Stressor Identification

April 2025

Redeye River Watershed Stressor Identification Report Update 2025

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

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

Author

Chuck Johnson

Contributors/acknowledgements

Jonathon Newkirk

Bonnie Goshey

Mark Hauck

Cover photo credit

Photo on cover is Leaf River, Wadena County. Photo taken by Chuck Johnson on August 15, 2023.

Document Number: wq-ws5-07010107b

Contents

List of tables

List of figures

Key terms and abbreviations

AUID	Assessment Unit Identification
DO	Dissolved Oxygen
EPA	U.S. Environmental Protection Agency
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
MIBI	Macroinvertebrate Index of Biotic Integrity
MPCA	Minnesota Pollution Control Agency
MSHA	Minnesota Stream Habitat Assessment
SID	Stressor Identification
TALU	Tiered Aquatic Life Use
TIV	Tolerance Index Value
TP	Total phosphorus
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
WID	Waterbody Identification

Introduction

Since 2008, the Minnesota Pollution Control Agency (MPCA) has substantially increased the use of biological monitoring and assessment as a means to determine and report the condition of the state's rivers and streams. This basic approach is to examine fish and aquatic macroinvertebrate communities and related habitat conditions at multiple sites throughout a major watershed. From these data, an Index of Biological Integrity (IBI) score can be developed, which provides a measure of overall community health. These scores are then compared to the appropriate IBI thresholds (stream class), which are determined by the type and location of the stream or river that was sampled. If the fish or macroinvertebrate IBI (MIBI) score fails to meet the standards set by the stream class, it is termed a "biological impairment" and is placed on the U.S. Environmental Protection Agency's (EPA's) impaired wasters list. If biological impairments are found, stressors to the aquatic community must be identified.

Stressor identification (SID) is a formal and rigorous process that identifies stressors causing biological impairment of aquatic ecosystems and provides a structure for organizing the scientific evidence supporting the conclusions (Cormier et al. 2000). In simpler terms, it is the process of identifying the probable factors causing harm to aquatic life. SID is a key component of the major watershed restoration and protection projects being carried out under Minnesota's Clean Water Legacy Act. Information on the SID process can be found on the EPA website http://www.epa.gov/caddis/. Specific information on Minnesota's processes for SID in streams can be found on MPCA's webpage "stressor identification" at https://www.pca.state.mn.us/water/your-water-stressed. Minnesota Department of Natural Resources (DNR) has a similar webpage for lakes - "Stressors to Biological Communities in Minnesota's Lakes" https://www.dnr.state.mn.us/waters/surfacewater_section/lake_ibi/index.html.

This report details the SID process for the Redeye River Watershed, following the second cycle of biological monitoring. This report also contains SID work that was completed after the first cycle of watershed monitoring, on stations that were channelized. Until the Tiered Aquatic Life Use (TALU) assessment process was written into rule in 2014, the MPCA did not have the tools to assess channelized streams. Stations that were sampled in 2010 on channelized streams, were not assessed until TALU criteria were finalized; as a result, these Assessment Unit Identification (AUIDs) were not included in the Cycle 1 SID Report (MPCA 2014).

Overview of the Redeye River Watershed

The Redeye River Hydrologic Unit Code (HUC)-8 Watershed (07010106) is divided into 10 Aggregated HUC-12 subwatersheds and 3 were studied in this report (Figure 1). Aggregated HUC-12 subwatersheds that were previously studied can be found in the Cycle 1 Redeye River Watershed SID Report Red Eye River Watershed Stressor Identification Report (state.mn.us).

Figure 1: Redeye River Stressor Identification Study Aggregated 12 HUC's

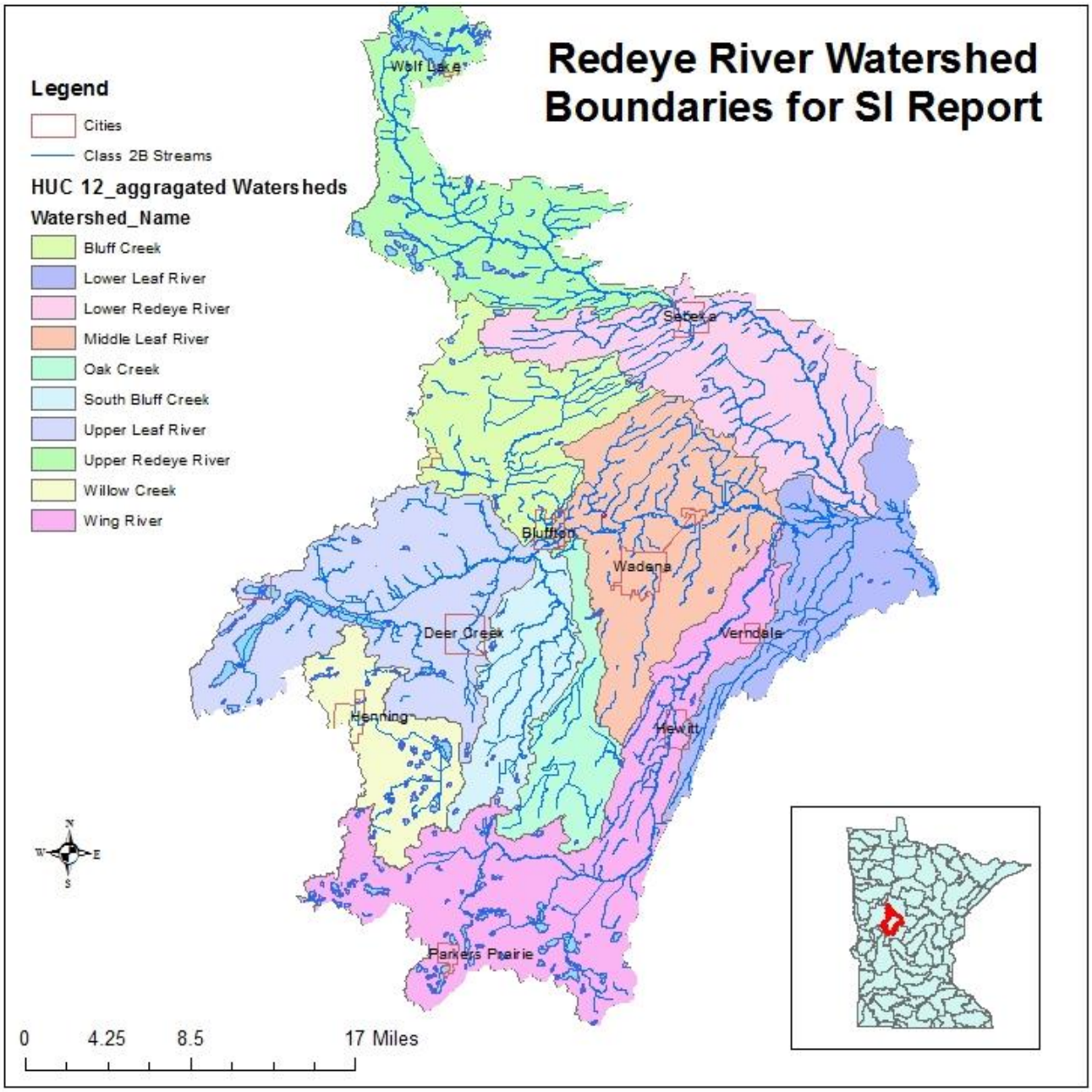
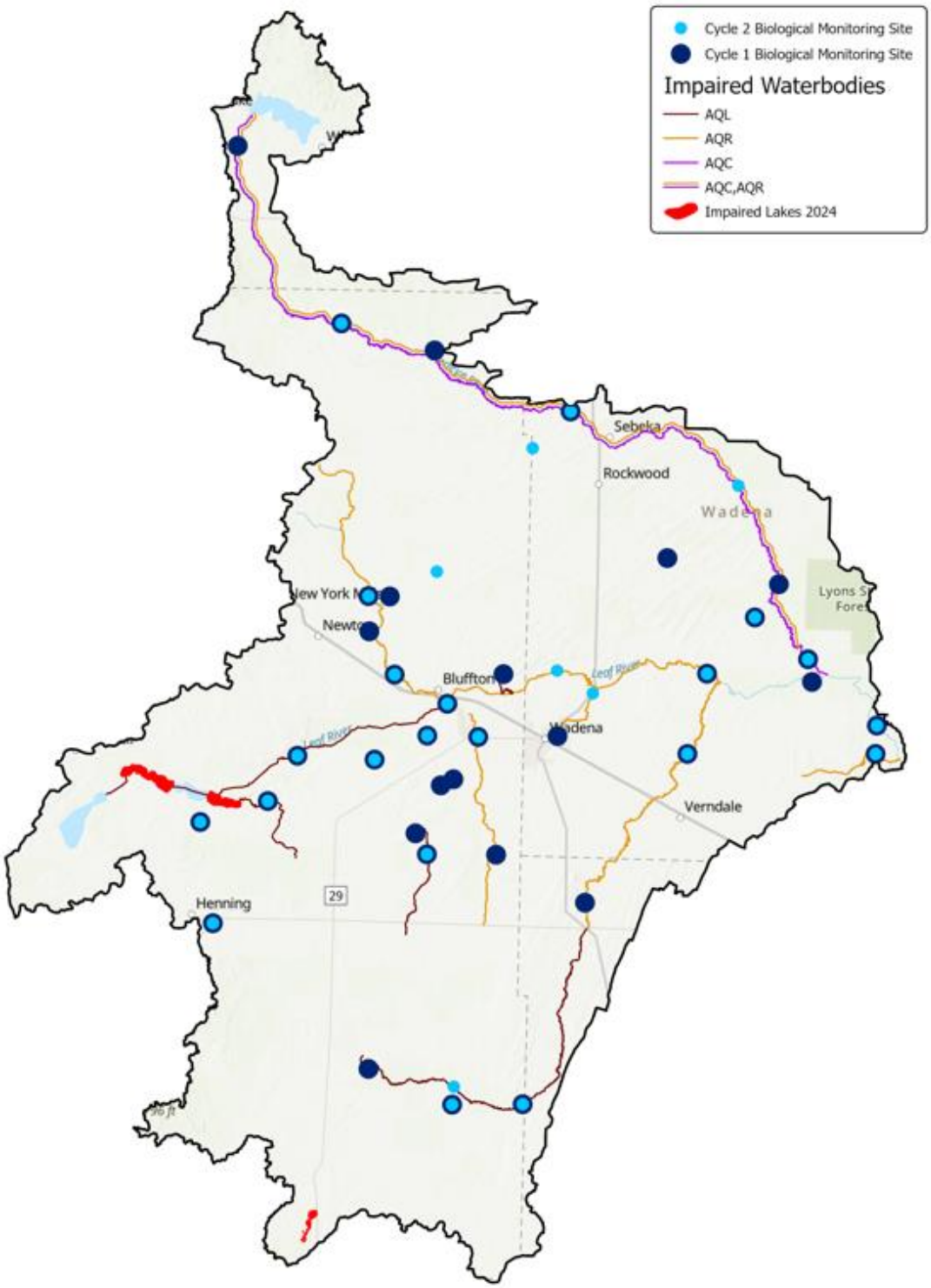


Figure 2: Biological Monitoring Stations and Biological Impairments within the Red Eye River Watershed. Lakes are impaired by mercury.



Biologically impaired streams

Biological sampling from the cycle II monitoring effort resulted in two stream reaches being assessed as having impaired fish and/or macroinvertebrate communities. In addition to the two new impairments from the cycle II monitoring, one stream reach that was sampled in the first cycle, but were deferred due to being channelized, was also assessed as impaired. These reaches were brought into the SID update process. These reaches are listed below (Table 1).

Table 1: Summary of aquatic life impairments and stressors in the Redeye River Watershed.

Stream	WID	Aquatic Life Impairment	Monitoring Data Source Year	Dissolved Oxygen	Nutrients	TSS	Connectivity	Hydrology/ Geomorphology	Habitat	Flow
Leaf River	-506	Fish/ Macroinvertebrates Vulnerable	Fish were opted in from old dataset.	x				x	x	
Union Creek	-508	Fish/ Macroinvertebrates	Coldwater section downstream of Whiskey Creek confluence	◊	x		x			
Union Creek	-509	Macroinvertebrates	Coldwater section upstream of Whiskey Creek confluence		x				X	
CD13	-549	Fish	Fish were listed based on 7/18/22 sample	x				x		X
Hay Creek	-526	Fish/Macroinvertebrates	Biological samples from 2021and 2022 show a decline in IBI	x	x					

x = direct stressor (stressor directly contributing to the biological impairment), X = secondary stressor (stressor that is not the direct stressor, but is still contributing to the biological impairment), ◊ = Possible contributing root cause (stressor that is not a direct or secondary stressor, but may be contributing to other stressors, causing stress to the biological communities, ? = Inconclusive

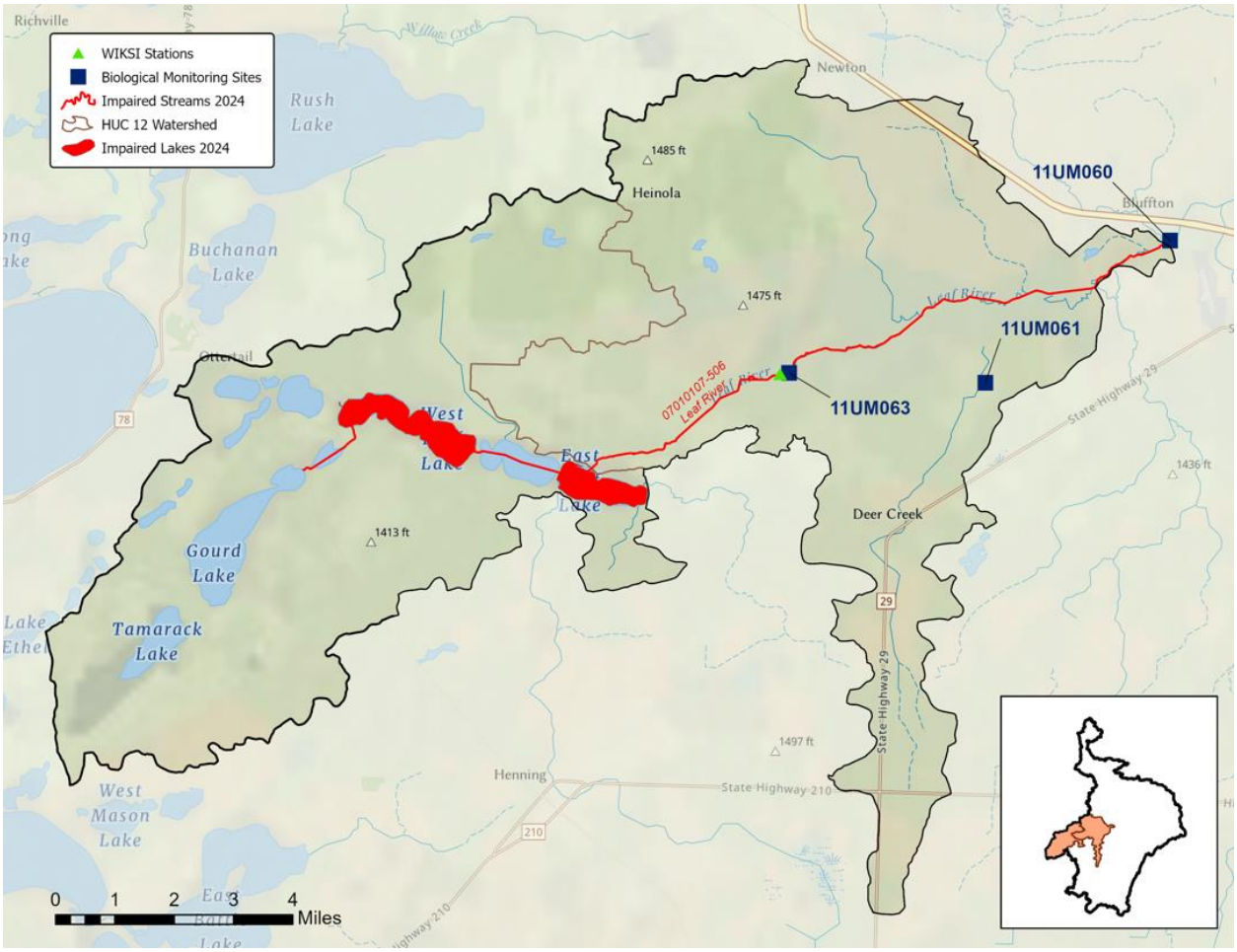
*Denotes channelized streams that may be part of a Judicial or County ditch system.

The SID data collection, analysis, and recommendations for each of these impaired waterbody identification (WID) will be discussed and sorted into HUC-12 subwatersheds for the duration of this report.

Deer Creek-Leaf River Subwatershed

The Deer Creek-Leaf River Subwatershed covers 37075 acres, located just South of Bluffton (Figure 3). Over half of the stream length within the subwatershed have been straightened. The two lakes that are impaired are West and East Leaf Lakes for mercury in fish tissue. No TMDL is needed for these lakes.

Figure 3: Monitoring stations in the Deer Creek-Leaf River Subwatershed. Lakes are impaired for mercury.



Leaf River (07010107-506)

Impairment: Leaf River (WID -506) flows for 17.39 miles. This WID is the headwaters of the Leaf Lake chain and is fed by WID 511 (Deer Creek) that is full support for biology. WID 506 and the upstream tributaries are all partially channelized. There is one biological monitoring stations (11UM063) that was sampled on the Leaf River (Figure 3). Fish were sampled at 11UM063 on 9/28/2011 and 6/22/2022 and macroinvertebrates were sampled in 2011 and 2022. The data indicated that the fish within Leaf River were not meeting standards and resulted in a new fish impairment for the 2020 Impaired waters list. The fish sample collected in 2022 scored above the general use threshold with a 50.4. Data conflicts with the original listing from the 2011 sample, which scored a 32.2 on the FIBI. The fish class at 11UM063 is fish class 5 (Northern Streams). The macroinvertebrate class at 11UM063 is class 4 (Northern Forest

Streams). The macroinvertebrate sample were above the general use threshold on 8/31/2011 (50.5) and again on 9/21/2022 (34.7; 57.7). Macroinvertebrate show full support.

Data and Analyses

Chemistry

Water chemistry data has been collected on Leaf River at station S012-039 from 2011-2023. A summary of the sampling results can be found in Table 2.

Table 2: Water chemistry data collected on Leaf River from 2011-2023. Data available at https://webapp.pca.state.mn.us/surface-water/search.

Parameters	Count of Result	Min. Result	Median Result	Max. Result	Avg. Result	# Meeting Standard	# Exceeding Standard	% Exceeding	Criteria Val	Unit
Ammonia-N	2	0	0	0	0	0	0	0		mg/L
Dissolved oxygen	21	1.33	4.99	9.14	5.27	10	11	52.4	5	mg/L
Inorganic nitrogen (nitrate and nitrite)	10	0	0	0.36	0.04	0	0	0		mg/L
pH	21	0	7.61	8.11	7.29	20	1	4.8	6.5	
pH	21	0	7.61	8.11	7.29	21	0	0	9	
Specific conductance	21	291	391.7	676	400.66	0	0	0		uS/cm
Total Phosphorus	10	0.02	0.03	0.07	0.04	10	0	0	0.1	mg/L
Total suspended solids	2	0	0.7	1.4	0.7	2	0	0	30	mg/L
Transparency, tube with disk	21	100	100	100	100	21	0	0	25	cm
Volatile suspended solids	1	0	0	0	0	0	0	0		mg/L
Water temperature (C)	21	11.37	21.8	26.32	20.71	0	0	0		deg C

Dissolved oxygen (DO) samples exceeded the state 5 mg/L standard 52.4% of the samples. This reach of the Leaf River has extensive submerged and emergent aquatic plant growth. Wild rice grows extensively in this upper portion of the Leaf River as can be seen from the below photo taken on August 1, 2023.

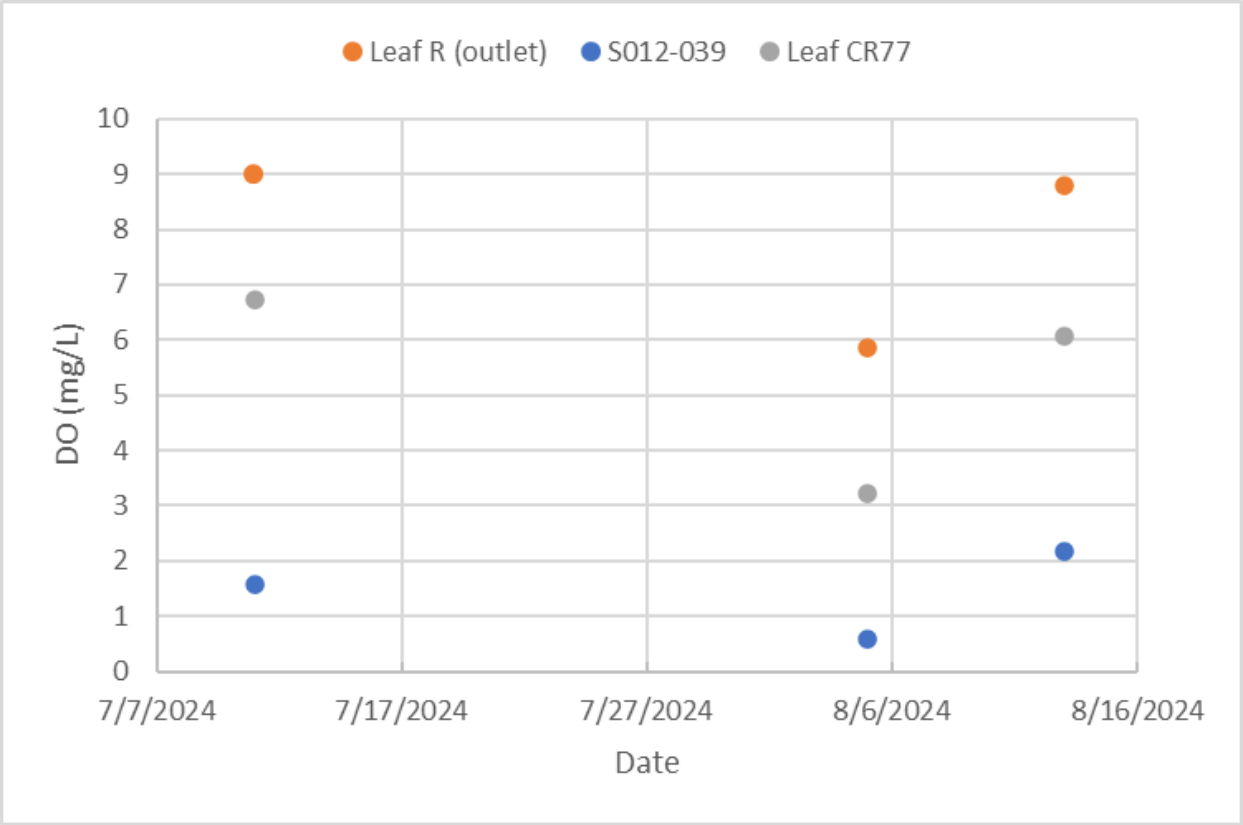
Figure 4: Leaf River wetland conditions, showing low gradient and wild rice growth in channel.

The extensive plant growth causes low DO concentrations during the evening hours as plant and periphyton growth respires. During the fall as the plant and periphyton start to die off the DO concentrations can stay below the standard during the entire 24 hour cycle. Fish were sampled on 9/28/2011, which is late in the summer season and was quite possibly after the wild rice started to decompose and DO levels were abnormally low in that reach. The 6/22/2022 fish sample would have occurred early enough in the growing season of the wild rice that the channel would have had above state standard levels of DO. Since fish are mobile it is anticipated that the fish would probably have moved outside of the area of low DO influence during these periods in the fall.

In 2024, a longitudinal survey of the Leaf River WID 506 was conducted during the summer of 2024. A pattern emerged with DO concentrations throughout the WID. At the outlet of East Leaf Lake, DO concentrations were above the 5 mg/L standard during the site visits. As we move downstream and sample at S012-039 which is the same location as the biological monitoring station, DO was well below

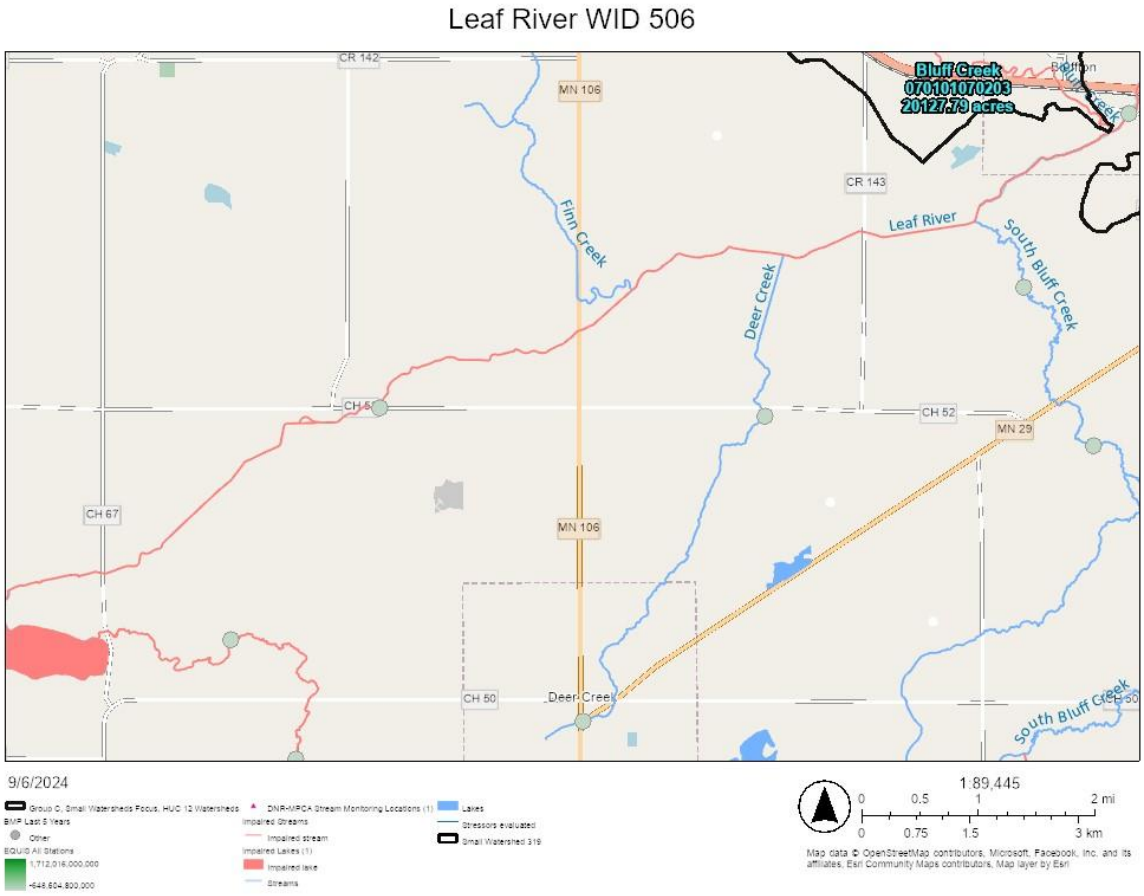
the 5 mg/L standard during July and August visits. Stream flow was elevated in 2024 and it is believed that the wetland is stripping DO from the water column and/or exporting low DO water through infiltration through the hydric soils along the wetland corridor. As we approach the downstream end of WID 506 at CR77 the DO concentrations rebound and are generally above the 5 mg/L standard. Figure 5 below graphically displays the results of the 2024 longitudinal DO sampling.

Figure 5: Longitudinal DO survey of Leaf River WID 506 in 2024.



As a result of this sampling, it appears that WID 506 has low DO during drier periods in the fall as emergent and submerged vegetation dies off and throughout the summer months during periods of wet weather. The entire WID runs through an extensive wetland complex once it leaves East Leaf Lake and until it crosses County Highway 143 downstream of S012-039. Figure 6 shows the street map that is associated with the sampling locations.

Figure 6: Leaf River WID 506 street map showing all crossings in the stream.



All other water quality standards are met.

Habitat

Habitat was classified as fair on Leaf River, through the Minnesota Stream Habitat Assessment (MSHA) evaluations during the fish and macroinvertebrate samples (Figure 7). During water quality sampling events in 2023 it was observed that there was extensive submerged and emergent aquatic plant growth in the channel from CR106 upstream to the outlet of East Leaf Lake. This section of stream has been historically ditched and flows through a large wetland complex and has very low gradient. Stream substrate scored poor and was dominated by sand and silt during the 2011 and 2022 site visit. Channel morphology also scores poor due to the nature of the old channelization.

Figure 7: MSHA scores for Leaf River WID 506

The Leaf River is 17.39 miles long for WID 07010107-506. The stretch of stream between the East Leaf Lake outlet and CR 77 was measured with Google Earth to have an idea of how much stream length was removed during the channelization project. The old historical channel length was measured at approximately 16.06 miles. The current channelized length was measured at 11.86 miles, a loss of 4.02 miles of stream length. This represents about a 25% reduction in total stream length in this segment of the Leaf River. Losing this amount of stream length reduces the stream sinuosity and also reduces the number of riffles and pool diversity within the channel. A loss of habitat variability will affect the species of fish that use this section of channel. Most of the fish sampled at 11UM063 were tolerant to low DO conditions. Sensitive fish and macroinvertebrates require well defined pools, riffles, and runs to feed, spawn, and to use as refuge during high precipitation events. Lack of habitat is a stressor to the aquatic life within 11UM063 due to poor channel morphology and substrate.

Hydrology and geomorphology

Over time, there have been many changes on the landscape that have changed the natural hydrology and geomorphology of Leaf River, and the entire subwatershed. The most significant historical changes to the landscape have been land conversion from mature forests to hay/pasture/crop land and woody wetlands and the channelization of the natural streams and wetlands. Leaf River has been straightened along the entire length of the AUID. Historically, Leaf River was comprised of multiple wetlands and small stream channels. The channel was altered to drain the landscape, starting from the Southwest and ending downstream of Highway 71. Prior to channelization the reach of stream was 16.06 miles long. Following the channelization project, the stream length is 11.86 miles. This equates to a loss of 4.2 miles of channel. This will affect the slope and the length of travel time that it takes water to flow through the stream reach. This channel alteration accelerates stream flow, resulting in higher flows during precipitation events, which achieves the agricultural land use drainage goals, but causes instability. Water leaves the landscape quickly, resulting in periods of higher flow than what would have naturally occurred. As the landscape drains, water that was once held in the upstream wetlands is flushed downstream, carrying low DO water throughout the reach. Then, as these flows quickly drain, the flow regime quickly transitions to slow moving discharge from East Leaf Lake, reaching low conditions

starting early in the late summer (Figure 8). Although 2023 was a dry summer, Leaf River maintained flow throughout the summer, a result from the large snowpack from the winter and the volume of water passing through the Leaf Lake chain of lakes. This reach is very low gradient and has very slow stream velocities for large portions of the summer and fall.

Figure 8: Leaf River at S012-039 on August 15, 2023.

A flow gaging station was installed in 2011 and operated through 2023 at the CR77 road crossing. This is near the end of WID 506. The flow pattern during this seven-year deployment, shows that during spring snowmelt flows are high and recede to baseflow by late summer. Flows are dependent of snowfall and summer rains keeping the Leaf Lake chain filled with water. All seven monitoring seasons did show that the stream does have flow throughout the open water season (Figure 9). Historically the highest flow follows snow melt and spring rainfall. All flow data is accessible on the DNR/MPCA Cooperative stream gaging website.

Figure 9: Stream flow for Leaf River at CR 77 (H13060001) from 2011 through 2023.

Streamflow will also temporarily increase after periods of heavy summertime rainfall. Figure 9 displays the summer flow pattern at station H13060001. This graph is displaying when flow was low enough for the fish crews to safely access the site. The station had persistently high enough flow during the summer to delay the fish sampling until late September. At this time the water temperature was dropping and the aquatic vegetation in the channel was dying off and causing a drop in the DO concentrations. During the 9/28/2011 field visit the DO was 3.613mg/L at 1430. Figure 10 and Figure 11 show the flow conditions during the 2011 and 2022 sampling events.

Figure 10: Flow conditions during the 9/28/2011 fish sampling event. FIBI score was 32.2 during this visit represented by the red circle on the graph.

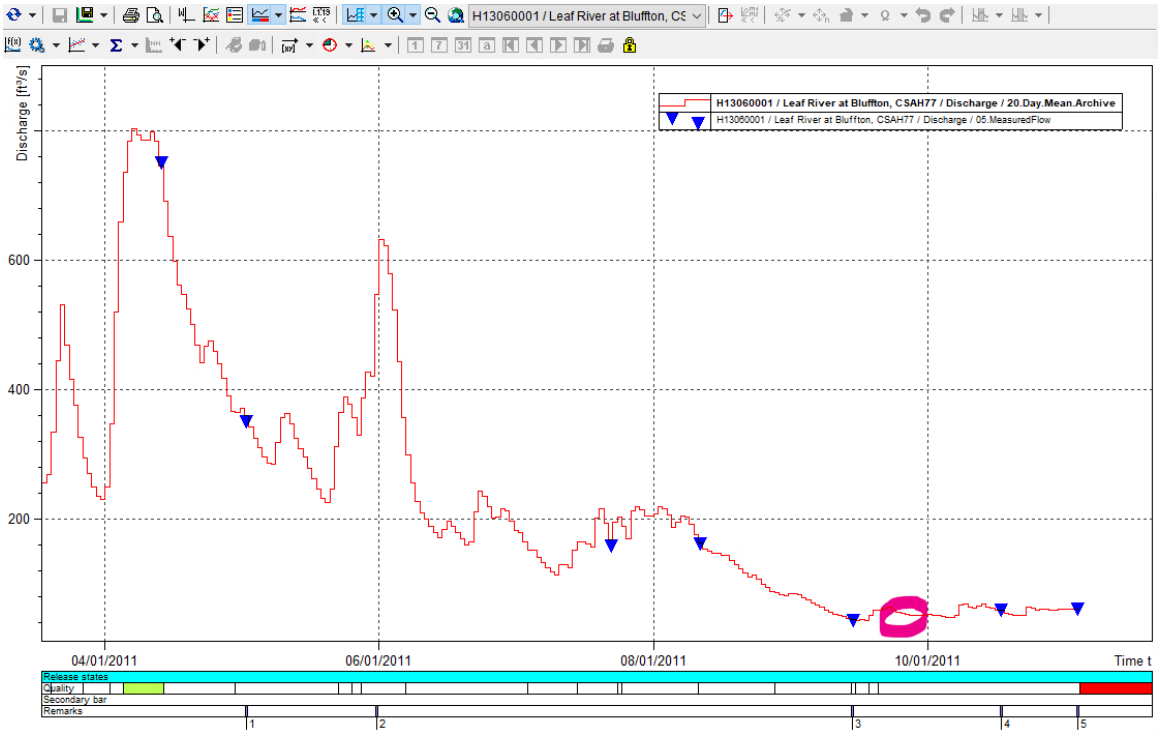
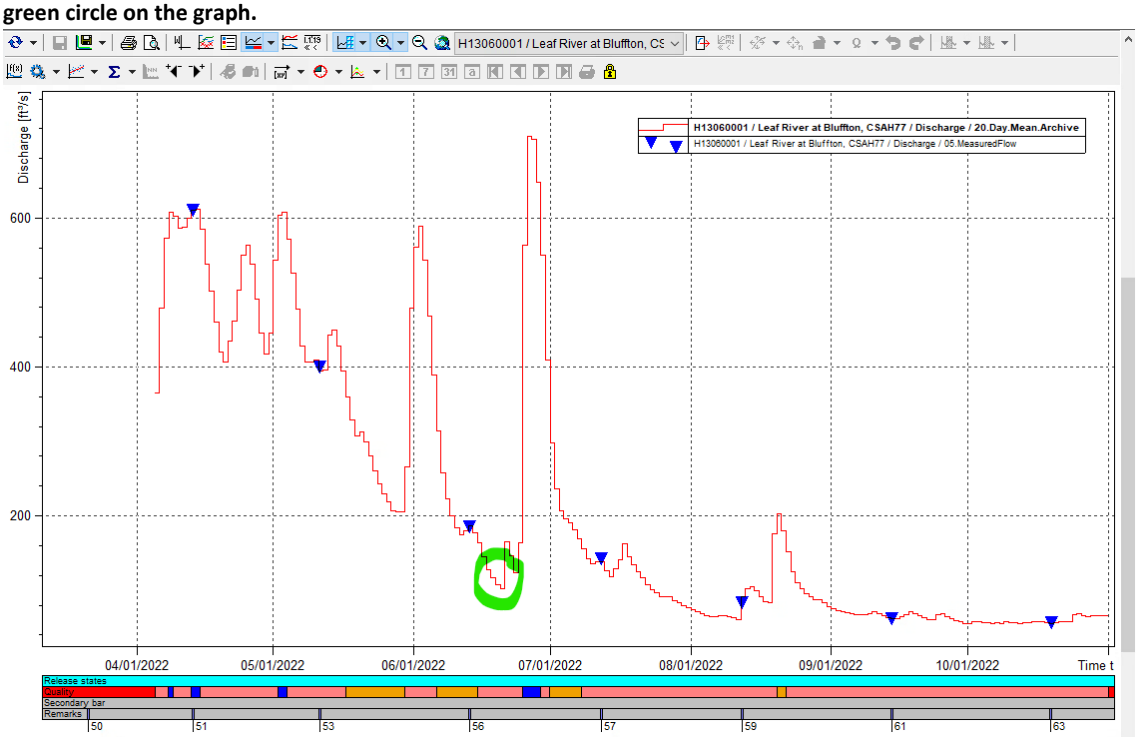


Figure 11: Flow conditions during the 6/22/2022 fish sampling event. FIBI score was 50.4 during this visit represented by the green circle on the graph.



Due to the old channelization of Leaf River, the river does not have a natural stream pattern that can be assessed for stability. Utilizing the biological monitoring sampling pictures and MSHA evaluations of stream bank condition, the banks appear to be stable and not actively eroding upstream of CR143. Between the CR143 and CR77 crossings there is evidence of channel erosion. This section runs through a slightly sandier section and therefore has a higher tendency for the banks to erode. The current channel size is most likely much larger than the historic stream channels that existed prior to the channelization and is showing signs that the channel is receiving excess sediment from the banks or the landscape, as sand was the only substrate noted within the MSHA evaluation. It is possible that this excess sediment would have historically settled out within the wetlands that made up most of the riparian pre-settlement, but due to the channelization, the sediment is flushed downstream during precipitation events. Altered hydrology and geomorphology is a secondary stressor within this upstream portion of the Leaf River.

Connectivity

All the investigated crossings from Highway 10 upstream to East Leaf Lake did not affect fish passage. Crossings are either bridges or large box culverts that allow fish passage at all flow regimes. The migratory fish community scored 18.02% above the class 5 average further supporting that connectivity is not an issue to the fish community. There is a small dam located on the outlet of East Leaf lake, which could partially impede movement between the lake and the upstream reaches of the Leaf River.

Stressor signals from biology

Fish

Fish were sampled in 2011 and 2022. A total of 18 fish species were collected, with the Central Mudminnow being the most dominate on 9/28/2011. The Central Mudminnow is one of the most pollution tolerant fish species within the State of Minnesota. There were 3 Very tolerant species, 2 tolerant species, 11 neutral species, 1 intolerant specie and 1 sensitive species collected in 2011. A total of 15 species were collected in June of 2022 with white sucker being the most dominant followed by yellow perch.

Tolerance index values (TIV) were calculated for Leaf River using the fish community. The total suspended solids (TSS) TIV found that the fish community has an 65% probability of coming from a stream that is meeting the TSS standard. One fish species that are tolerant and no sensitive of elevated TSS were found within the 2011 fish samples; however, the 2022 fish sample found no tolerant but five sensitive taxa to TSS, indicating a weak TSS signal from the biology. Therefore, the fish community response to TSS is weak, and therefore, is inconclusive currently.

DO TIV scores were also calculated for Leaf River using the fish communities. The two collected samples show a significantly different story. The 2011 fish sample had a 25% chance of passing the DO standard while the 2022 fish sample shows a 73% chance of passing the DO standard based on fish community characteristics. Many of the fish collected within the sample are either tolerant or very tolerant of low DO, indicating that low DO is a potential stressor to the fish community within Leaf River at various times of the year.

Phosphorus tolerance of the fish community was also investigated in Leaf River using the fish species characteristics. Three of the fish species collected within the sample were tolerant of elevated phosphorus. As for sensitive species, one fish species that is sensitive or intolerant of elevated phosphorus were found in the sample. The low presence of elevated phosphorus tolerant species and the absence of intolerant species indicates that phosphorus is not a stressor to the fish community within Leaf River.

Composite conclusion from biology

The fish TIVs are indicating that low DO is a potential stressor to the aquatic life within Leaf River. TSS does not appear to be stressor to the aquatic life within Leaf River. Phosphorus levels does not appear be a stressor to the aquatic life in Leaf River. The habitat and geomorphology are heavily altered in Leaf River and appear to be stressors to the aquatic life within Leaf River.

Conclusions about stressors

The fish TIVs indicate that DO is a potential stressor to the fish community within Leaf River; however, this may be the result of the low DO tolerant fish species also having the ability to survive in streams with poor habitat and altered hydrology. Therefore, altered hydrology is a stressor to the biology in Leaf River. Poor sinuosity, poor channel development, and fine sediment were noted within the MSHA assessment. These are the result of channel over widening and the creation of a new channel through large wetlands. Sensitive fish and macroinvertebrates require coarse substrate and good channel morphology to survive and reproduce. However, good sinuosity and the pools and riffles that naturally occur within streams and rivers, do not exist in Leaf River by design. As for the substrate in Leaf River, due to creating a channel through several wetlands, sand has covered most of the coarse substrates that would exist naturally. There is also a large amount of fine organics along the edges of the channel that encourage the growth of wild rice. During lower flow years the wild rice growth can be quite extensive as the channel does not have enough stream power to wash the rice seed downstream. The 2023 sampling season saw high snowmelt runoff with very little flow occurring after the snow melt was moved through. This was the perfect conditions for wild rice growth and the channel near S012-039 had heavy wild rice growth throughout the season. This led to periods of low DO after the wild rice started to die off as was documented in 2023. Additional early morning DO samples were collected on this WID of the Leaf River starting in July at East Leaf Lake outlet, S012-039 and CR 77. This helped explain the cause of the low DO water that has been documented in August through September in this WID. The DO is being stripped when it enters the wetland corridor between the three sampling locations as seen in Figure 5.

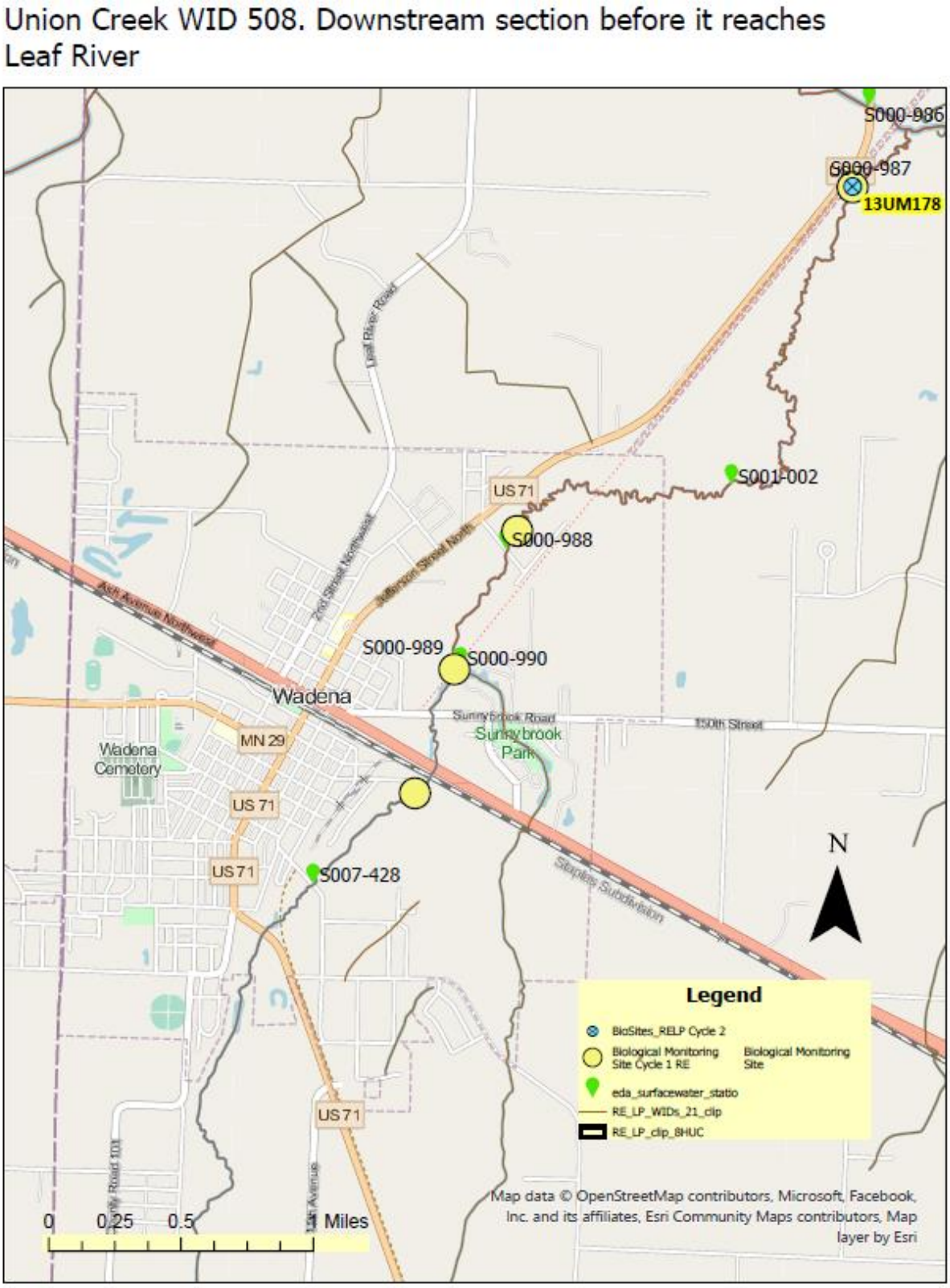
This would be a good candidate for a SWMR request to resample fish due to timing issues with fish samples.

Union Creek (07010107-508 and -509)

Impairment: Union Creek (WID-508; Whisky Cr to Leaf River) flows for 4.84 miles and is partly channelized. There are three biological monitoring stations (00UM095, 13UM177,13UM178) that were

sampled for fish and macroinvertebrates multiple times since 2011 (Figure 12). Biological station 13UM178 is on WID 509. Union Creek was assessed in 2021 as part of the TALU assessment process for assessing channelized streams. The Use Attainability Analysis (UAA) process determined that Union Creek should be assessed under the general use criteria, which resulted in a new macroinvertebrate impairment. The macroinvertebrate class is class 8 (Northern Coldwater). During the 2011 and 2022 macroinvertebrate sampling event at 13UM178, samplers collected bank habitat, wood and aquatic macrophytes. Samplers observed bank issues, beaver dams and wetland riparian characteristics. The fish stream class at 13UM178 is class 11 (Northern Coldwater), and the fish passed with an IBI score of 41.1 and 32.2. Further upstream at sampling location 13UM177, the 2011 fish IBI was 26.6 and the 2022 fish IBI was 32.2. Mottled sculpin a coldwater species was present in both samples and were the only coldwater species present. During the 2024 Watershed Assessment Team (WAT) meeting both the macroinvertebrates and the fish communities were assessed as nonsupporting. The following documentation is from the WAT meeting. This section of Union Creek (Whisky Creek to Leaf River) was sampled for benthic macroinvertebrates at one biological monitoring station (13UM178) during the summer of 2022. The resulting macroinvertebrate index of biological integrity (MIBI) score is below the coldwater general use lower confidence interval. Despite having coldwater temperatures consistent with other Northern coldwater stream, this section of Union Creek does not contain benthic macroinvertebrates consistent with coldwater streams. Recommend nonsupport for aquatic life based on benthic macroinvertebrates. | 02/05/2024 (FISH): This is the furthest downstream 4.82 mi 2A General use WID on Union Creek. In this assessment cycle, there is one fish sample from 13UM178 collected 6/22/2022 that falls just below the General Use Threshold but within the lower confidence interval in the Northern Coldwater Fish Class. BCG 5. there is supporting information collected in 2013 (just outside of the assessment window due to Covid delaying a year) at 13UM177, just upstream of 13UM178. this visit also falls just below the general use threshold, but within the lower confidence interval. Sampler comments indicate BP Gear type limited sample in two other nonreportable visits. Recommend not support for AQL based on FIBI.

Figure 12: Biological and water quality monitoring stations on Union Creek WID 508 and WID 509. Station S007-428 is on WID 509. WID 508 begins at the confluence of Whisky Creek downstream of Sunnybrook Road.



Data and Analyses

Chemistry

Water chemistry data is limited to the samples that were collected during 2011 through 2023 (Table 3).

Table 3: Water chemistry data collected on Union Creek (AUID 508 and 509).

Parameter	Applicable Standard	Avg. Results (WID-508)	Avg. Results (WID-509)	Max. Results (WID-508)	Max. Results (WID-509)
Temperature, water		16.2	16.87	22.78	18.14
Specific conductance		627	609	805	759
pH		7.86	7.74	8.11	7.85
Dissolved oxygen (DO)	7.0 mg/L	7.27	7.36	11.7	8.81
Inorganic nitrogen (nitate and nitrite)	10 mg/L	1.49	1.58	4.3	4.12
Total phosphorus	0.1 mg/L	0.11	0.09	0.17	0.18
Transparency, tube with disk	55	96.3	100	100	100
Total suspended solids	10	3.67	0.9	8	2.2

Nutrients – Phosphorus

Phosphorus values for WID-508 show that the average phosphorus concentration is 0.11 mg/L, which is slightly above the Central Region River Nutrient standard of 0.100 mg/L (Table 3). This reach is flowing through an area of hydric soil. The dataset has 55.6% of the samples exceeding the 0.100 mg/L phosphorus standard. The macroinvertebrate communities are dominated by taxa that are tolerant to high phosphorus concentrations.

Phosphorus values from WID-509 show that the average phosphorus concentration is 0.09 mg/L (Table 3). This is the upstream reach that flows from agricultural fields through the city of Wadena. The dataset has 33.3% of the samples exceeding the 0.100 mg/L phosphorus standard. The macroinvertebrate communities are dominated by taxa that are tolerant to high phosphorus concentrations.

Elevated phosphorus concentrations can encourage growth of aquatic plants and algae in the stream. This increased growth can lead to elevated DO concentrations during the day and a significant drop in DO concentrations in the evening. Both fish and macroinvertebrate TIV's indicate that low DO concentrations are affecting both communities. Decreasing the available phosphorus may help with improving the biological communities through lowering the daily fluctuations in DO concentrations.

This indicates that elevated phosphorus could be a stressor to aquatic life.

Nutrients-Nitrogen

Nitrogen values for WID-508 show that the average nitrogen concentration is 1.47 mg/L (Table 3). Currently the nitrogen standard is 10mg/L but that is based on drinking water safe concentrations. The maximum concentration was 4.30 mg/L. Review of the fish tolerance taxa show that both WID-508 and WID-509 are slightly being impacted by the elevated nitrogen concentrations. Nitrogen values in

WID509 averaged 1.58 mg/L with a maximum value of 4.12 mg/L. Macroinvertebrate TIV values indicate that nitrogen is a main stressor in WID 509. Between 72% and 81% of the macroinvertebrate community is tolerant to elevated nitrogen concentrations. The macroinvertebrate TIV for nitrogen shows that 41% to 52% of the communities on WID 508 are tolerant to elevated nitrogen. The elevated nitrogen concentrations are impacting the macroinvertebrate communities.

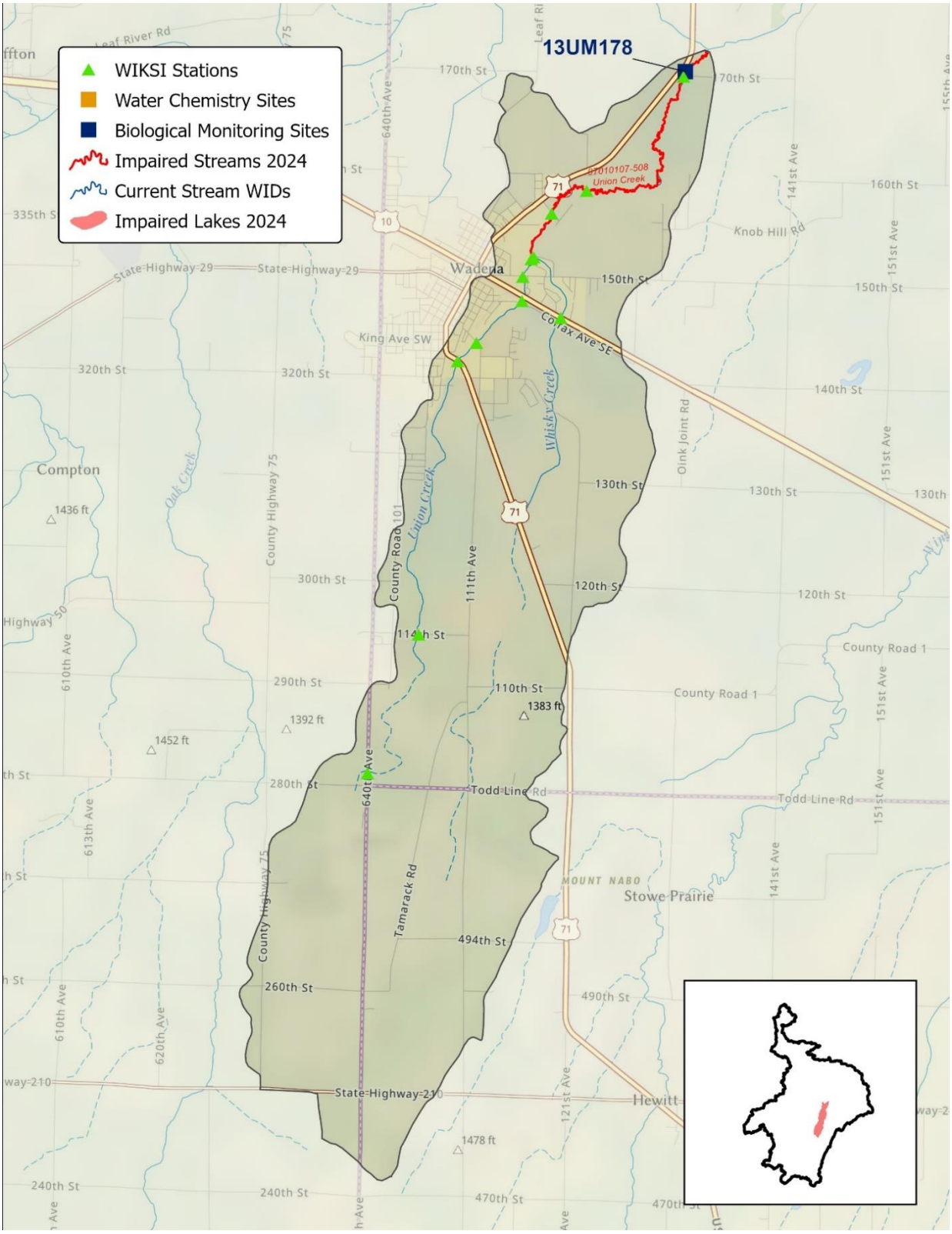
Elevated nitrogen is a stressor to the macroinvertebrate communities.

Dissolved Oxygen

If DO is below 7mg/L for extended periods of time, coldwater biological communities can be severely impacted. DO was collected 24 times between 2011 and 2023 on WID 508 (Table 6). The average DO concentration was 7.27 mg/L. Thirty three percent of the collected DO concentrations were below the 7 mg/L standard for 2A waters. The lowest recorded DO concentration was 2.30 mg/L and is low enough to have instant impacts on coldwater obligate fish species. DO was also collected in 2024 at two upstream locations on WID 509. DO samples show that at station S007-428 the DO was below 7 mg/L during June through August. Further suggesting that low DO is a systemic problem throughout this stream. WID 509 is listed for fish or macroinvertebrates but it is the main contributor of water to the downstream WID along with Whisky Creek. Limited DO data from Figure 13 shows the drainage area contributing to WID 508. Limited DO data from Whisky Creek also shows that this subwatershed is contributing low DO water. Both the fish and macroinvertebrate TIVs suggest that low DO is inhibiting the biological communities in both WID-508 and WID-509. The macroinvertebrate TIV data for WID-508 shows a slightly higher percentage of tolerant taxa than intolerant taxa to DO. The fish TIV values are below class average for similar streams on WID-508. The fish TIV values on WID-509 are also below class averages. The macroinvertebrate TIV data indicate that all four samples collected on WID-509 have a very similar number of low DO tolerant and low DO intolerant taxa. This mixed signal suggests that low DO is not driving the reduced MIBI score.

DO is a stressor to the stream fish biology in this coldwater resource.

Figure 13: Union Creek drainage area, AUID 509 is upstream of Whiskey Creek confluence and AUID 508 is downstream of Whiskey creek confluence.



Total Suspended Solids

TSS data on WID 508 is limited to 12 samples in 2011 through 2023 (Table 6). The values were well below the standard of 10 mg/L. TSS is not considered a stressor to the aquatic life.

Conductivity

Specific conductivity values are within range on Union Creek (Table 6) for both WID-508 and WID-509 and is not considered to be a stressor within Union Creek.

Temperature

Temperature values were within range on Union Creek (Table 6) for both WID508 and WID-509 and is not considered to be a stressor within Union Creek.

Habitat

Habitat was classified as fair on Union Creek (AUID 508), through the MSHA evaluation at the three fish sample sites.

Due to the historic channelization of the upstream portions of Union Creek, and fair MSHA score, the assessment of Union Creek was brought into the UAA process. It was determined that the habitat of Union Creek has the ability to support good quality habitat for aquatic life, as a result of the MSHA score. Therefore, Union Creek was assessed using the General Use TALU criteria.

Although the MSHA score was fair overall, substrate and channel morphology scored particularily low. Substrate was the first low scoring component of the MSHA score, as indicated by the dominance of sand and silt. Healthy fish communities need coarse substrate in order to build nests and spawn. Excessive fine sediment also affects juvenile fishes, as the sediment is stirred into the water column creating TSS, it can easily tear sensitive juvenile fish gills. Similarly, many sensitive macroinvertebrates also have specialized gills that are used to breathe DO. Excessive fine sediments can damage these gills, similar to juvenile fishes, making the creek inhabitable for sensitive species.

Channel morphology was another low scoring component of the MSHA evaluation. The MSHA indicated that there was minimal channel depth variability, fair sinuosity, and no channel development (no riffles or pools). Fish and macroinvertebrates need channel depth variability to use as cover from predation and refuge during high precipitation events. No change in the channel depth combined with fair sinuosity and poor channel development impedes the fish and macroinvertebrate's ability to inhabit the creek throughout the summer, especially during high flow events which can flush these communities downstream. The lack of good channel morphology is caused by the introduction of fine sediment to the creek, either through stormwater runoff, bank failure or row crop erosion. Fine sediment deposition and movement can be seen by observing sand dunes in the channel bottom near 13UM178. Lack of habitat is a stressor to the aquatic life in Union Creek.

Union Creek headwaters section is AUID 509. This upstream portion of Union Creek is located upstream of the confluence with Whiskey Creek. The habitat scores ranged from poor to fair during the five macroinvertebrate sampling events. The three categories that are lowering the score are land use, substrate, and channel morphology. Substrate is important for certain groups of macroinvertebrates. Coarse clean gravel is beneficial for the genera's of mayfly, stonefly and caddisfly which are the primary indicators of good water quality. There are mixed signals on habitat importance to the

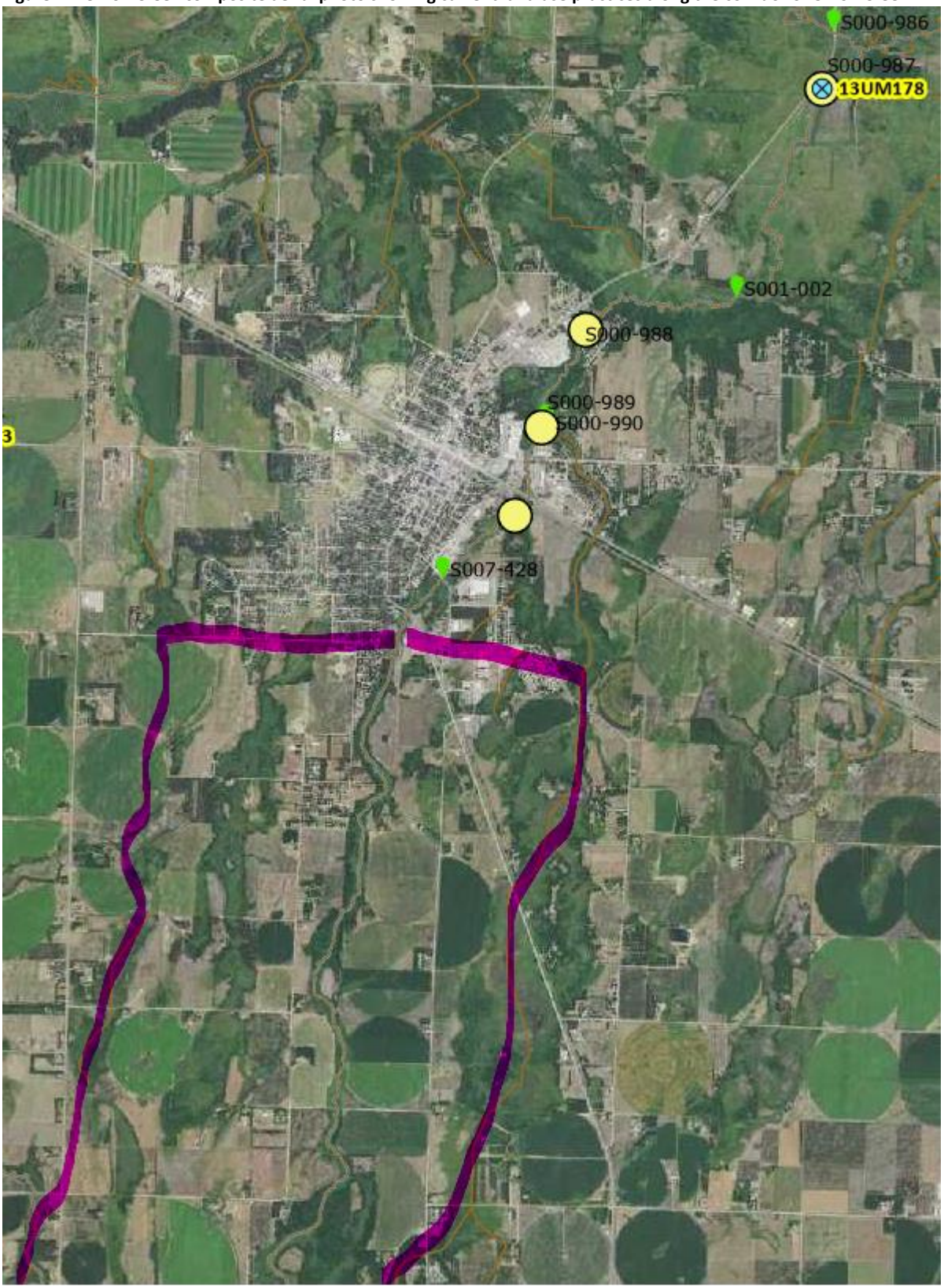
macroinvertebrate community based on the various TIV scores associated to habitat. The most recent samples collected in 2023 reveal that the percent embeddedness and percent fines are affecting the localized sample from 13UM176 but are showing little or no affect at 00UM095. At 13UM176 45.1% of the community are tolerant of stream embeddedness (which smothers quality habitat with fine material) and 28.5% of the community is tolerant of increased fine sediment in the sampling reach. At 00UM095 those numbers are much lower (0.6% and 1.5%). In general it appears that the increased potential for stormwater runoff via stormsewer networks is affecting the amount and distribution of either bank material being eroded or external sediment entering the stream from watershed runoff.

Hydrology and geomorphology

Over time, there have been many changes on the landscape that have changed the natural hydrology and geomorphology of Union Creek, and the entire subwatershed. The most significant historical changes to the landscape have been land conversion from mature forests and woody wetlands to city streets and housing developments along with the partial channelization of the natural streams and wetlands. Union Creek has been partially straightened along the upstream length of WID 509. There are also multiple impoundments along WID 509 both upstream and downstream of Highway 71. Historically, Union Creek was comprised of woody wetlands and a main stream channel flowing through deciduous forest.

As the channel was altered to drain the landscape, a new channel was cut through shrub/scrub and woody wetlands, creating a direct connection to Union Creek in the farthest upstream section. This channel alteration accelerates stream flow, resulting in higher flows during precipitation events which achieves the agricultural land use drainage goals, but causes instability. Water leaves the landscape quickly, resulting in periods of higher flow than what would have naturally occurred. As the landscape drains, water that was once held in the upstream wetlands is flushed downstream, carrying low DO water with increased temperature throughout the reach. The upstream WID 509 also has a number of center pivot irrigation fields that may be competing for shallow groundwater which supplies baseflow to the channel. Figure 14 below shows the upstream area of WID 509 which is agricultural field land use with center pivot irrigation, the center portion of the subwatershed has the city of Wadena with stormwater issues, and WID 508 flows through a wetland area with manipulated channels and drainage channels that are attempting to drain off the wetlands.

Figure 14: Union Creek composite aerial photo showing current land use practices along the corridor of Union Creek.



Connectivity

Stressor signals from biology

There is one connectivity barrier between 13UM177 and 13UM178. This barrier is located on an old path that accesses the stream off of US71 just upstream of 13UM178. This culvert is mainly a barrier during certain flow regimes where the velocity inhibits free passage of many smaller fish species as can be seen in Figure 15 below.

Figure 15: Drop on outlet of culvert at old access road just east of US71 and upstream of 13UM178.

7/18/2023 low flow **9/19/2023 low flow**

Macroinvertebrates

Macroinvertebrates were sampled in 2013 as part of the cycle I watershed monitoring effort. The macroinvertebrate community that was sampled in 2013, 71% of was comprised of taxa that are considered to be tolerant of pollutants, and 69.5% of the community was considered to be very tolerant of pollutants. This changed significantly during the 2022 sampling when 7.8% of the sample was tolerant to pollutants and 6.0 % were very tolerant of pollutants. *Hyallella (scud)* and *Baetis* (mayfly) dominated the sample and are both considered to be tolerant taxa in 2013. *Simulium* (blackflies) and *Baetis* (mayfly) dominated the sample and are both considered to be tolerant taxa in 2022.

TSS taxa tolerance was investigated using the macroinvertebrate communities. In the 2013 sample, no intolerant taxa, 11 tolerant taxa, and 4 very tolerant taxa were collected (Figure 6). In the 2022 sample, one intolerant, eight tolerant, and five very tolerant were collected. Overall, the macroinvertebrate community within Union Creek indicates that TSS is a potential stressor to the macroinvertebrate community and should be further investigated. This is further supported by the high number of macroinvertebrate taxa that are tolerant to percent fines. A measure of the amount of fine sediment that is on the stream bed. Table 4 shows the number of macroinvertebrate taxa that are tolerant and intolerant to percent fines in the stream bed.

DO tolerance was also investigated using the macroinvertebrate communities. In 2013, five very intolerant, eight intolerant taxa, six tolerant taxa, and three very tolerant taxa were collected (Table 4). Although there are tolerant taxa present, intolerant and very intolerant taxa dominated the sample, and indicate that low DO most likely is not a stressor to the macroinvertebrate community within Union Creek. In 2022, the number of all tolerant and intolerant taxa dropped compared to in 2013, as seen in

Table 4. Low DO values have been documented in Union creek; however, the macroinvertebrate community does not appear to be limited by DO.

The final tolerance indicator that was investigated within the macroinvertebrate community was phosphorus tolerance. In the 2013 sample, 2 intolerant taxa, 11 tolerant taxa, and 8 very tolerant taxa were collected (4). These tolerance indicators within the macroinvertebrate community indicate that phosphorus is a possible stressor to the macroinvertebrate community within Union Creek.

Table 4: Macroinvertebrate tolerance index values for Union Creek at station 13UM178 (508).

Parameter	Taxa Tolerance	2013 Sample	2022 Sample
DO	# Intolerant	8	3
	# Tolerant	6	3
	# Very Intolerant	5	3
	# Very Tolerant	3	0
Phosphorus	# Intolerant	2	3
	# Tolerant	11	8
	# Very Intolerant	0	1
	# Very Tolerant	8	4
TSS	# Intolerant	0	1
	# Tolerant	11	8
	# Very Intolerant	0	0
	# Very Tolerant	4	5
Percent Fines	# Intolerant	3	0
	# Tolerant	10	4
	# Very Intolerant	0	0
	# Very Tolerant	6	1

Fish

DO tolerance was investigated using the fish communities. Both fish sampling visits had greater than 28% of the community tolerant to low DO. There were no DO intolerant taxa collected for either fish sample in this WID. The fish samples at 13UM177 and 13UM178 show that fish DO TIVs are below class averages indicating that low DO is causing stress to the fish community.

The fish community metrics do not suggest that phosphorus is a stressor. Both samples are above class averages indicating that phosphorus is not a stressor to fish.

The fish community also suggest that TSS is not a stressor based on the above class average fish TIV's for TSS. There were no TSS intolerant taxa, one TSS intolerant taxa and one TSS sensitive taxa collected in each fish sample along this WID. However, the fish community is affected by deposition of fine sediment as can be seen by the above class average TIV for Fines in the fish community. Both samples had no intolerant or sensitive fish taxa to fines but had multiple tolerant and intolerant fish taxa to fines. This suggests that fine sediment is being deposited on the stream bottom and not being redistributed as TSS but moving along the bed when during periods of higher velocity stream flow. Sand dunes were observed in the channel near 13UM178 further providing evidence of mobile sand on the channel bottom.

Composite conclusion from biology

The DO TIVs were inconclusive for macroinvertebrates, but did indicate that TSS and phosphorus is a potential stressor to the macroinvertebrate community.

The habitat and geomorphology are altered within Union Creek and are the primary stressors to the aquatic life within the creek as can be seen by the percent fines and embeddedness TIV metrics.

Conclusions about stressors

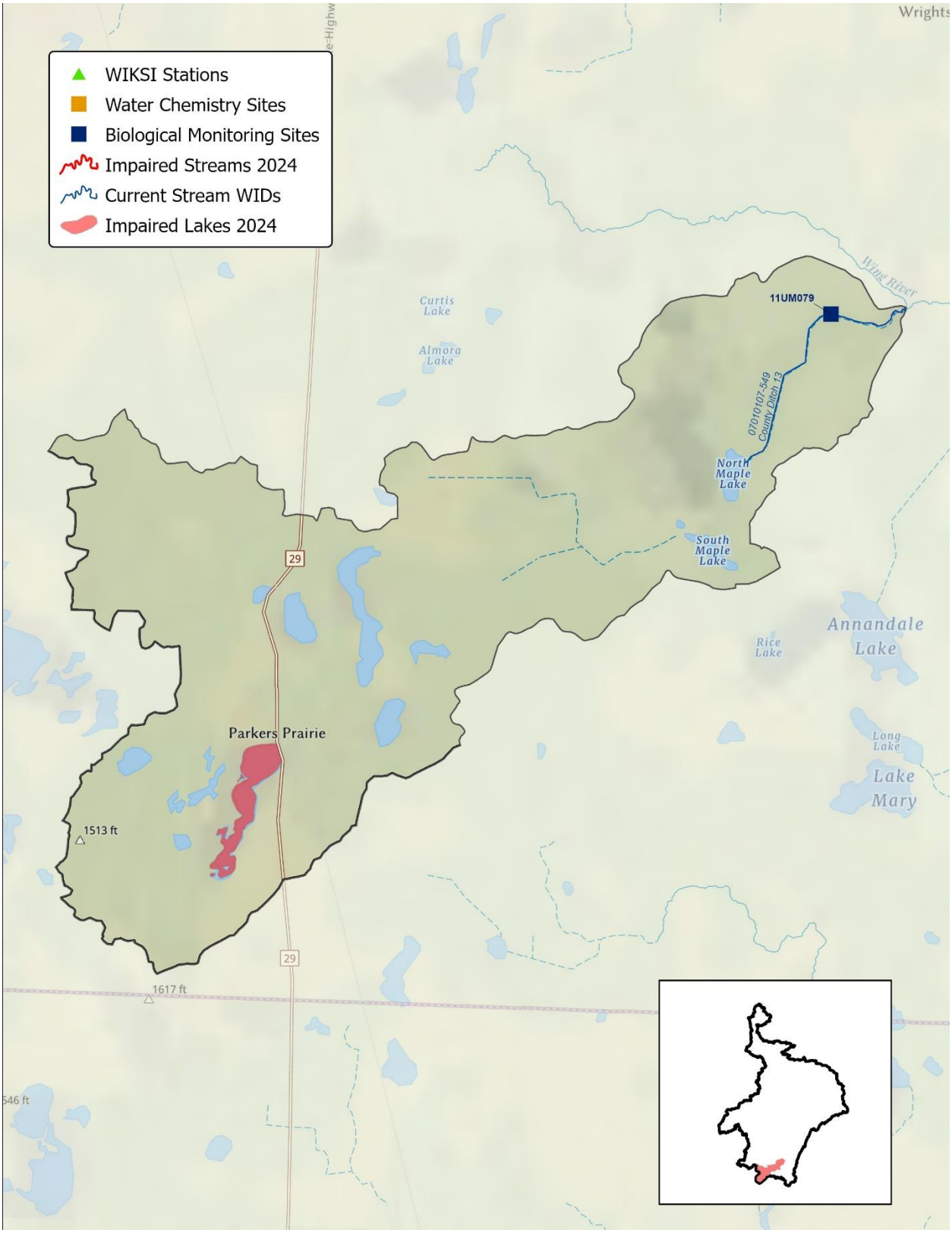
The fish sample from 2013 failed the IBI with a score of 32.2 and had 7 species sampled. The fish sample showed a high probability of low DO as a stressor when reviewing the fish TIV data. The macroinvertebrate TIVs were able to be used, which indicated that phosphorus and TSS has the potential to be a stressor to the aquatic life within Union Creek, while DO does not appear to be a stressor to the macroinvertebrates. The elevated total phosphorus (TP) and unstable DO levels within the chemistry dataset collected on Union Creek further indicate that TP and DO are stressors to the aquatic life within the creek.

Altered hydrology and geomorphology have also impacted the aquatic life within Union Creek, by removing habitat, increasing the amount of nutrients drained from the landscape, and altering the historic flow conditions. Good quality habitat such as coarse substrate, good channel development, and good depth variability are critical for the survival of sensitive fish and macroinvertebrates. Sensitive fish species like the Hornyhead Chub utilize coarse substrate to build nests for spawning. Similarly, sensitive macroinvertebrate taxa use coarse substrate, aquatic vegetation, and woody debris as attachment surfaces to avoid floating downstream, which allows them to feed. These important habitat types have been altered by stream sediment embeddedness and high percent of fine sediment. This fine sediment accumulation is probably being supplied by stormwater runoff along with unstable banks along the main corridor of Union creek as it flows through portions of the city of Wadena. Further investigation of the source of the fine sediment will need to be conducted as this report does not cover the sources of fine sediment in Union Creek.

County Ditch Number Thirteen (07010107-549)

Impairment: County Ditch Number Thirteen (WID-549) flows for 2.91 miles and is fully channelized. There is one biological monitoring stations (11UM079) that was sampled twice for fish and macroinvertebrates since 2011 (Figure 16). The CD13 was assessed in 2022 as part of the TALU assessment process for assessing channelized streams. The UAA process determined that CD13 should be assessed under the modified use criteria, which resulted in a new fish impairment. The macroinvertebrate class is class 5. During both macroinvertebrate sampling events the macroinvertebrate scores were well above the modified use threshold.

Figure 16: Biological monitoring stations on CD13: WID 549. The lake highlighted in red on the map below is listed for mercury.



Data and Analyses

Chemistry

Water chemistry data is limited to the samples that were collected during 2011 and 2023 (Table 5).

Table 5: Water chemistry data collected on CD13.

Parameter	Sample Count	Applicable Standard	Avg. Results	Min. Results	Max. Results
Temperature, water	14		20.23	9.70	27.90
Specific conductance	14		406	9	555
pH	14		7.82	7.50	8.06
Dissolved oxygen (DO)	14	5.0 mg/L	7.83	3.25	11.02
Inorganic nitrogen (nitate and nitrite)	7	10 mg/L	0.01	0.00	0.07
Total phosphorus	7	0.1 mg/L	0.04	0.03	0.07
Transparency, tube with disk	13	55	99.08	94	100
Total suspended solids	3	10	3.7	0.00	9.60

Nutrients – Phosphorus

Phosphorus values from the dataset show that the average phosphorus concentration is 0.07 mg/L, which is below the Central Region River Nutrient standard of 0.100 mg/L (Table 5). This reach is channelized through an area of hydric soil. This channelization is allowing for groundwater inputs and the low DO groundwater is causing phosphorus to bind to the iron precipitate as seen in Figure 17 below.

Nutrients – Inorganic nitrogen

Inorganic nitrogen values are well below the 10 mg/L statewide standard for drinking water. Levels are also well below the proposed inorganic nitrogen standards for aquatic life (around 3 mg/L). Inorganic nitrogen is not a stressor to aquatic life from the current dataset.

Dissolved Oxygen

If DO is below 5 mg/L for extended periods of time, biological communities can be severely impacted. DO was collected 14 times in 2011 and 2023 (Table 5). The average DO concentration was 7.83 mg/L. Of the DO concentrations collected, 21% were below the 5 mg/L standard for 2B waters. The low DO readings occurred during the mid to late summer months when water levels were below normal during the very dry summer of 2023. Much of central Minnesota was in a moderate to severe drought in 2023.

Figure 17: The photo below shows standing water only during a September 19, 2023, site visit.

Total Suspended Solids

TSS data is limited to three samples in 2023 (Table 5). The values were well below the standard. The iron precipitate can cause elevated TSS values and strips DO out of the water column. TSS is not considered a stressor to the macroinvertebrates.

Conductivity

Specific conductivity values are within range on CD13 (Table 5) and is not considered to be a stressor within CD13.

Temperature

Temperature values were within range on CD13 (Table 5) and is not considered to be a stressor within CD13.

Habitat

Habitat was classified as poor-fair on CD13, through the MSHA evaluation at the two fish sample sites (Figure 18).

Figure 18: MSHA habitat scores for CD13.

Due to the historic channelization of CD13, and poor-fair MSHA score, the assessment of CD13 was brought into the UAA process. It was determined that the habitat of CD13 does not have the ability to support good quality habitat for aquatic life, as a result of the MSHA score. Therefore, CD13 was assessed using the modified Use TALU criteria.

Although the MSHA score was poor-fair overall, substrate and channel morphology scored particularly low as noted in Figure 18. Substrate was the first low scoring component of the MSHA score, as indicated by the dominance of sand and silt. Healthy fish communities need coarse substrate in order to build nests and spawn. Excessive fine sediment also affects juvenile fishes, as the sediment is stirred into the water column creating TSS, it can easily tear sensitive juvenile fish gills. Similarly, many sensitive macroinvertebrates also have specialized gills that are used to breathe DO. Excessive fine sediments can damage these gills, similar to juvenile fishes, making the creek inhabitable for sensitive species.

Channel morphology was another low scoring component of the MSHA evaluation. The MSHA indicated that there was minimal channel depth variability, fair sinuosity, and no channel development (no riffles or pools). Fish and macroinvertebrates need channel depth variability to use as cover from predation and refuge during high precipitation events. No change in the channel depth combined with fair sinuosity and poor channel development impedes the fish and macroinvertebrate's ability to inhabit the creek throughout the summer, especially during high flow events which can flush these communities downstream. The lack of good channel morphology is caused by the channelization of the creek, as the manipulation of the channel has been designed to move water quickly, by mechanically removing channel sinuosity, pools, and riffles.

As a result of a modified use categorization it is acknowledged that habitat is limiting in CD13 and therefore a lack of habitat is considered a stressor to aquatic life.

Hydrology and geomorphology

Over time, there have been many changes on the landscape that have changed the natural hydrology and geomorphology of CD13, and the entire subwatershed. The most significant historical changes to the landscape have been land conversion from mature forests and woody wetlands to cultivated fields and pastures along with the channelization of the natural streams and wetlands. CD13 has been

straightened along the entire length of the AUID. Historically, CD13 was comprised of multiple woody wetlands and small stream channels.

As the channel was altered to drain the landscape, a new channel was cut through mixed forest and woody wetlands, creating a direct connection to Wing River. This channel alteration accelerates stream flow, resulting in higher flows during precipitation events which achieves the agricultural land use drainage goals, but causes instability. Water leaves the landscape quickly, resulting in periods of higher flow than what would have naturally occurred. As the landscape drains, water that was once held in the upstream wetlands is flushed downstream, carrying low DO water throughout the reach. Then, as these flows quickly drain, the flow regime quickly transitions to intermittent, reaching stagnant conditions starting mid- late in the summer (Figure 19, Figure 20). Although 2023 was a dry summer, CD13 was already mostly dry by late July. The water that was present in the channel was very shallow groundwater seeping into the channel.

Figure 19: CD13 on August 1, 2023. Channel was nearly dry and not connected either upstream or downstream of the road crossing.

Figure 20: CD13 on 9/19/23, showing a dry channel.

Therefore, due to the altered hydrology and geomorphology of CD13 causing the channel to dry up, it is considered to be the primary stressor within CD13.

Connectivity

The culvert crossing by 11UM079 off 106th Street. does appear to be a fish barrier. The culvert on 106th Street has very high velocities during high flows and very shallow water levels during low flows as seen in Figure 21 and Figure 22 below. This culvert is a barrier to fish movement during certain flow regimes.

Figure 21: CD13 on 4/25/2023, showing high velocity leaving culvert.

Figure 22: CD13 on 7/28/2023, showing very low water levels leaving culvert.

Stressor signals from biology

Macroinvertebrates

Macroinvertebrates were also sampled in 2010 as part of the cycle I watershed monitoring effort. Seventy-one percent of the macroinvertebrate community that was sampled in 2010 was comprised of taxa that are considered to be tolerant of pollutants, and 5.8% of the community was considered to be very tolerant of pollutants. *Simulium (blackfly)* and *Baetis* (mayfly) dominated the sample and are both considered to be tolerant taxa.

TSS taxa tolerance was investigated using the macroinvertebrate communities. In the 2011 sample, one intolerant taxa, six tolerant taxa, and no very tolerant taxa were collected (7). Overall, the

macroinvertebrate community within CD13 indicates that TSS is not a stressor to the macroinvertebrate community due to the presence of intolerant taxa in both years samples.

DO tolerance was also investigated using the macroinvertebrate communities. In 2011 and 2022, one very intolerant, one intolerant taxa, eight tolerant taxa, and two very tolerant taxa were collected (Table 6). Although there are a few intolerant taxa present, tolerant and very tolerant taxa dominated the sample, and indicate that low DO most likely is a stressor to the macroinvertebrate community within CD13. This low DO signature by the macroinvertebrate community may further suggest that low DO is a stressor to the fish community.

The final tolerance indicator that was investigated within the macroinvertebrate community was phosphorus tolerance. In the 2011 and 2022 sample, one and four intolerant taxa, nine and eight tolerant taxa, and three and five very tolerant taxa were collected (Table 6). These tolerance indicators within the macroinvertebrate community indicate that phosphorus is a possible secondary stressor to the macroinvertebrate community within CD13.

Table 6: Macroinvertebrate tolerance index values for CD13.

Parameter	Taxa Tolerance	2011 Sample	2022 Sample
DO	# Intolerant	1	1
	# Tolerant	8	8
	# Very Intolerant	1	1
	# Very Tolerant	2	3
Phosphorus	# Intolerant	1	4
	# Tolerant	9	8
	# Very Intolerant	0	1
	# Very Tolerant	3	5
TSS	# Intolerant	1	4
	# Tolerant	6	5
	# Very Intolerant	0	1
	# Very Tolerant	0	2

Fish

DO tolerance was also investigated using the fish communities. All three fish community TIVs show that low DO is evident in the fish samples. All three fish sampled showed over 86% DO tolerant species sampled at 11UM079. There are a no intolerant taxa present, tolerant and very tolerant taxa dominated the sample, and indicate that low DO most likely is a stressor to the fish community within CD13. The low DO signature by the macroinvertebrate community may further suggest that low DO is a stressor to the fish community.

TSS taxa tolerance was investigated using the fish communities. All three fish samples show that the conditional probability of meeting the TSS standard is between 63% and 70% based on the fish community sampled. Overall, the fish community within CD13 indicates that TSS is not a stressor to the fish community due to the presence of TSS sensitive taxa in both years samples.

The final tolerance indicator that was investigated within the fish community was phosphorus tolerance. All three samples showed near Class 7 average TIV scores for phosphorus. This indicates that phosphorus is not a stressor to the fish community based on the community TIV scores.

Composite conclusion from biology

The TSS TIVs were inconclusive for macroinvertebrates and suggested that TSS is not a stressor to the fish community, the DO TIVs show a strong stressor relationship for both macroinvertebrates and fish, and that phosphorus is a potential secondary stressor to the macroinvertebrate community and not a stressor to the fish community.

The habitat and geomorphology are heavily altered within CD13 and are the primary stressors to the aquatic life within the ditch. In August and September of 2023, the channel was dry with only stagnant pools of water left between large stretches of dry channel.

Conclusions about stressors

The fish sample from 2011 passed the IBI with a score of 38.6 and had 6 species sampled. Fish sampling during 2011 occurred during a high-water year as indicated by reviewing the hydrograph from Leaf river. In 2021, the area was under a significant drought, and it is believed that the channel would have been dry at certain periods of the year. The 2022 season had more normal rainfall and flow was probably not a problem this monitoring year as is seen in the flow patterns from the Leaf River gage (H13060001). The fish sample showed a high probability of low DO as a stressor when reviewing the fish TIV data and macroinvertebrate TIVs. The unstable DO levels within the chemistry dataset collected on CD13 further indicate that DO is a stressor to the aquatic life within the ditch. The low DO conditions appear to be connected to low flow conditions in the channel.

Altered hydrology and geomorphology have also impacted the aquatic life within CD13, by removing habitat, increasing the amount of nutrients drained from the landscape, and altering the historic flow conditions. Good quality habitat such as coarse substrate, good channel development, and good depth variability are critical for the survival of sensitive fish and macroinvertebrates. Sensitive fish species like the Hornyhead Chub utilize coarse substrate to build nests for spawning. Similarly, sensitive macroinvertebrate taxa use coarse substrate, aquatic vegetation, and woody debris as attachment surfaces to avoid floating downstream, which allows them to feed. These important habitat types have been removed by the ditching process. In August and September of 2023, the channel was dry with only stagnant pools of water left between large stretches of dry channel.

Connectivity is also a main stressor to the fish community in CD13. High velocities within the culvert during high flows will impede the ability of fish to migrate through the culvert. This channel also gets very low during periods of low rainfall. During this time the culvert is too shallow to allow for fish passage.

Hay Creek (07010107-526)

Impairment: Hay creek flows for 5.89 miles and is a Coldwater General Use WID. Fish were visited at two locations (15EM015, 11UM041). Fish IBI scores were below the general use threshold at both sites in 2021 and 2022. The macroinvertebrate IBI scores were below the general use threshold during both the 2011 and 2022 sampling events. The resulting low scores have resulted in biological impairment for both fish and macroinvertebrates.

Data and Analysis

Chemistry

Water chemistry data is limited to the samples during 2011 and 2023 (Table 7).

Table 7: Water chemistry data collected on Hay Creek.

Parameter	Sample Count	Applicable Standard	Avg. Results	Min. Results	Max. Results
Temperature, water	68		17.72	10.0	25.0
Specific conductance	11		561	487	650
pH	10	6.5-8.5	7.89	7.59	8.44
Dissolved oxygen (DO)	17	7.0 mg/L	8.41	5.10	14.8
Inorganic nitrogen (nitate and nitrite)	12	10 mg/L	2.06	0.54	4.58
Total phosphorus	11	0.1 mg/L	0.03	0.02	0.06
Transparency, tube with disk	68	55	86.62	26.00	100
Total suspended solids	11	10	2.87	0	11.0

Nutrients – Phosphorus

Phosphorus values from the dataset show that the average phosphorus concentration is 0.06 mg/L, which is below the Central Region River Nutrient standard of 0.100 mg/L (Table 7). This reach is below the TP standard and TP is not a stressor to the biology. This is further supported by the Fish TIV and macroinvertebrate TIVs also show that TP is not impacting the biological communities.

Nutrients – Inorganic nitrogen

Inorganic nitrogen values are well below the 10 mg/L statewide standard for drinking water. Maximum concentrations of nitrogen are above the proposed inorganic nitrogen standards for aquatic life (around 3 mg/L). While the average sample concentration is at 2.06 mg/L. The fish community TIV suggests that the fish community at site 11UM041 is being stressed by elevated nitrogen concentrations. Both fish samples had elevated percentage of fish species that are tolerant to nitrogen. Macroinvertebrate samples also had a high percentage of taxa that are tolerant or very tolerant to elevated nitrogen. This indicates that Inorganic nitrogen is a stressor to aquatic life from the current dataset.

Dissolved Oxygen

If DO is below 5mg/L for extended periods of time, biological communities can be severely impacted. DO was collected 14 times in 2011 and 2023 (Table 7). The average DO concentration was 8.41 mg/L.

Eighteen percent of the collected DO concentrations were below the 7 mg/L standard for 2A waters. All of the low DO readings were recorded at sampling site S012-025. There were four total samples collected in 2011 and 2022 and all four are below the standard. Based on this limited data it appears the most downstream section of WID 526 has a low DO issue. Biological sampling site 11UM041 is collocated with S012-025. This site also has a fish TIV score for DO that suggests that the fish community is affected by low DO. The macroinvertebrate TIV for DO also show that site 11UM041 has a high percentage of taxa that are tolerant to low DO. Reviewing the available data supports that low DO is a stressor in the lower section of Hay Creek.

Total Suspended Solids

TSS data is limited to 11 samples in 2023 (Table 7). The values were well below the standard. TSS is not considered a stressor to the macroinvertebrates.

Conductivity

Specific conductivity values are within range on Hay Creek (Table 7) and is not considered to be a stressor within Hay Creek.

Temperature

Temperature values were within range on Hay Creek (Table 7) and is not considered to be a stressor within Hay Creek.

Habitat

Habitat was classified as poor-good on Hay Creek, through the MSHA evaluation at the two fish sample sites (Figure 23).

Figure 23. MSHA habitat scores for Hay Creek.

Although the MSHA score was poor-good overall, land use and channel morphology scored particularly low as noted in Figure 17. Land use scores low because the monitoring sites are located in agricultural area. The immediate land use is row crop or pasture. There are also a high number of center pivot irrigation systems located along the channel. The withdrawal of near surface groundwater can have an impact on stream flow, which in turn can have an impact on the channel morphology. This lower flow regime can cause fine sediment to settle in the channel as the flows are minimized during periods of less precipitation. Substrate scored poorly in 2021 and 2022 at both sampling locations. Healthy fish

communities need coarse substrate in order to build nests and spawn. Excessive fine sediment also affects juvenile fishes, as the sediment is stirred into the water column creating TSS, it can easily tear sensitive juvenile fish gills. Similarly, many sensitive macroinvertebrates also have specialized gills that are used to breathe DO. Excessive fine sediments can damage these gills, similar to juvenile fishes, making the creek inhabitable for sensitive species.

Channel morphology was another low scoring component of the MSHA evaluation. The MSHA indicated that there was minimal channel depth variability, fair sinuosity, and no channel development (no riffles or pools). Fish and macroinvertebrates need channel depth variability to use as cover from predation and refuge during high precipitation events. No change in the channel depth combined with fair sinuosity and poor channel development impedes the fish and macroinvertebrate's ability to inhabit the creek throughout the summer, especially during high flow events which can flush these communities downstream. The lack of good channel morphology is caused by the land use surrounding the creek. The fish TIV for embeddedness indicates the fish community is affected by extra fines and sediment accumulating along the channel bottom. Both sampling sites had very high percentages of tolerant taxa to both embeddedness and fines.

Reviewing the available data suggest that habitat is a stressor to the biology.

Conclusions about stressors

The fish sample from 2011 passed the IBI with a score of 49.0 at site 11UM041. The other three fish samples all were below the FIBI threshold. Fish sampling during 2011 occurred during a high-water year as indicated by reviewing the hydrograph from Leaf River. In 2021 the area was under a significant drought, and it is believed that the channel would have been dry at certain periods of the year. The 2022 season had more normal rainfall and flow was probably not a problem this monitoring year as is seen in the flow patterns from the Leaf River gage (H13060001). The fish sample showed a high probability of low DO as a stressor when reviewing the fish TIV data and macroinvertebrate TIVs. The unstable DO levels within the chemistry dataset collected on the furthest downstream portion of Hay Creek further indicate that DO is a stressor to the aquatic life. The low DO conditions appear to be connected to wetland and land use conditions along the channel.

Land use and substrate have also impacted the aquatic life within Hay Creek, by smothering habitat, increasing the amount of nutrients drained from the landscape, and altering the historic flow conditions due to the increased amount of center pivot irrigation. Good quality habitat such as coarse substrate, good channel development, and good depth variability are critical for the survival of sensitive fish and macroinvertebrates. Sensitive fish species like the Hornyhead Chub utilize coarse substrate to build nests for spawning. Similarly, sensitive macroinvertebrate taxa use coarse substrate, aquatic vegetation, and woody debris as attachment surfaces to avoid floating downstream, which allows them to feed. These important habitat types have been impacted in the channel.