# Stressor Identification Update

# Nemadji River Watershed

## Lake Superior Basin, Cycle 2

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MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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# Executive summary

This report summarizes efforts completed in the Nemadji River Watershed to identify stressors to the macroinvertebrate community in Deer Creek and highlight Military Creek as a high-quality protection-priority coldwater stream. The Nemadji River Watershed was first sampled intensively for biology by Minnesota Pollution Control Agency (MPCA) in 2011-2012, then revisited in 2022-2023. This update report focuses on the 2022-2023 results.

A review of the biological community, water quality, aquatic habitat, and hydrology of Deer Creek concludes that the macroinvertebrate community in Deer Creek is being stressed by **poor physical habitat associated with elevated total suspended solids (TSS) concentrations and sedimentation, and high flow velocities associated with extreme precipitation runoff events. Stressors are caused and/or worsened by altered hydrology and stream channel instability.** Poor physical habitat conditions include loss of habitat features such as undercut banks and increased sedimentation that is smothering critical macroinvertebrate habitat. Increased magnitude and frequency of extreme flow events have direct and indirect impacts on the macroinvertebrate community. Consecutive flood events have led to the displacement of various species while also increasing instability in the stream and exacerbated an upstream dam breach and onset erosive processes within and upstream of the biological reach. A channel restoration project completed to address the dam breach was undermined during a subsequent record-high rainfall event. A resulting head-cut moved upstream through the restoration and continued to supply excess sediment to the downstream impaired reach. Evidence suggests that sedimentation affecting habitat has persisted through several normal to dry years following high flow years. Local watershed planners are actively seeking out funding and resources to implement repairs and stop the source of erosion.

Military Creek is a small perennial tributary stream to Clear Creek, located in Silver Brook Township of Carlton County. Protection-based monitoring was completed through the stressor identification (SID) process to better understand, protect, and highlight Military Creek as a high-quality stream. Buried sand and gravel deposits contribute to the watersheds unique geology and supply the stream with continuous groundwater flow. Groundwater discharge helps maintain cold stream temperatures that are optimal to trout growth throughout the warmest months of the year, making it the coldest monitored stream in the Nemadji River Watershed. Biological monitoring of fish and macroinvertebrates indicate a uniquely cold system that supports a robust brook trout population and vulnerable/imperiled macroinvertebrates. While over half of the land is in agricultural land use, land use practices such as wide forested riparian buffers help maintain good water quality, stream temperature, and habitat conditions in the perennial reaches.

Disruption to the current hydrologic conditions and groundwater springs leading to less optimal water temperature and streamflow conditions are the greatest long-term threats to the aquatic community, while barriers to fish movement (i.e., culverts and beaver dams) are the greatest short-term threats to the aquatic community. Current protection efforts include a proposed MPCA use-class designation change from a warmwater habitat (2B) stream to a coldwater habitat (2A) stream and a proposed Minnesota Department of Natural Resources (DNR) trout stream status designation. Going forward, conservation efforts to protect this valuable resource should be considered and include protecting groundwater reservoirs and springs, avoiding development that changes the hydrologic regime and/or applying conservation design in new development, restoring connectivity through improved stream-roadway crossings, maintaining or enhancing forested riparian buffers, and engaging private landowners in stream water quality.

# Introduction/Goals

Monitoring is essential to determining whether lakes and streams meet water quality standards designed to protect and/or restore healthy aquatic ecosystems. The SID process is designed to study and diagnose negative impacts on fish and aquatic macroinvertebrate communities. It can also help protect high-quality streams threatened by a variety of stressors.

Accordingly, SID and protection-based monitoring in the Nemadji River Watershed (Figure 1) focused on a few select subwatersheds. Focus subwatersheds were chosen based on the results of assessment-level water chemistry and biological monitoring completed between 2014 and 2023. The primary focus watershed, Deer Creek, was selected because the macroinvertebrate community did not meet criteria set for a healthy Northern Coldwater stream. The other focus watershed, Military Creek (a tributary to Clear Creek) was selected based on the need to protect high-quality water bodies.

**Figure 1. Map of Nemadji River Watershed (left) identifies SID focus streams based on protection and new impaired waters designations. Deer Creek (top right) has a new impairment designation for macroinvertebrates and Military Creek (bottom right) is highlighted for protection of high-quality waters.**


## What have we learned about stream health in the Nemadji River Watershed?

The Nemadji River Watershed was first sampled intensively for biology by MPCA in 2011-2012 (Cycle 1), then revisited in 2022-2023 (Cycle 2). A SID Report for Cycle 1 was completed in 2014 to investigate the stressors responsible for degraded aquatic fish and/or macroinvertebrate communities in six streams, including a fish impairment in Deer Creek.

The new Nemadji River Watershed Assessment and Trends Update Report, completed in Cycle 2, summarizes the findings from the recent 2022-2023 monitoring. Results include mention of the index of biological integrity for macroinvertebrates (M-IBI), a common tool used in evaluating the health of aquatic communities. Some highlights include:

- The M-IBI score for Deer Creek indicates an aquatic life impairment on Deer Creek for macroinvertebrates. Recent samples indicate a community that has degraded in structure and ecosystem function.
- Several high-quality yet vulnerable aquatic macroinvertebrate species were identified in four Nemadji River Watershed streams. Military Creek contained species that are known from only a few locations statewide, marking the westernmost known extent for some such taxa. The stream also supports a robust brook trout (*Salvelinus fontinalis*) population and is among the coldest streams in the greater Northeast Minnesota region.
- Several issues identified across the watershed in Cycle 1 such as elevated bacteria, excess sediment, and poor biological conditions persisted in Cycle 2. TSS in the Nemadji River showed a statistically significant change from 2008-2022, indicating an increasing trend of 3.5% per year or 0.65 mg/L per year.

# Part 1: Deer Creek (WID: 04010301-531) Macroinvertebrate SID

Deer Creek is a perennial tributary to the Nemadji River, is in Carlton County, Minnesota and drains approximately 5000 acres. Most of the watershed is undeveloped with 51% classified as forest, 29% as wetlands, and less than 1% as grass/shrub lands. Only 3% of the watershed is considered low to moderate intensity development and 16.5% is agricultural land use. Deer Creek is a major contributor of sediment to the Nemadji River. Channel incision, slumping banks, mass-wasting, muddy groundwater discharge and soil runoff are known contributors of sediment to the Deer Creek and Nemadji River Watersheds.

## 1.1 Deer Creek stream health information learned in Cycle 1

Deer Creek was listed as impaired for not meeting the biological criteria set for fish in Cycle 1. Follow-up SID identified several primary stressors to the fish community including altered hydrology, high levels of TSS, and poor habitat associated with excessive sedimentation. High levels of TSS in the water column, particularly in the form of silt and clay particles, can negatively affect fish behavior, physiology, and habitat. Sedimentation, the process of sediment settling over the stream bottom, can fill in pools and smother gravel and other habitat features that are critical to the health of aquatic life.

A total maximum daily load (TMDL) study for turbidity associated with excess sediment in Deer Creek was completed in 2013 to determine the maximum amount of TSS that the stream can receive and still meet water quality standards. Based on the TMDL, daily load reductions would be needed at all flow levels, very low to very high. During higher flows, 99% reductions are needed to meet standards, while reductions needed for moderate to very low flow conditions range from 56% to 95%.

The Deer Creek Watershed Total Maximum Daily Load Implementation Plan: Turbidity Impairment, completed in 2013, outlines the major sources of sediment to Deer Creek, some of which are summarized below in Section: 1.2.3 What is causing disturbance and/or degraded habitat?

SID for the Cycle 2 Deer Creek macroinvertebrate listing focused on 1) the biological community, 2) water quality, 3) habitat conditions, 4) disturbance, and 5) extremes of flow. This study found that the macroinvertebrate community in Deer Creek is being stressed by **sedimentation smothering critical habitat, site disturbance and associated erosion, and consecutive extreme flow events.**

### 1.1.1 Biological community

M-IBI scores at Deer Creek  biological station 11LS064 met expectations for a healthy Northern Coldwater stream in Cycle 1 but fell below the General Use (GU) standard of 32 in Cycle 2. The M-IBI score declined from 44 in 2011 to 22 and 25 respectively in 2022 and 2023. The decline in M-IBI scores was somewhat unique to Deer Creek compared to the greater Nemadji River Watershed. While Deer Creek M-IBI scores declined in Cycle 2, the average scores across the greater Nemadji River Watershed increased by 6.7 points (n = 14 sites), this however does not represent a statistically significant increase in biological condition across the watershed. Neighboring biological stations on characteristically similar streams, Rock Creek (11LS063) and Mud Creek (11LS058), showed a respective 10.9 and 25.7 increase in M-IBI scores between cycles.

**The macroinvertebrate community is suggestive of a disturbed system, with an increase in opportunistic and tolerant species and other generalist taxa.** More than half of the individuals sampled in 2022 and 2023 are considered tolerant to polluted environments. The Hilsenhoff Biotic Index (HBI) score, a measure of pollution tolerance for the entire community, worsened in Cycle 2. The index ranges from 0 to 10, with higher values indicating higher tolerance for pollution. The score degraded from 5.9 in Cycle 1 to 7.0 in Cycle 2 and partially rebounded to 6.5 in 2023. An increase in the number of taxa and individuals considered opportunistic species that are typically uncommon in undisturbed sites increased from 3% of the 2011 community to 32% and 20% of the respective 2022 and 2023 communities. *Cricotopus,* a nonbiting midge and one of five opportunistic taxa found in Cycle 2, was the dominant taxa in the 2022 sample and was the second-most dominant taxa in the 2023 sample. *Cricotopus* is regionally found in degraded habitats with excess sediment embedding gravel within riffle features.

**Species sensitive to pollution composed a smaller portion of the community in Cycle 2 samples.** Both diversity and richness of pollution intolerant species decreased in Cycle 2 samples. While 11 intolerant taxa accounted for 23% of the 2011 sample, numbers decreased to five intolerant taxa accounting for 3% of the 2022 sample. A partial rebound in the community was observed in 2023 with nine intolerant taxa accounting for 12% of the sample.

The intolerant community in 2011 was a healthy mix of caddisflies, mayflies, dragonflies, damselflies, and water snipe flies. Many of these declined or were absent in the Cycle 2 samples; however, a few stoneflies were captured in the latter samples that were not present in Cycle 1.

**Long-lived taxa, meaning those that require a year or more to complete their life cycle, decreased in Cycle 2.** The loss of long-lived species often is a response of habitat disturbance. Long-lived taxa sampled at 11LS064 were mostly dragonflies, damselflies, and riffle beetles. The riffle beetle *Optioservus* was the most abundant taxa in the 2011 sample and accounted for 10% of the Cycle 1 community. However, *Optioservus* numbers declined in Cycle 2 and the taxa comprised less than 1% of the 2022 sample. Percentages showed a partial rebound in 2023. Additionally, dragonflies and damselflies together declined from seven taxa accounting for 8% of the 2011 community to one taxon sampled in each 2022 and 2023.

## 1.1.2 Is water quality a stressor to Deer Creek?

Water quality parameters evaluated in Cycle 1 SID for fish were water temperature, TSS, and dissolved oxygen (DO). Cycle 2 SID revisited the same parameters to evaluate their effects on macroinvertebrates and detect potential changes in water quality between cycles. Nutrients (nitrogen and total phosphorus (TP)) were also evaluated.

The findings below conclude that high levels of TSS and related sedimentation are negatively impacting the macroinvertebrate community. While TP levels were also frequently high, TP at the site is not associated with eutrophication/rapid growth of algae but rather is bound to the clay particles that erode into the river and become TSS. All other water quality parameters met state water quality standards and were within adequate ranges to support aquatic life.

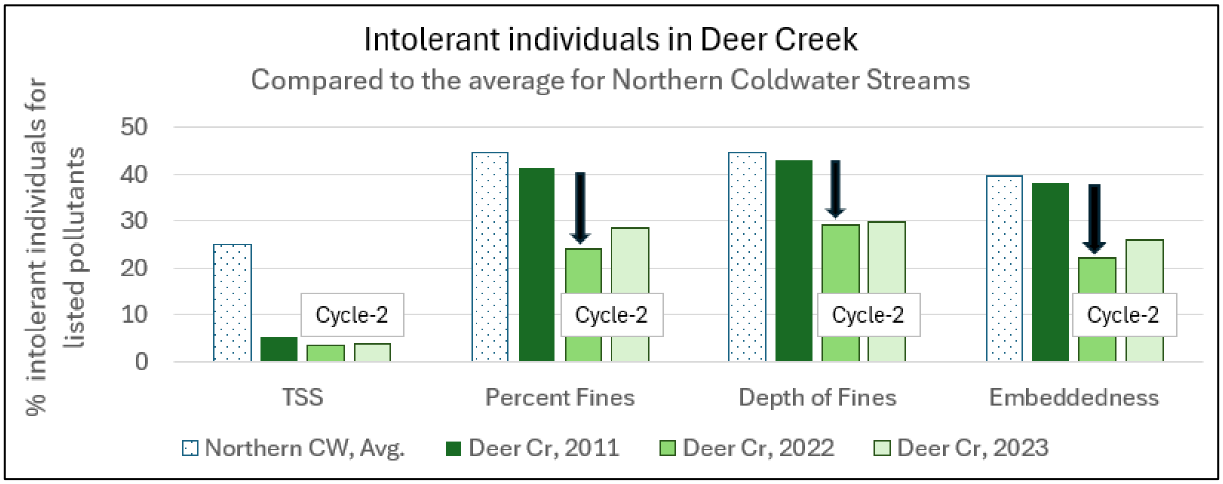
### Total suspended solids and sedimentation

TSS levels in Deer Creek are extremely high. Ten samples collected at 11LS064 exceed the standard of 10mg/L with values reaching excessive levels (maximum = 882 mg/L). Additionally, 88% of 271 samples collected since 2001 along the full seven-mile-length of Deer Creek exceed the standard. TSS is elevated at all flow levels, from very low to very high flows, but are most egregious during extreme high flow events. Sediment, rather than organic materials, accounts for most of the suspended solids in Deer Creek as confirmed through lab analysis of organic (animal/plant) verses inorganic (soil) materials.

Compared to the average for all Northern Coldwater Streams, Deer Creek has a low percentage of macroinvertebrates that are sensitive to TSS, meaning individuals that decline under elevated TSS conditions. The percentages of TSS-intolerant individuals at 11LS064 were 5% and 3% in respective Cycle 1 and Cycle 2 samples (Figure 2), which is much lower than the 25% found in an average Northern Coldwater Stream. The percentage of individuals intolerant to related metrics such as percent of the stream bottom covered by fine particles (fines), depth of fines, and embedded cobble/gravels were also evaluated. Figure 2 shows that percentages for those groups were comparable to those found in an average Northern Coldwater Stream in the Cycle 1 (2011) sample; however, decreased in Cycle 2.

Results show that taxa sensitive to suspended sediment were negatively affected by TSS in both cycles, and those affected more specifically by sediment settling on the stream bottom were affected in Cycle 2. Additionally, the dominance in Cycle 2 samples of *Cricotopus, an* opportunistic species often found in disturbed reaches with subpar sediment-laden riffle habitat, supports degraded habitat associated with sediment as a stressor.

**Figure 2. Bar graph shows low percentage of TSS-intolerant taxa for all sample years compared to the average for Northern Coldwater Streams and shows a decrease in taxa intolerant to fine sediment (% covering the stream bed, depth, and % embedding gravel) in Cycle 2 samples.**




## Eutrophication and dissolved oxygen in the water column

Eutrophication is the depletion of DO by excessive growth of algae and plants in the water; and is caused by high levels of nutrients (combined nitrogen and phosphorus) in the water. DO data supports that DO levels within the water column are not at stressful levels in Deer Creek. While TP levels are high, regression analysis indicates that phosphorous is primarily bound to suspended clay particles. The bound TP; therefore, is not readily available for plant uptake which limits the potential for eutrophication. Additionally, the lack of light penetration through the highly turbid water, further limits photosynthesis processes associated with eutrophication. Nitrate/nitrite (the available form of nitrogen to aquatic plants) levels in Deer Creek are very low. Additionally, there are no visible signs of algal blooms in Deer Creek, and negligible algal growth overall.

- **DO** levels in Deer Creek's water column are adequate to support aquatic life. All 60 samples collected at biological station 11LS064 meet the water quality standard of 7 mg/L, as does 227 of 228 samples along the full seven-mile length of Deer Creek. This includes 10 early-morning (before 9:00 am) samples when DO levels are typically lowest. Additionally, a sensor collecting 15-minute DO readings was placed in the stream at 11LS064 in September 2025 for a week and confirmed adequate levels and low (<0.8 mg/L) daily fluctuations. DO conditions within the finer sediments along the stream bottom were not monitored but it is probable that they could reach low levels if fines are deep enough. DO tolerance metrics show a 25% decrease in low DO sensitive taxa in the 2022 sample and 15% decrease in the 2023 compared to the Cycle 1 2011 sample.
- **Nitrate/nitrite** (the available form of nitrogen to aquatic plants) levels in Deer Creek are very low, limiting the potential for eutrophication and eliminating nitrogen toxicity as a potential stressor. Four samples collected at 11LS064 between 2011 and 2025 meet the water quality standard, as do all 60 samples collected since 2001 along the seven-mile WID. The highest individual value (1.8 mg/L) was well below the 10 mg/L standard and all four samples collected at 11LS064 were at or below the reporting limit of 1 mg/L.

- **TP** levels in Deer Creek are high with an average value that is ten times greater than the 0.05 mg/L river water quality standard. All ten samples collected at 11LS064 exceed the standard, as do 97% of 135 samples collected along the seven-mile WID. However, TP has a strong relationship ($r^2$ = 0.95 of 115 paired samples) with TSSs indicating that TP in the stream is primarily bound to suspended sediment.

Based on these findings of low nutrient availability, biological tolerance to nutrients was not further investigated.

### Other sampled pollutants

Few other pollutants were historically collected at Deer Creek station 11LS064. A few ammonia nitrogen samples show that levels are lower than the lab detection limit. Chloride was not sampled at 11LS064 but samples at a location one mile downstream reported low levels (<7 mg/L).

### Water temperature

**Water temperature data collected during the summer months of 2011 and 2022 indicate that Deer Creek was cold enough to support a healthy coldwater fish and macroinvertebrate community**. Water temperatures for the months of June to August were very similar in 2011 and 2022, covering both cycles. Temperatures both years were in an optimal range (7˚C to 20˚C) to support brook trout, a species highly sensitive to temperature; therefore, an indicator species for the overall coldwater community, 88% of the summer record. Additionally, the average summer water temperature was 17˚C both years. These statistics indicate stream temperatures were cold enough to support a healthy coldwater community.

Based on all MPCA data for Nemadji River Watershed streams with full summer continuous records, Deer Creek ranked slightly warmer than the median (53rd and 56th percentiles, where 0 is the coldest and 100th is the warmest). This number is conservatively skewed by a disproportionately large number of records in the dataset for a few uniquely cold streams that include Clear Creek, Military Creek, and the Blackhoof River. In the absence of those atypical sites with extremely cold summer temperatures, Deer Creek ranks colder (30th and 35th percentiles) than the median for the watershed.

Macroinvertebrate community data show a decline between cycles in coldwater individuals was regionally afflicted and not specific to Deer Creek. Samples show a 4% decline in the percentage of coldwater macroinvertebrates, those specifically adapted to and dependent on a coldwater environment, in Deer Creek between cycles. However, the decline was consistent with an average decline of 3% observed across the watershed.

**The decline in sensitive species in Deer Creek was independent of water temperature and coldwater individuals**. A similar comparison was made for the macroinvertebrates belonging to the sensitive orders of mayflies, stoneflies, caddisflies, and dragonflies; also known as the acronym POET, based on their scientific order names. Unlike coldwater macroinvertebrates, an observed decline in POET at 11LS064 was not consistent with the watershed trend. The percentage of POET in Deer Creek decreased by 7% between cycles, but there was an average increase of nearly 7% POET across the watershed. The contrasting relationships suggest that temperature was not a main driver in a decrease in sensitive taxa.

## 1.1.3 Is habitat a stressor to Deer Creek?

The MPCA's Stream Habitat Assessment (MSHA) is a tool used to evaluate the habitat conditions of Minnesota streams. The scores are categorized as good, fair, and poor. A good score indicates the habitat is suitable for supporting a healthy aquatic community, while a poor score indicates an unsuitable of degraded condition. MSHA scores at 11LS064 declined from being on the transition of fair/good in 2011 to fair/poor in 2022. The information below supports habitat as a stressor.

**The MPCA biologists noted degraded macroinvertebrate habitat in the 2022 and 2023 visits.** During Cycle 2 visits, rock and wood habitats were largely covered in a slimy biofilm and silt/clay mixture; and had few to no macroinvertebrates on the surfaces (Figure 3). The interstitial spaces between gravel in stream riffles were filled with silty clay sediment, and the stream water was a muddy brown color. While Deer Creek is most-often muddy in color, the amount of sediment on surfaces increased between cycles.

The MPCA Stream Habitat Assessment (MSHA) surveys collected during each sample visit indicate that stream substrate and poor channel development are the biggest factors limiting habitat in this reach. Five subcategories contributing to the MSHA score include land use, riparian, substrate, instream cover (habitat features), and channel development. Substrate and channel development most limited the overall habitat score. Siltation and sediment embedded gravels were the main factors limiting substrate scores, and unstable channel conditions most negatively affected the channel development score. Additionally, riparian scores declined between cycles mostly due to a higher severity of bank erosion in Cycle 2. The Cycle 2 surveys also documented a loss of undercut stream banks and some filling of pools in the instream cover category. These are common consequences of bank erosion and overall channel instability.

**Figure 3. Degraded habitat includes wood covered in silt and void of macroinvertebrates (left), sediment-biofilm covering rocks (center), and embedded gravel (right).**

**As discussed in the above sections, the Cycle 2 Deer Creek macroinvertebrate community is suggestive of a disturbed system**. Between 2011 and 2022, pollution sensitive taxa, particularly taxa that are intolerant to excess sediment, decreased. Generalist and pollution tolerant taxa increased, as did opportunistic taxa that are typically uncommon in undisturbed sites. Long-lived taxa that require more time to complete their life cycle also decreased which is another indication of habitat disturbance.

## 1.1.4 What is causing disturbance and/or degraded habitat?

SID began causal analysis of habitat disturbance through a more detailed investigation of sediment sources already broadly defined in the Deer Creek turbidity TMDL implementation plan. Stream instability metrics within the habitat surveys and biological metrics within the macroinvertebrate community suggested that stream flow was another candidate cause to consider. The watershed experienced extreme highs and below-normal lows throughout the combined monitoring cycles.

### Sources of excess sediment

**High levels of channel incision and limited floodplain access are documented in the watershed.** Deer Creek and its tributaries are cutting down deeper into the landscape. Channels show distinct reduction in sinuosity and width depth ratio and increased steepened slopes compared to historic conditions. During high flows, the water further erodes the incised channel banks as the high-velocity water is unable to spill out onto the landscape. Evidence of this within the biological reach includes steep, high, and severely eroded streambanks (Figure 4).

**Figure 4. Steep, high, and severely eroded streambanks along Deer Creek.**

**Altered hydrology due to land conversion from forest to open space results in faster flow velocities that exacerbate channel incision and streambank erosion.** Historic tree clearing, fire, and mid-20th century land conversion to agriculture have altered water yields in the area. Conversion from forest to agriculture within the watershed peaked at 50% around the mid-century (Riedel et al., 2002 ). Resulting increased runoff ratios caused channel incision as described above and initiated the channel evolution process in which disturbed channels go through various stages of erosion and deposition until they again reach a state of stability. Deer Creek and its tributary channels remain in an unstable state.

More recently, agriculture within the region has declined and forest regeneration has reduced agricultural land use to the present-day average of less than 20%. Analysis of recent land use data for the upstream drainage area showed less than 1% change within 15 different land cover types (e.g. developed, pasture hay, open land, etc.) between Cycle 1 and post-Cycle 2 years 2011 and 2024. Aerial imagery identified one upstream harvest completed just prior (2010) to the Cycle 1 sample. An estimated 55 acres along a ½-mile reach of Deer Creek was select-cut, meaning that some trees within the cut area were left standing to help maintain soil health and lessen surface runoff impacts. The location was one half-mile upstream of 11LS064. The overall lack of conversion, particularly between cycles, suggests that recent land conversion was not a major cause of new disturbance at 11LS064.

**Sediment volcanoes or muddy groundwater discharges into the stream channel and contributes persistent sediment loading during low flow conditions.** Formed in the 1990s because of beaver dams and subsequent dam removal, approximately ten mud volcanoes were identified in 2008, discharging approximately 100 gallons per minute (0.2 cfs) of muddy groundwater to the Creek. The nearest mud volcanoes are located approximately one mile upstream of 11LS064. There is no evidence of new increases in mud volcano discharge between cycles.

**Three of four 1970s red clay dams were assessed and found to be releasing sediment through failed pipes and berm breaches.** The largest contributor of sediment of the four dams is the most downstream structure built on a tributary to Deer Creek one-quarter-mile upstream of 11LS064. The dam initially breached sometime in the mid-2000s, releasing an estimated 9000 tons of sediment into Deer Creek. After the failure, the tributary cut through an embankment likely initiated by a 2012 flood event, causing further damage to the site. The 24-foot-tall nearly vertical slopes continued to slough off during heavy rains (BWSR, 2017), increasing the need for a resolution.

In 2016, the 500-foot-long stream reach was restored through the breached dam area. The design included floodplain grading, bank stabilization, logs placed as grade control structures, and riparian plantings. By 2019, a head-cut was reportedly migrating upstream through the project site, eroding away soil as the channel incised several feet below the restoration's grade control structures (Figure 5). Design limitations, a 2018 extreme flood event, and lack of upstream gravel bed load to lock in grade controls were critical contributing factors. Recent 2025 site inspections confirm that the head-cut continues to migrate upstream through the project site and the channel is completely disconnected from the floodplain. Local watershed planners are actively seeking out funding and resources to implement repairs and stop the source of erosion. In March 2026, a feasibility study outlined repair options. It stated that if left unaddressed, migration will continue upstream beyond the project site and into the natural channel expanding the zone of instability and sediment release.

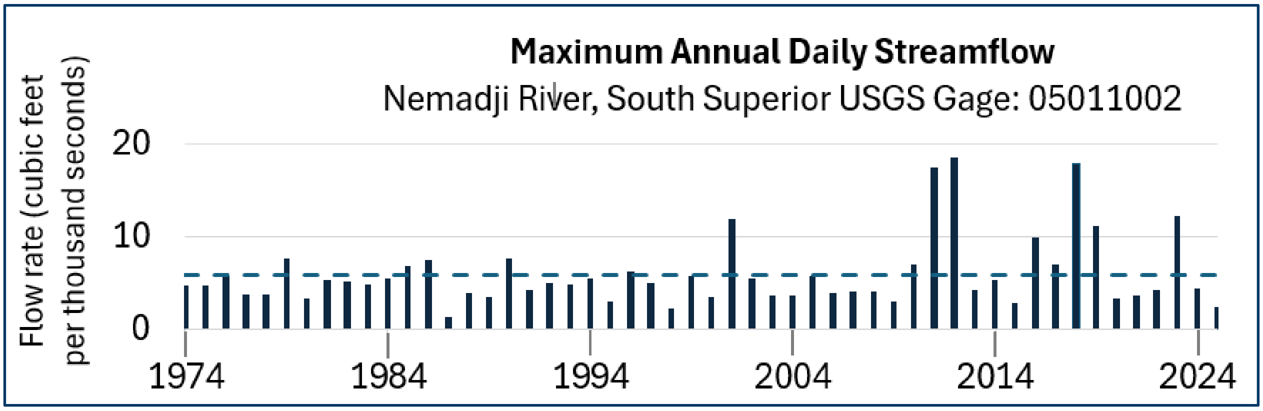
**Figure 5. The failure of a 1970's dam (left) released 9000 tons of sediment to Deer Creek and a head-cut in the post-dam, restored channel (right) actively erodes sediment.**

## Altered hydrology and streamflow extremes

Altered hydrology has led to higher water levels and faster flow volume and stream velocity in Deer Creek. The Nemadji River Watershed now receives on average 1.8 additional inches of rain from the historical average (1895-2018; MPCA, 2025). Furthermore, climate scientists suggest that precipitation events are becoming more intense. Higher magnitude and frequency of high streamflow events are shown in long-term flow records from the Nemadji River gage in Superior, Wisconsin (Figure 6). Extremes of flow, both extreme dry periods and high velocity flow events can impact the macroinvertebrate community. Record-high flooding affected the watershed twice between monitoring cycles, and conditions were severely dry in Cycle 2 sample year 2023.

The floods of 2012 and 2018 were significant events that caused extensive damage to roads, infrastructure, and stream crossings throughout the Nemadji River Watershed. Flood flows of 700 cfs were recorded on Deer Creek during the 2012 event at a gage located one-mile-downstream of 11LS064. The peak flow was five times greater than the average annual peak flow for years 2005 to 2013. Flows were likely higher during the 2018 flood based on record-high flows recorded on nearby Nemadji River.

**Figure 6. Nemadji River gage in South Superior, WI reports higher flows magnitudes and frequencies over the past 1.5 decades. Eight events exceeded the average (dash line) annual maximum daily flow (record 1974-2024) in the past 16 years.**



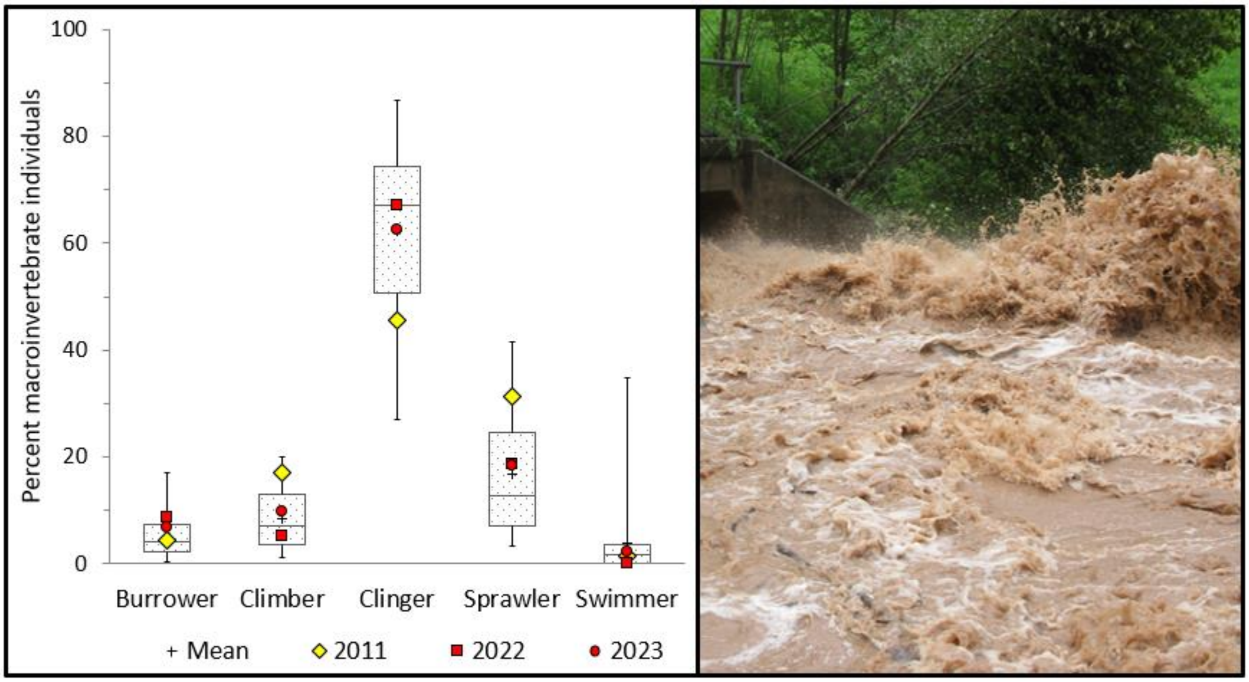

### *Extreme high flows*

**Floods can significantly impact macroinvertebrate communities** through habitat loss and disturbance, and rapid changes in water quality and flow velocity. This can lead to displacement, burial, and mortality. Furthermore, the repeated occurrence of extreme flood events can prevent communities from fully recovering, leading to long-term shifts in community structure and function. There are several signs in the 2022 community that suggest that consecutive extreme flood events negatively impacted the Deer Creek macroinvertebrate community. These include a 30% decrease in taxa richness, a shift in habitat/behavioral groups, and a decrease in long-lived species, particularly the riffle beetle *Optioservus*.

High flow impact to the community is supported by findings that taxa most capable of withstanding high velocity stream flows comprised a greater proportion of the post-flood community compared to the Cycle 1 sample. Different taxa have varying responses to extreme flow velocities. Some can burrow into sediment or seek refuge in macrophytes, wood, and within the gravel substratum, while those with less aerodynamic bodies, or the inability to burrow or cling to surfaces are more easily displaced. More loss occurs when macrophytes, wood, and substrate are washed downstream. Common macroinvertebrate groupings based on habitat and behavioral characteristics include burrowers, climbers, clingers, sprawlers, and swimmers. Burrowers bury themselves in sediment and clingers attach themselves to rocks and remain stationary in flowing water. Climbers and sprawlers move freely on submerged rocks, vegetation, and the stream bottom, are more abundant in lower energy environments, and are more easily displaced under extreme velocities.

A comparison of the percentage of individuals in such groups (Figure 7) for each sample year shows an increase in those more resilient to high velocities and a decrease in those more easily displaced in Cycle 2 post-flood years compared to the 2011 Cycle 1 sample. While the percentage of burrowers and clingers increased in Cycle 2 (post-flood) communities, the percentage of climbers and sprawlers or those most easily displaced by high flows decreased compared to the 2011 sample. This supports that portions of the macroinvertebrate community were displaced between cycles, particularly those most vulnerable to fast stream velocities.

**Figure 7. The boxplot (left) shows a decrease in groups (climbers/sprawlers) vulnerable to flow velocity and increase in more resilient groups (burrowers/clingers) in Cycle 2 (2022-23) communities. Flow velocities are extremely high in Deer Creek (right) during large precipitation events.**




However, with respect to all 38 biological samples collected in the Nemadji River between 1997 and 2025, the sprawlers, climbers, and clingers found in the Deer Creek 2022 and 2023 samples are close to the average and/or median for the overall watershed. The 2011 function groups, particularly the climbers/sprawlers and clingers, report outside of the interquartile range (middle 50% of the dataset). This shift in the 2011 community compared to the greater Nemadji River Watershed implies that stream velocities at 11LS064 were potentially lower in energy than other area streams leading up to 2011. If so, one explanation to this is that the upstream dam, even in a partially breached state, was buffering extreme velocities and streamflow during larger flow events.

**Another indicator that extreme high flows affected the biological community was a decrease (from 19% to 5%) in long-lived species, meaning those that take one or more years to complete their life cycle.** While species with shorter life cycles are often present in a stream reach for weeks or months of a season, long-lived species typically need a year or more in an undisturbed environment to complete their life cycle. Because of this, long-lived species are more vulnerable to disturbance including high flows.

As discussed in above sections, the decline in long-lived species was most apparent in the riffle beetle, *Optioservus*, which was one-of-two dominant species in the 2011 sample. Numbers declined from 29 individuals (8% of the community) in 2011 to two individuals (< 1%) in 2022; and then rebounded to 14 individuals (5%) in 2022. Studies have shown that extremes of flow, especially severe flood events, can have a detrimental effect on riffle beetles (Malcolm 2008). The study notes that adults are typically most affected, as many larvae are clingers and/or buried among roots, macrophytes, wood, and within the gravel substratum. Both can be displaced in turbulent flows that move such features. Evidence of extreme flow velocities (Figure 7) and scouring to the clay bed (Figure 8Figure 8) was observed in Deer Creek, as were the presence of round, less angular, rocks which are common in stream beds that have frequent rock movement. Extreme velocities were noted in the 2012 and 2018 floods; as well as a 2019 high flow event. Although recovery of long-lived species can be slow, the rebound in the percentage of individuals between 2022 and 2023 suggests that recovery is occurring.

**Figure 8. Evidence of high flow effects on Deer Creek includes observations of clay bed scour (left side of image) and smooth gravel and cobble (right side of image).**

### *Extreme low flows*

This section investigates the impact of low flow extremes on the biological community of the Cycle 2 samples. Stream flows collected one-mile downstream of 11LS064 reported similar flow rates (1.5 to 2 cfs) during the Cycle 1 and Cycle 2 samples. However, flow conditions leading up to the sample events were notably different in that the 2011 sample was preceded by several weeks of high-water levels while the 2022 and 2023 samples were preceded by several months of low water levels.

**Evidence of low water levels directly affecting the Cycle 2 macroinvertebrate community is inconclusive.** While several low-flow tolerant taxa were found only in the Cycle 2 samples, the numbers overall were low. Additionally, the community lacks conclusive evidence of a decline in taxa that are most vulnerable to dry conditions.

Macroinvertebrates in riffle habitats are generally more vulnerable to drying events than those in pool mesohabitats. Many riffle species belong to the insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT), with the common names of mayflies, stoneflies, and caddisflies respectively. EPT taxa richness and the percentage of EPT individuals did not change between cycles. The percentage of EPT that are hydropsychid caddisflies increased in the 2022 sample; and they tend to be some of the more tolerant EPT taxa in the region. They live on the upper parts of hard surfaces (rocks and logs), filtering organic particles from the water.

**Taxa including snails, worms, and flatworms that prefer still or slow-moving waters were not present in the 2011 sample and were found in low numbers in 2022 and 2023 samples.** This group accounted for 4% of the 2022 community and 8% of the 2023 community and could be associated with low flow conditions and habitat disturbance.

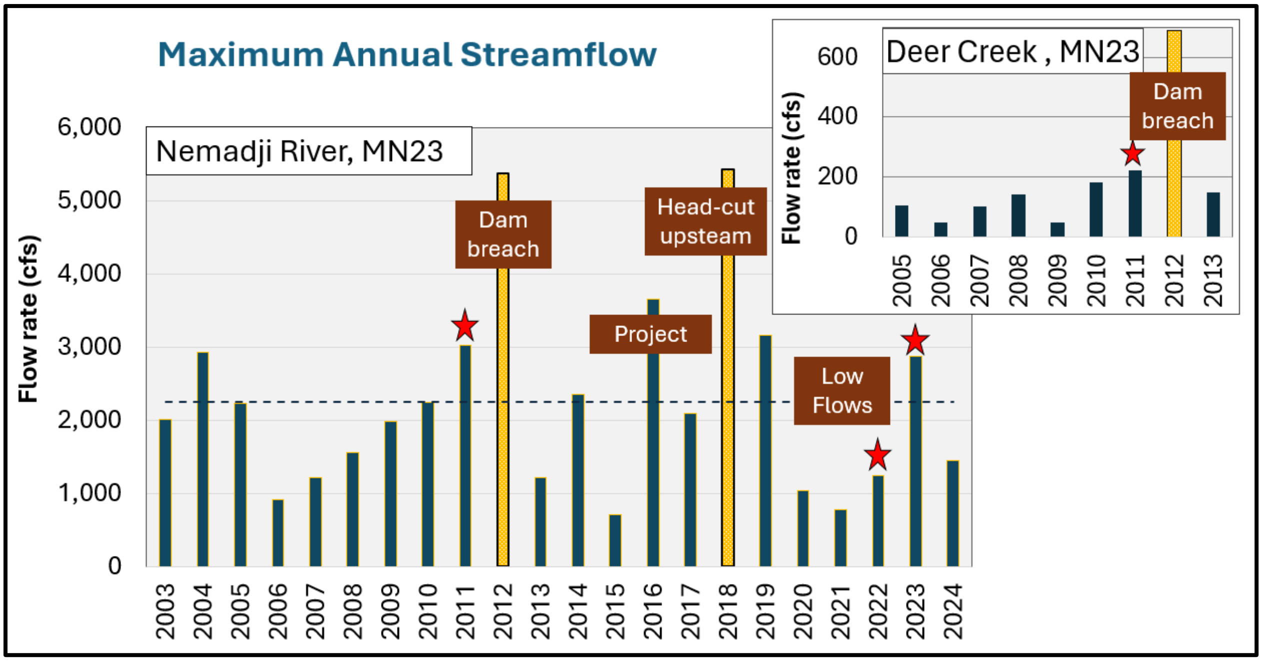
**Extreme low flow can lead to a build-up of fines and reduction in DO concentrations.** An overall high percentage of ubiquitous and tolerant Diptera (i.e., flies and midges) were found in all samples and increased from 40% to 60% between 2011 and 2022. Percentages this high are suggestive of a high-sediment, low-DO substratum environment. Additionally, only two pollution-sensitive Diptera, *Atherix* and *Dixella*, were sampled and decreased between cycles from a combined 8% to nearly zero. *Atherix* is commonly found in healthy Northern Coldwater Streams that maintain adequate flows. As mentioned in the Eutrophication section, overall DO sensitive taxa declined in Cycle 2 samples. Although DO concentrations in the water column met water quality standards, DO levels within fine bed sediments could have been lower. Low water levels and slower stream velocities could exacerbate siltation and poor substratum conditions, as is discussed in the next section.

### Sedimentation relationship with streamflow extremes

The macroinvertebrate community and field observations indicate habitat disturbance and associated sedimentation are primary stressors in Deer Creek. High velocity flood events also impacted the community both directly through displacement and indirectly through the sediment dynamics associated with extreme flows. The timeline of disturbance events and flow conditions of Deer Creek leading up to the Cycle 1 sample and through the Cycle 2 samples is shown in Figure 9.

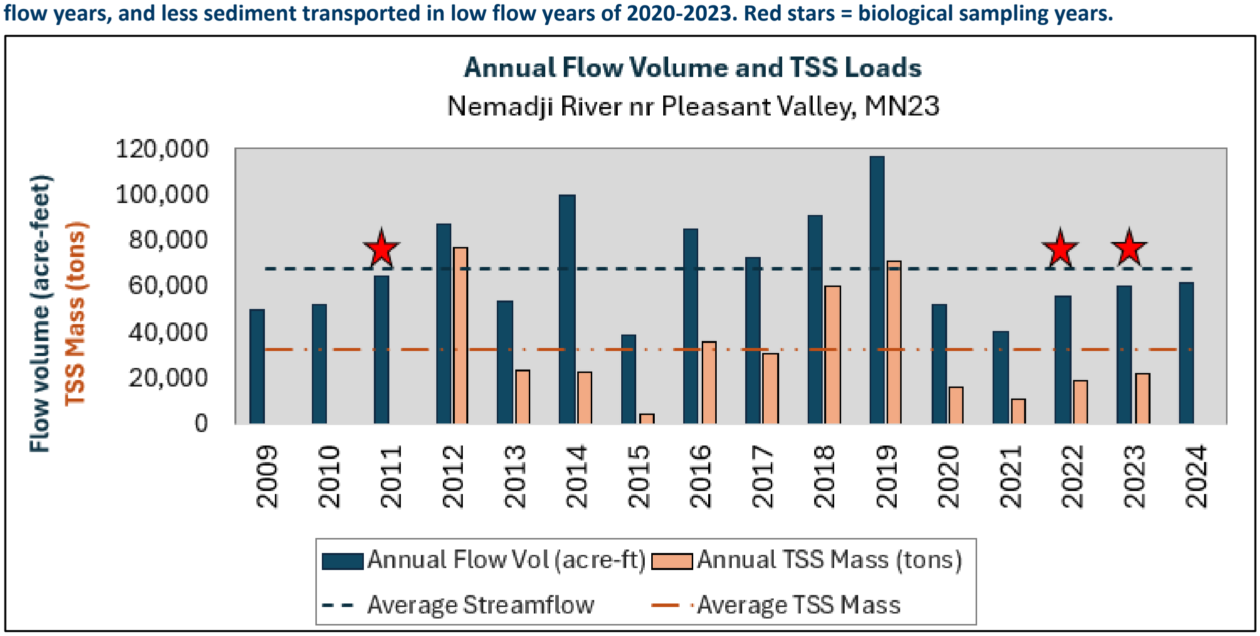
The Deer Creek graph in the upper right-hand corner of Figure 9 shows the extreme magnitude of the 2012-event flow compared to peak flows of adjacent years. Due to a short flow record for Deer Creek, annual peak flows for the Nemadji River are displayed in the main frame of Figure 9 to help fill gaps in the timeline. The timeline includes the 2012 flood, breach of the upstream dam and associated restoration, formation of a head-cut, and a low-flow period following the outlined disturbances. Erosion from the upstream dam/project site combined with additional bank and bed erosion within the biological reach are the most-likely sources of excess sediment deposited at 11LS064 between monitoring cycles. An actively migrating head-cut upstream and channel instability within the biological reach is causing continued erosion and soil loss. Resulting excess sediment is smothering macroinvertebrate habitat, covering wood and rocks, and filling spaces between gravels.

**Figure 9. Annual peak flows for Deer Creek (upper-right bar graph) are supplemented with data from the nearby Nemadji River gage H05013005 to show the interplay of flood years (yellow bars), disturbance events, and biological sampling years (red stars).**




Overall low flows and below-average annual peak flows between 2020 and 2024 were potentially too low to move deposited sediments out of the biological reach, exacerbating the problem. Figure 10 shows the relationship between flow and suspended sediment in Nemadji River, and that low flow years have less suspended sediment. This is the result of reduced overland flow/runoff and flow stress on the channel bed and banks and the inability of stream flow to adequately transport excess sediment downstream during low flow years. Until the migration of the upstream head-cut stops, the cycle of high and low flows affecting sedimentation in this reach will likely continue.

**Figure 10. Annual flow volume and TSS loads show more sediment suspended/transported in the water column during high flow years, and less sediment transported in low flow years of 2020-2023. Red stars = biological sampling years.**



## 1.1.5. Summary of Stressor Identification for Deer Creek

The macroinvertebrate community in Deer Creek is being stressed by poor physical habitat, elevated TSS concentrations, and extreme high flows associated with altered hydrology (Table 1) and stream channel instability. Poor physical habitat conditions include loss of habitat features such as undercut banks and increased sedimentation that is smothering critical macroinvertebrate habitat. Streambank and in-channel erosion caused by channel instability contribute to excess suspended and settled sediment. Additionally, increased magnitude and frequency of extreme flow events have direct and indirect impacts on the macroinvertebrate community. Consecutive flood events between 2012 and 2019 led to the direct displacement of various species while also increasing instability in the stream. Floods initiated and/or exacerbated an upstream dam breach and onset erosive processes within and upstream of the biological reach. A channel restoration project completed to address the dam breach was undermined during a large event and a head-cut moving upstream continues to supply excess sediment to the impaired reach. Evidence suggests that sedimentation affecting habitat has persisted through several normal to dry years following high flow years.

**Table 1. Summary of SID results for Deer Creek.**

| Deer Creek/Impaired WID: 04010301-531 , Macroinvertebrates | | |
|---|---|---|
| **Candidate Cause** | **Result** | **Summary** |
| **Total Suspended Solids** | ● | Nearly 90% of TSS samples exceeded the WQ standard. The percentage of TSS-intolerant macroinvertebrate taxa in samples was low compared to the average for Northern Coldwater Streams. |
| **Eutrophication/Nutrients** | X | TP was elevated but was mostly bound to TSS. Nitrate levels were extremely low. DO concentrations met WQ standards and daily fluctuations were low. No visible signs of eutrophication. |
| **Water Temperature** | X | Water temperatures measured in both cycles were within a range known to regionally support a coldwater community. |
| **Poor Habitat (sedimentation)** | ● | Sediment is covering rock, wood, and gravel habitat. The percentage of taxa that are sensitive to fines decreased between Cycle 1 and Cycle 2. |
| **Altered Hydrology and Stream Channel Instability** | ● | Historical land use changes, dams, dam failures, and changes in climate contributed to increases in magnitude and frequency of extreme high flow events. Multiple flood events resulted in displacement of taxa vulnerable to high velocities and contributed to habitat disturbance and on-going erosion and sedimentation. Channel instability also contributes to increased erosion, elevated TSS and poor habitat conditions. |
| **Dissolved Oxygen** | ○ | DO levels in the water column met WQ standards but were potentially low within the fines covering the stream bottom. The percentage of DO-sensitive taxa in Cycle 2 samples was low compared to the average for Northern Coldwater Streams. The percentage of ubiquitous to tolerant flies and midges increased by 20% between cycles. |
| Key: ● = Probable Candidate Cause ○ = Potential Candidate Cause X = Eliminated Candidate Cause | | |

# Part 2: Military Creek (WID: 04010301-769), protection of high-quality waters

Military Creek is a small (3.1 miles) perennial stream in Carlton County, Minnesota that enters Clear Creek (a tributary to Nemadji River) approximately six miles upstream of the Clear Creek - Nemadji River confluence. Protection-based monitoring was completed through the SID process to better understand, protect, and highlight Military Creek as a high-quality stream. Prior to SID work, limited stream health data was available for Military Creek beyond local knowledge that it historically supported native brook trout.

## 2.1 Watershed characteristics

Uncharacteristic of much of the Nemadji River Watershed that is dominated by clay and silt-rich soils, soils in the Military Creek Subwatershed are sandy and well-drained resulting in strong stream-groundwater interactions. Much of the Military Creek drainage area was formerly part of the Glacial Lake Duluth shoreline, which regionally is known to produce localized areas of groundwater springs.

Agricultural land use (hay and row crops) in the subwatershed is relatively high (55%) for the region. Other land cover types include forest (36%), low-intensity development and open space (5%), and grass/shrub land (2%). While no major development currently exists, the area was identified in May 2026 as a considered location for an artificial intelligence (AI) data center. No official proposals were submitted as of May 2026.

Military Creek is intersected by three roads, a state of Minnesota nonmotorized recreational trail, and multiple utility lines including both natural gas and liquid pipelines. A small restoration on Military Creek was completed during pipeline construction in 2021 as part of a broader pipeline replacement effort.

## 2.2 Reach characteristics

### 2.2.1 Protections and designations

Stream designations are currently assigned to two watershed IDs (WIDs), i.e. stream segments, of Military Creek (Figure 11 and Table 2). The most-downstream segment (WID: 04010301-529) extends for 0.3 miles upstream from the Clear Creek confluence. It is currently designated as a protected tributary to a trout stream (Clear Creek) by DNR, and a Class 2A (coldwater habitat) stream by MPCA. The upstream 2.8 miles (WID: 04010301-769) does not have a DNR trout stream designation and is classified by MPCA as a Class 2B (warmwater habitat) stream based on a lack of historical data to support more protective designations. New data collected through the SID effort initiated a recent proposal for DNR Trout Stream designation status for a 2.6 miles section that extends from the Clear Creek confluence upstream to Maere Road. It also initiated an MPCA use class designation change from warmwater habitat (2B) to coldwater habitat (2A) for upstream WID 04010301-769. These classifications have specific water quality standards set for the protection of the habitat type based on the sensitivity of the stream ecosystem to pollutants and other stressors.

**Figure 11. Military Creek Subwatershed map.**

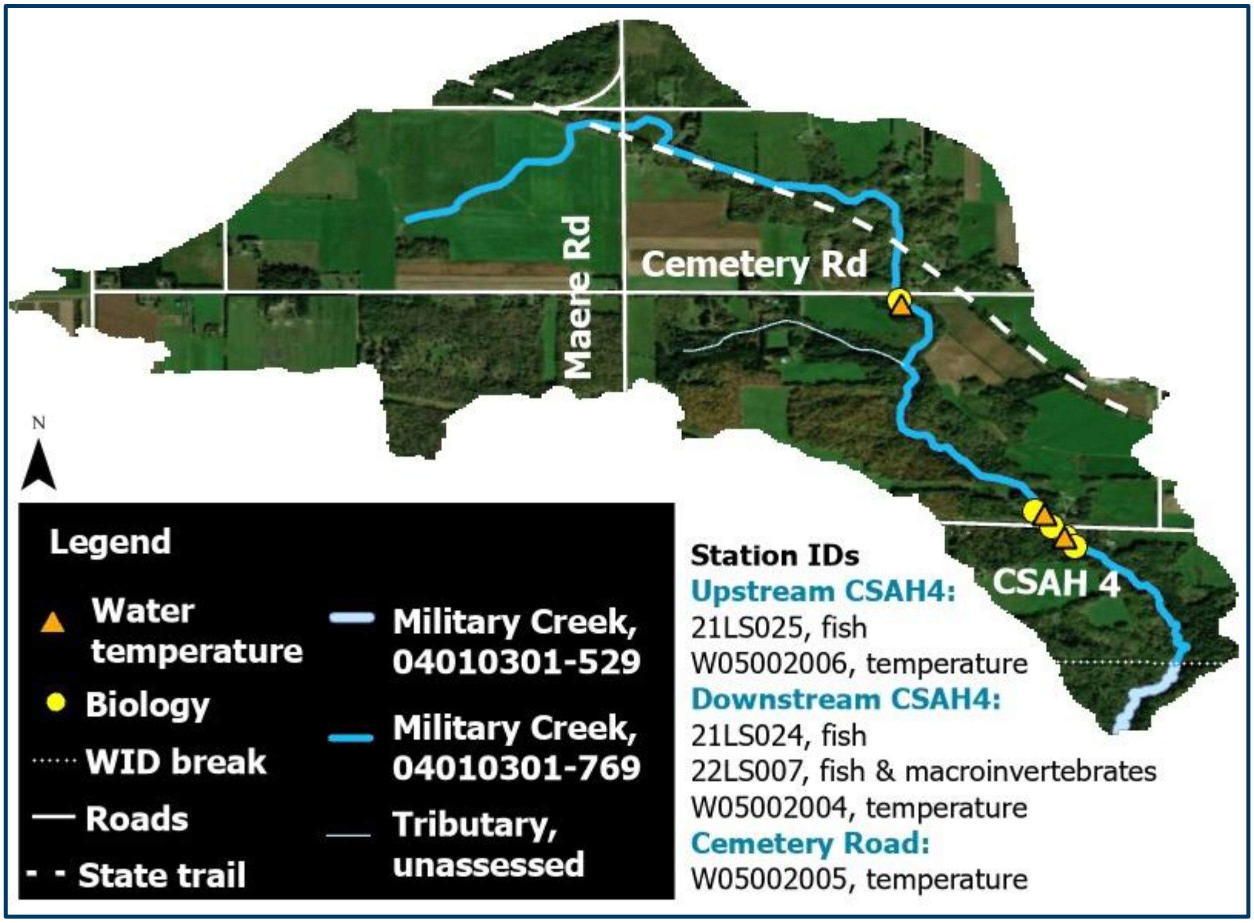



**Table 2. Military Creek reach segments defined by boundary endpoints such as road, trail, and powerline crossings.**

| WID | Location Description | Length (mi) | Stream/land use characteristics |
|---|---|---|---|
| 04010301-769 | Headwaters to Maere Rd | 0.5 | Negligible flow, agricultural land use |
| | Maere Rd to State trail | 0.8 | Some flow, cattle access/pasture, straightened 0.25 miles along state trail, areas of forest |
| | State trail to Cemetery Rd | 0.1 | Groundwater springs discharge to stream providing thermal refugia, rural residential with forest buffers |
| | Cemetery Rd to CSAH4 | 0.9 | Adequate flow, wide (90 to >200 feet) forested buffers in agricultural, rural residential, forest areas |
| | CSAH4 to WID break | 0.5 | Adequate flow, wide (90 to >200 feet) forested buffers in agricultural, rural residential, forest areas |
| 04010301-529 | WID break to Clear Creek | 0.3 | Adequate flow, forest |

## 2.2.2 Monitoring locations and stream segments

The MPCA monitored water temperature using continuous sensors that collected data every 15 minutes downstream of the Cemetery Road crossing and downstream of the County State Aid Highway (CSAH) 4 crossing in 2020, and at two locations on Clear Creek. Water temperature monitoring continued at the

CSAH4 crossing (upstream and downstream) in years 2021 to 2023. The MPCA sampled fish upstream and downstream of the CSAH4 crossing in late-July 2021, and sampled fish and macroinvertebrates only downstream of the crossing in 2022.

#### Groundwater influenced reaches

Several prominent springs discharge groundwater to Military Creek and help sustain healthy flow volumes and cold-water temperature throughout the summer season. Water temperature data and thermal imagery collected by drones identified the reach between the State trail and Cemetery Road as a reach with strong groundwater inputs. Groundwater inputs likely continue downstream through the CSAH4 crossing based on consistently cold temperatures recorded upstream and downstream of CSAH4 between 2020 and 2023.

## 2.3 Military Creek stream health information learned in Cycle 2

The MPCA's sampling efforts on Military Creek began in spring 2020 and continued through fall 2023. Continuous water temperature monitoring and biological monitoring of fish and macroinvertebrates indicate a uniquely cold system that supports a robust brook trout population and vulnerable/imperiled macroinvertebrates.

### 2.3.1 Water Quality

Water quality data was collected by infrequent measurements of DO, pH, and specific conductivity using a YSI handheld instrument and deploying continuous water temperature sensors that operated June 1 through September/October, measuring every 15-minutes, in years 2020, 2021, and 2022. YSI handheld measurements accounted for 12 DO readings and eleven specific conductivity readings. Measured values indicated adequate water quality, but these parameters could not be assessed against state water quality standards due to the small number of readings. A better understanding of the parameters could be accomplished through additional monitoring.

#### Water Temperature

Temperature data collected in Military Creek over the three-year period identified excellent thermal conditions to support a coldwater community. Temperatures for all years were in an optimal growth range to support brook trout for 99% to 100% of the June through August record with no records in the stressful or lethal temperature ranges. Average summer temperatures were extremely cold, ranging from 11.9˚C to 12.9˚C. The warmest temperatures on record were 19˚C in August of 2020 at the Cemetery Road Crossing and 18.2˚C in June of 2021 at the CSAH4 crossing. These combined statistics are representative of a stream that supports high relative densities of brook trout and other cold-water species with low taxa richness favoring coldwater species dominance. The slightly warmer maximum temperature measurements at the Cemetery Road crossing were likely associated with Beaver activity immediately upstream of the culvert. Thermal imagery photographed at the location in July 2023 showed warming in the beaver pond compared to temperatures of water entering the pond immediately upstream and flowing downstream of the crossing.

Based on all MPCA data for streams with full summer continuous records, Military Creek is the coldest monitored stream in the Nemadji River Watershed and ranks within the top 1% to 3% (year-dependent) coldest of stream temperature records (823) collected in the combined Nemadji River, Lake Superior

South, and Lake Superior North major watersheds. Clear Creek is also exceptionally cold with average summer temperatures of 1˚C to 2˚C warmer than those recorded in Military Creek. Cold temperatures are attributed to the high groundwater contributions to streamflow. However, based on stream observations during summer baseflow conditions, Military Creek provides substantially more rate of flow to downstream Clear Creek than Clear Creek's headwater reaches. During multiple visits, stagnant flow was observed in the nearby Clear Creek headwaters while Military Creek was flowing at a considerably good rate for summer conditions.

### Dissolved Oxygen

Measured DO levels in Military Creek were adequate to support aquatic life. Twelve measurements were recorded at the two sites, and all met the water quality standard for coldwater streams of 7 mg/L with a measured range of 7.3 mg/L to 11.5 mg/L.

### Specific Conductivity

Although there are no set water quality standards, specific conductivity readings, a measurement that reflects the concentration of dissolved ions in water, were slightly elevated (>300 µS/cm) for the area with concentrations ranging from 483 µS/cm to 519 µS/cm. Slightly higher values with a small range of variability are typical of streams with high groundwater contributions to streamflow as groundwater typically carries a higher concentration of dissolved ions.

## 2.3.2 Biological community

Three biological monitoring stations located on this reach, from upstream to downstream, are 21LS025, 21LS024, and 22LS007. MPCA conducted a single fish sample visit to each station (21LS025 and 21LS024 in July 2021 and 22LS007 in June 2022). Station 22LS007 was also sampled for macroinvertebrates in September 2022. The majority of 21LS024 overlaps with 22LS007 but were kept as separate stations due to differences in channel morphology for the small portion of stream that was not overlapping.

### Fish

Three fish samples spanning a two-year period confirmed the presence of adult and juvenile (age year-one) brook trout in the stream which indicated a naturally reproducing population. All three visits were assessed using the Northern Coldwater Fish IBI, with all three visits well above (21LS025 – FIBI =100, 21LS024 – FIBI =96.8, and 22LS007 – FIBI = 95.2) the general use threshold of impairment (35) and indicated excellent water quality. The highest achievable F-IBI score is 100. In addition, the Biological Condition Gradient (BCG) was a tier-2, which indicates the structure and function of the fish community is representative of an undisturbed site, with ecosystem level functions being fully maintained.

The fish community at all three visits were dominated by brook trout, with multiple year age classes present. Exceptionally cold temperatures, constant and adequate stream flow, and well-oxygenated water provide ideal habitat for brook trout, a highly pollution intolerant fish. Mottled sculpin, another coldwater and pollution sensitive fish, was also present at all visits (Figure 12). A single brook stickleback, a ubiquitous coolwater fish, was found in the 2022 sample at 22LS007.

Figure 12. Brook trout (left) and mottled sculpin (right) sampled in Military Creek.

## Macroinvertebrates

The 2022 macroinvertebrate sample from Military Creek station 22LS007 yielded a MIBI score of 33.9 in the Northern Coldwater Class, or two points above the general use threshold (32). The BCG was a tier-3, which indicates some evident changes in the structure of the biotic community and minimal changes in ecosystem function. A BCG tier 3 reach typically shows signs of decreases in highly sensitive taxa and increases in opportunistic and tolerant organisms compared to a natural system.

The lower BCG score was likely associated with the sample being dominated by *Simulium* (Count = 116), a pollution tolerant black fly, which could be representative of stress or a reflection of the limitation of the size of the small headwater stream. Their presence can be a sign of good stream flow, as they filter material out of passing water. They are typically abundant for short periods of time, as a few weeks later they've reached the adult stage of their life cycle.

**An abundance of pollution intolerant taxa including multiple vulnerable, imperiled and/or rare macroinvertebrates make this site a good candidate for restoration and protection efforts.**
Despite this dominance of *Simulium*, the sample contained an impressive diversity and number of pollution intolerant or sensitive caddisfly taxa including *Parapsyche apicalis*, *Rhyacophila invaria*, *Lype Diversa*, *Psychoglypha subborealis*, *Hesperophylax designatus*, *Lepidostoma*, *Glossosoma*, and *Micrasema rusticum*. Two mayfly taxa and two stonefly taxa were collected with an impressive amount of the stonefly *Capniidae* (Count = 36), making it the second-most dominant taxa in the sample. Overall, the presence of this diversity of uncommon and/or pollution intolerant taxa indicates the macroinvertebrate community structure and ecosystem function has largely been maintained.

Included in the taxa list above were several rare and vulnerable or imperiled species collected in the sample. Vulnerable (at moderate risk of extinction or decline) and imperiled (at a higher risk of extinction) species designations are defined within the State Wildlife Action Plan and are considered preliminary while the plan is in its review phase. This is a 10-year conservation plan aimed at preserving wildlife diversity and protecting rare species from decline.

Two vulnerable and pollution intolerant caddisflies collected at 22LS007 include *Hesperophylax designatus* and *Psychoglypha subborealis*. *Psychoglypha subborealis* is widely distributed across the Northern U.S., mountain west, and Canada but has only been collected from four locations in Minnesota and has limited records across Northern Wisconsin. *Hesperophylax designates* has been collected at 57 locations statewide, primarily in Southeast Minnesota but also at 11 locations in Northeast Minnesota, including Military Creek. The sample collected at 22LS007 produced a count of 18 individuals, which suggests that a healthy population is currently maintained at this location.

One preliminary imperiled species, *Parapsyche apicalis*, was also collected. *Parapsyche apicalis* is highly pollution intolerant and requires consistently cold and fast-flowing water, and riffle habitat. It has been collected five times statewide by the MPCA, all in Northeast Minnesota. In Michigan, it has been shown experimentally to have one of the lowest tolerances to warm water of any aquatic insect. Furthermore, it is almost exclusively found in very small (< 1 m (3 ft) wide) streams with dense canopy cover. The sample collected at 22LS007 produced a count of 17 individuals, which suggests that its specific habitat requirements have been met, and a healthy population is currently maintained at this location.

Another rare and pollution intolerant taxa sampled was the caddisfly *Rhyacophila invaria*, which has been collected at 13 locations statewide by the MPCA, all in Northeast Minnesota. Due to limited data, it has not currently received a conservation status assessment but, all other species of *Rhyacophila* in Minnesota are considered threatened or imperiled.

### 2.3.3 Stream habitat

Stream habitat data collected at all three fish visits and the one macroinvertebrate visit indicated good stream habitat for both fish and macroinvertebrates. Despite nearby rural residence and proximity to row crops, the stream has an adequate buffer of mostly mature trees that supplies a wide to extensive riparian area and moderate to heavy shading. The stream had a good variety of stream features (riffle/pool/run) and substrate types (Figure 13).

Stream bed materials included silt, clay, sand, gravel, and cobble materials. Despite cobble being on the smaller side of its range and the absence of large boulders, these habitats were productive in housing macroinvertebrates (Figure 14). Wood was also abundant and productive. Although some streambank erosion was noted at meander bends in the channel, there was low siltation of sediment on surfaces and only light embeddedness of gravel and cobble by finer sand and silt. Fish cover was moderate to extensive and consisted of undercut banks, large wood, rootwads, overhanging vegetation, and deep pools.

**Figure 13. Military Creek habitat includes a good riffle/pool habitat (left) and a wide to extensive riparian buffer (right).**

**Figure 14. Cobble housing a high number of macroinvertebrates including the caddisfly *Hesperophylax designatus*.**

## Beaver dams, periodic effects on habitat

Beaver activity in the watershed has been observed over the study period but was most pronounced in 2025 and 2026 (Figure 15 and Figure 16). Dams were initially observed upstream of the Cemetery Road crossing in 2020 and then extended to the State trail and CSAH4 crossings in 2026. While beaver dams can be beneficial by reducing peak flows, storing water, and retaining sediment in some watersheds, they can also have negative effects. These include impeding upstream movement of adult trout and downstream movement of juvenile trout, altering sediment transport and water temperature regimes (creating conditions unsuitable to support trout), and loss of suitable spawning gravels. Effects observed within the watershed in May 2026 included:

**State Trail** (Figure 15) – A major dam was located tens of feet downstream of the culvert outlet forming a large pool of muddy water with higher water levels than previously observed at the culvert outlet. Water clarity improved just downstream, in the vicinity of groundwater springs that discharge to Military Creek. The beaver dam is likely a complete barrier to fish passage; however, the channel upstream of the crossing is undefined and only flows ephemerally, therefore the distance of stream miles being impeded is negligible under most flow conditions.

**Cemetery Road** (Figure 15) – A beaver dam upstream of the culvert was present throughout most of the study. In 2026, the dam appeared to be a "secondary" dam to the more prominent dam upstream (State trail crossing) and/or a failed former "primary" dam. This dam is likely navigable by fish, although the culvert too acts as a barrier to fish passage.

**CSAH4** (Figure 16) – A four-feet high beaver dam was located within 10 feet of the culvert inlet on the upstream side of the crossing. The dam appeared to be a complete barrier to upstream movement of adult and juvenile trout. The forested riparian area was flooded beyond the stream banks at monitoring station 21LS025 which previously scored excellent (FIBI = 100) for fish. Additionally, a breached beaver dam was located tens of feet downstream of the culvert. Stream banks near the breach were steep and nonvegetated, and excess sediment and wood were observed in the channel, compared to previous years. Spawning gravels were covered in silt and the channel was noticeably wider. Additionally, a major gully formed within a small tributary on the upstream side of the dam causing severe erosion of the area that extended upstream to the highway and east of the main channel.

Figure 15. Beaver dam effects on Military Creek between State trail (left) and Cemetery Road (right) crossings.

Figure 16. Beaver dam effects on Military Creek at the CSAH4 crossing include flooding upstream (left) and a disturbed channel downstream (right).

## 2.3.4 Stream connectivity and barriers to fish movement

### Culvert barriers

In addition to beaver dams, several culverts act as barriers to fish passage. Culverts are located at three road crossings and one state trail crossing. At least two road culverts (Cemetery Road and CSAH4, Figure 17) are partial to full barriers to fish movement and a third (State trail) is causing localized erosion. The fourth culvert at Maere Road is not considered a barrier since the stream channel is undefined and flows ephemerally during high precipitation events; and otherwise, it is dry. The reach upstream of the state trail is also ephemeral with most of its baseflow initiating downstream through groundwater springs.

Crossings at CSAH4 and Cemetery Road are the highest priority crossings for barrier removal due to the high-quality habitat, perennial flow, cold temperatures, and presence of trout. CSAH4 is considered the highest priority culvert for replacement based on a greater distance (0.9 miles) of high-quality upstream habitat that removal would reconnect. Currently, both culverts are perched at the outlet, are undersized in diameter, and provide too shallow depth (0.1 feet) during baseflow conditions.

**Figure 17. Culvert assessment variables and prioritization for replacement for three crossings on Military Creek.**

| | State Rec Trail | Cemetery Road | CSAH 4 |
|---|---|---|---|
| **Stream type** | Ephemeral upstream / Perennial downstream | Perennial | Perrenial |
| **Trout presence** | Unknown (potential downstream) | Adult/juvenile observed | Adult/juvenile sampled |
| **Fish barrier** | Not applicable. Ephemeral upstream. | Perched. Culvert drop to bed = 1.2 feet. | Perched. Culvert drop to boulders = 0.8 ft and secondary drop to bed = additional 0.9 ft. |
| **Alignment** | Poor Directed at eroding valley wall | Fair | Fair |
| **Culvert diameter** | ~4.5 ft | 4.5 ft | 4 ft |
| **Stream width** | Undefined | ~5 feet | ~ 10 ft |
| **Next upstream barrier** | Not applicable | 650 ft | 0.9 miles |
| **Baseflow rate (May '26)** | Unknown | ~0.5 cfs | ~1.8 cfs |
| **Culvert baseflow depth** | Unknown | 0.1 ft | 0.1 ft |
| **Fish barrier priority** | **Low** - ephemeral flow upstream; misalignment causing sediment issues downstream of outlet | **Moderate** - perched and slightly undersized. 650-ft to next upstream barrier (State Rec Trail). Flow sourced from springs initiates | **High** - perched and undersized. 0.9-miles to next upstream barrier. Cold, high-quality habitat reach. |

Fish data support that the CSAH4 culvert partially to fully restricts fish passage from downstream to upstream during low flows when it is perched several feet above surface water levels.

While adult brook trout can potentially move from downstream to upstream through the culvert during the right conditions due to their known jumping abilities, the movement of juvenile brook trout and other fish species upstream through the culverts is highly unlikely. Depth of water within the culverts is likely too shallow for adults to navigate during low flows and too fast during high flow runoff events. The lack of substrate materials within the culvert and the undersized nature of the culvert creates faster than normal streamflow conditions within the culvert during high flow events.

Effects of the culvert on the fish community were observed in July 2021 samples, in that a greater number of brook trout and mottled sculpin were collected downstream of the CSAH4 culvert (21LS024) compared to upstream (21LS025). Over 100 brook trout and 63 mottled sculpin were sampled in the downstream reach and 51 brook trout, and 9 mottled sculpin were sampled upstream. Juveniles accounted for 53% of total brook trout in the downstream reach and 41% in upstream reach indicating that both reaches provide good quality spawning and rearing habitat.

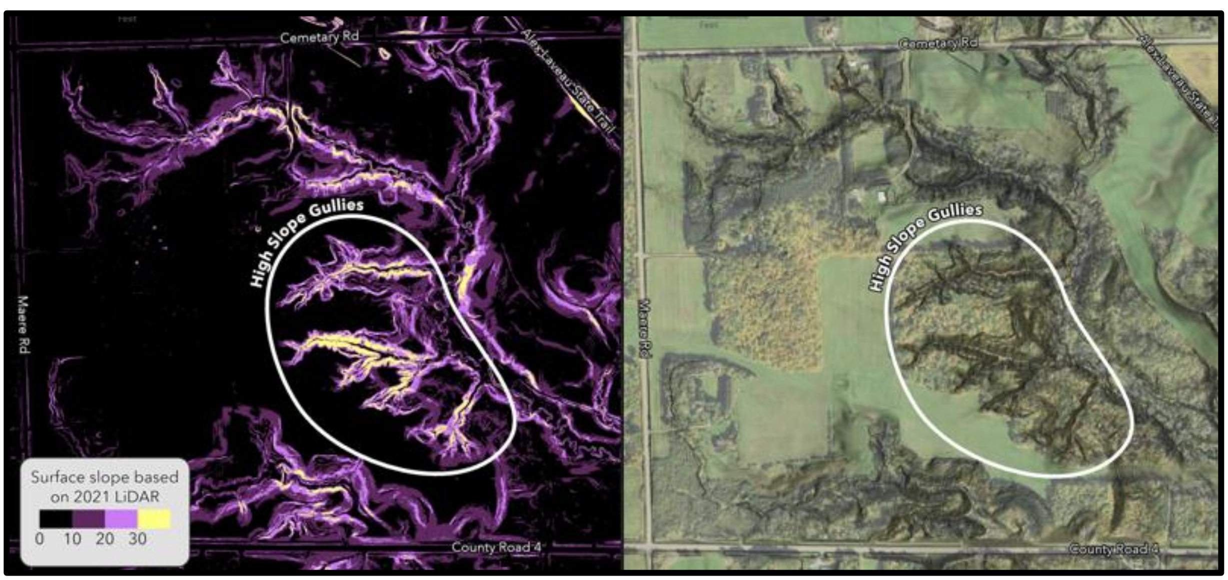
Fish count numbers sampled downstream of the culvert in June 2022 (station 22LS007) were lower than the year prior (21LS024), but no upstream sample was collected in 2022 to conduct an upstream to downstream comparison.

### 2.3.5 Erosional hotspots

The MPCA conducted a watershed storage and erosion hotspot analysis for the Nemadji River Watershed Restoration and Protection Strategy (WRAPS) Report to prioritize where wetland restoration would benefit the most in the Nemadji River Watershed. The process used *Optimized Hot Spot Analysis* in ArcGIS Pro to identify statistically significant areas where slopes were steeper than 30 degrees. Areas of high statistical significance were termed erosion hotspots. The headwater subwatersheds of Clear and Mud Creek, including the Military Creek Subwatershed, ranked highest for protection prioritization based on multiple factors including the relatively high percentage of “disturbed” land cover, low percentage of surficial water storage, and the presence of erosional hotspots.

Erosional hotspots included several steep gullies connected to the main channel of Military Creek (Figure 18). Aerial imagery shows that the riparian area of the gullies is forested and has been forested for at least several decades (images date back to 1992). The gullies are also visible in 1992 imagery, although the severity of the slope is unknown prior to 2021. Land near the heads of the gullies, i.e. location where they first cut into the landscape, is in agricultural land use and a buried utility line intersects the same area. It is possible that the gullies originated decades back when the line was first placed and/or the forests were first cleared; and sometime after the localized area was reforested and placed out of agricultural production.

**Figure 18. Analysis showing erosional hot spots in Military Creek (left) and recent land use (right) in the same area.**



## 2.4 Military Creek conclusions and next steps

Findings from this protection study demonstrate that Military Creek is among the highest quality coldwater habitats within the Nemadji River Watershed and ranks among the highest coldwater habitats in Northeast Minnesota. The study provided new information that led to the proposal of added protections associated with coldwater (2A) and DNR trout stream status. While water quality and habitat are overall good, the study identified some areas of temporary and/or long-term threats to the continued stability of Military Creek. A summary of key findings, potential threats to stream health, and recommended conservation efforts are summarized below.

Key findings from Cycle 2 data collection efforts show:

- Military Creek is a high-quality coldwater habitat that supports a high number of brook trout and multiple rare, vulnerable, and imperiled macroinvertebrates that are found in few other places in the state of Minnesota.
- Military Creek is the coldest monitored stream in the Nemadji River Watershed and within the top 3% coldest in the combined Nemadji River, Lake Superior South, and Lake Superior North major watersheds.
- Prominent groundwater springs produce critical thermal refuge and sustained year-round streamflow that supports a high-quality aquatic community. Springs initiate downstream of the State trail crossing and persist downstream to CSAH4 and potentially beyond.
- A separate MPCA study associated with WRAPS efforts recently prioritized the headwaters of Clear Creek (including Military Creek) as one of two most critical subwatersheds for watershed storage protection. The study also identified erosional hotspots in the Military Creek Subwatershed.

The main threats and suggested protections to Military Creek are:

- Military Creek, its tributaries, and groundwater springs are largely on private lands, requiring collaboration for long-term protection.
- The subwatershed currently has mostly extensive buffers, including alongside residential and agricultural lands. However, further forest removal and/or new development including industrial facilities have the potential to place added pressure on the riparian area and/or alter the hydrological processes that currently provide excellent habitat conditions for pollution-intolerant fish and macroinvertebrates.
- Perched culverts at roadway crossings and several active beaver dams prevent brook trout movement upstream and/or downstream, limiting their available area to spawn and potentially isolating populations. This also increases the risk of larger-scale fatalities if conditions in an isolated reach become unsuitable (stressfully/lethally warm summer temperatures, winter freezing, pollution exposure, etc.)
- Beaver dams, although temporary, caused recent degradation of sections of Military Creek, particularly near culvert crossings. The full extent of impact (positive or negative) on stream health is unknown. Some signs of degradation include the formation of gullies, loss of stream

bank and riparian vegetation, increased sedimentation within the channel, and loss of habitat through channel-widening, shallowing of pools, and siltation of spawning gravels.

Going forward, conservation efforts should:

- Protect high-quality coldwater habitat. Military Creek is currently included in a MPCA use designation change process that, if approved, will change the use designation status from warmwater habitat (2B) to coldwater habitat (2A). Additionally, DNR is pursuing a trout stream designation status change to gain added protection assigned to trout streams.
- Engage private landowners through easements, conservation incentives, stewardship programs, community outreach, and volunteer citizen monitoring.
    - Maintain and enhance conservation agricultural efforts through maintenance of healthy riparian buffers that protect soil and maintain stream stability and biodiversity.
    - Promote to landowners the protection of springs (Figure 19) through acts such as preserving healthy forests where springs are located, such as through Sustainable Forest Incentive Act and Woodland Stewardship Plans, and by not disturbing springs through disturbance of land for development. Landowners can also assist by adding spring locations to the DNR spring inventory: (https://www.dnr.state.mn.us/waters/groundwater_section/mapping/springs.html).
    - Promote the protection of clean water to landowners through citizen stream monitoring opportunities (https://www.pca.state.mn.us/get-engaged/volunteer-water-monitoring).

**Figure 19. Springs initiate downstream of the State trail (left) providing cold spring-fed water (left). Horizontal lines in left image are juvenile and age one trout in a pool near the Cemetery Road crossing.**

- Restore stream connectivity at road crossings. Reducing barriers will help sustain headwater populations and allow movement of fish from Clear Creek and beyond to excellent spawning and rearing habitat of the headwaters of Miliary Creek. Crossing designs such as open-bottom culverts, bridges, or traditional culverts with a diameter and slope that match the natural stream should replace undersized and misaligned culverts. A secondary benefit of right-sized culverts is that they can discourage beavers from damming. Beavers are more likely to block culverts that are too small, too steep, or too wide.

- Include Military Creek in future Nemadji River Watershed restoration and protection planning and implementation efforts. Actively seek funding opportunities to support protection of this high-quality coldwater habitat.

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