Stressor Identification Update

Buffalo River and Upper Red River of the North Watersheds

January 2023

Introduction

The Minnesota Pollution Control Agency (MPCA) utilizes a watershed approach to systematically monitor and assess surface water quality in each of the state's 80 major watersheds on a rotating 10-year basis. A key component of this approach is Intensive Watershed Monitoring (IWM), which includes biological (i.e., fish and macroinvertebrate) monitoring to evaluate overall stream health. Based on the results of biological monitoring, an Index of Biological Integrity (IBI) score is calculated for each fish (F-IBI) and macroinvertebrate (M-IBI) monitoring visit to a stream reach. A reach with an IBI score below an established class threshold may be assessed as "impaired", or unable to support its designated beneficial use, for aquatic life. Stressor identification (SID) is subsequently performed on reaches with a bioassessments impairment to determine the probable causes, or "stressors", that are likely contributing to the impairment. The findings from SID are then 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 the impaired condition.

Part 1: Cycle 1 (Previous) Assessment Results and SID Findings

The MPCA initially performed biological monitoring of watercourses in the Buffalo River Watershed (BRW) and Upper Red River of the North Watershed (URRW) in 2008 and 2009; the location of the watersheds is shown in Figure 1. A total of 15 reaches in the BRW and 2 reaches in the URRW had sufficient biological monitoring data following Cycle 1 IWM to be assessed. The assessment of the data identified eight bioassessments impairments along five reaches, including segments of the Buffalo River (Assessment Unit Identifier [AUID] 09020106-593), Buffalo River, South Branch (AUID 09020106-505), Deerhorn Creek (AUID 09020106-507), Spring Creek (AUID 09020106-534), and Whiskey Creek (AUID 09020104-520). These impairments were included on the 2012 Impaired Wates List. Additional information on the Cycle 1 IWM assessment process and results can be found in the *Buffalo River Watershed Monitoring and Assessment Report* (MPCA 2012) and the *Upper Red River of the North Watershed Monitoring and Assessment Report* (MPCA 2013).

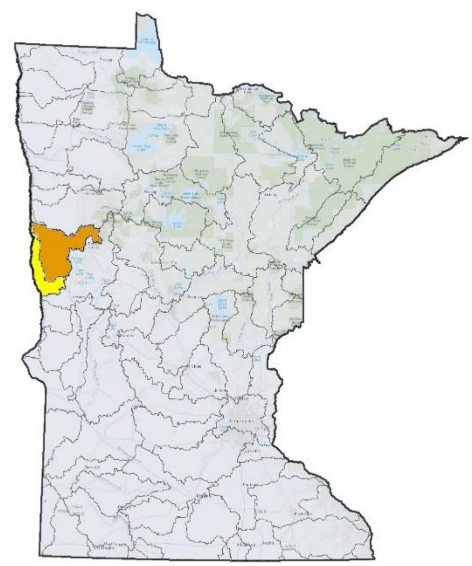

Figure 1. Map of the BRW (Orange) and the URRW (Yellow). Both watersheds are part of the Buffalo-Red River Watershed District (BRRWD) and Buffalo-Red River Watershed (BRRW) One Watershed One Plan (1W1P) Planning Area.

The bioassessments impairments identified from the assessment of Cycle 1 IWM data were evaluated in the *Buffalo River Watershed Stressor Identification Report* (MPCA 2014a) and the *Upper Red River of the North Watershed Biotic Stressor Identification Report* (MPCA 2016). Connectivity barriers (e.g., dams, perched culverts, and beaver dams) were found to be limiting fish passage along the impaired segments of the Buffalo River, Deerhorn Creek, and Spring Creek. The removal of the Ganz Dam, located just downstream of the U.S. Highway 10 crossing on the Buffalo River, South Branch (AUID 09020106-503), was proposed as “perhaps the single most important” potential action for improving the health of the fish community in the BRW. All the impaired reaches were determined to be prone to high and quick peak flows and/or prolonged periods of low or no discharge. Historical changes in land cover (e.g., conversion of native vegetation to cropland) and drainage patterns (e.g., channelization and ditching) were noted as the primary factors contributing to this “flashiness”. Alterations to the natural hydrology of the landscape were also found to be responsible for the degradation of instream habitat (e.g., bank erosion and embeddedness of coarse substrate) for most of the reaches. Four of the five impaired reaches were noted to be prone to periods of high total suspended solids (TSS). The farming of headwater streams, field erosion, and streambank/bed erosion were identified as factors affecting sediment loads. Lastly, low dissolved oxygen (DO) was a stressor for the impaired segments of the Buffalo River, South Branch, Deerhorn Creek, and Whiskey Creek. While the severity of low DO conditions varied amongst the reaches, the lowest concentrations generally occurred in the summer, when flow is low and the water temperature is high.

Part 2: Cycle 2 Assessment Results and SID Findings

Between 2019 and 2020, the MPCA performed a second round of biological monitoring in the BRW and URRW. A total of 26 reaches in the BRW and 7 reaches in the URRW had sufficient Cycle 2 biological monitoring data to be assessed. The assessment of the data resulted in the addition of nine bioassessments impairments to the 2022 Impaired Waters List; these impairments were located along nine reaches. Of these reaches, six had no prior bioassessments impairment. In addition to new impairments, the assessment of the Cycle 2 biological monitoring data resulted in the removal of the macroinvertebrate bioassessments impairment for the Buffalo River (AUID 09020106-593) and Whiskey Creek (AUID 09020104-520). Additional information on the Cycle 2 assessment process and results can be found in the *Buffalo River and Upper Red River of the North Watersheds - Watershed Assessment and Trends Update* (MPCA 2022b).

Due to the timing of Cycle 2 IWM monitoring and to align with the BRRW Comprehensive Watershed Management Plan (CWMP), Cycle 2 SID in the BRW and URRW was performed concurrently, and the associated findings are jointly presented in this update. Table 1 lists the 41 bioassessments impairments associated with 29 watercourse reaches in the watersheds that were evaluated as part of Cycle 2 SID. In addition to newly listed impairments, 26 deferred bioassessments impairments along 19 reaches were evaluated during the SID process. These impairments were added to the 2020 Impaired Waters List after an out of cycle, opt-in assessment was performed to assess previously unassessed Cycle 1 biological monitoring data under the tiered aquatic life uses framework, which was finalized after the initial Cycle 1 assessment was competed; the framework provided attainable standards for watercourses that have legally altered habitat due to past channelization or ditching. Additionally, the remaining six bioassessments impairments associated with four reaches from Cycle 1 were evaluated during the Cycle

2 SID process. These impairments were initially evaluated during Cycle 1 SID but were revisited for the purpose of further studying their associated stressors.

Stressors investigated as part of Cycle 2 SID included a loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, high TSS, low DO, high nitrate-nitrogen, and high temperature. The following subparts summarize the SID findings by stressor for the watersheds. A listing of the stressors associated with each of the bioassessments impairments is provided in Appendices A (BRW) and B (URRW). For data and information specific to each of the bioassessments impairments, including stressor analysis, please see the MPCA SID contact persons listed at the end of the report.

Table 1. List of the bioassessments impairments in the BRW and URRW that were evaluated during Cycle 2 SID.

Watershed	BRRW CWMP Planning Region[1]	Reach Name (AUID)	Reach Extent	Reach Length (mi)	Bioassessments Impairment[2]
Buffalo River	Central	Whisky Creek (09020106-509)	T137 R47W S13 to Buffalo R., S. Branch	6.9	F-IBI[D], M-IBI[D]
Buffalo River	Central	Stony Creek (09020106-510)	Headwaters to T137 R45W S2	2.1	M-IBI[D]
Buffalo River	Central	Spring Creek (09020106-534)	Unnamed Creek to Hay Creek	4.9	F-IBI[P], M-IBI[P]
Buffalo River	Central	Hay Creek (09020106-609)	T138 R46W S22 to Spring Creek	3.2	F-IBI[D], M-IBI[D]
Buffalo River	Central	Stony Creek (09020106-613)	170th St. S. to T137N R46W S5	4.3	F-IBI[N]
Buffalo River	Mainstem	Unnamed Stream (09020106-518)	Reep Lake to Unnamed Ditch	5.0	M-IBI[N]
Buffalo River	Mainstem	Unnamed Creek (09020106-576)	Unnamed Creek to Hay Creek	1.0	F-IBI[N]
Buffalo River	Mainstem	Unnamed Ditch (09020106-578)	Unnamed Creek to Unnamed Creek	1.5	M-IBI[D]
Buffalo River	Mainstem	Unnamed Creek (09020106-580)	Unnamed Creek to Buffalo Creek	3.2	F-IBI[D], M-IBI[D]
Buffalo River	Mainstem	County Ditch 16 (09020106-581)	Unnamed Creek to Buffalo Creek	6.8	F-IBI[D]
Buffalo River	Mainstem[A]	Buffalo River (09020106-593)	Buffalo Lake to Unnamed Ditch	25.7	F-IBI[P]
Buffalo River	Mainstem	Hay Creek (09020106-621)	Coord. -96.11, 46.86 to -96.12, 46.90	3.3	F-IBI[D]
Buffalo River	Northern	County Ditch 25 (09020106-538)	County Ditch 26 to Buffalo River	4.8	F-IBI[D], M-IBI[D]
Buffalo River	Northern	County Ditch 2 (09020106-556)	Unnamed Creek to Buffalo River	5.6	M-IBI[N]
Buffalo River	Northern	County Ditch 5 (09020106-563)	Headwaters to Buffalo River	6.8	F-IBI[N], M-IBI[D]
Buffalo River	Northern	County Ditch 3 (09020106-615)	130th St. N. to Buffalo River	6.2	F-IBI[D], M-IBI[D]
Buffalo River	Northern	County Ditch 39 (09020106-617)	110th St. N. to Buffalo River	6.2	F-IBI[N], M-IBI[D]
Buffalo River	Northern	County Ditch 10 (09020106-619)	80th St. N. to Buffalo River	5.8	M-IBI[D]
Buffalo River	Northern	Unnamed Creek (09020106-624)	Coord. -96.41, 46.92 to -96.45, 46.91	3.2	F-IBI[D], M-IBI[D]
Buffalo River	Southern	Buffalo R., S. Branch (09020106-505)	Deerhorn Creek to Whisky Creek	18.9	M-IBI[P]
Buffalo River	Southern	Deerhorn Creek (09020106-507)	Headwaters to Buffalo R., S. Branch	21.9	F-IBI[P], M-IBI[P]
Buffalo River	Southern	Lawndale Creek (09020106-530)	Unnamed Creek to Unnamed Ditch	0.6	F-IBI[D]

Watershed	BRRW CWMP Planning Region[1]	Reach Name (AUID)	Reach Extent	Reach Length (mi)	Bioassessments Impairment[2]
Buffalo River	Southern	Unnamed Creek (09020106-544)	Unnamed Ditch to Buffalo R., S. Branch	3.2	M-IBI[D]
Buffalo River	Southern	Buffalo R., S. Branch (09020106-605)	Unnamed Creek to Deerhorn Creek	7.9	F-IBI[D], M-IBI[D]
Upper Red River of the North	Upper Red	Unnamed Creek (09020104-516)	County Ditch 6A to Whiskey Creek	3.6	F-IBI[D], M-IBI[N]
Upper Red River of the North	Upper Red	Unnamed Creek (09020104-533)	Unnamed Creek to Whisky Creek	1.0	F-IBI[N]
Upper Red River of the North	Upper Red	Unnamed Ditch (09020104-537)	Unnamed Ditch to Red River	4.9	F-IBI[D]
Upper Red River of the North	Western	Wolverton Creek (09020104-549)	Unnamed Creek to Railroad Bridge	9.4	F-IBI[N]
Upper Red River of the North	Western	Wolverton Creek (09020104-550)	Railroad Bridge to Red River	3.3	F-IBI[D]

[1] A map of the BRRW CWMP Planning Regions is provided on the BRRWD's Public GIS Viewer.

[2] Aquatic life impairment for fish bioassessments (F-IBI) and/or benthic macroinvertebrate bioassessments (M-IBI).

[P] Prior (Cycle 1 IWM) bioassessments impairment.

[D] Deferred (Cycle 1 IWM) bioassessments impairment.

[N] New (Cycle 2 IWM) bioassessments impairment.

2.1 Loss of Longitudinal Connectivity

Longitudinal connectivity in stream ecosystems refers to how water features are linked to each other on the landscape and how locations within a stream are connected. Dams and other impediments (e.g., grade control structures and perched culverts) can directly block seasonal fish migration for reproduction and overwintering. Connectivity barriers can also change stream habitat by altering streamflow, water temperature, and sediment transport (Cummins and Klug 1979; Waters 1995).

Findings

- According to Table 2, 20 (91%) of the reaches with a fish bioassessments impairment were adversely affected by one or more connectivity-related barriers.
- The Ganz Dam (Figure 2), which is an eight-foot high, privately owned structure on the Buffalo River, South Branch (AUID 09020106-503), limits connectivity for all upstream watercourses in the subwatershed, including seven reaches with a fish bioassessments impairment. The dam is a barrier to fish passage at most flow conditions; connectivity can be restored during flood events.
- The Stinking Lake Dam, located on the upstream portion of Hay Creek (AUID 09020106-513), is 17 feet in height and is a complete barrier to connectivity for all upstream watercourses, including two reaches with a fish bioassessments impairment. The structure is owned and operated by the BRRWD as part of a flood storage project.
- Grade control structures obstruct connectivity on nine reaches with a fish bioassessments impairment.
- Perched culverts impact fish passage on eight of the impaired reaches, including Unnamed Creek (AUID 09020106-576); see Figure 2. Undersized culverts, which can act as a velocity barrier, are also a potential concern for many reaches.
- Beaver dams were noted along 14 of the reaches with a fish bioassessments impairment. Many of these beaver dams were a partial or complete barrier to fish passage.
- Reaches with connectivity stressors generally scored below the statewide average in the abundance of migratory and late-maturing fish taxa.

Figure 2. Images of connectivity-related issues, including the Ganz Dam located upstream of the US Highway 10 crossing along the Buffalo River, South Branch (AUID 09020106-503) on August 28, 2019 (left) and a perched culvert located at the 140th Ave crossing along Unnamed Creek (AUID 09020106-576) on April 12, 2021 (right).

Table 2. Summary of the proportion of fish bioassessments impaired reaches per BRRW CWMP planning region affected by a loss of longitudinal connectivity as a stressor.

Planning Region	Central	Mainstem	Northern	Southern	Upper Red	Western
# of impaired reaches affected/ # of impaired reaches	4/4	5/5	4/5	3/3	2/3	2/2

2.2 Flow Regime Instability

Flow is considered a "master variable" that affects many fundamental characteristics of stream ecosystems, including biodiversity (Power et al. 1995; Poff et al. 1997). The natural flow regime of most streams in the Red River of the North Basin has been anthropogenically altered, primarily to expedite drainage for agricultural purposes. Drainage-related practices (e.g., ditching, channelization, and subsurface tiling) are known to cause increased and quicker peak discharges following rain events and reduced base flows during dry periods (Franke and McClymonds, 1972; Mitsch and Gosselink 2007). This "flashiness" or instability in the flow regime tends to limit species diversity and favor taxa that are tolerant to disturbances (Bunn and Arthington 2002; Bragg et al. 2005; Poff and Zimmerman 2010).

Findings

- As identified in Table 3, flow regime instability was found to be a stressor for 28 (97%) of the bioassessments impaired reaches.
- Reaches affected by flow regime instability often experience insufficient baseflow during the late summer and/or high peak flows following the spring melt and high intensity rain events. Figure 3 contrasts a hydrograph for Stony Creek (AUID 09020106-502) and Wolverton Creek (AUID 09020104-550); Wolverton Creek has a relatively flashy flow regime compared to Stony Creek. Figure 4 shows Wolverton Creek at low flow conditions and during a flood event.

- Most (69%) of the impaired reaches have an associated subwatershed with a high proportion (>50%) of physically altered (i.e., channelized, ditched, or impounded) watercourses.
- The annual mean flow on the Buffalo River (AUID 09020106-595) near Hawley increased 125% between 1946 and 2020. Additionally, all 10 of the highest recorded flows on this reach have occurred since 1993 (MPCA 2022b).
- Mean annual precipitation in the BRRW increased at a rate of 0.01 inches/decade between 1895 and 2020 (BRRWD 2020). Additionally, the frequency of "mega-rain" events (≥ 6 inches) has increased statewide since 2000 (BRRWD 2020).
- According to the MPCA (2014a), Minnesota Department of Natural Resources (DNR) staff documented that the annual and 30-year mean flow on the Buffalo River (AUID 09020106-501) at Dilworth had increased at "a much faster rate than precipitation". Land use changes and drainage were noted as contributing to this difference.
- Flow regime instability was found to limit biotic diversity and favor fish and macroinvertebrate taxa that are generalist, early maturing, pioneering, short-lived, and tolerant to disturbances.

Table 3. Summary of the proportion of bioassessments impaired reaches per BRRW CWMP planning region affected by flow regime instability as a stressor.

Planning Region	Central	Mainstem	Northern	Southern	Upper Red	Western
# of impaired reaches affected/ # of impaired reaches	5/5	6/7	7/7	5/5	3/3	2/2

Figure 3. Comparison of 2020 flow data for Site H58057001 (90th St S crossing; 158 square mile drainage area) along Stony Creek (AUID 09020106-502) and Site H57037001 (130th Ave S crossing; 100 square mile drainage area) along Wolverton Creek (AUID 09020104-550).

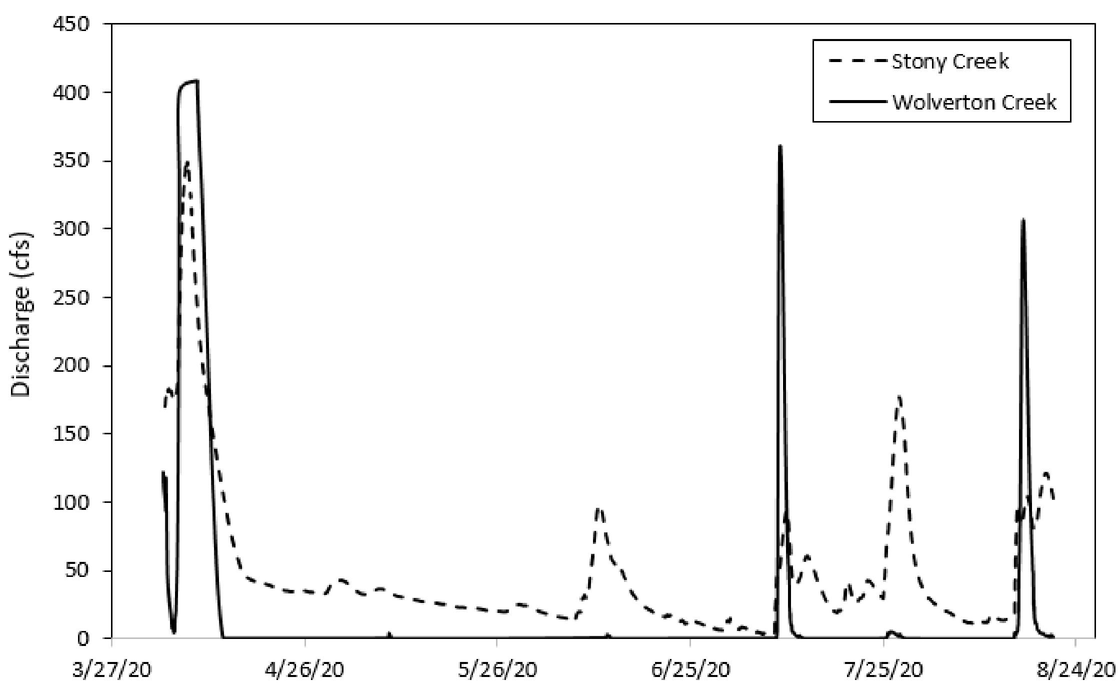

Figure 4. Images of flow conditions along Wolverton Creek, including low flow conditions at the 130th Ave S crossing (AUID 09020104-550) on August 14, 2019 (left) and flooding (post eight inch "mega-rain" event) at the 120th St crossing (AUID 09020104-549) on June 26, 2013 (right).

2.3 Insufficient Physical Habitat

Physical habitat is primarily a function of channel geomorphology (Rosgen 1996) and flow (Bovee 1986). Geomorphology is determined naturally by geology and climate (Leopold et al. 1994), but may be altered directly by channelization and indirectly by land use changes affecting runoff and the removal of riparian vegetation (Aadland et al. 2005). A high frequency of bank-full flows often results in a subsequent increase in channel cross-sectional area (Verry 2000) and a decrease in sinuosity (Verry and Dolloff 2000). These geomorphic changes can result in reduced habitat quality and diversity, loss of interstitial space due to embeddedness, loss of pool depth due to sedimentation, and loss of cover (Aadland et al. 2005). Biotic population changes can result from decreases in availability or quality of habitat by way of altered behavior, increased mortality, or decreased reproductive success (EPA 2012).

Findings

- According to Table 4, 26 (90%) of the bioassessments impaired reaches are affected by insufficient physical habitat as a stressor.
- Most (69%) of the impaired reaches had at least one MPCA Stream Habitat Assessment (MSHA) score that was characterized as "poor".
- Common habitat deficiencies noted in the watersheds included: bank erosion, minimal shading, absence of riffle habitat, absence of coarse substrate, embeddedness of coarse substrate, limited cover types (e.g., boulders, deep pools, and undercut banks), limited velocity types, poor channel stability, and poor channel development.
- A majority (59%) of the bioassessments impaired reaches had a channel that was mostly (>50%) altered, along with a subwatershed with mostly (>50%) altered watercourses (MPCA 2013).
- Of the bioassessments impaired reaches, the lowest MSHA scores occurred in the Northern and Upper Red planning regions. Generally, these reaches and the watercourses in their associated subwatershed are highly (>50%) altered. In addition, the surficial geology of these areas (i.e.,

lakeplain) inherently limits the availability of certain habitat facets, such as coarse substrate and riffles.

- Reaches with insufficient physical habitat generally lacked riffle dwelling, simple lithophilic spawning, and benthic insectivorous fish taxa, while the macroinvertebrate communities commonly lacked clinger taxa and contained a high percentage of burrower, legless, and sprawler taxa. These community compositions often indicate that critical habitat facets (e.g., coarse substrate and riffles) have been degraded or are naturally lacking.

Table 4. Summary of the proportion of bioassessments impaired reaches per BRRW CWMP planning region affected by insufficient physical habitat as a stressor.

Planning Region	Central	Mainstem	Northern	Southern	Upper Red	Western
# of impaired reaches affected/ # of impaired reaches	4/5	6/7	7/7	4/5	3/3	2/2

2.4 High Total Suspended Solids

TSS is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water. Soil erosion from agricultural fields is commonly the largest source of sediment to streams in the Red River Basin (Lauer et al. 2006). According to Waters (1995), high TSS can cause harm to fish and macroinvertebrates through two major pathways: 1) direct, physical effects (e.g., abrasion of gills and avoidance behavior) and 2) indirect effects (e.g., loss of visibility and increase in sediment oxygen demand). High TSS can also reduce the penetration of sunlight and thus impede photosynthetic activity and limit primary production (Munavar et al. 1991; Murphy et al. 1981).

Findings

- As identified in Table 5, high TSS was found to be a stressor for 15 (52%) of the bioassessments impaired reaches. This stressor was most prevalent in the Mainstem, Southern, and Upper Red planning regions.
- Wolverton Creek (AUID 09020104-550) has an existing TSS impairment that was initially included on the 2020 Impaired Waters List. A TMDL is scheduled to be developed for this impairment in 2023. Additionally, five reaches have an impairment for turbidity, which is often strongly correlated to TSS. A TMDL was completed for each of these impairments, except for the one associated with the Buffalo River (AUID 09020106-593). The TMDL for this impairment will be prepared in 2023.
- A total of 12 bioassessments impaired reaches had at least one monitoring site with a TSS standard exceedance rate of greater than 10% (minimum of nine TSS values). Nine of these reaches were in the Mainstem and Upper Red planning regions.
- The impact of high TSS on biological communities appears to be most pronounced in the Upper Red planning region. Figure 5 displays images of sediment-related issues in this region.
- Generally, there is a direct relationship between TSS concentrations and flow in the watersheds. High TSS is common during the spring snowmelt, when agricultural fields are particularly vulnerable to erosion, as well as following larger rain events (MPCA 2022b).
- Reaches prone to high TSS generally scored above the statewide average in the abundance of TSS tolerant taxa, as well as below the statewide average in the abundance TSS sensitive taxa.

Table 5. Summary of the proportion of bioassessments impaired reaches per BRRW CWMP planning region affected by high TSS as a stressor.

Planning Region	Central	Mainstem	Northern	Southern	Upper Red	Western
# of impaired reaches affected/ # of impaired reaches	1/5	4/7	1/7	3/5	2/3	1/2

Figure 5. Images of sediment-related issues in the Upper Red Planning Region, including a large sediment accumulation adjacent to 180th Ave along County Ditch 6A (AUID 09020104-515), just upstream of Unnamed Creek (AUID 09020104-516), on April 25, 2019 (left) and turbid conditions at Site S005-322 (130th Ave S crossing) along Wolverton Creek (AUID 09020104-550) on July 17, 2019 (right).

2.5 Low Dissolved Oxygen

DO refers to the concentration of oxygen gas within the water column. Oxygen diffuses into water from the atmosphere (turbulent flow enhances this diffusion) and from aquatic plants during photosynthesis. The concentration of DO changes seasonally and daily in response to shifts in ambient air and water temperature, along with various chemical, physical, and biological processes within the water column. Low or highly fluctuating DO concentrations can cause adverse effects (e.g., avoidance behavior, reduced growth rate, and fatality) for many fish and macroinvertebrate species (Allan 1995; Davis 1975; Marcy 2007; Nebeker et al. 1992; EPA 2012). The critical conditions for DO usually occur during the late summer, when the water temperature is high and stream flow is low. Additionally, eutrophication (i.e., increased phosphorus) can cause excessive aquatic plant and algal growth, which can ultimately result in a decline in daily minimum DO concentrations and an increase in the magnitude of daily DO concentration fluctuations.

Findings

- As noted in Table 6, of the 29 bioassessments impaired reaches, 16 (55%) were affected by low DO as a stressor. This stressor was most prevalent in the Northern and Southern planning regions.
- The following bioassessments impaired reaches also have an existing DO impairment on the Impaired Waters List: Buffalo River, South Branch (AUIDs 09020106-505 and 09020106-605), County

Ditch 10 (09020106-619), and Wolverton Creek (AUID 09020104-549). A TMDL for each of these impairments will be completed in 2023.

- The availability of discrete DO data was limited for most of the bioassessments impaired reaches. Four reaches had at least one monitoring site with a DO standard violation rate of greater than 10% (minimum of 10 DO measurements). However, very few of the discrete DO measurements were collected prior to 9:00 a.m., when values are typically lowest.
- Continuous DO monitoring was performed on 22 of the bioassessments impaired reaches between 2019 and 2021. Monitoring was conducted during the months of July and August, when the water temperature is often the highest; there is an inverse relationship between temperature and DO. Each reach was monitored at least once for a minimum period of seven consecutive days. A total of 14 of these reaches had at least 1 monitoring period in which at least 10% of the recorded values violated the applicable DO standard. Six of these reaches are in the Northern Planning Region.
- Eutrophication appeared to adversely impact the DO regime of most (81%) of the reaches with a low DO issue. The effects of eutrophication, such as high DO flux (Figure 6), were often exacerbated by low flow conditions. Figure 7 displays images of eutrophication documented in the watersheds.
- Total phosphorus (TP) is a causative variable for eutrophication. A total of 24 of the bioassessments impaired reaches had at least 1 monitoring site with a TP standard exceedance rate of greater than 10% (minimum of nine TP values). High TP concentrations are not only a concern for the bioassessments impaired reaches in these watersheds, but also Lake Winnipeg, which is located downstream (MPCA 2014b).
- Response indicators of eutrophication include chlorophyll-*a* (chl-*a*) and DO flux. Four reaches had at least one monitoring site with a chl-*a* standard exceedance rate of greater than 10% (minimum of nine chl-*a* values). The DO flux data for the reaches were derived from the continuous DO monitoring. A total of seven reaches had least one monitoring period in which the mean daily DO flux exceeded the applicable DO flux standard.
- Wetland conditions appeared to impact the DO regime of Unnamed Ditch (AUID 09020106-578) and Unnamed Creek (AUID 09020106-580). These reaches are located within or near the Hamden Slough National Wildlife Refuge.
- Reaches prone to low DO generally scored above the statewide average in the abundance of low DO tolerant taxa, as well as below the statewide average in the abundance low DO sensitive taxa.

Table 6. Summary of the proportion of bioassessments impaired reaches per BRRW CWMP planning region affected by low dissolved oxygen as a stressor.

Planning Region	Central	Mainstem	Northern	Southern	Upper Red	Western
# of impaired reaches affected/ # of impaired reaches	2/5	2/7	6/7	4/5	0/3	1/2

Figure 6. Continuous DO data (July 3-15, 2019) for Site W58042001 (CSAH 11 crossing) along County Ditch 25 (AUID 09020106-538). Excessive primary production caused DO supersaturation (maximum concentration of 19.5 mg/L) during the day, low DO concentrations at night, and high daily DO flux (mean of 10.1 mg/L).

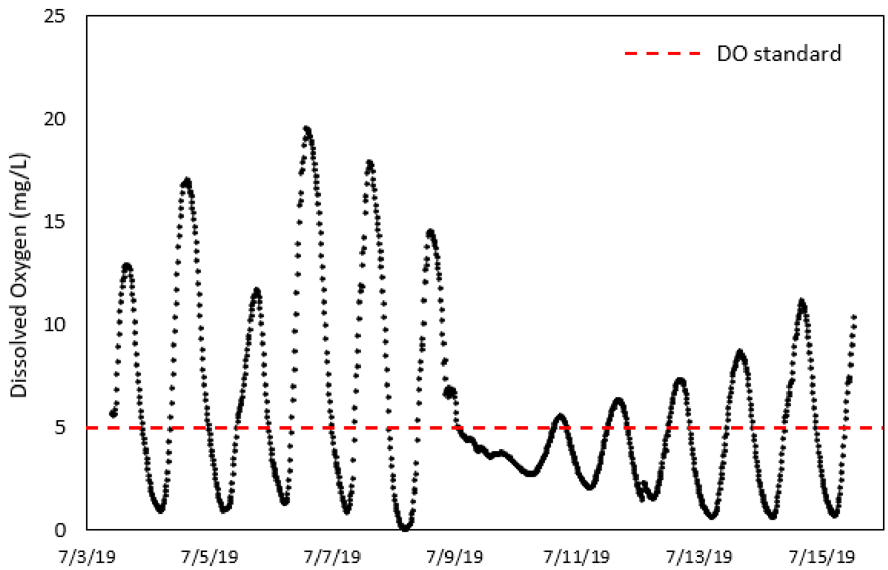

Figure 7. Images of eutrophication-related conditions, including excessive filamentous algae at Station 08RD067 (near US Highway 75 crossing) along Unnamed Ditch (AUID 09020104-537) on June 19, 2019 (left) and excessive filamentous algae and duckweed at Site S010-118 (near 190th Ave crossing) along Unnamed Stream (AUID 09020106-518) on July 29, 2021 (right).

2.6 High Nitrate-Nitrogen

Nitrate (NO3) is the most abundant form of nitrogen in aquatic ecosystems. The transport pathways of nitrogen in the environment vary depending on geology and hydrology. When water moves quickly through the soil profile, as in the case of areas that are heavily tiled or dominated by outwash, nitrate transport through leaching can be substantial. Apart from its function as a biological nutrient, some levels of nitrate can become toxic to organisms. Nitrate toxicity can affect fish and macroinvertebrates depending on the concentration, length of exposure, and sensitivity of the individual organism (Grabda et al. 1974; Camargo and Alonso 2006).

Findings

- High nitrate-nitrogen was not found to be a stressor for any of the bioassessments impaired reaches (Table 7).
- Currently, Minnesota has no aquatic life use standards for nitrate, though the MPCA (2022a) has developed proposed nitrate criteria for the protection of aquatic life. The proposed nitrate chronic criteria values are 5 mg/L for Class 2A (cold) waters and 8 mg/L for Class 2B (cool/warm) waters. Three reaches had at least one sample value that exceeded their applicable chronic criteria value.
- County Ditch 3 (AUID 09020106-615) had the highest proportion (18%) of nitrate values above its chronic criteria value in the watersheds. Sampling performed directly upstream of the reach yielded a maximum nitrate concentration of 16.3 mg/L.
- Wolverton Creek (AUID 09020104-550) had the highest maximum nitrate concentration (32.7 mg/L) of the reaches.
- According to *The Minnesota Nutrient Reduction Strategy* (MPCA 2014b), tile drainage is expected to further expand in the Red River of the North Basin, which could result in higher nitrate loading to surface waters. In the future, high nitrate-nitrogen may emerge as a stressor in the BRW and URRW.

Table 7. Summary of the proportion of bioassessments impaired reaches per BRRW CWMP planning region affected by high nitrate-nitrogen as a stressor.

Planning Region	Central	Mainstem	Northern	Southern	Upper Red	Western
# of impaired reaches affected/ # of impaired reaches	0/5	0/7	0/7	0/5	0/3	0/2

2.7 High Temperature

The factors that control water temperature and the biological effects of elevated temperature are complex. Water temperature naturally varies due to factors including air temperature, geology, shading, and water inputs from tributaries and groundwater. Human activities can increase stream temperatures. Different organisms are adapted to and prefer different temperature ranges and will thrive or decline based on the temperature ranges found in a stream. Water temperature affects metabolism, and thus food and oxygen needs, and regulates the ability of organisms to survive and reproduce (EPA 1986). Increases in temperature due to altered landscapes can lead directly to extirpation of coldwater taxa.

Findings

- High temperature was found to be a stressor to Lawndale Creek (AUID 09020106-530), which is the only designated Class 2A (cold) water and trout stream with a bioassessments impairment in the watersheds. The creek is located in the Southern BRRW CWMP Planning Region (Table 8).
- Continuous temperature monitoring was performed on Lawndale Creek (AUID 09020106-530) from August 14, 2019, to August 21, 2019, and June 16, 2020, to September 9, 2020. The 2019 monitoring period yielded a maximum temperature of 17.3°C. During the 2020 monitoring period, the maximum temperature was 24.3°C, with approximately 32% of the values exceeded the 19°C stress threshold for cold water species (e.g., brook trout); the highest proportion of exceedances occurred during July. None of the values exceeded the 25°C lethal threshold for brook trout.

- Fish samples collected at Lawndale Creek scored below the statewide average in the abundance of cold water, cool water, cold water sensitive, and native cold-water individuals. Only one cold-cool water species (i.e., brook stickleback) and one cold water sensitive species (i.e., finescale dace) were sampled.

Table 8. Summary of the proportion of bioassessments impaired reaches per BRRW CWMP planning region affected by high temperature as a stressor.

Planning Region	Central	Mainstem	Northern	Southern	Upper Red	Western
# of impaired reaches affected/ # of impaired reaches	0/5	0/7	0/7	1/5	0/3	0/2

Part 3: Recommendations

Table 9 provides recommended actions to eliminate or reduce the influence of stressors that are currently limiting or have the potential to limit the fish and macroinvertebrate communities of the watersheds. Among the most common stressors identified in the watersheds were flow regime instability, insufficient physical habitat, high TSS, and low DO. These stressors are directly influenced by land use activities and changes in hydrology. Additionally, climate-related challenges (e.g., an increase in the frequency and magnitude of large rain events) are expected to continue to exacerbate these stressors. The implementation of best management practices (BMPs) should focus on the detention and retention of water on the landscape. Recently completed and future projects in the watersheds that address water storage and sediment reduction (e.g., Upper Buffalo River Sediment Reduction and Restoration Projects and the Stony Creek Water Resource Management Project) will be critical in addressing the bioassessments impairments.

Table 9. Recommended actions and associated focus areas for stressors in the BRW and URRW.

Stressor	Recommended Action	Focus Area (BRRW CWMP Planning Region)
Loss of Longitudinal Connectivity	• Remove/modify barriers (e.g., dams and culverts) that are impeding fish passage, particularly the Ganz Dam on the Buffalo River, South Branch.	Central Mainstem Northern Southern Upper Red Western
Flow Regime Instability	• Increase runoff detention/retention efforts to attenuate peak flows and augment baseflows. • Mitigate activities that will further alter the hydrology of the watershed.	Central Mainstem Northern Southern Upper Red Western
Insufficient Physical Habitat	• Increase runoff detention/retention efforts to attenuate peak flows and augment baseflows. • Establish and/or protect riparian corridors using native vegetation whenever possible. • Reduce soil erosion through the implementation of BMPs, such as side inlet structures and conservation tillage.	Central Mainstem Northern Southern Upper Red Western

Stressor	Recommended Action	Focus Area (BRRW CWMP Planning Region)
	• Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities.	
High Total Suspended Solids	• Increase runoff detention/retention efforts to attenuate peak flows and augment baseflows. • Establish and/or protect riparian corridors using native vegetation whenever possible. • Reduce soil erosion through the implementation of BMPs, such as side inlet structures and conservation tillage. • Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities.	Mainstem Upper Red
Low Dissolved Oxygen	• Increase runoff detention/retention efforts to attenuate peak flows and augment baseflows. • Reduce soil erosion through the implementation of BMPs, such as side inlet structures and conservation tillage. • Improve agricultural nutrient management.	Northern Southern
High Temperature	Protect groundwater/springs and continue channel/riparian area restoration efforts along Lawndale Creek.	Southern
High Nitrate	• Improve agricultural nutrient management. • Manage and treat tile drainage water.	Central Northern Western

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Next Steps

The preparation of WRAPS and TMDL reports follows the completion of SID. For more information on these processes, go to https://www.pca.state.mn.us/water/watersheds/buffalo-river or https://www.pca.state.mn.us/water/watersheds/upper-red-river-north. Alternatively, search for "Buffalo River Watershed" or "Upper Red River of the North Watershed" on the MPCA website.

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Appendix A: Weight of evidence summary for stressors associated with bioassessments impairments in the BRW.

Reach Name (AUID)	BRRW CWMP Planning Region	Bioassessments Impairment[1]	Candidate Cause[2]						
			Loss of Longitudinal Connectivity	Flow Regime Instability	Insufficient Physical Habitat	High Total Suspended Solids	Low Dissolved Oxygen	High Nitrate-Nitrogen	High Temperature
Whisky Creek (09020106-509)	Central	F-IBI	+	+	++	+++	+	-	NA
		M-IBI	NA	++	+	+	0	0	NA
Stony Creek (09020106-510)	Central	M-IBI	NA	+	0	-	0	-	NA
Spring Creek (09020106-534)	Central	F-IBI	+	++	++	-	+	-	NA
		M-IBI	NA	++	++	-	+	0	NA
Hay Creek (09020106-609)	Central	F-IBI	+	++	+	-	0	0	NA
		M-IBI	NA	++	+	0	0	-	NA
Stony Creek (09020106-613)	Central	F-IBI	+	++	+	0	-	0	NA
Unnamed Stream (09020106-518)	Mainstem	M-IBI	NA	++	+	0	INSUF	-	NA
Unnamed Creek (09020106-576)	Mainstem	F-IBI	+++	INSUF	INSUF	INSUF	INSUF	INSUF	NA
Unnamed Ditch (09020106-578)	Mainstem	M-IBI	NA	+	+	-	++	-	NA
Unnamed Creek (09020106-580)	Mainstem	F-IBI	+	++	++	++	0	0	NA
		M-IBI	NA	++	++	+	0	0	NA

Reach Name (AUID)	BRRW CWMP Planning Region	Bioassessments Impairment[1]	Candidate Cause[2]						
			Loss of Longitudinal Connectivity	Flow Regime Instability	Insufficient Physical Habitat	High Total Suspended Solids	Low Dissolved Oxygen	High Nitrate-Nitrogen	High Temperature
County Ditch 16 (09020106-581)	Mainstem	F-IBI	+	+++	++	++	+	0	NA
Buffalo River (09020106-593)	Mainstem[3]	F-IBI	++	++	++	+++	0	-	NA
Hay Creek (09020106-621)	Mainstem	F-IBI	+	++	+	++	-	0	NA
County Ditch 25 (09020106-538)	Northern	F-IBI	INSUF	INSUF	INSUF	INSUF	INSUF	INSUF	NA
		M-IBI	NA	+++	+	++	++	-	NA
County Ditch 2 (09020106-556)	Northern	M-IBI	NA	+++	+	0	0	-	NA
County Ditch 5 (09020106-563)	Northern	F-IBI	++	+++	++	0	++	-	NA
		M-IBI	NA	+++	++	0	++	0	NA
County Ditch 3 (09020106-615)	Northern	F-IBI	++	++	++	0	++	0	NA
		M-IBI	NA	++	++	-	++	0	NA
County Ditch 39 (09020106-617)	Northern	F-IBI	+	++	++	0	++	-	NA
		M-IBI	NA	++	+	0	+	-	NA
		M-IBI	NA	+++	+	0	++	-	NA
County Ditch 10 (09020106-619)	Northern	F-IBI	+	+++	+	0	++	0	NA
	Northern	M-IBI	NA	++	+	-	++	0	NA

Reach Name (AUID)	BRRW CWMP Planning Region	Bioassessments Impairment[1]	Candidate Cause[2]						
			Loss of Longitudinal Connectivity	**Flow Regime Instability**	**Insufficient Physical Habitat**	**High Total Suspended Solids**	**Low Dissolved Oxygen**	**High Nitrate-Nitrogen**	**High Temperature**
Unnamed Creek (09020106-624)		M-IBI	NA	+	+	++	+	-	NA
Buffalo R., S. Branch (09020106-505)	Southern	F-IBI	++	++	++	0	0	-	NA
Deerhorn Creek (09020106-507)	Southern	M-IBI	NA	+++	++	+	0	0	NA
		F-IBI	++	+	0	++	+	-	++
Lawndale Creek (09020106-530)	Southern	M-IBI	NA	++	+	-	++	-	NA
Unnamed Creek (09020106-544)	Southern	F-IBI	+	+++	0	0	+	-	NA
Buffalo R., S. Branch (09020106-605)	Southern	M-IBI	NA	+++	+	0	++	-	NA

[1] Aquatic life impairment for fish bioassessments (**F-IBI**) and/or benthic macroinvertebrate bioassessments (**M-IBI**).

[2] **Key:** **+++** 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 bioassessments impairment or the use classification of the reach.

Appendix B: Weight of evidence summary for stressors associated with bioassessments impairments in the URRW.

Reach Name (AUID)	BRRW CWMP Planning Region	Bioassessments Impairment[1]	Candidate Cause[2]						
			Loss of Longitudinal Connectivity	Flow Regime Instability	Insufficient Physical Habitat	High Total Suspended Solids	Low Dissolved Oxygen	High Nitrate-Nitrogen	High Temperature
Unnamed Creek (09020104-516)	Upper Red	F-IBI	+	++	++	0	-	-	NA
		M-IBI	NA	0	+	+++	-	0	NA
Unnamed Creek (09020104-533)	Upper Red	F-IBI	0	++	++	INSUF	INSUF	INSUF	NA
Unnamed Ditch (09020104-537)	Upper Red	F-IBI	++	++	++	+	0	0	NA
Wolverton Creek (09020104-549)	Western	F-IBI	++	+++	+++	0	+	0	NA
Wolverton Creek (09020104-550)	Western	F-IBI	+	++	+++	+++	0	0	NA

[1] Aquatic life impairment for fish bioassessments (**F-IBI**) and/or benthic macroinvertebrate bioassessments (**M-IBI**).

[2] **Key: +++** 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 bioassessments impairment or the use classification of the reach.