Watershed assessment and trends update

Nemadji River

Lake Superior Basin

Summary

The Minnesota Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MNDNR), and local government partners have completed a study of the Nemadji River Watershed. The Beartrap-Nemadji River Watershed lies in northeastern Minnesota and northwestern Wisconsin and covers an estimated 1,928 square miles. Approximately 14% of the watershed lies within Minnesota and is solely comprised of the Nemadji River drainage, which encompasses 35 lakes (>10 acres) and numerous tributary streams. The lower reaches of the Nemadji River and its contributing waters are deeply incised into the red clay soils of Glacial Lake Duluth and often form a steep stream bank with exposed clay soils. This exposed clay soil is susceptible to slumping and accelerated erosion that contributes over 120,000 tons of sediment to Lake Superior annually.

Water quality throughout this watershed is in fair condition but problem areas do occur and persist. Impairments found within this watershed are likely a function of both natural and anthropogenic stressors. Although there are several streams that do not meet water quality standards, several others are of higher quality and may be worth additional protections. Numerous streams within this watershed are cold-water resources that support robust Brook, Brown, and/or Rainbow Trout populations. In addition, multiple rare and/or state threatened macroinvertebrate species have been collected.

Relatively few lakes exist within the Nemadji River Watershed and only two were evaluated during this cycle of monitoring. Chub Lake was assessed as fully supporting aquatic life and recreation, while Net Lake remains impaired for aquatic recreation due to excess nutrients and algae. A Total Maximum Daily Load (TMDL) study was approved for Net Lake by the Environmental Protection Agency (EPA) in 2017, which calls for a 27% reduction in phosphorus long-term in order to meet water quality standards. Projects are underway to reduce nutrient pollution to the lake, such as septic system replacements.

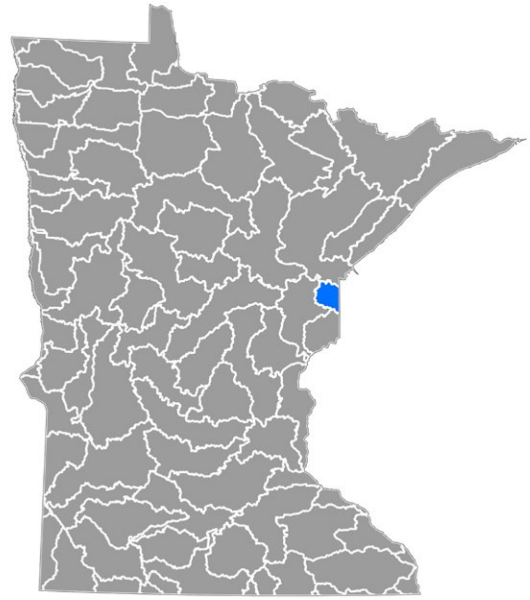
Instead of relying on chemical testing of the water alone, scientists reached their conclusions through studying the variety of fish and bugs living in the waters. Doing so offers a more comprehensive understanding of the watershed's health over time. Volunteer water quality monitors contributed to the assessment, which is funded by Minnesota's Clean Water Land and Legacy Amendment. Details in the full report will shape decisions on watershed management and pollution reduction measures for years to come.

Watershed Study

Water monitoring is essential to determining whether lakes and streams meet water quality standards that are designed to ensure that waters are fishable and swimmable. While local partners and state agencies monitor water quality on an ongoing basis, the Minnesota Pollution Control Agency (MPCA) and local partners conduct monitoring of major lakes and streams in each of the state's 80 watersheds every 10 years to detect any changes in water quality (Figure 1). This intensive monitoring looks at fish and macroinvertebrate (bug) communities as well as water chemistry to gauge water quality. The partners use the data to see which waters are healthy and need protection and which are impaired and need restoration. Waters are considered impaired if they fail to meet water quality standards.

The MPCA and partners monitored water quality conditions within the Nemadji River Watershed in 2011-2012 and again in 2022-2023 (Figure 1). Chemistry data collected by local partners between 2014 and 2023 were used to assess the conditions of waterbodies within the watershed, with a focus on whether they are meeting water quality standards that are designed to protect aquatic life, recreation, and aquatic consumption. The overall goal of these assessments is to ultimately determine which waters are healthy and in need of protection or are polluted and require restoration.

Figure 1. The headwaters of the Nemadji River begin in Minnesota and flow towards Lake Superior through Wisconsin.



Changes in water quality

To detect any changes in water quality, this recurring investigation looks at fish and macroinvertebrate communities as well as water chemistry. Scientists use a tool called the Index of Biological Integrity (IBI) to assess the health of biological communities in lakes, rivers, streams, and wetlands. High IBI scores indicate a healthy aquatic community, which are more likely to be attained when water quality, habitat, and hydrology are not compromised by human activities.

Over the past decade, scientists observed little change in water quality in the Nemadji River Watershed. While the biological condition in individual streams may have improved or declined between 2011 and 2022, the overall health of fish and macroinvertebrate communities did not change significantly over this period. Continued problems include elevated bacteria, excess sediment (turbidity) and poor biological community conditions. Water monitoring is essential to determining whether lakes and streams meet water quality standards designed to ensure that waters are fishable and swimmable

MPCA scientists monitored the fish and bugs, along with several water quality parameters, in the Nemadji River Watershed as part of the statewide effort to gauge the health of major lakes and rivers.

- Stream flow appears to be increasing at the Nemadji River near South Superior but appears to be a decreasing in the upper portion of the watershed at the Nemadji River near Pleasant Valley.

- Total suspended sediment (TSS) showed a statistically significant change from 2008-2022, indicating an increasing trend of 3.5% per year or 0.65 mg/L per year.
- An existing Aquatic Recreation (AQR) impairment due to high levels of Escherichia coli (E. coli) bacteria has declined and is now meeting standards on the Nemadji River. Several Best Management Practices (BMP) projects were implemented upstream that likely influenced the decline in bacteria counts and the restoration of this water body. Conversely, a new AQR impairment was added to the lower Blackhoof River based on recent E. coli bacteria levels that exceeded the water quality standard.
- Macroinvertebrate IBI score is now indicating an aquatic life impairment on Deer Creek. The more recent samples indicated a community which has degraded in both structure and ecosystem function.

Landowners, local partners, and state agencies have installed numerous BMPs to improve water quality, but many more are needed. It takes time for these practices to show results.

Highlights of monitoring

- Although Chub Lake was assessed as fully supporting for AQR in 2013 and as impaired for aquatic consumption in 2009, fish community data had not been collected to assess aquatic life until 2020. Chub Lake was found to fully support aquatic life use based on the fish IBI.
- Fish and macroinvertebrate communities are generally good in the headwaters, but conditions tend to deteriorate in the lower reaches of the watershed as it enters more erodible glacial lake sediments.
- The lower reaches of Elim Creek showed a significant increase in species diversity, the number of sensitive species present, and the Index of Biotic Integrity scores for fish between 2011 and 2022. The upper reaches continue to be impacted by a sediment dam established in the 1970s to reduce sediments within the Nemadji River Watershed. Additional monitoring is needed to determine the extent of an aquatic life impairment on this waterbody.
- Several streams are considered vulnerable due to one or more parameter near the aquatic life impairment threshold. These vulnerable streams are Skunk, Rock, Clear, Deer, Hunters, Mud, Nemadji (Creek), Stony, Net, and Blackhoof.
- Water temperatures in many streams in the Nemadji River Watershed are suitable for trout and support robust trout fisheries. Of the twenty-eight stream locations with published and complete summer temperature records in the Nemadji River Watershed, over half of the locations reported water temperatures optimal for Brook Trout growth for more than 90% of the summer.
- Several vulnerable/imperiled aquatic macroinvertebrate species (Goera stylata, Parapsyche apicalis, & Boyeria grafiana) were identified in Hunter Creek, Clear Creek, Tributary to Clear Creek, and Nemadji River.

Success story

Skunk Creek weir and culvert outlet before (above) and after (below) restoration.

Water quality monitoring and watershed studies completed over the past two decades have shown that Skunk and Elim Creeks are degraded by excess sediment. The excess sediment is a result of hydrologic changes caused by historical logging and other human activities that have altered stormwater runoff and stream flows. Other problems causing reduced stream and biological health include poor aquatic habitat and barriers limiting fish movement. Several red clay dams within a larger network of dams built in the 1970s are barriers to fish passage and contribute to sediment loading as some fail and others cause nearby stream instability.

Currently Skunk Creek and Elim Creek are included on Minnesota's impaired waters list. The former is impaired by turbidity associated with excess sediment and the latter did not meet the biological criteria for a healthy fish community in a cold-water habitat stream based on past sampling efforts.

In 2018, the Carlton County Transportation Department and Soil & Water Conservation District together addressed erosion, road stability, and fish passage issues on Skunk Creek by initiating the Skunk Creek Sediment Reduction Project. Combined Minnesota Clean Water Fund, U.S. Fish and Wildlife Service's National Fish Passage Program, and Carlton County funding supported the removal of a weir and pipe culvert and restored 1/3 mile of stream and fish passage on Skunk Creek.

When Skunk Creek was added to the 2014 impaired waters list, the average annual sediment load at the monitoring location was nearly 2,400 tons per year (MPCA 2017); the sediment loads were up to ten times greater at discrete locations during extreme precipitation events that caused road, culvert, and streambank failures. Projects have since reduced sediment loads by 224 tons and prevented over 17,000 tons of additional loading from roadway washouts and erosion during torrential precipitation events on Skunk Creek. Additional reductions are forecasted with the completion of projects listed in the 2020 EPA Clean Water Act Section 319 small watersheds focus grant.

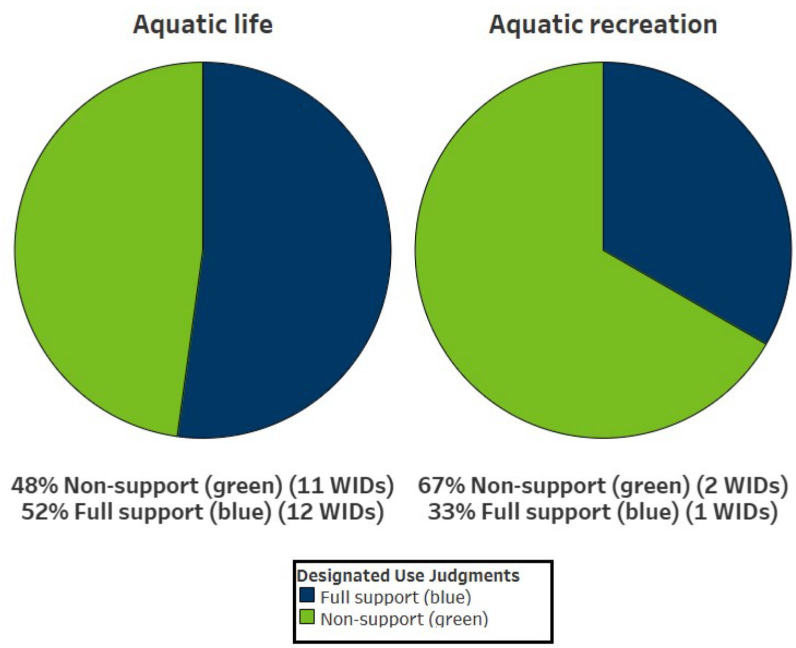
Prior to the Skunk Creek Sediment Reduction Project, few fish species were found in Elim Creek and upstream of the barrier in Skunk Creek, and trout were not present at both loactions. Following restoration work, a re-sampling of fish communities in both streams reported the presence of trout as well as a three-fold increase in the number of fish and fish species. Biologists sampled nine adult trout, both brook and brown trout, in Elim Creek as well as an age year-one brown trout indicating that species may already be spawning and rearing there. One adult brown trout was also sampled in the restored Skunk Creek reach. See the full story on the MPCA website: https://www.pca.state.mn.us/news-and-stories/after-restoration-projects-two-northeast-minnesota-streams-are-seeing-clearer-waters-and-more-fish

Watershed assessment results

Streams and rivers

Overall, about half of the stream reaches that were monitored passed the aquatic life standards within the Nemadji River Watershed (Figure 2). While streams like the upper reaches of the State Line Creek have fish and macroinvertebrate communities that are in good condition, the majority of streams, particularly in the glacial lake sediments, have biological communities that are severely degraded due to the accumulation of stressors (Figure 4). In general, fish and macroinvertebrate communities in the watershed exhibit signs of degradation characterized by a dominance of pollution-tolerant species. A combination of stressors, including vegetation alterations, draining of wetlands/lakes, undersized culverts, erosion, damming of streams, unstable geomorphology, and other hydrological alterations are all likely collectively contributing to the reduction of sensitive species throughout the watershed.

Figure 2. Watershed assessment results for aquatic life and aquatic recreation in streams.



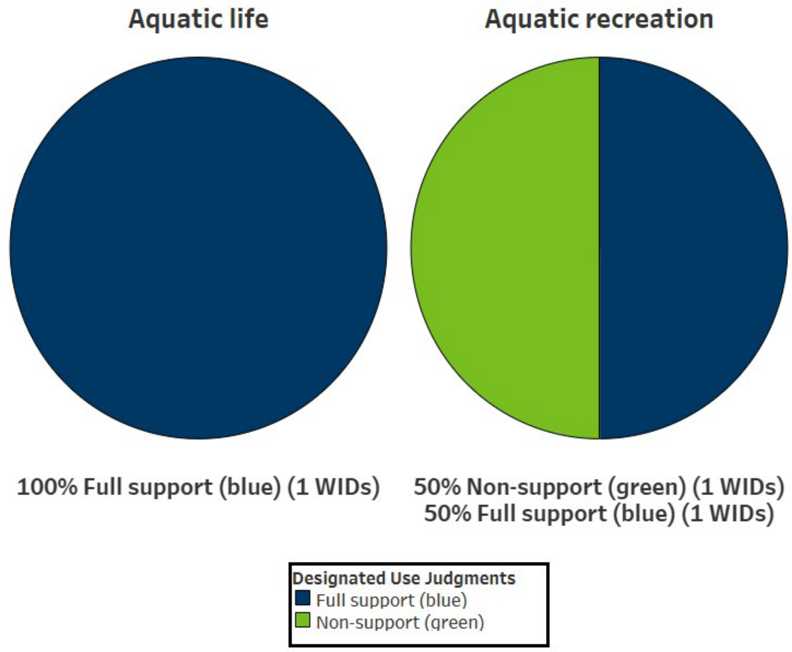
In the Nemadji River Watershed, Total Suspended Solids (TSS) was the primary chemical impairment found throughout the watershed. Streams in the watershed are prone to instability and mass wasting in part due to the composition of the soils within the stream corridors that consist of fine clays and clayey silts deposited by glacial Lake Duluth. Sediment and turbidity dynamics in the watershed are therefore a function of the watershed's geological setting, the river's geomorphology and current/historical land use practices. Water quality is impacted by the high sediment load in the form of excessive turbidity and ultimately deposition of sediments into the slower, low gradient portions of streams in the Nemadji River Watershed and Lake Superior.

Only two Aquatic Recreation (AQR) impairments were identified from the first round of monitoring (Figure 2). Both locations were monitored during this more recent cycle. The site on the Nemadji River showed that E. Coli levels now meet state standards, resulting in a delisting of this waterbody from the impaired waters list. Several BMP projects have been implemented upstream of this impaired reach that likely influenced the decline in bacteria counts and the restoration of this water body – such as septic system and feedlot improvements, and fencing projects that exclude cattle from waterways. However, the existing impairment on the Nemadji River, South Fork was reaffirmed by the more recent monitoring and a new AQR impairment was added to the Blackhoof River as a result from bacteria levels above state standards.

Lakes

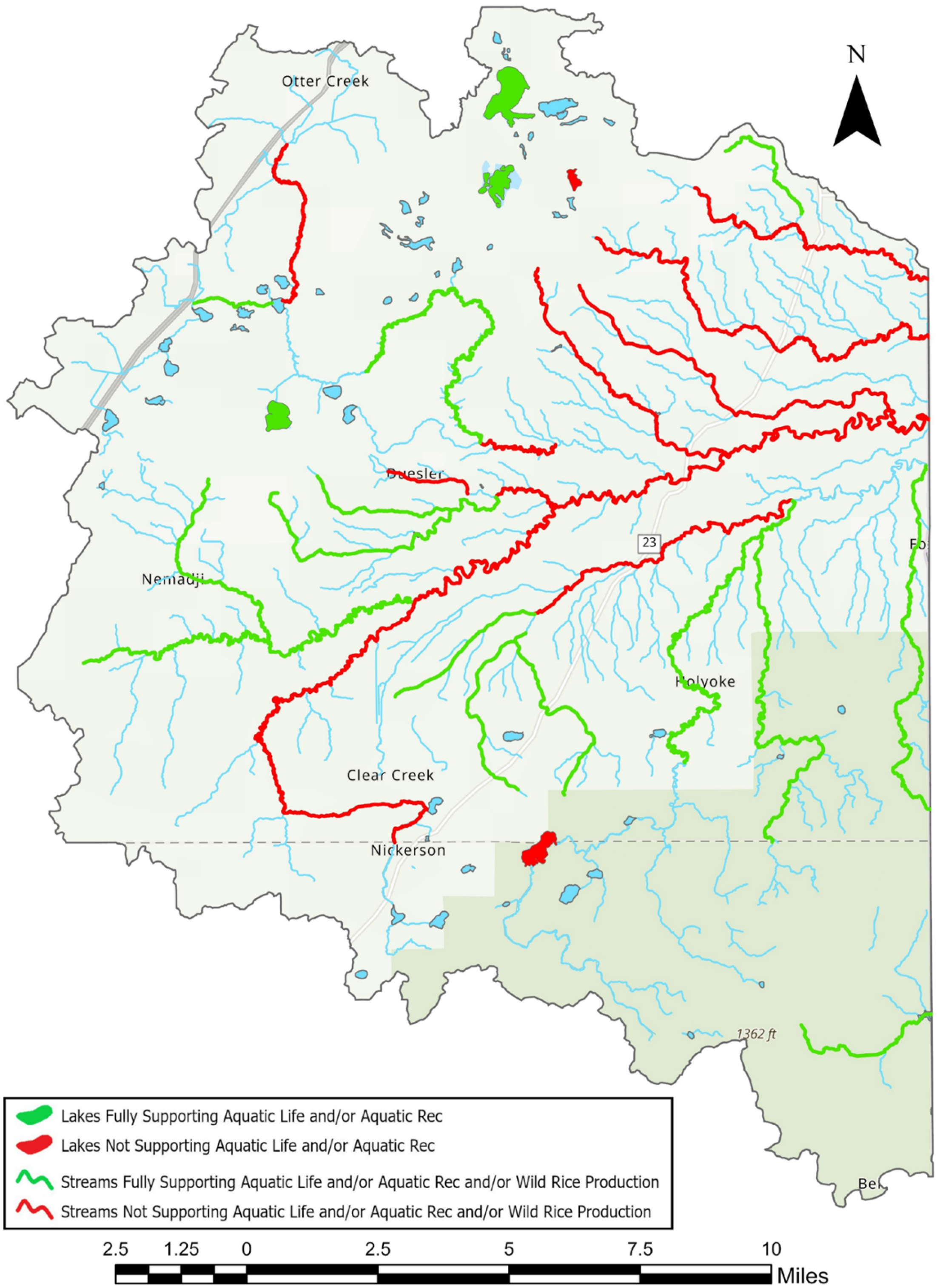
Lakes are relatively uncommon in the Nemadji River Watershed. Most are shallow with moderate fertility and algal biomass, and have naturally low clarity due to influence from wetlands. Five lakes were evaluated in this monitoring cycle highlighted by Chub and Net Lakes (Figure 3). Chub Lake, a highly valued lake, fully supports swimming by being in attainment of phosphorus, chlorophyll-a, and water clarity standards. Net Lake, in Pine County, remains impaired due to excess nutrients. A TMDL was approved by EPA in 2017, which calls for a 27% reduction in phosphorus to meet water quality standards. Projects are underway to reduce nutrient pollution to the lake, such as septic system replacements. In 2025, the MPCA will have formalized new eutrophication standards for shallow lakes in Minnesota's Northern Lakes and Forests Ecoregion, which should clarify assessments for some area lakes now assessed as Inconclusive – such as Hay, Sand, and Lac La Belle Lakes

Figure 3. Watershed assessment results for aquatic life in and aquatic recreation in lakes.



Although the Nemadji River Watershed contains several shallow lakes, only one was eligible to be assessed for aquatic life based on fish index of biological integrity (IBI) data. Other lakes in the basin were either subject to recent winterkill events that adversely impacted fish or were too small for the fish IBI to be appropriate. The one lake that was assessed, Chub Lake (Figure 3) was found to have a healthy fish community. During the fish IBI survey, 17 fish species were captured, including two intolerant species and no tolerant species. Chub lake is impacted by stressors, it is sensitive to nutrient enrichment due to substantial shoreline development.

Figure 4. Assessment result for aquatic life and aquatic recreation on rivers, streams, and lakes.



Trends

A key objective of the 2022 monitoring effort was to evaluate if and how water quality has changed since the initial monitoring. If water quality has improved, it is important to understand to what extant human actions may be responsible for the change. It is equally important to understand if water quality does not appear to be changing or is declining. Either way, the knowledge will help inform future activities.

Trends in four different aspects of water quality were analyzed to provide as robust a picture as possible of what is happening in the Nemadji River Watershed:

1) Streamflow, sediment (total suspended solids), TP, and nitrogen (nitrate)
2) Biological communities
3) Clarity of lakes
4) Climate

Figure 5. Average TSS flow weighted mean concentration by major watershed.

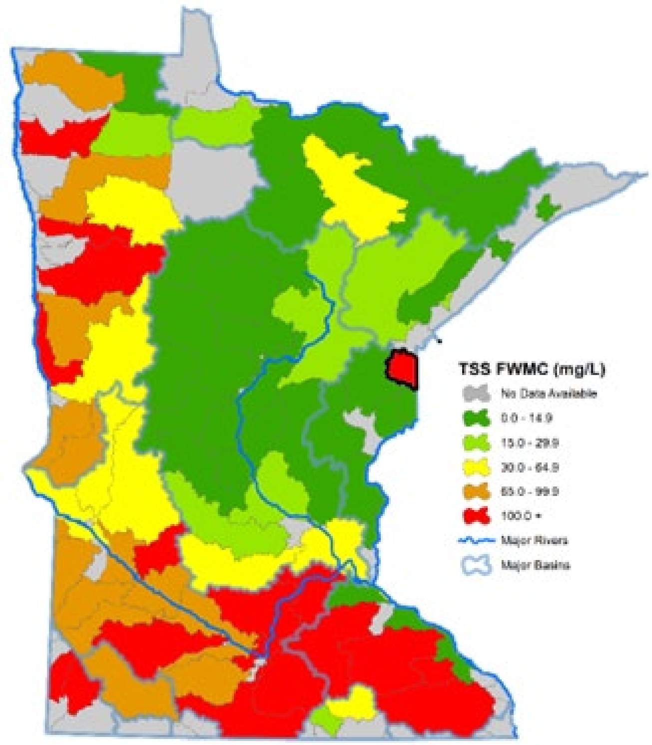
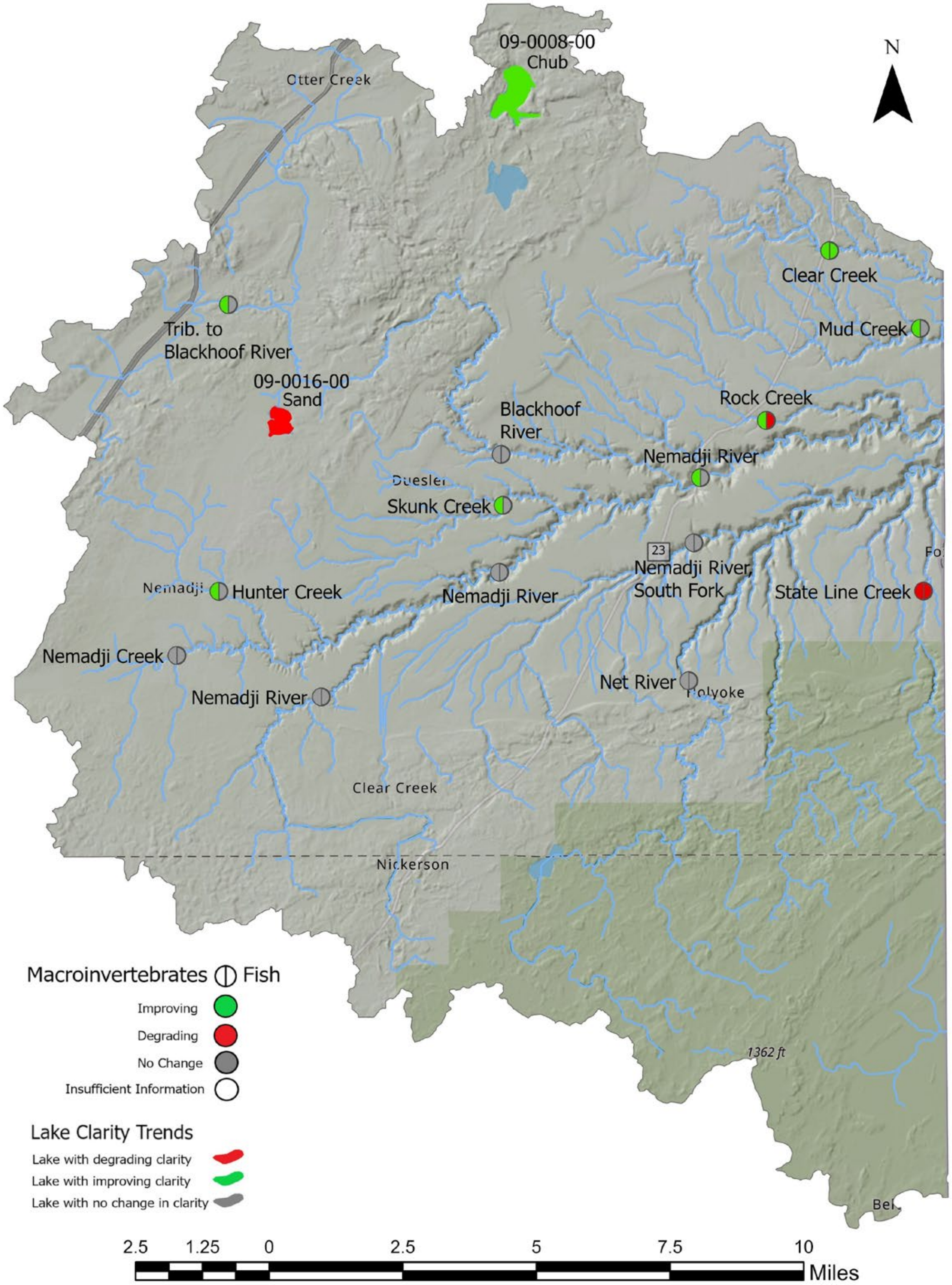


Figure 6. Change in water quality in the Nemadji River Watershed.



Streamflow and pollutant concentrations

In addition to the intensive monitoring completed every ten years, approximately 200 Watershed Pollution Load Monitoring Network (WPLMN) sites are operational year-round across Minnesota. At these sites, streamflow data collected in collaboration with the United States Geological Survey (USGS) and the MNDNR is paired with water chemistry data collected by state and federal agencies, Metropolitan Council Environmental Services, state universities, and local partners. This combination of regular streamflow and pollutant monitoring is crucial for conducting trend analysis, assessing year-over-year variations, and identifying pollutant sources and their contributions. Two WPLMN sites are currently established in the Nemadji River Watershed.

Table 1. WPLMN sites within the Nemadji River Watershed. Samples are collected by MPCA staff. Lab parameters are total suspended solids (TSS), total phosphorus (TP), nitrate + nitrite nitrogen (NOX), total Kjeldahl nitrogen (TKN), and dissolved orthophosphate phosphorus (DOP).

Site Name (WISKI ID)	Streamflow data available	Pollutant concentration data available	Sample collection	Lab Parameters
Nemadji River nr South Superior (E05011002)	1973-current (USGS)	2008-current	28-35 samples collected year-round (MPCA)	NOX, TKN, TSS, TP, DOP
Nemadji River nr Pleasant Valley, MN23 (H05011001)	2003-current (MN DNR)	2014-current	20-25 samples collected from ice out to Oct. 31 (MPCA)	NOX, TKN, TSS, TP,

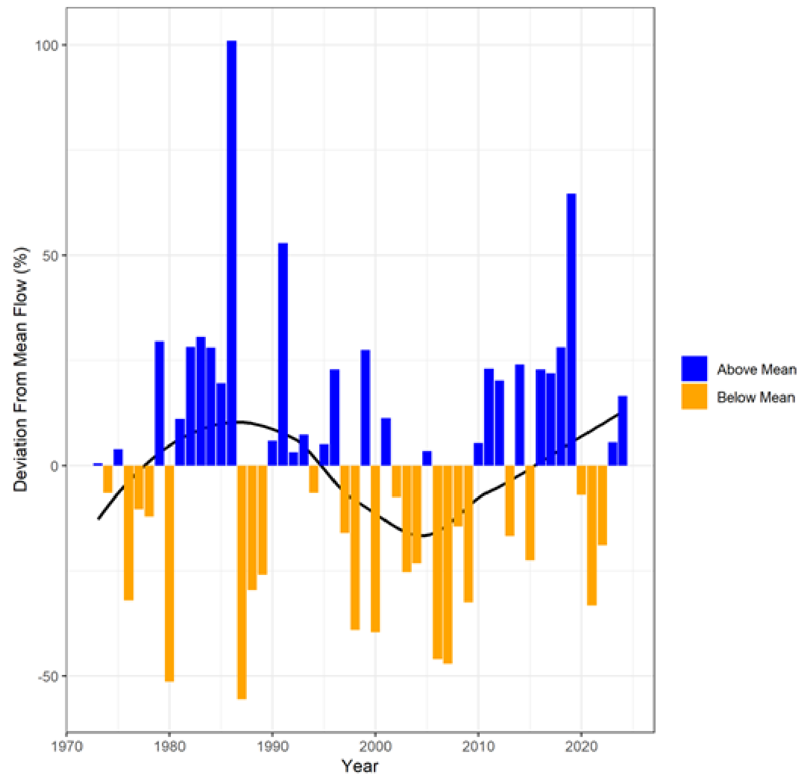
Water samples collected at WPLMN sites are analyzed for pollutants that are known to have an impact on water quality (Table 1). Combining sampled pollutant concentrations with streamflow data allows for the calculation of a flow-weighted mean concentration (FWMC) and total pollutant load. Loads represent the total amount of a pollutant moving through a system. Pollutant loads are important when considering the impact of pollutants on downstream resources such as Lake Superior where the pollutants may accumulate. The FWMC can be used to determine what the water quality is like on average, allowing for the equal comparison between watersheds differing in size and streamflow volume. During the period analyzed, the Nemadji River watershed experienced some extreme rain events resulting in some of the highest flows recorded at the site. Due to the high correlation of stream flow and suspended sediment, this likely contributed to the increasing TSS concentration trend.

Due to the highly erodible clay soils, FWMCs in the Nemadji Watershed are higher compared to other watersheds in the Lake Superior Basin (Figure 5). The other parameters measured (phosphorus and nitrate-nitrogen) are like the rest of the basin.

Since 2005 the mean annual streamflow appears to be increasing at the Nemadji River near South Superior (Figure 7). Interestingly there appears to be a decreasing stream flow in the upper portion of the watershed at the Nemadji River near Pleasant Valley site. Streamflow increases can increase stream channel erosion and pollutant loads, even when pollutant concentrations are stable.

To determine if sample pollutant concentrations (not FWMCs) in the Nemadji River Watershed experienced statistically significant changes over time, TSS, TP and NOX concentrations collected at the South Superior station were analyzed using a seasonal Mann-Kendall trend test. Only total suspended sediment (TSS) showed a statistically significant change from 2008-2022, indicating an increasing trend of 3.5% per year or 0.65 mg/L per year. No other trends were found. More information regarding the WPLMN program can be found at: https://www.pca.state.mn.us/water/watershed-pollutant-load-monitoring

Figure 7. Annual mean discharge departure from overall average discharge (0=391 cfs). Blue bars show higher than average flow and yellow bars show below average flow. The 30-year moving average shows an increasing trend at the Nemadji River near South Superior.

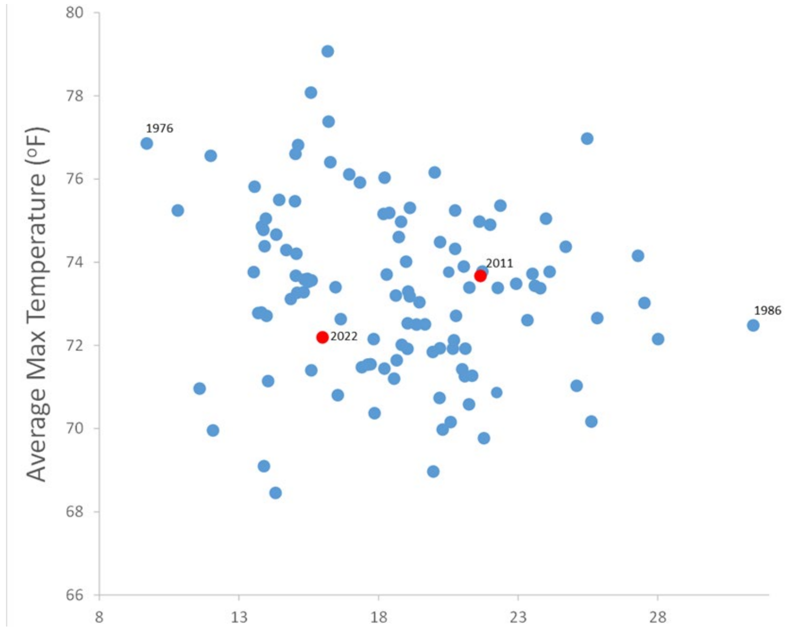


Biological communities

Fish and macroinvertebrate IBI scores from both monitoring periods (2011-2012 and 2022-2023) were analyzed using a paired t-test to determine if the biological condition of the watershed's rivers and streams has changed. A similar change analysis was not completed for lakes because comparable fish community data was not collected during the first time period. Independent tests were performed on each community with 14 sites evaluated for macroinvertebrates and fish (i.e., sites that were sampled in both time periods). The average macroinvertebrate IBI score for the watershed increased by 6.7 points between 2011 and 2022, this however does not represent a statistically significant change. Similarly, fish IBI scores increased by 1.1 points, which was also not statistically significant. While the overall health of fish and macroinvertebrate communities across the watersheds did not change between time periods, biological condition at individual stream sites may have improved or degraded (Figure 6).

The health of biological communities can be influenced by the climate and/or extreme weather events and obscure changes that result from restoration/protection efforts, changes in land use, and hydrologic alteration (i.e., changes related to policies, regulations, and management activities). Specifically, climate can change flow, water temperature, dissolved oxygen levels, habitat, and stream connectivity. However, it is difficult to make predictions of the impact of climatic conditions/weather events on stream aquatic life because the timing, magnitude, frequency and duration of events as well as the type of stream or biological community can all influence the response. For instance, a severe drought may negatively affect fish communities in headwater streams due to stressful conditions created by a lack of flowing water (i.e., ↑temperature, ↓dissolved oxygen). While in larger streams that retain flow during a drought, fish communities may be unaffected or appear in better condition because they are more concentrated into less available habitat, and therefore more susceptible to the sampling gear. Nonetheless, it is important to attempt to characterize the climatic conditions during each IWM cycle and compare these two periods in order to better interpret the causation of any observed changes (or lack thereof) in biological condition.

Figure 8. Characterization of air temperature and rainfall conditions for May-September period across historical record for the Nemadji River Watershed. Biological monitoring years for the watershed highlighted in red.



Across the historical record watershed-wide rainfall totals were estimated for May-September based on the gridded precipitation data set (State Climatology Office). Temperature was summarized for the May-September period by calculating the average maximum temperature at a monitoring station centrally located in the watershed that had a period of record sufficient to determine a normal value (*source:* Western Regional Climate Center, https://wrcc.dri.edu/summary/mnF.html). Rainfall and temperature normal values were determined by averaging each statistic over a 30-year period (1981-2010). Departure from normal values were calculated and used to characterize climatic conditions for each IWM year. This information was then used to estimate the likelihood (high, medium, or low) that climate/weather influenced biological condition in either IWM cycle. For instance, if both time periods fall within the bounds of near normal conditions then there would be a low likelihood that results in either time period are affected by climate/weather and thus any observed changes in condition are presumably driven by watershed scale factors.

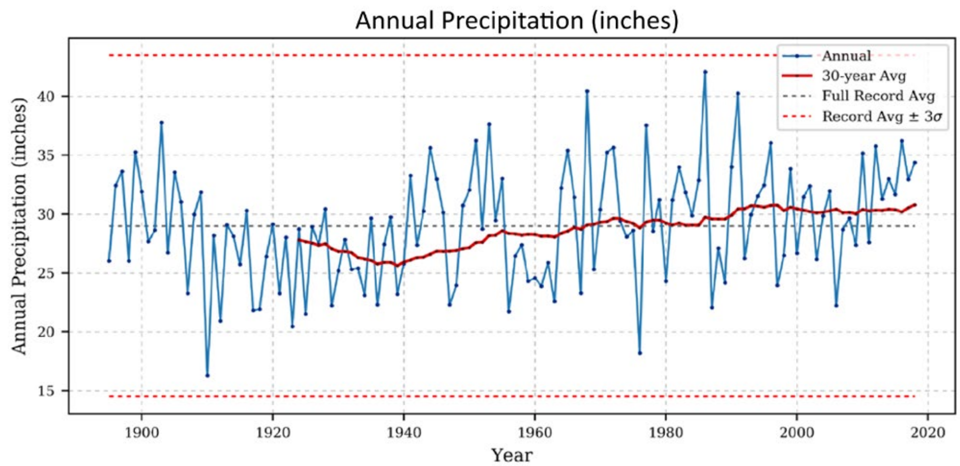
In 2011, the Nemadji River Watershed experienced slightly above normal precipitation (2.1 inches above normal) and near normal air temperature (-0.2 ºF) over the May to September time period (Figure 8). In comparison, the watershed had a moderate rainfall deficit (-3.6 in) and abnormally cooler temperatures (-1.7 ºF) in 2022 during May through September. Overall, given the relatively wet conditions affecting the watershed in 2011 and the substantially drier conditions present in 2022, there is a moderate likelihood that any observed changes in biological condition at either the watershed or individual site scale are at least partially due to differences in climatic conditions between the two periods.

Clarity of lakes

The Nemadji River Watershed has five lakes with some level of transparency data. Trend analysis was conducted on both Chub and Sand Lake (Figure 6) that met data requirements (50 Secchi measurements, eight years of data). Chub Lake exhibited a significant increasing trend, while Sand Lake showed a decreasing trend in transparency.

Climate

Figure 9: Average annual precipitation for the Nemadji River Watershed (1895-2018).



The Nemadji River Watershed now receives on average 1.8 additional inches of rain (Figure 9) from the historical average (1895-2018). Furthermore, climate scientists suggest that precipitation events are becoming more intense. In addition, temperatures in the watershed have increased by about one degree in spring and fall over this time period. Increased rainfall and temperature can worsen existing water quality problems. More precipitation and reduced snow cover can increase soil erosion, pollutant runoff, and streamflow's. Increased streamflow's in turn can lead to stream channel erosion and degraded habitat for fish and other aquatic life. Longer growing seasons with higher temperatures can lead to more algal blooms. These changes will complicate efforts to protect and restore the watershed. For more information on the climate of Nemadji River Watershed, please visit: DNR climate summary for the Nemadji River Watershed.

For more information

This study of the Nemadji River Watershed was conducted as part of Minnesota's Watershed Approach to restoring and protecting water quality. Efforts to monitor, assess, study, and restore impaired waters, and to protect healthy waters are funded by Minnesota's Clean Water, Land, and Legacy Amendment. Stressor identification for new impairments and updates to the Watershed Restoration and Protection Strategy follow the completion of monitoring and assessment. This approach allows for efficient and effective use of public resources in addressing water quality challenges across the state. The data and assessments produced by this study can inform local efforts to restore and protect waters in the Nemadji River Watershed, such as the One Watershed One Plan document, a comprehensive watershed management plan that targets projects to protect and restore the watershed's most valuable resources. For more information, go to the MPCA Nemadji River webpage, or search for "Nemadji River" on the MPCA website.

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