

Stressor Identification Update

Red Lake River and Grand Marais Creek Watersheds

October 2026

Introduction

Stressor identification (SID) is a formal and rigorous process for identifying the pollutant and nonpollutant causes, or “stressors”, that are likely contributing to the impairment of aquatic ecosystems. The Minnesota Pollution Control Agency (MPCA) conducts SID on fish and macroinvertebrate bioassessment impairments as a key component of the major watershed restoration and protection projects being carried out under Minnesota’s Clean Water Legacy Act. Once completed, the findings from SID are used to support the development of Watershed Restoration and Protection Strategy (WRAPS) and Total Maximum Daily Load (TMDL) reports, which help inform local water planning efforts to address impaired conditions.

The findings provided in this update are from the evaluation of bioassessment impairments associated with watercourses in the Red Lake River and Grand Marais Creek watersheds that were part of Cycle 2 SID. Information on prior SID work in these watersheds can be found within the *Red Lake River Watershed Stressor Identification Report* (MPCA, 2015b) and the *Grand Marais Creek Watershed Stressor Identification Report* (MPCA, 2015a). A total of three bioassessment-impaired reaches were evaluated during Cycle 2 SID, including the Black River (AUID 09020303-529), Judicial Ditch 60 (AUID 09020303-570), and the Grand Marais Creek (AUID 09020306-530). Two other bioassessment-impaired reaches (i.e., Unnamed Creek, AUID 09020303-569; and Unnamed Creek, AUID 09020306-527) were excluded from the SID process due to insufficient water quality data for analysis; a lack of sustained baseflow associated with these systems severely limited data collection efforts. Candidate causes investigated as stressors during Cycle 2 SID included: a loss of longitudinal connectivity, flow regime instability, inadequate physical habitat, high total suspended solids (TSS), low dissolved oxygen (DO), and high nitrate-nitrogen. An overview of each of these candidate causes is provided in *Stressors Candidate Causes* (MPCA, 2022). The following subparts summarize the Cycle 2 SID findings for the bioassessment impaired reaches within the watersheds.



Red Lake River Watershed

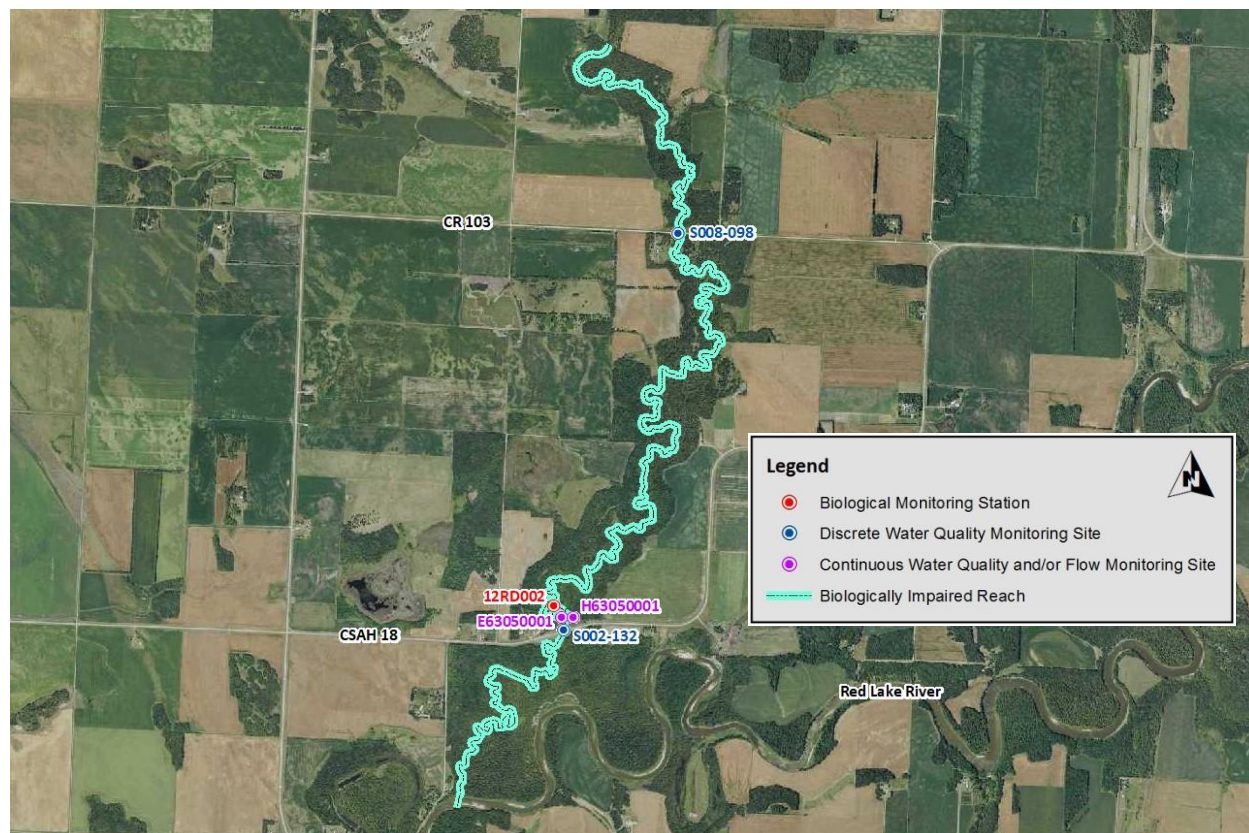
Black River (AUID 09020303-529)

Physical Setting

This reach represents the 8.4-mile segment of the Black River from the confluence with the Little Black River, to its confluence of the Red Lake River (Figure 1). The reach has a subwatershed area of 145 square miles (92,711 acres). According to the Minnesota Department of Natural Resources (DNR; 2026), the subwatershed contains 81 miles of intermittent drainage ditch, 64 miles of intermittent stream, and 33 miles of perennial river and stream, including the Black River. While the channel of this reach of the Black River is classified as natural, 57% of the watercourses in its subwatershed have been physically altered through channelization or ditching (MPCA, 2019). The National Land Cover Database (NLCD)

2019 (USGS, 2019) lists cultivated crops (75%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetland (17%), forest (3%), developed (3%), and hay/pasture (1%).

Figure 1. Map of the Black River (AUID 09020303-529) and associated biological monitoring station and water quality monitoring sites (2023 NAIP aerial image). Flow direction is north to south.



Biological Impairment

Macroinvertebrate (M-IBI)

The macroinvertebrate community of this segment of the Black River was monitored at Station 12RD002 (0.1 miles upstream of the CSAH 18 crossing) on July 31, 2012, August 7, 2013, August 1, 2023, and August 20, 2024. The location of the station is shown in Figure 1. The station is designated as General Use within the Southern Streams Riffle/Run Macroinvertebrate Index of Biological Integrity (M-IBI) Class (Class 5); the associated impairment threshold is an M-IBI score of 37, with a confidence limit of ± 13 . Overall, the station experienced a substantial decrease in M-IBI scores between 2012 (48) and 2013 (40), and 2023 (31) and 2024 (27). According to the MPCA biological monitoring staff: “The main driver for the decrease in IBI scores appears to be higher relative abundance of the dominant five taxa. Higher proportions of the samples from 2023 and 2024 were made up tolerant taxa such as *Hyalella*, *Cheumatopsyche*, and tolerant midges. Severe bank erosion and a deeply incised channel were noted in both sampling efforts in 2023 and 2024”.

Candidate causes

Flow regime instability

Available data

The DNR (2026) classified the flow regime of this reach of the Black River as perennial. The Red Lake Watershed District (RLWD) conducted flow monitoring at Site S002-132 (CSAH 18 crossing) from 2012 to 2019. Figure 2 depicts the daily discharge measurements for the site. Overall, the highest flow logged at the site was 2,912 cfs, while the lowest flow was 0 cfs. Figure 3 shows an example of high flow conditions at the site on April 8, 2014. No flow conditions were common at the site and comprised 73% of all values. StreamStats (USGS, 2026) estimated that the normal range of flow values at the downstream end of the reach to be less than 0.1 cfs (Q75; value exceeded 75% of the time) to 4.1 cfs (Q25; value exceeded 25% of the time). Additionally, the estimated 1.5-year peak flood flow was 426 cfs, while the 7 day, 10-year low flow value for the reach was less than 0.01 cfs. The MPCA biological monitoring staff observed only interstitial flow during a September 6, 2023, macroinvertebrate monitoring visit to Station 12RD002. Additionally, the MPCA SID staff conducted nine separate field visits to the reach between April and October of 2025; flow was estimated during each visit. Flow amounts estimated by staff ranged from less than 0.1 cfs (October 8, 2025; Figure 3), to 20 cfs (April 28, 2025). Overall, the available data suggest the reach is prone to occasional extreme peak flows, as well as frequent and extended periods of no flow.

Figure 2. Daily discharge data (2012-2019) for Site S002-132 (CSAH 18 crossing) along the Black River (09020303-529).

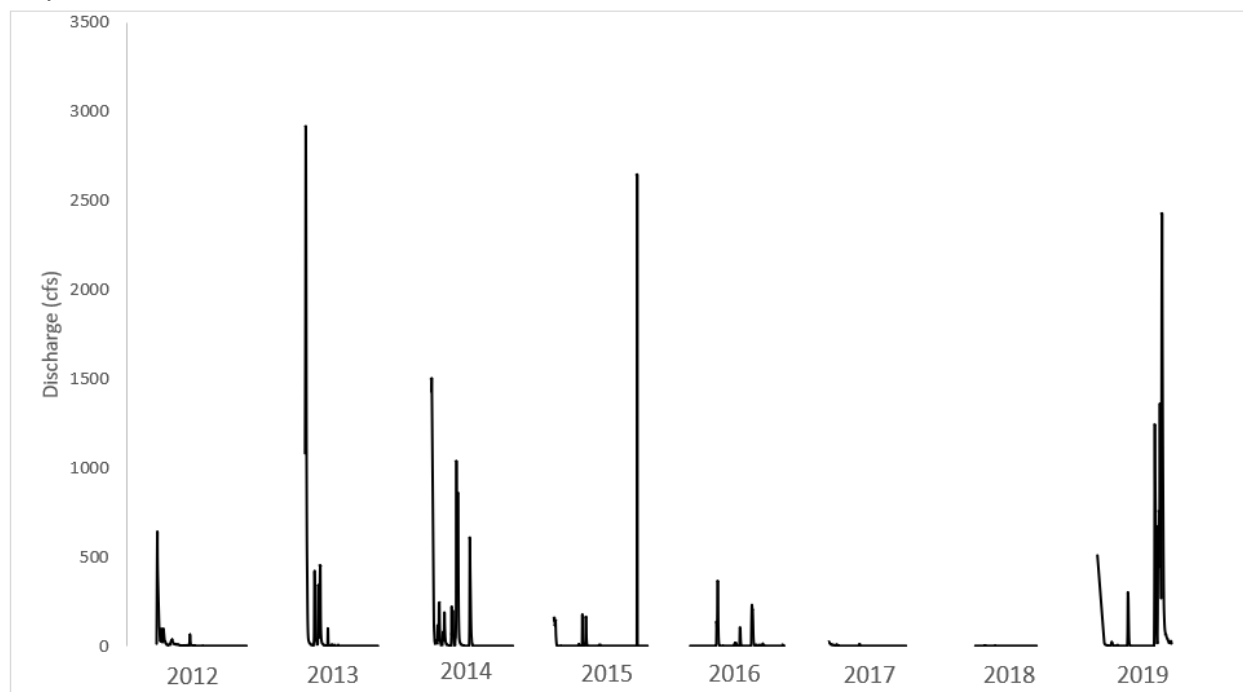


Figure 3. Flow-related images at the CSAH 18 crossing along the Black River (AUID 09020303-529), including near bankfull stage on April 8, 2014 (left; image courtesy of the RLWD), and (<0.1 cfs) flow on October 8, 2025 (right).



Biological response: Macroinvertebrate

Flow regime instability has been shown to limit the diversity and taxa richness of macroinvertebrates and favor tolerant taxa that can adapt to disturbances. Several authors have documented an inverse relationship between flow regime instability and the abundance of taxa belonging to the orders of Ephemeroptera, Plecoptera, and Trichoptera (Bunn and Arthington, 2002; Bragg et al., 2005; Dewson et al., 2007). Table 1 shows the flow regime instability-related metric scores for the macroinvertebrate community of this reach of the Black River. Nearly all the metric scores for Station 12RD002 failed to meet their respective statewide mean. In addition, some of the scores were outside one standard deviation from the mean. The multiple lines of evidence ***convincingly support*** the case for flow regime instability as a stressor to the macroinvertebrate community of this reach of the Black River.

Table 1. Summary of flow regime instability-related biological metric data for Station 12RD002 along the Black River (AUID 09020303-529), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
EPTPct	Relative abundance (%) of Ephemeroptera, Plecoptera, and Trichoptera (decrease)	44 $\pm$ 19	12RD002 ¹² (35)
			12RD002 ¹³ (50)
			12RD002 ²³ (24)
			12RD002 ²⁴ (31)
LongLivedPct	Relative abundance (%) of long-lived individuals (decrease)	9 $\pm$ 7	12RD002 ¹² (5)
			12RD002 ¹³ (5)
			12RD002 ²³ (2)
			12RD002 ²⁴ (1)

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
TaxaCountAllChir	Total taxa richness of macroinvertebrates (decrease)	43 $\pm$ 7	12RD002 ¹² (50)
			12RD002 ¹³ (50)
			12RD002 ²³ (39)
			12RD002 ²⁴ (33)
Tolerant2ChTxPct	Relative abundance (%) of taxa with tolerance values equal to or greater than six (increase)	71 $\pm$ 8	12RD002 ¹² (76)
			12RD002 ¹³ (78)
			12RD002 ²³ (80)
			12RD002 ²⁴ (76)
TrichwoHydroPct	Relative abundance (%) of non-hydropsychid Trichoptera individuals (decrease)	7 $\pm$ 8	12RD002 ¹² (1)
			12RD002 ¹³ (18)
			12RD002 ²³ (2)
			12RD002 ²⁴ (3)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams M-IBI Class (Class 5) and met or exceeded the IBI threshold (37).

¹² Sampled on July 31, 2012; ¹³ sampled on August 7, 2013; ²³ sampled on August 1, 2023; ²⁴ sampled on August 20, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Inadequate physical habitat

Available data

The physical habitat of this segment of the Black River was evaluated during five biological monitoring visits to Station 12RD002 using the MPCA Stream Habitat Assessment (MSHA). The station yielded MSHA score ranging from 48 (“fair”) on August 1, 2023, to 71 (“good”) on June 13, 2012. The presence of row crop within the immediate vicinity of the station somewhat limited its land use subcategory scores. The riparian subcategory scores were positively influenced by a mostly “extensive” riparian zone width; however, “severe” bank erosion was also noted during four of the visits. While the station offered limited riffle habitat, some coarse substrate (i.e., cobble and gravel) with a “light” to “moderate” amount of embeddedness was noted during each of the visits. The results from the June 21, 2023, fish monitoring visit to Station 12RD002 also support the availability of coarse substrate, as the assemblage was dominated by blackside darter, which is an insectivorous, simple lithophilic spawning species. The cover subcategory scores for the station were positively affected by a “moderate” amount of cover. Identified cover types included undercut banks, overhanging vegetation, deep pools, logs/woody debris, and macrophytes (emergent, submergent, and floating leaf). Lastly, the station scored relatively low in the morphology subcategory due in part to “low” channel stability.

In 2013 and 2025, DNR Clean Water staff completed a fluvial geomorphic assessment downstream of the CSAH 18 crossing along this reach of the Black River. The channel at this location was classified as a Bc/C stream type (moderate to high width-to-depth ratio and a sand and gravel stream). The Pfankuch

rating for this reach was poor (unstable). In addition, signs of instability were noted when comparing results from 2013 to 2025. Below is an excerpt from the assessment summary for the site:

“Mass wasting of the upper banks was frequent as was cutting on the lower banks. There was good vegetative bank protection, including mature trees, but the channel was incised below the influence of the roots in many locations; this had led to slumps and debris jams, leading to bank erosion and sediment deposition in the channel. The channel is currently moderately entrenched and in the process of developing a new floodplain at a lower base level; however, the floodplain needs more width to accommodate bankfull and higher floods, so the banks will continue to erode, and the channel and floodplain will continue to widen as the channel moves toward equilibrium.”

Overall, the available data suggests that the reach has some habitat-related deficiencies that limit its ability to support a healthy macroinvertebrate community.

Biological response: Macroinvertebrate

Clinger taxa require clean, coarse substrate, or other objects to attach themselves to or feed from, while burrower, legless, and sprawler macroinvertebrates are generally tolerant of degraded benthic habitat (Gore et al., 2001). Table 2 shows the inadequate physical habitat-related metric scores for the macroinvertebrate community of this reach of the Black River. Station 12RD002 had a low abundance of clinger individuals, which suggests that hard-aerated surfaces may be somewhat limited. Additionally, most of the visits to the station had an above average percentage of sprawler taxa, indicating the presence of degraded habitat facets. The multiple lines of evidence **somewhat support** the case for inadequate physical habitat as a stressor to the macroinvertebrate community in this reach of the Black River.

Table 2. Summary of inadequate physical habitat-related biological metric data for Station 12RD002 along the Black River (AUID 09020303-529), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean ± SD	Station (score)
BurrowerPct	Relative abundance (%) of burrower individuals (increase)	7 ± 6	12RD002 ¹² (13)
			12RD002 ¹³ (5)
			12RD002 ²³ (2)
			12RD002 ²⁴ (4)
ClingerPct	Relative abundance (%) of clinger individuals (decrease)	51 ± 15	12RD002 ¹² (18)
			12RD002 ¹³ (39)
			12RD002 ²³ (25)
			12RD002 ²⁴ (47)
LeglessPct	Relative abundance (%) of legless individuals (increase)	37 ± 18	12RD002 ¹² (47)
			12RD002 ¹³ (35)
			12RD002 ²³ (12)
			12RD002 ²⁴ (34)

Metric	Description (expected response to stressor)	Target score ¹ mean ± SD	Station (score)
SprawlerPct	Relative abundance (%) of sprawler individuals (increase)	16 ± 10	12RD002 ¹² (27)
			12RD002 ¹³ (14)
			12RD002 ²³ (65)
			12RD002 ²⁴ (37)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams M-IBI Class (Class 5) and met or exceeded the IBI threshold (37).

¹² Sampled on July 31, 2012; ¹³ sampled on August 7, 2013; ²³ sampled on August 1, 2023; ²⁴ sampled on August 20, 2024.

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High suspended sediment

Available data

According to Table 3, a combined 129 discrete TSS samples were collected at Sites S002-132 (CSAH 18 crossing) and S008-098 (CR 103 crossing) along this reach of the Black River. Collectively, TSS concentrations for the sites ranged from less than 1 mg/L (August 7, 2023) to 287 mg/L (June 14, 2014), with a mean of 25 mg/L. Approximately, 12% of the values exceeded the 65 mg/L TSS standard for the Southern TSS Region. In addition, the MPCA biological monitoring staff encountered a severe amount of bank erosion (Figure 4) and a deeply incised channel during their monitoring visits to Station 12RD002. Furthermore, the MPCA SID staff noted severe bank erosion (Figure 4) near Site S002-132 (CSAH 18 crossing) during an October 14, 2025, drone reconnaissance flight. Overall, the available data suggest the reach experiences occasional periods of high TSS.

Table 3. Discrete TSS data for Sites S002-132 (CSAH 18 crossing) and S008-098 (CR 103 crossing) along the Black River (AUID 09020303-529).

Site	Date range	<i>n</i>	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Standard (65 mg/L) exceedances	% Standard (65 mg/L) exceedances
S002-132	2002-2025	128	<1	287	25	14	11
S008-098	2014	1	112	112	112	1	100

Figure 4. Images of bank erosion along the Black River (AUID 09020303-529), including Station 12RD002 on June 13, 2012 (left), and near Site S002-132 (CSAH 18 crossing) on October 14, 2025 (right).



Biological response: Macroinvertebrate

High suspended sediment can adversely affect macroinvertebrates in various ways depending on the concentration and duration of exposure. Excessive suspended sediment often results in a limited macroinvertebrate community that is dominated by tolerant taxa (Henley et al., 2000; EPA, 2012; Jones et al., 2012). Sediment suspended in the water column can limit collector species and species that filter using a net-spinning casing. Table 4 shows the high TSS-related metric scores for the macroinvertebrate community of this reach of the Black River. In 2012 and 2013, nearly all scores for Station 12RD002 failed to meet their respective statewide mean. During the most recent monitoring visits, the station met the statewide mean for the TSS tolerance indicator value (TIV) and the abundance of high TSS tolerant taxa. However, according to M. Steininger, MPCA macroinvertebrate biologist (personal communication, 2026), the change in these metric values is likely driven by the presence of a lone intolerant taxa (i.e., *Neureclipsis*), rather than an actual improvement in the overall quality of the macroinvertebrate community. The multiple lines of evidence **somewhat support** the case for high TSS as a stressor to the macroinvertebrate community of this reach of the Black River.

Table 4. Summary of high TSS-related biological metric data for Station 12RD002 along the Black River (AUID 09020303-529), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
TSS TIV	Mean TSS (mg/L) tolerance indicator value (increase)	16 $\pm$ 2	12RD002 ¹² (18)
			12RD002 ¹³ (16)
			12RD002 ²³ (16)
			12RD002 ²⁴ (16)
ToITSS	Relative abundance (%) of high TSS tolerant taxa (increase)	33 $\pm$ 14	12RD002 ¹² (49)
			12RD002 ¹³ (37)
			12RD002 ²³ (28)
			12RD002 ²⁴ (33)
InToITSS	Relative abundance (%) of high TSS intolerant taxa (decrease)	6 $\pm$ 9	12RD002 ¹² (3)
			12RD002 ¹³ (3)
			12RD002 ²³ (2)
			12RD002 ²⁴ (0)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams M-IBI Class (Class 5) and met or exceeded the IBI threshold (37).

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Low dissolved oxygen

Available data

According to Table 5, a combined 217 discrete DO measurements were collected at Sites S002-132 (CSAH 18 crossing) and S008-098 (CR 103 crossing) along this reach of the Black River. Collectively, the

DO concentrations for the sites ranged from 3.5 mg/L (August 30, 2011) to 14.0 mg/L (October 8, 2012), with a mean of 8.9 mg/L. Only seven values failed to meet the 5.0 mg/L DO standard; however, only 26 of the measurements were collected prior to 9:00 a.m., when values are typically lowest. The RLWD conducted continuous DO monitoring at Site E63050001 from July 14, 2022, to September 7, 2022 (Table 6 and Figure 5). During the continuous monitoring period, 7% of the total values and 19% of the daily minimum values failed to meet the standard. Stagnant conditions were noted towards the end of this deployment period, which corresponded with a substantial fluctuation in DO concentrations. In addition, the MPCA conducted continuous DO monitoring at Site H63050001 from June 12, 2025, to June 24, 2025. The monitoring results are provided in Table 6, as well as displayed in Figure 6. During the continuous monitoring period, 10% of the total values and 18% of the daily minimum values failed to meet the standard. Lack of sustained baseflow appears to be the primary factor negatively affecting the DO regime of the reach. Overall, the available data suggest the reach experiences occasional periods of low DO.

Table 5. Discrete DO data for Sites S002-132 (CSAH 18 crossing) and S008-098 (CR 103 crossing) along the Black River (AUID 09020303-529).

Site	Date range	<i>n</i>	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Values below 5.0 mg/L standard	% Values below 5.0 mg/L standard
S002-132	2007-2025	216	3.5	14.0	8.8	7	3
S008-098	2014	1	8.9	8.9	8.9	0	0

Table 6. Continuous DO data for Site H63050001 and Site E63050001 along the Black River (AUID 09020303-529).

Site	Start date - End date	<i>n</i>	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
H63050001	6/12/2025 - 6/24/2025	1152	2.7	12.5	10	18	3.1
E63050001	7/14/2022 - 9/7/2022	2630	0	29.87	7	19	4.9

Figure 5. Continuous DO data (July 14, 2022-September 7, 2022) for Site E63050001 along the Black River (AUID 09020303-529).

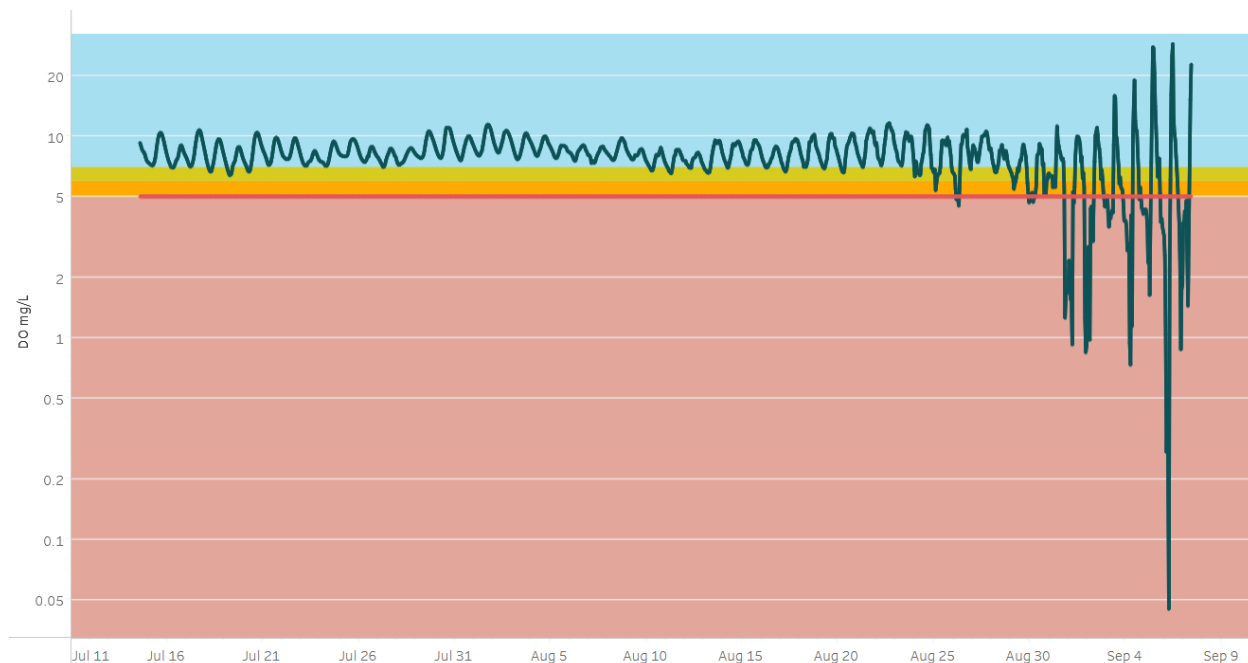
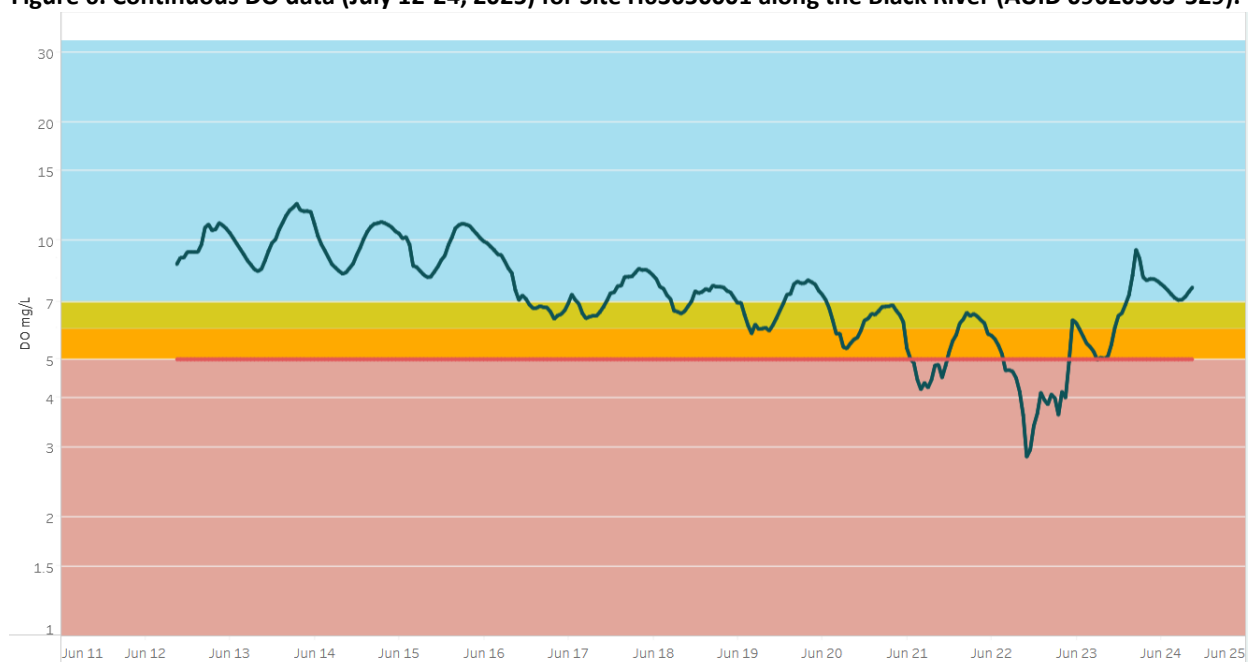


Figure 6. Continuous DO data (July 12-24, 2025) for Site H63050001 along the Black River (AUID 09020303-529).



Eutrophication-related data for the reach include the following parameters: total phosphorus (TP), chlorophyll-*a* (chl-*a*), and DO flux. A total of 120 discrete TP samples were collected at Sites S002-132 (CSAH 18 crossing) and S008-098 (CR 103 crossing) along the reach. Approximately 47% of the values exceeded the 150 µg/L Southern River Nutrient Region TP standard. Collectively, the highest TP concentration was 789 µg/L. A total of five discrete chl-*a* samples were collected at Site S002-132. None of the values exceeded the 40 µg/L Southern River Nutrient Region chl-*a* standard. Lastly, the mean daily DO flux measured during continuous monitoring was 4.9 mg/L at Site E63050001 (2022), and 3.1 mg/L at Site H63050001 (2025). Both monitoring periods met the 5.0 mg/L DO flux standard. In addition, the MPCA SID staff documented abundant rooted macrophytes and isolated patches of filamentous algae at

Site S002-132 starting in early June 2025. Towards the end of August 2025, primary production growth was widespread, covering much of the stream channel. Despite elevated TP concentrations, response variable data indicate that eutrophication is not the primary driver of low DO, and that lack of sustained baseflow is more likely the cause.

Biological response: Macroinvertebrate

Frequent or extended periods of low DO can alter a macroinvertebrate community by limiting the abundance of taxa that are intolerant of such conditions (Davis, 1975, EPA, 2012). Table 7 provides the low DO-related metric scores for the macroinvertebrate community of this reach of the Black River. Station 12RD002 had an above average abundance of low DO tolerant taxa, as well as a below average abundance of low DO intolerant taxa. The multiple lines of evidence **strongly support** the case for low DO as a stressor to the macroinvertebrate community of this reach of the Black River.

Table 7. Summary of low DO-related biological metric data for Station 12RD002 along the Black River (AUID 09020303-529), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
DO TIV	Mean DO (mg/L) tolerance indicator value (decrease)	7 $\pm$ 0	12RD002 ¹² (6)
			12RD002 ¹³ (7)
			12RD002 ²³ (6)
			12RD002 ²⁴ (7)
ToIDO	Relative abundance (%) of low DO tolerant taxa (increase)	8 $\pm$ 10	12RD002 ¹² (27)
			12RD002 ¹³ (7)
			12RD002 ²³ (64)
			12RD002 ²⁴ (33)
InToIDO	Relative abundance (%) of low DO intolerant taxa (decrease)	24 $\pm$ 15	12RD002 ¹² (1)
			12RD002 ¹³ (22)
			12RD002 ²³ (1)
			12RD002 ²⁴ (10)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams M-IBI Class (Class 5) and met or exceeded the IBI threshold (37).

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High nitrate-nitrogen

Available data

According to Table 8, 107 discrete nitrate-nitrogen (NO₃+NO₂-N) samples were collected at Site S002-132 (CSAH 18 crossing) along the reach. The nitrate-nitrogen concentrations for the site ranged from less than 0.1 mg/L to 5.5 mg/L, with a mean 0.4 mg/L. While Minnesota does not currently have an aquatic life use standard for nitrate, there is a chronic criteria value for nitrate of 8.0 mg/L (MPCA,

2022). None of the samples exceeded this criteria value. Overall, the available data suggest the reach does not experience periods of high nitrate-nitrogen.

Table 8. Discrete nitrate-nitrogen data for Site S002-132 (CSAH 18 crossing along the Black River (AUID 09020303-529)).

Site	Date range	<i>n</i>	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Criteria (8.0 mg/L) exceedances	% Criteria (8.0 mg/L) exceedances
S002-132	2007-2025	107	<0.1	5.5	0.4	0	0

Biological response: Macroinvertebrate

Nitrogen toxicity can affect the macroinvertebrate community depending on the concentration, length of exposure, and sensitivity of the individual organism (Camargo and Alonso, 2006). Table 9 shows the nitrogen (N)-related metric scores for the macroinvertebrate community of this reach of the Black River. Most metric scores for Station 12RD002 met their respective statewide mean. Two monitoring visits yielded a high abundance of nitrogen-tolerant taxa; however, this result is likely confounded by the effects of other stressors. The multiple lines of evidence *refute* the case for high nitrate-nitrogen as a stressor to the macroinvertebrate community of this reach of the Black River.

Table 9. Summary of high nitrate nitrogen-related macroinvertebrate metric data for Station 12RD002 along the Black River (AUID 09020303-529), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
N TIV	Mean N (mg/L) tolerance indicator value (increase)	3 ± 1	12RD002 ¹² (3)
			12RD002 ¹³ (3)
			12RD002 ²³ (3)
			12RD002 ²⁴ (3)
ToIN	Relative abundance (%) of high N tolerant taxa (increase)	45 ± 16	12RD002 ¹² (64)
			12RD002 ¹³ (64)
			12RD002 ²³ (28)
			12RD002 ²⁴ (45)
InToIN	Relative abundance (%) of high N intolerant taxa (decrease)	3 ± 6	12RD002 ¹² (4)
			12RD002 ¹³ (4)
			12RD002 ²³ (1)
			12RD002 ²⁴ (4)

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Summary of Stressors

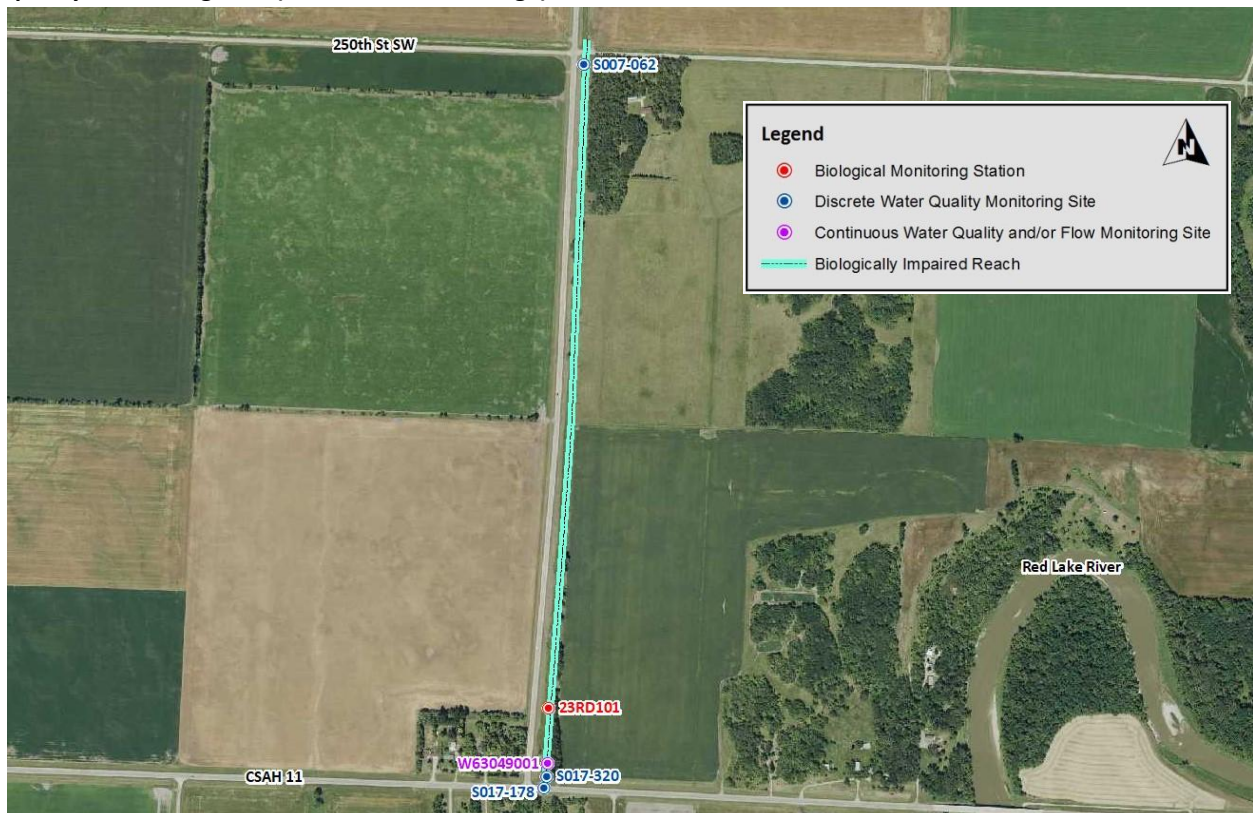
The evidence suggests that the macroinvertebrate bioassessment impairment associated with the Black River (AUID 09020303-529) is primarily attributed to flow regime instability, low DO, and to a lesser extent, inadequate physical habitat and high TSS. Flow regime instability, specifically high peak flows and extended periods of minimal to no flow, is adversely affecting the macroinvertebrate community. High flow conditions have resulted in channel stability issues, thereby degrading available physical habitat and increasing sediment loading. Conversely, the lack of sustained baseflow, particularly in the later summer months, is likely the main contributing factor to low DO concentrations.

Judicial Ditch 60 (09020303-570)

Physical Setting

This reach represents the one-mile segment of Judicial Ditch 60 from 250th St SW to CSAH 11. The reach has a subwatershed area of 26 square miles (16,700 acres). According to the DNR (2026), the subwatershed contains 42 miles of intermittent drainage ditch (including Judicial Ditch 60) and 11 miles of intermittent stream. Approximately 90% of the watercourses in the subwatershed of the reach have been physically altered (i.e., channelized or ditched), including the entire length of the reach itself (MPCA, 2019). The NLCD 2019 (USGS, 2019) lists cultivated crops (83%) as the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included wetland (8%), hay/pasture (5%), and developed (4%).

Figure 7. Map of Judicial Ditch 60 (AUID 09020303-570) and associated biological monitoring station and water quality monitoring sites (2023 NAIP aerial image). Flow direction is north to south.



Biological Impairment

Macroinvertebrate (M-IBI)

The macroinvertebrate community of this segment of Judicial Ditch 60 was monitored at Station 23RD101 (0.1 miles downstream of the CR 58 crossing) on August 15, 2024. The location of the station is shown in Figure 7. The station was designated as Modified Use within the Low Gradient Prairie Streams M-IBI Class (Class 7). Accordingly, the impairment threshold for the station is an M-IBI score of 22, with a confidence limit of ± 14 . Monitoring of the station yielded M-IBI score of 21, which is slightly below the impairment threshold. According to the MPCA biological monitoring staff, “30 taxa were observed, of which 87% belonged to tolerant groups and just 3 POET (Plecoptera, Odonata, Ephemeroptera, and Trichoptera) taxa were present. The community appears poor and indicates degraded water quality.”

Candidate Causes

Flow regime instability

Available data

The DNR (2026) classified the flow regime of Judicial Ditch 60 as intermittent. In 1999, the RLWD completed construction of the Parnell Impoundment (Project 81) upstream of the reach. The impoundment is designed to reduce downstream flooding by retaining up to 4,000 acre-feet of runoff, thereby decreasing peak flows on Judicial Ditch 60 up to 82% (30-hour, 5-year event). The RLWD conducted flow monitoring at Site S007-062 (250th St SW crossing) from 2012 to 2013. Figure 8 depicts the daily discharge measurements for the site. Overall, the highest flow logged at the site was 168 cfs, while the lowest flow was 0 cfs. No flow conditions were common at the site and comprised 72% of all values. Additionally, the RLWD calculated flow values for water quality monitoring visits to Site S007-062 between 2023 and 2024; this work was performed as part of a Surface Water Assessment Grant (SWAG). During this period, 22 monitoring visits were attempted at the site, and the highest flow was 27 cfs, while the lowest flow was 0 cfs. No flow conditions represented 50% of the values. StreamStats (USGS, 2026) estimated that the normal range of flow values at the downstream end of the reach to be less than 0.1 cfs (Q75; value exceeded 75% of the time) to 0.65 cfs (Q25; value exceeded 25% of the time). The estimated 1.5-year peak flood flow was 177 cfs, while the 7 day, 10-year low flow value for the reach was less than 0.01 cfs. The MPCA biological monitoring staff observed a dry streambed upstream of Station 23RD101 during an August 1, 2023, visit. Also, MPCA biological monitoring staff observed water permanence issues that could be impacting aquatic life during an August 14, 2024, visit to Station 23RD101. Lastly, MPCA SID staff conducted eight separate field visits to the reach between April and October of 2025; flow was estimated during each visit. Flow amounts estimated by staff ranged from no flow (October 8, 2025; Figure 9), to 20 cfs (April 28, 2025). Overall, the available data suggests the reach is prone to frequent and extended periods of no flow.

Figure 8. Daily discharge data (2012-2013) for Site S007-062 (250th St SW crossing) along Judicial Ditch 60 (09020303-570).

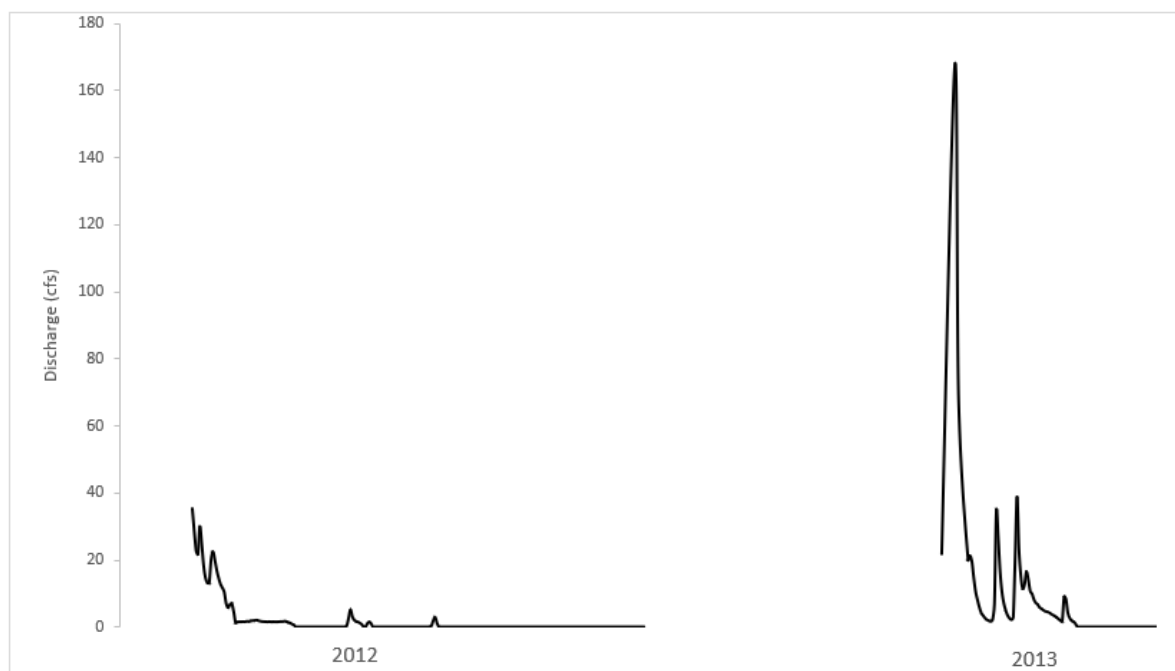


Figure 9. Image of no flow at the downstream end of the CSAH 18 crossing along Judicial Ditch 60 (AUID 09020303-570) on October 8, 2025.



Biological response: Macroinvertebrate

Flow regime instability has been shown to limit the diversity and taxa richness of macroinvertebrates and favor tolerant taxa that can adapt to disturbances. Several authors have documented an inverse relationship between flow regime instability and the abundance of taxa belonging to the orders of Ephemeroptera, Plecoptera, and Trichoptera (Bunn and Arthington, 2002; Bragg et al., 2005; Dewson et al., 2007). Table 10 shows the flow regime instability-related metric scores for the macroinvertebrate community of this reach of Judicial Ditch 60. While Station 23RD101 met the statewide mean for the abundance of EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa and tolerant taxa, it failed to meet the respective mean for three other metrics. The multiple lines of evidence ***strongly support*** the case for flow regime instability as a stressor to the macroinvertebrate community of this reach of Judicial Ditch 60.

Table 10. Summary of flow regime instability-related biological metric data for Station 23RD101 along Judicial Ditch 60 (AUID 09020303-570), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
EPTPct	Relative abundance (%) of Ephemeroptera, Plecoptera, and Trichoptera (decrease)	15 $\pm$ 13	23RD101 ²⁴ (21)
LongLivedPct	Relative abundance (%) of long-lived individuals (decrease)	4 $\pm$ 6	23RD101 ²⁴ (1)
TaxaCountAllChir	Total taxa richness of macroinvertebrates (decrease)	34 $\pm$ 5	23RD101 ²⁴ (31)
Tolerant2ChTxPct	Relative abundance (%) of taxa with tolerance values equal to or greater than six (increase)	90 $\pm$ 6	23RD101 ²⁴ (87)
TrichwoHydroPct	Relative abundance (%) of non-hydrosychid Trichoptera individuals (decrease)	2 $\pm$ 3	23RD101 ²⁴ (1)

¹ Target score included stations statewide that provided Modified Use habitat within the Low Gradient Prairie Streams M-IBI Class (Class 7) and met or exceeded the IBI threshold (22).

²⁴ Sampled on August 15, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Inadequate physical habitat

Available data

The physical habitat of this reach Judicial Ditch 60 was evaluated during two biological monitoring visits to Station 23RD101 using the MSHA. The station yielded MSHA score ranging from 28 (“poor”) on August 15, 2024, to 38 (“poor”) on June 15, 2023. The presence of row crop within the immediate vicinity of the station limited its land use subcategory scores. The riparian subcategory scores were positively influenced by a “moderate” riparian zone width; however, “severe” bank erosion was also noted. The substrate score was limited by low substrate diversity, with only clay, silt, and detritus documented along the stream bed. A small amount of gravel was observed, but this substrate was embedded and therefore provided limited functional habitat value. No natural riffle habitat was observed, which further reduced the overall habitat score. The cover subcategory scores for the station were positively affected by a “moderate” to “extensive” amount of cover. Identified cover types included undercut banks, overhanging vegetation, deep pools, and macrophytes (emergent, submergent, and floating leaf). Lastly, the station scored very low in the morphology subcategory due in part to “low” channel stability and “poor” channel development and sinuosity. The channel morphology score was limited by channel modifications including leveeing, dredging, and bank shaping. The MPCA biological monitoring staff also noted the presence of riprap to armor the ditch bank. Overall, the available data suggest the reach has inadequate physical habitat to support a healthy macroinvertebrate community.

Biological response: Macroinvertebrate

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

(Gore et al., 2001). Table 11 shows the inadequate physical habitat-related metric scores for the macroinvertebrate community of this reach of Judicial Ditch 60. Station 23RD101 had a low abundance of clinger individuals, which suggests that hard-aerated surfaces may be somewhat limited. Additionally, the station had a high abundance of sprawler taxa, indicating the presence of degraded habitat facets. The multiple lines of evidence **somewhat support** the case for inadequate physical habitat as a stressor to the macroinvertebrate community in this reach of Judicial Ditch 60.

Table 11. Summary of inadequate physical habitat-related biological metric data for Station 23RD101 along Judicial Ditch 60 (AUID 09020303-570), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
BurrowerPct	Relative abundance (%) of burrower individuals (increase)	16 $\pm$ 12	23RD101 ²⁴ (5)
ClingerPct	Relative abundance (%) of clinger individuals (decrease)	20 $\pm$ 13	23RD101 ²⁴ (14)
LeglessPct	Relative abundance (%) of legless individuals (increase)	62 $\pm$ 20	23RD101 ²⁴ (42)
SprawlerPct	Relative abundance (%) of sprawler individuals (increase)	29 $\pm$ 16	23RD101 ²⁴ (42)

¹ Target score included stations statewide that provided Modified Use habitat within the Low Gradient Prairie Streams M-IBI Class (Class 7) and met or exceeded the IBI threshold (22).

²⁴ Sampled on August 15, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

High suspended sediment

Available data

According to Table 12, a combined 33 discrete TSS samples were collected at Sites S007-062 (250th St SW crossing), S017-178 (near CSAH 11 crossing) and S017-320 (CSAH 11 crossing) along this reach of Judicial Ditch 60. Collectively, the TSS concentrations for the sites ranged from less than 1 mg/L (multiple visits) to 10 mg/L (July 10, 2012), with a mean of 3 mg/L. None of the values exceeded the 65 mg/L TSS standard for the Southern TSS Region. Additionally, the MPCA biological monitoring staff encountered areas of bank erosion (Figure 10) at Station 23RD101 during an August 1, 2023, drone reconnaissance flight. Furthermore, the MPCA SID staff completed longitudinal reconnaissance along this reach of Judicial Ditch 60 on October 8, 2025, and documented severe bank erosion (Figure 10) near Site S017-320. This erosion, as well as the bank instability issues found downstream of CSAH 11, which are described by HDR Engineering Inc. in an August 25, 2025, memo, likely stem from past peak flows, particularly prior to the construction of the Parnell Impoundment (Project 81). Despite the presence of bank erosion, the available data suggest the reach likely experiences infrequent periods of high TSS.

Table 12. Discrete TSS data for Sites S007-062 (250th St SW crossing), S017-178 (near CSAH 11 crossing) and S017-320 (CSAH 11 crossing) along Judicial Ditch 60 (AUID 09020303-570).

Site	Date range	<i>n</i>	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Standard (65 mg/L) exceedances	% Standard (65 mg/L) exceedances
S007-062	2012-2024	25	<1	10	3	0	0
S017-178	2023	1	2	2	2	0	0
S017-320	2024-2025	7	1	7	3	0	0

Figure 10. Images of bank erosion along Judicial Ditch 60 (AUID 09020303-570), including Station 23RD101 on June 13, 2012 (left) and near Site S017-320 on October 8, 2025 (right).



Biological response: Macroinvertebrate

High suspended sediment can adversely affect macroinvertebrates in various ways depending on the concentration and duration of exposure. Excessive suspended sediment often results in a limited macroinvertebrate community that is dominated by tolerant taxa (Henley et al., 2000; EPA, 2012; Jones et al., 2012). Sediment suspended in the water column can limit collector species and species that filter using a net-spinning casing. Table 13 shows the high TSS-related metric scores for the macroinvertebrate community of this reach of Judicial Ditch 60. Station 23RD101 met the statewide mean for the TSS tolerance indicator value and the abundance of TSS tolerant taxa. The score for the abundance of intolerant taxa was near the statewide mean. The multiple lines of evidence **refute** the case for high TSS as a stressor to the macroinvertebrate community of this reach of Judicial Ditch 60.

Table 13. Summary of high TSS-related biological metric data for Station 23RD101 along Judicial Ditch 60 (AUID 09020303-570), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
TSS TIV	Mean TSS (mg/L) tolerance indicator value (increase)	17 $\pm$ 2	23RD101 ²⁴ (15)
ToITSS	Relative abundance (%) of high TSS tolerant taxa (increase)	35 $\pm$ 20	23RD101 ²⁴ (26)
InToITSS	Relative abundance (%) of high TSS intolerant taxa (decrease)	1 $\pm$ 4	23RD101 ²⁴ (0)

¹ Target score included stations statewide that provided Modified Use habitat within the Low Gradient Prairie Streams M-IBI Class (Class 7) and met or exceeded the IBI threshold (22).

²⁴ Sampled on August 15, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Low dissolved oxygen

Available data

According to Table 14, a combined 57 discrete DO measurements were collected at Sites S007-062 (250th St SW crossing), S017-178 (near CSAH 11 crossing) and S017-320 (CSAH 11 crossing) along this reach of Judicial Ditch 60. Collectively, the DO concentrations for the sites ranged from 1.5 mg/L (August 26, 2024) to 19.3 mg/L (June 13, 2012), with a mean of 8.2 mg/L. A total of 13 values failed to meet the 5.0 mg/L DO standard; however, only two of the measurements were collected prior to 9:00 a.m., when values are typically lowest. The MPCA conducted continuous DO monitoring at Site W63049001 from June 12, 2025, to June 24, 2025. The monitoring results are provided in Table 15, as well as displayed in Figure 11. During the continuous monitoring period, 76% of the total values and 100% of the daily minimum values failed to meet the standard. During the continuous monitoring period, stagnant conditions and a heavy amount of macrophytes and duckweed growth were noted and likely contributed to low DO levels. Additionally, the streambed consisted of loose, unconsolidated sediment, a condition often linked to higher microbial activity and increased oxygen consumption. Overall, the available data suggest the reach experiences frequent periods of low DO.

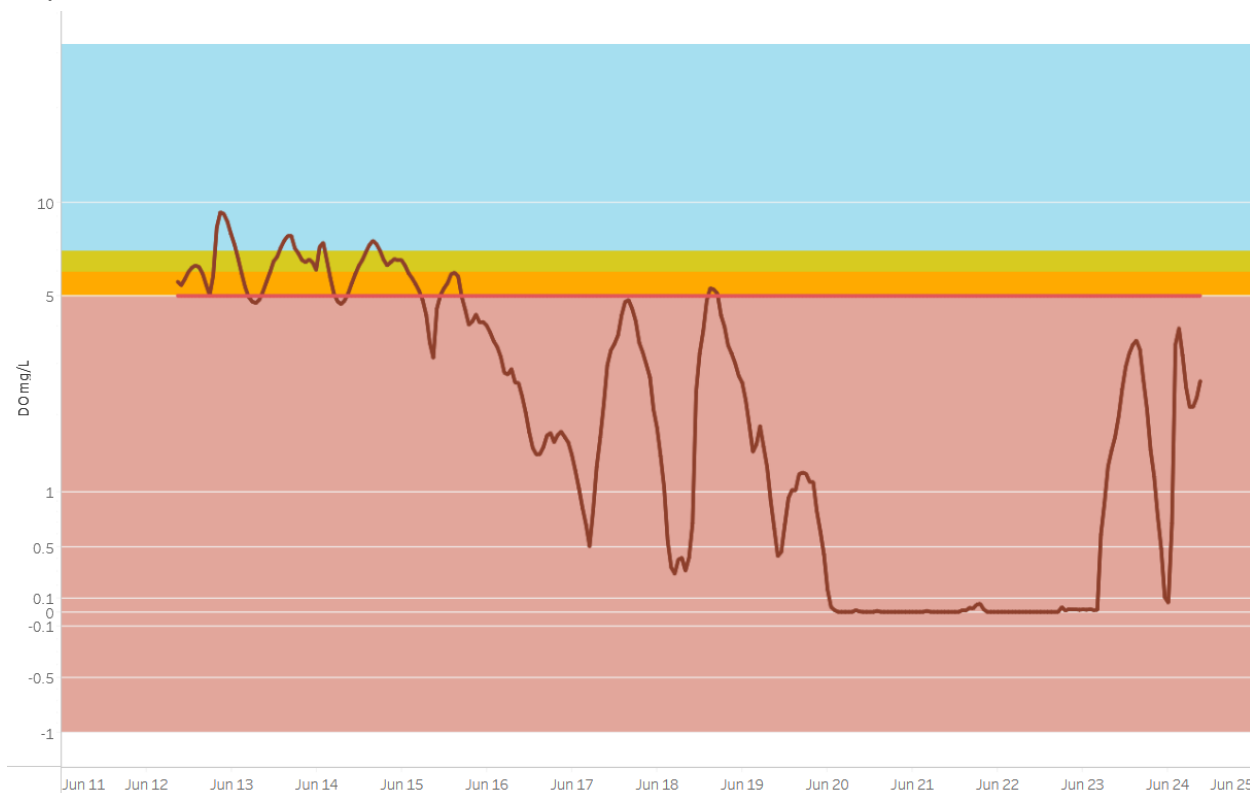
Table 14. Discrete DO data for Sites S007-062 (250th St SW crossing), S017-178 (near CSAH 11 crossing) and S017-320 (CSAH 11 crossing) along Judicial Ditch 60 (AUID 09020303-570).

Site	Date range	<i>n</i>	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Values below 5.0 mg/L standard	% Values below 5.0 mg/L standard
S007-062	2012-2024	54	1.5	19.3	8.4	12	22
S017-178	2023-2024	2	5.0	8.5	6.8	0	0
S017-320	2025	1	3.0	3.0	3.0	1	100

Table 15. Continuous DO data for Site W63049001 along the Judicial Ditch 60 (AUID 09020303-570).

Site	Start date - End date	<i>n</i>	Min. (mg/L)	Max. (mg/L)	% Total values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
W63049001	6/12/2025 - 6/24/2025	1153	0.0	9.5	76	100	2.7

Figure 11. Continuous DO data (July 12-24, 2025) for Site W63049001 along Judicial Ditch 60 (AUID 09020303-570).



Eutrophication-related data for the reach include the following parameters: TP, chl-*a*, and DO flux. A total of 31 discrete TP samples were collected at Sites S007-062 (250th St SW crossing), S017-178 (CSAH 11 crossing) and S017-320 (CSAH 11 crossing). Nineteen (61%) of the values exceeded the 150 µg/L Southern River Nutrient Region TP standard. Collectively, the highest TP concentration was 517 µg/L. A total of five discrete chl-*a* samples were collected at Site S017-320. None of the values exceeded the 40 µg/L Southern River Nutrient Region chl-*a* standard. Lastly, the mean daily DO flux measured during continuous monitoring was 2.7 mg/L at Site W63049001, which was well below the 5.0 mg/L DO flux standard. In addition, the MPCA biological monitoring staff documented excessive primary production at Station 23RD101 during an August 1, 2023, monitoring visit. The MPCA SID staff noted abundant rooted and floating macrophytes, along with some isolated patches of filamentous algae, at Site S017-320 during most of the 2025 sampling year. Towards the end of August 2025, primary production growth was widespread, covering much of the stream channel. Despite elevated TP concentrations, response variable data indicate that eutrophication is not the primary driver of low DO, and that lack of sustained baseflow is more likely the cause.

Biological response: Macroinvertebrate

Frequent or extended periods of low DO can alter a macroinvertebrate community by limiting the abundance of taxa that are intolerant of such conditions (Davis, 1975, EPA, 2012). Table 16 provides the low DO-related metric scores for the macroinvertebrate community of this reach of Judicial Ditch 60. All scores failed to meet the statewide class mean for metrics related to low DO. The multiple lines of evidence **strongly support** the case for low DO as a stressor to the macroinvertebrate community of this reach of Judicial Ditch 60.

Table 16. Summary of low DO-related biological metric data for Station 23RD101 along Judicial Ditch 60 (AUID 09020303-570), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
DO TIV	Mean DO (mg/L) tolerance indicator value (decrease)	6 $\pm$ 1	23RD101 ²⁴ (5)
TolDO	Relative abundance (%) of low DO tolerant taxa (increase)	39 $\pm$ 22	23RD101 ²⁴ (56)
InTolDO	Relative abundance (%) of low DO intolerant taxa (decrease)	1 $\pm$ 2	23RD101 ²⁴ (0)

¹ Target score included stations statewide that provided Modified Use habitat within the Low Gradient Prairie Streams M-IBI Class (Class 7) and met or exceeded the IBI threshold (22).

²⁴ Sampled on August 15, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

High nitrate-nitrogen

Available data

According to Table 17, a combined 20 discrete nitrate-nitrogen (NO₃+NO₂-N) samples were collected at Sites S007-062 (250th St SW crossing), S017-178 (near CSAH 11 crossing) and S017-320 (CSAH 11 crossing) along the reach. Collectively, the nitrate-nitrogen concentrations for the sites ranged from less than 0.1 mg/L to 0.3 mg/L, with a mean of less than 0.1 mg/L. While Minnesota does not currently have an aquatic life use standard for nitrate, there is a chronic criteria value for nitrate of 8.0 mg/L (MPCA, 2022). None of the samples exceeded this criteria value. Overall, the available data suggest the reach does not experience periods of high nitrate-nitrogen.

Table 17. Discrete nitrate-nitrogen data for Sites S007-062 (250th St SW crossing), S017-178 (near CSAH 11 crossing) and S017-320 (CSAH 11 crossing) along Judicial Ditch 60 (AUID 09020303-570).

Site	Date range	n	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Criteria (8.0 mg/L) exceedances	% Criteria (8.0 mg/L) exceedances
S007-062	2012-2013	14	<0.1	0.3	<0.1	0	0
S017-178	2023	1	<0.1	<0.1	<0.1	0	0
S017-320	2025	5	<0.1	0.1	<0.1	0	0

Biological response: Macroinvertebrate

Nitrogen toxicity can affect the macroinvertebrate community depending on the concentration, length of exposure, and sensitivity of the individual organism (Camargo and Alonso, 2006). Table 18 shows the N-related metric scores for the macroinvertebrate community of this reach of Judicial Ditch 60. Two of the three metric scores met their respective statewide mean. There was a lack of nitrogen intolerant taxa; however, the score was within one standard deviation of the mean. The multiple lines of evidence **refute** the case for high nitrate-nitrogen as a stressor to the macroinvertebrate community of this reach of Judicial Ditch 60.

Table 18. Summary of high nitrate nitrogen-related macroinvertebrate metric data for Station 23RD101 along Judicial Ditch 60 (AUID 09020303-570), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
N TIV	Mean N (mg/L) tolerance indicator value (increase)	4 $\pm$ 1	23RD101 ²⁴ (3)
ToIN	Relative abundance (%) of high N tolerant taxa (increase)	63 $\pm$ 20	23RD101 ²⁴ (30)
InToIN	Relative abundance (%) of high N intolerant taxa (decrease)	1 $\pm$ 5	23RD101 ²⁴ (0)

¹ Target score included stations statewide that provided Modified Use habitat within the Low Gradient Prairie Streams M-IBI Class (Class 7) and met or exceeded the IBI threshold (22).

²⁴ Sampled on August 15, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Summary of Stressors

The evidence suggests that the macroinvertebrate bioassessment impairment associated with Judicial Ditch 60 (AUID 09020303-570) is primarily attributed to flow regime instability, low DO, and to a lesser extent, inadequate physical habitat. The ditch system is prone to extended periods of minimal to no flow, particularly in the later summer months, which is likely the main contributing factor to low DO concentrations. Additionally, past high peak flows have resulted in channel stability issues, particularly along the lower segment of the reach near the CSAH 11 crossing. Lastly, the constructed channel of the ditch lacks many of the habitat facets (e.g., riffles and clean, coarse substrate) necessary to support a healthy macroinvertebrate community.

Grand Marais Creek Watershed

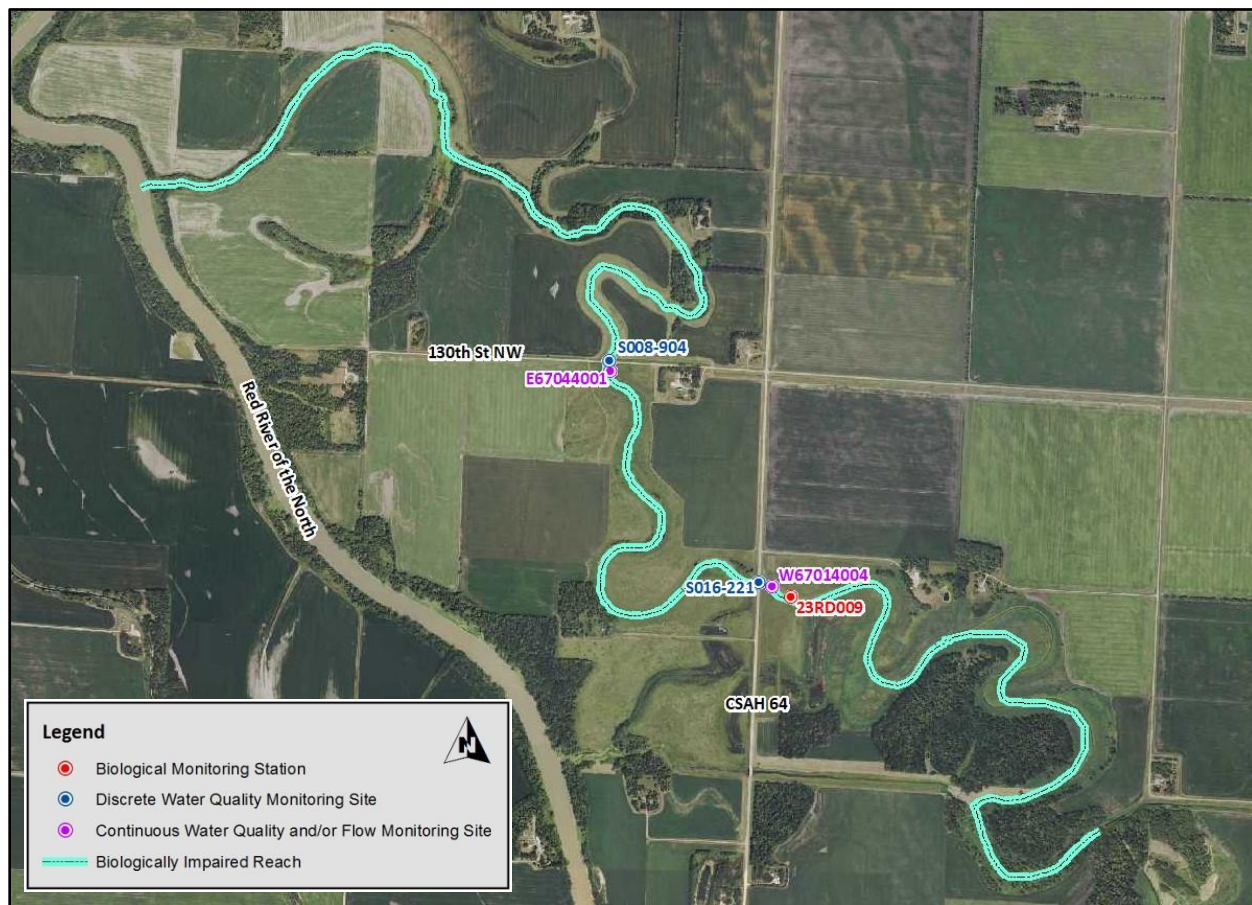
Grand Marais Creek (AUID 09020306-530)

Physical Setting

This reach represents the 5.7-mile segment of Grand Marais Creek from its confluence with Polk County Ditch 2, to its confluence with the Red River of the North (Figure 12). In 2015, the RLWD completed a major restoration project along this reach in which the creek was reconnected to its original channel. The reach has a subwatershed area of 305 square miles (195,374 acres). According to the DNR (2026),

the subwatershed contains 292 miles of intermittent drainage ditch, 65 miles of intermittent stream, and 38 miles of perennial stream, including Grand Marais Creek. Approximately 80% of the watercourses in the subwatershed of the reach have been physically altered (i.e., channelized or ditched). Based on the NLCD 2019 (USGS, 2019) cultivated crops (92%) was the predominant land cover in the subwatershed. Other notable land cover groups in the subwatershed included developed (4%), wetland (2%), and hay/pasture (1%).

Figure 12. Map of Grand Marais Creek (AUID 09020306-530) and associated biological monitoring station and water quality monitoring sites (2023 NAIP aerial image). The flow direction is from the southeast to northwest.



Biological Impairments

Fish (F-IBI)

The fish community of this segment of Grand Marais Creek was monitored at Station 23RD009 (0.1 miles upstream of the CSAH 64 crossing) on August 20, 2024. The location of the station is shown in Figure 12. The station was designated as General Use within the Southern Streams Fish Index of Biological Integrity (F-IBI) Class (Class 2). Accordingly, the impairment threshold for the station is an F-IBI score of 50, with a confidence limit of ± 9 . Monitoring of the station yielded a F-IBI score of 31, which was well below the impairment threshold. According to the MPCA biological monitoring staff: “Although eight species were identified, relatively few individuals were identified, and the sample community was largely dominated by tolerant taxa such as brook stickleback, common carp, black bullhead, and fathead minnow”.

Macroinvertebrate (M-IBI)

The macroinvertebrate community of the reach was monitored at Station 23RD009 on August 14, 2024. The station was designated as General Use within the Prairie Streams Glide/Pool M-IBI Class (Class 7). The impairment threshold for the station is an M-IBI score of 41, with a confidence limit of ± 14 . Monitoring of the station produced an M-IBI score of 24, which was below the impairment threshold. According to the MPCA biological monitoring staff: "The sample was dominated by very tolerant taxa such as black fly larva, scuds, and water boatmen. A few tolerant mayflies were present".

Candidate Causes

Loss of longitudinal connectivity

Available data

No connectivity-related issues were identified by the MPCA biological monitoring staff during the monitoring of Station 23RD009, which is located along the upstream extent of this reach of Grand Marais Creek. As part of the recent restoration project for this reach, a series of large rock weir structures and associated riprap were installed within the channel at its outlet to the Red River of the North. The rock weir structures and riprap control grade and stabilize the channel but also limit connectivity. According to a September 16, 2015, *Restoration Evaluation Program for Legacy Projects - Project Evaluation Form* that was completed by DNR and Minnesota Board of Water and Soil Resources (BWSR) staff after the conclusion of the project, "fish passage into the newly created/restored channel will likely occur during high waters in the spring and early summer before water levels recede below the high stream gradient of the rock channel at the confluence with the Red River". On September 16, 2025, the DNR (2026) completed a fluvial geomorphic assessment of the creek's outlet to the Red River of the North. As part of this assessment, staff also evaluated the impact of the rock weir structures and associated riprap at the outlet on connectivity. The placement of riprap within the channel was found to be above its grade which "results in water flowing below it, creating difficult conditions for aquatic life to move upstream or downstream during baseflow conditions". Based upon recent flow data that was collected upstream, the DNR estimated that water is "likely flowing under the riprap 50% of the measured days". When the stage of the creek is higher than the weir structures and riprap, connectivity is unimpeded. In addition to the weir structures and riprap, the DNR observed a beaver dam along the lower end of the creek during their geomorphic assessment. On October 15, 2025, the MPCA SID staff completed a connectivity assessment along the reach to its confluence with the Red River of the North with the use of a drone. No additional barriers to connectivity were found during the assessment. Lastly, the MPCA SID staff performed a detailed review of a March 29, 2025, aerial photo (courtesy of Google Earth) of the reach. No additional barriers were identified during this assessment. In summary, the rock weir structures and associated riprap at the outlet, as well as beaver dams (when present), interfere or have the potential to interfere with the longitudinal connectivity of the reach.

Figure 13. Images of riprap within the channel of Grand Marais Creek (AUID 09020306-530) near its outlet to the Red River of the North on September 16, 2025; images courtesy of the DNR.



Biological response: Fish

Migratory and late maturing fish species require well-connected environments to access the habitats and resources necessary to complete their life history (Saunders, 2007). Barriers to connectivity (e.g., dams) can limit the availability of critical habitats and resources, thereby reducing the abundance of these species, along with overall species diversity (Poole, 2002; Cross et al., 2013; Gardner et al., 2013; Aadland, 2015). Table 18 shows the loss of longitudinal connectivity-related metric scores for the fish community of this reach of Grand Marais Creek. Station 23RD009 scored well below the statewide mean in migratory and late maturing taxa. While connectivity-related issues likely contributed to these metric scores, the station would likely have yielded a far more robust fish community had it been sampled during the spring or during a period of higher stage. In May 2019, DNR Fisheries staff surveyed the lower end of the creek using trap nets during a period of higher stage and noted 15 fish species, including northern pike and channel catfish. According to M. Skoog, DNR Area Fisheries Supervisor (personal communication, 2026), the survey data suggest that large river species are successfully utilizing the restored channel of the creek during spring flows. The multiple lines of evidence strongly support the case for loss of longitudinal connectivity as a stressor to the fish community of this reach of Grand Marais Creek.

Table 18. Summary of loss of longitudinal connectivity-related fish metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy fish community.

Metric	Description (expected response to stressor)	Target score ¹ mean ± SD	Station (score)
MA>3-ToITxPct	Relative abundance (%) of taxa with a female mature age of ≥ 3 years, excluding tolerant taxa (decrease)	21 ± 11	23RD009 ²⁴ (0)
MgrTxPct	Relative abundance (%) of taxa that are migratory (decrease)	24 ± 8	23RD009 ²⁴ (13)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams F-IBI Class (Class 2) and met or exceeded the F-IBI threshold (50).

²⁴ Sampled on August 20, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Biological response: Macroinvertebrate

Macroinvertebrates are not readily affected by longitudinal connectivity barriers, as populations can re-establish in a segmented stream channel to reflect stable community composition upstream and downstream of a barrier. Therefore, loss of longitudinal connectivity is **not applicable** as a stressor to the macroinvertebrate community of this reach of Grand Marais Creek.

Flow Regime Instability

Available data

There are no flow monitoring data for this reach of Grand Marais Creek. According to C. Hanson, RLWD (personal communication, 2026), the lower portion of the creek is not monitored for flow due to backwater from the Red River of the North during high flows. However, the RLWD has monitored flow at Site S008-902 (110th St NW crossing; next crossing upstream of the reach) along Grand Marais Creek, as well as at Site S004-131 (CR 62 crossing) along Polk County Ditch 2, which discharges to the creek between the reach and Site S008-902. Together, these sites account for the flow along the downstream portion of the creek. The annual hydrographs for the sites are shown in Figure 14 and Figure 15. The highest flow logged at Site S008-902 was 1,634.2 cfs, while the lowest flow was 0 cfs; 40% of flow values were less than or equal to 1.0 cfs. The highest flow at Site S004-131 was 1,451.6 cfs, while the lowest flow was 0 cfs; the 40th percentile flow value was 0 cfs. StreamStats (USGS, 2026) estimated that the normal range of flow values at the upstream end of the reach to be 0.2 cfs (Q75; value exceeded 75% of the time) to 9.2 cfs (Q25; value exceeded 25% of the time). Also, the estimated 1.5-year peak flood flow was 683 cfs, while the 7 day, 10-year low flow value for the reach was less than 0.01 cfs. In August 2024, the MPCA biological monitoring staff encountered sufficient flow at Station 23RD009 to collect an assessable fish and macroinvertebrate sample. However, staff were unable to collect an assessable sample at the station during a June 20, 2023, fish monitoring visit, and a July 31, 2023, macroinvertebrate monitoring visit due to minimal to no flow. Furthermore, during the June 20, 2023, monitoring visit, staff documented a large accumulation of vegetative debris on the upstream side of the CSAH 64 crossing (Figure 16) that was deposited during a prior high flow event; the debris extended from the base of the channel to near the top of the crossing, which suggests that the high flow event exceeded the capacity of the box culverts. According to C. Hanson, RLWD (personal communication, 2026), “Drainage improvement projects, like RLWD Ditch 15, Ditch 16, and Ditch 17, are increasing the

capacity of drainage ditches and increasing runoff rates”. Additionally, the MPCA SID staff conducted eight separate field visits to the reach between April and October of 2025; flow was estimated during each visit. Flow amounts estimated by staff ranged from 0 cfs flow (October 15, 2025; Figure 16), to 20-30 cfs (May 27, 2025). Overall, the available data suggest the reach is prone to occasional extreme peak flows, as well as frequent periods of very minimal to no flow.

Figure 14. Annual hydrographs (2017-2024) for Site S008-902 (110th St NW crossing) along Grand Marais Creek (AUID 09020306-507).

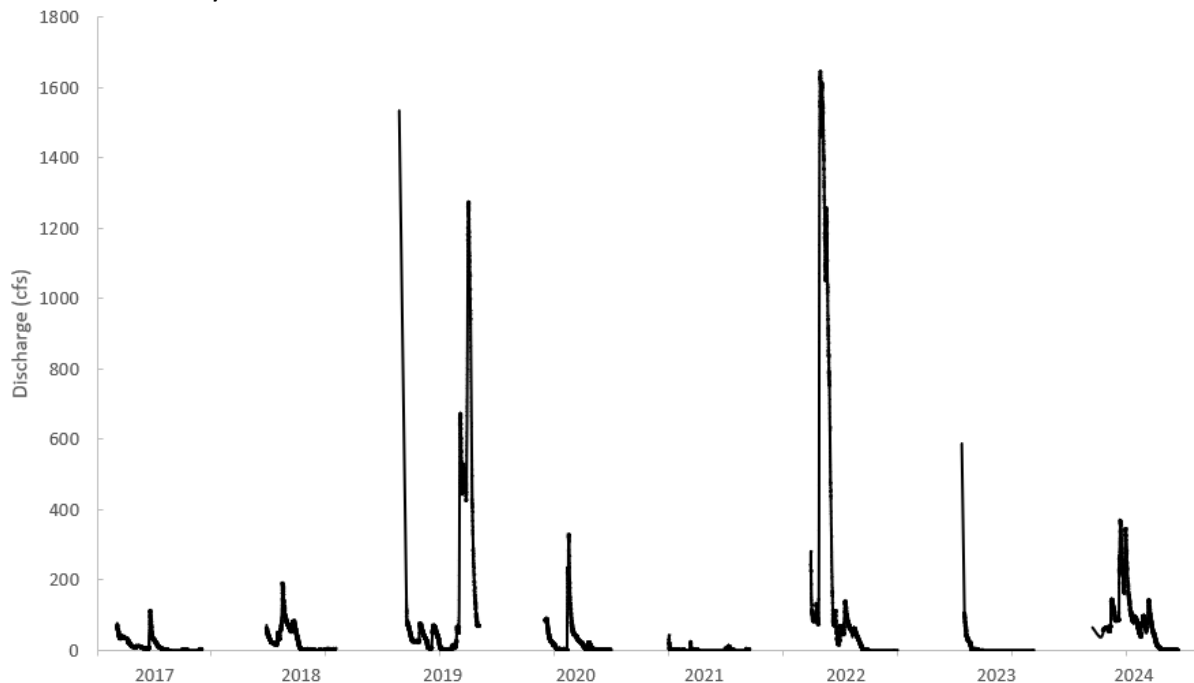


Figure 15. Annual hydrographs (available years 2006-2024) for Site S004-131 (CR 62 crossing) along Polk County Ditch 2 (AUID 09020306-515).

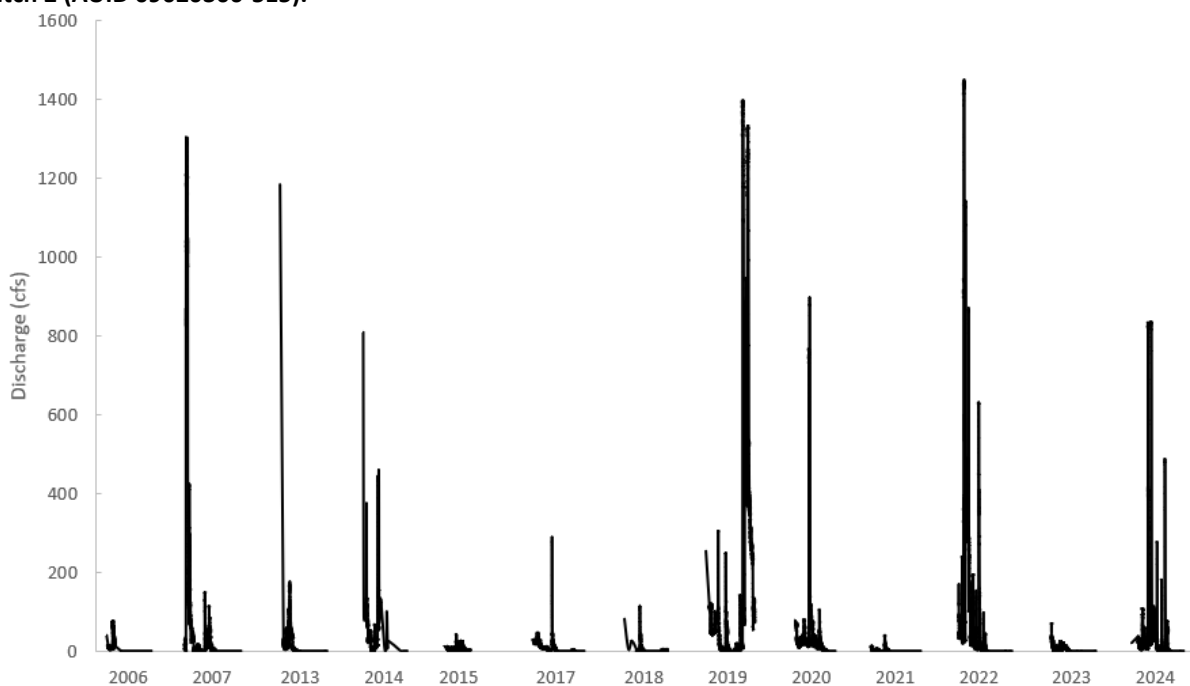


Figure 16. Flow-related images for Grand Marais Creek (AUID 09020306-530), including low flow conditions and vegetative debris deposited during a prior high flow event at Station 23RD009 (CSAH 64 crossing) on June 20, 2023 (left), and a dry streambed at the outlet to the Red River of the North on October 15, 2025 (right).



Biological response: Fish

Flow regime instability tends to limit fish species diversity and favor taxa that are generalists, early maturing, pioneering, short-lived, and tolerant to disturbances (Aadland et al., 2005; Poff and Zimmerman, 2010). Table 19 shows the flow regime instability-related metric scores for the fish community of this reach of Grand Marais Creek. Station 23RD009 yielded a high abundance of the two most abundant taxa, generalist individuals, early maturing taxa, and short-lived individuals, as well as no non-tolerant individuals. Additionally, three of the scores were outside one standard deviation from the mean. The multiple lines of evidence **convincingly support** the case for flow regime instability as a stressor to the fish community of this reach of Grand Marais Creek.

Table 19. Summary of flow regime instability-related fish metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy fish community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
DomTwoPct	Relative abundance (%) of the two most abundant taxa (increase)	47 $\pm$ 13	23RD009 ²⁴ (48)
GeneralTxPct	Relative abundance (%) of individuals that are generalists (increase)	33 $\pm$ 8	23RD009 ²⁴ (50)
MA<2TxPct	Relative abundance (%) of taxa with a female mature age $\leq$ 2 years (increase)	63 $\pm$ 10	23RD009 ²⁴ (75)

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
NumPerMeter-Tol	Number of individuals per meter of stream sampled, excluding tolerant species (decrease)	1.0 $\pm$ 0.9	23RD009 ²⁴ (0)
PioneerTxPct	Relative abundance (%) of taxa that are pioneers (increase)	19 $\pm$ 7	23RD009 ²⁴ (13)
SLvdPct	Relative abundance (%) of individuals that are short-lived (increase)	17 $\pm$ 13	23RD009 ²⁴ (26)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams F-IBI Class (Class 2) and met or exceeded the F-IBI threshold (50).

²⁴ Sampled on August 20, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Biological response: Macroinvertebrate

Flow regime instability has also been shown to limit the diversity and taxa richness of macroinvertebrates and favor tolerant taxa that can adapt to disturbances. Several authors have documented an inverse relationship between flow regime instability and the abundance of taxa belonging to the orders of Ephemeroptera, Plecoptera, and Trichoptera (Bunn and Arthington, 2002; Bragg et al., 2005; Dewson et al., 2007). Table 20 shows the flow regime instability-related metric scores for the macroinvertebrate community of this reach of Grand Marais Creek. All the metric scores for Station 23RD009 failed to meet their respective statewide mean. In addition, three of the scores were outside one standard deviation from the mean. The multiple lines of evidence **convincingly support** the case for flow regime instability as a stressor to the macroinvertebrate community of this reach of Grand Marais Creek.

Table 20. Summary of flow regime instability-related macroinvertebrate metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
EPTPct	Relative abundance (%) of Ephemeroptera, Plecoptera, and Trichoptera (decrease)	40 $\pm$ 20	23RD009 ²⁴ (4)
LongLivedPct	Relative abundance (%) of long-lived individuals (decrease)	8 $\pm$ 8	23RD009 ²⁴ (0)
TaxaCountAllChir	Total taxa richness of macroinvertebrates (decrease)	38 $\pm$ 7	23RD009 ²⁴ (19)
Tolerant2ChTxPct	Relative abundance (%) of taxa with tolerance values equal to or greater than six (increase)	81 $\pm$ 8	23RD009 ²⁴ (100)
TrichwoHydroPct	Relative abundance (%) of non-hydrosychid Trichoptera individuals (decrease)	5 $\pm$ 6	23RD009 ²⁴ (1)

¹ Target score included stations statewide that provided General Use habitat within the Prairie Streams Glide/Pool M-IBI Class (Class 7) and met or exceeded the M-IBI threshold (41).

²⁴ Sampled on August 14, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Inadequate physical habitat

Available data

The physical habitat of this segment of Grand Marias Creek was evaluated during both biological monitoring visits to Station 23RD009 using the MSHA. The station yielded “poor” MSHA results, with scores of 36 and 37. The predominance of agricultural row crops in the immediate vicinity of the station adversely affected its land use subcategory scores. The riparian zone subcategory scores were positively influenced by a mostly “extensive” riparian zone width and “little” to no bank erosion. The station scored very poorly in the substrate subcategory, offering no riffle habitat and only clay substrate. While the station had an “extensive” amount of cover, the types of cover were limited to deep pools, macrophytes (emergent, floating leaf, and submergent), and overhanging vegetation. Lastly, the station scored very poorly in the channel morphology subcategory due to several factors, including limited velocity types, as well as “poor” channel development.

On September 16, 2025, DNR Clean Water staff completed a fluvial geomorphic assessment of the creek’s outlet to the Red River of the North. Below is an excerpt from the assessment summary for the site:

“The cross-sectional area of the constructed channel was 82.9 square feet, and the width was 21.4 feet. The width-to-depth ratio was 5.53. The full flood-prone width was approximately 75 feet, creating a 3.5 entrenchment ratio (flood-prone to bankfull width). The Rosgen stream type at this location was an E (slightly entrenched, very low width-to-depth ratio, high sinuosity). The lower three cross-sections were in heavy riprap bed protection and were typed as B (moderately entrenched, moderate width/depth ratio, moderate sinuosity) stream types.”

Overall, the available data suggest the reach has inadequate physical habitat to support a healthy biotic community.

Biological response: Fish

Insectivorous (e.g., darters and sculpins), riffle dwelling, and simple lithophilic spawning fish species require quality benthic habitat (e.g., clean, coarse substrate and riffles) for feeding and/or reproduction purposes, while detritivorous species utilize decomposing organic matter (i.e., detritus) as a food resource and, therefore, are less dependent upon the quality of instream habitat (Aadland and Kuitunen, 2006). Table 21 shows the inadequate physical habitat-related metric scores for the fish community of this reach of Grand Marais Creek. Station 23RD009 had a low abundance of riffle dwelling, simple lithophilic spawning, and insectivorous taxa/individuals, which suggest that critical habitat facets (e.g., coarse substrate and riffles) have been degraded or are naturally lacking. Additionally, the station had a very high abundance of detritivorous taxa that are adapted to survive in systems with limited habitat. The multiple lines of evidence ***convincingly support*** the case for inadequate physical habitat as a stressor to the fish community of this reach of Grand Marais Creek.

Table 21. Summary of inadequate physical habitat-related fish metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy fish community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
BenInsect-TolTxPct	Relative abundance (%) of taxa that are benthic insectivores, excluding tolerant species (decrease)	29 $\pm$ 10	23RD009 ²⁴ (0)
DetNWQTxPct	Relative abundance (%) of taxa that are detritivorous (increase)	20 $\pm$ 6	23RD009 ²⁴ (50)
Insect-TolPct	Relative abundance (%) of individuals that are insectivorous excluding tolerant species (decrease)	36 $\pm$ 18	23RD009 ²⁴ (33)
RiffleTxPct	Relative abundance (%) of taxa that predominately utilize riffle habitats (decrease)	26 $\pm$ 12	23RD009 ²⁴ (13)
SLithopTxPct	Relative abundance (%) of taxa that are simple lithophilic spawning species (decrease)	33 $\pm$ 12	23RD009 ²⁴ (13)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams F-IBI Class (Class 2) and met or exceeded the F-IBI threshold (50).

²⁴ Sampled on August 20, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Biological response: Macroinvertebrate

Clinger taxa require clean, coarse substrate, or other objects to attach themselves to or feed from, while burrower, legless, and sprawler macroinvertebrates are generally tolerant of degraded benthic habitat (Gore et al., 2001). Table 22 shows the inadequate physical habitat-related metric scores for the macroinvertebrate community of this reach of Grand Marais Creek. Station 23RD009 had a slightly low abundance of clinger and sprawler individuals, which suggests that hard-aerated surfaces may be somewhat limited. The multiple lines of evidence **somewhat support** the case for inadequate physical habitat as a stressor to the macroinvertebrate community of this reach of Grand Marais Creek.

Table 22. Summary of inadequate physical habitat-related macroinvertebrate metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
BurrowerPct	Relative abundance (%) of burrower individuals (increase)	8 $\pm$ 8	23RD009 ²⁴ (5)
ClingerPct	Relative abundance (%) of clinger individuals (decrease)	40 $\pm$ 18	23RD009 ²⁴ (38)
LeglessPct	Relative abundance (%) of legless individuals (increase)	39 $\pm$ 20	23RD009 ²⁴ (19)
SprawlerPct	Relative abundance (%) of sprawler individuals (increase)	21 $\pm$ 12	23RD009 ²⁴ (26)

¹ Target score included stations statewide that provided General Use habitat within the Prairie Streams Glide/Pool M-IBI Class (Class 7) and met or exceeded the M-IBI threshold (41).

²⁴ Sampled on August 14, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

High suspended sediment

Available data

According to Table 23, a combined 51 discrete TSS samples were collected at Sites S008-904 (130th St NW crossing) and S016-221 (CSAH 64 crossing) along this reach of Grand Marais Creek. Site S008-904 had two exceedances of the 65 mg/L TSS standard for the Southern TSS Region, with the highest concentration being 239 mg/L (July 20, 2016). This exceedance occurred following a large rain event, approximately one year after the completion of the restoration project; the vegetative cover along the streambanks was likely not fully reestablished. All the samples for Site S016-211 were well below the TSS standard. In addition, the MPCA biological monitoring staff encountered “little” to no bank erosion during the MSHA evaluations at Station 23RD009. Additionally, the MPCA SID staff noted good clarity during five out of the six water quality monitoring visits to Site S016-211 in 2025. Overall, the available data suggest the reach experiences infrequent periods of high TSS.

Table 23. Discrete TSS data for Sites S008-904 (130th St NW crossing) and S016-221 (CSAH 64 crossing) along Grand Marais Creek (AUID 09020306-530).

Site	Date range	n	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Standard (65 mg/L) exceedances	% Standard (65 mg/L) exceedances
S008-904	2016-2025	33	<1	239	19	2	6
S016-221	2019-2025	18	<1	16	5	0	0

Biological response: Fish

Excessive suspended sediment can affect a fish community in various ways depending on the concentration and duration of exposure. According to Waters (1995), high TSS can cause harm to fish through two major pathways: 1) direct, physical effects (e.g., abrasion of gills and avoidance behavior) and 2) indirect effects (e.g., loss of visibility and increase in sediment oxygen demand). Table 24 shows the high TSS-related metric scores for the fish community of this reach of Grand Marais Creek. Monitoring of Station 23RD009 yielded a TSS tolerance indicator value (TIV) barely above the statewide mean, while the probability of meeting the TSS standard was slightly below its respective mean. The multiple lines of evidence **neither support nor refute** the case for high TSS as a stressor to the fish community of this reach of Grand Marais Creek.

Table 24. Summary of high TSS-related fish metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy fish community.

Metric	Description (expected response to stressor)	Target score ¹ mean ± SD	Station (score)
TSS TIV	Mean TSS (mg/L) tolerance indicator value (TIV) (increase)	17 ± 5	23RD009 ²⁴ (18)
CondProb	Probability of meeting the TSS standard (decrease)	44 ± 17	23RD009 ²⁴ (38)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams F-IBI Class (Class 2) and met or exceeded the F-IBI threshold (50).

²⁴ Sampled on August 20, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Biological response: Macroinvertebrate

High TSS can adversely affect macroinvertebrates in various ways depending on the concentration and duration of exposure. Excessive suspended sediment often results in a limited macroinvertebrate community that is dominated by tolerant taxa (Henley et al., 2000; EPA, 2012; Jones et al., 2012). Table 25 shows the high TSS-related metric scores for the macroinvertebrate community of this reach of Grand Marais Creek. Station 23RD009 met the statewide mean for the TSS tolerance indicator value (TIV) and the abundance of high TSS tolerant taxa. The multiple lines of evidence *refute* the case for high TSS as a stressor to the macroinvertebrate community of this reach of Grand Marais Creek.

Table 25. Summary of high TSS-related macroinvertebrate metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean ± SD	Station (score)
TSS TIV	Mean TSS (mg/L) tolerance indicator value (increase)	18 ± 3	23RD009 ²⁴ (16)
TolTSS	Relative abundance (%) of high TSS tolerant taxa (increase)	44 ± 19	23RD009 ²⁴ (24)
InTolTSS	Relative abundance (%) of high TSS intolerant taxa (decrease)	3 ± 7	23RD009 ²⁴ (0)

¹ Target score included stations statewide that provided General Use habitat within the Prairie Streams Glide/Pool M-IBI Class (Class 7) and met or exceeded the M-IBI threshold (41).

²⁴ Sampled on August 14, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Low dissolved oxygen

Available data

This reach of the Grand Marais Creek will be listed as impaired for aquatic life use due to low DO levels on the 2026 Impaired Waters List. According to Table 26, a combined 68 discrete DO measurements were collected at Sites S008-904 (130th St NW crossing) and S016-221 (CSAH 64 crossing) along the reach. Collectively, the DO concentrations for the sites ranged from 0.1 mg/L to 14.2 mg/L, with both sites having a high proportion (>10%) of values below the 5.0 mg/L DO standard; however, only three of the measurements were collected prior to 9:00 a.m., when DO concentrations are typically lowest. The RLWD conducted continuous DO monitoring at Site E67044001 (130th St NW crossing) from August 10, 2018, to September 5, 2018 (Table 27), and from July 22, 2019, to August 21, 2019 (Table 27 and Figure 17). Both monitoring periods had similar minimum (3.0 and 3.4 mg/L) and maximum (15.0 and 17.0 mg/L) DO concentrations; however, the 2018 period had a substantially higher proportion of daily minimum values (60%) below the DO standard. Additionally, the MPCA conducted continuous DO monitoring at Site W67014004 (CSAH 64 crossing) from June 12, 2025, to June 24, 2025 (Table 27 and

Figure 18). During this continuous monitoring period, less than 1% of the total values and 9% of the daily minimum values failed to meet the DO standard. Wetland and lentic conditions along the 38-mile segment of the Grand Marais Creek upstream of the reach (Figure 19) are likely naturally limiting DO concentrations; the French word *marais* translated directly to marsh or wetland. These conditions are a direct result of the low gradient nature of the glacial Lake Agassiz plain, as well as the fact that much of the channel is oversized for its watershed because of being formed by the larger Red Lake River, which later abandoned the channel for a more direct path to the Red River of the North. Additionally, the rock weir structures and associated riprap that were installed within the channel of the creek near its outlet to the Red River of the North likely restrict or obstruct flow during periods of low stage, resulting in stagnant conditions along the lower end of the reach that adversely affect DO. Overall, the available data suggest the reach experiences frequent periods of low DO.

Table 26. Discrete DO data for Sites S008-904 (130th St NW crossing) and S016-221 (CSAH 64 crossing) along Grand Marais Creek (AUID 09020306-530).

Site	Date range	<i>n</i>	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Values below 5.0 mg/L standard	% Values below 5.0 mg/L standard
S008-904	2015-2025	46	0.1	12.8	8.2	6	13
S016-221	2019-2025	22	0.7	14.2	5.1	12	55

Table 27. Continuous DO data for Sites E67044001 (130th St NW crossing) and W67014004 (CSAH 64 crossing) along Grand Marais Creek (AUID 09020306-530).

Site	Start date - End date	<i>n</i>	Min. (mg/L)	Max. (mg/L)	% Values below standard	% Daily min. values below standard	Mean daily flux (mg/L)
E67044001	8/10/2018 - 9/5/2018	1064	3.0	15.0	13	60	6.9
E67044001	7/22/2019 - 8/21/2019	2484	3.4	17.0	5	21	6.1
W67014004	6/12/2025 - 6/24/2025	1154	3.8	22.0	<1	9	9.5

Figure 17. Continuous DO data (July 22-August 21, 2019) for Site E67044001 (130th St NW crossing) along Grand Marais Creek (AUID 09020306-530).

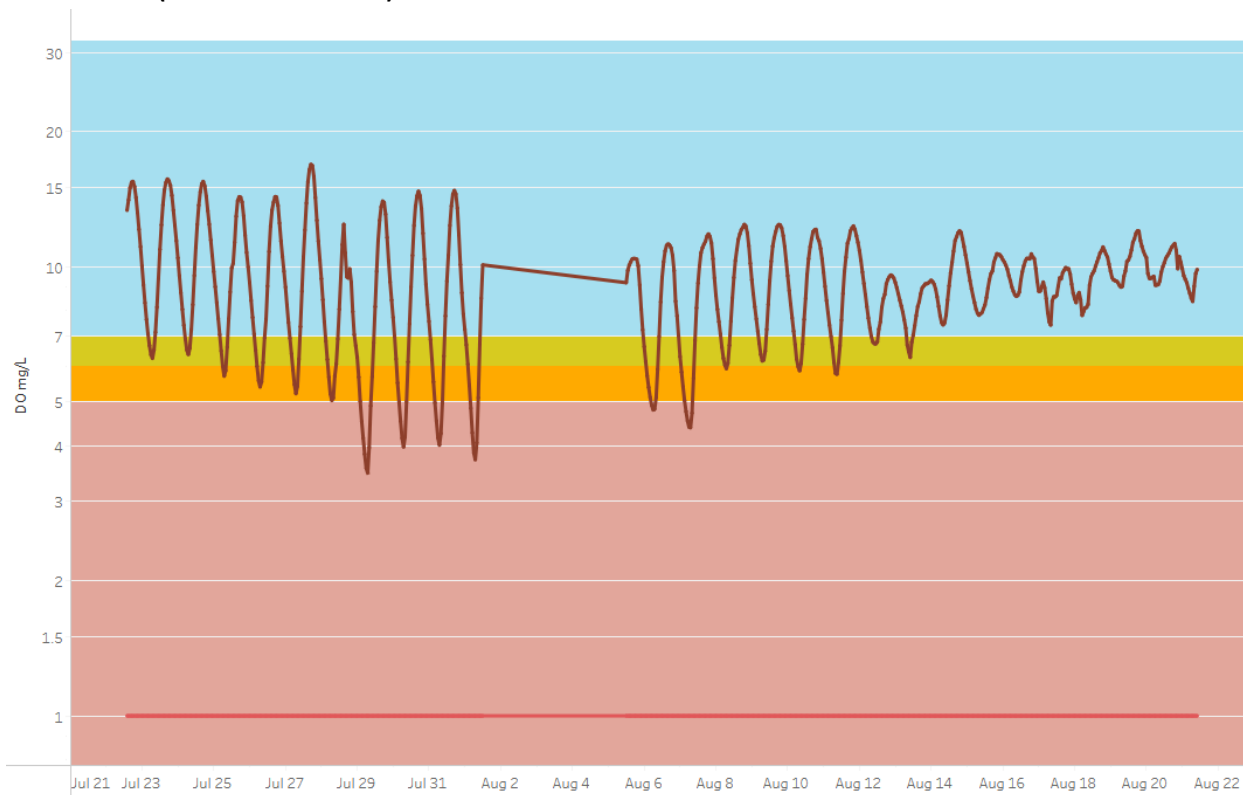


Figure 18. Continuous DO data (June 12-24, 2025) for W67014004 (CSAH 64 crossing) along Grand Marais Creek (AUID 09020306-530).

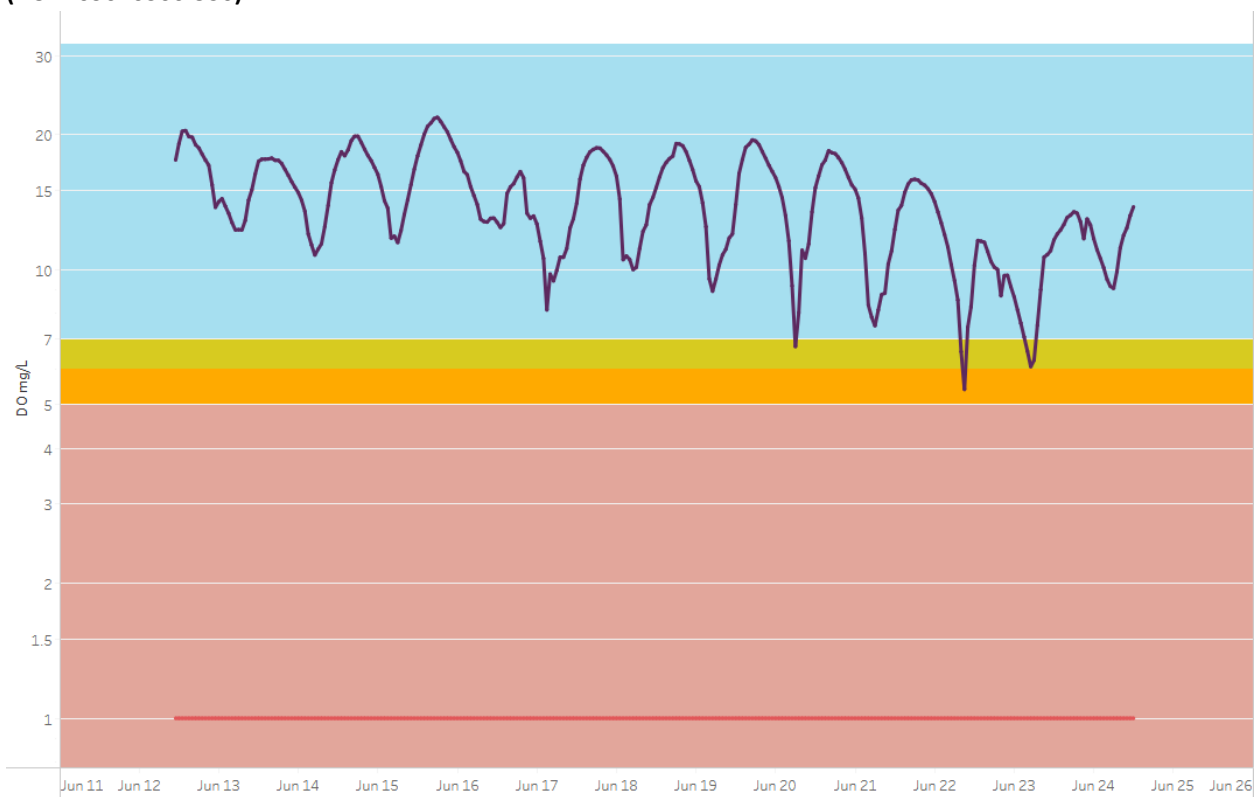


Figure 19. Images of lentic and wetland conditions upstream of Grand Marais Creek (AUID 09020306-530) on October 8, 2025, including the 130th St SW crossing along Grand Marais Creek (left), and the State Hwy. 220 crossing along Grand Marais Creek (right).



Eutrophication-related data for the reach include the following parameters: TP, chl-*a*, and DO flux. A total of 47 discrete TP samples were collected at Sites S008-904 (130th St NW crossing) and S016-221 (CSAH 64 crossing) along the reach. All the samples exceeded the 150 µg/L TP standard. The highest TP concentration was 738 µg/L, while the mean TP concentration was 448 µg/L. A total of five discrete chl-*a* samples were collected at Site S016-221. None of the values exceeded the 40 µg/L chl-*a* standard; the highest chl-*a* concentration was 19 µg/L. Lastly, the mean daily DO flux documented during continuous DO monitoring at Sites E67044001 (6.1 mg/L) and W67014004 (9.5 mg/L) exceeded the 5.0 mg/L DO flux standard. In addition, the MPCA biological monitoring staff documented an abundance of algae and macrophytes (Figure 20) during visits to Station 23RD009 on June 20, 2023, and August 14, 2024. Furthermore, the MPCA SID staff noted an excessive amount of filamentous algae and rooted macrophytes during five separate water quality monitoring visits to Site S016-221 (CSAH 64 crossing) between June and August of 2025. The available data suggest that eutrophication is likely adversely affecting the DO regime of the reach.

Figure 20. Images of eutrophication-related conditions at Station 23RD009 along Grand Marais Creek (AUID 09020306-530), including filamentous algae on June 20, 2023 (left), and filamentous algae and rooted macrophytes on August 14, 2024 (right).



Biological response: Fish

Frequent or extended periods of low DO can alter the fish community by limiting the abundance of species that are intolerant of such conditions (Davis, 1975; EPA, 2012). Table 28 shows the low DO-related metric scores for the fish community of this reach of Grand Marais Creek. The DO tolerance indicator value (TIV) met the statewide mean; however, the probability of meeting the DO standard was substantially below one standard deviation of the statewide mean. The multiple lines of evidence **somewhat support** the case for low DO as a stressor to the fish community of this reach of Grand Marais Creek.

Table 28. Summary of low DO-related fish metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy fish community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
DO TIV	Mean DO (mg/L) tolerance indicator value (decrease)	7 $\pm$ 0	23RD009 ²⁴ (8)
CondProb	Probability of meeting the DO standard (decrease)	80 $\pm$ 17	23RD009 ²⁴ (40)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams F-IBI Class (Class 2) and met or exceeded the F-IBI threshold (50).

²⁴ Sampled on August 20, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Biological response: Macroinvertebrate

Frequent or extended periods of low DO can alter a macroinvertebrate community by limiting the abundance of taxa that are intolerant of such conditions (Davis, 1975, EPA, 2012). Table 29 shows the low DO-related metric scores for the macroinvertebrate community of this reach of Grand Marais Creek. None of the metrics scores for Station 23RD009 met their respective statewide mean. Additionally, the DO TIV and abundance of low DO tolerant taxa scores were outside of one standard deviation of the mean. The multiple lines of evidence **convincingly support** the case for low DO as a stressor to the macroinvertebrate community of this reach of Grand Marais Creek.

Table 29. Summary of low DO-related macroinvertebrate metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
DO TIV	Mean DO (mg/L) tolerance indicator value (increase)	7 $\pm$ 0	23RD009 ²⁴ (6)
ToIDO	Relative abundance (%) of low DO tolerant taxa (increase)	15 $\pm$ 15	23RD009 ²⁴ (38)
InToIDO	Relative abundance (%) of low DO intolerant taxa (decrease)	10 $\pm$ 11	23RD009 ²⁴ (0)

¹ Target score included stations statewide that provided General Use habitat within the Prairie Streams Glide/Pool M-IBI Class (Class 7) and met or exceeded the M-IBI threshold (41).

²⁴ Sampled on August 14, 2024.

- Good: Score for the biologically impaired reach met or was equal to the statewide mean.
- Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.
- Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

High nitrate-nitrogen

Available data

According to Table 30, a combined 38 discrete nitrate-nitrogen (NO₃+NO₂-N) samples were collected at Sites S008-904 (130th St NW crossing) and S016-221 (CSAH 64 crossing) along the reach. Collectively, the nitrate-nitrogen concentrations for the sites ranged from less than 0.1 mg/L to 5.0 mg/L, with a mean of 0.3 mg/L. While Minnesota does not currently have an aquatic life use standard for nitrate, there is a chronic criteria value for nitrate of 8.0 mg/L (MPCA, 2022). None of the samples exceeded this criteria value. Overall, the available data suggest the reach does not experience periods of high nitrate-nitrogen.

Table 30. Discrete nitrate-nitrogen data for Sites S008-904 (130th St NW crossing) and S016-221 (CSAH 64 crossing) along Grand Marais Creek (AUID 09020306-530).

Site	Date range	<i>n</i>	Min. (mg/L)	Max. (mg/L)	Mean (mg/L)	# Criteria (8.0 mg/L) exceedances	% Criteria (8.0 mg/L) exceedances
S008-904	2016-2025	33	<0.1	5.0	0.3	0	0
S016-221	2025	5	<0.1	0.1	<0.1	0	0

Biological response: Fish

Nitrogen toxicity can affect the fish community depending on the concentration, length of exposure, and sensitivity of the individual organism (Camargo and Alonso, 2006). Table 31 shows the N TIV score for Station 23RD009 along this reach of Grand Marais Creek. While the TIV score slightly exceeded the statewide mean, the response is likely attributed to the confounding effects of other stressors, as there is no evidence that the reach experiences periods of high nitrate-nitrogen. The multiple lines of evidence **refute** the case for high nitrate-nitrogen as a stressor to the fish community of this reach of Grand Marais Creek.

Table 31. Summary of high nitrate nitrogen-related fish metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy fish community.

Metric	Description (expected response to stressor)	Target score ¹ mean ± SD	Station (score)
N TIV	Mean N (mg/L) tolerance indicator value (TIV) (increase)	2 ± 2	23RD009 ²⁴ (3)

¹ Target score included stations statewide that provided General Use habitat within the Southern Streams F-IBI Class (Class 2) and met or exceeded the F-IBI threshold (50).

²⁴ Sampled on August 20, 2024.

- Good: Score for the biologically impaired reach met or was equal to the statewide mean.
- Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.
- Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Biological response: Macroinvertebrate

Like fish, nitrogen toxicity can affect the macroinvertebrate community depending on the concentration, length of exposure, and sensitivity of the individual organism (Camargo and Alonso, 2006). Table 32 shows the N-related metric scores for the macroinvertebrate community of this reach of Grand Marais Creek. Most metric scores met their respective statewide mean. There was a lack of nitrogen intolerant taxa; however, the score was within one standard deviation of the mean. The multiple lines of evidence **refute** the case for high nitrate-nitrogen as a stressor to the macroinvertebrate community of this reach of Grand Marais Creek.

Table 32. Summary of high nitrate nitrogen-related macroinvertebrate metric data for Station 23RD009 along Grand Marais Creek (AUID 09020306-530), as well as statewide class scores from stations that support a healthy macroinvertebrate community.

Metric	Description (expected response to stressor)	Target score ¹ mean $\pm$ SD	Station (score)
N TIV	Mean N (mg/L) tolerance indicator value (increase)	3 $\pm$ 1	23RD009 ²⁴ (3)
ToIN	Relative abundance (%) of high N tolerant taxa (increase)	55 $\pm$ 18	23RD009 ²⁴ (15)
InToIN	Relative abundance (%) of high N intolerant taxa (decrease)	3 $\pm$ 6	23RD009 ²⁴ (0)

¹ Target score included stations statewide that provided General Use habitat within the Prairie Streams Glide/Pool M-IBI Class (Class 7) and met or exceeded the M-IBI threshold (41).

²⁴ Sampled on August 14, 2024.

■ Good: Score for the biologically impaired reach met or was equal to the statewide mean.

■ Fair: Score for the biologically impaired reach did not meet the statewide mean but was within one standard deviation of the mean.

■ Poor: Score for the biologically impaired reach did not meet the statewide mean and was outside of one standard deviation of the mean.

Summary of Stressors

The evidence suggests that the fish and macroinvertebrate bioassessment impairments associated with Grand Marais Creek (AUID 09020306-530) are primarily attributed to flow regime instability, and to a lesser extent, a loss of longitudinal connectivity, inadequate physical habitat, and low DO. The flow regime of the creek is characterized as flashy (i.e., prone to extreme peak flows and extended periods of minimal to no flow), which limits species diversity and favors taxa that are tolerant to disturbances. The rock weir structures and associated riprap that were installed within the channel at the outlet to the Red River of the North obstruct fish passage during periods of low flow, which are seasonally common. While the reach was part of a restoration project that was completed in 2015, the channel has habitat-related limitations (e.g., limited cover types) that affect its potential to support a healthy fish community. Lastly, the reach is prone to low DO and high DO flux, particularly during the summer months and during periods of low flow. Eutrophication is likely adversely affecting the DO regime of the reach.

Summary and Recommendations

Table 33 presents a summary of the stressors associated with the bioassessment-impaired reaches that were evaluated during Cycle 2 SID. Fish passage is limited along the downstream segment of the Grand Marais Creek (AUID 09020306-530). The rock weir structures and associated riprap within the channel at the outlet of the reach completely obstruct connectivity during low flow conditions. Each of the impaired reaches is prone to flow regime instability, including high and quick peak flows and/or

prolonged periods of minimal to no discharge. Historical changes in land cover (e.g., native vegetation to cropland) and drainage patterns (e.g., channelization and ditching), are contributing factors to this flashiness. Inadequate physical habitat was also found to be a stressor for each of the reaches. The impact of this stressor was most pronounced on the macroinvertebrate community of the impaired segment of the Grand Marais Creek, which naturally lacks habitat facets including riffles and clean, coarse substrate. High TSS was found to be a secondary stressor to the macroinvertebrate community of the downstream segment of the Black River (AUID 09020303-529). Streambank instability and soil erosion are the primary sources of this sediment. Lastly, low DO was determined to be a primary stressor for each of the impaired reaches, particularly in the summer months, when flow is low and the water temperature is high. A lack of sustained baseflow is a main contributing factor to low DO concentrations. Additionally, eutrophication appears to be adversely affecting the impaired segment of the Grand Marais Creek.

The actions listed below, as well as included in *The Aquatic Biota Stressor and Best Management Practice Selection Guide* (MPCA, 2016), are recommended to reduce or eliminate the influence of the stressors that are limiting the fish and macroinvertebrate communities of the impaired reaches.

Loss of Longitudinal Connectivity

- Modify the rock weir structures and associated riprap at the outlet of Grand Marais Creek to improve fish passage.

Flow Regime Instability

- Increase runoff detention/retention efforts to attenuate peak flows and restore a more natural flow regime.
- Mitigate activities that will further alter hydrology.

Insufficient Physical Habitat and High Suspended Solids

- Incorporate a two-stage ditch design into future drainage projects for Judicial Ditch 60.
- Increase runoff detention/retention efforts to attenuate peak flows and restore a more natural flow regime.
- Establish/protect riparian corridors along all waterways, using native vegetation whenever possible; utilize the DNR's *Native Plant Community Classification* as a guidance.
- Reduce soil erosion through the strategic implementation of best management practice's (BMPs).
- Incorporate Rosgen natural channel design principles into stream restoration projects.
- Integrate the DNR's Toe Wood-Sod Mat design into streambank restoration and stabilization projects, when possible.

Low Dissolved Oxygen

- Increase runoff detention/retention efforts to attenuate peak flows and restore a more natural flow regime.
- Reduce soil erosion through the strategic implementation of BMPs.
- Improve agricultural nutrient management.

Table 33. Summary of the stressors associated with the bioassessment impairments in the Red Lake River and Grand Marais Creek watersheds that were evaluated during Cycle 2 SID.

Reach Name (AUID)	Reach Extent	Bioassessment Impairment ¹	Candidate Cause ²					
			Loss of Longitudinal Connectivity	Flow Regime Instability	Inadequate Physical Habitat	High Suspended Solids	Low Dissolved Oxygen	High Nitrate-Nitrogen
Black River (09020303-529)	Little Black River to Red Lake River	M-IBI	NA	+++	+	+	++	-
Judicial Ditch 60 (09020303-570)	250th St SW crossing to CSAH 11 crossing	M-IBI	NA	++	+	-	++	-
Grand Marais Creek (09020306-530)	Polk County Ditch 2 to Red River of the North	F-IBI	++	+++	+++	0	+	-
		M-IBI	NA	+++	+	-	+++	-

¹ Aquatic life impairment for fish bioassessment (F-IBI) or benthic macroinvertebrate bioassessment (M-IBI).

² **Weight of Evidence:** +++ the multiple lines of evidence **convincingly support** the case for the candidate cause as a stressor; ++ the multiple lines of evidence **strongly support** the case for the candidate cause as a stressor; + the multiple lines of evidence **somewhat support** the case for the candidate cause as a stressor; 0 the multiple lines of evidence **neither support nor refute** the case for the candidate cause as a stressor; - the multiple lines of evidence **refute** the case for the candidate cause as a stressor; **INSUF** there is **insufficient information** to evaluate the candidate cause as a stressor; and **NA** the candidate cause is **not applicable** as a stressor due to type of bioassessment impairment or the use classification of the reach.

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References

- Aadland, L.P. 2015. Barrier effects on native fishes of Minnesota. Minnesota Department of Natural Resources, Division of Ecological and Water Resources, NW Region, Fergus Falls, MN.
- Aadland, L.P., and A. Kuitunen. 2006. Habitat suitability criteria for stream fishes and mussels of Minnesota. Special Publication 162. Minnesota Department of Natural Resources, St. Paul.
- Aadland, L.P., T.M. Koel, W.G. Franzin, K.W. Stewart, and P. Nelson. 2005. Changes in fish assemblage structure of the Red River of the North. American Fisheries Society Symposium 45:293-321.
- Bragg, O. M., A. R. Black, R. W. Duck, and J. S. Rowman. 2005. Approaching the physical-biological interface in rivers: a review of methods for ecological evaluation of flow regimes. Progress in Physical Geography 29:506-531.
- Bunn, S.E., and A.H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492-507.
- Camargo, J., and A. Alonso. 2006. Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment. Environmental International 32:831-849.
- Cross, W. F., C. V. Baxter, E. J. Rosi-Marshall, R. O. Hall, T. A. Kennedy, K. C. Donner, W. Kelly, A. Holly, S.E. Seegert, K.E. Behn, and M. D. Yard. 2013. Food-web dynamics in a large river discontinuum. Ecological Monographs 83:311-337.
- Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: A review. Journal of the Fisheries Research Board of Canada 32(12):2295-2331.
- Dewson, Z. S., B. W. Alexander, G. D. Russell. 2007. A review of the consequences of decreased flow for instream habitat and macroinvertebrates. Journal of the North American Benthological Society 26:401-415.

- Gardner, C., S. M. Coghlan, J. Zydlewski, and R. Saunders. 2013. Distribution and abundance of stream fishes in relation to barriers: Implications for monitoring stream recovery after barrier removal. *River Research and Applications* 29:65-78.
- Gore, J. A., J. B. Layzer, and J. I. M. Mead. 2001. Macroinvertebrate instream flow studies after 20 years: a role in stream management and restoration. *River Research and Applications* 17:527-542.
- Henley, W. F., M. A. Patterson, R. J. Neves, and A. D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs; a concise review for nature resources managers. *Reviews in Fisheries Science* 8:125-139.
- Jones, J. I., J. F. Murphy, A. L. Collins, D. A. Sear, P. S. Naden, and P. D. Armitage. 2012. The impact of fine sediment on Macroinvertebrates. *River Research and Applications* 28:1055-1071.
- Minnesota Department of Natural Resources (DNR). 2026. DNR Hydrography Dataset [Online]. Available at <https://gis.data.mn.gov/maps/d26eb1d402e84c4db9a302d29f4fc1c9/about> (verified 9 Jun. 2026).
- Minnesota Pollution Control Agency (MPCA). 2015a. Grand Marais Creek Stressor Identification Report [Online]. Available at <https://www.pca.state.mn.us/sites/default/files/wq-ws5-09020306a.pdf> (verified 5 Jan. 2026).
- Minnesota Pollution Control Agency (MPCA). 2015b. Red Lake River Watershed Stressor Identification Report [Online]. Available at <https://www.pca.state.mn.us/sites/default/files/wq-ws5-09020303a.pdf> (verified 5 Jan. 2026).
- Minnesota Pollution Control Agency. 2016. The aquatic biota stressor and best management practice selection guide [Online]. Available at <https://www.pca.state.mn.us/sites/default/files/wq-ws1-26.pdf> (verified 9 Jun. 2026).
- Minnesota Pollution Control Agency. 2019. Statewide altered watercourse project [Online]. Available at <https://gis.data.mn.gov/maps/46bd4a1aec66400fa4378c1497ce6fd2/about> (verified 2 Sept. 2026).
- Minnesota Pollution Control Agency (MPCA). 2022. Aquatic Life Water Quality Standards Draft Technical Support Document for Nitrate [Online]. Available at <https://www.pca.state.mn.us/sites/default/files/wq-s6-13.pdf> (verified 15 Sept. 2025).
- Poff, N.L., and J.K. Zimmerman. 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. *Freshwater Biology* 55:194-205.
- Poole, G. C. 2002. Fluvial landscape ecology: addressing uniqueness within the river discontinuum. *Freshwater Biology* 57:641-660.
- Saunders, D. A. 2007. Connectivity, corridors and stepping stones. Managing and designing landscapes for conservation: Moving from perspectives to principles. P. 280.
- United States Environmental Protection Agency (EPA). 2012. CADDIS: The Causal Analysis/Diagnosis Decision Information System [Online]. Available at <http://www.epa.gov/caddis/> (verified 9 Jun. 2026).

United States Geological Survey (USGS). 2019. National Land Cover Database 2019 [Online]. Available at <http://www.mrlc.gov> (verified 9 Jun. 2026).

United States Geological Survey (USGS). 2026. StreamStats [Online]. Available at <https://streamstats.usgs.gov/ss/> (verified 9 Jun. 2026).

Waters, T.F. 1995. Sediment in streams: Sources, biological effects, and control. American Fisheries Society, Bethesda, MD.