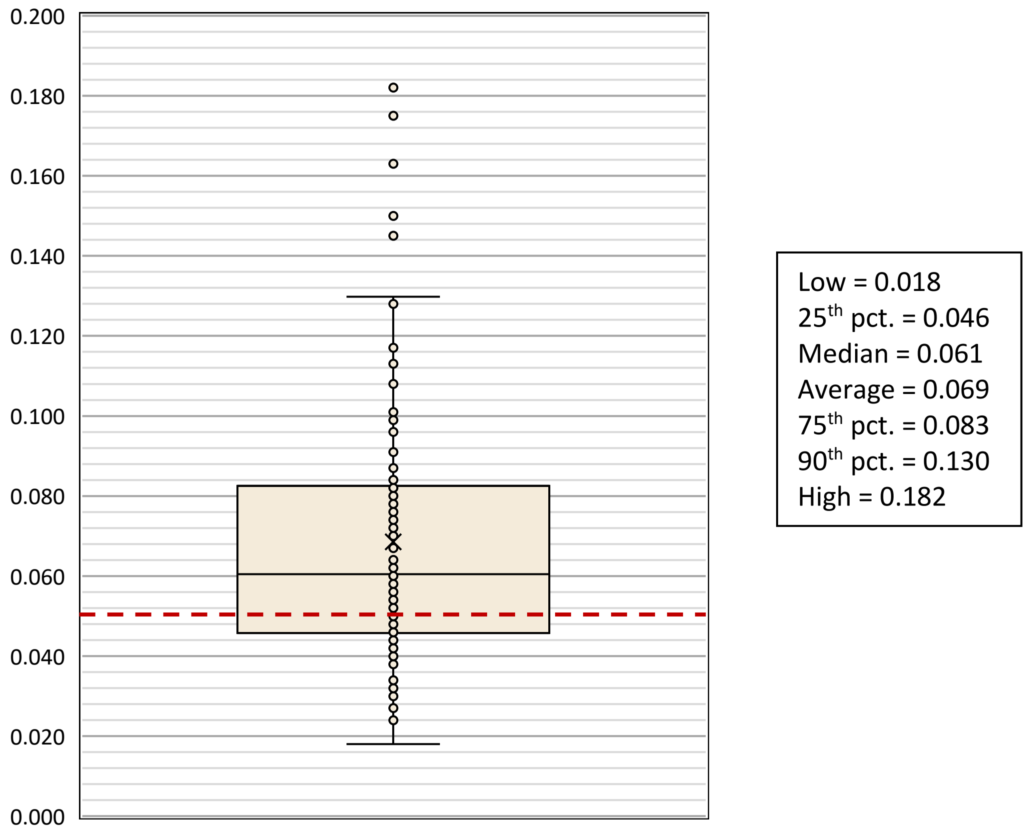
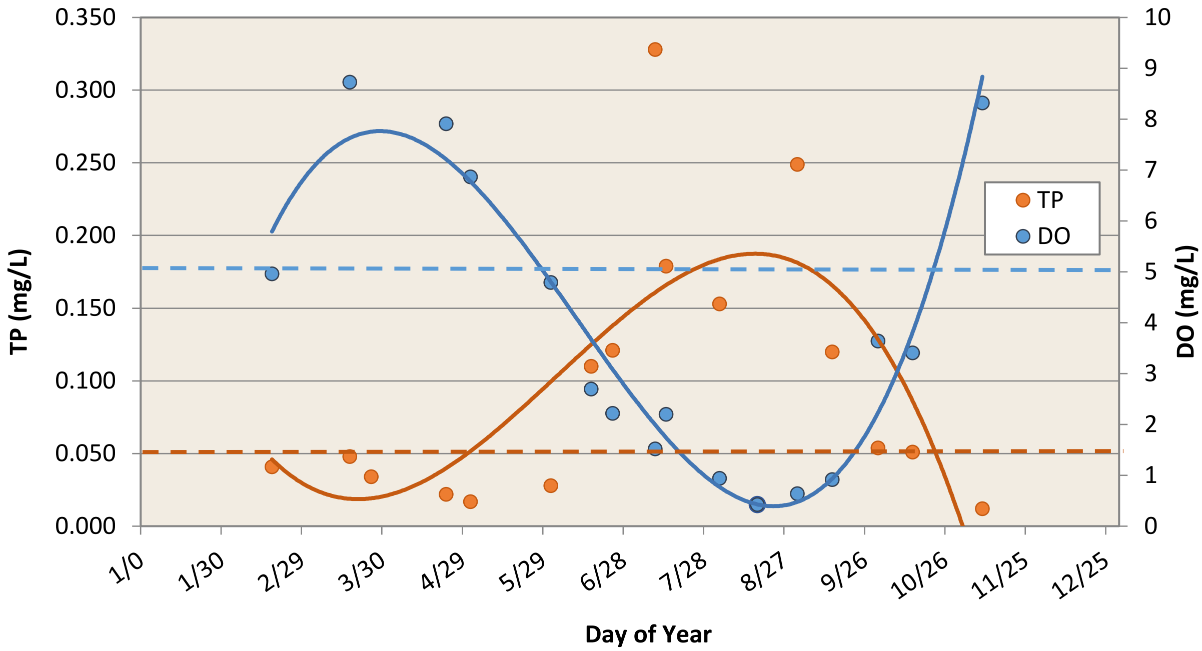


Figure 7. Seasonal TP and DO measurements and patterns from wetland-influenced Pokety Creek in the Leech Lake River Watershed. Dashed lines are the Minnesota standards for these parameters in warmwater streams.



IWM-1 biologically-impaired streams

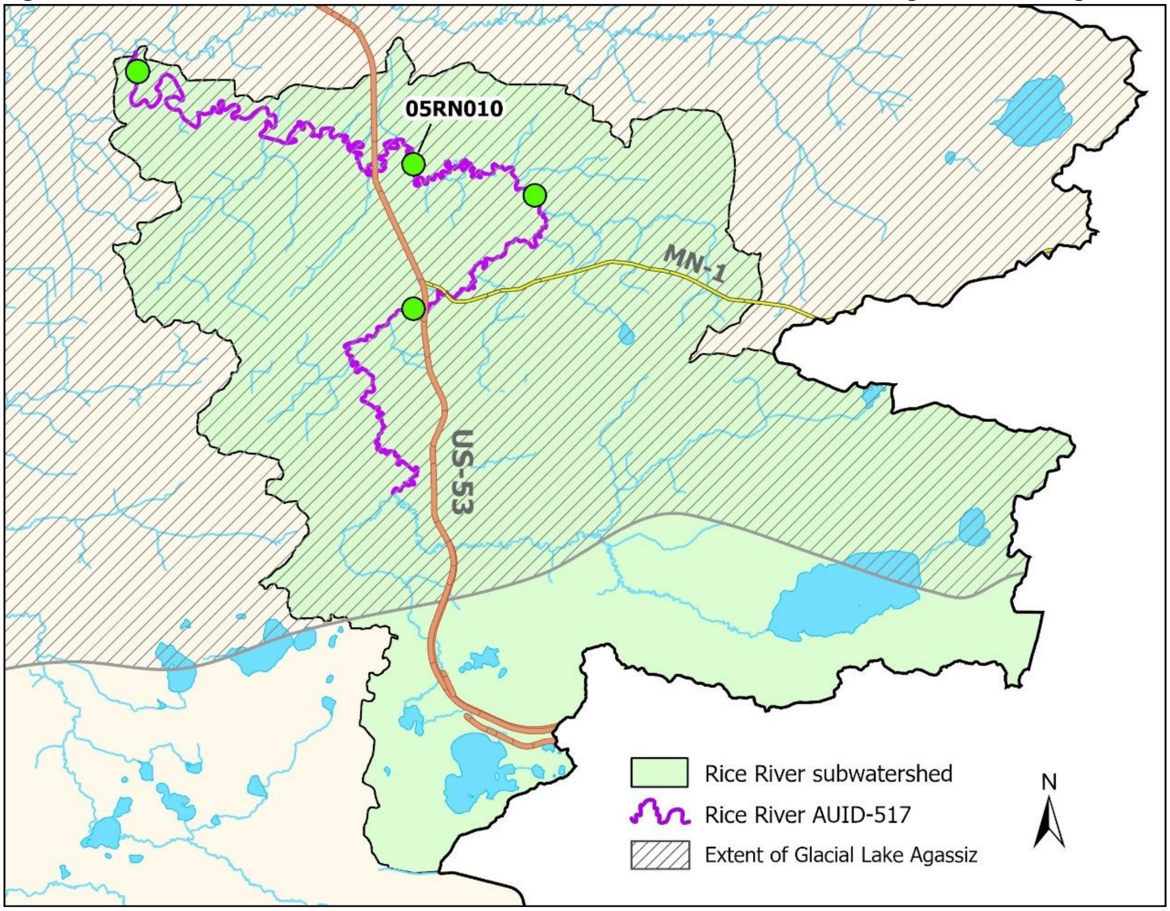
Rice River (AUID 09030005-517)

Impairment: Assessment Unit Identification (AUID)-517 is a 35.0 miles long reach of the Rice River. The full length of the AUID is a natural, unmodified channel. Three biological monitoring sites were sampled in AUID-517 (05RN010, 08RN002, and 08RN036) and used for the IWM-1 assessment. All three sites are in Fish Stream Class 5 (Northern Streams) and Macroinvertebrate Stream Class 4 (Northern Forest Streams - GP). The AUID was assessed in spring 2012 as having an impairment of the fish community, based on the 2005 sample at 05RN010. The other two sites had passing fish IBI scores. All three sites had passing macroinvertebrate IBI scores. A fourth site was added in IWM-2 (18RN014), and two of the IWM-1 sites were not included in IWM-2 sampling due to a modified site selection protocol for IWM-2.

Subwatershed characteristics

All of AUID-517 and most of the full length of Rice River flow through the bed of Glacial Lake Agassiz (Figure 8). Streams within the glacial lake bed generally have very low gradient. The land use and land cover in the subwatershed consists of a mix of perennial woody vegetation and wetlands, with a smaller amount of pasture/hay land and no row crop agriculture. Five registered feedlots are found in the subwatershed, all of them near the channel of AUID-517. There are no towns within the subwatershed boundary.

Figure 8. Rice River Subwatershed and extent of AUID-517, with locations of biological monitoring sites.



Additional biological sampling for reconsidering assessment

Several additional fish and macroinvertebrate samples were collected following the spring 2012 LFRW assessment process and determination of an impaired fish community in AUID-517. In the summer of 2012, site 05RN010 was resampled for both fish and macroinvertebrates. Because the 2012 samples at 05RN010 were quite good for both fish and again for macroinvertebrates (Table 2), it was determined that this AUID may not actually be impaired.

An internal report was written following the 2012 sampling, with a re-analysis of the all samples (both old and new biology and chemistry) and recommendations for additional sampling to attempt a delisting of the fish impairment (MPCA, 2014 - see Appendix 1). The MPCA protocol for delisting required additional samples be collected, which was done in summer of 2015. These samples confirmed the good scores collected in 2012 (Table 2). In total, 14 of 15 biological samples were better than the appropriate IBI passing thresholds, including 8 of 9 fish samples, and all macroinvertebrate samples. Also, several of the fish and macroinvertebrate scores were better than the Exceptional Use threshold, including both subsequent samples at 05RN010. As a result of the 2012, 2015, and 2018 samples, the de-listing process was begun, and in 2020, the MPCA's Assessment Consistency and Technical Team reviewed the data, following the de-listing process protocol, and determined that AUID-517 should not be considered impaired, and should be removed from the state's 303(d) list. The EPA approved the delisting in 2024.

Table 2. FIBI and MIBI scores for all samples on AUID-517. Sites listed in order from downstream to upstream.

Site	Year	FIBI Threshold	FIBI	MIBI Threshold	MIBI
08RN002	2008	47	55.1	51	52.9
08RN002	2015	47	58.5	--	--
08RN002	2018	47	54.2	51	59.6
05RN010	2005	47	44.5	51	83.0
05RN010	2012	47	61.6	51	82.1
05RN010	2015	47	69.8	--	--
08RN036	2008	47	73.2	51	65.3
08RN036	2015	47	73.9	--	--
18RN014	2018	47	70.3	51	86.3

Other notable findings

No chemical parameters appeared problematic based on the chemistry data available from IWM-2, with the possible exception of DO (Table 3). The assessment decision for DO levels was "inconclusive". There was one pre-9:00 a.m. measurement that was below the DO standard, though by a small amount. However, there were also several post-9:00 a.m. (even later afternoon) measurements that were above the standard by a relatively small amount, indicating DO concentrations likely were below 5.0 mg/L in the early mornings of those days. Additionally, a number of the samples were collected in September, when DO conditions generally improved due to cooler water temperatures setting in, so these were probably not reflective of DO levels during the warmest part of the summer.

Table 3. DO measurements from four monitoring sites along AUID-517 from several different years.

Bio Site #	Date	Time	DO	DO % Sat.
08RN002	8/26/2008	8:29	5.94	--
08RN002	7/8/2015	16:06	6.08	72
08RN002	9/10/2018	14:07	7.06	74
08RN002	9/11/2018	16:29	7.01	75
05RN010	8/16/2005	11:43	7.6	--
05RN010	9/18/2012	10:54	6.96	--
05RN010	7/28/2015	12:58	5.31	68
08RN036	8/25/2008	15:01	6.65	--
08RN036	7/8/2015	12:42	6.67	78
18RN014	9/7/2018	9:55	6.41	67
18RN014	8/16/2018	9:08	4.82	54

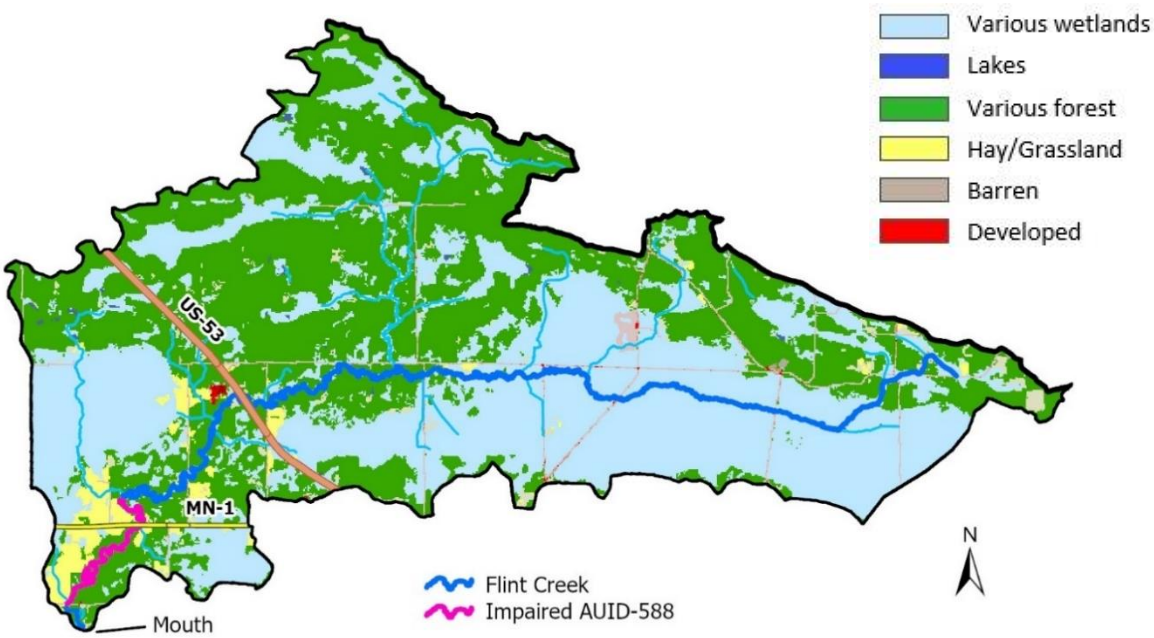
Flint Creek (AUID 09030005-588)

AUID-588 is an approximately 3.38 miles long reach, with several AUIDs upstream and one short AUID downstream of AUID-588. This section of Flint Creek is a natural, unmodified channel. There is one biological monitoring site on AUID-588, 08RN051 just downstream of State Highway 1. The stream is held to the General Use fish and macroinvertebrate standards. The AUID had passing IBI scores for the fish and macroinvertebrate communities but was assessed as having an aquatic life impairment of TSS and a recreational impairment of *E. coli* (bacteria). Additional TSS and *E. coli* monitoring was conducted after the assessments, and the results are presented in this report for TSS and in the Flint Creek *E. coli* TMDL Report for *E. coli* (MPCA 2026b). DNR conducted geomorphology assessment of Flint Creek, which is presented in a separate section toward the end of this document.

Subwatershed characteristics

The full length of Flint Creek (includes five AUIDs) flows through Glacial Lake Agassiz lakebed clay sediment. The land cover is mostly perennial woody vegetation or wetland, with a relatively small amount of pasture/hay field in the southwestern corner of the subwatershed near MN Highway 1 (Figure 9). There is no row crop agriculture, nor a city within the watershed, though a high school campus and a golf course are located here.

Figure 9. Land use/cover map of Flint Creek. The particular AUID of the creek that is listed as TSS-impaired is noted.



TSS investigations

A reconnaissance trip was made to observe Flint Creek at all of its road crossings to see if TSS appears to vary along the Creek's length and to look at the condition of banks, to help identify sediment sources or hot-spot areas of erosion. Visual observations indicated that TSS is higher in the downstream portions of the creek. Also from visual ground observations, Little Flint Creek, a tributary that enters Flint Creek at the border of AUIDs 612 and 613, appears to contribute high amounts of suspended sediment. Banks of Little Flint Creek were steep, unprotected exposed soil and the stream appeared to be incised. Some bank sloughing was observed (Figure 10 and Figure 11). Additionally, aerial photos of the confluence of Little Flint Creek with Flint Creek show much more turbid water in Little Flint Creek (Figure 12).

Because the conclusion of the observational visit was that TSS varies along the length of Flint Creek, longitudinal TSS sampling was conducted at several crossings of Flint Creek on 6/9/2022 during baseflow conditions. Sample sites and results are shown in Figure 13 and Table 4. Sampling included a near-mouth site on Little Flint Creek, which confirmed that it has higher TSS concentration than Flint Creek does where they join. Over the full length of Flint Creek, there is a general pattern of increasing TSS from upstream to downstream, with the highest measurement at the near mouth site at Hwy-1.

Because Little Flint Creek had signs of unstable banks and greater TSS concentrations, it would be beneficial to conduct a geomorphological survey at a representative site along the creek. This survey would determine the degree of channel instability and provide information that may be helpful in deciding if stream restoration efforts would reduce TSS exports from the creek.

Figure 10. Looking upstream on Little Flint Creek from Olson Road.

Figure 11. A closer view of a bank slump on Little Flint Creek.

Figure 12. The confluence of Little Flint Creek with Flint Creek, showing the greater turbidity of the water in Little Flint Creek. Photo date is 5/4/2015. Arrows show flow directions.

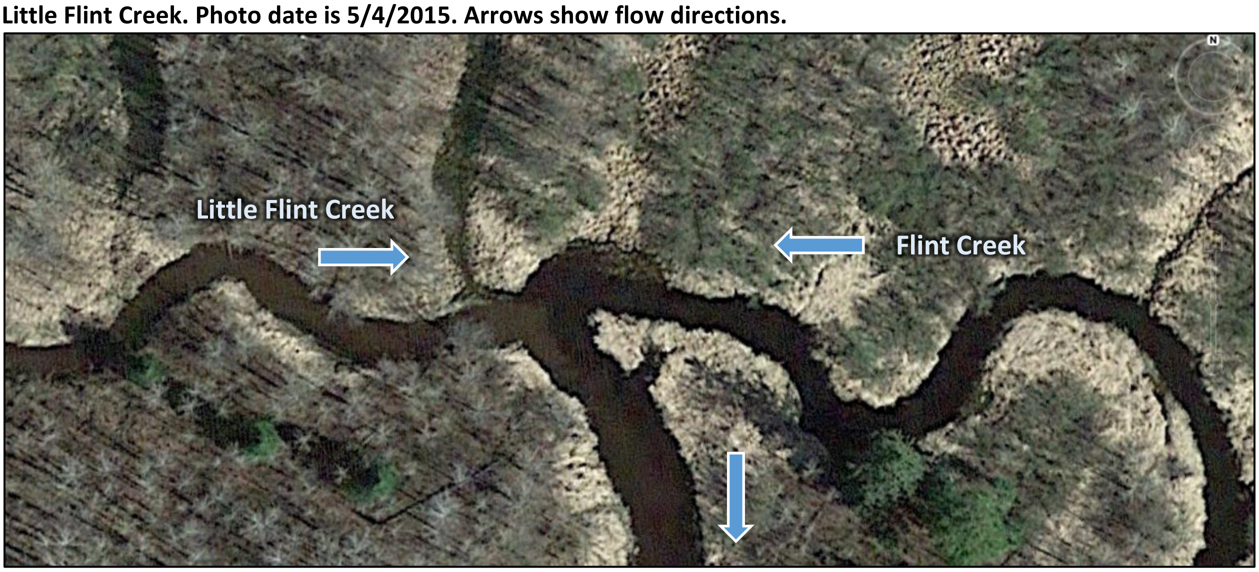


Figure 13. Map of longitudinal TSS sample sites on June 9, 2022.

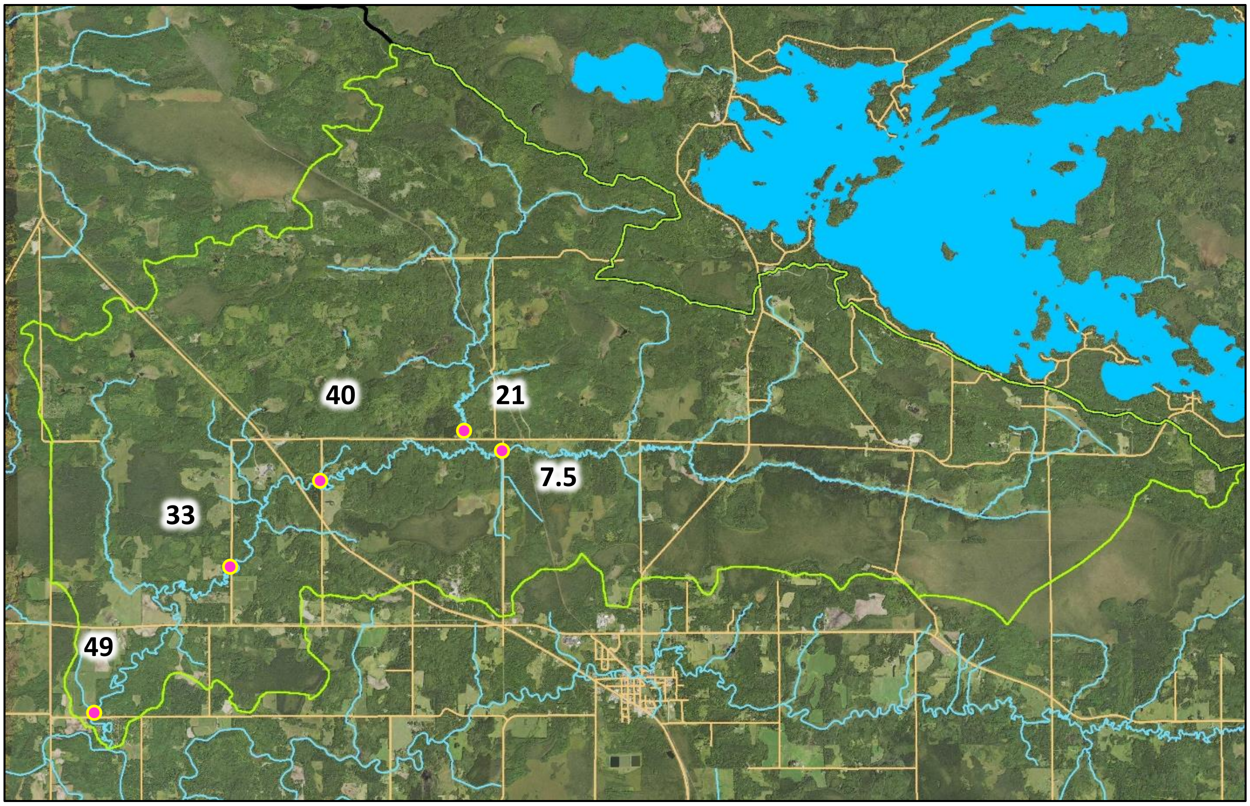


Table 4. TSS and TSVS sample results (mg/L) from longitudinal sampling of Flint Creek and Little Flint Creek, June 9, 2022. Locations are shown in Figure 8 above.

	Date	mg/L	S010-836	S016-763	S016-764	S013-987	S016-765
Flint Cr.	6/9/2022	TSS	7.5	40	33	49	--
Flint Cr.	6/9/2022	TSVS	--	--	--	9	--
Little Flint Cr.	6/9/2022	TSS	--	--	--	--	21

IWM-2 biologically-impaired streams

The individual AUIDs that came out of the assessment process as impaired are discussed separately from this point on. The general format will be: 1) a review and discussion of the data and possible stressors that were available at the start of the SID process; 2) a discussion of any additional data that were collected during the SID process; and 3) a discussion of the conclusions for the AUID based on all of the data reviewed.

Note: From this point on, the AUIDs referred to in the text (except main headings) will only include the unique part of the 11-number identifier, which is the last three digits.

Gilmore Creek (AUID 09030005-594)

Impairment: AUID-594 is a 3.6 miles long reach of Gilmore Creek. The upper half of the AUID is a straightened channel, while the lower half is natural. One biological monitoring site is located in AUID-594. Site 08RN031 is just upstream of CR-82 within the straightened section. The stream is held to the General Use fish and macroinvertebrate standards. The AUID was assessed as having an impairment of the macroinvertebrate community. The Macroinvertebrate Stream Class is 4 (Northern Forest Streams - GP). None of the conventional chemical parameters measured had enough data to assess them.

Subwatershed characteristics

The majority of the stream system upstream of site 08RN031 has been straightened. The majority of the land use and land cover within the upland areas of the subwatershed are forested, with a somewhat even mix of shrub/scrub and grassland/hay for the remainder (Figure 14). There is one registered feedlot and no row crop agriculture. Approximately one third of the area of the subwatershed is wetland, which is adjacent and hydrologically linked to the channel system (Figure 15). There are no towns in the Gilmore Creek Subwatershed and no permitted effluent dischargers to AUID-594 or anywhere on Gilmore Creek. A section of the stream located well upstream from the location of the biological sampling site was re-meandered as a restoration project in 2014. This stream occasionally becomes intermittent, as evident in the 2015 Google Earth aerial photo (downstream where beavers are not causing impoundment). Impoundments may retain water during these non-flowing periods.

Figure 14. Land use/cover of the Gilmore Creek Subwatershed. The black circled area is where a ditched stream section was re-meandered in 2014.

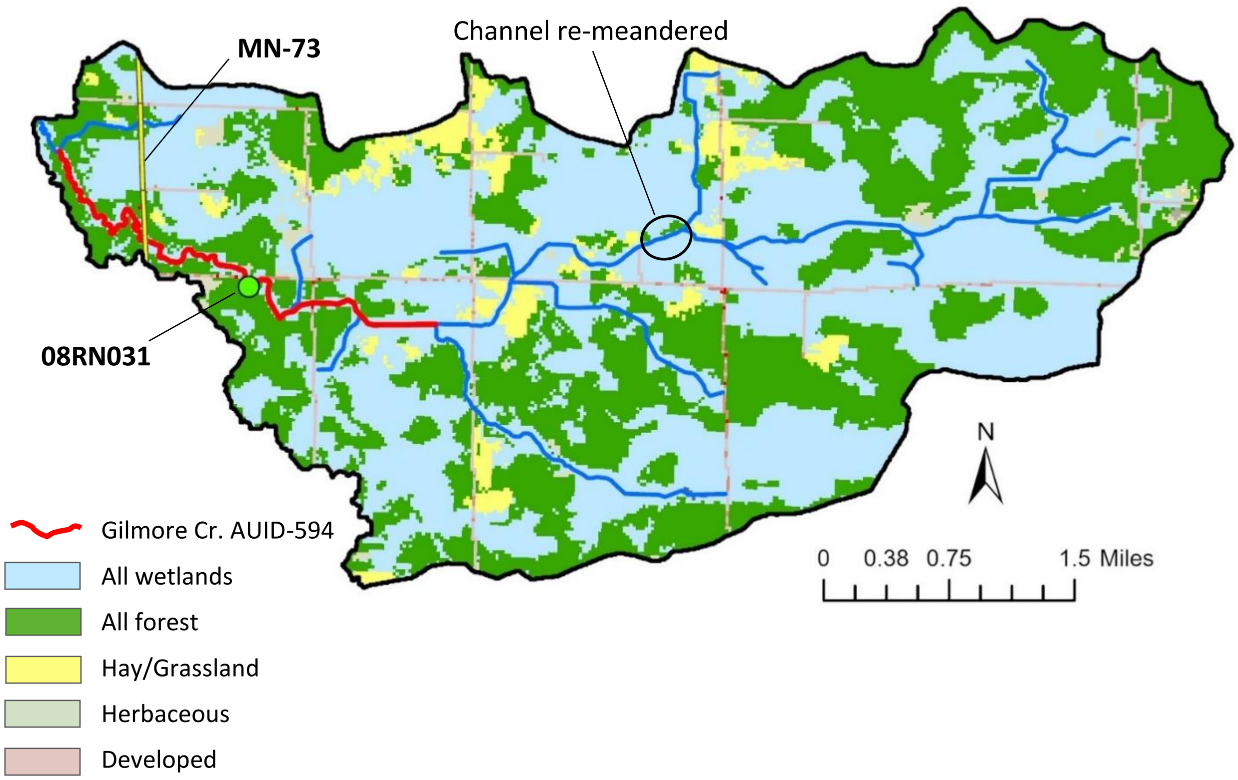
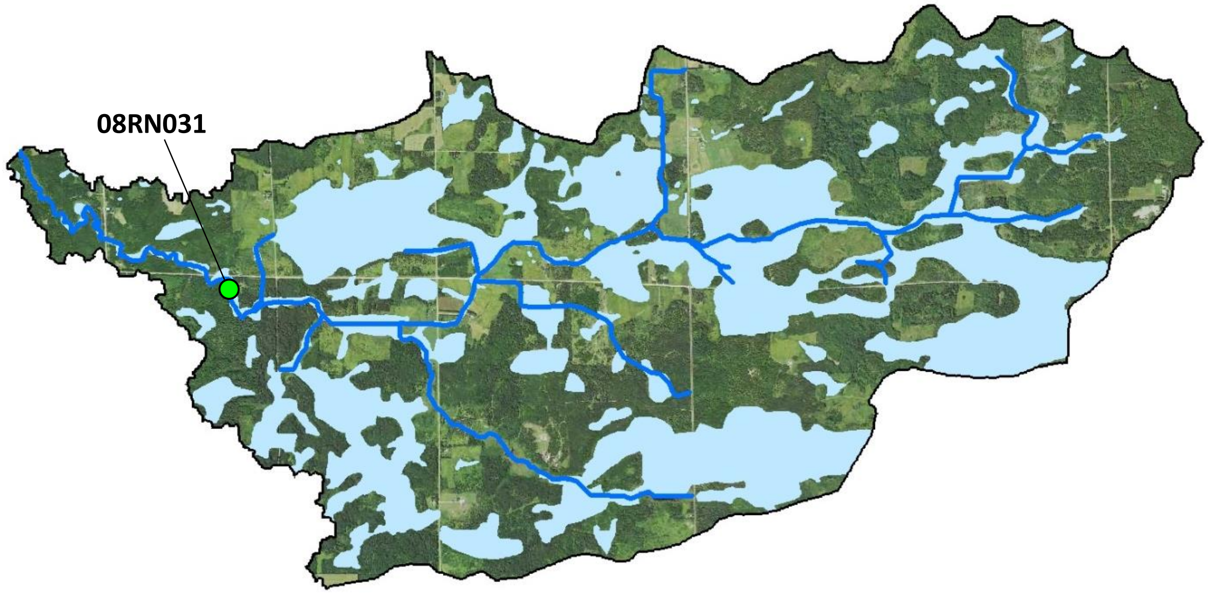


Figure 15. Wetland areas (light blue patches) within the Gilmore Creek Subwatershed from the NWI. These wetlands are hydrologically connected to the stream channel network.



Data and Analyses

Chemistry

The chemistry sampled at biological monitoring visits is presented in Table 5. Data are discussed below by parameter.

Table 5. IWM chemistry results from 2008, 2018, and 2019 at 08RN031.

Date	Time	Water Temp.	DO	DO %	Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	TSS	TSVS
6/18/2008	13:21	16.7	6.70	--	70	0.108	< 0.05	< 0.05	6.6	--	55	5.6
7/26/2018	8:45	18.9	1.89	20	92	0.150	< 0.02	< 0.1	--	49	14.5	--
8/16/2018	11:00	18.6	3.21	34	177	--	--	--	7.1	30	--	--
8/5/2019	7:45	23.1	5.19	59	171	0.091	< 0.02	< 0.1	7.1	36	5.4	--

Nutrients - phosphorus

Phosphorus concentrations were all much higher than the regional River Eutrophication Standard. It is likely that much of this phosphorus is natural as the stream is hydrologically-connected to large wetlands. There are very few residences located close enough to the stream where septic systems could possibly be a source of phosphorus.

Nutrients - nitrate and ammonia

Nitrate concentrations were all extremely low, as were ammonia concentrations. Levels this low suggest eutrophication is not occurring in the stream.

Dissolved oxygen

DO levels were low. Two measurements are well below the standard. DO percent saturation levels were also very low (far below 100%) suggesting the stream water has been in places with significant decay of organic material and/or that significant groundwater is feeding the stream. An additional investigation of stream DO levels was conducted as part of the SID work. On July 10, 2020, a longitudinal sampling of DO, DO % saturation, water temperature, and specific conductance was completed at several locations along AUID-594 (Table 6). Beaver impoundment appears to be negatively influencing DO concentrations at some locations.

Table 6. Longitudinal measurements along AUID-594 on July 10, 2020, listed from downstream to upstream. The day's weather was bright sunshine, and approximately 80°F.

Location	Time	DO	DO % Sat.	Temp	Sp. Cond	Notes
State Highway 73	13:54	3.81	45.4	23.9	98.2	Beaver dams present downstream of 08RN031.
CR-82 (Heino Rd)*	14:01	1.86	23.5	23.5	107.9	Estimate of 1-2 cfs flow volume.
Roini Road	14:11	1.06	12.1	24.4	125.0	Beaver impounded on both sides of the road.
Carpenter Road	14:22	6.82	80.3	23.4	181.3	Shallower water depth than downstream sites.
CSAH-25	14:48	6.01	70.5	23.0	136.8	--

*This is site 08RN031

Specific conductance

Specific conductance was low and at levels typical for natural conditions in northern Minnesota.

Suspended solids

The small dataset of TSS samples show that TSS can vary widely and can be over the Northern TSS standard. When TSS is high, the component that is mineral is very high in comparison to organic particulates. The sample from June 2018 was 90.8% mineral and 9.2% organic. It is not known how frequently the TSS is high.

Stressor signals from biology

Macroinvertebrates

Two recent macroinvertebrate samples were collected at 08RN031, in 2018 and again in 2019. The 2018 sample was dominated by two taxa, Oligochaetes (worms) and the midge *Paratanytarsus*. There were six relatively dominant taxa, including those mentioned; others were two additional midge taxa, the snail *Ferrissia*, and the amphipod *Hyalella azteca*. Many wetland-oriented taxa (several snail species, insects within the Order Hemiptera, and several aquatic beetles) were present. Few Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies [EPT]) taxa were present. In the 2019 sample, the community was very similar, with slight differences in the most abundant taxa present. The midge *Endochironomus* and again Oligochaetes were the dominant taxa. Again, there were six relatively dominant taxa, with others being three midge taxa and the Dipteran taxa Ceratopogonidae (a.k.a. "no-seeums"). There were also numerous snail, Hemipteran, and beetle taxa.

The Community TIV Index scores are shown in Table 7 and individual TIV metrics in Table 8. The DO TIV Index score was much poorer than the class average for all three samples, and the score is at a low percentile of DO TIV Index scores for stream class 4, particularly the two recent samples. The probability of the sampled community coming from a DO standard-meeting site is very low. The community is heavily skewed toward taxa that are low-DO tolerant in terms of the species that were present, and low-DO tolerant individuals comprised a high percentage of the sample.

The TSS TIV Index score for the three samples varies quite a bit relative to the class 4 average, once being better and twice being worse. The percentiles within class 4 streams varied substantially among the three sites, but the probability of the communities coming from a standard-meeting site is well below 50% for all three samples. The community is skewed toward TSS tolerant taxa in terms of both the taxa present and the percent of TSS tolerant individuals. There were only one or two TSS intolerant taxa present, while at least eight TSS tolerant taxa were present in each sample.

Given that the DO TIV Index score is very poor, and that the intolerant versus tolerant taxa presence and percent of individuals are strongly skewed toward low-DO Tolerance, the macroinvertebrate community shows strong evidence of stress from inadequate DO concentrations. There is moderate evidence that TSS is a stressor to the macroinvertebrate community, but not as strong as the evidence for low-DO stress.

Table 7. Macroinvertebrate Community DO and TSS Tolerance Index scores in AUID-594 at 08RN031 on three dates. For DO, a higher index score is better, while for TSS, a lower index score is better. "Percentile" is the rank of the index score within stream class 4. "Prob." is the probability a community with this score would come from a stream reach with DO or TSS that meet the standards.

Date	Parameter	TIV Index score	Class avg./median	Percentile	Prob. as %
8/5/2008	DO	5.49	6.30/6.49	13	29
8/16/2018	DO	4.41	6.30/6.49	5	11
8/5/2019	DO	4.60	6.30/6.49	6	13
8/5/2008	TSS	15.53	13.62/13.77	12	37
8/16/2018	TSS	13.31	13.62/13.77	59	42
8/5/2019	TSS	14.79	13.62/13.77	25	39

Table 8. Metrics involving low-DO and TSS tolerance for the sampled macroinvertebrate community at 08RN031 on three dates.

Date	Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
8/5/2008	Low DO	1	0	10	1	0.6	50.3
8/16/2018	Low DO	0	0	16	7	0.0	55.0
8/5/2019	Low DO	0	0	15	6	0.0	50.5
8/5/2008	TSS	2	0	11	6	0.9	17.3
8/16/2018	TSS	1	0	8	4	2.0	18.9
8/5/2019	TSS	2	0	9	4	0.6	35.2

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Temperature

The water temperature was cool to moderate at biological sampling visits and during the SID work, with no indication that temperature levels stressful to warmwater biological communities occur. Based on these data, temperature should not be a stressor to the biological communities.

Habitat

The biological sample reach was within a straightened section of stream. The Minnesota Stream Habitat Assessment (MSHA) procedure scored habitat in the "Fair" range in three of four visits, with the remaining visit rating "Poor". The UAA process rated habitat as sufficient to be placed into the General Use Tiered Aquatic Life Use (TALU) category. The total and sub-component scores are shown in Table 9. The 2008 survey scored best. Two of the recent survey scores were slightly lower than in 2008, with the last survey score being substantially lower. The reason behind the drop in the 2019 score is not known, but the scores for channel morphology and fish cover were scored far lower than any previous time. Reviewing the various factor scores within these broader categories, it appears that there may have been some observer variability in scoring between visits, as well as differences in water levels between years, which can affect scoring. In general, the poorest-scoring sub-component scores were "Substrate" and "Channel Morphology". These two components generally score poorly for ditched channels, which typically have little sinuosity, uniform bed topography, and lack of distinct channel features like pools or riffles. These characteristics were indeed responsible for the poor score for these MSHA components. Though small amounts of gravel, cobble, and boulders were found in the reach, clay was the far dominant substrate type, and the larger substrates were partially embedded. The morphology measurements found the channel to be very homogeneous, lacking distinctive bed features.

Notes from the macroinvertebrate samplers in both 2018 and 2019 recorded difficulty finding quality macroinvertebrate habitat to sample. The MSHA is somewhat more oriented to assessing habitat for fish, and the comments by the macroinvertebrate samplers suggest the scores may be indicative of better habitat than actually is present for the needs of macroinvertebrates. Lack of diverse habitat does appear to be a stressor for macroinvertebrates.

Table 9. MSHA scoring for site 08RN031.

MSHA Component	6/2008	7/2018	8/2018	8/2019	2018-19 Avg.	Maximum Poss. Score	2008 % of Maximum	2018-19 % of Maximum
Land Use	5	5	5	5	5.0	5	100	100
Riparian	11.5	11	9.5	10.5	10.3	14	76.7	73.6
In-stream Zone	7.6	13	13	10	12.0	28	28.1	42.9
Cover	14	13	16	6	11.7	18	82.4	65.0
Channel Morphology	21	14	12	5	10.3	35	58.3	29.4
Total MSHA Score	59.1	56	55.5	36.5	49.3	100	59.1 = "Fair"	49.3 = "Fair"

Hydrology

There has been significant modification of the natural hydrology of the subwatershed, as all of the AUID from the point of the biological sample location to the headwaters had been straightened. Recently, a mitigation project restored part of this stretch to its original channel, naturalizing the stream and its hydrological patterns partially. Several tributaries are also small ditches. These ditches allow water to move through the system quicker than would have occurred naturally, although beaver activity counteracts this effect. Therefore, it may be that the net effect on hydrology has not changed so much from pre-settlement times. Conversion of original forest land to pasture/hay lands has also changed watershed hydrology, potentially leading to more runoff or the timing of runoff (e.g., at snowmelt).

Geomorphology

No geomorphology studies were conducted on AUID-594. On the ground visits and reviews of aerial photos found little to no channel instability resulting from altered hydrology. This is a relatively small stream system, and it may be that even at high flows, there is not sufficient stream power to cause bank erosion leading to a destabilized channel. In the headwaters section, areas of bank stress (erosion) can be seen due to livestock trampling of bank areas.

Connectivity

Connectivity issues mostly affect the fish community, and much less the macroinvertebrate community. Though there are somewhat temporary fish migration barriers due to beaver dams, the fish are able to do well in this AUID. Thus, connectivity is not a stressor to the impairment of Gilmore Creek.

Conclusions about stressors

The majority of the length of Gilmore Creek has very low gradient, meaning that water moves in the channel very slowly, making it attractive habitat for beavers to create dams and impoundments. Beavers are abundant in this part of Minnesota, and significant activity was seen visually from the ground and on aerial photography. There is also a large amount of wetland habitat that is hydrologically connected to Gilmore Creek. All of these factors contribute to creating low-DO concentration conditions in Gilmore Creek. This has been clearly shown to be a stressor to the macroinvertebrate community. Neither the nutrient data, visual observations of the amount of aquatic macrophytes/algae, nor afternoon DO measurements suggest that the creek is experiencing eutrophication as the cause of low DO levels.

Additionally, there is a relative lack of desired habitat features for macroinvertebrates. Larger hard substrates (gravel/cobble and large, stable wood pieces) and lack of areas with swifter flow velocity are notable habitat features that are not present. These missing features may be in part natural, and in part due to the excavation done to straighten the channel decades ago. There is slight evidence that elevated TSS may also be a stressor, but this is not certain, and there are no obvious situations present that would be sources of the TSS (e.g., channel instability or large areas of tilled soils).

Natural Background determination

Because low DO is sometimes caused by natural conditions (generally relating to wetland influence and/or beaver impoundment), and SID monitoring and observations suggested that beavers and their numerous impoundments in Gilmore Cr. were causing low DO conditions in the stream, an argument for moving this impairment from Class 5 (TMDL needed for pollutant reduction) to Class 4D (impairment due to natural conditions) was brought to the MPCA ACCT for a decision. The decision was to deny moving Gilmore Creek to the natural background impairment category. A prior consultation about whether it could be moved to impairment category 4C (nonpollutant anthropogenic impairment) ended with a recommendation to attempt a move to 4D. A written record of the determination is kept by MPCA. The ACCT (regarding class 4D) cited channel straightening of Gilmore Creek as a potential stressor that cannot be ruled out.

Recommendations

Collection of additional TSS samples would be beneficial, in order to better determine if concentrations can be at stressful levels sometimes, as the June 18, 2008, sample suggests may be the case. Some TSS samples should target rain events, since baseflow TSS concentrations meet the standard. Addressing poor physical habitat will be difficult, because the characteristics found are typical of ditches, especially if they are maintained. Allowing ditches to develop some habitat features by reducing maintenance/clean-outs will improve biological community health. A re-meandering project in the straightened portions of the creek is unlikely to be a practical solution to achieving a passing macroinvertebrate community. Beaver will likely continue to be active in the future in Gilmore Creek, leading to insufficient DO for a thriving macroinvertebrate community in this low gradient stream.

Timber Creek (AUID 09030005-630)

Impairment: AUID-630 is an approximately 4.5 miles long natural reach within US Steel Minn Tac property. There were three biological monitoring stations (18RN001, 18RN002, 18RN003) used in assessing Timber Creek. A fourth site (20EM075) was sampled after the assessment of the creek. It is a randomly chosen site used in a separate national monitoring project that is done every five years and led by EPA. The channel is natural, and the stream is held to the General Use fish and macroinvertebrate standards. The AUID was assessed as having an impairment of the macroinvertebrate community. The fish community scored very well. The Macroinvertebrate Stream Class is 3 (Northern Forest Streams - RR) for sites 18RN001, 18RN002, and 18RN003, and Class 4 (Northern Forest Streams - GP) for site 20EM075; the Fish Stream Class is 6 (Northern Headwaters) for sites 18RN001, 18RN002, and 18RN003, and Class 7 (Low Gradient) for site 20EM075. None of the conventional chemical parameters had enough data from IWM monitoring to assess them against standards.

Subwatershed characteristics

Timber Creek flows within a natural landscape, though also quite near the large tailing ponds of the Minn Tac Mine (Figure 16). The tailings basin is not within the subwatershed of Timber Creek (due to the large berm surrounding the tailings basin), so no surface runoff should be moving from the tailings area to the creek. It is possible that there could be groundwater connectivity from the tailings area with the stream (i.e., groundwater moving from tailings area to the creek). There are no cities/towns in the subwatershed. There are no permitted effluent dischargers to AUID-630, however there is a discharge permit to the headwater channel of the Dark River, extremely close to the downstream end of AUID-630. Also, there is some documented hydrological connection to the tailing basin via groundwater as the stream’s specific conductivity is far above the natural levels for this area of Minnesota (though parts of Minnesota have natural conductivity levels in this range). Beavers are very active in this and other streams in this region (Figure 17)

Figure 16. The subwatershed outline of Timber Creek, AUID-630 (orange outline), as delineated by the USGS internet tool StreamStats. The black line is the boundary that separates the Little Fork River (above) and St. Louis River (below) watersheds. Arrows show flow direction.

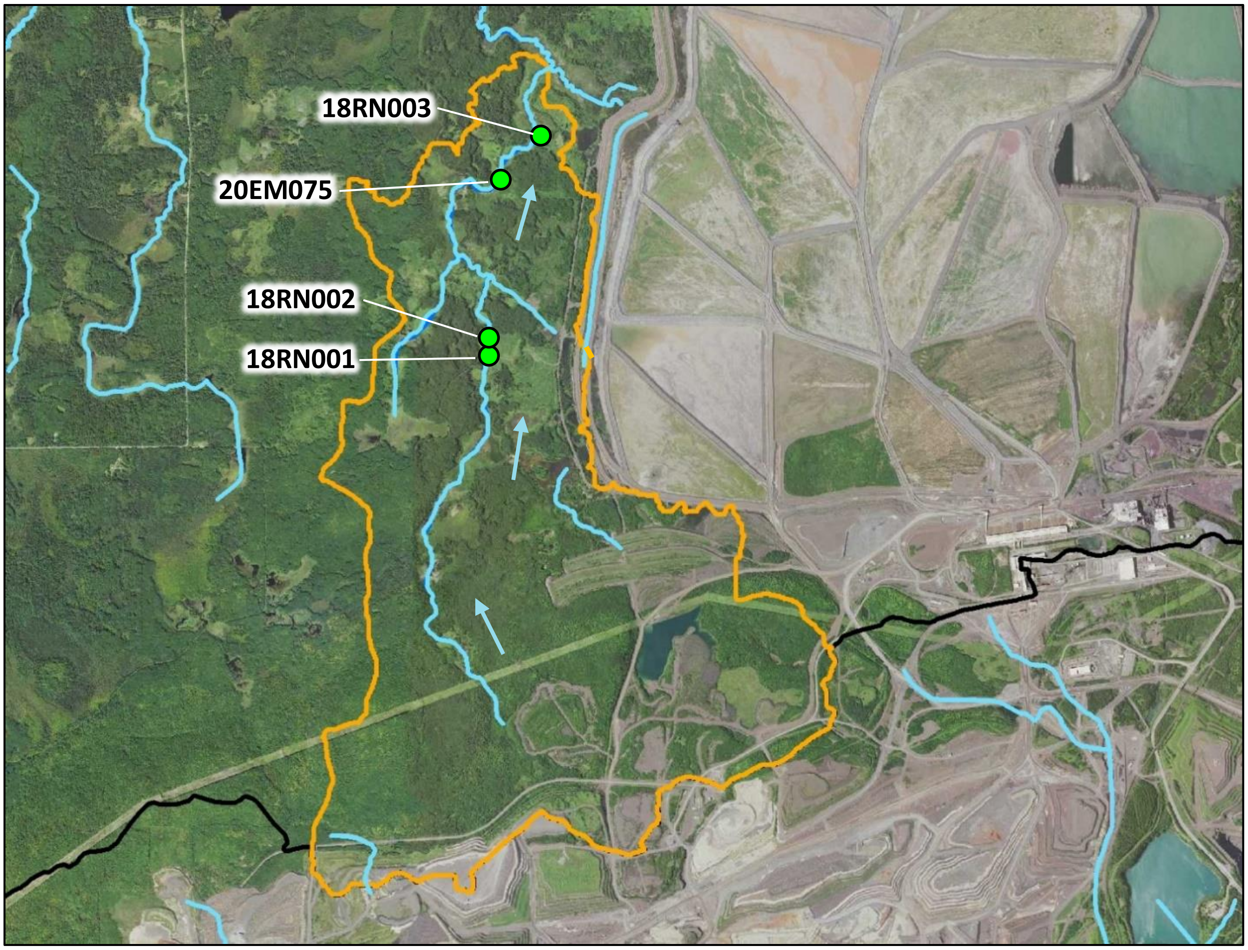


Figure 17. Stream channel upstream of 18RN003. Orange dots signify where beaver dams are located. Arrows show direction of flow. The yellow pins show the upstream and downstream ends of the 18RN003 sample reach.

Data and Analyses

Chemistry

The chemistry sampled at biological monitoring visits is presented in Table 10. Data are discussed below by parameter.

Table 10. Water chemistry results from 2018 and 2019 biological sampling visits at 18RN001, 18RN002, and 18RN003.

Date	Time	Water Temp.	DO	DO %	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	TSS
18RN001											
8/7/2018	15:56	21.4	7.87	89	1452	--	--	--	8.45	> 100	--
8/9/2018	13:28	24.3	8.25	99	1664	--	--	--	8.17	> 100	--
7/20/2019	11:15	21.2	5.23	59	1422	--	--	--	7.81	--	--
7/22/2019	--	--	--	--	--	--	--	--	--	--	--

Date	Time	Water Temp.	DO	DO %	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	TSS
9/18/2019	10:30	18.08	5.95	63	958	--	--	--	7.83	--	--
18RN002											
8/6/2018	14:50	21.8	8.31	95	1689	--	--	--	8.46	85	--
8/9/2018	10:47	21.4	7.37	88	1559	--	--	--	8.17	> 100	--
18RN003											
8/6/2018	11:45	19.5	7.09	77	1444	--	--	--	8.09	--	--
8/9/2018	8:24	17.8	4.61	49	1277	--	--	--	7.73	> 100	--
8/29/2018	9:45	14.9	6.05	60	1307	--	--	--	7.65	> 100	--
7/20/2019	8:55	19.5	4.25	46	1178	--	--	--	7.52	--	--
9/18/2019	9:00	17.1	4.67	49	804	--	--	--	7.34	--	--
20EM075											
8/25/2020	14:50	20.4	3.27	36.3	861	0.128	< 0.02	< 0.10	7.41	> 100	--

Nutrients - phosphorus

No phosphorus data were collected during the 2018 - 2019 monitoring. One sample was collected from the EMAP site in 2020. TP in that sample was high, though such levels are commonly found in small northern Minnesota streams in similar landscape settings (i.e., moderate gradient small streams with much beaver impounding and having substantial riparian wetlands).

Nutrients - nitrate and ammonia

No nitrate data were collected in the 2018 - 2019 monitoring. One sample was collected from the EMAP site in 2020. Nitrate and ammonia were both extremely low and below the laboratory's detection limits for these parameters. Low concentrations such as these are the norm in the forested parts of northern Minnesota that have only moderate human activity. Nitrate toxicity to macroinvertebrates is not occurring here.

Dissolved oxygen

DO levels from earlier morning measurements among the biological sampling visits (Table 10) indicate that DO levels can drop below the standard at site 18RN003. There were no early morning measurements at the other three sites. Measurement at the new 2020 site (20EM075) also found a DO level significantly below the standard, even though the time of day the measurement was taken coincides with the normal daily peak of DO concentration. Though the DO appears to be fairly different at the two most-upstream sites from these few measurements, this is probably attributable in part to the time of day they were sampled. It is normal for morning measurements to be lower than mid-day levels, and site 18RN003 generally had much earlier measurements than the other two sites.

DO percent saturation levels were also quite low in the morning, being substantially below 100%, suggesting the stream water has been in places with significant decay of organic material (where microbes utilize the oxygen) and/or the stream has large amounts of aquatic plants or algae (these consume oxygen during the night). The EMAP sample was in a wetland fringed area and indeed, it was found that the substrate was silt and detritus.

In addition to the instantaneous measurements collected at the biological sampling visits, during 2018 the mining company deployed continuously-recording sondes in the creek at 18RN001 and 18RN003 in 2018. At 18RN001, the range of measurements (at 15 minute increments) from June 27 to October 5 was between 4.99 - 10.90 mg/L (Figure 18). Essentially all measurements of DO during this deployment met the state DO standard. Water temperature and DO have an inverse relationship when no other factors are involved (i.e., as water gets colder, it holds more oxygen). There was a strong relationship between water temperature and DO level at 18RN001, suggesting other factors such as aquatic plant photosynthesis and respiration are relatively minor factors in driving the DO level (Figure 18). This can also be seen in the “mirror image” of the DO and temperature in Figure 19, which again suggests that there is not an abundant amount of aquatic plant life/algae within the stream channel in the upstream vicinity of 18RN001. Another piece of evidence supporting this case is that the daily DO flux is in a narrow range, typically fluctuating only about 2 mg/L from minimum to maximum. When plants are abundant, their nighttime use of oxygen (respiration) and their daytime production of oxygen (photosynthesis) results in an increased range of daily minimum and maximum DO concentrations.

Figure 18. The relationship of DO and water temperature at 18RN001, with regression trendline and correlation coefficient.

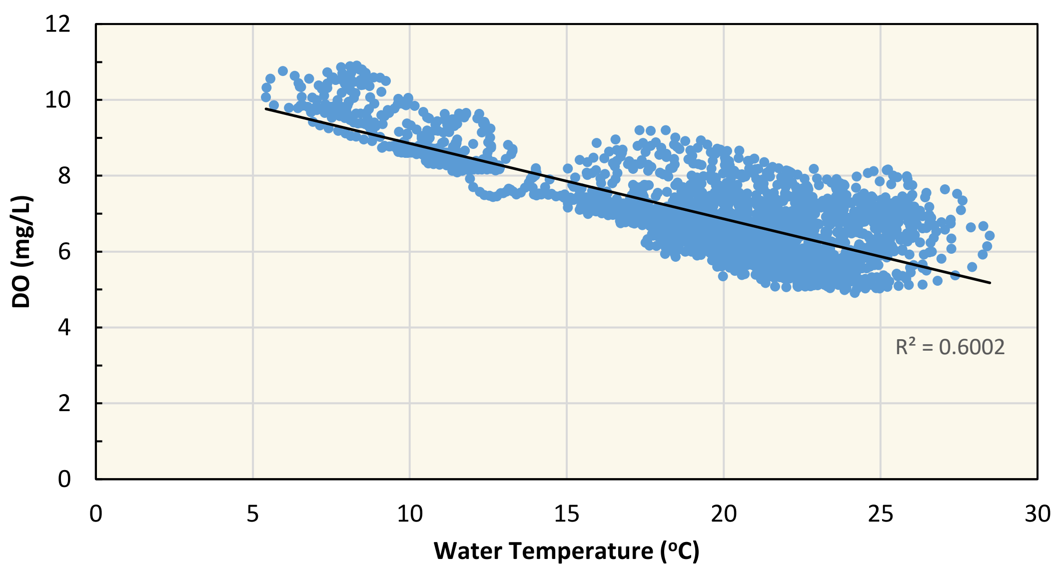
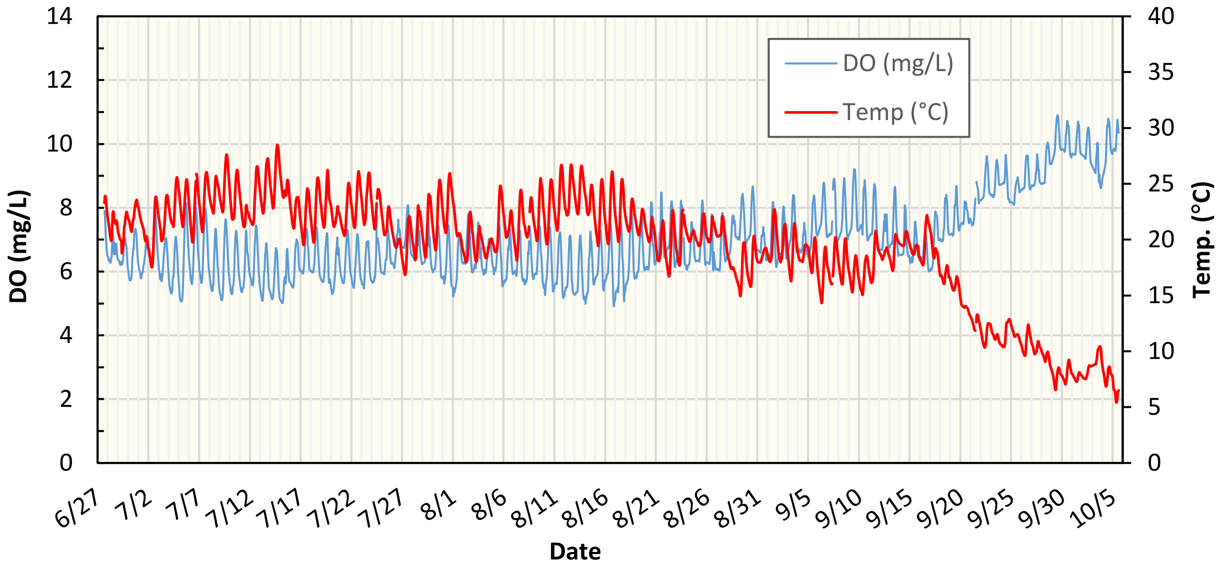


Figure 19. Sonde measurements of DO concentration and water temperature at site 18RN001 from June 27, 2018, to October 5, 2018.



At 18RN003, the range of measurements from the same June 27 to October 5 period was between 1.62 - 12.09 mg/L (Figure 20), a much wider range than at 18RN001. From the June 27 deployment until September 20 (the last date that DO dropped below the standard of 5.0 mg/L), the daily minimum DO concentrations were always below the standard, and generally substantially so. The amount of time during June 27 through September 20 that the DO was below 3.0, 4.0, and 5.0 mg/L was 14.5%, 33.5%, and 50.6% of the time, respectively.

The relationship between water temperature and DO level is different and more complicated at 18RN003 (Figure 21) than at 18RN001. At 18RN003, there is really not a “mirror image” pattern in the DO and temperature readings until mid-September. During the fall (September 15 - October 5), the normal negative relationship of water temperature and DO holds true (Figure 22). However, for the June 27 - September 15 period, the relationship between DO and water temperature is actually a strongly positive relationship (Figure 23). This means that there must be some other factor(s) that are altering the normal temperature/DO relationship.

Two plausible factors to explain the DO/temperature relationship at 18RN003 are aquatic plant and algae growth, and microbial decomposition of organic material. Warmer temperatures are associated with summer and also with days having more sunshine. These are times when aquatic plants are growing and producing oxygen, creating higher DO levels at mid-day. On these same summer nights, aquatic plants/algae are respiring (removing oxygen from the water) and driving DO levels down. Additionally, warmer environmental conditions will lead to greater metabolism of decomposition microbes that are breaking down organic matter in the channel and adjacent wetlands. Their utilization of DO also drives down DO at night. The return of the “mirror-image” relationship begins when plants/algae would have begun seasonal senescence and decline in their influence on DO levels, further supporting the idea that plants are responsible for some of the positive relationship of temperature and

DO in Figure 23. The lower gradient area upstream of 18RN003 is both conducive to plant growth as well as deposition/accumulation of organic material.

Figure 20. Sonde measurements of DO concentration and water temperature at site 18RN003 from June 27, 2018, to October 5, 2018. The horizontal red line is the state DO standard.

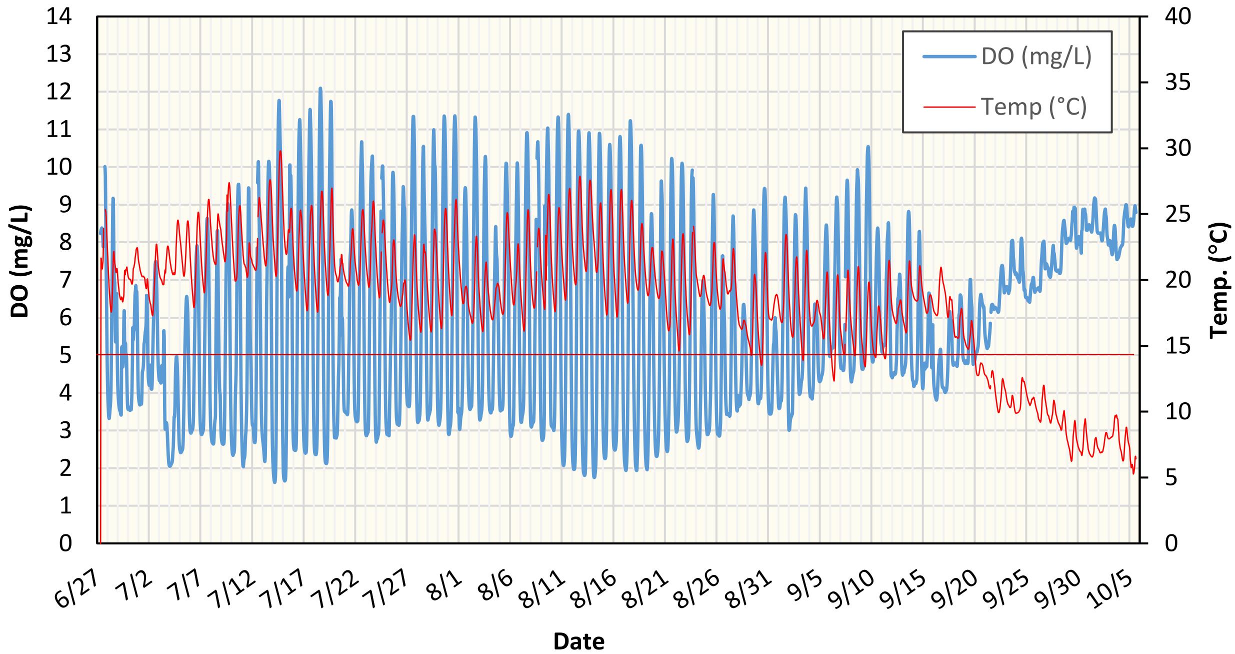


Figure 21. Strength of relationship of water temperature and DO at 18RN003. The trendline (the black line) applies to the whole dataset. Temperature has no correlation with DO level over the full period, as shown by the nearly flat trendline, and extremely small R^2 value. The observed DO level pattern within the red dashed box is largely caused by aquatic plants/algae and decomposition (See figures 9 and 10).

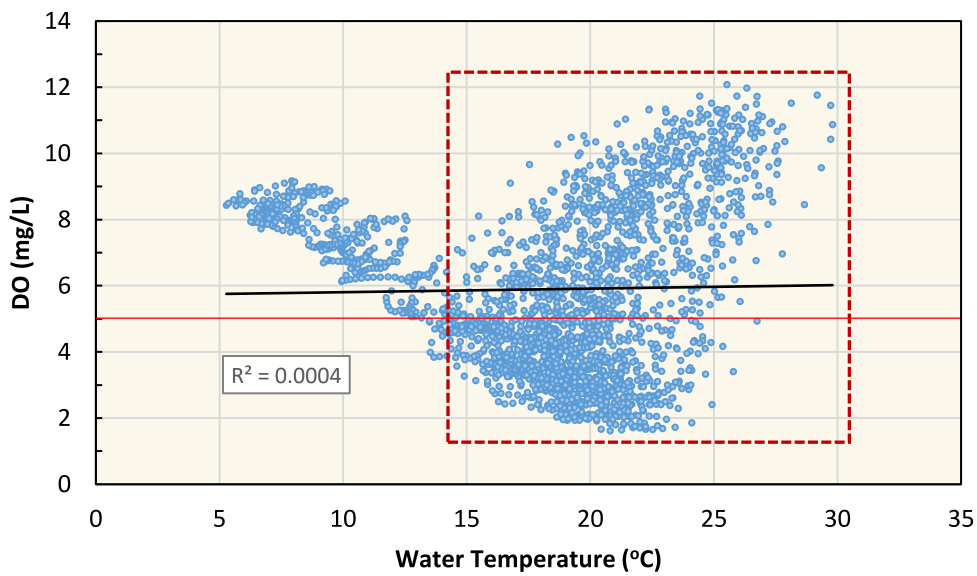


Figure 22. Strength of relationship of water temperature and DO at 18RN003 for measurements from September 15 through October 5 (the dark dots), a time when plant life has largely senesced. For these dates, the trendline shows that water temperature is highly and negatively correlated with DO level (per the high R2 value).

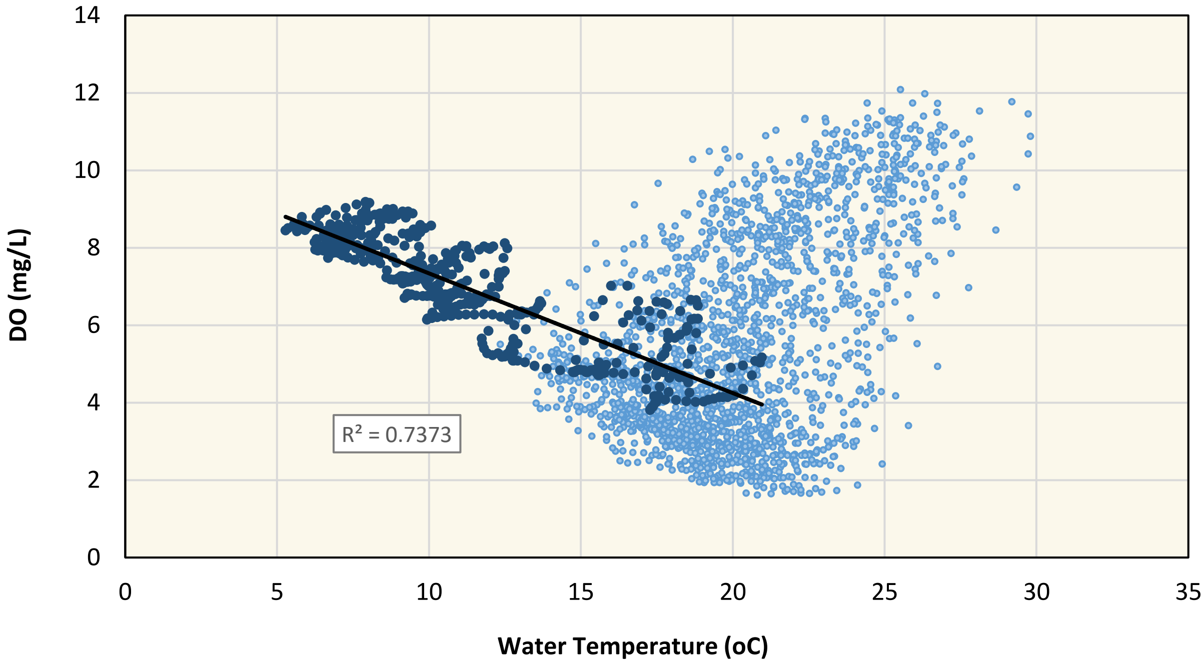
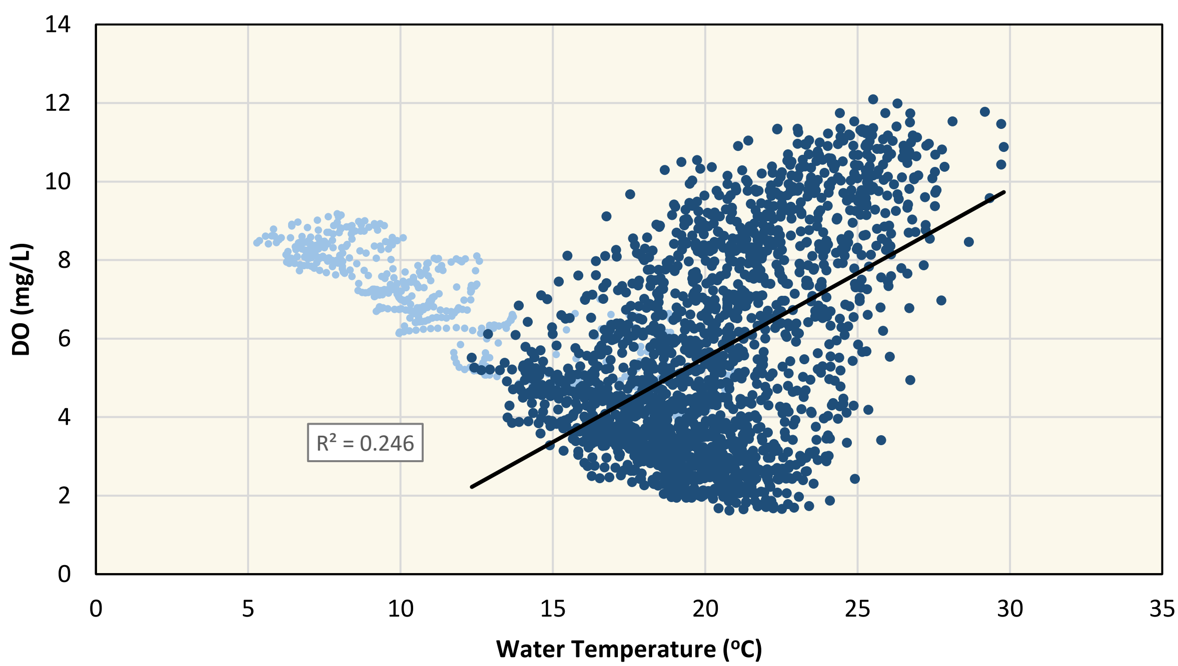


Figure 23. Strength of relationship of water temperature and DO at 18RN003 for measurements from the beginning deployment date of June 27 through September 14 (the dark dots), a time when aquatic plant life is vigorously growing. The trendline for this date period shows that water temperature is positively (though fairly weakly) correlated with DO level (with a moderate the R^2 value).



Specific conductance

Specific conductance was atypically high for natural streams in this part of Minnesota. Specific conductance levels were somewhat similar among the three sites, though generally decreased from 18RN001 to 18RN003 (i.e., from upstream to downstream, Table 11). The apparent springs from the wetland located along Timber Creek in an all-natural area, on the opposite side of Timber Creek from the tailing ponds, may be diluting the specific conductivity somewhat at 18RN003 (Figure 24).

The group conducting the Timber Creek study selected McNiven Creek (18RN005) as a reference stream to which Timber Creek data could be compared. It is located a few miles straight west of Timber Creek and flows parallel with it (Figure 25). McNiven Creek had conductivity levels in the normal range for northeastern Minnesota. Timber Creek's average specific conductance was 11.8 times higher than at McNiven Creek (Table 11) for the 2018-2019 period.

Table 11. Specific conductance at the four Timber Creek sites and reference McNiven Creek reference site on same/similar dates.

Date	18RN001	18RN002	18RN003	20EM075	Date	McNiven Cr.
8/6/2018	--	1689	1444	--	8/6/2018	--
8/7/2018	1452	--	--	--	8/9/2018	92.8
8/9/2018	1664	1559	1277	--	8/23/2018	92.3
7/20/2019	1422	--	1178	--	7/21/2019	154.8
9/18/2019	958	--	804	--	9/17/2019	57*
8/16/2022	1038	1026	1148	--	--	--
8/25/2020	--	--	--	861	--	--
Average	**1306.8**	**1424.7**	**1170.2**	**NA**	**Average**	**99.4**

*Flow was high and rain falling.

Figure 24. There are several small channels coming into Timber Creek from the wetland on the west side (the side opposite of the tailings basin), midway between 18RN001 and 18RN003.

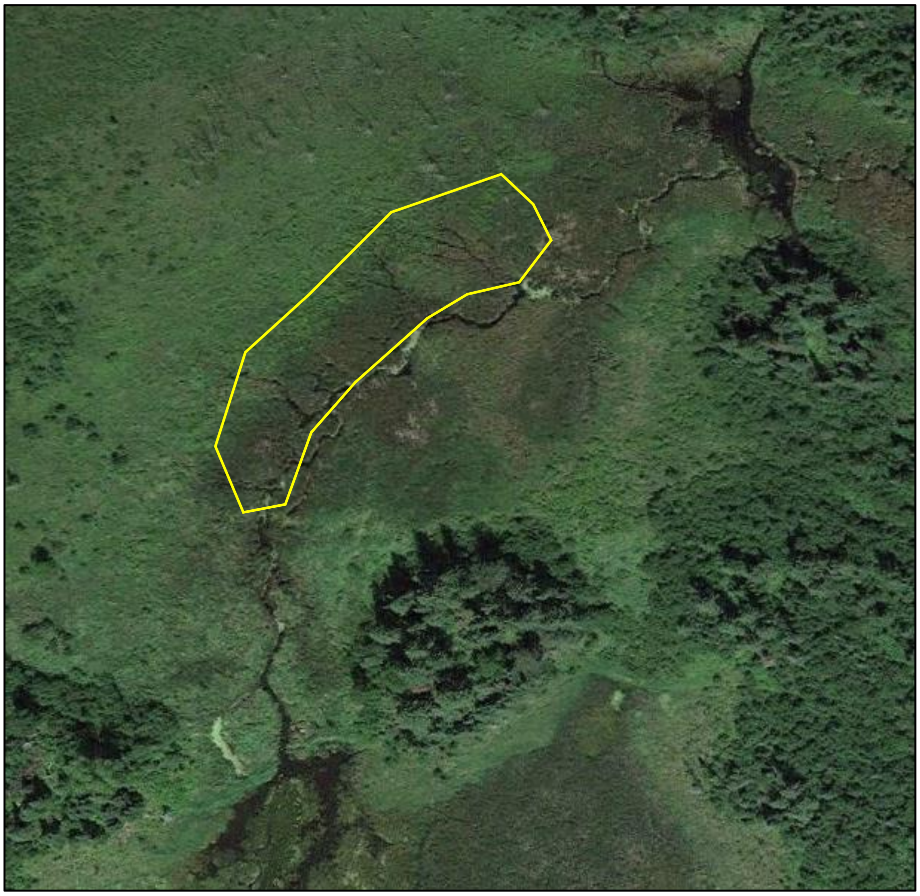
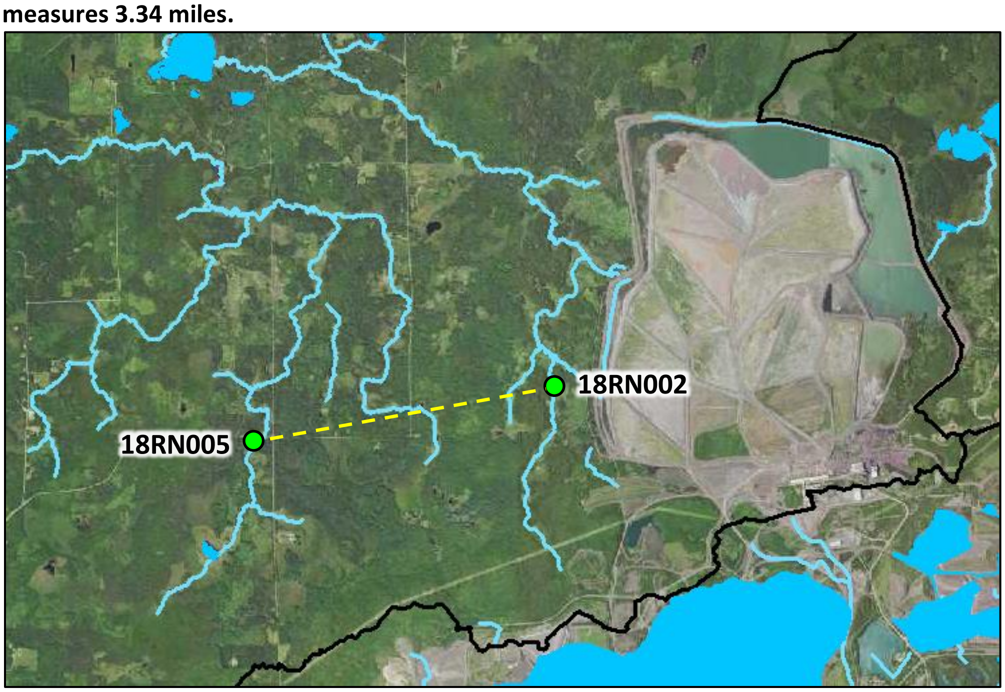


Figure 25. Relative locations of Timber Creek and the reference stream, McNiven Creek. The dotted line measures 3.34 miles.



Suspended solids

There were no TSS samples collected from Timber Creek. Several clarity measurements have been collected, and six of seven were > 100 cm, with the lone exception being 85 cm. Thus, at least at times, TSS is very low.

pH

The pH levels were slightly basic, and at levels that are very healthy for aquatic biology.

Stressor signals from biology

Two fish and three macroinvertebrate samples were collected in 2018, 2019, and 2022 at 18RN001 and 18RN003. A midway site, 18RN002 was sampled for each community in 2018, and again for macroinvertebrates in 2022. MIBI and Fish-based lake Index of Biological Integrity (FIBI) scores are shown in Table 12. For both the fish and macroinvertebrate communities, the upper site had the better IBI scores compared to the lower site. All fish samples easily passed their health threshold. All but one macroinvertebrate sample failed their impairment threshold; the 2019 upstream site sample passed the health threshold by a few points. The nearby reference stream, McNiven Creek, had passing fish scores in both 2018 and 2019. The macroinvertebrate samples did not have passing scores in either 2018 or 2019.

Another sample site was added to the Timber Creek reach in 2020, a randomly chosen site that is part of the national stream study by EPA done every five years. That site (20EM075) had passing fish and macroinvertebrate scores. The fish sample was collected in 2021 due to COVID-19 restrictions on staff for electrofishing.

Table 12. MIBI and FIBI scores for four sites sampled on Timber Creek, and one on McNiven Creek (18RN005). Scores from samples collected outside of MPCA's index period were not included. See Figure 16 and Figure 25 above for locations. Note that site 20EM075 is a different stream class (used a different IBI), so this score is not directly comparable to the scores from other sites. Scores in green text passed the health criterion.

Site	Health criterion	2018	2019	2020	2021	2022	Average
Fish 18RN001	42	**73.0**	**70.6**	--	--	--	71.80
Fish 18RN002	42	**58.2**	--	--	--	--	NA
Fish 18RN003	42	**61.1**	**68.6**	--	--	--	64.85
Fish 18RN005	42	**65.1**	**71.0**	--	--	--	68.1
Fish 20EM075	42	--	--	--	**58.4**	--	NA
MI 18RN001	53	39.0	**57.9**	--	--	**56.0**	51.0
MI 18RN002	53	37.3	--	--	--	46.8	42.05
MI 18RN003	53	31.8	40.4	--	--	37.3	36.5
MI 18RN005	53	35.8	50.9	--	--	--	43.4
MI 20EM075	51	--	--	**61**	--	--	NA

Macroinvertebrates

Macroinvertebrate samples were collected from Timber Creek at 18RN001, 18RN002, 18RN003 in 2018, 2019, and 2022 (except not 18RN002 in 2019). An additional Timber Creek site (20EM075) was sampled in 2020. Among the three sites sampled in 2018-2019 and 2022, the macroinvertebrate scores were higher at the upstream site than the downstream site. Site 20EM075 was closer to the downstream-most site, and it has different habitat/flow characteristics, which meant using a different IBI than the other three sites. A passing MIBI score was achieved at 20EM075.

At 18RN001, the caddisfly *Hydropsyche* was the most abundant taxon for all three samples. Other relatively abundant taxa varied among the samples. For the single sample at 18RN002, the caddisfly taxa *Cheumatopsyche* followed by *Hydropsyche* (both from the family Hydropsychidae) were the dominant taxa. At 18RN003, *Cheumatopsyche* were the most abundant taxon for two of the four samples. They were relatively abundant on the other two visits. In the September 2019 sample, the black fly *Simulium* was most abundant, though it was relatively low in abundance in the other three samples. The fourth sample was dominated by the midge *Rheotanytarsus*. The commonality among these most-abundant taxa is that they live in locations where there is a fair amount of current. All four of these genera are filter feeders, which intercept food particles from the water moving by.

Among the EPT group of aquatic insects, caddisflies were well represented, with several taxa present at each site. There were two stonefly taxa present at 18RN001 (*Taeniopteryx* and *Capniidae*) and one taxon present at 18RN003 (*Perlesta*). Mayflies, which normally will have numerous taxa present in healthy streams, were low in both the number of taxa and abundance. At 18RN001, there were 1, 0, and 1 taxon present in the three visits, respectively. The taxa were *Baetis brunneicolor* and *Caenis latipennis*. In the lone sample at 18RN002, there were two taxa, *B. brunneicolor* and Heptageniidae. At 18RN003, there were 2, 2, 0, and 2 in the four samples, respectively. The taxa present were *Baetis sp.*, *C. lattipennis*, and Leptophlebiidae. So, in combination, there were just four mayfly taxa found at the three sites.

The Community TIV Index scores are shown in Table 13 and individual TIV metrics in Table 14. The DO TIV Index score varies quite a bit among the sites. The upstream site (18RN001) has better DO Index scores than the downstream site, with the upstream site being above the stream class average, while the downstream site was below the class average. The probability of the sampled communities of the various visits coming from a DO standard-meeting site are also quite varied depending among both the sites and the dates of sampling, ranging from 46% to 80%. At 18RN001, the macroinvertebrate community is quite skewed toward taxa that are low-DO intolerant in terms of both the species that were present, and the much greater abundance of low-DO intolerant individuals versus low-DO tolerant ones.

The TSS TIV Index scores for all sites are poorer than the class average, with several of the samples being at extremely low percentiles for this stream class. For all visits and sites, the community was skewed toward TSS tolerant taxa regarding the abundance of individuals. The upper site was balanced regarding TSS intolerant and tolerant species present. The downstream site was quite skewed toward TSS tolerant species presence vs TSS intolerant species. There has been very little TSS information collected for Timber Creek. Based on the small size of the stream and natural landscape, TSS would not be expected to be elevated or problematic. It may be that there is another stressor in Timber Creek that is somewhat correlated with TSS as to its effect on specific macroinvertebrate taxa.

The Conductivity TIV Index scores are moderately higher at the downstream site, even though measured conductivity is lower than at the upstream site. The reason the water's conductivity and Conductivity Index scores do not have a positive correlation in Timber Creek isn't known. Comparing the Conductivity TIV scores to their class averages finds that eight of the nine samples have higher TIV scores (i.e., the Timber Creek macroinvertebrate community has more individuals that tolerate higher conductivities) than the average site within the two appropriate stream classes. The Conductivity TIV score percentiles of these nine samples are below the 50th percentile (in this ranking, high percentile scores are considered the better scores, and these have relatively lower Community Conductivity TIV scores), with the single exception being an 80th percentile rank. Finally, the Conductivity TIV scores for all three sites having both August 2018 and August 2022 samples were very similar between years 2018 and 2022, suggesting conductivity has had very similar effects on the macroinvertebrate community during this time interval of four years. The better scores achieved in 2019 at two of these sites may be attributable to the date sampled. Some macroinvertebrates can be present in late September that aren't present in early August due to their differing annual reproduction and hatching schedules. The percent tolerant individuals increased a bit in 2022 at 18RN001, while on the same date, they decreased a bit more at 18RN002, though the number of very tolerant taxa did increase considerably (from 0 to 3). The percentage intolerant individuals increased considerably (a positive) at 18RN003 in 2022. Some of these changes and contradictions may be due to the newer tailing groundwater interception, if a site's conductivity has changed more relatively to another site. Longer term monitoring of specific conductivity at each of the sites may inform the interpretation of these varying macroinvertebrate responses between years and sites.

Table 13. Macroinvertebrate Community DO, TSS, and Conductivity Tolerance Index scores in AUID-630 at 18RN001, 18RN002, 18RN003, and 20EM075. For DO, a higher index score is better, while for TSS and conductivity, a lower index score is better. "Percentile" is the rank of the index score within the appropriate stream class. High percentiles are better for all parameters. "Prob." is the probability a community with this score would come from a stream reach with DO or TSS that meet the standards (for TSS, this is the north region standard*). There is not a standard for conductivity, so no probabilities can be calculated.

Site	Stream class	Date	Parameter	TIV Index score	Class avg./median	Percentile w/in Class	Probability as %
18RN001	3	8/7/2018	DO	7.28	7.02/7.14	64	75
18RN001	3	7/20/2019	DO	7.41	7.02/7.14	75	78
18RN001	3	9/18/2019	DO	6.24	7.02/7.14	10	48
18RN001	3	8/16/2022	DO	7.12	7.02/7.14	48	71
18RN002	3	8/6/2018	DO	7.53	7.02/7.14	86	80
18RN002	3	8/16/2022	DO	7.36	7.02/7.14	70	77
18RN003	3	8/6/2018	DO	7.08	7.02/7.14	45	71
18RN003	3	8/29/2018	DO	6.70	7.02/7.14	24	61
18RN003	3	7/20/2019	DO	6.90	7.02/7.14	35	66
18RN003	3	9/18/2019	DO	6.29	7.02/7.14	10	50

Site	Stream class	Date	Parameter	TIV Index score	Class avg./median	Percentile w/in Class	Probability as %
18RN003	3	8/16/2022	DO	7.10	7.02/7.14	46	71
20EM075	4	8/25/2020	DO	6.15	6.30/6.49	33	46
18RN001	3	8/7/2018	TSS	15.26	13.41/13.47	12	38*
18RN001	3	7/20/2019	TSS	13.70	13.41/13.47	43	43
18RN001	3	9/18/2019	TSS	12.59	13.41/13.47	70	43
18RN001	3	8/16/2022	TSS	15.01	13.41/13.47	16	38
18RN002	3	8/6/2018	TSS	14.51	13.41/13.47	24	39
18RN002	3	8/16/2022	TSS	14.47	13.41/13.47	25	39
18RN003	3	8/6/2018	TSS	17.72	13.41/13.47	1	32
18RN003	3	8/29/2018	TSS	16.09	13.41/13.47	3	36
18RN003	3	7/20/2019	TSS	14.98	13.41/13.47	16	38
18RN003	3	9/18/2019	TSS	14.11	13.41/13.47	32	40
18RN003	3	8/16/2022	TSS	15.56	13.41/13.47	8	37
20EM075	4	8/25/2020	TSS	12.76	13.63/13.78	73	43
18RN001	3	8/7/2018	Spec. Cond.	493.6	452.5/455.9	19	--
18RN001	3	7/20/2019	Spec. Cond.	470.0	452.5/455.9	38	--
18RN001	3	9/18/2019	Spec. Cond.	415.3	452.5/455.9	80	--
18RN001	3	8/16/2022	Spec. Cond.	500.0	452.5/455.9	15	--
18RN002	3	8/6/2018	Spec. Cond.	465.3	452.5/455.9	41	--
18RN002	3	8/16/2022	Spec. Cond.	467.7	452.5/455.9	39	--
18RN003	3	8/6/2018	Spec. Cond.	502.9	452.5/455.9	14	--
18RN003	3	8/29/2018	Spec. Cond.	506.5	452.5/455.9	12	--
18RN003	3	7/20/2019	Spec. Cond.	507.8	452.5/455.9	11	--
18RN003	3	9/18/2019	Spec. Cond.	465.1	452.5/455.9	41	--
18RN003	3	8/16/2022	Spec. Cond.	502.1	452.5/455.9	14	--
20EM075	4	8/25/2020	Spec. Cond.	499.8	477.2/486.7	36	--

*These TSS probabilities are deceptively low. This is due to the limited range of TSS concentrations typically seen in northern streams. Even the best scoring macroinvertebrate sample in the region was only calculated as having a 59% chance of being from a TSS standard-meeting stream. Therefore this metric has limited usefulness. The within-class percentile is a better metric for comparison of sites regarding TSS influence.

Table 14. Metrics involving low-DO, TSS, and conductivity tolerance for the sampled macroinvertebrate community at 18RN001, 18RN002, and 18RN003 on multiple dates, 2018-2022, and 20EM075 in 2020.

Date	Parameter/ Site	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
8/7/2018	Low DO-001	7	3	1	0	20.3	0.3
7/20/2019	Low DO-001	6	2	1	0	30.8	1.3
9/18/2019	Low DO-001	10	6	4	1	12.4	6.9
8/16/2022	Low DO-001	6	3	3	1	20.3	11.5
8/6/2018	Low DO-002	7	3	0	0	37.4	0.0
8/16/2022	Low DO-002	8	3	1	0	32.0	0.6
8/6/2018	Low DO-003	2	1	2	0	4.9	6.5
8/29/2018	Low DO-003	2	0	3	1	5.1	9.7
7/20/2019	Low DO-003	3	0	3	1	5.8	5.2
9/18/2019	Low DO-003	5	0	5	0	2.8	7.7
8/16/2022	Low DO-003	2	0	3	1	3.9	9.8
8/25/2020	Low DO-075	2	2	13	5	2.4	44.0
8/7/2018	TSS - 001	5	1	5	2	10.8	50.7
7/20/2019	TSS - 001	5	1	4	1	8.8	28.6
9/18/2019	TSS - 001	8	3	5	1	12.1	35.2
8/16/2022	TSS - 001	4	2	5	2	5.2	39.0
8/6/2018	TSS - 002	5	1	5	2	19.2	51.6
8/16/2022	TSS - 002	5	1	6	2	16.8	47.2
8/6/2018	TSS - 003	0	0	8	3	0.0	29.0
8/29/2018	TSS - 003	1	0	6	2	1.8	48.0
7/20/2019	TSS - 003	2	0	7	2	4.9	42.2
9/18/2019	TSS - 003	2	1	7	2	3.1	33.7
8/16/2022	TSS - 003	1	0	6	1	1.0	45.0
8/25/2020	TSS - 075	4	1	9	3	5.2	7.6
8/7/2018	Sp. Cond-001	3	1	6	2	2.8	24.8
7/20/2019	Sp. Cond-001	4	1	5	0	4.9	13.6
9/18/2019	Sp. Cond-001	3	4	7	2	5.5	15.5
8/16/2022	Sp. Cond-001	4	2	8	3	3.9	26.9
8/6/2018	Sp. Cond-002	2	1	4	0	13.7	29.9
8/16/2022	Sp. Cond-002	3	1	7	3	8.4	22.7
8/6/2018	Sp. Cond-003	0	0	7	2	0.0	26.4
8/29/2018	Sp. Cond-003	2	0	8	4	3.2	45.8

Date	Parameter/ Site	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
7/20/2019	Sp. Cond-003	2	0	9	4	4.9	43.2
9/18/2019	Sp. Cond-003	1	3	11	4	4.0	37.8
8/16/2022	Sp. Cond-003	3	0	9	3	12.1	32.9
8/25/2020	Sp. Cond-075	5	2	14	8	6.4	36.7

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Temperature

Water temperature data collected during the summer by the mining company (based on the deployed sonde data) showed peak water temperatures generally below 27°C, which is below the thresholds for high stream water temperatures in Minnesota rule. There is nothing human-caused happening in Timber Creek Subwatershed that would raise stream temperatures. The impoundments made by beavers may be raising stream temperatures relative to a scenario without beaver activity.

Hydrology

Because Timber Creek's drainage area landscape is very natural, the natural hydrological regime should not be negatively altered, as many Minnesota streams are. The adjacent tailings basin actually covers part of the natural drainage area, and since that part is sealed off from surface runoff to the creek by the basin's western berm, it actually has a smaller-than-original drainage area contributing runoff to the channel. It may, however, have more groundwater input than it naturally had, from seepage contributed by the tailings basin's elevated water table. There are known areas of seepage at the bottom of the tailings basin western walls that enter the creek, though some interception of this groundwater flow is now occurring by mine company technology installation and re-routed back into the tailing's basin.

Habitat

Habitat was assessed with the MSHA protocol (Table 15). Each site had three or four assessments done by different staff on different dates (all included an MPCA staff person). The site scores fell within the lower part of the "Good" range, or upper part of the "Fair" range. There can be natural variability in habitat scores between different dates, often due to flow conditions. Streams with MSHA scores in the ranges found at the three 2018 sites are sufficient to meet the General Use IBI thresholds. Thus, stream habitat should not be a stressor leading to the impairment.

Table 15. MSHA scoring for sites 18RN001, 18RN002, and 18RN003. Site 21EM075 has a different habitat assessment procedure. Date of scoring are shown in the table.

MSHA Component	Max. Poss. Score	18RN001			18RN002			18RN003			
		8/9 2018	8/17 2018	8/16 2022	8/6 2018	8/9 2018	8/16 2022	8/6 2018	8/9 2018	8/29 2018	8/16 2022
Land Use	5	5	3.75	2.5	3.75	5	2.5	3.75	5	5	2.5
Riparian	14	11	10	14	14	14	14	14	13.5	14	14

MSHA Component	Max. Poss. Score	18RN001			18RN002			18RN003			
		8/9 2018	8/17 2018	8/16 2022	8/6 2018	8/9 2018	8/16 2022	8/6 2018	8/9 2018	8/29 2018	8/16 2022
In-stream Zone	28	19.45	17.3	18.2	20.05	20.3	19.5	18.15	16	15	21
Cover	18	13	11	14	7	12	9	13	11	16	16
Channel Morphology	35	20	17	18	19	17	18	19	16	19	20
Maximum MSHA Score	100	100	100	100	100	100	100	100	100	100	100
Measurement score	--	68.45	59.05	66.7	63.8	68.3	63.0	67.9	61.5	69.0	73.5
Condition (Good/Fair/Poor)	--	G	F	G	G	F	F	G	F	G	G

Geomorphology

Because the hydrological regime of the system has likely not become flashier, as happens with land cover change/development, the channel has not likely developed the bank instability, excess bedded sediment, etc. that occurs with excess flow volumes from human landscape changes.

Connectivity

Blockages of aquatic organism movement causing impairment are mostly pertinent to the fish community. Connectivity barriers are not a stressor in this case as it is the macroinvertebrate, and not the fish community that is impaired.

Conclusions

The current analysis suggests that there are at least two factors influencing the macroinvertebrate community, these being low DO and specific conductivity. Given the natural land use/cover of the Timber Creek Subwatershed, the presence of significant riparian wetlands, and the numerous beaver impoundments on Timber Creek, the low DO levels are likely natural. Low DO also appears to be a significant stressor, because the MIBI scores are higher where the DO is above the standard, and lower where DO is commonly below the standard. Also, the upper site with better MIBI scores has higher conductivity than the lower-scoring downstream site does. The lower site's macroinvertebrate community does have a moderately higher overall conductivity tolerance based on the Community Conductivity TIV Index. Perhaps conductivity has more influence when other stressors are present (e.g., the low DO in this case), though we are not aware of specific evidence to substantiate that possibility.

Given that low DO concentrations are likely preventing better MIBI scores, conductivity may also be playing a role. EPT taxa were shown to be affected as a group in a Virginia stream receiving high conductivity effluent (Echols et al., 2009). The exception in that study was the Trichopteran (caddisfly) family Hydropsychidae, which seem to be unaffected and abundant at their high conductivity sites. The Echols et al. (2009) study also found the abundance of mayfly individuals to be far fewer in their higher conductivity sites. The community in Timber Creek is similar, in that hydropsychid caddisflies were abundant in the samples, while few mayfly and stonefly taxa were present (the community composition of the samples was discussed above). Mayfly abundance was also very low in Timber Creek thus, the Timber Creek macroinvertebrate community does have similarities with at least one other conductivity-macroinvertebrate study, those being few mayfly and stonefly taxa or individuals, and abundant hydropsychid caddisfly individuals. Blinn and Ruiter (2006) studied caddisfly sensitivity to specific conductance and also found that hydropsychids were abundant at their higher conductivity sites in the Lower Colorado River Basin. The specific ions that were present in the effluent in the Echols et al. (2009) study at the highest concentrations were chloride (2970 mg/L), sodium (1640 mg/L), and sulfate (483 mg/L). Sulfate levels in Timber Creek are known to be abnormally high (MPCA correspondence).

Biological community comparison of Timber Creek to reference stream McNiven Creek

A nearby similar-sized stream (McNiven Creek) was sampled by mine contractor GEI as a reference stream to Timber Creek (Figure 25). McNiven Creek has a very natural, undisturbed subwatershed, though like Timber Creek, it has low DO in mid-summer. A comparison was made with macroinvertebrates to the three sites on Timber Creek using 2018 data. A fourth site on Timber Creek was not compared due to its different stream class type (Glide/Pool). For macroinvertebrates, taxa within the insect orders EPT are in general the most sensitive aquatic insect orders to water quality disturbance. The EPT list from the two streams were compared. The MSHA habitat scores were similar between the two streams.

Between the two streams, there were 15 EPT taxa present in 2018, with 8 being found in both McNiven and Timber Creeks. No taxa that were found in McNiven Creek were not also in Timber Creek, while seven taxa were found in at least one site of Timber Creek and not in McNiven Creek's only site. None of these seven taxa unique to Timber Creek were found in all three Timber Creek sites. While it is expected that an anthropogenically-stressed stream would have fewer EPT taxa, the opposite is seen here. However, it is also expected that if more sites were sampled in McNiven Creek (as was done in Timber Creek), additional EPT taxa would likely be found. It is somewhat notable though that none of the 2018 taxa found in the one McNiven Creek site were missing from the site-composited samples from Timber Creek, potentially suggesting that elevated conductivity is not eliminating any taxa found in a non-anthropogenically stressed similar local stream. As additional years of macroinvertebrate sampling have been done after the original 2018 sampling, a comparison of the total taxa list from all years was also done (Table 16 and Table 17). When comparing this data, there is one EPT taxon, the mayfly *Maccaffertium*, found in McNiven Creek and not in any Timber Creek site, while 8 to 10 EPT taxa are found in Timber Creek and not in McNiven Creek.

Caveats for the taxa list comparison include uneven sampling effort between streams and potentially the subsampling methodology used in the processing protocol of macroinvertebrate samples may also be an influence. When a stream has a few very dominant taxa, the less abundant taxa will have a greater likelihood of not showing up in the sample's taxa list due to the 300-count subsampling protocol. A more robust comparison between the two creeks could be achieved by adding another riffle-run site or two at McNiven Creek, as well as a few more years of sampling. Having several reference streams to compare Timber Creek to would also provide a more concrete conclusion.

Lastly, a number of EPT taxa were found in Timber Creek in 2022 that were not found in 2018-2019 sampling. The groundwater interception technology was installed between these two sampling periods, and it may be reducing ionic concentrations to which the macroinvertebrate community is responding.

Table 16. Sample dates for the sites on Timber and McNiven Creeks.

Stream and site	August 2018	July 2019	September 2019	August 2022
Timber - 001	X	X	X	X
Timber - 002	X			X
Timber - 003	X	X	X	X
McNiven - 005	X	X	X	

Table 17. List of EPT taxa found at each site/stream. The bold red taxa are those found in Timber Creek but not in McNiven Creek per the sampling that has occurred thus far. The bold blue taxa are genera in the family Limnephilidae and may be unique. The bold pink taxon was found in McNiven Cr. and not Timber Cr. The designation u.g. means "unknown genus" due to either damaged or very immature specimens.

Timber - 001	Timber - 002	Timber - 003	McNiven - 005
Baetis	*Baetis brunneicolor*	*Caenis latipennis*	*Baetis*
Caenis latipennis	*Caenis latipennis*	*Cheumatopsyche*	Caenidae u.g.
Capniidae u.g.	*Cheumatopsyche*	*Chimarra*	Capniidae u.g.
Cheumatopsyche	*Chimarra*	*Hydatophylax argus*	*Cheumatopsyche*
Chimarra	***Helicopsyche borealis***	*Hydropsyche*	*Hydropsyche*
Helicopsyche	*Hydropsyche*	*Hydroptila*	*Hydroptila*
Hydatophylax argus	*Hydroptila*	Leptophlebiidae u.g.	Limnephilidae u.g.
Hydropsyche	Leptophlebiidae u.g.	*Oecetis*	*Lype diversa*
Hydroptila	*Lype diversa*	***Perlesta***	***Maccaffertium***
Lepidostoma	*Protoptila*	Phryganaeidae u.g.	*Oecetis*
Leptophlebiidae u.g.	*Stenonema*	**Polycentropodidae u.g.**	*Paraleptophlebia*
Lype diversa		*Trianodes*	*Ptilostomis*
Ochrotrichia			*Stenonema femoratum*
Oecetis			*Taeniopteryx*
Protoptila			
Ptilostomus			
Pycnopsyche			
Stenonema			
Taeniopteryx			
Trianodes			

Recommendations

Because the land area of the full subwatershed of Timber Creek is corporately owned, it is unlikely that restoration will proceed via the normal route that other subwatersheds use, where restoration funding and guidance is provided by BWSR to local governments to implement solutions. The MPCA is working to address the issue of elevated ionic concentrations from the adjacent mine's tailings basin (via tailings infiltration to groundwater and then movement of groundwater to the stream channel) via a new permit. The mine owners in recent years have installed some technology to intercept some of the tailings basin groundwater seepage before it gets to the stream and transfer this water back to the tailing's basin.

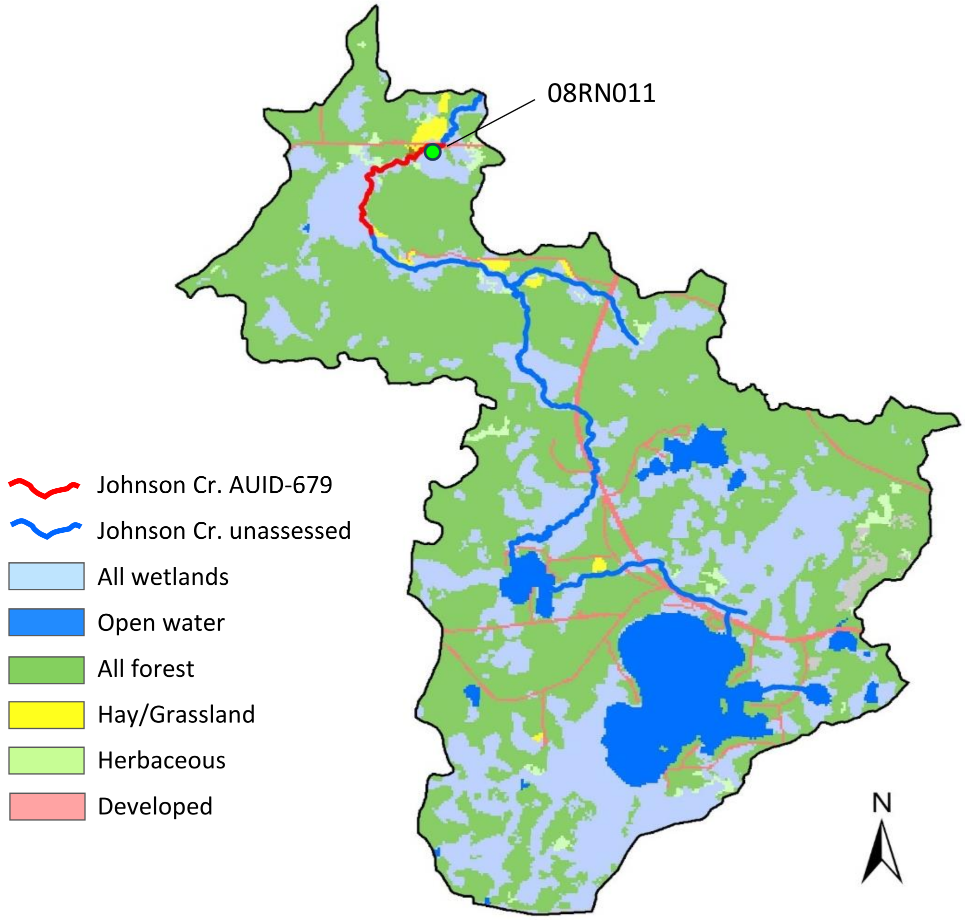
Johnson Creek (AUID 09030005-679)

Impairment: AUID-679 is a 1.4 miles long natural reach in T60N R18W S6, from the south section line to the north line. There is one biological monitoring station (08RN011), located on the upstream side of CR-652 (Goodell Road). A very small section of the AUID (approximately 77 meters) has been straightened along CR-622; this section was included in the biological sample reach. The stream is held to the General Use fish and macroinvertebrate standards. The AUID was assessed in 2020 as having an impairment of both the fish and macroinvertebrate communities. Previous biological monitoring in 2008 had shown the stream to be supporting both healthy macroinvertebrate and fish communities. Sampling in 2018 found a substantial drop in IBI scores for both communities. Another sampling in 2019 found better IBI scores for both communities; neither had improved to the point of reaching the passing threshold, but the fish community was close. Prior to the 2020 assessment, AUID-679 was coldwater use class. Through the assessment process and recent water temperature monitoring, the stream was determined to belong to warmwater use class, and the change was made official. The 2008 passing scores mentioned above used IBI scores for warmwater streams. The Macroinvertebrate Stream Class is 4 (Northern Forest Streams - GP) and the Fish Stream Class is 7 (Low Gradient). None of the conventional chemical parameters had enough data to assess them.

Subwatershed characteristics

Johnson Creek begins as the outflow of Little Sand Lake and ends where it meets the Rice River. The land use and land cover of the subwatershed of AUID-679 is shown in Figure 26. A very high percentage of the land area is in natural, perennial vegetative cover. There is a very small amount of grassland/hay/pasture and no cultivated acreage. Development is very light and there are no cities/towns in the subwatershed, though there are numerous residences in the headwaters area of Johnson Creek, and around Little Sand Lake, upstream of AUID-679. A divided four-lane highway (US-53) does cross the subwatershed, passing over Johnson Creek twice at locations upstream of AUID-679. The great majority of the landscape is forest or wetland. There are no permitted effluent dischargers to AUID-679, or anywhere on Johnson Creek.

Figure 26. The Johnson Creek Subwatershed, with land use categorization simplified from the NLCD 2016. Johnson Creek flows north.



Data and Analyses

Chemistry

The chemistry sampled at biological monitoring visits is presented in Table 18. Data are discussed below by parameter.

Table 18. IWM chemistry results from 2008, 2018, and 2019 at 08RN011.

Date	Time	Water Temp.	DO	DO %	Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	TSS	TSVS
6/18/2008	16:51	20.4	7.75	--	112	0.096	< 0.05	< 0.05	7.3	--	48	8
7/30/2018	14:20	21.6	3.42	39	154	0.048	< 0.02	< 0.1	6.8	> 100	2.2	--
8/16/2018	12:08	19.4	1.7	18	169	--	--	--	6.9	> 100	--	--
7/8/2019	19:18	25.5	0.9	11	177	0.046	< 0.02	< 0.1	6.7	> 100	< 4	--
8/5/2019	17:35	24.2	0.81	10	183	--	--	--	6.7	43	--	--

Nutrients - phosphorus

Two of the three phosphorus concentrations were below, though close to, the regional River Eutrophication Standard. The third sample was almost double the standard. In this sample, there was much TSS, and much of the TP may have been sediment-bound, or organic-particulate phosphorus. It is likely that much of this phosphorus is natural as the stream is hydrologically-connected to large wetlands. There are only a small number of residences that are close enough to the stream where septic systems could possibly be a source of phosphorus.

Nutrients - nitrate and ammonia

Nitrate concentrations were all extremely low, as were ammonia concentrations. Levels this low suggest eutrophication is not occurring in the stream.

Dissolved oxygen

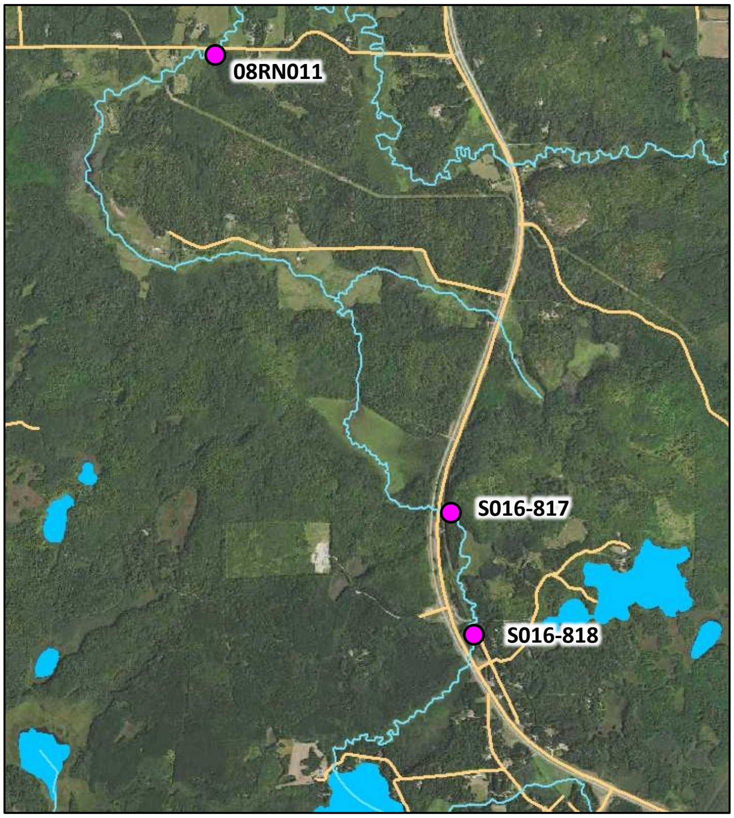
DO levels were below the standard at four of the five visits for biological sampling. Three of these were very or extremely low concentrations. DO percent saturation levels were also very low, far below 100%, suggesting that either the stream water has been in places with significant decay of organic material, that large amounts of organic material has collected within the channel, or that significant groundwater is feeding the stream. All three of these possibilities are likely happening in AUID-679. Biological sampling crews have noted very deep, soft silt in parts of the sampled reach.

Additional investigation of DO levels was done as part of the SID work. On July 10, 2020, a measurement of DO, DO % saturation, water temperature, and specific conductance was completed at 08RN011, and again, very low DO levels were encountered (Table 19). A return sampling visit in late June 2022 added two more sampling sites longitudinally, both upstream of 08RN011 as well as upstream of the AUID that is assessed as impaired (Figure 27). At that date, the DO level was very good at 08RN011, while the two upstream sites had lower DO concentrations, particularly at the upstream-most site (Table 19). Thus, it may not be a human influence within the part of the Johnson Creek Subwatershed that specifically adds runoff to AUID-679 that is responsible for the low DO at 08RN011.

Table 19. SID measurements within Johnson Creek, 2020 and 2022.

Location	AUID	Date	Time	DO	DO % Sat.	Temp	Sp. Cond	Weather Conditions
08RN011	-679	7/10/2020	15:15	2.18	25.5	23.3	131	~ 80°F, full sunshine
08RN011	-679	6/24/2022	12:45	8.14	97.4	24.4	149	~ 72 °F, overcast
S016-817	-678	6/24/2022	13:15	3.90	45.6	23.3	138	~ 72 °F, overcast
S016-818	-678	6/24/2022	13:30	5.16	61.2	23.9	145	~ 72 °F, overcast

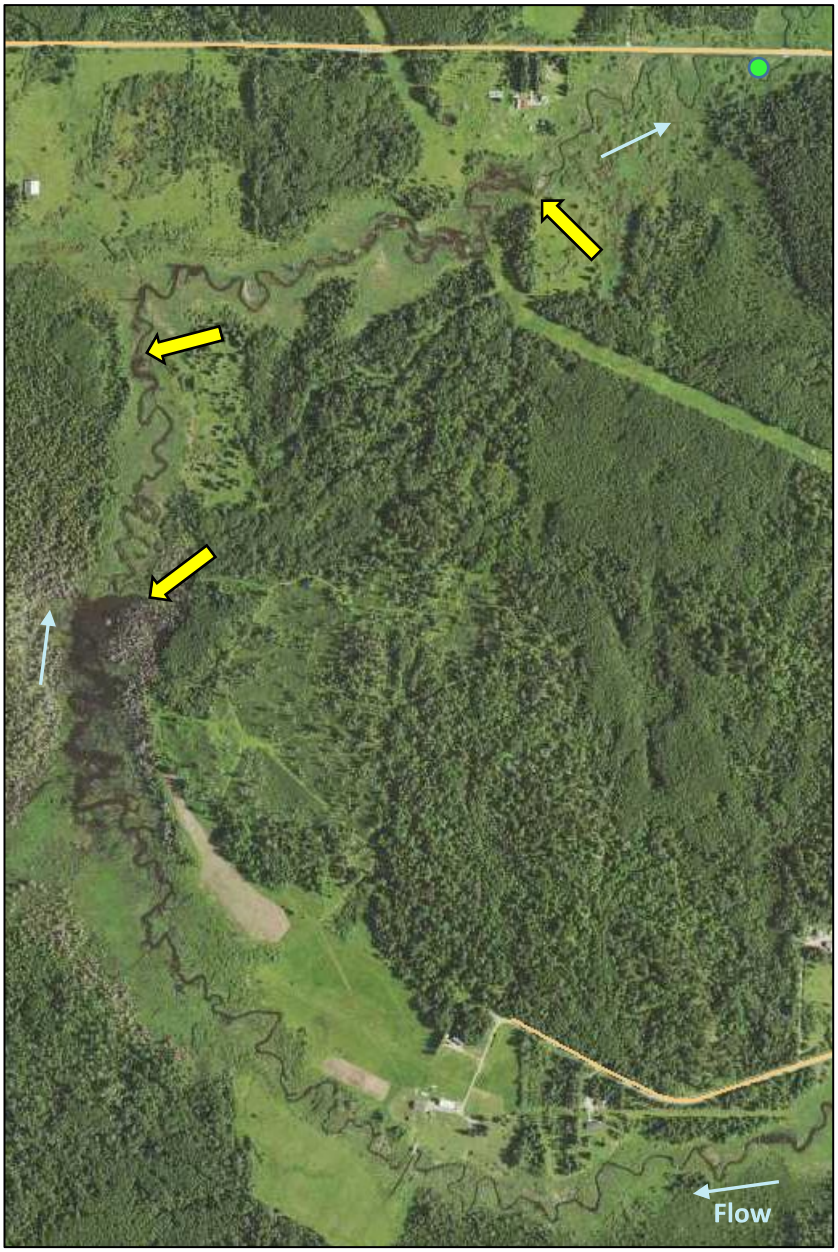
Figure 27. Location of DO monitoring sites on Johnson Creek.



Looking at the full set of available DO measurements, DO was at a healthy level in 2008, when the biological communities were healthy. Then, at the 2018 and 2019 biological visits, DO concentrations were poor, and biological communities had declined. DO concentrations were still poor at the 2020 SID monitoring visit and finally, DO concentrations appear to be back to good conditions in the summer of 2022.

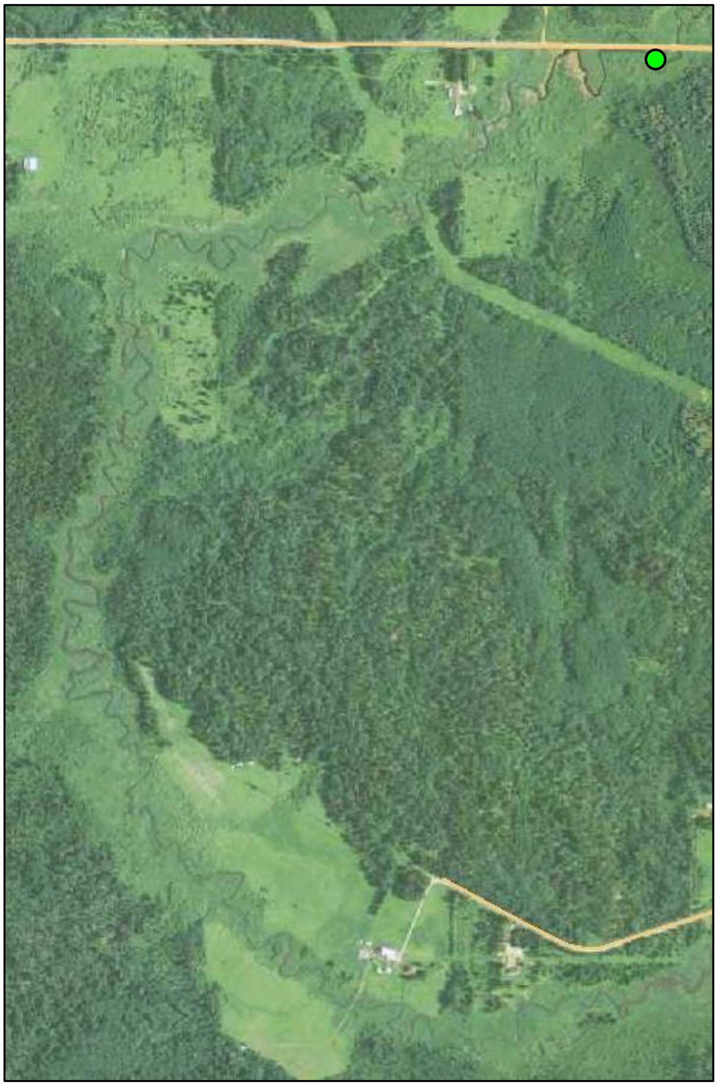
In addition to the low gradient nature of the channel, another strong influence on the creek is the significant beaver activity, which is common on the low gradient streams of this forested region. There are many beaver dams in this subwatershed, and a significant amount of the stream channel length of the AUID and the adjacent upstream AUID were impounded in 2019 (Figure 28), and thus likely also in 2018 when the biological monitoring of Cycle 2 occurred. A review of multiple past years of aerial photos shows that beaver moved into the area a short distance upstream of the biological monitoring site in approximately 2014-2015. No beaver dams or impoundments were present in AUID-679 in 2008, 2009, 2010, or 2013 (Figure 29) aerial photos (there aren't 2011 or 2012 photos). They created an impounded channel for a significant distance, starting at a straight-line distance of 0.26 miles upstream and impounding the channel upstream of there.

Figure 28. 2019 aerial photo, showing three beaver dams that are impounding a long stretch of the channel just upstream of the biological monitoring site 08RN011.



This is highly likely the explanation of the poor DO found in the stream in 2018, 2019, and 2020. These dams and impounded water were not present in 2008 when the first cycle biological samples were collected and IBI scores passed; the stream was free flowing at that point in time. Beaver dams are commonly found to substantially drop DO concentrations in the resulting impoundments. The low gradient nature of the channel downstream of the dams does not promote improvement of the DO concentrations by the time the water reaches the biological monitoring site.

Figure 29. The 2013 aerial photo of the same extent as Figure 28 shows no beaver dams where they existed later, in 2019 (and where they started to appear in the 2015 and 2017 photos).



The amount and/or influence by beaver impoundments has varied year to year. As mentioned above, a late June 2022 measurement found DO and DO % saturation at good levels. A review of 2021 aerial photography shows that the nearest two dams upstream of 08RN011 that were present in 2019 had been breached by the landowner and were not impounding water (Figure 30). This could explain the improved DO level in the 2022 SID measurement. In 2022, the channel distance from the nearest upstream impoundment was then three to four times longer than in 2019.

Figure 30. The 2021 aerial photo of the same extent as Figure 28 shows the two nearest upstream dams that existed in 2019 (and where they started to appear in the 2015 and 2017 photos) are not impounding water any longer.

In addition to the beaver dams/impoundments, the stream is susceptible to low DO due to significant groundwater inputs. Evidence for this includes prior coldwater designation by DNR, and high iron content visible in aerial photography. The 2021 FSA aerial photography was taken at a time (i.e., second half of summer) when high iron concentrations (which come from groundwater inputs) in streams can strongly show up. The lower part of the Johnson Creek Subwatershed had several areas like this (Figure 31 and Figure 32). Groundwater is typically low in DO due to its extended period of not being interactive with the atmosphere.

Figure 31. The lower portion of the Johnson Creek Subwatershed, with areas having observable high iron content circled in white. Letters indicate areas associated with following aerial photography close-up views. The green dot is the biological sampling location.

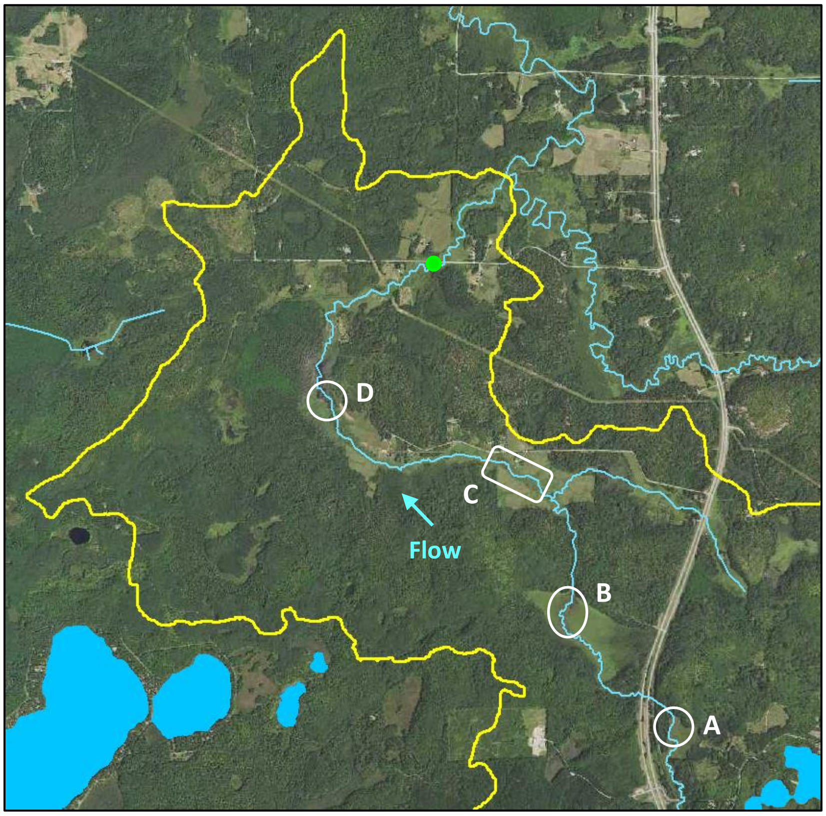
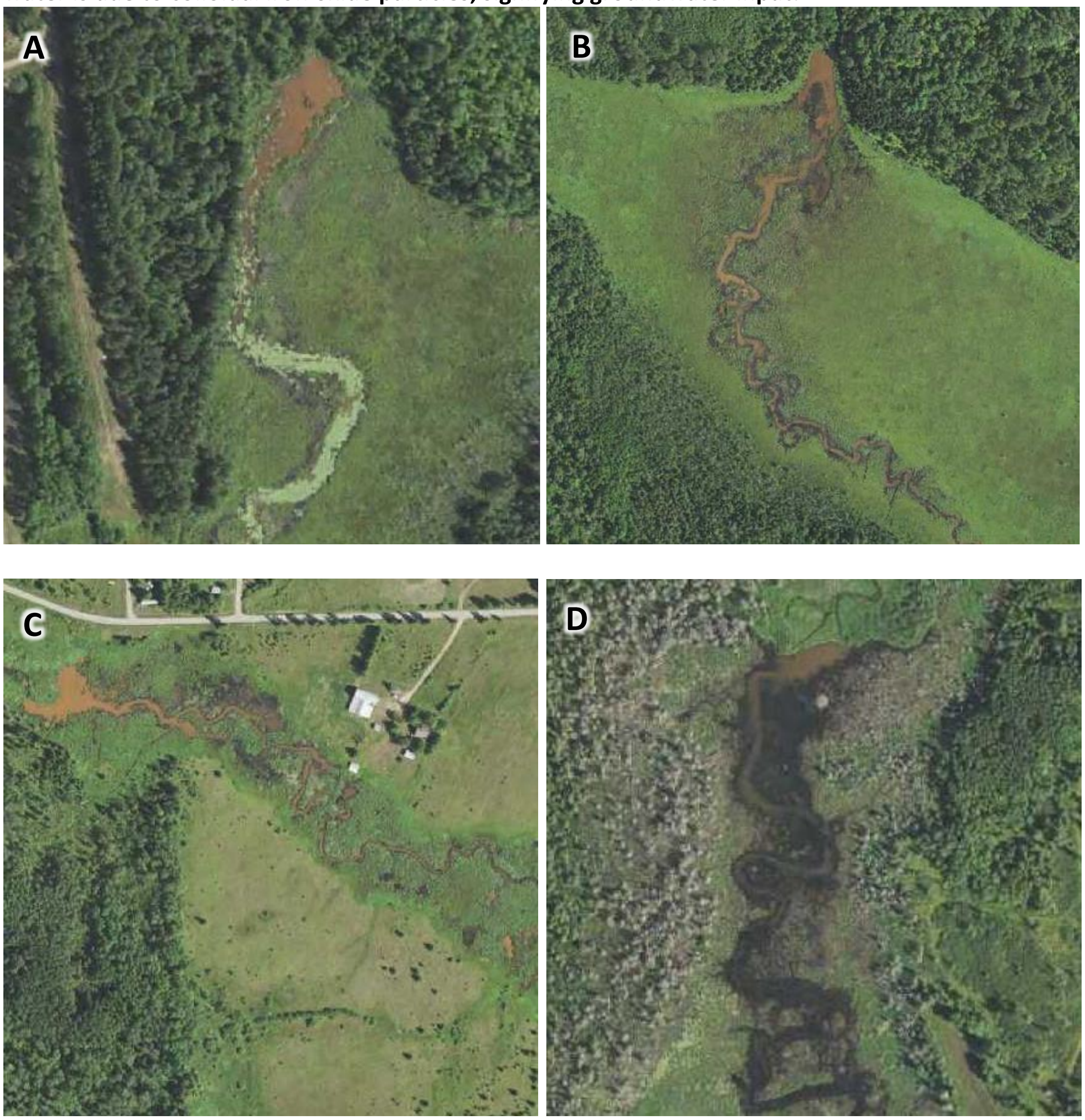


Figure 32. Close ups of the channel at the four encircled locations shown in Figure 30. The orange color of the water is due to colloidal iron oxide particles, signifying groundwater input.



Specific conductance

Specific conductance was low and at levels typical for natural conditions in northern Minnesota.

Suspended solids

The small dataset of TSS samples, along with observations of water clarity at other visits, find that TSS is at least typically very low. The 2008 record of very high TSS seems questionable, as the sampling photos from that day show water clarity that appears to have much lower TSS. In this lone high TSS sample, the component that is mineral is very high in comparison to organic particulates, being 85.7% mineral and 14.3% organic. No other evidence exists of high TSS or turbid conditions.

Stressor signals from biology

Fish

Two recent fish samples were collected at 08RN011, in 2018 and again in 2019. Both samples were highly dominated by central mudminnow (each sample was >90% mudminnows), which are very tolerant to low levels of DO. There were six taxa in each of the recent samples. The 2008 sample is greatly contrasted with the recent samples in that central mudminnow was very low in abundance (only seven individuals of 228), and the sample contained 10 species.

The Community TIV Index scores are shown in Table 20 and individual TIV metrics in Table 21. The DO TIV Index scores for the recent samples dropped significantly from the 2008 score and are now much lower than the class average. The 2008 score is at a fairly high percentile of DO TIV Index scores for stream class 7, but the two recent samples are at very low percentiles. The probability of the sampled community coming from a DO-meeting site was fair for the 2008 sample but is extremely low for the 2018 and 2019 samples. In all three samples, the community is skewed toward taxa that are low-DO tolerant in terms of the species that were present. In the two recent samples, the low-DO tolerant individuals comprised an extremely high percentage of the sample. Central Mudminnow, classified as "very tolerant" to low-DO, was highly dominant in the 2018 and 2019 samples.

The TSS TIV Index scores for all three samples were much better than the class 7 average, especially in 2019. The TIV Index scores were all at good or very good percentiles within class 7 streams. The likelihoods that these communities would come from a stream meeting the TSS standard are very high. The community is not skewed toward either TSS tolerant or intolerant taxa in terms of the taxa present. The only taxa of either one was an intolerant taxon in the 2008 sample.

For the parameters of DO and TSS, it clearly appears that low-DO is a stressor to the fish community, and that TSS is not.

Table 20. Fish Community DO and TSS Tolerance Index scores in AUID-679 at 08RN011 on three dates. For DO, a higher index score is better, while for TSS, a lower index score is better. "Percentile" is the rank of the index score within stream class 7. "Prob." is the probability a community with this score would come from a stream reach with DO or TSS that meet the standards.

Date	Parameter	TIV Index score	Class avg./median	Percentile	Prob. as %
6/18/2008	DO	6.70	6.21/6.16	78	47.7
7/30/2018	DO	5.40	6.21/6.16	7	2.2
7/8/2019	DO	5.40	6.21/6.16	7	2.2
6/18/2008	TSS	12.09	14.99/13.36	84	90.4
7/30/2018	TSS	12.48	14.99/13.36	72	89.7
7/8/2019	TSS	11.95	14.99/13.36	89	90.6

Table 21. Metrics involving low-DO and TSS tolerance for the sampled fish community at 08RN011 on three dates.

Date	Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
6/18/2008	Low DO	0	0	3	2	0.0	31.1
7/30/2018	Low DO	0	0	3	3	0.0	95.1
7/8/2019	Low DO	0	0	5	4	0.0	95.4
6/18/2008	TSS	1	0	0	0	0.3	0.0
7/30/2018	TSS	0	0	0	0	0.0	0.0
7/8/2019	TSS	0	0	0	0	0.0	0.0

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

Two recent macroinvertebrate samples were collected at 08RN011, in 2018 and again in 2019. The 2018 sample was dominated by two taxa, Oligochaetes (worms) and the amphipod *Hyalella azteca*. Neither of these should be dominant in a healthy stream. There were numerous taxa present that are tolerant of low DO; the oligochaetes, several snail species, leeches, the Hemipteran insect Corixidae, and notoriously, the midge *Chironomus*. Only one taxon from the insect Order group EPT was represented, the mayfly *Paraleptophlebia*, and only with three individuals. There were 28 total taxa present in the 2018 sample. The 2019 sample had much fewer oligochates, but this time was highly dominated by the midge *Paratanytarsus*. *Hyalella azteca* was again common at about the same level. There was somewhat better representation of the EPT, with four taxa present: the mayflies *Caenis diminuta* and *Leptophlebia*, and the caddisflies *Oxyethira* and Phryganeidae. There were 26 total taxa present in the 2019 sample.

Comparing the two recent samples with the 2008 sample, which had a very good IBI score, notably there were many more taxa present in the 2008 sample (42), and many more EPT taxa (12).

The Community TIV Index scores are shown in Table 22 and individual TIV metrics in Table 23. The DO TIV Index score was much better than the class average in 2008, but much poorer than the class average in the 2018 and 2019 samples, though 2019 was significantly better than 2018. The 2018 and 2019 scores were low percentages of DO TIV Index scores for stream class 4, particularly the 2018 sample, which was at the 1st percentile. The probability of the 2018 sampled community coming from a DO-meeting site was extremely low, while that in 2019 was better but still well below 50%. The community is heavily skewed toward taxa that are low-DO tolerant in terms of the species that were present, and low-DO tolerant individuals comprised a high percentage of the sample.

The TSS TIV Index score for the three samples varies quite a bit relative to the class 4 average, once being much better and twice being slightly worse. The scoring pattern among the three years does not show the same pattern as the DO TIV scores (which were good, then poor, then somewhat better). Likewise, the percentile within class 4, northern TSS region streams has varied, and the probability of the community coming from a standard-meeting site for all three samples was quite moderate (this is somewhat an artifact of the northern region not having a broad range of TSS concentrations). The community is skewed toward TSS tolerant taxa in terms of the taxa present, though all three samples did have at least one TSS intolerant taxa present. The community is not skewed in regard to the percentage of TSS tolerant versus TSS intolerant individuals; within all samples, the percentages of each are about equal. The most recent sample (2019) found a large drop in the number of TSS very tolerant taxa present.

Given that the DO TIV Index scores are very poor, and that the intolerant versus tolerant taxa presence and percent of individuals are strongly skewed toward low-DO Tolerance, the macroinvertebrate community shows strong evidence of stress from inadequate DO concentrations. Using these same analyses for TSS, there is moderate evidence that TSS is a stressor to the macroinvertebrate community, but not as strong as the evidence for low-DO stress.

Table 22. Macroinvertebrate Community DO and TSS Tolerance Index scores in AUID-679 at 08RN011 on three dates. For DO, a higher index score is better, while for TSS, a lower index score is better. "Percentile" is the rank of the index score within stream class 4. "Prob." is the probability a community with this score would come from a stream reach with DO or TSS that meet the standards.

Date	Parameter	TIV Index score	Class avg./median	Percentile	Prob. as %
8/5/2008	DO	6.80	6.30/6.49	72	64
8/16/2018	DO	3.12	6.30/6.49	1	3
8/5/2019	DO	5.85	6.30/6.49	21	38
8/5/2008	TSS	13.96	13.63/13.77	44	40
8/16/2018	TSS	8.45	13.63/13.77	99	53
8/5/2019	TSS	14.02	13.63/13.77	42	40

Table 23. Metrics involving low-DO and TSS tolerance for the sampled macroinvertebrate community at 08RN011 on three dates.

Date	Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
8/5/2008	Low DO	0	0	7	0	0.0	18.6
8/16/2018	Low DO	0	0	10	5	0.0	38.1
8/5/2019	Low DO	0	0	8	2	0.0	76.2
8/5/2008	TSS	5	1	8	4	8.0	13.0
8/16/2018	TSS	1	0	7	6	2.9	4.9
8/5/2019	TSS	2	1	4	1	1.8	1.2

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Both fish and macroinvertebrates show strong influence of insufficient DO levels. The indications from TSS metrics are less conclusive, and are somewhat inconsistent among the macroinvertebrate data, and between the two communities. For instance, the TSS Community TIV score for macroinvertebrates was excellent for the 2018 sample, but mediocre (below the 50^{th} percentile in class 4 streams) in 2008 and 2019. The fish samples show no evidence among the three samples that there is any influence of TSS stress.

Temperature

The six temperature measurements that have been collected at 08RN011 within the months of June, July, and August ranged from 19.4°C to 25.5°C. These are within the normal range of warm water stream temperatures and thus water temperature is not a stressor to the biological communities.

Hydrology

The vast amount of the Johnson Creek Subwatershed is covered by perennial vegetation, consisting of forest or wetland. The primary impervious cover is Highway 53, which forms only a very small percentage of the land surface of the subwatershed. There is no notable change in land use between 2008, when passing biological scores were attained, and 2018, when they were not. There is no evidence that alteration of hydrology in the subwatershed is responsible for the failing biological communities.

Habitat

Habitat was assessed with the MSHA protocol (Table 24). Five assessments have been done, one in IWM-1 in 2008, and the other four in IWM-2 in 2018-2019. The 2008 score is rated “Fair”, while all of the more recent scores, and their average, rated “Poor”. The poorest scoring categories by far, both in 2008 and the latter years are “In-stream Zone” and “Channel Morphology”. Both of these categories scored much lower in 2018-2019 than in 2008. Based on the records of scoring, and comments from the samplers, there is some suggestion that there may have been more fine sediment deposition on the stream bed in the recent years relative to 2008. It is not known why this may be. Potentially a large rain event between IWM-1 and IWM-2 is responsible. Habitat may naturally be somewhat limiting to biological communities here, as the majority of the subwatershed is in a largely natural condition and thus landscape alteration is not likely to be causing negative anthropogenic consequences to the stream channel.

Table 24. MSHA scoring for site 18RN011.

MSHA Component	June 2008	July 2018	Aug. 2018	July 2019	Aug. 2019	2018-19 Avg.	Maximum Poss. Score	2008 % of Maximum	2018-19 % of Maximum
Land Use	5	5	5	4.5	5	4.9	5	100	98.0
Riparian	9.5	9.5	9	8	9.5	9.0	14	67.8	64.3
In-stream Zone	10	6	5	4	7	5.5	28	35.7	19.6
Cover	13	12	14	13	11	12.5	18	72.2	69.4
Channel Morphology	17	10	12	7	7	9	35	48.6	25.7
Total MSHA Score	54.5	42.5	45	36.5	39.5	40.9	100	54.5 = “Fair”	40.9 = “Poor”

Geomorphology

The creek was visited at three locations, and there were no notable signs of channel instability at any of the locations. Channel instability and its related problems of bank erosion and habitat degradation are therefore not considered to be stressors within Johnson Creek.

Connectivity

Reviewing all of the available aerial photo sets from 2008 - 2021, there have been no barriers to fish colonization into the sampled portion of AUID-679. The biological monitoring reach is only about 0.75 miles from the confluence with the larger Rice River. Thus, a migration barrier is not responsible for the poor fish community score.

Conclusions

The impairment assessment for the macroinvertebrate and fish communities in Johnson Creek hereby attributed to low DO concentrations in the stream. This is based on both the signals from the taxa that constitute the macroinvertebrate and fish communities and from actual measurements of DO along Johnson Creek. Several factors likely contribute to this condition; a significant amount of riparian wetland, numerous springs that enter the stream, and beaver activity causing impoundment of the stream.

Natural Background determination

Low DO is sometimes caused by natural conditions (generally relating to wetland influence and/or beaver impoundment), and SID monitoring and observations suggested that beavers and their numerous impoundments in Johnson Cr. were likely causing low DO conditions in the stream. Additionally, there are numerous groundwater springs that occur along and, in the creek upstream of the monitoring site. It is common for groundwater to have very low DO. An argument for moving this impairment from Class 5 (TMDL needed for pollutant reduction) to Class 4D, Impairment due to natural conditions, was brought to the MPCA ACCT for a decision. The ACCT agreed with the argument that this impairment is a natural condition with contributions from beaver impoundments and groundwater inputs. A written record of the determination is kept by MPCA. This change will be submitted with the 2026 Draft Impaired Waters List (MPCA, 2026c) seeking EPA for approval.

Geomorphology investigations

Before describing the specifics of geomorphology investigations on two LFRW streams, it is worth noting that two previous reports and one subsequent one have been conducted on this topic for the LFRW. The first was a study conducted by mostly internal MPCA staff, though assisted by other agencies, that examined hydrological change and the potential role that historic original logging had on LFRW stream channels (Anderson et al., 2006). A second study was done by three researchers from the University of Minnesota who conducted a study for MPCA to better understand sources of high TSS in the Little Fork River, which included examining the effect of the glaciation that occurred in the region (Gran et al., 2007). The most recent study that included a component of some geomorphology work was led by the USGS for MPCA (Fitzpatrick et al., 2023). These studies provide very good background to channel instability and the high levels of TSS in many LFRW streams, especially the main stem of the Little Fork River.

Unnamed Tributary to Little Fork River (AUID 09030005-676)

In 2010 and 2011, the MPCA conducted its every-five-year randomized, EPA-sponsored biological monitoring that assesses the Nation's streams and rivers. One of the randomly-chosen sites was assigned to an unnamed tributary of the Little Fork River at the very northern part of the LFRW. The site is assigned to the number 10EM129, and is downstream of CR-79, 12.5 miles southwest of International Falls. Because of high flow conditions the year of the study, the fish sample was determined to be un-assessable, and a macroinvertebrate sample was never collected. From the MSHA, it is a mostly clay-lined channel. The overall MSHA score was "Fair".

When viewing the photographs taken by the biological crew, this report's author, who has been trained in geomorphological assessment, felt that the channel appeared to be showing signs of an unstable condition, potentially contributing significant sediment amounts to the Little Fork River's already sediment-laden condition (Figure 33). A request was made to the DNR geomorphology group in the Grand Rapids office to do an actual surveyed assessment of channel stability at this location.

Figure 33. The channel condition at the mid-point of the 10EM129 study reach. Signs of channel instability are steep, raw soil banks, exposed tree roots, and many streamside trees tilting into the channel.

The DNR conclusions are as follows:

> "The visual evidence suggests that this stream is incised and currently in a very unstable state. However, taking all the aspects (surveyed and observed) as a whole, the level of instability is difficult to accurately quantify. There are apparent indicators of instability such as incision, meander and deposition patterns, and channel blockage types and others that may be obscured by confounding factors (beaver activity and proximity to the main stem) which could be slowing the channel evolution process. Future repeated surveys in the area could help to clarify the situation. It seems

> likely that this reach is impaired for TSS. Whether it truly is or is not, the stream could benefit from being re-connected to its flood plain….To be clear, this stream is unstable to some degree, but further surveys and studies are needed to draw more detailed conclusions on the level of instability and the underlying causes."

Further details about the specifics of the geomorphology survey conducted on this stream, please contact the Watershed Specialists at the Grand Rapids office of DNR.

Flint Creek (AUIDs 09030005-612, -588, and -574)

The DNR conducted Rosgen Level Two surveys (Rosgen, 1996) on two reaches of Flint Creek within AUID 09030005-612, which is on Minnesota's 303(d) list as impaired for TSS. The surveys were done to assess the channel condition as a possible source of suspended sediment. A 705-foot section was completed in Flint Creek near the North Woods School, approximately 0.2 miles downstream of US Hwy-53, first in 2011 and again in 2021. Another section, on a 690-foot of channel length approximately 0.25 miles upstream of the US Hwy-53 crossing, was completed the same years.

The results of the two sites were somewhat similar, with the upstream reach, and its lower gradient, having somewhat less bank erosion. For both sections, beaver activity is noted as likely helping to reduce erosion. The stream; however, is in an incised and unstable condition, resulting in significant sediment input to the stream. An excerpt from the DNR report's conclusion section for the downstream reach:

> "Overall, this reach of Flint Creek shows indications of channel instability. While determination of the BKF elevation is difficult due to lack of clear indicators, a fact exacerbated by the high water during the time of the survey, the channel appears to be incised and disconnected from its floodplain. There are many eroding banks with bare soil evident. The cross sectional area of the channel when measured from the top of bank is about double what the Regional curve would predict, suggesting that the top of bank is well above the actual bankfull elevation. Bank Height ratios calculated using an elevation determined by the regional curve area were 2.46. In the Stream Quantification tool, this ranks as 'Not Functioning'. There is also evidence of meander scrolls that suggest a channel that has been actively laterally migrating. On the other hand, pool depths, pool to pool spacing and bank erosion rates suggest a more stable system. However, the slow to erode adhesive clays that make up the bed and banks, combined with long-term impoundment by beaver dams have likely mitigated the erosion and evolution rates. Initiation of channel instability is likely similar to many streams in NE MN, with historic logging altering run-off as well as possible direct impacts to stream banks. Regrowth of forests and subsequent return of a more normal hydrologic regime, combined with the above factors all contribute to a slowing of the channel evolution process. The sediment impairment on the stream is likely the result of the channel instability, and reconnecting the channel to its floodplain would mitigate many sediment issues."

Photos of Flint Creek have also been taken by the MPCA biological monitoring crew during their sampling visits at two sites farther downstream from the DNR sites, which also show tell-tale signs of channel instability, such as excessive fine sediment deposition on the stream bed (Figure 34), steep, raw soil banks (Figure 35), high amounts of large woody debris in the channel from undermined trees that have fallen into the channel (Figure 36).

Figure 34. The Flint Creek channel at 08RN051, showing deposition of fine sediment in the middle of the channel that has accumulated smaller branches. Mid-channel sediment bars are a known sign of excessive fine sediment inputs to a stream.

Figure 35. Substantial erosion is occurring on the outer bank, with large amounts of exposed tree roots and chunks of missing bank. Photo is at the midpoint of reach 08RN051, which is just downstream from State Highway 1.

Figure 36. A logjam at reach 08RN051 in 2018.

In addition to the geomorphology work by DNR and review of biological monitoring photos of the channel, the second generation LiDAR elevation Geographic Information System (GIS) layer was reviewed on part of Flint Creek as another way of determining potential hot spots where there may be very localized erosion occurring along the channel, such as the stream channel flowing up against the valley wall, or gullies along the bank similar to what occurs on the mainstem of the Little Fork River. Examples of such analysis are shown in Figure 37 and Figure 38. A similar approach could be used in other locations of the LFRW. These are areas that could be selected to take an erosion control management practice if field verification shows significant erosion.

Figure 37. Locations along Flint Creek between Wood Rd. and North Woods School, mostly on AUID-612 where, via use of the Minnesota Gen 2 LiDAR elevation layer in GIS, the current channel of Flint Creek is flowing up against the valley wall ☆ and where gullies occur ★. Colors are elevation levels with dark orange being highest elevation and dark purple the lowest.

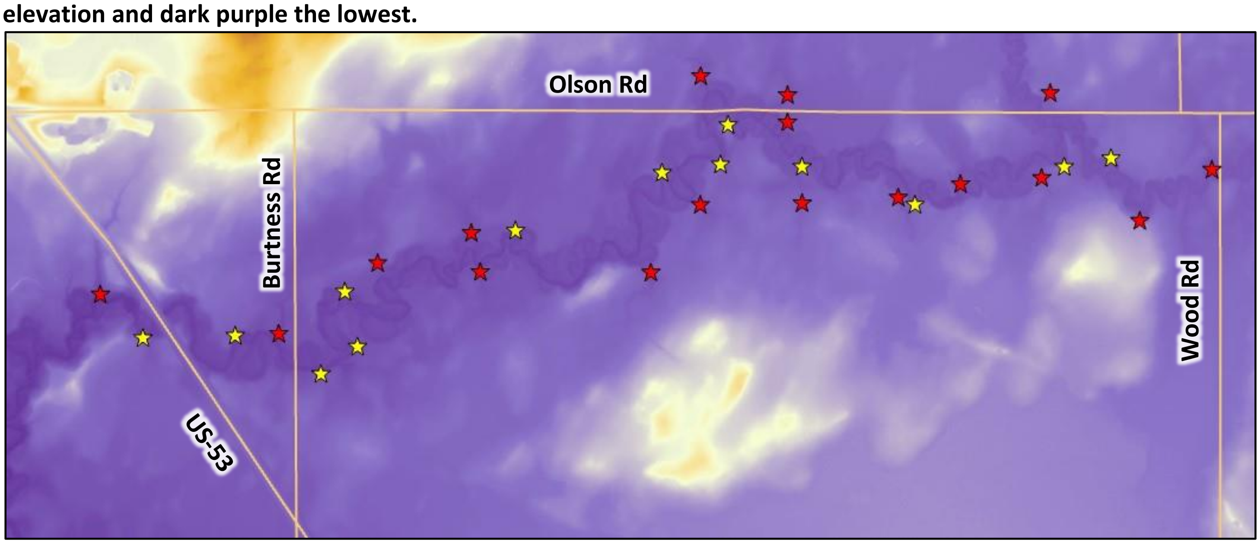
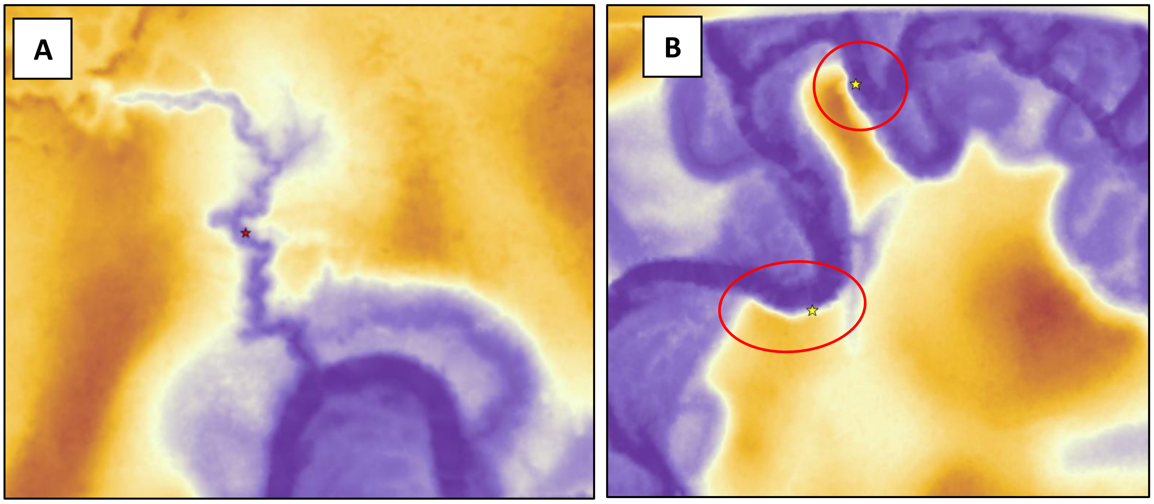


Figure 38. Close up views of starred sites from Figure 35: A) A short gully tributary to Flint Creek, B) a couple locations where the channel (darkest purple tone) is flowing right up against the valley wall (orange area), making a high, steep bank susceptible to erosion.



Recommendations regarding geomorphology issues

Restoring incised channels is difficult. Stabilizing streambanks along the length of the Unnamed Creek and Flint Creek would be cost prohibitive. Some methods are available that would help raise the elevation of the stream bed, moving in the direction of being un-incised. This requires geomorphological expertise, such as exists in DNR. Guidance or detailed information is available on the internet (for example, Fischenich and Morrow, 2000). One confounding factor is that alleviating the incision means the stream will revert back to being able to spill onto the floodplain during periods of highest flow volumes. Since these incision issues likely originated a hundred years ago, streamside property owners have likely never experienced regular, seasonal flooding on their land, and may be averse to having that happening again.

It is more likely to be cost-effective to work on reducing peak flows in the river using land management best management practices (BMPs). This will reduce the erosivity of flows and help the river evolve to a more stable condition. Efforts to make restoration progress in these streams would be a long-term process. Focusing on very localized erosion hotspots, using bank protection BMPs (e.g., rock veins in the channel to divert flow away from unstable banks) will likely be a better track to take, in combination with reducing peak flows. It is advised to consult DNR stream managers before such work occurs for help in making proper designs. Also, DNR permits may be required.

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