Vermilion River Watershed

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# Vermilion River Watershed Restoration and Protection Strategy Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

## Authors

Moriya Rufer, HEI
Scott Kronholm, HEI
Nathaniel Baeumler, HEI
Jeremiah Jazdzewski, HEI
Section 1.1.1, Drinking Water Protection, provided by MDH
Edits by Amy Mustonen, MPCA



## Contributors/acknowledgements

**MPCA**
Amy Mustonen
Kevin Stroom
Angus Vaughn
Jesse Anderson
Karsten Klimek
Ben Lundeen
Wesley Sigl
Mel Markert

**DNR**
Ben Nicklay
Kevin Peterson
Edie Evarts
Brent Flatten
Dean Paron
Karl Koller
Sam Martin
Cliff Bentley
Taylor Nelson
Tom Burri
Melissa Thompson
Kristen Patterson
Richard Biemiller

**BWSR**
Erin Loeffler
Jeff Hrubes

**MDH**
Chris Parthun
Tracy Lund

**USFS**
Marty Rye
Darren Lilja
Jason Butcher
Emily Creighton

**Voyageurs National Park**
Ryan Maki

**1854 Treaty Authority**
Tyler Kaspar

**North St. Louis SWCD**
Phil Norvitch
Becca Reiss
Anita Provinzino

**Science Museum of Minnesota—Saint Croix Watershed Research Station**
Mark Edlund

**Vermilion Community College**
Wade Klingsporn

## Editing and graphic design

PIO staff
Graphic design staff
Administrative Staff

Cover photo: Vermilion Falls, Crane Lake, MN
Scott Kronholm, HEI

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# Key terms

**Assessment Unit Identifier (AUID):** The unique waterbody identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

**Aquatic life impairment:** The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired by impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

**Aquatic recreation impairment:** Streams are considered impaired by impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired by impacts to aquatic recreation if total phosphorus and either chlorophyll-a or Secchi disc depth standards are not met.

**Hydrologic Unit Code (HUC):** A HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Rainy River Basin and Lake of the Woods is assigned a HUC-4 of 0903 and the Vermilion River Watershed is assigned a HUC-8 of 09030002.

**Impairment:** Waterbodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, and aquatic consumption.

**Index of Biotic Integrity (IBI):** A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

**Protection:** This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

**Restoration:** This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

**Source (or pollutant source):** This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

**Stressor (or biological stressor):** This is a broad term that includes both pollutant sources and nonpollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

**Total Maximum Daily Load (TMDL):** A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

# Acronyms and abbreviations

| | |
|---|---|
| AIS | aquatic invasive species |
| BMP | best management practice |
| BWCAW | Boundary Waters Canoe Area Wilderness |
| BWSR | Minnesota Board of Water and Soil Resources |
| Chl-*a* | chlorophyll-*a* |
| CLMP | Citizen Lake Monitoring Program |
| CWLA | Clean Water Legacy Act |
| DO | dissolved oxygen |
| *E. coli* | *Escherichia coli* |
| EPA | United States Environmental Protection Agency |
| FWMC | flow-weighted mean concentration |
| GHG | greenhouse gas |
| GWUDI | groundwater under direct influence of surface water |
| HSPF | Hydrological Simulation Program-FORTRAN |
| HSPF-SAM | Hydrological Simulation Program-FORTRAN Scenario Application Manager |
| HUC | hydrologic unit code |
| IBI | index of biotic integrity (M-IBI for macroinvertebrate IBI; F-IBI for fish IBI) |
| IWM | Intensive Watershed Monitoring |
| LBCA | Lake Benefit Cost Assessment |
| LPSS | Lakes of Phosphorus Sensitivity Significance |
| MDA | Minnesota Department of Agriculture |
| MDH | Minnesota Department of Health |
| DNR | Minnesota Department of Natural Resources |
| MPCA | Minnesota Pollution Control Agency |
| MS4 | Municipal Separate Storm Sewer System |
| NLCD | National Land Cover Database |
| NLF | Northern Lakes and Forests |
| NMW | Northern Minnesota Wetlands |
| $NO_3$+$NO_2$-N | nitrate plus nitrite nitrogen |
| NRCS | Natural Resources Conservation Service |

| | |
|---|---|
| NSLSWCD | North Saint Louis Soil and Water Conservation District |
| 1W1P | One Watershed One Plan |
| NPDES | National Pollutant Discharge Elimination System |
| SDS | State Disposal System |
| SID | Stressor Identification |
| SNF | Superior National Forest |
| SSTS | subsurface sewage treatment system |
| SWCD | Soil and Water Conservation District |
| TALU | Tiered Aquatic Life Uses |
| TMDL | Total Maximum Daily Load |
| TN | total nitrogen |
| TP | total phosphorus |
| TSS | total suspended solids |
| USDA | United States Department of Agriculture |
| USFS | United States Forest Service |
| USGS | United States Geological Survey |
| VNP | Voyageurs National Park |
| VRW | Vermilion River Watershed |
| WHAF | Watershed Health Assessment Framework |
| WID | waterbody identifier |
| WPLMN | Watershed Pollutant Load Monitoring Network |
| WRAPS | Watershed Restoration and Protection Strategy |

# Executive summary

The Minnesota Pollution Control Agency (MPCA) employs a watershed approach to restoring and protecting Minnesota's rivers, lakes, and wetlands. To characterize watershed health, intensive water quality monitoring and assessments are conducted in each of the state's 80 major watersheds every 10 years. This is followed by the identification of stressors to aquatic life and investigation of problems identified by watershed characterization. The Watershed Restoration and Protection Strategy (WRAPS) Report builds on the work completed during intensive water quality assessment and stressor identification (SID) summarized in the *Vermilion River Watershed Monitoring and Assessment Report* (MPCA, 2018b) and the *Vermilion River Stressor Identification (SID) Report* (MPCA, 2019). It also guides future restoration and protection strategies in the watershed.

The Vermilion River Watershed (VRW - hydrologic unit code (HUC) ID 09030002) is in Northeastern Minnesota, just south of the Canadian border. It covers 1,035 square miles (662,427 acres) and is fully within St. Louis County. Much of the watershed is forested and under public ownership, contributing to the excellent water quality found throughout the watershed. The wilderness nature of the VRW also makes it a popular outdoor recreation destination for camping, hiking, boating, and fishing. The watershed contains Lake Vermilion, a highly valued resource and the fifth largest lake in Minnesota by size. The Superior National Forest (SNF) makes up approximately half of the VRW. A small section of Voyageurs National Park (VNP) lies in the upper portion of the VRW, and a portion of the Boundary Waters Canoe Area Wilderness (BWCAW) sits just east of Lake Vermilion. There are two wildlife management areas (Pike Bay and Pine Island), four scientific and natural areas, two state parks (Lake Vermilion-Soudan Underground Mine and Bear Head Lake), five state forests (Bear Island, Burntside, Lake Jeanette, Sturgeon River, and Kabetogama), and sections of Bois Forte Band of Chippewa Native American Reservation within the watershed. Most of the watershed lies within the 1854 Ceded Territory.

The two largest population centers are the cities of Tower and Orr, with 496 and 282 residents, respectively. The total population of the watershed is approximately 14,423 people.

The largest land use pressures on the watershed come from the timber industry and outdoor recreation. Additionally, metallic mining companies own rights within the watershed boundary and metallic mining activities discharge wastewater to waters in the VRW (MPCA, 2019). Small scale gravel mining also takes place within the watershed.

Overall, water quality in the VRW is excellent. Utilizing available data collected within the last 10 years and during intensive watershed monitoring (IWM), the MPCA assessed 21 of 196 stream reaches and 32 of 565 lakes greater than 10 acres in size against aquatic life and recreational use standards (MPCA, 2018b). Of these, only two lakes and one stream are listed as impaired against these standards, and two of these waters, Echo Lake (69-0615-00) and Tributary to Sand River (-645), were determined to be impaired by natural conditions. Myrtle Lake (69-0749-00), impaired by phosphorus and subsequent eutrophication, was the only waterbody that required a Total Maximum Daily Load (TMDL) study (MPCA, 2021). This study establishes pollutant load reductions needed to meet water quality standards as well as provide strategies for restoration.

With minimal aquatic life and aquatic recreation use impairments in the watershed, the Vermilion River WRAPS focuses on protection strategies that will help maintain high water quality and protect water bodies near impairment from becoming impaired.

A Core Team of representatives from local, state, federal, and tribal agencies met throughout the watershed approach process to guide assessment, problem investigation, and strategy development. Key protection candidates include outstanding resources such as wild rice waters, drinking water, lakes near impairment for recreation, lakes with declining transparency, coldwater habitat, and streams with exceptional biologic communities. Forest change, development, and climate change are risks identified by the core team that could impact many of these waters. Several protection-focused management strategy themes were developed to address risks identified by Core Team members. Each of these strategy themes has implementation actions associated with them in the protection strategy table in Section 3.3.3. They include:

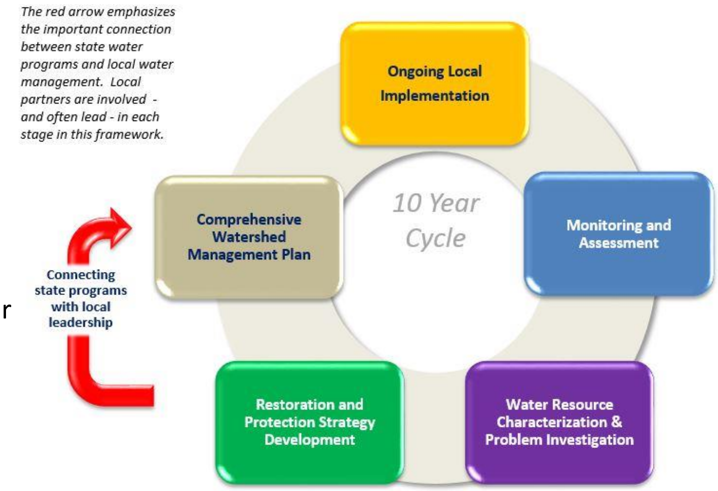
- drinking water protection;
- forestland management;
- habitat and aquatic connectivity management;
- lake management;
- recreational management;
- septic system improvement;
- stormwater runoff control; and
- streambank and gully protection.

The Core Team associated various "risks" and "qualities" with each of the strategy types and attributed them to the waterbodies within the watershed. This formed the basis for the protection prioritization and targeting process.

Additionally, the Hydrological Simulation Program-FORTRAN (HSPF) model was used to determine potential future changes in runoff, sediment, and nutrient loading under increased development, climate change, and increased forest disturbance scenarios. This process was guided by the Core Team. The HSPF model was updated to extend the time series through 2019 in this watershed (MPCA, 2020b). Although all models make assumptions and are unable to predict future outcomes with certainty, they are important tools that inform management plans by filling data gaps and forecasting potential future conditions. Results help prioritize and target areas in need of additional protection. These results are incorporated into prioritization and targeting in this report.

Finally, each protection strategy theme is associated with various BMPs, some of which apply at the major watershed scale (i.e., all waterbodies in the VRW) and others that apply at minor watershed or lakeshed scale.

# What is the WRAPS report?




Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota watershed approach incorporates **water quality assessment, watershed analysis, public participation, planning, implementation, and measurement of results** into a 10-year cycle that addresses both restoration and protection.

As part of the watershed approach, the MPCA developed a process to identify and address threats to water quality in each of these major watersheds.

This process is called Watershed Restoration and Protection Strategy (WRAPS) development. The WRAPS reports have two components: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and TMDL studies are developed for them. The TMDLs are incorporated into the WRAPS reports. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple waterbodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, the WRAPS report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. The WRAPS report also serves as the basis for addressing the U.S. Environmental Protection Agency's (EPA) Nine Minimum Elements of watershed plans, to help qualify applicants for eligibility for Clean Water Act Section 319 implementation funds.

| | |
|---|---|
| Purpose | •Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning<br>•Summarize watershed approach work done to date including the following reports:<br>  •*Vermilion River Watershed Monitoring and Assessment*<br>  •*Vermilion River Watershed Stressor Identification*<br>  •*Vermilion River Watershed Total Maximum Daily Load* |
| Scope | •Impacts to aquatic recreation and impacts to aquatic life in streams<br>•Impacts to aquatic recreation in lakes |
| Audience | •Local working groups (local governments, SWCDs, watershed management groups, etc.)<br>•State, Federal, and Tribal agencies (MPCA, DNR, BWSR, USFS, 1854 Treaty Authority, etc.) |

This report focuses on conventional pollutants and stressors, including aquatic macroinvertebrate assessments, fish bioassessmets, fecal bacteria, nutrients and eutrophication indicators, dissolved oxygen (DO), pH, temperature, and TSS. Minnesota's TMDL Priorities for 2016 through 2022 document focuses on TMDL completion for conventional pollutants and states: "For the other nonconventional pollutants, Minnesota is using (or is in the process of developing) other strategies. MPCA will continue to develop TMDLs for nonconventional pollutants, such as mercury and chloride, during this time period, but those impairments are not included in Minnesota TMDL Completion Priority List." Also, when appropriate, other processes (e.g., permitting) are used to address nonconventional pollutants.

# 1. Watershed background and description

The VRW (HUC ID 09030002) is located in the Rainy River Basin in Northeast Minnesota, just south of the Canadian border. This remote watershed hosts high quality surface water and largely undeveloped lands, contributing to its popularity as an outdoor recreation destination, the quality for which it is most widely known. These include Lake Vermilion, Pelican Lake, Crane Lake, and waters within VNP, the SNF, the Boundary Waters Canoe Area Wilderness (BWCAW), five state forests, and two state parks.

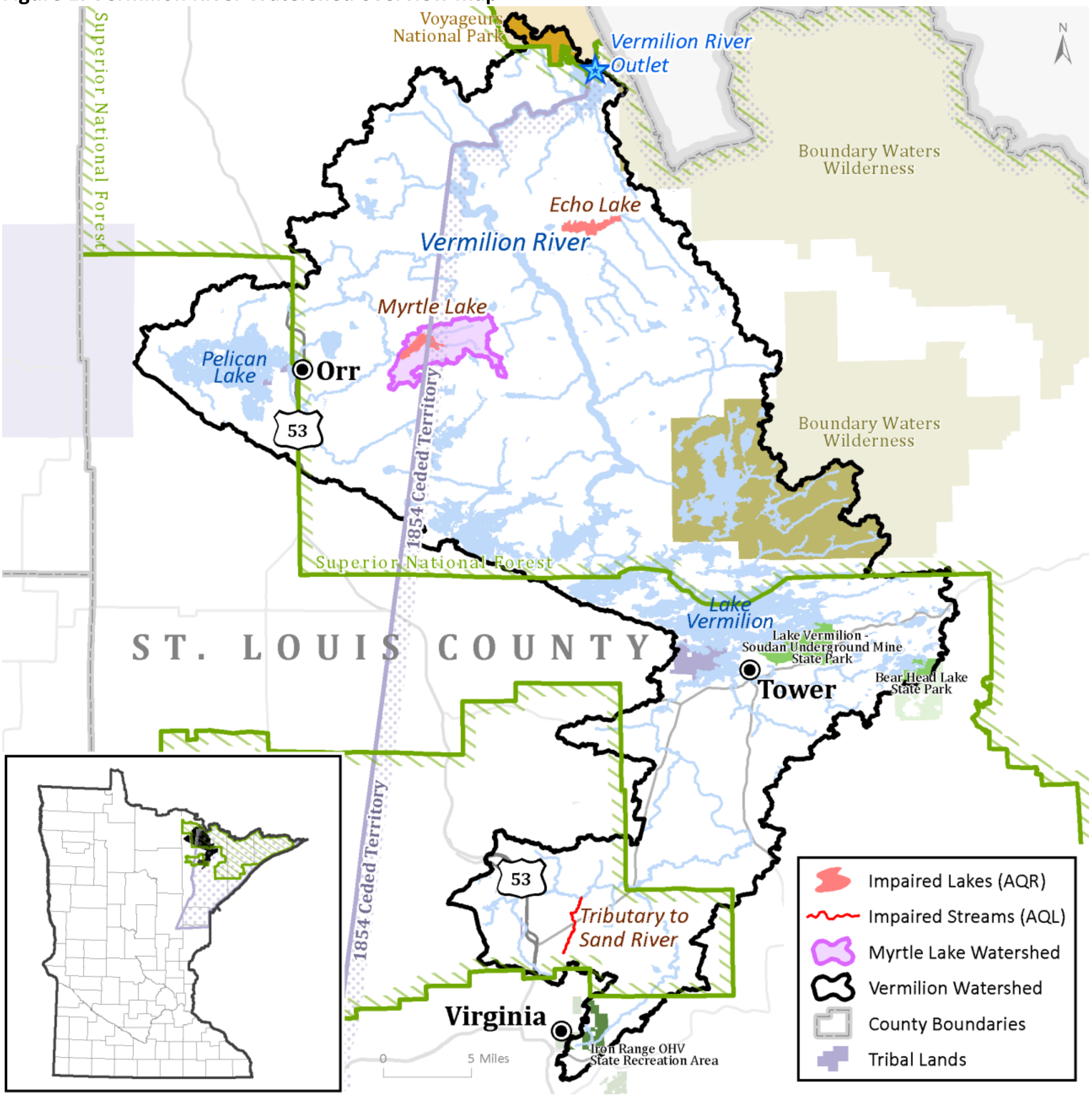
Lake Vermilion boasts the most shoreline for any lake in Minnesota (370 miles). It is a highly valued resource and is one of the most popular and developed lakes in the watershed. Despite this, the majority of the VRW is relatively undeveloped compared to other watersheds in Minnesota. The population of the entire watershed is approximately 14,423 people, about 14 people per square mile. A five year summary of American Community Survey data indicates the majority of the watershed lies within a census tract with at least 40% of people with reported income less than 185% of the federal poverty level. Based on this data, the MPCA considers this an area of concern for environmental justice. The two largest population centers are the cities of Tower and Orr, with 496 and 282 residents respectively (MPCA, 2018b). Because of the undeveloped nature of the watershed, recreational tourism is the major economic driver, with some forest industry, and a small amount of farming also occurring.

The watershed abuts the Bois Forte Band of Chippewa Reservation at Nett Lake and includes the Vermilion Sector of the Reservation along the shores of Lake Vermilion as well as parcels on Pelican Lake (Figure 1). In addition, Most of the VRW falls within the 1854 Treaty Area, where the Bois Forte, Grand Portage and Fond du Lac bands of the Lake Superior Chippewa have retained treaty rights to hunt, fish and gather. Wild rice is found in waters throughout the watershed, and these waters have high cultural significance to the Lake Superior Chippewa tribes.

The watershed is fully within St. Louis County and drains 1,035 square miles (662,427 acres) of land within the Northern Lakes and Forests (NLF) ecoregion (NRCS, 2007). Within the watershed there are 196 stream reaches with waterbody identifier (WID) numbers, and 565 lakes larger than 10 acres (MPCA 2018). Located just north of the Laurentian Divide, the watershed drains to the north, discharging at Crane Lake.

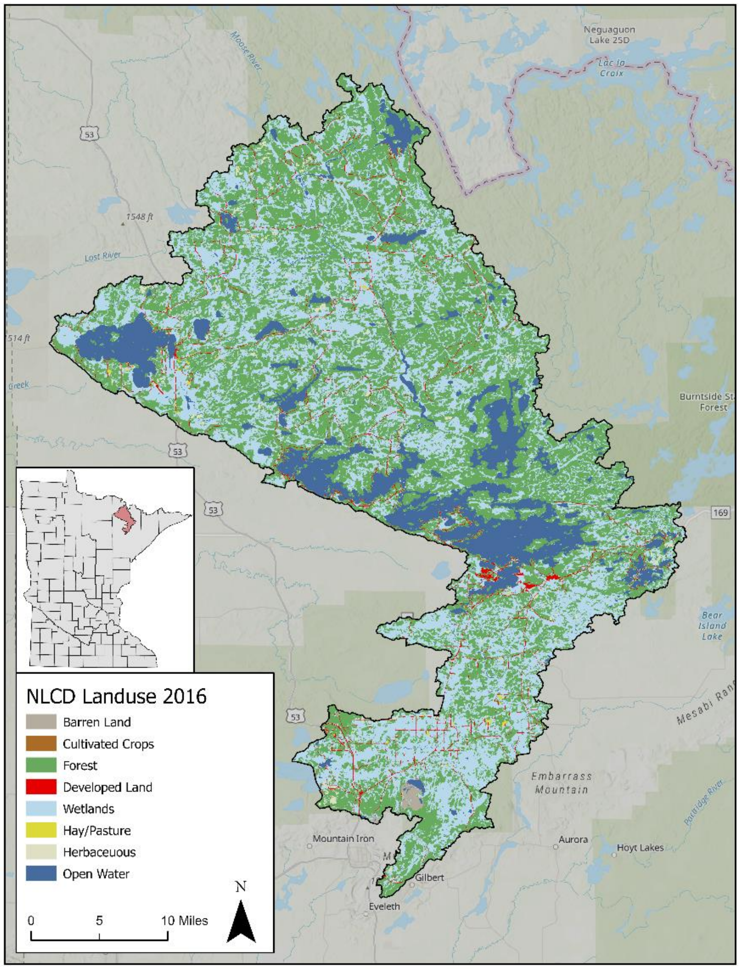
The largest river system within the watershed is the Vermilion River, starting at the outlet of Lake Vermilion in the south-central portion of the watershed. From its head at Wolf Bay of Lake Vermilion, the Vermilion River flows north for approximately 42 miles through a remote region where it eventually empties into Crane Lake near VNP, the pour point of the watershed. Major waterbodies and geographical highlights are shown in Figure 1.

**Figure 1. Vermilion River Watershed overview map**




The largest land uses on the watershed are the timber harvest and recreational use (MPCA, 2018b). Additionally, mining companies own rights within the watershed boundary and there is a tailings pond present in the southern end of the watershed near Virginia, the Inland Steel Tailings Pond owned by Cleveland Cliffs Minorca Mine Inc. In addition, the US Steel Corp Minntac Tailing Basin discharges to the watershed.

**Figure 2. Vermilion River Watershed land use (NLCD 2016)**




Most of the watershed is owned by federal (28%), state (31%), and local governments (<1%). Private landowners make up another 39% of the watershed and tribal governments own less than 1% of the watershed (USDA NRCS, 2007). The majority of the watershed is covered with forests, wetlands, and open water. Only 2% of the watershed is developed, and less than 1% is considered agricultural land (Table 1 and Figure 2).

**Table 1. Vermilion River Watershed land use (NLCD 2016)**

| Land Use | % |
|---|---|
| Forest | 47% |
| Wetlands | 28% |
| Open water | 13% |
| Herbaceous/Shrub | 10% |
| Developed | 2% |
| Barren Land | <1% |
| Cultivated Crop | <1% |
| Hay/Pasture | <1% |

The majority of the VRW (99.8%) lies within the NLF EPA Level III Ecoregion, with the remainder of the watershed within the Northern Minnesota Wetlands (NMW) (MPCA, 2018b). The watershed is part of the Canadian Shield region. Soils are generally 20 to 40 inches deep.

Through multiple glacial advancements and recessions, the landscape has been scoured, leaving behind the current topographic relief within the watershed. The depressions within the landscape have formed into small to moderately sized wetlands, due in part to the cool and wet climate of the region. Organic soils and peat have developed in wetlands due to saturated conditions, slowing runoff during precipitation events due to the low hydraulic conductivity properties of the peat in the region (MPCA, 2018b).

The 30-year precipitation average (1981 through 2010) for the watershed is 28.4 inches per year (liquid equivalent), with higher precipitation totals in the eastern portion of the watershed (DNR, 2017). Over the last 20 years, there has been no statistically significant increase in precipitation on an annual basis for the northeast region of Minnesota. However, over the last 100 years, the northeastern section of Minnesota has seen significant increases in annual precipitation, matching similar trends throughout the state.

Average annual temperatures within the watershed (1981 through 2010) range between 37 °F to 40°F (MPCA, 2018b). This is a 1.7 °F increase compared to the average of the entire climate record (1895 through 2018) (DNR, 2019). Climate change pressures threaten coldwater fish communities in the watershed as well as enhance conditions that support increased algae growth altering the quality of recreational use.

Additional pressures from insect damage on forests threaten to change forest hydrology in the VRW. Trees such as ash, balsam, and tamarack are susceptible to damage from invasive species such as the emerald ash borer, and increased activity from native insects such as the spruce budworm and the larch beetle. The loss of these common tree species could alter the hydrologic regime within riparian areas in the watershed.

Most of the watercourses within the watershed are in their natural state (57.5%) (DNR, 2017). There are ten active dams spread throughout the watershed, which were built between 1912 and 2011. A small percentage of watercourses are considered to be altered (2.9%) and/or impounded (1.8%) (DNR, 2017). The majority of altered streams are south of Lake Vermilion. Impounded streams are scattered throughout the lower half of the watershed and around the unincorporated town of Crane Lake in the northeastern portion of the watershed. The remaining 37.8% of watercourses within the watershed have no definable channel, which is defined by the MPCA as a channel that does not exist or does not represent flowing waters such as a wetland (MnGeo, 2013).

# 2. Watershed conditions

Utilizing water quality data collected within the past 10 years and during the 2015 and 2016 IWM effort, the MPCA assessed 21 of 196 stream reaches and 32 of 565 lakes greater than 10 acres in size against aquatic life and recreational standards (Figure 3). Streams were assessed for both aquatic life and aquatic recreation uses, while lakes were only sampled for aquatic recreation use attainment as the sampling protocol for aquatic biology health is currently being developed for the region by the Minnesota Department of Natural Resources (DNR) (MPCA, 2018b).

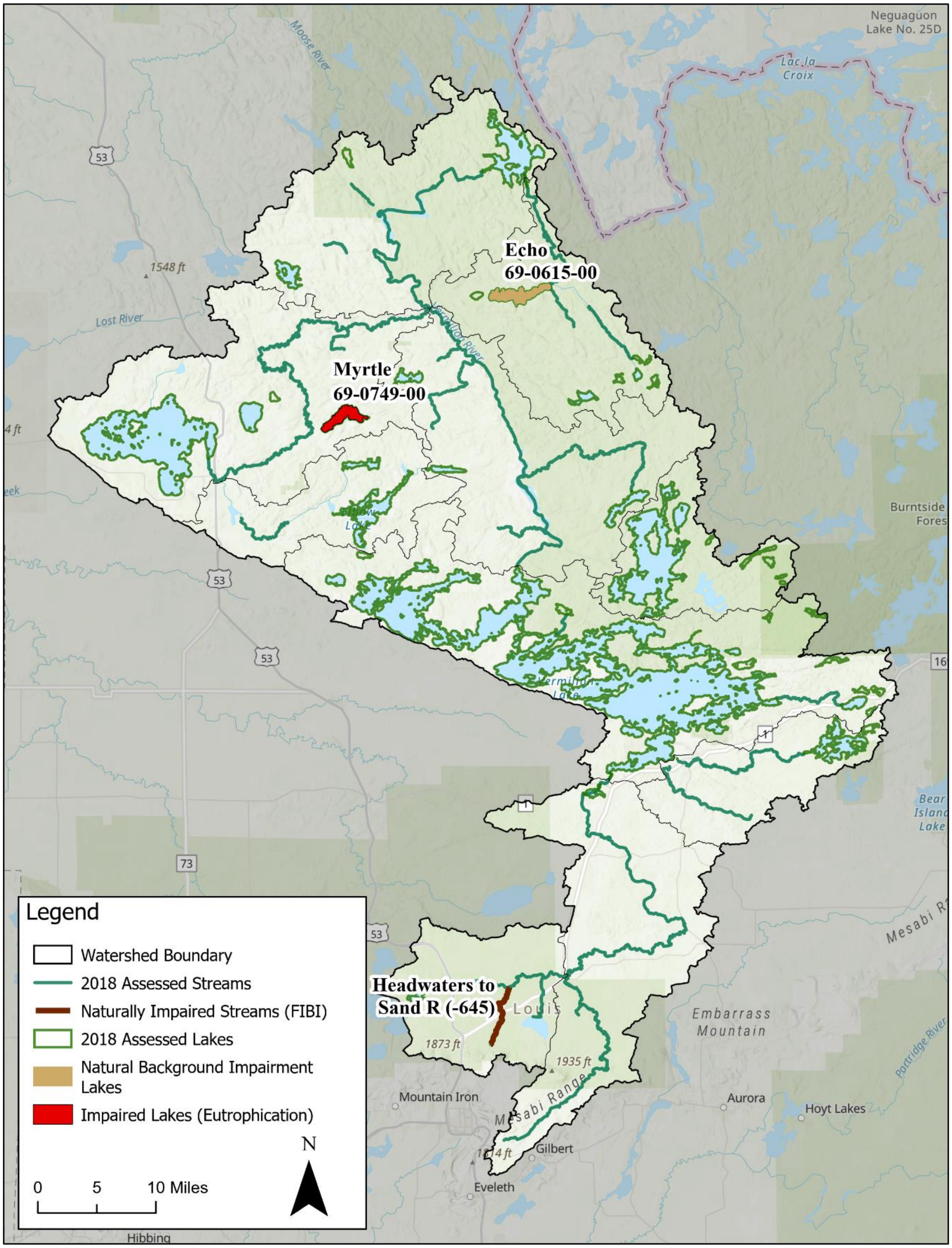
Overall, waters within the VRW are considered to be in excellent health. All but one of the 21 assessed stream reaches fully support aquatic life. Only one stream, a tributary to Sand River (-645) did not meet aquatic life standards based on the fish community and naturally occurring low DO from wetland influence. Nine stream reaches were assessed for aquatic recreation, and all fully supported aquatic recreation use. Pelican River (-530) is not impaired but was investigated due to observed low DO and fish community data that suggested the fish community is influenced by low DO levels. As with the tributary to Sand River it was determined that wetland conditions are naturally influencing the water quality of the Pelican River (MPCA 2019).

Of the 32 lakes assessed for aquatic recreation use, 21 had sufficient data to determine if they met aquatic recreation use standards. Of these, two lakes did not meet water quality standards for aquatic recreation use—Myrtle Lake (69-0749-00) and Echo Lake (69-0615-00). These lakes both exceed standards for total phosphorus (TP) and chlorophyll-a (Chl-*a*) concentrations (MPCA, 2018b) with nuisance algal blooms occurring during summer months. Although Echo Lake did not meet the standards for aquatic recreational use, it was determined that the conditions are naturally occurring (MPCA, 2018b). The lakeshore is largely undeveloped and the drainage is predominantly forest and wetlands. A TMDL is being completed to address the aquatic recreation impairment on Myrtle Lake.

One of the most popular lakes in the VRW, Lake Vermilion, has been intensively monitored by the MPCA and citizen volunteers for decades. It meets standards for TP, Chl-*a*, and Secchi transparency. Data collected from 1976 to 2000 indicates no change in water clarity in the East and West basins of Lake Vermilion. However, Pike Bay of Lake Vermilion has been increasing in clarity by .9 feet per decade according to MPCA trend analysis on years 1983 to 2020. The highest quality, most at-risk lakes include the Eagles Nest Chain. Pelican Lake by Orr is also a strong candidate for protection, as it is close to the impairment threshold, is a valuable recreation resource, and is one of the most developed lakes in the watershed.

A more detailed description of the quality analysis performed on the waters within the VRW can be found in the Vermilion River Watershed Monitoring and Assessment Report (WMAR) (MPCA, 2018b) and the Vermilion River SID Report (MPCA, 2019).

**Figure 3. Summary of Vermilion River Watershed aquatic life and aquatic recreation assessments**



## 2.1 Condition status

The condition of the streams and lakes within the VRW was assessed as part of the MPCA IWM during 2016 and 2017. Condition status primarily comes from these efforts and additional investigation documented in the VRW SID Report (MPCA, 2019).

Due to the generally low population density, there are no Municipal Separate Storm Sewer System (MS4) permits within the watershed. Areas of high population density, in general, can cause water quality stressors. However, due to the limited population within the watershed, it is expected that these urban stressors are very localized and are only impacting Tower and Orr or lakeshore developments (MPCA, 2019). Less dense development poses potential water quality risks due to the lack of localized or regional sanitation infrastructure. Rural areas often have subsurface sewage treatment system (SSTS) that can create localized pollution issues if not properly maintained. Old septic systems that are not up to current design standards or septic systems that are failing can create localized pollution issues (MPCA, 2019). Recent statistics for St. Louis County suggest that 65% of SSTS are meeting system compliance standards, 32% are considered to be "failing," and 3% of the SSTS are designated "Imminent Public Health Threats" (MPCA, 2019).

A significant portion of the watershed area is forested. As such, protection strategies specific to forestland management are important to maintaining and protecting water bodies in the watershed. Forest loss can impact the local environment by reducing stream shading and increasing erosion. In the late 1800s and early 1900s, there was large-scale timber harvesting of mature forest within the watershed. Since then, the region's forests have reestablished and many continue to be managed for forest harvest at varying levels of intensity. In addition to harvest, forest loss can occur from insect damage, disease, large scale blowdowns, and wildfires. Current forestland management activities in the VRW, especially on public lands, have successfully protected waterbodies and should be maintained. Additional BMPs should highlight past successes.

In general, the candidate stressors in the VRW include low DO concentrations, excess sediment, altered hydrology, altered geomorphology, habitat loss, connectivity loss, elevated phosphorus, and mining/industrial stressors (MPCA, 2019).

Some streams and lakes within the VRW are either currently impaired or in need of protection so they do not become impaired in the future. Impairment classification is based on determining if a waterbody can meet aquatic life and/or aquatic recreation standards. Factors used to determine whether a waterbody is capable of supporting and harboring aquatic life (aquatic life standards) include the fish and macroinvertebrate index of biotic integrity (IBI) (F-IBI and M-IBI, respectively), DO concentration, suspended sediment concentration (expressed as total suspended solids [TSS]), along with other physical descriptions and characteristics of the stream or lake. The factors used to assess the suitability of a waterbody for aquatic recreation (aquatic recreation standard) is the concentration of *Escherichia coli* (*E. coli*) bacteria in streams, and eutrophication indicators such as phosphorus and Chl-*a* in lakes. Streams and lakes with aquatic life aquatic recreation impairments will be targeted with restoration practices, while the waterbodies that currently meet aquatic life and aquatic recreation criteria will be the focus of protection efforts.

With wetlands covering 28% of the VRW, many surface waters are influenced by surrounding wetlands. This can lead to naturally high dissolved organic matter, low DO, and low pH in area lakes and streams

(MPCA, 2018b). It is important to consider this when determining restoration or protection strategies for waterbodies within the watershed. Some waterbodies may be at or near impairment level as a result of natural processes, while waters that are impacted by human activity may require restoration or protection. Wetland loss is not common in VRW. Where it has occurred is primarily the result of changes in land use over time such as industrial development, urbanization, and roads.

There are 36 waterbodies in the VRW that are impaired by mercury in fish tissue (Table 2). Of these impairments, 20 mercury TMDLs were approved as part of the 2018 Statewide Mercury TMDL Appendix A. Revisions to Appendix A of the Minnesota Statewide Mercury TMDL (MPCA 2007) are submitted to the EPA every two years with the impaired waters list. Water resources with mercury concentrations greater than 0.572 mg/kg are not part of Appendix A, and according to Minnesota's draft 2020 list of impaired water bodies, TMDLs for these 16 water bodies are expected to be completed between 2025 and 2033.

For more information on mercury impairments, see the statewide mercury TMDL: https://www.pca.state.mn.us/water/statewide-mercury-reduction-plan.

**Table 2. Summary of mercury impairments in the Vermilion River Watershed**
**Source: Minnesota 2020 303(d) list**

| Water Body Name | Water Body Type | WID | Year Added to 303(d) List | Approved TMDL [a] |
|---|---|---|---|---|
| Armstrong | Lake | 69-0278-00 | 2002 | Y |
| Astrid | Lake | 69-0589-00 | 1998 | N |
| Ban | Lake | 69-0742-00 | 1998 | N |
| Bass | Lake | 69-0446-00 | 2016 | Y |
| Bell | Lake | 69-0805-00 | 2012 | N |
| Crane | Lake | 69-0616-00 | 1998 | N |
| Crellin | Lake | 69-0459-00 | 1998 | N |
| Eagles Nest #3 | Lake | 69-0285-03 | 1998 | Y |
| Eagles Nest No. Four | Lake | 69-0218-00 | 1998 | Y |
| East Vermilion | Lake | 69-0378-01 | 1998 | Y |
| Echo | Lake | 69-0615-00 | 1998 | N |
| Elbow | Lake | 69-0744-00 | 1998 | N |
| Elephant | Lake | 69-0810-00 | 1998 | Y |
| Kabustasa | Lake | 69-0679-00 | 2002 | Y |
| Kjostad | Lake | 69-0748-00 | 1998 | N |
| Little Trout | Lake | 69-0455-00 | 1998 | Y |
| Marion | Lake | 69-0755-00 | 1998 | Y |
| Maude | Lake | 69-0590-00 | 1998 | N |
| Moose | Lake | 69-0806-00 | 1998 | N |
| Myrtle | Lake | 69-0749-00 | 1998 | Y |
| Nigh | Lake | 69-0457-00 | 2002 | N |
| Oriniack | Lake | 69-0587-00 | 2006 | Y |
| Pauline | Lake | 69-0588-00 | 1998 | N |
| Pelican | Lake | 69-0841-00 | 1998 | Y |

| Water Body Name | Water Body Type | WID | Year Added to 303(d) List | Approved TMDL [a] |
|---|---|---|---|---|
| Picket | Lake | 69-0591-00 | 2004 | Y |
| Pike Bay | Lake | 69-0378-03 | 1998 | Y |
| Pike River Flowage | Lake | 69-0580-00 | 1998 | N |
| Susan | Lake | 69-0741-00 | 1998 | Y |
| Trout | Lake | 69-0498-00 | 1998 | Y |
| Vermilion River (Hilda Cr to Pelican R) | Stream | 09030002-529 | 2004 | N |
| Vermilion River (Pelican R to Crane Lk) | Stream | 09030002-531 | 2004 | N |
| Vermilion River (Vermilion Lk to Hilda Cr) | Stream | 09030002-527 | 2004 | N |
| West Robinson | Lake | 69-0217-00 | 2012 | Y |
| West Vermilion | Lake | 69-0378-02 | 1998 | Y |
| Winchester | Lake | 69-0690-00 | 2004 | Y |
| Wolf | Lake | 69-0582-00 | 1998 | Y |

In 2021, the EPA added several waters to Minnesota's 2020 Impaired Waters List as impaired by excess sulfate, including six waterbodies in the VRW (Table 3). These waterbodies exceed the sulfate standard of 10 mg/L applicable to waters used for production of wild rice (Minn. R. 7050.0224). Wild rice growth is negatively affected by excess sulfate that converts to sulfide in the sediment where the rice takes root. Sulfate sources can include discharges from mining operations, municipal wastewater treatment plants, industrial facilities, and natural sources. The MPCA is currently working to determine the next steps to address sulfate impairments throughout the state and is committed to implementing the existing standard to ensure these waters are restored.

**Table 3. Summary of sulfate impairments in the Vermilion River Watershed**
**Source: Minnesota 2020 303(d) list**

| Water Body Name | Water Body Type | WID | Year Added to 303(d) List | TMDL Developed |
|---|---|---|---|---|
| East Vermilion | Lake | 69-0378-01 | 2021 | N |
| Vermilion; Pike Bay | Lake | 69-0378-03 | 2021 | N |
| Little Sandy Lake | Lake | 69-0729-00 | 2021 | N |
| Sandy Lake | Lake | 69-0730-00 | 2021 | N |
| Sand River | River | 09030002-501 | 2021 | N |
| Pike River | River | 09030002-503 | 2021 | N |

## 2.1.1 Streams

The IWM conducted by the MPCA looked at many parameters to determine if assessed stream reaches met aquatic life and aquatic recreation standards. On average, between 2009 and 2015, the rivers within the VRW had some of the lowest annual sediment and nutrient concentrations in the state, indicating excellent water quality in streams throughout the watershed. Only one naturally occurring aquatic life impairment was identified in VRW streams, a tributary to the Sand River (-645). One other additional stream reach, Pelican River (-530), was further investigated due to low DO and a low, though not impaired, fish community IBI score.

The tributary to Sand River (-645) does not meet the aquatic life standard due to low DO and the fish community not meeting the IBI standard. Additional problem investigation indicates wetland influence and beaver impoundments are naturally contributing to the low DO and fish community condition at this site. The MPCA Assessment Consistency and Technical Team's Natural Background Review Committee concludes the aquatic life impairment is due to natural conditions (MPCA 2019) and the reach is categorized as a natural background impairment (Category 4D). Category 4D waters do not require a TMDL. Beavers are a natural part of the ecosystem and the MPCA does not recommend removal of beaver dams in the impaired reach.

The Pelican River (-530) was assessed as supporting aquatic life and aquatic recreation use, although both biologic monitoring sites scored slightly under the passing fish IBI threshold. Despite low fish IBI scores, the fish community sampled in the Pelican River is appropriate for the naturally low gradient, wetland influenced stream. DO samples show that levels were below the 5 mg/L standard, likely limiting fish populations. The Pelican River Subwatershed is a natural landscape, densely forested in the uplands with numerous lakes and riparian wetlands. With additional monitoring, it was noted that TP was elevated, even though no anthropogenic sources of phosphorus were likely based on aerial photography analysis.

A biological sampling station (S008-597) was located downstream of Pelican Lake and a large wetland supplies water to the reach. A second water chemistry station (S014-887) was installed upstream of the wetland so samples could be analyzed from discharge solely originating from Pelican Lake. Comparing seasonal data collected at the two sites showed seasonal changes in phosphorus concentrations. Lake discharge registered higher concentrations of TP than the downstream wetland location in the spring. The TP concentrations were similar among the two sites from late June to mid-August. In late summer and fall, however, TP concentrations were higher in the downstream wetland location. This could be a result of the contributing wetlands becoming relatively anoxic in mid-summer and exporting dissolved phosphorus. It was concluded that the fish community is limited due to a combination of natural conditions including low channel gradient, limited habitat diversity, and wetland influence which contributes to low DO. More detail on this reach of the Pelican River can be found in the VRW SID Report (MPCA, 2019).

The stream segments that were assessed during IWM are shown in Table 4. (MPCA, 2018b). The table shows the results of assessment including if the reach supports its aquatic life or aquatic recreation use designation or if the reach is impaired. It also shows the aquatic life indicators used in the assessments and if the reach meets or exceeds each aquatic life indicator standard. A description of each stream, monitoring results, and assessment decisions can be found in the VRW Monitoring and Assessment Report (MPCA, 2018b).

**Table 4. Assessment status of river reaches in the Vermilion River Watershed**

| HUC-12 Name | WID (last 3 digits) | Reach Name | Reach Description | Aquatic Life Indicators | | | | | | | Aquatic Life | Aquatic Rec. (Fecal Bacteria) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fish IBI | Invert IBI | Dissolved Oxygen | TSS | Chloride | pH | Eutrophication | | |
| Sand River | 645 | Trib. to Sand River | Headwaters to Sand R | EXS | MTS | EXS | IF | - | IF | - | IMP | NA |
| | 501 | Sand River | Headwaters (Sandy Lk 69-0730-00) to Pike R | MTS | - | IF | IF | - | MTS | IF | SUP | SUP |
| | 572 | Wouri Creek | Unnamed Cr to Sand R | MTS | - | IF | IF | - | IF | - | SUP | NA |
| Pike River | 502 | Pike River | Headwaters to Sand R | MTS | MTS | IF | IF | - | IF | - | SUP | NA |
| | 503 | Pike River | Sand R to Vermilion Lk | MTS | MTS | IF | IF | MTS | MTS | MTS | SUP | SUP |
| East and West Two Rivers | 509 | West Two River | Headwaters to T61 R15W S6, north line | MTS | MTS | IF | IF | MTS | IF | MTS | SUP | SUP |
| | 647 | East Two River | Headwaters (Eagles Nest Lk 2 69-0285-02) to Unnamed Cr | MTS | MTS | IF | IF | - | IF | - | SUP | NA |
| | 648 | East Two River | Unnamed Cr to T62 R15W S32, west line | MTS | MTS | IF | IF | MTS | MTS | IF | SUP | SUP |
| Vermilion Lake | 505 | Armstrong River | Headwaters (Armstrong Lk 69-0278-00) to Vermilion Lake | MTS | MTS | IF | IF | - | IF | IF | SUP | NA |
| Upper Vermilion River | 610 | Two Mile Creek | Unnamed Cr to Vermilion R | MTS | - | IF | IF | - | IF | IF | SUP | NA |
| | 528 | Hilda Creek | Headwaters (Oriniak Lk 69-0587-00) to Vermilion R | MTS | MTS | IF | IF | - | IF | IF | SUP | NA |

| HUC-12 Name | WID (last 3 digits) | Reach Name | Reach Description | Aquatic Life Indicators | | | | | | | Aquatic Life | Aquatic Rec. (Fecal Bacteria) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Fish IBI | Invert IBI | Dissolved Oxygen | TSS | Chloride | pH | Eutrophication | | |
| | 529 | Vermilion River | Hilda Cr to Pelican R | MTS | - | IF | MTS | MTS | MTS | MTS | SUP | SUP |
| | 644 | Trib. to Vermilion River | Headwaters to Vermilion R | MTS | MTS | IF | IF | - | IF | IF | SUP | NA |
| | 646 | Trib. to Vermilion River | Unnamed lk (69-1056-00) to Vermilion R | MTS | MTS | IF | IF | - | IF | IF | SUP | NA |
| Elbow River | 604 | Elbow River | Unnamed Cr to Rice Lk | MTS | MTS | IF | IF | MTS | IF | IF | SUP | SUP |
| Pelican River | 530 | Pelican River | Pelican Lk to Vermilion R | EXP | - | IF | IF | MTS | IF | MTS | SUP | SUP |
| Echo River | 583 | Hunting Shack River | Headwaters (Pauline Lk 69-0588-00) to Unnamed Cr | MTS | MTS | IF | IF | - | IF | IF | SUP | NA |
| | 532 | Echo River | Echo Lk to Crane Lk | MTS | MTS | IF | IF | MTS | MTS | MTS | SUP | SUP |
| Lower Vermilion River | 531 | Vermilion River | Pelican R to Crane Lk | MTS | MTS | IF | MTS | MTS | MTS | MTS | SUP | SUP |
| | 593 | Bug Creek | Unnamed Cr to Elephant Cr | MTS | MTS | IF | IF | - | IF | IF | SUP | NA |
| | 565 | Flap Creek | Unnamed Cr to Marion Cr | MTS | MTS | IF | IF | - | IF | IF | SUP | NA |

Sup = found to meet the water quality standard, Imp = does not meet the water quality standard and, therefore, is impaired, IF = the data collected was insufficient to make a finding, NA = not assessed, MTS =meets the standard, IF = insufficient information, EXS = fails standard

Key for Cell Shading: ☐ = existing impairment, listed prior to 2020 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐ = insufficient information

### 2.1.2 Lakes

Lakes are assessed for impairment using Northern Lakes and Forest ecoregion standards developed by the MPCA. To assess aquatic recreation use, a minimum of 8 TP, Chl-*a,* and Secchi depth observations are required within a 10-year period per current evaluation criteria. Lakes were not assessed for fish community health in the watershed as the DNR is currently developing biological health metrics for the Canadian Shield lakes within the drainage basin. To enhance the assessment dataset, the MPCA sampled large lakes within the VRW including Vermilion, Elbow, Pelican, Myrtle, and Crane lakes in 2015 and 2016. The MPCA also partnered with North St. Louis and Koochiching County SWCDs, UMD NRRI, and Vermilion Community College through contract agreements to monitor additional waters, many of which are remote in nature, including Winchester, Ban, Astrid, Trout, and Myrtle Lakes. Citizen volunteers sampled 11 lakes throughout the watershed, working with MPCA's Citizen Lake Monitoring Program (CLMP). Citizen monitors on Pelican Lake assisted with supplemental monitoring during the WRAPS cycle.

In all, 21 lakes had enough information to determine if they met standards for aquatic recreation use. A total of 19 of those 21 lakes met the standard, while two lakes did not: Myrtle Lake (69-0749-00) and Echo Lake (69-0615-00) (Table 5).

Myrtle Lake (69-0749-00), in the Pelican River Aggregated 12-HUC, did not meet the standard for aquatic recreation use due to elevated concentrations of Chl-*a* and TP. The average Chl-*a* concentration of 26 µg/L is the highest among all sampled lakes within the VRW, and also among all 106 lakes assessed within St. Louis County. The lakeshore around Myrtle Lake is moderately developed on the southern shore, with one resort. The northern shore is managed by the SNF and is largely undeveloped (MPCA, 2018b). A TMDL has been developed to guide restoration efforts on this lake. More information on the impairment and the TMDL can be found in Section 2.4 and in the VRW TMDL Report (MPCA 2021)

Echo Lake (69-0615-00), in the Echo River Aggregated 12-HUC, is a shallow, nutrient-rich lake on the Canadian Shield. Echo Lake is a sentinel lake and is part of a long-term effort to assess environmental variables that affect lake chemistry and biology. It is not supporting of aquatic recreation use due to naturally high Chl-*a* and TP concentrations that are above the Northern Lakes and Forest ecoregion water quality standards. The high productivity in the lake is likely due to the lake's shallow basin and large wetland-dominated drainage area. There is very little development or other anthropogenic land use within the area. Therefore, this impairment is due to natural background conditions and a TMDL is not required (MPCA, 2018b).

Pelican Lake, although not impaired, had elevated Chl-*a* concentrations based on the 2016 watershed assessments. This is a popular recreation destination and has been targeted protection efforts. It is one of the most developed lakes in the watershed and is known to regularly experience nuisance algae blooms. In recent years, the water clarity trend is increasing, though it is unknown what mechanisms have changed in the lake in recent years to improve water quality or if the trend is long term. As such, there is a desire to protect this popular recreation destination from further degradation.

**Table 5. Assessment status of lakes in the Vermilion River Watershed**

| Aggregated HUC-12 Name HUC ID | Lake Name | WID | Area (acres) | Max depth (ft) | Total Phosphorus | Chlorophyll-a | Secchi Depth | Aquatic Recreation |
|---|---|---|---|---|---|---|---|---|
| Sand River 09030000201-03 | Little Sandy | 69-0729-00 | 85 | 3 | IF | IF | NA | IF |
| | Sandy | 69-0730-00 | 119 | 3 | IF | IF | NA | IF |
| Two Rivers 0903000202-03 | Eagles Nest # 4 | 69-0218-00 | 175 | 49 | IF | IF | MTS | IF |
| | Eagles Nest #1 | 69-0285-01 | 318 | 76 | MTS | MTS | MTS | FS |
| | Eagles Nest #2 | 69-0285-02 | 398 | 39 | MTS | MTS | MTS | FS |
| | Eagles Nest #3 | 69-0285-03 | 1,018 | 49 | MTS | MTS | MTS | FS |
| Vermilion Lake 0903000202-01 | West Robinson | 69-0217-00 | 116 | 8 | MTS | MTS | MTS | FS |
| | Mud | 69-0275-00 | 153 | 30 | IF | IF | IF | IF |
| | Clear | 69-0277-00 | 105 | 24 | IF | IF | MTS | IF |
| | Armstrong | 69-0278-00 | 373 | 34 | MTS | MTS | MTS | FS |
| | Little Armstrong | 69-0279-00 | 65 | 26 | IF | IF | MTS | IF |
| | East Vermilion | 69-0378-01 | 25,622 | 75 | MTS | MTS | MTS | FS |
| | West Vermilion | 69-0378-02 | 11,330 | 57 | MTS | MTS | MTS | FS |
| | Pike Bay | 69-0378-03 | 2,054 | 10 | MTS | MTS | IF | FS |
| | Black | 69-0740-00 | 117 | 8 | IF | IF | IF | IF |
| | Sunset | 69-0764-00 | 301 | 5 | IF | IF | IF | IF |
| Trout Lake 0903000202-02 | Trout | 69-0498-00 | 7,375 | 98 | MTS | MTS | MTS | FS |
| Upper Vermilion River 0903000205-02 | Winchester | 69-0690-00 | 318 | 50 | MTS | MTS | MTS | FS |
| | Kjostad | 69-0748-00 | 443 | 58 | MTS | MTS | MTS | FS |
| Elbow River 0903000203-02 | Susan | 69-0741-00 | 277 | 10 | IF | MTS | IF | FS |
| | Ban | 69-0742-00 | 388 | 15 | MTS | MTS | MTS | FS |
| | Elbow | 69-0744-00 | 1,677 | 60 | MTS | MTS | IF | FS |
| Pelican River 0903000203-01 | Myrtle | 69-0749-00 | 876 | 20 | EX | EX | IF | NS |
| | Bell | 69-0805-00 | 108 | 7 | IF | IF | IF | IF |
| | Moose | 69-0806-00 | 922 | 8 | IF | IF | IF | IF |
| | Pelican | 69-0841-00 | 11,466 | 38 | MTS | EX | MTS | FS |
| Echo River 0903000204-01 | Astrid | 69-0589-00 | 116.3 | 30 | MTS | MTS | MTS | FS |
| | Maude | 69-0590-00 | 91.6 | 26 | | | | IF |
| | Echo | 69-0615-00 | 1,125 | 10 | EX | EX | IF | NS |
| Lower Vermilion River 0903000205-01 | Crane | 69-0616-00 | 3,047 | 80 | MTS | MTS | IF | FS |
| | Marion | 69-0755-00 | 184 | 13 | IF | MTS | MTS | FS |
| | Elephant | 69-0810-00 | 717 | 30 | MTS | IF | MTS | FS |

Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information

Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Not Support (Impaired, exceeds standard)

Key for Cell Shading: ☐ = existing impairment, listed prior to 2020 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐ = insufficient information

## 2.2 Water quality trends

The MPCA completes a trend analysis for transparency on all lakes with sufficient data annually. The trend is calculated using the Mann-Kendall Statistic and a minimum of eight years of data are required to determine the trend. Much of this transparency data is collected by volunteers through the MPCA's CLMP. A total of 11 lakes in the VRW have enough data for a trend analysis. Only one lake is declining (Eagles Nest #2), while three lakes are improving (Pelican, Ban, and Eagle's Nest #1). The rest of the lakes show no trend (Table 6).

**Table 6. Long-term trends in lake water clarity in the VRW.**

| County | Lake ID | Lake Name | Trend Description |
|---|---|---|---|
| | 69-0742-00 | Ban | ↑ |
| | 69-0373-00 | Boulder | **NT** |
| | 69-0616-00 | Crane | **NT** |
| | 69-0285-01 | Eagles nest #1 | ↑ |
| | 69-0285-02 | Eagles nest #2 | ↓ |
| | 69-0285-03 | Eagles nest #3 | **NT** |
| | 69-0218-00 | Eagles nest #4 | **NT** |
| | 69-0378-01 | East Vermilion | **NT** |
| | 69-0810-00 | Elephant | **NT** |
| | 69-0841-00 | Pelican | ↑ |
| St. Louis | 69-0378-02 | West vermilion | **NT** |

↑ Improving trend ↓ Degrading trend **NT** no trend

## 2.3 Stressors and sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated. Biological SID is conducted for river reaches with either fish or macroinvertebrate biota impairments, and encompasses the evaluation of both pollutant and nonpollutant-related (e.g., altered hydrology, fish passage, habitat) factors as potential stressors. Pollutant source assessments are done where a biological SID process identifies a pollutant as a stressor, as well as for the typical pollutant impairment listings. Section 3 provides further detail on stressors and pollutant sources.

### 2.3.1 Stressors of biologically impaired river reaches

Potential stressors to fish and/or aquatic macroinvertebrates evaluated within the VRW included low DO, elevated TP, high suspended sediment concentration, insufficient and disconnected physical habitat, altered hydrology or channel alterations, and mining/industrial activity (Table 7).

The Tributary to Sand River Headwaters (-645) in the Sand River HUC-12 is designated impaired because its fish community is not meeting the IBI standard. Additional problem investigation has indicated that the impairment is caused by natural conditions including low DO from wetland influence and beaver dams. No recommendation is made to mitigate natural factors in such impairments (MPCA, 2019).

Pelican River (-530) is not impaired, but was studied as it has F-IBI scores just below the IBI threshold. It was determined that the fish community is limited due to a combination of natural conditions including low channel gradient, limited habitat diversity, and wetland influence which contributes to low DO. There are no recommendations for improving the F-IBI score as the fish community found within this reach corresponds with the natural conditions that exist there (MPCA, 2019).

**Table 7. Potential stressors to aquatic life considered in the tributary to the Sand River (-645)**

| HUC-12 Sub-watershed | WID (Last 3 digits) | River | Reach description | Biological impairment | Primary stressor: Dissolved oxygen | Phosphorus | Sediment/Turbidity | Connectivity | Altered hydrology* | Channel alteration | Habitat loss | Mining/industrial stressors |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sand River | 645 | Tributary to Sand River | Headwaters to Sand River | Fish | ● | | | ○ | | | | |

* Includes intermittency and/or geomorphology/physical channel issues
• Determined to be a direct stressor.
o A stressor, but determined to have very little to no anthropogenic cause. Includes beaver dams as natural stressors.

## 2.3.2 Pollutant sources

Pollutant sources vary by subwatershed and ecoregion depending on upstream loading conditions, NPDES permitted discharges, and nonpoint sources within the watershed. Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification, while point source pollution comes from a single identifiable source of pollution such as a wastewater treatment plant or discharge pipe (EPA, 2020).

### Nonpoint sources

HSPF was used to estimate nonpoint source loads to the watershed. It is important to note that these estimates are result of modeling in which there is some inherent uncertainty in the breakdown between sources. These results are a tool to assist with management decisions in combination with sample data, local knowledge, and professional judgement. We can use models to estimate conditions where we may not have watershed data. A representative dataset that contains a robust range of conditions (flows, chemistry and field measurements) supports model calibration that can mimic measured conditions. Once the model is calibrated to existing conditions using existing data, the model can then be used to estimate conditions throughout the watershed.

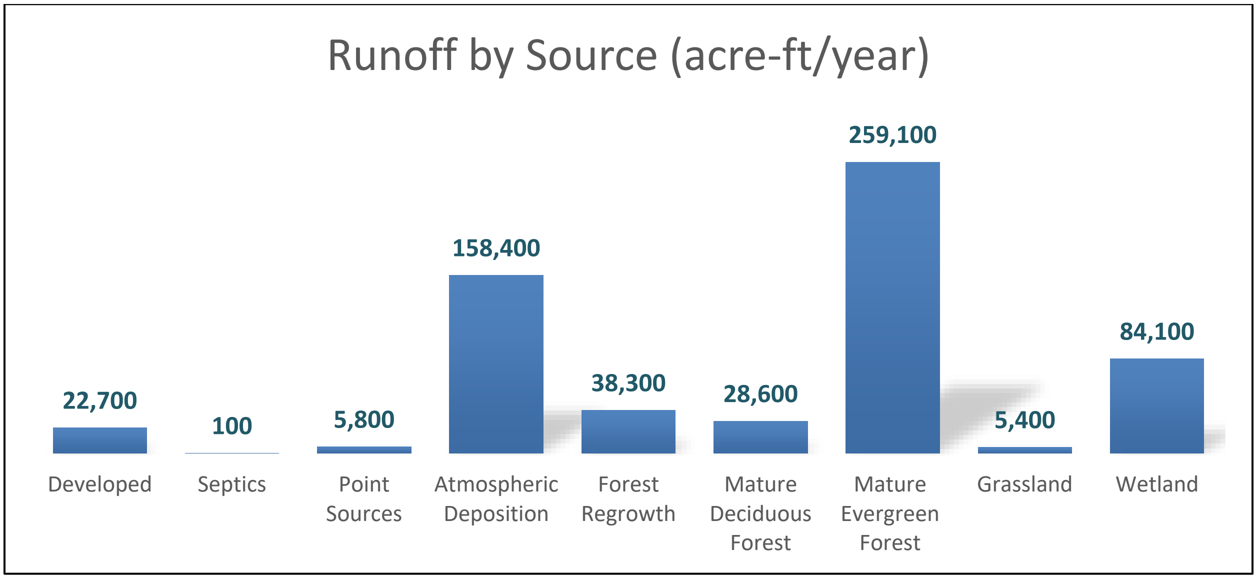
Nonpoint sources account for ≥ 99% of runoff and sediment, 93% of TP, and 92% of total nitrogen (TN) delivered to streams and lakes in the VRW. Nonpoint sources of TSS, TP, and/or TN as well as runoff were modeled for the VRW using HSPF (Figure 4). The resulting values represent the source load which is the constituent load contributed from each different source for the entire watershed. In addition, the Hydrologic Simulation Program-FORTRAN Scenario Application Manager (HSPF-SAM) was used to evaluate TSS, TP, and TN yields by subwatershed within the VRW (Figure 6, Figure 7, Figure 8).

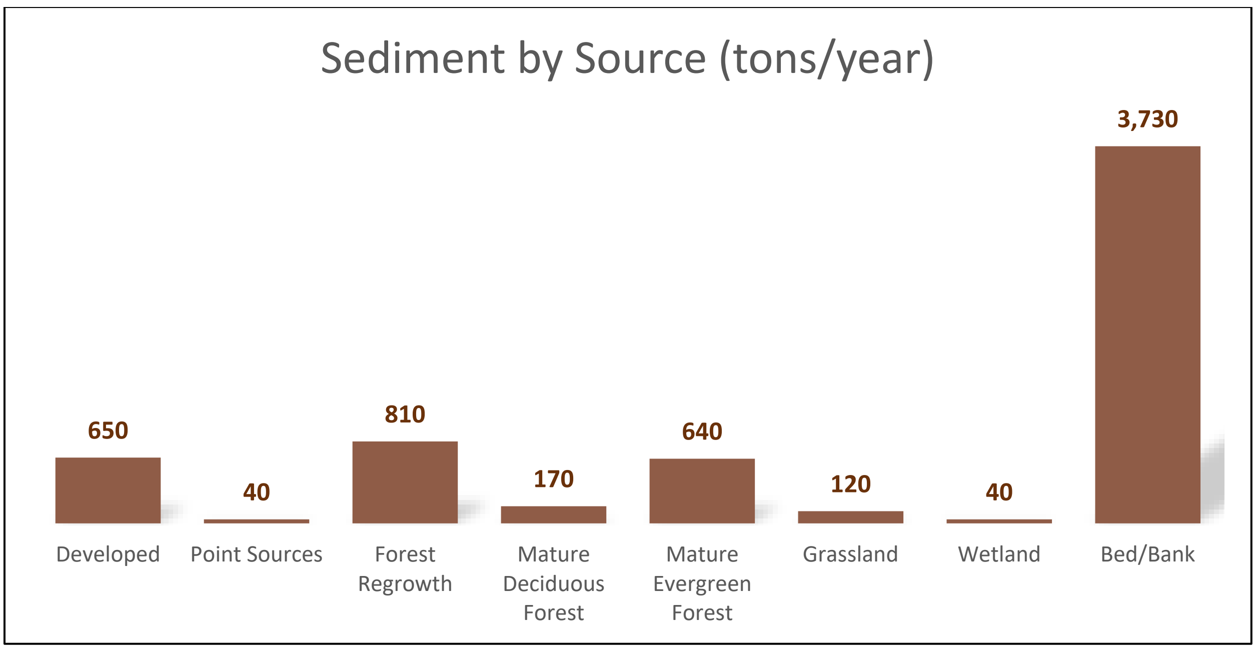
Although the HSPF subwatersheds are presented at a finer spatial scale and do not perfectly overlap the Aggregated HUC-12 subwatersheds, general spatial trends can be inferred from the figures. In general, the southwestern portion of the watershed showed higher TSS, TP, and TN yields than the northeastern portion. This reflects the level of development in the southwestern part of the watershed compared to the less developed northeastern portion.

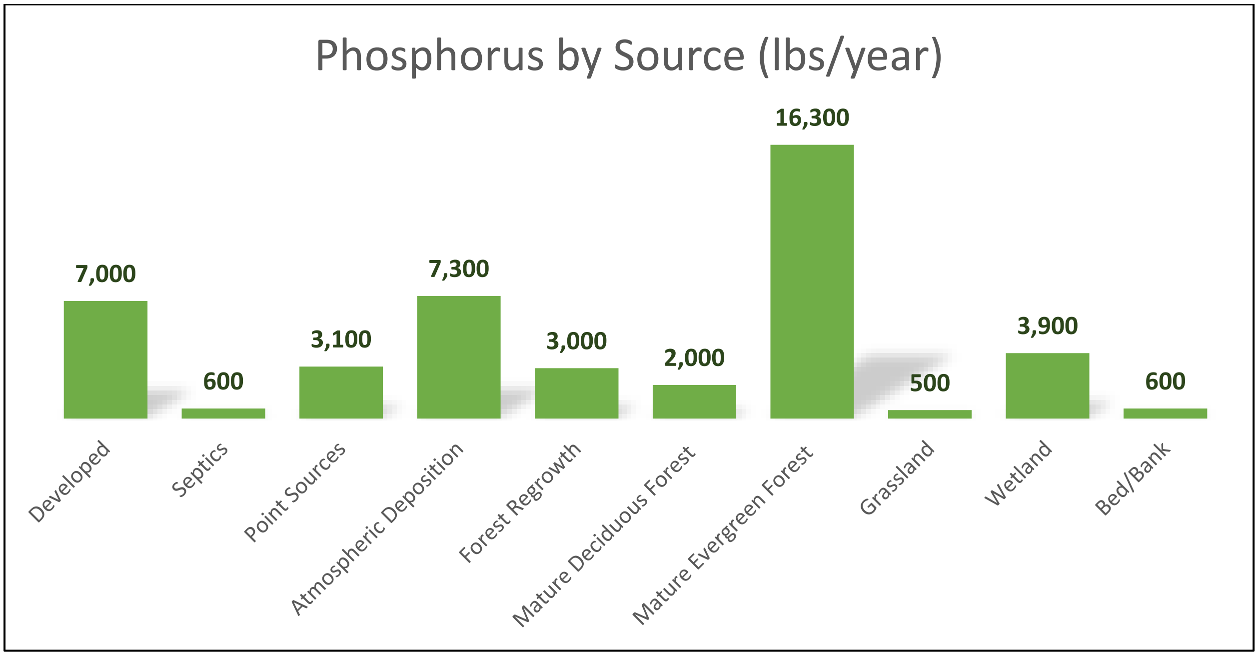
Additionally, nonpoint sources to Myrtle Lake were identified as part of TMDL development (Table 8). Myrtle Lake is impaired by eutrophication, impacting aquatic recreation. As no point sources are known to contribute to the impairment, nonpoint sources of nutrients are the focus of implementation efforts. A further discussion of these sources are discussed in Section 2.4 and in the VRW TMDL Report (MPCA 2021).

When compared to other watersheds throughout the state, the VRW has some of the lowest TSS, TP, and nitrate plus nitrite nitrogen annual flow-weighted mean concentration (FWMC; Figure 5). The nitrate nitrogen levels measured from the Vermilion River were low from a statewide perspective, but were also low when compared to other watersheds within the Rainy River Basin. TSS and TP levels measured from the Vermilion River were also very low when compared to other Minnesota watersheds. These factors combined indicate excellent water quality within the VRW.

**Figure 4. Breakdown of runoff, sediment, and nutrient sources in the Vermilion River Watershed**
Results are estimates from the HSPF model.




Phosphorus by Source (lbs/year)
7,000
600
3,100
7,300
3,000
2,000
16,300
500
3,900
600
Developed
Septics
Point Sources
Atmospheric Deposition
Forest Regrowth
Mature Deciduous Forest
Mature Evergreen Forest
Grassland
Wetland
Bed/Bank

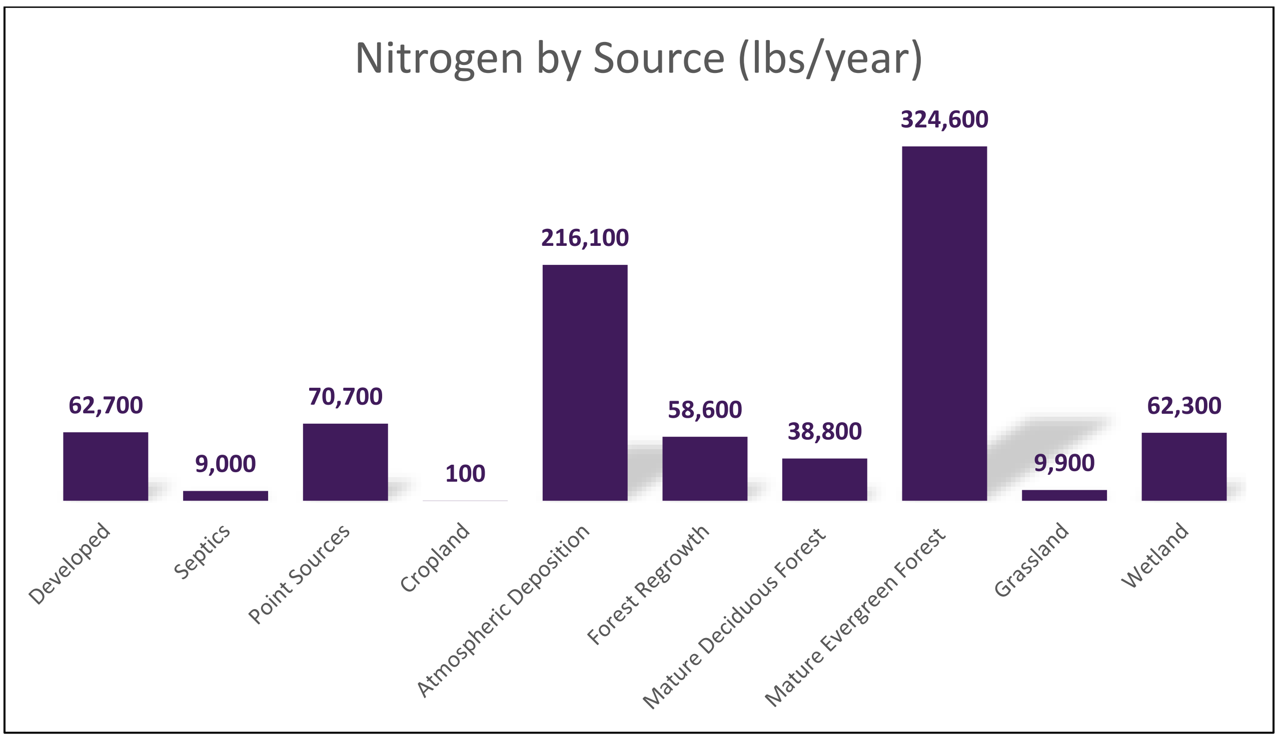

Nitrogen by Source (lbs/year)
62,700
9,000
70,700
100
216,100
58,600
38,800
324,600
9,900
62,300
Developed
Septics
Point Sources
Cropland
Atmospheric Deposition
Forest Regrowth
Mature Deciduous Forest
Mature Evergreen Forest
Grassland
Wetland

**Figure 5. 2007-2015 average annual TSS, TP, NO3+NO2-N flow weighted mean concentrations, and runoff by major watershed**

(MPCA, 2018b)

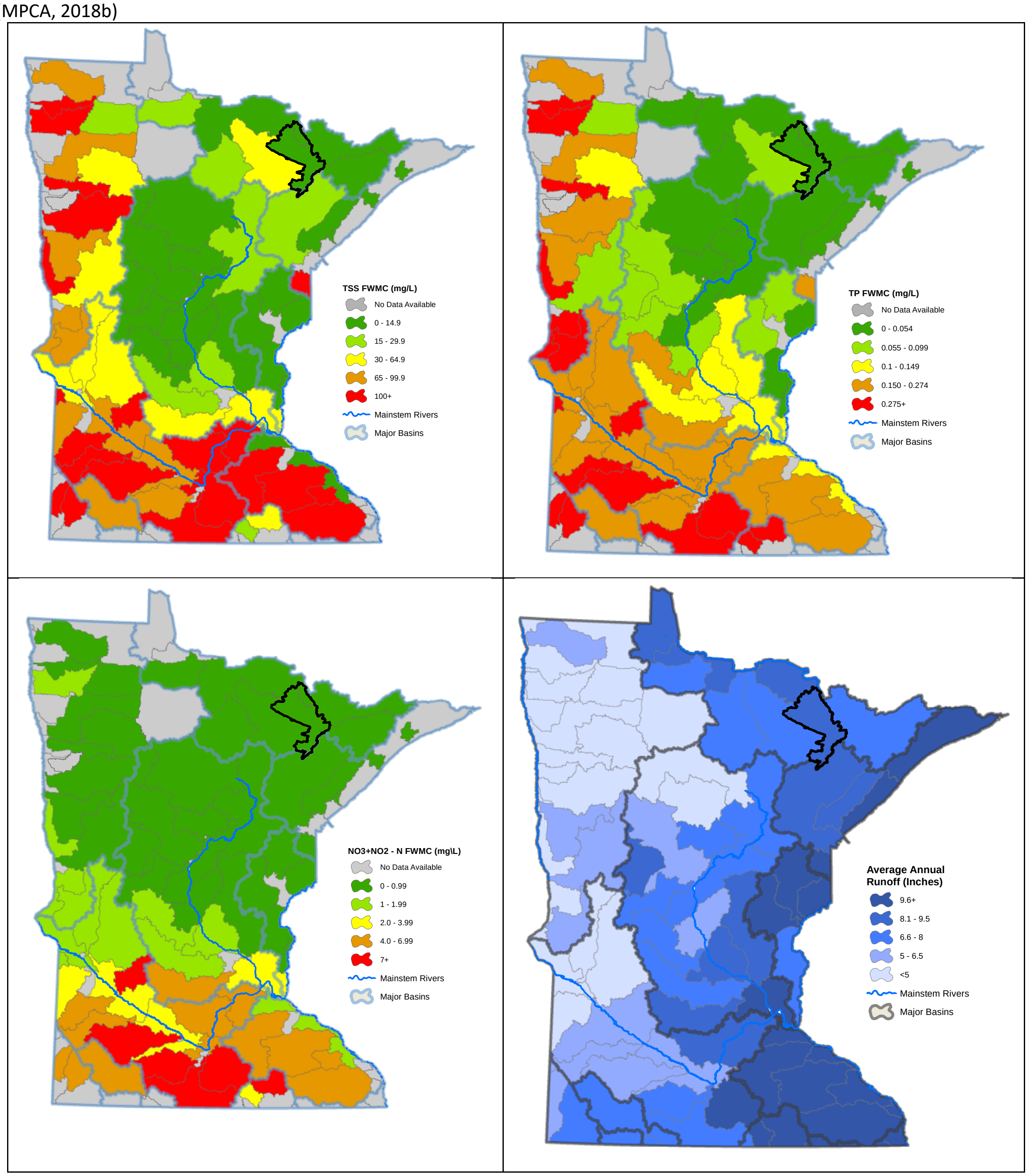


**Figure 6. HSPF modeled TSS yield by subwatershed within the Vermilion River Watershed**

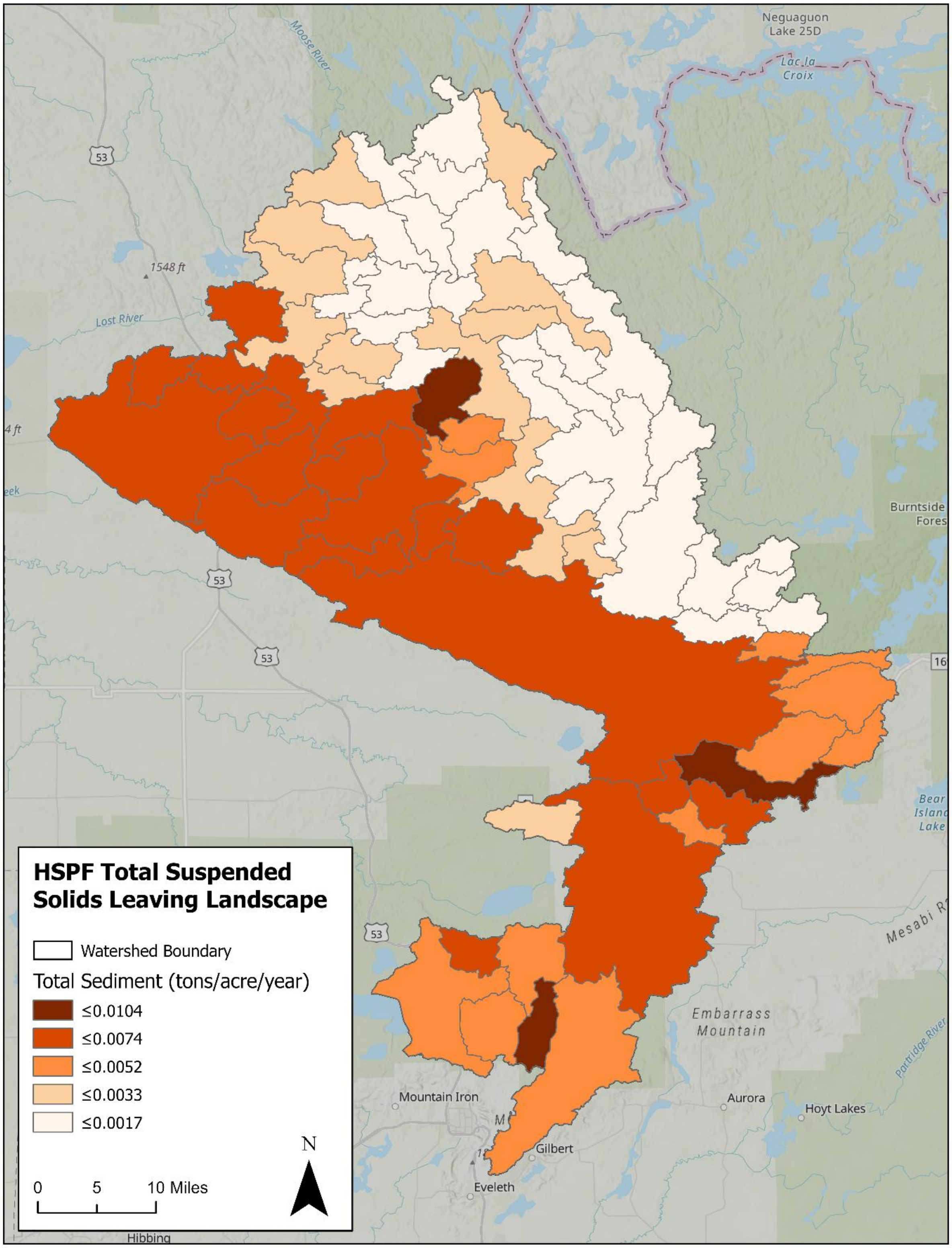


**Figure 7. HSPF modeled TP yield by subwatershed within the Vermilion River Watershed**

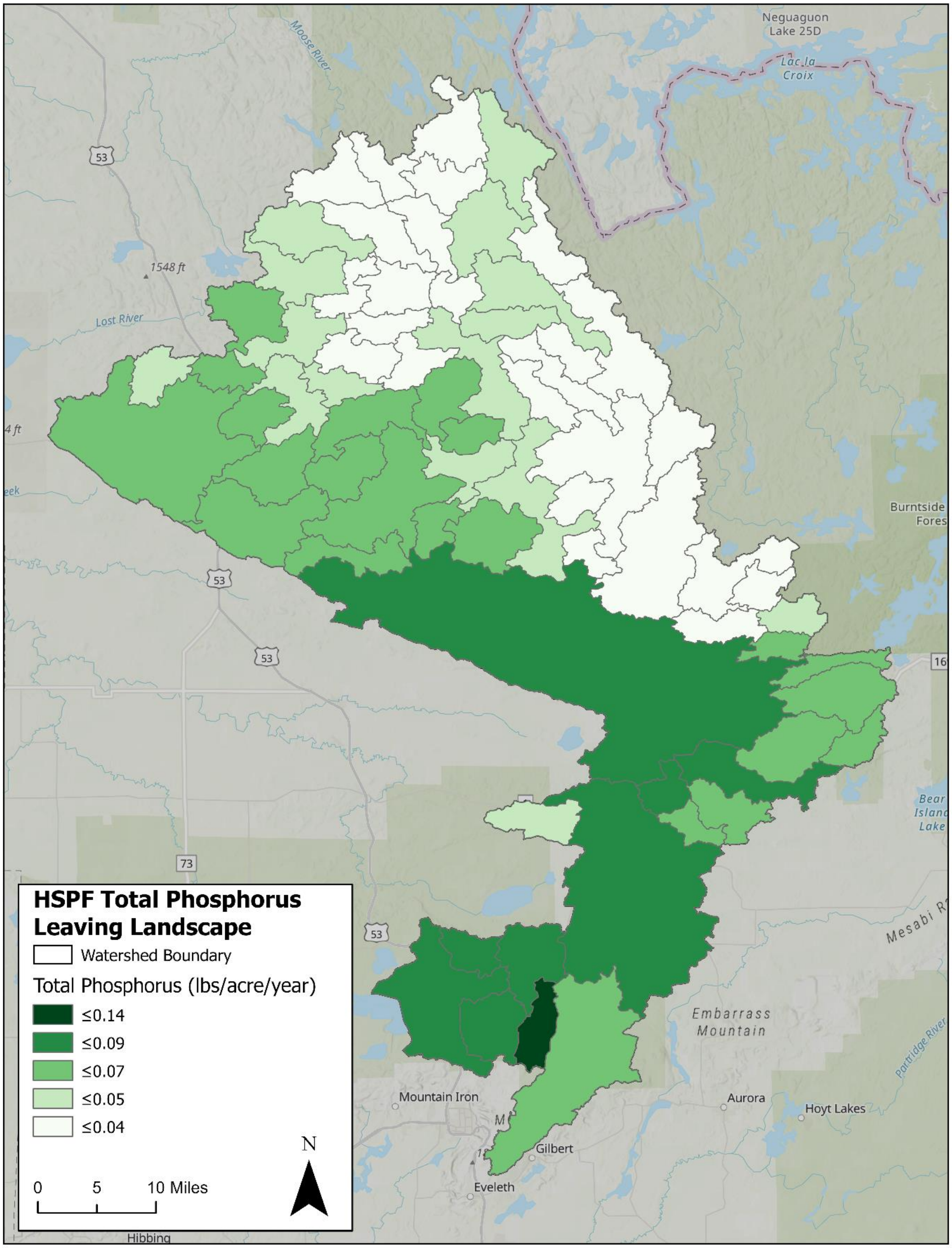


**Figure 8. HSPF modeled TN yield by subwatershed within the Vermilion River Watershed**

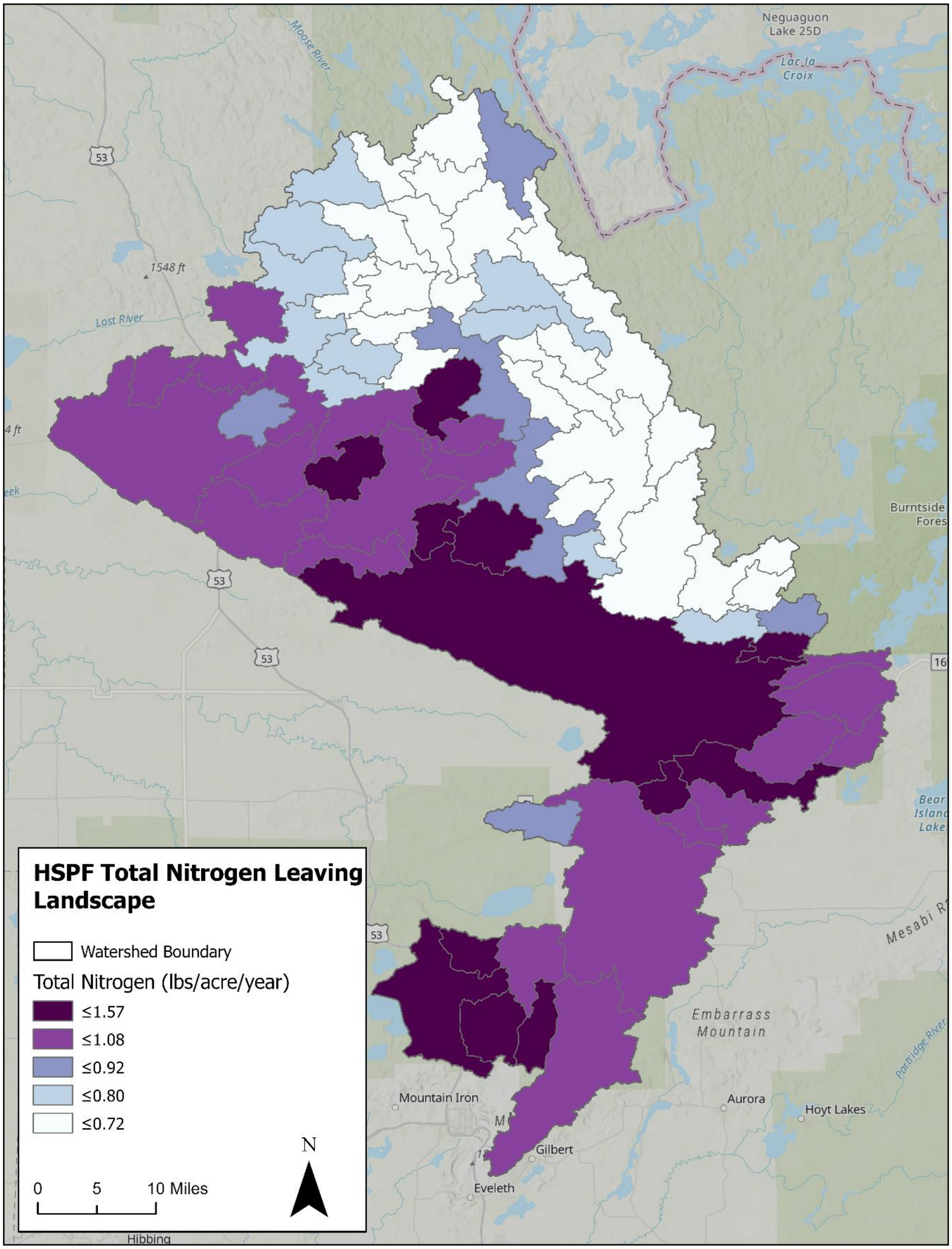


**Table 8. Nonpoint sources of pollution to impaired Myrtle Lake within the Vermilion River Watershed**
Relative magnitudes of contributing sources are indicated.

| Aggregated HUC-12 Subwatershed | Lake Name (WID) | Pollutant | Pollutant sources | | | |
|---|---|---|---|---|---|---|
| | | | Watershed Runoff | Subsurface Sewage Treatment Systems | Internal Loading and Unidentified Sources | Atmospheric Deposition |
| Pelican River (0903000203-01) | Myrtle Lake (69-0749-00) | TP | ■ | ■ | ■ | ■ |

**Key:** ■ = High ■ = Moderate ■ = Low

## Point sources

For the VRW WRAPS, point sources refer to entities that are permitted under the National Pollutant Discharge Elimination Systems (NPDES) and/or the State Disposal Systems (SDS) permit programs. Point sources in the VRW are summarized in Table 9Table 9 as of January 2020, from the MPCA's WIMN dataset. These point sources are not thought to be contributing to the Myrtle Lake TMDL or existing natural background impairments. However, restoration efforts on waterbodies impaired by sulfate will need to consider impacts from point source discharges. Sulfate sources can include discharges from mining operations, municipal wastewater treatment plants and industrial facilities. The MPCA is currently working to determine the next steps to address sulfate impairments. The MPCA recognizes that removing sulfate from wastewater discharges can be expensive, and plans to work with facilities to find innovative approaches.

**Table 9. Active point sources in the Vermilion River Watershed**

| Aggregated HUC-12 | Name | Permit | Activity |
|---|---|---|---|
| Sand River (0903000201-03) | US Steel Corp Minntac Tailing Basin* | MN0057207 | Industrial wastewater |
| Sand River (0903000201-02) | Cleveland-Cliffs-Mincora Mine Inc. | MN0055964 | Industrial wastewater |
| East and West Two Rivers (0903000202-03) | Tower/Breitung WWTP | MNG580186 | Municipal wastewater |
| Vermilion Lake (0903000202-05) | Lake Vermilion Soudan Underground Mine State Park | MN0070700 | Industrial wastewater |
| Vermilion Lake (0903000202-02, 903000202-05) | DNR Soudan State Park | MN0060151 | Industrial wastewater |
| Pelican River (0903000203-01) | Orr WWTP | MN0024422 | Municipal wastewater |
| Lower Vermilion River (0903000205-06) | Crane Lake WWTP | MN0066371 | Municipal wastewater |
| | Nelson's Resort Inc. | MN0051403 | Municipal wastewater |
| Various | Various | MNG490000 | Industrial Stormwater (Multi-Sector and Nonmetallic Mining) |
| Various | Various | MNR050000 | Industrial Stormwater |
| Various | Various | MNR100001 | Construction Stormwater |

***** US Steel Corp Minntac Tailing Basin is located just outside the VRW; however, the permit includes one surface water discharge station that discharges to the VRW and several ground water monitoring wells located in the VRW.

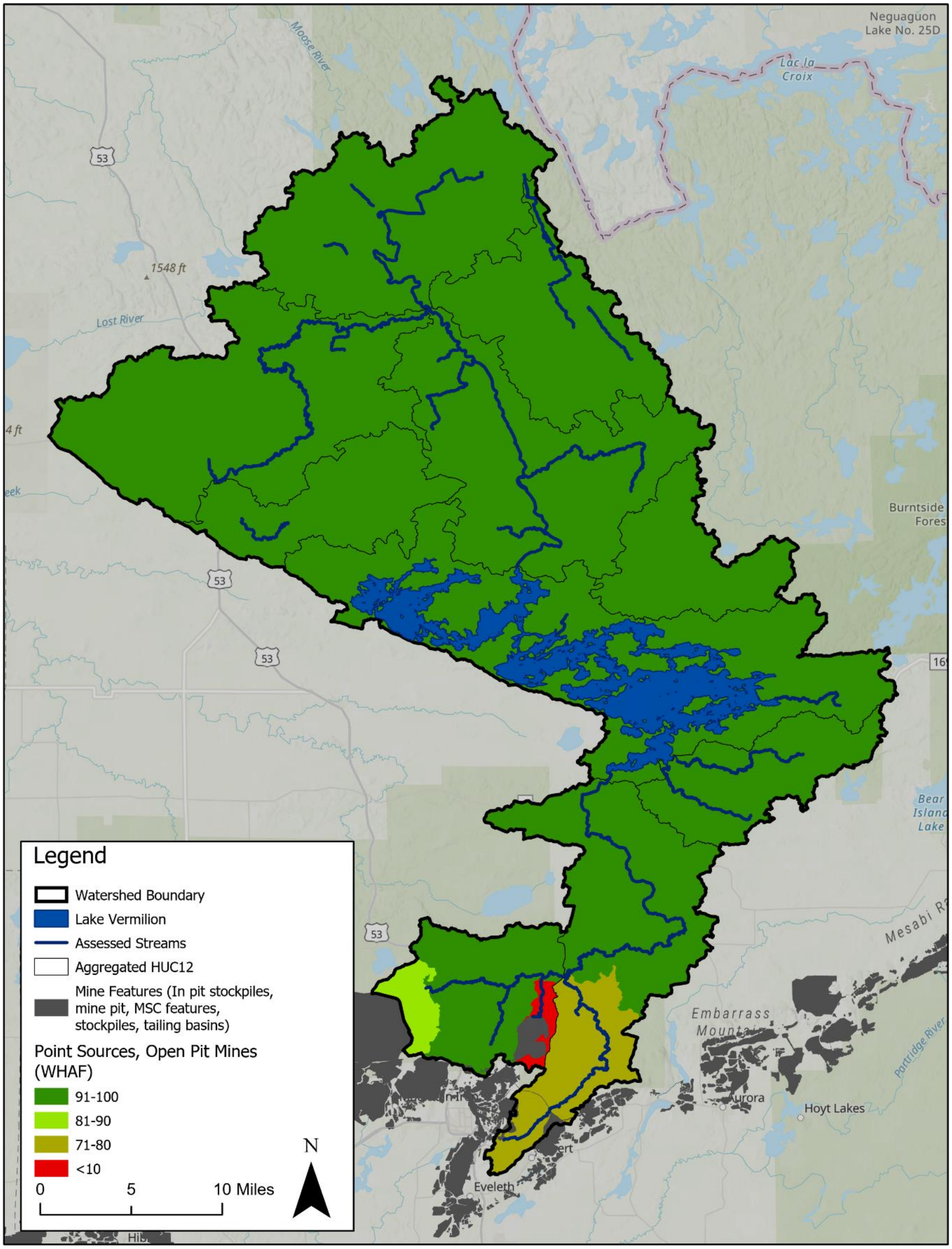
There is little industrial activity within the VRW; however, metallic mining activities currently discharge wastewater to the VRW. The DNR's Watershed Health Assessment Framework (WHAF) identifies areas most impacted by metallic mining activities (Figure 9). Potential impacts to natural resources during and following mining activity include altered hydrology, soil disturbance, tailings management, and existing waste rock seepage which can lead to changes in water quality, flow, and temperature.

Factors such as changes to flow, temperature, and water quality should be considered as part of mine expansion and closure. Other programs such as Environmental Review and the NPDES/SDS permits program consider these impacts and set discharge limits protective of water quality standards. Permits include enforceable requirements about how the facilities are constructed, operated and eventually closed. Permits also include extensive requirements for monitoring and reporting to the MPCA during operations to ensure that facilities operate in compliance with permit requirements. NPDES/SDS permit conditions are consistent with attainment of water quality standards.

Additionally, potential impacts from gravel pits in the VRW include contributions of sediment to nearby waters. Best management practices (BMPs) such as maintaining buffers and restoring gravel pits upon closure provide protection from these impacts.

**Figure 9. Mining features and the water quality health index score from the WHAF**

The index score is based on the amount of land area within a catchment disturbed by mining activity. Scores range from 0 to 100, with 15% or greater disturbance of land area = 0; no mines present = 100.



## 2.4 TMDL summary

Myrtle Lake (69-0749-00), located in the northern portion of the VRW, does not meet the NLF Ecoregion eutrophication water quality standard (Table 10), and is classified as impaired (Table 10, Table 11). The cause of impairment is high levels of phosphorus resulting in excessive production of algae, as measured by Chl-*a*. Elevated phosphorus affects the aquatic recreation designated use by fueling nuisance algae blooms. A summary of phosphorus loading to Myrtle Lake is provided in Table 12. Internal loading within the lake and unidentified sources are the most significant factors contributing to the impairment, with watershed runoff from the direct drainage to the lake also playing a major role. A TMDL for TP has been developed for Myrtle Lake and is described in full in the VRW TMDL (MPCA 2021).

**Table 10. Myrtle Lake water quality data summary**

| Parameter | Average of Annual Growing Season Means (Jun–Sep) 2015, 2016, 2018 | NLF Water Quality Standard for 2B lakes |
|---|---|---|
| TP (µg/L) | 38 | ≤ 30 |
| Chl-*a* (µg/L) | 27 | ≤ 9 |
| Secchi (m) | 1.5 | ≥ 2.0 |

Reductions in TP delivered to Myrtle Lake will be necessary to achieve the numeric water quality standards and meet the water quality goal. The phosphorus loading capacity was determined using the lake response model BATHTUB, an eutrophication model developed by the U.S. Army Corps of Engineers. Watershed runoff volumes and loads were derived from a HSPF model of the watershed. The models were calibrated to monitored water quality data. A 10% explicit margin of safety accounts for uncertainty. An estimated 29% reduction of TP is needed to meet water quality standards.

Table 13 shows the maximum allowable load of TP that can be delivered to Myrtle Lake while still allowing the lake to meet water quality goals (loading capacity). The table also shows the allowable amount of TP which can come from nonpoint sources (load allocation) and point sources (wasteload allocation; WLA).

Other waterbodies, such as Echo Lake (69-0615-00) and Unnamed Creek (-645) also failed to meet water quality standards (Table 10) but did not receive TMDLs because anthropogenic influences were insignificant, and impairments were due primarily to natural conditions within the waterbody or direct drainage area.

**Table 11. Impairments and TMDL status within the Vermilion River Watershed**

| Water Body Name | WID [a] | Year Added to 303(d) List | Designated Use Class | Affected Designated Use | Pollutant or Stressor | EPA category [b] | TMDL Developed |
|---|---|---|---|---|---|---|---|
| Myrtle Lake | 69-0749-00 | 2018 | 2B, 3C | Aquatic Recreation | Nutrient /eutrophication biological indicators | 4A [c] | Yes |
| Echo Lake | 69-0615-00 | 2010 | 2B, 3C | Aquatic Recreation | Nutrient/ eutrophication biological indicators | 4D | No |
| Unnamed creek (Headwaters to Sand R) | 09030002-645 | 2018 | 2Bg, 3C | Aquatic Life | Fishes bioassessments | 4D | No |

[a] WID = waterbody identification

[b] 4A: Impaired or threatened but a TMDL study has been approved by EPA.
4D: Impaired or threatened but doesn't require a TMDL because the impairment is due to natural conditions with only insignificant anthropogenic influence.

[c] Myrtle Lake will be 4A upon EPA-approval of the TMDL report.

**Table 12. Summary of phosphorus loads to Myrtle Lake**

| Source | | TP Load | |
|---|---|---|---|
| | | lb/yr | % |
| Watershed runoff | Wetland | 18 | 1% |
| | Developed | 71 | 5% |
| | Forest | 319 | 21% |
| | Grasslands | 9 | 1% |
| SSTS | | 29 | 2% |
| Internal and unidentified | | 900 | 60% |
| Atmospheric deposition | | 151 | 10% |
| *Total* | | *1,497* | *100%* |

**Table 13. Myrtle Lake (69-0749-00) phosphorus TMDL summary**

| TMDL Parameter | TMDL TP Load | |
|---|---|---|
| | lb/yr | lb/day |
| WLA for construction stormwater (MNR100001) | 0.77 | 0.0021 |
| WLA for industrial stormwater (MNR050000 and MNG490000) | 0.77 | 0.0021 |
| Load allocation | 956 | 2.6 |
| Margin of safety | 106 | 0.29 |
| Loading capacity | 1,064 | 2.9 |
| **Other** | | |
| Existing load | 1,497 | 4.1 |
| Percent load reduction | 29% | 29% |

Loads are rounded to two significant digits, except in the case of values greater than 100, which are rounded to the nearest whole number.

## 2.5 Protection considerations

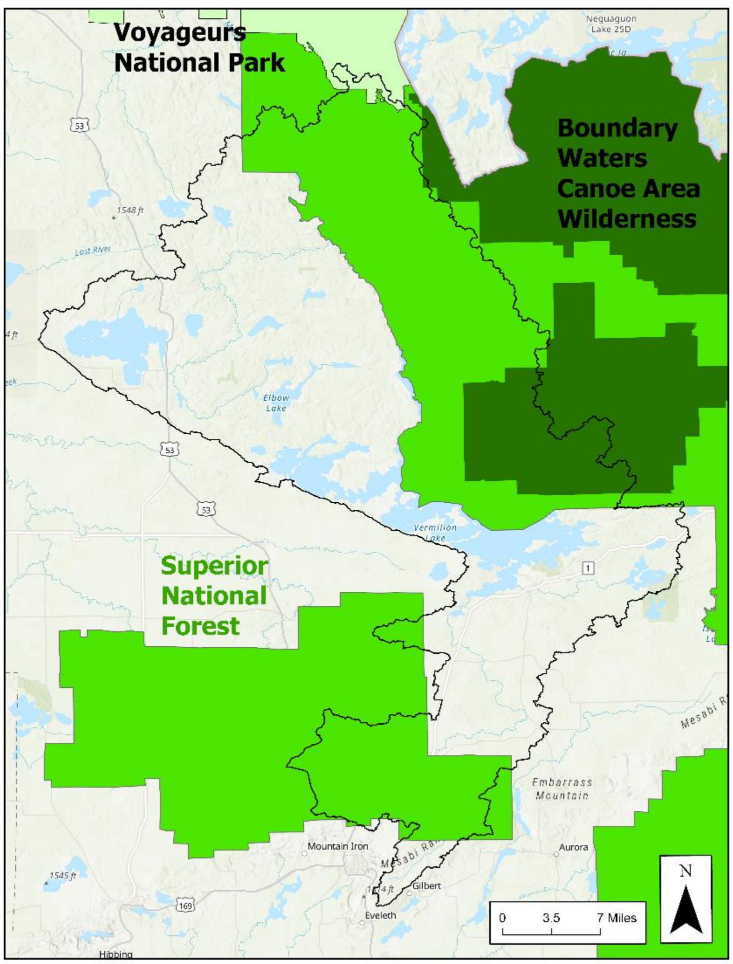
The definition of protection can vary in different regions based on the water quality, land cover, and local values. Protection can mean limiting further degradation from current water quality, preserving a specific resource such as wild rice, active land management such as forest harvesting, or permanent protection, such as the BWCAW. The VRW is a relatively pristine landscape, encompassing a wide variety and breadth of protections, which are described in this section. Also, waterbodies were prioritized for protection based on existing data and criteria.

### 2.5.1 Protected areas

A large portion of the VRW is afforded protections by being managed as public lands. About 60% of land in the VRW is under state or federal ownership (approximately 30% each) (MPCA, 2018b). These areas have various restrictions on human activity, which help preserve the outstanding natural resources.

Minnesota's newest state park, Lake Vermilion-Soudan Underground Mine State Park, is fully within the VRW on the southeast corner of Lake Vermilion. Bear Head Lake State Park is on the watershed boundary. Much of the western side of the watershed is the Kabetogama State Forest, which covers 55% of the watershed.

**Figure 10. Federal land in the VRW**




Federally owned land includes the SNF, BWCA, and VNP (Figure 10). The SNF was championed by General Christopher C. Andrews, the First Chief Fire Warden of Minnesota, and later its Forestry Commissioner. It started with 500,000 acres of forest in Lake and Cook Counties in 1902, and then over a series of additions grew to 1,018,638 acres by 1909. Today, the SNF covers three million acres of land in northeast Minnesota's Arrowhead region and comprises 45% of the VRW. The SNF is managed for multiple uses including recreation and timber harvest. The United States Forest Service (USFS) uses principles of ecosystem management to maintain the forest and the ecosystem services it provides.

The BWCAW lies within the boundaries of the SNF (Figure 10). The BWCAW was established in 1949, but was officially designated a wilderness area in 1978. It consists of 1,029,000 acres of lakes, streams, forests, and exposed bedrock and makes up 7% of the VRW. This area has more strict protections than the SNF and is some of the most protected land in the nation. It is protected from motorized vehicles (except for some border lakes), mining, and forest harvest, and a permit is required year-round for visitors to control human access (USDA USFS, 2020b).

VNP was established in 1975 and its name commemorates the Voyageurs – the French-Canadian fur traders who were the first European settlers to frequently travel through the area. The park covers 0.5% of the VRW in the far northern corner and includes part of Crane Lake. The park allows numerous recreational activities.

### 2.5.2 Prioritizing streams for protection

All streams should have a certain level of protection; however, some waters require special consideration because they show a statistically higher risk of degradation. Knowledge of current habitat and biological characteristics, or where watershed risk has been rated as highly susceptible to disturbance can help prioritize streams in need of additional protection. Five streams with high quality biologic communities were identified during IWM: Bug Creek, Hilda Creek, Hunting Shack River, Echo River, and Flap Creek. Although these streams did not meet the requirements to be included as exceptional waters under the Tiered Aquatic Life Use standards (TALU), fish community surveys indicate that these waters harbor sensitive fish species. Three of these streams, Bug, Hilda, and Echo contain fish communities above the exceptional use threshold.

The MPCA collaborated with the DNR, Minnesota Board of Water and Soil Resources (BWSR), Minnesota Department of Health (MDH), and the Minnesota Department of Agriculture (MDA) to develop guidance for incorporating protection strategies into WRAPS reports, local water plans, and/or One Watershed One Plan (1W1P) documents.

The stream protection and prioritization tool (MPCA, 2018a) is designed to generate a prioritized list of streams based on the results of water quality assessments, the level of risk posed from nearshore areas (riparian), the level of risk posed from the contributing watershed, as well as the level of protection already in place in the watershed. The data is split into thirds; the top third is high (A) priority, the next third medium (B) priority, and the final third are low (C) priority (Table 14). These streams represent those that are most at risk for future impairment. These categories include:

- ‘Community Nearly Impaired’ means that the IBI scores for macroinvertebrate and/or fish are on average within five points of the assigned threshold;
- ‘Riparian risk’ is based on road density and disturbed land use within the riparian area; and
- The current level of protection is based on the percentage of public and easement protected land in the watershed area.

This list should be used in conjunction with local knowledge to help further prioritize these streams for protection efforts.

**Table 14. Stream protection and prioritization results (MPCA, 2018a)**

| WID | Stream Name | TALU | Vulnerable | Cold/Warm | Community Nearly Impaired* | Riparian Risk | Watershed Risk | Current Protection Level | Protection Priority Class |
|---|---|---|---|---|---|---|---|---|---|
| 09030002-505 | Armstrong River | General | N | warm | neither | med/low | med/low | med/high | C |
| 09030002-593 | Bug Creek | General | N | warm | one | med/high | low | high | B |
| 09030002-647 | East Two River | General | N | cold | neither | low | low | medium | C |
| 09030002-648 | East Two River | General | N | warm | neither | med/high | med/low | medium | B |
| 09030002-532 | Echo River | General | N | warm | neither | low | low | high | C |
| 09030002-604 | Elbow River | General | N | warm | one | low | low | medium | B |
| 09030002-565 | Flap Creek | General | N | warm | neither | low | low | high | C |
| 09030002-528 | Hilda Creek | General | N | warm | one | low | low | high | B |
| 09030002-583 | Hunting Shack River | General | N | warm | neither | med/high | low | high | C |
| 09030002-530 | Pelican River | General | N | warm | one | low | low | high | B |
| 09030002-502 | Pike River | General | N | warm | neither | low | low | medium | C |
| 09030002-503 | Pike River | General | N | warm | neither | low | medium | medium | C |
| 09030002-501 | Sand River | General | N | warm | neither | med/low | medium | medium | C |
| 09030002-610 | Two-mile Creek | General | N | warm | one | med/low | low | medium | B |
| 09030002-644 | Unnamed creek | General | N | warm | neither | med/high | low | medium | C |
| 09030002-646 | Unnamed creek | General | N | warm | one | low | low | med/high | B |
| 09030002-529 | Vermilion River | General | N | warm | neither | med/low | low | medium | C |
| 09030002-531 | Vermilion River | General | N | warm | one | low | low | med/high | B |
| 09030002-509 | West Two River | General | N | cold | neither | medium | low | high | C |
| 09030002-572 | Wouri Creek | General | N | warm | neither | medium | med/low | med/low | B |

*"one" indicates that either the macroinvertebrate or the fish community in this stream reach is close to the applicable IBI threshold. "both" indicates that both communities are close to their IBI thresholds.

### 2.5.3 Prioritizing lakes for protection

Many Minnesota lakes have water quality that is substantially better than their applicable standards, especially throughout the NLF ecoregion in the north-central and northeastern parts of the state. The VRW is no different with all but two of the 21 lakes with enough data for assessment meeting water quality standards for eutrophication.

With a focus on the susceptibility of a lake to phosphorus pollution, the DNR - Ecological and Water Resources (EWR) Division created a database of Lakes of Phosphorus Sensitivity Significance (LPSS) and Lake Benefit Cost Assessment (LBCA) with the intent to support planning, natural resource management, research, and other resource protection-related activities. The sensitivity of a lake to phosphorus inputs was assessed for the lakes of the VRW by estimating the change in water clarity that would result with increased phosphorus loading to the lake. The LBCA index was formulated to rank lakes as they relate to the state's priority of focusing on "high-quality, high-value lakes that likely provide the greatest return on investment". Lakes were assigned a protection priority class based on estimated phosphorus sensitivity, lake size, lake TP concentration, proximity to MPCA's phosphorus impairment thresholds, and watershed disturbance (MPCAa, 2018). This prioritization aligns with the MPCA's policy of focusing protection efforts on high quality, unimpaired lakes that have the greatest risk of becoming impaired. For lakes, the top 25th percentile is the high (A) priority, $50^{th}$ to $75^{th}$ percentile is medium (B) priority, and the bottom half of the lakes are the lower (C) priority.

In 2019, the lakes identified as the highest priority for additional protection based on LPSS (Priority Class A) were the Eagles Nest Chain of Lakes and Kjostad Lake. The next highest priority (Priority Class B) includes Pelican, Susan, Armstrong, Marion, Vermilion, Elephant, and Elbow Lakes. The LBCA analysis identified Eagles Nest #3, Pelican, and Lake Vermilion as providing the highest cost-benefit for TP reduction in the watershed (MPCAa, 2018). Lakes categorized as LPSS Priority Class A and LBCA Priority Class 'Highest' are shown in bold (Table 15).

These tables should be used alongside additional local knowledge of the watershed to further prioritize protection efforts. For example, Lake Vermilion is listed by LPSS as class B, but is a recreation destination with statewide importance. It also has tribal lands, an active lake association, and is a lake of outstanding biological significance.

The MPCA has established a basic method to identify monitored lakes close to their regional TP standards. These lakes, identified as "nearly or barely" impaired by eutrophication are within 10% above or below the standard, and are thus identified as vulnerable ("nearly" impaired) or suitable candidates for restoration ("barely" impaired) (Anderson, 2018). Pelican Lake, was identified as nearly impaired as part of this process using data collected between 2007 and 2016. Pelican Lake is one of the most developed lakes in the watershed and is known to regularly experience nuisance algal blooms. It is also a recreation destination lake with tribal land and an active lake association. As such, there is a desire to protect this popular recreation destination from further degradation. Other lakes included on the 2020 "Nearly / Barely" analysis of lake eutrophication include Moose (69-0806-00), Susan (69-0741-00), and Marion (69-0755-00).

Lakes with moderate development identified by the core team for protection efforts include Eagle's Nest # 2, Elephant Lake, and West Vermilion. Eagles Nest #2 is a high quality, sensitive lake experiencing a declining trend in water quality. Elephant Lake meets the NLF TP standard but is barely exceeding the NLF Chl-*a* standard of 9 µg/L. West Vermilion meets both the TP and Chl-*a* standards, but Chl-*a* levels are close to the standard.

**Table 15. Vermilion River Watershed Lake Prioritization Summary for Total Phosphorus Risk**

| WID | Lake Name | Mean TP (ug/L) | Target TP (ug/L) | Predicted Load (lb/yr) | Load Target (lb/yr) | 5% Load Reduction Goal (lb/yr) | LPSS Priority Class | LBCA Priority Class |
|---|---|---|---|---|---|---|---|---|
| **69-0285-03** | **Eagles Nest #3** | 10 | 8 | 333 | 283 | 17 | **A** | **Highest** |
| **69-0841-00** | **Pelican** | 24 | 20 | 5058 | 4345 | 253 | B | **Highest** |
| **69-0378-01** | **Vermilion** | 19 | 16 | 36673 | 32142 | 1834 | B | **Highest** |
| **69-0748-00** | **Kjostad** | 10 | 8 | 88 | 75 | 4 | **A** | Higher |
| **69-0285-01** | **Eagles Nest #1** | 5 | 5 | 171 | 145 | 9 | **A** | Higher |
| **69-0218-00** | **Eagles Nest No. Four** | 6 | 5 | 33 | 28 | 2 | **A** | Higher |
| **69-0285-02** | **Eagles Nest #2** | 9 | 7 | 250 | 210 | 12 | **A** | Higher |
| 69-0498-00 | Trout | 11 | 9 | 2848 | 2470 | 142 | C | Higher |
| 69-0744-00 | Elbow | 12 | 10 | 1100 | 939 | 55 | B | Higher |
| 69-0278-00 | Armstrong | 12 | 10 | 276 | 233 | 14 | B | High |
| 69-0810-00 | Elephant | 19 | 16 | 454 | 384 | 23 | B | High |
| 69-0690-00 | Winchester | 8 | 7 | 110 | 92 | 5 | C | High |
| 69-0749-00 | Myrtle | 38 | 32 | 1311 | 1107 | 66 | NA | High |
| 69-0741-00 | Susan | 32 | 26 | 259 | 216 | 13 | B | High |
| 69-0742-00 | Ban | 21 | 18 | 333 | 279 | 17 | C | High |
| 69-0217-00 | West Robinson | 19 | 16 | 129 | 107 | 6 | C | High |
| 69-0764-00 | Sunset | 24 | 20 | 265 | 220 | 13 | C | High |
| 69-0615-00 | Echo | 38 | 32 | 4654 | 3929 | 233 | NA | High |
| 69-0730-00 | Sandy | 17 | 14 | 285 | 234 | 14 | C | High |
| 69-0381-00 | Buck | 18 | 15 | 226 | 189 | 11 | C | High |
| 69-0729-00 | Little Sandy | 20 | 17 | 254 | 208 | 13 | C | High |
| 69-0589-00 | Astrid | 13 | 11 | 144 | 120 | 7 | C | High |
| 69-0755-00 | Marion | 31 | 26 | 168 | 140 | 8 | B | High |
| 69-0616-00 | Crane | 18 | 15 | 41986 | 36060 | 2099 | C | High |
| 69-0579-00 | Hay | 22 | 18 | 108 | 88 | 5 | C | High |
| 69-0861-00 | Gabrielson | 23 | 19 | 7 | 6 | 0 | C | High |
| 69-0588-00 | Pauline | 50 | 42 | 323 | 268 | 16 | C | High |
| 69-0803-00 | Rice | 28 | 23 | 1917 | 1570 | 96 | C | High |
| 69-0590-00 | Maude | 78 | 65 | 600 | 499 | 30 | C | High |
| 69-0457-00 | Nigh | 57 | 48 | 271 | 223 | 14 | C | High |
| 69-0740-00 | Black | 88 | 74 | 1216 | 1005 | 61 | C | High |

### 2.5.4 Drinking water protection

*Section provided by Minnesota Department of Health*

Drinking water is important in any watershed in Minnesota. The majority of Minnesotans (75%) rely on groundwater for their drinking water source, and whether the source is a public or private well, that groundwater quality can be highly impacted by nearby surface water features. The remaining 25% of Minnesotans rely on surface water, primarily from the 23 city-owned and operated community public water suppliers active throughout the state. These surface water-using communities are highly dependent on the health of the watersheds in which they are located. Therefore, the protection of drinking water should be a high priority for all watersheds in Minnesota.

The VRW contributes to one downstream community public water supply—International Falls—and five noncommunity public water supplies that use surface water or groundwater under the direct influence of surface water (GWUDI) as a source for drinking water. The City of International Falls, while not in the watershed, relies on the Rainy River for their drinking water and likewise benefits from restoration and protection of surface water in the watershed. The Vermilion River is a major tributary to the Rainy River.

Many of the implementation activities conducted by government agencies, SWCDs, businesses, private landowners, and other local entities can help address surface water quality. The main issues for public water suppliers in this watershed include:

- Naturally generated elevated organic carbon concentrations in many waterbodies leading to disinfection byproduct formation when combined with drinking water disinfection via chlorination; and
- Elevated nutrient concentrations in some waterbodies.

#### Noncommunity public water supplies

The noncommunity public water supplies in the watershed rely on surface water from the many lakes and rivers present in the watershed for drinking water. Noncommunity public water supplies include bars, restaurants, camps, and resorts that serve customers for shorter periods. The following waterbodies either serve as drinking water sources or appear to contribute flow to nearby drinking water wells:

- Crane Lake;
- Kabustasa (and/or Echo) Lake;
- Lake Vermilion; and
- Pelican Lake

#### Community public water supplies

The Source Water Assessment area for International Falls is shown in Figure 11. The areas were delineated using the following criteria:

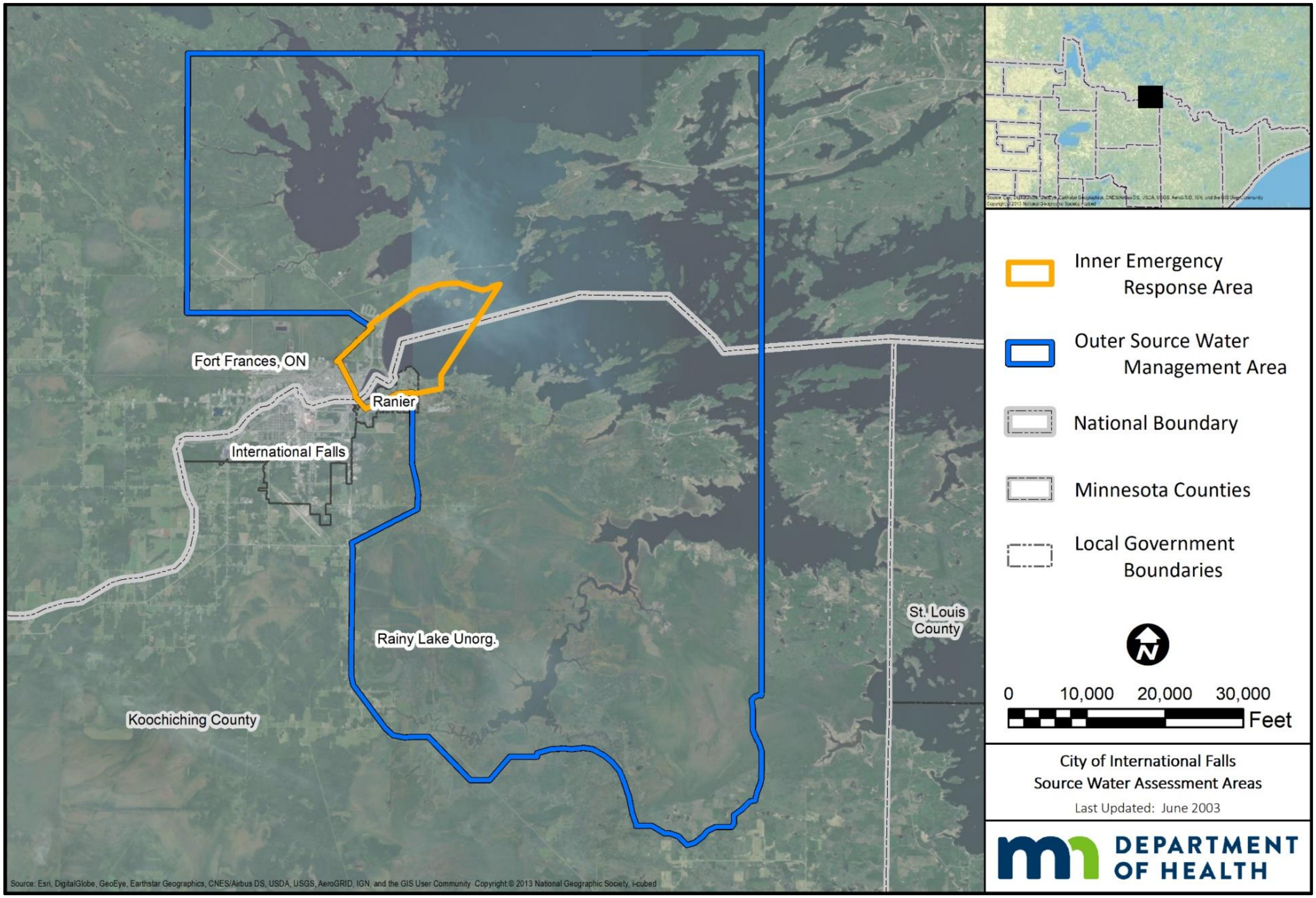
- The Inner Emergency Response Area is defined as the area in which the public water supply utility would have little or no time to respond to a direct discharge of contamination, other than to close the intake. The area closest to the intake was designed to help the public water supplier address contaminant releases, which present an immediate (acute) health concern to water users. The geographic area is defined by the amount of notification time the PWS would need to close the surface intake and a buffer time to accommodate unanticipated delays in notification and shutdown. Three different sets of criteria were developed and used to delineate an ERA for different types of surface waterbodies, including 1) rivers and streams, 2) lakes, and 3) mine pits. Information about the intake, water supply treatment system, water storage capacity, and treatment methods were also considered.

- The Outer Source Water Management Area is defined as the area where the impacts to drinking water from point and nonpoint sources of contamination can be minimized by preventive management. This area was delineated to protect water users from long-term (chronic) health effects related to low levels of chemical contamination or the periodic presence of contaminants at low levels in the surface water used by the PWS.

Figure 11 shows the city of International Falls and the surface runoff and watershed area that contributes to the city's drinking water intake. Each of the streams and lakes inside the two Source Water Assessment areas are important places to focus on when planning implementation and restoration activities.

The International Falls Source Water Assessment will be updated using new guidance and definitions by 2025. The current document, which will be replaced by the new amended Assessment when it is completed, is available at the MDH Source Water Assessment webpage: https://www.health.state.mn.us/communities/environment/water/swp/swa.html.

**Figure 11. Source Water Assessment areas for the city of International Falls**



### Class 1 drinking water

Waterbodies in Minnesota are classified for specific beneficial uses in statute as required by the Clean Water Act. Class 1 waters are designated for human consumption, which means they are clean enough to drink. Class 1A waters are water sources that can be consumed without treatment and are generally restricted to groundwater. Class 1B waters are surface or groundwater that can be consumed with approved disinfection such as chlorination. Class 1C waters are generally surface waters that can be consumed with treatment consisting of coagulation, sedimentation, filtration, storage, and chlorination, or other equivalent treatment processes.

There are 16 Class 1 lakes in the VRW, as illustrated in Figure 15 in Section 3.1 and identified individually in *Appendix B: Vermilion River Watershed Protection Prioritization Criteria*. The majority of these lakes sit above bedrock and have minimal human impact. These lakes are still susceptible to localized fecal bacteria issues from campsites, waste disposal, and septic systems.

## 2.5.5 Outstanding resources

The VRW has many outstanding natural resources that can be targeted for specific protections. These include wild rice and coldwater fisheries.

### Wild rice

Wild rice, a native grain with both ecological and cultural importance, has been identified in waters in the VRW in surveys from the DNR, 1854 Treaty Authority, and the MPCA. It is an important food source for waterfowl and wildlife, and several Native American cultures consider wild rice to be a sacred component of their culture. It grows in shallow water in small lakes and slow-flowing streams. Wild rice is protected, and a harvesting license is needed for non-Native American people.

Wild rice is vulnerable to changes in water levels and the addition of sulfate, which can negatively impact wild rice stands. Sulfate is typically found in low concentrations in natural streams but can become elevated due to mining activities in sulfide bearing rocks. According to Pastor et al., 2017, sulfate in the oxygenated water column becomes toxic to wild rice once converted to sulfide in the anoxic sediment.

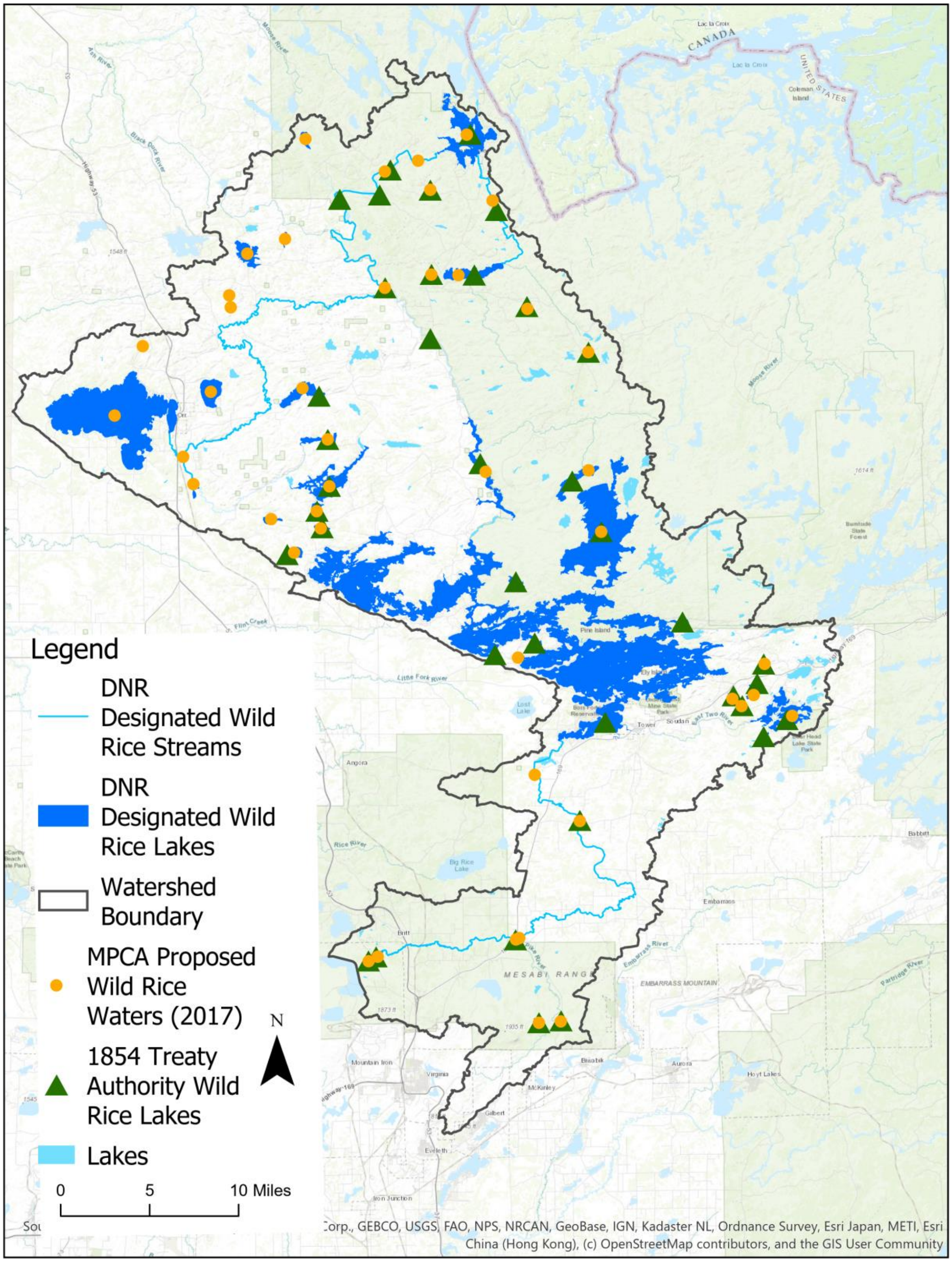
Minnesota has had a sulfate standard for waters used for the production of wild rice since 1973, but appropriate implementation has been a source of contention. In 2021, the EPA added several waters to Minnesota's 2020 Impaired Waters List as impaired for sulfate, including 6 waterbodies in the VRW (Table 3). These waterbodies exceed the sulfate standard of 10 mg/L applicable to waters used for production of wild rice (Minn. R. 7050.0224). The listings represent an important first step toward resolving the long-standing issue of implementing the existing standard after a state law prohibited the agency from enforcing the current standard (Laws of Minnesota 2017, ch. 93, article 2, section 149) and an administrative law judge rejected a 2018 proposal to revise the standard. The MPCA is currently working to determine the next steps to address sulfate impairments throughout the state and is committed to implementing the existing wild rice water quality standard to ensure these waters are restored.

Sandy Lake, Little Sandy Lake, Sand River, and the Pike River have been regularly sampled by the 1854 Treaty Authority since 2010 (Vogt, 2021). Results have indicated elevated sulfate levels in these waters.

Recent survey results from the 1854 Treaty Authority have found few wild rice stalks remaining on Sandy and Little Sandy lakes, which have historically produced good stands of wild rice (Vogt, 2020).

Multiple surveys have identified waters within the VRW that harbor wild rice (Figure 12 and Appendix B). The DNR maintains a data set of waters containing wild rice in the state of Minnesota, and the 1854 Treaty Authority conducts ongoing wild rice surveys within the 1854 Ceded Territory. Additionally, in 2017, the MPCA undertook a survey of wild rice waters.These datasets identify numerous lakes in the VRW that contain wild rice.

**Figure 12. Wild rice waters in the VRW**



### Coldwater fisheries

Northern Minnesota has cold, deep lakes left behind after the glaciers retreated. These lakes can support fish that can only survive in cold, well-oxygenated water, such as cisco, lake trout, and lake whitefish. These fish can also be considered the "canary in the coal mine" because they are indicators of changing lake conditions. These fish are threatened by two main causes: climate change and reduced DO caused by eutrophication (Jacobsen et al, 2010). Climate change can warm the waters and reduce the size of cool, well-oxygenated areas of the lake, which reduce suitable habitat for these fish. Eutrophication is caused by the addition of nutrients such as phosphorus from surrounding lands impacted by humans, enhancing algae growth. The decay of the additional plant material utilizes oxygen and lowers DO. Protecting lakes with coldwater fisheries by maintaining or increasing forest cover in the watershed and limiting runoff from developed areas will help these fish continue to survive in these lakes.

Fisheries research from the DNR indicates that keeping at least 75% of a lakeshed forested is crucial to maintaining habitat for coldwater fish species such as lake trout, cisco, and lake whitefish (Jacobson et al. 2016). The deepest and clearest lakes are expected to be most resilient to the warming climate and provide coldwater habitat well into the future. These are designated as Cisco Refuge Lakes by the DNR. In addition, there are coldwater lakes and streams categorized as Use Class 2A in Minn. R. 7050. These waters are held to a water quality standard "as to permit the propagation and maintenance of a healthy community of coldwater aquatic biota, and their habitats" (Table 16).

**Table 16. Northern Lakes and Forest ecoregion lake eutrophication standards**

| Use Class | TP (ppb) | Chl-*a* (ppb) | Secchi (meters) |
|---|---|---|---|
| NLF-Lake Trout (Class 2A) | <12 | <3 | >4.8 |
| NLF-Stream Trout (Class 2A) | <20 | <6 | >2.5 |
| NLF-Aquatic Recreation Use (Class 2B) | <30 | <9 | >2.0 |

There is one lake that supports trout in the VRW (Trout Lake), which is also a designated Cisco Refuge Lake. Two lakes, Trout Lake and Crane Lake, and two river systems, East Two River and West Two River, are designated as class 2A waters. These lakes are shown in Figure 19 in Section 3.1 as High-Quality Lakes and identified individually in Appendix B.

In addition, there are a number of lakes within the VRW known to harbor lake trout, lake whitefish, and cisco. Recent collaboration between the DNR and the MPCA has resulted in a draft list of these lakes (Figure 16). This work is preliminary only and is included here solely to assist in identifying lakes in need of additional protections.

## 2.5.6 Climate change

Minnesota's climate is changing, and these changes can impact the natural resources in the VRW. Long-term trend data show an increase in temperature and precipitation in Northeast Minnesota (Figure 13 and Figure 14). In addition, a shorter term decreasing trend in precipitation has been seen in the last 25 years. The reasons for this recent precipitation decline are still unclear. Snowfall totals have appeared to remain relatively stable (GLISA, 2020). Along with increased precipitation, increases in temperature are expected to increase evapotranspiration which could create dry spells between rain events.

**Figure 13. Annual average temperature trends in the VRW alongside the 30-year running average (DNR, 2015)**

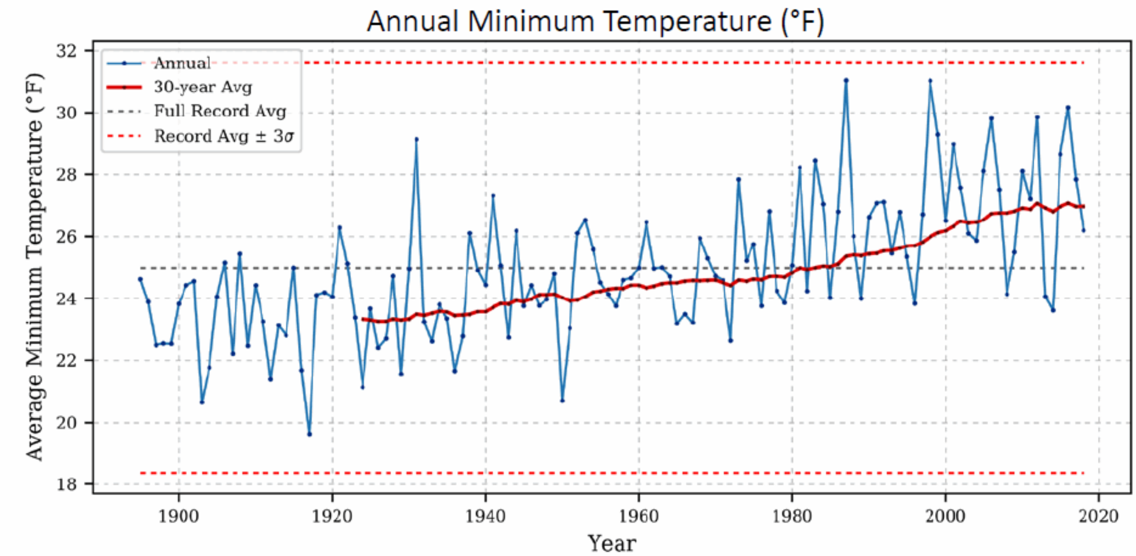
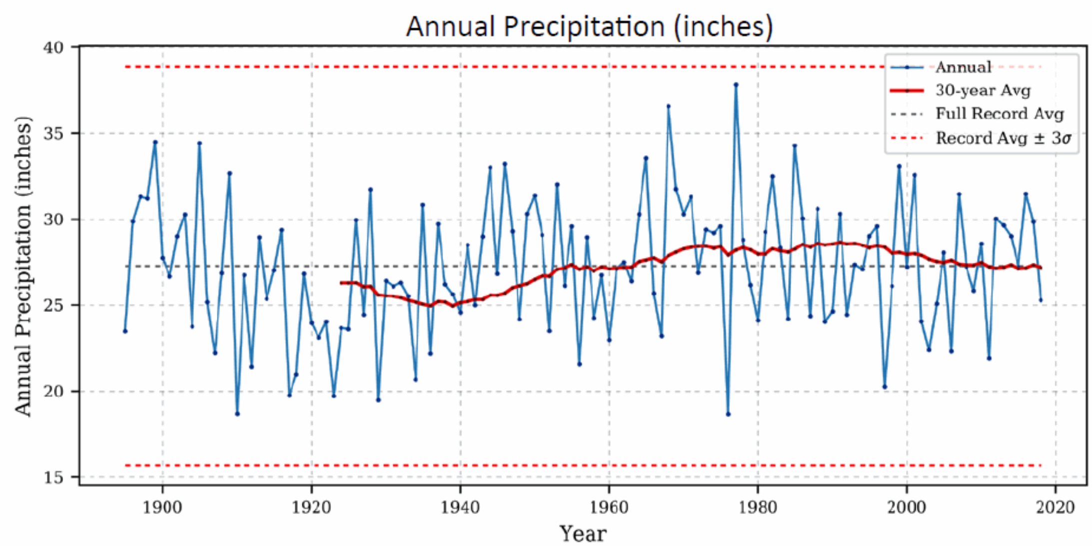



**Figure 14. Annual precipitation trend in the VRW alongside the 30-year running average (DNR, 2015)**




The impacts of climate change to this region can include the loss of coldwater fish habitat (Jacobson et al., 2010), decreased lake ice cover (Magnuson et al., 2000), increased frequency of algal blooms (Paerl et al., 2016), change in tree species composition, increased risk of forest fire, and increased risk of new aquatic and terrestrial invasive species invasions. Warming surface waters can alter thermal stratification in lakes. Shallow lakes, which are usually unstratified, may see increased temporary stratification events which release nutrients from the lake sediment leading to higher internal nutrient loading and increases in algae production. Forest species composition changes potentially include a decrease in balsam fir, black ash, black spruce, jack pine, northern white cedar, paper birch, quaking aspen, and white spruce, and an increase in red maple and eastern white pine (Handler et al., 2017).

As part of this project, the impact of climate change to water quality was modeled in the VRW. The HSPF-SAM includes multiple default climate change scenarios. These scenarios were used to show the impacts of climate change in the watershed. The three climate change options available include:

- **Mild**: 1°F increase in average air temperature and a 4% increase in extreme precipitation;
- **Moderate**: 2°F increase in average air temperature and 8% increase in extreme precipitation; and
- **Severe**: 4°F increase in average air temperature and a 12% increase in extreme precipitation.

The climate change options adjust the existing climate record for the HSPF model. For air temperature increases, the change is applied across the whole record. For the change in extreme precipitation, the percent increase is applied to the extreme precipitation events to represent storm intensification due to climate change.

It is important to note that these estimates are result of modeling that does not include any changes that might occur to the overall forest community which in turn could also impact forest hydrology. Since we can only collect data in the present, we can use models to predict conditions under different environmental conditions and scenarios. These results are a tool to assist with management decisions in combination with sample data, local knowledge, and professional judgement.

All three climate change options were modeled to estimate the amount of change under the existing climate change projections. HSPF-SAM incorporates change in precipitation along a gradient rather than just an overall increase. Overall, the model increases the total amount of precipitation and surface water runoff in all three scenarios. Additionally, the highest precipitation events increase while the lowest precipitation events are reduced. No change is made to median storm events. Sediment transport is highly influenced by larger storms, which scour and increase sediment wash-off occurring during large events. The increase in surface water runoff and extreme precipitation events in all three scenarios resulted in increased sediment loading.

Additionally, the model incorporates increases in temperatures in all three scenarios. This increases evapotranspiration and decreases 'total runoff', which is a combination of surface runoff and groundwater flow. Although groundwater flow may be small relative to surface runoff from a storm event on a daily timescale, it occurs throughout the year and can be a significant contributor to flow and nutrient loading in a watershed. And although nutrients bound to sediment will increase with increased sediment loading, this decrease in groundwater flow has a stronger influence on the resulting modeled nutrient loading. Overall, with less 'total runoff', nutrient loading decreased. To see detailed results of the modeling scenarios, see the *Vermilion River HSPF Model – Scenario Modeling Technical Memorandum* in Appendix C.

### 2.5.7 Land cover change

Compared to other watersheds in Minnesota, the VRW is relatively unimpacted by human changes to land cover. Land use consists of 68% forest, 17% wetland/shrub, and 13% open water. Agricultural land use is extremely low, with <1% of the watershed area. Development pressure is moderate, as there are no large cities in the watershed. Therefore, potential water quality impacts are localized around increased shoreline and woodland development surrounding lakes, especially Vermilion, the Eagles Nest Chain, and Pelican.

The Core Team identified two primary future impacts to the watershed: an increase in development and an increase in forest disturbance. These impacts were modeled using HSPF-SAM to estimate how these changes in land use might impact water quality in the watershed. To see more detail of how the model was set up and the resulting maps, see the *Vermilion River HSPF Model – Scenario Modeling Technical Memorandum* in Appendix C. As stated earlier, these are modeled values with inherent uncertainty, and they are meant to be used in combination of local knowledge, and professional judgement to assist the development of management decisions.

### Development

With a population of approximately 14 people per square mile, the watershed is currently sparsely developed and according to the US Census Bureau, the population has decreased .6% over the past 10 years. Limited road access throughout the watershed combined with the desired types of development (i.e., recreational and/or residential) indicates future development is likely to be largely focused in predictable areas (e.g., lakes, rivers, road access, etc.).

The Core Team provided input of specific lakes and rivers that are likely to see future development. Additionally, the Core Team provided input on which land use types are not likely to be developed. A key concern for this watershed is shoreland development. This includes development such as residential (e.g., houses and cabins) and commercial (e.g., resorts and camping).

The development scenario included an overall 10% increase in development in the watershed (excluding federal and state lands), conversion of municipalities to entirely 'Developed', an increase of septic system loading at a rate consistent with the population density loading from the existing model, and development of privately-owned lands within 500 feet of lakes and rivers identified by the Core Team. Overall, the changes in loading from the septic systems is relatively small compared to the changes in land types. Although it is unlikely that all the lands within the modeled scenario will become developed, the results can help us better understand how increased development can impact runoff and pollutant loading.

The scenario results show the most change occurred around Eagles Nest #3 and #4 lakes, with an increase in runoff of 140% and an increase in phosphorus of 400%. This is likely the result of the relative amount of area within the watershed converted to 'Developed' in the model as the scenario converted all privately-owned lands within 500 feet of lakes. The Eagle's Nest Chain of Lakes are high quality lakes with a largely forested watershed and much private lakeshore land. Table 17 shows the modeled average yields for land types in the VRW. The differences in these values illustrate the impact development can have on runoff, sediment, and nutrient loading. To see more detail of how the model was set up and the resulting maps, see the *Vermilion River HSPF Model – Scenario Modeling Technical Memorandum* in Appendix C.

**Table 17. Average yields for land types in the Vermilion River Watershed, based on HSPF model result.**

| Land Use Type | Discharge | Sediment | Nitrogen | Phosphorus |
|---|---|---|---|---|
| | (acre-ft/acre/year) | (tons/acre/year) | (lbs/acre/year) | (lbs/acre/year) |
| Wetland | 0.629 | 0.00030 | 0.323 | 0.023 |
| Forest mature deciduous | 0.787 | 0.0048 | 0.872 | 0.038 |
| Forest regrowth | 0.892 | 0.0195 | 1.124 | 0.046 |
| Forest mature evergreen | 0.713 | 0.0018 | 0.712 | 0.029 |
| Grassland | 0.949 | 0.0205 | 1.415 | 0.054 |
| Cropland high till | 0.818 | 0.2151 | 5.481 | 1.573 |
| Feedlot | 1.083 | 0.1096 | 8.985 | 0.982 |

| Land Use Type | Discharge (acre-ft/acre/year) | Sediment (tons/acre/year) | Nitrogen (lbs/acre/year) | Phosphorus (lbs/acre/year) |
|---|---|---|---|---|
| Developed-all | 1.453 | 0.035 | 2.894 | 0.446 |
| Developed-pervious | 1.163 | 0.0326 | 2.800 | 0.441 |
| Developed-impervious | 23.951 | 0.1843 | 10.216 | 0.836 |

### Forests

Approximately 68% of the watershed is forested. This substantial percentage indicates that forest disturbances could have significant impacts on water quality within the watershed and its resources. Forest disturbance could include forest loss due to disease, insect damage, harvest, wildfire, and blowdowns. Persistent warmer winters have allowed spruce budworm, a native insect, to flourish in neighboring watersheds causing massive die off of balsam fir. And other forest pests such as the emerald ash borer and the larch beetle may threaten ash and tamarack stands in the future, which are important species present in riparian areas of the VRW. Forested land is protective of water quality, reducing runoff and holding sediment and nutrients on the landscape.

The HSPF model was used to explore the possible impact of increased forest disturbance on the VRW. The Core Team provided input on how to set up the scenario. The resulting increased forest disturbance scenario changed mature forest (excluding BWCAW) to young forest at a rate of 10%, 20%, and 30% to show different degrees of change. These disturbance rates are not anticipated, but were chosen to better understand the cause-effect relationship between forested lands and pollutant runoff/loading to lakes and streams.

Variations in runoff and loading results between subwatersheds are largely a result of differences in amount of existing mature forest. For example, subwatersheds with more mature forest experiencing a 10% change to forest regrowth experience greater change than a watershed that has less mature forest as there is less land converted in the scenario. This can be seen in the results with a higher modeled impact in the northern region, where there is a higher percentage of mature forest.

Overall, with a 10% increase in forest disturbance, runoff increased from 1% to 2%, the sediment load increased by 9% to 29%, and the phosphorus load increased by 1% to 2%. Eagles Nest #3 and #4 showed the most change in sediment load with an increase of 29%. These loading numbers almost doubled in the 20% increase in the forest disturbance scenario. In the third scenario, with forest disturbance increasing by 30%, the runoff, phosphorus, and sediment increased by almost double the percentage of the second scenario, resulting in large increases in sediment (28% to 87%).

Furthermore, changes in runoff, sediment, and nutrients are all relative to the average yield of different land types. The overall change in a subwatershed is dependent of the yields from its contained land types. Small changes in loading could be buffered or exaggerated depending on the composition of the subwatershed. Another way to judge the impact of disturbing different land types in the watershed is to look at how the modeled conversion of different land types to Forest Regrowth changed on an acre-by-acre basis. Table 18 shows the overall yields and relative changes of Mature Forest to Forest Regrowth in the VRW. These values are averaged across the whole watershed. Small differences between climate zones may exist but the averaged values show the potential differences in loading between the Mature Forest land types and the Forest Regrowth land type. These modeled results show a greater change in runoff, sediment, and nutrients from disturbed mature evergreen forest than from mature deciduous.

To see more detail of how the model was set up and the resulting maps, see the Vermilion River HSPF Model – Scenario Modeling Technical Memorandum in Appendix C.

**Table 18. Average yields from Forest Areas in the Vermilion River Watershed, based on HSPF results.**

| Land type | Discharge (acre-ft/acre/year) | Sediment (tons/acre/year) | Nitrogen (lbs/acre/year) | Phosphorus (lbs/acre/year) |
|---|---|---|---|---|
| Mature evergreen forest | 0.713 | 0.0018 | 0.712 | 0.029 |
| Mature deciduous forest | 0.787 | 0.0048 | 0.872 | 0.038 |
| Forest regrowth | 0.892 | 0.0195 | 1.124 | 0.046 |
| **Forest disturbance impact** | | | | |
| Change from conversion of mature evergreen forest to forest regrowth | 0.179 | 0.01768 | 0.411 | 0.0162 |
| Percent change from converting mature evergreen forest to regrowth | 25.1% | 966.7% | 57.7% | 55.2% |
| Change from conversion of mature deciduous forest to forest regrowth | 0.104 | 0.01467 | 0.2521 | 0.0075 |
| Percent change from converting mature deciduous forest to regrowth | 13.3% | 302.8% | 28.9% | 19.6% |

The VRW is relatively undisturbed and very pristine. It is renowned for its outdoor recreation opportunities within the BWCAW and Lake Vermilion. The Vermilion River and the majority of its tributaries and lakes are in excellent health. Continuing to protect this area will ensure citizens can continue to experience the truly wild and natural environment that the watershed offers. Minimizing significant land use change should be a top priority.

# 3. Strategies for restoration and protection

The Clean Water Legacy Act (CWLA) requires that WRAPS contain strategies that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources, including water quality goals, strategies, and targets by parameter of concern, and an example of the scales and timeline of adoption to meet water quality protection and restoration goals.

This section of the WRAPS report provides the results of watershed strategy development. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed, it is imperative to create social capital (trust, networks, and positive relationships) with those who will be needed to voluntarily implement BMPs. Thus, effective ongoing public participation is fully a part of the overall plan for moving forward.

The restoration and protection strategies and geographical prioritization were developed by the Core Team over a series of meetings in 2020. The Core Team is comprised of members from the MPCA, DNR, BWSR, MDA, MDH, USFS), VNP, 1854 Treaty Authority, and North St. Louis SWCD.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts (HSPF-SAM) and professional judgment based on what is known at this time and, thus, should be considered approximate. Furthermore, many strategies are predicated on needed funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

Section 3 is organized by the strategy types identified throughout this process:

- Restoration Strategies:
    - Myrtle Lake Nutrient Management
- Protection Strategies:
    - Drinking water protection
    - Forestland management
    - Habitat and stream connectivity management
    - Lake management
    - Recreational management
    - Septic system improvement
    - Stormwater runoff control
    - Streambank and gully protection

Targeted geographic areas for each strategy type are provided in Section 3.1, additional information on the Core Team meetings and public engagement is provided in Section 3.2, and strategy types are expanded upon to include BMP actions in Section 3.3.

## 3.1 Targeting of geographic areas

Because of its remote and relatively undisturbed nature, the VRW has very few impairments and water quality concerns (MPCA, 2018b). Myrtle Lake, where aquatic recreation use is impaired by eutrophication parameters, is a restoration target. The majority of the watershed is meeting existing water quality standards and has a protection focus.

To prioritize areas for protection, criteria were developed by the Core Team. Prioritization for protection lies at the intersection of quality and risk. Therefore some of the criteria identify risks, such as declining water quality trends, and some of the criteria identify qualities, such as the presence of wild rice or the quality of a coldwater stream. Lakes and streams with many risks and qualities can be targeted with protection strategies.

The prioritization criteria were matched with applicable strategy types. These strategy types are explained further in Table 19. The criteria are also illustrated on individual summary maps, per strategy type. These maps are shown in Figure 16 through Figure 23. The intent is that the risks and qualities associated with the priority waterbodies drive the protection or restoration strategies that should be implemented to protect or restore water quality. For example, to target septic system improvement strategies, developed shoreline around lakes is highlighted in Figure 20. This targeting helps in the decision of where to implement improvements in the future. Criteria scores per waterbody can be found in Appendix B. Additional options for prioritization are shown in Table 20.

The WHAF was used in the Figures of this section to show geographical changes throughout the watershed. The WHAF provides health scores, which include an index of 0-100 that combine many available data sources. For example, the Aquatic Connectivity WHAF score is based on statewide data for dams, bridges, and culverts and scored on a state-wide scale. A score of 100 is the best score and 0 is the poorest score.

**Table 19. Strategy themes and the descriptions for prioritizing resources and geographic areas**

| Figure | Strategy Type | Description |
|---|---|---|
| Figure 15 | Drinking water protection | Drinking water protection incorporates both the risk of near surface pollution sensitivity of groundwater and the quality of Class 1 drinking water lakes. |
| Figure 16, Figure 17 | Forestland management | Forestland management is targeted around Class 2A coldwater lakes and streams and Class 1 drinking water lakes. Forestland risks include the percentage of young forest in a catchment, which can identify areas of disturbance including forest harvest, forest fires, and tree loss from insect damage and disease. Forest practices may include promotion of forest species and age class diversity as well as choosing tree species resilient to climate change.<br>Recent collaboration between the DNR and MPCA has also generated a proposed list of lake trout, whitefish, and cisco lakes. |
| Figure 18, Figure 12 | Habitat and aquatic connectivity management | Designated Coldwater Streams (2A) and aquatic connectivity scores from the WHAF can be used to prioritize stream reaches. Stream reaches with the highest densities of culverts, bridges, and dams potentially limiting the free flow of water produce a lower the aquatic connectivity score. In addition, protecting high value wild rice waters should be considered in planning efforts. Coldwater habitat is considered in the forestland and lake management strategies. |
| Figure 19, Figure 12 | Lake management | Lake Management is prioritized for water quality restoration and protection by risk criteria and quality criteria. This includes managing lakes for aquatic recreation use, drinking water, and coldwater habitat (cisco, whitefish and trout). 'High Risk' lakes are defined here as having scored 'Highest' in the LPSS or LBCA protection prioritization described in Section 2.5.3. In addition, protecting high value wild rice waters should also be considered in planning efforts. |
| Figure 1 | Recreational management | The VRW includes a small area of the BWCAW, VNP, the SNF, Lake Vermilion – Soudan Underground Mine State Park, and Bear Head Lake State Park. In addition, the watershed is a popular recreation destination including fishing, boating, canoeing, hiking, hunting, camping, and OHV trail use. Recreational management strategies can be targeted to areas with high recreational use such lakes and rivers, ATV trails, and campsites. Encouraging mindful recreation to reduce potential environmental impacts to land and water resources is recommended. |
| Figure 20 | Septic system improvement | Septic system improvement is targeted around waterbodies that are at risk of contamination from fecal bacteria (Class 1 drinking water lakes) and additional nutrient inputs that could boost algal productivity. |
| Figure 21, Figure 22 | Stormwater runoff control | The VRW does not have large urban areas, but there are developed areas focused around lakes and the towns of Orr and Tower. Because of this localized stormwater focus, the criteria used to target these practices include identifying waterbodies at risk to additional nutrient inputs and that have high disturbance or development density in their catchment. The HSPF modeling scenario for increased development can be used to target locations where improvements will best enhance water quality (Appendix C). Priority waterbodies from the Core Team include Elephant Lake, Pelican Lake, Crane Lake, Myrtle Lake, and Lake Vermilion. |
| Figure 23 | Streambank and gully protection | Streambank and gully protection is targeted around waterbodies that are impaired, altered, designated as coldwater, and a high priority for protection based on high quality biologic communities. |

**Figure 15. Geographical targeting for drinking water protection strategies**
Septic systems are also a drinking water risk and more detail about them can be viewed in Figure 20.

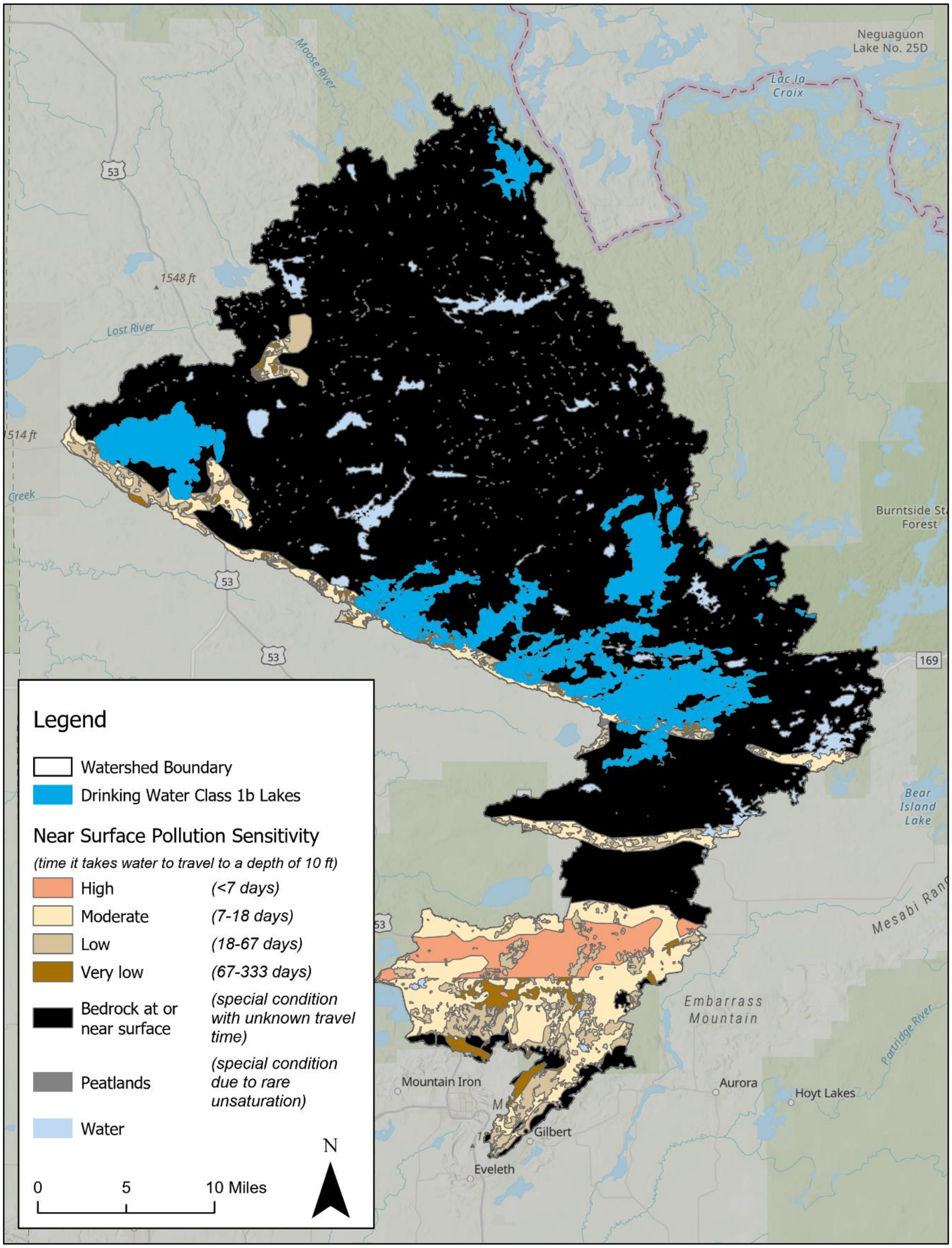


**Figure 16. Geographical targeting for forestland management strategies**

Maintaining forested watersheds at 75% or more healthy forest is protective of coldwater lakes and provides additional protections to all waters. Young forest (a result of harvest and tree loss through disease or fire) is not as effective at this protection. Watersheds close to 25% young forest with coldwater habitat should be evaluated for additional protection.

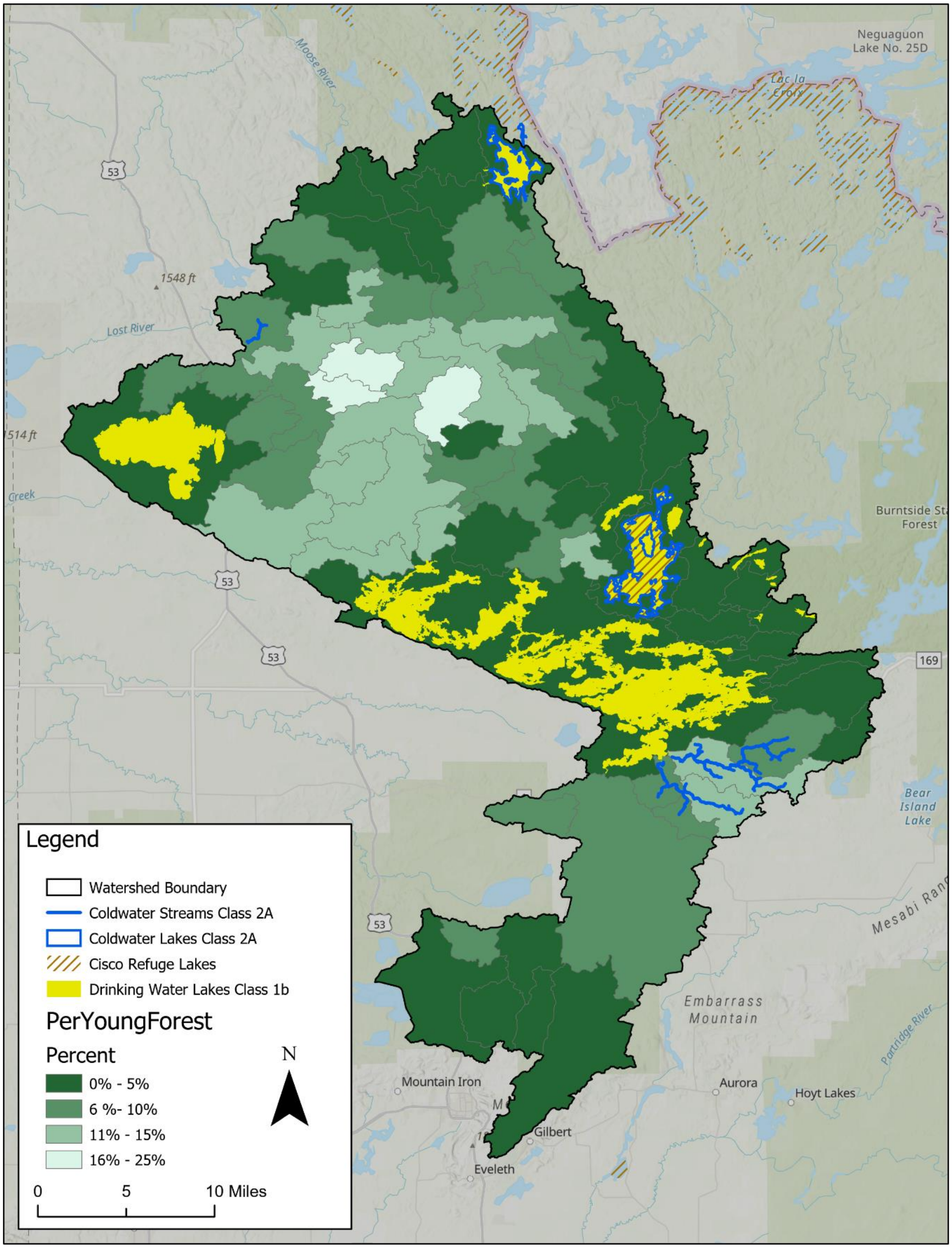


**Figure 17. Proposed coldwater lake designations**

A recent collaboration between the MCPA and DNR has identified lakes that support coldwater species (lake trout, lake whitefish, and cisco). Although this proposal is in draft form, this data can help identify coldwater fish habitat in need of protection (data provided by Will Bouchard, MPCA and Derek Bahr, DNR).

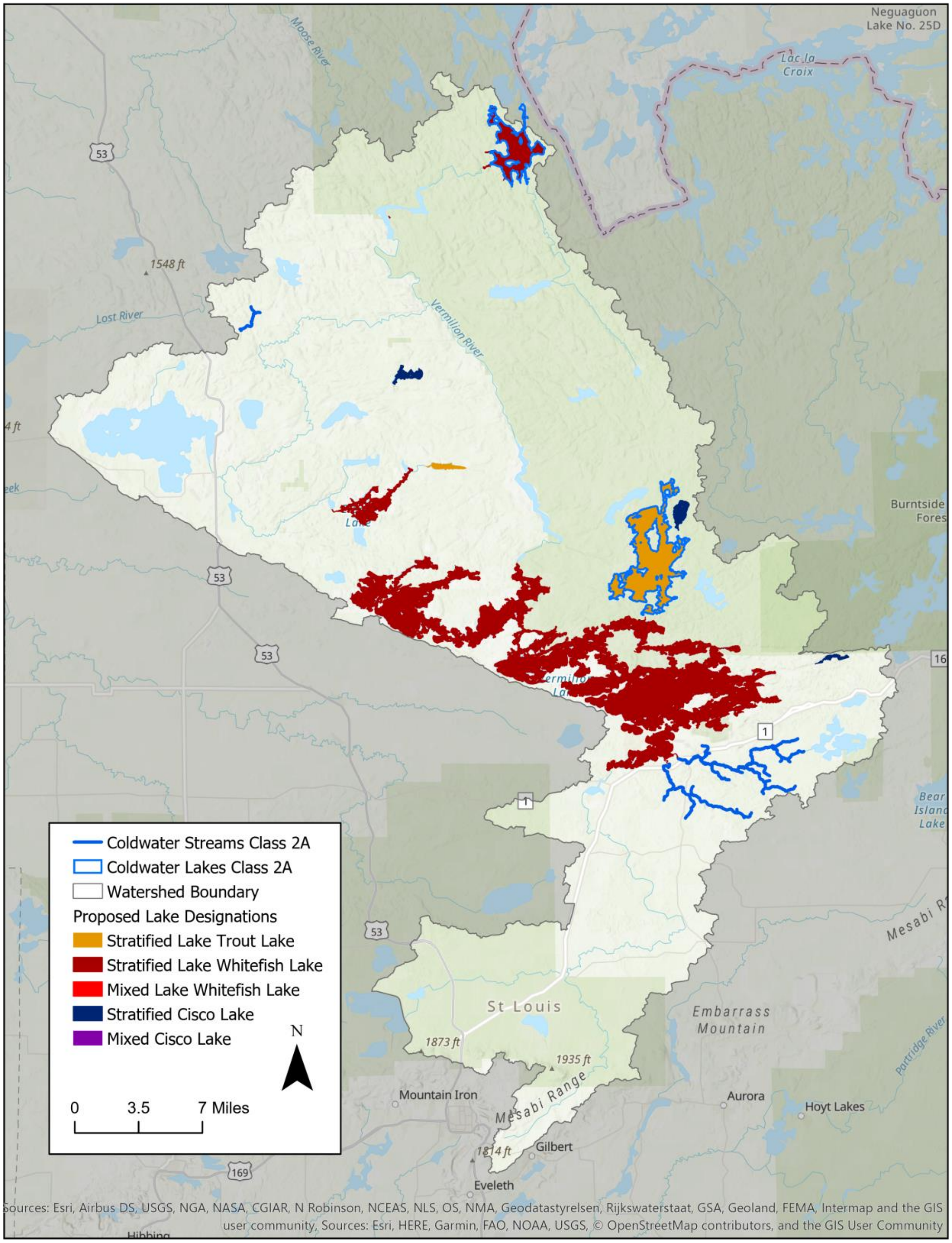


**Figure 18. Geographical targeting for stream connectivity and habitat management protection strategies**

The aquatic connectivity ecological heath score from the WHAF is based on the density of culverts, bridges and dams in each watershed. The higher the density of structures limiting the free flow of water, the lower the aquatic connectivity score.

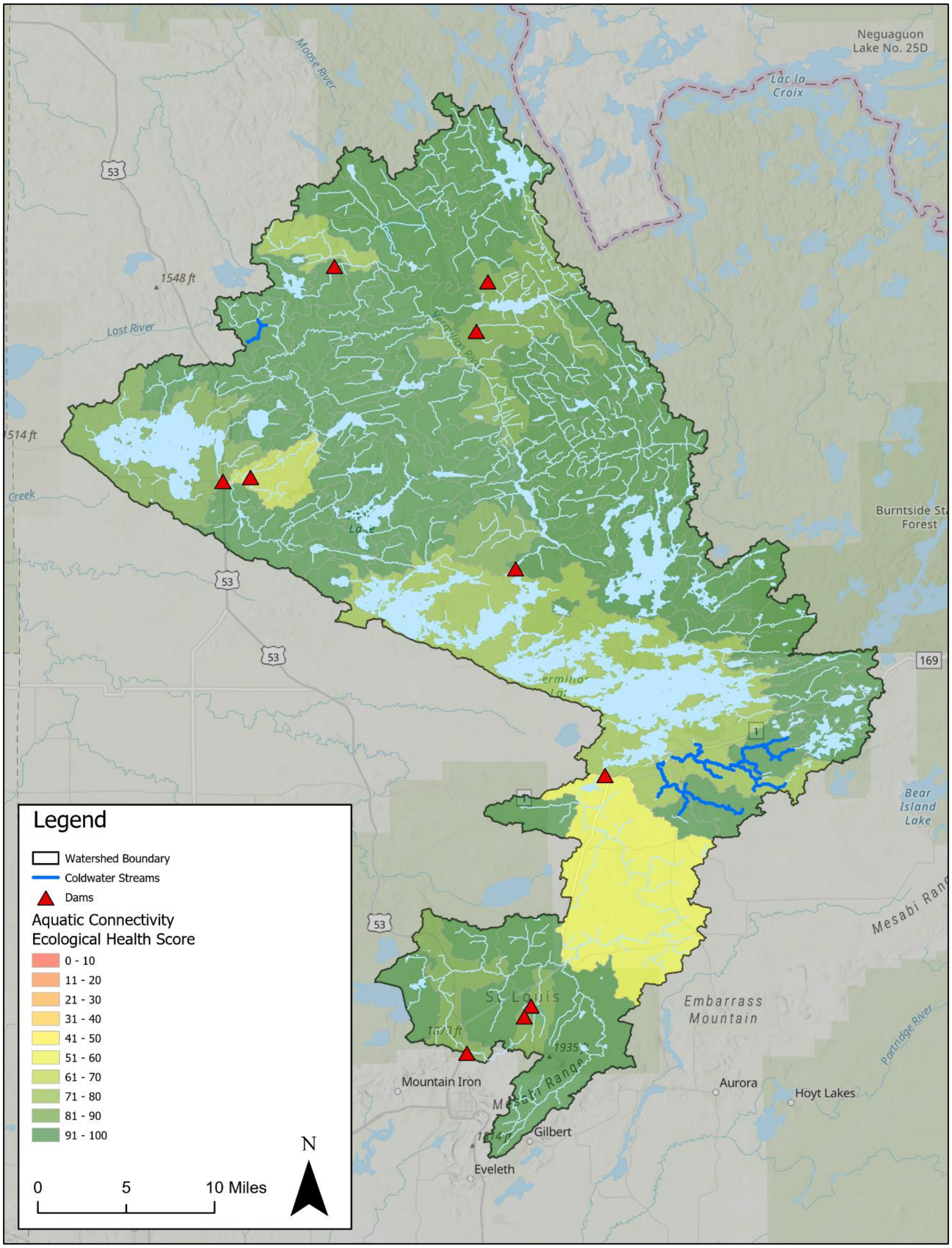


**Figure 19. Geographical targeting for lake management protection strategies**

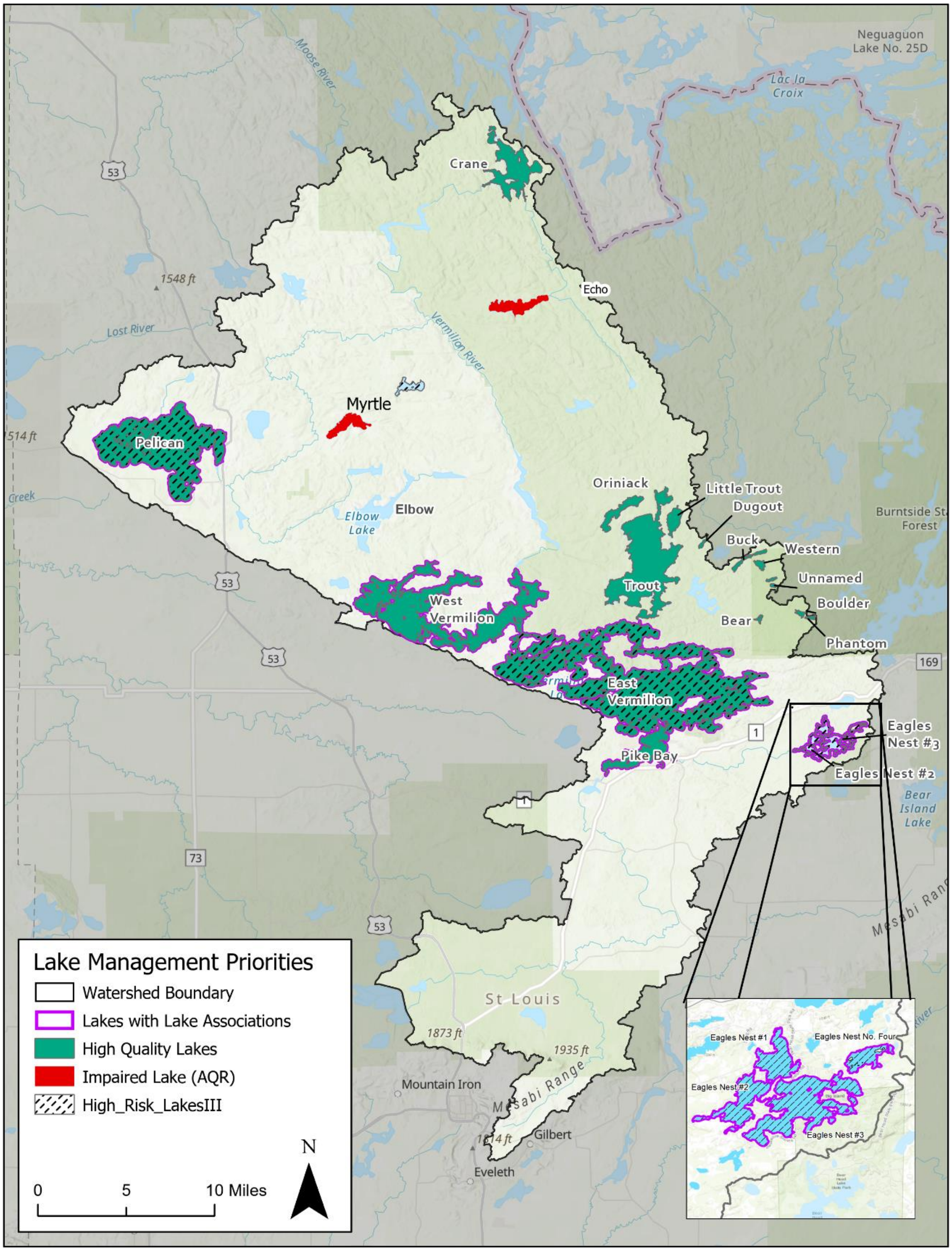


**Figure 20. Geographical targeting for septic and wastewater management protection strategies**

The septic systems health score from the WHAF provides a conservative estimate of actual septic system density. The metric score is based on well density per square km of land area in a catchment. Scores range from 0 to 100, with a density of 15.587 wells/km2 or greater = 0; no wells present = 100.

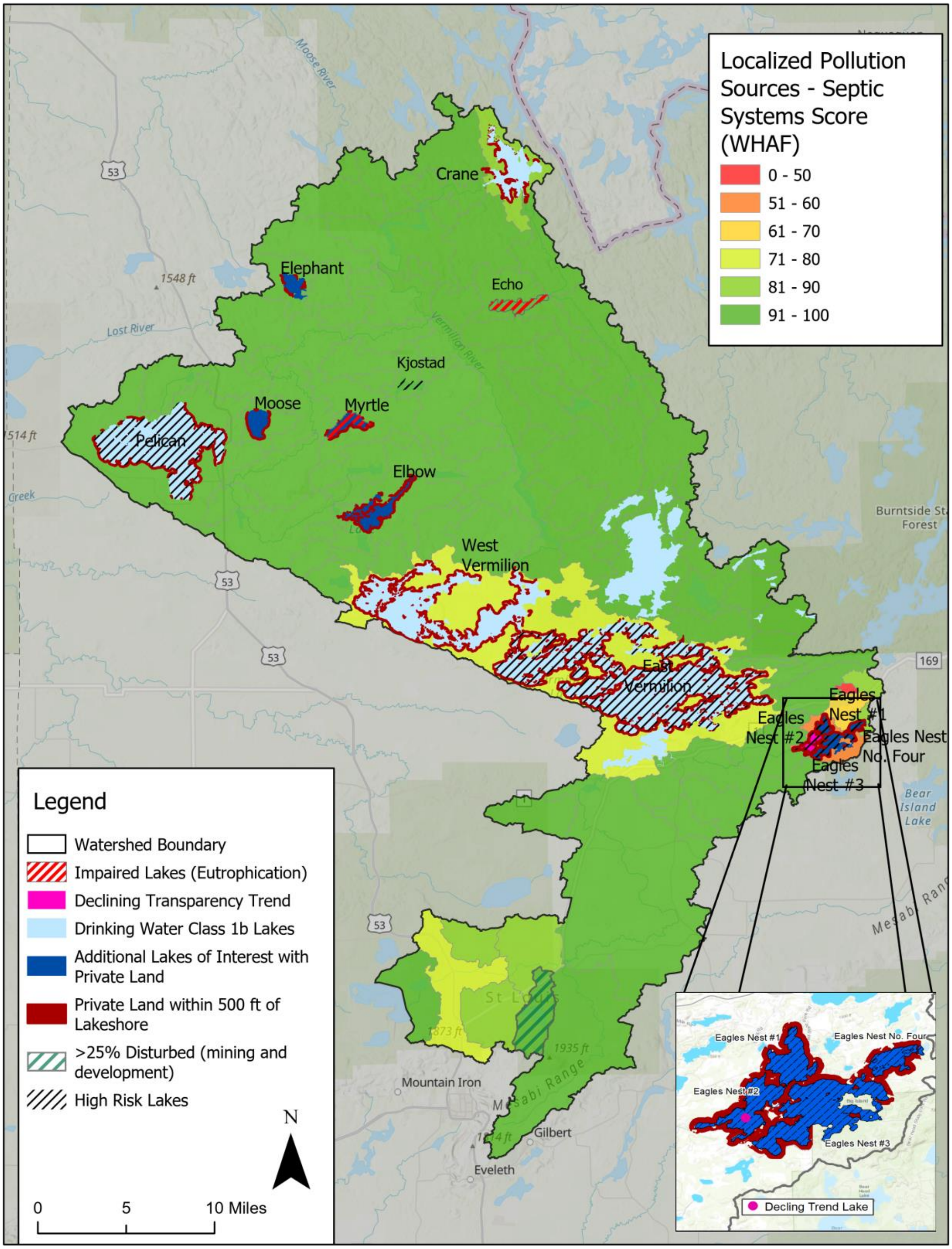


**Figure 21. Geographical targeting for stormwater runoff control protection strategies**

High risk lakes have been classified as 'Highest' phosphorus sensitivity and/or 'Highest' benefit to cost assessment.

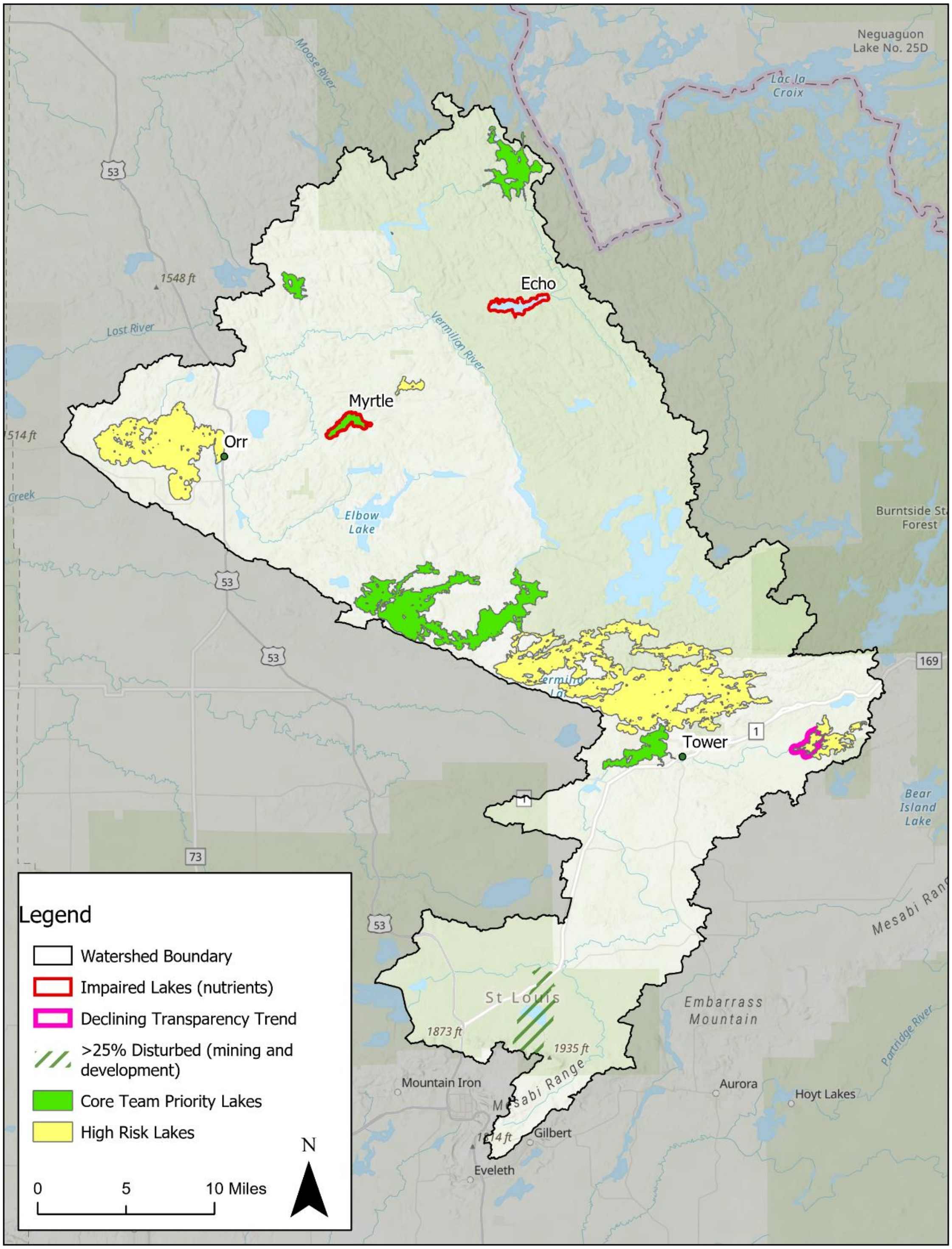


**Figure 22. Changes in annual average runoff volume per acre for the increased development scenario**

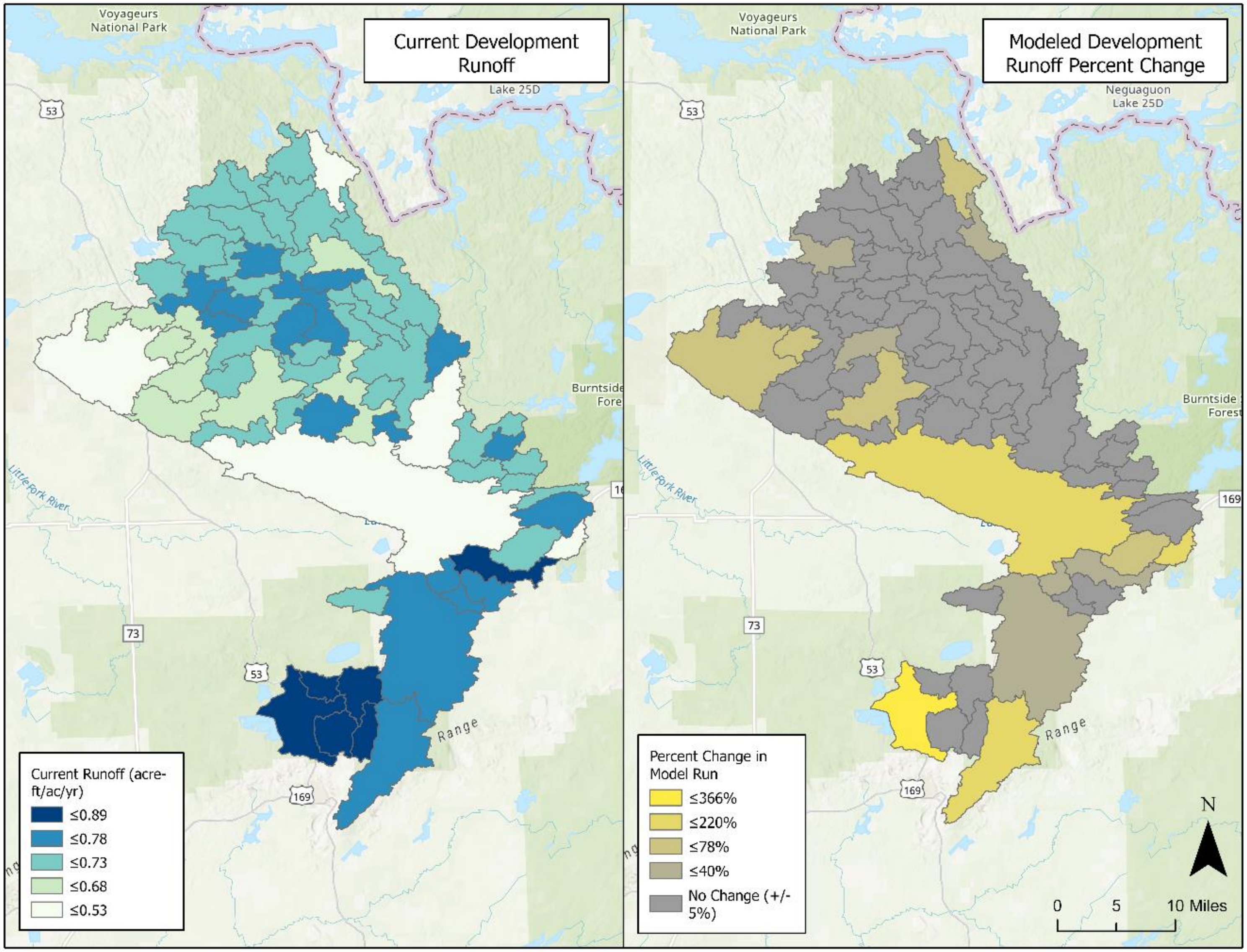


**Figure 23. Geographical targeting for streambank and gully protection strategies**

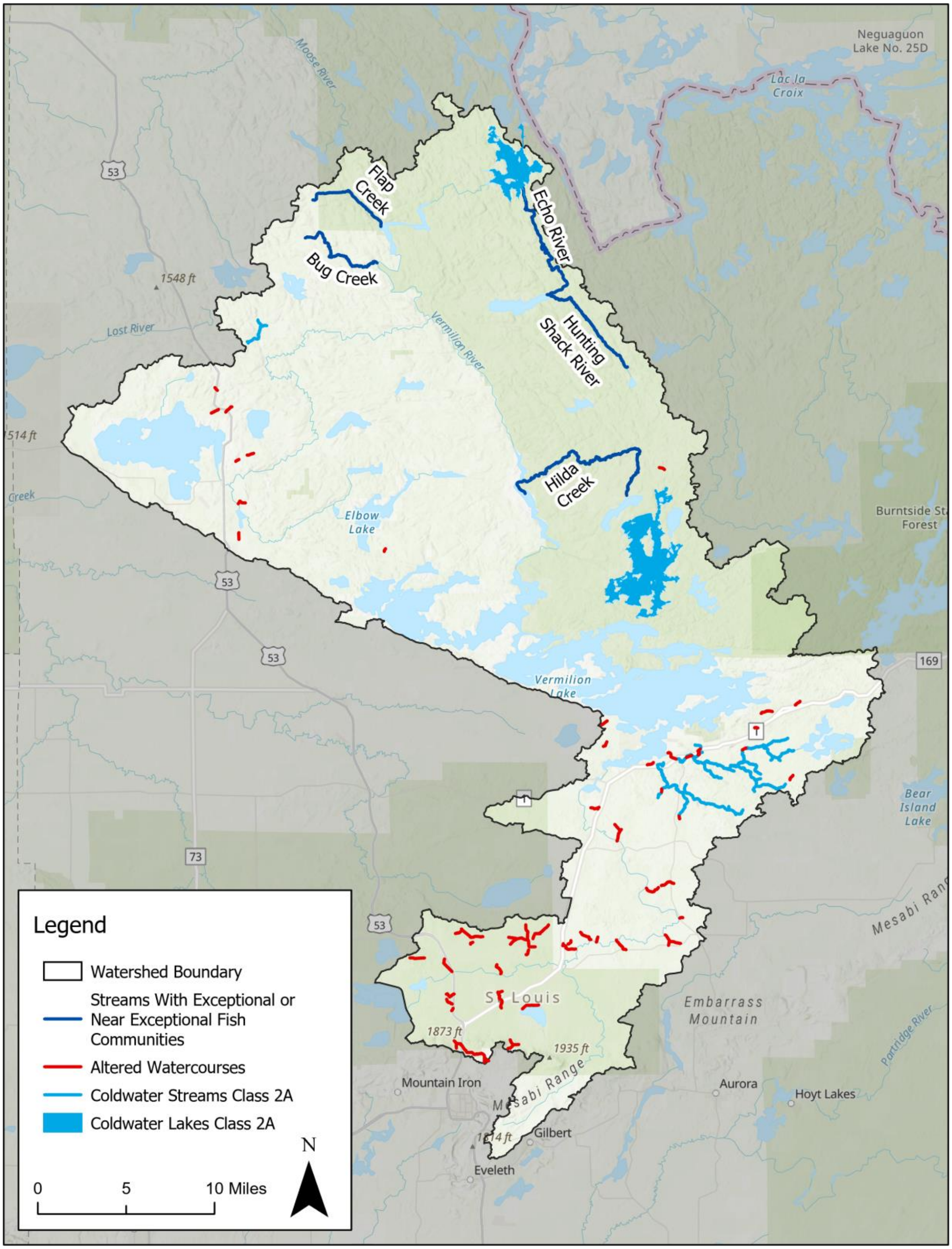


**Table 20. Additional tools that can be used for prioritization in the watershed**

| Tools | Description | How can the tool be used? | Notes | Link to information and data |
|---|---|---|---|---|
| **Board of Water and Soil Resources (BWSR) Landscape Resiliency Strategies** | These webpages describe strategies for integrated water resources management to address soil and water resource issues at the watershed scale and to increase landscape and hydrological resiliency in agricultural areas. | In addition to providing key strategies, the webpages provide links to planning programs and tools such as Stream Power Index, PTMApp, Nonpoint Priority Funding Plan, and local water management plans. | These data layers are available on the BWSR website.<br><br>The MPCA download link offers spatial data that can be used with GIS software to make maps or perform other geography-based functions. | Landscape Resiliency - Water Planning<br><br>Landscape Resiliency - Agricultural Landscapes<br><br>MPCA download |
| **Zonation** | This tool serves as a framework and software for large-scale spatial conservation prioritization, and a decision support tool for conservation planning. The tool incorporates values-based priorities to help identify areas important for protection and restoration. | Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity, in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells). | The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. (Paul Radomski, DNR, has expertise with this tool.) | Software |
| **Restorable wetland inventory** | A GIS data layer that shows potential wetland restoration sites across Minnesota. Created using a compound topographic index (CTI) (10-meter resolution) to identify areas of ponding, and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) soils with a soil drainage class of poorly drained or very poorly drained. | Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface and groundwater quality, and reducing flood damage risk. | The GIS data layer is available for viewing and download on the Minnesota 'Restorable Wetland Prioritization Tool' website. | Restorable Wetlands |

| Tools | Description | How can the tool be used? | Notes | Link to information and data |
|---|---|---|---|---|
| **National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD)** | The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams, and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations. | General mapping and analysis of surface-water systems. These data have been used for fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of this data set is to identify riparian buffers around rivers. | The layers are available on the USGS website. | USGS |
| **Light Detection and Ranging (LiDAR)** | Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure land surface elevation and features on the earth. | General mapping and analysis of elevation/terrain. These data have been used for erosion analysis, water storage and flow analysis, siting, and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments. | The layers are available on the Minnesota Geospatial Information Office (MGIO) website. | MGIO |
| **Hydrological Simulation Program – FORTRAN (HSPF) Model** | Simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. Typically used in large watersheds (greater than 100 square miles). | Incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. Addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches. | Local or other partners can work with MPCA HSPF modelers to evaluate at the watershed scale: 1) the efficacy of different kinds or adoption rates of BMPs, and 2) the effects of proposed or hypothetical land use changes. | EPA Models<br>USGS |

## 3.2 Public Participation

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful public participation. Public participation refers to education, outreach, marketing, training, technical assistance, and other methods of working with stakeholders to achieve water resource management goals.

### Public Meetings and Outreach

The WRAPS and TMDL processes for the VRW included three public stakeholder meetings that were held in Orr between 2017 and 2019. The meetings provided an overview of the MPCA's watershed approach, details on exceptional use waters and impairments within the watershed, WRAPS development, TMDL development, and SID. Two workshops on water resource management were also held in the VRW covering shoreline restoration and septic system maintenance. These workshops were well attended with 85 people total for both. A canoe trip on the Pike River was organized in partnership with Lake Vermilion-Soudan Underground Mine State Park and Vermilion Lake Association in August 2019. All the public meetings and events are summarized in Table 21.

**Table 21. Summary of VRW public meetings and outreach during the WRAPS process**

| Date | Location | Topic | Style | Target |
|---|---|---|---|---|
| 11/9/2017 | Virtual meeting | Impaired Waters Listing Public Notice | Presentation/Q&A | Public |
| 11/13/2017 | Orr | Watershed Approach Update | Presentation/Discussion/Open House | Public |
| 11/16/2017 | Ely | Watershed Approach Update | Presentation/Q&A/Open House | Public |
| 8/3/2018 | Orr | Myrtle Lake Impairment | Presentation/Discussion/Open House | Myrtle Lake property owners and local community |
| 9/2018 | Orr | Shoreline Workshop | Workshop | Public |
| 7/19/2019 | Virginia | Vermilion Lake Association | Discussion | Lake Vermilion Lakeshore owners |
| 7/24/2019 | Orr | Myrtle Lake Impairment | Presentation (guest)/Discussion/Open House | Myrtle Lake property owners and local community |
| 8/2019 | Pike River | Watershed and Monitoring | Canoe Trip | Public |
| 9/2019 | Orr | Septic Workshop | Workshop | Public |
| 9/8/2021 | Virtual Meeting | WRAPS and TMDL Reports Public Notice | Presentation/Q&A | Public |
| 10/8/2021 | Virtual Meeting | WRAPS and TMDL Reports Public Notice | Presentation/Q&A | Public |

In addition to meetings and workshops, the NSLSWCD also created numerous outreach tools, strengthened partnerships, and enhanced their online presence. These items are listed below.

- Completed a watershed section on the North Saint Louis SWCD Website that includes a story map of the watershed

- Created a communications network list for the VRW
- Created a public participation plan consistent with activities planned and implemented
- Produced several public participation tools listed below
  - Shoresmart packets for Vermilion Lake Association Members at an annual meeting
  - Pelican Lake Factsheet
  - Lake Vermilion Factsheet
  - Myrtle Lake Factsheet
  - "Life is better at the Lake" booklet
  - Three newsletter articles for the Vermilion Lake Association
  - Watersheds are Like a Giant Puzzle Pop-up banner
  - Bumble Bee Bliss Rain Garden Pop-up banner
- Partnerships were built and strengthened between North Saint Louis SWCD and the Vermilion Lake Association, the Pelican Lake Association, the Eagles Nest Lake Association, and Lake Vermilion-Soudan Underground Mine State Park
- A crowd-source hydrology site was prepped for engaging the public in data collection and water quality issues
- Promoted MPCA Citizen Lake and Stream Monitoring Program through meetings with community groups including:
  - Eagles Nest Lake Association Board Meeting in 2018
  - Pelican Lake Association Annual Meeting in 2018
  - Myrtle Lake Meeting in 2018
  - Vermilion Country School Programs in 2018
  - Quad Cities Rotary Meeting in 2019
  - Myrtle Lake Meeting in 2019

**Core Team Meetings**

A core team of regional resource professionals met 10 times to provide their professional judgement on water quality issues within the watershed and provide guidance to WRAPS and TMDL development. This core team included representatives from various entities:

- North Saint Louis Soil and Water Conservation District (SWCD)
- DNR
- 1854 Treaty Authority
- MPCA
- BWSR

- MDH
- USFS

A strategy development kickoff meeting was held in February 2020, at the MPCA office in Duluth. In March 2020, the COVID19 Pandemic began, and meetings were held remotely throughout the rest of the project. The Core Team meetings specific to WRAPS Report development are summarized in the list below.

1. February 3, 2020
    - Kickoff with Houston Engineering (HEI) and VRW WRAPS Overview
    - Vermilion River WMAR and SID Report Overview
    - Agency and Local Government lightning round of activities in the watershed
    - Protection Discussion in small groups about protection priorities in the watershed and data analyses needed
    - Restoration Discussion in small groups about protection priorities in the watershed and data analyses needed
2. April 16, 2020
    - Reviewed summarized priorities from the February meeting
    - Reviewed and discussed prioritization metrics for prioritizing waterbodies
3. May 5, 2020
    - HSPF Model Introduction
    - Discussed scenario options based on priorities identified at the earlier meetings and introduced an online survey to gather input on modeling scenarios and priority areas
4. August 8, 2020
    - Reviewed TMDL results
    - Reviewed strategy types and waterbody prioritization (Appendix B)
5. October 8, 2020
    - Reviewed draft strategies table
    - Reviewed draft WRAPS

### 3.2.1 Accomplishments and future plans

Many organizations in the VRW are involved in public participation and outreach, including SWCDs, Counties, Lake Associations, and civic organizations. Active lake associations in the area include the Vermilion Lake Association, Eagles Nest Lakes Association, and the Pelican Lake Association. These groups are actively involved in water quality monitoring, aquatic plant surveys, aquatic invasive species (AIS) monitoring and prevention, and education and outreach.

The Vermilion Lake Association is very active in fisheries management and AIS monitoring and prevention on Lake Vermilion. They are continually on the lookout for new AIS that could affect the lake. They have completed numerous risk assessments, annual aquatic vegetation surveys, public access boat inspections, water quality monitoring, and education and outreach activities. Their studies and reports can be found on their website: https://www.vermilionlakeassociation.org/.

North Saint Louis SWCD is currently pursuing opportunities to provide additional protection to Pelican Lake. This popular recreation destination was identified in 2017 as nearly impaired by eutrophication indicators. Pelican Lake is one of the most developed lakes in the watershed and is known to regularly experience nuisance algae blooms. Recent monitoring suggest an improving trend in water quality; however, it is unknown what mechanisms are driving this improvement or if the trend will continue. There is a local desire to protect this popular recreation destination from further degradation and foster enhanced water quality. The Section 319 Small Watersheds Focus Program might be a good fit for funding protection efforts within the Pelican lakeshed. This program focuses on supporting efforts of local units of government and citizens to address nonpoint sources of pollution.

In addition to the public participation activities listed in the sections above, the North Saint Louis SWCD also completed a survey of the local community values. Seven community capacity interviews were conducted through a collaborative project with the MPCA, Koochiching SWCD, and the Lake of the Wood Sustainability Foundation across the Rainy Basin in both Ontario, Canada, and Minnesota. The goals of the project were to:

- Determine the drivers and constraints for taking part in water protection/restoration among those who live in the watershed
- Better understand how involvement or interest in water protection/restoration initiatives varies across the binational watershed
- Inform strategies for policy-makers, resource professionals, and other local actors to best design and promote water resource programs that are ecologically, hydrologically, and socially relevant and responsive to changing conditions

Due to COVID-19 restrictions, the interviews were recorded by phone. The interviews have been delivered to the MPCA for transcription and analysis. At the local level, the district has gained insight into the local communities and concerns of residents and professionals in the watershed. Study findings will inform conservation program development, outreach, and planning into the future.

Currently, implementation in the watershed is led by local county water plans. In the future, the local entities in the VRW will embark on a 1W1P effort to unify implementation using the watershed boundary. This WRAPS will provide the data and analyses needed to prioritize and plan for future implementation.

Existing plans in the watershed include:

- St Louis County Comprehensive Water Management Plan, 2010-2020

### 3.2.2 Public notice for comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from August 30, 2021 through October 29, 2021. No comment letters were received as a result of the public comment period.

## 3.3 Restoration and protection strategies

The VRW is a relatively natural watershed and has very few impaired waterbodies in need of restoration (Table 11). As a result, protecting the tremendous natural resources will be extremely important in the VRW. This section outlines existing BMPs in the watershed, restoration strategies, and protection strategies.

### 3.3.1 Existing BMPS

Watershed partners have completed many projects to protect and improve the water quality in the VRW (Figure 24). A list of existing BMPs that have been implemented or installed within the VRW is available from the MPCA and is shown in Table 21. All BMPs were implemented to reduce nonpoint source pollution within the watershed.

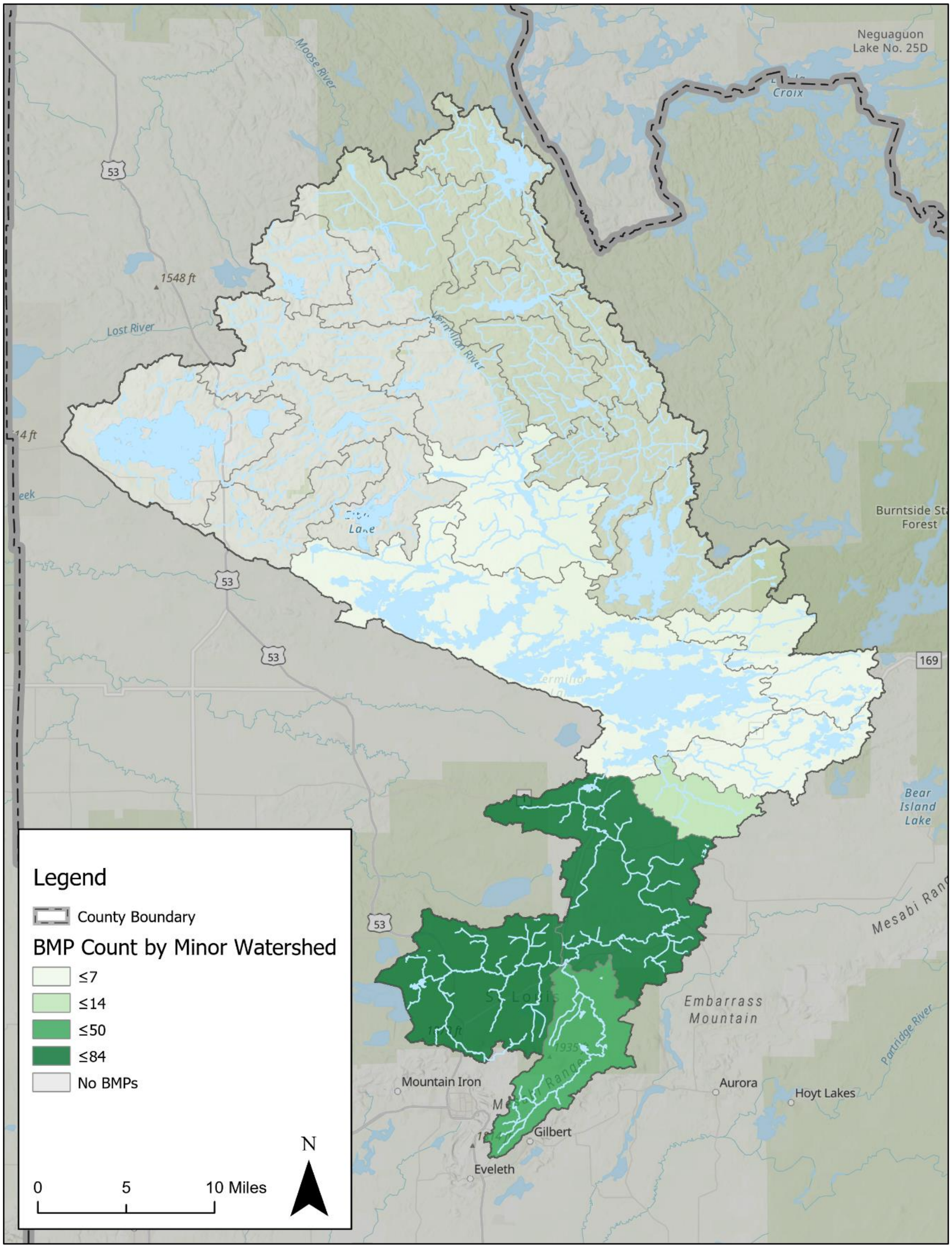



**Figure 24. Best Management Practices implemented in the VRW (MCPA Healthier Watersheds)**

**Table 22. BMPs installed in the Vermilion River Watershed between 2009 - 2019**
Source: MPCA Healthier Watersheds

| Strategy type | BMP | NRCS BMP code | Number of BMPs installed | Installed Amount (by unit) | Units |
|---|---|---|---|---|---|
| Habitat & stream connectivity | Tree/Shrub Establishment | 612 | 55 | 96 | Acres |
| Other | Integrated Pest Management (IPM) | 595 | 31 | 31 | Acres |
| Other | Tree/Shrub Site Preparation | 490 | 24 | 11 | Acres |
| Other | Early Successional Habitat Development/Management | 647 | 14 | 40 | Acres |
| Habitat & stream connectivity | Upland Wildlife Habitat Management | 645 | 12 | 5 | Acres |
| Septic System Improvements | Septic System Improvement | 126M | 10 | 10 | Count |
| Other | Forest Management Plan - Written | 106 | 9 | 11 | Count |
| Other | Prescribed Grazing | 528A | 9 | 168 | Acres |
| Other | Restoration and Management of Rare and Declining Habitats | 643 | 9 | 5 | Acres |
| Other | Forest Stand Improvement | 666 | 7 | 17 | Acres |
| Other | Hedgerow Planting | 422 | 4 | 5,630 | Feet |
| Other | Watering Facility | 614 | 4 | 15 | Count |
| Buffers and filters - field edge | Conservation Cover | 327 | 3 | 3 | Acres |
| Nutrient management (cropland) | Nutrient Management | 590 | 3 | 90 | Acres |
| Other | Seasonal High Tunnel System for Crops | 798 | 3 | 3,898 | Feet |
| Other | Well Decommissioning | 351 | 3 | 3 | Count |
| Pasture management | Access Control | 472 | 2 | 6 | Acres |
| Other | Fence | 382 | 2 | 8,276 | Feet |
| Other | Livestock Pipeline | 516 | 2 | 8,862 | Feet |
| Other | Tree/Shrub Pruning | 660 | 2 | 41 | Acres |
| Other | Waste Utilization | 633 | 2 | 42 | Acres |
| Other | Woody Residue Treatment | 384 | 2 | 12 | Acres |
| Other | Dam | 402 | 1 | 1 | Count |
| Other | Forest Trails and Landings | 655 | 1 | 940 | Feet |
| Other | Heavy Use Area Protection | 561 | 1 | 4,800 | Feet |
| Other | Mulching | 484 | 1 | 0 | Acres |
| Other | Waste Storage Facility | 313 | 1 | 1 | Count |
| Other | Windbreak/Shelterbelt Establishment | 380 | 1 | 1,400 | Feet |

## 3.3.2 Restoration Strategies

High levels of phosphorus resulting in excessive production of algae, as measured by Chl-*a*, are impairing Myrtle Lake. Elevated phosphorus affects the aquatic recreation designated use by fueling nuisance algae blooms. Myrtle Lake had the highest measured Chl-*a* concentration of any sampled lake in St. Louis County and a significant effort will be required to reduce the amount of TP in the lake.

Achieving water quality goals in Myrtle Lake will require reductions in nonpermitted sources. Load reductions are needed from watershed runoff, SSTS, and internal loading (Table 13), which are all nonpermitted sources. The implementation strategies presented below and in Table 23 address these priority sources.

**Watershed runoff:** Work with landowners to encourage the protection and maintenance of healthy vegetative buffers along the shoreline, and assist with restoration in areas that lack a protective vegetative buffer. Encourage landowners to use lawn management practices that minimize nutrient loading to the lake. Install rain gardens to enhance runoff infiltration and nutrient uptake. Protect healthy buffers on tributaries to the lake. Assess road crossings and roads adjacent to tributaries for erosion, pollutant runoff, and flow restriction, and work with road authorities and landowners to make improvements where appropriate.

**Septic system improvements:** Complete an updated inventory of SSTS in the Myrtle Lake Watershed, identifying total number of systems and compliance status. Prioritize SSTS according to compliance status; identify all "imminent threat to public health and safety" systems as high priority for maintenance and replacement. Work with private landowners to achieve compliance.

**Internal loading:** Consider addressing internal loading reductions in addition to external loading reductions. If external loading is not adequately addressed, in-lake treatment efforts will be short-lived. Costs of in-lake treatments such as alum (aluminum sulfate) should consider the longevity of effectiveness as recurring applications may be needed to sustain water quality. Treatments tend to be shorter lived on shallow lakes like Myrtle Lake, lasting from one to eleven years (MPCA 2020a). Treatment would likely need to occur across the entire lake basin as shown by the sediment core transects. Sediment core incubations and DO and temperature monitoring suggest internal loading is likely a major contributor to phosphorus loading, and internal load management may be required to achieve water quality goals.

**Fisheries management:** Collaborate with the DNR to verify that fish populations are not contributing to impairment through trophic interactions that enhance algae growth. Because other nutrient sources are also driving algae production, fisheries management should only be considered in the context of a comprehensive watershed management plan that includes nutrient reductions from other sources.

**Education and outreach:** Provide education and outreach for pollution reduction activities. Provide information or hands-on workshops to landowners on septic system maintenance, lawn care, and maintaining healthy vegetative shoreline buffers.As previously mentioned, 6 waterbodies in the VRW were recently added to Minnesota's 2020 Impaired Waters List due to exceedance of the sulfate standard of 10 mg/L, applicable to waters used for production of wild rice (Table 3). The MPCA is currently working to determine the next steps to address sulfate impairments and is committed to implementing the existing wild rice water quality standard to ensure these waters are restored. The MPCA plans to work with facilities to find innovative approaches to removing sulfate from wastewater discharges.

Some waterbodies are impaired or stressed due to natural conditions within the watershed. Restoration strategies have not been specifically assigned to these waterbodies.

With high quality waters identified throughout the watershed, most of the VRW's waters are not currently impaired and should be protected from potential degradation and future impairment. See Protection Strategies in Section 3.3.3.

**Table 23. Restoration strategies and actions proposed for the Vermilion River Watershed**

Estimated reductions were taken from the Vermilion River Watershed TMDL. Red cells indicate an impaired designation.

| Waterbody and location | | | Water quality | | | Strategies to achieve final water quality goal | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | EXAMPLE Best Management Practice (BMP) Reductions from TMDL | |
| **HUC-12 Sub-watershed** | **Waterbody (ID)** | **Location and upstream influence counties** | **Pollutant/ Stressor** | **Current WQ conditions** (conc. & load as related to impairment) | **Final WQ Goal** (% and load to reduce) | **Strategy type** | **BMP** [NRCS BMP code included if available] | **Estimated reduction (lbs/yr)** *as applicable* |
| Pelican River (0903000203-01) | Myrtle Lake (69-0749-00) | Saint Louis County | Phosphorus | Mean TP concentration 31 µg/L Mean Chl-*a* concentration 26 µg/L | 29% TP load reduction (433 lbs/yr) | Septic system improvements | Septic system improvement [126M] | 3 |
| | | | | | | Lake internal load management and *unidentified sources | Alum addition - In Lake [563M] | 368 |
| | | | | | | | Fish management [392M] (Evaluate trophic interactions) | |
| | | | | | | | *Update inventory of STSS in the lake watershed | |
| | | | | | | Buffers | Enhance and maintain vegetative buffer along areas of shoreline development | 62 |
| | | | | | | Buffers | Protect healthy buffers on tributaries | |
| | | | | | | Stormwater runoff control | Assess road/stream crossings for erosion, pollutant runoff, and flow restriction. | |
| | | | | | | Stormwater runoff control | Install rain gardens | |
| | | | | | | sum of above (= to final WQ goal) | | *433* |

## 3.3.3 Protection strategies

Protection strategies for the VRW were developed from data on existing BMPs (Section 3.3.1), existing reports, Core Team input, and the analyses conducted during the WRAPS process. Many protection strategies apply to all waterbodies in the VRW; these are identified in Table 24 (labeled "All" under HUC-12 Aggregated Watersheds a Waterbody ID). The water quality goal for unimpaired lakes could range from maintaining current water quality in high-quality protection lakes to reducing phosphorus loading by 5% in at-risk lakes as provided in the LPSS/LBCA dataset, shown in Figure 20. Current phosphorus concentrations, target concentrations, and phosphorus reduction goals are provided per lake in Table 15. Current assessment status for streams is provided in Table 4, and stream data related to TALU, biological impairments, riparian risk, watershed risk, and current protection level are provided in Table 14.

The strategies in Table 24 are organized per strategy type:

- Drinking water protection;
- Forestland management;
- Habitat and stream connectivity management;
- Lake management;
- Recreational management;
- Septic system improvement;
- Stormwater runoff control; and
- Streambank and gully protection.

Priority lakes identified by the Core Team are further analyzed in Appendix D with individual lake source assessments. These source assessments quantify phosphorus loading from different land uses within the lakes' direct drainage area using HSPF-SAM and target parcels for BMPs such as rain gardens and permanent protection strategies such as conservation easements. It is important to note that these are modeled results that should be used in combination with best professional judgement.

The strategies table (Table 24) contains strategies that directly affect the quality of the waterbody, but there are many other strategies, such as education and outreach, that lay the groundwork for water quality improvement. Those items are summarized below.

### Lake management outreach strategies

- Develop lake management plans for individual lakes
- Encourage formation and organization of lake associations
- Conduct outreach to lakeshore landowners about BMPs
- Coordinate education and outreach messages and delivery methods with and between federal and state agencies, county and local governments, lake associations, tribal governments and agencies, and other groups

Climate protection co-benefit of strategies and adaptation BMPsMany agricultural BMPs which reduce the load of nutrients and sediment to receiving waters also act to decrease emissions of greenhouse gases (GHGs) to the air. Agriculture is the third largest emitting sector of GHGs in Minnesota. Important sources of GHGs from crop production include the application of manure and nitrogen fertilizer to cropland, soil organic carbon oxidation resulting from cropland tillage, and carbon dioxide ($CO_2$) emissions from fossil fuel used to power agricultural machinery or in the production of agricultural chemicals. Reduction in the application of nitrogen to cropland through optimized fertilizer application rates, timing, and placement is a source reduction strategy; while conservation cover, riparian buffers, vegetative filter strips, field borders, and cover crops reduce GHG emissions as compared to cropland with conventional tillage.

The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has developed a ranking tool for cropland BMPs that can be used by local units of government to consider ancillary GHG effects when selecting BMPs for nutrient and sediment control. Practices with a high potential for GHG avoidance include: conservation cover, forage and biomass planting, no-till and strip-till tillage, multi-story cropping, nutrient management, silvopasture establishment, other tree and shrub establishment, and shelterbelt establishment. Practices with a medium-high potential to mitigate GHG emissions include: contour buffer strips, riparian forest buffers, vegetative buffers and shelterbelt renovation. A longer, more detailed assessment of cropland BMP effects on GHG emission can be found at NRCS, *et al*., "COMET-Planner: Carbon and Greenhouse Gas Evaluation for NRDC Conservation Practice Planning http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf. Although agricultural use is minimal in this watershed there are locations where agriculture related BMPs such as riparian buffers and conversion of open lands to forest can reduce GHG emissions in addition to providing water quality benefits. Additionally, many partner organizations have guidance in place for climate adaptation strategies.

A study on Wisconsin lakes offers some adaptation strategies for northern lakes facing climate change that can also apply in the VRW (Magee et al., 2019). These include:

- Water levels: Perform lake level monitoring and education to adjust user expectations from static to fluctuating water levels. Also enact policies that protect the land near lakes, which could minimize property damage during high water.
- Water quality: Traditional strategies such as BMPs may not be enough to reduce nutrients and runoff in the watershed. Adaptive strategies such as increased restrictions on watershed land use and increased protection may be necessary.
- Invasive species: Controlling AIS vectors and pathways through policy changes and pathway-specific prevention approaches could help reduce the new invasive species entering the area.
- Fisheries: Protecting forest cover around coldwater fisheries can minimize the impact of climate change (Jacobson et al., 2010).

Subsequent local planning steps (i.e., 1W1P) will describe more specific planning elements such as intended projects and efforts, goals, resource needs for each project, who will be involved, and project timeframes.

**Table 24. Protection strategies table for the VRW**

| Waterbody and location | | Water quality | | | Strategies to achieve final water quality goal | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | EXAMPLE Best Management Practice (BMP) Scenario | | |
| **HUC-12 Aggregated Watersheds** | **Waterbody (ID)** | **Pollutant/ Stressor** | **Current WQ conditions** | **WQ Goal** (% and load to reduce) | **Strategy type** | **BMP** [NRCS BMP code included if available] | **Amount** | **Estimated reduction** *as applicable* |
| All | All | Sediment, nutrients (phosphorus and nitrogen), invasive species, forest loss, climate change | Table 4, Table 5, Table 14, Table 15 | 5% phosphorus reduction in at-risk lakes d. Table 15) | Forestland management | Maintain existing forest cover - prevent new losses and maintain at least 75% forested watersheds surrounding coldwater lakes and streams | - | - |
| | | | | | | Riparian zone forestland management – maintain forested riparian zones and convert short lived species to conifers and other long lived species to promote diverse mature forests, as applicable | - | - |
| | | | | | | Terrestrial invasive species prevention and mitigation | - | - |
| | | | | | | Prescribed burning | - | - |
| | | | | | | Forestland management and improvement [147M, 490, 666] | - | - |
| | | | | | | Roads and trails improvement [655] | - | - |
| | | | | | | Implement DNR's Private Managed Forest Program and encourage enrollment of private land in 2c Managed Forest Lands or SFIA | - | - |
| | | | | | | Forest erosion control on harvested lands | - | - |
| | | | | | | Encourage easements and practices that reduce parcelization | | |
| | | | | | | Prepare and adjust for pests, invasive species, and other effects of climate change by considering underplanting and replacement species | - | - |
| | | Fish passage, invasive species, sediment, temperature | | | Habitat and stream connectivity management | Protection of vulnerable ecosystems & habitats. Includes protection of coldwater streams and lakes and wild rice waters through easements, forestland management, education, and water level management | - | - |
| | | | | | | Build upon current culvert surveys | - | - |
| | | | | | | Protect the existing connections stream channels have to their floodplains | - | - |
| | | | | | | Modify/replace culverts & fish passage barriers | - | - |
| | | | | | | Riparian tree planting to improve shading [390, 612] | - | - |
| | | Sediment, phosphorus, altered hydrology | | | Streambank and gully protection | Restore riffle substrate | - | - |
| | | | | | | Stream channel stabilization | - | - |
| | | | | | | Maintain riparian herbaceous cover and improve quality of existing cover [390] | - | - |
| | | Trash, invasive species, sediment/TSS | | | Recreational management | Develop long-term solution to littering and trash collection near and in recreational areas | - | - |
| | | | | | | Manage ATV trail impacts | - | - |
| | | | | | | Promote care and stewardship of trails and wilderness areas | - | - |
| | | Sediment/TSS phosphorus, chloride | | | Stormwater runoff controls | Outreach to promote smart salting practices, encourage rain barrels, and increase awareness of stormwater impacts to water quality | | |
| | | | | | | Enhanced road salt management | - | - |

| Waterbody and location | | Water quality | | | Strategies to achieve final water quality goal | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | EXAMPLE Best Management Practice (BMP) Scenario | | |
| **HUC-12 Aggregated Watersheds** | **Waterbody (ID)** | **Pollutant/ Stressor** | **Current WQ conditions** | **WQ Goal** (% and load to reduce) | **Strategy type** | **BMP** [NRCS BMP code included if available] | **Amount** | **Estimated reduction** *as applicable* |
| | | | | | | Implement stormwater BMPs to reduce runoff from built structures | - | - |
| | | | | | | Bioretention/biofiltration/rain garden (urban) [567M, 712M] | - | - |
| | | | | | | Permeable surfaces and pavements | - | - |
| | | Nutrients (phosphorus and nitrogen), bacteria/*E. coli* | | | Septic system improvements | Septic system maintenance and improvement [126M] | - | - |
| | | | | | | Continue to enforce septic system ordinances | - | - |
| | | | | | | Increase inspections and conduct inventory to support prioritization | - | - |
| | | Phosphorus, sediment, temperature, invasive species | | | Lake management | Enforce shoreland management regulations as property develops and redevelops, and discourage variances that increase shoreland run-off/reduce riparian vegetation. Encourage voluntary actions to mitigate the impacts of past development | - | - |
| | | | | | | Implement DNR Fisheries Management Plans | - | - |
| | | | | | | Proactively protect beneficial uses by taking positive actions to halt or minimize the spread of aquatic invasive species | - | - |
| | | | | | | Continue to monitor water quality and evaluate water quality trends | - | - |
| | | | | | | Encourage formation of organization and lake associations | - | - |
| | | | | | | Aquatic Invasive Species management | - | - |
| | | | | | | Maintenance of adequate water levels during low flow periods | - | - |
| | | | | | | Protect and restore wild rice waters through ordinances, easements, water level management, and education | - | - |
| | | Sediment/TSS Invasive species, bacteria/*E. coli* | Table 4, Table 5, Table 14, Table 15 | 5% phosphorus reduction in at-risk lakes d. Table 15) | Recreational management | Develop long-term solution to littering and trash collection near and in recreational areas | - | - |
| | | | | | | Campsite stabilizations | - | - |
| | | | | | | Promote care and stewardship of trails and wilderness | - | - |
| | | | | | | Improve signage and education about aquatic hitchhikers on watercraft entering and exiting the BWCA and VNP | - | - |
| | | | | | | Stabilization of portage trails | - | - |
| | | | | | | Update and modernize the required video before entering the BWCA | - | - |

# 4. Monitoring plan

Continued monitoring is critical for determining if progress has been made in restoration and protection and for determining the effects of future impacts on water quality. This section describes existing and recommended future monitoring activities in the watershed.

As part of the state's watershed approach, the MPCA conducts IWM at the HUC-8 watershed scale approximately every 10 years. This two-year intensive monitoring program of lakes and streams informs assessments of water quality throughout the watershed and identifies impaired waters. The next round of IWM for the VRW will start in 2026.

In addition, the MPCA coordinates two programs aimed at encouraging long term citizen surface water monitoring: the CLMP and the Citizen Stream Monitoring Program (CSMP). This provides long-term data needed to help evaluate current status and trends. Citizen monitoring is especially effective at helping to track water quality changes that occur in the years between intensive monitoring years.

The MPCA's Watershed Pollutant Load Monitoring Network (WPLMN) measures and compares pollutant load data from Minnesota's rivers and streams and tracks water quality trends. Two WPLMN sites are located on the Vermilion River, bracketing the entry of the Pelican River downstream from Myrtle Lake. These long term sites are expected to be monitored yearly throughout the monitoring season and can help with future calibration of the HSPF model for the VRW (RESPEC 2016, MPCA 2020b)

Monitoring in the VRW is conducted by many different entities, including state agencies such as the MPCA, DNR, and MDH, along with counties, SWCDs, lake associations, 1854 Treaty Authority, and USFS.

DNR Fisheries staff regularly collect data in support of fishery management. Some lake associations, such as Lake Vermilion, have been collecting water quality condition data for over 10 years.

Some specialized monitoring has been conducted by local groups in the VRW including:

- Sulfate monitoring in the Sand River and Sandy and Little Sandy Lakes (1854 Treaty Authority, 2021);
- Sentinel Lakes monitoring in Echo and Elephant lakes (DNR);
- AIS surveys and monitoring;
- Aquatic plant surveys in Lake Vermilion; and
- Calcium monitoring in Lake Vermilion to determine susceptibility to zebra mussel infestation.

It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction and protection. Watershed partners already have good momentum with BMPs already implemented (Figure 24 and Table 22) and there are many existing programs for protection such as the Sustainable Forest Incentive Act. Barriers that could slow future progress include landowner willingness to implement practices, limitations of face-to-face contact with landowners due to the COVID-19 Pandemic, and challenging fixes (e.g., stream restoration, culvert and dam replacement, invasive species, and issues larger than the scope of the watershed. Conversely, there may be faster progress for some impaired waters, especially where high-impact fixes are slated to occur.

As implementation occurs in the watershed, monitoring can track the response in waterbodies. In addition to the continuing monitoring occurring by MPCA, DNR, and local organizations such as SWCDs and Lake Associations, possible monitoring and research recommendations include:

- Monitoring the potential impact of climate change including:
    - Streamflow and stream temperature
    - DO and temperature profiles in coldwater lakes
- Expanded culvert inventories to identify priority areas limiting fish passage and exacerbating water quality degradation
- Monitoring for the prevention of AIS
- Updated LiDAR data to better support desktop analysis
- Stormwater monitoring and analysis near towns to better understand stormwater impacts within the watershed
- Water quality monitoring in the Pelican Lake lakeshed to better delineate internal loading rates and ensure water quality continues to improve
- Continued citizen monitoring of lakes and streams within the watershed including high priority lakes such as Pelican, Vermilion, Myrtle, and Eagles Nest Chain
- Fill additional data gaps in the Myrtle Lake Watershed to better understand the role of internal loading such as:
    - Flow and load monitoring of tributaries and outlet to quantify watershed loads and improve the phosphorus mass balance
    - Additional high frequency buoy monitoring to better understand the link between climate/meteorological conditions and summer stratification and internal loading in Myrtle Lake
    - Evaluate relationship between high panfish densities, walleye stocking practices, zooplankton assemblages, and water quality to determine if trophic interactions are contributing to high Chl-*a* concentrations

# 5. References and further information

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Minnesota Pollution Control Agency (MPCA). 2015a. *Prioritization Plan for Minnesota 303(d) Listings to Total Maximum Daily Loads.* 520 Lafayette Road North Saint Paul, MN 55155. Document#: wq-iw1-54. September 2015. https://www.pca.state.mn.us/sites/default/files/wq-iw1-54.pdf

Minnesota Pollution Control Agency (MPCA). 2015b. *Proposed Approach for Minnesota's Sulfate Standard to Protect Wild Rice*. 520 Lafayette Road North Saint Paul, MN 55155. Document #wq-s6-43l. March 2015. https://www.pca.state.mn.us/sites/default/files/wq-s6-43l.pdf

Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, Minnesota Board of Soil and Water Resources (MPCA). 2018a. *Protection and prioritization: Tools available to help prioritize waters for protection efforts.* https://www.pca.state.mn.us/sites/default/files/wq-ws1-29.pdf

Minnesota Pollution Control Agency (MPCA). 2021. *Vermilion River Watershed Total Maximum Daily Load.* Document #wq-iw10-17b. August 2021.

Minnesota Pollution Control Agency (MPCA). 2018b. *Vermilion River Watershed Monitoring and Assessment Report*. 520 Lafayette Road North Saint Paul, MN 55155. July 2018. Document number: wq-ws3-09030002b. https://www.pca.state.mn.us/sites/default/files/wq-ws3-09030002b.pdf

Minnesota Pollution Control Agency (MPCA). 2019. *Vermilion Stressor Identification Report.* 520 Lafayette Road North Saint Paul, MN 55155. April 2019. Document number: wq-ws5-09030002a. https://www.pca.state.mn.us/sites/default/files/wq-ws5-09030002a.pdf

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## Additional Vermilion River Watershed resources

During the WRAPS process, a bibliography of studies and data within the watershed was collected from the Core Team and is included in **Appendix A**.

# 6. Appendices

A Vermilion River Watershed Bibliography

B Vermilion River Watershed Protection Prioritization Criteria

C Vermilion River Watershed HSPF Model – Scenario Modeling Technical Memorandum

D Vermilion River Watershed Lake Source Assessments for Protection – Technical Memorandum

# Appendix A: Vermilion Watershed Bibliography

The purpose of this table is to provide a comprehensive bibliography of all watershed and water quality related studies and projects previously completed in the VRW.

**Table 1: Vermilion Watershed Literature**

| Authors | Year | Title | Agency/Organization | Link or Journal (if available) | Hydrology/Altered Hydrology | Sediment | Water Quality | Watershed Modeling | In Stream Hydraulic Modeling | Flooding | Aquatic Invasive Species | Watershed Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Anderson, J.; Heiskary, S.** | 2000 | Lake Assessment Program – Lake Vermilion | MPCA | https://www.vermilionlakeassociation.org/pdf/MPCA_2000_%20LAP_%2069-0378.pdf | | | X | X | | | | X |
| **Anderson, J.; Heiskary, S.** | 2008 | Citizen Lake Monitoring Program: Advancing Volunteer Lake Monitoring on Lake Vermilion | MPCA | https://www.pca.state.mn.us/sites/default/files/wq-clmp69-0378.pdf | X | X | X | X | | | | X |
| **Anderson, P.; et. al.** | 2000 | Minnesota State and Regional Government Review of Internal Phosphorus Load Control: An important option in the lake management toolbox | MPCA, DNR, BWSR, Metropolitan Council | https://www.pca.state.mn.us/sites/default/files/wq-s1-98.pdf | | | X | | | | | |
| **Bartosiewicz. M, et. al.** | 2019 | Hot tops, cold bottoms: Synergistic climate warming and shielding effects increase carbon burial in lakes | University of Basel, University of Montreal | *Limnology and Oceanography, 4:* 132– 144 https://aslopubs.onlinelibrary.wiley.com/doi/full/10.1002/lol2.10117 | X | | X | | | | | |

| Authors | Year | Title | Agency/Organization | Link or Journal (if available) | Hydrology/Altered Hydrology | Sediment | Water Quality | Watershed Modeling | In Stream Hydraulic Modeling | Flooding | Aquatic Invasive Species | Watershed Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Borkholder, B.; et al.** | 2020 | Spring Adult and Fall Juvenile Walleye Population Surveys within the 1854 Ceded Territory of Minnesota, 2019 | Fond du Lac Resource Management Division and 1854 Treaty Authority | http://www.fdlrez.com/%5C/RM/fisheries/2019WalleyeReport.pdf | | | X | | | | | |
| **Corman, J.R.; et al.** | 2018 | Nitrogen and Phosphorus Loads to Temperate Seepage Lakes Associated with Allochthonous Dissolved Organic Carbon Loads | University of Wisconsin-Madison | *AGU Geophysical Research Letters, 45,* 5481–5490. https://doi.org/10.1029/2018GL077219 | X | | X | | | | | |
| **Edlund, M.B.; Ramstack Hobbs, J. M.; Heathcote, A. J.** | 2019 | A Paleolimnological Study of Myrtle Lake, St. Louis Co., Minnesota. | St. Croix Watershed Research Station, Science Museum of Minnesota | https://www.pca.state.mn.us/sites/default/files/wq-ws1-36.pdf | X | X | X | | | | | X |
| **Hauck, Emelia** | 2016 | Aquatic Vegetation Survey | RMB Environmental Laboratories, Inc | https://www.vermilionlakeassociation.org/pdf/rmb-vermilion-vegetation-report-2016.pdf | | | | | | | X | |
| **Hauck, Emelia** | 2017 | Aquatic Vegetation Survey | RMB Environmental Laboratories, Inc | https://www.vermilionlakeassociation.org/pdf/Vermilion_vegetation_Report_3.pdf | | | | | | | X | |

| Authors | Year | Title | Agency/Organization | Link or Journal (if available) | Hydrology/Altered Hydrology | Sediment | Water Quality | Watershed Modeling | In Stream Hydraulic Modeling | Flooding | Aquatic Invasive Species | Watershed Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Henneck, Jerald; Ruzycki Elaine; Bernhardt, Beth** | 2017 | East Two River calcium load study: Headwaters to Lake Vermilion | NRRI and Lake Vermilion Association | https://www.vermilionlakeassociation.org/wp-content/uploads/2017/02/2016CalciumStudyonEastTwoRiver-Updated2-27-17.pdf | | | | | | | X | X |
| **Heiskary, S; et. al.** | 2012 | Sentinel Lake Assessment Report Echo Lake (69-0615) | MPCA, DNR | https://wrl.mnpals.net/islandora/object/WRLrepository%3A2746 | X | | X | | | | | X |
| **Heiskary, S; et. al.** | 2012 | Sentinel Lake Assessment Report Elephant Lake (69-0810) | MPCA, DNR | https://wrl.mnpals.net/islandora/object/WRLrepository%3A2918 | X | | X | | | | | X |
| **Jacobson, P.C.; Stefan, H.G.; Pereira, D.L** | 2002 | Coldwater fish oxythermal habitat in Minnesota lakes: influence of total phosphorus, July air temperature, and relative depth | DNR and U of M, Saint Anthony Falls Hydraulic Laboratory | *Journal of Fish and Aquatic Science, 67*, 2002–2013 | | | X | X | | | | |
| **Kallemeyn, L.W.; Holmberg, K.L.; Perry, J. A.; Odde, B.Y.** | 2003 | Aquatic Synthesis for Voyageurs National Park | USGS/USDI | https://www.cerc.usgs.gov/pubs/center/pdfdocs/ITR2003-0001.pdf | X | | X | X | X | | | X |
| **Karsten Klimek, et. al.** | 2018 | Vermilion River Watershed Monitoring and Assessment Report | MPCA | https://www.pca.state.mn.us/sites/default/files/wq-ws3-09030002b.pdf | | | X | | | | | X |

| Authors | Year | Title | Agency/Organization | Link or Journal (if available) | Hydrology/Altered Hydrology | Sediment | Water Quality | Watershed Modeling | In Stream Hydraulic Modeling | Flooding | Aquatic Invasive Species | Watershed Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Magee, M.R.; et. al.** | 2019 | Scientific advances and adaption strategies for Wisconsin lakes facing climate change | University of Wisconsin-Madison, WIDNR | *Lake and Reservoir Management, 35,* 364–381 https://doi.org/10.1080/10402381.2019.1622612 | X | | X | | | | | |
| **DNR** | 2015 | Watershed Health Assessment Framework (WHAF): Watershed Report Card | DNR | http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_73.pdf | | | | | | | | X |
| **DNR** | 2017 | Watershed Health Assessment Framework (WHAF): Watershed Context Report | DNR | http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/context_report_major_73.pdf | | | | | | | | X |
| **DNR** | 2019 | Watershed Health Assessment Framework (WHAF): Climate Summary for Watersheds | DNR | http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/climate_summary_major_73.pdf | | | | | | | | X |
| **MPCA, DNR, BSWR** | 2018 | Protection and Prioritization: Tools available to help prioritize waters for protection efforts | MPCA, DNR, BSWR | https://www.pca.state.mn.us/sites/d | X | X | X | | | | | |

| Authors | Year | Title | Agency/Organization | Link or Journal (if available) | Hydrology/Altered Hydrology | Sediment | Water Quality | Watershed Modeling | In Stream Hydraulic Modeling | Flooding | Aquatic Invasive Species | Watershed Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | efault/files/wq-ws1-29.pdf | | | | | | | | |
| **NRCS** | | Rapid Watershed Assessment Vermilion | NRCS | https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021816.pdf | | | | | | | | X |
| **Oswald, Phillip** | 2019 | Aquatic Vegetation Survey | RMB Environmental Laboratories, Inc | https://www.vermilionlakeassociation.org/wp-content/uploads/2019/09/2019-RMB-report-vermilion.pdf | | | | | | | X | |
| **Oswald, Phillip; Rufer, Moriya** | 2018 | Aquatic Vegetation Survey | RMB Environmental Laboratories, Inc | https://www.vermilionlakeassociation.org/pdf/2018%20RMB%20Vegetation%20Survey%20Report%20-%20Vermilion.pdf | | | | | | | X | |
| **Radomski, P; Carlson, K.** | 2018 | Prioritizing lakes for conservation in lake-rich areas | DNR | *Lake and Reservoir Management, 34*, 401–416 | | | X | X | | | | |
| **Reavie, E.D.** | 2005 | Lake Vermilion Elemental Paleoecology | NRRI | https://www.vermilionlakeassociation.org/pdf/Final%20Report%20to%20SCLV22Apr05.pdf | | X | X | | | | | |

| Authors | Year | Title | Agency/Organization | Link or Journal (if available) | Hydrology/Altered Hydrology | Sediment | Water Quality | Watershed Modeling | In Stream Hydraulic Modeling | Flooding | Aquatic Invasive Species | Watershed Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stroom, Kevin** | 2019 | Vermilion Stressor Identification Report | MPCA | https://www.pca.state.mn.us/sites/default/files/wq-ws5-09030002a.pdf | | | X | | | | | |
| **Saint Louis County** | 2009 | Lake Vermilion Land Use Plan | Saint Louis County | http://mn.gov/frc/documents/council/landscape/NE%20Landscape/NE_Update_2011/LakeVermillion-LandUsePlan-2009.pdf | X | | | | | | | X |
| **Vogt, D. J.** | 2020 | Sandy Lake and Little Sandy Lake Monitoring (2010-2019) | 1854 Treaty Authority | https://www.1854treatyauthority.org/management/biological-resources/fisheries/reports.html?id=220&task=document.viewdoc | X | X | X | | | | | |
| **Vogt, D. J.** | 2021 | Wild Rice Monitoring and Abundance in the 1854 Ceded Territory (1998-2020) | 1854 Treaty Authority | https://www.1854treatyauthority.org/management/biological-resources/fisheries/reports.html?id=228&task=document.viewdoc | | | | | | | | |

## Other Data Compiled:

| Data Name | Source | Date (if applicable) | Type of Data | Information contained |
|---|---|---|---|---|
| **Arrowhead Pilot Project Brief** | Arrowhead Pilot Project | 2019 | Word Document | Description of sustainable forest initiative |
| **Statewide List of Nearly/Barely Impaired lakes** | MPCA | 2020 | Excel | Proximity of lakes to the aquatic recreation standards |
| **Vermilion River Watershed Impaired Lakes Water Levels** | DNR | 2017 | Excel | Echo Lake elevation readings |
| **Vermilion River Water Appropriation Permits Summary** | DNR | 2017 | Word Document | Water Appropriations Summary |
| **Vermilion River Outlet Structures** | DNR | 2017 | Shapefiles | Location of river outlet structures |
| **Vermilion Stream and Lake Protection Prioritization Spreadsheet** | MPCA, DNR | 2020 | Excel | Breakdown of lakes, stream prioritization and ranking criteria |

# Appendix B: Vermilion River Watershed Protection Prioritization Criteria

Several protection-focused management strategy themes were developed to address key issues identified by Core Team members. To geographically target where the different strategy types should be implemented, prioritization criteria were developed to best describe each strategy type. Prioritization lies at the intersection of quality and risk, therefore some of the criteria identify risks, such as declining water quality trends, and some of the criteria identify qualities, such as the presence of wild rice or the quality of a coldwater fishery (cisco and trout). Lakes and streams with many risks and qualities can be targeted for protection and restoration.

The Core Team developed the prioritization criteria during a meeting in April of 2020. When choosing criteria, it is important to choose factors that vary across the watershed so that local geographic areas can be targeted. In addition, it is helpful to choose just a few criteria per strategy type to keep geographical targeting as simple as possible. The prioritization criteria are further described in Table 1.

The prioritization criteria were matched with applicable strategy types, shown in Table 2. The intent is that when strategies are developed, under each strategy type, their implementation can be prioritized and targeted. In other words, the risks and qualities associated with the priority waterbodies drive the protection or restoration strategies that should be implemented to protect or restore water quality. For example, lakes with developed shorelines are priorities for septic system improvements. The criteria results for each specific lake and stream are provided in Table 4 and Table 5, respectively. The overall total risks and qualities are also shown, indicating which lakes and streams have the most risks and qualities.

**Table 1. Prioritization criteria descriptions**

| Risk or Quality | Name | Description |
|---|---|---|
| Risk | Altered Watercourses | Altered Rivers and Streams were identified from the MnGEO shapefile which was developed by the MPCA and MnGEO. Altered watercourses are type AVETYPE = 1. |
| | Stream Connectivity (WHAF) | Stream Connectivity (WHAF) comes from the DNR Watershed Assessment Health Score Stream Connectivity shapefile. The Aquatic Connectivity Index is based on the density of culverts, bridges and dams in each watershed. The higher the density of structures limiting the free flow of water, the lower the Aquatic Connectivity score. |
| | Declining Trend | The lake has a declining trend in transparency as documented in the 2019 MPCA trend results by county. |
| | Development Density (Lakeshore) | Current development area (determined as the perimeter of development raster cells from HSPF PERLAND data) divided by the developable area (private land) around the lakeshore within 500 ft of the lake. |
| | Disturbance (HSPF Subwatershed) | The percent disturbance in the HSPF reach was determined based on the HSPF land use raster. If a subwatershed had greater than 25% of the land use in agriculture, mining or developed land, it was considered disturbed. In the case of this watershed, the disturbance was mining. |
| | HSPF Scenario Model Results: Development Scenario | Increases in sediment, total phosphorus, and total nitrogen loading as a result of estimated increased development in the modeling scenario. |
| | Impaired | Lake is on the 2020 Draft Impaired Waters List for Eutrophication |
| | Local Priorities – Lakes | Lakes identified by the Core Group as potentially being developed. Outlined areas where private land exists on the lakeshore. |
| | Near Surface Pollution Sensitivity (WHAF) | The Pollution Sensitivity of Near-Surface Materials delineates different rates at which contaminants may travel through the top 10 feet of the soil profile. The different rates across the state show the range in risk level for contamination to infiltrate toward groundwater resources. In some areas, the surface is so hard that it limits infiltration of water but increases the risk that contaminants may run over the surface directly into lakes and streams. |
| | Nearly Impaired | Lakes identified by the MPCA as "nearly or barely" impaired for recreational use are within a set percentage above or below the standard and are thus identified as vulnerable ("nearly" impaired) or suitable candidates for restoration ("barely" impaired). |
| | Phosphorus Sensitivity | Phosphorus sensitivity was estimated for each lake by the DNR by predicting how much water clarity would be reduced with additional phosphorus loading to the lake. The lake is identified on the Lakes of Phosphorus Sensitivity Significance (DNR) study as the "Highest" level of sensitivity and "Highest" level of cost/benefit. |
| | Septic Systems (WHAF) | Septic Systems (WHAF) comes from the DNR Watershed Assessment Health Score Septic Systems shapefile. This metric provides a conservative estimate of actual septic system density. The metric score is based on well density per square km of land area in a catchment. Scores range from 0 to 100, with a density of 15.587 wells/km2 or greater = 0; no wells present = 100. |
| | Stream Barriers | Information gathered from the Stressor Identification Report and Local information. |
| | % Young Forest | Shows forest disturbance from logging and forest fires based on PERLAND HSPF model data. |
| Quality | BWCAW | The Boundary Waters Canoe Area Wilderness allows camping, but entrance is by permit only, and with several exceptions, motorized travel is not allowed in the vast majority of the BWCAW. |
| | Class 1B & 1C Drinking Water | The lake is designated Class 1 Drinking Water, which means that it is suitable for drinking with minimal treatment. |

| Risk or Quality | Name | Description |
|---|---|---|
| | Coldwater Habitat | Lakes known to harbor coldwater species including lake trout, lake whitefish, and cisco |
| | Coldwater lakes and streams | Class 2A waters and Cisco Refuge Lakes. Class 2A waters are defined in Minnesota Administrative Rule 7050 as having water quality that permits the propagation and maintenance of a healthy community of coldwater aquatic biota, and their habitats. Cisco Refuge Lakes are defined by the DNR as having waters “deep and clear enough that they will still provide suitable coldwater fish habitat even after significant climate warming.” These waters provide habitat for sensitive coldwater species such as lake trout, cisco, and lake whitefish |
| | Exceptional Waters (TALU) | Streams that meet the Exceptional Standard for Tiered Aquatic Life Uses (TALU). There are currently no ‘Exceptional Use’ streams identified in the VRW |
| | Locally Defined Recreational Areas | The Core Team identified areas popular for recreation such as Crane Lake, Lake Vermilion, Voyageurs National Park, Superior National Forest, and the BWCAW that may experience higher impact from use (litter, trail erosion, campsite impacts) |
| | Outstanding Biological Significance | DNR Lakes of Biological Significance – Outstanding. These lakes have high aquatic plant richness, wild rice, exceptional fishery, endangered or threatened lake bird species. |
| | Voyageurs National Park | Voyageurs National Park is valued for its outstanding interconnected water resources and provides both recreational opportunities and protection from development. |
| | Wild Rice | Waters identified in multiple datasets by DNR, 1854 Treaty Authority, and the MPCA. The MPCA list was generated in 2017 as a proposed list of wild rice waters. These lists are combined here to assist local partners with protection planning. |

**Table 2. Strategy Types matched with the criteria used to prioritize waterbodies and geographic areas for protection and restoration**

| Strategy Type | Prioritization Criteria | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Risks | | | | | | | | | | | | | | | Qualities | | | | | | |
| | Aquatic life and aquatic recreation impairment | "Nearly" Impaired for aquatic recreation | Declining Water Quality Trend | Highest Phosphorus Sensitivity | Disturbance (HSPF stream reach) | Development Density (Lakeshore) | HSPF Scenario Model Results: Development Scenario | Near surface pollution sensitivity (WHAF) | Altered Watercourses | Local Priorities | Aquatic Connectivity (WHAF) | Stream Barriers (SID, local information) | Septic Systems (WHAF) | % Young Forest | School Trust Land Forests | Outstanding Biological Significance | Class 1 Drinking Water Lakes | Coldwater lakes and streams | Wild Rice (DNR, 1854 Treaty Authority, MPCA Proposed) | Boundary Waters Canoe Area | Voyageurs National Park | Locally Defined Recreational Concern Areas |
| **Drinking Water Protection** | | | • | • | | | | • | | | | | | | | | • | | | | | |
| **Forestland Management** | | | • | • | • | | | | | | | | | • | • | | • | • | | | | |
| **Habitat and stream connectivity management** | | | | | | | | | | | • | • | | | | | | • | • | | | |
| **Lake Management** | • | • | • | • | | | • | | | | | | • | • | | • | • | • | • | | | |
| **Recreational Management** | | | | | | | | | | | | | | | | | | | | • | • | • |
| **Septic system and waste management improvement** | • | • | • | • | | • | | | | • | | | • | | | • | • | • | | | | |
| **Stormwater runoff control** | • | • | • | • | • | • | • | | | | | | | | | | | | | | | |
| **Streambank, bluff, and ravine protection** | • | • | | | | | | | • | • | | | | | | | | • | | | | |

**Table 3. Strategy Types matched with the criteria used to prioritize waterbodies and geographic areas for protection and restoration.**

| Strategy Type | Prioritization Criteria | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Risks | | | | | | | | | | | | | | | Qualities | | | | | | |
| | Aquatic life and aquatic recreation impairment | "Nearly" Impaired for aquatic recreation | Declining Water Quality Trend | Highest Phosphorus Sensitivity | Disturbance (HSPF stream reach) | Development Density (Lakeshore) | HSPF Scenario Model Results: Development Scenario | Near surface pollution sensitivity (WHAF) | Altered Watercourses | Local Priorities | Aquatic Connectivity (WHAF) | Stream Barriers (SID, local information) | Septic Systems (WHAF) | % Young Forest | School Trust Land Forests | Outstanding Biological Significance | Class 1 Drinking Water Lakes | Coldwater lakes and streams | Wild Rice (DNR, 1854 Treaty Authority, MPCA Proposed) | Boundary Waters Canoe Area | Voyageurs National Park | Locally Defined Recreational Concern Areas |
| **Drinking Water Protection** | | | ● | ● | | | | ● | | | | | | | | | ● | | | | | |
| **Forestland Management** | | | ● | ● | ● | | | | | | | | | ● | ● | | ● | ● | | | | |
| **Habitat and aquatic connectivity management** | | | | | | | | | | | ● | ● | | | | | | ● | ● | | | |
| **Lake Management** | ● | ● | ● | ● | | | ● | | | | | | ● | ● | | ● | ● | ● | ● | | | |
| **Recreational Management** | | | | | | | | | | | | | | | | | | | | ● | ● | ● |
| **Septic system improvement** | ● | ● | ● | ● | | ● | | | | ● | | | ● | | | ● | ● | ● | | | | |
| **Stormwater runoff control** | ● | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | |
| **Streambank and gully protection** | ● | ● | | | | | | | ● | ● | | | | | | | | ● | | | | |

**Table 4. Individual lakes and prioritization criteria. The risks and qualities are summed in the "Totals" columns. Lakes are in alphabetical order. Lakes in the watershed that did not fit any of these criteria were not included in the table.**

| General Info | | Risks | | | | | | Qualities | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Phosphorus | | Coldwater Habitat | | | | | | |
| **Lake Name** | **Lake ID** | Impaired (eutrophication) | Declining trend | Development density (lakeshore) | Local priorities | Lake phosphorus sensitivity significance (LPSS) "A" | Lake benefit/cost assessment (LBCA) priority score "Highest" | Cisco refuge lakes | Class 2A coldwater lakes & Draft proposed lake trout (LKT), whitefish (LKW) lakes & cisco lakes (TLC) | Wild rice (DNR/1854 Treaty Authority/Proposed MPCA, 2017) | Lakes of outstanding biological significance | Class 1B & 1C drinking water designation | **Total Risk** | **Total Qualities** |
| Astrid | 69-0589-00 | | | | | | | | | 1854, MPCA | | | | 1 |
| Ban | 69-0742-00 | | | | | | | | | 1854, MPCA | | | | 1 |
| Bear | 69-0380-00 | | | | | | | | | | | 1B | | 1 |
| Black | 69-0740-00 | | | | | | | | | 1854, MPCA | | | | 1 |
| Bog | 69-0811-00 | | | | | | | | | MPCA | | | | 1 |
| Boulder | 69-0302-00 | | | | | | | | | | | 1B | | 1 |
| Buck | 69-0381-00 | | | | | | | | | | | 1B | | 1 |
| Camp 97 Impoundment | 69-0594-00 | | | | | | | | | 1854, MPCA | | | | 1 |
| Crane | 69-0616-00 | | | | X | | | | 2A, LKW, TLC | DNR, 1854, MPCA | X | 1B | 1 | 4 |
| Dugout | 69-0451-00 | | | | | | | | | | | 1B | | 1 |
| Eagles Nest #1 | 69-0285-01 | | | 10% | X | X | | | | | | | 2 | 1 |
| Eagles Nest #2 | 69-0285-02 | | X | 18% | X | X | | | | | | | 3 | |
| Eagles Nest #3 | 69-0285-03 | | | 3% | X | X | X | | | DNR, 1854, MPCA | | | 3 | 1 |
| Eagles Nest No. Four | 69-0218-00 | | | 13% | X | X | | | | | | | 2 | |
| East Vermilion | 69-0378-01 | | | | X | | X | | LKW, TLC | DNR, 1854, MPCA | X | 1C | 2 | 4 |

| General Info | | Risks | | | | | | Qualities | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Phosphorus | | Coldwater Habitat | | | | | | |
| Lake Name | Lake ID | Impaired (eutrophication) | Declining trend | Development density (lakeshore) | Local priorities | Lake phosphorus sensitivity significance (LPSS) "A" | Lake benefit/cost assessment (LBCA) priority score "Highest" | Cisco refuge lakes | Class 2A coldwater lakes & Draft proposed lake trout (LKT), whitefish (LKW) lakes & cisco lakes (TLC) | Wild rice (DNR/1854 Treaty Authority/Proposed MPCA, 2017) | Lakes of outstanding biological significance | Class 1B & 1C drinking water designation | Total Risk | Total Qualities |
| Echo | 69-0615-00 | X | | | | | | | | DNR, 1854, MPCA | | | 1 | 1 |
| Elbow | 69-0744-00 | | | | X | | | | LKW, TLC | 1854, MPCA | | | 1 | 2 |
| Elephant | 69-0810-00 | | | | X | | | | | MPCA | X | | 1 | 2 |
| Five Mile | 69-0288-00 | | | | | | | | | DNR, 1854, MPCA | | | | 1 |
| Four Mile | 69-0281-00 | | | | | | | | | DNR, 1854, MPCA | | | | 1 |
| Gafvert | 69-0280-00 | | | | | | | | | DNR, 1854, MPCA | | | | 1 |
| Glenmore | 69-0292-00 | | | | | | | | | | | 1B | | 1 |
| Gowan | 69-0454-00 | | | | | | | | | | | 1B | | 1 |
| Hay | 69-0579-00 | | | | | | | | | DNR, 1854, MPCA | X | | | 2 |
| Hoodoo | 69-0802-00 | | | | | | | | | DNR, MPCA | | | | 1 |
| Kabustasa | 69-0679-00 | | | | | | | | | 1854, MPCA | | | | 1 |
| Kjostad | 69-0748-00 | | | | | X | | | TLC | | | | 1 | 1 |
| Little Sandy | 69-0729-00 | | | | | | | | | DNR, 1854, MPCA | X | | | 2 |
| Little Trout | 69-0455-00 | | | | | | | | TLC | | | 1B | | 2 |
| Marion | 69-0755-00 | | | | | | | | | MPCA | | | | 1 |
| Merritt | 69-0583-00 | | | | | | | | | | | 1B | | 1 |
| Moose | 69-0806-00 | | | | X | | | | | MPCA | | | 1 | 1 |
| Mud | 69-0275-00 | | | | | | | | TLC | | | | | 1 |
| Myrtle | 69-0749-00 | X | | | X | | | | | DNR, 1854, MPCA | | | 2 | 1 |

| General Info | | Risks | | | | | | Qualities | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Phosphorus | | Coldwater Habitat | | | | | | |
| **Lake Name** | **Lake ID** | Impaired (eutrophication) | Declining trend | Development density (lakeshore) | Local priorities | Lake phosphorus sensitivity significance (LPSS) "A" | Lake benefit/cost assessment (LBCA) priority score "Highest" | Cisco refuge lakes | Class 2A coldwater lakes & Draft proposed lake trout (LKT), whitefish (LKW) lakes & cisco lakes (TLC) | Wild rice (DNR/1854 Treaty Authority/Proposed MPCA, 2017) | Lakes of outstanding biological significance | Class 1B & 1C drinking water designation | **Total Risk** | **Total Qualities** |
| Needle Boy | 69-0282-00 | | | | | | | | | DNR | | | | 1 |
| Oriniack | 69-0587-00 | | | | | | | | | DNR, 1854, MPCA | | 1B | | 2 |
| Pat Zakovec Impoundment | 69-1463-00 | | | | | | | | | MPCA | | | | 1 |
| Pelican | 69-0841-00 | | | | X | | X | | | DNR, MPCA | X | 1C | 2 | 3 |
| Phantom | 69-0303-00 | | | | | | | | | | | 1B | | 1 |
| Pike Bay | 69-0378-03 | | | | X | | | | LKW, TLC | DNR, 1854 | | 1C | 1 | 3 |
| Pine | 69-0448-00 | | | | | | | | | | | 1B | | 1 |
| Rice | 69-0578-00 | | | | | | | | | DNR, 1854, MPCA | | | | 1 |
| Rice | 69-0803-00 | | | | | | | | | DNR, MPCA | X | | | 2 |
| Sandy | 69-0730-00 | | | | | | | | | DNR, 1854, MPCA | X | | | 2 |
| Six Mile | 69-0283-00 | | | | | | | | | 1854, MPCA | | | | 1 |
| Skeleton | 69-0256-00 | | | | | | | | | DNR, 1854 | | | | 1 |
| South Bog | 69-0807-00 | | | | | | | | | MPCA | | | | 1 |
| Sunset | 69-0764-00 | | | | | | | | | DNR, 1854, MPCA | | | | 1 |
| Susan | 69-0741-00 | | | | | | | | | DNR, 1854, MPCA | | | | 1 |
| Swan | 69-0863-00 | | | | | | | | | MPCA | | | | 1 |
| Trout | 69-0498-00 | | | | | | | X | 2A, LAT, TLC | 1854, MPCA | X | 1B | | 5 |
| Unnamed | 69-0594-00 | | | | | | | | | DNR | | | | 1 |

| General Info | | Risks | | | | | | Qualities | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Phosphorus | | Coldwater Habitat | | | | | | |
| **Lake Name** | **Lake ID** | Impaired (eutrophication) | Declining trend | Development density (lakeshore) | Local priorities | Lake phosphorus sensitivity significance (LPSS) "A" | Lake benefit/cost assessment (LBCA) priority score "Highest" | Cisco refuge lakes | Class 2A coldwater lakes & Draft proposed lake trout (LKT), whitefish (LKW) lakes & cisco lakes (TLC) | Wild rice (DNR/1854 Treaty Authority/Proposed MPCA, 2017) | Lakes of outstanding biological significance | Class 1B & 1C drinking water designation | **Total Risk** | **Total Qualities** |
| Unnamed (Serell) | 69-0293-00 | | | | | | | | | | | 1B | | 1 |
| Unnamed | 69-0301-00 | | | | | | | | | | | 1B | | |
| Unnamed | 69-0308-00 | | | | | | | | | | | 1B | | |
| Unnamed | 69-0447-00 | | | | | | | | | | | 1B | | |
| Unnamed | 69-0449-00 | | | | | | | | | | | 1B | | |
| Vermilion River | 69-0613-00 | | | | | | | | | DNR, 1854, MPCA | | | | 1 |
| West Vermilion | 69-0378-02 | | | | X | | | | LKW. TLC | DNR, 1854 | | 1C | 1 | 3 |
| Western | 69-0379-00 | | | | | | | | | | | 1B | | 1 |
| Winchester | 69-0690-00 | | | | | | | | LAT, TLC | | | | | 1 |
| Wolf | 69-0582-00 | | | | | | | | | 1854 | | | | 1 |

**Table 5. Individual streams and prioritization criteria**

Risks and qualities are summed for each stream reach in the "Total" column. Streams are listed in alphabetical order. Streams in the watershed that did not fit any of these criteria were not included in table.

| General Info | | Risks | | | Qualities | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Stream Name** | **WID** | Impaired (aquatic life or recreation) | Disturbance (HSPF reach more than 25% disturbed) | Altered watercourses | Class 2A coldwater | Fish or macroinvertebrate IBI score above or near 'exceptional' | Wild rice | **Total Risks** | **Total Qualities** |
| Armstrong River | -505 | | | X | | | | 1 | |
| Bug Creek | -593 | | | | | X | | | 1 |
| Camp 40 Creek | -586 | | | | | | MPCA, 1854 | | 1 |
| East Two River | -648 | | | | X | | | | 1 |
| East Two River | -647 | | | | X | | | | 1 |
| Echo River | -532 | | | | | X | MPCA, 1854 | | 2 |
| Elbow River | -602 | | | | | | MPCA | | 1 |
| Flap Creek | -565 | | | | | X | | | 1 |
| Fullers Creek (West Two River Tributary) | -539 | | | | X | | | | 1 |
| Gustafson Creek | -574 | | | X | | | | 1 | |
| Hilda Creek | -528 | | | | | X | | | 1 |
| Huntingshack River | -583 | | | | | X | | | 1 |
| Owens Creek (East Two River Tributary) | -536 | | | | X | | | | 1 |
| Pelican Lake | -597 | | | X | | | | 1 | 1 |
| Pelican River | -530 | | | | | | MPCA, 1854 | | 1 |
| Phantom Creek | -545 | | | X | | | | 1 | |
| Picket Creek | -614 | | | | | | | | |
| Pike River | -503 | | | | | | MPCA, 1854 | | 1 |
| Sand River | -501 | | | | | | MPCA, 1854 | | 1 |
| Unnamed creek (Pelican Lake Tributary) | -541 | | | X | X | | | 1 | 1 |

| General Info | | Risks | | | Qualities | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Stream Name** | **WID** | Impaired (aquatic life or recreation) | Disturbance (HSPF reach more than 25% disturbed) | Altered watercourses | Class 2A coldwater | Fish or macroinvertebrate IBI score above or near 'exceptional' | Wild rice | **Total Risks** | **Total Qualities** |
| Unnamed creek (Vermilion River Tributary) | -646 | | | X | | | | 1 | |
| Unnamed creek (Pelican Lake Tributary) | -542 | | | | X | | | | 1 |
| Unnamed creek (Sand River Tributary) | -645 | X | | | | | | 1 | |
| Unnamed creek (Vermilion Lake Tributary) | -908 | | | X | | | | 1 | |
| Unnamed creek (East Two River Tributary) | -534 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -535 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -537 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -538 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -624 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -625 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -626 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -627 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -628 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -629 | | | | X | | | | 1 |
| Unnamed creek (West Two River Tributary) | -540 | | | | X | | | | 1 |
| Unnamed creek (West Two River Tributary) | -630 | | | | X | | | | 1 |
| Unnamed creek (West Two River Tributary) | -631 | | | | X | | | | 1 |
| Unnamed creek (Headwaters to Vermilion R) | -639 | | | | | | 1854 | | 1 |
| Unnamed creek | -632 | | | | X | | | | 1 |
| Unnamed creek (East Two River Tributary) | -900 | | | | X | | | | 1 |
| Unnamed creek (West Two River Tributary) | -901 | | | | X | | | | 1 |
| Vermilion River (Vermilion Lk to Hilda Cr) | -527 | | | | | | 1854 | | 1 |

| General Info | | Risks | | | Qualities | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Stream Name** | **WID** | Impaired (aquatic life or recreation) | Disturbance (HSPF reach more than 25% disturbed) | Altered watercourses | Class 2A coldwater | Fish or macroinvertebrate IBI score above or near 'exceptional' | Wild rice | **Total Risks** | **Total Qualities** |
| Vermilion River (Hilda Cr to Pelican R) | -529 | | | | | | 1854 | | 1 |
| Vermilion River (Pelican R to Crane Lk) | -531 | | | | | | MPCA, 1854 | | 1 |
| West Two River | -509 | | | | X | | | | 1 |
| Wouri Creek | -572 | | X | | | | | 1 | |

# Appendix C: Vermilion River Watershed HSPF Model – Scenario Modeling Technical Memorandum

# Technical Memorandum

**To:** Vermilion River Core Team

**From:** Houston Engineering, Inc.

**Subject:** Vermilion River HSPF Model – Scenario Modeling

**Date:** October 14, 2020

**Project:** 6074-0023

Edits from Core Team review incorporated by MPCA June 2021

## INTRODUCTION

This technical memorandum (TM) describes the development and results of multiple Hydrologic Simulation Program-Fortran (HSPF) modeling scenarios, created as part of the Watershed Restoration and Protection Strategy (WRAPS) project for the Vermilion River watershed (watershed).

This TM describes:

- How the scenarios were selected and developed;
- How the scenario concepts were translated info HSPF modifications; and
- The results of the scenarios.

The results of these modeling scenarios will be used in the WRAPS process as criteria to prioritize and target protections and restoration strategies. The results will ultimately be incorporated into the WRAPS report where they can guide implementation via the WRAPS strategies table.

It is important to note that the modeled results are the result of modeling in which there is inherent uncertainty in the breakdown between sources. In forested watersheds, the relative contributions from minor land cover classes and different forest classes are poorly constrained by the HSPF model. In addition, the climate change scenario does not include any changes that might occur to the overall forest community which in turn could also impact forest hydrology. These values are meant to be used in combination of sample data, local knowledge, and professional judgement to assist the development of management decisions.

## SCENARIO DEVELOPMENT

On May 1st, 2020, the Vermilion River WRAPS Core Team met to begin discussing HSPF scenario modeling for the watershed. The purpose of the meeting was to:

- introduce HSPF modeling to the group;
- describe how modeling scenarios could be incorporated into the WRAPS report; and
- discuss some recommended scenarios.

Following the meeting, on May 5, 2020, a survey was sent out to the Core Team, soliciting input on the modeling scenarios. The survey was closed on May 14, 2020. Survey responses assisted scenario development. The three scenarios focused on included:

1. Increased development, primarily along shorelines;
2. Climate change; and
3. Increased impacts to forests.

## INCREASED DEVELOPMENT

With approximately fourteen people per square mile, the watershed is currently sparsely developed. Limited road access throughout the watershed combined with the desired types of development (i.e., recreational and/or residential) indicates future development is likely to be largely focused in predictable areas (e.g., lakes, rivers, road access, etc.).

The Core Team provided input of specific lakes and rivers that are likely to see future development. Additionally, the Core Team provided input on which land use types should or should not be considered for potential future development. A key concern for this watershed is shoreland development. This includes development such as residential (e.g., houses and cabins) and commercial/commercial (e.g., resorts and camping). The Core Team provided additional information that was used to better estimate shoreline development in the modeling scenarios.

The following process was used to simulate an increased development HSPF model scenario:

- All privately owned lands (with the exclusion of wetlands) within 500 feet of Core Team identified lakes and rivers were converted to developed land use in the model. Key public land exclusions in the watershed include Voyageurs National Park (VNP), Federal/State/Tribal lands, and the Boundary Waters Canoe Area Wilderness (BWCAW). Core Team-identified lakes and rivers included:
    - Lake Vermilion
    - Pelican Lake
    - Myrtle Lake
    - Eagles Nest Chain of Lakes
    - Crane Lake
    - Elbow Lake
    - Elephant Lake
    - Twin Lakes
    - Moose Lake
    - Pike River

  - Sand River

- Additionally, all of the subwatersheds within the model were given a general development increase of 10% (i.e., the amount of developed land in the subwatershed was increased by 10%). This was done to account for generalized non-shoreland development.
- Municipalities within the watershed were converted to entirely developed (i.e., all of the municipality land was considered developed).
- Septic point source loading was increased at a rate consistent with population density loading from the existing model (i.e., where development was added, point source septic loading was scaled to match the development increase).

A comparison of the existing condition developed land use and the increased development scenario land use is shown in **Figure 1** and **Figure 2**.

Figure 1. Existing land use and model subwatershed development percentages.

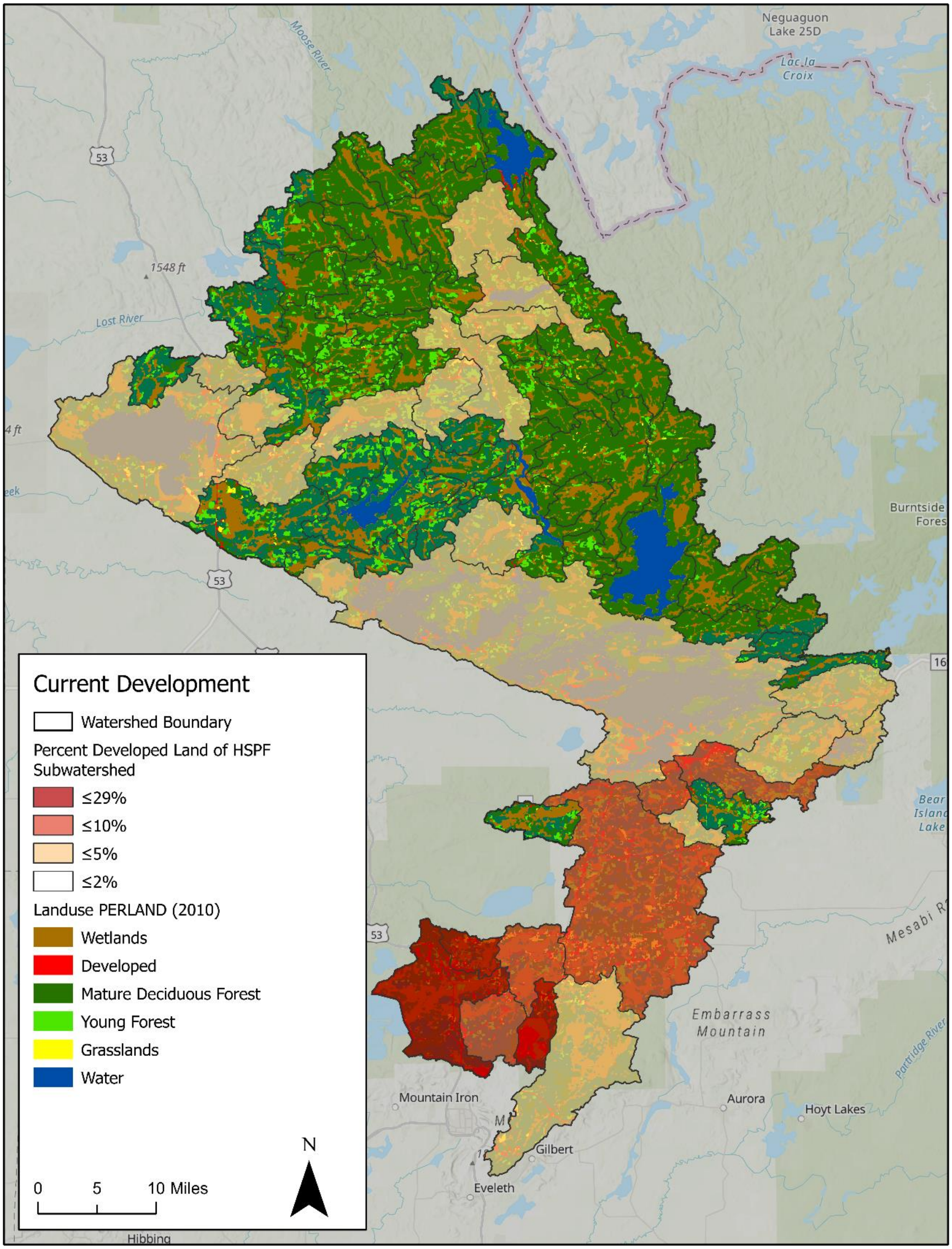
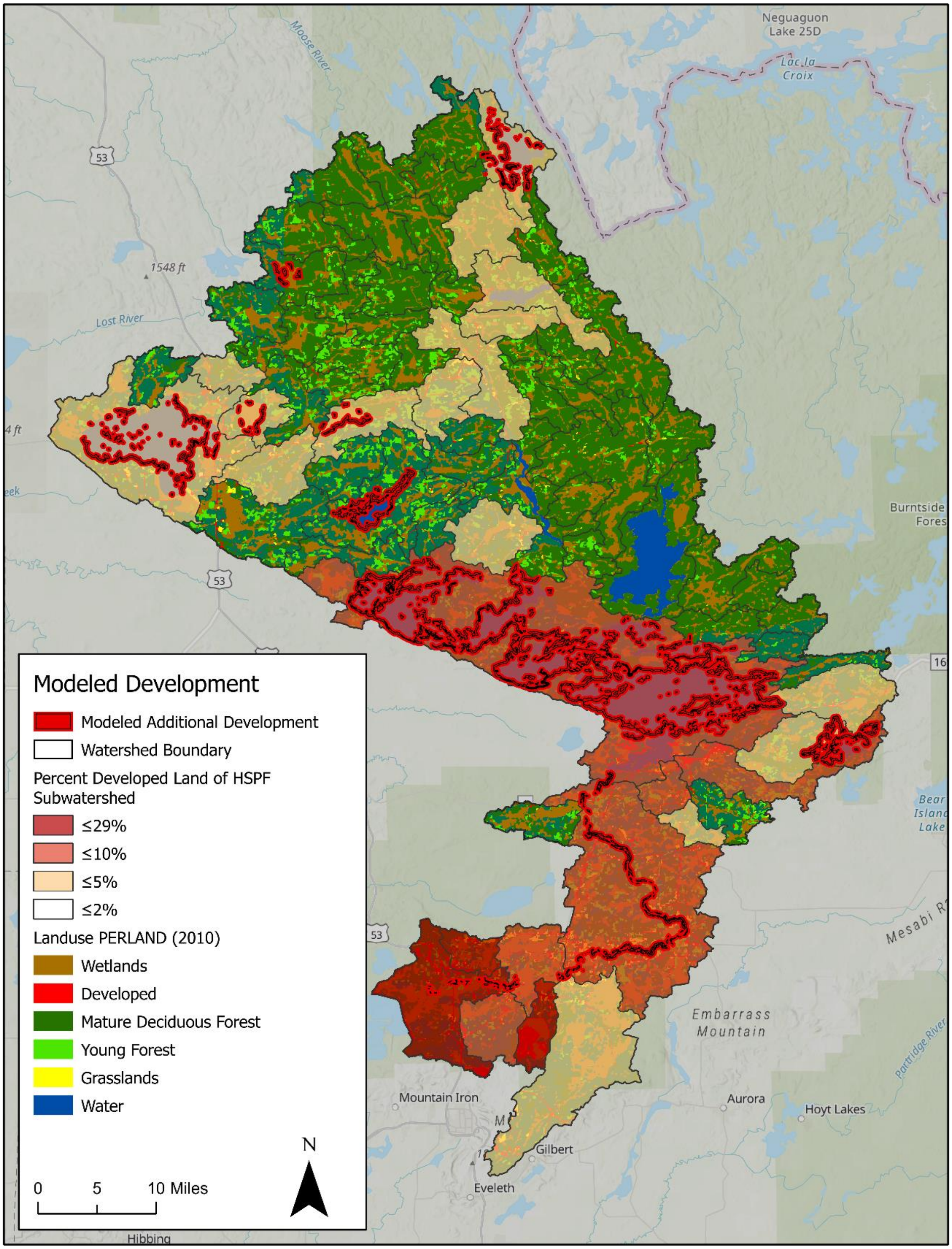


Figure 2. Increased development scenario land use and model subwatershed development percentages.



## FOREST DISTURBANCE

Approximately 68% of the watershed is forested. This substantial percentage indicates that forest disturbances could have significant impacts on water quality within the watershed and its resources. Forest disturbance ranges from timber harvesting to large-scale blowdowns and wildfires.

### *Increased Forest Disturbance*

Similar to the increased development scenario, the Core Team provided input on subwatersheds to include in the scenario all of the VRW was selected. Additionally, the Core Team provided input on which land use types should be considered for potential future forest disturbance.

The following process was used to simulate the forest disturbance HSPF model scenario:

- Within Core Team-identified subwatersheds, all mature forest land uses on public lands (with the exclusion of BWCAW and VNP) were reduced and the reduction lands were converted to young forest.
- Three different versions of this scenario were modeled, each one representing a greater degree of forest disturbance. The mature forest reductions modeled are 10%, 20%, and 30%. For example, in the 10% simulation, 10% of mature forest within the identified subwatersheds was converted to young forest, to simulate forest disturbance. Modeling several degrees of forest disturbance provides information about how the watershed water quality might respond to increased forest disturbance.

The existing condition forest land use (mature and young forest) are shown in **Figure 3**. The subwatersheds that did not undergo any forest modification are also shown.

Based on the input criteria from the Core Team, the specific areas within the watersheds that were subject to mature forest reduction modifications are shown in **Figure 4**. These specific areas were modified by 10%, 20%, and 30% in the various versions of the scenario and the modifications were extrapolated out to changes in the subwatershed land use percentages.

**Figure 3. Existing forest land use and unmodified subwatersheds.**

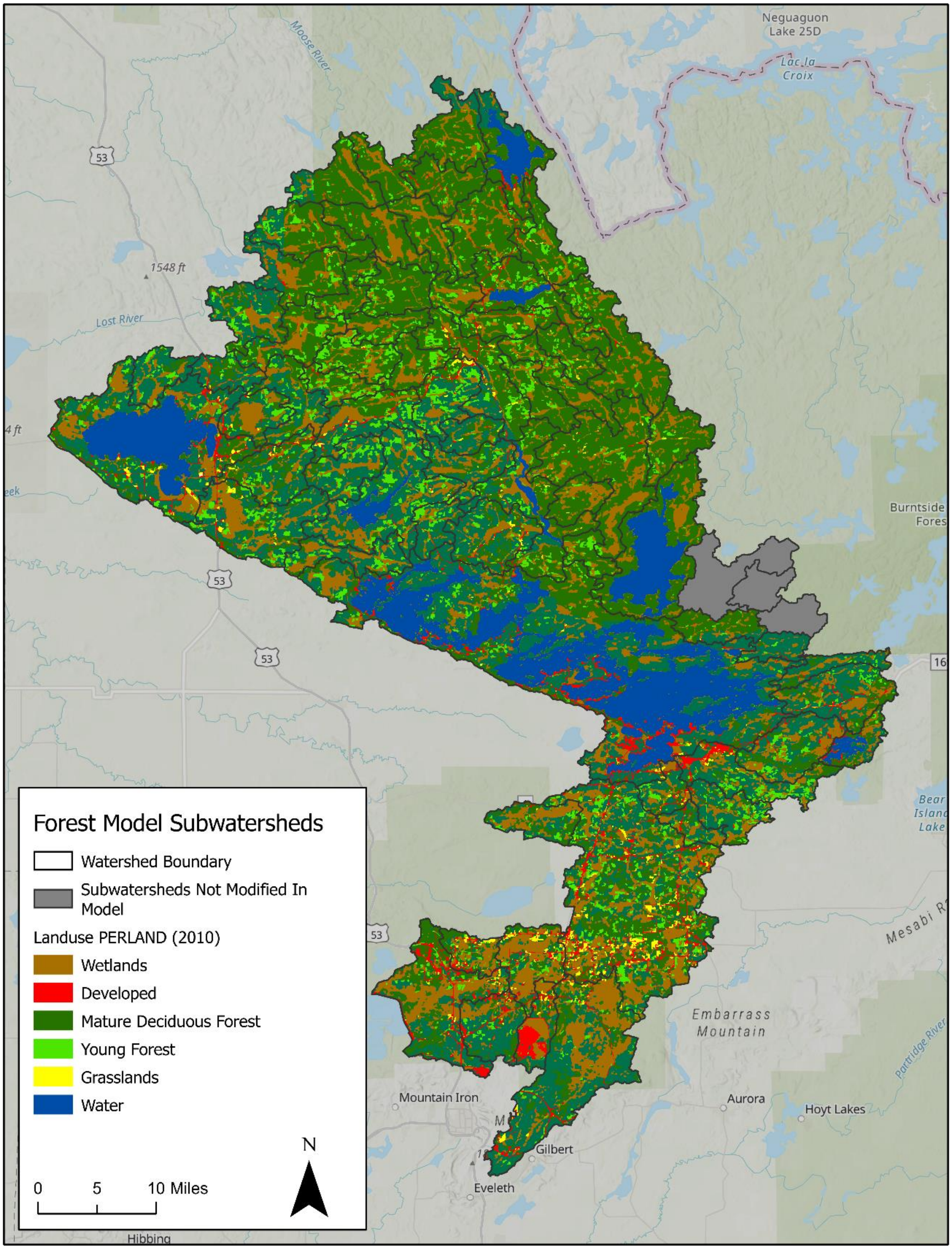
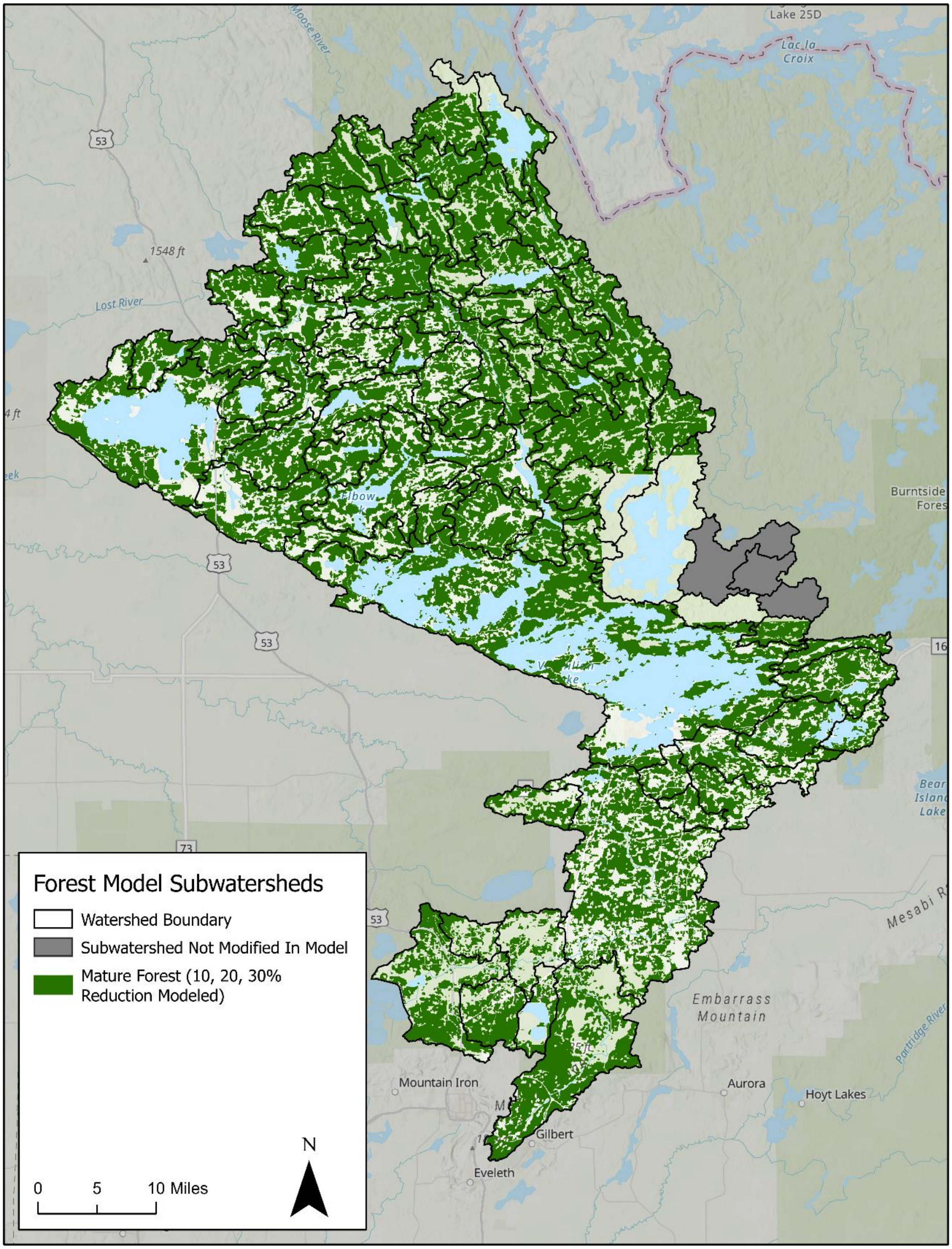


**Figure 4. Specific forest land use modified for forest disturbance scenario.**



### *CLIMATE CHANGE*

Potential climate related impacts that may occur in the upper Midwest, including areas of the watershed, are described in the National Climate Assessment for the Midwest (Pryor et al., 2014). Some of the impacts discussed include changes in forest composition, increases in heatwave intensity and frequency, increased humidity, degraded air quality, reduced water quality and increased rainfall and flooding. Additional analysis of potential climate impacts to the watershed are included in the Climate Change Scenario Details section of this TM.

The HSPF Scenario Application Manager (HSPF-SAM) includes multiple default climate change scenarios. These scenarios were used to show the impacts of climate change in the watershed. The three climate change options available:

- Mild: 1 ˚F increase in average air temperature and 4% increase in extreme precipitation.
- Moderate: 2 °F increase in average air temperature and 8% increase in extreme precipitation.
- Severe: 4 °F increase in average air temperature and 12% increase in extreme precipitation.

The climate change options adjust the existing climate record for the HSPF model. For air temperature increases, the change is applied across the whole record. For the change in extreme precipitation, the percent increase in applied to the extreme precipitation events to represent storm intensification due to climate change.

All three climate change options were modeled to show the expected rate of change under the existing climate change projections. Overall, the most probable climate change scenario is best represented in the severe option.

## SCENARIO RESULTS

As part of the HSPF scenario development survey, the Core Team provided input about key locations in the watershed (i.e., subwatersheds/resources) where they would like details about how the scenarios impact changes in annual averages (volumes and pollutant loading). This TM presents the scenario modeling results in two formats:

- Figures indicating the percent change in average annual runoff volume and loading (sediment, total phosphorus [TP], and total nitrogen [TN]) as compared to the existing condition. Because of the resolution of the HSPF model, the results are mapped at a subwatershed scale; and
- Tables identifying the numeric changes in loading for key subwatersheds/resources, identified by the Core Team during the scenario development. The table includes the annual average runoff volumes and loading for both the existing condition and the scenario, as well as the percent changes for each parameter.

### *INCREASED DEVELOPMENT*

The scenario results show the most change occurred around Eagles Nest #3 and #4 lakes, with an increase in runoff of 140% and an increase in phosphorus of 400%. This is likely the result of the relative amount of area within the watershed converted to 'Developed' in the model as the scenario converted all privately-owned lands within 500 feet of lakes. The Eagle's Nest Chain of Lakes are high quality lakes with a largely forested watershed and much private lakeshore land. **Table 1** shows the modeled average yields for land types in the

VRW. The differences in these values illustrate the impact development can have on runoff, sediment, and nutrient loading.

The results for the increased development scenario are shown for annual average runoff volume per acre in **Figure 5**, sediment in **Figure 6**, TP loading in **Figure 7**, and TN loading in **Figure 8**. The numeric results at key locations are shown in **Table 2**.

**Table 1. Average yields for land types in the Vermilion River Watershed, based on HSPF model result.**

| Land Use Type | Discharge (acre-ft/acre/year) | Sediment (tons/acre/year) | Nitrogen (lbs/acre/year) | Phosphorus (lbs/acre/year) |
|---|---|---|---|---|
| Wetland | 0.629 | 0.00030 | 0.323 | 0.023 |
| Forest mature deciduous | 0.787 | 0.0048 | 0.872 | 0.038 |
| Forest regrowth | 0.892 | 0.0195 | 1.124 | 0.046 |
| Forest mature evergreen | 0.713 | 0.0018 | 0.712 | 0.029 |
| Grassland | 0.949 | 0.0205 | 1.415 | 0.054 |
| Cropland high till | 0.818 | 0.2151 | 5.481 | 1.573 |
| Feedlot | 1.083 | 0.1096 | 8.985 | 0.982 |
| Developed-all | 1.453 | 0.035 | 2.894 | 0.446 |
| Developed-pervious | 1.163 | 0.0326 | 2.800 | 0.441 |
| Developed-impervious | 23.951 | 0.1843 | 10.216 | 0.836 |

**Figure 5. Changes in annual average runoff volume per acre for the increased development scenario.**

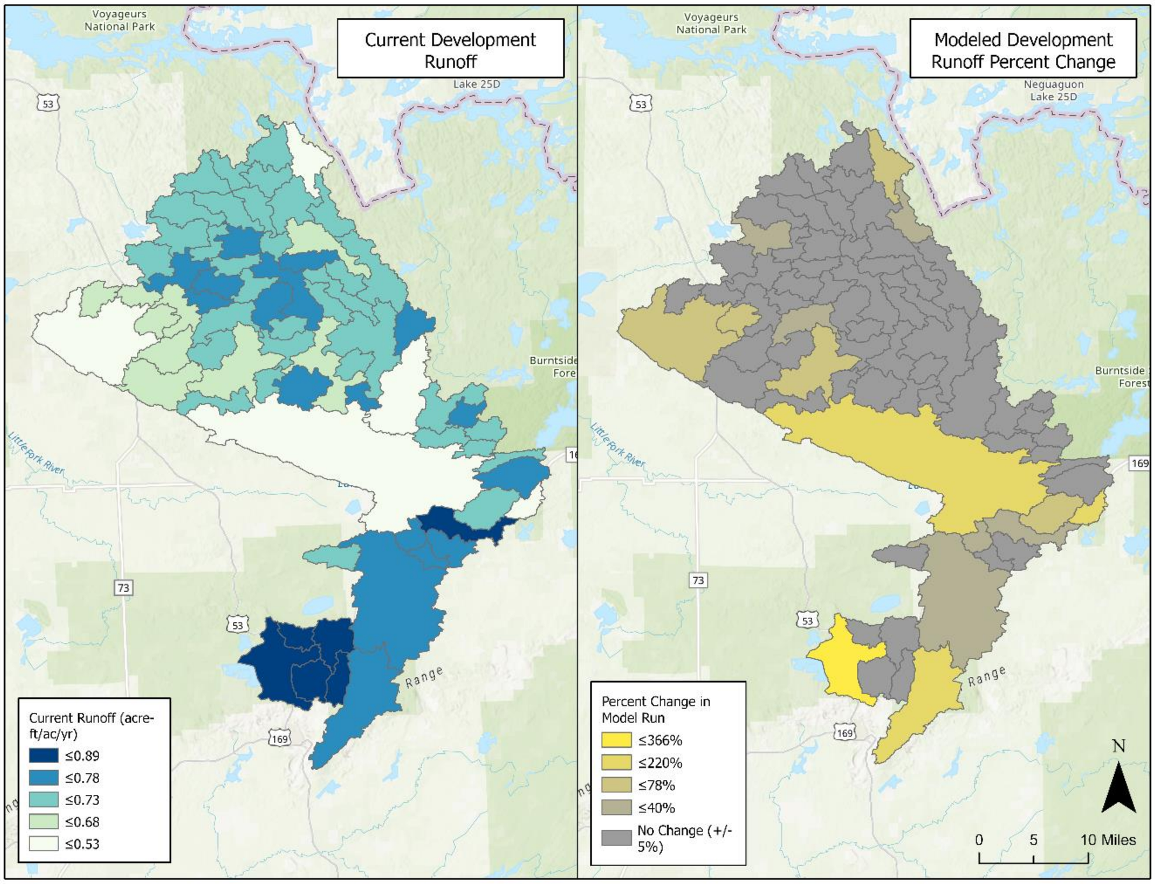


**Figure 6. Changes in annual average annual average sediment loading for the increased development scenario.**

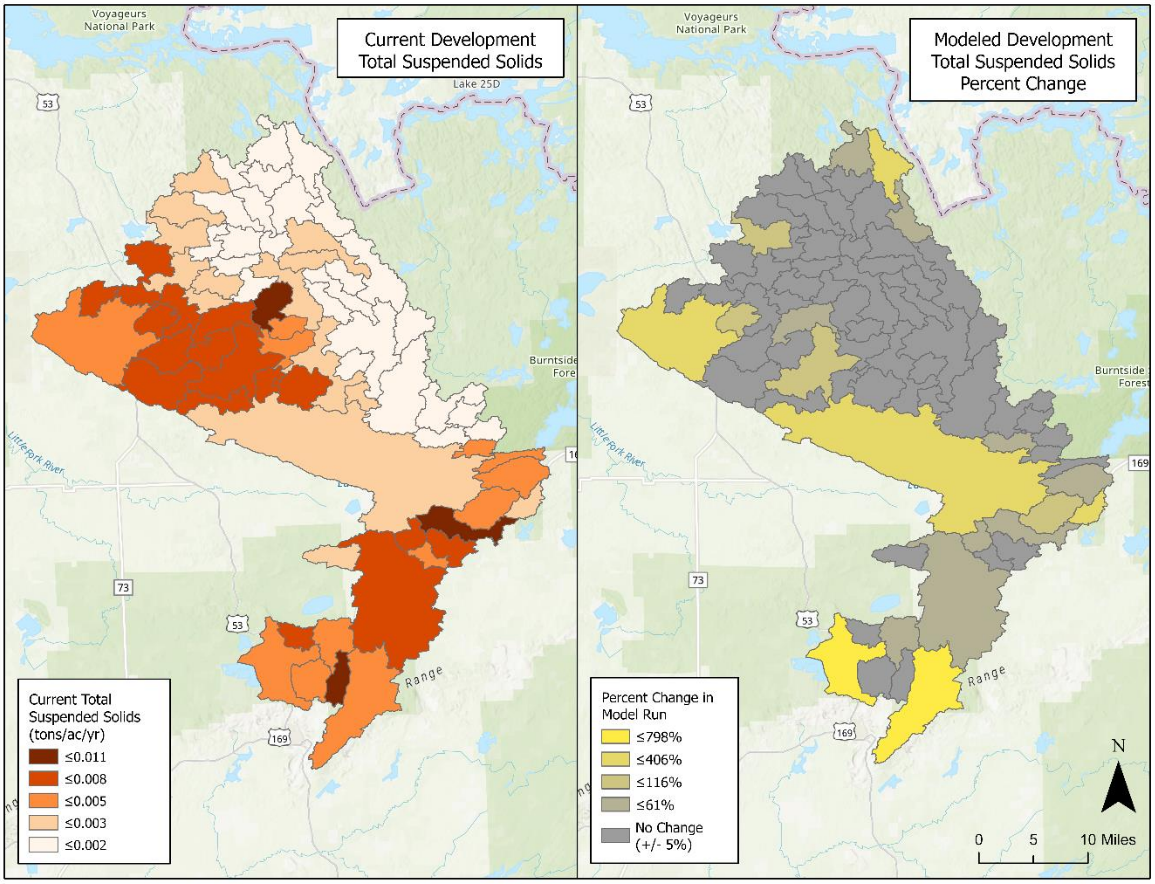


Figure 7. Changes in annual average annual average TP loading for the increased development scenario.

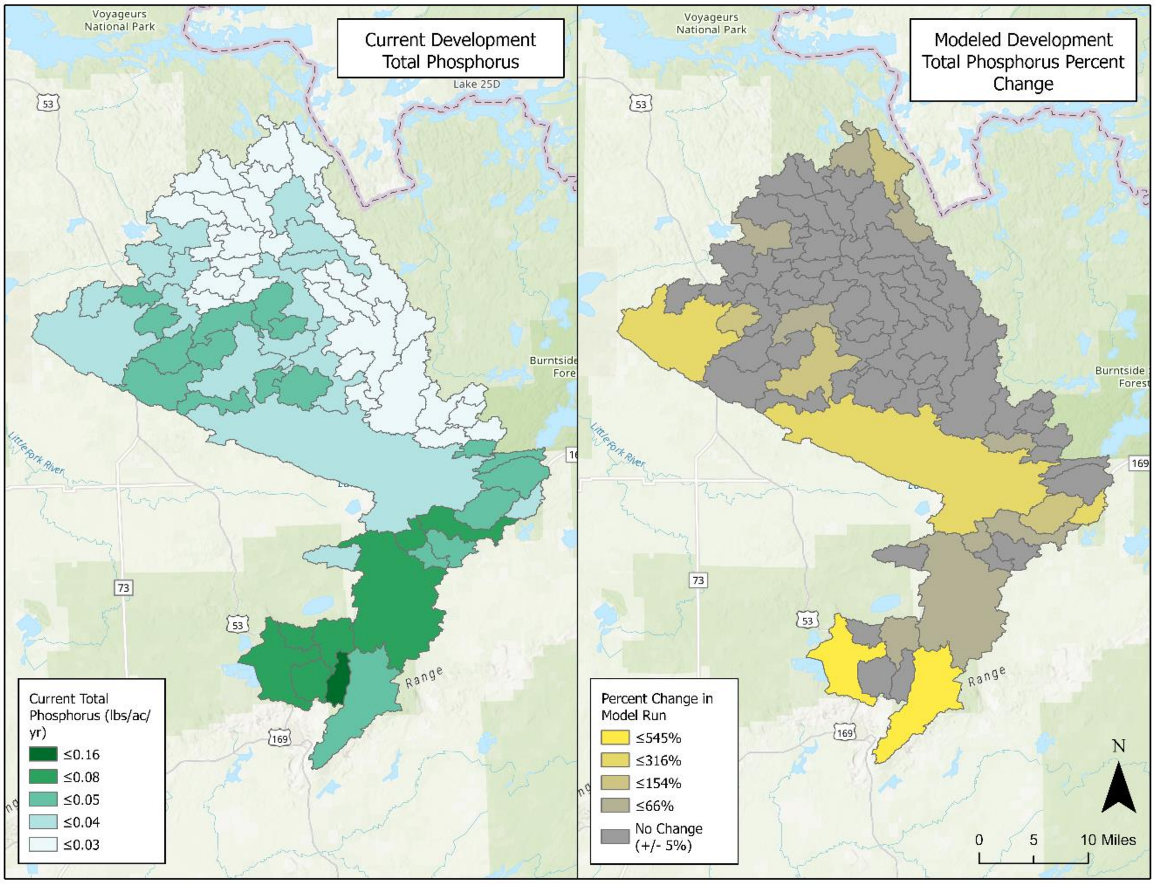


Figure 8. Changes in annual average annual average TN loading for the increased development scenario.

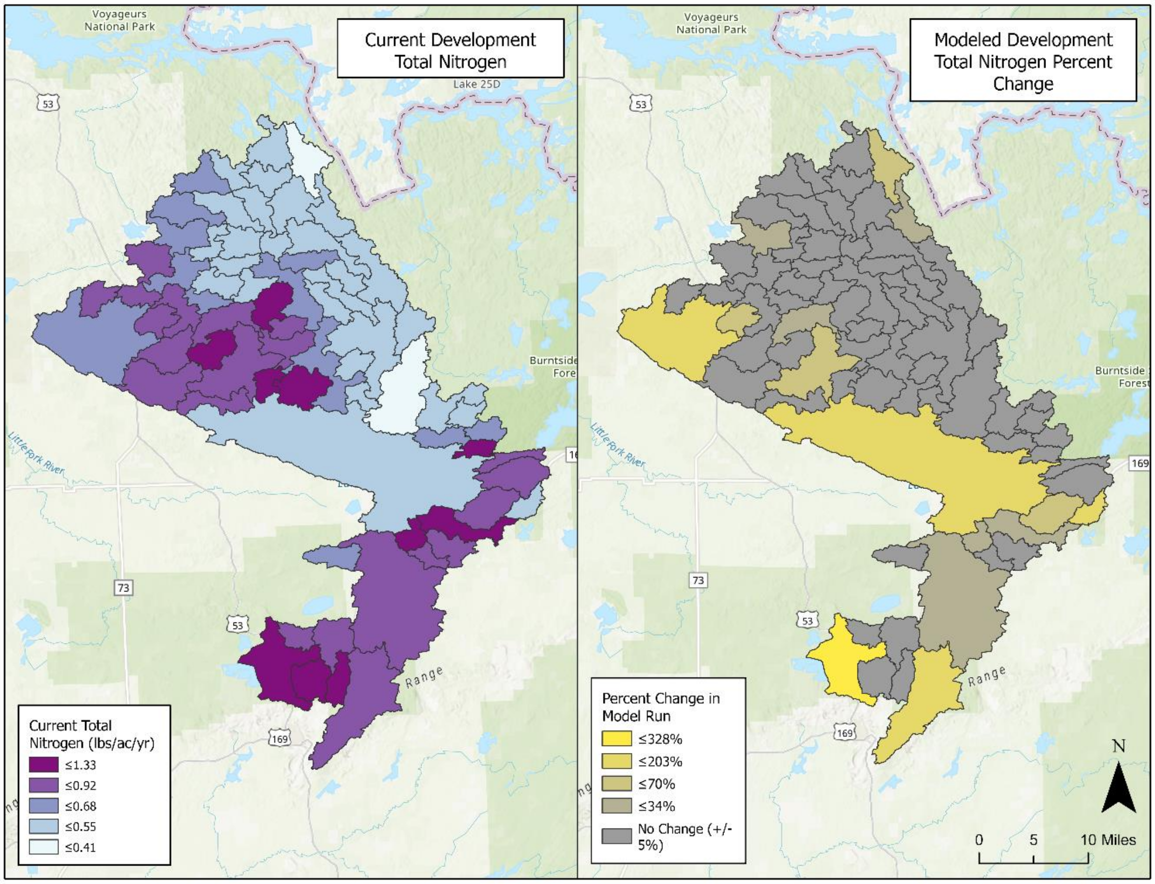


**Table 2. Parameter changes at key locations for the increased development scenario.**

| | | Annual Runoff Volume (ac-ft) | | | Annual Total Sediment Load (tons) | | | Annual Total Phosphorus Load (lb) | | | Annual Total Nitrogen Load (lb) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HSPF Reach | Key Resources | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change |
| 46 | Eagles Nest 3 & 4 | 1,956 | 4,690 | 139.8% | 9 | 48 | 405.9% | 138 | 506 | 267.8% | 2,020 | 4,853 | 140.2% |
| 47 | Eagles Nest 1 & 2 | 6,465 | 9,658 | 49.4% | 39 | 84 | 115.9% | 381 | 824 | 116.1% | 7,060 | 10,631 | 50.6% |
| 80 | Lake Vermilion outlet | 41,685 | 97,956 | 135.0% | 308 | 1,122 | 264.6% | 3,304 | 11,034 | 234.0% | 52,668 | 113,521 | 115.5% |
| 220 | Pelican Lake | 15,857 | 28,176 | 77.7% | 157 | 612 | 288.5% | 1,275 | 5,304 | 316.1% | 19,943 | 54,984 | 175.7% |
| 241 | Myrtle Lake | 5,651 | 6,863 | 21.4% | 59 | 78 | 32.7% | 387 | 556 | 43.5% | 6,561 | 7,870 | 20.0% |
| 420 | Namakan Lake Inflow | 3,924 | 6,228 | 58.7% | 14 | 45 | 229.5% | 203 | 515 | 153.7% | 3,571 | 6,082 | 70.4% |

## FOREST DISTURBANCE

Variations in runoff and loading results between subwatersheds are largely a result of differences in amount of existing mature forest. For example, subwatersheds with more mature forest experiencing a 10% change to forest regrowth experience greater change than a watershed that has less mature forest as there is less land converted in the scenario. This can be seen in the results with a higher modeled impact in the northern region, where there is a higher percentage of mature forest.

Overall, with a 10% increase in forest disturbance, runoff increased from 1%-2%, the sediment load increased by 9%-29%, and the phosphorus load increased by 1-2%. Eagles Nest #3 and #4 showed the most change in sediment load with an increase of 29%. These loading numbers almost doubled in the 20% increase in the forest disturbance scenario. In the third scenario, with forest disturbance increasing by 30%, the runoff, phosphorus, and sediment increased by almost double the percentage of the second scenario, resulting in large increases in sediment (28%-87%).

Furthermore, changes in runoff, sediment, and nutrients are all relative to the average yield of different land types. The overall change in a subwatershed is dependent of the yields from its contained land types. Small changes in loading could be buffered or exaggerated depending on the composition of the subwatershed. Another way to judge the impact of disturbing different land types in the watershed is to look at how the modeled conversion of different land types to Forest Regrowth changed on an acre-by-acre basis. **Table 3** shows the overall yields and relative changes of Mature Forest to Forest Regrowth in the VRW. These values are averaged across the whole watershed. Small differences between climate zones may exist but the averaged values show the potential differences in loading between the Mature Forest land types and the Forest Regrowth land type. These modeled results show a greater change in runoff, sediment, and nutrients from disturbed mature evergreen forest than from mature deciduous.

The results for the forest disturbance scenarios are shown for annual average runoff volume per acre in **Figure 9**, sediment in **Figure 10**, TP loading in **Figure 11**, and TN loading in **Figure 12**. The numeric results at key locations are shown in **Table 4** through **Table 6**

**Table 3. Average yields from Forest Areas in the Vermilion River Watershed, based on HSPF results.**

| Land type | Discharge (acre-ft/acre/year) | Sediment (tons/acre/year) | Nitrogen (lbs/acre/year) | Phosphorus (lbs/acre/year) |
|---|---|---|---|---|
| Mature evergreen forest | 0.713 | 0.0018 | 0.712 | 0.029 |
| Mature deciduous forest | 0.787 | 0.0048 | 0.872 | 0.038 |
| Forest regrowth | 0.892 | 0.0195 | 1.124 | 0.046 |
| **Forest disturbance impact** | | | | |
| Change from conversion of mature evergreen forest to forest regrowth | 0.179 | 0.01768 | 0.411 | 0.0162 |
| Percent change from converting mature evergreen forest to regrowth | 25.1% | 966.7% | 57.7% | 55.2% |
| Change from conversion of mature deciduous forest to forest regrowth | 0.104 | 0.01467 | 0.2521 | 0.0075 |
| Percent change from converting mature deciduous forest to regrowth | 13.3% | 302.8% | 28.9% | 19.6% |

**Figure 9. Changes in annual average runoff volume per acre for the forest disturbance scenarios.**

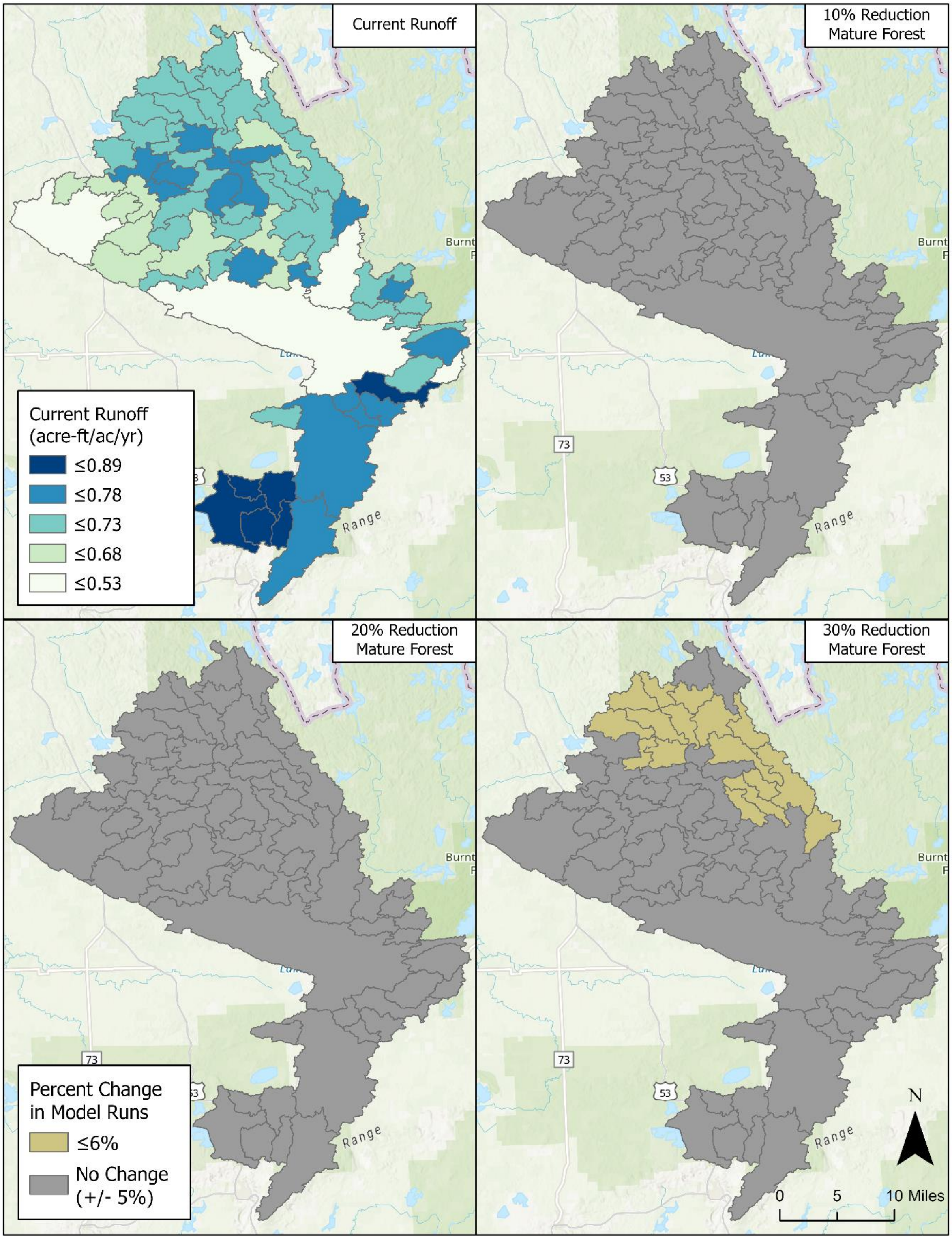


**Figure 10. Changes in annual average annual average sediment loading for the forest disturbance scenarios.**

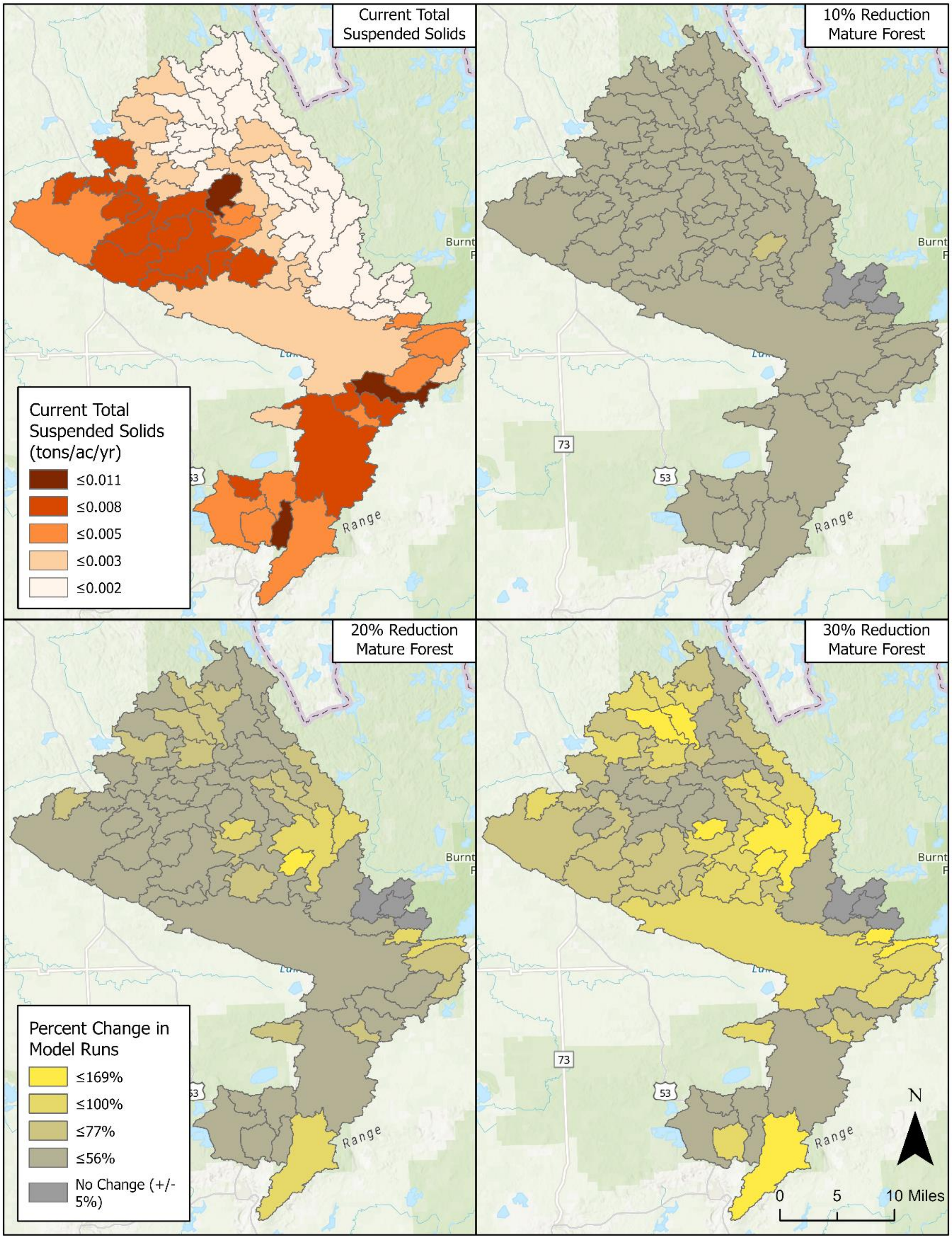


**Figure 11. Changes in annual average annual average TP loading for the forest disturbance scenarios.**

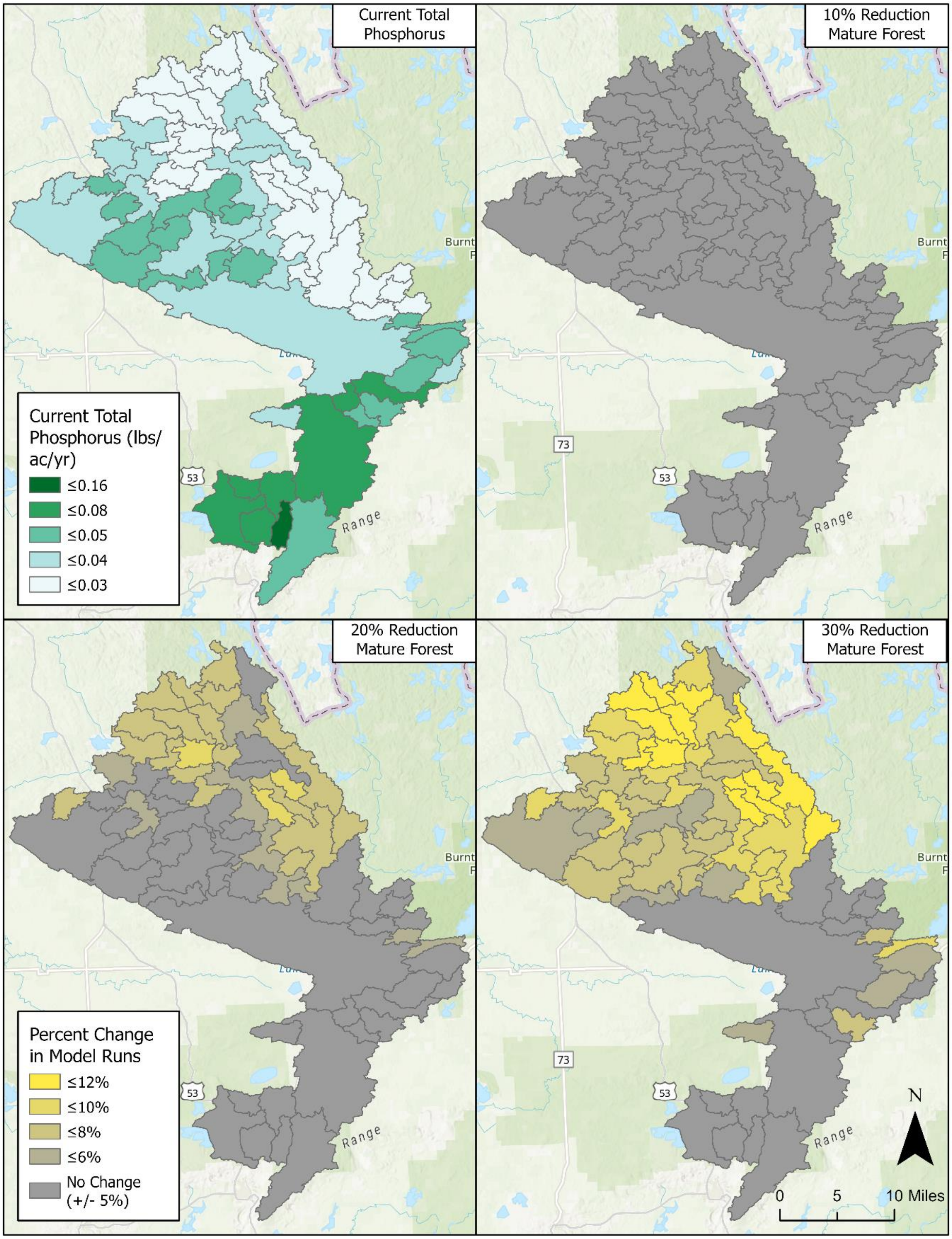


**Figure 12. Changes in annual average annual average TN loading for the forest disturbance scenarios.**

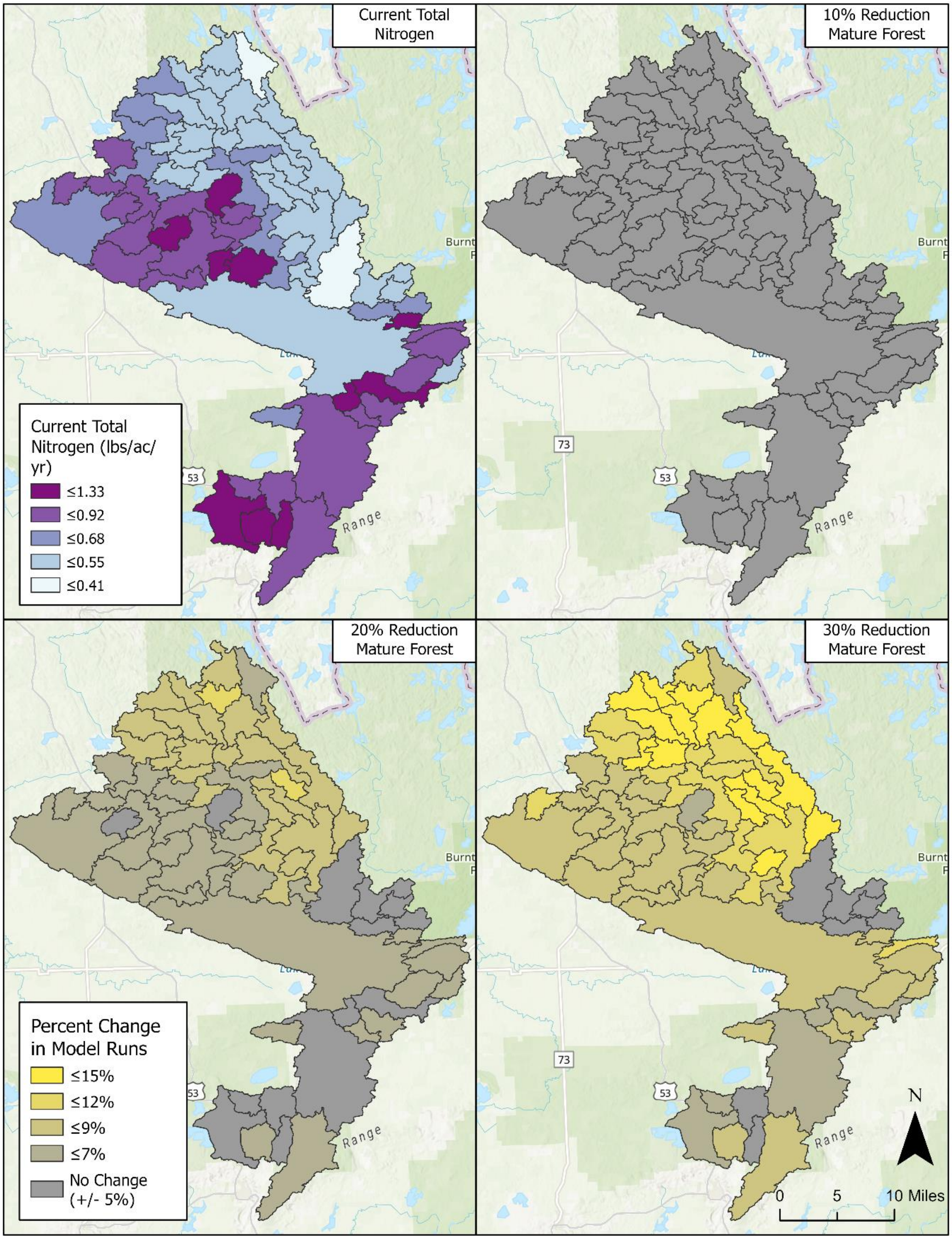


Table 4. Parameter changes at key locations for the forest disturbance scenarios, 10% disturbance.

| | | Annual Runoff Volume (ac-ft) | | | Annual Total Sediment Load (tons) | | | Annual Total Phosphorus Load (lb) | | | Annual Total Nitrogen Load (lb) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HSPF Reach | Key Resources | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change |
| 46 | Eagles Nest 3 & 4 | 1,956 | 1,984 | 1.4% | 9 | 12 | 28.9% | 138 | 140 | 1.6% | 2,020 | 2,080 | 2.9% |
| 47 | Eagles Nest 1 & 2 | 6,465 | 6,549 | 1.3% | 39 | 49 | 27.6% | 381 | 389 | 1.9% | 7,060 | 7,256 | 2.8% |
| 80 | Lake Vermilion outlet | 41,685 | 42,279 | 1.4% | 308 | 392 | 27.3% | 3,304 | 3,357 | 1.6% | 52,668 | 54,091 | 2.7% |
| 220 | Pelican Lake | 15,857 | 16,071 | 1.4% | 157 | 189 | 20.1% | 1,275 | 1,297 | 1.7% | 19,943 | 20,471 | 2.6% |
| 241 | Myrtle Lake | 5,651 | 5,727 | 1.3% | 59 | 68 | 14.7% | 387 | 394 | 1.8% | 6,561 | 6,730 | 2.6% |
| 420 | Namakan Lake Inflow | 3,924 | 3,982 | 1.5% | 14 | 15 | 9.5% | 203 | 207 | 1.8% | 3,571 | 3,663 | 2.6% |

Table 5. Parameter changes at key locations for the forest disturbance scenarios, 20% disturbance.

| | | Annual Runoff Volume (ac-ft) | | | Annual Total Sediment Load (tons) | | | Annual Total Phosphorus Load (lb) | | | Annual Total Nitrogen Load (lb) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HSPF Reach | Key Resources | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change |
| 46 | Eagles Nest 3 & 4 | 1,956 | 2,012 | 2.9% | 9 | 15 | 57.7% | 138 | 142 | 3.2% | 2,020 | 2,139 | 5.9% |
| 47 | Eagles Nest 1 & 2 | 6,465 | 6,632 | 2.6% | 39 | 60 | 55.3% | 381 | 396 | 3.9% | 7,060 | 7,452 | 5.6% |
| 80 | Lake Vermilion outlet | 41,685 | 42,873 | 2.8% | 308 | 476 | 54.6% | 3,304 | 3,411 | 3.2% | 52,668 | 55,514 | 5.4% |
| 220 | Pelican Lake | 15,857 | 16,286 | 2.7% | 157 | 221 | 40.3% | 1,275 | 1,319 | 3.5% | 19,943 | 20,998 | 5.3% |
| 241 | Myrtle Lake | 5,651 | 5,803 | 2.7% | 59 | 77 | 29.4% | 387 | 401 | 3.7% | 6,561 | 6,900 | 5.2% |
| 420 | Namakan Lake Inflow | 3,924 | 4,040 | 2.9% | 14 | 16 | 19.0% | 203 | 210 | 3.6% | 3,571 | 3,756 | 5.2% |

**Table 6. Parameter changes at key locations for the forest disturbance scenarios, 30% disturbance.**

| | | Annual Runoff Volume (ac-ft) | | | Annual Total Sediment Load (tons) | | | Annual Total Phosphorus Load (lb) | | | Annual Total Nitrogen Load (lb) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HSPF Reach | Key Resources | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change |
| 46 | Eagles Nest 3 & 4 | 1,956 | 2,040 | 4.3% | 9 | 18 | 86.6% | 138 | 144 | 4.9% | 2,020 | 2,198 | 8.8% |
| 47 | Eagles Nest 1 & 2 | 6,465 | 6,715 | 3.9% | 39 | 71 | 82.9% | 381 | 404 | 5.8% | 7,060 | 7,648 | 8.3% |
| 80 | Lake Vermilion outlet | 41,685 | 43,466 | 4.3% | 308 | 560 | 82.0% | 3,304 | 3,464 | 4.9% | 52,668 | 56,936 | 8.1% |
| 220 | Pelican Lake | 15,857 | 16,501 | 4.1% | 157 | 253 | 60.4% | 1,275 | 1,341 | 5.2% | 19,943 | 21,526 | 7.9% |
| 241 | Myrtle Lake | 5,651 | 5,879 | 4.0% | 59 | 85 | 44.2% | 387 | 408 | 5.5% | 6,561 | 7,070 | 7.8% |
| 420 | Namakan Lake Inflow | 3,924 | 4,097 | 4.4% | 14 | 18 | 28.5% | 203 | 214 | 5.5% | 3,571 | 3,848 | 7.8% |

## *CLIMATE CHANGE*

All three climate change options were modeled to estimate the amount of change under the existing climate change projections. HSPF-SAM incorporates change in precipitation along a gradient rather than just an overall increase. Overall, the model increases the total amount of precipitation and surface water runoff in all three scenarios. Additionally, the highest precipitation events increase while the lowest precipitation events are reduced. No change is made to median storm events. Sediment transport is highly influenced by larger storms, which scour and increase sediment wash-off occurring during large events. The increase in surface water runoff and extreme precipitation events in all three scenarios resulted in increased sediment loading.

Additionally, the model incorporates increases in temperatures in all three scenarios. This increases evapotranspiration and decreases 'total runoff', which is a combination of surface runoff and groundwater flow. Although groundwater flow may be small relative to surface runoff from a storm event on a daily timescale, it occurs throughout the year and can be a significant contributor to flow and nutrient loading in a watershed. And although nutrients bound to sediment will increase with increased sediment loading, this decrease in groundwater flow has a stronger influence on the resulting modeled nutrient loading. Overall, with less 'total runoff', nutrient loading decreased.

The results for the climate change scenario are shown for annual average runoff volume in **Figure 13**, sediment in **Figure 14**, TP loading in **Figure 15**, and TN loading in **Figure 16**. The numeric results at key locations are shown in **Table 7** through **Table 9**.

**Figure 13. Changes in annual average runoff volume per acre for the climate change scenario**

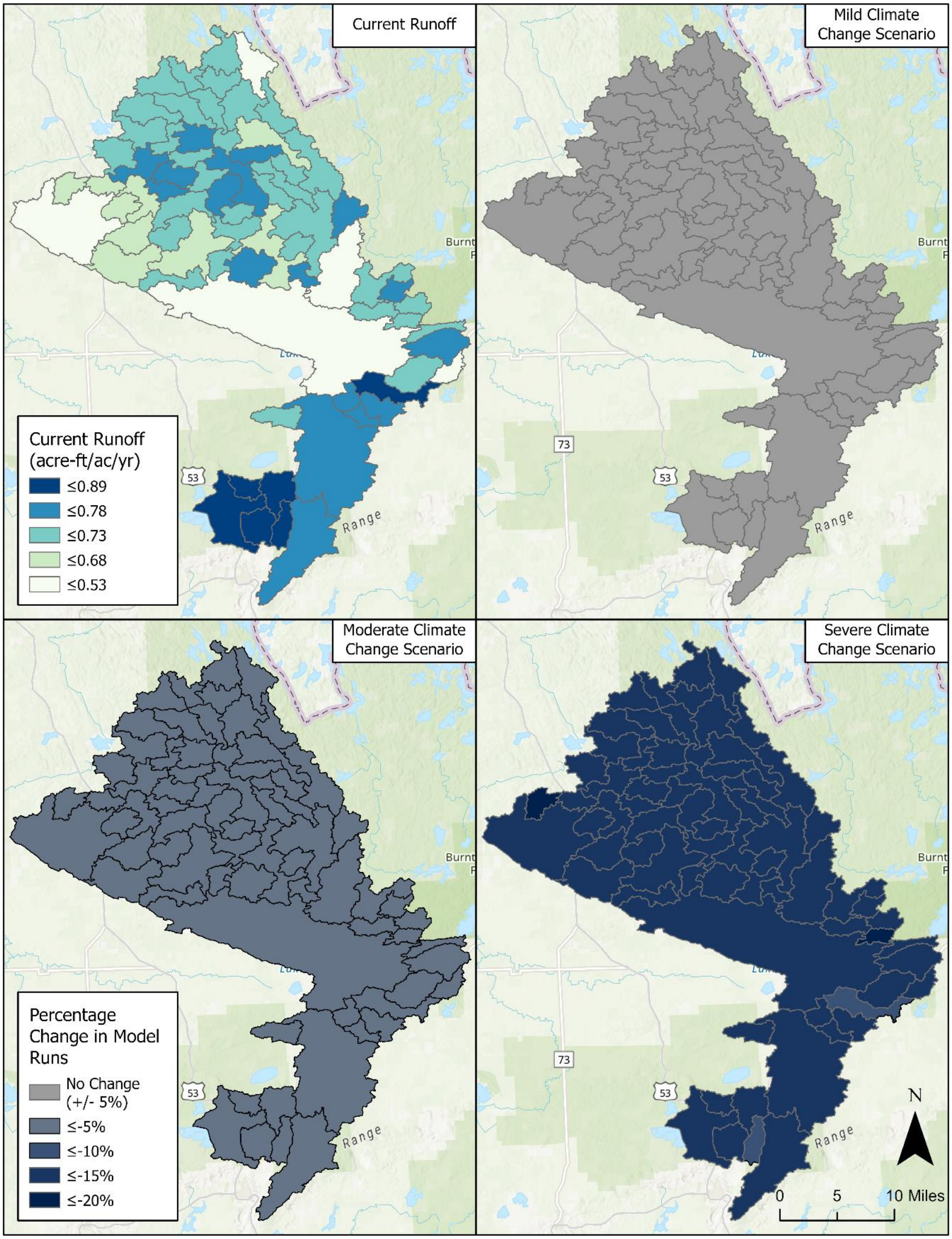


**Figure 14. Changes in annual average annual average sediment loading for the climate change scenario**

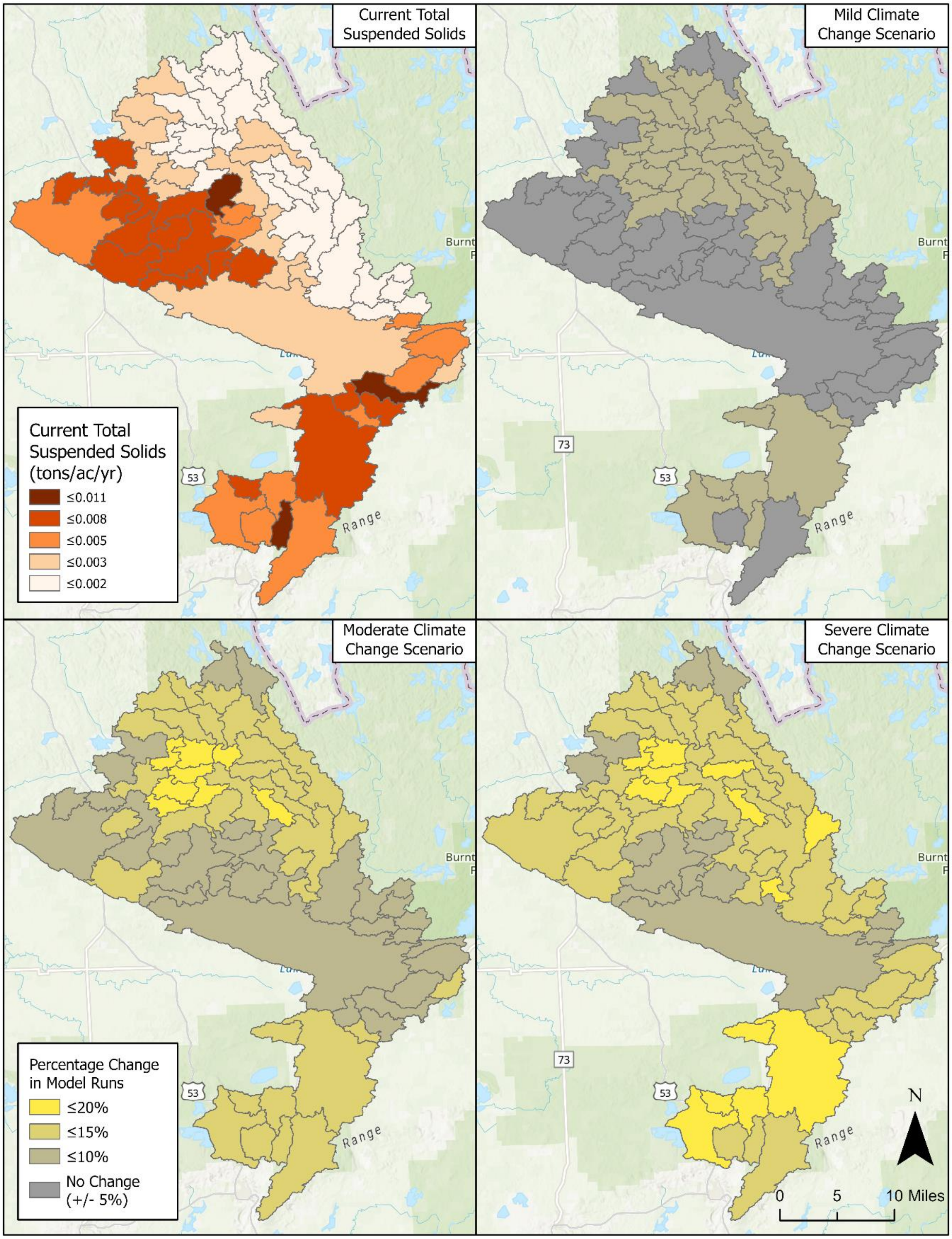


**Figure 15. Changes in annual average annual average TP loading for the climate change scenario**

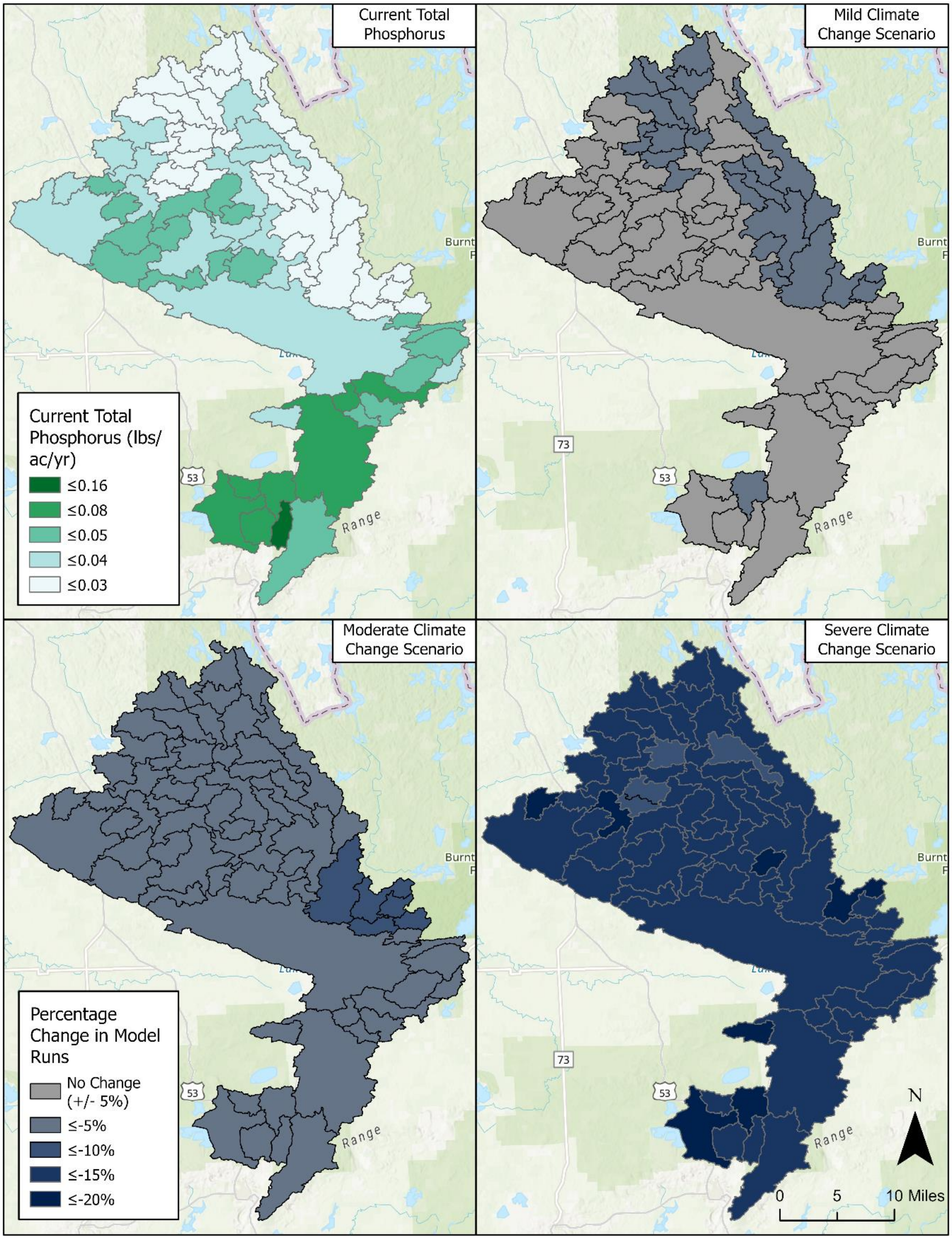


**Figure 16. Changes in annual average annual average TN loading for the climate change scenario**

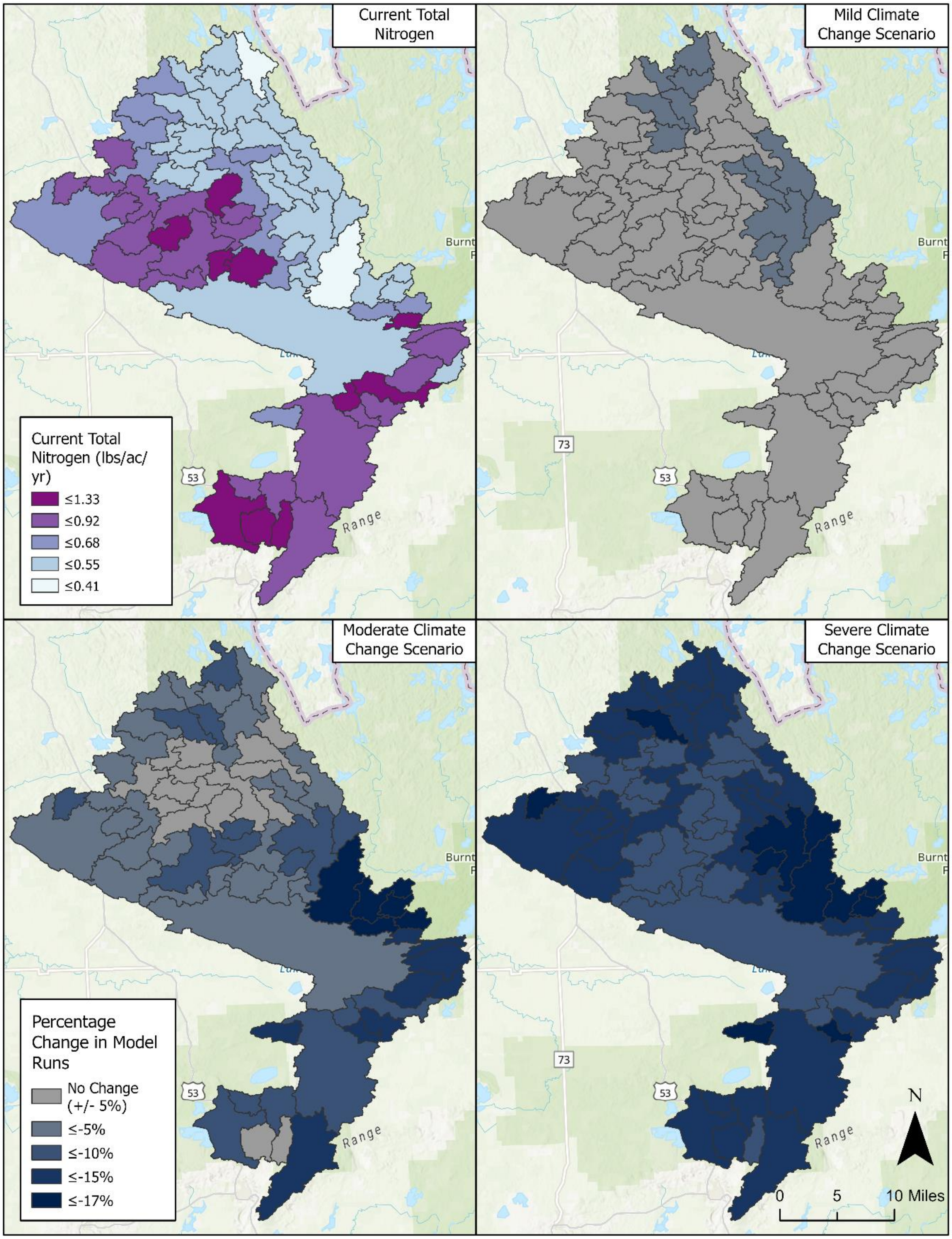


Table 7. Parameter changes at key locations for the mile climate change scenario.

| HSPF Reach | Key Resources | Annual Runoff Volume (ac-ft) Existing | Annual Runoff Volume (ac-ft) Scenario | Annual Runoff Volume (ac-ft) Percent Change | Annual Total Sediment Load (tons) Existing | Annual Total Sediment Load (tons) Scenario | Annual Total Sediment Load (tons) Percent Change | Annual Total Phosphorus Load (lb) Existing | Annual Total Phosphorus Load (lb) Scenario | Annual Total Phosphorus Load (lb) Percent Change | Annual Total Nitrogen Load (lb) Existing | Annual Total Nitrogen Load (lb) Scenario | Annual Total Nitrogen Load (lb) Percent Change |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | Eagles Nest 3 & 4 | 1,956 | 1,882 | -3.8% | 9 | 10 | 4.5% | 138 | 133 | -3.6% | 2,020 | 1,957 | -3.1% |
| 47 | Eagles Nest 1 & 2 | 6,465 | 6,212 | -3.9% | 39 | 40 | 4.0% | 381 | 368 | -3.6% | 7,060 | 6,857 | -2.9% |
| 80 | Lake Vermilion outlet | 41,685 | 40,233 | -3.5% | 308 | 321 | 4.4% | 3,304 | 3,210 | -2.8% | 52,668 | 50,916 | -3.3% |
| 220 | Pelican Lake | 15,857 | 15,237 | -3.9% | 157 | 165 | 4.7% | 1,275 | 1,236 | -3.1% | 19,943 | 19,235 | -3.5% |
| 241 | Myrtle Lake | 5,651 | 5,441 | -3.7% | 59 | 62 | 5.1% | 387 | 375 | -3.1% | 6,561 | 6,336 | -3.4% |
| 420 | Namakan Lake Inflow | 3,924 | 3,779 | -3.7% | 14 | 14 | 4.3% | 203 | 194 | -4.3% | 3,571 | 3,401 | -4.8% |

Table 8. Parameter changes at key locations for the moderate climate change scenario.

| HSPF Reach | Key Resources | Annual Runoff Volume (ac-ft) Existing | Annual Runoff Volume (ac-ft) Scenario | Annual Runoff Volume (ac-ft) Percent Change | Annual Total Sediment Load (tons) Existing | Annual Total Sediment Load (tons) Scenario | Annual Total Sediment Load (tons) Percent Change | Annual Total Phosphorus Load (lb) Existing | Annual Total Phosphorus Load (lb) Scenario | Annual Total Phosphorus Load (lb) Percent Change | Annual Total Nitrogen Load (lb) Existing | Annual Total Nitrogen Load (lb) Scenario | Annual Total Nitrogen Load (lb) Percent Change |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | Eagles Nest 3 & 4 | 1,956 | 1,812 | -7.3% | 9 | 10 | 10.0% | 138 | 126 | -4.5% | 2,020 | 1,860 | -7.9% |
| 47 | Eagles Nest 1 & 2 | 6,465 | 5,971 | -7.6% | 39 | 42 | 8.8% | 381 | 349 | -15.6% | 7,060 | 6,516 | -7.7% |
| 80 | Lake Vermilion outlet | 41,685 | 38,832 | -6.8% | 308 | 334 | 8.4% | 3,304 | 3,062 | -6.7% | 52,668 | 49,799 | -5.4% |
| 220 | Pelican Lake | 15,857 | 14,679 | -7.4% | 157 | 173 | 9.7% | 1,275 | 1,194 | -4.2% | 19,943 | 18,872 | -5.4% |
| 241 | Myrtle Lake | 5,651 | 5,253 | -7.1% | 59 | 66 | 11.2% | 387 | 364 | -6.8% | 6,561 | 6,252 | -4.7% |
| 420 | Namakan Lake Inflow | 3,924 | 3,640 | -7.2% | 14 | 15 | 8.2% | 203 | 189 | -10.3% | 3,571 | 3,371 | -5.6% |

Table 9. Parameter changes at key locations for the severe climate change scenario

| | | Annual Runoff Volume (ac-ft) | | | Annual Total Sediment Load (tons) | | | Annual Total Phosphorus Load (lb) | | | Annual Total Nitrogen Load (lb) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HSPF Reach | Key Resources | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change | Existing | Scenario | Percent Change |
| 46 | Eagles Nest 3 & 4 | 1,956 | 1,605 | -17.9% | 9 | 11 | 12.3% | 138 | 112 | -18.6% | 2,020 | 1,702 | -15.8% |
| 47 | Eagles Nest 1 & 2 | 6,465 | 5,261 | -18.6% | 39 | 43 | 12.1% | 381 | 309 | -19.0% | 7,060 | 5,936 | -15.9% |
| 80 | Lake Vermilion outlet | 41,685 | 34,459 | -17.3% | 308 | 336 | 9.1% | 3,304 | 2,729 | -17.4% | 52,668 | 45,787 | -13.1% |
| 220 | Pelican Lake | 15,857 | 12,934 | -18.4% | 157 | 176 | 11.5% | 1,275 | 1,050 | -17.6% | 19,943 | 16,846 | -15.5% |
| 241 | Myrtle Lake | 5,651 | 4,653 | -17.7% | 59 | 67 | 13.5% | 387 | 320 | -17.3% | 6,561 | 5,563 | -15.2% |
| 420 | Namakan Lake Inflow | 3,924 | 3,214 | -18.1% | 14 | 15 | 8.8% | 203 | 169 | -16.7% | 3,571 | 3,027 | -15.2% |

# CLIMATE CHANGE SCENARIO DETAILS

Potential climate related impacts that may occur in the upper Midwest, including areas of the watershed, are described in the National Climate Assessment for the Midwest (Pryor et al., 2014). Some of the impacts discussed include changes in forest composition, increases in heatwave intensity and frequency, increased humidity, degraded air quality, reduced water quality and increased rainfall and flooding.

The Intergovernmental Panel on Climate Change (IPCC) released the Physical Science Basis Working Group Report for the IPCC 5th Reassessment in 2013 (IPCC, 2013), incorporating results from Global Climate Model (GCM) simulations from the Coupled Model Intercomparison Project round 5 (CMIP5). At higher spatial resolution, the U.S. Geological Survey (USGS) National Climate Change Viewer (NCCV) (https://www2.usgs.gov/landresources/lcs/nccv.asp) provides a quick overview of the range of simulated potential changes in climate for the watershed. The NCCV allows the user to visualize projected changes in climate (maximum and minimum air temperature and precipitation) and the water balance (snow water equivalent, runoff, soil water storage and evaporative deficit) for any state, county and USGS Hydrologic Unit (HUC).

The projections are based on monthly summary data extracted from the 30 Global Circulation Models (GCM) future climate simulations conducted for CMIP5 that have been statistically downscaled for local predictions over the continental U.S. in the NASA Earth Exchange (NEX) Downscaled Climate Projections (NASA NEX-DCP30) dataset (Thrasher et al., 2013). The suite of models is in agreement in predicting a steady increase in maximum and minimum air temperature throughout the 21st century, although trends diverge after about 2050 depending on the greenhouse gas concentration trajectory. There is less agreement as to future trends in precipitation, although most models tend to predict some increase in winter and spring precipitation and a decrease in summer precipitation in the watershed. Rising temperatures will cause winter snowpack to decrease while summer evaporation rates will increase, likely leading to declining soil water storage based on the simple water balance accounting method of McCabe and Wolock (2011). Resulting impacts on runoff, which integrates the effects of precipitation and evaporation are uncertain in the McCabe and Wolock (2011) analysis, although total runoff volume appears likely to not change greatly.

The following summarizes the climate projects from the NCCV for select parameters, including maximum and minimum air temperature, precipitation, and evaporative deficit. Evaporative deficit is the evaporative demand not met by the available water and can be used as an index of the potential effects of drought stress. The summary results are the mean model for the RCP4.5 emissions scenario, in which atmospheric greenhouse gas concentrations are stabilized so as not to exceed a radiative equivalent of about 650 ppm CO2.

**Figure 17** shows the average monthly maximum air temperature for the watershed for two periods, 1981-2010 and 2050-2074. The annual average maximum air temperature is 49.9 °F for the 1981-2010 period and a projected 54.7 °F for the 2050-2074, with a projected increase of 4.8 °F between the periods. **Figure 18** shows the average monthly minimum air temperature for the watershed. The annual average minimum air temperature is 26.6 °F for the 1981-2010 period and a projected 31.8 °F for the 2050-2074, with a projected increase of 5.2 °F between the periods.

**Figure 17. Average maximum air temperature by month for 1981-2010 and 2050-2074, based on the mean model, for the RCP4.5 emissions scenario.**

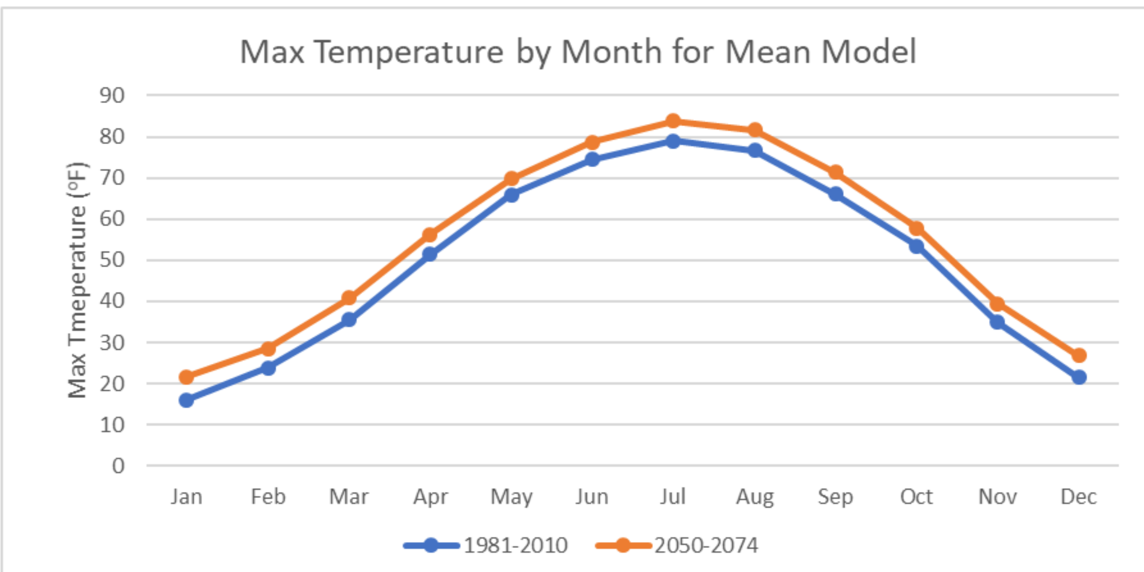


**Figure 18. Average minimum air temperature by month for 1981-2010 and 2050-2074, based on the mean model, for the RCP4.5 emissions scenario.**

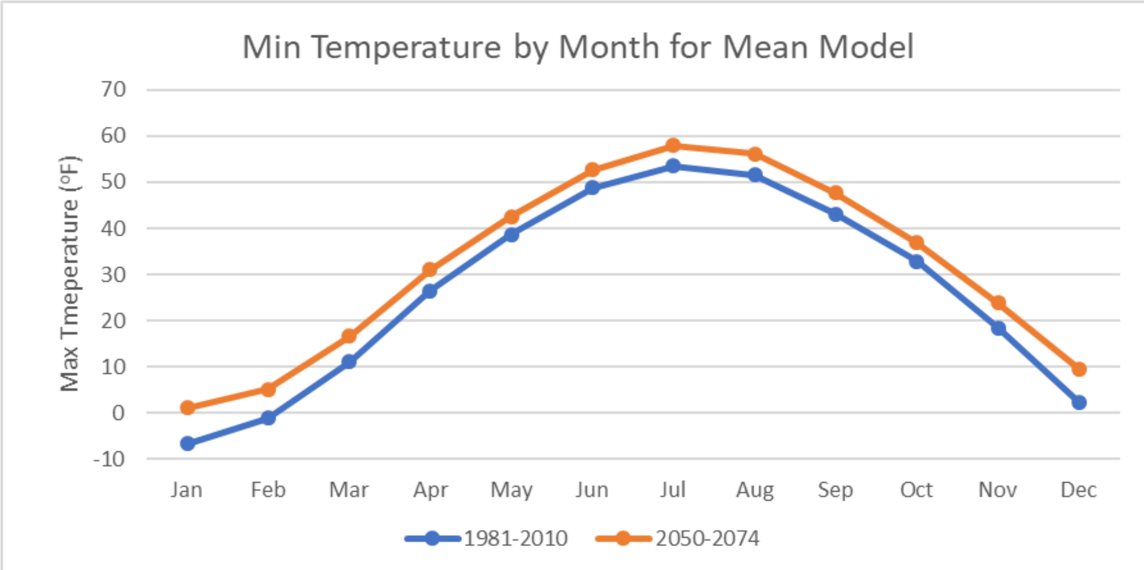



**Figure 19** shows the average monthly precipitation for the watershed for two periods, 1981-2010 and 2050-2074. The annual average monthly precipitation is 27.7 inches for the 1981-2010 period and a projected 29.2 inches for the 2050-2074, with a projected increase of 1.5 inches between the periods. **Figure 20** shows the average monthly evaporative deficit for the watershed. The annual average evaporative deficit is 0.91 inches for the 1981-2010 period and a projected 1.88 inches for the 2050-2074, with a projected increase of 0.97 inches between the periods.

Figure 19. Average precipitation by month for 1981-2010 and 2050-2074, based on the mean model, for the RCP4.5 emissions scenario.

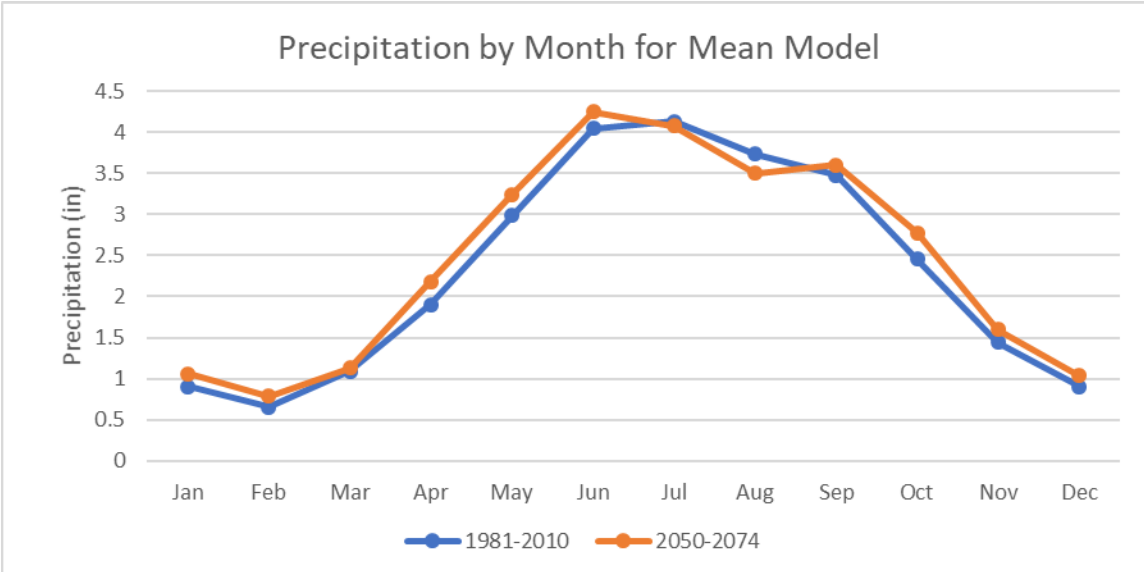
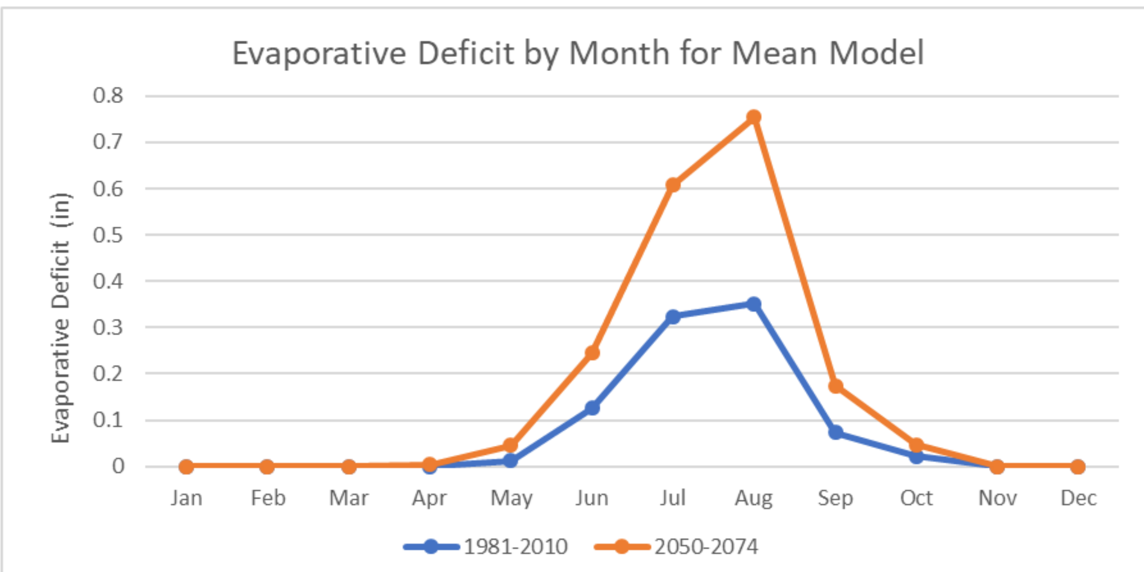



Figure 20. Average evaporative deficit by month for 1981-2010 and 2050-2074, based on the mean model, for the RCP4.5 emissions scenario.




Overall, the watershed is projected to see an increase in air temperature of about 5 ˚F, an increase in average annual precipitation of 1.5 inches (5.5% increase), and an increase in evaporative deficit of 0.97 inches (107% increase). Potential impacts form these climate changes could include increased peak flows, prolonged drier conditions, and lower summer flows, when evaporative demand peaks.

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# Appendix D: Vermilion River Watershed Lake Source Assessments for Protection – Technical Memorandum

# Technical Memorandum

**To:** Vermilion River Core Team

**From:** Houston Engineering, Inc.

**Subject:** Vermilion River Watershed – Lake Source Assessments

**Date:** October 19, 2020

**Project:** 6074-0023

## PURPOSE

This technical memorandum (TM) provides detailed lake source assessment data for five lakes, identified by the Core Team, to be priority lakes for protection within the Vermilion River Watershed (VRW). These five lakes include:

- Pelican Lake;
- Eagles Nest Lake #1;
- Eagles Nest Lake #2;
- Eagles Nest Lake #3; and
- Eagles Nest Lake #4.

The lake sections of this TM includes details about seasonal water quality dynamics for phosphorus, dissolved oxygen (DO), and chlorophyll-*a* (Chl-*a*). Also included is land use targeting within the lake drainage area, phosphorus source assessment data extracted from the Hydrologic Simulation Program FORTRAN (HSPF) model, and recommendation for goal setting and monitoring. The modeling data is provided as a tool to assist management decisions alongside best professional judgement and actual field data.

Additionally, this information is meant to supplement the MPCA and DNR Lake Protection Priority list that is summarized in Section 2.5.3 of the Vermilion River WRAPS Report. The MPCA and DNR Lake Protection Priority list uses a robust framework to estimate loading and provide a 5% reduction goal. In the future, BATHTUB, a more lake-specific model than HSPF-SAM, could be used to better detail phosphorus load reductions to these lakes.

## PELICAN LAKE

Pelican Lake is a local priority for the VRW Core Team and has some qualities identified during the VRW Watershed Restoration and Protection Strategy (WRAPS) development. Qualities in need of protection include wild rice, outstanding biological significance, and Class 1B drinking water designation. It is also an important recreation destination with numerous resorts, and fishing, swimming, and boating use. The lake approaches the water quality standards periodically, which is a concern for future aquatic recreational use. Increased protection and management can keep this lake from becoming impaired. For more information, see Appendix C of the VRW WRAPS Report.

## WATER QUALITY

Phosphorus concentrations from 2015-2019 average 26 µg/L and approach the eutrophication standard for the Northern Lakes and Forests (NLF) Ecoregion, which is 30 µg/L, several times. Phosphorus concentrations remain relatively consistent from May through September, as shown in **Figure 1**.

Pelican Lake is a mesotrophic lake of moderate depth (max depth of 38 feet). It is classified as a deep lake for assessment, but it behaves more like a shallow lake. Dissolved oxygen profiles shown in **Figure 2** indicate that the lake is polymictic. DO profiles and hypolimnion phosphorus samples were collected in 2015-2016. The data show that the hypolimnion did not become anoxic (i.e. DO concentrations lower than 5 mg/L) and the hypolimnion phosphorus concentration shown in **Figure 3** did not indicate internal loading (when the hypolimnion phosphorus concentration is higher than the surface phosphorus concentration). Continuous water quality monitoring with DO and temperature sensors would provide better data to analyze internal loading potential.

The Chl-*a* concentration in Pelican Lake averages 10 µg/L and exceeded the eutrophication standard for the NLF Ecoregion (9 µg/L) at the end of the summer in 2015, 2016 and 2018. Minnesota Pollution Control Agency (MPCA) data comparing user perceptions with Chl-*a* concentrations has concluded that lake users perceive a major algae bloom when the Chl-*a* concentration reaches 20 µg/L (Heiskary & Wilson, 2008) In Pelican Lake, an algae bloom was observed in 2015, 2016, and 2018, as shown in **Figure 4**.

The transparency, expressed via Secchi depth, in Pelican Lake averages 12.5 feet. Data show the transparency is highest in June, when it can be as high as 20-25 feet. In August, the transparency decreases to 5-10 feet as the lake experiences algae blooms as shown in **Figure 5**. Long-term trend analysis shows that there is an improving trend in transparency as shown in **Figure 6**. This recent trend in clarity is not understood and unknown if short term or longer term. Continued monitoring is recommended.

**Figure 1. Seasonal phosphorus concentration dynamics: Pelican Lake (site 202, EQuIS).**

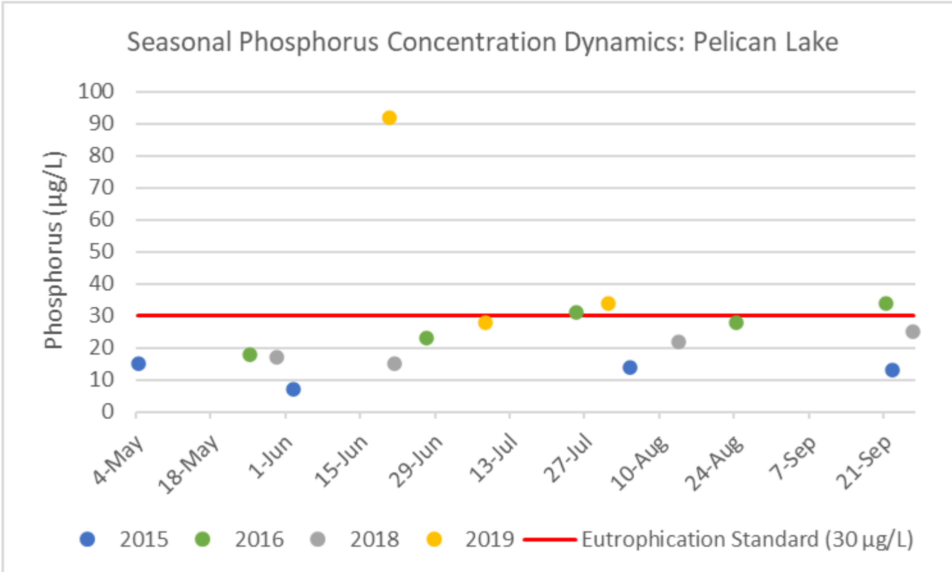



**Figure 2. Dissolved oxygen profiles for Pelican Lake in 2016 (site 202, EQuIS).**

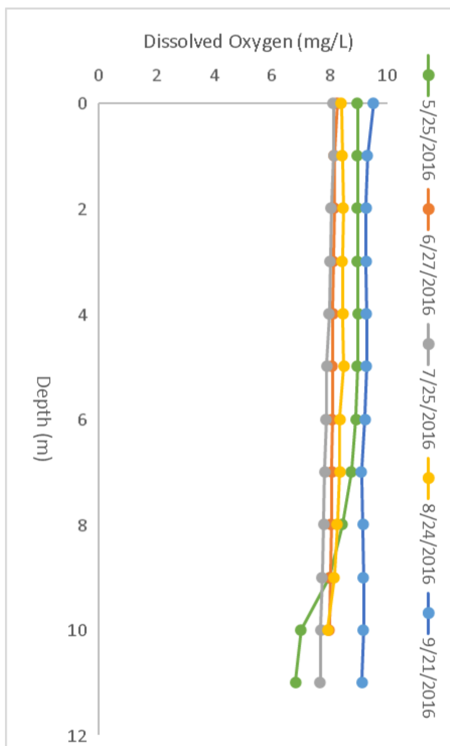


Figure 3. Surface and hypolimnion (bottom) phosphorus concentrations in Pelican Lake in 2015 and 2016 (site 202, EQuIS).

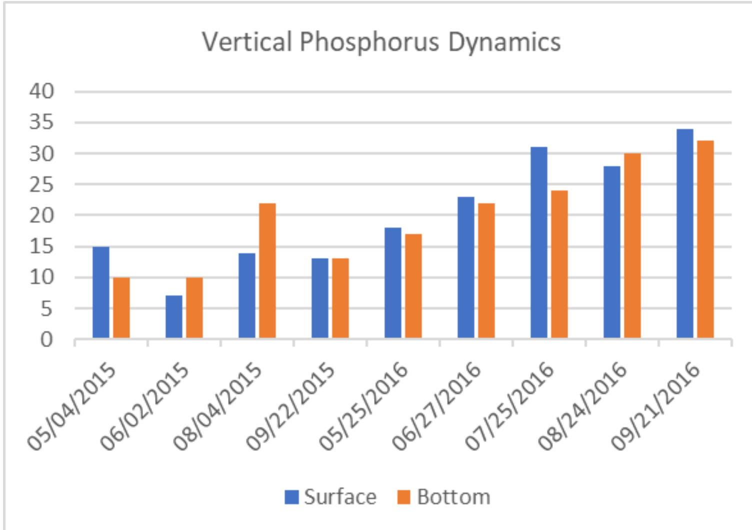



Figure 4. Seasonal Chl-*a* concentration dynamics: Pelican Lake (site 202, EQuIS).

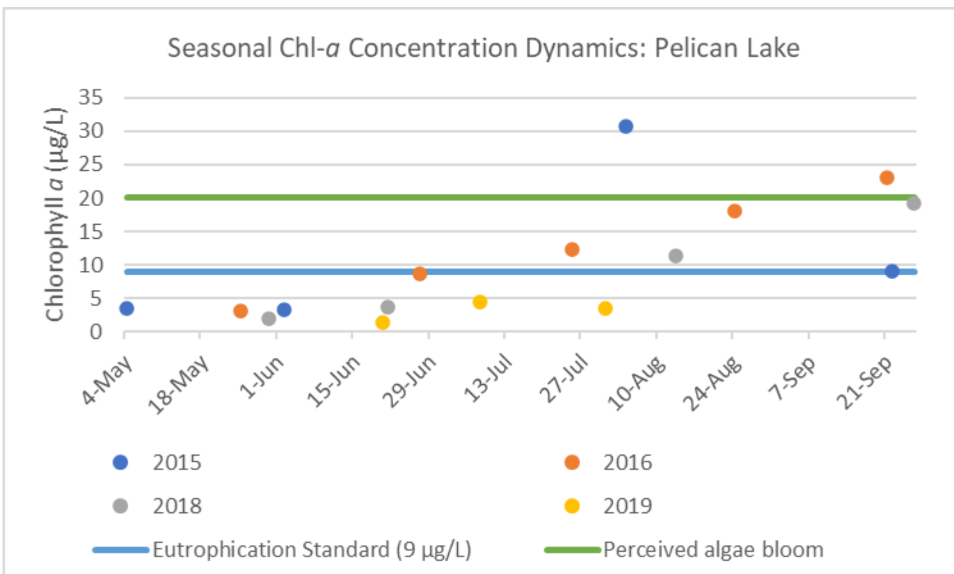


**Figure 5. Seasonal transparency dynamics: Pelican Lake (site 202, EQuIS).**

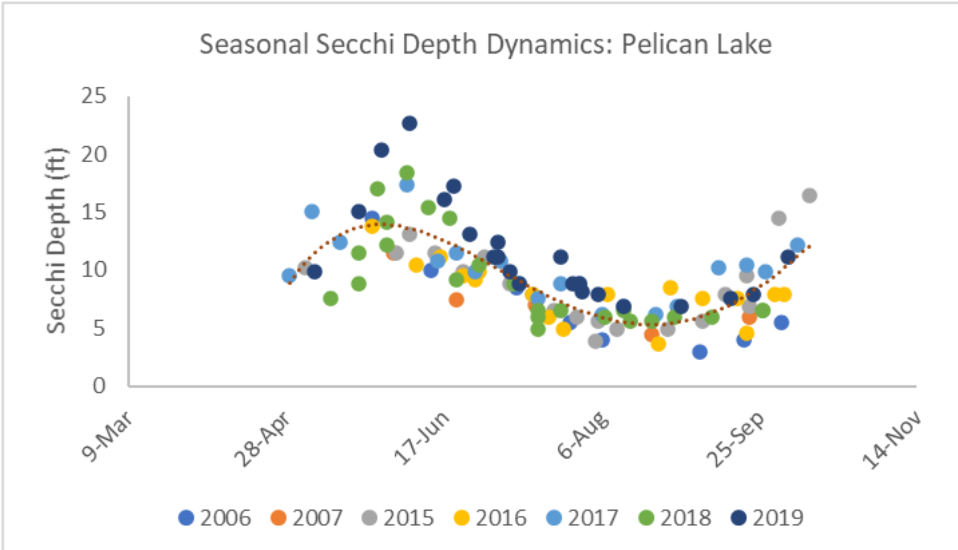
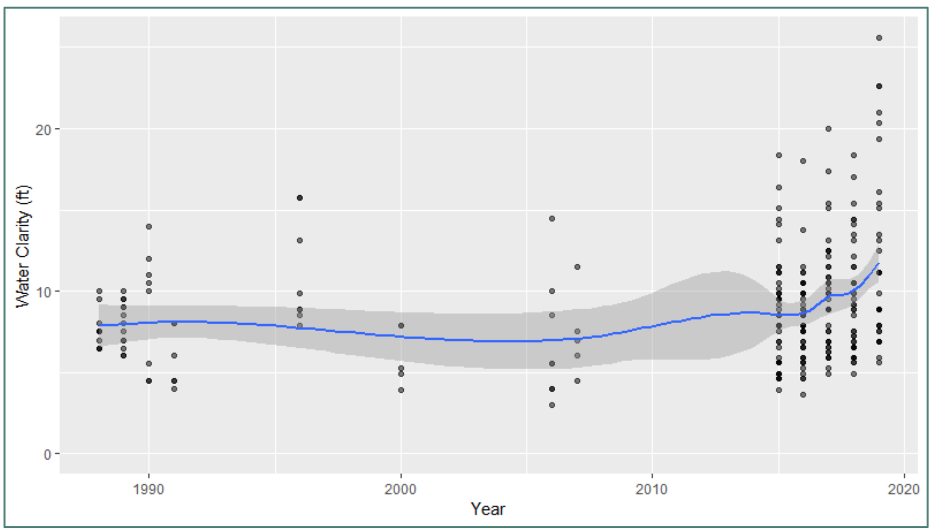


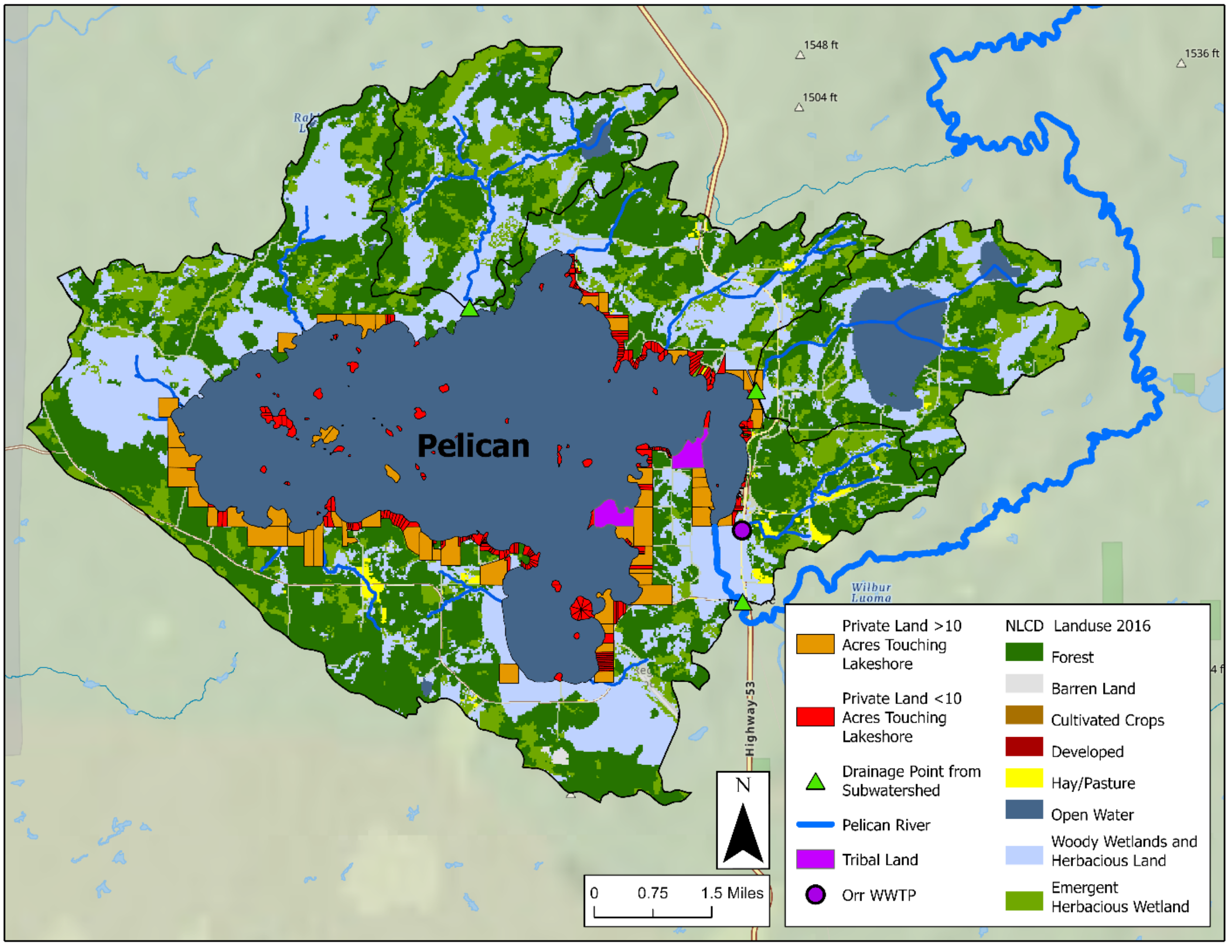

**Figure 6. Long-term transparency trend (Secchi depth): Pelican Lake (MPCA Citizen Data website).**




## LAKE DRAINAGE LAND USE

The land use of the watershed contributing to the lake is primarily forests and wetlands with some development along the lakeshore. The City of Orr sits on the eastern side of the lake. There are some small streams draining into the lake, but the drainage area to the lake is relatively small. The Pelican River outlets the lake near Orr and drains to the east and then north, eventually joining the Vermilion River as shown in **Figure 7.**

Figure 7. Land use, tributaries, and developed land identification in the Pelican Lake watershed.




## *PHOSPHORUS LOADING*

The HSPF Scenario Application Manager (SAM) was used for a source assessment analysis to quantify the phosphorus loading to the lake from the different land uses within the lake drainage area. HSPF-SAM is not a lake-specific model and there is significant uncertainty involved. These loading numbers are intended to be used as tool for planning and prioritizing efforts and not to indicate day-to-day loading conditions.

The model results suggest two upstream reaches that drain into the lake provide 13% of the phosphorus loading as shown in **Figure 8**. The model shows the remaining 87% of the phosphorus loading coming from the direct drainage area of the lake (i.e. nearshore). The Orr Wastewater Treatment Plant (WWTP) discharges into the Pelican River at the outlet of the lake, so is not included in the modeled lake loading numbers. Internal loading is not quantified in **Figure 8** or **Figure 9**.

The phosphorus loading to Pelican Lake within its direct drainage area (i.e. HSPF reach) was broken down by land use in **Figure 9**, which can help guide implementation activities for reducing phosphorus loading to the lake. Given the large size of the lake and small watershed (watershed to surface area ratio = 4:1), the model results show atmospheric deposition as the highest phosphorus source to the lake at 51%. The second highest phosphorus source is forests, but again that is due to the amount of acreage in forest cover and the low development density in the watershed. The modeling results showed some areas of phosphorus loading that can be reduced with best management practices. Results indicate developed areas contribute about 13% and septic systems contribute 1% of the phosphorus loading to the lake as shown in **Figure 9**.

**Figure 8. Upstream reach vs. nearshore phosphorus loading to Pelican Lake (HSPF-SAM Basin Source Fate).**

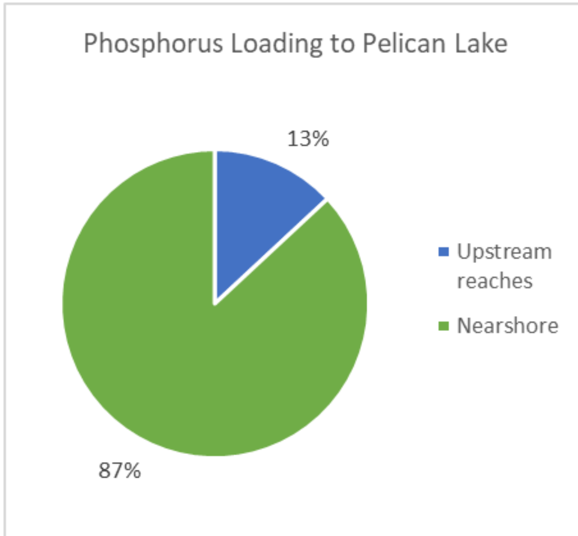
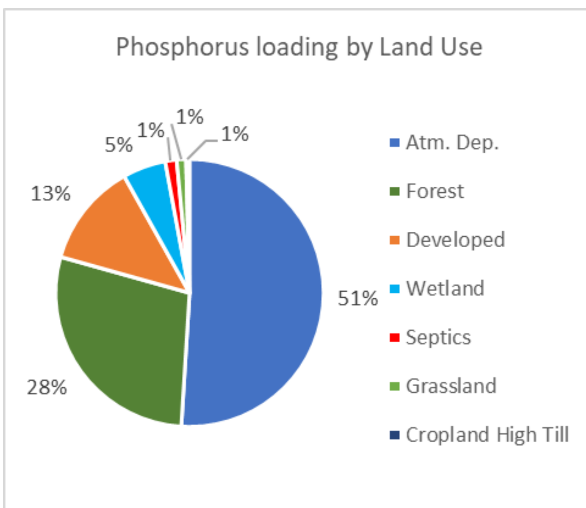



**Figure 9. Direct drainage phosphorus loading to Pelican Lake, by land use (HSPF-SAM Source Fate)**




## *GOAL SETTING*

Pelican Lake is not on the 303d Impaired Waters List, so does not require a total maximum daily load (TMDL) or specific reduction at this time. Any current phosphorus goals would be for protection. Typically, short-term goals (i.e., 10-year timeframe) for lake protection have been set to a 5% reduction based on the Minnesota Department of Natural Resources' (DNR) phosphorus sensitivity modeling analysis (MPCA and DNR, 2019). A reduction could be reached through a combination of stormwater best management practices (BMPs) such as rain gardens and lakeshore buffers, septic system inventory and improvements, and education and outreach to lakeshore property owners. The privately-owned lakeshore in **Figure 7** (red and orange) could be targeted for phosphorus reduction practices. Landowners can work with the North St. Louis SWCD to install these BMPs.

Other protection practices, such as easements and acquisitions, could be targeted to the orange colored parcels (privately-owned lakeshore greater than 10 acres) in **Figure 7**. Protection of these areas could prevent future increases in phosphorus loading to the lake from increased development. Landowners can contact the North St. Louis SWCD or Minnesota Land Trust to learn more about conservation easement options. If there is undeveloped shoreline that is important for fish spawning, the DNR could be contacted for Aquatic Management Area options.

### *MONITORING*

Pelican Lake is vulnerable to decline since it is already close to the impairment standards. Continued monitoring can track any changes to the lake as best management practices are implemented. In addition, a better understanding of the dissolved oxygen dynamics and internal loading can help understand the proportion of phosphorus loading coming from internal sources. BATHTUB, a more lake-specific model than HSPF-SAM, could be used to better detail phosphorus load reductions to the lake and the lake's response to those reductions.

## EAGLES NEST LAKE CHAIN

The Eagles Nest Lake Chain is a local priority for the VRW Core Team and has some risks and qualities identified during the VRW WRAPS development. Eagles Nest #1 and #2 have the majority of their shorelines developed, while Eagles Nest #3 and #4 are moderately developed. Eagles Nest #2 has a declining transparency trend and all four lakes are in the "Highest" phosphorus sensitivity category (MPCA and DNR, 2019). The HSPF modeling scenarios (VRW WRAPS Appendix D) showed that these lakes are vulnerable to future changes in the watershed including additional development, increased forest disturbance, and climate change.

### *WATER QUALITY*

Phosphorus concentrations in the Eagles Nest Lake Chain remain well below the eutrophication standard for the NLF Ecoregion, which is 30 µg/L, as shown in **Figure 10**. Phosphorus concentrations remain relatively consistent in all lakes throughout the summer.

DO profiles were collected in 2016 in Eagles Nest #1, #2, and #3, and in 1998 in Eagles Nest #4. The data show that the hypolimnion did become anoxic in late summer (i.e., DO concentrations lower than 5 mg/L) as shown in **Figure 11**.

The Chl-*a* concentrations in the Eagles Nest Lake Chain remain well below the eutrophication standard for the NLF Ecoregion (9 µg/L), as shown in **Figure 12**. MPCA data comparing user perceptions with Chl-*a* concentrations has concluded that lake users perceive a major algae bloom when the Chl-*a* concentration reaches 20 µg/L (Heiskary & Wilson, 2008). In the Eagles Nest Lake Chain, the data show no major algae blooms occurred during the years monitored.

The transparency, expressed via Secchi depth, in the Eagles Nest Lake Chain has been monitored by volunteers for many years. When graphed together, as shown in **Figure 13**, comparisons can be made. Eagles

Nest #1 consistently has the best transparency, but it is also the deepest lake in the chain. Table 1 shows transparency trends for the Eagles Nest Lake Chain. Eagles Nest #2 is showing a declining trend. Continued monitoring is recommended to track the trends in the future.

**Figure 10. Seasonal phosphorus concentration dynamics: Eagles Nest Lake Chain (EQuIS)**

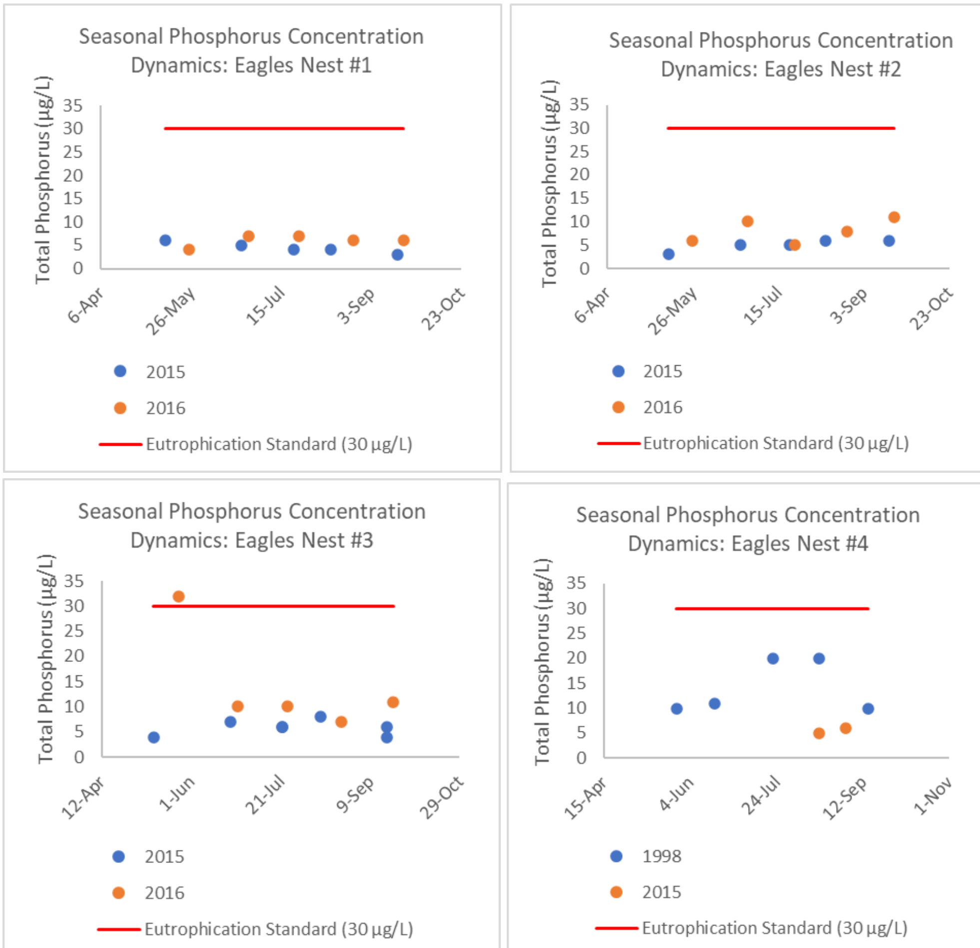


**Figure 11. Dissolved oxygen profiles for the Eagles Nest Lake Chain (EQuIS).**

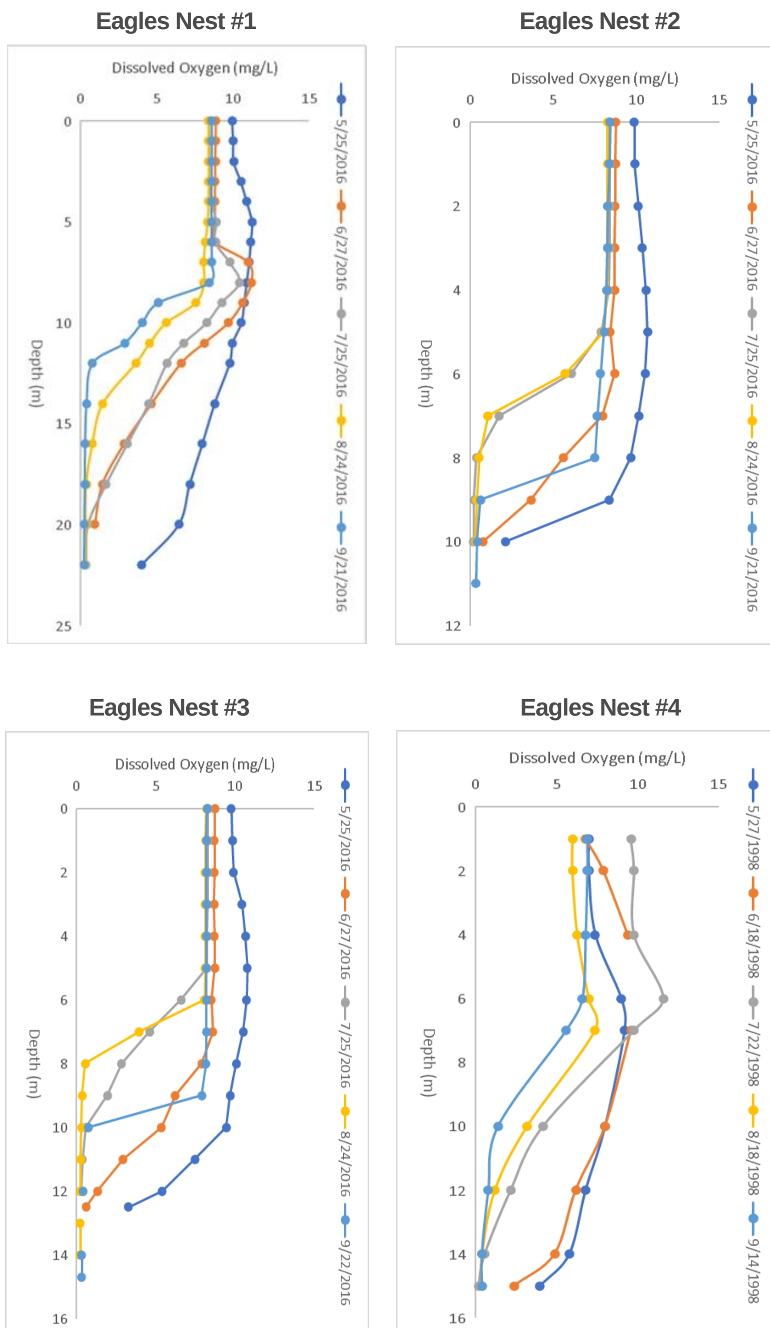


Figure 12. Seasonal Chl-a concentration dynamics: Eagles Nest Lake Chain (EQuIS).

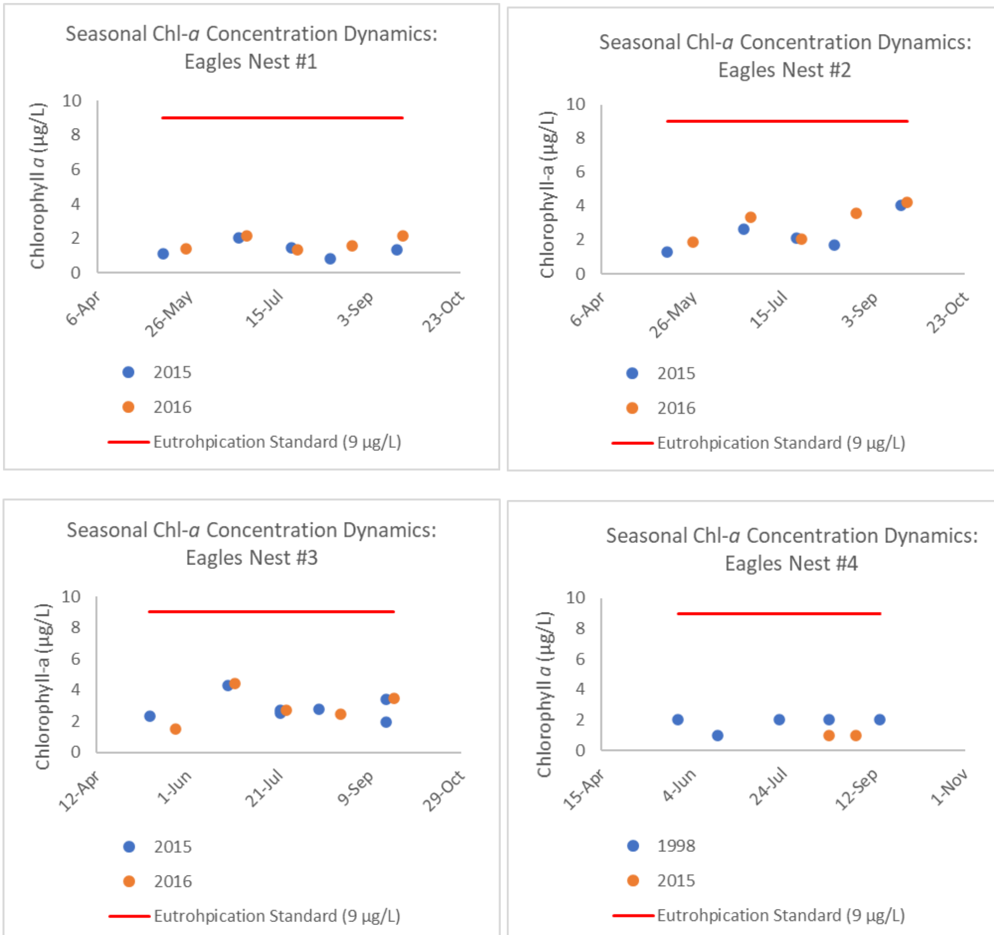


**Figure 13. Seasonal transparency (Secchi depth) dynamics: Eagles Nest Lake Chain (EQuIS).**

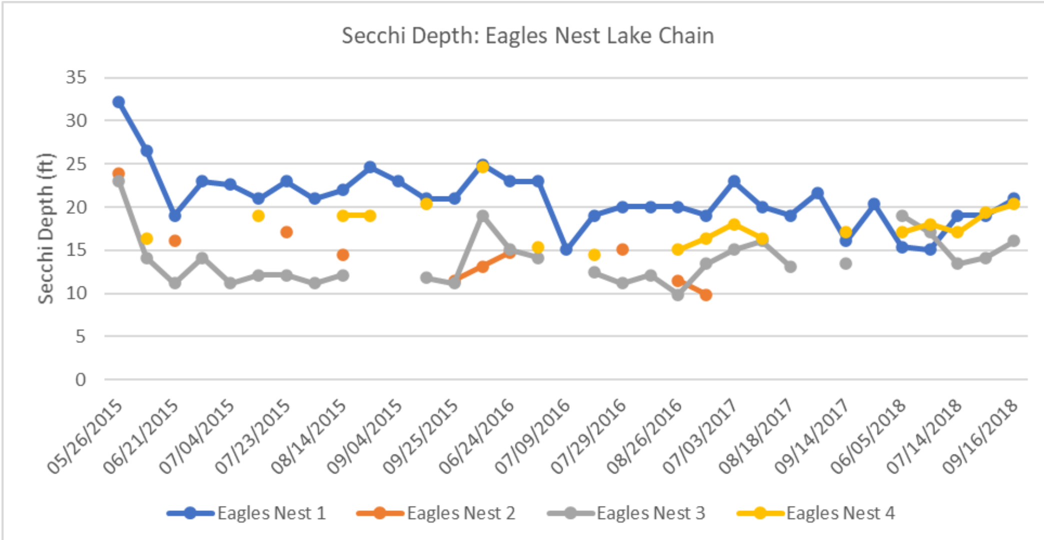



**Table 1. Transparency trends for the Eagles Nest Lake Chain (MPCA).**

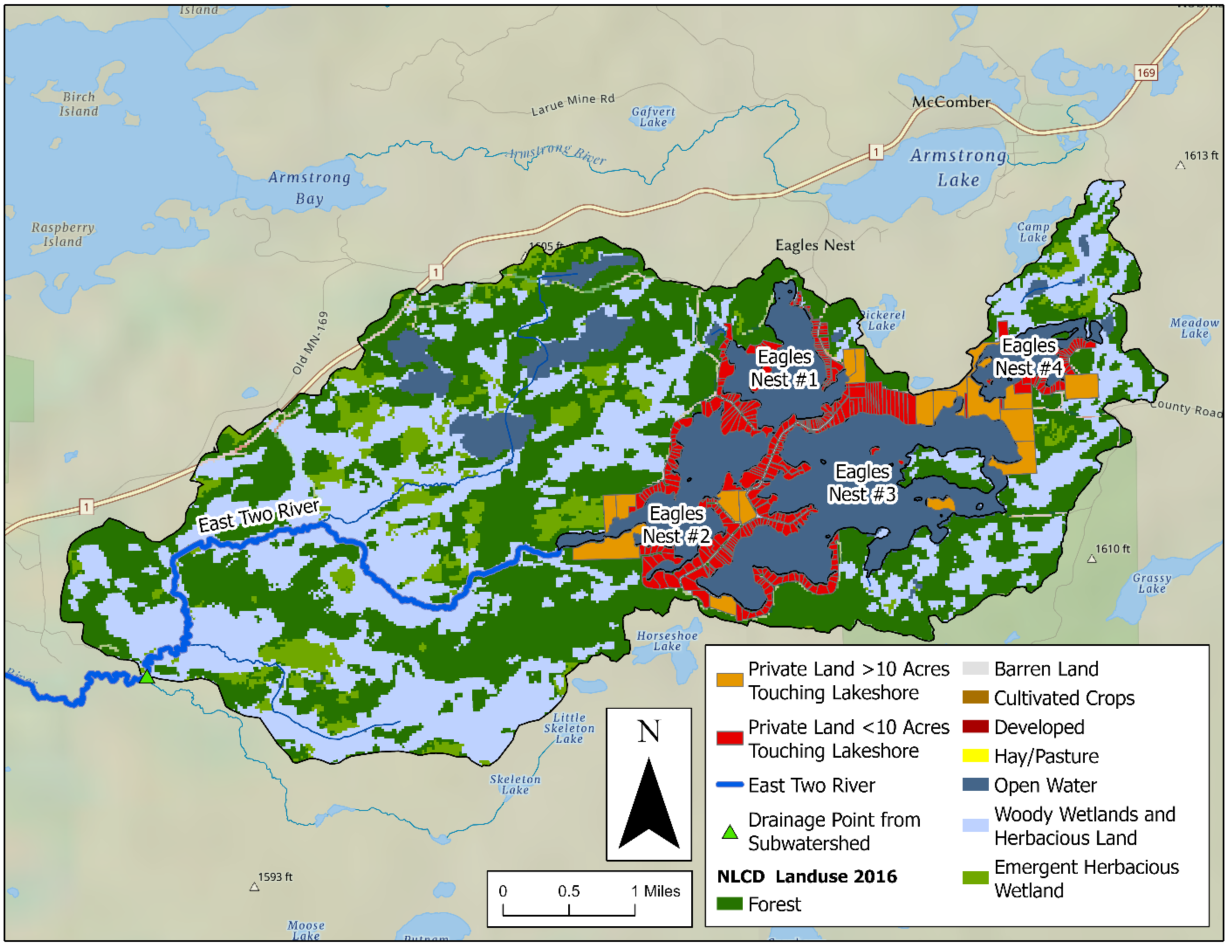
| Lake ID | Lake Name | Transparency Trend |
|---|---|---|
| 69-0285-01 | Eagles Nest #1 | ↑ |
| 69-0285-02 | Eagles Nest #2 | ↓ |
| 69-0285-03 | Eagles Nest #3 | **NT** |
| 69-0218-00 | Eagles Nest #4 | **NT** |

↑ Improving trend
↓ Degrading trend
NT No trend

## *LAKE DRAINAGE LAND USE*

The land use of the watershed contributing to the lake is primarily forests and wetlands with some development along the lakeshore. Eagles Nest #1 and #2 are more developed than Eagles Nest #3 and #4. The East Two River exits Eagles Nest #2 and flows west as shown in **Figure 14**.

Figure 14. Land use, tributaries, and developed land identification in the Eagles Nest Lake Chain watershed.




## PHOSPHORUS LOADING

The HSPF-SAM was used for a source assessment analysis to quantify the phosphorus loading to the lake from the different land uses within the drainage area. HSPF-SAM is not a lake-specific model and there is significant uncertainty involved. However, these loading numbers are intended to be used as tool for planning and prioritizing efforts and not to indicate day-to-day loading conditions.

Eagles Nest #1 and #2 share an HSPF reach and Eagles Nest #3 and #4 share an HSPF reach. Eagles Nest #3 and #4 are a headwater reach, meaning there are no other upstream reaches. Therefore, it was not necessary to show watershed loading. The phosphorus loading to the Eagles Nest Lake Chain within its direct drainage area (i.e., HSPF reach) was broken down by land use in **Figure 15** and **Figure 16**, which can help guide implementation activities for reducing phosphorus loading to the lake. Sources such as atmospheric deposition and wetlands are difficult to reduce with best management practices; however, the modeling results did show some areas of phosphorus loading that can be reduced with best management practices. Developed areas contribute approximately 16% of the phosphorus load in Eagles Nest #1 and #2 and 18% of the phosphorus load in Eagles Nest #3 and #4 as shown in **Figure 15** and **Figure 16.**

Figure 15. Direct drainage phosphorus loading to Eagles Nest #1 and #2, by land use (HSPF-SAM Source Fate)

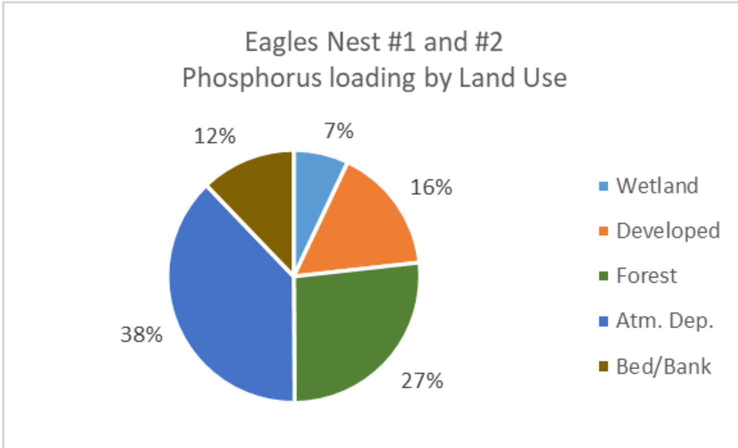
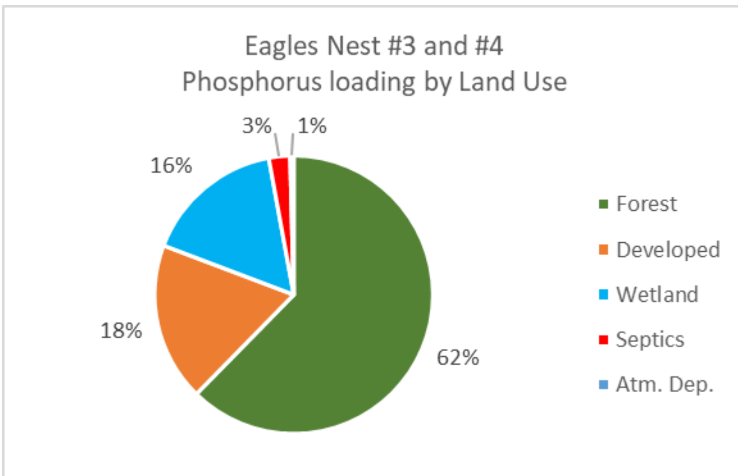



Figure 16. Direct drainage phosphorus loading to Eagles Nest #3 and #4, by land use (HSPF-SAM Source Fate)




## GOAL SETTING

The Eagles Nest Lake Chain is not impaired, so does not require a TMDL or specific reduction at this time. Any current phosphorus goals would be for protection. Typically, short-term goals (i.e., 10-year timeframe) for lake protection have been set to a 5% reduction based on the DNR's phosphorus sensitivity modeling analysis (MPCA and DNR, 2019. This reduction could be reached through a combination of stormwater BMPs such as rain gardens and lakeshore buffers, septic system inventory and improvements, and education and outreach to lakeshore property owners. The privately-owned lakeshore in **Figure 14** (red and orange) could be targeted for phosphorus reduction practices. Landowners can work with the North St. Louis SWCD to install these BMPs.

Other protection practices such as easements and acquisitions, could be targeted to the orange colored parcels (privately-owned lakeshore greater than 10 acres) in **Figure 14**. Protection of these areas could prevent future increases in phosphorus loading to the lake from increased development. Landowners can contact the North St. Louis SWCD or Minnesota Land Trust to learn more about conservation easement options. If there is undeveloped shoreline that is important for fish spawning, the DNR could be contacted for Aquatic Management Area options.

## *MONITORING*

The Eagles Nest Chain are vulnerable to decline and Eagles Nest #2 already has a declining transparency trend. It is important to continue transparency monitoring to track this trend into the future. If the declining trend continues, BATHTUB, a more lake-specific model than HSPF-SAM, could be used to better detail phosphorus load reductions to the lake.

# REFERENCES

Heiskary, Steven and Bruce Wilson. 2008. Minnesota's approach to lake nutrient criteria development. Lake and Reservoir Management. 24(3):282-297.

Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Natural Resources (DNR). 2019. Lakes of Phosphorus Sensitivity Significance (LPSS). May 24, 2019