Stressor identification update

Root River Watershed

March 2022

Introduction/Goals

Water monitoring is essential to determining whether lakes and streams meet water quality standards designed to ensure that waters have healthy aquatic communities and are safe for recreation. The stressor identification (SID) process is designed to study and diagnose negative impacts to fish and bug communities. The scope of Cycle 2 SID work was broadened beyond this specific intention to include field and technical work in support of local water planning goals and priorities.

Accordingly, the Root River Cycle 2 work focused on select subwatersheds. Some were new biological impairments, while others had been studied previously but lacked sufficient information on stressors or source identification. Some of the subwatersheds are identified as high priority during local watershed planning or were high focus for implementation projects. Overall, the goal of the Root River Cycle 2 SID work was to add value and better understanding of the water resources and problems in the watershed. Identifying impairments and stressors will aid in focusing best management practices (BMPs) and protection efforts.

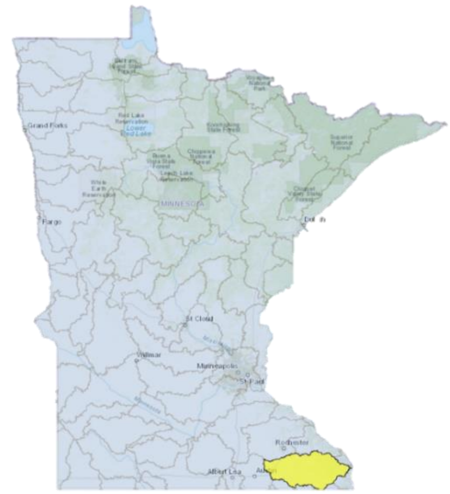

Figure 1. Root River Watershed

What have we learned about stream health in the Root River?

The Root River Watershed was first sampled intensively for biology by Minnesota Pollution Control Agency (MPCA) in 2008, then revisited in 2018. The new Root Water Assessment and Trends Update Report summarizes the findings from the recent monitoring in 2018. The information in this report is one of the building blocks for the Root River Cycle 2 SID work in this report. Some recent monitoring and SID highlights include:

- Overall, the biology in the Root River did show a statistically significant increase in Index of Biological Integrity (IBI) scores, which may be attributed to the different climate conditions between 2008 and 2018 (See Root Water Assessment and Trends Update Report for more detail).
- Ten streams with new biological impairments were identified since the original assessment. Most of these streams had not been officially assessed previously (i.e. new sites or new assessments). Those in this report include sections of: Mill Creek, South Branch Headwaters, Bridge Creek, Riceford Creek, and Upper Bear Creek.
- Most of the biological assessments from Cycle 1 were re-affirmed in Cycle 2. However, there were seven previously identified aquatic life impaired streams that are proposed for delisting or correction (See appendix table). A few of those discussed in this report include: Pine Creek, Riceford Creek, and Silver Creek.

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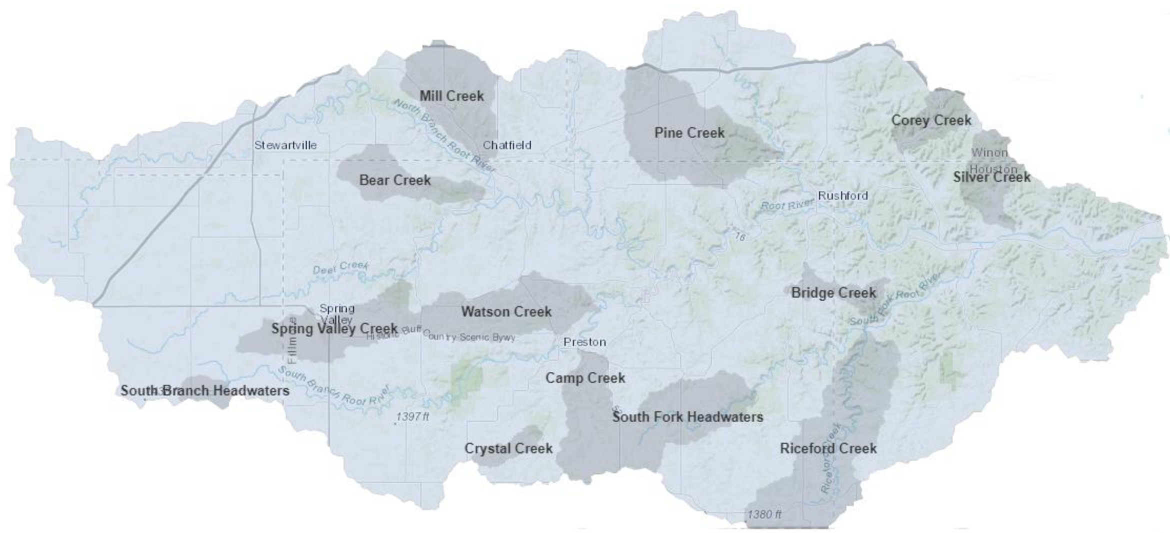
- Multiple streams in this report were studied in Cycle 1 SID, but needed more information and details on the stressors identified (or were inconclusive). These areas had high local interest or focus and aimed to get a better understanding of the conclusions in the original Root River Cycle 1 SID Report.
- Further investigation of hydrology in the watershed (see hydrology section) provides the information needed to confidently conclude flow alteration as a stressor. It is implicated as a contributor (either directly or indirectly) to the stressors observed throughout the watershed (i.e. habitat, nitrate, total suspended solids (TSS), etc.)
- The most common stressors in the watershed relate to nutrients and sediment. Habitat loss due to bedded sediment remains the most common stressor identified in the Root and the state of Minnesota.

Part 1: Root Watershed SID Overview

Cycle 2 Stressor ID: Areas of focus

The Root River Watershed is a large watershed and the SID process for Cycle 2 prioritized specific areas to study further. The following map and list of streams were studied and are further detailed in the next section of this report. Some of these streams needed additional information to understand stressor connections, while others needed information on source assessment for restoration prioritization. Some areas are considered local water planning priorities and were focus areas for additional data collection and analysis (Priority 1). Some areas were not studied as intensively but had some data collection or analysis and are also included in this report (Priority 2). The full list and map of streams studied are found in Figure 2.

Figure 2. Map and list of stream studied in this report by priority.



Priority 1 Watersheds (high level of effort)		Priority 2 Watersheds (moderate-lower level of effort)	
• Watson Creek	• Upper Bear Creek	• Silver Creek	• Crystal Creek
• Riceford Creek	• Spring Valley Creek	• Corey Creek	• South Fork Headwaters
• Mill Creek	• Camp Creek	• Bridge Creek	• South Branch Headwaters
		• Pine Creek	

Root River Watershed Hydrology Summary

Hydrology is one of the most important variables impacting stream health of the Root River Watershed and virtually tied to all of the stressors observed in this watershed. Recent developments related to hydrology information in the Root River Watershed have allowed for better analysis of the connections of this stressor to stream health. The Root River Evaluation of Hydrologic Change (EHC) Technical Summary done by the Minnesota Department of Natural Resources (DNR) summarizes hydrology in the watershed in the last 90 years and provides the following conclusions:

- There's been an increase in precipitation in the watershed since 1978. This is consistent with many other studies on the precipitation in the Root River and from other watersheds of Minnesota.
- Baseflow and mid-range flows have increased considerably since 1991. This has linkages to sediment transport in the watershed. Streams that are entrenched (not connected to their floodplains) and have consistently higher channel velocities are likely eroding at correspondingly higher rates.
- The "rise rate" or the median of all positive differences between consecutive daily discharge values, has increased by 40%. This increase in flashiness is likely due to increased frequencies of moderate rainfall events as well as the increase in disconnection of the river to its floodplain contributing to stream instability.

- Peak flows have not changed significantly in the Root Watershed when looking at peak flow magnitude, but when looking at timing and seasonality-the occurrence of snowmelt peak flows appear to be decreasing while mid-summer and even late summer peak flows are increasing.

There have also been other recent important studies on sediment and hydrology done by Patrick Belmont, and others at Utah State University (USU). One of his recent studies found that regionally both precipitation and agricultural drainage contribute to flow increases observed in rivers in the upper Midwest (Kelly et al. 2017) In the Root River specifically, Belmont and Vaughan found that as flow increases, TSS also significantly increases. They found the **Root River has some of the highest flow/TSS relations in the state of Minnesota**. (Vaughan et al. 2017) These trends or relationships are mostly controlled by geomorphic setting and bank erosion. Particularly susceptible areas include those with significant changes in stream slope and those with high stream power. In previous research in the Root River, Belmont has also found that shifts in hydrologic regime and sediment flux are sensitive to both magnitude and sequence of flood events in the Root River. Geomorphic analysis indicates that many river reaches have accessible near-channel sources of sediment (floodplains and terraces/streambanks) which contribute the dominant proportion of sediment to the stream channel.

Lenhart et al., 2013 used Impacts of Hydrologic Alteration (IHA) analysis to look at 16 different watersheds in the Midwest, one which was the Root River at Houston. While this analysis is a bit more dated, its findings were consistent with the more recent analysis by Belmont et al., and the DNR. The results showed increased streamflow overall for the Root River near Houston, with the largest percent flow increase occurring during baseflow periods. Increased low to moderately high flows appear to have increased on average for many streams in the Upper Midwest, not just the Root River.

The most robust flow datasets used to understand hydrology occur at large scales in the watershed (i.e. mainstem/watershed outlet). The results from these larger scales are relevant across the watershed, even at smaller scales. Often flow information to determine trends at smaller watershed scales is lacking and more variables exist in those settings. Overall, multiple studies on hydrology in the past decade have concluded similar results related to changes in hydrology in the Root River. This makes understanding the current hydrology and its changes a critical restoration consideration moving forward.

Root River protection recommendations and threatened areas

Some streams were identified as vulnerable to impairment during the most recent assessment. These streams need continued study to monitor aquatic life health. A stream that are considered threatened, or vulnerable to aquatic life impairment is Wisel Creek (07040008-513). Both Crystal Creek and Pine Creek are streams that require protection of macroinvertebrate communities, and are included in this report. Crystal Creek has high nitrate (new nitrate impairment) and Pine Creek has moderately high nitrate as well (6-7 mg/L). Both of these streams would benefit from reducing nitrate or protecting against further degradation so that macroinvertebrates do not become impaired.

High quality streams like Forestville Creek need protection as well. Forestville Creek has a history of very high IBI scores, with exceptional habitat. However, it remains threatened due to high nitrate concentrations and periods of high TSS. The naturally occurring karst landscape in the Forestville Creek Watershed complicates sediment and nutrient transport with the ever changing hydrology and climate. Forestville Creek is a MPCA Long Term biological monitoring site, so this stream will continue to be monitored over time to ensure biology remains healthy.

Part 2: Specific Streams or Areas of Focus

Watson Creek (07040008-552)

Biological Community Summary

Watson Creek (07040008-552) was listed in Cycle 1 for fish and macroinvertebrates. Since then, one additional biological site was added to the upper part of Watson Creek (18LM018; Figure 3). This site scored well for fish and macroinvertebrates, while the lower two stations did not score as well. Interestingly, both macroinvertebrate scores at the lower two stations and the fish score at 08LM004 were higher in 2018 compared to 2008. The boost in macroinvertebrate scores was at least partially due to increased caddisflies that are also collector/filterers, and more coldwater sensitive taxa boosting coldwater IBI metrics. It's unclear exactly what might be causing this shift, but it is likely due to available habitat and conditions leading up to sampling during the two time periods. This variability can be normal and doesn't necessarily mean stressors are improving in Watson Creek. Additional biological data collection moving forward in Watson Creek will be important to help understand this variability over time.

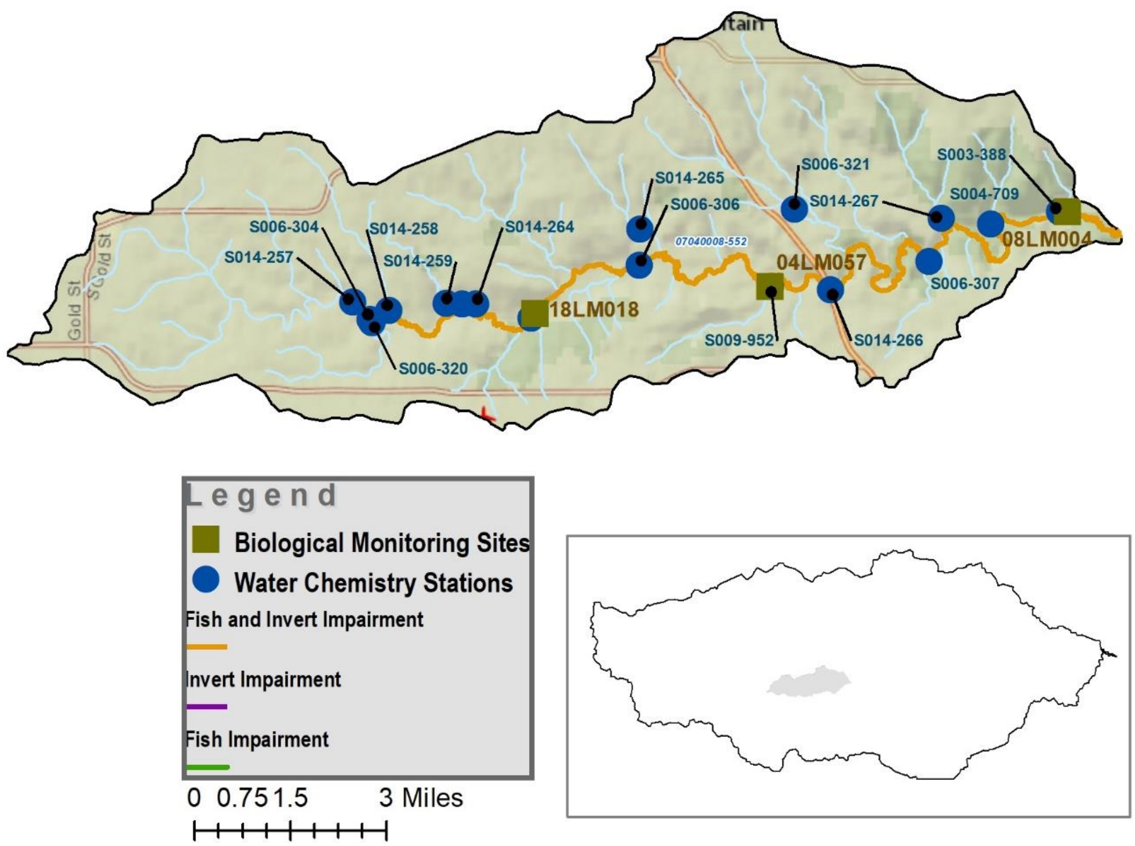


Figure 3. Map of Watson Creek Watershed showing biological monitoring and water chemistry stations. Watson Creek (07040008-552) is impaired for fish and macroinvertebrates.

What do the monitoring data tell us now?

During Cycle 1 SID, multiple stressors were identified in Watson Creek, including temperature, nitrate, TSS and habitat. The goal of Cycle 2 SID work in Watson Creek was to get additional longitudinal information related to stressors identified in Cycle 1. This information was needed to help direct future watershed work in Watson Creek specifically related to sediment and nutrients including potential sources or areas of interest. Multiple chemistry stations were added to help in this effort (Figure 3).

Temperature	• Temperature is often higher than suitable and is variable depending on seasonal flow conditions. Temperature is not the main limiting stressor but its contributing stress to coldwater individuals and fish reproduction in the middle to lower reaches.
Nitrate	• Nitrate concentrations are high. There are high amount of nitrate tolerant inverts and fewer Trichoptera and other nitrate intolerant inverts. Highest concentrations are at the headwaters and decrease slightly moving downstream (from a median of 12 mg/L to a median of 9 mg/L)
TSS (Total Suspended Solids)	• Elevated TSS concentrations (>10) and low secchi tube measurements are well documented. Fish and macroinvertebrates present are very tolerant to high TSS; concentrations increasing moving downstream-notably between CR119 and CR11.
DO/Eutrophication	• Additional sonde data collected in 2018 verified adequate DO levels throughout the stream. This stressor was previously inconclusive but has now been ruled out as a stressor with additional information.
Habitat	• Habitat issues persist in Watson Creek and are largely impacted by sedimentation. Bank erosion and fine substrate common. There are few riffles, and a general lack of habitat diversity, except in upper reaches where there are some coarse substrates.
Connectivity	• Beaver Dams could be a variable source of connectivity stress but would have more impact related to habitat as opposed to fish passage issues. At this time there are no connectivity stressor concerns in Watson Creek.
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Watson Creek has TSS and habitat stressors that are likely attributed to changes in land use, precipitation and flow, all of which impact sedimentation dynamics

Summary of stream health and recommendations in Watson Creek

Additional biological and water chemistry information throughout Watson Creek has provided focus areas for sediment and nitrate stress in Watson Creek. Prioritization of future work should consider these stressor impacts at various locations in the watershed.

- Temperature is similar to many trout streams in Southeast Minnesota-cooler in the headwaters and then quickly increasing temperature moving downstream. Lack of shade and sedimentation play a large role in how quickly these temperatures increase. Additionally, the input (springs and seeps) and loss (stream sinks, sieves) of cold groundwater impacts temperatures throughout the system. Spring sources and important coldwater tributaries (like Thunderhead spring and Stagecoach spring) are essential coldwater inputs to Watson Creek and should be protected from any degradation. Temperature isn't the main limiting factor, but it's impacting the middle/lower reaches of the watershed.
- Nitrate is highest in the headwaters and decreases slightly when moving through the watershed. Multiple drinking water listings are documented in the Watson Creek Watershed (levels >10 mg/L). This includes an old listing on the main part of the stream, and new tributary listings (E61, E62, E63, and E75). The largest source of nitrate to Watson Creek is the headwaters area; Stagecoach and Thunderhead springs. Thunderhead springshed is a priority area for nitrogen

reduction as it has the highest nitrate concentrations in the watershed and is a significant flow contribution (average nitrate of 13 mg/L and up to 15 mg/L). Both springsheds could be prioritized for nitrate reduction. The surface watersheds to these springs are delineated in Figure 4; however, the true springsheds extend outside of these boundaries and should be considered in addition.

- Sedimentation is an issue throughout much of the creek, impacting water clarity and habitat. Sediment concentrations show a notable increase between CR117 and CR11, as evidenced by longitudinal sampling and increasing erosion (Figure 4, Figure 5). DNR geomorphology information suggests that much of Watson Creek is unstable and susceptible to elevated amounts of bank erosion (Figure 6). The combination of channel incision and flat slope serves to slow water velocity which can result in deposition of sand and silt from streambanks in critical riffle and pool habitats.
- Flow alteration is a likely contributor to sedimentation issues and stream instability. Watson Creek has TSS and habitat stressors that are tied to changes in land use, precipitation, and flow- all of which impact sedimentation dynamics throughout the stream. Encouraging practices in the watershed that reduce storm impact, promote water storage, and increase infiltration are helpful. Vegetative cover, adequate buffers, and good grazing practices are also important throughout the watershed.

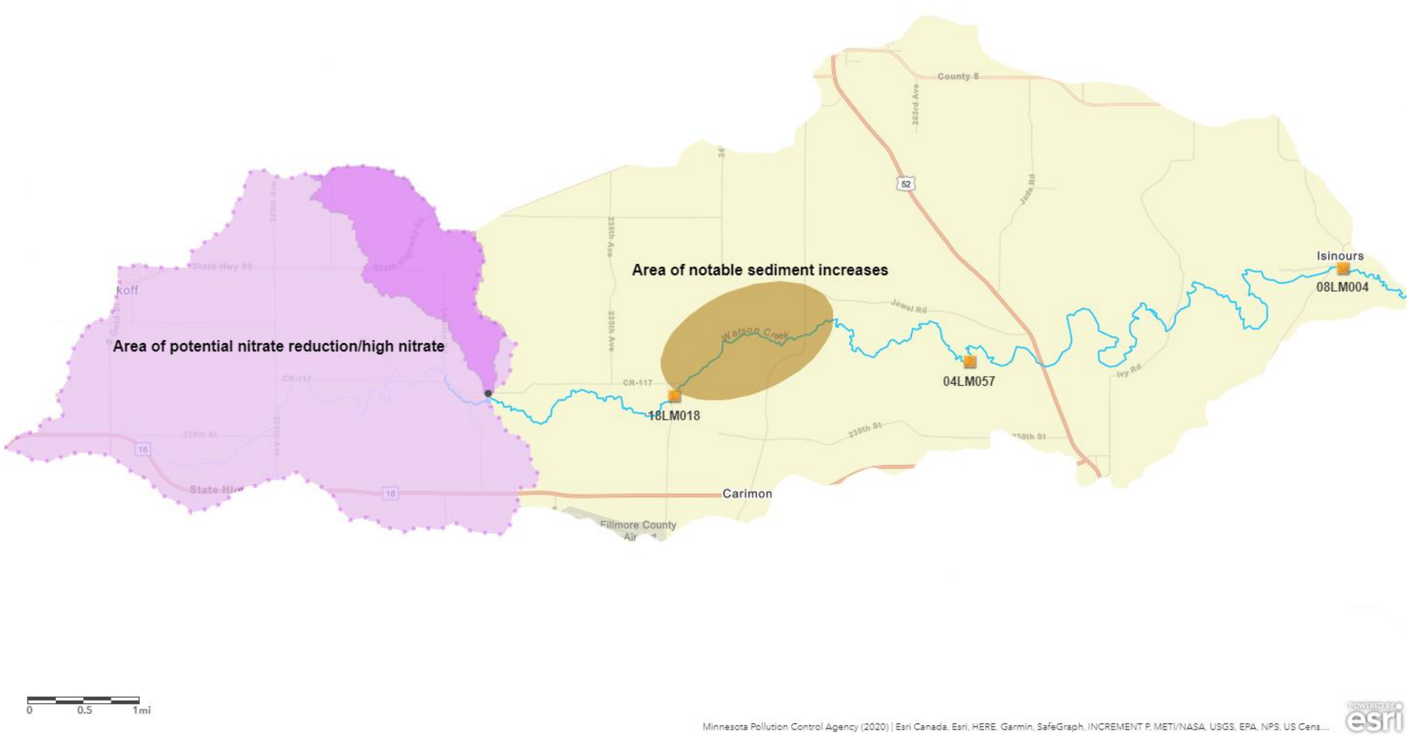


Figure 4. Map of the Watson Creek Watershed showing potential opportunities for nitrate and sediment reductions. Purple shaded areas include Stagecoach/Thunderhead spring watersheds (true springshed delineation not shown, but differs and includes a much larger area of consideration than shown). Brown shaded circle indicates the area between CR117 and CR11, where notable sediment increases and stream instability have been documented.

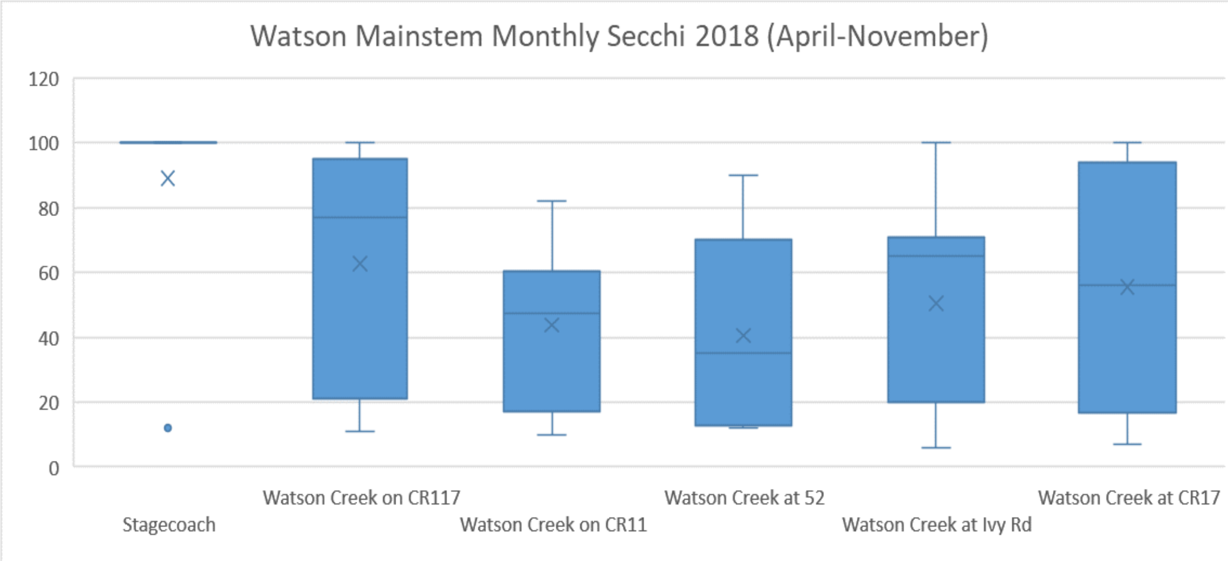


Figure 5. Monthly longitudinal secchi boxplots from Watson Creek showing the notable sediment increases (decreased transparency/secchi measurements) between CR117 and CR11 in 2018.

Figure 6. Photos of bank erosion near 18LM018, July 2018. (Downstream of CR117, the area of increasing sedimentation as noted in previous figures).

Riceford Creek (07040008-518, 07040008-519 and 07040008-H01)

Biological Community Summary

Two reaches of Riceford Creek (518-coldwater and 519-warmwater) were listed in Cycle 1 for macroinvertebrate impairment. A subsequent assessment (H01-warmwater modified stream) added another macroinvertebrate listing. These three impaired reaches cover almost the entire length of Riceford Creek (Figure 7). The new listing (07040008-H01) was added because it was previously deferred due to stream channelization, and is located in the headwaters near Mabel. After adoption of Tiered Aquatic Life Use (TALU) standards for modified streams, the reach was assessed and determined to be impaired.

The farthest downstream reach (07040008-519) has shown variability in macroinvertebrate IBI (MIBI) scores. After a full review of all available data and standards it was determined that this reach should be removed from the impaired waters list (list correction). The middle coldwater reach (07040008-518) is still showing macroinvertebrate impairment with the most recent data indicating a significant drop in MIBI score at 08LM140. This was due to an increase in more tolerant chironomids (midges), and decreases in macroinvertebrates like mayflies, caddisflies, and simuliidae (black flies). The other two sites on this stream reach (04LM117 and 08LM111) were not visited during Cycle 2 monitoring. In summary, even while the lower reach is being removed from the impaired waters list, the macroinvertebrates in Riceford Creek are still stressed; mainly in the headwaters and middle-coldwater reach.

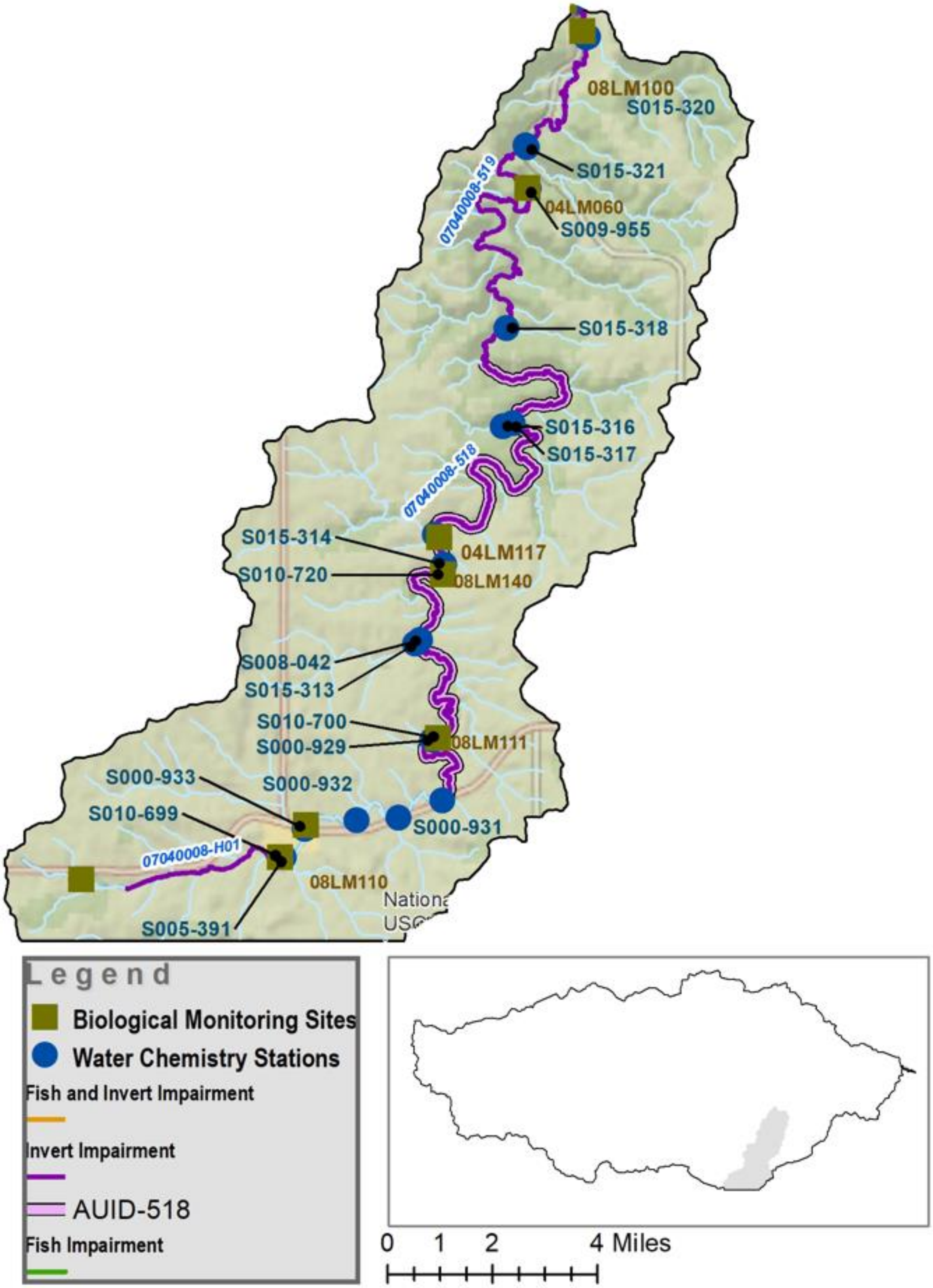


Figure 7. Map of the Riceford Creek Watershed showing biological monitoring and water chemistry stations. Riceford Creek (07040008-H01) farthest upstream and warmwater, is a new impairment for macroinvertebrates. The next section of stream moving downstream (07040008-518) is also impaired for macroinvertebrates and is coldwater. The farthest downstream section of stream (0704008-519) is warmwater and a proposed macroinvertebrate impairment correction.

What do the monitoring data tell us now?

During Cycle 1 SID (for -518 and -519) the stressors identified in Riceford Creek were habitat and nitrate. TSS and DO were considered inconclusive in the middle coldwater reach (518). Temperature and connectivity were ruled out as potential stressors throughout the stream. Cycle 2 SID work focused on understanding longitudinal differences in sediment, habitat, and nitrate throughout the stream to help determine potential pollutant sources and areas of highest impact of those stressors in the watershed. This included the addition of many water chemistry sampling stations (Figure 7).

Temperature	• Temperature was ruled out as a stressor previously. Additional data over time may be useful in better understanding thermal dynamics and potential changes over time in Riceford Creek.
Nitrate	• Nitrate was identified as a stressor previously. The middle-coldwater reach and its tributaries show the most consistent response for nitrate stress, (with higher concentrations ~6-8 mg/L.)
TSS (Total Suspended Solids)	• Severe bank erosion has been documented throughout the stream. Additional transparency data, coupled with biological response show transparency is getting worse in the headwater site in Mabel since 2008. This inconclusive stressor has now been confirmed as a stressor in Riceford Creek.
DO/Eutrophication	• Both communities show most DO related metrics have improved in Cycle 2 and do not have indications that low DO or eutrophication are leading to any biological stress. This stressor that was inconclusive can now be ruled out.
Habitat	• Habitat issues begin in the headwater/channelized reach and show impacts from streambank instability and erosion moving downstream. The biology reflects in-stream habitat conditions that are impacted by sedimentation
Connectivity	• Ruled out as a stressor previously. Fish are not impaired and there was no reason to investigate further
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Riceford Creek has TSS and habitat stressors that are likely attributed to changes in land use, precipitation and flow, all of which impact sedimentation dynamics

Summary of stream health and recommendations in Riceford Creek

The stressors in Riceford Creek include nitrate, TSS, habitat and flow alteration. These stressors have various impacts throughout its length. New water chemistry information collected helped confirm a previously inconclusive TSS stressor, further emphasizing the importance of reducing sedimentation throughout watershed. Depending on the time of year and flow conditions, multiple areas of the watershed are susceptible to erosion and sediment issues. In addition, high nitrate concentrations in the stream baseflow (groundwater inputs) are impacting macroinvertebrates in Riceford Creek. Temperature, connectivity and dissolved oxygen (DO) are all typical of southeast Minnesota trout streams and not stressing the biology in Riceford Creek.

- Nitrate concentrations are highest in the middle of the watershed (coldwater section-518; Figure 8). Efforts to reduce nitrate should be prioritized in this area since nitrate stress to biology is also most prominent (Figure 9). Differences in land use (more cropland and less forest) in addition to geology are likely factors for the higher nitrate concentrations upstream. Downstream of Mabel, where the stream crosses the Houston County line, it changes to coldwater with many groundwater/spring inputs contributing flow (and nitrate) to the stream. Areas of cropland in the middle and upper part of the watershed could all be contributing to these groundwater nitrate inputs (springsheds do not follow surface watershed boundaries and could cover a larger area).

- TSS was inconclusive as a stressor previously but with additional information, is now considered a stressor. Sediment and water clarity in 2019 show that the stream is very dynamic and sources of sediment impacting the stream system appear to be dependent on a number of factors:
    - Transparency in early spring was lower in the headwater area and clarity improved moving downstream. This is likely due to less crop cover in early spring (more overland flow impacts), less gradient (sediment settling out slower) and more spring/groundwater inputs in the coldwater reach (dilution and thus increases in clarity during that time). The area upstream of Mabel is also heavily altered or channelized which impacts sediment transport and concentrations.
        - Further: CSMP transparency data from the headwater site in Mabel shows a degrading trend in water clarity from 2008 to 2020. (https://webapp.pca.state.mn.us/cmp/stations/S005-391/trends).
    - Larger storm events and increases in streamflow later in the year (2019 monitoring data) produced high sediment transport in the middle/lower reaches, likely due to higher flows resulting in more bank erosion (Figure 10). Further evidence of this was the channel widening/severe bank erosion at 08LM100 in 2019. During biological sampling this resulted in the sampling reach adding 367 meters of reach length since it was first sampled in 2008 (sampling reach length is based on stream width and adjusted accordingly).
    - Overall, more protection in the upper part of the watershed in early spring when soils are most vulnerable would help reduce any overland contributions to the stream. Bank erosion moving downstream is an issue and contributing sediment especially during high flows. Practices throughout the watershed to slow and reduce flow would reduce sediment impacts on the stream system. Well-managed (not overgrazed) pastures in Riceford Creek Watershed should be encouraged.

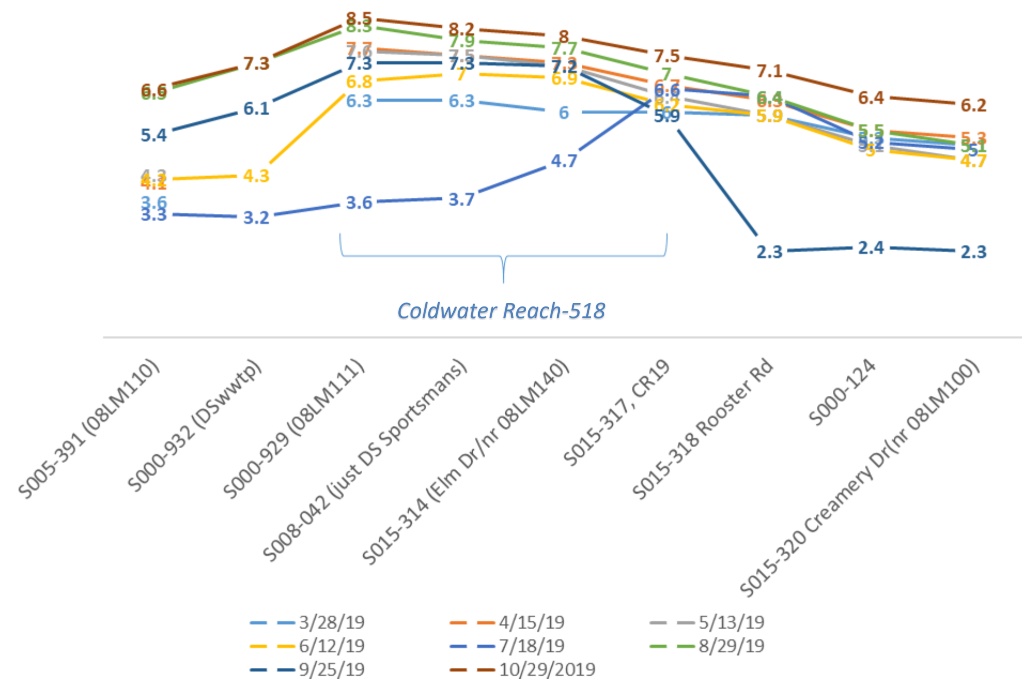


Figure 8. Nitrate results from longitudinal chemistry sampling in 2019. The sites are organized upstream to downstream (left to right). Nitrate was highest through the middle (coldwater) reaches; commonly 6-8 mg/L at baseflow (lower concentrations noted were storm event samples when dilution was occurring). The upper warmwater reach (2 sites farthest left) were slightly elevated; but concentrations increased when moving towards the coldwater reach-518, likely due to increased groundwater inputs. Then farther downstream concentrations showed decreases as well; likely related to the geology and changes in land use moving downstream

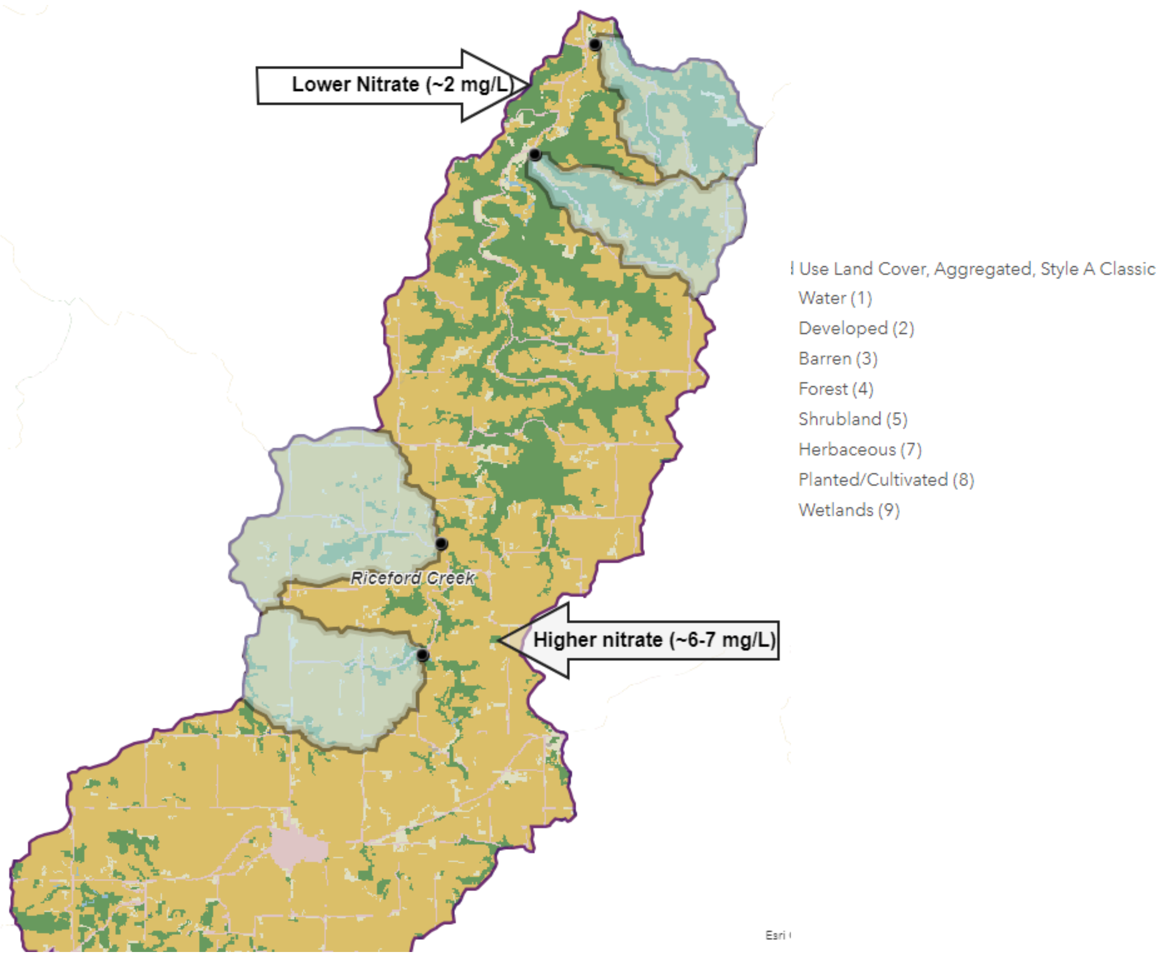


Figure 9. Tributary monitoring showing range of nitrate concentrations throughout the watershed. The middle sections of Riceford Creek (Coldwater reach-518) had the highest nitrate concentrations, including the tributaries in this map. Efforts to reduce nitrate may make the most impact in the middle to upper parts of the watershed as opposed to the lower end.


Figure 10. Areas of bank erosion and sedimentation in Riceford Creek.

Mill Creek (07040008-536)

Biological Community Summary

Mill Creek (07040008-536) biological data indicate both fish and macroinvertebrate impairment (Figure 11). The stream was deferred in Cycle 1 due to channelization of the stream channel at the sampling site. In 2011, an additional site was established nearby on a natural channel reach of Mill Creek near Chatfield. Multiple biological samples have been collected at the two sites from 2007 through 2018, and confirm impairment for both fish and macroinvertebrates. SID work began in 2019 with additional chemistry monitoring at multiple stations (Figure 11). The goal was to better understand sediment and nutrient sources and impacts throughout the watershed.

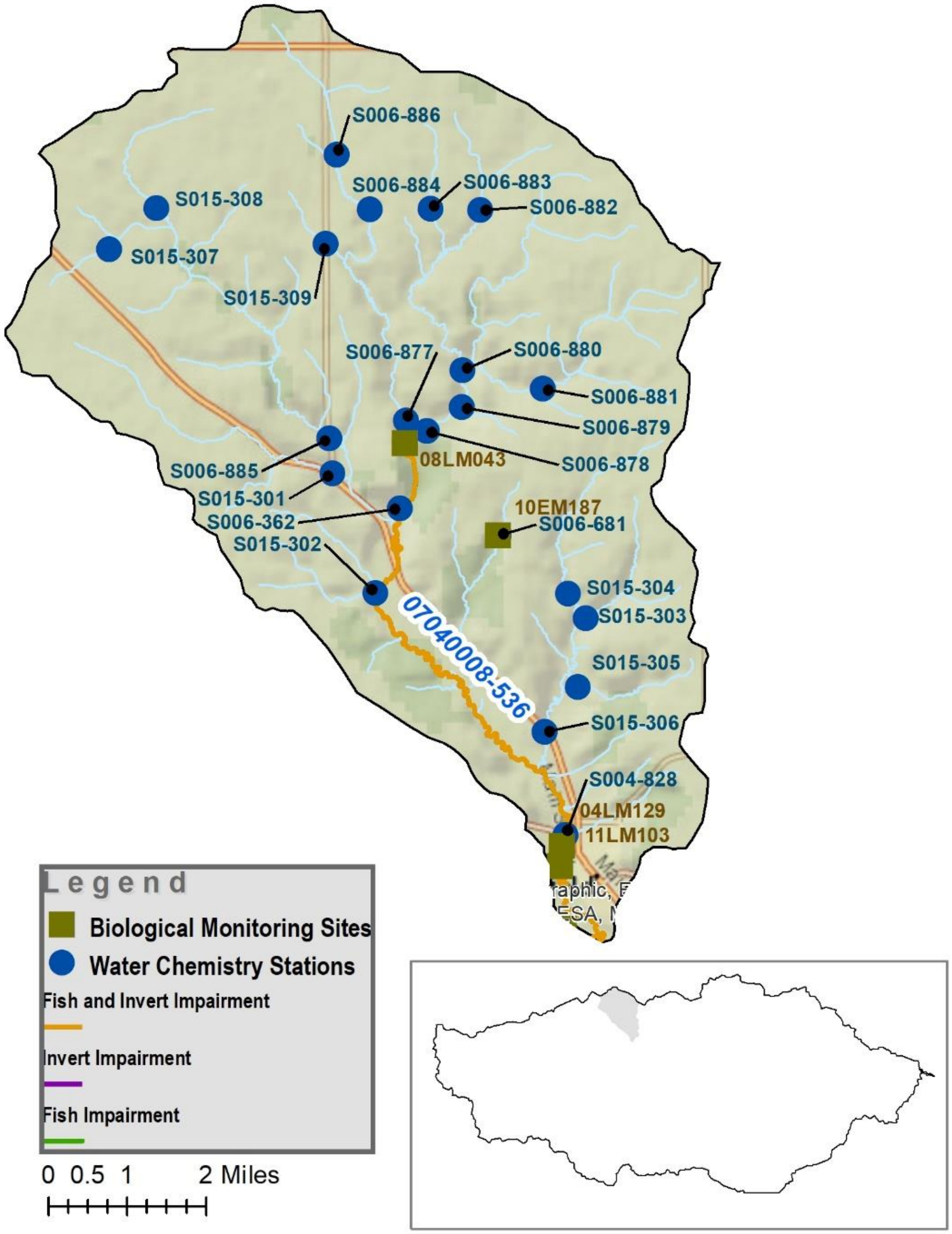


Figure 11. Map of the Mill Creek Watershed showing biological monitoring and water chemistry stations. Mill Creek (07040008-536) is impaired for fish and macroinvertebrates.

What do the monitoring data tell us now?

Nitrate and sediment were identified as potential limiting factors due to chemistry sampling that had occurred previously in Mill Creek. Recent SID work focused on understanding longitudinal differences in sediment and nitrate to help determine potential pollutant sources and areas of highest impact of those stressors in the watershed. Continuous temperature and multi-parameter sonde data were also collected to help understand the other potential stressors present (e.g. DO or temperature).

Temperature	• Temperatures are suitable; July and August Average temperatures were 15-16°C. The site near Chatfield was 1-2 degrees warmer than the site near Hwy 52 (Spring Rd). Coldwater fish and macroinvertebrate species are moderate in numbers
Nitrate	• Nitrate concentrations are high in Mill Creek, which led to a new nitrate listing (i.e. >10 mg/L). There are high amount of nitrate tolerant inverts and fewer Trichoptera/nitrate intolerant inverts. Areas of highest nitrate are in the upper NW part of the watershed, where row crop percentages are higher
TSS (Total Suspended Solids)	• TSS and transparency data indicate the stream sees high sediment loads. Streambank erosion and sedimentation issues have been documented throughout Mill Creek and are impacting water clarity and also habitat conditions throughout the stream
DO/Eutrophication	• Sonde data collected in 2018 and 2019 verified adequate DO levels with a minimal DO flux. The biological response data is mixed, likely due to the large drainage area for a coldwater stream and a few more warmwater species present. Overall biology does not appear to be suffering from DO issues.
Habitat	• Habitat issues in the form of sedimentation impacts available habitat in Mill Creek. Habitat improvement projects upstream of Chatfield have likely had positive impacts to available habitat. However, upstream sediment contributions still need to be addressed
Connectivity	• Beaver dams may inhibit movement in the upper reaches. This is also an area where the stream often dries up (naturally). In the trout stream portion of Mill Creek there are no connectivity stressor concerns and its unlikely causing any chronic stress to aquatic life
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Mill Creek has TSS and habitat stressors that are likely attributed to changes in land use, precipitation and flow, all of which impact sedimentation dynamics

Summary of stream health and recommendations in Mill Creek

Fish and macroinvertebrates in Mill Creek are stressed by high nitrate, TSS, habitat, and flow alteration. Temperature and DO levels are typical of a coldwater stream and were ruled out as stressors. Some headwater reaches of Mill Creek periodically lose all flow, depending on time of year and hydrologic conditions. These areas are upstream of the trout stream portion of Mill Creek.

- Efforts to reduce nitrate should be focused in the upper headwater area where concentrations are well above 10 mg/L. The northwest part of the watershed is significantly higher (~2x) relative to the southeast part of the watershed (Figure 12 and Figure 13). This is likely driven by a combination of geology (springs and groundwater coming from different/more protected geologic units) and land use (50% to 77% row crop compared to 30% to 50% row crop).
- TSS and transparency measurements throughout the watershed indicate high sediment concentrations. Half of the 32 TSS samples taken at S004-828 (outlet) exceed the standard of 10 mg/L. The upland/headwater area is a source of sediment (Figure 14) with many water monitoring sites showing comparatively higher sediment coming from uplands/headwater areas. Areas of instability and bank erosion have also been documented in multiple upstream reaches, which are likely sources of sediment (Figure 15 and Figure 16). The monitoring data shows that sediment concentrations are often highest in these upstream tributary areas, then level off once reaching the main channel and do not continue to significantly increase when continuing downstream to the mouth. In 2019, the water clarity values were consistent among the three sites on the main stem. In 2020, many of the sampling days saw increasing (better) clarity moving downstream on the main stem. These differences are likely due to the precipitation of 2019 (wet) and 2020 (more normal) impacting the various sediment sources.

Springs in the downstream reaches are likely diluting some of the high sediment concentrations, but it's also possible that near-channel sources of sediment (i.e. streambank erosion) have been mitigated by habitat improvement projects that have taken place upstream of Chatfield. Much of the habitat improvement work in recent years has focused on bank sloping and channel narrowing. Lastly, looking at the biological metrics there is consistency in the fish and macroinvertebrates that signal TSS stress, further evidence that sediment issues could use improvement.

- The habitat issues in Mill Creek are driven by sedimentation and erosion from the uplands and streambanks, as previously discussed. Severe bank erosion has been documented in many places in the Mill Creek Watershed and moderate siltation of riffle habitats has been documented during habitat assessments. Localized habitat improvement projects in the lower part of Mill Creek upstream of Chatfield have likely increased available habitat and addressed some sedimentation issues in the project reaches. Upstream contributions of sediment need to be addressed as they can be large sources of sediment to Mill Creek.
- Flow alteration is a contributor to sedimentation issues and stream bank erosion/instability. Mill Creek has TSS and habitat stressors that are driven by changes in land use, precipitation, and flow-all of which impact sedimentation dynamics throughout the stream. Encouraging practices in the watershed that reduce storm impacts, promote water storage, and increase infiltration are helpful. Vegetative cover, adequate buffers, and good grazing practices are also important considerations to minimize sediment delivery to the stream.
- Future monitoring of Mill Creek for aquatic life assessment could be considered a bit farther upstream of Chatfield. The watershed outlet of Mill Creek in Chatfield is transitional and has a large drainage area. Its proximity to the Middle Branch Root River favors a mix of more warmwater fish species, which may not represent greater Mill Creek. The best trout stream habitat and a more representative coldwater fishery are likely located upstream of the current monitoring locations (upstream of Chatfield but downstream of Highway 52).

Figure 12. Nitrate sampling from multiple sites in Mill Creek from 2019 and 2020 (n=~15 samples/site), showing tributaries in the north and western areas with significantly higher concentrations relative to the southern and eastern subwatersheds.

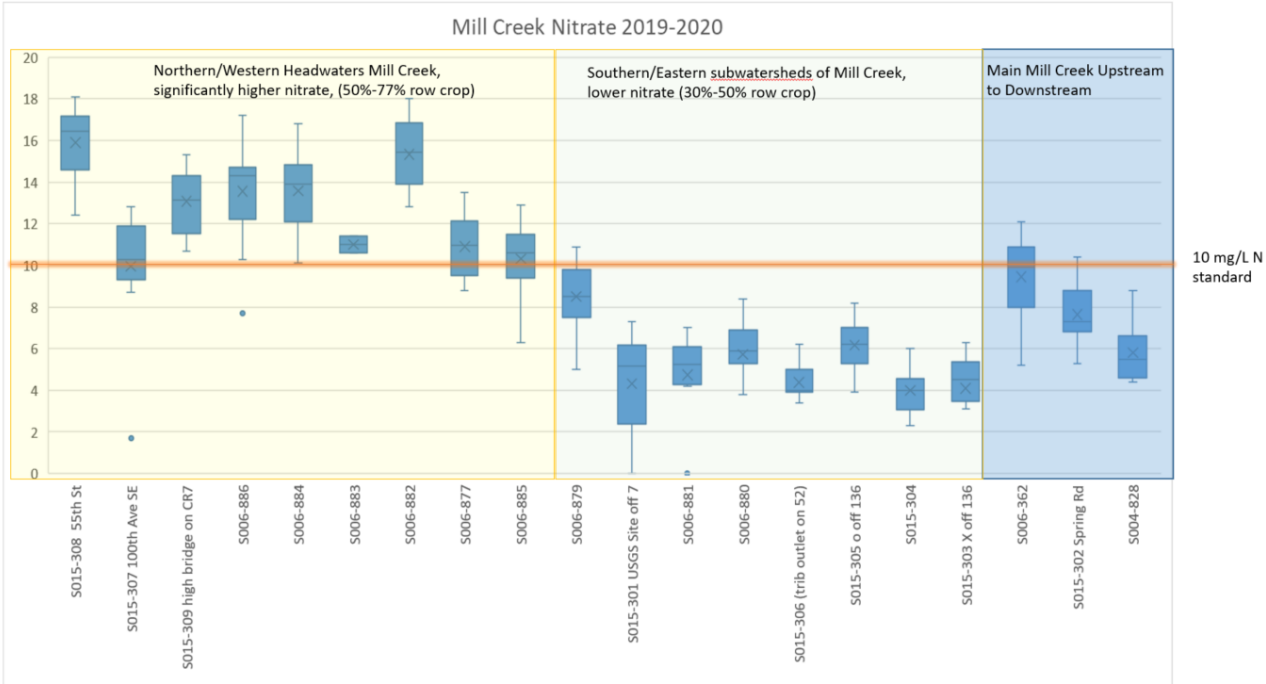


Figure 13. Map of Mill Creek Watershed showing the potential focus area of higher nitrate concentrations in the watershed based on nitrate sampling completed in 2019 and 2020.

Figure 14. Headwater area erosion from a field June 2020 vs July 2020.

Figure 15. Some of the areas of severe bank erosion contributing sediment to the stream in the upper parts of Mill Creek.

Camp Creek (07040008-559)

Biological Community Summary

Camp Creek (07040008-559) was listed in Cycle 1 for fish and macroinvertebrates (Figure 16). Both biological monitoring stations were sampled in 2008 and 2018. Fish still show impairment at both sites, with lower scores at the upstream station 08LM075. Site 08LM046, towards the mouth of the watershed, scored right at impairment threshold for fish in both 2008 and 2018, with mostly brown trout and white suckers present. The upstream site 08LM075 has a much different fish community present, with a larger mix of species and fewer trout. Site 08LM046 indicated a good macroinvertebrate community in 2008, but the score was lower in 2018. Conversely, 08LM075 scored poorly in 2008, but in 2018 was above the impairment threshold. Overall, the invertebrate community as a whole has not made a significant change despite changing scores, and remains stressed. Additional biological monitoring at these sites over time might help understand the variability in scores at these two sites.

Figure 16. Map of the Camp Creek Watershed showing biological monitoring and water chemistry stations. Camp Creek (07040008-559) is impaired for fish and macroinvertebrates, and covers most of the length of the watershed.

What do the monitoring data tell us now?

Previously, the stressors identified in Camp Creek (temperature, nitrate, and habitat) showed most impact at the upper site, 08LM075. Cycle 2 SID work focused on temperature monitoring throughout Camp Creek to understand the thermal differences throughout the stream (temperature impacts had been previously documented by DNR, related to the quarry; report link below). DO and TSS were further examined via Cycle 2 work, since they were inconclusive as stressors in Cycle 1. This included sonde deployments to study DO dynamics and longitudinal sampling for transparency to better understand sediment concentrations throughout the stream system. In addition, elevated nitrate was identified as a potential need to better understand throughout the stream.

Temperature	• New temperature data confirms thermal stress most prominent at the upper site (08LM075) but not the lower site (08LM046). Temperatures warm considerably downstream of the headwater quarry to 08LM075, then get cooler moving downstream to 08LM046 due to more spring inputs in that area
Nitrate	• Nitrate data collected longitudinally in 2019 shows fairly consistent nitrate concentrations (4-8 mg/L) depending on hydrologic conditions. Nitrate is highest in the headwaters and decreases slightly moving downstream
TSS (Total Suspended Solids)	• Transparency data from 2019 showed some instances of high turbidity throughout the stream during storm events. Multiple instances also found the worst transparency at the headwater quarry site, revealing impacts of the quarry on turbidity. There are also many areas of instability and bank erosion. TSS as a stressor has been confirmed, but was previously inconclusive
DO/Eutrophication	• DO was inconclusive as a stressor previously. New sonde data collected at both biological stations in July of 2019 showed that DO levels are ok. Some higher DO flux was observed at the lower site, likely due to more instream aquatic vegetation
Habitat	• Habitat issues persist in Camp Creek and are largely impacted by sedimentation. Bank erosion and fine substrate impact habitat availability and smother important habitat for coldwater fish and macroinvertebrates (like riffle and coarse substrate)
Connectivity	• There are no connectivity stressor concerns in Camp Creek and this stressor was previously ruled out
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Camp Creek has TSS and habitat stressors that are likely attributed to changes in land use, precipitation, and flow, impacting sedimentation dynamics. The headwater quarry is also a direct alteration impacting sediment, flow and temperature

Summary of stream health and recommendations in Camp Creek

Camp Creek is stressed by temperature, nitrate, TSS, habitat, and flow alteration. The headwater quarry is impacting the stream due to changes in flow and temperature dynamics, in addition to being a source of sediment at the headwaters of the watershed. Moving downstream there are additional sediment sources from overgrazing and bank erosion contributing sediment to the stream as well. The lowest 3.5 miles of Camp Creek improve significantly due to more groundwater inputs (reducing temperature and improving water quality overall), but are also still stressed due to the activities going on upstream.

- Longitudinal nitrate monitoring shows that nitrate concentrations are fairly uniform throughout the stream. The highest concentrations were found upstream in the headwater area and decrease slightly moving downstream (median concentrations at all sites was between 5-6 mg/L). The adjacent warmwater tributary (Partridge Creek; eastern part of the watershed) was slightly higher than the rest of Camp Creek (median nitrate of 6 mg/L). Efforts to reduce nitrate would be beneficial throughout the Camp Creek Watershed as not one specific area sticks out as a priority for nitrate reductions. Biologically, there are a high amount of nitrate tolerant inverts and fewer Trichoptera and other nitrate intolerant inverts, which all signal nitrate stress throughout the stream.

- Transparency data taken in 2019 throughout Camp Creek showed in multiple instances, the worst transparency (water clarity) occurred at the headwater site next to the quarry. Most samples showed the best transparency readings found at the lowest site in the watershed (08LM046). Reasons for this include a combination of fewer sediment sources (quarry, bank erosion/overgrazing/land use) and more springs which improve water quality. Areas of severe bank erosion (Figure 17) occur throughout much of Camp Creek. Sedimentation issues related to habitat are apparent, especially at the upstream site 08LM075. The lower site (08LM046) includes habitat improvement projects (from 2015), and does not show as much habitat stress comparatively. Fine substrate and sedimentation impact available habitat for coldwater fish and macroinvertebrates throughout Camp Creek, and reductions in sediment are needed to improve conditions.
- Flow alteration is a likely contributor to sedimentation issues and stream instability. Camp Creek has TSS and habitat stressors that are tied to changes in land use, precipitation, and flow-all of which impact sedimentation dynamics throughout the stream. Encouraging practices in the watershed that reduce storm flow impact, promote water storage, and increase infiltration in the watershed are helpful. Vegetative cover, adequate buffers, and good grazing practices (minimize pasture overgrazing) are also important to reduce impacts from excess sedimentation.
- New temperature data collected throughout the stream show the upper biological monitoring station (08LM075) has an average temperature 5.4 degrees C higher than the lower site (08LM046). The maximum temperature difference between the two stations was 9.3 degrees C. Seasonally, the warmest temperatures throughout Camp Creek are found at 08LM075 (middle of the watershed) in the summer months. In the early spring, this is where the coldest temps are observed throughout the stream, likely indicating fewer groundwater inputs or springs. Past reports from DNR mention spring inputs just upstream of 08LM046. The DNR also documented quarry impacts on temperature to Camp Creek due to alteration of the headwater springs and noted that temperature near the quarry is warmed/altered significantly. (https://files.dnr.state.mn.us/publications/waters/hdraulic-impacts-of-quarries.pdf)

Figure 17. Areas of intense pasture/bank erosion failure near CR22, upstream of 08LM075.

Upper Bear Creek/Lost Creek (07040008-A18 and 07040008-540)

Biological Community Summary

Upper Bear Creek (also known as Lost Creek) was listed in Cycle 1 for fish and macroinvertebrates on the lower part of the stream (see Figure 18, 07040008-540), but also has a new fish and macroinvertebrate impairment upstream (07040008-A18) . Two additional biological sites were recently added upstream with recent monitoring, 18LM019 and 18LM005 (Figure 18), to better understand the entire stream systemFigure 18. The monitoring site 18LM005 represents the coldwater/headwaters area, then 18LM019 represents the middle/warmwater part of the stream. The stream transitions back to coldwater in its lowest section, where 08LM027 is located.

The natural complexity of Upper Bear Creek includes documented losing reaches in the middle sections (in the area of 18LM019; warmwater section). These karst-related dynamics are dependent on yearly hydrologic conditions. The warmwater site scored well for fish and macroinvertebrates in 2018 while the new coldwater site in the headwaters scored poorly and resulted in a new stream impairment for both fish and macroinvertebrates (07040008-A18). The goal of Cycle 2 work was to understand the temperature regimes and variations in stream health across this entire stream system and determine if the same stressors were affecting the stream throughout its length, or are more localized to specific areas of the stream.

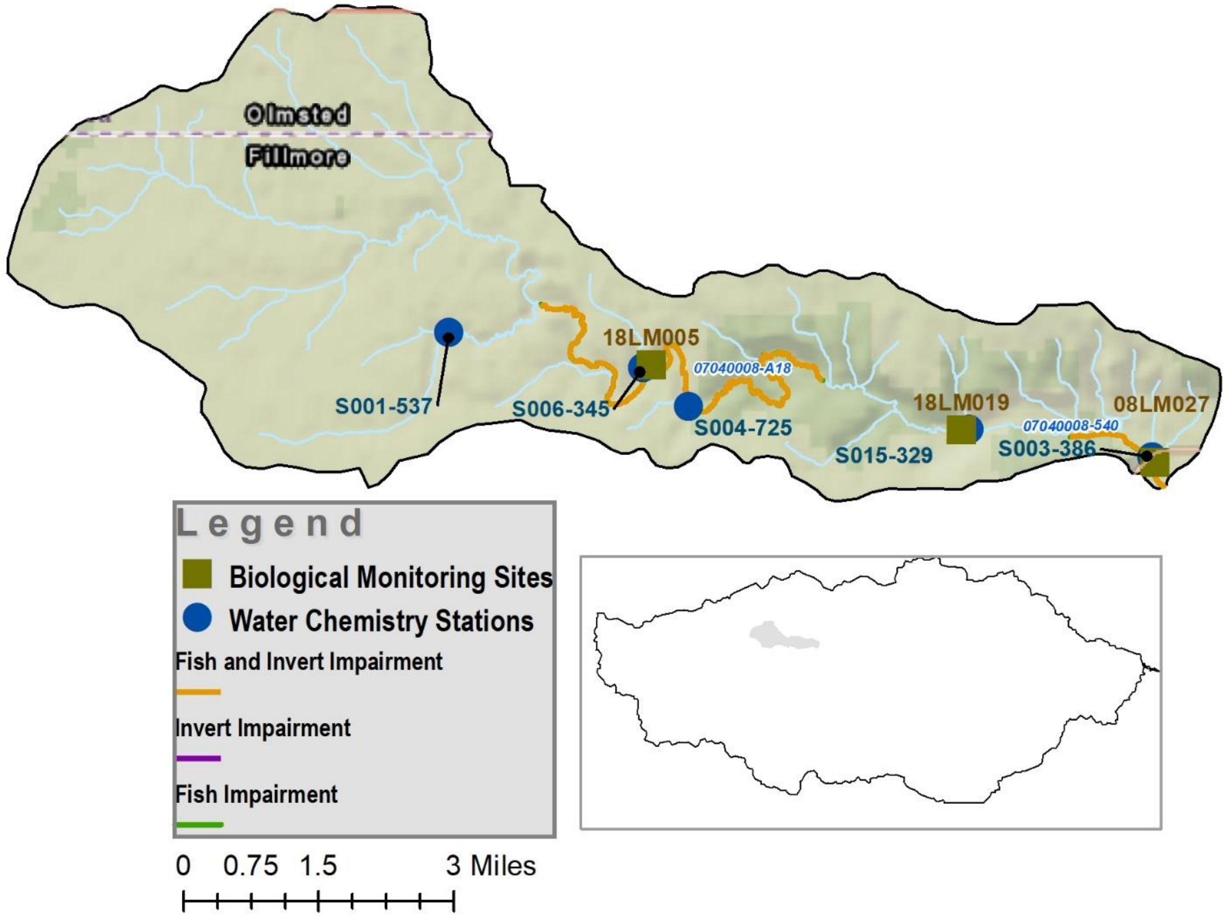


Figure 18. Map of the Upper Bear Creek Watershed showing biological monitoring and water chemistry stations. Upper Bear Creek (07040008-540 and 07040008-A18) are both impaired for fish and macroinvertebrates. It is known to disappear in the middle warmwater section during certain years, the reason it's also widely known as "Lost Creek".

What do the monitoring data tell us now?

During Cycle 1 SID, the stressors identified in Upper Bear Creek (07040008-540) were nitrate and habitat. However, other stressors were considered inconclusive (connectivity, temperature, and TSS). Cycle 2 SID aimed to help understand these potential stressors further, throughout the watershed and determine if the same stressors were impacting the stream throughout its length, including the new impairment in the headwater area.

Stressor	Summary
Temperature	Temperature was inconclusive previously in the lower reach. New continuous temperature data, show temperature is normal throughout and can now be ruled out as a stressor. Continued temperature monitoring may be helpful over time as the hydrology in Upper Bear Creek is very dynamic
Nitrate	Nitrate was identified as a stressor previously. Longitudinal monitoring in 2019 show that nitrate concentrations are fairly uniform, but increase slightly moving upstream through the watershed (from 5 mg/L at the mouth to 6 near the headwaters)
TSS (Total Suspended Solids)	TSS was inconclusive previously but now confirmed as a stressor. Additional transparency information shows the stream can stay turbid for long periods of time and biologically, there is consistent evidence showing abundance of TSS tolerant fish and macroinvertebrates
DO/Eutrophication	Ruled out as a stressor previously in the lower reach. Additional DO information was also collected throughout the stream in 2019; showing adequate oxygen levels and further confirm this stressor is not an issue
Habitat	Habitat was a stressor previously and persists in Cycle 2. Stream instability and sedimentation are key contributing issues for the macroinvertebrate community. Fish do not seem to be responding as much to habitat stress
Connectivity	Inconclusive as a stressor previously, and remains such. Hydrology is dynamic and can vary impacting connectivity and stream flow year to year (disappearing in the middle reaches during dry years). This could be a potential source of stress during those time periods
Flow Alteration	All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Upper Bear Creek has TSS and habitat stressors that are likely attributed to changes in land use, precipitation and flow, all of which impact sedimentation dynamics

Summary of stream health and recommendations in Upper Bear Creek

Additional biological and water chemistry information collected throughout Upper Bear Creek has provided additional layers of information on the stream throughout its length. Abundant transparency information helped confirm that TSS is a stressor throughout the stream (was inconclusive in Cycle 1). Prioritization of future work in the watershed should consider:

- Nitrate concentrations are fairly uniform throughout the watershed, with a slight increase moving upstream (6 mg/L near the headwaters to 5 mg/L at the mouth). Efforts to reduce nitrate would be beneficial throughout the watershed. Biologically, there are a high amount of nitrate tolerant inverts and fewer Trichoptera and other nitrate intolerant inverts, which all signal nitrate stress.
- An extensive transparency dataset in the headwater area (measurements taken almost daily through the monitoring season and after events) demonstrated that turbidity can often be long lasting, which stresses aquatic communities. The most dramatic example is in 2018 when the stream was below 50 cm transparency for thirteen consecutive days. Many years had a week duration or more during which transparency was reduced significantly. The poor transparency and biological responses throughout the stream confirm sediment is a stressor throughout the watershed (Figure 19).
- Macroinvertebrate habitat is impacted by stream instability and sedimentation. However, this this varies significantly depending on flow conditions. Some habitat improvement work (DNR) has occurred in the lower part of the stream near 08LM027. Reducing sediment inputs and storm flow impacts to the stream should be a priority throughout its length to help with habitat loss and TSS issues. Encouraging practices in the watershed that slow water movement,

promote water storage, and increase infiltration are helpful. Vegetative cover, adequate buffers, and good grazing practices are also important.

- Temperature was evaluated with more recent information that confirmed that the Lost Creek thermal regime is typical of a southeast Minnesota trout stream. More springs and coldwater inputs in the lower section (07040008-540) keep temperatures cold in that reach; around 3 degrees cooler there relative to the upper coldwater section (07040008-A18). Continued monitoring going forward will be important in documenting any temperature changes that may come with a changing climate (highly dependent on groundwater inputs, and areas of the stream that are sinking underground).
- Connectivity is a concern for fish migration, due to the natural hydrology and part of the stream disappearing, but not a likely cause of impairment. Migratory fish are present throughout the creek (50% or more of the population), which is a good sign there are not significant impacts to fish. In 2018 and 2019, photos and observations showed the stream flowed throughout the year and did not “disappear” (flow was not entirely lost to groundwater). However, in 2021 the stream did for some period of time disappear in the middle reaches (Figure 20). Additional data over time is needed to ensure this doesn’t become a chronic issue/stressor.
- DO data collected throughout the stream in 2019 shows adequate oxygen levels throughout the stream and can now be ruled out as a potential stressor.

Figure 19. Three sites throughout the watershed from September 3, 2019 during a storm event, showing high sediment concentrations throughout Upper Bear Creek. (Left: Upper Site-18LM005, Middle: 18LM019, Right: Lower Site-08LM027)

Figure 20. Same three sites in the watershed from October 7, 2021, showing the middle warmwater site/photo completely dry with no flowing water. Both coldwater sites did have flowing water. (Left: Upper Site-18LM005, Middle: 18LM019, Right: Lower Site-08LM027)

Spring Valley Creek (07040008-548)

Biological Community Summary

Spring Valley Creek (07040008-548) was listed in Cycle 1 for fish and macroinvertebrates (Figure 21). Since Cycle 1, there was one additional site near the city of Spring Valley that was sampled in 2015 that scored below impairment threshold for both fish and macroinvertebrates. The site in the middle part of the watershed (04LM058) indicated higher scores for fish and macroinvertebrates in 2018 (compared to 2004). Both scores were just above impairment threshold. The site farthest downstream (08LM006) had only a macroinvertebrate sampling visit from 2018 (fish were not sampled). That site score increased significantly from the 2008 sample, but is still just below impairment threshold for macroinvertebrates. The boost in macroinvertebrate scores was at least partially due to increased caddisflies and collector/filterers, boosting both of those coldwater IBI metrics. There was also increases in mayflies and decreases in more tolerant macroinvertebrates like snails. It’s unclear exactly what might be causing this shift, but it likely is due to available habitat as water chemistry has not changed recently. Overall, the current data show the stream is still impaired.

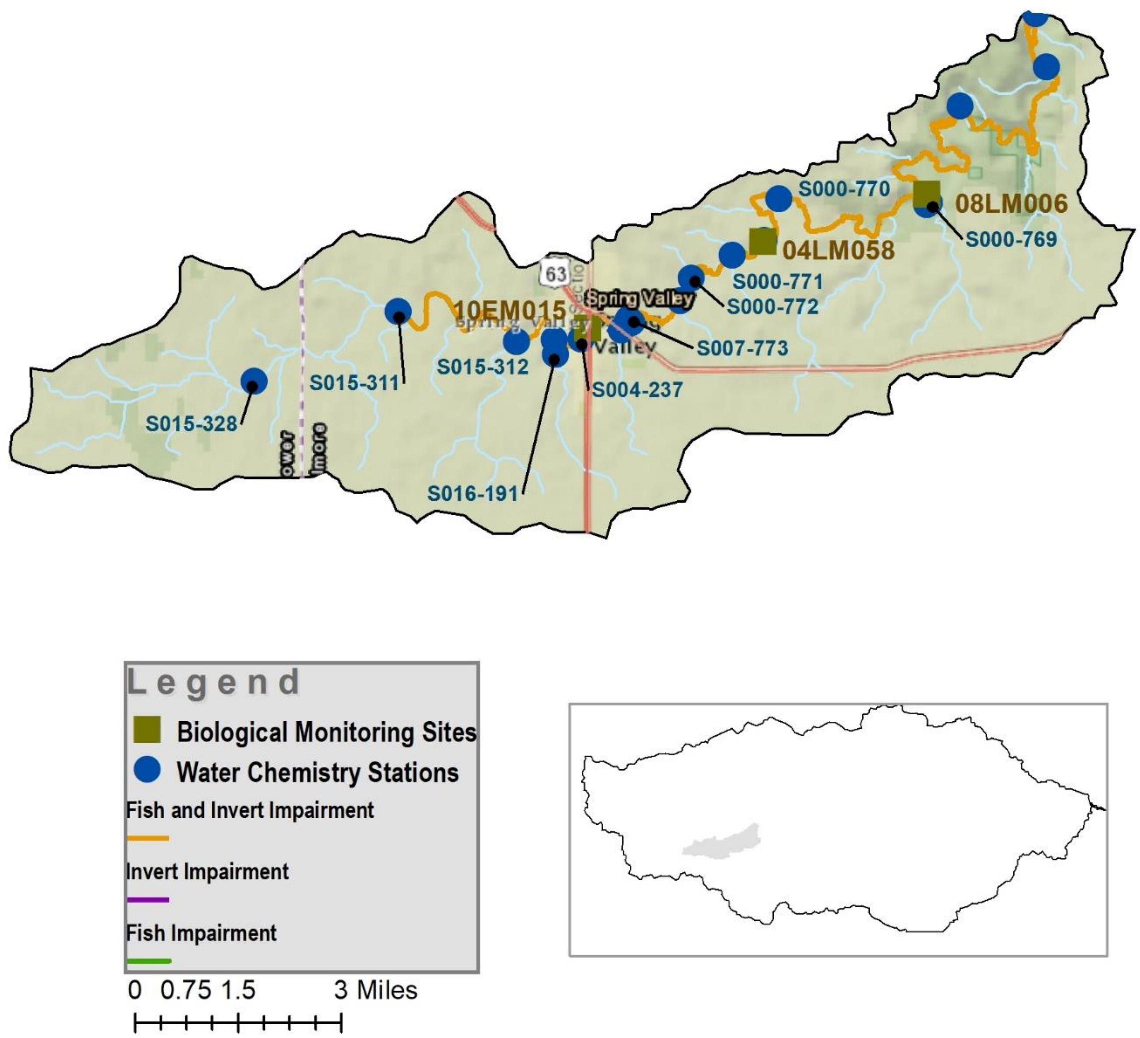


Figure 21. Map of the Spring Valley Creek Watershed showing biological monitoring and water chemistry stations. Spring Valley Creek (07040008-548) covering the majority of its length, is impaired for fish and macroinvertebrates.

What do the monitoring data tell us now?

Previously, the stressors identified in Spring Valley Creek were temperature, nitrate, and habitat. The goal of Cycle 2 SID work was to better understand the potential sources of nitrate and understand how nitrate varies longitudinally throughout the stream system. Additional data on DO was also needed and collected in 2018.

Temperature	• Temperature is a stressor in the lower part of the stream (near 08LM006). It's not the main limiting stressor to Spring Valley Creek. Previous SID work identified increases in temperature due to the trout hatchery ponds that pond spring water and discharge it to the stream. Data collected upstream and downstream of the WWTP show minimal impact to summer temperatures, and is not likely contributing to thermal stress
Nitrate	• Nitrate is high throughout the watershed, as evidenced by a new nitrate listing on this stream (548). It is highest in the headwaters (10-14 mg/L) and decreases moving downstream (to 6-8 mg/L). A small tributary (07040008-D53) is also high at 12 mg/L and is a new nitrate listing. Macroinvertebrates show a consistent response at all sites
TSS (Total Suspended Solids)	• TSS was previously inconclusive and has now been confirmed as a stressor. A fairly robust transparency dataset shows the stream is more turbid than normal which led to a new TSS listing. Biological data shows many TSS tolerant fish and inverts. Tributary with site S015-312 showed consistently poor transparency near the city of Spring Valley
DO/Eutrophication	• Additional DO data was collected but still isn't enough to completely rule out this potential stressor. DO dynamics and corresponding variables (chlorophyll-a, phosphorus, etc) should be collected at more locations to ensure levels remain suitable and are not impacting aquatic life throughout the stream
Habitat	• Habitat was identified as a stressor previously and has shown some potential improvements but also some hints at degradation. Sedimentation issues in the watershed are evidenced by the added TSS listing/stressor and these additional impacts to habitat including photos showing evidence of severe erosion
Connectivity	• Beaver Dams and road crossings could be a variable source of connectivity stress but would have more impact related to habitat as opposed to fish passage issues. At this time there are no connectivity stressor concerns in Spring Valley Creek
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Spring Valley Creek has TSS and habitat stressors that are likely attributed to changes in land use, precipitation and flow, all of which impact sedimentation dynamics

Summary of stream health and recommendations in Spring Valley Creek

Spring Valley Creek is stressed mostly by nitrate, TSS, habitat and flow alteration. Temperature is also still considered a stressor but it is more of an issue in the lower part of the stream, near 08LM006. Nitrate and TSS are issues throughout the stream but show the highest concentrations upstream and near the city of Spring Valley. One tributary (07040008-D53/Site S015-312; Figure 22) is an area of concern, with high nitrate and turbidity comparatively. New drinking water listings (nitrate >10 mg/L) in the watershed on the main stem of Spring Valley Creek (07040008-548) and tributary (07040008-D53) further demonstrate the occurrence of high nitrates. Habitat issues are still prevalent in the watershed and mostly linked to the high levels of sediment and erosion (Figure 25)

- Efforts to reduce nitrate would be beneficial throughout the watershed. However, the highest areas of nitrate as indicated by the 2019 sampling include the area upstream of the city of Spring Valley and the two tributaries (S015-312 and S016-191; Figure 22, Figure 23). The land use in the upper half of the watershed is largely agricultural row crop, and is a large source of nitrate, while the lower part of the watershed has more forest mixed in. The WWTP discharge contributes some nitrate to the stream; its location can be referenced in Figure 23.

- Efforts to reduce sediment should be focused throughout the watershed as well; one tributary did show elevated sediment from low transparency readings (S015-312; Figure 24). While this tributary does not have a large flow volume it does have both high concentrations of sediment and nutrients being delivered to Spring Valley Creek.
- Flow alteration is a likely contributor to sedimentation issues and stream instability. Spring Valley Creek has TSS and habitat stressors that are tied to changes in land use, precipitation, and flow-all of which impact sedimentation dynamics throughout the stream. Encouraging practices in the watershed that reduce storm impact, promote water storage, and increase infiltration are helpful. Vegetative cover, adequate buffers, and good grazing practices are also important.
- Aside from SID, a more recent study on Spring Valley Creek (Fairbairn, et al 2019) is currently attempting to understand the potential influence of other chemicals to the stream and aquatic life (i.e. contaminants of emerging concern [CEC]). The preliminary data collected in 2019 confirm that agriculture, storm water runoff from the city of Spring Valley, and the wastewater treatment plant (WWTP) are all CEC sources in the watershed. Increased mortalities of zebrafish embryos associated with the storm water runoff and WWTP effluent were found, and may be linked to biological stressors observed. However, additional information is needed to better understand these relationships and determine the influence to Spring Valley Creek in conjunction with other stressors. This work started in 2019 and is planned to continue through the next few years.

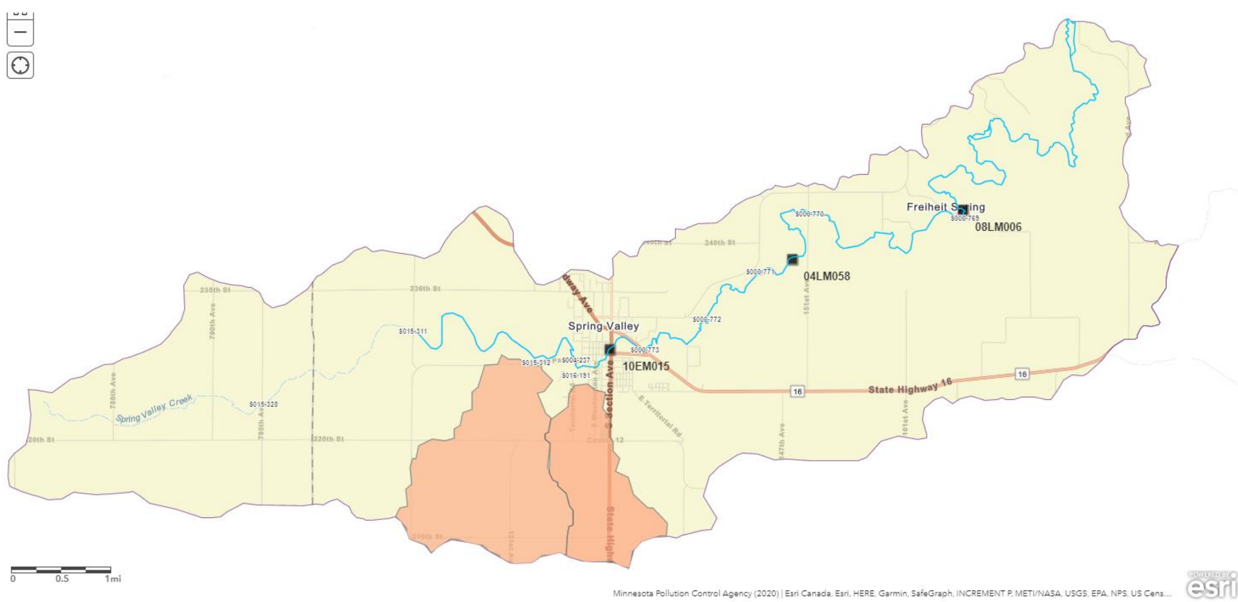


Figure 22. Map of Spring Valley Creek Watershed and two tributaries with high nitrate (>10 mg/L; shown in orange). The west tributary watershed (S015-312; left) also had lower transparency readings comparatively in 2019 as well.

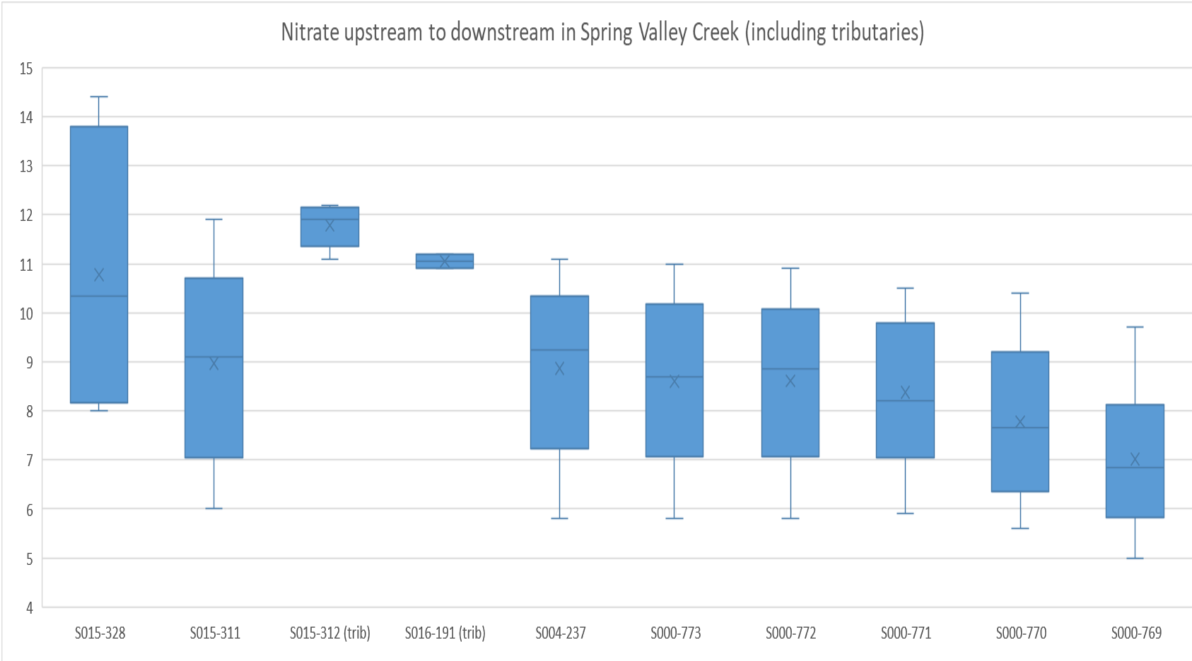


Figure 23. Boxplot comparison of nitrate concentrations in Spring Valley Creek in 2019. The two tributaries showed the highest concentrations, but nitrate is highest upstream (left) and decreases moving downstream (right). The Spring Valley WWTP discharge location is also noted, with sampling sites just upstream and downstream of the outfall location.

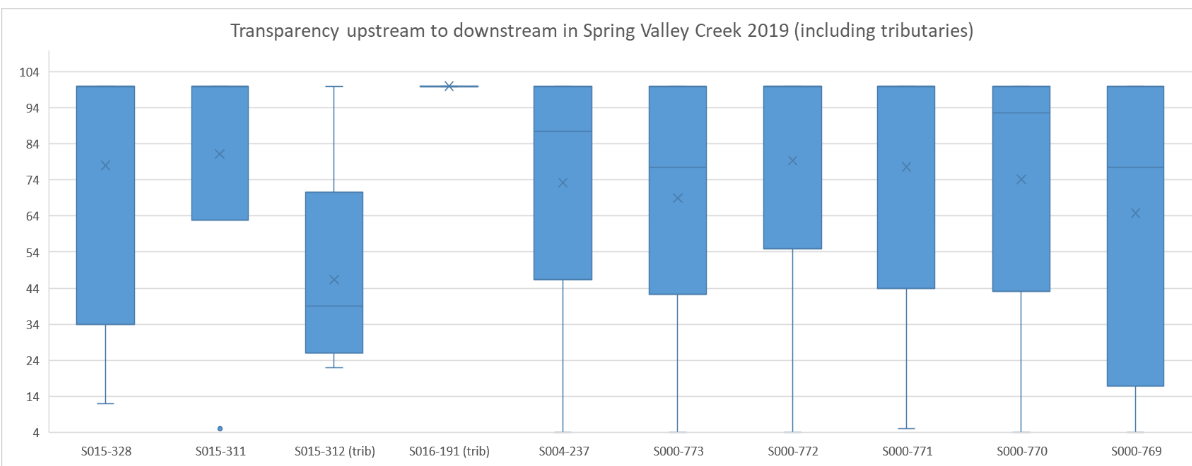


Figure 24. Transparency boxplot of sites in Spring Valley Creek from 2019. Tributary S015-312 had the worst transparency readings comparatively throughout the entire watershed.

Figure 25. Photo of 08LM006 on 6/5/2019 showing severe bank erosion.

Silver Creek (07040008-640)

Biological Community Summary

Silver Creek (640) was listed as impaired for fish and macroinvertebrates in Cycle 1 (Figure 26). Since then, additional data collected at 08LM060 has indicated the stream is recovering from the historic 2007 flood that severely affected the stream channel. The recovery has been more significant for fish, with a dramatic increase in fish scores and sensitive species (brook trout) present when comparing 2008 to 2019 data. After additional monitoring in Cycle 2, the fish IBI score increase was enough to remove it from the impaired waters list for fish. The macroinvertebrate community has improved slightly, but it is still considered impaired.

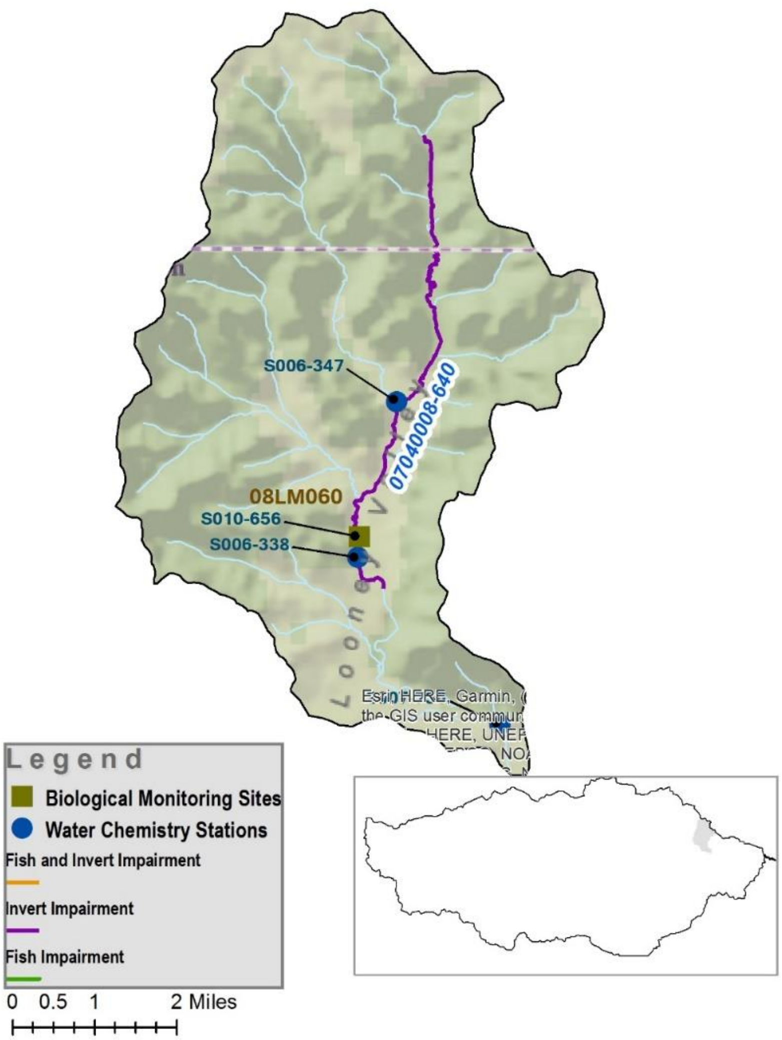


Figure 26. Map of the Silver Creek Watershed showing biological monitoring and water chemistry stations. Silver Creek (07040008-640) is impaired for macroinvertebrates (previously impaired for fish and delisted).

What do the monitoring data tell us now?

During Cycle 1 SID, the only stressor identified in Silver Creek was habitat. The flood of 2007 caused a major disruption in sediment transport and stream channel habitat availability. Previous inconclusive stressors (due to insufficient information) included nitrate, temperature, and TSS. The goal of new SID work in Silver Creek was to further understand the changes in habitat and stream health since the flood, and determine if any of the previous inconclusive stressors could be ruled out.

Stressor	Notes
Temperature	• Temperature was inconclusive previously. New continuous temperature data, and increases in coldwater fish and invertebrate individuals show temperature can now be ruled out as a stressor
Nitrate	• Nitrate was inconclusive previously. While data is limited, the concentrations remain low (~1 mg/L) and do not support it is a likely stressor. Other stressors are making the predominant impact
TSS (Total Suspended Solids)	• Additional chemical information on TSS is needed as the data continue to be limited. Biologically, fish show major improvements with TSS related metrics, while inverts do not. Sediment related habitat issues are the known stressor, but TSS is still less clear
DO/Eutrophication	• DO was ruled out as a stressor previously. Both communities show improvements in most DO related metrics from 2008 to now which further affirms this stressor is not an issue in this stream
Habitat	• Improvements in habitat and recovery of the stream have occurred since 2008. Both fish and inverterbrates show improvements in habitat related metrics, but habitat problems for invertebrates still exist
Connectivity	• Ruled out as a stressor previously. Improvements in fish community are further evidence that connectivity is not a concern for fish movement. Beaver dams may cause localized habitat issues
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Silver Creek has habitat stressor that could be attributed to changes in land use, precipitation and flow, all of which impact sedimentation dynamics

Summary of stream health and recommendations in Silver Creek

Additional information collected confirmed that neither temperature nor nitrate are stressors, further underscoring habitat as the primary cause of impairment. Fish habitat has improved significantly in recent years (more pools/depth variability providing refuge and cover for fish). The initial fish sample was immediately following the 2007 and 2008 floods, and the more recent sample occurs during a more typical condition (Figure 27). However, largely due to lack of good stream substrate, the macroinvertebrate community is still not meeting coldwater standards.

- Multiple aspects of habitat for both fish and macroinvertebrates show positive improvements from 2008 to 2018. More recovery time could result in continued improvements in habitat for macroinvertebrates in Silver Creek as they are more impacted by the degraded habitat conditions (sedimentation, lack of coarse substrates, and lack of woody habitat). The habitat sampled at all three visits in Silver Creek was undercut banks/overhanging vegetation only.
- More data is needed to determine if sediment is driving any stress beyond habitat (e.g. long periods of suspended sediment). The increased abundance of brook trout Indicates that baseflow water chemistry and stream temperatures are good.
- Large storm events could adversely impact stream habitat, as evidenced by the 2008 sampling. Instability upstream can also cause a flux in habitat and sediment over time, so it will be important to monitor conditions of the watershed over time. Aerial photos from 2020 do suggest there is instability upstream of the monitoring location that is contributing to sedimentation and habitat issues at the biological monitoring locations.

Figure 27. Aerial photos comparing the stream in 2008 (top) to 2020 (bottom). The stream channel has narrowed and healed from the flood of 2007 in this location, increasing available fish habitat and fish IBI scores.

Corey Creek (07040008-631)

Biological Community Summary

Corey Creek (07040008-631) was listed in Cycle 1 as a fish impairment (Figure 28). With the most recent round of monitoring, one additional biological site was added upstream to better understand the entire stream system (18LM016). The addition of 18LM016 provided a sampling of a more representative condition of Corey Creek and shows that the fish community in Corey Creek is doing well, typical of a coldwater stream in southeast Minnesota. The old site, 08LM018-is at the “bottom” of the stream system and it is downstream of a perched culvert. This additional site and biological data help rule out other potential stressors and confirm the stream is healthy.

Figure 28. Map of the Corey Creek Watershed showing biological monitoring and water chemistry stations. Corey Creek (07040008-631) is impaired for fish.

What do the monitoring data tell us now?

The previous SID process found stressors of temperature, habitat, and connectivity. TSS was considered inconclusive. These stressors were all associated with a perched culvert and less than ideal sampling location. Therefore, these stressors do still exist but only affect a very small portion of Corey Creek (the most downstream 0.25 mile stream section) and the remaining portions of Corey Creek are in good health as evidenced by the new biological monitoring site 18LM016.

Summary of stream health and recommendations in Corey Creek

Overall, aquatic life throughout most of Corey Creek is healthy. The new biological sample collected at 18LM016 helped confirm this and determine the stressors to Corey Creek are restricted to the mouth of the watershed, downstream of the perched culvert, at site 08LM018.

- The current fish community impairment is a direct result of the site location (08LM018), which is downstream of a perched culvert. This culvert causes changes in flow and sediment transport, which also degraded the habitat and temperature conditions in this specific reach. The culvert also is a fish barrier and disrupts free movement of fish to occupy the full length of the stream.
    - A quick fix to this problem would be to replace the perched culvert. However, the cost of the fix might outweigh the net benefit as only a small section of stream would be restored
- Additional biological monitoring upstream in 2018 (18LM016) helped confirm that Corey Creek is healthy overall despite the impaired waters listing for fish. Temperature data also confirm temperatures are suitable in this location as opposed to the lower site. Many sensitive fish and macroinvertebrates are present at this location and also signal that TSS can likely be ruled out as a stressor. Therefore, no additional work or investigation of stressors is necessary in Corey Creek.
- Corey Creek (07040008-631) was approved for a 4C re-categorization in 2020, with the recommendation being forwarded to the U.S. Environmental Protection Agency (EPA) for final approval. As a result, Corey Creek will remain on the impaired waters list, but as 4C, which indicates that pollutant stressors are not the cause of impairment and a total maximum daily load (TMDL) is not needed.

Pine Creek (07040008-526)

Biological Community Summary

Pine Creek (07040008-526) was listed in Cycle 1 for macroinvertebrates (Figure 29). With the more recent monitoring, one additional station was added (18LM020) to help better characterize the differences between sites throughout Pine Creek. This site was located in an area of new habitat improvement work, and in-between sites 04LM097 and 04LM095. The biological data collected at 18LM020 and the previously established stations indicate that while the fish and macroinvertebrate indicators vary somewhat given the significant length of the monitored stream reach, the overall aquatic health of the system is good and typical of a coldwater stream in southeast Minnesota and thus a macroinvertebrate delisting is proposed on the entire stream. This area could be prioritized for protection to ensure macroinvertebrates remain healthy.

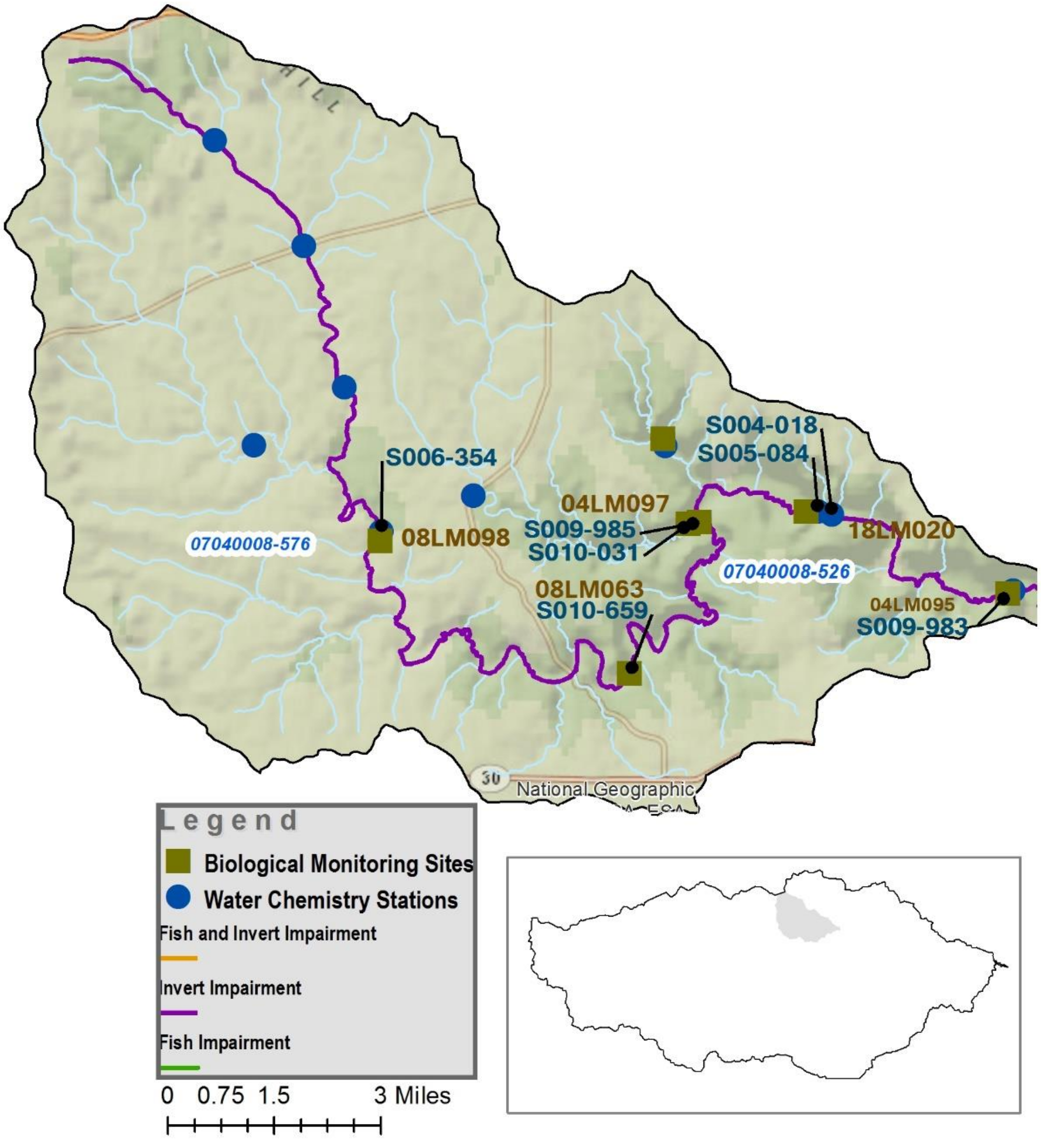


Figure 29. Map of the Pine Creek Watershed showing biological monitoring and water chemistry stations. Pine Creek (07040008-526) is impaired for macroinvertebrates.

What do the monitoring data tell us now?

Previously, the stressor identified to Pine Creek was habitat. DO, nitrate, and TSS were inconclusive as stressors. The goal of new SID work was to understand any other potential stressors and differences in habitat conditions throughout Pine Creek. With the addition of a new biological site and updated information biological sampling information, this stream is a proposed delisting. The data show that habitat is good at 18LM020 (new site with recent habitat improvement work) and the habitat parameters for macroinvertebrates show improvements at 04LM095 and 04LM097 as well. Not only are there fewer burrowers (which can indicate sedimentation in riffle habitats) but there were more clingers (which need coarse substrates and woody debris to thrive). This likely points to the potential of better habitat conditions at these two sites and thus the increase in IBI scores.

Summary of stream health and recommendations in Pine Creek

While habitat remains the largest concern in Pine Creek, other potential stressors should not be overlooked for future protection. Nitrate is elevated in the watershed and there are hints that TSS/erosion issues could be a threat as well. Sedimentation issues often play into habitat dynamics so it's important to keep tabs on these issues to ensure things don't degrade in the watershed. Recent data shows things have improved for macroinvertebrates and with available habitat/bank erosion issues, but this should be watched over time to ensure changes in hydrology/flow alteration, bank erosion, and sedimentation do not lead to declines in macroinvertebrates. It's possible the flood of 2007 had impacts to the macroinvertebrate community, which hadn't fully recovered when the sites were originally sampled in 2008. The stabilization of streambanks and habitat improvement projects (3 separate projects have occurred from 2012 through 2015 between school section road and 04LM095) have likely improved some forms of habitat for macroinvertebrates in Pine Creek. Other more recent conservation practices that have occurred due to other projects in the watershed (MRBI) may also be playing a role in improving the health of the watershed and habitat more generally. The hydrology from year to year is another key driving force that will need to be considered moving forward. In combination, all of these factors likely play a role in available habitat, nitrate concentrations and thus macroinvertebrate community in Pine Creek.

South Fork Headwaters (07040008-573)

Biological Community Summary

The South Fork Headwaters (07040008-573) was listed in Cycle 1 for macroinvertebrates (Figure 30). Since its first assessment, station 04LM113 has been visited multiple times with varying results. Fish have scored well, but macroinvertebrates have been highly variable. In 2004, 2011, and 2012, the MIBI scores were below impairment threshold (scores of 14, 27 and 6 respectively) and in 2018, the MIBI score jumped to 47, which is above impairment threshold. This jump in score was likely attributed to the presence of more mayflies, caddisflies, and odonata (dragonflies and damselflies) than had been sampled previously. Snails (tolerant, indicator of stress) were also still present but did not dominate the community as in previous years, which drove the score down.

Figure 30. Map of the South Fork Headwaters Watershed showing biological monitoring and water chemistry stations. This stream (07040008-573) is impaired for macroinvertebrates.

What do the monitoring data tell us now?

The stressors identified in Cycle 1 were DO, nitrate, TSS, and habitat. The Cycle 1 SID process found that flow is a huge driver to the stressors and IBI scores seen in any given year. Increases in MIBI score in recent years could be tied to positive changes in habitat and/or flow. Sonde data collected in 2018 show oxygen levels haven't really changed; the stream still sees periods of low DO and high DO flux, despite positive changes in MIBI score. However, other years with less flow may have more critically low DO and greater impact on the macroinvertebrate community. More data over time would help understand these changes better as the synergistic stressor impacts could vary significantly year to year.

Summary of stream health and recommendations in the South Fork Headwaters

The stressors identified in Cycle 1 are still relevant, despite an increase in IBI score in 2018. Severity and connection of the stressors to each other is largely tied to flow in any given year.

- Embeddedness and lack of riffle/woody debris are largest limiting factors related to habitat. Local land use was noted as large contributor to stress (Figure 32). Improvement in the riparian corridor may have helped increase the MIBI score in 2018, but more data over time would help understand if 2018 had other impacts (like more flow) that also helped boost that score. While macroinvertebrates seemingly improved, it’s a little too early to say that this is due solely to the improved habitat.
- Opportunities still exist to improve water quality in the headwater area of the South Fork Watershed (Figure 31). Feedlot improvements, practices that help reduce erosion and sedimentation in the stream channel, ensuring the stream is not excessively grazed, and has adequate buffers could help water quality. A study by Winona State Water Resources Center determined that this reach had high levels or organic fractions of sediment during baseflow conditions, which were likely tied to near stream agricultural land uses (Dogweiler 2010).
- Streamflow remains as one of the largest drivers of potential stress to this stream and is connected to all of the stressors observed. The lack of flow in late summer months can drive oxygen dynamics further exacerbated by high sediment/organic and nutrient inputs.
- The South Fork Root River is in the 1W1P focus area, and the headwaters specifically has also seen improvements due to MRBI conservation investments. Future monitoring over time will help understand if any possible changes in water quality occur due to these focused efforts.

Figure 31. Photo looking upstream from biological monitoring station on 8/7/2018 during sonde deployment showing stagnant water and foam/scum. This was also observed in photos when sonde was picked up on 8/20/2018.

Figure 32. Aerial photo comparison showing positive changes in riparian corridor at the biological monitoring station (04LM113) from 1991 to 2015.

South Branch Headwaters (07040008-H18)

Biological Community Summary

The South Branch Headwaters is a new "modified" macroinvertebrate listing (07040008-H18), with two biological stations that have been visited multiple times in recent years (Figure 33). The modified use designation for this stream means that habitat has been modified (due to channelization) and separate standards have been applied (TALU). This site has been sampled regularly due to the Root River Field to Stream (RRFSP) project. Overall, the biology in the South Branch Headwaters shows mixed results in terms of stream health. The fish community is doing well, while macroinvertebrates are not. The community lacks more sensitive macroinvertebrates (stoneflies, dragonflies/damselflies, mayflies, and caddisflies), while having an overabundance of very tolerant macroinvertebrates like physella (snails), and worms or midges. These macroinvertebrates are tolerant of poor habitat and water quality conditions.

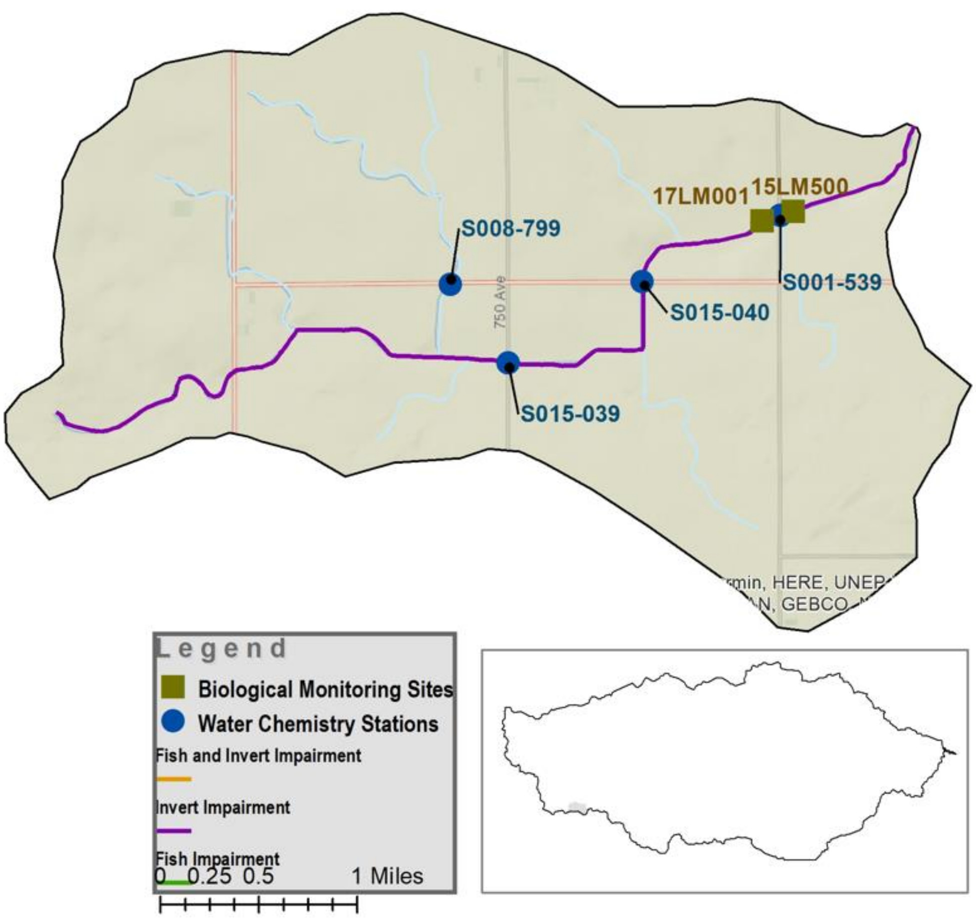


Figure 33. Map of the South Branch Headwaters Watershed showing biological monitoring and water chemistry stations. This stream (07040008-H18) is impaired for macroinvertebrates.

What do the monitoring data tell us now?

Water chemistry in the South Branch Headwaters is quite typical of other headwater ditch systems. This includes generally higher nitrate levels when drainage tiles are flowing in the spring. TSS concentrations show that this stream can have very high amounts of sediment moving through the system during storm events. Almost half of the stormflow samples taken at this site exceed the TSS standard of 65 mg/L. However, the concentrations often recover to acceptable levels during baseflow conditions. It is possible these high TSS concentrations during storm events are shaping the macroinvertebrate community present, especially as it relates to yearly hydrologic conditions (wet/dry cycles) but it is not likely the predominant stressor. Continued data collection on sediment, other stressors, and aquatic life will help understand the variability among years and if any changes are occurring.

Other stressors impacting the macroinvertebrates include dissolved oxygen and habitat. A multi-parameter sonde (device that measures water quality every 15 minutes) was deployed in August 2019 (August 7 through September 3) showed that DO was low, correlating to when water flow was low. DO levels in the stream dipped lower than the warmwater standard (5 mg/L) for multiple days in a row, which can be stressful to aquatic life. The lowest DO concentration measured was around 4 mg/L. DO flux during this time period was around 5 mg/L on average. Total phosphorus (TP), biochemical oxygen demand (BOD), and chlorophyll-a collected at time of sonde deployment all were low (meeting standards for the central river eutrophication region). Similarly, baseflow samples of TP have been low; very rarely exceeding the standard of 0.150 mg/L (130 samples collected from 2010 through 2019). These results suggest eutrophication/elevated phosphorus is not the likely contributor to the low DO observed. Rather limitations related to flow and ditched stream channel are driving the DO dynamics.

Flow data collected by DNR since 2008 reveals that every year the stream has long periods of very low flow in the late summer. Flow is commonly observed to be “little or no flow” from July through early fall, sometimes later depending on rainfall events. These conditions reduce available habitat and provide less oxygen, both of which affect aquatic life health and survival. The stream is dominated by legless tolerant macroinvertebrates that can thrive in poor habitat and oxygen environments. There are also fewer sensitive macroinvertebrates like caddisflies, stoneflies, and mayflies. Similarly, there are fewer clingers-which require habitat conditions this stream does not support (like rock and woody debris). The main habitat type available for macroinvertebrates are banks and overhanging vegetation, both of which are highly dependent on water levels and flow. Without suitable flows, and extensive channelization, those habitats are further minimized.

Temperature	• Unlikely stressor in a warmwater stream system. However, higher temps could become an issue during low (no) flow conditions and extreme high air temps
Nitrate	• Nitrate is highest in May/June, some values >20 mg/L. Median nitrate often between 9-15 mg/L. Macroinvertebrate species present are very tolerant to high nitrate. Missing species intolerant to high nitrate, like Trichoptera
TSS (Total Suspended Solids)	• High sediment during storm events; stress is likely dependent on yearly high flow conditions. Continued data collection will help understand the variability from year to year
DO/Eutrophication	• Available oxygen depends on yearly low flow conditions. There are many low DO tolerant bugs present. The stream often sees DO values below 5 mg/L. Eutrophication is not the likely cause of low DO, it is due to flow conditions.
Habitat	• Dominated by tolerant bugs that can thrive in poor habitat and oxygen environments. Few EPT taxa, and clingers-which require good habitat. Available habitat is dependent on flow on ditch characteristics are limiting available habitat
Connectivity	• No known physical barriers or disruptions to longitudinal connectivity. Fish community is meeting standards
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Every year this stream has long periods of very low flow in the late summer. These conditions reduce available habitat and provide less oxygen. Ditching and tile drainage impact flows (high and low) and directly impacts available habitat and increases nitrate transport

Summary of stream health and recommendations in the South Branch Headwaters

The macroinvertebrates in the South Branch Headwaters are stressed by flow alteration; in addition to other connecting stressors like poor habitat, low oxygen, and high nitrate levels. These are common stressors in a watershed dominated by tile drainage and channelization (ditching).

- Nitrate concentrations are variable (often 9-15 mg/L) and likely causing stress to aquatic life (macroinvertebrates only), and concentrations can be quite high (>20 mg/L) when tiles are flowing early in the year.
- High streamflow early in the year can result in sediment spikes (TSS) that can be stressful to aquatic life and result in degraded habitat (embedded substrates, filled-in pools).
- Additionally, during the summer baseflow period the stream experiences lack of flow. Every year since 2008 this stream experiences very low to almost no flow in August. Often this begins in July and will persist into the fall depending on rainfall.
    - Low DO and poor habitat have the biggest impact to aquatic life during these low flow periods, as these are directly dependent on the streamflow in the channel in any given year. Disturbances related to ditching and channelization (i.e. ditch cleanouts and management) are also a concern as they cause direct changes to the available habitat. Eutrophication/phosphorus is not the likely driver of low DO.

- In July 2017, there was an aerial application of chlorpyrifos (agricultural pesticide) in the watershed that then caused a water sample exceedance of the acute standard. The chemical sample was taken in July just before the biological sample in August. This presented an opportunity to potentially see an impact to aquatic life. However, the results from biological sampling did not show a noticeable difference (relative to IBI score or metrics from other years) due to this event. Information on pesticides and its connection to aquatic life is lacking in Minnesota. More complete datasets in future years will provide better understanding of connections between aquatic life and pesticides in the South Branch Headwaters.

Bridge Creek (07040008-G92)

Biological Community Summary

Bridge Creek (07040008-G92) has been sampled regularly in recent years due to the RRFSP (Root River Field to Stream) project. Early on, the stream was not designated coldwater and therefore aquatic life assessments were not official until it was confirmed to be a coldwater stream. In anticipation of aquatic life impairment, SID work began on Bridge Creek in Cycle 1 and new information in recent years has added a lot of value to understanding this stream. Overall, the aquatic life results at 08LM103 in Bridge Creek shows mixed results over time (Figure 34). Fish are doing quite well, with a community that has been dominated by brook trout each year it was sampled. The macroinvertebrates; however, have shown a wide range of IBI scores over time. In 2008 when the site was first sampled, the macroinvertebrate score was very low, enough to be considered impaired for a coldwater stream. This was due to a large number of snails in the sample, due to the lack of habitat for coldwater macroinvertebrates. This lack of habitat in 2008 was a consequence of a beaver dam, which created an upstream-reaching pool effect, thus greatly slowing current and resulting in the in-filling of stream-bed habitat. Sometime after that, when the beaver dam was removed, better in stream habitat for macroinvertebrates became available and was reflected in increased MIBI scores.

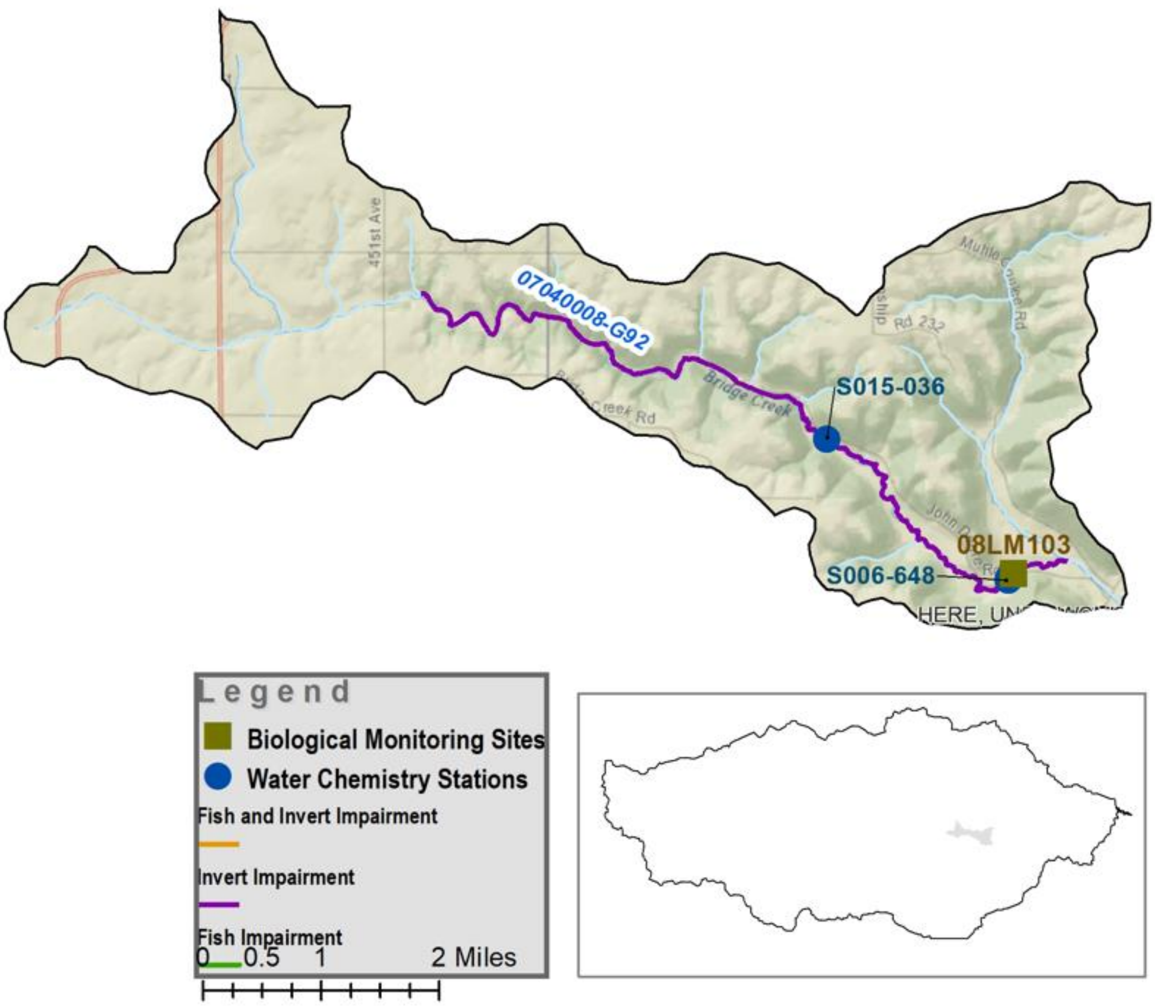


Figure 34. Map of the Bridge Creek Watershed showing biological monitoring and water chemistry stations. This stream (07040008-F54) is impaired for macroinvertebrates.

What do the monitoring data tell us now?

Water chemistry in Bridge Creek is typical of a bluffland karst coldwater stream, but TSS levels can be concerning in Bridge Creek during storm events. Continuous sediment monitoring data shows this stream does not stay turbid for long durations and often clears up within one or two days of a rainfall event. Large amounts of sediment during storm events or sediment settling out covers rocks and cobble, which is necessary habitat for macroinvertebrates. These conditions vary yearly depending on streamflow conditions in that year and the storm events leading up to the biological sample (up to one year prior). Due to the beaver dam in 2008, riffles were not an available habitat for macroinvertebrates at all, which caused the lower macroinvertebrate IBI score. In 2015 and 2016, the scores increased due to better riffle habitat. Then the scores dropped back down again in 2017 and 2019, but they were not nearly as low as 2008. This change could be due to shifts in available habitat during those years. For example, in 2017 there was only 5% riffle habitat; much lower than 2015 and 2016, which noted significantly higher proportions of riffle habitat. Hydrologically, 2017 was noted as a more normal flow year, with not as many storm events. The sequence of storm events and large flooding events can also be a factor that can have a large impact on available habitat. In 2019, Bridge Creek saw a lot of storm events and high flows that may have stressed the bugs in the form of TSS, erosion, or sedimentation. These streamflows have the ability to scour streambeds clean and reveal this prime habitat, but also have the potential of causing erosion and thus depositing sediment to cover those very habitats. This constant influx can be normal and may be one of the reasons we are seeing variable macroinvertebrate scores in Bridge Creek over time.

Temperature	• Temperatures are suitable; July and August Average temperatures 15-16°C, which is normal. There is an abundance of coldwater sensitive species present.
Nitrate	• Nitrate concentrations in Bridge Creek are quite low; on average 2.6 mg/L. There is also very little indication that the bug community is suffering from nitrate.
TSS (Total Suspended Solids)	• Baseflow concentrations of TSS are suitable. Sediment monitoring data shows this stream does not stay turbid for long durations and often clears up within one or two days. However, sedimentation affecting habitat is a concern. TSS should continue to be monitored to ensure its not causing adverse impacts to aquatic life.
DO/Eutrophication	• Dissolved oxygen levels are normal and there are low DO intolerant macroinvertebrates present in addition to fish that require good oxygen levels.
Habitat	• Macroinvertebrates have been limited in some years by a combination of habitat, sedimentation, and/or beaver dam issues. Macroinvertebrates responded significantly to changes in habitat from 2008 to 2015.
Connectivity	• Beaver Dams could be a variable source of stress related to habitat. However, there is little evidence that beaver dams or the perched culvert @ John Deere Rd are causing chronic stress to aquatic life at this time.
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Bridge Creek has habitat issues that are likely attributed to the changes in sedimentation dynamics in the watershed

Summary of stream health and recommendations in Bridge Creek

Overall, fish are doing quite well in Bridge Creek with brook trout dominating the community. Macroinvertebrates are suffering due to available habitat in any given year. More recent increases in the MIBI scores are directly attributed to changes in available habitat at the site location. Reducing erosion and sedimentation to the stream is important.

- Nitrate concentrations in Bridge Creek are low, on average 2.6 mg/L, similar to other bluffland coldwater streams. DO and temperature are both considered suitable in Bridge Creek and what we would expect for a stream like this. Coldwater sensitive species like brook trout require specific temperature and oxygen levels in order to be present.
- Macroinvertebrates have been limited in some years by a combination of habitat, sedimentation, and/or beaver dam issues. Macroinvertebrates responded significantly to changes in habitat from 2008 to 2015. There was a documented increase in riffle habitat, which dramatically increased the IBI scores in 2015.
- High sediment transport is common in this stream, and could be part of the reason for variations in available habitat, especially as it relates to coarse substrates. Land use practices that help keep sediment and flows in check will be important moving forward to stabilize habitat conditions and provide coarse substrates and riffle habitat needed for coldwater macroinvertebrates to thrive.

Crystal Creek (07040008-601)

Biological Community Summary

Aquatic life in Crystal Creek (07040008-601; 12LM103) is meeting standards for fish and bugs but the data indicate it is vulnerable to future impairment (Figure 35). Both fish and MIBI scores are hovering right around the aquatic life impairment threshold. The fish community has seen some small improvements in recent years, with a more dominant community of brown trout. Macroinvertebrates show a mix of scores over time but they could be at risk due to evidence of some potential stressors present. Additionally, Crystal Creek has also been added as a new nitrate (drinking water) impairment.

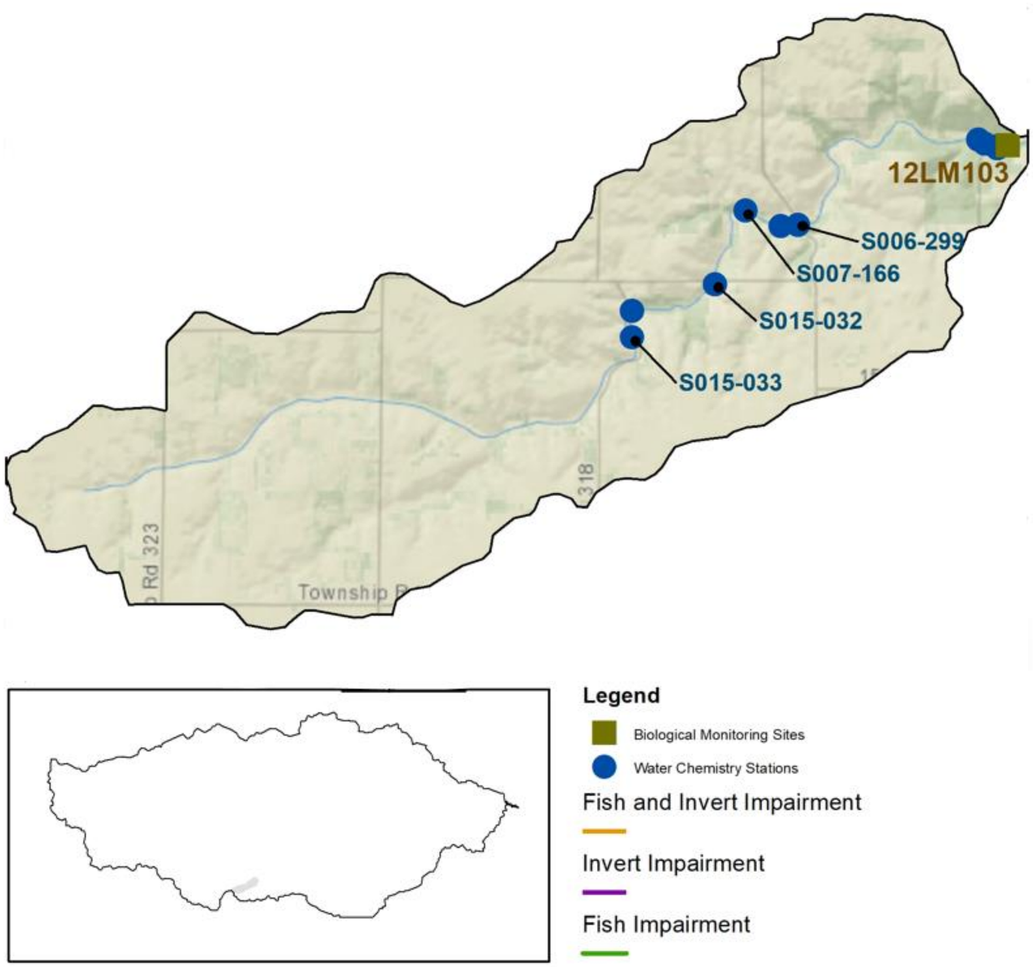


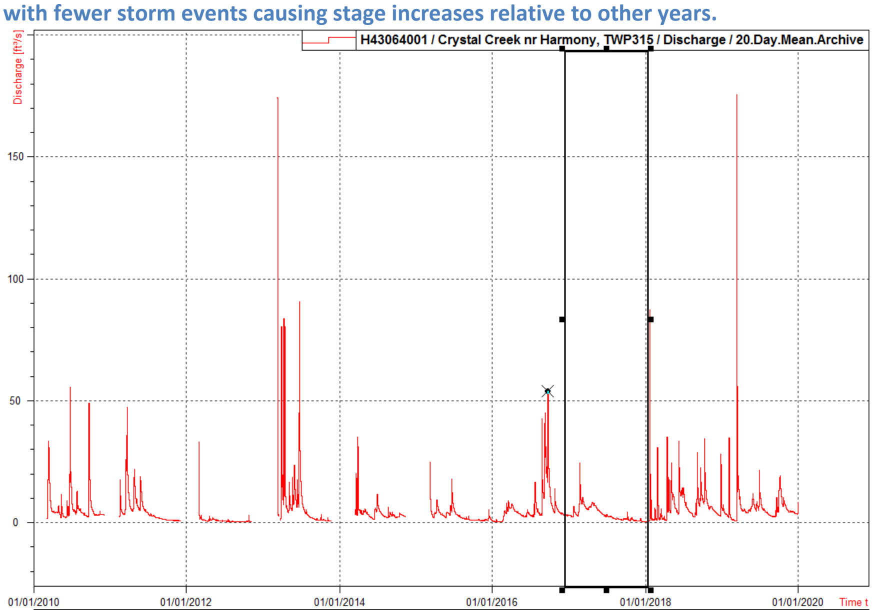
Figure 35. Map of the Crystal Creek Watershed showing biological monitoring and water chemistry stations. This stream (07040008-601) is not currently impaired for aquatic life.

What do the monitoring data tell us now?

Water chemistry in Crystal Creek is pretty typical of a karst dominated coldwater stream. Elevated nitrates are present with an average of 7.75 mg/L; likely leading to some aquatic life stress for macroinvertebrates. These elevated concentrations are persistent across all seasons and do not fluctuate significantly. Even though the macroinvertebrate community currently meets the goal for biological health, it is vulnerable and can be stressed due to these chronically higher concentrations. The biological evidence reveals moderate amounts of nitrate tolerant macroinvertebrate species and few nitrate intolerant species. Additionally, chronic exposure to high nitrate concentrations can magnify the accumulating impacts of other stressors like degraded habitat and stormflow sediment peaks, both of which can vary year to year and seasonally.

High sediment transport is common in this stream as it is in many other small coldwater streams in Southeast Minnesota. Sediment monitoring data shows this stream does not stay turbid for long durations and often clears up within one or two days of a rainfall event. Therefore, the biggest concern is the high spikes of sediment during storm events and/or sediment settling out and smothering available habitat (like rocks and cobble) for macroinvertebrates. Notes from biological sampling in 2017 describe excess sedimentation on the streambed, which corresponds to when the MIBI scores have been lowest (2017). Few storm events during that year may have caused a longer period of sediment buildup on the streambed prior to sampling (Figure 36). These hydrologic conditions vary yearly and greatly impact conditions leading up to the biological sample. Climate fluctuations, including storm events and floods have a large impact on available habitat in many ways. They have the potential to scour streambeds clean and uncover this habitat, but can also deposit sediment thus covering those very habitats. This constant flux may be one of the reasons we are seeing slightly variable macroinvertebrate scores in Crystal Creek. More data will help tease out these potential impacts and how they compare to these variables over time.

Figure 36. Stream flow/discharge data from Crystal Creek from 2010-2020. Black box outline indicates the water year 2017, with fewer storm events causing stage increases relative to other years.



Temperature	• Water temps are sufficient and expected for a small coldwater stream. There are also moderate amounts of both coldwater fish and bug species present
Nitrate	• Inverts show a little indication of stress with high nitrate concentrations. Data are consistently between 6-10 mg/L, with higher amounts of nitrate tolerant species and few intolerant species
TSS (Total Suspended Solids)	• There are some indications that sedimentation generally is an issue in Crystal Creek, but low flow TSS values are good. Both fish and bugs show a mix of responses
DO/Eutrophication	• DO levels are good and not showing any signs of stress for a coldwater stream. The fish and macroinvertebrate metrics also don't point to DO stress
Habitat	• Habitat doesn't appear to be causing major stress to fish or bugs. However, there is a possibility that sedimentation could play a role in available habitat and vary depending on hydrologic conditions
Connectivity	• Fish are most impacted by connectivity issues. Migratory fish like brown trout are abundant and do not appear to be limited by any connectivity issues
Flow Alteration	• All watersheds in the Root are either directly or indirectly impacted by flow alteration (see hydrology section at beginning of report). Crystal Creek has potential TSS and habitat stressors that could likely be attributed to changes in land use, precipitation and flow, all of which impact sedimentation dynamics

Summary of stream health and recommendations in Crystal Creek

Overall, fish and macroinvertebrates in Crystal Creek are doing okay, but they are vulnerable. The fish community has made improvements, with more brown trout present in recent years.

- Macroinvertebrates seem to be potentially limited by high nitrates and sedimentation issues that affect available habitat. This was supported in the 2017 data with slightly higher nitrates on average due to fewer storm events. It was noted specifically during biological sampling in 2017 that there was a lot of fine sediment on the streambed as well. Fewer storm events had an impact on not only the nitrate concentrations observed that year, but provided an opportunity for sediment to settle out and smother habitat (Figure 36). The hydrograph from 2010 through 2020 shows the flow from Crystal Creek and how variability in flows may be one explanation for the slight changes we see in biology/stressors. The flow year 2017 (in black box) is showing a hydrograph with fewer storm event peaks and less magnitude (compared to other years generally). The conditions leading up to 2017 (i.e. 2016 stormflows) may have also played a role in sedimentation dynamics and effects.
- DO and temperatures are typical and suitable for a small coldwater stream. The temperature and oxygen levels are good and the biological metrics show moderate amounts of coldwater fish and bug species. TSS does not appear to be causing stress to aquatic life at this time, but settling of sediment (i.e. sedimentation) on the streambed is more of a concern related to habitat conditions. This appears highly variable depending on the hydrology in any given year.
- Continued monitoring over time will be important to track any future changes in both fish and macroinvertebrate communities as they relate to flow conditions, habitat impacts and nitrate. Practices that reduce sediment and nitrate should be a focus to keep aquatic life from becoming impaired.

Part 3: Conclusion and Recommendations

Summary of Stressors

The stressors identified as part of Cycle 2 SID are included in Table 1. The top part of the table includes new information on impairments or streams that haven't had SID study previously. The bottom part of the table includes streams that have been previously studied; gray shading indicates stressor status has changed since the original Root SID report was completed. There were a total of 40 biological impairments covered by Cycle 1 SID Report, 10 of which are also covered in this Cycle 2 Report. The entire list of streams with biological impairments in the Root River are shown in Appendix Table 1.

			STRESSORS						
Stream Name	**AUID**	**Aquatic Life Impairment**	**Temperature**	**Nitrate**	**TSS**	**DO/Eutro**	**Habitat**	**Connectivity**	**Flow Alteration**
New impairments/streams studied since previous SID									
Riceford Creek	07040008-H01	Macros	---	●	●	---	●	---	●
Upper Bear Creek	07040008-A18	Fish and Macros	---	●	●	---	●	o	●
Mill Creek	07040008-536	Fish and Macros	---	●	●	---	●	---	●
South Branch Headwaters	07040008-H18	Macros	---	●	o	●	●	---	●
Crystal Creek	07040008-601	*Not impaired*	---	o	o	---	o	---	o
Previously studied impairments also covered in this report									
Camp Creek	07040008-559	Fish and Macros	●	●	●	---	●	---	●
Riceford Creek	07040008-518	Macros	---	●	●	---	●	---	●
Corey Creek	07040008-631	Fish	●	---	---	---	●	●	●
Spring Valley Creek	07040008-548	Fish and Macros	●	●	●	o	●	---	●
Upper Bear Creek	07040008-540	Fish and Macros	---	●	●	---	●	o	●
Silver Creek	07040008-640	Fish and Macros	---	---	o	---	●	---	●
Bridge Creek	07040008-G92	Macros	---	---	o	---	●	---	●
Watson Creek	07040008-552	Fish and Macros	●	●	●	---	●	---	●
South Fork	07040008-573	Macros	o	●	●	●	●	---	●
Pine Creek	07040008-526	Macros *(delisting)*	---	o	o	o	o	---	o

Table 1. Updated stressor determinations for the Root River Watershed.
KEY: ● = stressor; o = inconclusive/potential stressor; --- = not an identified stressor
gray shading= change in stressor status

Recommendations and Additional Monitoring

In the Root River Watershed, the most common stressors identified are habitat, nitrate and TSS. These stressors are connected to the overall land use activities in the watershed and heavily impacted by changes in hydrology. With increased precipitation and climate challenges, BMPs should focus on slowing water flow to the extent possible and creating more storage of water on the landscape. The table below contains general recommendations to address many of these stressors.

Table 3. Recommended prioritization of restoration activities relative to the stressors contributing to the biological impairments in the Root River Watershed.

	Priority	Example restoration activities to address stressor
Habitat	High	Re-establish quality riparian corridor to increase woody debris, stream stability, and stream shading. Protect streambanks, reduce erosion and overall stream sedimentation.
Nitrate	High	Utilize a variety of nutrient reducing BMPs including but not limited to: cover crops, nutrient management, saturated buffers, soil health practices, etc.
Flow Alteration	High	Slow flow. Promote additional water storage on the landscape and increase infiltration through perennial vegetation, floodplain restoration, etc
Suspended Solids	High	Focus on reducing sediment input from the near channel riparian corridor (cattle pastures) and immediate stream channel (stream banks), in addition to ravines and gullies.
Temperature	Med	Encourage protection of groundwater/springs that feed coldwater streams, promote shading and reduce sedimentation of streams/areas vulnerable to temperature stress

Watershed projects like the Root River Field to Stream Partnership (RRFSP) will be critical in assessing these BMPs and the impacts to water quality in the Root River Watershed. Continued support (via monitoring or technical analysis/coordination) for projects like this will enhance our knowledge and understanding of these complex sediment and nutrient issues that also impact southeast Minnesota more generally.

Additionally, many other monitoring efforts in the region will provide useful information related to these important regional sediment and nutrient issues. A recent memo by Basin Alliance for the Lower Mississippi in Minnesota (BALMM) specifically describes the importance of continued nitrate monitoring and study in the region. The memo calls out understanding of nitrate "lag time", nitrate impacts to karst, growing or organizing nitrate monitoring networks/datasets, and further understanding nitrate loss. Similarly, continuing to understand hydrology and sediment dynamics, as described in the hydrology section of this report will continue to be useful. The current network of water sampling and streamflow gaging in the Root River is a critical foundation to understanding these issues. Long-term continuous monitoring of streams in the Root River remains one of the best tools we have in understanding watershed health and pollutant transport, so continuing these monitoring efforts are critical.

Specific streams in the Root River that could potentially use other additional monitoring efforts include:

1. Stream that have aquatic life impairments, with limited or no info to help understand the issues
    a. Future Example: streams that weren't studied in Cycle 2 monitoring due to low priority, may need to be revisited to determine if priorities have changed. Reference Table 1 in the appendix.
    b. Future Example: streams with changes in aquatic life use or other watershed changes
2. Streams that are identified as vulnerable or need protection (Some listed in protection section of this report)
3. Streams that are locally identified as important or continue to need more information
    a. Keep long term/continuous datasets going when possible to provide the best resolution of information

b. Support for projects especially related to BMP's and effectiveness monitoring

c. Problem investigation monitoring

For more information

Watershed Restoration and Protection Strategy (WRAPS) development including necessary TMDL's follow the completion of the SID process. For more information, go to https://www.pca.state.mn.us/water/watersheds/root-river or search for "Root River Watershed" on the MPCA website.

The information presented in this report is general summary of the recent SID findings. Detailed stressor analysis and more specific monitoring data and information related to each stream is available upon request, please see contact person below.

Contact person

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CLEAN WATER LAND & LEGACY AMENDMENT

MINNESOTA POLLUTION CONTROL AGENCY

Appendix

Table 1. Biologically impaired AUIDs in the Root Watershed. ✓=yes *=deferred. Grayed out AUIDs were studied in Cycle 1 SID, but not in Cycle 2 SID.

				Assess info		Impairments		
HUC 10	**Stream name**	**AUID/WID 07040008-###**	**Impairments**	**C1**	**C2**	**NEW since C1?**	**Delisting/ Correction**	**In this report?**
Root River	Root River	07040008-501	Macros	✓				
	Root River	07040008-502	Macros	✓				
	Silver Creek	07040008-640	Fish and Macros	✓	✓		✓-Fish	✓
City of Rushford	Root River	07040008-520	Macros	✓	✓			
	Root River	07040008-522	Macros	✓				
	Unnamed creek	07040008-659	Macros	✓				
	Root River	07040008-527	Macros	✓	✓			
Trout Run	Trout Run Creek	07040008-G87	Macros	✓				
	Middle Branch	07040008-528	Macros	✓	✓		✓-Macros	
	Middle Branch	07040008-534	Macros	✓				
	Money Creek	07040008-F48	Macros	✓				
	Wadden Valley Creek	07040008-605	Fish and Macros	✓	✓	✓-Fish		
	Rice Creek	07040008-581	Fish and Macros	✓	✓			
Middle Branch	Middle Branch	07040008-506	Macros	✓	✓		✓-Macros	
	Jordan Creek	07040008-713	Macros	*		✓-Macros		
	North Fork Bear Creek	07040008-F45	Macros	*		✓-Macros		
	County Ditch 8	07040008-F44	Macros	*		✓-Macros		
	Upper Bear Creek	07040008-A18	Fish and Macros		✓	✓-Fish and Macros		✓
	Upper Bear Creek	07040008-540	Fish and Macros	✓	✓			✓
	Bear Creek	07040008-544	Macros	✓				
	Spring Valley Creek	07040008-548	Fish and Macros	✓	✓			✓
	Curtis Creek	07040008-G90	Macros	✓				
Money Creek	Corey Creek	07040008-631	Fish	✓	✓			✓
North Branch	Unnamed creek	07040008-706	Macros	✓				
	Mill Creek	07040008-536	Fish and Macros	*	✓	✓-Fish and Macros		✓
	North Branch	07040008-716	Macros	✓				
	Unnamed creek	07040008-F46	Macros	✓				
	North Branch	07040008-717	Macros	✓				
Rush Creek	Rush Creek	07040008-524	Macros	✓				
	Pine Creek	07040008-526	Macros	✓	✓		✓-Macros	✓
	Pine Creek	07040008-576	Macros	✓				
South Branch	South Branch Headwaters	07040008-H18	Macros	*	✓	✓-Macros		✓
	Judicial Ditch 1	07040008-561	Macros	*		✓-Macros		
	Unnamed creek (Willow Trib)	07040008-F08	Fish and Macros	*		✓-Fish and Macros		
	Root River, South Branch	07040008-550	Macros	✓	✓		✓-Macros	

				Assess info		Impairments		
HUC 10	**Stream name**	**AUID/WID 07040008-###**	**Impairments**	**C1**	**C2**	**NEW since C1?**	**Delisting/ Correction**	**In this report?**
	Watson Creek	07040008-552	Fish and Macros	✓	✓			✓
	South Branch	07040008-556	Macros	✓	✓		✓-Macros	
	Willow Creek	07040008-558	Macros	✓				
	Camp Creek	07040008-559	Fish and Macros	✓	✓			✓
	Etna Creek	07040008-597	Macros	✓				
South Fork	South Fork	07040008-508	Macros	✓				
	South Fork	07040008-509	Macros	✓				
	South Fork	07040008-510	Macros	✓				
	Riceford Creek	07040008-518	Macros	✓	✓			✓
	Riceford Creek	07040008-519	Macros	✓	✓		✓-Macros	✓
	South Fork	07040008-573	Macros	✓	✓			✓
	Sorenson Creek	07040008-F52	Macros	✓				
	Bridge Creek	07040008-G92	Macros	✓	✓	✓-Macros		✓
	Riceford Creek	07040008-H01	Macros	*		✓-Macros		✓

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